

# INTERNATIONAL STANDARD



**Information technology – Small Computer System Interface (SCSI) –  
Part 263: SAS Protocol Layer – 3 (SPL-3)**

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**Information technology – Small Computer System Interface (SCSI) –  
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## INFORMATION TECHNOLOGY – SMALL COMPUTER SYSTEM INTERFACE (SCSI) –

### Part 263: SAS Protocol Layer - 3 (SPL-3)

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This International Standard has been approved by vote of the member bodies and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2 except as described in 3.4 and 3.5.

A bilingual version of this publication may be issued at a later date.

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## INTRODUCTION

The SCSI family of standards provides for many different transport protocols that define the rules for exchanging information between different SCSI devices. This document defines the rules for exchanging information between SCSI devices using a serial interconnect. Other SCSI transport protocol standards define the rules for exchanging information between SCSI devices using other interconnects.

Figure 1 shows the organization of the layers of this document.

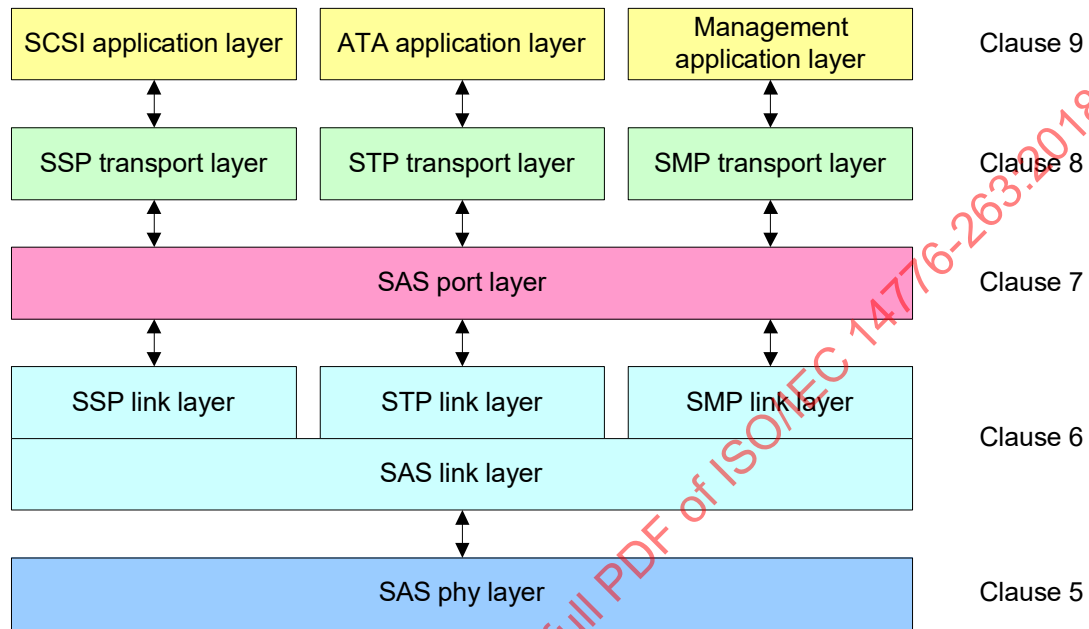


**Figure 1 — Organization of this document**

## SCSI standards family

Figure 2 shows the relationship of this document to the other standards and related projects in the SCSI family of standards.

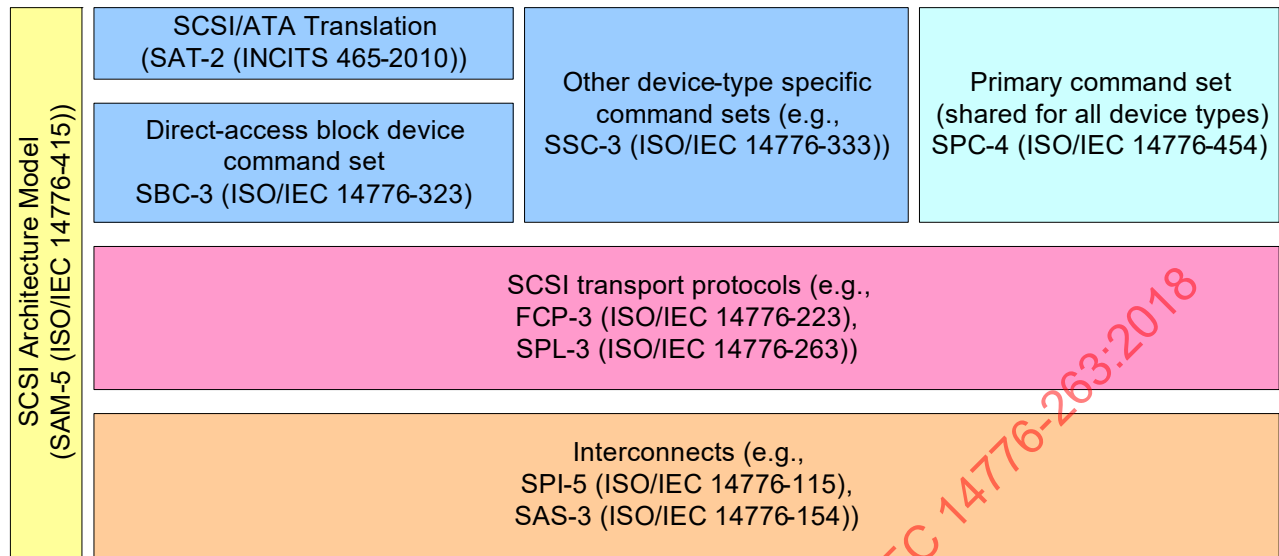


**Figure 2 — SCSI document relationships**

This document also defines the rules for exchanging information between ATA hosts and ATA devices using the same serial interconnect. Other ATA transport protocol standards define the rules for exchanging information between ATA hosts and ATA devices using other interconnects.

Figure 3 shows the relationship of this document to other standards and related projects in the ATA family of standards.

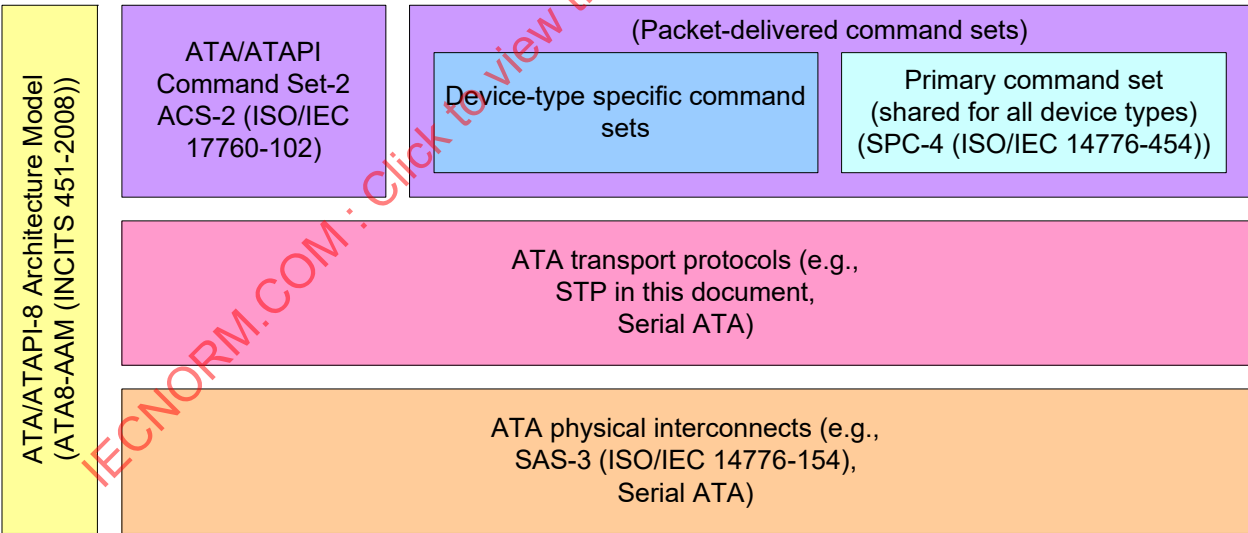


**Figure 3 — ATA document relationships**

Figure 2 and figure 3 show the general relationship of the documents to one another, and do not imply any hierarchy, protocol stack, or system architecture relationship.

These standards specify the interfaces, functions and operations necessary to ensure interoperability between conforming implementations. This document is a functional description. Conforming implementations may employ any design technique that does not violate interoperability.

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## INFORMATION TECHNOLOGY – SMALL COMPUTER SYSTEM INTERFACE (SCSI) –

### Part 263: SAS Protocol Layer - 3 (SPL-3)

#### 1 Scope

This document defines the protocol layer of the Serial Attached SCSI (SAS) interconnect and three transport protocols that use the SAS interconnect:

- a) Serial SCSI Protocol (SSP): a mapping of SCSI supporting multiple initiators and targets;
- b) Serial ATA Tunneled Protocol (STP): a mapping of Serial ATA expanded to support multiple initiators and targets; and
- c) Serial Management Protocol (SMP): a management protocol.

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## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Additional availability contact information is provided in Annex L.

ISO/IEC 17760-102, *Information technology - AT Attachment - Part 102: ATA/ATAPI Command Set - 2* (ACS-2)

ISO/IEC 14776-151, *Information technology - Small Computer System Interface (SCSI) - Part 151: Serial Attached SCSI - 1.1* (SAS-1.1)

ISO/IEC 14776-323, *Information technology - Small Computer System Interface (SCSI) - Part 323: SCSI Block Commands - 3* (SBC-3)

ISO/IEC 14776-154, *Information technology - Small Computer System Interface (SCSI) - Part 154: Serial Attached SCSI - 3* (SAS-3)

ISO/IEC 14776-454, *Information technology - Small Computer System Interface (SCSI) - Part 454: SCSI Primary Commands - 4* (SPC-4)

INCITS 451-2008, *AT Attachment - 8 ATA/ATAPI Architecture Model* (ATA8-AAM)

INCITS 515, *Information technology - SCSI Architecture Model - 5* (SAM-5) (planned as ISO/IEC 14776-415)

INCITS 518, *Information technology - SCSI Enclosure Services - 3* (SES-3) (planned as ISO/IEC 14776-373)

For information on the current status of the listed documents, or regarding availability, contact the indicated organization.

*Serial ATA Revision 3.1* (SATA). 18-July-2011 <sup>1</sup>

SFF-8485, *Serial GPIO* (SGPIO) Bus <sup>2</sup>

---

1. Serial ATA specifications are available from the Serial ATA International Organization (see <http://www.sata-io.org>)

2. SFF specifications are available from the SNIA SFF Technology Affiliate (see <http://www.snia.org/sff>).

### 3 Terms, definitions, symbols, abbreviations, keywords, and conventions

#### 3.1 Terms and definitions

For the purposes of this document the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

##### 3.1.1

###### **8b10b coding**

coding scheme that represents an 8-bit byte (i.e., a control byte or data byte) as a 10-bit character (i.e., a control character or data character)

Note 1 to entry: See 5.2.

##### 3.1.2

###### **8b10b encoding**

method of encoding an 8-bit byte (i.e., a control byte or data byte) into a 10-bit character (i.e., a control character or data character)

Note 1 to entry: See 5.2.

##### 3.1.3

###### **10b8b decoding**

method for decoding a 10-bit character (i.e., a control character or data character) into an 8-bit byte (i.e., a control byte or data byte)

Note 1 to entry: See 5.2.

##### 3.1.4

###### **active cable assembly**

cable assembly (see SAS-3) that requires power for internal circuitry used in the transmission of the signal through the cable assembly

Note 1 to entry: See SAS-3.

##### 3.1.5

###### **active phy power condition**

normal power condition for a SAS phy or expander phy

Note 1 to entry: See 4.10.1.2.

##### 3.1.6

###### **active zone manager**

zone manager (see 3.1.258) that locks a zoning expander device (see 3.1.262)

Note 1 to entry: See 4.8.6.

##### 3.1.7

###### **affiliation**

STP target port (see 3.1.229) state of limiting acceptance of connection requests to those from one or more STP initiator ports (see 3.1.224)

Note 1 to entry: See 6.19.4.



**3.1.8****affiliation context**

set of registers maintained by an STP target port for an STP initiator port holding an affiliation

Note 1 to entry: See 6.19.4.

**3.1.9****aggregation**

form of association that defines a whole-part relationship between the whole (i.e., aggregate) class and its parts

Note 1 to entry: This definition only applies when used in relation to UML.

Note 2 to entry: See 3.6.

**3.1.10****application client**

object that is the source of SCSI commands and task management function requests (see SAM-5), ATA commands (see ATA8-AAM), or SMP function requests

Note 1 to entry: See 4.1.5.

**3.1.11****association**

relationship between two or more classes that specifies connections among their objects

Note 1 to entry: This definition only applies when used in relation to UML.

Note 2 to entry: An association is a relationship that specifies that objects of one class are connected to objects of another class.

Note 3 to entry: See 3.6.

**3.1.12****attached**

attribute of a class used when an instance of that class is only accessible over a service delivery subsystem

**3.1.13****attached SAS address**

SAS address (see 3.1.169) of the attached phy or the SAS address of the STP target port in an STP SATA bridge (see 4.5.2)

Note 1 to entry: For example, the SAS address of an attached phy may be received in the incoming IDENTIFY address frame during the initialization sequence (see 4.1.2).

**3.1.14****attribute**

named property of a class that describes a range of values that its objects may hold

Note 1 to entry: This definition only applies when used in relation to UML.

Note 2 to entry: See 3.6.

**3.1.15****AT Attachment****ATA**

standard for the internal attachment of storage devices to hosts

Note 1 to entry: See ATA8-AAM.

**3.1.16****ATA device**

storage peripheral that processes ATA commands and device management functions

Note 1 to entry: Analogous to a SCSI target device (see 3.1.195).

Note 2 to entry: See ATA8-AAM.

**3.1.17****ATA domain**

I/O system consisting of an ATA host and one or more ATA devices that communicate with one another by means of a service delivery subsystem (see 3.1.203)

Note 1 to entry: Analogous to a SCSI domain (see 3.1.191).

Note 2 to entry: See ATA8-AAM.

**3.1.18****ATA host**

host device that originates requests to be processed by an ATA device

Note 1 to entry: Analogous to a SCSI initiator device (see 3.1.192).

Note 2 to entry: See ATA8-AAM.

**3.1.19****big-endian**

format for storage or transmission of binary data in which the most significant byte appears first

Note 1 to entry: In a multi-byte value, the byte containing the most significant bit is stored in the lowest memory address and transmitted first, and the byte containing the least significant bit is stored in the highest memory address and transmitted last (e.g., for the value 0080h, the byte containing 00h is stored in the lowest memory address, and the byte containing 80h is stored in the highest memory address).

**3.1.20****bi-phase mark code****BMC**

encoding in which a transition occurs at the beginning of each TTIU bit cell (see 3.1.247), a one is represented by a transition in the middle of the TTIU bit cell, and a zero is represented by no transition within the TTIU bit cell

Note 1 to entry: See 5.8.

**3.1.21****Broadcast**

information about an event in the SAS domain, communicated between phys with the BROADCAST primitive sequence (see 6.2.6.4) and/or the SMP ZONED BROADCAST function (see 9.4.3.20)

Note 1 to entry: See 4.1.15.

**3.1.22****Broadcast propagation processor****BPP**

object within an expander function (see 3.1.69) that manages Broadcasts (see 3.1.21)

Note 1 to entry: See 4.5.5.

**3.1.23****burst time**

part of an OOB signal where the OOB burst is transmitted

Note 1 to entry: See SAS-3.

**3.1.24****byte**

sequence of eight contiguous bits considered as a unit

**3.1.25****cable assembly**

bulk cable with a separable connector at each end plus any retention, backshell, shielding features, or circuitry used for cable management or signal transmission

Note 1 to entry: See SAS-3.

**3.1.26****character**

sequence of ten contiguous bits considered as a unit

Note 1 to entry: A byte is encoded as a character using 8b10b coding (see 5.2).

**3.1.27****class**

description of a set of objects that share the same attributes, operations relationships, and semantics

Note 1 to entry: Classes may have attributes and may support operations.

**3.1.28****class diagram**

diagram that shows a collection of classes and their contents and relationships

Note 1 to entry: See 3.6.

**3.1.29****command descriptor block****CDB**

structure used to communicate a command from a SCSI application client to a SCSI device server

Note 1 to entry: See SAM-5.

**3.1.30****commonly supported setting**

supported settings bit (see table 53) with a value set to one by both the phy and the attached phy as transmitted during the most recent SNW-3

**3.1.31****compliant jitter tolerance pattern****CJTPAT**

test pattern for jitter testing

Note 1 to entry: See A.2 and SAS-3.

**3.1.32****configuration subprocess**

subprocess invoked from the discover process (see 3.1.58) to configure an externally configurable expander device (see 3.1.76)

Note 1 to entry: See 4.7.

**3.1.33****confirmation**

information passed from a lower layer state machine to a higher layer state machine, usually responding to a request from that higher layer state machine

Note 1 to entry: For an example of a response from a peer layer state machine see figure 41 in 4.5.6.2.

Note 2 to entry: See 3.7.

**3.1.34****connection**

temporary association between a SAS initiator port and a SAS target port using a pathway (see 3.1.140)

Note 1 to entry: See 4.1.12 and 6.14.

**3.1.35****connection rate**

effective rate of dwords through the pathway (see 3.1.140) between a SAS initiator phy and a SAS target phy, established through the connection request

**3.1.36****connection request**

request to establish a connection originated by a SAS phy (see 3.1.175) using an OPEN address frame (see 6.8.3)

Note 1 to entry: See 6.14.2.1.

**3.1.37****connector**

electro-mechanical components consisting of a receptacle and a plug that provide a separable interface between two transmission segments

Note 1 to entry: See SAS-3.

**3.1.38****constraint**

mechanism for specifying semantics or conditions that are maintained as true between entities

Note 1 to entry: This definition only applies when used in relation to UML.

Note 2 to entry: An example of a constraint is a required condition between associations.

Note 3 to entry: See 3.6.

**3.1.39****control byte**

byte containing control information defined in table 50

Note 1 to entry: See 5.3.7.

**3.1.40****control character****Kxx.y**

character containing control information defined in table 50

Note 1 to entry: See 5.3.7.

**3.1.41****credit advance**

SSP phy feature that increments a transmit SSP frame credit on receipt of an OPEN address frame without waiting for an RRDY

Note 1 to entry: See 4.1.14.

**3.1.42****cyclic redundancy check****CRC**

error checking mechanism that checks data integrity by computing a polynomial algorithm based checksum

Note 1 to entry: See 6.5.

**3.1.43****D.C. idle**

differential signal level that is nominally 0 V peak-to-peak

Note 1 to entry: See SAS-3.

**3.1.44****D.C. mode**

mode in which D.C. idle is used, during the idle time and negation time of an OOB signal (see SAS-3), and during the RCDT time of speed negotiation windows (see 5.10.4.2.2)

**3.1.45****data byte**

byte containing data information defined in table 49

Note 1 to entry: See 5.3.6.

**3.1.46****data character****Dxx.y**

character containing data information defined in table 49 (see 5.2)

Note 1 to entry: See 5.3.6.

**3.1.47****data dword**

dword containing four data bytes or four data characters with correct disparity

**3.1.48****deadlock**

condition in which two or more processes (e.g., connection requests) are waiting on the others to complete, resulting in none of the processes completing

**3.1.49****deletable primitive**

primitive which may be deleted by a receiver instead of being placed into its elasticity buffer (see 6.3)

Note 1 to entry: See 6.2.5.

**3.1.50****dependency**

relationship between two classes where a change to one class (i.e., the independent class) may cause a change in the other class (i.e., the dependent class)

Note 1 to entry: This definition only applies when used in relation to UML.

Note 2 to entry: See 3.6.

**3.1.51****device name**

worldwide unique name for a device within a transport protocol

Note 1 to entry: See 4.2.6.

**3.1.52****device server**

object that processes SCSI commands (see SAM-5), ATA commands (see ATA8-AAM), or SMP functions

Note 1 to entry: See 4.1.5.

**3.1.53****differential high signal level**

signal level that exists when the Tx+ signal of a transmitter circuit (see SAS-3) is higher than the voltage measured on the Tx- signal of a transmitter circuit

**3.1.54****differential low signal level**

signal level that exists when the Tx+ signal of a transmitter circuit (see SAS-3) is lower than the voltage measured on the Tx- signal of a transmitter circuit

**3.1.55****direct current****D.C.**

non-alternating current component (see SAS-3) of a signal

Note 1 to entry: See SAS-3.

**3.1.56****direct routing attribute**

attribute of an expander phy that indicates that the expander phy may be used by the ECM (see 3.1.66) to route a connection request to an end device

Note 1 to entry: See 4.5.7.1.

**3.1.57****direct routing method**

method the ECM (see 3.1.66) uses to route connection requests to an attached end device or an attached expander device

Note 1 to entry: See 4.5.7.1.

**3.1.58****discover process**

process performed by a management application client to discover all the SAS devices and expander devices in the SAS domain

Note 1 to entry: The discover process invokes the configuration subprocess (see 3.1.32) as needed

Note 2 to entry: See 4.6.

**3.1.59****disparity**

difference between the number of ones and zeros in a character (see 5.2)



**3.1.60****domain**

I/O system consisting of devices that communicate with one another by means of a service delivery subsystem

Note 1 to entry: Examples of domains are a SAS domain (see 3.1.171), a SCSI domain (see 3.1.191), or an ATA domain (see 3.1.17).

Note 2 to entry: See 4.1.9.

**3.1.61****dword**

sequence of four contiguous bytes or four contiguous characters considered as a unit

Note 1 to entry: The meaning depends on the context (e.g., when discussing the bits being transmitted over a physical link, dword represents four characters (i.e., 40 bits) and when discussing the contents of a frame before 8b10b encoding (see 3.1.2) or after 10b8b decoding (see 3.1.3), dword represents four bytes (i.e., 32 bits)).

**3.1.62****dword synchronization**

detection of an incoming stream of dwords from a physical link by a phy

Note 1 to entry: See 5.13.

**3.1.63****enclosure**

box, rack, or set of boxes providing the powering, cooling, mechanical protection, EMI protection, and external electronic interfaces for one or more end device(s) (see 3.1.64) and/or expander device(s) (see 3.1.68)

Note 1 to entry: The enclosure provides the outermost electromagnetic boundary and acts as an EMI barrier; an enclosure is not a class in this document.

**3.1.64****end device**

SAS device (see 3.1.170) or SATA device (see 3.1.181) that is not contained within an expander device (see 3.1.68)

**3.1.65****event notification**

information passed from the SSP transport layer to the SCSI application layer notifying the SCSI application layer that a SCSI event has occurred

Note 1 to entry: See SAM-5.

**3.1.66****expander connection manager****ECM**

object within an expander function (see 3.1.69) that manages routing

Note 1 to entry: See 4.5.3.

**3.1.67****expander connection router****ECR**

portion of an expander function (see 3.1.69) that routes messages between expander phys

Note 1 to entry: See 4.5.4.

**3.1.68****expander device**

device that is part of a service delivery subsystem (see 3.1.203), facilitates communication between SAS devices (see 3.1.170) and SATA devices (see 3.1.181), and is either an externally configurable expander device (see 3.1.76) or a self-configuring expander device (see 3.1.197)

Note 1 to entry: See 4.1.7.

**3.1.69****expander function**

object within an expander device (see 3.1.68) that contains an expander connection manager (see 3.1.66), expander connection router (see 3.1.67), and Broadcast propagation processor (see 3.1.22)

Note 1 to entry: See 4.5.1.

**3.1.70****expander logical phy**

expander phy (see 3.1.71) or a multiplexed portion of an expander phy

Note 1 to entry: See 4.1.2.

**3.1.71****expander phy**

phy in an expander device (see 3.1.68) that interfaces to a service delivery subsystem (see 3.1.203)

**3.1.72****expander port**

expander device object that interfaces to a service delivery subsystem (see 3.1.203) and to SAS ports in other devices

Note 1 to entry: See 4.5.2.

**3.1.73****expander route entry**

SAS address and an enable/disable bit in an expander route table (see 3.1.75)

**3.1.74****expander route index**

value used in combination with a phy identifier to select an expander route entry in an expander route table (see 3.1.75) in an externally configurable expander device (see 3.1.76)

Note 1 to entry: See 4.5.7.4.

**3.1.75****expander route table**

table of expander route entries (see 3.1.73) within an expander device (see 3.1.68)

Note 1 to entry: The table is used by the expander function (see 3.1.69) to resolve connection requests.

Note 2 to entry: See 4.5.7.4.

**3.1.76****externally configurable expander device**

non-self-configuring expander device (see 3.1.68) that contains an expander route table (see 3.1.75)

Note 1 to entry: An externally configurable expander device that is configurable with the SMP CONFIGURE ROUTE INFORMATION function (see 9.4.3.27).

Note 2 to entry: See 4.1.7.

**3.1.77****field**

group of one or more contiguous bits

**3.1.78****Final-SNW**

final speed negotiation window for 1.5 Gbit/s or 3 Gbit/s without training (see 5.10.4.2.3.2)

**3.1.79****frame**

sequence of data dwords between a start of frame primitive and an end of frame primitive

Note 1 to entry: Start of frame primitives are SOF, SOAF, and SATA\_SOF.

Note 2 to entry: End of frame primitives are EOF, EOAF, and SATA\_EOF.

**3.1.80****frame information structure****FIS**

SATA frame format

Note 1 to entry: See SATA.

**3.1.81****generalization**

relationship among classes where one class (i.e., the superclass) shares the attributes and operations of one or more other classes (i.e., the subclasses)

Note 1 to entry: This definition only applies when used in relation to UML.

Note 2 to entry: See 3.6.

**3.1.82****hard reset**

SAS device or expander device action in response to a reset event in which the device performs the operations described in 4.4.2

**3.1.83****hard reset sequence**

sequence that causes a hard reset (see 3.1.82)

Note 1 to entry: See 4.4 and 6.9.

**3.1.84****hardware maximum physical link rate**

maximum physical link rate capability of a phy

**3.1.85****hardware minimum physical link rate**

minimum physical link rate capability of a phy

**3.1.86****hash**

mathematical function that maps values from a larger set of values into a smaller set of values, reducing a long value into a shorter hashed value

**3.1.87****highest priority commonly supported setting**

commonly supported setting based on the priority defined in table 56

**3.1.88****I\_T nexus**

nexus between a SAS initiator port and a SAS target port or a nexus between a SCSI initiator port and a SCSI target port

Note 1 to entry: When referring to SAS ports, a nexus between a SAS initiator port and a SAS target port.

Note 2 to entry: When referring to SCSI ports, a nexus between a SCSI initiator port and a SCSI target port.

Note 3 to entry: See SAM-5.

**3.1.89****I\_T nexus loss**

condition where a SAS port determines that another SAS port is no longer available or an I\_T nexus loss operation occurs in a SCSI port

Note 1 to entry: When referring to SAS ports (see 3.1.177), a condition where a SAS port determines that another SAS port is no longer available.

Note 2 to entry: When referring to SCSI ports (see 3.1.194) (e.g., SSP ports), a condition resulting from the events defined by SAM-5 in which the SCSI device performs the I\_T nexus loss operations described in SAM-5, SPC-4, and the appropriate command standards.

Note 3 to entry: See 4.4.3 and SAM-5.

**3.1.90****I\_T nexus loss event**

event that results in an I\_T nexus loss condition (see SAM-5)

Note 1 to entry: See 4.4.3 and SAM-5.

**3.1.91****I\_T nexus loss timer event**

event that starts an I\_T nexus loss timer (see 7.2.2.1)

Note 1 to entry: See 4.4.3.

**3.1.92****I\_T\_L nexus**

nexus between a SCSI initiator port, a SCSI target port, and a logical unit

Note 1 to entry: See SAM-5.

**3.1.93****I\_T\_L\_Q nexus**

nexus between a SCSI initiator port, a SCSI target port, a logical unit, and a command or task management function

Note 1 to entry: See SAM-5.

**3.1.94****IDENTIFY (PACKET) DEVICE data**

IDENTIFY DEVICE data from an ATA device, or IDENTIFY PACKET DEVICE data from an ATAPI device

Note 1 to entry: See ACS-2.

**3.1.95****identification sequence**

sequence where phys exchange IDENTIFY address frames

Note 1 to entry: See 4.4 and 6.9.

**3.1.96****idle dword**

vendor specific data dword that is scrambled and is transmitted outside a frame

Note 1 to entry: See 6.4.

**3.1.97****idle time**

part of an OOB signal (see 3.1.135) where OOB idle (see 3.1.133) is being transmitted

Note 1 to entry: See 5.6.

**3.1.98****indication**

information passed from a lower layer state machine to a higher layer state machine, usually responding to a request from that higher layer state machine (e.g., see figure 40)

Note 1 to entry: See 3.7.

**3.1.99****information unit**

portion of an SSP frame that carries command, task management function, data, response, or transfer ready information

Note 1 to entry: See 8.2.2.

**3.1.100****initiator connection tag**

value in the OPEN address frame used for SSP and STP connection requests to provide a SAS initiator port an alternative to using the SAS target port's SAS address for context lookup when the SAS target port originates a connection request

Note 1 to entry: See 6.8.3.

**3.1.101****initiator port transfer tag**

value that allows an SSP initiator port to establish a context for commands and task management functions

Note 1 to entry: See 8.2.1.

**3.1.102****invalid character**

character that is not a control character (see 3.1.40) or a data character (see 3.1.46)

**3.1.103****invalid dword**

dword that is not a data dword (see 3.1.47) or a primitive (see 3.1.155)

Note 1 to entry: In the character context, a dword that contains an invalid character, a control character in other than the first character position, a control character other than K28.3 or K28.5 in the first character position, or one or more characters with a running disparity error.

**3.1.104****jitter tolerance pattern****JTPAT**

test pattern for jitter testing

Note 1 to entry: See SAS-3.

**3.1.105****least significant bit****LSB**

bit or bit position with the smallest numerical weighting in a group of bits that, when taken as a whole, represent a numerical value

Note 1 to entry: This definition only applies when used in relation to binary codes.

Note 2 to entry: For example in the number 0001b, the LSB bit is the bit that is set to one.

**3.1.106****left-aligned**

type of field containing ASCII data in which unused bytes are placed at the end of the field (highest offset) and are filled with ASCII space (20h) characters

Note 1 to entry: See SPC-4.

**3.1.107****link reset sequence**

phy reset sequence

Note 1 to entry: For a SATA a link reset sequence is only a phy reset sequence (see 3.1.146).

Note 2 to entry: For SAS a link reset sequence is a phy reset sequence followed by an identification sequence (see 3.1.95), or a phy reset sequence followed by a hard reset sequence (see 3.1.83), another phy reset sequence, and an identification sequence.

Note 3 to entry: See 4.4 and 6.9.

**3.1.108****little-endian**

format for storage or transmission of binary data in which the least significant byte appears first

Note 1 to entry: In a multi-byte value, the byte containing the least significant bit is stored in the lowest memory address and transmitted first, and the byte containing the most significant bit is stored in the highest memory address and transmitted last (e.g., for the value 0080h, the byte containing 80h is stored in the lowest memory address, and the byte containing 00h is stored in the highest memory address)

**3.1.109****livelock**

condition where two or more processes (e.g., connection requests) repeatedly change their state in response to changes in other processes, resulting in none of the processes completing

**3.1.110****local**

attribute of a class used when an instance of that class is accessible without having to access any service delivery subsystem

**3.1.111****locked zoning expander device**

zoning expander device (see 3.1.262) that has been locked by a zone manager (see 3.1.258)

Note 1 to entry: See 4.8.6.2.

**3.1.112****logical link**

physical link or a multiplexed portion of a physical link

Note 1 to entry: See 4.1.3.



**3.1.113****logical link rate**

link rate between two logical phys established as a result of speed negotiation and multiplexing negotiation between the physical phys containing those logical phys

**3.1.114****logical phy**

phy (see 3.1.143) or a multiplexed portion of a phy

Note 1 to entry: See 4.1.2.

**3.1.115****logical unit**

object that implements a device model and manages and processes commands sent by a SCSI application client

Note 1 to entry: See SAM-5.

**3.1.116****logical unit number****LUN**

identifier for a logical unit (see 3.1.115)

Note 1 to entry: See SAM-5.

**3.1.117****low phy power condition**

partial phy power condition or the slumber phy power condition

Note 1 to entry: See 4.10.1.

**3.1.118****medium**

material on which data is stored

Note 1 to entry: The plural of medium is media.

Note 2 to entry: An example of a medium on which data is stored is a magnetic disk.

**3.1.119****message**

information sent between state machines

Note 1 to entry: See 3.7.

**3.1.120****most significant bit****MSB**

bit or bit position with the largest numerical weighting in a group of bits that, when taken as a whole, represent a numerical value

Note 1 to entry: This definition only applies when used in relation to binary codes.

Note 2 to entry: For example in the number 1000b the MSB bit is the bit that is set to one.

**3.1.121****multiplexing**

interleaving of dwords

Note 1 to entry: Multiplexing divides a single physical link into two logical links by creating two logical phys from a single physical phy.

Note 2 to entry: See 5.15.

**3.1.122****multiplicity**

indication of the range of allowable instances of an object or an attribute

Note 1 to entry: This definition only applies when used in relation to UML.

Note 2 to entry: See 3.6.

**3.1.123****narrow link**

physical link that attaches a narrow port to another narrow port

Note 1 to entry: See 4.1.4.

**3.1.124****narrow port**

port that contains exactly one phy

Note 1 to entry: See 4.1.4.

**3.1.125****negation time**

part of an OOB signal (see 3.1.135) during which OOB idle (see 3.1.133) is transmitted after the last OOB burst (see 3.1.132)

Note 1 to entry: See 5.6.

**3.1.126****negotiation idle**

transmission of OOB idle (see 3.1.133)

Note 1 to entry: See 5.12.4.2.

**3.1.127****negotiated logical link rate**

current operational logical link rate (see 3.1.113)

**3.1.128****negotiated physical link rate**

current operational physical link rate (see 3.1.148)

**3.1.129****nexus**

relationship between two SAS devices or two SCSI devices

Note 1 to entry: When referring to SAS devices (see 3.1.170), a relationship between two SAS devices, and the SAS initiator port and the SAS target port objects within those SAS devices.

Note 2 to entry: When referring to SCSI devices (see 3.1.190), a relationship between two SCSI devices, and the SCSI initiator port and the SCSI target port objects within those SCSI devices.

Note 3 to entry: See SAM-5.

**3.1.130****object**

entity with a well-defined boundary and identity that encapsulates state and behavior

Note 1 to entry: All objects are instances of classes (i.e., a concrete manifestation of a class is an object).

**3.1.131****object diagram**

diagram that encompasses objects and their relationships at a point in time

Note 1 to entry: See 3.6.

**3.1.132****OOB burst**

transmission of signal transitions for a burst time

Note 1 to entry: See SAS-3.

**3.1.133****OOB idle**

transmission of D.C. idle when D.C mode (see 3.1.44) is enabled, or a defined sequence of dwords when optical mode (see 3.1.137) is enabled

Note 1 to entry: See SAS-3.

**3.1.134****OOB sequence**

sequence where two phys exchange OOB signals (see 3.1.135)

Note 1 to entry: See 5.10.2.1 and 5.10.4.1.

**3.1.135****OOB signal**

pattern of idle time (see 3.1.97), burst time, and negation time (see 3.1.125) used during the link reset sequence

Note 1 to entry: See 5.6.

**3.1.136****operation**

service that may be requested from any object of the class in order to affect behavior

Note 1 to entry: This definition only applies when used in relation to UML

Note 2 to entry: Operations describe what a class is allowed to do and may be a request or a query.

Note 3 to entry: An operation that is a request may change the state of the object but an operation that is a query should not.

Note 4 to entry: See 3.6.

**3.1.137****optical mode**

mode in which a defined sequence of dwords is used during the idle time and negation time of an OOB signal (see SAS-3) and during the RCDT time of speed negotiation windows (see 5.10.4.2.2)

**3.1.138****partial pathway**

set of logical links participating in a connection request that have not yet conveyed a connection response

Note 1 to entry: See 4.1.11.

**3.1.139****partial phy power condition**

low phy power condition for a SAS phy or expander phy

Note 1 to entry: See 4.10.1.3.

**3.1.140****pathway**

set of logical links between a SAS initiator phy and a SAS target phy being used by a connection (see 3.1.34)

Note 1 to entry: See 4.1.11.

**3.1.141****pathway blocked count**

number of times the port has retried this connection request due to receiving OPEN\_REJECT (PATHWAY BLOCKED), OPEN\_REJECT (RESERVED STOP 0), or OPEN\_REJECT (RESERVED STOP 1)

**3.1.142****persistent connection**

connection that may be extended indefinitely

**3.1.143****phy**

object in a device that is used to interface to other devices (e.g., an expander phy (see 3.1.71) or a SAS phy (see 3.1.175))

Note 1 to entry: See 4.1.2 and SAS-3.

**3.1.144****phy identifier**

value by which a phy is identified within a device

Note 1 to entry: See 4.2.10.

**3.1.145****phy ready state**

condition of a phy when its SP state machine is in the SP15:SAS\_PHY\_Ready state (see 5.12.4.10)

**3.1.146****phy reset sequence**

OOB sequence (see 3.1.134) followed by a speed negotiation sequence (see 3.1.213)

Note 1 to entry: See 4.4 and 5.10.

**3.1.147****physical link**

two differential signal pairs, one pair in each direction, that connect two physical phys

Note 1 to entry: See 4.1.2 and SAS-3.

**3.1.148****physical link rate**

link rate between two physical phys established as a result of speed negotiation between those phys

**3.1.149****physical phy**

phy that contains a transceiver and electrically interfaces to a physical link to communicate with another physical phy

Note 1 to entry: See 4.1.2 and SAS-3.

**3.1.150****port**

SAS port (see 3.1.177) or an expander port (see 3.1.72)

Note 1 to entry: Each port contains one or more phys (see 3.1.143).

Note 2 to entry: See 4.1.4.

**3.1.151****port identifier**

value by which a port is identified within a domain

Note 1 to entry: See 4.2.9.

**3.1.152****port name**

worldwide unique name for a port within a transport protocol

Note 1 to entry: See 4.2.8.

**3.1.153****potential pathway**

set of logical links between a SAS initiator phy and a SAS target phy

Note 1 to entry: See 4.1.11.

**3.1.154****power on**

power being applied

**3.1.155****primitive**

8b10b coded dword in which the first byte is a control byte (i.e., 7Ch or BCh) or a control character (i.e., K28.3 or K28.5)

Note 1 to entry: For a phy that supports being attached to SATA phy, an 8b10b coded dword containing a 7Ch or BCh control byte followed by three data bytes, or a K28.3 or K28.5 control character with correct disparity followed by three data characters with correct disparity.

Note 2 to entry: For a phy that does not support being attached to SATA phy, an 8b10b coded dword containing a BCh control byte followed by three data bytes, or a K28.5 control character with correct disparity followed by three data characters with correct disparity.

Note 3 to entry: See 6.2.

**3.1.156****primitive sequence**

set of primitives treated as a single entity

Note 1 to entry: See 6.2.4.

**3.1.157****programmed maximum physical link rate**

maximum operational physical link rate of a phy

Note 1 to entry: The programmed maximum physical link rate may be programmed via the SMP PHY CONTROL function (see 9.4.3.28) or the Phy Control and Discover mode page (see 9.2.7.5).

**3.1.158****programmed minimum physical link rate**

minimum operational physical link rate of a phy

Note 1 to entry: The programmed minimum physical link rate may be as programmed via the SMP PHY CONTROL function (see 9.4.3.28) or the Phy Control and Discover mode page (see 9.2.7.5))

**3.1.159****rate**

data transfer rate of a physical or logical link

Note 1 to entry: Rate examples are 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, and 12 Gbit/s.

**3.1.160****read data**

data transferred to the SCSI application client's data-in buffer from the SCSI device server, as requested by the Send Data-In transport protocol service (see 9.2.1.6)

**3.1.161****receiver device****Rx**

device downstream from a receiver device compliance point containing a portion of the physical link and a receiver circuit

Note 1 to entry: See SAS-3.

**3.1.162****request**

information passed from a higher layer state machine to a lower layer state machine, usually to initiate some action

Note 1 to entry: See 3.7.

**3.1.163****reset event**

event that triggers a hard reset (see 4.4.2) in a SAS device

**3.1.164****response**

information passed from a higher layer state machine to a lower layer state machine, usually in response to an indication (see 3.1.98)

Note 1 to entry: See 3.7.

**3.1.165****role**

label at the end of an association (see 3.1.11) or aggregation (see 3.1.9) that defines a relationship to the class on the other side of the association or aggregation

Note 1 to entry: This definition only applies when used in relation to UML.

Note 2 to entry: See 3.6.

**3.1.166****route table optimization**

configuration subprocess (see 3.1.32) algorithm that reduces the number of entries required in an expander route table (see 3.1.75) in an externally configurable expander device (see 3.1.76)

Note 1 to entry: See 4.7.3.

**3.1.167****run length**

number of consecutive identical bits in the transmitted signal

Note 1 to entry: For example the pattern 00 11111010b includes the following run lengths of five 1s, one 0, one 1, and indeterminate run lengths of 0s at the start and end.

**3.1.168****running disparity****RD**

binary parameter with a negative (-) or positive (+) value indicating the cumulative encoded signal imbalance between the one and zero signal state of all characters since dword synchronization has been achieved

Note 1 to entry: See 5.3.5.

**3.1.169****SAS address**

identifier assigned to a SAS port (see 3.1.177) or expander device (see 3.1.68)

Note 1 to entry: See 4.2.4.

**3.1.170****SAS device**

SAS initiator device and/or a SAS target device

Note 1 to entry: See 4.1.6.

**3.1.171****SAS domain**

I/O system defined by this document that may serve as a SCSI domain

Note 1 to entry: See 4.1.9.

**3.1.172****SAS initiator device**

device containing SSP, STP, and/or SMP initiator ports in a SAS domain

Note 1 to entry: See 4.1.6.

**3.1.173****SAS initiator phy**

logical phy (see 3.1.114) in a SAS initiator device

**3.1.174****SAS initiator port**

SSP initiator port (see 3.1.217), STP initiator port (see 3.1.224), and/or SMP initiator port (see 3.1.206) in a SAS domain

**3.1.175****SAS phy**

phy in a SAS device that interfaces to a service delivery subsystem (see 3.1.203)

**3.1.176****SAS logical phy**

SAS phy (see 3.1.175) or a multiplexed portion of a SAS phy

Note 1 to entry: See 4.1.2.



**3.1.177****SAS port**

SAS initiator port (see 3.1.174) and/or a SAS target port (see 3.1.180)

**3.1.178****SAS target device**

device containing SSP, STP, and/or SMP target ports in a SAS domain

Note 1 to entry: See 4.1.6.

**3.1.179****SAS target phy**

logical phy (see 3.1.114) in a SAS target device

**3.1.180****SAS target port**

SSP target port (see 3.1.221), STP target port (see 3.1.229), and/or SMP target port (see 3.1.210) in a SAS domain

**3.1.181****SATA device**

ATA device that contains a SATA device port in an ATA domain; analogous to a SAS target device (see 3.1.178)

**3.1.182****SATA device port**

ATA device object that interfaces to a service delivery subsystem (see 3.1.203) with SATA

Note 1 to entry: Analogous to a SAS target port (see 3.1.180).

**3.1.183****SATA host**

ATA host that contains a SATA host port in an ATA domain

Note 1 to entry: Analogous to a SAS initiator device (see 3.1.172).

**3.1.184****SATA host port**

ATA host object that interfaces to a service delivery subsystem (see 3.1.203) with SATA

Note 1 to entry: Analogous to a SAS initiator port (see 3.1.174).

**3.1.185****SATA phy**

phy in a SATA device or SATA port selector that interfaces to a service delivery subsystem (see 3.1.203)

Note 1 to entry: Analogous to a SAS phy (see 3.1.175).

**3.1.186****SATA port selector**

device that attaches to two SATA host ports (i.e., two ATA domains) and one SATA device port, and provides the means for one SATA host to access the device at any given time (see SATA)

**3.1.187****SATA spinup hold**

state entered by an expander phy attached to a SATA device in which it halts the automatic phy reset sequence to delay temporary consumption of additional power

Note 1 to entry: An example when a SATA device consumes additional power is during spin up of rotating media.

Note 2 to entry: See 5.16.

**3.1.188****saturating counter**

counter that remains at its maximum value after reaching its maximum value

**3.1.189****scrambling**

modifying data by XORing each bit with a pattern generated by a linear feedback shift register to minimize repetitive character patterns

Note 1 to entry: See 6.6.

**3.1.190****SCSI device**

device that contains one or more SCSI ports that are connected to a service delivery subsystem (see 3.1.203) and supports a SCSI application protocol

Note 1 to entry: See SAM-5.

**3.1.191****SCSI domain**

I/O system consisting of a set of SCSI devices that communicate with one another by means of a service delivery subsystem (see 3.1.203)

Note 1 to entry: See SAM-5.

**3.1.192****SCSI initiator device**

SCSI device containing SCSI application clients and SCSI initiator ports that originates device service and task management requests to be processed by a SCSI target device and receives device service and task management responses from SCSI target devices

Note 1 to entry: See SAM-5.

**3.1.193****SCSI initiator port**

SCSI initiator device object that acts as the connection between SCSI application clients and a service delivery subsystem (see 3.1.203) through which requests and confirmations are routed

Note 1 to entry: See SAM-5.

**3.1.194****SCSI port**

SCSI initiator port and/or a SCSI target port

Note 1 to entry: See SAM-5.

**3.1.195****SCSI target device**

SCSI device containing logical units and SCSI target ports that receives device service and task management requests for processing and sends device service and task management responses to SCSI initiator devices

Note 1 to entry: See SAM-5.

**3.1.196****SCSI target port**

SCSI target device object that contains a task router and acts as the connection between SCSI device servers and task managers and a service delivery subsystem (see 3.1.203) through which requests, indications, responses, and confirmations are routed

Note 1 to entry: See SAM-5.

**3.1.197****self-configuring expander device**

expander device (see 3.1.68) containing an SMP initiator port and a management application client to perform the discover process (see 3.1.58) to configure its own expander route table (see 3.1.75)

Note 1 to entry: See 4.6.4.

**3.1.198****Serial ATA****SATA**

protocol defined in SATA (see clause 2)

**3.1.199****Serial ATA Tunneled Protocol****STP**

protocol defined in this document used by STP initiator ports (see 3.1.224) to communicate with STP target ports (see 3.1.229) in a SAS domain

Note 1 to entry: See 6.19 and 8.3.

**3.1.200****Serial Attached SCSI****SAS**

set of protocols defined by this document and the interconnects defined in SAS-3

**3.1.201****Serial Management Protocol****SMP**

protocol defined in this document used by SMP initiator ports (see 3.1.206) to communicate with SMP target ports (see 3.1.210) in a SAS domain

Note 1 to entry: See 6.20 and 8.4

**3.1.202****Serial SCSI Protocol****SSP**

protocol defined in this document used by SSP initiator ports (see 3.1.217) to communicate with SSP target ports (see 3.1.221) in a SAS domain

Note 1 to entry: See 6.18 and 8.2.

**3.1.203****service delivery subsystem**

part of a SCSI I/O system that transmits information between a SCSI initiator port and a SCSI target port, or the part of an ATA I/O system that transmits information between an ATA host and an ATA device, or the part of a SAS I/O system that transmits information between a SAS initiator port and a SAS target port

Note 1 to entry: See 4.1.8.

**3.1.204****slumber phy power condition**

low phy power condition for a SAS phy or expander phy

Note 1 to entry: See 4.10.1.4.

**3.1.205****SMP initiator phy**

SAS initiator phy (see 3.1.173) in an SMP initiator port (see 3.1.206)

**3.1.206****SMP initiator port**

SAS initiator device object in a SAS domain that interfaces to a service delivery subsystem with SMP

**3.1.207****SMP phy**

SAS logical phy (see 3.1.176) in an SMP port

**3.1.208****SMP port**

SMP initiator port (see 3.1.206) and/or an SMP target port (see 3.1.210)

**3.1.209****SMP target phy**

SAS target phy (see 3.1.179) in an SMP target port (see 3.1.210)

**3.1.210****SMP target port**

SAS target device object in a SAS domain that interfaces to a service delivery subsystem (see 3.1.203) with SMP

**3.1.211****SMP zone configuration function**

SMP function that configures zoning expander shadow values (see 3.1.264) and is only accepted by a locked zoning expander device

Note 1 to entry: See 4.8.6.3.

**3.1.212****SNW-3 bit cell time**

time for transmitting a phy capabilities bit during SNW-3 (see 5.10.4.2.3.3)

**3.1.213****speed negotiation sequence**

sequence in which two phys negotiate the operational physical link rate

Note 1 to entry: See 5.10.2.2 and 5.10.4.2.

**3.1.214****speed negotiation window****SNW**

portion of the SAS speed negotiation sequence

Note 1 to entry: See 5.10.4.2.3.

**3.1.215****spread spectrum clocking****SSC**

technique of modulating the operating frequency of a transmitted signal (i.e., the physical link rate) to reduce the measured peak amplitude of radiated emissions

Note 1 to entry: See SAS-3.

**3.1.216****SSP initiator phy**

SAS initiator phy (see 3.1.173) in an SSP initiator port (see 3.1.217)

**3.1.217****SSP initiator port**

SCSI initiator port in a SAS domain that implements SSP

**3.1.218****SSP phy**

SAS logical phy (see 3.1.176) in an SSP port

**3.1.219****SSP port**

SSP initiator port (see 3.1.217) and/or an SSP target port (see 3.1.221)

**3.1.220****SSP target phy**

SAS target phy (see 3.1.179) in an SSP target port (see 3.1.221)

**3.1.221****SSP target port**

SCSI target port in a SAS domain that implements SSP

**3.1.222****state machine variable**

variable that exists within the context of a state machine

Note 1 to entry: A state machine variable may contain status from one state that is used in another state of the same state machine.

Note 2 to entry: The value contained in a state machine variable may affect subsequent state transitions or state machine outputs.

**3.1.223****STP initiator phy**

SAS initiator phy (see 3.1.173) in an STP initiator port (see 3.1.224)

**3.1.224****STP initiator port**

SAS initiator device object in a SAS domain that interfaces to a service delivery subsystem (see 3.1.203) with STP

**3.1.225****STP phy**

SAS logical phy (see 3.1.176) in an STP port

**3.1.226****STP port**

STP initiator port (see 3.1.224) and/or an STP target port (see 3.1.229)

**3.1.227****STP primitive**

primitive used only inside STP connections and on SATA physical links

Note 1 to entry: See 6.2.2.

**3.1.228****STP target phy**

SAS target phy (see 3.1.179) in an STP target port (see 3.1.229)

**3.1.229****STP target port**

SAS target device object in a SAS domain that interfaces to a service delivery subsystem (see 3.1.203) with STP

**3.1.230****STP SATA bridge**

expander device object containing an STP target port, a SATA host port, and the functions required to forward information between the STP target port and SATA host port to enable STP initiator ports in a SAS domain to communicate with SATA devices in an ATA domain

**3.1.231****subtractive routing attribute**

attribute of an expander phy that indicates that the expander phy may be used by the ECM (see 3.1.66) to route connection requests to an attached expander device that were not resolved using the direct routing method or table routing method

Note 1 to entry: See 4.5.7.1.

**3.1.232****subtractive routing method**

method the ECM (see 3.1.66) uses to route connection requests not resolved using the direct routing method or table routing method to an attached expander device (see 3.1.68)

Note 1 to entry: See 4.5.7.1.

**3.1.233****table routing attribute**

attribute of an expander phy that indicates that the expander phy may be used by the ECM (see 3.1.66) to route connection requests using an expander route table (see 3.1.75)

Note 1 to entry: See 4.5.7.1.

**3.1.234****table routing method**

method the ECM (see 3.1.66) uses to route connection requests to an attached expander device (see 3.1.68) using an expander route table (see 3.1.75)

Note 1 to entry: See 4.5.7.1.

**3.1.235****target port transfer tag**

optional value that allows an SSP target port to establish the write data context when receiving a write DATA frame

Note 1 to entry: See 8.2.1.

**3.1.236****task management function**

task manager service capable of being requested by a SCSI application client to affect the processing of one or more commands

Note 1 to entry: See SAM-5.

**3.1.237****task manager**

object that controls the sequencing of SCSI commands and processes SCSI task management functions

Note 1 to entry: See SAM-5.

**3.1.238****Train\_Rx-SNW**

speed negotiation window with receiver training

Note 1 to entry: See 5.10.4.2.3.5.

**3.1.239****Train\_Rx-SNW window time**

actual duration of Train\_Rx-SNW

**3.1.240****Train\_Tx-SNW**

speed negotiation window with transmitter training

Note 1 to entry: See 5.10.4.2.3.4.

**3.1.241****transmitter device****Tx**

device upstream from a transmitter device compliance point containing a portion of the physical link and a transmitter circuit (see SAS-3)

**3.1.242****transport protocol service confirmation**

information passed from the SSP transport layer to the SCSI application layer (e.g., from the SSP initiator port to the SCSI application client) that notifies the SCSI application layer that a SCSI transport protocol service has completed

**3.1.243****transport protocol service indication**

information passed from the SSP transport layer to the SCSI application layer notifying the SCSI application layer (e.g., from the SSP target port to the SCSI device server) to begin a SCSI transport protocol service

**3.1.244****transport protocol service request**

information passed from the SCSI application layer to the SSP transport layer (e.g., from the SCSI application client to the SCSI initiator port) to begin a SCSI transport protocol service



**3.1.245****transport protocol service response**

information passed from the SCSI application layer to the SSP transport layer (e.g., from the SCSI device server to the SSP target port) that completes the SCSI transport protocol service

**3.1.246****transmitter training information unit****TTIU**

32 TTIU bit cells that follow a pattern marker transmitted during Train\_Tx-SNW (see 5.10.4.2.3.4)

Note 1 to entry: See 5.10.4.2.3.5.

**3.1.247****TTIU bit cell**

group of ten UIs that encode a single bit of BMC (see 3.1.20) information

**3.1.248****unit interval****UI**

time period that has the normalized, dimensionless, nominal duration of a symbol (see SAS-3)

EXAMPLE - Examples of unit intervals are:  $666.\overline{6}$  ps at 1.5 Gbit/s,  $333.\overline{3}$  ps at 3 Gbit/s,  $166.\overline{6}$  ps at 6 Gbit/s, and  $83.\overline{3}$  ps at 12 Gbit/s.

Note 1 to entry: See SAS-3.

**3.1.249****valid character**

character that is a control character (see 3.1.40) or a data character (see 3.1.46)

**3.1.250****valid dword**

dword that is a data dword (see 3.1.47) or a primitive (see 3.1.155)

**3.1.251****virtual phy**

phy (see 3.1.143) that interfaces with a vendor specific interface to another virtual phy inside the same device

Note 1 to entry: See 4.1.2.

**3.1.252****wide link**

group of physical links that attaches a wide port to another wide port

Note 1 to entry: See 4.1.4.

**3.1.253****wide port**

port that contains more than one phy

Note 1 to entry: See 4.1.4.

**3.1.254****word**

sequence of 16 contiguous bits considered as an unit

**3.1.255****wrapping counter**

counter that wraps back to zero after reaching its maximum value

**3.1.256****write data**

data transferred from the SCSI application client's data-out buffer to the SCSI device server, as requested by the Request Data-Out transport protocol service (see 9.2.1.8)

**3.1.257****zone group**

set of phys in a ZPSDS (see 3.1.260) that all have the same access permission

Note 1 to entry: See 4.8.

**3.1.258****zone manager**

entity responsible for configuring a ZPSDS (see 3.1.260)

Note 1 to entry: See 4.8.1.

**3.1.259****zone permission table**

table that defines access permission between the zone group of a source phy and the zone group of the destination phy

Note 1 to entry: See 4.8.3.3.

**3.1.260****zoned portion of a service delivery subsystem****ZPSDS**

group of zoning expander devices (see 3.1.262) that cooperate to control access between phys; the ZPSDS may include all or part of a service delivery subsystem (see 3.1.203)

Note 1 to entry: See 4.8.

**3.1.261****zoning expander current values**

current zone permission table (see 3.1.259) and zone phy information in a zoning expander device (see 3.1.262)

Note 1 to entry: See 4.8.6.

**3.1.262****zoning expander device**

expander device (see 3.1.68) that supports zoning

Note 1 to entry: See 4.8.

**3.1.263****zoning expander phy**

expander phy in a zoning expander device (see 3.1.262)

**3.1.264****zoning expander shadow values**

shadow zone permission table (see 3.1.259) and zone phy information in a zoning expander device, which are changed by SMP zone configuration functions (see 3.1.211) but do not become active until the activate step (see 4.8.6.4) is performed

Note 1 to entry: See 4.8.6.

## 3.2 Symbols and abbreviations

### 3.2.1 Abbreviations

See Annex L for abbreviations of standards bodies (e.g., ISO).

Abbreviations used in this standard

| Abbreviation | Meaning                                                                |
|--------------|------------------------------------------------------------------------|
| ACA          | auto contingent allegiance (see SAM-5)                                 |
| ACK          | acknowledge (see 6.2.7.1)                                              |
| AIP          | arbitration in progress (see 6.2.6.1)                                  |
| ATA          | AT attachment (see 3.1.15)                                             |
| ATAPI        | AT attachment packet interface                                         |
| ATA8-AAM     | AT Attachment - 8 ATA/ATAPI Architecture Model standard (see clause 2) |
| ACS-2        | ATA/ATAPI Command Set-2 standard (see clause 2)                        |
| AWT          | arbitration wait time                                                  |
| BCH          | Bose, Chaudhuri and Hocquenghem code (see 4.2.5)                       |
| BIST         | built in self test                                                     |
| BMC          | bi-phase mark code (see 3.1.20)                                        |
| BPP          | Broadcast propagation processor (see 3.1.22)                           |
| CDB          | command descriptor block (see 3.1.29)                                  |
| CJTPAT       | compliant jitter tolerance pattern (see 3.1.31)                        |
| CRC          | cyclic redundancy check (see 3.1.42)                                   |
| CRN          | command reference number (see SAM-5)                                   |
| D.C.         | direct current (see 3.1.55)                                            |
| ECM          | expander connection manager (see 3.1.66)                               |
| ECR          | expander connection router (see 3.1.67)                                |
| EMI          | electromagnetic interference                                           |
| EOAF         | end of address frame (see 6.2.6.6)                                     |
| EOF          | end of frame (see 6.2.7.4)                                             |
| FIS          | frame information structure (see 3.1.80)                               |
| G1           | generation 1 physical link rate (i.e., 1.5 Gbit/s)                     |
| G2           | generation 2 physical link rate (i.e., 3 Gbit/s)                       |
| G3           | generation 3 physical link rate (i.e., 6 Gbit/s)                       |
| G4           | generation 4 physical link rate (i.e., 12 Gbit/s)                      |
| Gbit/s       | gigabits per second (i.e., $10^9$ bits per second)                     |
| ID           | identifier                                                             |
| JTPAT        | jitter tolerance pattern (see 3.1.104)                                 |
| LED          | light-emitting diode                                                   |
| LSB          | least significant bit (see 3.1.105)                                    |
| LUN          | logical unit number (see 3.1.116)                                      |
| MA           | management application layer (see 9.4)                                 |
| MRTT         | maximum receiver training time (see table 70)                          |

| Abbreviation | Meaning                                                                                          |
|--------------|--------------------------------------------------------------------------------------------------|
| MSB          | most significant bit (see 3.1.120)                                                               |
| MT           | SMP transport layer state machines (see 8.4.5)                                                   |
| MTTT         | maximum transmitter training time (see table 70)                                                 |
| MTWT         | maximum Train_Rx-SNW window time (see table 70)                                                  |
| MTXT         | maximum Train_Tx-SNW window time (see table 70)                                                  |
| N/A          | not applicable                                                                                   |
| NAA          | network address authority (see 4.2)                                                              |
| NAK          | negative acknowledge (see 6.2.7.6)                                                               |
| NVRAM        | non-volatile random-access memory                                                                |
| OOB          | out-of-band                                                                                      |
| OOBI         | out-of-band interval                                                                             |
| OUI          | organizationally unique identifier (i.e., company identifier)                                    |
| PL           | port layer state machines (see 7.2)                                                              |
| PTT          | phy layer transmitter training state machines (see 5.14)                                         |
| RCDT         | rate change delay time (see table 70)                                                            |
| RD           | running disparity (see 3.1.168)                                                                  |
| RRDY         | receiver ready (see 6.2.7.7)                                                                     |
| Rx           | receiver device (see 3.1.161)                                                                    |
| SA           | SCSI application (see 9.2)                                                                       |
| SAM-5        | SCSI Architecture Model - 5 standard (see clause 2)                                              |
| SA_PC        | SCSI application layer power condition state machine (see 9.2.10.2)                              |
| SAS          | Serial Attached SCSI (see 3.1.200)                                                               |
| SATA         | Serial ATA (see 3.1.198) or the Serial ATA 3.1 specification (see clause 2)                      |
| SBC-3        | SCSI Block Commands - 3 standard (see clause 2)                                                  |
| SCSI         | Small Computer System Interface family of standards                                              |
| SL           | link layer for SAS phys state machines (see 6.16)                                                |
| SL_IR        | link layer identification and hard reset state machines (see 6.10)                               |
| SL_CC        | connection control state machine (see 6.16.4)                                                    |
| SL_P         | SL_P_C or SL_P_S                                                                                 |
| SL_P_C       | link layer power consumer device state machine (see 6.12.5)                                      |
| SL_P_S       | link layer power source device state machine (see 6.12.4)                                        |
| SL_RA        | connection control state machine (see 6.16.3)                                                    |
| SMP          | Serial Management Protocol (see 3.1.201), or link layer for SMP phys state machines (see 6.20.5) |
| SNLT         | speed negotiation lock time (see table 70)                                                       |
| SNTT         | speed negotiation transmit time (see table 70)                                                   |
| SNW          | speed negotiation window (see 3.1.214)                                                           |
| SNW-1        | speed negotiation window for 1.5 Gbit/s without training (see 5.10.4.2.3.2)                      |
| SNW-2        | speed negotiation window for 3 Gbit/s without training (see 5.10.4.2.3.2)                        |
| SNW-3        | speed negotiation window negotiating physical link rates with training (see 5.10.4.2.3.3)        |
| SNWT         | speed negotiation window time (see table 70)                                                     |
| SOAF         | start of address frame (see 6.2.6.18)                                                            |

| Abbreviation | Meaning                                                                                            |
|--------------|----------------------------------------------------------------------------------------------------|
| SOF          | start of frame (see 6.2.7.8)                                                                       |
| SP           | phy layer state machine (see 5.12)                                                                 |
| SP_DWS       | phy layer dword synchronization state machine (see 5.13)                                           |
| SPC-4        | SCSI Primary Commands - 4 standard (see clause 2)                                                  |
| SSP          | Serial SCSI Protocol (see 3.1.202), or link layer for SSP phys state machines (see 6.18.9)         |
| ST           | SSP transport layer state machines (see 8.2.6)                                                     |
| STP          | Serial ATA Tunneled Protocol (see 3.1.199), or link layer for STP phys state machines (see 6.19.8) |
| TLT          | training lock time (see table 70)                                                                  |
| TT           | STP transport layer state machines (see 8.3.3)                                                     |
| TTIU         | transmitter training information unit (see 3.1.246)                                                |
| Tx           | transmitter device (see 3.1.241)                                                                   |
| UI           | unit interval (see 3.1.248)                                                                        |
| VPD          | vital product data (see 9.2.11)                                                                    |
| XL           | link layer for expander phys state machine (see 6.17)                                              |
| ZPSDS        | zoned portion of a service delivery subsystem (see 3.1.260)                                        |

### 3.2.2 Units

Units used in this standard:

| Units | Meaning                               |
|-------|---------------------------------------|
| µs    | microsecond (i.e., $10^{-6}$ seconds) |
| m     | meter                                 |
| ms    | millisecond (i.e., $10^{-3}$ seconds) |
| ns    | nanosecond (i.e., $10^{-9}$ seconds)  |
| s     | second (unit of time)                 |
| V     | volt                                  |

### 3.2.3 Symbols

Symbols used in this standard:

| Symbols  | Meaning                                                                                                                                 |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Kxx.y    | control character (see 3.1.40)                                                                                                          |
| Dxx.y    | data character (see 3.1.46)                                                                                                             |
| ZP[s, d] | zone permission bit for a source zone group (i.e., s) and a destination zone group (i.e., d) in the zone permission table (see 4.8.3.3) |
| ®        | registered trademark                                                                                                                    |

### 3.2.4 Mathematical operators

Mathematical operators used in this standard:

| Mathematical Operators | Meaning                                   |
|------------------------|-------------------------------------------|
| NE                     | not equal                                 |
| XOR                    | exclusive logical OR                      |
| ^                      | exclusive logical OR                      |
| <                      | less than                                 |
| ≤                      | less than or equal to                     |
| >                      | greater than                              |
| ≥                      | greater than or equal to                  |
| +                      | plus                                      |
| -                      | minus                                     |
| ±                      | plus or minus                             |
| ×                      | multiplied by                             |
| /                      | divided by                                |
| v                      | the absolute value (i.e., magnitude) of v |
| ~                      | approximately equal to                    |
| ∈                      | set membership                            |

### 3.3 Keywords

#### 3.3.1

##### **invalid**

keyword used to describe an illegal or unsupported bit, byte, word, field or code value

Note 1 to entry: Receipt of an invalid bit, byte, word, field or code value shall be reported as an error.

#### 3.3.2

##### **mandatory**

keyword indicating an item that is required to be implemented as defined in this standard

#### 3.3.3

##### **may**

keyword that indicates flexibility of choice with no implied preference (equivalent to “may or may not”)

#### 3.3.4

##### **may not**

keywords that indicate flexibility of choice with no implied preference (equivalent to “may or may not”)

#### 3.3.5

##### **obsolete**

keyword indicating that an item was defined in prior standards but has been removed from this standard

**3.3.6****optional**

keyword that describes features that are not required to be implemented by this standard

Note 1 to entry: If any optional feature defined in this standard is implemented, then it shall be implemented as defined in this standard.

**3.3.7****reserved**

keyword referring to bits, bytes, words, fields, and code values that are set aside for future standardization

Note 1 to entry: A reserved bit, byte, word or field shall be set to zero, or in accordance with a future extension to this standard.

Note 2 to entry: Recipients are not required to check reserved bits, bytes, words or fields for zero values; receipt of reserved code values in defined fields shall be reported as an error.

**3.3.8****restricted**

keyword referring to bits, bytes, words, and fields that are set aside for other identified standardization purposes

Note 1 to entry: A restricted bit, byte, word, or field shall be treated as a reserved bit, byte, word or field in the context where the restricted designation appears.

**3.3.9****shall**

keyword indicating a mandatory requirement

Note 1 to entry: Designers are required to implement all such mandatory requirements to ensure interoperability with other products that conform to this standard.

**3.3.10****should**

keyword indicating flexibility of choice with a strongly preferred alternative (equivalent to "is strongly recommended")

**3.3.11****vendor specific**

something (e.g., a bit, field, or code value) that is not defined by this standard

Note 1 to entry: Specification of the referenced item is determined by the SCSI device vendor and may be used differently in various implementations

**3.4 Editorial conventions**

Certain words and terms used in this standard have a specific meaning beyond the normal English meaning. These words and terms are defined either in clause 3 or in the text where they first appear.

Names of signals, address frames, primitives and primitive sequences, SMP functions, state machines, SCSI and ATA commands, SCSI statuses, SCSI sense keys, and SCSI additional sense codes are in all uppercase (e.g., REQUEST SENSE command).

Names of messages, requests, confirmations, indications, responses, event notifications, timers, SCSI diagnostic pages, SCSI mode pages, and SCSI log pages are in mixed case (e.g., Disconnect-Reconnect mode page).

Names of fields are in small uppercase (e.g., DESTINATION SAS ADDRESS). Normal case is used when the contents of a field are being discussed. Fields containing only one bit are usually referred to as the NAME bit instead of the NAME field.



Names of procedure calls are identified by a name in bold type (e.g., **Execute Command**). For more information on procedure calls see 3.9.

Lists sequenced by lowercase or uppercase letters show no ordering relationship between the listed items.

EXAMPLE 1 -The following list shows no relationship between the named items:

- a) red, specifically one of the following colors:
  - A) crimson; or
  - B) amber;
- b) blue; or
- c) green.

Lists sequenced by numbers show an ordering relationship between the listed items.

EXAMPLE 2 -The following list shows an ordered relationship between the named items:

- 1) top;
- 2) middle; and
- 3) bottom.

Lists are associated with an introductory paragraph or phrase, and are numbered relative to that paragraph or phrase (i.e., all lists begin with an a) or 1) entry).

If a conflict arises between text, tables, or figures, the order of precedence to resolve the conflicts is text, then tables, and finally figures. Not all tables or figures are fully described in the text. Tables show data format and values.

Notes and example do not constitute any requirements for implementers and notes are numbered consecutively throughout this standard.

## 3.5 Numeric and character conventions

### 3.5.1 Numeric conventions

A binary number is represented in this standard by any sequence of digits consisting of only the Arabic numerals 0 and 1 immediately followed by a lower-case b (e.g., 0101b). Underscores or spaces may be included between characters in binary number representations to increase readability or delineate field boundaries (e.g., 00010101 11001110b, 00010101\_11001110b, 0 0101 1010b, or 0\_0101\_1010b).

A hexadecimal number is represented in this standard by any sequence of digits consisting of only the Arabic numerals 0 to 9 and/or the upper-case English letters A to F immediately followed by a lower-case h (e.g., FA23h). Underscores or spaces may be included between characters in hexadecimal number representations to increase readability or delineate field boundaries (e.g., B FD8C FA23h or B\_FD8C\_FA23h).

A decimal number is represented in this standard by any sequence of digits consisting of only the Arabic numerals 0 to 9 not immediately followed by a lower-case b or lower-case h (e.g., 25).

A range of numeric values is represented in this standard in the form "a to z", where a is the first value included in the range, all values between a and z are included in the range, and z is the last value included in the range (e.g., the representation "0h to 3h" includes the values 0h, 1h, 2h, and 3h).

This standard uses the following conventions for representing decimal numbers:

- a) the decimal separator (i.e., separating the integer and fractional portions of the number) is a period;
- b) the thousands separator (i.e., separating groups of three digits in a portion of the number) is a space;
- c) the thousands separator is used in both the integer portion and the fraction portion of a number; and
- d) the decimal representation for a year is 1999 not 1 999.

Table 1 shows some examples of decimal numbers using various numbering conventions.

**Table 1 — Numbering conventions**

| French       | English      | This standard |
|--------------|--------------|---------------|
| 0,6          | 0.6          | 0.6           |
| 3,141 592 65 | 3.14159265   | 3.141 592 65  |
| 1 000        | 1,000        | 1 000         |
| 1 323 462,95 | 1,323,462.95 | 1 323 462.95  |

A decimal number represented in this standard with an overline over one or more digits following the decimal point is a number where the overlined digits are infinitely repeating (e.g., 666. $\overline{6}$  means 666.666 666... or 666  $\frac{2}{3}$ , and 12. $\overline{142\ 857}$  means 12.142 857 142 857... or 12  $\frac{1}{7}$ ).

### 3.5.2 Units of measure

This standard represents values using both decimal units of measure and binary units of measure. Values are represented by the following formats:

- a) for values based on decimal units of measure:
  - 1) numerical value (e.g., 100);
  - 2) space; and
  - 3) prefix symbol and unit:
    - 1) decimal prefix symbol (e.g., M) (see table 2); and
    - 2) unit abbreviation (e.g., B);

and
- b) for values based on binary units of measure:
  - 1) numerical value (e.g., 1 024);
  - 2) space; and
  - 3) prefix symbol and unit:
    - 1) binary prefix symbol (e.g., Gi) (see table 2); and
    - 2) unit abbreviation (e.g., b).

Table 2 compares the prefix, symbols, and power of the binary and decimal units.

**Table 2 — Comparison of decimal prefixes and binary prefixes**

| Decimal     |               |                 | Binary      |               |                |
|-------------|---------------|-----------------|-------------|---------------|----------------|
| Prefix name | Prefix symbol | Power (base-10) | Prefix name | Prefix symbol | Power (base-2) |
| kilo        | k             | $10^3$          | kibi        | Ki            | $2^{10}$       |
| mega        | M             | $10^6$          | mebi        | Mi            | $2^{20}$       |
| giga        | G             | $10^9$          | gibi        | Gi            | $2^{30}$       |
| tera        | T             | $10^{12}$       | tebi        | Ti            | $2^{40}$       |
| peta        | P             | $10^{15}$       | pebi        | Pi            | $2^{50}$       |
| exa         | E             | $10^{18}$       | exbi        | Ei            | $2^{60}$       |
| zetta       | Z             | $10^{21}$       | zebi        | Zi            | $2^{70}$       |
| yotta       | Y             | $10^{24}$       | yobi        | Yi            | $2^{80}$       |

### 3.5.3 Byte encoded character strings conventions

When this standard requires one or more bytes to contain specific encoded characters, the specific characters are enclosed in single quotation marks. The single quotation marks identify the start and end of the characters that are required to be encoded but are not themselves to be encoded. The characters that are to be encoded are shown in the case that is to be encoded.

An ASCII space character (i.e., 20h) may be represented in a string by the character '¬' (e.g., 'SCSI¬device').

The encoded characters and the single quotation marks that enclose them are preceded by text that specifies the character encoding methodology and the number of characters required to be encoded.

EXAMPLE - Using the notation described in this subclause, stating that eleven ASCII characters 'SCSI device' are to be encoded is the same as writing out the following sequence of byte values: 53h 43h 53h 49h 20h 64h 65h 76h 69h 63h 65h.

## 3.6 UML notation conventions

### 3.6.1 Notation conventions overview

This standard uses class diagrams and object diagrams with notation that is based on the Unified Modeling Language (UML).

See 3.6.3 for the conventions used for class diagrams.

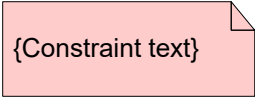
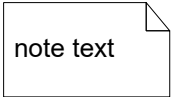
See 3.6.4 for the conventions used for object diagrams.

### 3.6.2 Constraint and note conventions

Class diagrams and object diagrams may include constraints, which specify requirements, and notes, which are informative.

Table 3 shows the notation used for constraints and notes.

**Table 3 — Constraint and note notation**

| Notation                                                                          | Description                                                                                                                                        |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
|  | The presence of the curly brackets (i.e., {}) defines constraint that is a normative requirement. An example of a constraint is shown in figure 5. |
|  | The absence of curly brackets defines a note that is informative. An example of a note is shown in figure 6.                                       |

### 3.6.3 Class diagram conventions

Table 4 shows the notation used for classes in class diagrams.

**Table 4 — Class diagram notation for classes**

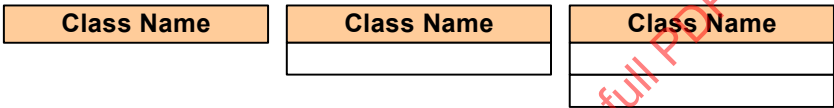
| Notation                                                                             | Description                               |
|--------------------------------------------------------------------------------------|-------------------------------------------|
|  | A class with no attributes or operations. |

Table 4 — Class diagram notation for classes

| Notation                                                                                                                                                                                                              | Description       |                   |                |                |                                            |                                                                                          |  |  |                                            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------|----------------|----------------|--------------------------------------------|------------------------------------------------------------------------------------------|--|--|--------------------------------------------|
| <table><tr><td><b>Class Name</b></td><td><b>Class Name</b></td></tr><tr><td>Attribute01[1]</td><td>Attribute01[1]</td></tr><tr><td>Attribute02[1]</td><td>Attribute02[1]</td></tr><tr><td></td><td></td></tr></table> | <b>Class Name</b> | <b>Class Name</b> | Attribute01[1] | Attribute01[1] | Attribute02[1]                             | Attribute02[1]                                                                           |  |  | A class with attributes and no operations. |
| <b>Class Name</b>                                                                                                                                                                                                     | <b>Class Name</b> |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Attribute01[1]                                                                                                                                                                                                        | Attribute01[1]    |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Attribute02[1]                                                                                                                                                                                                        | Attribute02[1]    |                   |                |                |                                            |                                                                                          |  |  |                                            |
|                                                                                                                                                                                                                       |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| <table><tr><td><b>Class Name</b></td></tr><tr><td></td></tr><tr><td>Operation01()</td></tr><tr><td>Operation02()</td></tr></table>                                                                                    | <b>Class Name</b> |                   | Operation01()  | Operation02()  | A class with operations and no attributes. |                                                                                          |  |  |                                            |
| <b>Class Name</b>                                                                                                                                                                                                     |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
|                                                                                                                                                                                                                       |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Operation01()                                                                                                                                                                                                         |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Operation02()                                                                                                                                                                                                         |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| <table><tr><td><b>Class Name</b></td></tr><tr><td>Attribute01[1]</td></tr><tr><td>Attribute02[1]</td></tr><tr><td>Operation01()</td></tr><tr><td>Operation02()</td></tr></table>                                      | <b>Class Name</b> | Attribute01[1]    | Attribute02[1] | Operation01()  | Operation02()                              | A class with attributes and operations.                                                  |  |  |                                            |
| <b>Class Name</b>                                                                                                                                                                                                     |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Attribute01[1]                                                                                                                                                                                                        |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Attribute02[1]                                                                                                                                                                                                        |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Operation01()                                                                                                                                                                                                         |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Operation02()                                                                                                                                                                                                         |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| <table><tr><td><b>Class Name</b></td></tr><tr><td>Attribute01[1..*]</td></tr><tr><td>Attribute02[1]</td></tr><tr><td>Operation01()</td></tr><tr><td>Operation02()</td></tr></table>                                   | <b>Class Name</b> | Attribute01[1..*] | Attribute02[1] | Operation01()  | Operation02()                              | A class with attributes that have a specified multiplicity (see table 5) and operations. |  |  |                                            |
| <b>Class Name</b>                                                                                                                                                                                                     |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Attribute01[1..*]                                                                                                                                                                                                     |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Attribute02[1]                                                                                                                                                                                                        |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Operation01()                                                                                                                                                                                                         |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |
| Operation02()                                                                                                                                                                                                         |                   |                   |                |                |                                            |                                                                                          |  |  |                                            |

Table 5 shows the notation used to indicate multiplicity of classes and attributes in class diagrams.

Table 5 — Multiplicity notation

| Notation <sup>a</sup>                                                         | Description                                                                   |
|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| not specified                                                                 | The number of instances of a class or attribute is not specified.             |
| 1                                                                             | One instance of the class or attribute exists.                                |
| 0..*                                                                          | Zero or more instances of the class or attribute exist.                       |
| 1..*                                                                          | One or more instances of the class or attribute exist.                        |
| 0..1                                                                          | Zero or one instance of the class or attribute exists.                        |
| n..m                                                                          | n to m instances of the class or attribute exist (e.g., 2..8).                |
| x, n..m                                                                       | Multiple disjoint instances of the class or attribute exist (e.g., 2, 8..15). |
| <sup>a</sup> See figure 4 and figure 5 for examples of multiplicity notation. |                                                                               |

Table 6 shows the notation used to denote association (i.e., “knows about”) relationships between classes.

Unless the two classes in an association relationship also have an aggregation relationship, association relationships have multiplicity notation (see table 5) at each end of the relationship line.

**Table 6 — Class diagram notation for associations**

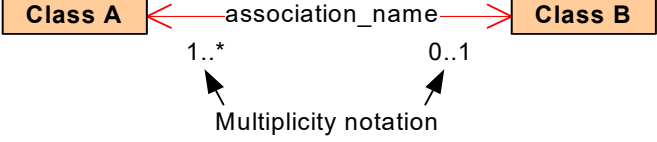
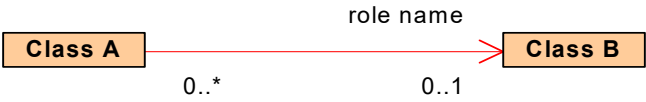
| Notation                                                                          | Description                                                                                                                                                        |
|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Class A knows about Class B (i.e., read as “Class A association_name Class B”) and Class B knows about Class A (i.e., read as “Class B association name Class A”). |
|  | Class B knows about Class A (i.e., read as “Class B knows about Class A”) but Class A does not know about Class B.                                                 |
|  | Class A knows about Class B (i.e., read as “Class A uses the role name attribute of Class B”) but Class B does not know about Class A.                             |
| Note - The use of role names and association names are optional.                  |                                                                                                                                                                    |

Figure 4 shows examples of association relationships between classes.

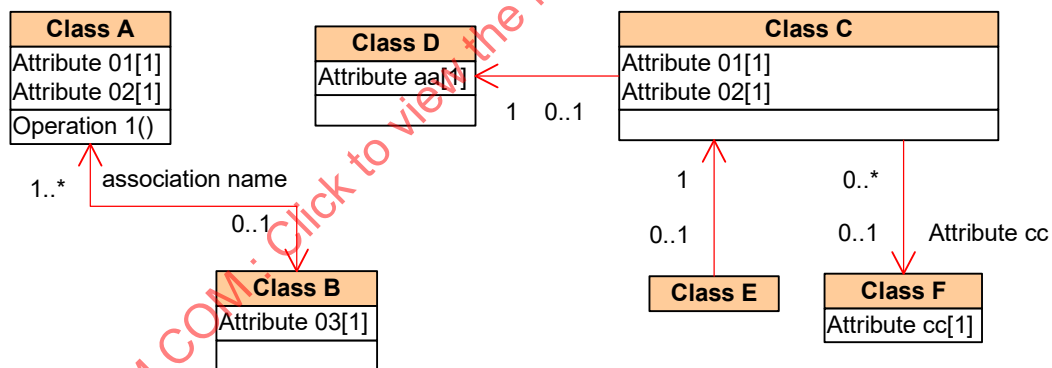


**Figure 4 — Examples of association relationships in class diagrams**

Table 7 shows the notation used to denote aggregation (i.e., “is a part of” or “contains”) relationships between classes. The aggregation relationship is a specific type of association (see table 6) and always include multiplicity notation (see table 5) at each end of the relationship line.

**Table 7 — Class diagram notation for aggregations**

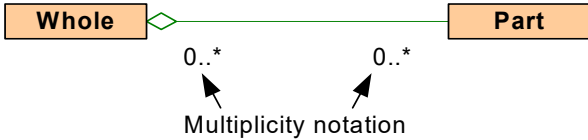
| Notation                                                                          | Description                                                                                                                                                                                   |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | The Part class is part of the Whole class and may continue to exist even if the Whole class is removed (i.e., read as “the whole contains the part”).                                         |
|  | The Part class is part of the Whole class, shall only belong to one Whole class, and shall not continue to exist if the Whole class is removed (i.e., read as “the whole contains the part”). |

Figure 5 shows examples of aggregation relationships between classes.

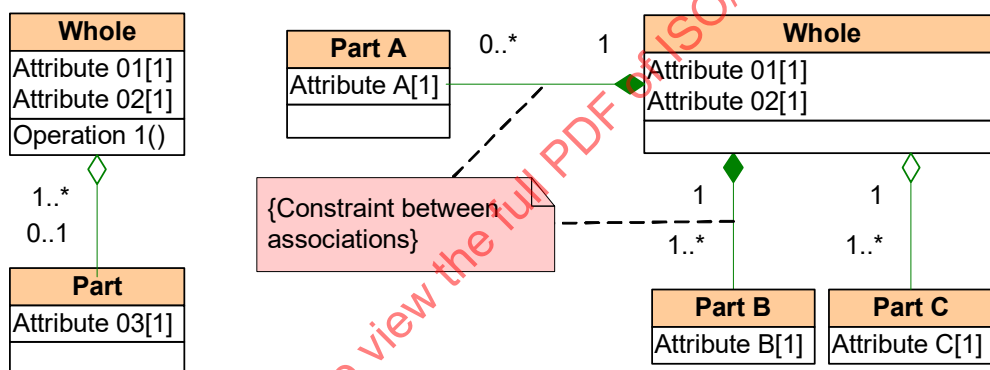


**Figure 5 — Examples of aggregation relationships in class diagrams**

Table 8 shows the notation used to denote generalization (i.e., “is a kind of”) relationships between classes.

**Table 8 — Class diagram notation for generalizations**

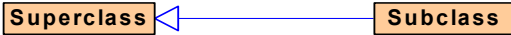
| Notation                                                                            | Description                                                                                                                                                |
|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Subclass is a kind of superclass. A subclass shares all the attributes and operations of the superclass (i.e., the subclass inherits from the superclass). |



Figure 6 shows examples of generalization relationships between classes.

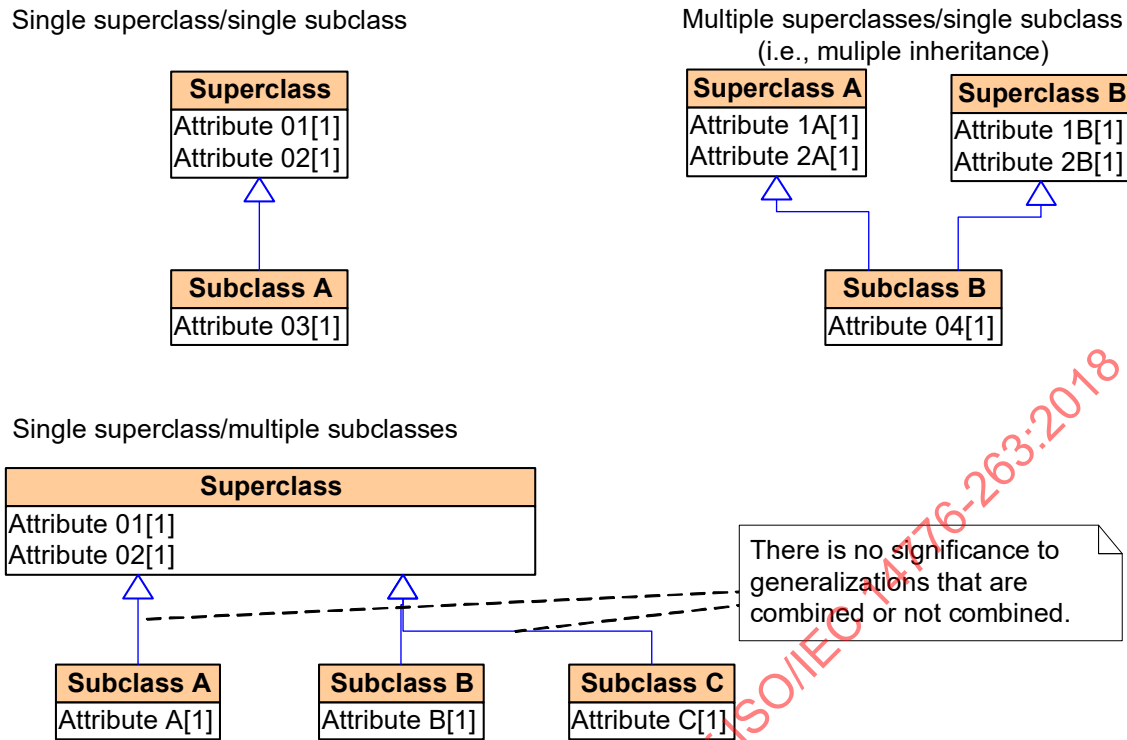


Figure 6 — Example of generalization relationships in class diagrams

Table 9 shows the notation used to denote dependency (i.e., “depends on”) relationships between classes.

Table 9 — Class diagram notation for dependency

| Notation | Description                                                                           |
|----------|---------------------------------------------------------------------------------------|
|          | <p>Class A depends on class B. A change in class B may cause a change in class A.</p> |

Figure 7 shows an example of a dependency relationship between classes.

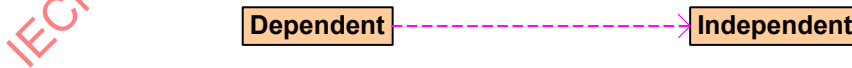


Figure 7 — Example of a dependency relationship in class diagrams

### 3.6.4 Object diagram conventions

Table 10 shows the notation used for objects in object diagrams.

**Table 10 — Object diagram notation for objects**

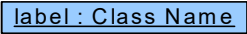
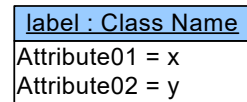
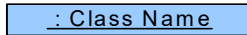
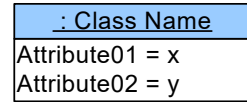
| Notation                                                                           | Description                                          |
|------------------------------------------------------------------------------------|------------------------------------------------------|
|   | Notation for a named object with no attributes.      |
|   | Notation for a named object with attributes.         |
|   | Notation for an anonymous object with no attributes. |
|  | Notation for an anonymous object with attributes.    |

Table 11 shows the notation used to denote link relationships between objects.

**Table 11 — Object diagram notation for link**

| Notation                                                                            | Description                                                  |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------|
|  | An instance of an association between object A and object B. |

Figure 8 shows examples of a link relationships between objects.

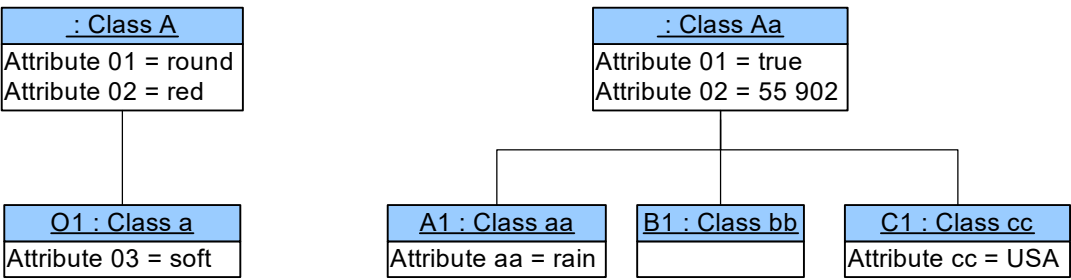


Figure 8 — Examples of link relationships for object diagrams

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### 3.7 State machine conventions

#### 3.7.1 State machine conventions overview

Figure 9 shows how state machines are described. See 4.3 for a summary of the state machines in this standard.

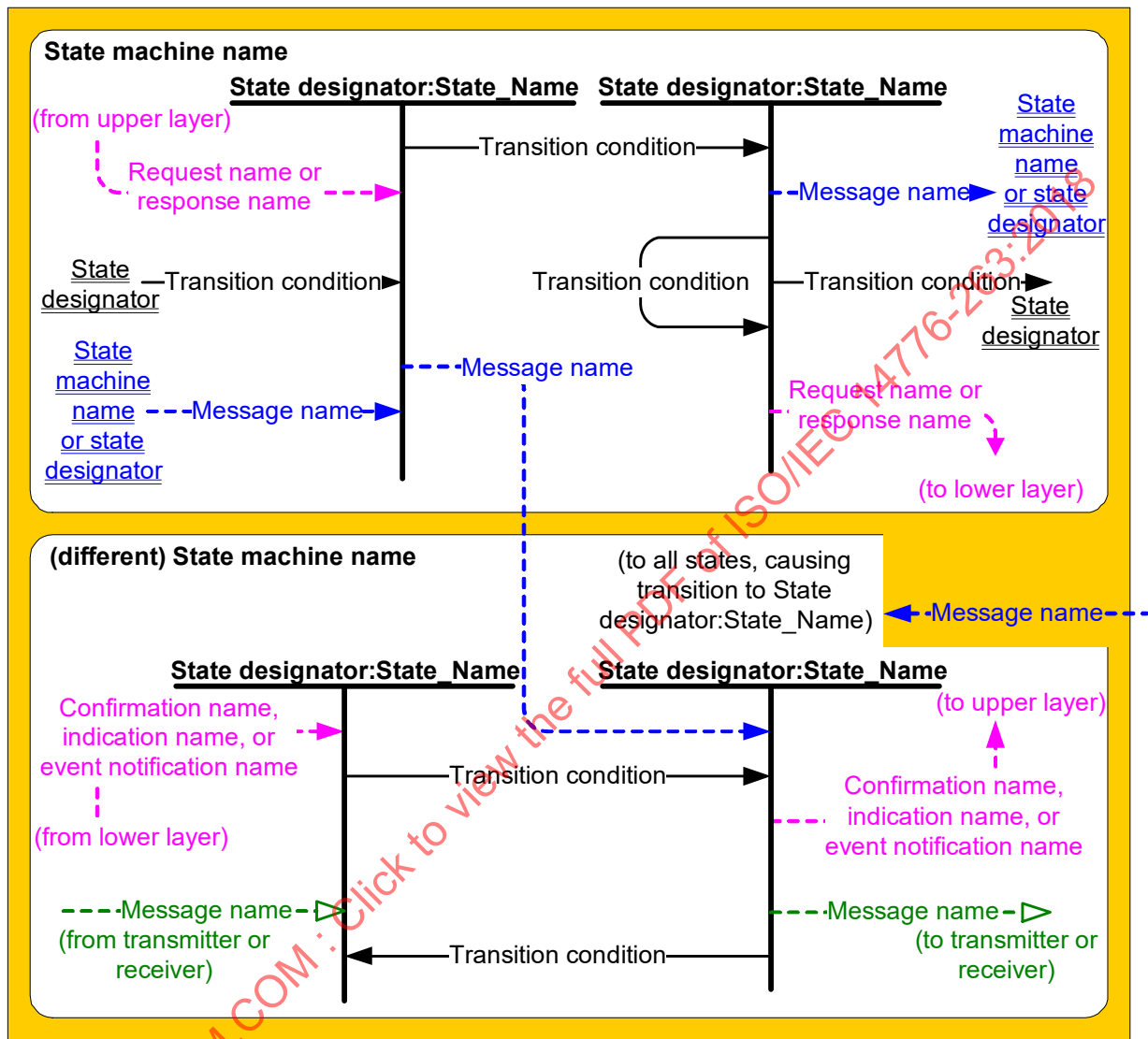


Figure 9 — State machine conventions

When multiple state machines are present in a figure, they are enclosed in boxes with rounded corners.

Each state machine is identified by a state machine name. In state machines with one state, the state machine is identified by a state designer. In state machines with multiple states, each state is identified by a state designer and a state name. The state designer (e.g., SL1) is unique among all state machines in this standard. The state name (e.g., Idle) is a brief description of the primary action taken during the state, and the same state name may be used by other state machines. Actions taken while in each state are described in the state description text.

### 3.7.2 Transitions

Transitions between states are shown with solid lines, with an arrow pointing to the destination state. A transition may be labeled with a transition condition label (i.e., a brief description of the event or condition that causes the transition to occur).

If the state transition in one figure goes to or comes from a state machine or state in a different figure, then the transition is shown going to or coming from a state machine name or a state designator label with double underlines.

The conditions and actions are described fully in the transition description text. In case of a conflict between a figure and the text, the text shall take precedence.

Upon entry into a state, all actions to be processed in that state are processed. If a state is re-entered from itself, all actions to be processed in the state are processed again. A state may be entered and exited in zero time if the conditions for exiting the state are valid upon entry into the state. Transitions between states are instantaneous.

### 3.7.3 Messages, requests, indications, confirmations, responses, and event notifications

Messages passed between state machines are shown with dashed lines labeled with a message name. When messages are passed between state machines within the same layer of the protocol, they are identified by either:

- a) a dashed line to or from a state machine name label with double underlines and/or state name label with double underlines, if the destination is in a different figure from the source;
- b) a dashed line to or from a state in another state machine in the same figure; or
- c) a dashed line from a state machine name label with double underlines to a "(to all states)" label, if the destination is every state in the state machine.

The meaning of each message is described in the state description text.

Requests, indications, confirmations, responses, and event notifications are shown with curved dashed lines originating from or going toward the top or bottom of the figure. Each request, indication, confirmation, response, and event notification is labeled. The meaning of each request, indication, confirmation, response, and event notification is described in the state description text.

Messages with unfilled arrowheads are passed to or from the state machine's transmitter or receiver, not shown in the state machine figures, and are directly related to data being transmitted on or received from the physical link.

The state machine description text for each state wholly defines the messages sent while the state machine is in that state. If a state is repeatedly sending a message transitions to another state, then that state stops sending that message before making the transition.

### 3.7.4 State machine counters, timers, and variables

State machines may contain counters, timers, and variables that affect the operation of the state machine.

The following properties apply to counters, timers, and variables:

- a) their scope is the state machine itself;
- b) they are created and deleted within the state machines with which they are associated;
- c) their initialization and modification is specified in the state descriptions and the transition descriptions; and
- d) their current values may be used to determine the behavior of a state and select the transition out of a state.

State machine timers may continue to run while a state machine is in a given state, and a timer may cause a state transition upon reaching a defined threshold value (e.g., zero for a timer that counts down).

### 3.7.5 State machine arguments

State machines may contain one or more arguments received in a message or confirmation as state machine arguments. The following properties apply to state machine arguments:

- the state machine that sends an argument owns that argument's value;
- the state machine that receives an argument shall not modify that argument's value;
- the state machine that sends an argument may resend that argument with a different value;
- the scope of a state machine argument is the state machine itself; and
- state machine argument usage is described in the state descriptions and the transition descriptions.

### 3.8 Bit and byte ordering

In a field in a table consisting of more than one bit that contains a single value (e.g., a number), the least significant bit (LSB) is shown on the right and the most significant bit (MSB) is shown on the left (e.g., in a byte, bit 7 is the MSB and is shown on the left and bit 0 is the LSB and is shown on the right). The MSB and LSB are not labeled if the field consists of 8 or fewer bits.

In a field in a table consisting of more than one byte that contains a single value (e.g., a number), the byte containing the MSB is stored at the lowest address and the byte containing the LSB is stored at the highest address (i.e., big-endian byte ordering). The MSB and LSB are labeled.

NOTE 1 - SATA numbers bits within fields the same as this standard, but uses little-endian byte ordering.

In a field in a table consisting of more than one byte that contains multiple fields each with their own values (e.g., a descriptor), there is no MSB and LSB of the field itself and thus there are no MSB and LSB labels. Each individual field has an MSB and LSB, but they are not labeled.

In a field containing a text string (e.g., ASCII or UTF-8), the MSB label is the MSB of the first character, and the LSB label is the LSB of the last character.

Multiple byte fields are represented by only two rows, where a non-sequentially increasing byte number indicates the presence of additional bytes.

A data dword consists of 32 bits. Table 12 shows a data dword containing a single value, where the MSB is on the left in bit 31, and the LSB is on the right in bit 0.

**Table 12 — Data dword containing a value**

|     |    |    |    |    |    |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |    |   |   |   |   |   |     |   |   |   |   |
|-----|----|----|----|----|----|----|----|----|-------|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|-----|---|---|---|---|
| 31  | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22    | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4   | 3 | 2 | 1 | 0 |
| MSB |    |    |    |    |    |    |    |    | Value |    |    |    |    |    |    |    |    |    |    |    |    |   |   |   |   |   | LSB |   |   |   |   |

Table 13 shows a data dword containing four one-byte fields, where byte 0 (the first byte) is on the left and byte 3 (the fourth byte) is on the right. Each byte has an MSB on the left and an LSB on the right.

**Table 13 — Data dword containing four one-byte fields**

|                                          |    |    |    |    |    |    |    |                                           |    |    |    |    |    |    |    |                                          |    |    |    |    |    |   |   |                                           |   |   |   |   |   |   |   |
|------------------------------------------|----|----|----|----|----|----|----|-------------------------------------------|----|----|----|----|----|----|----|------------------------------------------|----|----|----|----|----|---|---|-------------------------------------------|---|---|---|---|---|---|---|
| 31                                       | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23                                        | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15                                       | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7                                         | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| MSB      Byte 0<br>(First byte)      LSB |    |    |    |    |    |    |    | MSB      Byte 1<br>(Second byte)      LSB |    |    |    |    |    |    |    | MSB      Byte 2<br>(Third byte)      LSB |    |    |    |    |    |   |   | MSB      Byte 3<br>(Fourth byte)      LSB |   |   |   |   |   |   |   |

### 3.9 Notation for procedures and functions

In this standard, the model for functional interfaces between objects is the callable procedure. Such interfaces are specified using the following notation:

**[Result =] Procedure Name (IN ([input-1] [,input-2] ...), OUT ([output-1] [,output-2] ...))**

where:

|                               |                                                                                                  |
|-------------------------------|--------------------------------------------------------------------------------------------------|
| Result                        | A single value representing the outcome of the procedure or function.                            |
| Procedure Name                | A descriptive name for the function to be performed.                                             |
| IN (Input-1, Input-2, ...)    | A comma-separated list of names identifying caller-supplied input data objects.                  |
| OUT (Output-1, Output-2, ...) | A comma-separated list of names identifying output data objects to be returned by the procedure. |
| [...]                         | Brackets enclose optional or conditional parameters and arguments.                               |

This notation allows data objects to be specified as inputs and outputs. An interface between entities may require only inputs. If a procedure call has no output arguments, the word OUT, preceding comma, and associated pair of balanced parentheses are omitted.

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## 4 General

### 4.1 Architecture

#### 4.1.1 Architecture overview

A SAS domain (see 4.1.9) contains one or more SAS devices and a service delivery subsystem. A SAS domain may be a SCSI domain (see SAM-5).

A SAS device (see 4.1.6) contains one or more SAS ports (see 4.1.4). A SAS device may be a SCSI device (see SAM-5).

A SAS port (see 4.1.4) contains one or more phys (see 4.1.2). A SAS port may be a SCSI port (see SAM-5).

The service delivery subsystem (see 4.1.8) in a SAS domain may contain expander devices (see 4.1.7).

Expander devices contain expander ports (see 4.1.4) and one SMP port.

An expander port contains one or more phys (see 4.1.2).

An expander device shares its phys with the SAS device(s) contained within the expander device.

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Figure 10 shows the class diagram for a SAS domain, showing the relationships between SAS Domain, SCSI Domain, Service Delivery Subsystem, Expander Device, Expander Port, SAS Device, SCSI Device, SAS Port, SCSI Port, and Phy classes. Not all attributes are shown.

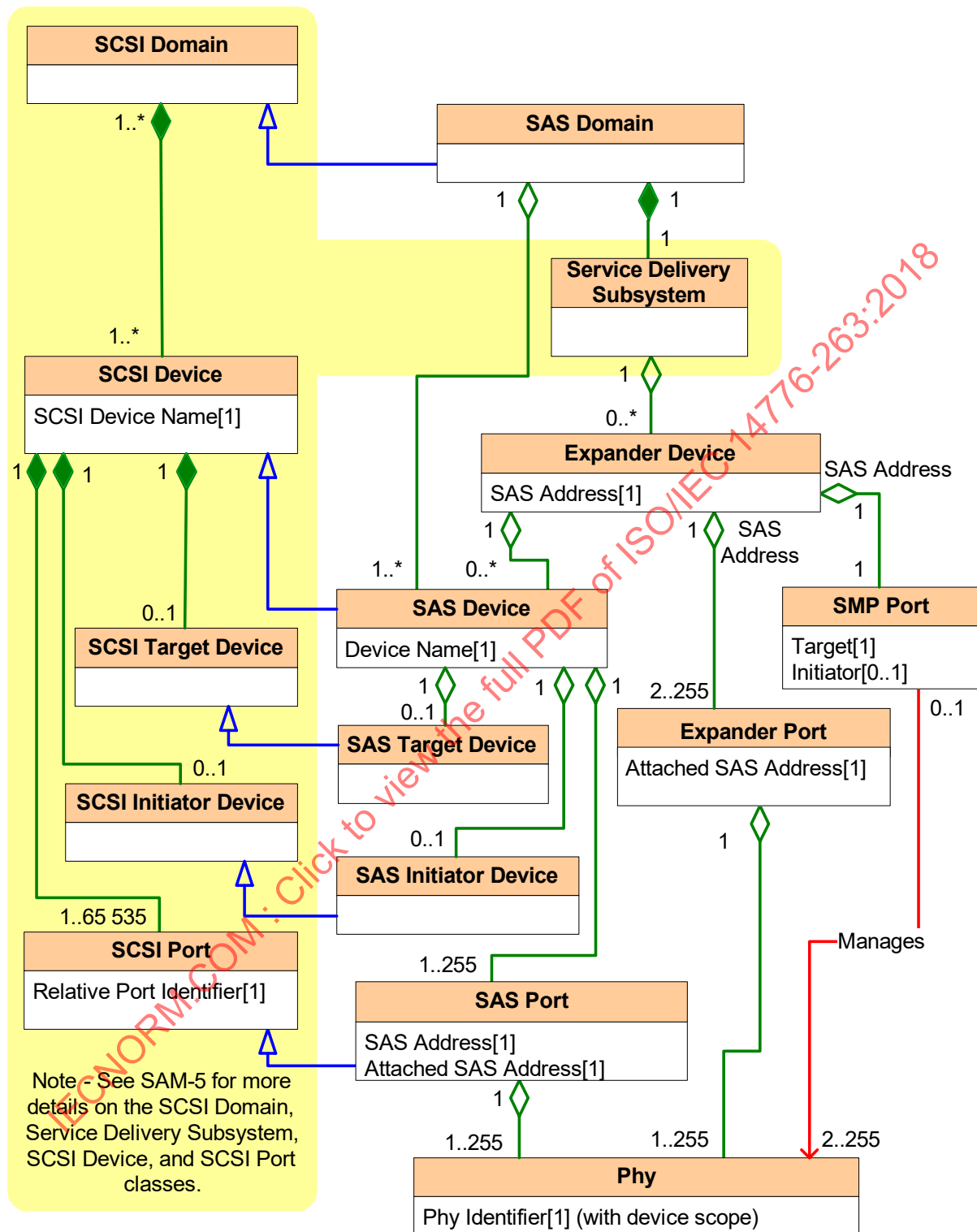


Figure 10 — SAS Domain class diagram

#### 4.1.2 Physical links and phys

For the electrical and mechanical specifications of the physical link and physical phy, see SAS-3.

A device (i.e., a SAS device (see 4.1.6) or expander device (see 4.1.7)) contains one or more phys.

Each phy has:

- a) a SAS address (see 4.2.4), inherited from the SAS port (see 4.1.4) or expander device;
- b) a phy identifier (see 4.2.10) that is unique within the device;
- c) optionally, support for being an SSP initiator phy;
- d) optionally, support for being an STP initiator phy;
- e) optionally, support for being an SMP initiator phy;
- f) optionally, support for being an SSP target phy;
- g) optionally, support for being an STP target phy; and
- h) optionally, support for being an SMP target phy.

A phy may be used as one or two logical phys based on multiplexing (see 5.15).

During the identification sequence (see 6.9), a logical phy:

- a) transmits an IDENTIFY address frame including the device type (i.e., end device or expander device) of the device containing the phy, the SAS address of the SAS port or expander device containing the logical phy, and other information; and
- b) receives an IDENTIFY address frame containing the same set of information from the attached logical phy, including the attached device type, the attached SAS address, the attached device name, and other attached information.

Figure 11 defines the Phy classes, showing the relationships between the following classes:

- a) Phy;
- b) Logical Phy;
- c) SAS Phy;
- d) SAS Logical Phy;
- e) Expander Phy;
- f) Expander Logical Phy;
- g) SAS Initiator Phy;
- h) SAS Target Phy;
- i) SSP Phy;
- j) STP Phy; and
- k) SMP Phy.

SATA phys are also referenced in this standard but are defined by SATA.

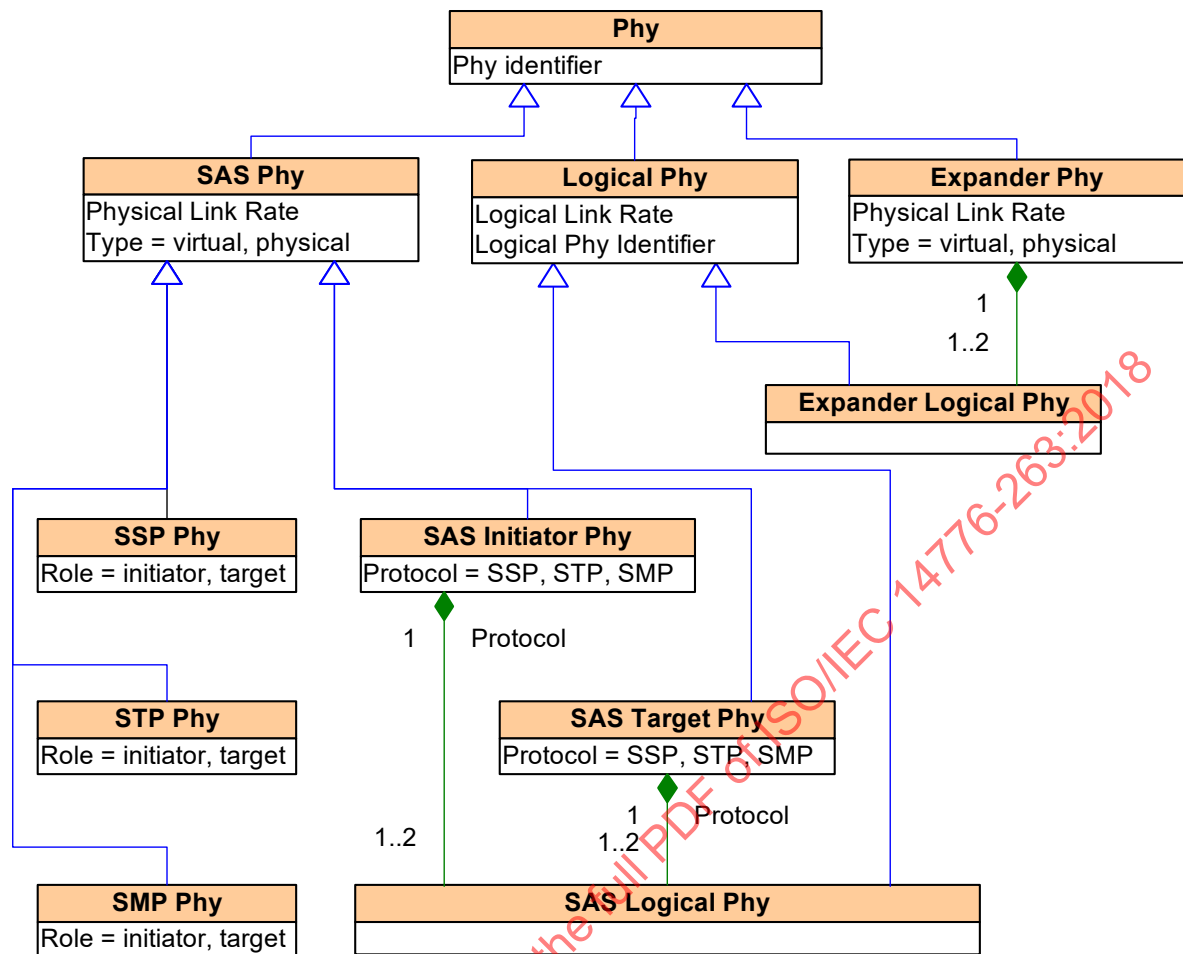


Figure 11 — Phy class diagram

Figure 12 shows example objects instantiated from the SAS Phy class, including:

- SSP initiator phy;
- SSP target phy;
- virtual SMP initiator phy;
- virtual SMP target phy;
- STP initiator phy; and
- SAS logical phy.

A SAS phy is represented by one of these objects during each connection. A SAS phy may be represented by different phy objects in different connections.

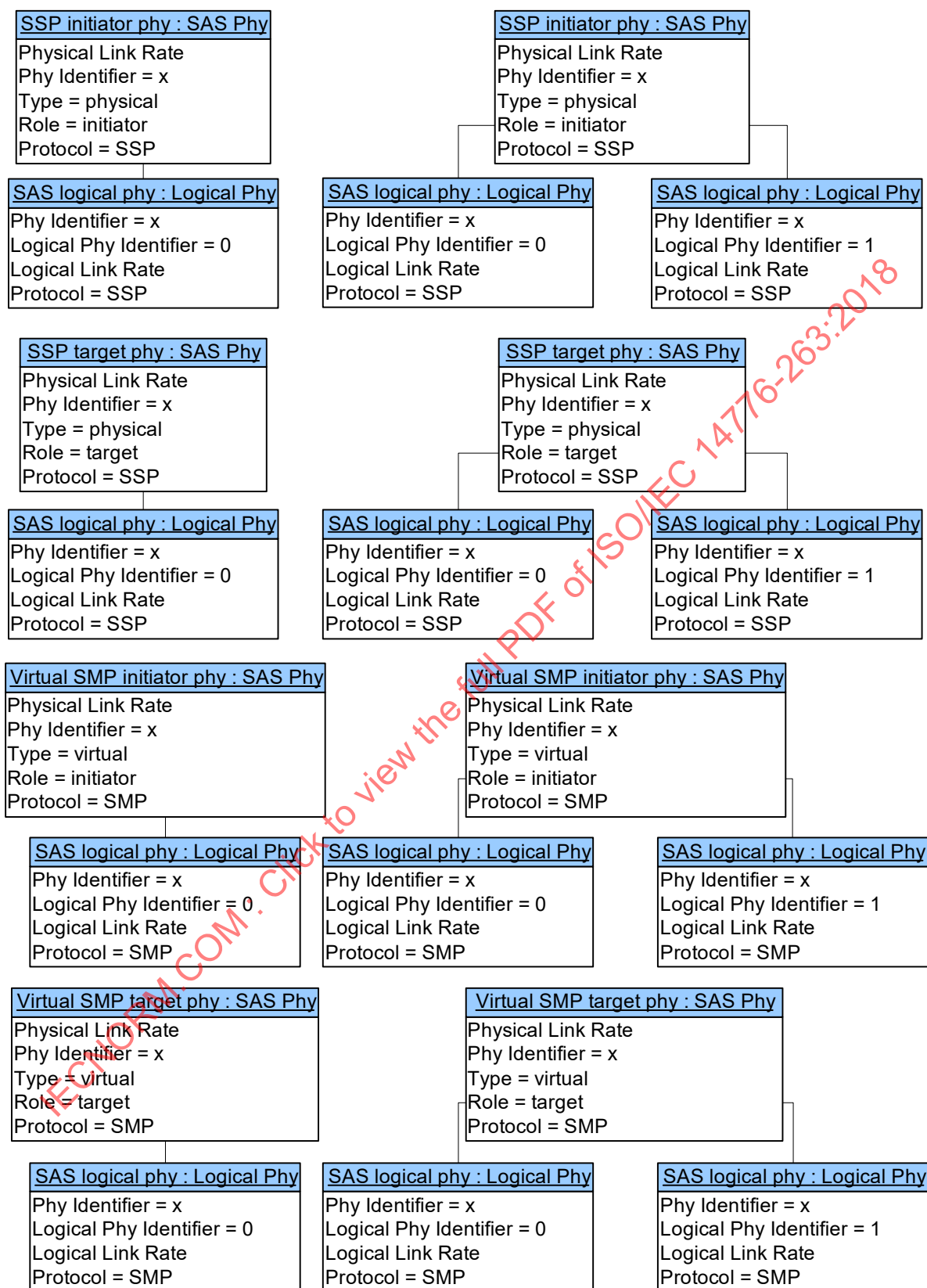


Figure 12 — SAS phy object diagram

Figure 13 shows the objects instantiated from the Expander Phy class, including:

- a) expander phy;
- b) virtual expander phy; and
- c) expander logical phy.

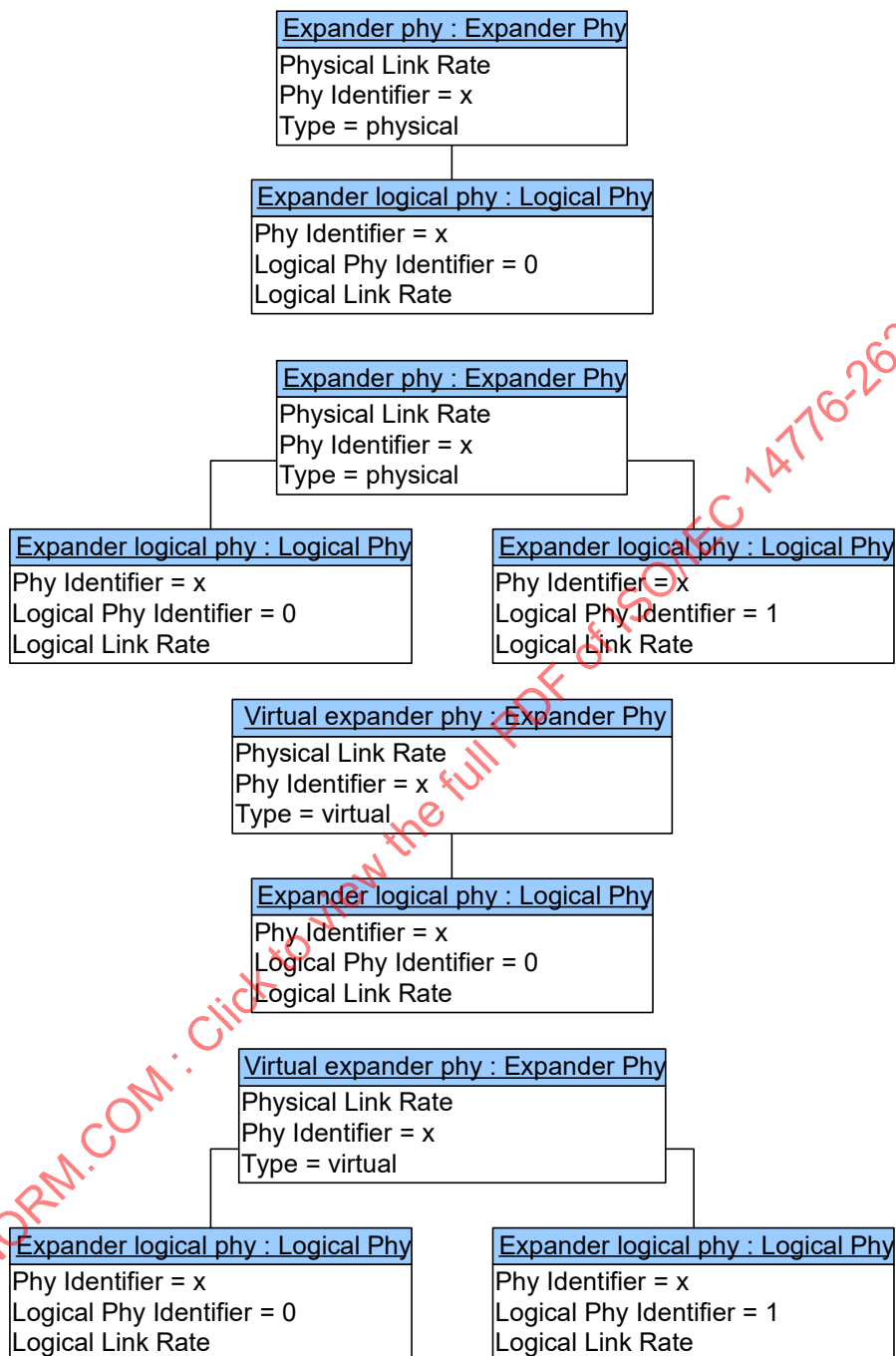


Figure 13 — Expander phy object diagram

### 4.1.3 Logical links

A physical link with a physical link rate greater than 1.5 Gbit/s may be multiplexed into two logical links as defined in table 14.

**Table 14 — Logical links**

| Physical link rate | Logical link(s)              |
|--------------------|------------------------------|
| 12 Gbit/s          | One 12 Gbit/s logical link   |
|                    | Two 6 Gbit/s logical link    |
| 6 Gbit/s           | One 6 Gbit/s logical link    |
|                    | Two 3 Gbit/s logical links   |
| 3 Gbit/s           | One 3 Gbit/s logical link    |
|                    | Two 1.5 Gbit/s logical links |
| 1.5 Gbit/s         | One 1.5 Gbit/s logical link  |

Multiplexing is defined in 5.15.

### 4.1.4 Narrow ports and wide ports

A port contains one or more phys. Ports in a device are associated with physical phys based on the identification sequence (see 6.9). Ports are associated with virtual phys based on the design of the device.

A port is a narrow port if there is only one phy in the port.

A port is a wide port if there is more than one phy in the port.

A narrow port is created after transmitting and receiving SAS addresses, unless a wide port is created.

A wide port is created from two or more physical phys if, during the identification sequence (see 6.9), the phys:

- transmitted the same SAS address (see 4.2.4) that the other physical phys in that port also transmitted in their outgoing IDENTIFY address frames (i.e., the SAS address is the same); and
- received the same SAS address that the other physical phys in that port also received in their incoming IDENTIFY address frames (i.e., the attached SAS address is the same).

A narrow link is the physical link that attaches a narrow port to another narrow port. A wide link is the set of physical links that attach a wide port to another wide port.

Attaching a phy within a wide port to another phy in the same port (i.e., the SAS address transmitted in the outgoing IDENTIFY address frame is the same as the SAS address received in the incoming IDENTIFY address frame) is outside the scope of this standard.

Phys that are able to become part of the same wide port shall set the following bits and fields in the IDENTIFY address frame (see 6.8.2) transmitted during the identification sequence to the same set of values on each phy:

- DEVICE TYPE field;
- BREAK\_REPLY CAPABLE bit;
- SSP INITIATOR PORT bit;
- STP INITIATOR PORT bit;
- SMP INITIATOR PORT bit;

- f) SSP TARGET PORT bit;
- g) STP TARGET PORT bit;
- h) SMP TARGET PORT bit;
- i) SAS ADDRESS field;
- j) INSIDE ZPSDS PERSISTENT bit;
- k) REQUESTED INSIDE ZPSDS bit;
- l) SLUMBER CAPABLE bit;
- m) PARTIAL CAPABLE bit; and
- n) PERSISTENT CAPABLE bit.

Recipient wide ports are not required to check the consistency of these fields across their phys.

Each phy in a port may be in a different phy power condition (see 4.10).

Figure 14 shows examples of narrow ports and wide ports, with a representation of the SAS address transmitted during the identification sequence. Although several phys on the left transmit SAS addresses of B, only phys attached to the same SAS addresses become part of the same ports. The set of phys with SAS address B attached to the set of phys with SAS address Y become one port, while the set of phys with SAS address B attached to the set of phys with SAS address Z become another port.

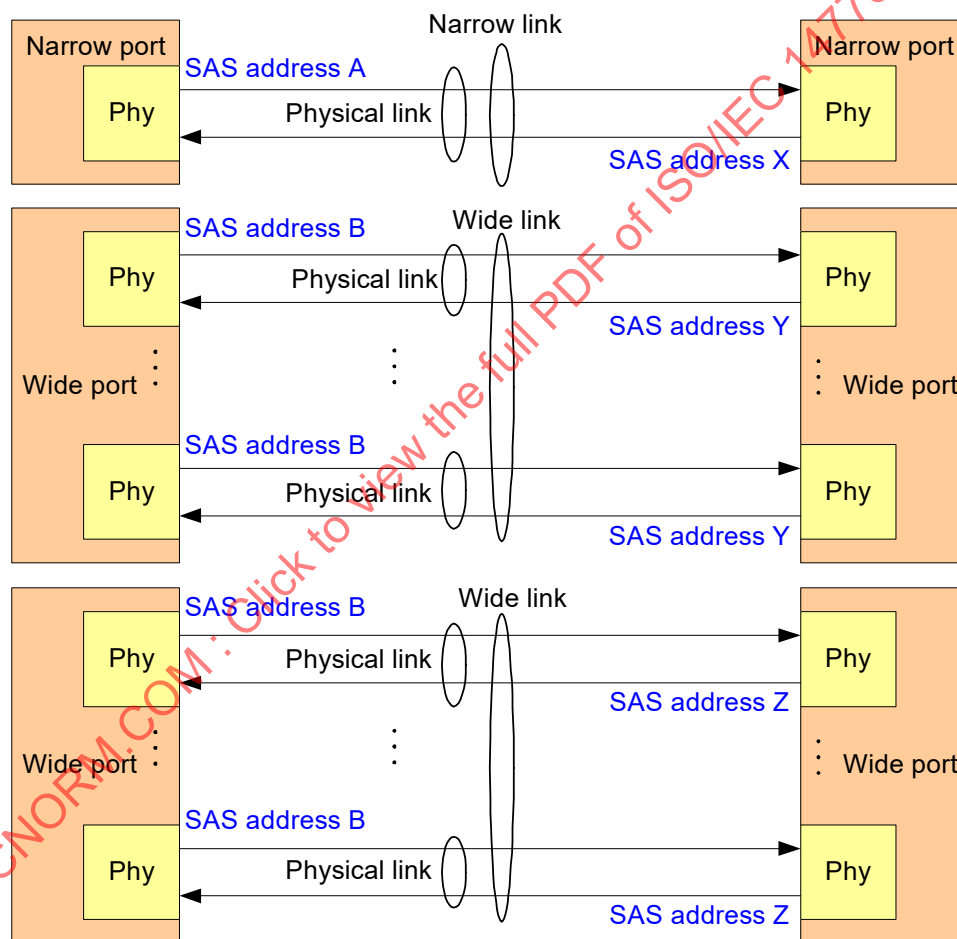


**Figure 14 — Ports (narrow ports and wide ports)**

In figures in this standard that show ports but not phys, the phy level of detail is not shown, however, each port always contains one or more phys.



Figure 15 defines the Port classes, showing the relationships between the following classes:

- a) Port;
- b) Expander Port;
- c) SAS Port;
- d) SAS Initiator Port;
- e) SAS Target Port;
- f) SSP Port;
- g) STP Port; and
- h) SMP Port.

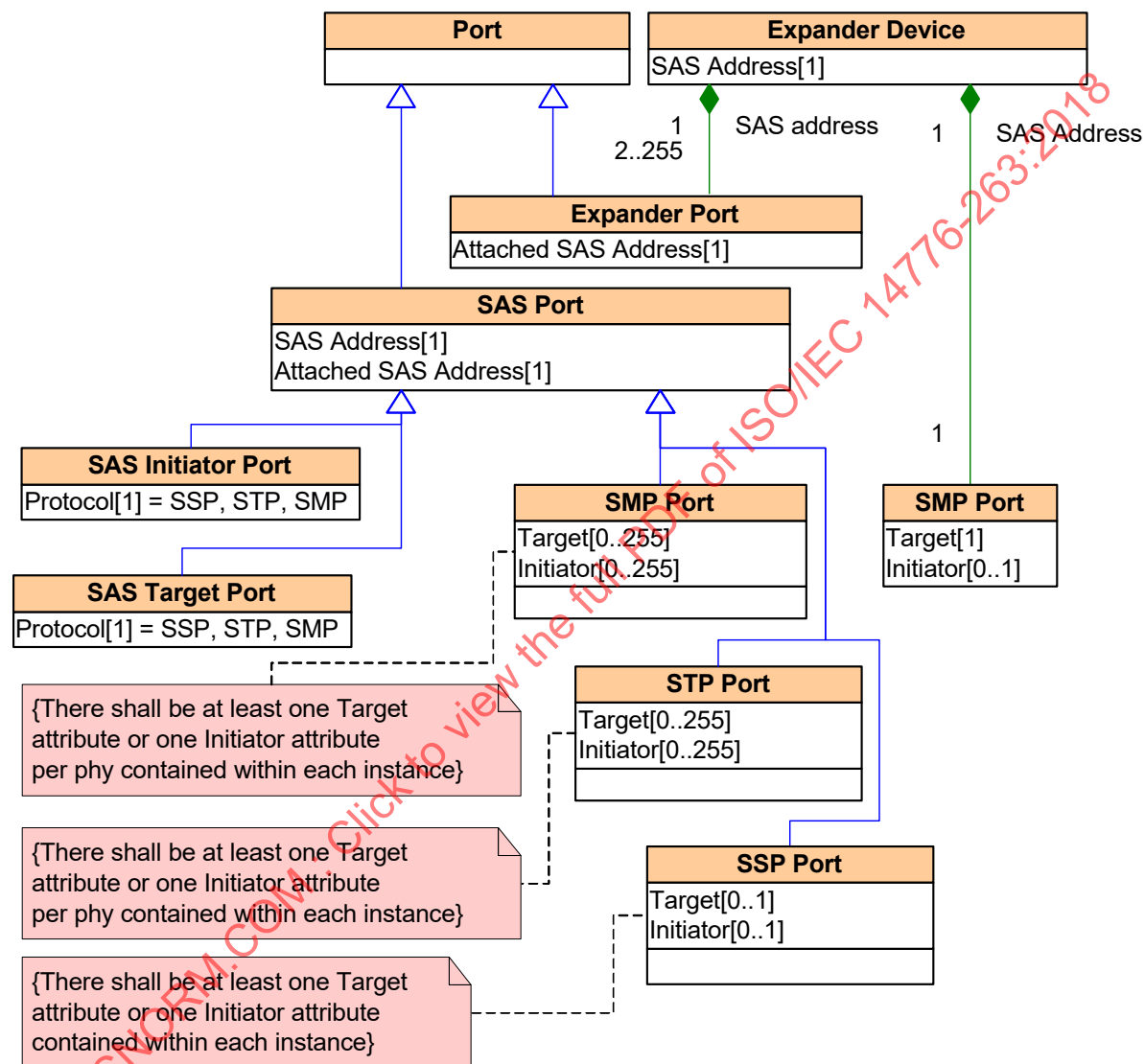


Figure 15 — Port class diagram

Figure 16 shows the objects instantiated from the Port classes:

- a) SAS Target Port class (i.e., SSP target port, STP target port, SMP target port);
- b) SAS Initiator Port class (i.e., SSP initiator port, STP initiator port, SMP initiator port);
- c) STP Port class (i.e., STP initiator port, STP target port, STP port);
- d) SMP Port class (i.e., SMP initiator port, SMP target port, SMP port);
- e) SSP Port class (i.e., SSP initiator port, SSP target port, SSP port);
- f) Expander Device SMP Port class (i.e., SMP target port, SMP port); and

g) Expander Port class (i.e., expander port).

Port objects remain instantiated even while no connection is open on any of the phys within the port.

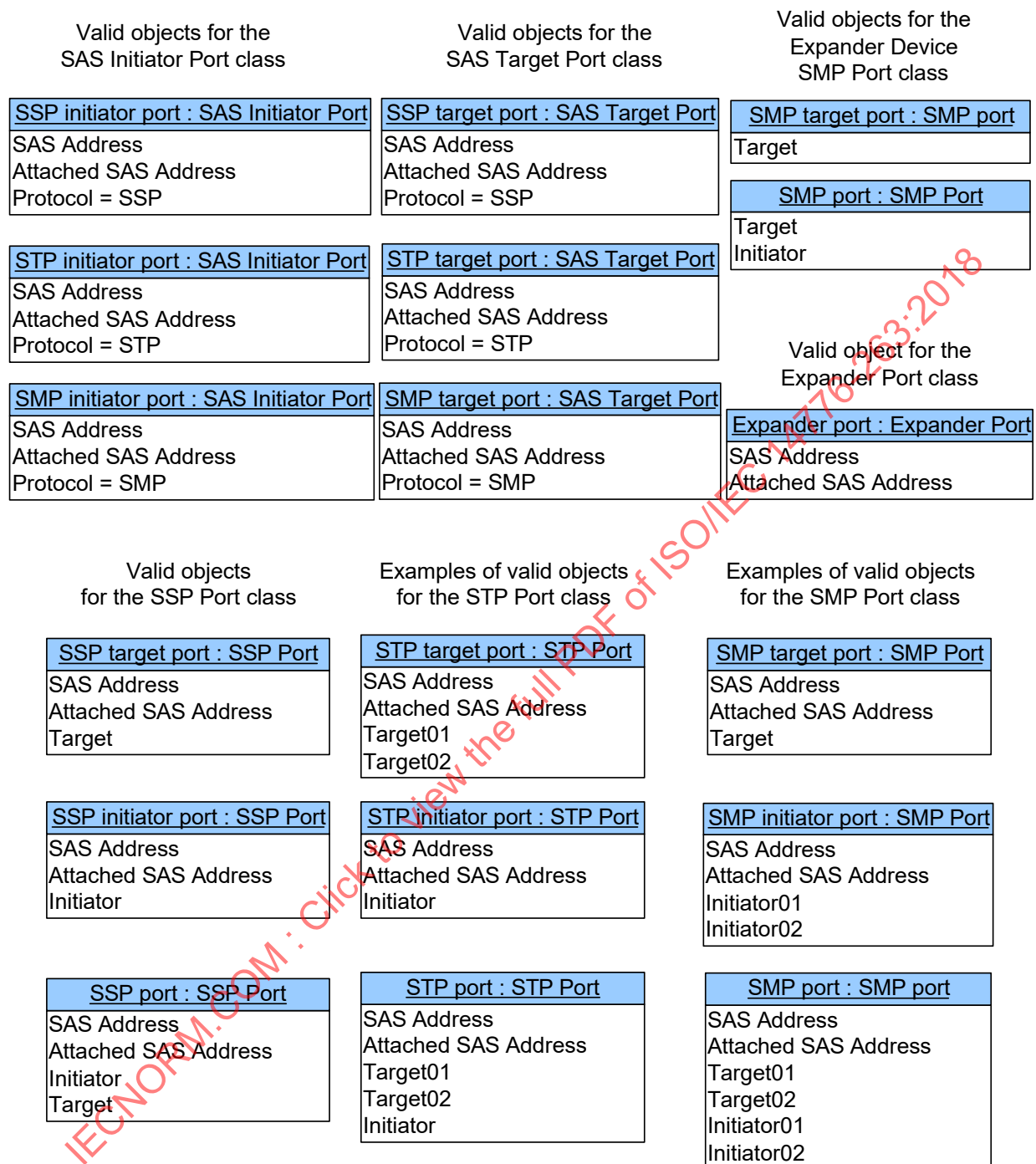


Figure 16 — Port object diagram

#### 4.1.5 Application clients and device servers

This standard defines the following application clients:

- a) a SCSI application client (see SAM-5) is the source of SCSI commands and task management function requests. A SCSI application client uses an SSP initiator port to interface to a service delivery subsystem;
- b) an ATA application client (see ATA8-AAM) is the source of ATA commands and device management operation requests. An ATA application client uses an STP initiator port to interface to a service delivery subsystem; and
- c) a management application client is the source of SMP function requests. A management application client uses an SMP initiator port to interface to a service delivery subsystem.

This standard defines the following device servers:

- a) a SCSI device server (see SAM-5) processes SCSI commands. A SCSI device server uses an SSP target port to interface to a service delivery subsystem;
- b) an ATA device server (see ATA8-AAM) processes ATA commands and device management functions. An ATA device server uses an STP target port to interface to a service delivery subsystem; and
- c) a management device server processes SMP functions. A management device server uses an SMP target port to interface to a service delivery subsystem.

A SCSI to ATA translation layer (see SAT-2) may be implemented to enable SCSI application clients to communicate with ATA devices.

#### 4.1.6 SAS devices

A SAS device contains one or more SAS ports, each containing one or more phys (i.e., a SAS port may be a narrow port or a wide port).

Figure 17 shows examples of SAS devices with different port and phy configurations.

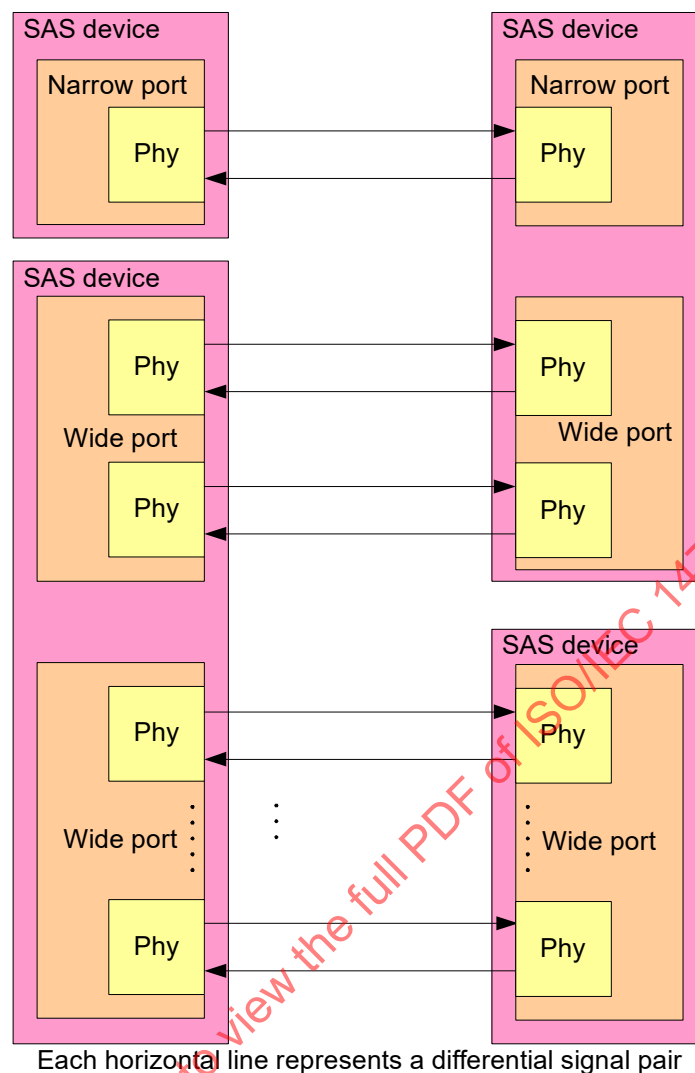


**Figure 17 — SAS devices**

An end device is a SAS device that is not contained in an expander device (see 4.1.7).

#### 4.1.7 Expander devices

Expander devices are part of a service delivery subsystem and facilitate communication between multiple SAS devices. Expander devices contain two or more external expander ports. Each expander device:

- contains one SMP target port and one management device server;
- contains one SMP initiator port and one management application client, if the expander device is self-configuring;
- may contain one SMP initiator port and one management application client, if the expander device is not self-configuring; and
- may contain SAS devices (e.g., an expander device may include an SSP target port for access to a logical unit with a peripheral device type set to 0Dh (i.e., enclosure services device) (see SPC-4 and SES-3)).

Figure 18 shows an expander device.

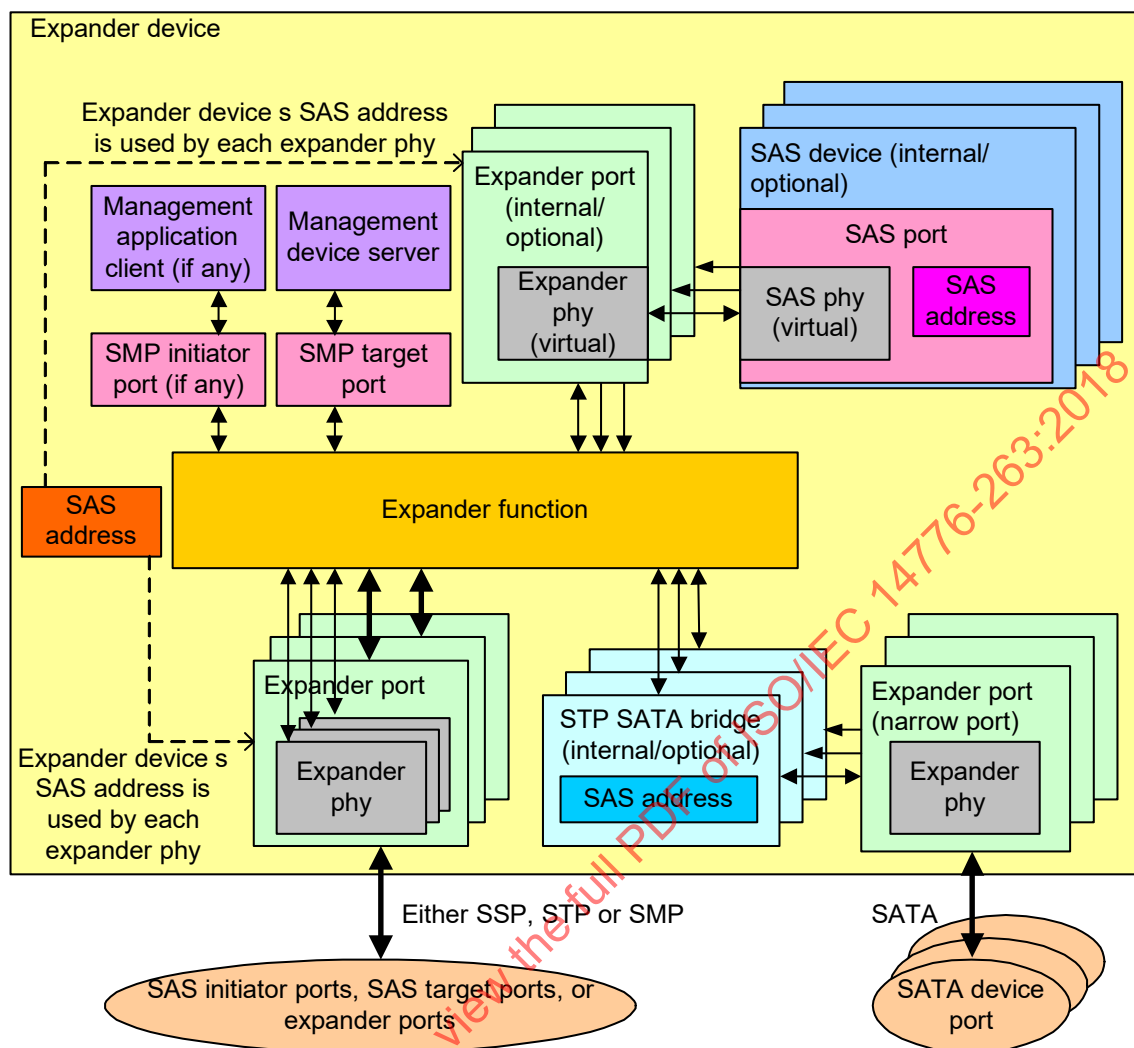


**Figure 18 — Expander device**

See 4.5 for a detailed model of an expander device.

Each expander phy has one of the following routing attributes (see 4.5.7.1):

- a) direct routing attribute;
- b) table routing attribute; or
- c) subtractive routing attribute.

Expander devices containing expander phys with the table routing attribute also contain an expander route table (see 4.5.7.4). An externally configurable expander device depends on a management application client within the SAS domain to use the discover process (see 4.6) and the configuration subprocess (see 4.7) to configure the expander route table. A self-configuring expander device contains a management application client and an SMP initiator port. The management application client performs the discover process (see 4.6) and configures the expander device's own expander route table.

#### 4.1.8 Service delivery subsystem

A service delivery subsystem is either:

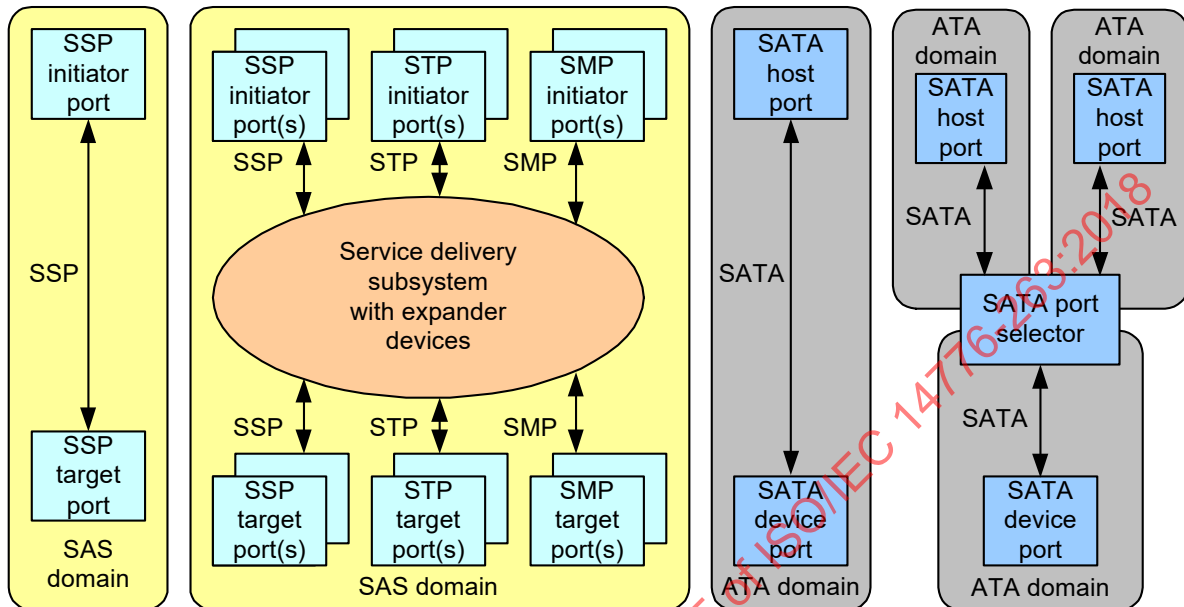
- a) a set of physical links between a SAS initiator port and a SAS target port; or

- b) a set of physical links and expander devices, supporting more than two SAS ports.

See 4.1.10 for rules on constructing service delivery subsystems from multiple expander devices.

#### 4.1.9 Domains

Figure 19 shows examples of SAS domains and ATA domains.



Note - If expander devices are present, SAS target ports may be located in SAS devices contained in expander devices.

Figure 19 — Domains

Figure 20 shows a SAS domain bridging to one or more ATA domains.

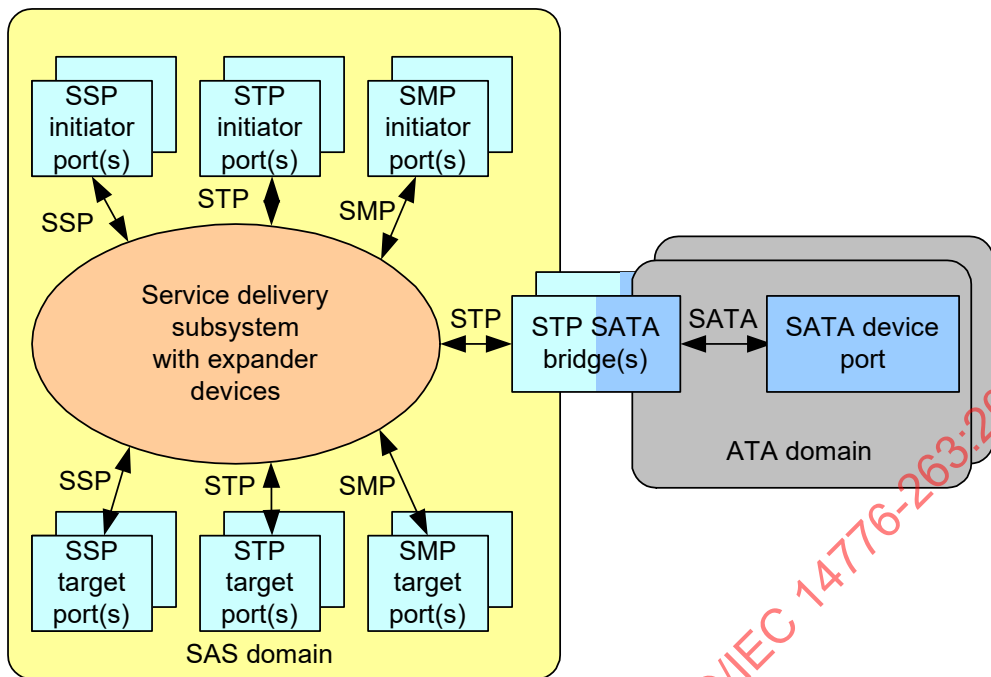


Figure 20 — SAS domain bridging to ATA domains

Figure 21 shows two SAS domains bridging to one or more ATA domains containing SATA devices with SATA port selectors.

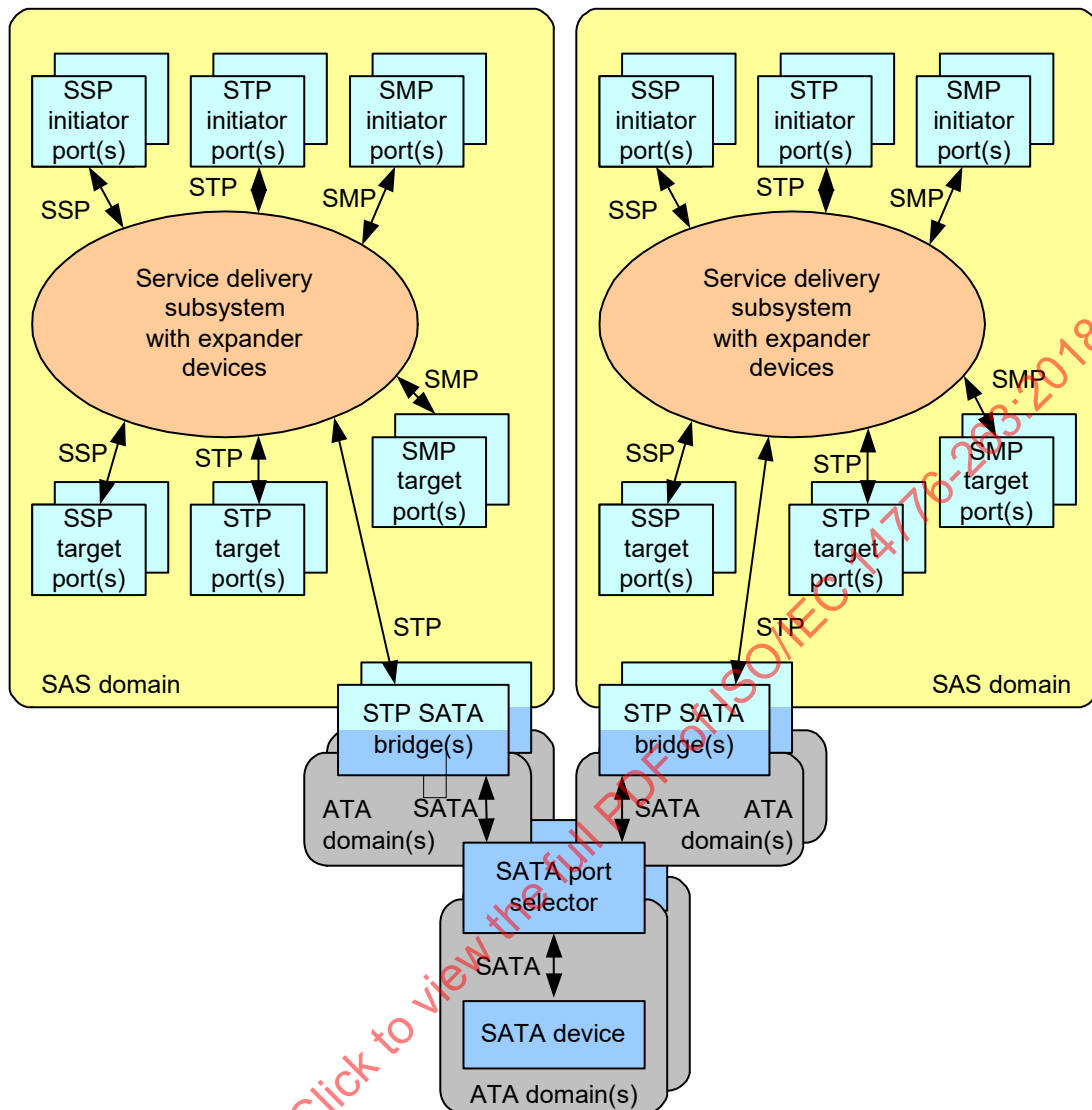


Figure 21 — SAS domains bridging to ATA domains with SATA port selectors



Figure 22 shows SAS initiator devices and SAS target devices with SAS ports in the same SAS domains and in different SAS domains. If a SAS device has ports in the same SAS domain, then the ports shall have different SAS addresses. If a SAS device has ports in different SAS domains, then the ports may have the same SAS address (see 4.2.4).

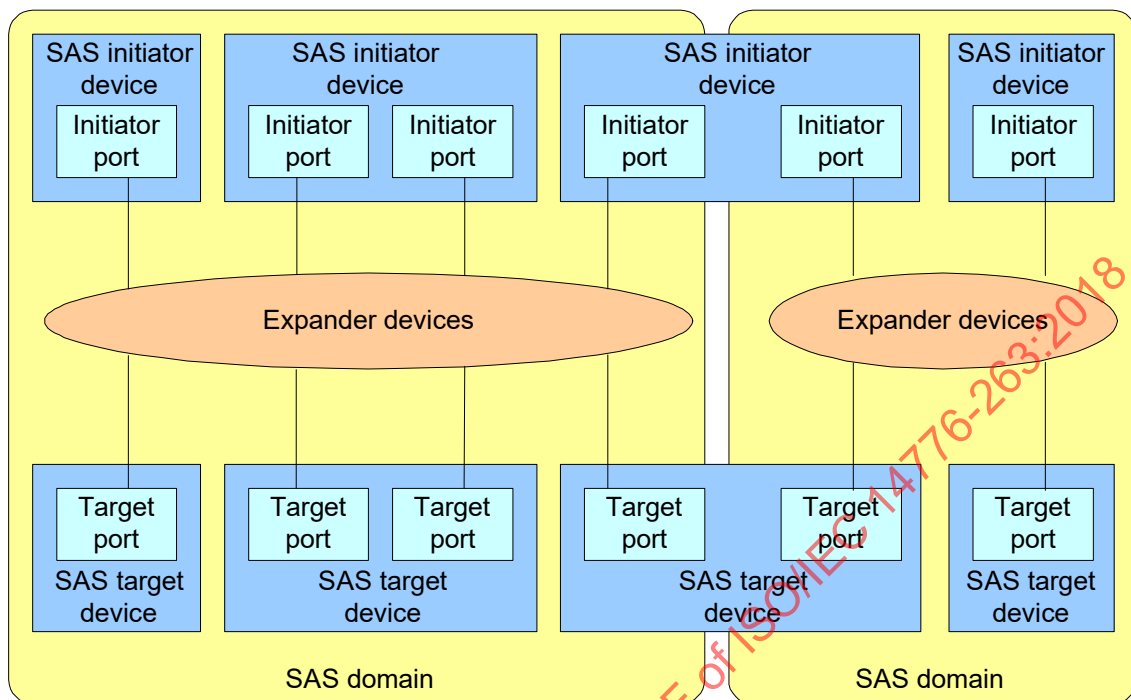


Figure 22 — Devices spanning SAS domains

#### 4.1.10 Expander device topologies

##### 4.1.10.1 Expander device topology overview

More than one expander device may be part of a service delivery subsystem.

To avoid an overflow of an expander route index during the configuration subprocess (see 4.7), a SAS domain containing an externally configurable expander device shall be constructed such that the number of expander route indexes available for each expander phy with the table routing attribute is greater than or equal to the number of SAS addresses addressable through that expander phy.

4.1.10.2 Expander device topologies

Figure 23 shows an example of an expander topology with one expander device.

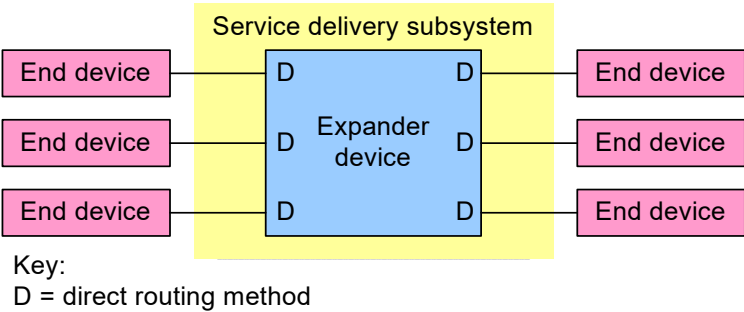


Figure 23 — Single expander device topology example

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Figure 24 shows examples of expander topologies with multiple expander devices.

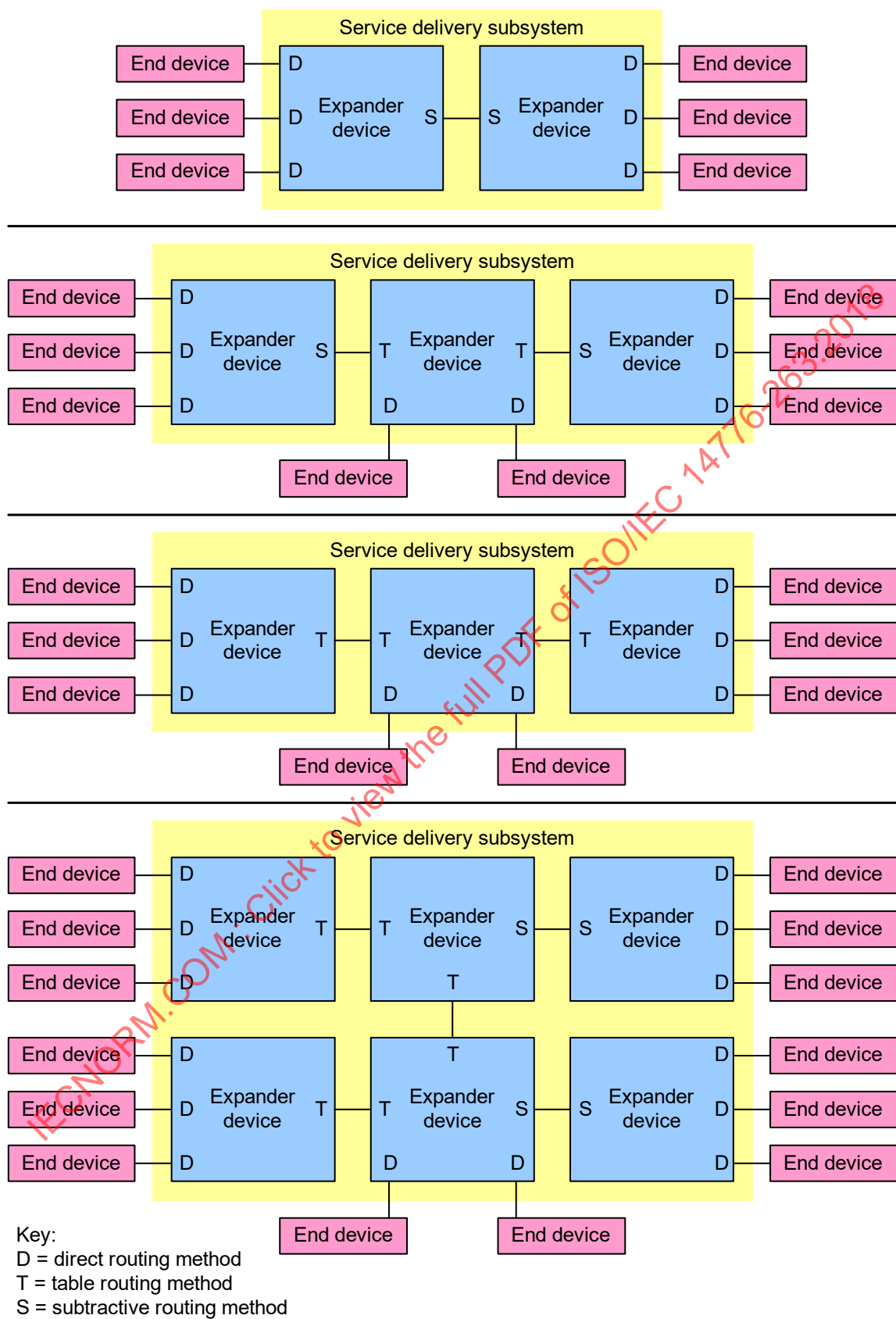


Figure 24 — Multiple expander device topologies and routing methods

#### 4.1.11 Pathways

A potential pathway is a set of logical links between a SAS initiator phy and a SAS target phy. If a SAS initiator phy is directly attached to a SAS target phy with a non-multiplexed physical link, then there is one potential pathway. If the physical link is multiplexed or there are expander devices between a SAS initiator phy and a SAS target phy, then it is possible that there is more than one potential pathway, each consisting of a set of logical links between the SAS initiator phy and the SAS target phy. The physical links may or may not be using the same physical link rate.

A pathway is a set of logical links between a SAS initiator phy and a SAS target phy being used by a connection (see 4.1.12).

Figure 25 shows examples of potential pathways.

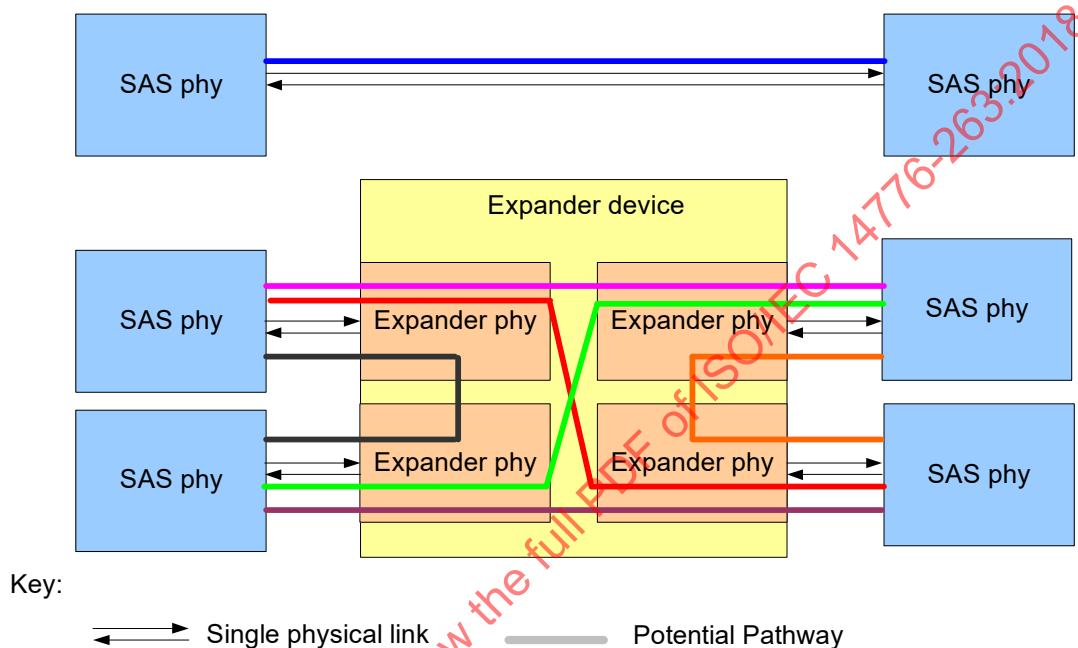


**Figure 25 — Potential pathways**

A partial pathway is the set of logical links participating in a connection request that have not yet conveyed a connection response (see 6.14).

A partial pathway is blocked while path resources that it requires are held by another partial pathway (see 6.14).

#### 4.1.12 Connections

A connection is a temporary association between a SAS initiator phy and a SAS target phy. During a connection, all dwords from the SAS initiator phy that are not deletable primitives are forwarded to the SAS target phy via a pathway, and all dwords from the SAS target phy that are not deletable primitives are forwarded to the SAS initiator phy via the same pathway. A source phy transmits an OPEN address frame (see 6.8.3) specifying the SAS address of a destination phy to attempt to establish a connection.

A connection is pending when an OPEN address frame has been delivered along a completed pathway to the destination phy but the destination phy has not yet responded to the connection request. A connection is established when the source phy receives an OPEN\_ACCEPT (see 6.14) from the destination phy.

A connection enables communication for one protocol:

- a) SSP;

- b) STP; or
- c) SMP.

For SSP and STP, connections may be opened and closed multiple times during the processing of a command (see 6.14).

The connection rate is the effective rate of dwords through the pathway between a SAS initiator phy and a SAS target phy, established through the connection request. Every logical phy shall support a 1.5 Gbit/s connection rate regardless of its logical link rate.

No more than one connection is active on a logical link at a time. If the connection is an SSP or SMP connection and there are no dwords to transmit associated with that connection, idle dwords are transmitted. If the connection is an STP connection and there are no dwords to transmit associated with that connection, then SATA\_SYNCs, SATA\_CONTs, or vendor specific scrambled data dwords are transmitted as defined in SATA. If there is no connection on a logical link, then idle dwords are transmitted.

The number of connections established by a SAS port shall not exceed the number of SAS logical phys within the SAS port (i.e., only one connection per SAS logical phy is allowed). There shall be a separate connection on each logical link.

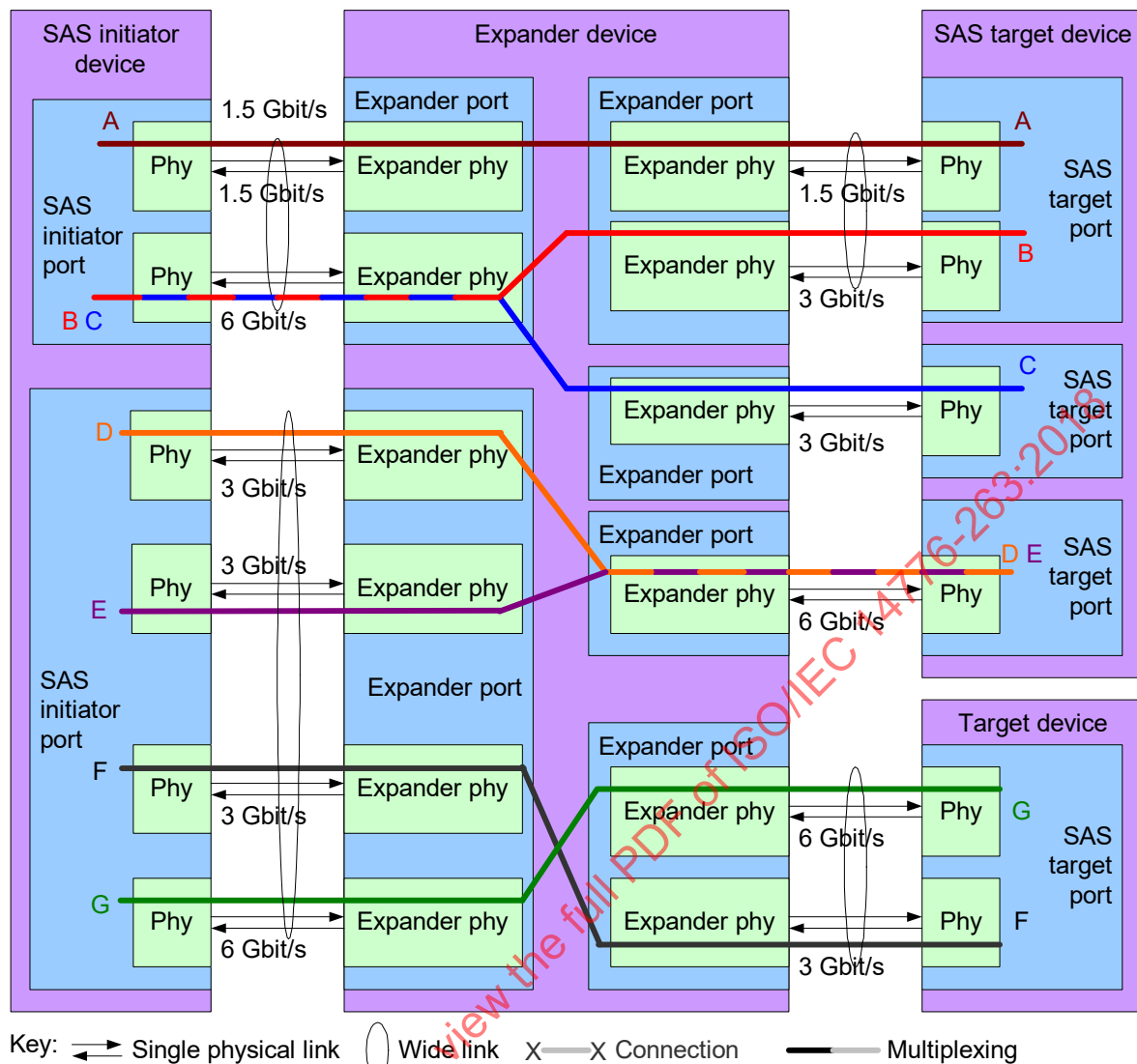
If multiple potential pathways exist between the SAS initiator port(s) and the SAS target port(s), multiple connections may be established by a SAS port between the following:

- a) one SAS initiator port to multiple SAS target ports;
- b) one SAS target port to multiple SAS initiator ports; or
- c) one SAS initiator port to one SAS target port.

Once a connection is established, the pathway used for that connection shall not be changed (i.e., all the logical links that make up the pathway remain dedicated to the connection until the connection is closed).

Figure 26 shows examples of connections between wide and narrow ports. All the connections shown may occur simultaneously. For the connections shown in figure 26:

- a) those labeled A, B, and C are an example of one SAS initiator port with connections to multiple SAS target ports;
- b) those labeled E and F are an example of multiple connections between one SAS initiator port and multiple SAS target ports; and
- c) those labeled C, D, E, and F are an example of one SAS initiator port with connections to multiple SAS target ports with one of those SAS target ports having multiple connections with that SAS initiator port.



Note - The expander device, each SAS initiator port, and each SAS target port has a unique SAS address. Connections D and E represent a wide SAS initiator port with two simultaneous connections to a narrow SAS target port supporting multiplexing. Connections F and G represent a wide SAS initiator port with two simultaneous connections to a wide SAS target port.

**Figure 26 — Multiple connections on wide ports**

#### 4.1.13 Persistent connections

##### 4.1.13.1 Persistent connection operation

A persistent connection is an SSP connection (see 4.1.12) that:

- is established after an EXTEND\_CONNECTION (NORMAL) (see 6.2.7.5) has been transmitted and received inside the SSP connection;
- persists as long as the connected SAS initiator phy and SAS target phy:
  - transmit SSP frames; or
  - periodically exchange EXTEND\_CONNECTION (NORMAL)s (see 6.18.9.12);
- causes the PL\_PM state machine to ignore the Bus Inactivity Time Limit timer, the Maximum Connect Time Limit timer (see 7.2.3.4.1), and the MAXIMUM BURST SIZE field (see 9.2.7.2.4); and
- ends:

- A) after a DONE is received;
- B) if a Phy Layer Not Ready confirmation from the phy layer occurs during the SSP connection; or
- C) if an abort connection occurs (see 6.14.5).

#### 4.1.13.2 Persistent connection support

If an end device's SSP phy supports persistent connections (e.g., the SSP PERSISTENT CAPABLE bit is set to one in the Protocol Specific Port Information VPD page (see 9.2.11.4) for the SSP phy), then that SSP phy sets the PERSISTENT CAPABLE bit to one in the IDENTIFY address frame (see 6.8.2).

Support for persistent connections on attached phys is reported using the SMP DISCOVER function (see 9.4.3.10).

#### 4.1.14 Advancing credit

If an SSP phy has receive resources available, then it may advance credit. To advance credit an SSP phy shall:

- 1) set the CREDIT ADVANCE bit to one in the OPEN address frame; and
- 2) request that the SSP transmitter send an RRDY after an OPEN\_ACCEPT is received.

If an SSP phy that implements credit advance receives an OPEN address frame with the CREDIT ADVANCE bit set to one, then the SSP phy:

- 1) increments the transmit SSP frame credit by one (see 6.18.9.1); and
- 2) ignores the next RRDY.

A destination SSP phy that does not implement the CREDIT ADVANCE bit (see 6.8.3) does not advance credit.

#### 4.1.15 Broadcasts

Broadcasts are used to notify SAS ports and expander devices in the SAS domain about certain events. Broadcasts are transmitted using BROADCAST (see 6.2.6.4) and/or the SMP ZONED BROADCAST function (see 9.4.3.20).

Table 15 defines the Broadcast types.

**Table 15 — Broadcast types** (part 1 of 2)

| Broadcast                                                                                                                                                                                                                                       | Primitive <sup>a</sup> | Description                                                                                                                                                                                                                                                                                      |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Broadcast (Change)                                                                                                                                                                                                                              | yes                    | Originated by an expander device to notify SAS initiator ports that a SAS domain change has occurred (see 6.13). May also be originated by SAS initiator ports. SAS target ports shall ignore this Broadcast.<br><br>See 4.6.2 for management application client handling of Broadcast (Change). |
| Broadcast (Reserved Change 0)                                                                                                                                                                                                                   | yes                    | Reserved. SAS ports (i.e, SAS initiator ports and SAS target ports) shall process this Broadcast the same as Broadcast (Change).                                                                                                                                                                 |
| Broadcast (Reserved Change 1)                                                                                                                                                                                                                   | yes                    | Reserved. SAS ports shall process this Broadcast the same as Broadcast (Change).                                                                                                                                                                                                                 |
| <sup>a</sup> All Broadcasts are supported by the SMP ZONED BROADCAST function (see 9.4.3.20), which defines additional reserved Broadcast types. Broadcasts labeled "yes" are also transmitted via BROADCAST primitive sequences (see 6.2.6.4). |                        |                                                                                                                                                                                                                                                                                                  |

Table 15 — Broadcast types (part 2 of 2)

| Broadcast                                                                                                                                                                                                                                       | Primitive <sup>a</sup> | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Broadcast (SES)                                                                                                                                                                                                                                 | yes                    | <p>Originated by a logical unit with a peripheral device type set to 0Dh (i.e., enclosure services device) (see SPC-4 and SES-3) accessible through a SAS target port in the SAS domain to notify SAS initiator ports of an asynchronous event.</p> <p>A SCSI application client should poll all the logical units in the SAS domain with peripheral device types set to 0Dh to determine the source.</p> <p>SAS target ports shall ignore this Broadcast.</p>                                                                                                                                                                                                                                                                  |
| Broadcast (Expander)                                                                                                                                                                                                                            | yes                    | <p>Originated by an expander device to notify SAS initiator ports that an expander event has occurred, including:</p> <ul style="list-style-type: none"> <li>a) the expander device is going to have reduced functionality for a period of time (see 4.5.8);</li> <li>b) a phy event peak value detector has reached its threshold value; or</li> <li>c) a phy event peak value detector has been cleared by an SMP CONFIGURE PHY EVENT function (see 9.4.3.30).</li> </ul> <p>Expander events do not include SAS domain changes, which are communicated with Broadcast (Change).</p> <p>SAS target ports shall ignore this Broadcast.</p> <p>See 4.5.9 for management application client handling of Broadcast (Expander).</p> |
| Broadcast (Asynchronous Event)                                                                                                                                                                                                                  | yes                    | <p>Originated by an SSP target port when an event occurs (e.g., a hard reset) that causes one or more unit attention conditions to be established for one or more logical units accessible through the SSP target port.</p> <p>An SSP target port shall only originate one Broadcast (Asynchronous Event) for each event that affects multiple logical units accessible through the SSP target port (e.g., only one Broadcast (Asynchronous Event) is originated when a hard reset occurs).</p> <p>SAS ports other than SSP initiator ports shall ignore this Broadcast.</p>                                                                                                                                                    |
| Broadcast (Reserved 3)                                                                                                                                                                                                                          | yes                    | Reserved. SAS ports shall ignore this Broadcast.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Broadcast (Reserved 4)                                                                                                                                                                                                                          | yes                    | Reserved. SAS ports shall ignore this Broadcast.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Broadcast (Zone Activate)                                                                                                                                                                                                                       | no                     | <p>Initiates the zone activate step (see 4.8.6.4).</p> <p>Devices that are not locked zoning expander devices shall ignore this Broadcast.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <sup>a</sup> All Broadcasts are supported by the SMP ZONED BROADCAST function (see 9.4.3.20), which defines additional reserved Broadcast types. Broadcasts labeled “yes” are also transmitted via BROADCAST primitive sequences (see 6.2.6.4). |                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |



When an expander port receives a Broadcast, the BPP (see 4.5.5) shall forward the Broadcast on at least one phy in each other expander port if zoning is disabled, or forward the Broadcast as described in 4.8.5 if zoning is enabled.

An expander device is not required to queue multiple identical Broadcasts for the same expander port. If a second identical Broadcast is requested before the first Broadcast has been transmitted, then the second Broadcast may be ignored.

A SAS device or expander device may implement counters for Broadcasts it originates and report them in the REPORT BROADCAST response (see 9.4.3.9). If counters are supported, then the SAS device or expander device shall, for each combination of Broadcast type and Broadcast reason that the SAS device or expander device supports:

- a) if the Broadcast is related to a phy, then maintain a separate Broadcast counter for each phy; or
- b) if the Broadcast is not related to a phy, then maintain one originated Broadcast counter.

Broadcast (Change)s originated by an expander device are counted and reported in the REPORT GENERAL response (see 9.4.3.4) and other SMP response frames containing an EXPANDER CHANGE COUNT field.

An expander device may implement counters for Broadcasts received from attached end devices and report them in the REPORT BROADCAST response (see 9.4.3.9).

A SAS device or an expander device is not required to maintain originated Broadcast count information in non-volatile storage or across reset events.

See 4.12 for details on phy events.

## 4.2 Names and identifiers

### 4.2.1 Names and identifiers overview

Device names are worldwide unique names for devices within a transport protocol.

Port names are worldwide unique names for ports within a transport protocol.

Port identifiers are the values by which ports are identified within a domain. Phy identifiers are the values by which phys are identified within a device.

Table 16 describes the definitions of names and identifiers for SAS.

**Table 16 — Names and identifiers**

| Attribute                                                                                                                                             | Format                                                                                                                                                          | SAS usage                                                                                                                                                                                                        | Reference(s)    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Device name                                                                                                                                           | SAS address (see 4.2.4) for SAS devices and expander devices.<br><br>NAA IEEE Registered format (see 4.2.2) for SATA devices with worldwide names. <sup>a</sup> | Reported in:<br>a) the IDENTIFY address frame (see 6.8.2) DEVICE NAME field;<br>b) the Device Identification VPD page (see 9.2.11.2); and<br>c) the DISCOVER response (see 9.4.3.10) ATTACHED DEVICE NAME field. | 4.2.6 and 4.2.7 |
| Port name                                                                                                                                             | Not defined                                                                                                                                                     |                                                                                                                                                                                                                  | 4.2.8           |
| Port identifier                                                                                                                                       | SAS address (see 4.2.4)                                                                                                                                         | Reported in:<br>a) the IDENTIFY address frame (see 6.8.2) for SAS ports; and<br>b) the Device Identification VPD page (see 9.2.11.2)                                                                             | 4.2.9           |
| Phy identifier                                                                                                                                        | 8-bit value                                                                                                                                                     | Phy identifier                                                                                                                                                                                                   | 4.2.10          |
| <sup>a</sup> For SATA devices without worldwide names, a device name may be set in the PHY CONTROL request (see 9.4.3.28) ATTACHED DEVICE NAME field. |                                                                                                                                                                 |                                                                                                                                                                                                                  |                 |

Table 17 describes the identifier attributes and name attributes for SCSI architecture model objects (see SAM-5) using SAS SSP.

**Table 17 — SCSI architecture model object attribute mapping**

| SCSI architecture model object attribute | SAS SSP implementation                           |
|------------------------------------------|--------------------------------------------------|
| Initiator port identifier                | SAS address of an SSP initiator port             |
| Initiator port name                      | Not defined                                      |
| Target port identifier                   | SAS address of an SSP target port                |
| Target port name                         | Not defined                                      |
| SCSI device name                         | Device name of SAS device containing an SSP port |

#### 4.2.2 NAA IEEE Registered format identifier

Table 18 defines the NAA IEEE Registered format identifier used by device names and port identifiers. This format is the same as that defined in SPC-4.

**Table 18 — NAA IEEE Registered format**

| Byte\Bit                   | 7               | 6 | 5 | 4 | 3     | 2 | 1 | 0 |
|----------------------------|-----------------|---|---|---|-------|---|---|---|
| 0                          | NAA (5h)        |   |   |   | (MSB) |   |   |   |
| 1                          | IEEE COMPANY ID |   |   |   |       |   |   |   |
| 2                          |                 |   |   |   |       |   |   |   |
| 3                          | (LSB)           |   |   |   |       |   |   |   |
| 4                          |                 |   |   |   |       |   |   |   |
| 5                          |                 |   |   |   |       |   |   |   |
| 6                          |                 |   |   |   |       |   |   |   |
| 7                          |                 |   |   |   |       |   |   |   |
| VENDOR SPECIFIC IDENTIFIER |                 |   |   |   |       |   |   |   |

The NAA field shall be set as shown in table 18 for the NAA IEEE Registered format.

The IEEE COMPANY ID field contains a 24-bit canonical form company identifier (i.e., OUI) assigned by the IEEE.

NOTE 2 - Information about IEEE company identifiers is obtained from the IEEE Registration Authority web site (see <http://standards.ieee.org/regauth/oui>).

The VENDOR SPECIFIC IDENTIFIER field contains a 36-bit value that is assigned by the organization associated with the company identifier in the IEEE COMPANY ID field. The VENDOR SPECIFIC IDENTIFIER field shall be assigned so the NAA IEEE Registered format identifier is worldwide unique.

### 4.2.3 NAA Locally Assigned format identifier

Table 19 defines the NAA Locally Assigned format identifier used by device names and port identifiers. This format is the same as that defined in SPC-4.

**Table 19 — NAA Locally Assigned format**

| Byte\Bit | 7        | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|----------|---|---|---|---|---|---|---|
| 0        | NAA (3h) |   |   |   |   |   |   |   |
| 1        |          |   |   |   |   |   |   |   |
| 2        |          |   |   |   |   |   |   |   |
| 3        |          |   |   |   |   |   |   |   |
| 4        |          |   |   |   |   |   |   |   |
| 5        |          |   |   |   |   |   |   |   |
| 6        |          |   |   |   |   |   |   |   |
| 7        |          |   |   |   |   |   |   |   |

The NAA field shall be set as shown in table 19 for the NAA Locally Assigned format.

The LOCALLY ADMINISTERED VALUE field contains a 60-bit value that is assigned by an administrator to be unique within the set of SCSI domains that are accessible by a common instance of an administration tool or tools.

### 4.2.4 SAS address

A SAS address is an identifier using either.

- the NAA IEEE Registered format (see 4.2.2); or
- the NAA Locally Assigned format (see 4.2.3).

A SAS address should use the NAA IEEE Registered format (see 4.2.2).

A SAS address of 00000000 00000000h indicates an invalid identifier.

### 4.2.5 Hashed SAS addresses

SSP frames include hashed versions of SAS addresses of SAS ports to provide an additional level of verification of proper frame routing.

The code used for the hashing algorithm is a cyclic binary Bose, Chaudhuri, and Hocquenghem (BCH) (63, 39, 9) code. Table 20 lists the parameters for the code.

**Table 20 — Hashed SAS address code parameters**

| Parameter                    | Value |
|------------------------------|-------|
| Number of bits per code word | 63    |
| Number of data bits          | 39    |
| Number of redundant bits     | 24    |
| Minimum distance of the code | 9     |

The generator polynomial for this code is:

$$G(x) = (x^6 + x + 1) (x^6 + x^4 + x^2 + x + 1) (x^6 + x^5 + x^2 + x + 1) (x^6 + x^3 + 1)$$

After multiplication of the factors, the generator polynomial is:

$$G(x) = x^{24} + x^{23} + x^{22} + x^{20} + x^{19} + x^{17} + x^{16} + x^{13} + x^{10} + x^9 + x^8 + x^6 + x^5 + x^4 + x^2 + x + 1$$

Annex D contains additional information on SAS address hashing.

#### 4.2.6 Device names and expander device SAS addresses

Each expander device and SAS device shall include a SAS address (see 4.2.4) as its device name.

A SAS address used as a device name shall not be used as any other name or identifier (e.g., a device name, port name, port identifier, or logical unit name (see SAM-5)), except the SAS address of an expander device is the same as the SAS address of the SMP port in that expander device.

SAS devices and expander devices report their device names in the IDENTIFY address frame (see 6.8.2).

Logical units accessed through SSP target ports report SAS target device names through SCSI vital product data (see 9.2.11).

See Annex I for more information on SAS addresses.

#### 4.2.7 Device names for SATA devices with world wide names

Table 21 defines the NAA IEEE Registered format identifier (see 4.2.2) used by device names for SATA devices that provide world wide names in their IDENTIFY (PACKET) DEVICE data.

**Table 21 — Device name created from the IDENTIFY (PACKET) DEVICE world wide name**

| Subformat field name <sup>a</sup> | Specific bits in | Contents <sup>b</sup>                                          |
|-----------------------------------|------------------|----------------------------------------------------------------|
| NAA                               | Byte 0 bits 7:4  | IDENTIFY (PACKET) DEVICE data word 108 bits 15:12 <sup>c</sup> |
| IEEE COMPANY_ID                   | Byte 0 bits 3:0  | IDENTIFY (PACKET) DEVICE data word 108 bits 11:8               |
|                                   | Byte 1           | IDENTIFY (PACKET) DEVICE data word 108 bits 7:0                |
|                                   | Byte 2           | IDENTIFY (PACKET) DEVICE data word 109 bits 15:8               |
|                                   | Byte 3 bits 7:4  | IDENTIFY (PACKET) DEVICE data word 109 bits 7:4                |
| VENDOR SPECIFIC IDENTIFIER        | Byte 3 bits 3:0  | IDENTIFY (PACKET) DEVICE data word 109 bits 3:0                |
|                                   | Byte 4           | IDENTIFY (PACKET) DEVICE data word 110 bits 15:8               |
|                                   | Byte 5           | IDENTIFY (PACKET) DEVICE data word 110 bits 7:0                |
|                                   | Byte 6           | IDENTIFY (PACKET) DEVICE data word 111 bits 15:8               |
|                                   | Byte 7           | IDENTIFY (PACKET) DEVICE data word 111 bits 7:0                |

<sup>a</sup> See table 18.  
<sup>b</sup> IDENTIFY (PACKET) DEVICE data words 108 to 111 contain the world wide name field (see ACS-2).  
<sup>c</sup> This 4-bit field is required to be set to 5h (i.e., IEEE Registered) by ACS-2.

#### 4.2.8 Port names

Port names are not defined in SAS.

See Annex I for more information on SAS addresses.

#### 4.2.9 Port identifiers and SAS port SAS addresses

Each SAS port (e.g., including the STP target port in each STP SATA bridge) shall include a SAS address (see 4.2.4) as its port identifier.

A SAS address used as a port identifier shall not be used as any other name or identifier (e.g., a device name, port name, or logical unit name (see SAM-5)) except:

- a) a SAS address may be used as a port identifier in one or more other SAS domains (see 4.1.4); and
- b) the SAS address of an SMP port in an expander device is the same as the SAS address of the expander device containing that SMP port.

Expander ports do not have port identifiers.

SAS ports in end devices report their port identifiers in the IDENTIFY address frame (see 6.8.2). Expander devices containing SAS ports (e.g., SAS ports attached to virtual phys, or STP target ports in STP SATA bridges) report the port identifiers of those SAS ports in the SMP DISCOVER response (see 9.4.3.10).

Port identifiers are used as source and destination SAS addresses in OPEN address frames (see 6.8.3).

Logical units accessed through SSP target ports report SAS target port identifiers through SCSI vital product data (see 9.2.11).

See Annex I for more information on SAS addresses.

#### 4.2.10 Phy identifiers

Each SAS phy and expander phy shall be assigned an identifier called a phy identifier that is unique within the SAS device and/or expander device. Each SAS logical phy within a SAS phy shall use the same phy identifier. Each expander logical phy within an expander phy shall use the same phy identifier. The phy identifier is used for SMP functions (see 9.4).

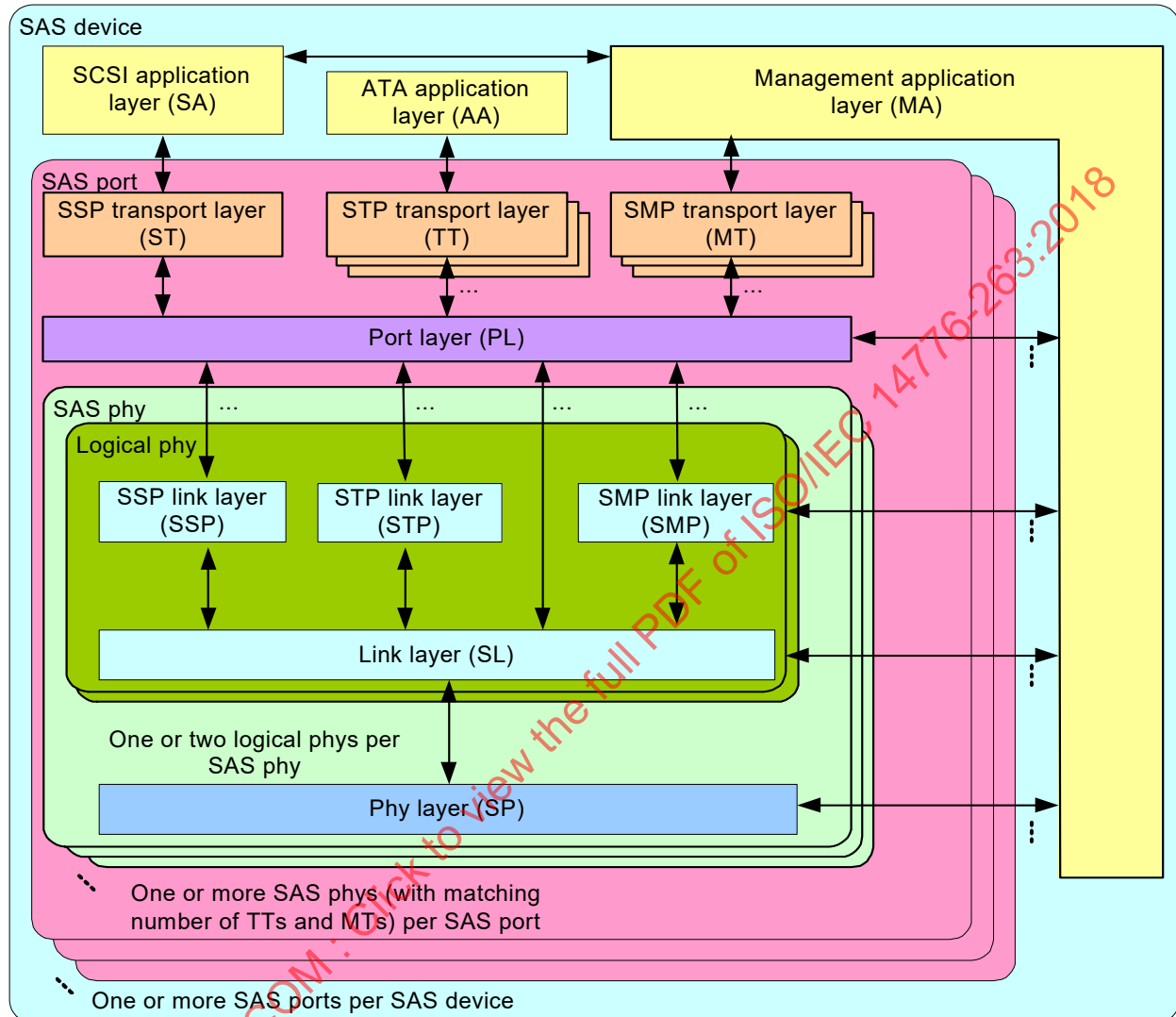
Phy identifiers shall be greater than or equal to 00h and less than or equal to FEh (i.e., 254) and should be numbered starting with 00h. In an expander device or in a SAS device containing an SMP target port, phy identifiers shall be less than the value of the NUMBER OF PHYS field in the SMP REPORT GENERAL response (see 9.4.3.4). In a SAS device containing an SSP target port, phy identifiers shall be less than the value of the NUMBER OF PHYS field in the Phy Control And Discover mode page (see 9.2.7.5).

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## 4.3 State machines

### 4.3.1 State machine overview

Figure 27 shows the state machines for SAS devices and their relationships to each other and to the SAS Device, SAS Port, and SAS Phy classes.



Note 1 - The link layer includes the SL\_IR state machines.

Note 2 - The phy layer includes the PTT state machines.

**Figure 27 — State machines for SAS devices**



Figure 28 shows the state machines for expander devices and their relationships to each other and to the Expander Device, Expander Port, and Expander Phy classes. Expander function state machines are not defined in this standard, but the interface to the expander function is defined in 4.5.6.

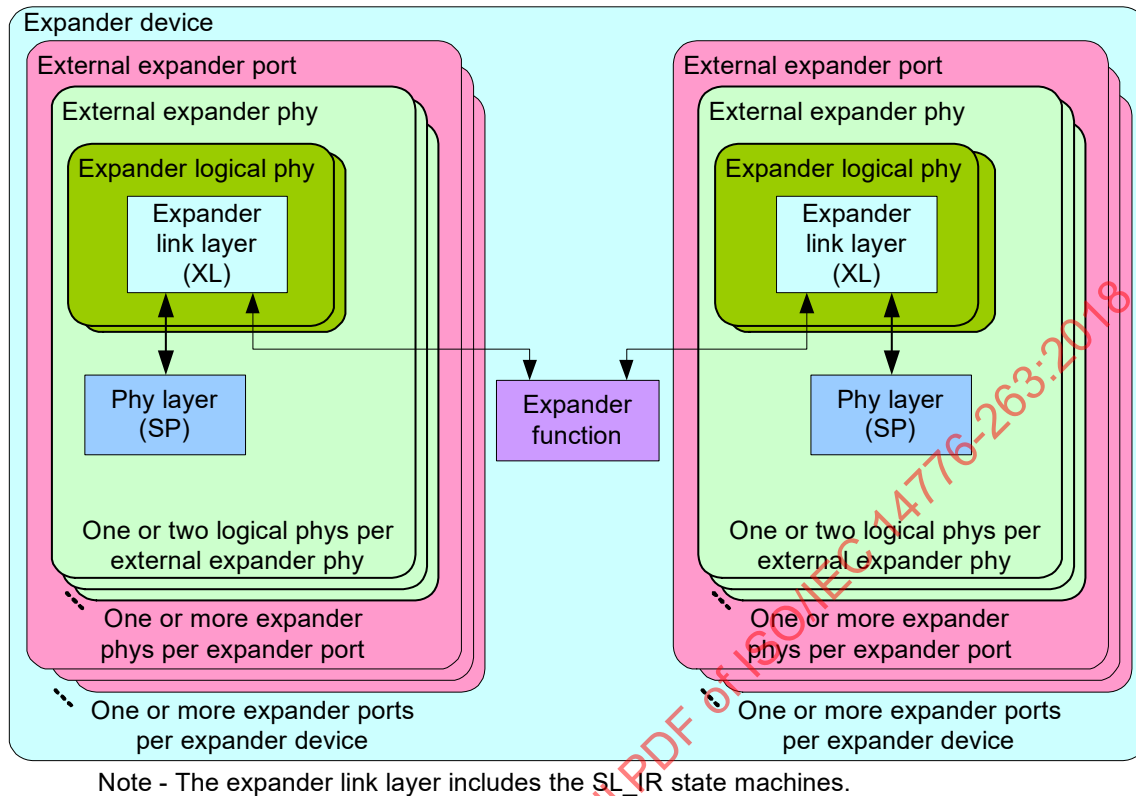


**Figure 28 — State machines for expander devices**

#### 4.3.2 Transmit data path

Figure 29 shows the transmit data path in a SAS phy, showing the relationship between:

- the SP state machine (see 5.12), the PTT state machines (see 5.14), and the SP transmitter (see 5.12.2 and 5.14.2);
- multiplexing (see 5.15);
- the SL\_IR state machines (see 6.10) and the SL\_IR transmitter (see 6.10.2);
- physical link rate tolerance management (see 6.3);
- the SL\_P\_S transmitter (see 6.12.4.2);
- the SL state machines (see 6.16) and the SL transmitter (see 6.16.2);
- rate matching (see 6.15); and
- the SSP transmit data path (see figure 30), SMP transmit data path (see figure 31), and STP transmit data path (see figure 32).

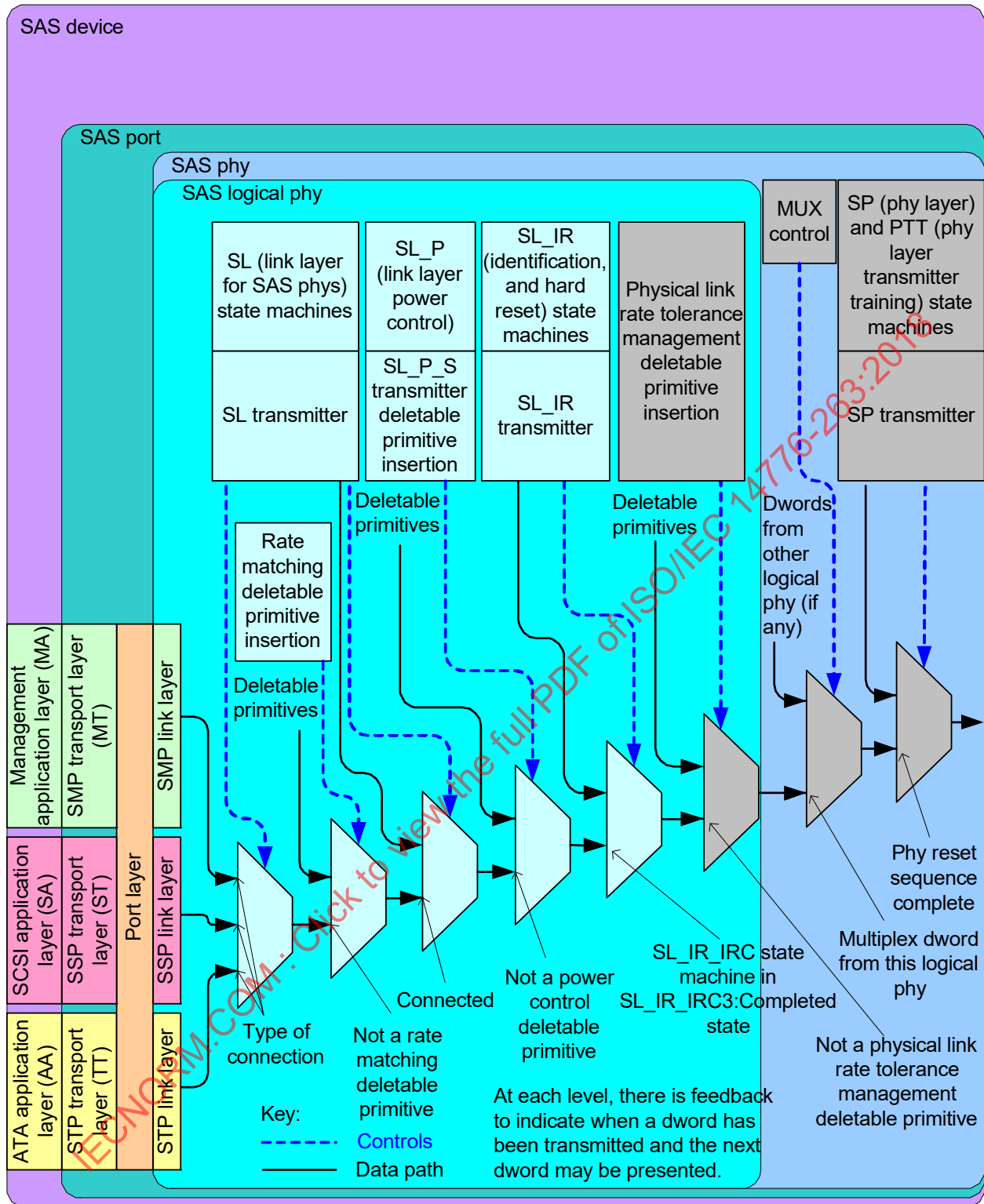


Figure 29 — Transmit data path in a SAS phy

Figure 30 shows the transmit data path for the SSP link layer, including:

- the SSP state machines and the SSP transmitter (see 6.18.9 and 6.18.9.2); and
- the communication to the port layer, SSP transport layer, and SCSI application layer.

Only the SSP link layer (i.e., not the port layer, SSP transport layer, or SCSI application layer) transmits dwords.

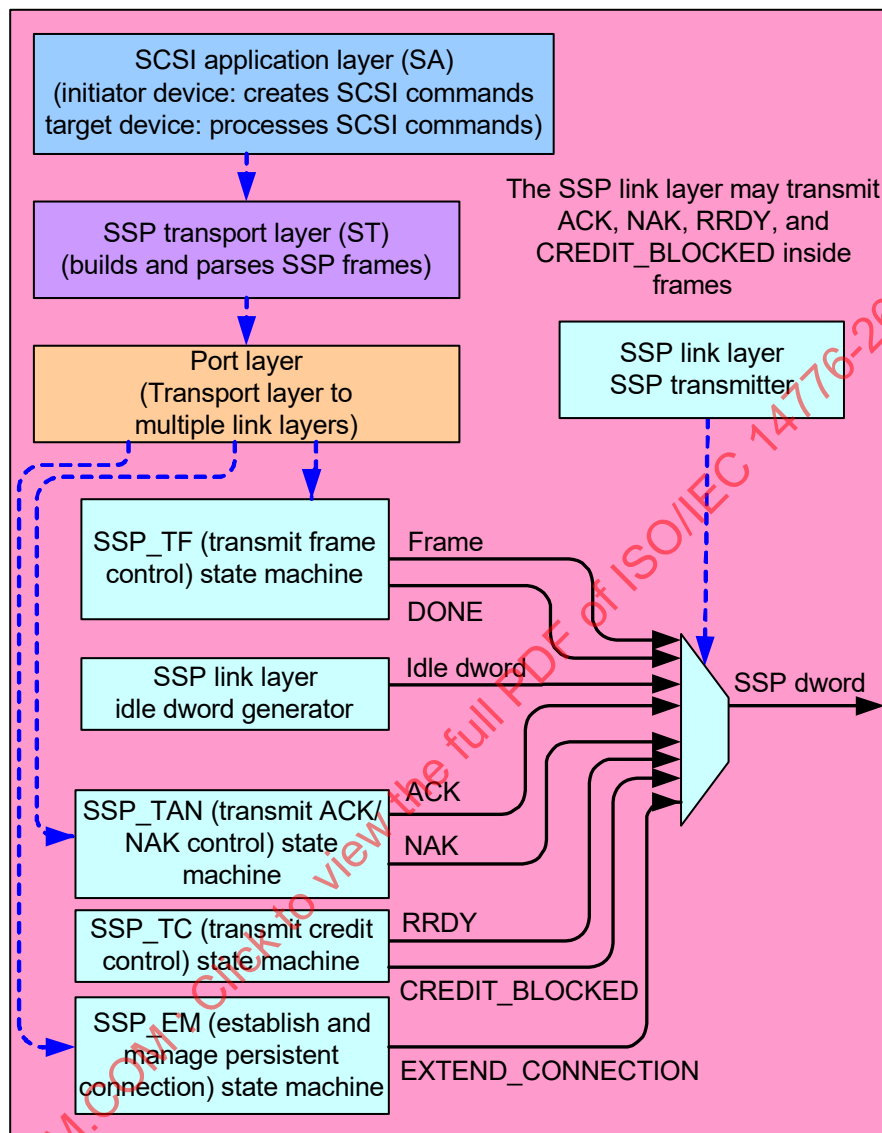


**Figure 30 — SSP link, port, SSP transport, and SCSI application layer state machines**

Figure 31 shows the transmit data path for the SMP link layer, including:

- a) the SMP state machines and the SMP transmitter (see 6.20.5 and 6.20.5.2); and
- b) the communication to the port layer, SMP transport layer, and management application layer.

Only the SMP link layer (i.e., not the port layer, SSP transport layer, or SCSI application layer) transmits dwords.

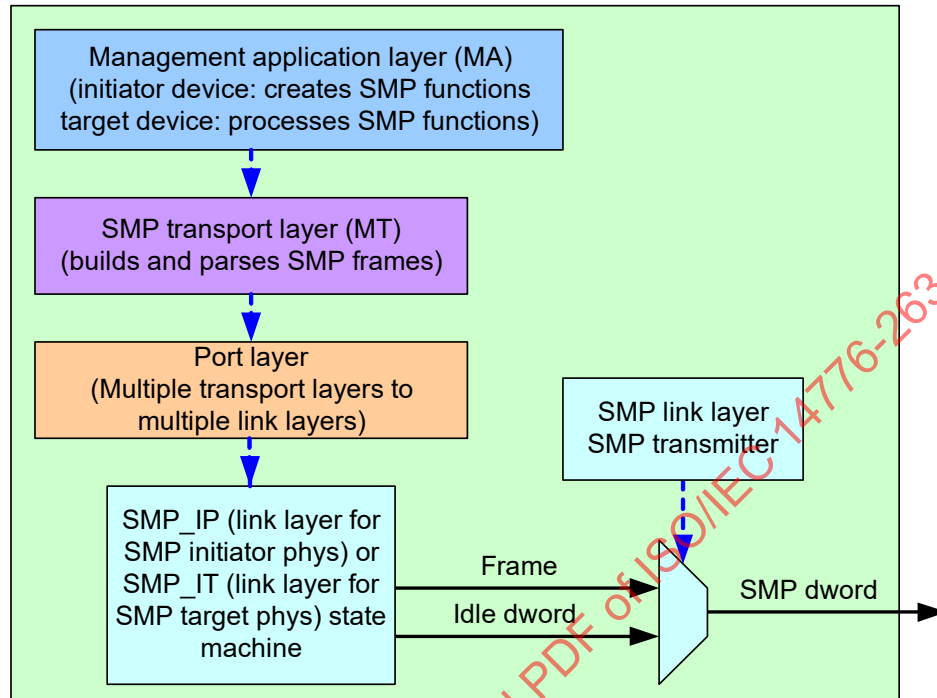


Figure 31 — SMP link, port, SMP transport, and management application layer state machines



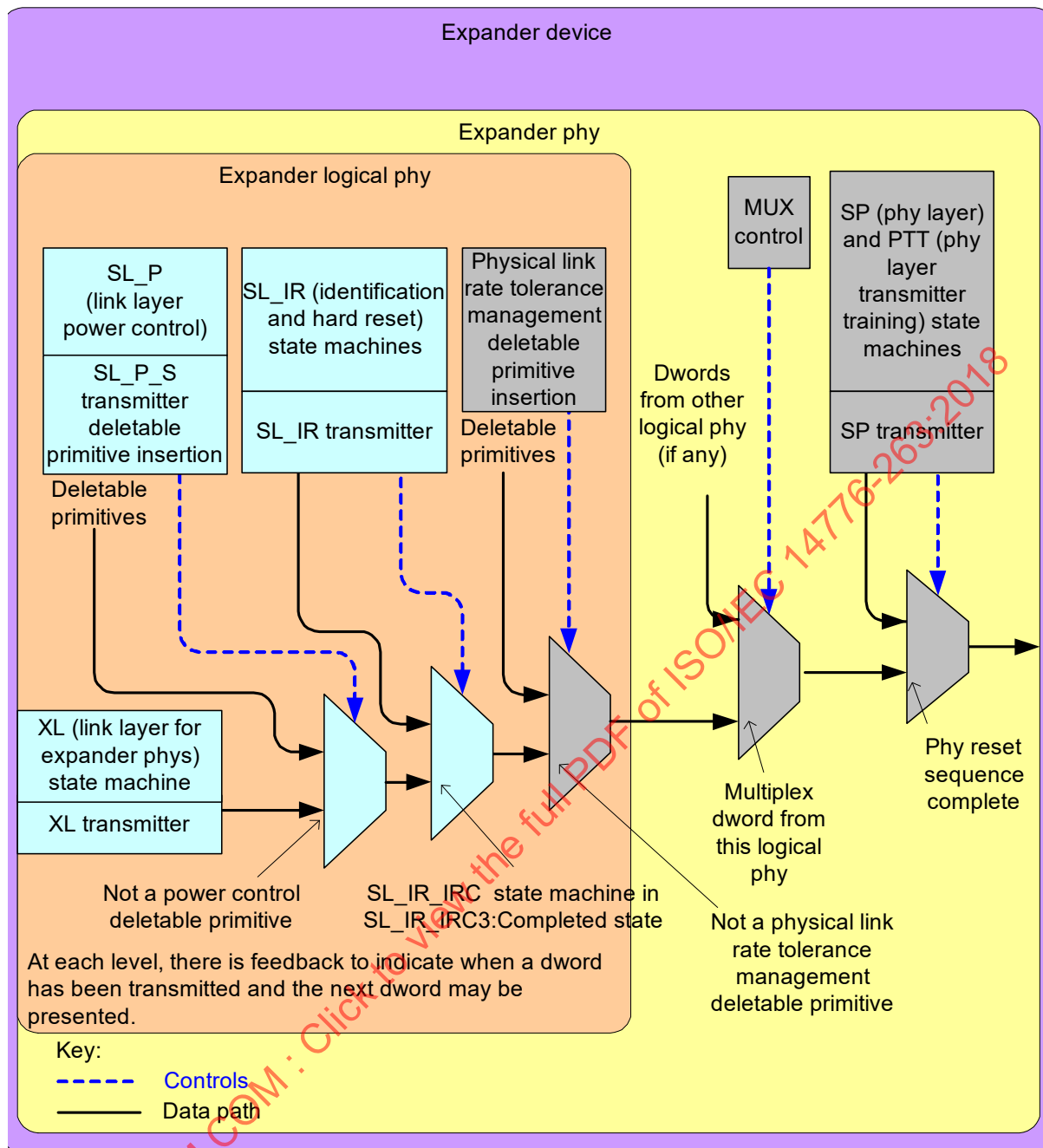


Figure 33 — Transmit data path and state machines in an expander phy

#### 4.3.3 Receive data path

The SP\_DWS receiver (see 5.13.2) establishes dword synchronization and sends dwords to:

- the SP\_DWS state machine (see 5.13); and
- the link layer state machine receivers.

If multiplexing (see 5.15) is enabled (see table 55), then the SP\_DWS receiver uses incoming MUXs to determine the logical link numbers and route the dwords to the appropriate link layer receivers.

Figure 34 shows the receive data path in a SAS phy, showing the relationship between:

- the SP state machine (see 5.12) and the SP receiver (see 5.12.2);

- b) the SP\_DWS state machine (see 5.13) and the SP\_DWS receiver (see 5.13.2);
- c) the SL\_IR state machines (see 6.10) and the SL\_IR receiver (see 6.10.2);
- d) the SL\_P\_S state machine (see 6.12.4) and the SL\_P\_S receiver (see 6.12.4.2);
- e) the SL\_P\_C state machine (see 6.12.5) and the SL\_P\_C receiver (see 6.12.5.2);
- f) the SL state machines (see 6.16) and the SL receiver (see 6.16.2);
- g) the SSP state machines (see 6.18.9) and the SSP receiver (see 6.18.9.2);
- h) the SMP state machines (see 6.20.5) and the SMP receiver (see 6.20.5.2); and
- i) the STP state machines and the STP receiver (see 6.19.8).

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See figure 114 in 6.3.1 for more information about the elasticity buffer, which is not shown in figure 34.

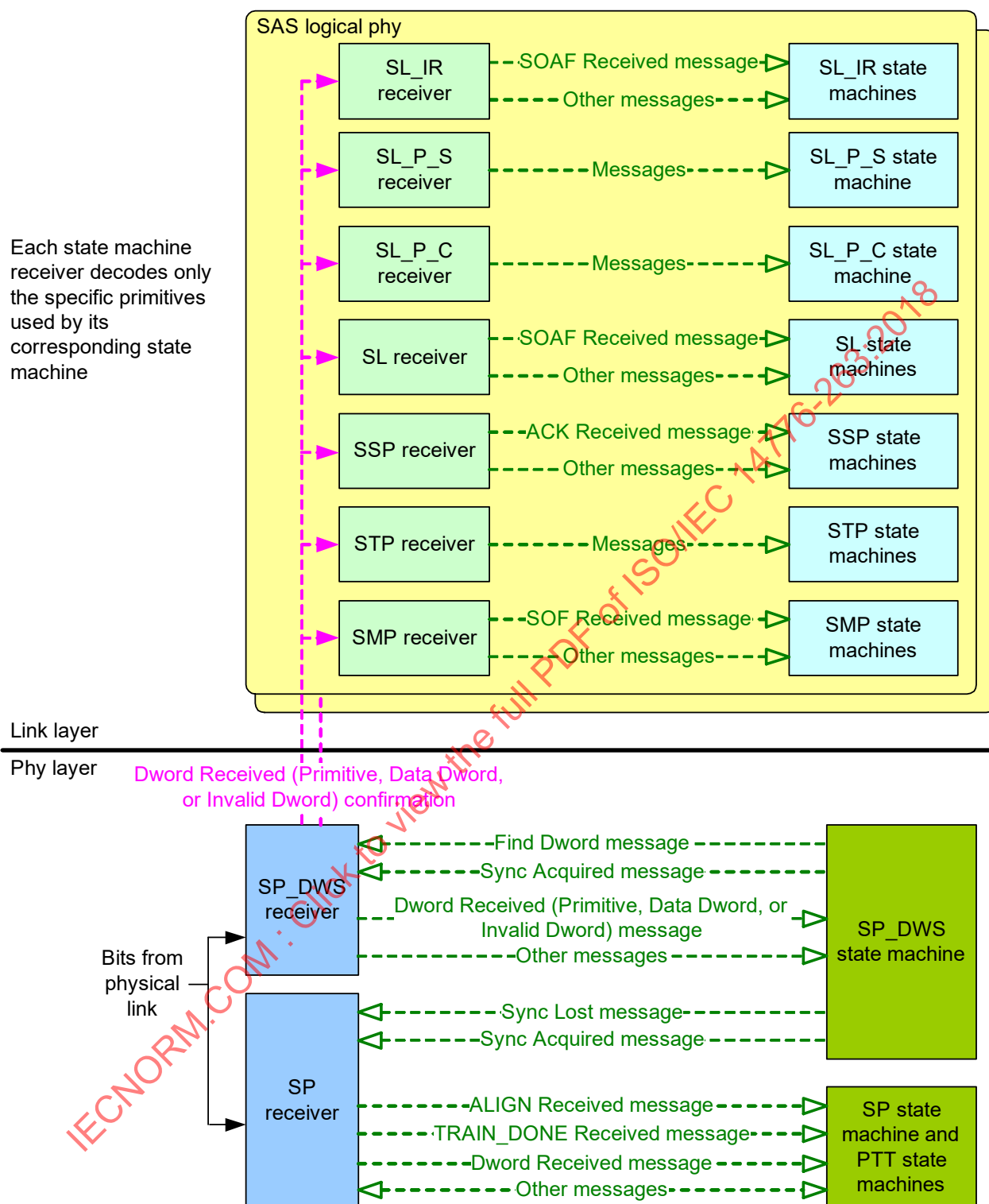


**Figure 34 — Receive data path in a SAS phy**

Figure 35 shows the receive data path in an expander phy showing the relationship between:

- the SP state machine (see 5.12) and the SP receiver (see 5.12.2);
- the SP\_DWS state machine (see 5.13) and the SP\_DWS receiver (see 5.13.2);



- c) the SL\_IR state machines (see 6.10) and the SL\_IR receiver (see 6.10.2);
- d) the SL\_P\_S state machine (see 6.12.4) and the SL\_P\_S receiver (see 6.12.4.2); and
- e) the XL state machine (see 6.17) and the XL receiver (see 6.17.2).

See figure 114 in 6.3.1 for more information about the elasticity buffer, which is not shown in figure 35.

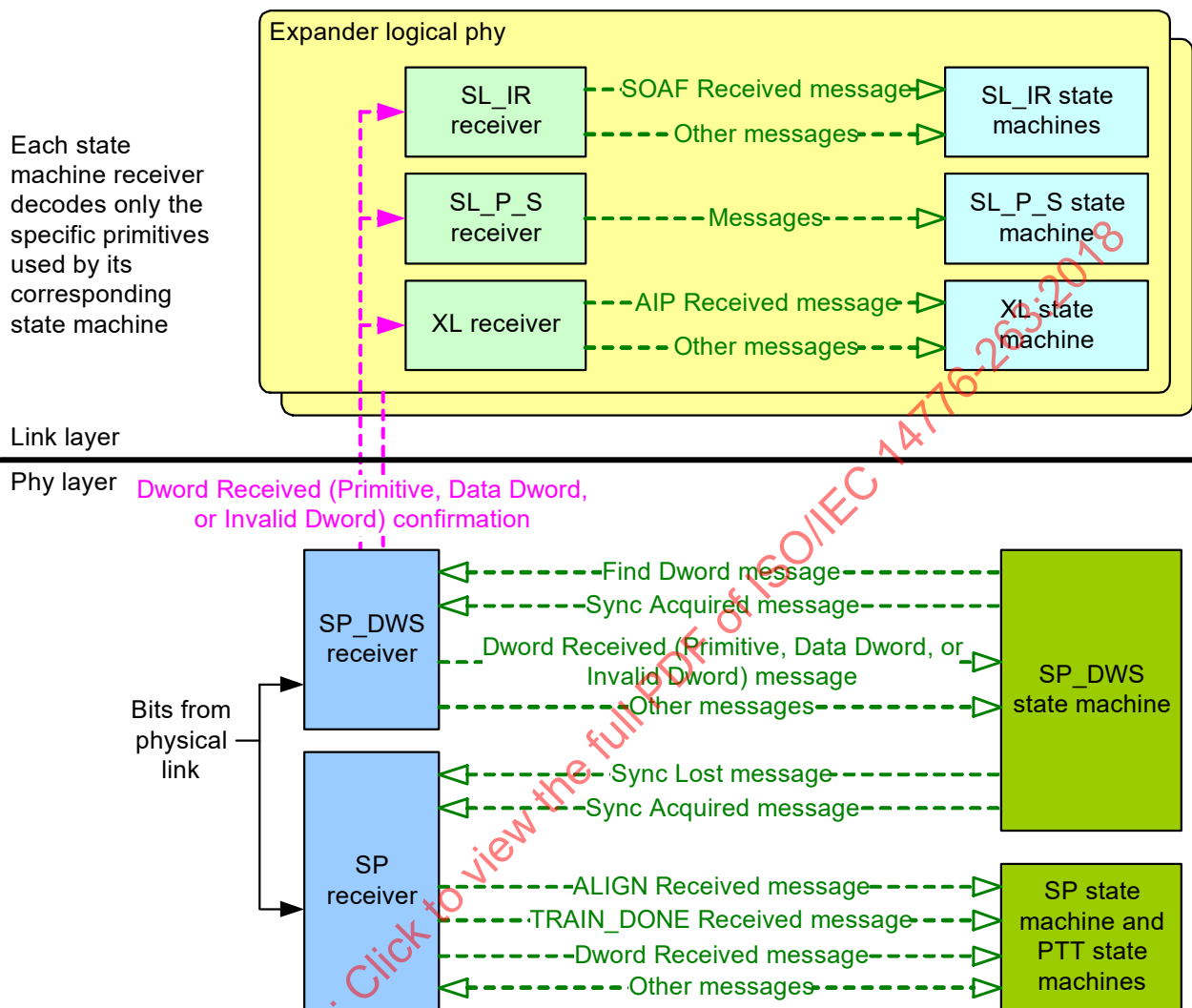


Figure 35 — Receive data path in an expander phy

#### 4.3.4 State machines and SAS Device, SAS Port, and SAS Phy classes

Figure 36 shows which state machines are contained within the SAS Device, SAS Port, SAS Phy, and SAS Logical Phy classes.

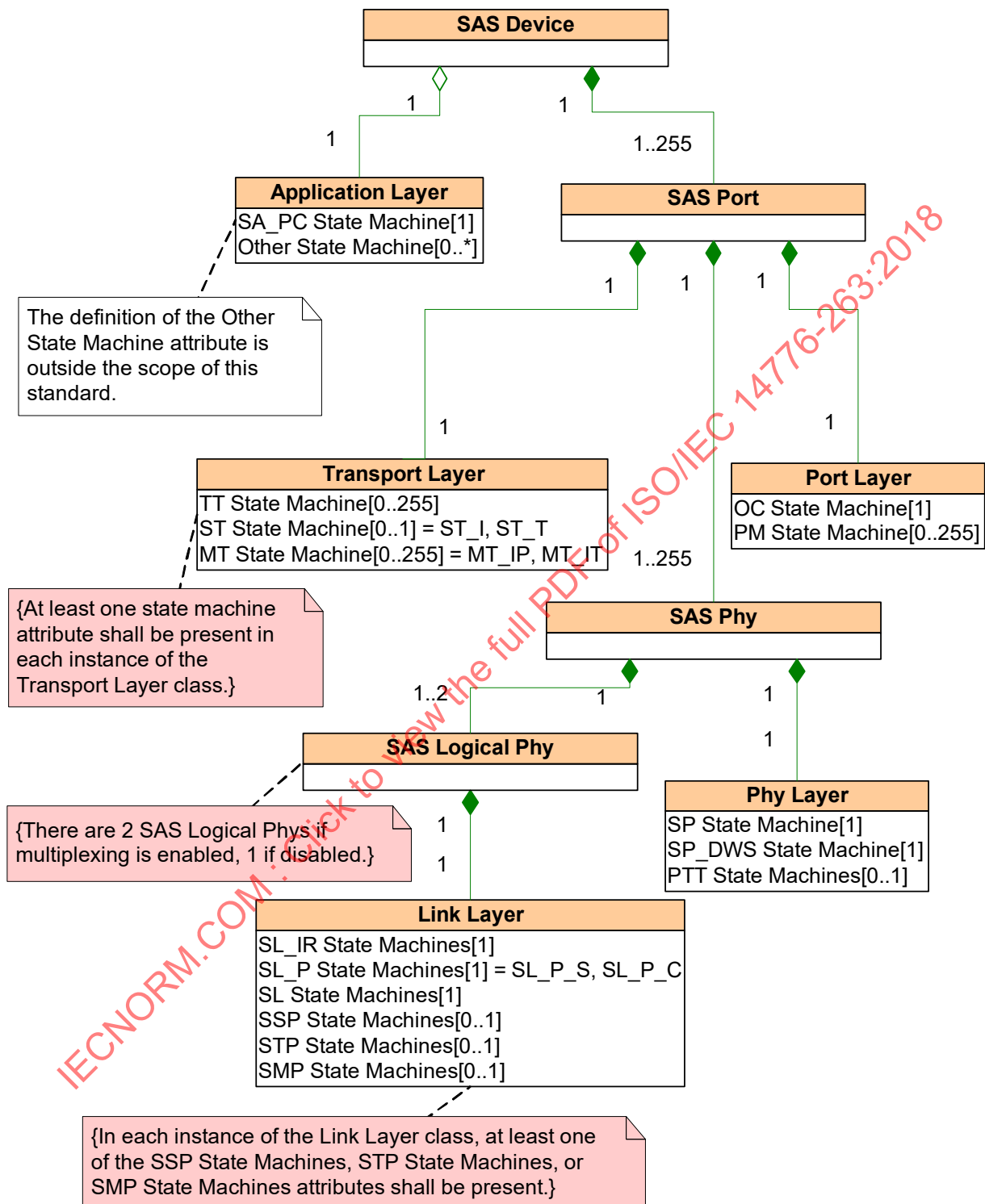


Figure 36 — State machines and SAS Device classes

Figure 37 shows which state machines are contained within the Expander Device, Expander Port, Expander Phy, Expander Logical Phy, SMP Port, SMP Phy, and SMP Logical Phy classes.

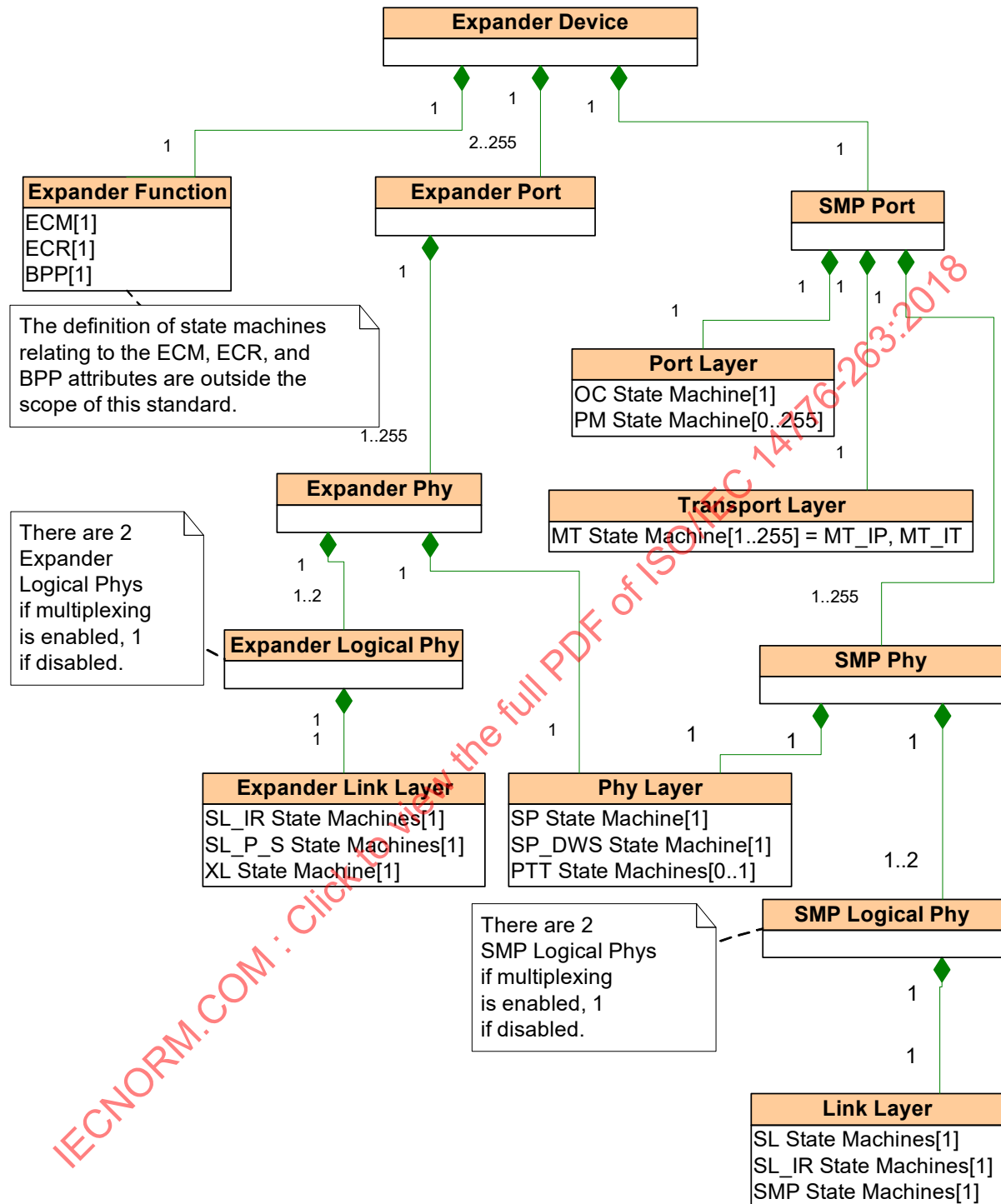


Figure 37 — State machines and Expander Device classes

## 4.4 Events

### 4.4.1 Reset sequences

Figure 38 shows the reset terminology used in this standard:

- a) link reset sequence (see 6.9);
- b) phy reset sequence (see 5.10);
- c) SATA OOB sequence (see 5.10.2.1);
- d) SATA speed negotiation sequence (see 5.10.2.2);
- e) SAS OOB sequence (see 5.10.4.1);
- f) SAS speed negotiation sequence (see 5.10.4.2);
- g) identification sequence (see 6.9); and
- h) hard reset sequence (see 6.9).

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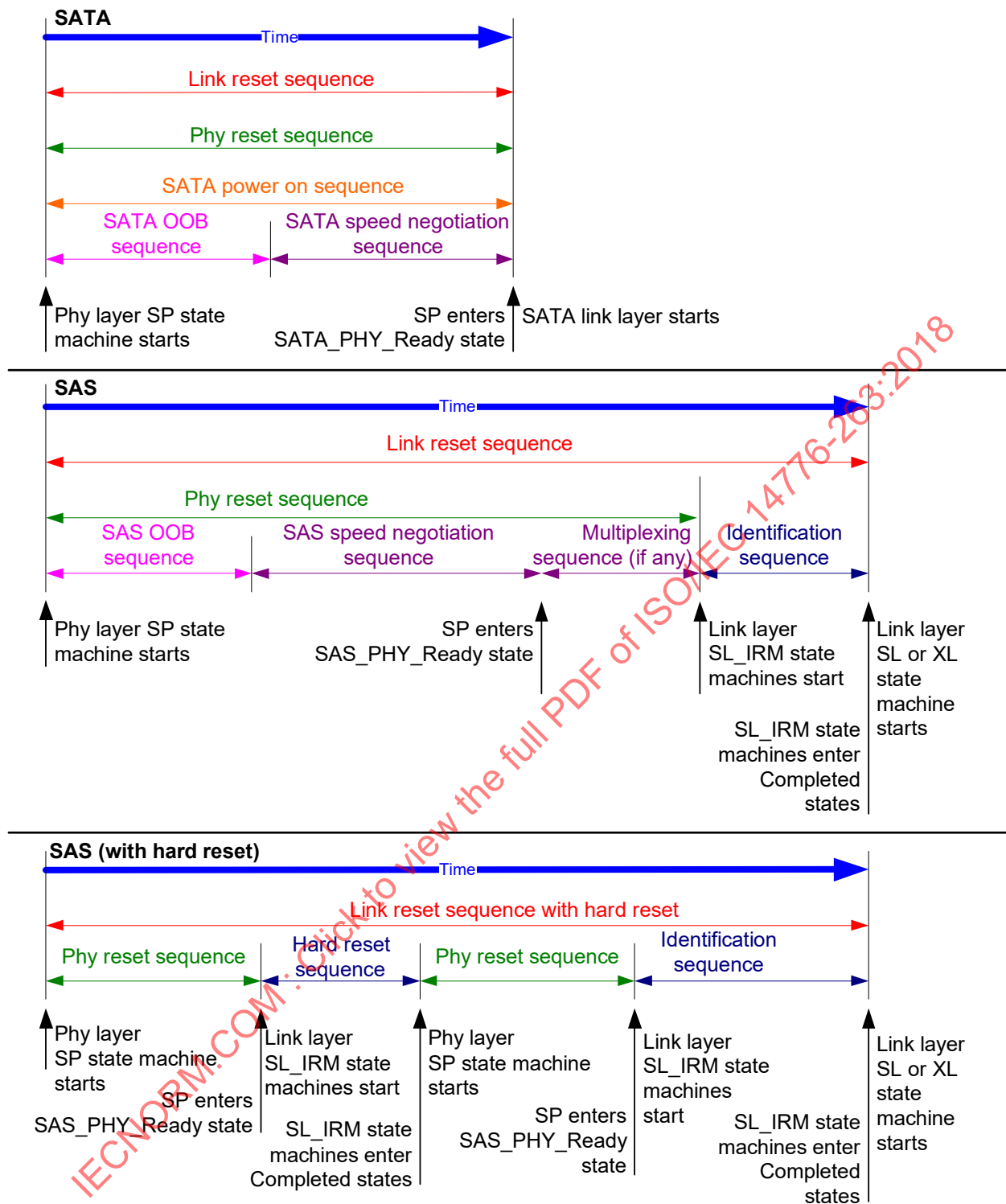


Figure 38 — Reset terminology

The phy reset sequences, including the OOB sequence, the speed negotiation sequence, and the multiplexing sequence, if any, are implemented by the SP state machine and the SP\_DWS state machine and are described in 5.10, 5.12, and 5.13. The identification sequence and hard reset sequence are implemented by the SL\_IR state machines and are described in 6.9 and 6.10.

The link reset sequence has no effect on the transport layer and application layer unless the link reset sequence disrupts frame transmission. A hard reset sequence replaces the identification sequence to initiate a hard reset. The link reset sequence serves as a hard reset for SATA devices (see SATA).

#### 4.4.2 Hard reset

##### 4.4.2.1 Hard reset overview

If, after the phy reset sequence, a phy receives a HARD\_RESET primitive sequence before an IDENTIFY address frame, then the phy shall consider this to be a reset event, and the port containing the phy shall process a hard reset.

When a port processes a hard reset, the port shall stop transmitting valid dwords on each of the phys contained in that port. Each phy may then participate in new phy reset sequences (e.g., respond to incoming COMINITs) and shall originate a new link reset sequence if one is not detected. The hard reset shall not affect any other ports in the device.

If a SAS device is contained in an expander device, then the SSP ports, STP ports, and/or SATA ports in the expander device shall initiate a hard reset when an SMP PHY CONTROL function with a phy operation of HARD RESET and phy identifier specifying a virtual expander phy attached to such a SAS port is processed (see 9.4.3.28).

##### 4.4.2.2 Additional hard reset processing by SAS ports

If the port processing the hard reset is an SSP port, then the hard reset causes a Transport Reset event notification to be sent to the SCSI application layer (see 9.2.5), and the SCSI device shall perform the actions defined for hard reset in SAM-5. After processing a hard reset, each logical unit to which the SSP target port has access shall establish a unit attention condition for all SSP initiator ports with the additional sense code set to SCSI BUS RESET OCCURRED (see SAM-5 and SPC-4).

If the port processing the hard reset is an STP port in an STP SATA bridge, then the SATA host port shall originate a link reset sequence.

If the port processing the hard reset is an STP port that is not in an STP SATA bridge, then the STP target device shall perform the actions defined for power on or hardware reset in ATA8-AAM.

##### 4.4.2.3 Additional hard reset processing by expander ports

If the port processing a hard reset is an expander port, then the expander device shall not originate a hard reset sequence on any of its other phys.

If the port processing a hard reset is an expander port, then the expander function and other expander ports in the expander device shall not be affected by hard reset. SAS devices contained in the expander device shall not be affected by hard resets received by external expander ports in the expander device.

#### 4.4.3 I\_T nexus loss

A SAS port that maintains an I\_T nexus loss timer (see 7.2.2.1) for a destination port uses the I\_T nexus loss timer to delay detection of an I\_T nexus loss (e.g., for cases where a phy on the pathway between the SAS initiator port and SAS target port loses dword synchronization and performs a new link reset sequence).

The SAS port establishes an I\_T nexus loss timer event for a destination port (see 7.2.2.3.3) if:

- a) a connection request to the destination port results in an OPEN\_REJECT (NO DESTINATION), OPEN\_REJECT (RESERVED INITIALIZE 0), or OPEN\_REJECT (RESERVED INITIALIZE 1) (see table 109);
- b) a connection request to the destination port results in the Open Timeout timer expiring (see 6.14.2);
- c) a connection request to the logical phy on the destination port receives a BREAK (see 7.2.2.3.3);
- d) a management application client completing the discover process (see 4.6) detects that the destination port is no longer in the SAS domain; or

- e) there are no phys in the SAS port (see 7.2.2.2).

The SAS port initializes and starts an I\_T nexus loss timer for a destination port after establishing an I\_T nexus loss timer event for the destination port. The SAS port stops the I\_T nexus loss timer if:

- a) a connection request to the destination port results in an OPEN\_REJECT (RESERVED CONTINUE 0), OPEN\_REJECT (RESERVED CONTINUE 1), or OPEN\_REJECT (RETRY) (see table 109);
- b) a connection to the destination port is established; or
- c) a management application client completing the discover process (see 4.6) detects that the destination port is in the SAS domain;

After the SAS port establishes an I\_T nexus loss timer event for a destination port, the SAS port retries any connection request to that destination port until:

- a) a connection to that destination port is established; or
- b) an I\_T nexus loss event occurs.

The SAS port establishes an I\_T nexus loss event for a destination port if:

- a) the I\_T nexus loss timer expires (see 7.2.2.1, 9.2.7.4, and 9.4.3.18);
- b) a connection request to the destination port results in an abandon-class OPEN\_REJECT (see table 108); or
- c) the SAS port receives a vendor specific indication (e.g., SGPIO presence detection) that the destination port is no longer in the SAS domain.

An I\_T nexus loss occurs for a destination port if an I\_T nexus loss event occurs (see SAM-5).

I\_T nexus loss is handled by the port layer state machines (see 7.2.2.3). In some cases, the I\_T nexus loss timer is overridden for connection requests through self-configuring expander devices as described in 4.6.1.

If an I\_T nexus loss occurs in an SSP port, then the SSP port sends a Nexus Loss event notification to the SCSI application layer (see 9.2.5) and the SCSI device shall perform the actions defined for I\_T nexus loss in SAM-5. If an I\_T nexus loss occurs in an SSP initiator port, a SCSI application client should send an I\_T NEXUS RESET task management function to the SSP target port during the next connection between that SSP initiator port and that SSP target port.

If an I\_T nexus loss occurs in an STP initiator port, then the STP initiator port shall send a Transport Event Notification (Nexus Loss, [Device]) indication to the ATA application client (i.e., create a nexus loss event) (see ATA8-AAM). The ATA application client shall consider any commands for the lost STP target port to be completed with an error.

If an I\_T nexus loss occurs in an STP target port, then the ATA device server shall abort all outstanding commands for the lost STP initiator port. If the STP target port is in an STP SATA bridge, then the STP SATA bridge shall originate a link reset sequence to the SATA device so the ATA device server in the SATA device aborts all outstanding commands.

If an I\_T nexus loss occurs in an SMP initiator port, then the SMP initiator port shall stop attempting to establish connections to the lost SMP target port.

If an I\_T nexus loss occurs in an initiator port due to I\_T nexus loss timer expiration, then a management application client should cause a link reset sequence on the phy(s) attached to the lost target port (e.g, if directly attached, then the phys in the initiator port, if attached via expander device(s), then the phys in the expander device attached to the target port).

#### 4.4.4 Power loss expected

If, after the phy reset sequence, a phy receives a NOTIFY (POWER LOSS EXPECTED), then the phy shall consider this to be a power loss expected event, and the port containing the phy shall process a power loss expected (see 6.2.5.3.3).

## 4.5 Expander device model

### 4.5.1 Expander device model overview

An expander device shall contain the following:

- a) an expander function containing:
  - A) an expander connection manager (ECM) (see 4.5.3);
  - B) an expander connection router (ECR) (see 4.5.4); and
  - C) a Broadcast propagation processor (BPP) (see 4.5.5);
- b) two or more physical expander phys;
- c) an expander port available per phy; and
- d) an SMP target port and a management device server.

An expander device may contain any of the following:

- a) an SMP initiator port and a management application client; or
- b) SAS devices with SSP ports, STP ports, and/or SMP ports and their associated device servers and/or application clients.

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Figure 39 shows a model of an expander device showing the state machines in each expander port. The internal SMP ports are not shown.

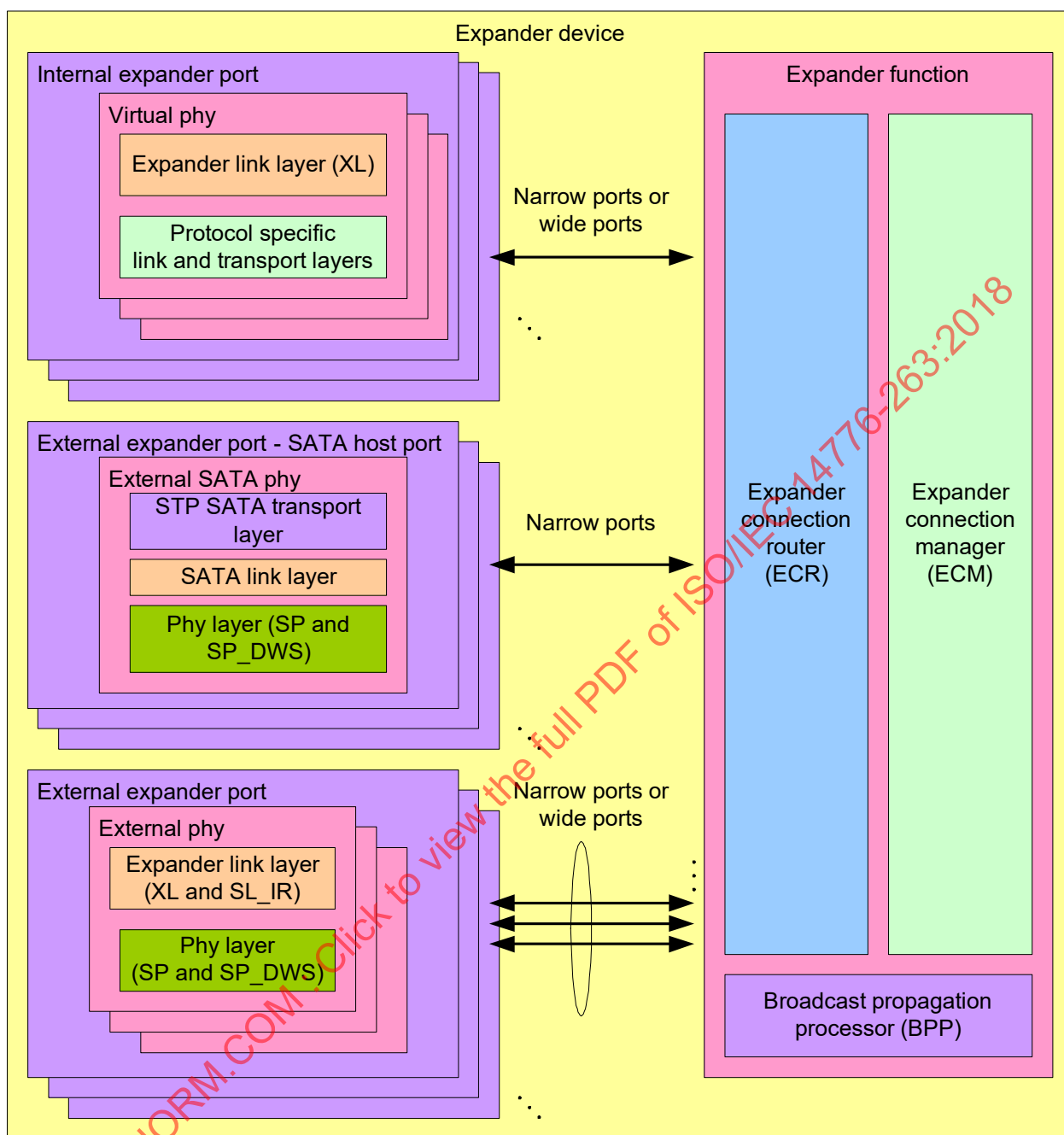


Figure 39 — Expander device model

#### 4.5.2 Expander ports

An external expander port contains one or more physical phys (see 4.1.2). Since each phy in the expander device has the same SAS address, expander ports are created based on the attached SAS addresses (see 4.1.4).

Each phy in an expander port shall have the same routing attribute (see 4.5.7.1). The management device server shall return the same value in the ROUTING ATTRIBUTE field for each phy in an expander port in the SMP DISCOVER response (see 9.4.3.10).

Each phy in an expander port containing phys with table routing attributes in an externally configurable expander device shall have the same number of routing table entries (see 4.5.7.4).

A set of expander phys with table routing attributes in an expander device not supporting table-to-table attachments using the same external connector is called an enclosure out port (see SAS-3). A set of expander phys with subtractive routing attributes using the same external connector is called an enclosure in port (see SAS-3). A set of expander phys with table routing attributes in an expander device supporting table-to-table attachments using the same external connector is called an enclosure universal port (see SAS-3).

Each phy in an expander port shall have the same zone phy information (see 4.8.3.1). The zone phy information associated with each of the phys in an expander port is treated as the zoning properties of the expander port.

Each expander logical phy contains an expander link layer with an XL state machine (see 6.17) and one set of SL\_IR state machines (see 6.10). The XL state machine in each expander logical phy within an expander port processes connection requests independently of the XL state machines in other expander logical phys.

An internal expander port contains a virtual phy with an expander link layer and a protocol specific transport layer (e.g., to provide access as an SSP target port to a logical unit with a peripheral device type set to 0Dh (i.e., enclosure services device) (see SPC-4 and SES-3)).

Each expander device shall include one internal SMP port using the expander device's SAS address.

Any additional internal SAS ports shall be inside SAS devices contained in the expander device, and thus have SAS addresses different from that of the expander device. These SAS ports shall be attached to internal expander ports with virtual phys.

Each STP SATA bridge shall have a unique SAS address. This SAS address is reported in the ATTACHED SAS ADDRESS field in the SMP DISCOVER response (see 9.4.3.10) for the expander phy containing the STP SATA bridge (i.e., the expander phy attached to the SATA device or SATA port selector).

#### 4.5.3 Expander connection manager (ECM)

The ECM performs the following functions:

- a) maps a destination SAS address in a connection request to a destination phy using direct, subtractive, or table routing methods;
- b) arbitrates and assigns or denies path resources for connection requests following SAS arbitration and pathway recovery rules;
- c) configures the ECR; and
- d) manages phy power conditions (see 4.10).

#### 4.5.4 Expander connection router (ECR)

The ECR routes messages between pairs of expander logical phys as configured by the ECM. Enough routing resources shall be provided to support at least one connection.

While forwarding dwords during a connection from a phy with a higher logical link rate to a phy with a lower logical link rate, rate matching (see 6.15) ensures the dwords are at a connection rate equal to or less than the lower logical link rate. However, the ECR may be requested to forward more dwords than the receiving phy is able to accept if:

- a) an invalid dword occurs during a deletable primitive;
- b) an invalid dword occurs during a CLOSE primitive sequence; or
- c) multiple invalid dwords occur during a BREAK primitive sequence.

If an elasticity buffer (see 6.3) overflow occurs, then the ECR may discard dwords and count that event as an elasticity buffer overflow (see 4.12).

While forwarding dwords from a SATA physical link with a higher physical link rate to a SAS logical link with a lower logical link rate, the SATA host port in the STP SATA bridge shall throttle incoming FISes with SATA\_HOLD (see 6.19.2).

NOTE 3 - SATA allows the receiver of a SATA\_HOLD to transmit up to 20 data dwords after detection of SATA\_HOLD. Therefore, the transmitter of SATA\_HOLD receives up to 21+n data dwords for Gen1 or Gen2, or 25+n data dwords for Gen3 (see 6.19.2). SATA\_HOLD does not affect primitives (see SATA). The STP SATA bridge expands or contracts repeated and continued primitives without changing their functional meaning.

When forwarding dwords from a SAS logical link with a lower logical link rate to a SATA physical link with a higher physical link rate, the SATA host port in the STP SATA bridge shall perform a process similar to rate matching (see 6.15) by inserting ALIGN (0) and/or SATA\_HOLD on the SATA physical link whenever it underflows.

NOTE 4 - SATA requires that ALIGN (0) be transmitted in pairs (see SATA).

#### **4.5.5 Broadcast propagation processor (BPP)**

The BPP receives Broadcasts from each expander logical phy or from the management device server on behalf of an expander logical phy and requests transmission of those Broadcasts on all expander ports except the expander port from which the Broadcast was received.

In a zoning expander device with zoning enabled (see 4.8.2), Broadcasts are forwarded as described in 4.8.5.

#### **4.5.6 Expander device interfaces**

##### **4.5.6.1 Expander device interface overview**

The expander device arbitrates and routes between expander logical phys. All routing occurs between expander logical phys, not expander ports. The interaction between an XL state machine and the expander function consists of requests, confirmations, indications, and responses. This interaction is called the expander device interface.

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Figure 40 describes the interfaces present within an expander device.

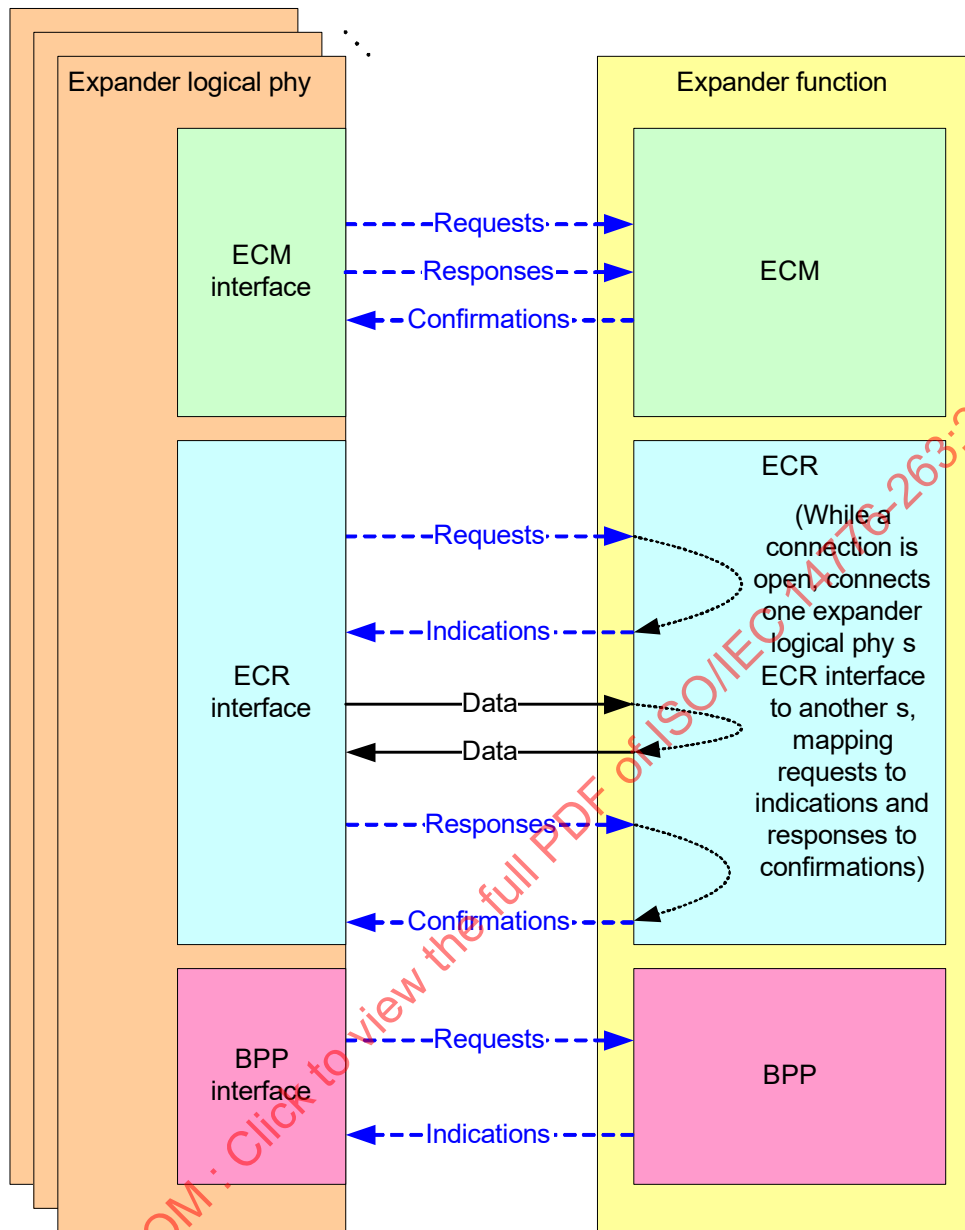


Figure 40 — Expander device interfaces

## 4.5.6.2 Expander device interfaces detail

Figure 41 shows the interface requests, confirmations, indications, and responses used by an expander device to manage connections.

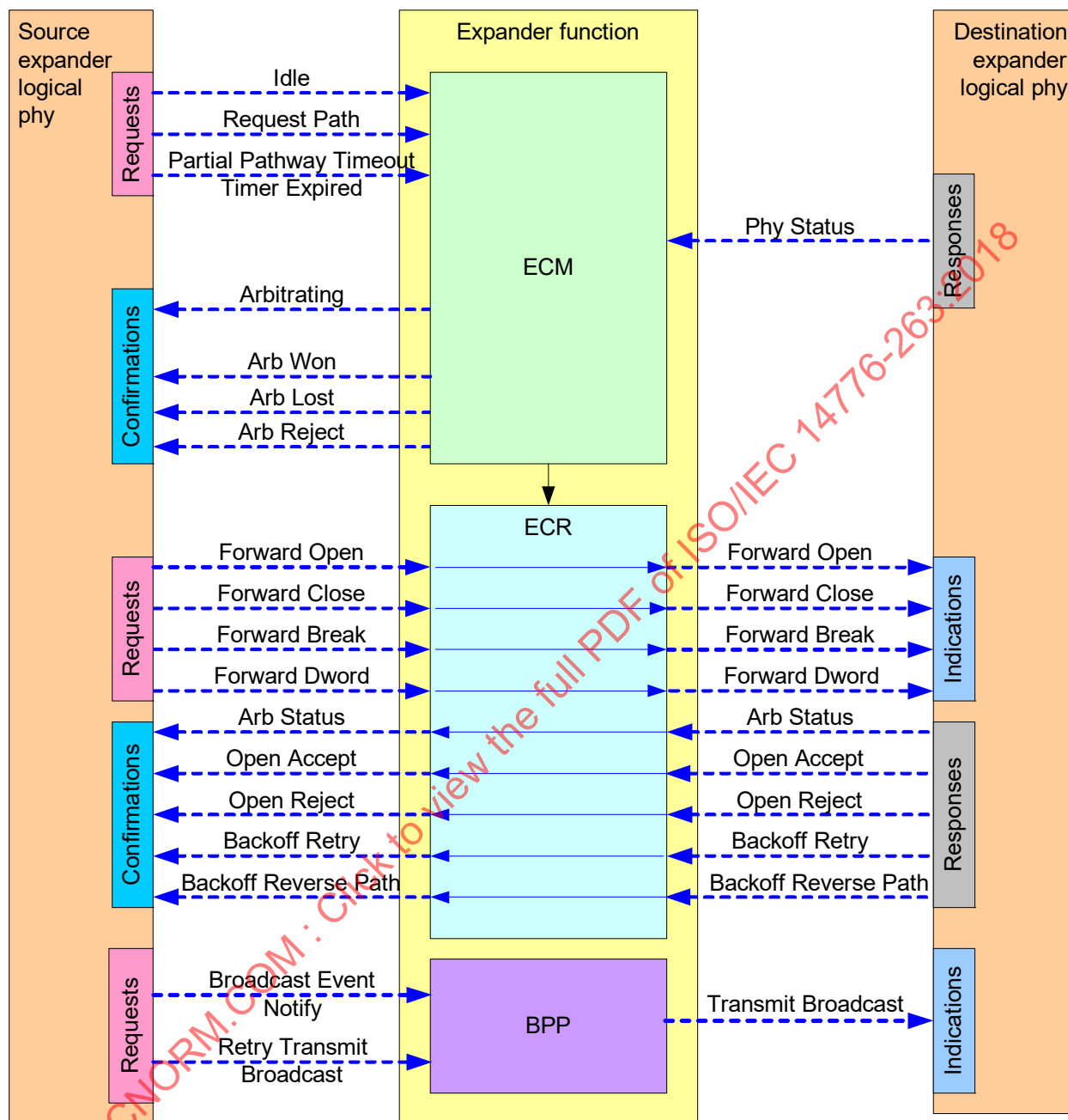


Figure 41 — Expander device interface detail

#### 4.5.6.3 ECM interface

Table 22 describes the requests from an expander logical phy to the ECM. The XL state machine (see 6.17) defines when each request is sent.

**Table 22 — Expander logical phy to ECM requests**

| Request                               | Description                                                                                                         |
|---------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Idle                                  | The XL state machine is in the XL0:Idle state (e.g., after receiving an Enable Disable SAS Link (Disable) message). |
| Request Path (arguments)              | Request for a connection.                                                                                           |
| Partial Pathway Timeout Timer Expired | The Partial Pathway Timeout Timer expired.                                                                          |

Table 23 describes the responses from an expander logical phy to the ECM. The XL state machine (see 6.17) defines when each response is sent.

**Table 23 — Expander logical phy to ECM responses**

| Response                             | Description                                                                                                                                                                                     |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phy Status (Partial Pathway)         | Response meaning that an expander logical phy:<br>a) is being used for an unblocked partial pathway; or<br>b) is waiting on another expander logical phy being used for a partial pathway.      |
| Phy Status (Blocked Partial Pathway) | Response meaning that an expander logical phy:<br>a) is being used for a blocked partial pathway; or<br>b) is waiting on another expander logical phy being used for a blocked partial pathway. |
| Phy Status (Connection)              | Response meaning that an expander logical phy:<br>a) is being used for a connection; or<br>b) is waiting on another expander logical phy being used for a connection.                           |
| Phy Status (Breaking Connection)     | Response meaning that an expander logical phy is breaking a connection.                                                                                                                         |

Table 24 describes the confirmations from the ECM to an expander logical phy. These confirmations are sent in confirmation of a Request Path request. See 6.14.4 for specific definitions for when each confirmation is sent.

**Table 24 — ECM to expander logical phy confirmations**

| Confirmation                               | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Arbitrating (Normal)                       | Confirmation that the ECM has received the Request Path request.                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Arbitrating (Waiting On Partial)           | Confirmation that the ECM is waiting on a partial pathway (see 4.1.11).                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Arbitrating (Blocked On Partial)           | Confirmation that the ECM is waiting on a blocked partial pathway (see 4.1.11).                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Arbitrating (Waiting On Connection)        | Confirmation that the ECM is waiting for a connection to complete (see 4.1.12).                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Arb Won                                    | Confirmation that an expander logical phy has won path arbitration.                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Arb Lost                                   | Confirmation that an expander logical phy has lost path arbitration.                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Arb Reject (No Destination)                | Confirmation that the request is rejected because the expander device is not configuring (see 4.6.4) and there is no path to the destination.                                                                                                                                                                                                                                                                                                                                                                                               |
| Arb Reject (Bad Destination)               | Confirmation that the request is rejected because the path to the destination maps back to the requesting expander port.                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Arb Reject (Connection Rate Not Supported) | Confirmation that the request is rejected because there is a destination port capable of routing to the requested destination SAS address but no phys within the destination port are configured to support the requested connection rate.                                                                                                                                                                                                                                                                                                  |
| Arb Reject (Zone Violation)                | Confirmation that the request is rejected because the expander device is not locked and there is a zoning violation (see 4.8.3).                                                                                                                                                                                                                                                                                                                                                                                                            |
| Arb Reject (Pathway Blocked)               | Confirmation that the request is rejected because SAS pathway recovery rules require the requesting expander logical phy to back off (see 6.14.4.2.5).                                                                                                                                                                                                                                                                                                                                                                                      |
| Arb Reject (Retry)                         | Confirmation that the request is rejected because: <ul style="list-style-type: none"> <li>a) the expander device is configuring (see 4.6.4) and the ECM detects a connection that results in an Arb Reject (No Destination) if the condition is not resolved;</li> <li>b) the expander device is locked (see 4.8.6.2) and the ECM detects a connection that results in an Arb Reject (Zone Violation) if the condition is not resolved; or</li> <li>c) the expander device has reduced functionality (see 4.5.8 and 6.14.4.2.5).</li> </ul> |

#### 4.5.6.4 ECR interface

Table 25 describes the requests from an expander logical phy to the ECR and the corresponding indications from the ECR to another expander logical phy. The XL state machine (see 6.17) defines when each request is sent.

**Table 25 — Expander logical phy to ECR to expander logical phy requests and indications**

| Request/indication       | Description                                          |
|--------------------------|------------------------------------------------------|
| Forward Open (arguments) | Request/indication to forward an OPEN address frame. |
| Forward Close            | Request/indication to forward a CLOSE.               |
| Forward Break            | Request/indication to forward a BREAK.               |
| Forward Dword            | Request/indication to forward a dword.               |

Table 26 describes the responses from an expander logical phy to the ECR and the corresponding confirmations from the ECR to another expander logical phy. These responses are sent in response to a Forward Open indication. The XL state machine (see 6.17) defines when each response is sent.

**Table 26 — Expander logical phy to ECR to expander logical phy responses and confirmations** (part 1 of 2)

| Response/confirmation              | Description                                                                                                                                                                                                                   |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Arb Status (Normal)                | Confirmation/response that AIP (NORMAL) has been received.                                                                                                                                                                    |
| Arb Status (Waiting On Partial)    | Confirmation/response that AIP (WAITING ON PARTIAL) has been received.                                                                                                                                                        |
| Arb Status (Waiting On Connection) | Confirmation/response that AIP (WAITING ON CONNECTION) has been received.                                                                                                                                                     |
| Arb Status (Waiting On Device)     | Confirmation/response that either:<br>a) AIP (WAITING ON DEVICE) has been received; or<br>b) the expander logical phy has completed the forwarding of an OPEN address frame and has entered the XL6:Open_Response_Wait state. |



**Table 26 — Expander logical phy to ECR to expander logical phy responses and confirmations** (part 2 of 2)

| Response/confirmation | Description                                                                                                                                                                                                                                                                                                                                                            |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Open Accept           | Confirmation/response that OPEN_ACCEPT has been received.                                                                                                                                                                                                                                                                                                              |
| Open Reject           | Confirmation/response that either:<br>a) OPEN_REJECT has been received; or<br>b) that the phy is in the slumber phy power condition (see 4.10.1.4).                                                                                                                                                                                                                    |
| Backoff Retry         | Confirmation/response that the phy is in the partial phy power condition (see 4.10.1.3) or:<br>a) a higher priority OPEN address frame has been received (see 6.14.3); and<br>b) the source SAS address and connection rate of the received OPEN address frame are not equal to the destination SAS address and connection rate of the transmitted OPEN address frame. |
| Backoff Reverse Path  | Confirmation/response that:<br>a) a higher priority OPEN address frame has been received (see 6.14.3); and<br>b) the source SAS address and connection rate of the received OPEN address frame are equal to the destination SAS address and connection rate of the transmitted OPEN address frame.                                                                     |

#### 4.5.6.5 BPP interface

Table 27 describes the requests from an expander logical phy to the BPP. Requests from the management device server about SMP ZONED BROADCAST requests (see table 311) received from the SMP target port in zoning expander devices with zoning enabled are not described by this standard. See 4.8.5 for more information on how zoning expander devices with zoning enabled handle Broadcasts.

**Table 27 — Expander logical phy to BPP requests**

| Request                                                   | Description                                                                                                                                                                                                                                                                                              |
|-----------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Broadcast Event Notify (Phy Not Ready)                    | Request to originate a Broadcast (Change) because the expander logical phy's SP state machine transitioned from the SP15:SAS_PHY_Ready state, SP22:SATA_PHY_Ready state, SP31:SAS_PS_Low_Phy_Power state, SP32:SAS_PS_ALIGN0 state, or SP33:SAS_PS_ALIGN1 state to the SP0:OOB_COMINIT state (see 5.12). |
| Broadcast Event Notify (SATA Spinup Hold)                 | Request to originate a Broadcast (Change) because the SATA spinup hold state has been reached (see 5.12 and 5.16) by the expander phy.                                                                                                                                                                   |
| Broadcast Event Notify (Identification Sequence Complete) | Request to originate a Broadcast (Change) because the expander logical phy has completed the identification sequence (see 6.9).                                                                                                                                                                          |
| Broadcast Event Notify (SATA Port Selector Change)        | Request to originate a Broadcast (Change) because the expander phy detected that a SATA port selector appeared or disappeared.                                                                                                                                                                           |
| Broadcast Event Notify (Change Received)                  | Request to forward a Broadcast (Change) because the expander logical phy received a Broadcast (Change). See 6.13 and 6.17.                                                                                                                                                                               |
| Broadcast Event Notify (Reserved Change 0 Received)       | Request to forward a Broadcast (Reserved Change 0) because the expander logical phy received a Broadcast (Reserved Change 0). See 6.13 and 6.17.                                                                                                                                                         |
| Broadcast Event Notify (Reserved Change 1 Received)       | Request to forward a Broadcast (Reserved Change 1) because the expander logical phy received a Broadcast (Reserved Change 1). See 6.13 and 6.17.                                                                                                                                                         |
| Broadcast Event Notify (SES Received)                     | Request to forward a Broadcast (SES) because the expander logical phy received a Broadcast (SES). See 6.17.                                                                                                                                                                                              |
| Broadcast Event Notify (Expander Received)                | Request to forward a Broadcast (Expander) because the expander logical phy received a Broadcast (Expander). See 6.17.                                                                                                                                                                                    |
| Broadcast Event Notify (Asynchronous Event Received)      | Request to forward a Broadcast (Asynchronous Event) because the expander logical phy received a Broadcast (Asynchronous Event). See 6.17.                                                                                                                                                                |
| Broadcast Event Notify (Reserved 3 Received)              | Request to forward a Broadcast (Reserved 3) because the expander logical phy received a Broadcast (Reserved 3). See 6.17.                                                                                                                                                                                |
| Broadcast Event Notify (Reserved 4 Received)              | Request to forward a Broadcast (Reserved 4) because the expander logical phy received a Broadcast (Reserved 4). See 6.17.                                                                                                                                                                                |

Table 28 describes the indications from the BPP to an expander logical phy. Indications to the management application client to generate SMP ZONED BROADCAST functions from the SMP initiator port in a zoning expander device with zoning enabled are not described. See 4.8.5 for more information on how zoning expander devices with zoning enabled handle Broadcasts.

**Table 28 — BPP to expander logical phy indications**

| Message                   | Description                                                                    |
|---------------------------|--------------------------------------------------------------------------------|
| Transmit Broadcast (type) | Indication to transmit a BROADCAST primitive sequence with the specified type. |

#### 4.5.7 Expander device routing

##### 4.5.7.1 Routing attributes and routing methods

Each expander phy in an expander device shall support one of the following routing attributes:

- a) a direct routing attribute;
- b) a table routing attribute; or
- c) a subtractive routing attribute.

The routing attributes allow the ECM to determine which routing method to use when routing connection requests to the expander logical phys in the expander phy:

- a) the table routing method routes connection requests to attached expander devices using an expander route table;
- b) the subtractive routing method routes unresolved connection requests to an attached expander device; or
- c) the direct routing method routes connection requests to attached end devices, the SMP port of an attached expander device, or SAS devices contained in the expander device.

Table 29 describes the routing methods that the ECM uses based on the routing attributes of an expander phy.

**Table 29 — Routing attributes and routing methods**

| Routing attribute of an expander phy                                                                                                                              | Routing method used by ECM for the expander phy |                                                                                                           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                   | If attached to an end device                    | If attached to an expander device                                                                         |
| Direct                                                                                                                                                            | Direct <sup>a</sup>                             |                                                                                                           |
| Table                                                                                                                                                             | Direct                                          | Direct for the SAS address of the expander device.<br>Table for SAS addresses beyond the expander device. |
| Subtractive                                                                                                                                                       | Direct                                          | Subtractive                                                                                               |
| <sup>a</sup> If attached to an expander device, then the ECM is only able to route to the expander device itself through a phy with the direct routing attribute. |                                                 |                                                                                                           |

An expander device may have zero or more phys with the table routing attribute. A self-configuring expander device may support table-to-table attachment (i.e., having its table routing phys attached to the table routing

phys of other expander devices). An externally configurable expander device shall not support table-to-table attachment.

An expander device shall have at most one defined port containing phys with the subtractive routing attribute.

The SMP REPORT GENERAL function (see 9.4.3.4) reports whether or not the expander device is self-configuring and supports table-to-table attachment. The SMP DISCOVER function (see 9.4.3.10) reports the routing attribute of each expander phy (see 9.4.3.4).

#### 4.5.7.2 Expander device topology routing attribute restrictions

If an expander device does not support table-to-table attachment, then its table-routing phys shall not be attached to table routing phys in other expander devices (e.g., they may be attached to subtractive routing phys).

If multiple phys within an expander device have subtractive routing attributes and are attached to expander devices, then they shall be attached to phys with identical SAS addresses (i.e., the same expander device).

If multiple phys within an expander device have subtractive routing attributes and are attached to expander devices that do not have identical SAS addresses, then the management application client that is performing the discover process (see 4.6) shall report an error in a vendor specific manner.

#### 4.5.7.3 Connection request routing

The ECM shall determine how to route a connection request from a source expander logical phy to a destination expander logical phy in a different expander port if the destination expander logical phy is enabled, operating at a valid logical link rate (see 9.4.3.10), and not excluded because of zoning (see 4.8.2) using the following precedence:

- 1) route to an expander logical phy with the direct routing attribute or table routing attribute when the destination SAS address matches the attached SAS address;
- 2) route to an expander logical phy with the table routing attribute when the destination SAS address matches an enabled SAS address in the expander route table;
- 3) route to an expander logical phy with the subtractive routing attribute; and
- 4) return an Arb Reject confirmation (see 4.5.6.3) to the source expander logical phy.

If the destination expander logical phy only matches an expander logical phy in the same expander port from which the connection request originated, then the ECM shall return an Arb Reject confirmation (see 4.5.6.3).

If the destination SAS address of a connection request matches a disabled SAS address in an expander route table, then the ECM shall ignore the match.

If low phy power conditions (see 4.10.1) are enabled in the expander device, then the ECM should use the following precedence in selecting the destination expander logical phy when the expander port contains multiple expander logical phys:

- 1) expander logical phys in the active phy power condition (see 4.10.1.2);
- 2) expander logical phys in the partial phy power condition (see 4.10.1.3); and
- 3) expander logical phys in the slumber phy power condition (see 4.10.1.4).

#### 4.5.7.4 Expander route table

##### 4.5.7.4.1 Expander route table overview

An expander device that supports the table routing method shall contain an expander route table. The expander route table is a structure that provides an association between destination SAS addresses (i.e., routed SAS addresses) and the expander phys to which connection requests to those destination SAS addresses are forwarded.

Zoning expander devices include additional fields in their expander route tables (see 4.8.3.4).

Table 30 defines the types of expander route tables.

**Table 30 — Expander route table types**

| Type           | SMP functions to access                                                                | Reference |
|----------------|----------------------------------------------------------------------------------------|-----------|
| Phy-based      | REPORT ROUTE INFORMATION (see 9.4.3.13) and CONFIGURE ROUTE INFORMATION (see 9.4.3.27) | 4.5.7.4.2 |
| Expander-based | REPORT EXPANDER ROUTE TABLE LIST (see 9.4.3.17)                                        | 4.5.7.4.3 |

#### 4.5.7.4.2 Phy-based expander route table

Figure 42 shows a representation of a phy-based expander route table.

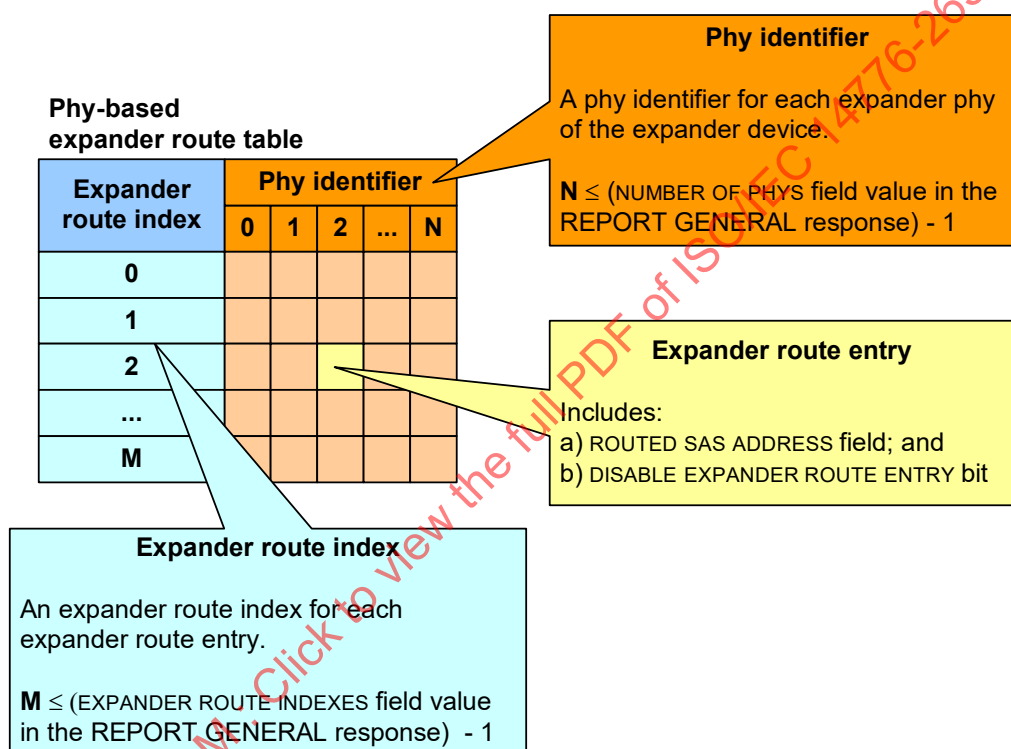


**Figure 42 — Phy-based expander route table**

For each expander route index and phy identifier combination, the phy-based expander route table contains an expander route entry containing a ROUTED SAS ADDRESS field and a DISABLE EXPANDER ROUTE ENTRY bit.

A management application client may access a specific expander route entry within a phy-based expander route table with the SMP REPORT ROUTE INFORMATION function (see 9.4.3.13) and the SMP CONFIGURE ROUTE INFORMATION function (see 9.4.3.27).

An expander device reports the maximum expander route index in the EXPANDER ROUTE INDEXES field and indicates if the phy-based expander route table is configurable in the EXTERNALLY CONFIGURABLE ROUTE TABLE bit in the SMP REPORT GENERAL response (see 9.4.3.4).

Each expander route entry shall be disabled after power on.

#### 4.5.7.4.3 Expander-based expander route table

Figure 43 shows a representation of an expander-based expander route table.

**Expander-based expander route table**

| Routed SAS address | Phy bit map |   |   |     |   |
|--------------------|-------------|---|---|-----|---|
|                    | 0           | 1 | 2 | ... | N |
| SAS address A      |             |   |   |     |   |
| SAS address B      |             |   |   |     |   |
| SAS address C      |             |   |   |     |   |
| ...                |             |   |   |     |   |

Indicates the expander phy(s) to which connection requests to the routed SAS address may be forwarded.

1 indicates the expander phy is used for forwarding connection requests, 0 indicates it is not

**Figure 43 — Expander-based expander route table**

Routed SAS addresses are not required to be sorted in any particular order.

For each routed SAS address, the expander-based expander route table contains a phy bit map.

A management application client may access an expander-based expander route table with the SMP REPORT EXPANDER ROUTE TABLE LIST function (see 9.4.3.17).

An expander device reports the size of its expander-based expander route table in the MAXIMUM NUMBER OF ROUTED SAS ADDRESSES field in the SMP REPORT GENERAL response (see 9.4.3.4).

#### 4.5.8 Expander device reduced functionality

An expander device shall originate a Broadcast (Expander) to indicate that the expander device is going to have reduced functionality for a period of time (e.g., if, during a microcode update, the expander device disables the ECM and ECR access to its SMP target port or to one or more expander phys, or if the expander device experiences reduced performance). The maximum period of time that the expander device is going to have reduced functionality is indicated:

- in the REPORT SUPPORTED OPERATION CODES command parameter data (see SPC-4) for the WRITE BUFFER command reported by a logical unit with a peripheral device type set to 0Dh (i.e., enclosure services device) accessed via an SSP target port contained in the expander device; and
- from the contents of the MAXIMUM REDUCED FUNCTIONALITY TIME field in the REPORT GENERAL response (see 9.4.3.4).

After the expander device originates a Broadcast (Expander) to indicate that it is going to have reduced functionality for a period of time, the expander device shall:

- set the REDUCED FUNCTIONALITY bit to one in the REPORT GENERAL response (see 9.4.3.4);
- initialize the reduced functionality delay timer to the value indicated by the INITIAL REDUCED FUNCTIONALITY DELAY field in the REPORT GENERAL response (see 9.4.3.4) and start the reduced functionality delay timer;
- wait for the reduced functionality delay timer to expire before reducing any expander functionality; and
- not stop or restart the reduced functionality delay timer until after the expander device enters the reduced functionality condition.

If the expander device receives a connection request that maps to an expander phy or its SMP target port that is not accessible because of the reduced functionality, then the expander device shall respond with an OPEN REJECT (RETRY) until the operation that caused the expander device to have reduced functionality is complete.

After the operation that caused the expander device to have reduced functionality is complete, the expander device shall:

- 1) set the REDUCED FUNCTIONALITY bit to zero in the REPORT GENERAL response (see 9.4.3.4); and
- 2) originate a Broadcast (Change) or a link reset sequence on each expander phy.

#### 4.5.9 Broadcast (Expander) handling

After receiving a Broadcast (Expander), a management application client behind an SMP initiator port should issue a REPORT GENERAL function (see 9.4.3.4) to all expander devices to determine:

- a) the expander devices, if any, that are reducing their functionality (i.e., the REDUCED FUNCTIONALITY bit is set to one in the REPORT GENERAL response) (see 4.5.8); and
- b) the amount of time remaining until the reduced functionality occurs (i.e., the contents of the TIME TO REDUCED FUNCTIONALITY field in the REPORT GENERAL response).

If an expander device is found that is reducing its functionality, then the management application client should:

- a) terminate any outstanding I\_T\_L\_Q nexuses whose connections are through that expander device; and
- b) not create any new I\_T\_L\_Q nexuses whose connections go through that expander device.

### 4.6 Discover process

#### 4.6.1 Discover process overview

Management application clients direct an SMP initiator port to request SMP functions from an SMP target port. Management application clients are located in every SAS initiator device and every self-configuring expander device. A management application client performs a discover process to discover all the SAS devices and expander devices in the SAS domain (i.e., determining their device types, SAS addresses, and supported protocols). A SAS initiator device uses this information to determine SAS addresses with which it is able to establish connections (i.e., establish I\_T nexuses) and to select connection rates for connection requests (see 6.8.3). A self-configuring expander device uses this information to fill in its expander route table.

#### 4.6.2 Starting the discover process (Broadcast (Change) handling)

In a SAS initiator device, a management application client behind an SMP initiator port should perform a discover process after a link reset sequence or after receiving a Broadcast (Change).

In a self-configuring expander device, the management application client behind an SMP initiator port in a self-configuring expander device shall perform a discover process after a link reset sequence or after receiving a Broadcast (Change).

When a discover process is performed after a link reset sequence, the management application client discovers all the devices in the SAS domain. When a discover process is performed after a Broadcast (Change), the management application client determines which devices have been added to or removed from the SAS domain.

During a discover process a management application client in a SAS initiator device:

- a) may request that the SAS port establish an I\_T nexus loss timer event (see 7.2.2) for each device that has been removed from the SAS domain; and
- b) shall request that the SAS port stop the I\_T nexus loss timer (see 7.2.2), if any, for each device that has been added to the SAS domain.

#### 4.6.3 Discover process traversal

A management application client performing the discover process shall perform a level-order (i.e., breadth-first) traversal of the SAS domain. The management application client shall discover devices in the following order:

- 1) the device(s) to which the device containing the management application client is attached;
- 2) for each expander phy with the subtractive routing attribute or the table routing attribute, if the attached device is an expander device, then every device attached to that expander device; and
- 3) repeat step 2) for each additional expander device found attached to that expander device.

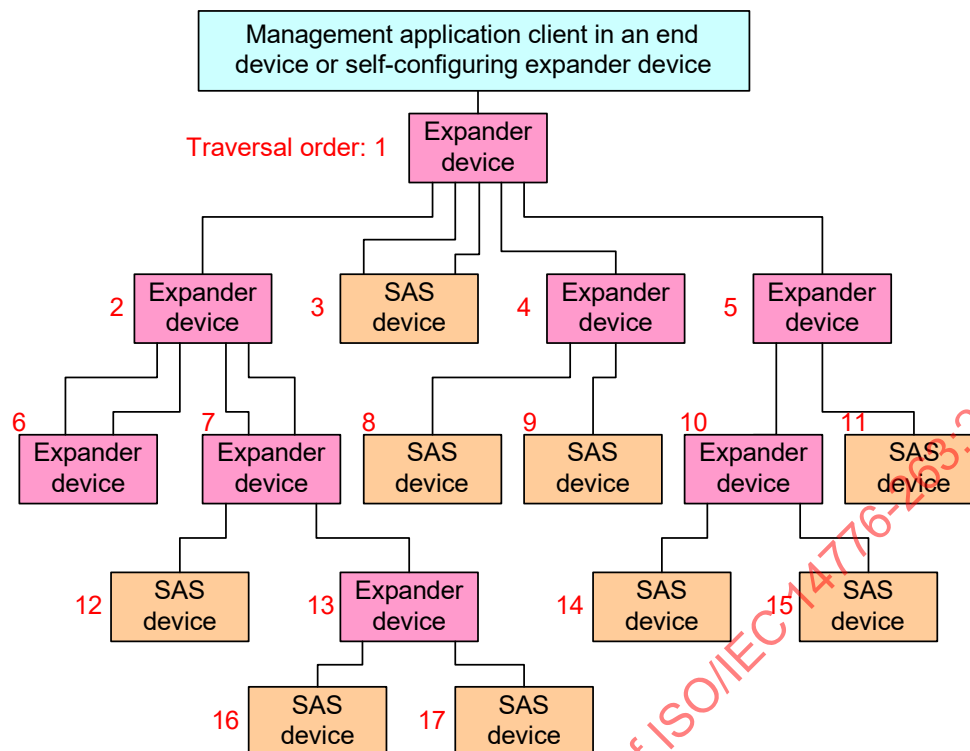
The discover process completes when all expander devices have been traversed. If the management application client discovers an externally configurable expander device that is not located beyond a self-configuring expander device with the CONFIGURES OTHERS bit set to one in the REPORT GENERAL response (see 9.4.3.4), then the management application client shall perform the configuration subprocess (see 4.7) to configure the expander route table before attempting to establish connections with devices attached two or more levels (see 4.7.4) beyond that externally configurable expander device.

If a management application client is in an end device or a self-configuring expander device that is directly attached to a self-configuring expander device with the CONFIGURES OTHERS bit set to one in the REPORT GENERAL response (see 9.4.3.4), then the management application client is not required to perform the configuration subprocess. If all the expander devices in the SAS domain are self-configuring expander devices, then management application clients in end devices are not required to perform the configuration subprocess.

If the management application client is inside a self-configuring expander device, then the discover process shall be repeated on each expander port.



Figure 44 shows an example of level-order traversal.



Note - Assume that the phy with the lowest phy identifier in each expander device is on the top right, and the remaining phys have increasing phy identifiers assigned in a counter-clockwise direction

**Figure 44 — Level-order traversal example**

The management application client determines whether an expander device or SAS device is attached at each point in the traversal. For the first device (i.e., the device that is directly attached), this is determined from the DEVICE TYPE field in the IDENTIFY address frame (see 6.8.2) information received by the phy that the management application client is using. For other devices (i.e., devices that are not directly attached), this is determined from ATTACHED DEVICE TYPE field the SMP DISCOVER response (see 9.4.3.10).

If an expander device is attached, then the management application client shall use the SMP REPORT GENERAL function (see 9.4.3.4) to determine how many phys are in the expander device and then use the SMP DISCOVER function (see 9.4.3.10) and/or the SMP DISCOVER LIST function (see 9.4.3.15) to determine what is attached to each expander phy (e.g., the device type, SAS address, and supported protocol(s)).

NOTE 5 - Expander devices compliant with SAS-1.1 do not implement the SMP DISCOVER LIST function.

If the expander device's EXTERNALLY CONFIGURABLE ROUTE TABLE bit is set to zero in the SMP REPORT GENERAL response, its own management application client shall configure its own expander route table as described in 4.7.

If a self-configuring expander device's SELF CONFIGURING bit is set to one in the SMP REPORT GENERAL response, then any connection request in which there is no path to the requested destination returns OPEN\_REJECT (RETRY) instead of OPEN\_REJECT (NO DESTINATION) (see 4.5.6.3, 4.6.4, and 4.8.6.3).

If a SAS device is attached, then the discover process is not required to obtain any more information about the SAS device. Additional discovery software may access that SAS device, however, as follows:

- a) if the SAS device supports an SMP target port, then the management application client may use SMP functions (e.g., REPORT GENERAL and REPORT MANUFACTURER INFORMATION) to determine additional information about the SAS target device;
- b) if the SAS device supports an SSP target port, then a SCSI application client may transmit SCSI commands (e.g., INQUIRY and REPORT LUNS) to determine additional information about the SCSI target device; and
- c) if the end device supports an STP target port, then an ATA application client may transmit ATA commands (e.g., IDENTIFY DEVICE and IDENTIFY PACKET DEVICE (see ACS-2)) to determine additional information about the ATA device.

The result of the discover process is that the management application client has the necessary information (e.g., the device type, SAS address, and supported protocol(s)) to communicate with each SAS device and expander device in the SAS domain and each externally configurable expander device is configured with the necessary expander route entries to allow routing of connection requests through the SAS domain.

The discover process may be aborted prior to completion and restarted if there is an indication that it may be using incorrect information (e.g., reception of a Broadcast (Change) or a change in the EXPANDER CHANGE COUNT field returned in an SMP response frame).

#### 4.6.4 Discover process in a self-configuring expander device

The management application client of a self-configuring expander device shall configure:

- a) the expander routing table in that expander device; and
- b) the expander routing table in each externally configurable expander device in the SAS domain that is not located behind another self-configuring expander device with the CONFIGURES OTHERS bit set to one in the REPORT GENERAL response (see 9.4.3.4).

When a self-configuring expander device receives a Broadcast (Change) the management application client shall start the discover process using the expander port that received the Broadcast (Change). If a change to the expander route table is identified, then the management device server shall set its SELF CONFIGURING bit to one in the SMP REPORT GENERAL response (see 9.4.3.4).

If zoning is enabled, then the management application client in a self-configuring expander device shall use the SMP DISCOVER response (see 9.4.3.10) or SMP DISCOVER LIST response (see 9.4.3.15) values to set the zone group values in the zoning expander route table for all SAS addresses in the zoning expander route table (see 4.8.3.4).

The management device server shall set the SELF CONFIGURING bit to zero when the discover process is complete. When the SELF CONFIGURING bit changes from one to zero:

- a) a zoning expander device with zoning enabled shall originate a Broadcast (Change) on each expander port that has access to the expander port through which the discover process was performed based on the zone permission table; and
- b) an expander device with zoning disabled shall originate a Broadcast (Change) on each expander port other than the one through which the discover process was performed.

After receiving a Broadcast (Change), a self-configuring expander device shall continue to route connection requests for each previously valid SAS address until the expander device determines that the SAS address is no longer valid. After determining that a SAS address is no longer valid, the self-configuring expander device shall continue to route connection requests for other SAS addresses.

If the SELF CONFIGURING bit is set to one and there is a connection request in which there is no path to the requested destination, then the expander device shall return OPEN\_REJECT (RETRY) instead of OPEN\_REJECT (NO DESTINATION) (see 4.5.6.3).

The management application client in a self-configuring expander device shall maintain self-configuration status for the last vendor specific number of errors encountered during self-configuration and should maintain at least one self-configuration status per phy. The management device server shall assign descriptors to the

statuses sequentially starting at 0001h and shall return the descriptors in the SMP REPORT SELF-CONFIGURATION STATUS response (see 9.4.3.6). The management device server shall return the index of the last self-configuration status descriptor in the SMP REPORT GENERAL response (see 9.4.3.4), the SMP REPORT SELF-CONFIGURATION STATUS response (see 9.4.3.6), and the SMP DISCOVER LIST response (see 9.4.3.15). The management device server shall wrap the index to 0001h when the highest supported descriptor index has been used.

The management device server shall support self-configuration status descriptor indexes from 0001h to FFFFh. The actual number of self-configuration status descriptors that the management device server maintains for retrieval with the REPORT SELF-CONFIGURATION STATUS request is vendor specific and is indicated by the MAXIMUM NUMBER OF STORED SELF-CONFIGURATION STATUS DESCRIPTORS field defined in the REPORT GENERAL response (see 9.4.3.4). The volatility of these stored descriptors is vendor specific. The management device server shall replace the oldest self-configuration status descriptor with a new one once the number of recorded descriptors exceeds the value indicated by the MAXIMUM NUMBER OF STORED SELF-CONFIGURATION STATUS DESCRIPTORS field.

#### 4.6.5 Enabling multiplexing

A management application client may configure multiplexing (see 5.15) in expander devices. Self-configuring expander devices may configure multiplexing for their own phys. The choice of whether or not to enable multiplexing on a physical link is vendor specific.

If the SAS domain contains all 12 Gbit/s SAS phys, then the management application clients should disable multiplexing on every phy.

If the SAS domain contains 12 Gbit/s and 6 Gbit/s SAS phys, then the management application clients should:

- a) multiplex each 12 Gbit/s physical link into two 6 Gbit/s logical links; and
- b) not multiplex 6 Gbit/s physical links.

If the SAS domain contains 6 Gbit/s and 3 Gbit/s SAS phys, then the management application clients should:

- a) multiplex each 6 Gbit/s physical link into two 3 Gbit/s logical links; and
- b) not multiplex 3 Gbit/s physical links.

If the SAS domain contains 6 Gbit/s, 3 Gbit/s, and 1.5 Gbit/s SAS phys, then the management application client should:

- a) multiplex each 6 Gbit/s physical link into two 3 Gbit/s logical links; and
- b) multiplex each 3 Gbit/s physical link into two 1.5 Gbit/s logical links.

NOTE 6 - Rate matching is used for 1.5 Gbit/s connections carried on 3 Gbit/s logical links.

### 4.7 Configuration subprocess

#### 4.7.1 Configuration subprocess overview

As part of the discover process (see 4.6), if the management application client discovers an externally configurable expander device, then the management application client performs the configuration subprocess to configure the expander routing table in that externally configurable expander device with SAS addresses discovered two or more levels beyond each table routing phy in that externally configurable expander device. A single discover process performs the configuration subprocess at least once per externally configurable expander device.

Configuring the routing table in an expander device is required before connections are able to be established with devices attached two or more levels beyond that expander device.

#### 4.7.2 Allowed expander device topologies

If the management application client detects:

- a) an expander phy with the table routing attribute in an externally configurable expander device; or
- b) an expander phy with the table routing attribute in a self-configuring expander device with the TABLE TO TABLE bit set to zero in the SMP REPORT GENERAL response,

attached to:

- a) an expander phy with either the direct routing attribute or the table routing attribute in either an externally configurable expander device or a self-configuring expander device,

then the management application client shall report an error in a vendor specific manner.

If the management application client detects an overflow of an expander route index, then it shall report an error in a vendor specific manner.

If the route table optimization (see 4.7.3) is disabled and the management application client detects an expander route entry that references the SAS address of the expander device itself (i.e., self-reference), then the management application client shall disable the expander route entry by setting the DISABLE EXPANDER ROUTE ENTRY bit to one in the SMP CONFIGURE ROUTE INFORMATION request (see 9.4.3.27). The management application client shall disable each expander route entry in the expander route table by setting the DISABLE EXPANDER ROUTE ENTRY bit to one in the SMP CONFIGURE ROUTE INFORMATION request (see 9.4.3.27) for each expander phy that has its attached device type set to 000b (i.e., no device attached).

If the management application client detects a port that:

- a) the configuration subprocess has not already configured with a SAS address; and
- b) it has already found attached to another expander device,

then the management application client should use the SMP PHY CONTROL function (see 9.4.3.28) to disable all the expander phys attached to that SAS address except for phys in the expander device with the

lowest SAS address. Figure 45 shows some invalid topologies.

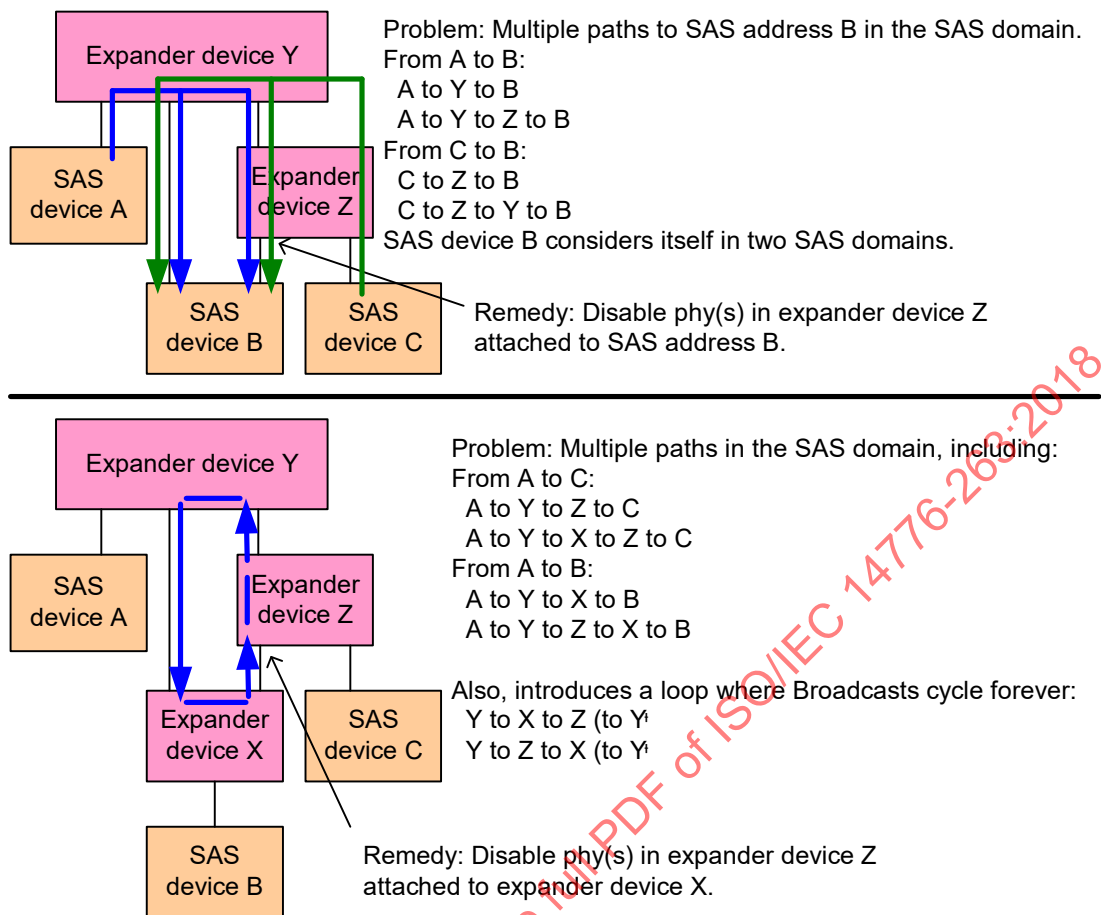


Figure 45 — Examples of invalid topologies

#### 4.7.3 Externally configurable expander device route table optimization

The management application client shall support a route table optimization that reduces the number of entries required in an expander route table in an externally configurable expander device. The method used to enable and disable the route table optimization is vendor specific.

If the route table optimization is enabled, then the management application client shall exclude discovered SAS addresses from the expander route table when any of the following conditions are met:

- a) in the SMP DISCOVER response (see 9.4.3.10) for the discovered phy:
  - A) the FUNCTION RESULT field is set to a non-zero value (i.e., not SMP FUNCTION ACCEPTED);
- b) in the SMP DISCOVER response for the discovered phy:
  - A) the FUNCTION RESULT field is set to zero (i.e., SMP FUNCTION ACCEPTED);
  - B) the ROUTING ATTRIBUTE field is set to 1h (i.e., subtractive) or 2h (i.e., table); and
  - C) the ATTACHED DEVICE TYPE field is set to zero (i.e., no device attached);
- c) in the SMP DISCOVER response for the discovered phy:
  - A) the FUNCTION RESULT field is set to zero (i.e., SMP FUNCTION ACCEPTED);
  - B) the ROUTING ATTRIBUTE field is set to 1h (i.e., subtractive) or 2h (i.e., table);
  - C) the ATTACHED DEVICE TYPE field is set to a non-zero value (e.g., end device or expander device); and
  - D) the ATTACHED SAS ADDRESS field contains the SAS address of the expander device being configured (i.e., a self-referencing address);
- d) in the SMP DISCOVER response for the discovered phy:

- A) the FUNCTION RESULT field is set to zero (i.e., SMP FUNCTION ACCEPTED);
- B) the ROUTING ATTRIBUTE field is set to 1h (i.e., subtractive) or 2h (i.e., table);
- C) the ATTACHED DEVICE TYPE field is set to a non-zero value (e.g., end device or expander device); and
- D) the ATTACHED SAS ADDRESS field contains the SAS address of a device directly attached to the expander device being configured;

or

- e) in the SMP DISCOVER response for the discovered phy:
  - A) the FUNCTION RESULT field is set to zero (i.e., SMP FUNCTION ACCEPTED);
  - B) the ROUTING ATTRIBUTE field is set to 1h (i.e., subtractive) or 2h (i.e., table);
  - C) the ATTACHED DEVICE TYPE field is set to a non-zero value (e.g., end device or expander device); and
  - D) the ATTACHED SAS ADDRESS field contains a SAS address that already exists in the expander route table.

If the discovered SAS address being included in the expander route table is for a device that is not attached (i.e., the ATTACHED DEVICE TYPE field is set to zero (i.e., no device attached) and the ROUTING ATTRIBUTE field is set to 0h (i.e., direct)), then the entry shall be inserted with the ROUTED SAS ADDRESS field set to 00000000 00000000h and the DISABLE EXPANDER ROUTE ENTRY bit set to one (see 9.4.3.27).

If route table optimization is disabled, then all SAS addresses shall be qualified for insertion in the expander route table.

If the management application client supports route table optimization, then the management application client should provide a vendor specific method for initiating a check of the resulting expander route tables. The check should be performed under the following situations:

- a) when an I\_T nexus loss occurs for a destination port that is expected to be present;
- b) when a discover process has been completed;
- c) when another SMP initiator port is discovered in the SAS domain; or
- d) when a self-configuring expander device is discovered in the SAS domain.

If the management application client detects an inconsistency in the expander route tables when route table optimization is enabled (e.g., detects entries that appear to have been filled in by a discover process with route table optimization disabled), then the management application client shall report an error in a vendor specific manner and shall disable route table optimization. The management application client should then reinitiate a discover process with route table optimization disabled.

#### 4.7.4 Externally configurable expander device expander route index order

The expander route table in an externally configurable expander device shall be configured for each expander phy that has a table routing attribute.

If the expander phy is not attached to an expander device, then every expander route entry for that expander phy shall be disabled (i.e., the ROUTED SAS ADDRESS field shall be set to 00000000 00000000h and the DISABLE EXPANDER ROUTE ENTRY bit shall be set to one).

If the expander phy is attached to an expander device, then the expander route table shall be configured for that expander phy as follows. For purposes of configuring the expander route table for that phy, the expander devices attached to the expander phy are assigned levels:

- 1) the expander device in which the expander route table is being configured is level 0;
- 2) the attached expander device is considered level 1;
- 3) devices attached to the level 1 expander device, except for the level 0 expander device, are considered level 2;
- 4) devices attached to level 2 expander devices, except for level 1 expander devices, are considered level 3; and
- 5) for each n greater than 3, devices attached to level n-1 expander devices, except for level n-2 expander devices, are considered level n.

The expander route table for each expander phy shall be configured starting from expander route index 0 by level (e.g., if there are three levels, then all level 1 entries first, then all level 2 entries, then all level 3 entries) up to the value of the EXPANDER ROUTE INDEXES field reported by the SMP REPORT GENERAL function (see 9.4.3.4).

If the level 1 expander device has expander phys attached to N phys with qualified SAS addresses (see 4.7.3), then the first N entries shall be used for those SAS addresses in expander phy order (i.e., the addresses attached to lower expander phy numbers first).

For each of the level 2 devices that:

- a) is an expander device attached to M phys with qualified SAS addresses; and
- b) is attached to an expander phy in the level 1 expander device with the table routing attribute,

the next M entries shall be used for the level 2 expander device's qualified SAS addresses in expander phy order (i.e., lower phy numbers first).

This process shall be repeated for all levels of expander devices.

SAS addresses of devices attached beyond expander phys that are attached table-to-table shall not be included in the expander route table. The SAS address of the first expander device that is attached table-to-table shall be included and the SAS address of every device attached beyond that expander device shall not be included. As a result, end devices in SAS domains containing externally configurable expander devices and table-to-table attachments may not be able to establish connections to each other.

NOTE 7 - Not including those SAS addresses provides compatibility with management application clients compliant with SAS-1.1. End devices in SAS domains containing only self-configuring expander devices supporting table-to-table attachments are able to establish connections to any other end device.



Figure 46 shows an example of a route table that does not include SAS addresses beyond a table-to-table attachment.

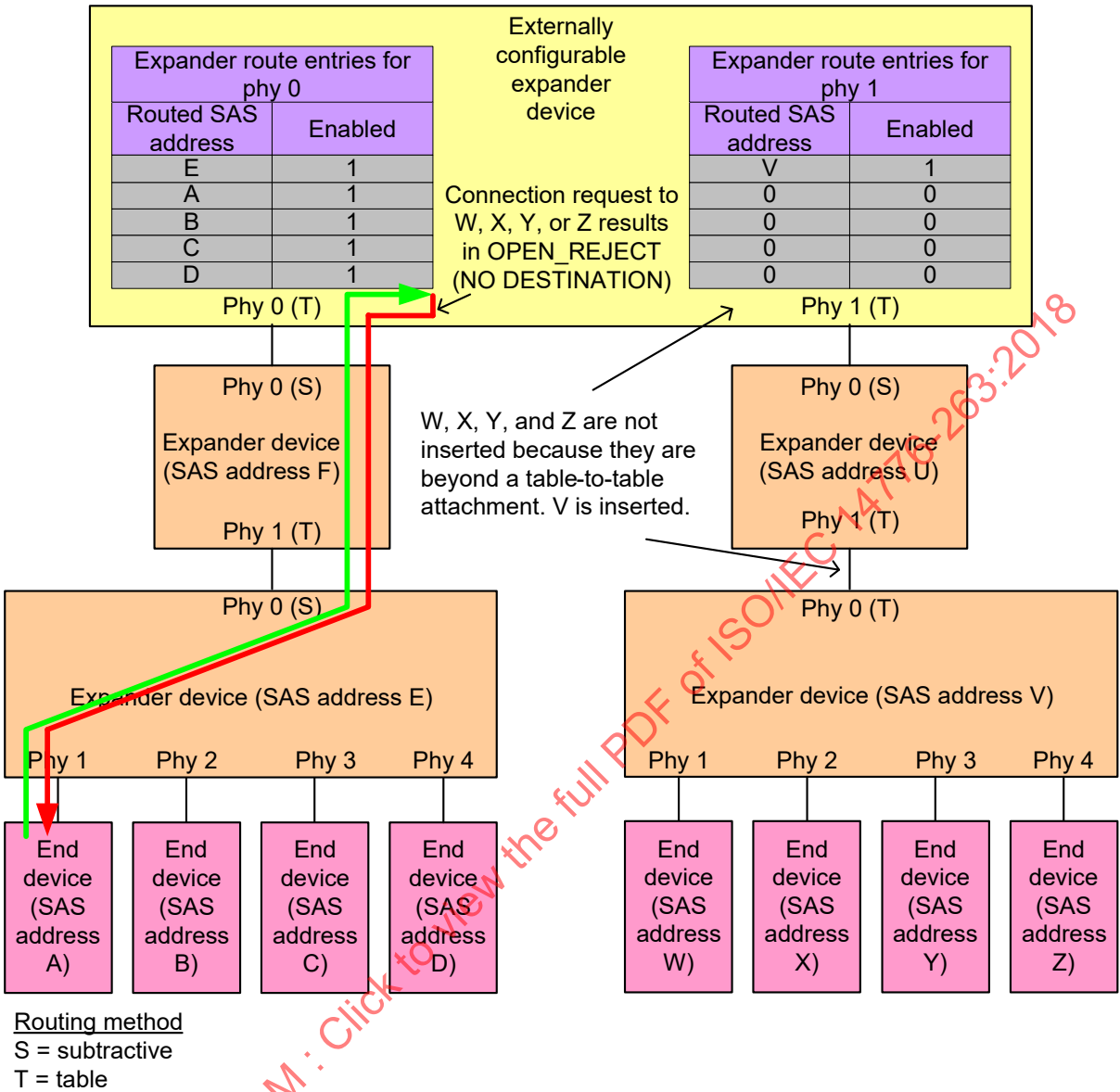


**Figure 46 — Externally configurable expander device and table-to-table attachment**

After the expander route table has been configured with entries for all levels of expander devices, all remaining expander route entries, if any, shall be disabled (i.e., the ROUTED SAS ADDRESS field shall be set to 00000000 00000000h and the DISABLE EXPANDER ROUTE ENTRY bit shall be set to one). The management application client is not required to disable entries if the topology of expander devices has not changed.



Figure 47 shows a portion of a SAS domain, where phy A in expander device R is being configured.

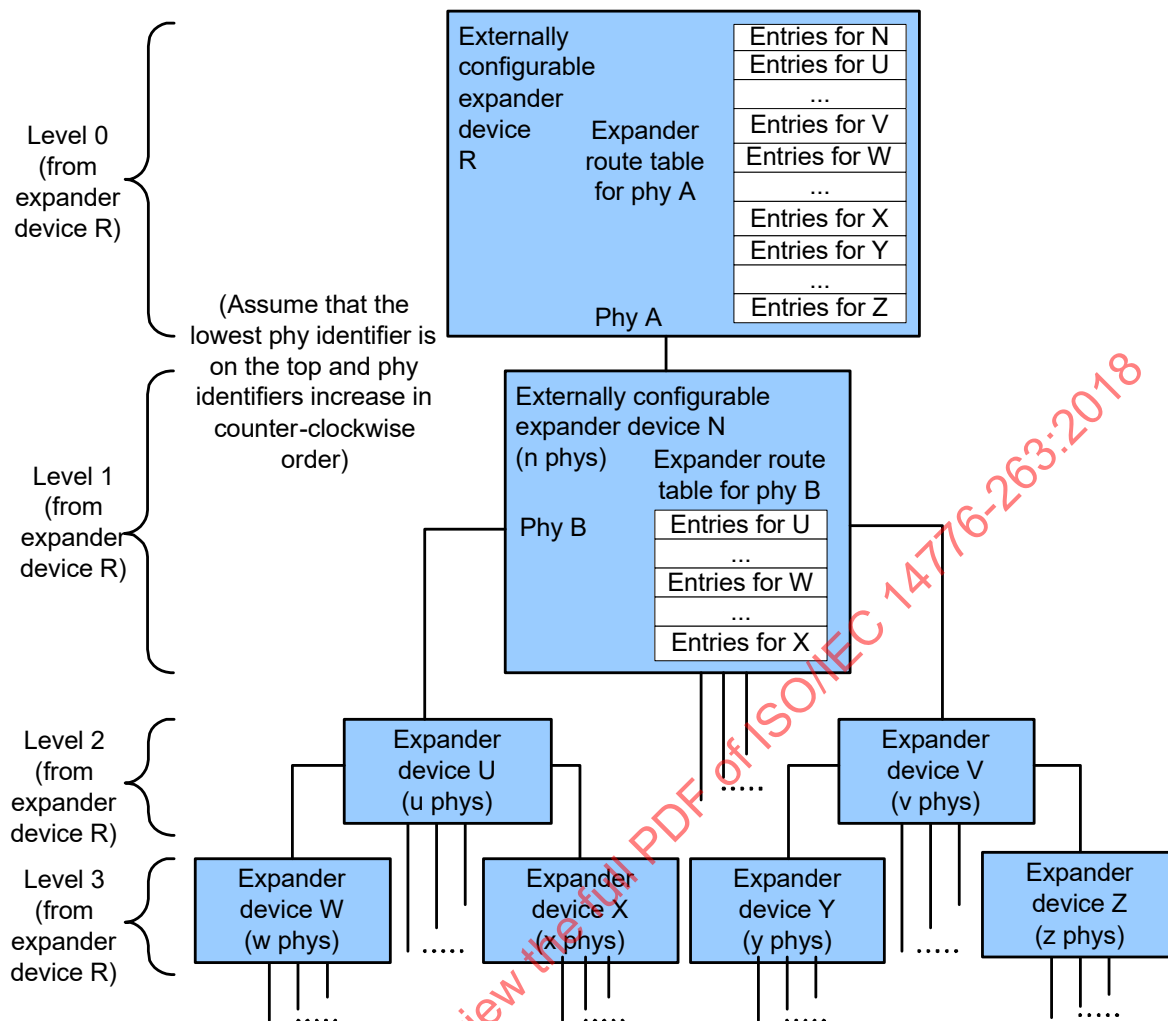


**Figure 47 — Expander route index levels example**

Table 31 shows how the expander route table is configured for externally configurable expander device R phy A in figure 47.

**Table 31 — Expander route table levels for externally configurable expander device R phy A**

| Expander route index                     | Expander route entry contents                                            |
|------------------------------------------|--------------------------------------------------------------------------|
| Level 1 (from expanded device R) entries |                                                                          |
| 0 .. ( $\leq n$ entries)                 | Qualified SAS addresses attached to expander device N                    |
| Level 2 (from expanded device R) entries |                                                                          |
| ( $\leq u$ entries)                      | Qualified SAS addresses attached to expander device U                    |
| ...                                      | ...additional qualified SAS addresses for expander devices at level 2... |
| ( $\leq v$ entries)                      | Qualified SAS addresses attached to expander device V                    |

**Table 31 — Expander route table levels for externally configurable expander device R phy A**

| Expander route index                     | Expander route entry contents                                            |
|------------------------------------------|--------------------------------------------------------------------------|
| Level 3 (from expanded device R) entries |                                                                          |
| ( $\leq w$ entries)                      | Qualified SAS addresses attached to expander device W                    |
| ...                                      | ...additional qualified SAS addresses for expander devices at level 3... |
| ( $\leq x$ entries)                      | Qualified SAS addresses attached to expander device X                    |
| ( $\leq y$ entries)                      | Qualified SAS addresses attached to expander device Y                    |
| ...                                      | ...additional qualified SAS addresses for expander devices at level 3... |
| ( $\leq z$ entries)                      | Qualified SAS addresses attached to expander device Z                    |
| Entries for additional levels            |                                                                          |
| ...                                      | ...                                                                      |
| Disabled entries                         |                                                                          |
| ...                                      | ...                                                                      |

Table 32 shows how the expander route table is configured for externally configurable expander device N phy B in figure 47.

**Table 32 — Expander route table levels for externally configurable expander device N**

| Expander route index                     | Expander route entry contents                                            |
|------------------------------------------|--------------------------------------------------------------------------|
| Level 1 (from expanded device N) entries |                                                                          |
| 0 .. ( $\leq u$ entries)                 | Qualified SAS addresses attached to expander device U                    |
| Level 2 (from expanded device N) entries |                                                                          |
| ( $\leq w$ entries)                      | Qualified SAS addresses attached to expander device W                    |
| ...                                      | ...additional qualified SAS addresses for expander devices at level 2... |
| ( $\leq x$ entries)                      | Qualified SAS addresses attached to expander device X                    |
| Entries for additional levels            |                                                                          |
| ...                                      | ...                                                                      |
| Disabled entries                         |                                                                          |
| ...                                      | ...                                                                      |

Figure 48 shows an example topology.

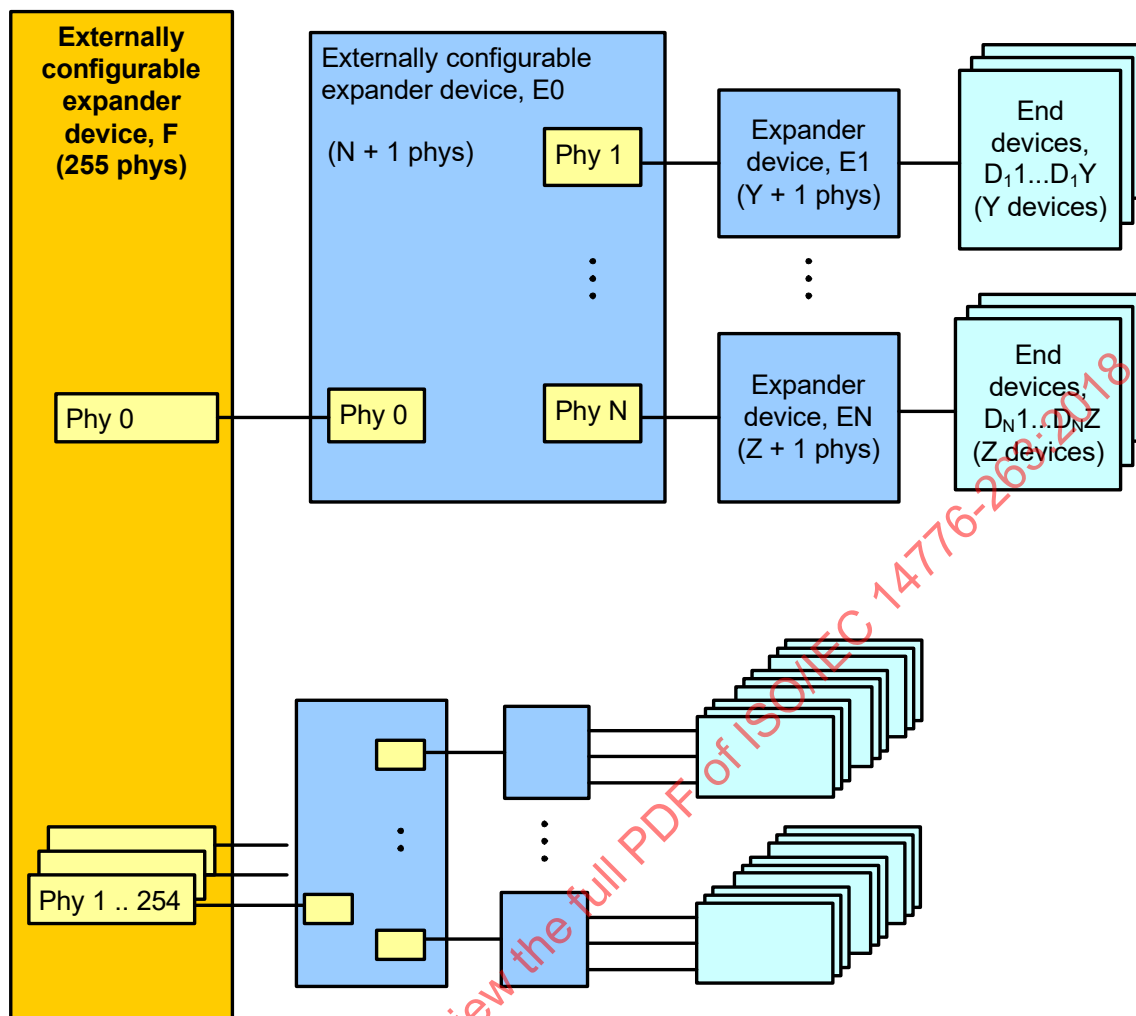


Figure 48 — Expander route index order example

Table 33 shows the expander route index order for externally configurable expander device E0 phy 1 in figure 48, assuming that all phys are present and not subject to exclusion by route table optimization (see 4.7.3).

Table 33 — Expander route entries for externally configurable expander device E0 phy 1

| Expander route index | Expander route entry contents                                                       |
|----------------------|-------------------------------------------------------------------------------------|
| Level 1 entries      |                                                                                     |
| 0                    | SAS address (e.g., $D_{11}$ ) of the device attached to phy 1 of expander device E1 |
| 1                    | SAS address (e.g., $D_{12}$ ) of the device attached to phy 2 of expander device E1 |
| ...                  | ...                                                                                 |
| $Y - 1$              | SAS address (e.g., $D_{1Y}$ ) of the device attached to phy Y of expander device E1 |

**Table 33 — Expander route entries for externally configurable expander device E0 phy 1**

| Expander route index | Expander route entry contents      |
|----------------------|------------------------------------|
| Level 2 and beyond   |                                    |
|                      | No entries                         |
| Disabled entries     |                                    |
|                      | Any remaining entries are disabled |

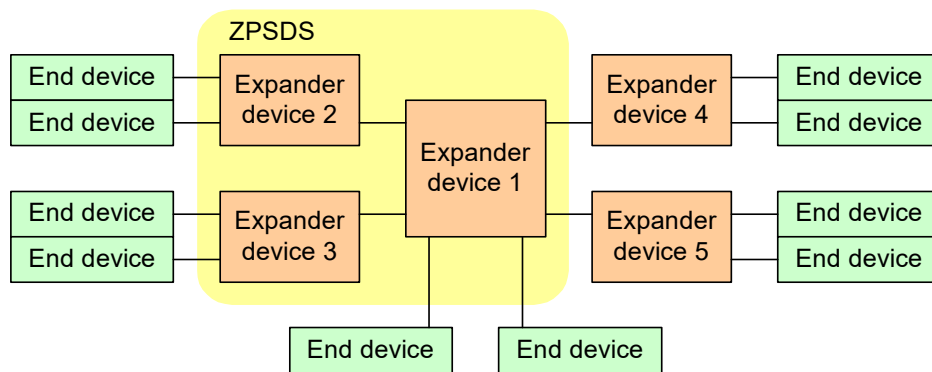
Table 34 shows the expander route index order for externally configurable expander device F phy 0 in figure 48, assuming that all phys are present and not subject to exclusion by route table optimization (see 4.7.3).

**Table 34 — Expander route entries for externally configurable expander device F phy 0**

| Expander route index | Expander route entry contents                                                              |
|----------------------|--------------------------------------------------------------------------------------------|
| Level 1 entries      |                                                                                            |
| 0                    | SAS address (e.g., E1) of the device attached to phy 1 of expander device E0               |
| ...                  | ...additional qualified SAS addresses for expander device E0...                            |
| N - 1                | SAS address (e.g., EN) of the device attached to phy N of expander device E0               |
| Level 2 entries      |                                                                                            |
| N                    | SAS address (e.g., D <sub>1</sub> 1) of the device attached to phy 1 of expander device E1 |
| ...                  | ...additional qualified SAS addresses for expander device E1...                            |
|                      | SAS address (e.g., D <sub>1</sub> Y) of the device attached to phy Y of expander device E1 |
| ...                  | ...additional qualified SAS addresses for expander devices E2 to EN-1...                   |
|                      | SAS address (e.g., D <sub>N</sub> 1) of the device attached to phy 1 of expander device EN |
| ...                  | ...additional qualified SAS addresses for expander device EN...                            |
|                      | SAS address (e.g., D <sub>N</sub> Z) of the device attached to phy Z of expander device EN |
| Level 3 and beyond   |                                                                                            |
|                      | No entries since all devices attached to E1 to EN, except for E0, are end devices          |
| Disabled entries     |                                                                                            |
|                      | Any remaining entries are disabled                                                         |



Figure 50 shows an example of one ZPSDS in a SAS domain.



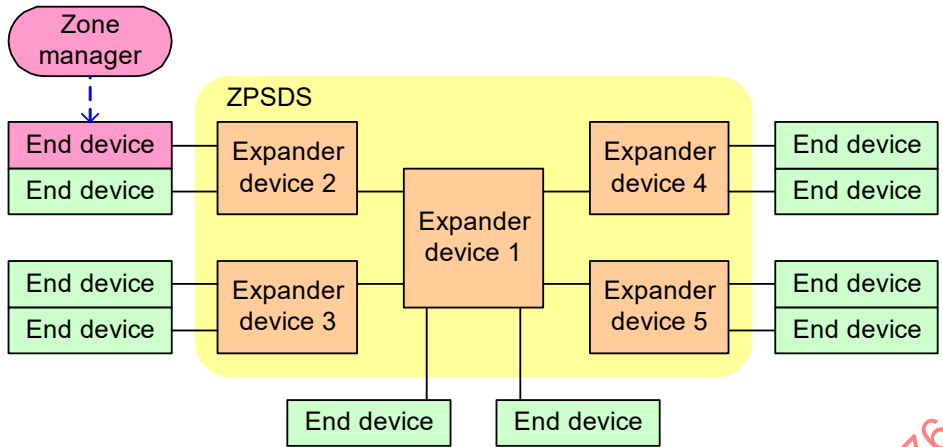
Expander devices 1, 2, and 3 have zoning enabled.  
Expander devices 4 and 5 have zoning disabled.

**Figure 50 — One ZPSDS example**

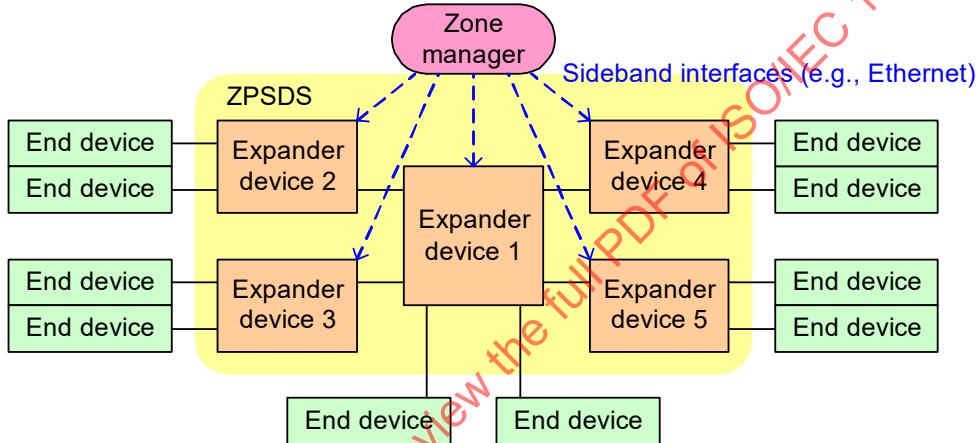
A ZPSDS has a zone manager responsible for its configuration. The zone manager may have access to an end device with a SAS port whose zone group (see 4.8.3.2) has access to zone group 2, or may have access to one or more zoning expander devices through a sideband interface (e.g., Ethernet) outside the scope of this standard. The SAS address reported for a sideband zone manager is 00000000 00000000h.

Figure 51 shows examples of zone manager locations in a SAS domain.

Zone manager attached to an end device with a SAS port whose zone group has access to zone group 2



Zone manager attached directly to the expander devices in the ZPSDS



Zone manager attached directly to one expander device in the ZPSDS

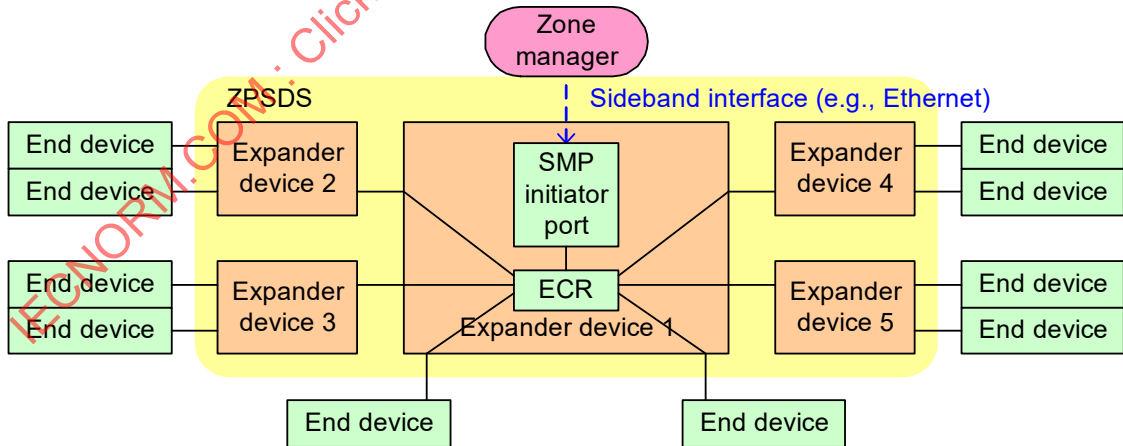


Figure 51 — Zone manager location examples

There may be any number of non-overlapping ZPSDSes in a service delivery subsystem, particularly as a SAS domain is being reconfigured (e.g., as a user is attaching enclosures together). A SAS domain with more than one ZPSDS should be transitory. A ZPSDS may encompass some or all of a service delivery subsystem.

Figure 52 shows an example of three ZPSDSes in a SAS domain.

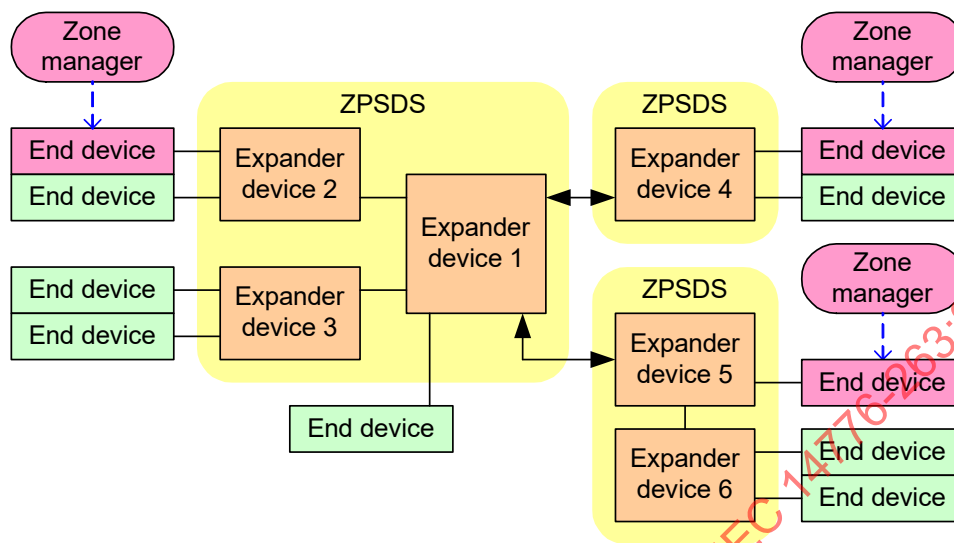


**Figure 52 — Three ZPSDSes example**

The zone manager assigns zone groups (see 4.8.3.2) to all zoning expander phys inside the ZPSDS. There are 128 or 256 zone groups numbered 0 to 127 or 0 to 255. All phys in a wide port shall be assigned to the same zone group. Zone groups are assigned to zoning expander phys as part of the zone phy information (see 4.8.3.1) and are stored along with SAS addresses in the zoning expander route table (see 4.8.3.4). The zone groups assigned in one ZPSDS have no relationship to the zone groups assigned in another ZPSDS.

The zone manager shall assign each zoning expander phy attached to another zoning expander phy inside a ZPSDS to zone group 1. The zone manager shall assign each zoning expander phy on the boundary of the ZPSDS (i.e., with the INSIDE ZPSDS bit set to zero) to a zone group. All phys in the SAS domain beyond that boundary zoning expander phy are considered to be in the same zone group as that zoning expander phy.

Each zoning expander device contains a zone permission table (see 4.8.3.3) that controls whether a connection is allowed between phys based on their zone groups. As defined in 4.8.3.5, a requested connection shall only be established if the zone permission table indicates that access between the zone group of the source port and the zone group of the destination port is allowed.

The zoning expander route table (see 4.8.3.4) is an extended version of the expander route table (see 4.5.7.4) that also includes the zone group of each SAS address.

Physical presence detection is a mechanism used to allow management access. The definition of physical presence detection is vendor specific (e.g., a user pressing a button or inserting a key).



The zone manager password is a value used to allow management access. The zone manager password is 32 bytes long and is specified in table 35.

**Table 35 — Zone manager password**

| Code                                                                              | Name     | Description                                                                                                        |
|-----------------------------------------------------------------------------------|----------|--------------------------------------------------------------------------------------------------------------------|
| 00000000 00000000<br>00000000 00000000<br>00000000 00000000<br>00000000 00000000h | ZERO     | Well-known value that provides access to any zone manager that presents it.                                        |
| FFFFFFFF FFFFFFFF<br>FFFFFFFF FFFFFFFF<br>FFFFFFFF FFFFFFFF<br>FFFFFFFF FFFFFFFFh | DISABLED | Well-known value that does not provide access to any zone manager (e.g., zone manager password usage is disabled). |
| All others                                                                        |          | Random value, providing access only to a zone manager that presents the correct value.                             |

The expander device:

- a) shall maintain a current value;
- b) shall maintain a shadow value;
- c) may maintain a saved value; and
- d) shall have a default value,

for each of the following settings:

- a) zoning enabled;
- b) the zone permission table; and
- c) zone phy information.

The expander device:

- a) shall maintain a current value;
- b) may maintain a saved value; and
- c) shall have a default value,

for the zone manager password, if any.

Support or lack of support for saved values for one setting does not imply support or lack of support for saved values for any other setting (e.g., the expander device may maintain a saved value for zoning enabled but not for the zone permission table).

For each setting, after power on or expander device reduced functionality, the expander device shall set the current value to the saved value, if any, or the default value, if there is no saved value.

#### 4.8.2 Zoning expander device requirements

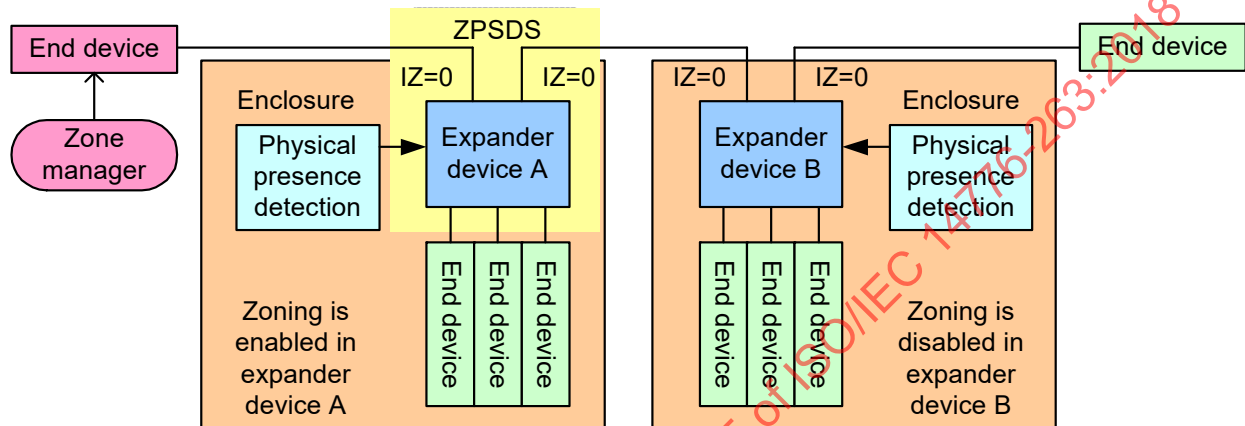
In addition to the requirements for expander devices described in 4.5, a zoning expander device shall:

- a) contain a zoning expander route table (see 4.8.3.4);
- b) contain current and shadow zone permission tables that supports 128 or 256 zone groups (see 4.8.3.3);
- c) contain current and shadow zone phy information for each phy;
- d) if zoning is enabled, allow or deny connection requests based on the current zone permission table (see 4.8.3.5);
- e) support fields related to zoning in its SMP REPORT GENERAL response (see 9.4.3.4);
- f) support the zone lock inactivity timer;

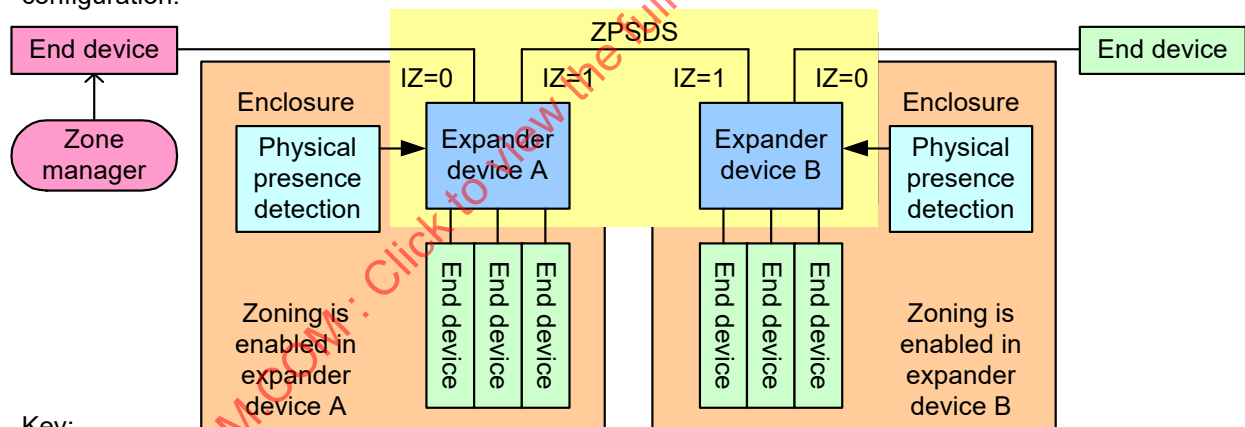
- g) be self-configuring;
- h) contain an SMP initiator port (see 4.5.1); and
- i) support zoning-related SMP functions.

A zoning expander device may support physical presence detection and/or a zone manager password to allow management access.

Figure 53 shows an example of two enclosures with physical presence detection where zoning is enabled in the expander device in the left enclosure, but is not enabled in the expander devices in the right enclosure. The zone manager is able to configure zoning in zoning expander device A because the zone group of its SMP initiator port has access to zone group 2. However, the zone manager is not able to enable or configure zoning in expander device B unless physical presence is asserted or the zone manager presents the correct zone manager password for that expander device.



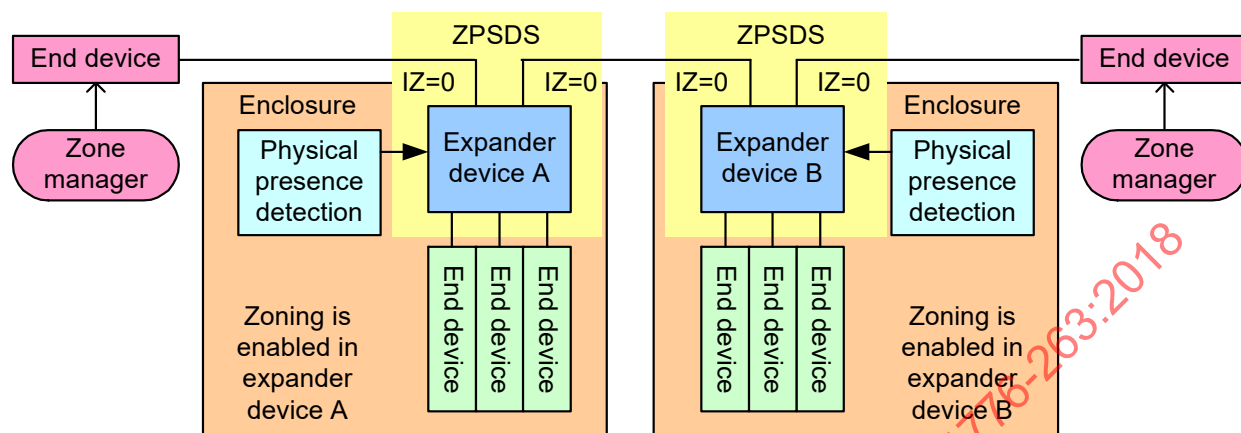
The ZPSDS is extended as shown below after the zone manager on the left completes zone configuration.



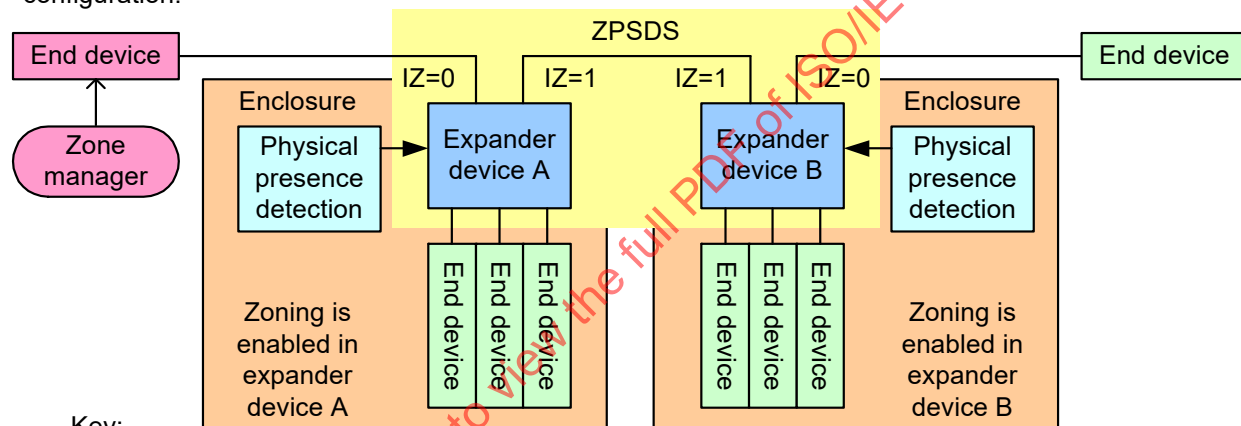
Key:  
IZ = INSIDE ZPSDS bit in the zone phy information

Figure 53 — Extending a ZPSDS example

Figure 54 shows an example of two enclosures with physical presence detection where zoning is enabled in both expander devices. The zone manager is able to configure zoning in zoning expander device A because the zone group of its SMP initiator port has access to zone group 2. However, the zone manager is not able to configure zoning in expander device B unless physical presence is asserted or the zone manager presents the correct zone manager password for that expander device.



The ZPSDS is extended as shown below after the zone manager on the left completes zone configuration.



Key:  
IZ = INSIDE ZPSDS bit in the zone phy information

Figure 54 — Overtaking a ZPSDS example

### 4.8.3 Zoning operation

#### 4.8.3.1 Zone phy information

Each phy of a zoning expander device shall support the zone phy information fields defined in table 36.

**Table 36 — Zone phy information**

| Field                                                                                                     | Description                                                                                                    | Recommended default |
|-----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------|
| INSIDE ZPSDS bit                                                                                          | Indicates if the phy is inside or on the boundary of a ZPSDS                                                   | N/A <sup>a</sup>    |
| REQUESTED INSIDE ZPSDS bit                                                                                | Used to establish the boundary of the ZPSDS                                                                    | 0                   |
| INSIDE ZPSDS PERSISTENT bit                                                                               | Used to determine the value of the INSIDE ZPSDS bit after a link reset sequence                                | 0                   |
| ZONE GROUP PERSISTENT bit                                                                                 | Used to determine the zone group of the phy after a link reset sequence if the INSIDE ZPSDS bit is set to zero | 0                   |
| ZONE GROUP field                                                                                          | The zone group to which the phy belongs                                                                        | 00h                 |
| <sup>a</sup> The INSIDE ZPSDS bit is determined from the values exchanged during the link reset sequence. |                                                                                                                |                     |

Table 37 lists the usage of the current values of the zone phy information fields.

**Table 37 — Zone phy information usage**

| Field                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Transmitted in IDENTIFY address frame <sup>a</sup> | Indicated in DISCOVER function and DISCOVER LIST function <sup>b</sup> | Attached value indicated in DISCOVER function <sup>c</sup> | Programmable with the CONFIGURE ZONE PHY INFORMATION function <sup>d</sup> | Changeable by the expander device after a link reset sequence <sup>e</sup> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| INSIDE ZPSDS bit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | No                                                 | Yes                                                                    | No                                                         | No                                                                         | Yes                                                                        |
| REQUESTED INSIDE ZPSDS bit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Yes                                                | Yes                                                                    | Yes                                                        | Yes                                                                        | Yes                                                                        |
| INSIDE ZPSDS PERSISTENT bit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Yes                                                | Yes                                                                    | Yes                                                        | Yes                                                                        | No                                                                         |
| ZONE GROUP PERSISTENT bit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | No                                                 | Yes                                                                    | No                                                         | Yes                                                                        | No                                                                         |
| ZONE GROUP field                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | No                                                 | Yes                                                                    | No                                                         | Yes                                                                        | Yes <sup>f</sup>                                                           |
| <sup>a</sup> Defined in the IDENTIFY address frame (see 6.8.2).<br><sup>b</sup> Defined in the DISCOVER response (see 9.4.3.10) and the DISCOVER LIST response SHORT FORMAT descriptor (see 9.4.3.15.4).<br><sup>c</sup> Defined in the DISCOVER response (see 9.4.3.10).<br><sup>d</sup> Defined in the zone phy configuration descriptor (see 9.4.3.25.3). Current values are not updated until the activate step (see 4.8.6.4). The saved values are also programmable with this function.<br><sup>e</sup> See 4.8.4.<br><sup>f</sup> Only changes to 00h after a link reset sequence. See 4.8.4. |                                                    |                                                                        |                                                            |                                                                            |                                                                            |

All phys in an expander port shall have the same zone phy information.

The expander device shall preserve the zone phy information while:

- a) zoning is disabled;
- b) no power loss occurs; and
- c) there is no expander device reduced functionality (see 4.5.8).

The INSIDE ZPSDS bit indicates if the phy is inside or on the boundary of a ZPSDS. An INSIDE ZPSDS bit set to zero indicates that:

- a) zoning is disabled;
- b) the phy is attached to an end device;
- c) the phy is attached to an expander device that does not support zoning;
- d) the phy is attached to an expander device that supports zoning, but zoning is disabled; or
- e) the phy is attached to an expander device that supports zoning, zoning is enabled, but is outside the ZPSDS (i.e., is in another ZPSDS).

An INSIDE ZPSDS bit set to one indicates that the phy is attached to a zoning expander device with zoning enabled and is thus inside a ZPSDS. The INSIDE ZPSDS bit only changes following a link reset sequence (see 4.8.4), based on:

- a) the REQUESTED INSIDE ZPSDS bit;
- b) the REQUESTED INSIDE ZPSDS bit received in the incoming IDENTIFY address frame (see 6.8.2);
- c) the INSIDE ZPSDS PERSISTENT bit; and
- d) the INSIDE ZPSDS PERSISTENT bit received in the incoming IDENTIFY address frame.

The REQUESTED INSIDE ZPSDS bit is used to establish the boundary of the ZPSDS. The REQUESTED INSIDE ZPSDS bit is used to indicate the values of other zone phy information fields after a link reset sequence (see 4.8.4).

The INSIDE ZPSDS PERSISTENT bit is used to indicate the value of the INSIDE ZPSDS bit after a link reset sequence (see 4.8.4).

The ZONE GROUP field contains the zone group to which the phy belongs (see 4.8.3.2). The zone group of the SMP initiator port and SMP target port in a zoning expander device shall be 01h.

The ZONE GROUP PERSISTENT bit is used to indicate the method of determining the zone group of the phy after a link reset sequence if the INSIDE ZPSDS bit is set to zero (see 4.8.4).

#### 4.8.3.2 Zone groups

The zone groups are defined in table 38.

**Table 38 — Zone groups**

| Zone group                                                                                                                                    | Configurable in the zone permission table <sup>a</sup> | Description                                                                                                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| 0                                                                                                                                             | No                                                     | Phys in zone group 0 have access to phys in zone group 1 and do not have access to phys in other zone groups. |
| 1                                                                                                                                             | No                                                     | Phys in zone group 1 have access to phys in all zone groups.                                                  |
| <sup>a</sup> A zone group defined as configurable is able to be changed with the SMP CONFIGURE ZONE PERMISSION TABLE function (see 9.4.3.26). |                                                        |                                                                                                               |

Table 38 — Zone groups

| Zone group                                                                                                                                    | Configurable in the zone permission table <sup>a</sup> | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2                                                                                                                                             | Yes                                                    | <p>Phys in zone group 2 have access to phys in the zone groups indicated by the zone permission table.</p> <p>A management device server in a zoning expander device with zoning enabled only allows management application clients using phys in zone groups with access to zone group 2 to perform the following SMP functions:</p> <ul style="list-style-type: none"> <li>a) CONFIGURE GENERAL (see 9.4.3.18);</li> <li>b) ZONE LOCK (see 9.4.3.21); and</li> <li>c) SMP zone configuration functions (see 4.8.6.1) performed while the zoning expander device is locked.</li> </ul> <p>A management device server in a zoning expander device with zoning enabled only allows management application clients to perform certain SMP phy-based control and configuration functions (e.g., PHY CONTROL, PHY TEST FUNCTION, and CONFIGURE PHY EVENT) if the zone group of the management application client's phy has access to zone group 2 or the zone group of the specified phy.</p> |
| 3                                                                                                                                             | Yes                                                    | <p>Phys in zone group 3 have access to phys in the zone groups indicated by the zone permission table.</p> <p>A management device server in a zoning expander device with zoning enabled only allows management application clients using a phy in a zone group with access to zone group 3 to perform certain SMP zoning-related functions (i.e., ZONED BROADCAST (see 9.4.3.20)).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 4 to 7                                                                                                                                        | Reserved                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 8 to 255                                                                                                                                      | Yes                                                    | Phys in zone groups 8 to 255 have access to phys in the zone groups indicated by the zone permission table.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <sup>a</sup> A zone group defined as configurable is able to be changed with the SMP CONFIGURE ZONE PERMISSION TABLE function (see 9.4.3.26). |                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

#### 4.8.3.3 Zone permission table

The zone permission table specifies access permission between zone groups. If a bit in the zone permission table is set to one, then connection requests shall be permitted between phys in the zone groups. If a bit in the zone permission table is set to zero, then connection requests between phys in the zone groups shall be rejected with OPEN\_REJECT (ZONE VIOLATION) or OPEN\_REJECT (RETRY) as described in 4.8.3.5.

The zone permission table structure is shown in table 39.

**Table 39 — Zone permission table**

| Destination zone group (i.e., d)                                                                                                                                                                                                                                                                                      | Source zone group (i.e., s) <sup>a b</sup> |   |                                |          |                                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|---|--------------------------------|----------|------------------------------------|
|                                                                                                                                                                                                                                                                                                                       | 0                                          | 1 | 2 to 3                         | 4 to 7   | 8 to (z-1) <sup>c</sup>            |
| 0                                                                                                                                                                                                                                                                                                                     | 0                                          | 1 | 0                              | 0        | 0                                  |
| 1                                                                                                                                                                                                                                                                                                                     | 1                                          | 1 | 1                              | 1        | 1                                  |
| 2 to 3                                                                                                                                                                                                                                                                                                                | 0                                          | 1 | ZP[s = 2 to 3, d = 2 to 3]     | Reserved | ZP[s = 8 to (z-1), d = 2 to 3]     |
| 4 to 7                                                                                                                                                                                                                                                                                                                | 0                                          | 1 | Reserved                       | Reserved | Reserved                           |
| 8 to (z-1) <sup>c</sup>                                                                                                                                                                                                                                                                                               | 0                                          | 1 | ZP[s = 2 to 3, d = 8 to (z-1)] | Reserved | ZP[s = 8 to (z-1), d = 8 to (z-1)] |
| <sup>a</sup> Shading identifies configurable zone groups.<br><sup>b</sup> All reserved ZP bits shall be set to zero (e.g., bits ZP[4 to 7, 4 to (z-1)] are set to zero).<br><sup>c</sup> The number of zone groups (i.e., z) is reported in NUMBER OF ZONE GROUPS field in the REPORT GENERAL response (see 9.4.3.4). |                                            |   |                                |          |                                    |

A ZP[s, d] bit set to one specifies that the source zone group (i.e., s) has permission to access the destination zone group (i.e., d). A ZP[s, d] bit set to zero specifies that the source zone group (i.e., s) does not have permission to access the destination zone group (i.e., d).

ZP[s, d] shall be set to the same value as ZP[d, s].

The zoning expander device:

- shall preserve the zone permission table while zoning is disabled; and
- may or may not preserve the zone permission table through power loss and expander device reduced functionality.



If the zoning expander device preserves whether or not zoning is enabled and does not preserve the zone permission table, then the zoning expander device shall set the current zone permission table to grant minimal permissions after power on or expander device reduced functionality as specified in table 40.

**Table 40 — Zone permission table granting minimal permissions**

| Destination zone group (i.e., d) | Source zone group (i.e., s) <sup>a b</sup> |   |          |          |                         |
|----------------------------------|--------------------------------------------|---|----------|----------|-------------------------|
|                                  | 0                                          | 1 | 2 to 3   | 4 to 7   | 8 to (z-1) <sup>c</sup> |
| 0                                | 0                                          | 1 | 0        | 0        | 0                       |
| 1                                | 1                                          | 1 | 1        | 1        | 1                       |
| 2 to 3                           | 0                                          | 1 | 0        | Reserved | 0                       |
| 4 to 7                           | 0                                          | 1 | Reserved | Reserved | Reserved                |
| 8 to (z-1) <sup>c</sup>          | 0                                          | 1 | 0        | Reserved | 0                       |

<sup>a</sup> Shading identifies configurable zone groups.  
<sup>b</sup> All reserved ZP bits shall be set to zero (e.g., bits ZP[4 to 7, 4 to (z-1)] are set to zero).  
<sup>c</sup> The number of zone groups (i.e., z) is reported in NUMBER OF ZONE GROUPS field in the REPORT GENERAL response (see 9.4.3.4).

If a zone manager enables zoning on zoning capable expander devices that report different values in the NUMBER OF ZONE GROUPS field in the REPORT GENERAL response (see 9.4.3.4) (e.g., some support 128 and others support 256), then the zone manager shall:

- configure all zoning enabled expander devices contained within the ZPSDS to use the highest number of zone groups supported by all of the zoning enabled expander devices in the ZPSDS (e.g., 128);
- configure the zone phy information in all the zoning expander devices to set each phy to a zone group less than the highest number of zone groups supported by all of the zoning enabled expander devices in the ZPSD; and
- configure the zone permission table in all the zoning expander devices to set each entry to zero that is higher than the highest number of zone groups supported by all of the zoning enabled expander devices in the ZPSDS.

#### 4.8.3.4 Zoning expander route table

A zoning expander route table is an expander-based expander route table (see 4.5.7.4) that is able to hold the zone group of each routed SAS address.

Figure 55 shows a representation of the zoning expander route table.

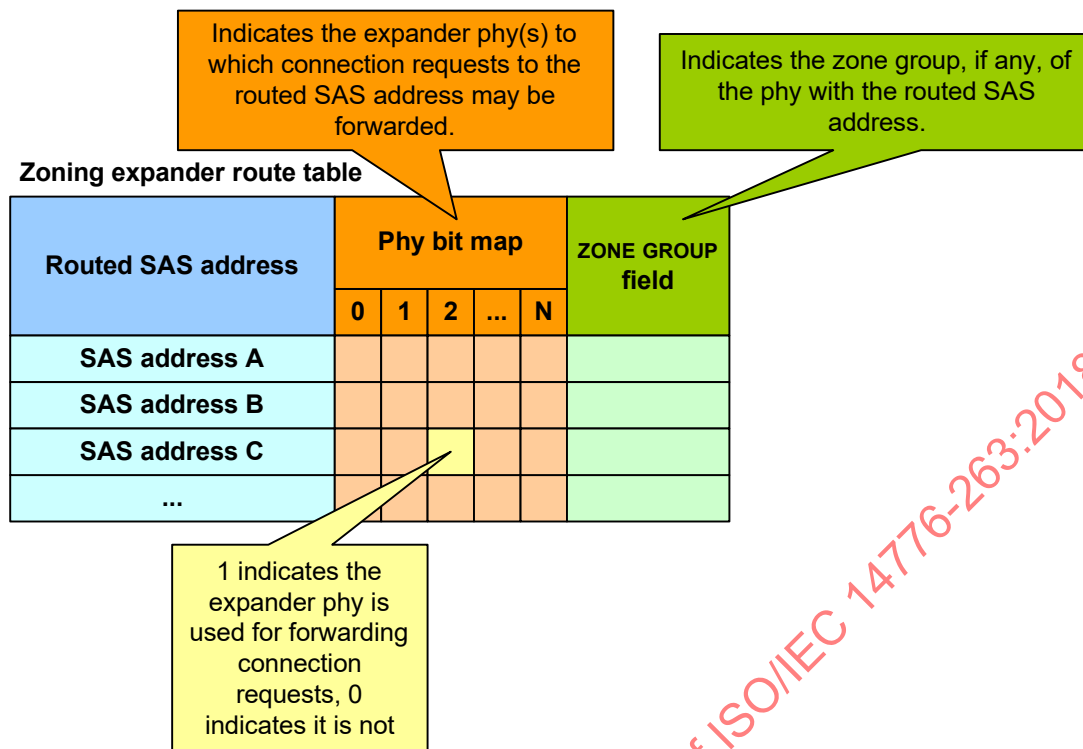


**Figure 55 — Zoning expander route table**

The zoning expander route table:

- shall include discovered SAS addresses discovered behind each expander phy with the ROUTING ATTRIBUTE field set to 2h (i.e., table) in the DISCOVER response; and
- may include discovered SAS addresses discovered behind expander phys with the ROUTING ATTRIBUTE field set to 1h (i.e., subtractive) in the DISCOVER response as long as they do not prevent inclusion of SAS addresses for expander phys with the ROUTING ATTRIBUTE field set to 2h (i.e., table). The determination of which such SAS addresses to include is vendor specific.

The total number of routed SAS addresses shall not exceed the value indicated in the MAXIMUM NUMBER OF ROUTED SAS ADDRESSES field in the REPORT GENERAL response.

#### 4.8.3.5 Source zone group and destination zone group determination

When a zoning expander device with zoning enabled receives an OPEN address frame (see 6.8.3):

- the zone group of the source port (i.e., s) is identified as defined in table 41; and
- the zone group of the destination port (i.e., d) is identified as defined in table 42.

If the ZP[s, d] bit is set to one, then access between the source and destination phys shall be permitted, and the zoning expander device shall perform the ECM arbitration procedure. If the ZP[s, d] bit is set to zero, then access between the source and destination phys is not permitted and the zoning expander device shall transmit an OPEN\_REJECT in response to the connection request as follows:

- OPEN\_REJECT (RETRY) if the zoning expander device is locked; or
- OPEN\_REJECT (ZONE VIOLATION) if the zoning expander device is unlocked.

Zoning expander devices with zoning enabled shall follow the rules in table 41 to determine the zone group of the source port.

**Table 41 — Source zone group determination**

| INSIDE ZPSDS bit of the expander phy that received the OPEN address frame | Source zone group                                                                             |
|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| 0                                                                         | Zone group of the receiving expander phy                                                      |
| 1                                                                         | Source zone group specified by the SOURCE ZONE GROUP field in the received OPEN address frame |

Zoning expander devices with zoning enabled shall follow the rules in table 42 to determine the zone group of the destination port.

**Table 42 — Destination zone group determination**

| Routing method of the destination expander phy | Destination zone group                                                                                                                                                                                                                                                                                                                                |
|------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Direct                                         | Zone group of the destination expander phy                                                                                                                                                                                                                                                                                                            |
| Subtractive                                    | <p>If the destination SAS address is in the zoning expander route table, then the zone group stored in the zoning expander route table for the destination SAS address.</p> <p>If the destination SAS address is not in the zoning expander route table, then the zone group of the destination expander phy (i.e., the subtractive routing phy).</p> |
| Table                                          | The zone group stored in the zoning expander route table for the destination SAS address                                                                                                                                                                                                                                                              |

#### 4.8.4 Zone phy information and link reset sequences

At the completion of a link reset sequence (see 4.4), if a SATA device is attached to an expander phy, then the zoning expander device with zoning enabled shall set the INSIDE ZPSDS bit to zero for that expander phy.

At the completion of a link reset sequence, if a SATA device is not attached to an expander phy, then the zoning expander device with zoning enabled shall update the current REQUESTED INSIDE ZPSDS bit and INSIDE ZPSDS PERSISTENT bit as defined in table 43 based on:

- a) the REQUESTED INSIDE ZPSDS bit and the INSIDE ZPSDS PERSISTENT bit in the zone phy information (i.e., the bits transmitted in the outgoing IDENTIFY address frame (see 6.8.2)); and

- b) the REQUESTED INSIDE ZPSDS bit and INSIDE ZPSDS PERSISTENT bit received in the incoming IDENTIFY address frame.

**Table 43 — REQUESTED INSIDE ZPSDS bit and INSIDE ZPSDS PERSISTENT bit changes after a link reset sequence**

| REQUESTED INSIDE ZPSDS bit |          | INSIDE ZPSDS PERSISTENT bit |          | Zone phy information field changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------|----------|-----------------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Transmitted                | Received | Transmitted                 | Received |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 0                          | 0 or 1   | 0 or 1                      | 0 or 1   | The zoning expander device shall set the INSIDE ZPSDS bit to zero.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 1                          | 0        |                             |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 1                          | 1        | 0                           | 0        | <p>If the SAS ADDRESS field received in the IDENTIFY address frame during the identification sequence is different from the SAS ADDRESS field received prior to the completion of the link reset sequence, then the zoning expander device shall:</p> <p>a) set the REQUESTED INSIDE ZPSDS bit to zero; and</p> <p>b) set the INSIDE ZPSDS bit to zero.</p> <p>If the SAS ADDRESS field received in the IDENTIFY address frame during the identification sequence is the same as the SAS ADDRESS field received prior to the completion of the link reset sequence, then the zoning expander device shall set the INSIDE ZPSDS bit to one.</p> |
|                            |          | 0                           | 1        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                            |          | 1                           | 0        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                            |          | 1                           | 1        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                            |          |                             |          | The zoning expander device shall set the INSIDE ZPSDS bit to one.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

If the ZONE GROUP PERSISTENT bit is set to one, then the zone group of an expander shall be set as shown in table 44. If the ZONE GROUP PERSISTENT bit is set to zero, then table 45 specifies events based on the initial condition of an expander phy that shall cause a zoning expander device with zoning enabled to change the ZONE GROUP field of the expander phy to its reset value (i.e., the saved value, if any, or the default value (e.g., 00h) if there is no saved value).

**Table 44 — ZONE GROUP field values if the ZONE GROUP PERSISTENT bit is set to one**

| Current<br>INSIDE<br>ZPSDS Bit <sup>a</sup>                                                                                                                        | New INSIDE<br>ZPSDS Bit <sup>b</sup> | ZONE GROUP field change                                                                                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0                                                                                                                                                                  | 0                                    | No change.                                                                                                                                                     |
| 0                                                                                                                                                                  | 1                                    | The zoning expander device shall set the ZONE GROUP field to 01h.                                                                                              |
| 1                                                                                                                                                                  | 0                                    | The zoning expander device shall set the ZONE GROUP field to its reset value (i.e., the saved value, if any, or the default value if there is no saved value). |
| 1                                                                                                                                                                  | 1                                    | The zoning expander device shall set the ZONE GROUP field to 01h.                                                                                              |
| <sup>a</sup> Current INSIDE ZPSDS bit is the value before the link reset sequence.<br><sup>b</sup> New INSIDE ZPSDS bit is the computed value based upon table 43. |                                      |                                                                                                                                                                |

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**Table 45 — Conditions that cause the ZONE GROUP field to be updated if the ZONE GROUP PERSISTENT bit is set to zero**

| Initial condition                                         | Event after the initial condition is established                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Completed link reset sequence with a SAS device attached  | <p>A subsequent link reset sequence completes and:</p> <p>a) any of the following fields received in the IDENTIFY address frame (see 6.8.2) during the identification sequence are different from their values prior to the completion of the link reset sequence:</p> <p>A) SAS ADDRESS field; or</p> <p>B) REQUESTED INSIDE ZPSDS field;</p> <p>or</p> <p>b) a SATA device is attached.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Completed link reset sequence with a SATA device attached | <p>Either:</p> <p>a) a subsequent link reset sequence completes and:</p> <p>A) a hot-plug timeout (see 5.10.5) occurred between the time of the initial condition and the time the link reset sequence completed;</p> <p>B) the zoning expander device has detected the possibility that a new SATA device has been inserted. The method of detection is outside the scope of this standard (e.g., an enclosure services process reports a change in the ELEMENT STATUS CODE field in the Device or Array Device element (see SES-3), or a change in the WORLD WIDE NAME field in the attached SATA device's IDENTIFY (PACKET) DEVICE data (see ACS-2); or</p> <p>C) a SAS phy or expander phy is attached;</p> <p>or</p> <p>b) the expander phy is disabled with the SMP PHY CONTROL function (see 9.4.3.28) DISABLE phy operation.</p> |

#### 4.8.5 Broadcast processing in a zoning expander device with zoning enabled

The BPP determines the source zone group(s) of the Broadcast as follows:

- if the BPP receives a Broadcast Event Notify request from an expander logical phy (i.e., a zoning expander logical phy received a BROADCAST primitive sequence), then the Broadcast has a single source zone group set to the zone group of that expander phy; or
- if the BPP receives a message from the management device server indicating that the management device server received an SMP ZONED BROADCAST request (see table 311) from an SMP initiator port that has access to zone group 3, then the Broadcast has each of the source zone groups specified in the SMP ZONED BROADCAST request.

The BPP forwards the Broadcast to each expander port other than the one on which the Broadcast was received (i.e., the expander port that received the BROADCAST primitive sequence or SMP ZONED BROADCAST request) if:

- the Broadcast is not a Broadcast (Zone Activate) and any of the source zone groups have access to the zone group of the expander port;
- the Broadcast is a Broadcast (Zone Activate), the BPP is in a locked zoning expander device, the INSIDE ZPSDS bit is set to one, and the source zone group has access to zone group 2; or
- the Broadcast is a Broadcast (Zone Activate), the BPP is not in a locked zoning expander device, and any of the source zone groups have access to the zone group of the expander port.

To forward a Broadcast to an expander port:

- a) if the expander port's INSIDE ZPSDS bit is set to one, then the BPP shall request that the SMP initiator port establish a connection on at least one phy in the expander port to the SMP target port of the attached expander device and transmit an SMP ZONED BROADCAST request specifying the source zone group(s); or
- b) if the expander port's INSIDE ZPSDS bit is set to zero, then the BPP shall send a Transmit Broadcast message to at least one phy in the expander port, causing it to transmit a BROADCAST primitive sequence.

#### 4.8.6 Zone configuration

##### 4.8.6.1 Zone configuration overview

Zoning expander devices implement a lock to coordinate zoning configuration by zone manager(s).

There are four steps in the zone configuration process:

- 1) lock (see 4.8.6.2);
- 2) load (see 4.8.6.3);
- 3) activate (see 4.8.6.4); and
- 4) unlock (see 4.8.6.5).

The management device server in a zoning expander device only accepts SMP zone configuration function requests, SMP ZONE ACTIVATE requests, and SMP ZONE UNLOCK requests while it is locked, and only accepts SMP zone configuration function requests from the zone manager that locked the zoning expander device (i.e., the active zone manager). SMP zone configuration functions change zoning expander shadow values. When changes are complete, the zone manager activates the changes and the zoning expander device sets the zoning expander current values equal to the zoning expander shadow values. The zone manager then unlocks the zoning expander devices.

A ZPSDS only functions correctly while all zoning expander devices within the ZPSDS have identical values in their zone permission tables. To change zone permission tables, a zone manager device locks all zoning expander devices in a ZPSDS.

To change zone phy information, a zone manager locks only the zoning expander devices containing the phys to be changed.

When a zoning expander device with zoning disabled is being added to a ZPSDS (see figure 53 in 4.8.1) or two or more ZPSDSes are being merged (see figure 54 in 4.8.1), the zone manager locks all of the zoning expander devices that are to be included in the final ZPSDS. The zone manager configures the zone phy information in each zoning expander device (e.g., sets the REQUESTED INSIDE ZPSDS bit to one for phys inside the final ZPSDS) and configures all of the zone permission tables to be identical.

If the zone lock inactivity timer expires, then the zoning expander device performs the unlock step. The zoning expander device is unlocked and the zoning expander shadow values are not activated.

##### 4.8.6.2 Lock step

The lock step ensures that the same zone manager locks each zoning expander device. A zone manager sends the SMP ZONE LOCK request (see 9.4.3.21) to lock a zoning expander device. A zoning expander device is locked while the ZONE LOCKED bit is set to one in the SMP REPORT GENERAL response and after the SAS address of the zone manager has been stored. The management device server in a locked zoning expander device processes SMP zone configuration function requests, SMP ZONE ACTIVATE requests, and SMP ZONE UNLOCK requests.

If more than one zone manager attempts to lock a group of zoning expander devices, then the following rules ensure that any concurrent requests are resolved:

- a) if the first SMP ZONE LOCK response received by a zone manager has the FUNCTION RESULT field set to ZONE LOCK VIOLATION (see 9.4.3.3), then the group of zoning expander devices is locked by

another zone manager, and the zone manager should originate no further requests until it receives a Broadcast (Change);

- b) if at least one SMP ZONE LOCK request is successful and at least one other response has:
  - A) the FUNCTION RESULT field set to ZONE LOCK VIOLATION (see 9.4.3.3); and
  - B) the ZONE CONFIGURING bit set to one (see 4.8.6.3),

then at least one zoning expander device is locked and being configured by another zone manager. The zone manager that failed to lock the zoning expander devices should unlock all zoning expander devices that it has locked. When a Broadcast (Change) is received, then the zone manager should retry the lock step; and

- c) if at least one SMP ZONE LOCK request is successful and at least one other response has:
  - A) the FUNCTION RESULT field set to ZONE LOCK VIOLATION (see 9.4.3.3); and
  - B) the ZONE CONFIGURING bit set to zero,

then another zone manager has locked at least one zoning expander device in the group of zoning expander devices, and the zone manager shall evaluate the ACTIVE ZONE MANAGER SAS ADDRESS field in the SMP ZONE LOCK response as follows:

- A) if the returned SAS address has a lower numeric value than the SMP port SAS address of the zone manager, then the zone manager with the higher numeric value SAS address shall repeat the SMP ZONE LOCK request to all zoning expander devices that it has not already locked until all required zoning expander devices are locked, or until a Broadcast (Change) is received; or
- C) if the returned ACTIVE ZONE MANAGER SAS ADDRESS field has a higher numeric value than the SMP port SAS address of the zone manager, then the zone manager with the lower numeric value SAS address shall originate an SMP ZONE UNLOCK request to unlock all zoning expander devices that it locked.

The lock step is complete after a zone manager receives a successful SMP ZONE LOCK response from all required zoning expander devices.

#### 4.8.6.3 Load step

The load step stores SMP zone configuration information as zoning expander shadow values. A zoning expander device only processes SMP zone configuration function requests originated by the active zone manager while the zoning expander device is locked.

The SMP zone configuration functions are:

- a) SMP CONFIGURE ZONE PHY INFORMATION (see 9.4.3.25);
- b) SMP CONFIGURE ZONE PERMISSION TABLE (see 9.4.3.26); and
- c) SMP ENABLE DISABLE ZONING (see 9.4.3.19).

After a locked zoning expander device processes any SMP zone configuration function request, it sets the ZONE CONFIGURING bit to one in the SMP REPORT GENERAL response (see 9.4.3.4).

If the ZONE CONFIGURING bit is set to one and a zoning violation occurs on a connection request, then the expander device shall return OPEN\_REJECT (RETRY) instead of OPEN\_REJECT (ZONE VIOLATION) (see 4.5.6.3).

SMP zone configuration functions change the zoning expander shadow values and do not affect the zoning expander current values. The zoning expander shadow values become zoning expander current values during the activate step (see 4.8.6.4).

If the active zone manager receives a response to an SMP zone configuration function with the FUNCTION RESULT field set to ZONE LOCK VIOLATION (see 9.4.3.3), then it should unlock all locked zoning expander devices.

The load step may be skipped when a locked zoning expander device is unlocked:

- a) by a zone manager with a higher SAS address during the lock step (see 4.8.6.2); or
- b) because the zone lock inactivity timer expires.



#### 4.8.6.4 Activate step

The activate step:

- a) saves the zoning expander shadow values, if saving was requested;
- b) copies the zoning expander shadow zone permission table to the current zone permission table;
- c) for each phy with the INSIDE ZPSDS bit set to zero, copies the shadow zone phy information to the current zone phy information; and
- d) for each phy with the INSIDE ZPSDS bit set to one:
  - A) sets the current zone group to 01h; and
  - B) for the remaining fields in the zone phy information, copies the shadow zone phy information to the current zone phy information.

The active zone manager originates one of the following:

- a) a Broadcast (Zone Activate) (see 4.1.15); or
- b) an SMP ZONE ACTIVATE request (see 9.4.3.22) to all locked zoning expander devices.

After a locked zoning expander device receives a Broadcast (Zone Activate) or processes an SMP ZONE ACTIVATE request the zoning expander device shall:

- a) copy the zoning expander shadow zone permission table to the current zone permission table;
- b) for each phy with the INSIDE ZPSDS bit set to zero, copy the shadow zone phy information to the current zone phy information; and
- c) for each phy with the INSIDE ZPSDS bit set to one:
  - A) set the current zone group to 01h; and
  - B) for the remaining fields in the zone phy information, copy the shadow zone phy information to the current zone phy information.

If the active zone manager receives an SMP ZONE ACTIVATE response with the FUNCTION RESULT field set to ZONE LOCK VIOLATION (see 9.4.3.3), then it should unlock all locked zoning expander devices.

The activate step may be skipped when a locked zoning expander device is unlocked:

- a) by a zone manager with a higher SAS address during the lock step (see 4.8.6.2); or
- b) because the zone lock inactivity timer expires.

#### 4.8.6.5 Unlock step

The unlock step ensures that:

- a) the active zone manager unlocks the locked zoning expander devices; or
- b) if the zone manager fails, then the zone lock inactivity timer expires, and the zoning expander devices unlock.

If the active zone manager originated Broadcast (Zone Activate), then it sends an SMP ZONE UNLOCK request (see 9.4.3.23) with the ACTIVATE REQUIRED bit set to one to each of the locked zoning expander devices. This ensures that the activate step precedes the unlock step in each zoning expander device. If the active zone manager receives an SMP ZONE UNLOCK response with the FUNCTION RESULT field set to NOT ACTIVATED (see 9.4.3.3), then it retries the SMP ZONE UNLOCK request a vendor specific number of times, then originates an SMP ZONE ACTIVATE request to each locked zoning expander device.

If the active zone manager originated SMP ZONE ACTIVATE request(s), then after all the SMP ZONE ACTIVATE functions have completed without error, it sends an SMP ZONE UNLOCK request with the ACTIVATE REQUIRED bit set to zero to each of the locked zoning expander devices. If the active zone manager receives an SMP ZONE UNLOCK response with the FUNCTION RESULT field set to BUSY (see 9.4.3.3), then it retries the SMP ZONE UNLOCK request.

When the SMP ZONE UNLOCK request is successful or the zone lock inactivity timer expires, then the zoning expander device is unlocked and shall:

- a) set the ZONE LOCKED bit to zero in the SMP REPORT GENERAL response (see 9.4.3.4);
- b) set the ZONE CONFIGURING bit to zero in the SMP REPORT GENERAL response;

- c) if the zone lock timer expired, originate a Broadcast (Change) from zone group 1; and
- d) if the management device server processed an SMP ZONE UNLOCK request, originate a Broadcast (Change) (see 6.13) from either:
  - A) each zone group whose zone permission table entries or zone phy information has changed; or
  - B) zone group 1.

When all SMP ZONE UNLOCK requests are successful, the zone configuration process is complete.

#### 4.8.6.6 Zone lock inactivity timer

The zone lock inactivity timer ensures that if the zone manager disappears without performing the unlock step that all locked zoning expander devices are unlocked.

When a zoning expander device processes an SMP ZONE LOCK request (see 9.4.3.21) then the zone lock inactivity timer default value is set to the value of the ZONE LOCK INACTIVITY TIME LIMIT field.

The zone lock inactivity timer is initialized and started if the default value is non-zero and:

- a) the zoning expander device completes processing of any SMP zone configuration function request or SMP ZONE ACTIVATE request while the ZONE LOCKED bit is set to one in the SMP REPORT GENERAL response (see 9.4.3.4); or
- b) the zoning expander device completes processing of a successful SMP ZONE LOCK request.

The zone lock inactivity timer is stopped if:

- a) the ZONE LOCK INACTIVITY TIME LIMIT field is set to zero in an SMP ZONE LOCK request; or
- b) the ZONE LOCKED bit is set to zero in the SMP REPORT GENERAL response (e.g., an SMP ZONE UNLOCK request (see 9.4.3.23) is processed, or the zone lock inactivity timer expires).

If the zone lock inactivity timer expires then the zoning expander device:

- a) sets the ZONE LOCKED bit to zero in the SMP REPORT GENERAL response;
- b) sets the ZONE CONFIGURING bit to zero in the SMP REPORT GENERAL response; and
- c) sends Broadcast (Change) on all ports.

If the zone lock inactivity timer expires while the zoning expander device is processing an SMP configuration function then the zoning expander device may complete the request without error or return a function result of ZONE LOCK VIOLATION.

#### 4.8.6.7 Enable a zoning expander device

If a zoning expander device has the ZONING SUPPORTED bit set to one and the ZONING ENABLED bit set to zero in the REPORT GENERAL response (see 9.4.3.4), then a zone manager configures the zoning expander device using the zone configuration process. This ensures that the zone permission table is the same in all zoning expander devices inside the ZPSDS.

Changes made by the SMP ENABLE DISABLE ZONING function sent by the active zone manager become active during the activate step (see 4.8.6.4).

### 4.9 SAS device and expander device power conditions

SCSI idle and standby power conditions, implemented with the START STOP UNIT command (see SBC-3) and the Power Condition mode page (see SPC-4), may be supported by SSP initiator ports and SSP target ports as described in 9.2.10.

Except for Sleep mode (e.g., requested with the ATA SLEEP command), the ATA Power Management feature set, Extended Power Management feature set, or Advanced Power Management feature set (see ACS-2) may be supported by an ATA application client using an STP initiator port.

## 4.10 Phy power conditions

### 4.10.1 Low phy power conditions

#### 4.10.1.1 Low phy power conditions overview

Low phy power conditions are phy conditions where the phy is in a reduced power state (e.g., has disabled circuitry in order to reduce power). This standard defines low phy power conditions that are differentiated by time to return to the active phy power condition (see 4.10.1.2 and table 68) and the amount of power consumed in that low phy power condition. The low phy power conditions include the partial phy power condition (see 4.10.1.3) and the slumber phy power condition (see 4.10.1.4).

A phy in a low phy power condition shall not change to a different low phy power condition without first making a change to the active phy power condition (see 5.11.2).

Low phy power conditions shall only be enabled on a phy if multiplexing (see 5.15) and optical mode are disabled.

If the partial phy power condition is enabled and the received IDENTIFY address frame has the PARTIAL CAPABLE bit set to one (see 6.8.2), then the phy may generate PS\_REQ (PARTIAL) primitive sequences. If the slumber phy power condition is enabled and the received IDENTIFY address frame has the SLUMBER CAPABLE bit set to one (see 6.8.2), then the phy may generate PS\_REQ (SLUMBER) primitive sequences. If low phy power conditions are enabled, then the phy may reply with a PS\_ACK primitive sequence to accept a low phy power condition request. If low phy power conditions are supported and disabled, then the phy shall reject a low phy power condition request by replying with a PS\_NAK primitive sequence.

If a SAS phy or expander phy is in a low phy power condition and that phy is requested to transmit a NOTIFY, then that phy shall not transmit the NOTIFY and shall remain in the same low phy power condition.

#### 4.10.1.2 Active phy power condition

While in the active phy power condition:

- a) the phy is capable of transmitting information and responding to received information; and
- b) the phy may consume more power than while the phy is in a low phy power condition.

#### 4.10.1.3 Partial phy power condition

While in the partial phy power condition:

- a) the phy is only capable of processing a COMINIT or COMWAKE;
- b) the phy may take less time to return to the active phy power condition (see table 68) than while in the slumber phy power condition; and
- c) the power consumed by the phy should be less than the power consumed while the phy is in the active phy power condition and may be greater than the power consumed while the phy is in the slumber phy power condition.

#### 4.10.1.4 Slumber phy power condition

While in the slumber phy power condition:

- a) the phy is only capable of processing a COMINIT or COMWAKE;
- b) the phy may take more time to return to the active phy power condition (see table 68) than while in the partial phy power condition; and
- c) the power consumed by the phy should be less than the power consumed while the phy is in the active phy power condition and while the phy is in the partial phy power condition.

#### 4.10.1.5 End device low phy power conditions

Low phy power conditions are reported in SAS target devices using the Phy Control And Discover mode page (see 9.2.7.5).

Partial phy power condition may be enabled and disabled in SAS target devices using the Enhanced Phy Control mode page (see 9.2.7.7).

Slumber phy power condition may be enabled and disabled in SAS target devices using the Enhanced Phy Control mode page (see 9.2.7.7).

The management application layer shall only:

- a) enable a low phy power condition (i.e., send a Manage Power Conditions (Accept Partial) request or Manage Power Conditions (Accept Slumber) request); and
- b) request a phy enter a low phy condition (i.e., send a Change Phy Power Condition request),

after receiving a Phy Power Condition Status (Enable Low Phy Power Conditions) message from the SA\_PC state machine (see 9.2.10.2).

The management application layer:

- a) shall disable a low phy power condition (i.e., send a Manage Power Conditions (Reject Partial) request and Manage Power Conditions (Reject Slumber) request); and
- b) shall not request that a phy enter a low phy power condition (i.e., send a Change Phy Power Condition request),

after receiving a Phy Power Condition Status (Disable Low Phy Power Conditions) message from the SA\_PC state machine (see 9.2.10.2).

If a SAS phy is in a low phy power condition, then to originate a Broadcast the management application layer:

- 1) shall initiate the exit power condition procedure (see 5.11.2) on that SAS phy;
- 2) shall originate the Broadcast; and
- 3) may initiate the procedure to return that SAS phy to a low phy power condition.

#### 4.10.1.6 Expander device low phy power conditions

Low phy power conditions are reported in expander devices using the SMP DISCOVER function (see 9.4.3.10).

Partial phy power conditions may be enabled and disabled in expander devices using the SMP PHY CONTROL function (see 9.4.3.28).

If an expander phy is in the partial phy power condition and the ECM receives a connection request routed to that expander phy, then the expander device initiates the exit power condition procedure (see 5.11.2) on that expander phy and responds with AIP (NORMAL) until the OPEN address frame is forwarded to that expander phy.

Slumber phy power conditions may be enabled and disabled in expander devices using the SMP PHY CONTROL function (see 9.4.3.28).

If an expander phy is in slumber phy power condition and the ECM receives a connection request routed to that expander phy, then the expander device initiates the exit power condition procedure (see 5.11.2) on that expander phy and responds with OPEN\_REJECT (RETRY) until a phy ready state (see 5.12.4.10) is established for that expander phy.

If an expander phy is in a low phy power condition, then to originate or forward a Broadcast the BPP:

- 1) shall initiate the exit power condition procedure (see 5.11.2) on that expander phy;
- 2) shall originate or forward the Broadcast; and
- 3) may initiate the procedure to return that expander phy to a low phy power condition.

#### 4.10.2 SATA phy power conditions

STP initiator ports shall not generate SATA\_PMREQ\_P, SATA\_PMREQ\_S, or SATA\_PMACK. If an STP initiator port receives SATA\_PMREQ\_P or SATA\_PMREQ\_S, then the STP initiator port shall reply with:

- a) SATA\_X\_RDY if the STP initiator port has a FIS ready to transmit to the STP target port; or
- b) a CLOSE primitive sequence.

NOTE 8 - SAS-2 required the STP initiator port to transmit SATA\_PMNAK.

SATA interface power management sequences (see SATA) may be enabled in an expander phy using the SMP PHY CONTROL function (see 9.4.3.28).

If an expander device receives SATA\_PMREQ\_P or SATA\_PMREQ\_S from a SATA device while an STP connection is not open, then it shall not forward the primitive to any STP initiator port and shall reply with SATA\_PMNAK or SATA\_PMACK as defined by SATA. If SATA interface power management sequences are not enabled, then the expander device shall reply with SATA\_PMNAK.

If an expander device receives SATA\_PMREQ\_P or SATA\_PMREQ\_S while an STP connection is open, then the expander device may or may not forward the primitive to the STP initiator port. If the expander device forwards a SATA\_PMREQ\_P or SATA\_PMREQ\_S to the STP initiator port during an STP connection, then the expander device shall not reply with SATA\_PMACK or SATA\_PMNAK within that connection.

### 4.11 Phy test functions

#### 4.11.1 Phy test functions overview

Phy test functions (e.g., transmission of test patterns) are used for phy and interconnect characterization and diagnosis. The phy may be attached to test equipment while performing a phy test function. The following optional mechanisms are defined for invoking phy test functions:

- a) the Protocol Specific diagnostic page for SAS (see 9.2.9.2) invokes a phy test function in a selected phy in a SAS target device with an SSP target port. The SEND DIAGNOSTIC command (see SPC-4) may be sent through any SSP target port to any logical unit in the SAS target device that contains the phy that is to perform the phy test function. The phy test function starts some time after the SSP target port receives an ACK for the RESPONSE frame transmitted in response to the SEND DIAGNOSTIC command; and
- b) the SMP PHY TEST FUNCTION function (see 9.4.3.29) invokes a phy test function in a phy controlled by a management device server other than the phy that receives the function. The phy test function starts some time after the SMP target port transmits the SMP response frame.

Each phy test function is optional.

If the phy test function requires a specific phy test pattern and/or phy test function physical link rate, then the mechanism for invoking the phy test function specifies the phy test pattern and phy test function physical link rate.

The phy test function on one phy may affect the negotiated settings on other phys (e.g., in a device with a common SSC clock, the SSC modulation type may change from none to down-spreading even on phys that negotiated no SSC).

While a phy is performing a phy test function, the link layer receivers (i.e., the SL\_IR receiver, SL receiver, SSP receiver, STP receiver, and SMP receiver) shall ignore all incoming dwords and the OOB signal detector shall detect COMINIT. The phy shall ignore any other OOB signals (i.e., COMSAS and COMWAKE).

A phy stops performing a phy test function:

- a) after the SCSI device server, if any, processes a Protocol Specific diagnostic page specifying the phy and specifying a phy test function of 00h (i.e., STOP);

- b) after the management device server, if any, processes an SMP PHY TEST FUNCTION request specifying the phy and specifying a phy test function of 00h (i.e., STOP);
- c) after the phy receives COMINIT; or
- d) upon power off.

The time it takes for a phy to stop performing the phy test function is vendor specific. After a phy stops performing a phy test function, the phy performs a link reset sequence.

#### 4.11.2 Transmit pattern phy test function

While a phy is performing the transmit pattern phy test function, the test equipment attached to that phy:

- a) shall not transmit COMSAS or COMWAKE; and
- b) shall not transmit COMINIT except to stop the phy test function.

While performing the transmit pattern phy test function, a phy:

- a) shall ignore all dwords received; and
- b) shall repeatedly transmit the specified pattern at the specified physical link rate.

#### 4.12 Phy events

Phys shall count the following events using saturating counters and report them in the Protocol Specific Port log page (see 9.2.8.1) and/or the SMP REPORT PHY ERROR LOG function (see 9.4.3.11):

- a) invalid dwords received;
- b) dwords received with running disparity errors;
- c) loss of dword synchronization; and
- d) phy reset problems.

The saturating counters are each up to 4 bytes wide.

Phys may count those events and certain other events (e.g., elasticity buffer overflows) using wrapping counters and record peak values for certain events (e.g., the longest connection time) using peak value detectors, reporting them in the Protocol Specific Port log page (see 9.2.8.1), SMP REPORT PHY EVENT function (see 9.4.3.14), and/or the SMP REPORT PHY EVENT LIST function (see 9.4.3.16). The wrapping counters and peak value detectors are each 4 bytes wide. Peak value detectors trigger Broadcast (Expander) under certain circumstances (see 6.2.6.4).

The number of additional events monitored is vendor specific. For phys not controlled by SMP target ports, the events that are monitored are vendor specific. For phys controlled by SMP target ports, the SMP CONFIGURE PHY EVENT function (see 9.4.3.30) allows for specification of the events to monitor.

The management device server shall maintain phy events for the last vendor specific number of events and should maintain at least one phy event per phy. The management device server shall assign descriptors to the events sequentially starting at 0001h and shall return the descriptors in the SMP REPORT PHY EVENT LIST response (see 9.4.3.16). The management device server shall return the index of the descriptor for the last phy event in the SMP REPORT GENERAL response (see 9.4.3.4), the SMP REPORT PHY EVENT LIST response (see 9.4.3.16), and the SMP DISCOVER LIST response (see 9.4.3.15). The management device server shall wrap the index to 0001h when the highest supported descriptor index has been used.

The management device server shall support phy event list descriptor (see 9.4.3.16.4) indexes from 0001h to FFFFh. The actual number of phy event list descriptors that the management device server maintains for retrieval with the REPORT PHY EVENT LIST request is vendor specific and is indicated by the MAXIMUM NUMBER OF STORED PHY EVENT LIST DESCRIPTORS field defined in the REPORT GENERAL response (see 9.4.3.4). The volatility of these stored descriptors is vendor specific. The management device server shall replace the oldest phy event list descriptor with a new one once the number of recorded descriptors exceeds the value indicated by the MAXIMUM NUMBER OF STORED PHY EVENT LIST DESCRIPTORS field.



The PHY EVENT SOURCE field, defined in table 46, is used in the Protocol Specific Port log page (see 9.2.8.1), the REPORT PHY EVENT function (see 9.4.3.14), the REPORT PHY EVENT LIST function (see 9.4.3.16), and the CONFIGURE PHY EVENT function (see 9.4.3.30) and indicates or specifies the type of phy event in the accompanying PHY EVENT field.

**Table 46 — PHY EVENT SOURCE field (part 1 of 5)**

| Code                                                                                                                                                                                                                                                                     | Name                                             | Type <sup>a</sup> | Description                                                                                                                                                                                                                                                                                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h                                                                                                                                                                                                                                                                      | No event                                         | N/A               | No event. The PHY EVENT field is not valid.                                                                                                                                                                                                                                                                  |
| Phy layer-based phy events (01h to 1Fh)                                                                                                                                                                                                                                  |                                                  |                   |                                                                                                                                                                                                                                                                                                              |
| 01h                                                                                                                                                                                                                                                                      | Invalid dword count <sup>b</sup>                 | WC                | Number of invalid dwords (see 3.1.103) that have been received outside of phy reset sequences (i.e., between when the SP state machine (see 5.12) sends a Phy Layer Ready (SAS) confirmation or Phy Layer Ready (SATA) confirmation and when it sends a Phy Layer Not Ready confirmation to the link layer). |
| 02h                                                                                                                                                                                                                                                                      | Running disparity error count <sup>b</sup>       | WC                | Number of dwords containing running disparity errors (see 5.3.5) that have been received outside of phy reset sequences.                                                                                                                                                                                     |
| 03h                                                                                                                                                                                                                                                                      | Loss of dword synchronization count <sup>b</sup> | WC                | Number of times the phy has restarted the link reset sequence because it lost dword synchronization (i.e., the SP state machine transitioned from SP15:SAS_PHY_Ready or SP22:SATA_PHY_Ready to SP0:OOB_COMINIT (see 5.12)).                                                                                  |
| 04h                                                                                                                                                                                                                                                                      | Phy reset problem count <sup>b</sup>             | WC                | Number of times a phy reset problem has occurred (see 5.10.4.2.4).                                                                                                                                                                                                                                           |
| 05h                                                                                                                                                                                                                                                                      | Elasticity buffer overflow count                 | WC                | Number of times the phy's elasticity buffer (see 6.3) has overflowed outside of phy reset sequences (e.g., because it did not receive a sufficient number of deletable primitives).                                                                                                                          |
| 06h                                                                                                                                                                                                                                                                      | Received ERROR count                             | WC                | Number of times the phy received an ERROR.                                                                                                                                                                                                                                                                   |
| 07h to 1Fh                                                                                                                                                                                                                                                               | Reserved for phy layer-based phy events          |                   |                                                                                                                                                                                                                                                                                                              |
| SAS arbitration-related phy events (20h to 3Fh)                                                                                                                                                                                                                          |                                                  |                   |                                                                                                                                                                                                                                                                                                              |
| 20h                                                                                                                                                                                                                                                                      | Received address frame error count               | WC                | Number of times the phy detected an invalid address frame (see 6.8) (e.g., because of a CRC error).                                                                                                                                                                                                          |
| <sup>a</sup> The Type column indicates the source type:<br>a) WC = wrapping counter;<br>b) PVD = peak value detector; and<br>c) N/A = not applicable.<br><sup>b</sup> This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11). |                                                  |                   |                                                                                                                                                                                                                                                                                                              |

**Table 46** — PHY EVENT SOURCE field (part 2 of 5)

| Code                                                                                                                                                                                                                                                                     | Name                                        | Type <sup>a</sup> | Description                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 21h                                                                                                                                                                                                                                                                      | Transmitted abandon-class OPEN_REJECT count | WC                | Number of times the phy received an OPEN address frame and transmitted an abandon-class OPEN_REJECT (see 6.2.6.10). In expander devices, forwarded OPEN_REJECTs shall not be counted.                                                                                    |
| 22h                                                                                                                                                                                                                                                                      | Received abandon-class OPEN_REJECT count    | WC                | Number of times the phy originated an OPEN address frame and received an abandon-class OPEN_REJECT (see 6.2.6.10). In expander devices, OPEN_REJECTs in response to forwarded OPEN address frames shall not be counted.                                                  |
| 23h                                                                                                                                                                                                                                                                      | Transmitted retry-class OPEN_REJECT count   | WC                | Number of times the phy received an OPEN address frame and transmitted a retry-class OPEN_REJECT (see 6.2.6.10). In expander devices, forwarded OPEN_REJECTs shall not be counted.                                                                                       |
| 24h                                                                                                                                                                                                                                                                      | Received retry-class OPEN_REJECT count      | WC                | Number of times the phy originated an OPEN address frame and received a retry-class OPEN_REJECT (see 6.2.6.10). In expander devices, OPEN_REJECTs in response to forwarded OPEN address frames shall not be counted.                                                     |
| 25h                                                                                                                                                                                                                                                                      | Received AIP (WAITING ON PARTIAL) count     | WC                | Number of times the phy received an AIP (WAITING ON PARTIAL) or AIP (RESERVED WAITING ON PARTIAL). In expander devices, forwarded AIPs shall be counted.                                                                                                                 |
| 26h                                                                                                                                                                                                                                                                      | Received AIP (WAITING ON CONNECTION) count  | WC                | Number of times the phy received an AIP (WAITING ON CONNECTION). In expander devices, forwarded AIPs shall be counted.                                                                                                                                                   |
| 27h                                                                                                                                                                                                                                                                      | Transmitted BREAK count                     | WC                | Number of times the phy transmitted a BREAK primitive sequence that was not a response to a BREAK primitive sequence it received (e.g., a Close Timeout was detected by the SL state machines interfacing to the SMP target port).                                       |
| 28h                                                                                                                                                                                                                                                                      | Received BREAK count                        | WC                | Number of times the phy received a BREAK primitive sequence that was not a response to a BREAK primitive sequence that it transmitted.                                                                                                                                   |
| 29h                                                                                                                                                                                                                                                                      | Break Timeout count                         | WC                | Number of times the phy transmitted a BREAK primitive sequence and did not receive a BREAK primitive sequence or BREAK_REPLY primitive sequence in response (e.g., as detected by the XL state machine and/or the SL state machines interfacing to the SMP target port). |
| 2Ah                                                                                                                                                                                                                                                                      | Connection count                            | WC                | Number of connections in which the phy was involved.                                                                                                                                                                                                                     |
| <sup>a</sup> The Type column indicates the source type:<br>a) WC = wrapping counter;<br>b) PVD = peak value detector; and<br>c) N/A = not applicable.<br><sup>b</sup> This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11). |                                             |                   |                                                                                                                                                                                                                                                                          |



**Table 46** — PHY EVENT SOURCE field (part 3 of 5)

| Code                                                                                                                                                                                                                                                                     | Name                                                 | Type <sup>a</sup> | Description                                                                                                                                                                                                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2Bh                                                                                                                                                                                                                                                                      | Peak transmitted pathway blocked count               | PVD               | Peak value of a PATHWAY BLOCKED COUNT field in an OPEN address frame transmitted by the phy. Since the maximum value of the PATHWAY BLOCKED COUNT field is FFh, only byte 3 of the PHY EVENT field is used.                |
| 2Ch                                                                                                                                                                                                                                                                      | Peak transmitted arbitration wait time               | PVD               | Peak value of an ARBITRATION WAIT TIME field in an OPEN address frame transmitted by the phy. Since the maximum value of the ARBITRATION WAIT TIME field is FFFFh, only byte 2 and byte 3 of the PHY EVENT field are used. |
| 2Dh                                                                                                                                                                                                                                                                      | Peak arbitration time                                | PVD               | Peak time in microseconds after transmitting an OPEN address frame that the phy has waited for connection response (e.g., OPEN_ACCEPT or OPEN_REJECT).                                                                     |
| 2Eh                                                                                                                                                                                                                                                                      | Peak connection time                                 | PVD               | The peak duration, in microseconds, of any connection in which the phy was involved.                                                                                                                                       |
| 2Fh                                                                                                                                                                                                                                                                      | Persistent connection count                          | WC                | Number of persistent connections (see 4.1.13) in which the phy was involved.                                                                                                                                               |
| 30h to 3Fh                                                                                                                                                                                                                                                               | Reserved for SAS arbitration-related phy information |                   |                                                                                                                                                                                                                            |
| SSP-related phy events (40h to 4Fh)                                                                                                                                                                                                                                      |                                                      |                   |                                                                                                                                                                                                                            |
| 40h                                                                                                                                                                                                                                                                      | Transmitted SSP frame count                          | WC                | Number of SSP frames transmitted.                                                                                                                                                                                          |
| 41h                                                                                                                                                                                                                                                                      | Received SSP frame count                             | WC                | Number of SSP frames received.                                                                                                                                                                                             |
| 42h                                                                                                                                                                                                                                                                      | Transmitted SSP frame error count                    | WC                | Number of times the phy was used in a connection involving the SSP target port, transmitted an SSP frame, and received a NAK or an ACK/NAK timeout.                                                                        |
| 43h                                                                                                                                                                                                                                                                      | Received SSP frame error count                       | WC                | Number of times the phy was used in a connection involving the SSP target port, detected an invalid SSP frame, and transmitted a NAK (CRC ERROR) (e.g., because of a CRC error).                                           |
| 44h                                                                                                                                                                                                                                                                      | Transmitted CREDIT_BLOCKED count                     | WC                | Number of times the phy transmitted a CREDIT_BLOCKED.                                                                                                                                                                      |
| 45h                                                                                                                                                                                                                                                                      | Received CREDIT_BLOCKED count                        | WC                | Number of times the phy received a CREDIT_BLOCKED.                                                                                                                                                                         |
| <sup>a</sup> The Type column indicates the source type:<br>a) WC = wrapping counter;<br>b) PVD = peak value detector; and<br>c) N/A = not applicable.<br><sup>b</sup> This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11). |                                                      |                   |                                                                                                                                                                                                                            |

**Table 46** — PHY EVENT SOURCE **field** (part 4 of 5)

| Code                                                                                                                                                                                                                                                                     | Name                                         | Type <sup>a</sup> | Description                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 46h to 4Fh                                                                                                                                                                                                                                                               | Reserved for SSP-related phy events          |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| STP and SATA-related phy events (50h to 5Fh)                                                                                                                                                                                                                             |                                              |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 50h                                                                                                                                                                                                                                                                      | Transmitted SATA frame count                 | WC                | Number of STP or SATA frames transmitted.                                                                                                                                                                                                                                                                                                                                                                                                             |
| 51h                                                                                                                                                                                                                                                                      | Received SATA frame count                    | WC                | Number of STP or SATA frames received.                                                                                                                                                                                                                                                                                                                                                                                                                |
| 52h                                                                                                                                                                                                                                                                      | SATA flow control buffer overflow count      | WC                | <p>Number of times the phy's STP flow control buffer (see 6.19.2) has overflowed (e.g., because it received more data dwords than allowed after transmitting SATA_HOLD during an STP connection).</p> <p>In an expander device, this count should be maintained in the expander phy transmitting the SATA_HOLD and receiving the data dwords, but may be maintained in the expander phy receiving the SATA_HOLD and transmitting the data dwords.</p> |
| 53h to 5Fh                                                                                                                                                                                                                                                               | Reserved for STP and SATA-related phy events |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| SMP-related phy events (60h to 6Fh)                                                                                                                                                                                                                                      |                                              |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 60h                                                                                                                                                                                                                                                                      | Transmitted SMP frame count                  | WC                | Number of SMP frames transmitted.                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 61h                                                                                                                                                                                                                                                                      | Received SMP frame count                     | WC                | Number of SMP frames received.                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 62h                                                                                                                                                                                                                                                                      | Reserved for SMP-related phy events          |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <sup>a</sup> The Type column indicates the source type:<br>a) WC = wrapping counter;<br>b) PVD = peak value detector; and<br>c) N/A = not applicable.<br><sup>b</sup> This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11). |                                              |                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

**Table 46** — PHY EVENT SOURCE **field** (part 5 of 5)

| Code                                                                                                                                                                                                                                                                     | Name                                | Type <sup>a</sup> | Description                                                                                                                                                                                     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 63h                                                                                                                                                                                                                                                                      | Received SMP frame error count      | WC                | Number of times the phy was used to access the SMP target port and the SMP target port detected an invalid SMP frame and transmitted a BREAK primitive sequence (e.g., because of a CRC error). |
| 64h to 6Fh                                                                                                                                                                                                                                                               | Reserved for SMP-related phy events |                   |                                                                                                                                                                                                 |
| Other (70h to FFh)                                                                                                                                                                                                                                                       |                                     |                   |                                                                                                                                                                                                 |
| 70h to CFh                                                                                                                                                                                                                                                               | Reserved                            |                   |                                                                                                                                                                                                 |
| D0h to FFh                                                                                                                                                                                                                                                               | Vendor specific                     |                   |                                                                                                                                                                                                 |
| <sup>a</sup> The Type column indicates the source type:<br>a) WC = wrapping counter;<br>b) PVD = peak value detector; and<br>c) N/A = not applicable.<br><sup>b</sup> This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11). |                                     |                   |                                                                                                                                                                                                 |

## 4.13 Using POWER DISABLE signal to create a power on event

### 4.13.1 Using POWER DISABLE signal to create a power on event overview

The POWER DISABLE signal (see SAS-3) allows a SAS initiator device or an expander device to cause a power on event (see SAM-5) for a SAS target device by:

- 1) asserting the POWER DISABLE signal for the minimum hold time (see SAS-3); and
- 2) negating the POWER DISABLE signal.

### 4.13.2 Discovering POWER DISABLE signal support

A SCSI application client determines if a SAS target device supports the POWER DISABLE signal by verifying that the PWR\_D\_S bit is set to one in the Protocol Specific Port Information VPD page (see 9.2.11.4).

If a SCSI application client has determined that a SAS target device supports the POWER DISABLE signal, then the management application client determines if the management device server in the SAS initiator device or expander device attached to that SAS target device is capable of controlling the POWER DISABLE signal by examining the DISCOVER function response data (see 9.4.3.10) for a phy associated with the SAS target device and verifying that:

- a) the ATTACHED PWR\_DIS CAPABLE bit is set to one; and
- b) the PWR\_DIS CONTROL CAPABLE field is set to 01b.

If the DISCOVER function response data indicates that the management device server in the SAS initiator device or expander device is not capable of controlling the POWER DISABLE signal (i.e., the PWR\_DIS CONTROL CAPABLE field is not set to 01b), then the POWER DISABLE signal may be controlled by a method outside the scope of this standard.

#### 4.13.3 Using a management device server to control the POWER DISABLE signal

If a management device server is capable of controlling the POWER DISABLE signal (see 4.13.2), then the management application client uses the PWR\_DIS CONTROL field in the PHY CONTROL function (see 9.4.3.28) to assert and negate the POWER DISABLE signal as required (see 4.13.1). The management application client may examine the PWR\_DIS SIGNAL field in the DISCOVER function response data (see 9.4.3.10) to verify that the POWER DISABLE signal is at the expected level.

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## 5 Phy layer

### 5.1 Phy layer overview

The phy layer defines 8b10b coding, BMC coding, and OOB signals. Phy layer state machines interface between the link layer and the physical layer to perform the phy reset sequence and keep track of dword synchronization.

### 5.2 8b10b coding

#### 5.2.1 8b10b coding overview

All information transferred in SAS is encoded into 10-bit characters using 8b10b encoding. 10-bit characters are transmitted serially bit-by-bit across the physical link.

Out of all 1 024 possible 10-bit characters:

- a) some of the characters are data characters, representing the 256 possible 8-bit data bytes;
- b) some of the characters are control characters, used for primitives (e.g., frame delimiters) and other control purposes; and
- c) the rest of the characters are invalid characters.

8b10b coding ensures that sufficient transitions are present in the serial bit stream to make clock recovery possible at the receiver. 8b10b coding also increases the likelihood of detecting any single or multiple bit errors that occur during transmission and reception. In addition, some of the control characters of the transmission code contain a distinct bit pattern, called a comma pattern, which assists a receiver in achieving character and dword alignment on the incoming bit stream.

#### 5.2.2 8b10b coding notation conventions

This subclause uses letter notation for describing information bits and control variables. Such notation differs from the bit notation specified by the remainder of this standard. The following text describes the translation process between these notations and provides a translation example. This subclause also describes the conventions used to name valid characters. This text is provided for the purposes of terminology clarification only.

An unencoded information byte is composed of:

- a) eight information bits labeled A, B, C, D, E, F, G, and H. Each information bit contains either a binary zero or a binary one; and
- b) a control variable labeled Z. A control variable has either the value D or the value K:
  - A) D means the information byte is a data byte; and
  - B) K means the information byte is a control byte.

The information bit labeled A corresponds to bit 0 in the numbering scheme of this standard, B corresponds to bit 1, and so on, as shown in table 47. Bit H is the most significant bit of the byte and bit A is the least significant bit of the byte.

**Table 47 — Bit designations**

| Bit notation           | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Control variable |
|------------------------|---|---|---|---|---|---|---|---|------------------|
| Unencoded bit notation | H | G | F | E | D | C | B | A | Z                |

Each valid character is named using the following convention:

Zxx.y

where:

- Z is the control variable of the unencoded information byte. The value of Z is used to indicate whether the character is a data character (i.e., Z = D) or a control character (i.e., Z = K).
- xx is the decimal value of the binary number composed of the bits E, D, C, B, and A of the unencoded information byte in that order.
- y is the decimal value of the binary number composed of the bits H, G, and F of the unencoded information byte in that order.

Table 48 shows the conversion from byte notation to the character naming convention.

**Table 48 — Conversion from byte notation to character name example**

| Byte notation                                                            | BCh |   |    |   |   |   |   |   |         |  |
|--------------------------------------------------------------------------|-----|---|----|---|---|---|---|---|---------|--|
| Bit notation                                                             | 7   | 6 | 5  | 4 | 3 | 2 | 1 | 0 | Control |  |
|                                                                          | 1   | 0 | 1  | 1 | 1 | 1 | 0 | 0 | K       |  |
| Unencoded bit notation                                                   | H   | G | F  | E | D | C | B | A | Z       |  |
|                                                                          | 1   | 0 | 1  | 1 | 1 | 1 | 0 | 0 | K       |  |
| Unencoded bit notation reordered to conform with Zxx.y naming convention | Z   | E | D  | C | B | A | H | G | F       |  |
|                                                                          | K   | 1 | 1  | 1 | 0 | 0 | 1 | 0 | 1       |  |
| Character name                                                           | K   |   | 28 |   |   | . |   | 5 |         |  |

Most Kxx.y combinations do not result in valid characters within the 8b10b coding scheme. Only those combinations that result in control characters defined in table 50 (see 5.3.7) are considered valid.

## 5.3 Character encoding and decoding

### 5.3.1 Character encoding and decoding overview

This subclause describes how to select valid characters (i.e., 8b10b encoding) and check the validity of received characters (i.e., 10b8b decoding), and specifies the ordering rules to be followed when transmitting the bits within a character.

### 5.3.2 Bit transmission order

An information byte is encoded into a 10-bit character containing bits labeled a, b, c, d, e, i, f, g, h, and j. Bit a shall be transmitted first, followed by bits b, c, d, e, i, f, g, h, and j, in that order.

### 5.3.3 Character transmission order

Characters within primitives shall be transmitted sequentially beginning with the control character used to distinguish the primitive (e.g., K28.3 or K28.5) and proceeding character by character from left to right within the definition of the primitive until all characters of the primitive are transmitted.

### 5.3.4 Frame transmission order

The contents of a frame shall be transmitted sequentially beginning with the primitive used to denote the start of frame (e.g., SOAF, SOF, or SATA\_SOF) and proceeding character-by-character from left to right within the definition of the frame until the primitive used to denote the end of frame (e.g., EOAF, EOF, or SATA\_EOF) is transmitted.

### 5.3.5 Running disparity (RD)

RD is a binary parameter with a negative (-) or positive (+) value. After power on, the transmitter may initialize the current RD to either positive or negative.

Each data character and control character is defined in a table by two columns that represent two characters that may or may not be different, corresponding to the current value of the running disparity (i.e., current RD- or current RD+).

Upon transmission of any character, the transmitter shall calculate a new value for its RD based on the contents of the transmitted character.

After power on, the receiver shall assume either the positive or negative value for its initial RD. Upon reception of any character, the receiver shall determine whether the character is valid or invalid and shall calculate a new value for its RD based on the contents of the received character.

The following rules for RD shall be used to calculate the new RD value for characters that have been transmitted (i.e., the transmitter's RD) and that have been received (i.e., the receiver's RD).

RD for a character shall be calculated on the basis of sub-blocks, where the first six bits (i.e., bits a, b, c, d, e, and i) form one sub-block (i.e., the six-bit sub-block) and the second four bits (i.e., bits f, g, h, and j) form the other sub-block (i.e., the four-bit sub-block). RD has the following properties:

- a) RD at the beginning of the six-bit sub-block is the RD at the end of the preceding character;
- b) RD at the beginning of the four-bit sub-block is the RD at the end of the preceding six-bit sub-block; and
- c) RD at the end of the character is the RD at the end of the four-bit sub-block.

RD for the sub-blocks shall be calculated as follows:

- a) if the sub-block contains more ones than zeros, then RD at the end of a sub-block is positive;
- b) if the sub-block contains more zeros than ones, then RD at the end of a sub-block is negative; or
- c) if the sub-block contains equal numbers of zeros and ones, then:
  - A) if it is a six-bit sub-block containing 000111b, then RD at the end of the sub-block is positive;
  - B) if it is a six-bit sub-block containing 111000b, then RD at the end of the sub-block is negative;
  - C) if it is a four-bit sub-block containing 0011b, then RD at the end of the sub-block is positive;
  - D) if it is a four-bit sub-block containing 1100b, then RD at the end of the sub-block is negative; or
  - E) otherwise, RD at the end of the sub-block is the same as at the beginning of the sub-block.

All sub-blocks with equal numbers of zeros and ones have neutral disparity (i.e., the ending disparity is the same as the beginning disparity). In order to limit the run length of zeros or ones across adjacent sub-blocks, the 8b10b code rules specify that sub-blocks encoded as 000111b or 0011b are generated only when the RD at the beginning of the sub-block is positive, ensuring that RD at the end of these sub-blocks is also positive. Likewise, sub-blocks containing 111000b or 1100b are generated only when the RD at the beginning of the sub-block is negative, ensuring that RD at the end of these sub-blocks is also negative.

Running disparity (RD) shall be maintained separately on each physical link in each direction. During a connection (see 4.1.12), expander devices shall convert incoming 10-bit characters to 8-bit bytes and generate the 10-bit character with correct disparity for the output physical link. Phys within a device may or may not begin operation with the same disparity.

### 5.3.6 Data characters

Table 49 defines the data characters (i.e., Dxx.y characters), and shall be used for both generating characters (i.e., encoding) and checking the validity of received characters (i.e., decoding).

Table 49 defines the data characters.

Table 49 — Data characters (part 1 of 5)

| Name  | Data byte                               |                               | Data character<br>(binary representation) |                            |
|-------|-----------------------------------------|-------------------------------|-------------------------------------------|----------------------------|
|       | Binary<br>representation<br>(HGF EDCBA) | Hexadecimal<br>representation | Current RD-<br>abcdei fghj                | Current RD+<br>abcdei fghj |
| D00.0 | 000 00000                               | 00h                           | 100111 0100                               | 011000 1011                |
| D01.0 | 000 00001                               | 01h                           | 011101 0100                               | 100010 1011                |
| D02.0 | 000 00010                               | 02h                           | 101101 0100                               | 010010 1011                |
| D03.0 | 000 00011                               | 03h                           | 110001 1011                               | 110001 0100                |
| D04.0 | 000 00100                               | 04h                           | 110101 0100                               | 001010 1011                |
| D05.0 | 000 00101                               | 05h                           | 101001 1011                               | 101001 0100                |
| D06.0 | 000 00110                               | 06h                           | 011001 1011                               | 011001 0100                |
| D07.0 | 000 00111                               | 07h                           | 111000 1011                               | 000111 0100                |
| D08.0 | 000 01000                               | 08h                           | 111001 0100                               | 000110 1011                |
| D09.0 | 000 01001                               | 09h                           | 100101 1011                               | 100101 0100                |
| D10.0 | 000 01010                               | 0Ah                           | 010101 1011                               | 010101 0100                |
| D11.0 | 000 01011                               | 0Bh                           | 110100 1011                               | 110100 0100                |
| D12.0 | 000 01100                               | 0Ch                           | 001101 1011                               | 001101 0100                |
| D13.0 | 000 01101                               | 0Dh                           | 101100 1011                               | 101100 0100                |
| D14.0 | 000 01110                               | 0Eh                           | 011100 1011                               | 011100 0100                |
| D15.0 | 000 01111                               | 0Fh                           | 010111 0100                               | 101000 1011                |
| D16.0 | 000 10000                               | 10h                           | 011011 0100                               | 100100 1011                |
| D17.0 | 000 10001                               | 11h                           | 100011 1011                               | 100011 0100                |
| D18.0 | 000 10010                               | 12h                           | 010011 1011                               | 010011 0100                |
| D19.0 | 000 10011                               | 13h                           | 110010 1011                               | 110010 0100                |
| D20.0 | 000 10100                               | 14h                           | 001011 1011                               | 001011 0100                |
| D21.0 | 000 10101                               | 15h                           | 101010 1011                               | 101010 0100                |
| D22.0 | 000 10110                               | 16h                           | 011010 1011                               | 011010 0100                |
| D23.0 | 000 10111                               | 17h                           | 111010 0100                               | 000101 1011                |
| D24.0 | 000 11000                               | 18h                           | 110011 0100                               | 001100 1011                |
| D25.0 | 000 11001                               | 19h                           | 100110 1011                               | 100110 0100                |
| D26.0 | 000 11010                               | 1Ah                           | 010110 1011                               | 010110 0100                |
| D27.0 | 000 11011                               | 1Bh                           | 110110 0100                               | 001001 1011                |
| D28.0 | 000 11100                               | 1Ch                           | 001110 1011                               | 001110 0100                |
| D29.0 | 000 11101                               | 1Dh                           | 101110 0100                               | 010001 1011                |
| D30.0 | 000 11110                               | 1Eh                           | 011110 0100                               | 100001 1011                |
| D31.0 | 000 11111                               | 1Fh                           | 101011 0100                               | 010100 1011                |
| D00.1 | 001 00000                               | 20h                           | 100111 1001                               | 011000 1001                |
| D01.1 | 001 00001                               | 21h                           | 011101 1001                               | 100010 1001                |
| D02.1 | 001 00010                               | 22h                           | 101101 1001                               | 010010 1001                |
| D03.1 | 001 00011                               | 23h                           | 110001 1001                               | 110001 1001                |
| D04.1 | 001 00100                               | 24h                           | 110101 1001                               | 001010 1001                |
| D05.1 | 001 00101                               | 25h                           | 101001 1001                               | 101001 1001                |
| D06.1 | 001 00110                               | 26h                           | 011001 1001                               | 011001 1001                |
| D07.1 | 001 00111                               | 27h                           | 111000 1001                               | 000111 1001                |
| D08.1 | 001 01000                               | 28h                           | 111001 1001                               | 000110 1001                |
| D09.1 | 001 01001                               | 29h                           | 100101 1001                               | 100101 1001                |
| D10.1 | 001 01010                               | 2Ah                           | 010101 1001                               | 010101 1001                |
| D11.1 | 001 01011                               | 2Bh                           | 110100 1001                               | 110100 1001                |
| D12.1 | 001 01100                               | 2Ch                           | 001101 1001                               | 001101 1001                |
| D13.1 | 001 01101                               | 2Dh                           | 101100 1001                               | 101100 1001                |
| D14.1 | 001 01110                               | 2Eh                           | 011100 1001                               | 011100 1001                |
| D15.1 | 001 01111                               | 2Fh                           | 010111 1001                               | 101000 1001                |
| D16.1 | 001 10000                               | 30h                           | 011011 1001                               | 100100 1001                |
| D17.1 | 001 10001                               | 31h                           | 100011 1001                               | 100011 1001                |



Table 49 — Data characters (part 2 of 5)

| Name  | Data byte                               |                               | Data character<br>(binary representation) |                            |
|-------|-----------------------------------------|-------------------------------|-------------------------------------------|----------------------------|
|       | Binary<br>representation<br>(HGF EDCBA) | Hexadecimal<br>representation | Current RD-<br>abcdei fghj                | Current RD+<br>abcdei fghj |
| D18.1 | 001 10010                               | 32h                           | 010011 1001                               | 010011 1001                |
| D19.1 | 001 10011                               | 33h                           | 110010 1001                               | 110010 1001                |
| D20.1 | 001 10100                               | 34h                           | 001011 1001                               | 001011 1001                |
| D21.1 | 001 10101                               | 35h                           | 101010 1001                               | 101010 1001                |
| D22.1 | 001 10110                               | 36h                           | 011010 1001                               | 011010 1001                |
| D23.1 | 001 10111                               | 37h                           | 111010 1001                               | 000101 1001                |
| D24.1 | 001 11000                               | 38h                           | 110011 1001                               | 001100 1001                |
| D25.1 | 001 11001                               | 39h                           | 100110 1001                               | 100110 1001                |
| D26.1 | 001 11010                               | 3Ah                           | 010110 1001                               | 010110 1001                |
| D27.1 | 001 11011                               | 3Bh                           | 110110 1001                               | 001001 1001                |
| D28.1 | 001 11100                               | 3Ch                           | 001110 1001                               | 001110 1001                |
| D29.1 | 001 11101                               | 3Dh                           | 101110 1001                               | 010001 1001                |
| D30.1 | 001 11110                               | 3Eh                           | 011110 1001                               | 100001 1001                |
| D31.1 | 001 11111                               | 3Fh                           | 101011 1001                               | 010100 1001                |
| D00.2 | 010 00000                               | 40h                           | 100111 0101                               | 011000 0101                |
| D01.2 | 010 00001                               | 41h                           | 011101 0101                               | 100010 0101                |
| D02.2 | 010 00010                               | 42h                           | 101101 0101                               | 010010 0101                |
| D03.2 | 010 00011                               | 43h                           | 110001 0101                               | 110001 0101                |
| D04.2 | 010 00100                               | 44h                           | 110101 0101                               | 001010 0101                |
| D05.2 | 010 00101                               | 45h                           | 101001 0101                               | 101001 0101                |
| D06.2 | 010 00110                               | 46h                           | 011001 0101                               | 011001 0101                |
| D07.2 | 010 00111                               | 47h                           | 111000 0101                               | 000111 0101                |
| D08.2 | 010 01000                               | 48h                           | 111001 0101                               | 000110 0101                |
| D09.2 | 010 01001                               | 49h                           | 100101 0101                               | 100101 0101                |
| D10.2 | 010 01010                               | 4Ah                           | 010101 0101                               | 010101 0101                |
| D11.2 | 010 01011                               | 4Bh                           | 110100 0101                               | 110100 0101                |
| D12.2 | 010 01100                               | 4Ch                           | 001101 0101                               | 001101 0101                |
| D13.2 | 010 01101                               | 4Dh                           | 101100 0101                               | 101100 0101                |
| D14.2 | 010 01110                               | 4Eh                           | 011100 0101                               | 011100 0101                |
| D15.2 | 010 01111                               | 4Fh                           | 010111 0101                               | 101000 0101                |
| D16.2 | 010 10000                               | 50h                           | 011011 0101                               | 100100 0101                |
| D17.2 | 010 10001                               | 51h                           | 100011 0101                               | 100011 0101                |
| D18.2 | 010 10010                               | 52h                           | 010011 0101                               | 010011 0101                |
| D19.2 | 010 10011                               | 53h                           | 110010 0101                               | 110010 0101                |
| D20.2 | 010 10100                               | 54h                           | 001011 0101                               | 001011 0101                |
| D21.2 | 010 10101                               | 55h                           | 101010 0101                               | 101010 0101                |
| D22.2 | 010 10110                               | 56h                           | 011010 0101                               | 011010 0101                |
| D23.2 | 010 10111                               | 57h                           | 111010 0101                               | 000101 0101                |
| D24.2 | 010 11000                               | 58h                           | 110011 0101                               | 001100 0101                |
| D25.2 | 010 11001                               | 59h                           | 100110 0101                               | 100110 0101                |
| D26.2 | 010 11010                               | 5Ah                           | 010110 0101                               | 010110 0101                |
| D27.2 | 010 11011                               | 5Bh                           | 110110 0101                               | 001001 0101                |
| D28.2 | 010 11100                               | 5Ch                           | 001110 0101                               | 001110 0101                |
| D29.2 | 010 11101                               | 5Dh                           | 101110 0101                               | 010001 0101                |
| D30.2 | 010 11110                               | 5Eh                           | 011110 0101                               | 100001 0101                |
| D31.2 | 010 11111                               | 5Fh                           | 101011 0101                               | 010100 0101                |
| D00.3 | 011 00000                               | 60h                           | 100111 0011                               | 011000 1100                |
| D01.3 | 011 00001                               | 61h                           | 011101 0011                               | 100010 1100                |
| D02.3 | 011 00010                               | 62h                           | 101101 0011                               | 010010 1100                |
| D03.3 | 011 00011                               | 63h                           | 110001 1100                               | 110001 0011                |
| D04.3 | 011 00100                               | 64h                           | 110101 0011                               | 001010 1100                |
| D05.3 | 011 00101                               | 65h                           | 101001 1100                               | 101001 0011                |
| D06.3 | 011 00110                               | 66h                           | 011001 1100                               | 011001 0011                |
| D07.3 | 011 00111                               | 67h                           | 111000 1100                               | 000111 0011                |

Table 49 — Data characters (part 3 of 5)

| Name  | Data byte                               |                               | Data character<br>(binary representation) |                            |
|-------|-----------------------------------------|-------------------------------|-------------------------------------------|----------------------------|
|       | Binary<br>representation<br>(HGF EDCBA) | Hexadecimal<br>representation | Current RD-<br>abcdei fghj                | Current RD+<br>abcdei fghj |
| D08.3 | 011 01000                               | 68h                           | 111001 0011                               | 000110 1100                |
| D09.3 | 011 01001                               | 69h                           | 100101 1100                               | 100101 0011                |
| D10.3 | 011 01010                               | 6Ah                           | 010101 1100                               | 010101 0011                |
| D11.3 | 011 01011                               | 6Bh                           | 110100 1100                               | 110100 0011                |
| D12.3 | 011 01100                               | 6Ch                           | 001101 1100                               | 001101 0011                |
| D13.3 | 011 01101                               | 6Dh                           | 101100 1100                               | 101100 0011                |
| D14.3 | 011 01110                               | 6Eh                           | 011100 1100                               | 011100 0011                |
| D15.3 | 011 01111                               | 6Fh                           | 010111 0011                               | 101000 1100                |
| D16.3 | 011 10000                               | 70h                           | 011011 0011                               | 100100 1100                |
| D17.3 | 011 10001                               | 71h                           | 100011 1100                               | 100011 0011                |
| D18.3 | 011 10010                               | 72h                           | 010011 1100                               | 010011 0011                |
| D19.3 | 011 10011                               | 73h                           | 110010 1100                               | 110010 0011                |
| D20.3 | 011 10100                               | 74h                           | 001011 1100                               | 001011 0011                |
| D21.3 | 011 10101                               | 75h                           | 101010 1100                               | 101010 0011                |
| D22.3 | 011 10110                               | 76h                           | 011010 1100                               | 011010 0011                |
| D23.3 | 011 10111                               | 77h                           | 111010 0011                               | 000101 1100                |
| D24.3 | 011 11000                               | 78h                           | 110011 0011                               | 001100 1100                |
| D25.3 | 011 11001                               | 79h                           | 100110 1100                               | 100110 0011                |
| D26.3 | 011 11010                               | 7Ah                           | 010110 1100                               | 010110 0011                |
| D27.3 | 011 11011                               | 7Bh                           | 110110 0011                               | 001001 1100                |
| D28.3 | 011 11100                               | 7Ch                           | 001110 1100                               | 001110 0011                |
| D29.3 | 011 11101                               | 7Dh                           | 101110 0011                               | 010001 1100                |
| D30.3 | 011 11110                               | 7Eh                           | 011110 0011                               | 100001 1100                |
| D31.3 | 011 11111                               | 7Fh                           | 101011 0011                               | 010100 1100                |
| D00.4 | 100 00000                               | 80h                           | 100111 0010                               | 011000 1101                |
| D01.4 | 100 00001                               | 81h                           | 011101 0010                               | 100010 1101                |
| D02.4 | 100 00010                               | 82h                           | 101101 0010                               | 010010 1101                |
| D03.4 | 100 00011                               | 83h                           | 110001 1101                               | 110001 0010                |
| D04.4 | 100 00100                               | 84h                           | 110101 0010                               | 001010 1101                |
| D05.4 | 100 00101                               | 85h                           | 101001 1101                               | 101001 0010                |
| D06.4 | 100 00110                               | 86h                           | 011001 1101                               | 011001 0010                |
| D07.4 | 100 00111                               | 87h                           | 111000 1101                               | 000111 0010                |
| D08.4 | 100 01000                               | 88h                           | 111001 0010                               | 000110 1101                |
| D09.4 | 100 01001                               | 89h                           | 100101 1101                               | 100101 0010                |
| D10.4 | 100 01010                               | 8Ah                           | 010101 1101                               | 010101 0010                |
| D11.4 | 100 01011                               | 8Bh                           | 110100 1101                               | 110100 0010                |
| D12.4 | 100 01100                               | 8Ch                           | 001101 1101                               | 001101 0010                |
| D13.4 | 100 01101                               | 8Dh                           | 101100 1101                               | 101100 0010                |
| D14.4 | 100 01110                               | 8Eh                           | 011100 1101                               | 011100 0010                |
| D15.4 | 100 01111                               | 8Fh                           | 010111 0010                               | 101000 1101                |
| D16.4 | 100 10000                               | 90h                           | 011011 0010                               | 100100 1101                |
| D17.4 | 100 10001                               | 91h                           | 100011 1101                               | 100011 0010                |
| D18.4 | 100 10010                               | 92h                           | 010011 1101                               | 010011 0010                |
| D19.4 | 100 10011                               | 93h                           | 110010 1101                               | 110010 0010                |
| D20.4 | 100 10100                               | 94h                           | 001011 1101                               | 001011 0010                |
| D21.4 | 100 10101                               | 95h                           | 101010 1101                               | 101010 0010                |
| D22.4 | 100 10110                               | 96h                           | 011010 1101                               | 011010 0010                |
| D23.4 | 100 10111                               | 97h                           | 111010 0010                               | 000101 1101                |
| D24.4 | 100 11000                               | 98h                           | 110011 0010                               | 001100 1101                |
| D25.4 | 100 11001                               | 99h                           | 100110 1101                               | 100110 0010                |
| D26.4 | 100 11010                               | 9Ah                           | 010110 1101                               | 010110 0010                |
| D27.4 | 100 11011                               | 9Bh                           | 110110 0010                               | 001001 1101                |
| D28.4 | 100 11100                               | 9Ch                           | 001110 1101                               | 001110 0010                |
| D29.4 | 100 11101                               | 9Dh                           | 101110 0010                               | 010001 1101                |

Table 49 — Data characters (part 4 of 5)

| Name  | Data byte                               |                               | Data character<br>(binary representation) |                            |
|-------|-----------------------------------------|-------------------------------|-------------------------------------------|----------------------------|
|       | Binary<br>representation<br>(HGF EDCBA) | Hexadecimal<br>representation | Current RD-<br>abcdei fghj                | Current RD+<br>abcdei fghj |
| D30.4 | 100 11110                               | 9Eh                           | 011110 0010                               | 100001 1101                |
| D31.4 | 100 11111                               | 9Fh                           | 101011 0010                               | 010100 1101                |
| D00.5 | 101 00000                               | A0h                           | 100111 1010                               | 011000 1010                |
| D01.5 | 101 00001                               | A1h                           | 011101 1010                               | 100010 1010                |
| D02.5 | 101 00010                               | A2h                           | 101101 1010                               | 010010 1010                |
| D03.5 | 101 00011                               | A3h                           | 110001 1010                               | 110001 1010                |
| D04.5 | 101 00100                               | A4h                           | 110101 1010                               | 001010 1010                |
| D05.5 | 101 00101                               | A5h                           | 101001 1010                               | 101001 1010                |
| D06.5 | 101 00110                               | A6h                           | 011001 1010                               | 011001 1010                |
| D07.5 | 101 00111                               | A7h                           | 111000 1010                               | 000111 1010                |
| D08.5 | 101 01000                               | A8h                           | 111001 1010                               | 000110 1010                |
| D09.5 | 101 01001                               | A9h                           | 100101 1010                               | 100101 1010                |
| D10.5 | 101 01010                               | AAh                           | 010101 1010                               | 010101 1010                |
| D11.5 | 101 01011                               | ABh                           | 110100 1010                               | 110100 1010                |
| D12.5 | 101 01100                               | ACH                           | 001101 1010                               | 001101 1010                |
| D13.5 | 101 01101                               | ADh                           | 101100 1010                               | 101100 1010                |
| D14.5 | 101 01110                               | A Eh                          | 011100 1010                               | 011100 1010                |
| D15.5 | 101 01111                               | AFh                           | 010111 1010                               | 101000 1010                |
| D16.5 | 101 10000                               | B0h                           | 011011 1010                               | 100100 1010                |
| D17.5 | 101 10001                               | B1h                           | 100011 1010                               | 100011 1010                |
| D18.5 | 101 10010                               | B2h                           | 010011 1010                               | 010011 1010                |
| D19.5 | 101 10011                               | B3h                           | 110010 1010                               | 110010 1010                |
| D20.5 | 101 10100                               | B4h                           | 001011 1010                               | 001011 1010                |
| D21.5 | 101 10101                               | B5h                           | 101010 1010                               | 101010 1010                |
| D22.5 | 101 10110                               | B6h                           | 011010 1010                               | 011010 1010                |
| D23.5 | 101 10111                               | B7h                           | 111010 1010                               | 000101 1010                |
| D24.5 | 101 11000                               | B8h                           | 110011 1010                               | 001100 1010                |
| D25.5 | 101 11001                               | B9h                           | 100110 1010                               | 100110 1010                |
| D26.5 | 101 11010                               | BAh                           | 010110 1010                               | 010110 1010                |
| D27.5 | 101 11011                               | BBh                           | 110110 1010                               | 001001 1010                |
| D28.5 | 101 11100                               | BCh                           | 001110 1010                               | 001110 1010                |
| D29.5 | 101 11101                               | BDh                           | 101110 1010                               | 010001 1010                |
| D30.5 | 101 11110                               | BEh                           | 011110 1010                               | 100001 1010                |
| D31.5 | 101 11111                               | BFh                           | 101011 1010                               | 010100 1010                |
| D00.6 | 110 00000                               | C0h                           | 100111 0110                               | 011000 0110                |
| D01.6 | 110 00001                               | C1h                           | 011101 0110                               | 100010 0110                |
| D02.6 | 110 00010                               | C2h                           | 101101 0110                               | 010010 0110                |
| D03.6 | 110 00011                               | C3h                           | 110001 0110                               | 110001 0110                |
| D04.6 | 110 00100                               | C4h                           | 110101 0110                               | 001010 0110                |
| D05.6 | 110 00101                               | C5h                           | 101001 0110                               | 101001 0110                |
| D06.6 | 110 00110                               | C6h                           | 011001 0110                               | 011001 0110                |
| D07.6 | 110 00111                               | C7h                           | 111000 0110                               | 000111 0110                |
| D08.6 | 110 01000                               | C8h                           | 111001 0110                               | 000110 0110                |
| D09.6 | 110 01001                               | C9h                           | 100101 0110                               | 100101 0110                |
| D10.6 | 110 01010                               | CAh                           | 010101 0110                               | 010101 0110                |
| D11.6 | 110 01011                               | CBh                           | 110100 0110                               | 110100 0110                |
| D12.6 | 110 01100                               | CCh                           | 001101 0110                               | 001101 0110                |
| D13.6 | 110 01101                               | CDh                           | 101100 0110                               | 101100 0110                |
| D14.6 | 110 01110                               | CEh                           | 011100 0110                               | 011100 0110                |
| D15.6 | 110 01111                               | CFh                           | 010111 0110                               | 101000 0110                |
| D16.6 | 110 10000                               | D0h                           | 011011 0110                               | 100100 0110                |
| D17.6 | 110 10001                               | D1h                           | 100011 0110                               | 100011 0110                |
| D18.6 | 110 10010                               | D2h                           | 010011 0110                               | 010011 0110                |
| D19.6 | 110 10011                               | D3h                           | 110010 0110                               | 110010 0110                |

Table 49 — Data characters (part 5 of 5)

| Name  | Data byte                               |                               | Data character<br>(binary representation) |                            |
|-------|-----------------------------------------|-------------------------------|-------------------------------------------|----------------------------|
|       | Binary<br>representation<br>(HGF EDCBA) | Hexadecimal<br>representation | Current RD-<br>abcdei fghj                | Current RD+<br>abcdei fghj |
| D20.6 | 110 10100                               | D4h                           | 001011 0110                               | 001011 0110                |
| D21.6 | 110 10101                               | D5h                           | 101010 0110                               | 101010 0110                |
| D22.6 | 110 10110                               | D6h                           | 011010 0110                               | 011010 0110                |
| D23.6 | 110 10111                               | D7h                           | 111010 0110                               | 000101 0110                |
| D24.6 | 110 11000                               | D8h                           | 110011 0110                               | 001100 0110                |
| D25.6 | 110 11001                               | D9h                           | 100110 0110                               | 100110 0110                |
| D26.6 | 110 11010                               | DAh                           | 010110 0110                               | 010110 0110                |
| D27.6 | 110 11011                               | DBh                           | 110110 0110                               | 001001 0110                |
| D28.6 | 110 11100                               | DCh                           | 001110 0110                               | 001110 0110                |
| D29.6 | 110 11101                               | DDh                           | 101110 0110                               | 010001 0110                |
| D30.6 | 110 11110                               | DEh                           | 011110 0110                               | 100001 0110                |
| D31.6 | 110 11111                               | DFh                           | 101011 0110                               | 010100 0110                |
| D00.7 | 111 00000                               | E0h                           | 100111 0001                               | 011000 1110                |
| D01.7 | 111 00001                               | E1h                           | 011101 0001                               | 100010 1110                |
| D02.7 | 111 00010                               | E2h                           | 101101 0001                               | 010010 1110                |
| D03.7 | 111 00011                               | E3h                           | 110001 1110                               | 110001 0001                |
| D04.7 | 111 00100                               | E4h                           | 110101 0001                               | 001010 1110                |
| D05.7 | 111 00101                               | E5h                           | 101001 1110                               | 101001 0001                |
| D06.7 | 111 00110                               | E6h                           | 011001 1110                               | 011001 0001                |
| D07.7 | 111 00111                               | E7h                           | 111000 1110                               | 000111 0001                |
| D08.7 | 111 01000                               | E8h                           | 111001 0001                               | 000110 1110                |
| D09.7 | 111 01001                               | E9h                           | 100101 1110                               | 100101 0001                |
| D10.7 | 111 01010                               | EAh                           | 010101 1110                               | 010101 0001                |
| D11.7 | 111 01011                               | EBh                           | 110100 1110                               | 110100 1000                |
| D12.7 | 111 01100                               | ECh                           | 001101 1110                               | 001101 0001                |
| D13.7 | 111 01101                               | EDh                           | 101100 1110                               | 101100 1000                |
| D14.7 | 111 01110                               | EEh                           | 011100 1110                               | 011100 1000                |
| D15.7 | 111 01111                               | EFh                           | 010111 0001                               | 101000 1110                |
| D16.7 | 111 10000                               | F0h                           | 011011 0001                               | 100100 1110                |
| D17.7 | 111 10001                               | F1h                           | 100011 0111                               | 100011 0001                |
| D18.7 | 111 10010                               | F2h                           | 010011 0111                               | 010011 0001                |
| D19.7 | 111 10011                               | F3h                           | 110010 1110                               | 110010 0001                |
| D20.7 | 111 10100                               | F4h                           | 001011 0111                               | 001011 0001                |
| D21.7 | 111 10101                               | F5h                           | 101010 1110                               | 101010 0001                |
| D22.7 | 111 10110                               | F6h                           | 011010 1110                               | 011010 0001                |
| D23.7 | 111 10111                               | F7h                           | 111010 0001                               | 000101 1110                |
| D24.7 | 111 11000                               | F8h                           | 110011 0001                               | 001100 1110                |
| D25.7 | 111 11001                               | F9h                           | 100110 1110                               | 100110 0001                |
| D26.7 | 111 11010                               | FAh                           | 010110 1110                               | 010110 0001                |
| D27.7 | 111 11011                               | FBh                           | 110110 0001                               | 001001 1110                |
| D28.7 | 111 11100                               | FCh                           | 001110 1110                               | 001110 0001                |
| D29.7 | 111 11101                               | FDh                           | 101110 0001                               | 010001 1110                |
| D30.7 | 111 11110                               | FEh                           | 011110 0001                               | 100001 1110                |
| D31.7 | 111 11111                               | FFh                           | 101011 0001                               | 010100 1110                |

### 5.3.7 Control characters

Table 50 defines the control characters (i.e., Kxx.y characters), and shall be used for both generating characters (i.e., encoding) and checking the validity of received characters (i.e., decoding).

Table 50 — Control characters

| Name                  | Control byte                            |                               | Control character<br>(binary representation) <sup>a</sup> |                            |
|-----------------------|-----------------------------------------|-------------------------------|-----------------------------------------------------------|----------------------------|
|                       | Binary<br>representation<br>(HGF EDCBA) | Hexadecimal<br>representation | Current RD-<br>abcdei fghj                                | Current RD+<br>abcdei fghj |
| K28.0                 | 000 11100                               | 1Ch                           | 001111 0100                                               | 110000 1011                |
| K28.1 <sup>b</sup>    | 001 11100                               | 3Ch                           | <u>001111</u> 1001                                        | <u>110000</u> 0110         |
| K28.2                 | 010 11100                               | 5Ch                           | 001111 0101                                               | 110000 1010                |
| K28.3                 | 011 11100                               | 7Ch                           | 001111 0011                                               | 110000 1100                |
| K28.4                 | 100 11100                               | 9Ch                           | 001111 0010                                               | 110000 1101                |
| K28.5 <sup>b</sup>    | 101 11100                               | BCh                           | <u>001111</u> 1010                                        | <u>110000</u> 0101         |
| K28.6                 | 110 11100                               | DCh                           | 001111 0110                                               | 110000 1001                |
| K28.7 <sup>b, c</sup> | 111 11100                               | FCh                           | <u>001111</u> 1000                                        | <u>110000</u> 0111         |
| K23.7                 | 111 10111                               | F7h                           | 111010 1000                                               | 000101 0111                |
| K27.7                 | 111 11011                               | FBh                           | 110110 1000                                               | 001001 0111                |
| K29.7                 | 111 11101                               | FDh                           | 101110 1000                                               | 010001 0111                |
| K30.7                 | 111 11110                               | FEh                           | 011110 1000                                               | 100001 0111                |

<sup>a</sup> Comma patterns, which are two bits of one polarity followed by five bits of the opposite polarity (i.e., 0011111b or 1100000b), are underlined.

<sup>b</sup> K28.1, K28.5, and K28.7 are the only characters that contain comma patterns. Comma patterns do not appear in any data characters and do not appear across any adjacent data characters.

<sup>c</sup> The K28.7 control character introduces an additional comma pattern starting with bits i and f when followed by any of the following characters: K28.y; D3.y; D11.y; D12.y; D19.y; D20.y; or D28.y, where y is a value in the range 0 to 7, inclusive. None of the other control characters introduce a comma pattern when adjacent to any other character. Therefore, K28.7 is not used, ensuring that comma patterns do not appear in any sequence of characters except the first 7 bits of K28.1 or K28.5.

The only control characters used in this standard are K28.3, K28.5, and K28.6, as defined in table 51.

**Table 51 — Control character usage**

| First character of a dword | Usage in SAS physical links                        | Usage in SATA physical links |
|----------------------------|----------------------------------------------------|------------------------------|
| K28.3                      | Primitives used only inside STP connections        | All primitives except ALIGN  |
| K28.5                      | ALIGN and most primitives defined in this standard | ALIGN                        |
| K28.6                      | Not used                                           | SATA_ERROR                   |

See 6.2 for details on primitives, which use those control characters.

### 5.3.8 Encoding characters in the transmitter

To transmit a data byte, the transmitter shall select the appropriate character from table 49 based on the current value of the transmitter's RD. To transmit a control byte, the transmitter shall select the appropriate character from table 50 based on the current value of the transmitter's RD. After transmitting the character, the transmitter shall calculate a new value for its RD based on that character. This new value shall be used as the transmitter's current RD for the next character transmitted. This process is called 8b10b encoding.

### 5.3.9 Decoding characters in the receiver

After receiving a character, the receiver shall search the character column in table 49 and table 50 corresponding to its current RD to determine the data byte or control byte to which the character corresponds. This process is called 10b8b decoding. If the received character is not found in the proper column, then the character shall be considered invalid and the dword containing the character shall be considered an invalid dword.

Regardless of the received character's validity, the received character shall be used to calculate a new value of RD in the receiver. This new value shall be used as the receiver's current RD for the next received character.

Detection of a code violation in a character does not always indicate that the character in which the code violation was detected is in error. Code violations may result from an error in a previous character that altered the RD of the bit stream but did not result in a detectable error in the character in which the error occurred. Table 52 shows an example of this behavior. Code violation errors may span dword boundaries. Expanders

forwarding a dword in which a code violation was detected, forward the dword as an ERROR (see 6.2.6.7).

**Table 52 — Delayed code violation example**

|                              | RD | First character                                            | RD | Second character    | RD | Third character                                                     | RD |
|------------------------------|----|------------------------------------------------------------|----|---------------------|----|---------------------------------------------------------------------|----|
| Transmitted character stream | -  | D21.1                                                      | -  | D10.2               | -  | D23.5                                                               | +  |
| Transmitted bit stream       | -  | 101010 1001                                                | -  | 010101 0101         | -  | 111010 1010                                                         | +  |
| Bit stream after error       | -  | 101010 10 <u>1</u><br>(error in second to last bit)        | +  | 010101 0101         | +  | 111010 1010                                                         | +  |
| Decoded character stream     | -  | D21.0<br>(rather than D21.1)<br>(not detected as an error) | +  | D10.2<br>(no error) | +  | Code violation<br>(although D23.5 was<br>received without<br>error) | +  |

## 5.4 Dwords, primitives, data dwords, and invalid dwords

All characters transferred in SAS are grouped into four-character sequences called dwords.

A primitive is a dword whose first character is K28.3 or K28.5 and whose remaining three characters are data characters with correct disparity.

Primitives are defined with both negative and positive starting RD (see 5.3.5). SAS defines primitives starting with K28.5 (see 6.2.6 and 6.2.7). SATA defines primitives starting with K28.3 and K28.5, which are used in SAS during STP connections (see 6.2.8).

A data dword is a dword that contains four data characters with correct disparity.

A dword containing an invalid character shall be considered an invalid dword.

## 5.5 Bit order

Dwords transmitted in an STP connection shall be transmitted in the bit order specified by SATA.

Dwords for other types of connections and outside connections shall be transmitted in the bit order shown in figure 56.

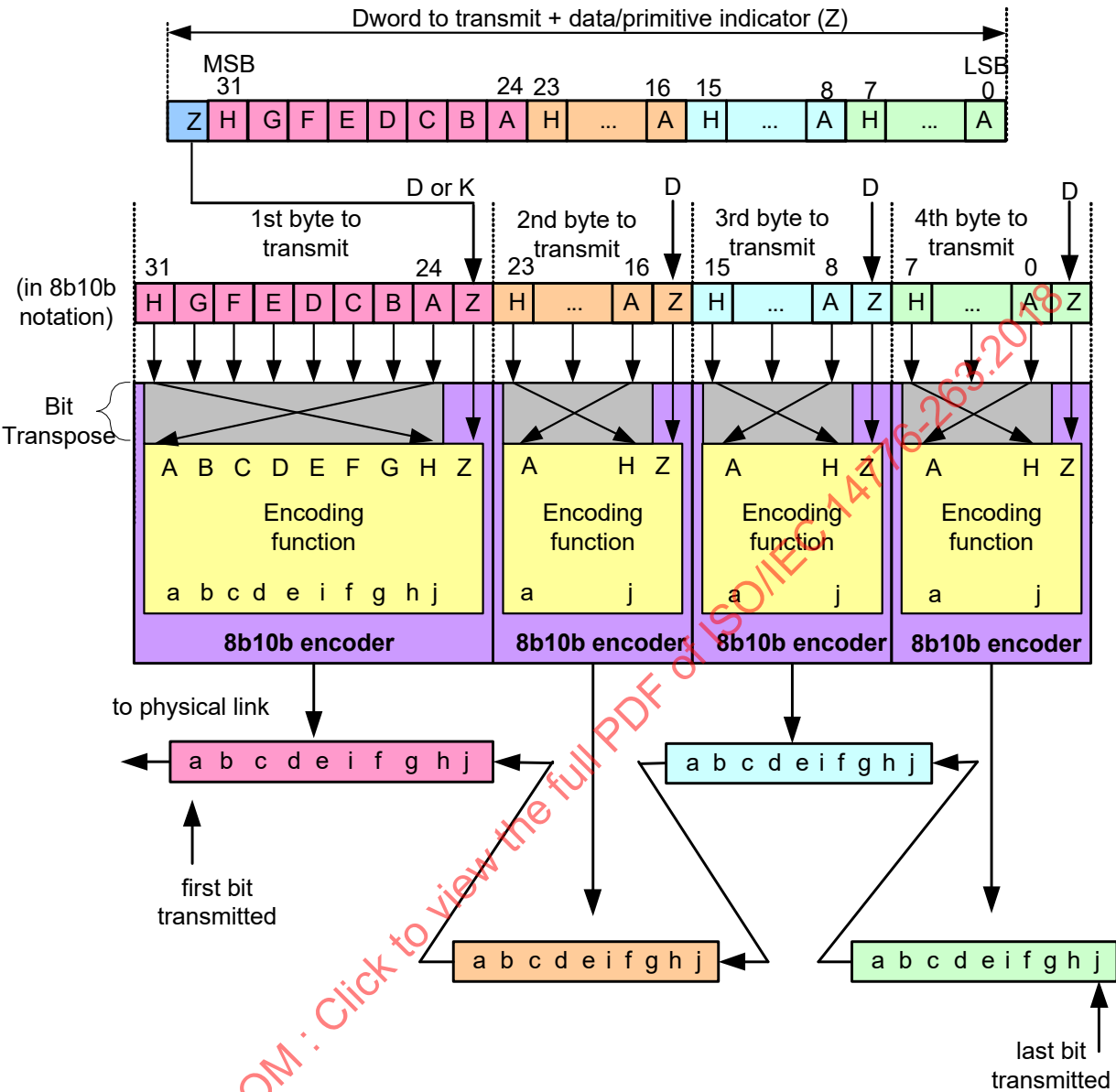


Figure 56 — SAS bit transmission logic



Figure 57 shows the SAS bit reception order.

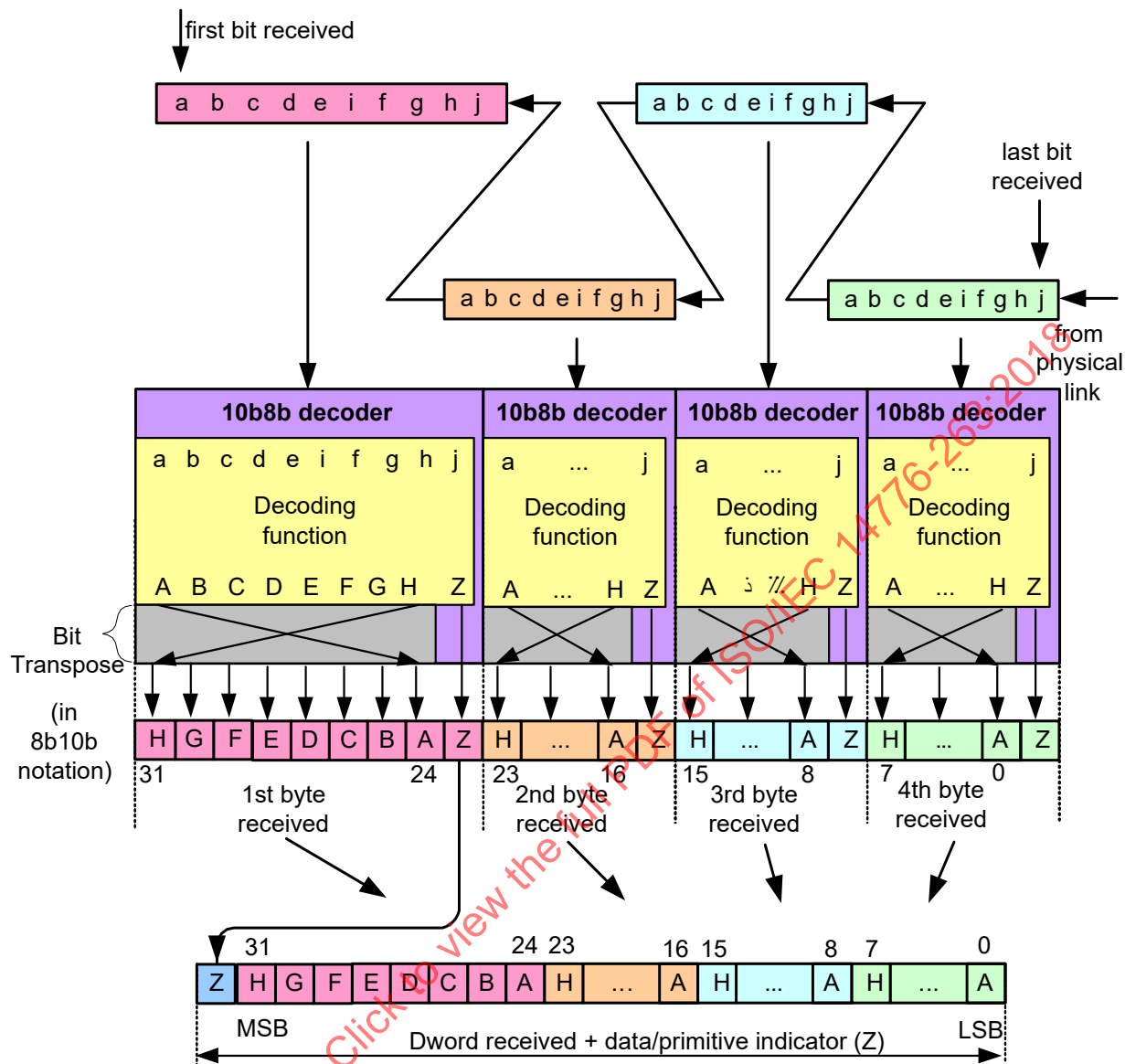


Figure 57 — SAS bit reception logic

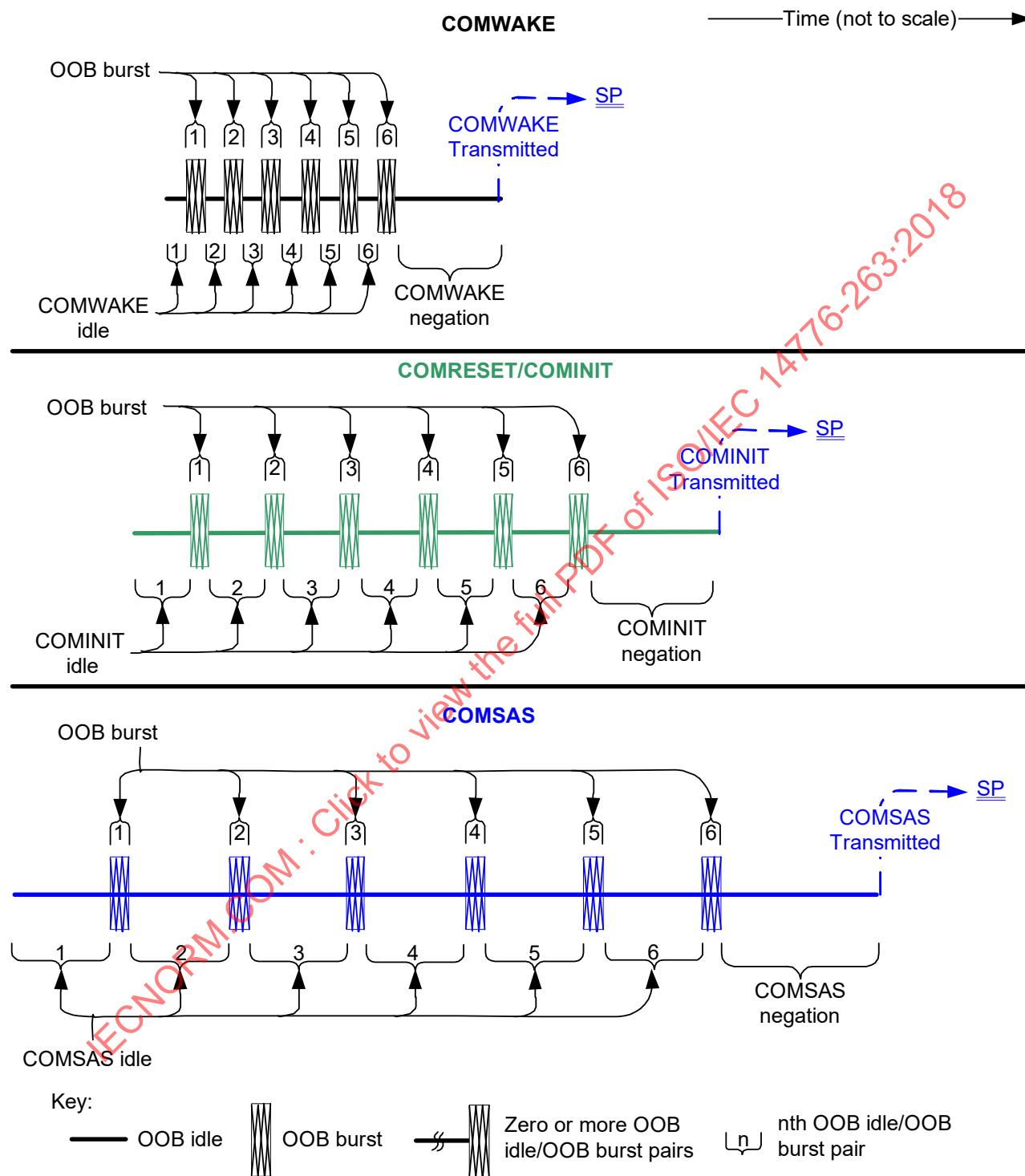
## 5.6 Out of band (OOB) signals

### 5.6.1 OOB signals overview

For the timing and timing characteristics of transmitted and received OOB signals see SAS-3.

### 5.6.2 Transmission of OOB signals

Figure 58 describes OOB signal transmission by the SP transmitter (see 5.12.2 and 5.14.2). The COMWAKE Transmitted, COMINIT Transmitted, and COMSAS Transmitted messages are sent to the SP state machine (see 5.12).



Note - OOB idle is shown here as a neutral signal for visual clarity only.

Figure 58 — OOB signal transmission

### 5.6.3 Receiver detection of OOB signals

The detection of OOB signals is disabled and enabled by the SP state machine (see 5.12.4.13).

If detection of OOB signals is disabled, then the SP receiver (see 5.12.2 and 5.14.3) shall ignore all OOB signals.

If detection of OOB signals is enabled and either optical mode is enabled or D.C. mode is enabled, then a receiver device shall detect an OOB signal after receiving four consecutive idle time/burst time pairs (see figure 59) while the SP\_DWS state machine (see 5.13) has not achieved dword synchronization (see 5.12.4.10 and 5.12.6.8). If detection of OOB signals is enabled and optical mode is enabled, then a receiver device shall detect an OOB signal after receiving four consecutive idle time/burst time pairs while the SP\_DWS state machine has achieved dword synchronization. It is not an error to receive more than four idle time/burst time pairs. A receiver device shall not detect the same OOB signal again until it has detected the corresponding negation time (e.g., a COMINIT negation time for a COMINIT) or has detected a different OOB signal (e.g., if a receiver device that previously detected COMINIT receives four COMWAKE idle time/burst time pairs, then that receiver device detects COMWAKE and may then detect COMINIT at a later time).

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Figure 59 describes OOB signal detection by the SP receiver (see 5.12.2 and 5.12.3). The COMWAKE Detected, COMWAKE Completed, COMINIT Detected, COMSAS Detected, and COMSAS Completed messages are sent to the SP state machine (see 5.12) to indicate that an OOB signal has been partially or fully detected.

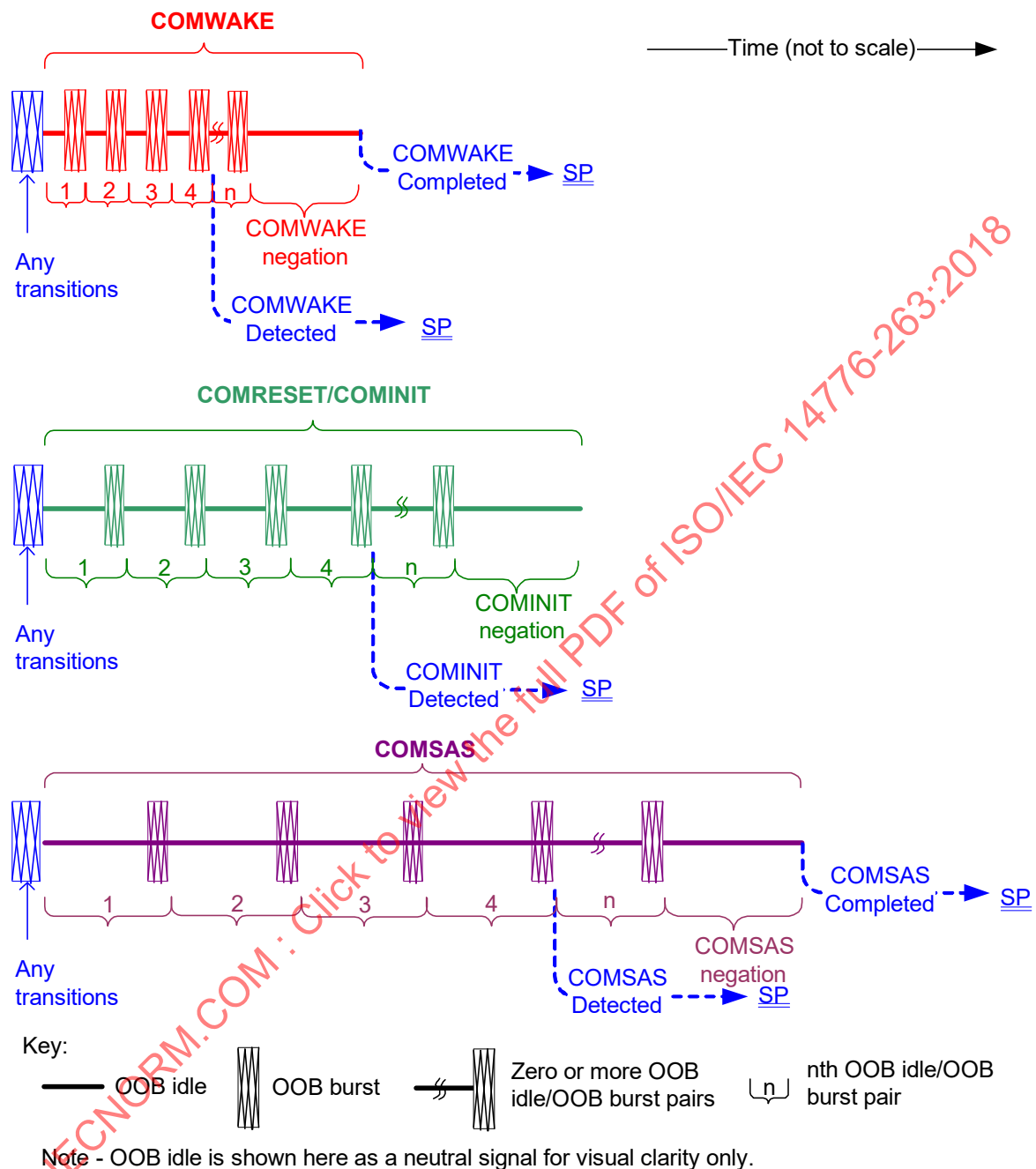


**Figure 59 — OOB signal detection**

Expander devices shall not forward OOB signals. An expander device shall run the link reset sequence independently on each physical phy.

### 5.6.4 SATA port selection signal

For the timing characteristics of transmitted SATA port selection signal see SAS-3.

See 5.12.7 and 9.4.3.28 for information on usage of the SATA port selection signal.

### 5.6.5 Phy power conditions

During a low phy power condition (see 4.10.1) the phy shall transmit D.C. idle (see SAS-3). A phy that is in a low phy power condition shall meet the phy wakeup timeout requirements shown in table 68.

## 5.7 Phy capabilities bits

Table 53 defines the SNW-3 (see 5.10.4.2.3.3) phy capabilities. For each bit defined as reserved, the phy shall transmit a zero (i.e., OOB idle) and shall ignore the received value. Byte 0 shall be transmitted first and byte 3 shall be transmitted last. Within each byte, bit 7 shall be transmitted first and bit 0 shall be transmitted last (e.g., overall, the START bit is transmitted first and the PARITY bit is transmitted last).

**Table 53 — SNW-3 phy capabilities**

| Byte\Bit | 7                  | 6           | 5              | 4           | 3                           | 2           | 1              | 0           |
|----------|--------------------|-------------|----------------|-------------|-----------------------------|-------------|----------------|-------------|
| 0        | START (1b)         | TX SSC TYPE | Reserved       | Reserved    | REQUESTED LOGICAL LINK RATE |             |                |             |
| 1        | Supported settings |             |                |             |                             |             |                |             |
|          | G1 WITHOUT SSC     | G1 WITH SSC | G2 WITHOUT SSC | G2 WITH SSC | G3 WITHOUT SSC              | G3 WITH SSC | G4 WITHOUT SSC | G4 WITH SSC |
| 2        | Reserved           |             |                |             |                             |             |                |             |
| 3        | Reserved           |             |                |             |                             |             |                | PARITY      |

The START bit shall be set as shown in table 53 for the SNW-3 phy capabilities.

A TX SSC TYPE bit set to one indicates that the phy's transmitter uses center-spreading SSC while SSC is enabled (e.g., the phy is an expander phy) (see SAS-3). A TX SSC TYPE bit set to zero indicates that the phy's transmitter uses down-spreading SSC while SSC is enabled (e.g., the phy is a SAS phy), or that the phy does not support SSC.

NOTE 9 - The phy's receiver uses the TX SSC TYPE bit to optimize its clock data recovery circuitry (see SAS-3).

The REQUESTED LOGICAL LINK RATE field indicates if the phy supports multiplexing (see 5.15) and, if so, the logical link rate that the phy is requesting.

Table 54 defines the requested logical link rate based on the transmitted and received REQUESTED LOGICAL LINK RATE fields.

**Table 54 — Requested logical link rate**

| Transmitted REQUESTED LOGICAL LINK RATE field | Received REQUESTED LOGICAL LINK RATE field | Requested logical link rate   |
|-----------------------------------------------|--------------------------------------------|-------------------------------|
| 0h (i.e., no multiplexing)                    | Any                                        | Negotiated physical link rate |
| 8h (i.e., 1.5 Gbit/s)                         | 8h (i.e., 1.5 Gbit/s)                      | 1.5 Gbit/s                    |
|                                               | 9h (i.e., 3 Gbit/s)                        |                               |
|                                               | Ah (i.e., 6 Gbit/s)                        |                               |
|                                               | Bh (i.e., 12 Gbit/s)                       |                               |
|                                               | Ch to Fh (i.e., future rates)              |                               |
| 9h (i.e., 3 Gbit/s)                           | 8h (i.e., 1.5 Gbit/s)                      | 1.5 Gbit/s                    |
|                                               | 9h (i.e., 3 Gbit/s)                        | 3 Gbit/s                      |
|                                               | Ah (i.e., 6 Gbit/s)                        |                               |
|                                               | Bh (i.e., 12 Gbit/s)                       |                               |
|                                               | Ch to Fh (i.e., future rates)              |                               |
| Ah (i.e., 6 Gbit/s)                           | 8h (i.e., 1.5 Gbit/s)                      | 1.5 Gbit/s                    |
|                                               | 9h (i.e., 3 Gbit/s)                        | 3 Gbit/s                      |
|                                               | Ah (i.e., 6 Gbit/s)                        | 6 Gbit/s                      |
|                                               | Bh (i.e., 12 Gbit/s)                       |                               |
|                                               | Ch to Fh (i.e., future rates)              |                               |
| Bh (i.e., 12 Gbit/s)                          | 8h (i.e., 1.5 Gbit/s)                      | 1.5 Gbit/s                    |
|                                               | 9h (i.e., 3 Gbit/s)                        | 3 Gbit/s                      |
|                                               | Ah (i.e., 6 Gbit/s)                        | 6 Gbit/s                      |
|                                               | Bh (i.e., 12 Gbit/s)                       | 12 Gbit/s                     |
|                                               | Ch to Fh (i.e., future rates)              |                               |

Table 55 defines whether or not multiplexing is enabled and defines the negotiated logical link rate based on the requested logical link rate (see table 54) and the negotiated physical link rate (see 5.10.4.2.4).

**Table 55 — Multiplexing negotiation**

| Requested logical link rate<br>(see table 54) | Negotiated<br>physical link rate | Multiplexing | Negotiated<br>logical link rate |
|-----------------------------------------------|----------------------------------|--------------|---------------------------------|
| 1.5 Gbit/s                                    | 1.5 Gbit/s                       | Disabled     | 1.5 Gbit/s                      |
|                                               | 3 Gbit/s                         | Enabled      | 1.5 Gbit/s                      |
|                                               | 6 Gbit/s                         |              | 3 Gbit/s                        |
|                                               | 12 Gbit/s                        |              | 6 Gbit/s                        |
| 3 Gbit/s                                      | 1.5 Gbit/s                       | Disabled     | 1.5 Gbit/s                      |
|                                               | 3 Gbit/s                         |              | 3 Gbit/s                        |
|                                               | 6 Gbit/s                         | Enabled      | 3 Gbit/s                        |
|                                               | 12 Gbit/s                        |              | 6 Gbit/s                        |
| 6 Gbit/s                                      | 1.5 Gbit/s                       | Disabled     | 1.5 Gbit/s                      |
|                                               | 3 Gbit/s                         |              | 3 Gbit/s                        |
|                                               | 6 Gbit/s                         |              | 6 Gbit/s                        |
|                                               | 12 Gbit/s                        | Enabled      | 6 Gbit/s                        |
| 12 Gbit/s                                     | 1.5 Gbit/s                       | Disabled     | 1.5 Gbit/s                      |
|                                               | 3 Gbit/s                         |              | 3 Gbit/s                        |
|                                               | 6 Gbit/s                         |              | 6 Gbit/s                        |
|                                               | 12 Gbit/s                        | Enabled      | 6 Gbit/s                        |
| Negotiated physical link rate                 | 1.5 Gbit/s                       | Disabled     | 1.5 Gbit/s                      |
|                                               | 3 Gbit/s                         |              | 3 Gbit/s                        |
|                                               | 6 Gbit/s                         |              | 6 Gbit/s                        |
|                                               | 12 Gbit/s                        |              | 12 Gbit/s                       |

The supported settings bits include the G1 WITHOUT SSC bit, the G1 WITH SSC bit, the G2 WITHOUT SSC bit, the G2 WITH SSC bit, the G3 WITHOUT SSC bit, the G3 WITH SSC bit, the G4 WITHOUT SSC bit, and the G4 WITH SSC bit.

A G1 WITHOUT SSC bit set to one indicates that the phy supports G1 (i.e., 1.5 Gbit/s) without SSC. A G1 WITHOUT SSC bit set to zero indicates that the phy does not support G1 without SSC.

A G1 WITH SSC bit set to one indicates that the phy supports G1 (i.e., 1.5 Gbit/s) with SSC. A G1 WITH SSC bit set to zero indicates that the phy does not support G1 with SSC.

A G2 WITHOUT SSC bit set to one indicates that the phy supports G2 (i.e., 3 Gbit/s) without SSC. A G2 WITHOUT SSC bit set to zero indicates that the phy does not support G2 without SSC.

A G2 WITH SSC bit set to one indicates that the phy supports G2 (i.e., 3 Gbit/s) with SSC. A G2 WITH SSC bit set to zero indicates that the phy does not support G2 with SSC.

A G3 WITHOUT SSC bit set to one indicates that the phy supports G3 (i.e., 6 Gbit/s) without SSC. A G3 WITHOUT SSC bit set to zero indicates that the phy does not support G3 without SSC.

A G3 WITH SSC bit set to one indicates that the phy supports G3 (i.e., 6 Gbit/s) with SSC. A G3 WITH SSC bit set to zero indicates that the phy does not support G3 with SSC.

A G4 WITHOUT SSC bit set to one indicates that the phy supports G4 (i.e., 12 Gbit/s) without SSC and that transmitter training is enabled. A G4 WITHOUT SSC bit set to zero indicates that the phy does not support G4 without SSC.

A G4 WITH SSC bit set to one indicates that the phy supports G4 (i.e., 12 Gbit/s) with SSC and that transmitter training is enabled. A G4 WITH SSC bit set to zero indicates that the phy does not support G4 with SSC.

Table 56 defines the priority of the supported settings bits.

**Table 56 — Supported settings bit priorities**

| Priority                                                                                                                                                                                                                                                                                                        | Bit                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| Highest                                                                                                                                                                                                                                                                                                         | G4 WITH SSC bit <sup>a</sup>    |
| ...                                                                                                                                                                                                                                                                                                             | G4 WITHOUT SSC bit <sup>a</sup> |
| ...                                                                                                                                                                                                                                                                                                             | G3 WITH SSC bit                 |
| ...                                                                                                                                                                                                                                                                                                             | G3 WITHOUT SSC bit              |
| ...                                                                                                                                                                                                                                                                                                             | G2 WITH SSC bit                 |
| ...                                                                                                                                                                                                                                                                                                             | G2 WITHOUT SSC bit              |
| ...                                                                                                                                                                                                                                                                                                             | G1 WITH SSC bit                 |
| Lowest                                                                                                                                                                                                                                                                                                          | G1 WITHOUT SSC bit              |
| <sup>a</sup> If optical mode is enabled or there is an active cable assembly attached to the phy, then transmitter training is disabled (see 5.12.4.12.1) and the phy's transmitter coefficients shall be set to a default value. The determination of the default value is outside the scope of this standard. |                                 |

The PARITY bit provides for error detection for the SNW-3 phy capabilities bits. The PARITY bit shall be set to one or zero such that the total number of SNW-3 phy capabilities bits that are set to one is even, including the START bit and the PARITY bit. If the PARITY bit received is incorrect based upon the received SNW phy capabilities bits, then the parity is bad and the phy shall consider a phy reset problem (see 5.10.4.2.4) to have occurred.



Table 57 lists some example SNW-3 phy capabilities values.

**Table 57 — Example SNW-3 phy capabilities values**

| Code <sup>a</sup>                                                                                                                               | Description                                                                                                   |
|-------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| 80540000h                                                                                                                                       | Down-spreading SSC<br>G1, G2, and G3 with SSC supported                                                       |
| 80550001h                                                                                                                                       | Down-spreading SSC<br>G1, G2, G3, and G4 with SCC supported                                                   |
| 80FC0001h                                                                                                                                       | Down-spreading SSC<br>G1, G2, and G3 with and without SSC supported                                           |
| 80FF0001h                                                                                                                                       | Down-spreading SSC<br>G1, G2, G3, and G4 with and without SCC supported                                       |
| 80A80000h                                                                                                                                       | G1, G2, and G3 without SSC supported                                                                          |
| 80AA0001h                                                                                                                                       | G1, G2, G3, and G4 without SCC supported                                                                      |
| C0FC0000h                                                                                                                                       | Center-spreading SSC<br>G1, G2, and G3 with and without SSC supported                                         |
| C0FF0000h                                                                                                                                       | Center-spreading SSC<br>G1, G2, G3, and G4 with and without SSC supported                                     |
| C9FC0000h                                                                                                                                       | Center-spreading SSC<br>Requested 3 Gbit/s logical link rate<br>G1, G2, and G3 with and without SSC supported |
| C8F00001h                                                                                                                                       | Center-spreading SSC<br>Requested 1.5 Gbit/s logical link rate<br>G1 and G2 with and without SSC supported    |
| <sup>a</sup> Expressed as a 32-bit value with byte 0 bit 7 (i.e., the START bit) as the MSB and byte 3 bit 0 (i.e., the PARITY bit) as the LSB. |                                                                                                               |

## 5.8 BMC coding

### 5.8.1 BMC coding overview

BMC is a coding method in which TTIU bits (see 5.10.4.2.3.5) and a clock signal are combined to form a single self-synchronizing signal. The self-synchronizing signal is a differential coding that indicates a:

- a) one with a transition at the midpoint of the TTIU bit cell; or
- b) zero with no transition within the TTIU bit cell.

BMC coding ensures that at least one transition occurs for each transmitted TTIU bit allowing the receiver to perform clock recovery.

All TTIU bits are encoded into BMC and transmitted serially bit-by-bit across the physical link as shown in figure 60.

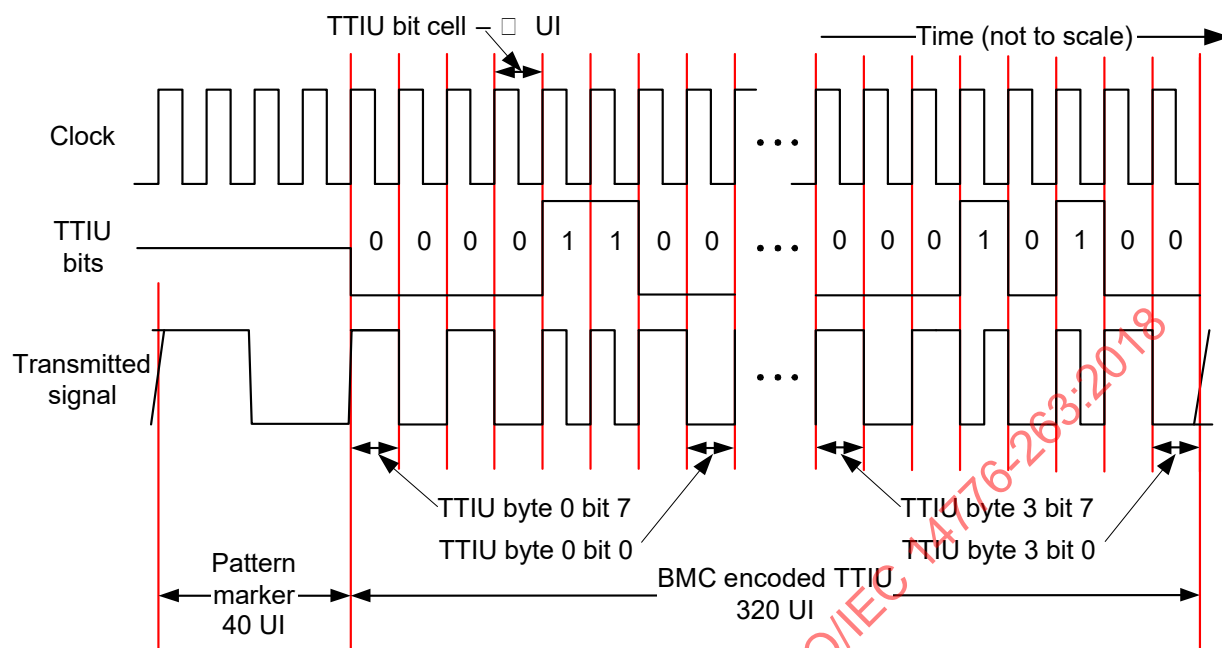


Figure 60 — TTIU transmitter BMC encoding

### 5.8.2 TTIU bit cell encoding in the transmitter

A TTIU bit cell shall be 10 UIs.

A TTIU bit cell may be formed from a clock (see figure 61) with a period of 10 UIs (e.g., 833.3 ps at 12 Gbit/s) with a duty cycle of:

- five UIs differential high followed by five UIs differential low; or
- five UIs differential low followed by five UIs differential high.

The transmitter shall cause a transition (i.e., low to high or high to low) to begin a TTIU bit cell as shown in figure 61.

The transmitter shall encode a one in a TTIU bit cell as a transition five UIs from the beginning of that TTIU bit cell (e.g., a low to high transition of a clock signal) as shown in figure 61.

The transmitter shall encode a zero in a TTIU bit cell by making no transition within a TTIU bit cell as shown in figure 61.

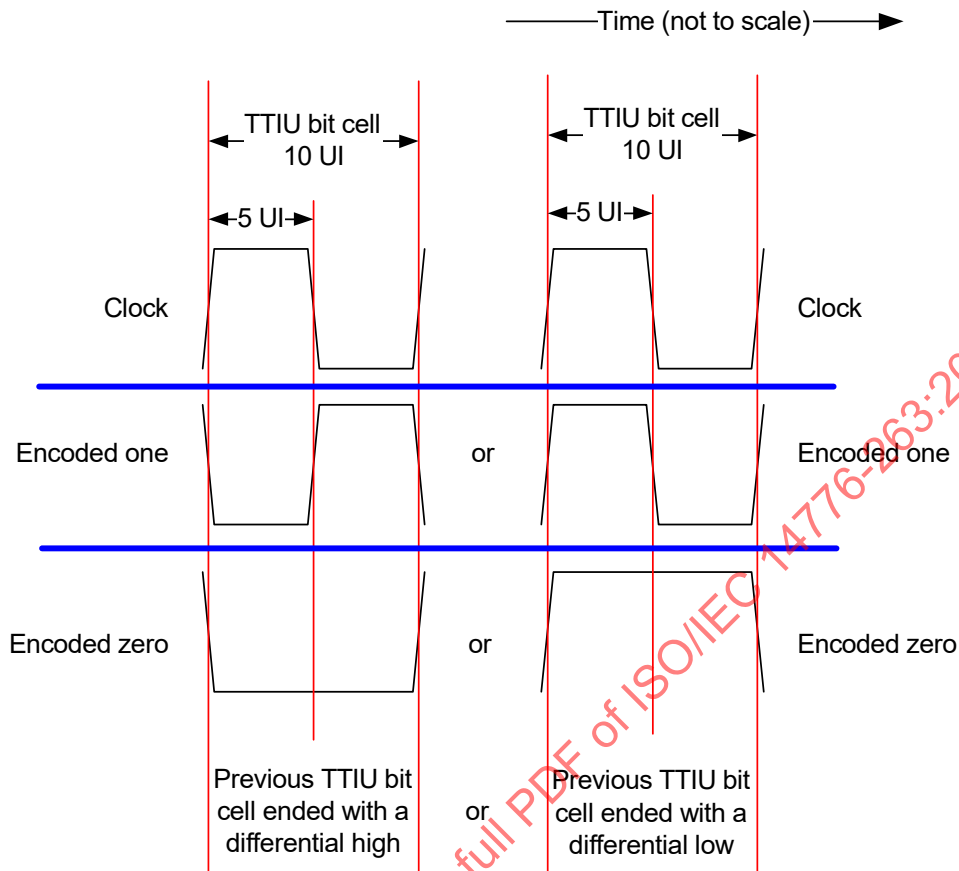


Figure 61 — TTIU bit cell transmitter encoding

### 5.8.3 TTIU bit transmission order

A TTIU shall be encoded as 32 consecutive TTIU bit cells as follows:

- 1) the first TTIU bit cell transmitted contains byte 0 bit 7 of the TTIU;
- 2) the eighth TTIU bit cell transmitted contains byte 0 bit 0 of the TTIU;
- 3) the ninth TTIU bit cell transmitted contains byte 1 bit 7 of the TTIU;
- 4) the 16<sup>th</sup> TTIU bit cell transmitted contains byte 1 bit 0 of the TTIU;
- 5) the 17<sup>th</sup> TTIU bit cell transmitted contains byte 2 bit 7 of the TTIU;
- 6) the 24<sup>th</sup> TTIU bit cell transmitted contains byte 2 bit 0 of the TTIU;
- 7) the 25<sup>th</sup> TTIU bit cell transmitted contains byte 3 bit 7 of the TTIU; and
- 8) the 32<sup>nd</sup> TTIU bit cell transmitted contains byte 3 bit 0 of the TTIU.

### 5.8.4 TTIU bit cell decoding in the receiver

After receiving a TTIU bit cell if the receiver detects a transition:

- a) after or at three UIs from the beginning of the TTIU cell; and
- b) before or at seven UIs from the beginning of the TTIU cell,

then the received bit shall be considered a one as shown in figure 62.

After receiving a TTIU bit cell if the receiver detects no transition:

- a) after or at three UIs from the beginning of the TTIU cell; and

b) before or at seven UIs from the beginning of the TTIU cell,  
then the received bit shall be considered a zero as shown in figure 62.

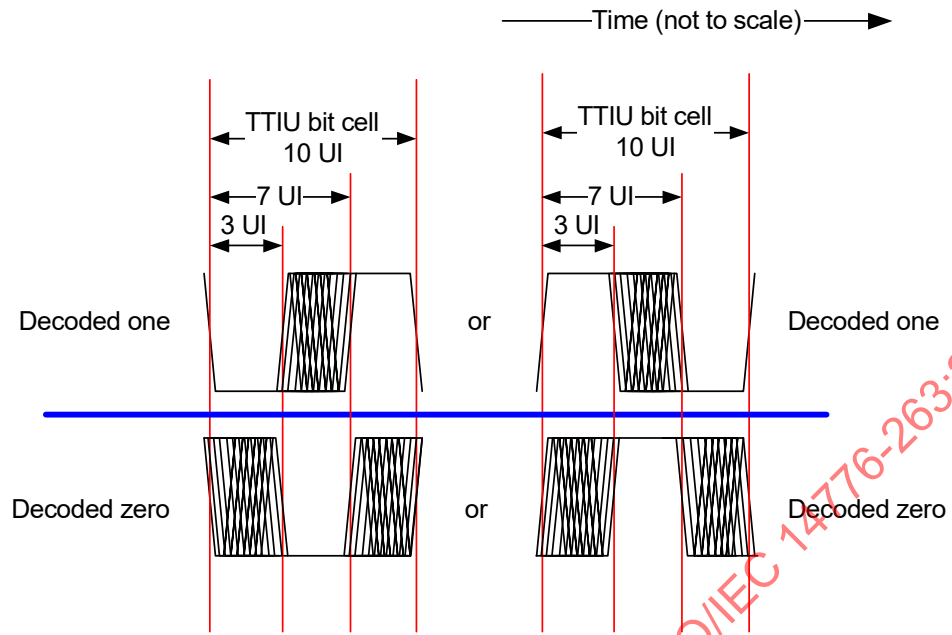


Figure 62 — TTIU bit cell receiver decoding

## 5.9 Train\_Tx-SNW TTIUs

### 5.9.1 Train\_Tx-SNW TTIU format

Table 58 defines the content of each Train\_Tx-SNW TTIU bit.

Table 58 — Train\_Tx-SNW TTIU bit

| Value | Transmitted                  |
|-------|------------------------------|
| One   | BMC encoded one (see 5.8.2)  |
| Zero  | BMC encoded zero (see 5.8.2) |

Table 59 defines the Train\_Tx-SNW TTIU. For each Train\_Tx-SNW TTIU bit defined as reserved, the phy shall transmit a zero. Byte 0 shall be transmitted first and byte 3 shall be transmitted last. Within each byte, bit 7 shall be transmitted first and bit 0 shall be transmitted last.

Table 59 — Train\_Tx-SNW TTIU

| Byte\Bit | 7                     | 6 | 5 | 4 | 3 | 2 | 1 | 0 |  |  |  |  |  |
|----------|-----------------------|---|---|---|---|---|---|---|--|--|--|--|--|
| 0        | PATTERN TYPE          |   |   |   |   |   |   |   |  |  |  |  |  |
| 1        |                       |   |   |   |   |   |   |   |  |  |  |  |  |
| 2        | PATTERN TYPE SPECIFIC |   |   |   |   |   |   |   |  |  |  |  |  |
| 3        |                       |   |   |   |   |   |   |   |  |  |  |  |  |

Table 60 defines the PATTERN TYPE field, which defines the format of the PATTERN TYPE SPECIFIC field.

Table 60 — PATTERN TYPE field

| Code                                                                                                                                                                                       | Name of TTIU          | Type | Reference |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|------|-----------|
| 000b                                                                                                                                                                                       | Control/Status TTIU   | M    | 5.9.2     |
| 001b to 110b                                                                                                                                                                               | Reserved <sup>a</sup> |      |           |
| 111b                                                                                                                                                                                       | Error Response TTIU   | M    | 5.9.3     |
| Key:<br>M = TTIU implementation is mandatory.                                                                                                                                              |                       |      |           |
| <sup>a</sup> If a phy receives a pattern type that is reserved, then that phy shall transmit an Error Response TTIU with the ERROR CODE field set to RESERVED PATTERN TYPE (see 5.14.5.4). |                       |      |           |

The PATTERN TYPE SPECIFIC field contains the transmitter training information, the form of which is defined by the PATTERN TYPE field (see table 60).

The total number of bits within a TTIU that are set to zero shall be even.

### 5.9.2 Control/Status TTIU

When the local phy receives a Control/Status TTIU:

- the Training Control word specifies adjustments to the local phy's transmitter coefficients; and
- the Training Status word indicates the status of the attached phy's transmitter.

When the local phy sends a Control/Status TTIU:

- the Training Control word specifies adjustments to the attached phy's transmitter coefficients; and
- the Training Status word indicates the status of the local phy's transmitter.

Table 61 — Control/Status TTIU

| Byte\Bit | 7                        | 6       | 5                     | 4        | 3                     | 2 | 1                     | 0 |
|----------|--------------------------|---------|-----------------------|----------|-----------------------|---|-----------------------|---|
| 0        | Training Control word    |         |                       |          |                       |   |                       |   |
|          | PATTERN TYPE (000b)      |         |                       | Reserved | COEFFICIENT SETTINGS  |   | Reserved              |   |
| 1        | Coefficient Request byte |         |                       |          |                       |   |                       |   |
|          | Reserved                 |         | COEFFICIENT 3 REQUEST |          | COEFFICIENT 2 REQUEST |   | COEFFICIENT 1 REQUEST |   |
| 2        | Training Status word     |         |                       |          |                       |   |                       |   |
|          | TRAIN COMP               | TX INIT | BALANCE               | Reserved |                       |   |                       |   |
| 3        | Reserved                 |         | COEFFICIENT 3 STATUS  |          | COEFFICIENT 2 STATUS  |   | COEFFICIENT 1 STATUS  |   |

If a TTIU bit that is defined as reserved in the Training Control word is set to one or the Training Status word is set to one, then the phy shall transmit an Error Response TTIU with the ERROR CODE field set to RESERVED TTIU BIT SET TO ONE (see 5.14.5.4).

The PATTERN TYPE field shall be set to the value shown in table 60.

Table 62 defines the COEFFICIENT SETTINGS field.

Table 62 — COEFFICIENT SETTINGS field

| Code                                                          | Name            | Description                                                                                                                                                                                                                                                                                 | Type |
|---------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 00b                                                           | normal          | If a coefficient change is specified (see table 63) and the TRAIN COMP bit is set to zero, then the local phy's transmitter coefficients shall be changed as specified in the:<br>a) COEFFICIENT 1 REQUEST field;<br>b) COEFFICIENT 2 REQUEST field; and<br>c) COEFFICIENT 3 REQUEST field. | M    |
| 01b                                                           | reference_1     | The local phy's transmitter coefficients shall be set to the reference 1 values specified in SAS-3.                                                                                                                                                                                         | M    |
| 10b                                                           | reference_2     | The local phy's transmitter coefficients shall be set to the reference 2 values specified in SAS-3.                                                                                                                                                                                         | M    |
| 11b                                                           | no_equalization | The local phy's transmitter coefficients shall be set to the no equalization values specified in SAS-3.                                                                                                                                                                                     | M    |
| Key:<br>M = Coefficient settings implementation is mandatory. |                 |                                                                                                                                                                                                                                                                                             |      |

If the COEFFICIENT SETTINGS field is set to 00b and the TRAIN COMP bit is set to zero, then the COEFFICIENT 3 REQUEST field specifies the adjustment, if any, (see table 63) that the local phy's transmitter shall make to its transmitter coefficient 3 (see SAS-3). If the COEFFICIENT SETTINGS field is set to a value other than 00b or the TRAIN COMP bit is set to one, then the COEFFICIENT 3 REQUEST field shall be ignored by the local phy's transmitter.

If the COEFFICIENT SETTINGS field is set to 00b and the TRAIN COMP bit is set to zero, then the COEFFICIENT 2 REQUEST field specifies the adjustment, if any, (see table 63) that the local phy's transmitter shall make to its transmitter coefficient 2 (see SAS-3). If the COEFFICIENT SETTINGS field is set to a value other than 00b or the TRAIN COMP bit is set to one, then the COEFFICIENT 2 REQUEST field shall be ignored by the local phy's transmitter.

If the COEFFICIENT SETTINGS field is set to 00b and the TRAIN COMP bit is set to zero, then the COEFFICIENT 1 REQUEST field specifies the adjustment, if any, (see table 63) that the local phy's transmitter shall make to its transmitter coefficient 1 (see SAS-3). If the COEFFICIENT SETTINGS field is set to a value other than 00b or the TRAIN COMP bit is set to one, then the COEFFICIENT 1 REQUEST field shall be ignored by the local phy's transmitter.

**Table 63 — COEFFICIENT 1 REQUEST field, COEFFICIENT 2 REQUEST field, and COEFFICIENT 3 REQUEST field**

| Code                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Name                  | Description                                                                         | Type |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------------------------------------------------------------------------------------|------|
| 00b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | hold                  | The local phy shall make no adjustment to the specified coefficient.                | M    |
| 01b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | increment             | The local phy shall adjust the specified coefficient by one increment. <sup>a</sup> | M    |
| 10b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | decrement             | The local phy shall adjust the specified coefficient by one decrement. <sup>a</sup> | M    |
| 11b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Reserved <sup>b</sup> |                                                                                     |      |
| Key:<br>M = Coefficient request implementation is mandatory.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                       |                                                                                     |      |
| <sup>a</sup> See SAS-3 for the amount of adjustment represented by one increment and one decrement to the coefficient.<br><sup>b</sup> If a phy receives one coefficient request that is reserved, then that phy shall transmit an Error Response TTIU (see 5.14.5.4) that indicates the coefficient request that was reserved with the ERROR CODE field set to:<br>a) RESERVED COEFFICIENT 1 REQUEST;<br>b) RESERVED COEFFICIENT 2 REQUEST; or<br>c) RESERVED COEFFICIENT 3 REQUEST.<br>If a phy receives more than one coefficient request that is reserved, then that phy shall transmit an Error Response TTIU (see 5.14.5.4) with the ERROR CODE field set to MULTIPLE RESERVED COEFFICIENTS REQUESTED. |                       |                                                                                     |      |

See table 64 for the combinations of coefficient requests that are mandatory or reserved.

**Table 64 — Valid coefficient requests**

| Coefficient Request byte                                                                                                                                                                         |                             |           |                             |           |                             |           |      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------|-----------------------------|-----------|-----------------------------|-----------|------|
| Code                                                                                                                                                                                             | COEFFICIENT 3 REQUEST field |           | COEFFICIENT 2 REQUEST field |           | COEFFICIENT 1 REQUEST field |           | Type |
|                                                                                                                                                                                                  | Code                        | Name      | Code                        | Name      | Code                        | Name      |      |
| 00h                                                                                                                                                                                              | 00b                         | hold      | 00b                         | hold      | 00b                         | hold      | M    |
| 01h                                                                                                                                                                                              | 00b                         | hold      | 00b                         | hold      | 01b                         | increment | M    |
| 02h                                                                                                                                                                                              | 00b                         | hold      | 00b                         | hold      | 10b                         | decrement | M    |
| 04h                                                                                                                                                                                              | 00b                         | hold      | 01b                         | increment | 00b                         | hold      | M    |
| 05h                                                                                                                                                                                              | 00b                         | hold      | 01b                         | increment | 01b                         | increment | M    |
| 08h                                                                                                                                                                                              | 00b                         | hold      | 10b                         | decrement | 00b                         | hold      | M    |
| 0Ah                                                                                                                                                                                              | 00b                         | hold      | 10b                         | decrement | 10b                         | decrement | M    |
| 10h                                                                                                                                                                                              | 01b                         | increment | 00b                         | hold      | 00b                         | hold      | M    |
| 14h                                                                                                                                                                                              | 01b                         | increment | 01b                         | increment | 00b                         | hold      | M    |
| 20h                                                                                                                                                                                              | 10b                         | decrement | 00b                         | hold      | 00b                         | hold      | M    |
| 28h                                                                                                                                                                                              | 10b                         | decrement | 10b                         | decrement | 00b                         | hold      | M    |
| All others                                                                                                                                                                                       | Reserved <sup>a</sup>       |           |                             |           |                             |           |      |
| <div>Key:</div> <div>M = Coefficient Request byte's coefficient request combination implementation is mandatory.</div>                                                                           |                             |           |                             |           |                             |           |      |
| <div><sup>a</sup> If a phy receives a Coefficient Request byte with a combination of coefficient requests that is reserved, then that phy shall transmit an Error Response (see table 63).</div> |                             |           |                             |           |                             |           |      |

A training complete (TRAIN COMP) bit set to one indicates the local phy's receiver has determined the attached phy's transmitter coefficients are set to their optimum value. A TRAIN COMP bit set to zero indicates the local phy's receiver may be requesting the attached phy's transmitter coefficients to be adjusted as indicated in the COEFFICIENT SETTINGS field, COEFFICIENT 3 REQUEST field, COEFFICIENT 2 REQUEST field, and COEFFICIENT 1 REQUEST field.

A transmitter initializing (TX INIT) bit set to one indicates the local phy is initializing and not ready for training. A TX INIT bit set to zero indicates the local phy is ready and may be adjusted by the attached phy's receiver.

The BALANCE bit shall be set to one or zero such that the total number of bits within the TTIU that are set to zero is even, including the BALANCE bit (see 5.14.5.4.1).

The COEFFICIENT 3 STATUS field indicates the status (see table 65) of the local phy's transmitter coefficient 3 (see SAS-3).

The COEFFICIENT 2 STATUS field indicates the status (see table 65) of the local phy's transmitter coefficient 2 (see SAS-3).



The COEFFICIENT 1 STATUS field indicates the status (see table 65) of the local phy's transmitter coefficient 1 (see SAS-3).

**Table 65 — COEFFICIENT 1 STATUS field, COEFFICIENT 2 STATUS field, and COEFFICIENT 3 STATUS field**

| Code                                                                | Name            | Description                                                                                                                                  | Type |
|---------------------------------------------------------------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------|------|
| 00b                                                                 | ready           | The indicated local phy's transmitter coefficient may be adjusted by the attached phy.                                                       | M    |
| 01b                                                                 | update complete | The local phy's transmitter has completed the last indicated coefficient adjustment requested by the attached phy's receiver (see 5.14.2.5). | M    |
| 10b                                                                 | minimum         | The indicated local phy's transmitter coefficient is at a minimum value (see 5.14.2.7). <sup>a</sup>                                         | M    |
| 11b                                                                 | maximum         | The indicated local phy's transmitter coefficient is at a maximum value (see 5.14.2.6). <sup>a</sup>                                         | M    |
| Key:<br>M = Coefficient status value implementation is mandatory.   |                 |                                                                                                                                              |      |
| <sup>a</sup> See SAS-3 for the minimum value and the maximum value. |                 |                                                                                                                                              |      |

### 5.9.3 Error Response TTIU

The Error Response TTIU is used by a phy to report requests to process:

- a) unsupported optional features;
- b) reserved code values; and
- c) TTIU reserved bits.

**Table 66 — Error Response TTIU**

| Byte\Bit | 7                   | 6 | 5                              | 4        | 3                              | 2 | 1                              | 0 |
|----------|---------------------|---|--------------------------------|----------|--------------------------------|---|--------------------------------|---|
| 0        | PATTERN TYPE (111b) |   |                                | Reserved | RECEIVED COEFFICIENT SETTINGS  |   | Reserved                       |   |
| 1        | Reserved            |   | RECEIVED COEFFICIENT 3 REQUEST |          | RECEIVED COEFFICIENT 2 REQUEST |   | RECEIVED COEFFICIENT 1 REQUEST |   |
| 2        | Reserved            |   | BALANCE                        | Reserved |                                |   |                                |   |
| 3        | ERROR CODE          |   |                                |          |                                |   |                                |   |

The PATTERN TYPE field shall be set as shown in table 66 for the Error Response TTIU.

The RECEIVED COEFFICIENT SETTINGS field shall be set to the contents of the COEFFICIENT SETTINGS field received in the Training Control word of the Control/Status TTIU that contained any unsupported or illegal request.

The RECEIVED COEFFICIENT 3 REQUEST field shall be set to the contents of the COEFFICIENT 3 REQUEST field received in the Training Control word of the Control/Status TTIU that contained any unsupported or illegal request.

The RECEIVED COEFFICIENT 2 REQUEST field shall be set to the contents of the COEFFICIENT 2 REQUEST field received in the Training Control word of the Control/Status TTIU that contained any unsupported or illegal request.

The RECEIVED COEFFICIENT 1 REQUEST field shall be set to the contents of the COEFFICIENT 1 REQUEST field received in the Training Control word of the Control/Status TTIU that contained any unsupported or illegal request.

The BALANCE bit shall be set to one or zero such that the total number of bits within the TTIU that are set to zero is even, including the BALANCE bit.

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The ERROR CODE field is defined in table 67.

**Table 67 — ERROR CODE field**

| Code <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Name                                     | Description                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Error codes returned for all TTIUs                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                          |                                                                                                                                                                                                                                                   |
| 00h                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | UNKNOWN                                  | The cause of the error is indeterminate.                                                                                                                                                                                                          |
| 01h                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | UNSUPPORTED PATTERN TYPE                 | Unsupported transmitter training pattern type requested. The information returned in the Error Response TTIU does not contain information about the pattern type that was in error (see table 60).                                                |
| 02h                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | RESERVED PATTERN TYPE                    | Reserved transmitter training pattern type requested. The information returned in the Error Response TTIU does not contain information about the pattern type that was in error (see table 60).                                                   |
| 03h                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | RESERVED TTIU BIT SET TO ONE             | Reserved TTIU bit set to one (e.g., reserved bits in table 61).                                                                                                                                                                                   |
| 04h to 0Fh                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Reserved                                 |                                                                                                                                                                                                                                                   |
| Error codes returned for Control/Status TTIUs                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                          |                                                                                                                                                                                                                                                   |
| 10h                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | MULTIPLE RESERVED COEFFICIENTS REQUESTED | More than one coefficient request value is set to a reserved value (see table 63).                                                                                                                                                                |
| 11h                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | RESERVED COEFFICIENT 1 REQUEST           | Coefficient 1 is set to a reserved value (see table 63).                                                                                                                                                                                          |
| 13h                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | RESERVED COEFFICIENT 2 REQUEST           | Coefficient 2 is set to a reserved value (see table 63).                                                                                                                                                                                          |
| 15h                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | RESERVED COEFFICIENT 3 REQUEST           | Coefficient 3 is set to a reserved value (see table 63).                                                                                                                                                                                          |
| 1Ah                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | RESERVED COEFFICIENT REQUEST COMBINATION | If the following occurs:<br>a) none of the coefficient requests are set 11b (i.e., reserved) (see table 63); and<br>b) the combination of the coefficient 3 request, coefficient 2 request, and coefficient 1 request is reserved (see table 64). |
| 1Bh to 1Fh                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Reserved                                 |                                                                                                                                                                                                                                                   |
| Reserved error codes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                          |                                                                                                                                                                                                                                                   |
| 20h to FFh                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Reserved                                 |                                                                                                                                                                                                                                                   |
| <sup>a</sup> If more than one error condition is true, then the phy shall use the following priority to determine which error condition to report in the ERROR CODE field:<br>1) UNSUPPORTED PATTERN TYPE or RESERVED PATTERN TYPE;<br>2) RESERVED TTIU BIT SET TO ONE;<br>3) MULTIPLE RESERVED COEFFICIENTS REQUESTED;<br>4) RESERVED COEFFICIENT 1 REQUEST, RESERVED COEFFICIENT 2 REQUEST, or RESERVED COEFFICIENT 3 REQUEST;<br>5) RESERVED COEFFICIENT REQUEST COMBINATION; and<br>6) UNKNOWN. |                                          |                                                                                                                                                                                                                                                   |

## 5.10 Phy reset sequences

### 5.10.1 Phy reset sequences overview

The phy reset sequence consists of:

- 1) an OOB sequence (see 5.10.2.1 and 5.10.4.1);
- 2) a speed negotiation sequence (see 5.10.2.2 and 5.10.4.2); and
- 3) if the physical link is a SAS physical link and multiplexing (see 5.15) is enabled (see table 63), a multiplexing sequence (see 5.10.4.3).

The phy reset sequence shall only affect the phy, not the port or device containing the phy or other phys in the same port or device.

A phy shall originate a phy reset sequence after:

- a) power on;
- b) hard reset (i.e., receiving a HARD\_RESET primitive sequence before an IDENTIFY address frame) (see 4.4.2);
- c) a management application layer request (see 5.12.1);
- d) losing dword synchronization and not attempting to re-acquire dword synchronization (see 5.12.4.10 and 5.12.6.8);
- e) the Receive Identify Timeout timer expires (see 6.10);
- f) a hot-plug timeout (see 5.10.5) occurs for an expander phy;
- g) a hot-plug timeout occurs while in a low phy power condition (see 4.10.1); or
- h) the SNTT timer expires while in a low phy power condition.

A SAS phy may originate a phy reset sequence after a hot-plug timeout (see 5.10.5).

After receiving a HARD\_RESET primitive sequence before an IDENTIFY address frame, a phy should start the phy reset sequence within 250 ms.

Table 68 defines phy reset sequence timing parameters used by the SP state machine (see 5.12).

**Table 68 — Phy reset sequence timing specifications**

| Parameter                  | Minimum | Maximum | Comments                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------------------------|---------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hot-plug timeout           | 10 ms   | 500 ms  | The time after which: <ol style="list-style-type: none"> <li>a) an expander phy shall retry an unsuccessful phy reset sequence;</li> <li>b) a SAS initiator phy should retry an unsuccessful phy reset sequence (see 5.10.5); and</li> <li>c) a phy shall initiate a phy reset sequence if that phy does not receive a COMWAKE Completed message as defined in the SP31:SAS_PS_Low_Phy_Power state (see 5.12.5.2).</li> </ol> |
| Phy wakeup partial timeout | none    | 10 µs   | While a phy is in the partial phy power condition (see 4.10.1.3) the time within which the phy shall become active after receiving a Phy Wakeup message (see 5.12.2).                                                                                                                                                                                                                                                         |
| Phy wakeup slumber timeout | none    | 10 ms   | While a phy is in the slumber phy power condition (see 4.10.1.4) the time within which the phy shall become active after receiving a Phy Wakeup message (see 5.12.2).                                                                                                                                                                                                                                                         |

## 5.10.2 SATA phy reset sequence

### 5.10.2.1 SATA OOB sequence

Figure 63 shows the SATA OOB sequence between a SATA host and SATA device. The SATA OOB sequence is defined by SATA.

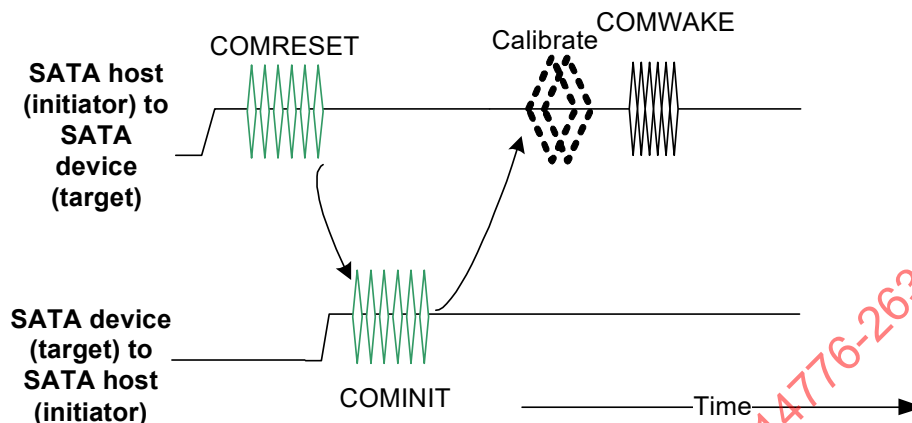


Figure 63 — SATA OOB sequence

### 5.10.2.2 SATA speed negotiation sequence

Figure 64 shows the speed negotiation sequence between a SATA host and SATA device. The SATA speed negotiation sequence is defined by SATA (see SATA).

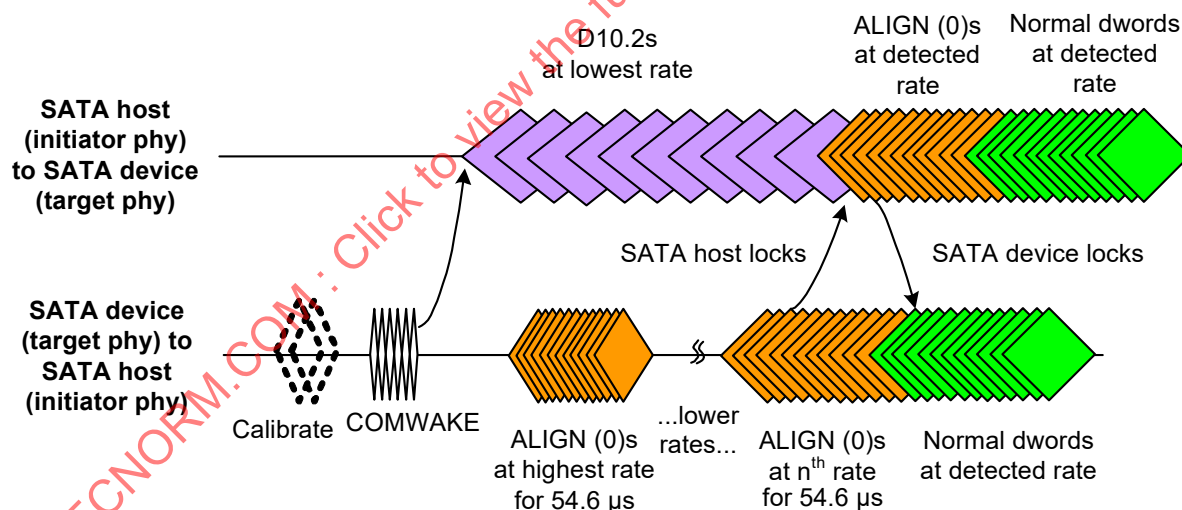


Figure 64 — SATA speed negotiation sequence

Table 69 defines SATA speed negotiation sequence timing parameters used by the SP state machine (see 5.12).

**Table 69 — SATA speed negotiation sequence timing specifications**

| Parameter                                                                                                                                                                                                     | Time                          | Comments                                                                                                                                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Await ALIGN timeout                                                                                                                                                                                           | $873.813 \bar{\mu}\text{s}^a$ | The minimum time during SATA speed negotiation that a phy shall allow for an ALIGN (0) to be received after detecting COMWAKE Completed.       |
| COMWAKE response time                                                                                                                                                                                         | $533 \text{ ns}^b$            | The maximum time during SATA speed negotiation after detecting COMWAKE Completed before which a phy shall start transmitting D10.2 characters. |
| <sup>a</sup> $873.813 \bar{\mu}\text{s}$ is $32\,768 \times 40 \times \text{nominal OOB I}$ (see SAS-3 and SATA).<br><sup>b</sup> $533 \text{ ns}$ is $200 \times 40 \times \text{nominal OOB I}$ (see SATA). |                               |                                                                                                                                                |

The transmitter device shall use SATA signal output levels during the SATA speed negotiation sequence as described in SAS-3.

The phy shall not perform for physical link rate tolerance management (see 6.3) during the SATA speed negotiation sequence.

### 5.10.3 SAS to SATA phy reset sequence

SAS initiator phys and expander phys may support SATA (e.g., support being directly attached to a SATA device or a SATA port selector).

To initiate a phy reset sequence a SAS initiator phy or expander phy shall:

- 1) transmit a COMINIT; and
- 2) in response to receiving a COMINIT, transmit a COMSAS.

The COMSAS identifies the phy as a SAS phy or expander phy instead of a SATA phy.

If a SATA phy is attached to the physical link, then that SATA phy either:

- a) misinterprets the COMSAS to be a COMRESET and responds with a COMINIT; or
- b) ignores the COMSAS and provides no response within a COMSAS detect timeout.

Either response indicates to the SAS initiator phy or expander phy that a SATA phy is attached. As a result, the SAS initiator phy or expander phy shall transmit COMWAKE and enter the SATA speed negotiation sequence (see 5.10.2.2).

Figure 65 shows an OOB sequence between a SAS phy or expander phy (i.e., a phy compliant with this standard) and a SATA phy (i.e., a phy in a SATA device, defined by SATA). The two possible cases are presented. The first case is that the SATA phy ignores the COMSAS and provides no response within a COMSAS detect timeout. The second case is that the SATA phy misinterprets the COMSAS to be a COMRESET and responds with a COMINIT. The SP state machine treats these two cases the same (see

5.12.3.9), and determines that a SATA phy is attached after a COMSAS detect timeout. The SATA speed negotiation sequence is entered after COMWAKE is detected.

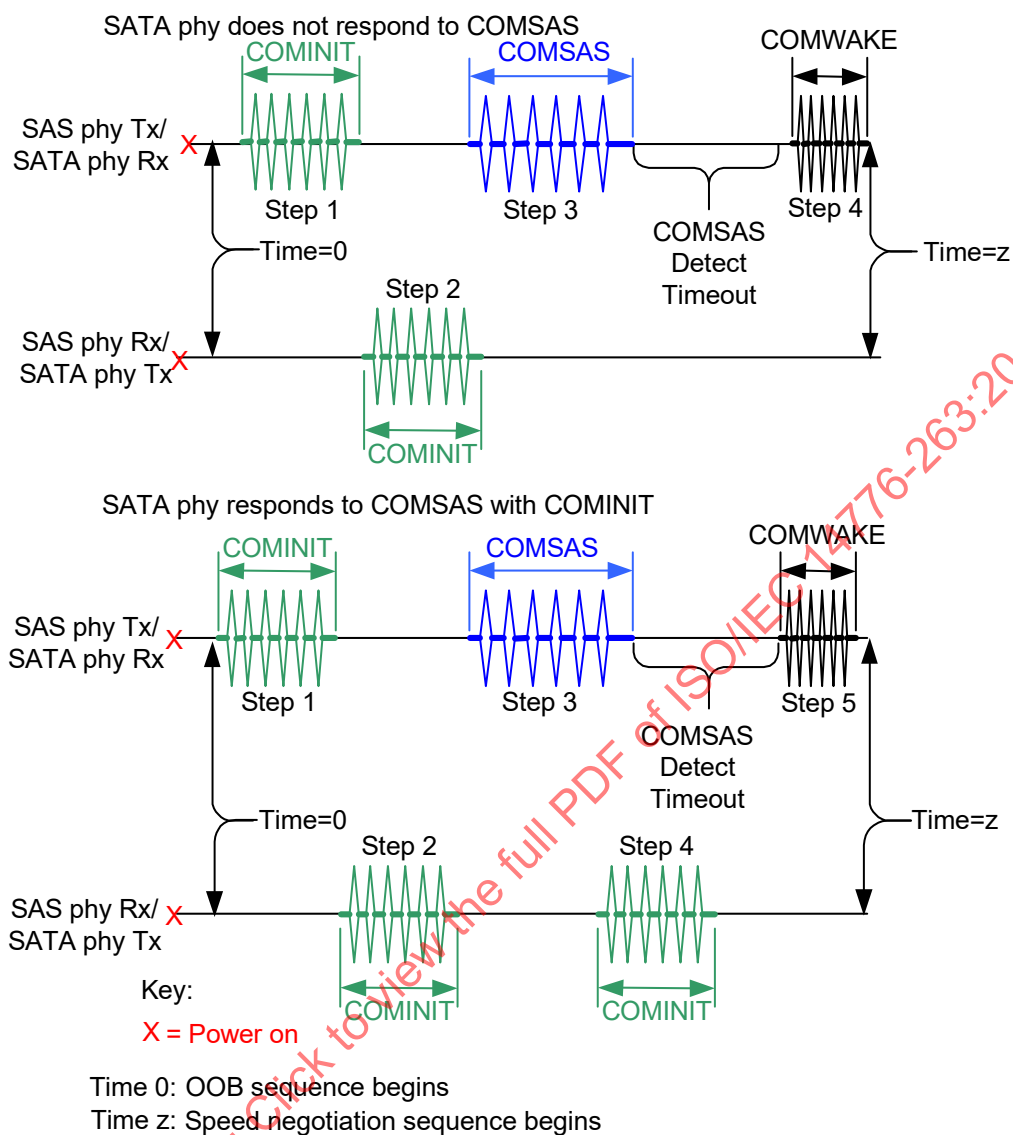


Figure 65 — SAS to SATA OOB sequence

#### 5.10.4 SAS to SAS phy reset sequence

##### 5.10.4.1 SAS OOB sequence

To initiate a SAS OOB sequence a phy transmits a COMINIT.

On receipt of a COMINIT the receiving phy either:

- a) if the phy has not yet transmitted a COMINIT, transmit a COMINIT followed by a COMSAS; or
- b) if the phy has transmitted a COMINIT, transmit a COMSAS.

If the receiving phy does not respond to a COMINIT within the minimum hot-plug timeout (see 5.10.5), then the attached phy may transmit another COMINIT. If repeated, then this results in a livelock.

On receipt of a COMSAS, if the receiving phy has not yet transmitted a COMSAS, then the phy transmits a COMSAS.

After completing the transmission of a COMSAS and the successful receipt of a COMSAS the SAS OOB sequence is complete and the SAS speed negotiation sequence begins.

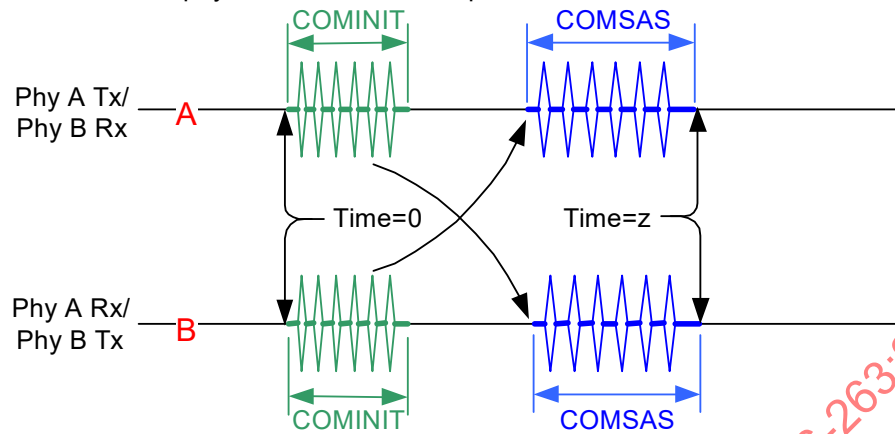
A phy distinguishes between COMINIT and COMSAS and continues with a SAS speed negotiation sequence (see 5.10.4.2) after completing the SAS OOB sequence.

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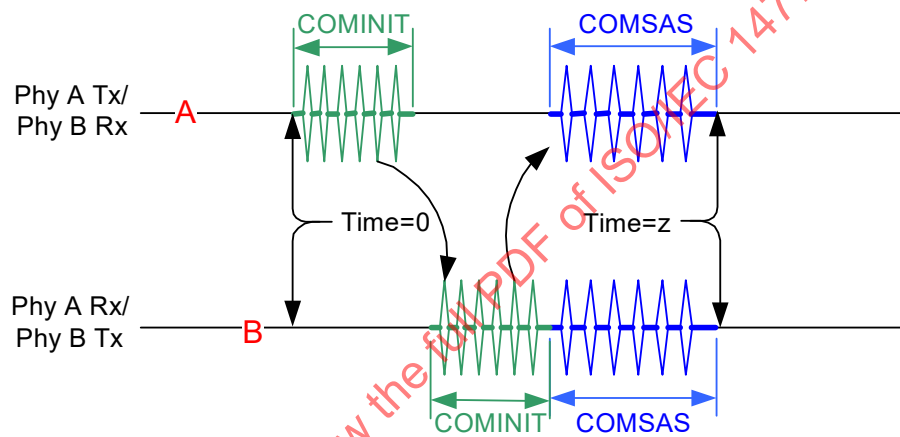


Figure 66 shows several different SAS OOB sequences between phy A and phy B, with phy A starting the SAS OOB sequence at the same time as phy B, before phy B, and before phy B powers on.

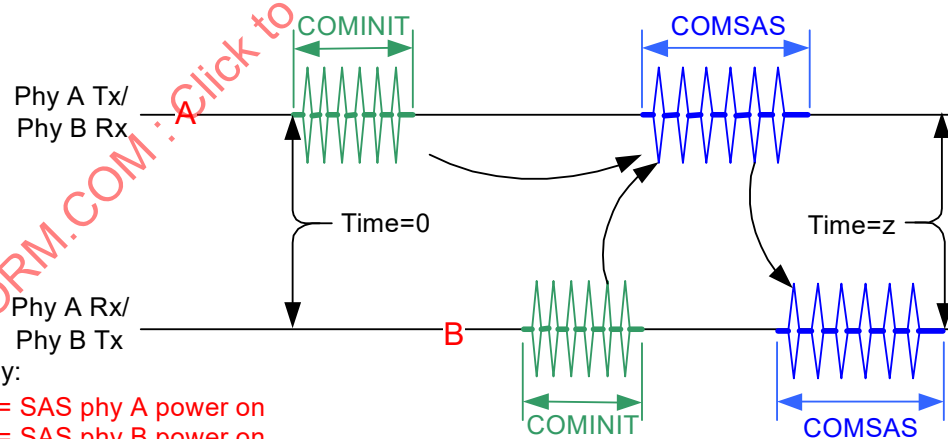
Scenario 1: Both SAS phys start SAS OOB sequence at same time



Scenario 2: SAS phy A starts SAS OOB sequence



Scenario 3: SAS phy B misses SAS phy A's COMINIT



Key:

A = SAS phy A power on

B = SAS phy B power on

Time 0: SAS phy reset sequence begins

Time z: SAS speed negotiation sequence begins

Figure 66 — SAS to SAS OOB sequence

#### 5.10.4.2 SAS speed negotiation sequence

##### 5.10.4.2.1 SAS speed negotiation sequence overview

The SAS speed negotiation sequence establishes communications between the two phys on a physical link at the highest possible transmission rate.

The SAS speed negotiation sequence is a peer-to-peer negotiation technique that does not assume initiator and target (i.e., host and device) roles. The rules for speed negotiation are the same for both participating phys.

The SAS speed negotiation sequence consists of a set of speed negotiation windows (SNWs). Each SNW is identified by a name (e.g., Speed Negotiation Window-1 or SNW-1).

SNWs conform to one of the following types:

- a) speed negotiation without training (i.e., SNW-1, SNW-2, and Final-SNW) (see 5.10.4.2.3.2);
- b) phy capabilities exchange (i.e., SNW-3) (see 5.10.4.2.3.3);
- c) phy receiver training (i.e., Train\_Rx-SNW) (see 5.10.4.2.3.5); or
- d) phy transmitter training (i.e., Train\_Tx-SNW) (see 5.10.4.2.3.4).

Many of the timing parameters used for defining the SNWs are common to multiple SNW types. All of the timing specifications for all SNW types are defined in 5.10.4.2.2.

Phys may implement a subset of SNWs provided that the subset implements a valid speed negotiation sequence. SAS speed negotiation sequences are defined in 5.10.4.2.4.

The transmitter device shall use SAS signal output levels during the SAS speed negotiation sequence as described in SAS-3.

The phy shall not perform physical link rate tolerance management (see 6.3) during the SAS speed negotiation sequence.

## 5.10.4.2.2 SAS speed negotiation sequence timing specifications

Table 70 defines the timing specifications for the SAS speed negotiation sequence.

**Table 70 — SAS speed negotiation sequence timing specifications** (part 1 of 2)

| Parameter                       | Acronym | Time <sup>a</sup>        | Comments                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------------|---------|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rate change delay time          | RCDT    | 750 000 OOB <sup>b</sup> | The time the transmitter device shall transmit negotiation idle at the beginning of:<br>a) SNW-1;<br>b) SNW-2;<br>c) SNW-3;<br>d) Final-SNW; and<br>e) Train_Rx-SNW or Train_Tx-SNW.                                                                                                                                                                                                            |
| Speed negotiation transmit time | SNTT    | 163 840 OOB <sup>c</sup> | During SNW-1, SNW-2, and Final-SNW, the time after RCDT during which ALIGN (0) or ALIGN (1) is transmitted.<br><br>During SNW-3, the time after RCDT in which bit cells and OOB idle are transmitted.<br><br>During low phy power conditions, the maximum time for a phy to transmit ALIGN (0)s or ALIGN (1)s while in the SP32:SAS_PS_ALIGN0 state or SP33:SAS_PS_ALIGN1 state (see 5.12.5.4). |
| Speed negotiation lock time     | SNLT    | 153 600 OOB <sup>d</sup> | The maximum time for a phy to reply with ALIGN (1) during SNW-1, SNW-2, and Final-SNW.<br><br>During low phy power conditions, the maximum time for a phy to reply with an ALIGN (0) or ALIGN (1) while in the SP32:SAS_PS_ALIGN0 state or SP33:SAS_PS_ALIGN1 state (see 5.12.5.4).                                                                                                             |
| Actual lock time                | none    |                          | The time during SNW-1, SNW-2, and Final-SNW at which actual dword synchronization occurs to the received ALIGN (0) or ALIGN (1) and the phy begins transmitting ALIGN (1) rather than ALIGN (0).                                                                                                                                                                                                |

<sup>a</sup> OOB is defined in SAS-3.  
<sup>b</sup> 750 000 OOB (e.g., RCDT) is nominally 500  $\mu$ s (i.e.,  $18\,750 \times 40$  OOB).  
<sup>c</sup> 163 840 OOB (e.g., SNTT) is nominally 109.226  $\mu$ s (i.e.,  $4\,096 \times 40$  OOB).  
<sup>d</sup> 153 600 OOB (e.g., SNLT) is nominally 102.4  $\mu$ s (i.e.,  $(4\,096 - 256) \times 40$  OOB).  
<sup>e</sup> 913 840 OOB (e.g., SNWT) is nominally 609.226  $\mu$ s (i.e., RCDT + SNTT).  
<sup>f</sup> 2 200 OOB is nominally 1 466.6 ns (i.e., COMWAKE signal time (see SAS-3)).  
<sup>g</sup> 29 998 080 OOB (e.g., MRTT) is nominally 19.998 72 ms (i.e.,  $11\,718 \times 64 \times 40$  OOB). This is the time of the maximum number of complete receiver training patterns that fit into 20 ms.  
<sup>h</sup> 28 497 920 OOB (e.g., TLT) is nominally 18.998 613 ms (i.e.,  $11\,132 \times 64 \times 40$  OOB). This is the time of the maximum number of complete receiver training patterns that fit into 19 ms.  
<sup>i</sup> 30 748 080 OOB (e.g., MTWT) is nominally 20.498 72 ms (i.e., RCDT + MRTT).  
<sup>j</sup> 750 000 000 OOB (e.g., MTTT) is nominally 500 ms.  
<sup>k</sup> 750 750 000 OOB (e.g., MTXT) is nominally 500.5 ms (i.e., MTTT + RCDT).

**Table 70 — SAS speed negotiation sequence timing specifications** (part 2 of 2)

| Parameter                         | Acronym | Time <sup>a</sup>              | Comments                                                                   |
|-----------------------------------|---------|--------------------------------|----------------------------------------------------------------------------|
| SNW time                          | SNWT    | 913 840 OOB I <sup>e</sup>     | The duration of SNW-1, SNW-2, SNW-3, or Final-SNW.                         |
| SNW-3 Bit cell time               | none    | 2 200 OOB I <sup>f</sup>       | The time to transmit a COMWAKE or OOB idle during SNW-3.                   |
| Maximum receiver training time    | MRTT    | 29 998 080 OOB I <sup>g</sup>  | The maximum time for receiver training to complete during Train_Rx-SNW.    |
| Training lock time                | TLT     | 28 497 920 OOB I <sup>h</sup>  | The maximum time for a phy to reply with TRAIN_DONE during Train_Rx-SNW.   |
| Train_Rx-SNW time                 | none    |                                | The actual duration of Train_Rx-SNW.                                       |
| Maximum Train_Rx-SNW time         | MTWT    | 30 748 080 OOB I <sup>i</sup>  | The maximum duration of Train_Rx-SNW.                                      |
| Maximum transmitter training time | MTTT    | 750 000 000 OOB I <sup>j</sup> | The maximum time for transmitter training to complete during Train_Tx-SNW. |
| Maximum Train_Tx time             | MTXT    | 750 750 000 OOB I <sup>k</sup> | The maximum duration of Train_Tx-SNW.                                      |

<sup>a</sup> OOB I is defined in SAS-3.  
<sup>b</sup> 750 000 OOB I (e.g., RCDT) is nominally 500  $\mu$ s (i.e.,  $18\,750 \times 40$  OOB I).  
<sup>c</sup> 163 840 OOB I (e.g., SNTT) is nominally 109.226  $\mu$ s (i.e.,  $4\,096 \times 40$  OOB I).  
<sup>d</sup> 153 600 OOB I (e.g., SNLT) is nominally 102.4  $\mu$ s (i.e.,  $(4\,096 - 256) \times 40$  OOB I).  
<sup>e</sup> 913 840 OOB I (e.g., SNWT) is nominally 609.226  $\mu$ s (i.e., RCDT + SNTT).  
<sup>f</sup> 2 200 OOB I is nominally 1 466.6 ns (i.e., COMWAKE signal time (see SAS-3)).  
<sup>g</sup> 29 998 080 OOB I (e.g., MRTT) is nominally 19.998 72 ms (i.e.,  $11\,718 \times 64 \times 40$  OOB I). This is the time of the maximum number of complete receiver training patterns that fit into 20 ms.  
<sup>h</sup> 28 497 920 OOB I (e.g., TLT) is nominally 18.998 613 ms (i.e.,  $11\,132 \times 64 \times 40$  OOB I). This is the time of the maximum number of complete receiver training patterns that fit into 19 ms.  
<sup>i</sup> 30 748 080 OOB I (e.g., MTWT) is nominally 20.498 72 ms (i.e., RCDT + MRTT).  
<sup>j</sup> 750 000 000 OOB I (e.g., MTTT) is nominally 500 ms.  
<sup>k</sup> 750 750 000 OOB I (e.g., MTXT) is nominally 500.5 ms (i.e., MTTT + RCDT).

#### 5.10.4.2.3 Speed negotiation window (SNW) definitions

##### 5.10.4.2.3.1 SNW definitions overview

During each SNW, a phy shall either:

- if it supports the SNW, transmit and receive as defined for the SNW; or
- if it does not support the SNW, transmit negotiation idle and ignore the SNW information received.

If a phy supports the SNW and receives the expected transmission, then the SNW is valid. If a phy does not receive the expected transmission from the attached phy, then the SNW is invalid.

NOTE 10 - If a phy transmits negotiation idle during an SNW, then the attached phy does not receive the expected transmission and the SNW is invalid.

#### 5.10.4.2.3.2 SNW-1, SNW-2, and Final-SNW

Figure 67 defines SNW-1, SNW-2, and Final-SNW, including:

- SNW time (SNWT);
- rate change delay time (RCDT);
- speed negotiation transmit time (SNTT);
- speed negotiation lock time (SNLT); and
- actual lock time.

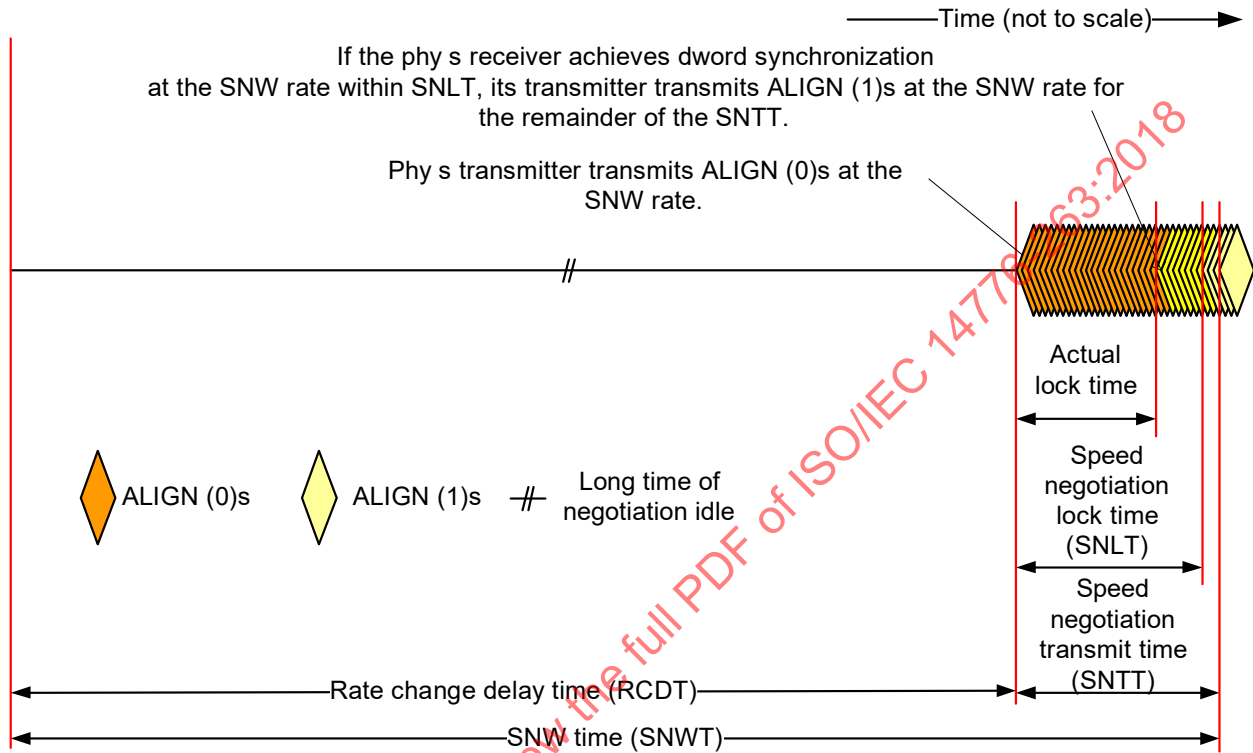


**Figure 67 — SNW-1, SNW-2, and Final-SNW**

If the phy supports the SNW, then it shall transmit:

- 1) negotiation idle for an RCDT; and
- 2) ALIGNs at the SNW rate for the remainder of the SNWT (i.e., for SNTT).

If the phy does not support the SNW, then it shall transmit negotiation idle for the entire SNWT.

Table 71 defines the SNW rate used in SNW-1, SNW-2, and Final-SNW.

**Table 71 — SNW rates used in SNW-1, SNW-2, and Final-SNW**

| SNW       | SNW rate                                                                                                                                                      |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SNW-1     | 1.5 Gbit/s                                                                                                                                                    |
| SNW-2     | 3 Gbit/s                                                                                                                                                      |
| Final-SNW | Based on SNW-1, SNW-2, and SNW-3 validity:<br>a) 1.5 Gbit/s if SNW-1 is valid and SNW-2 is invalid; or<br>b) 3 Gbit/s if SNW-2 is valid and SNW-3 is invalid. |

If the phy supports the SNW, then after RCDT it shall attempt to attain dword synchronization on an incoming series of dwords (e.g., ALIGN (0) or ALIGN (1) primitives) at that rate for the SNLT and:

- a) if the phy achieves dword synchronization within the SNLT, then it shall change from transmitting ALIGN (0) primitives to transmitting ALIGN (1) primitives for the remainder of the SNTT (i.e., the remainder of the SNW time). The point at which the phy achieves dword synchronization is called the actual lock time; or
- b) if the phy does not achieve dword synchronization within the SNLT, then it shall continue transmitting ALIGN (0) primitives for the remainder of the SNTT (i.e., the remainder of the SNW time).

At the end of the SNTT:

- a) if the phy is both transmitting and receiving ALIGN (1) primitives, then it shall consider the SNW to be valid; or
- b) if the phy is not both transmitting and receiving ALIGN (1) primitives, then it shall consider the SNW to be invalid.

The phy shall disable SSC (see SAS-3) during SNW-1, SNW-2, and Final-SNW.

#### 5.10.4.2.3.3 SNW-3

SNW-3 allows the phys to exchange phy capabilities (see 5.7) to establish phy parameters used in Train\_Rx-SNW and Train\_Tx-SNW.

Figure 68 defines SNW-3, including:

- a) SNW time (SNWT);
- b) rate change delay time (RCDT); and
- c) speed negotiation transmit time (SNTT).

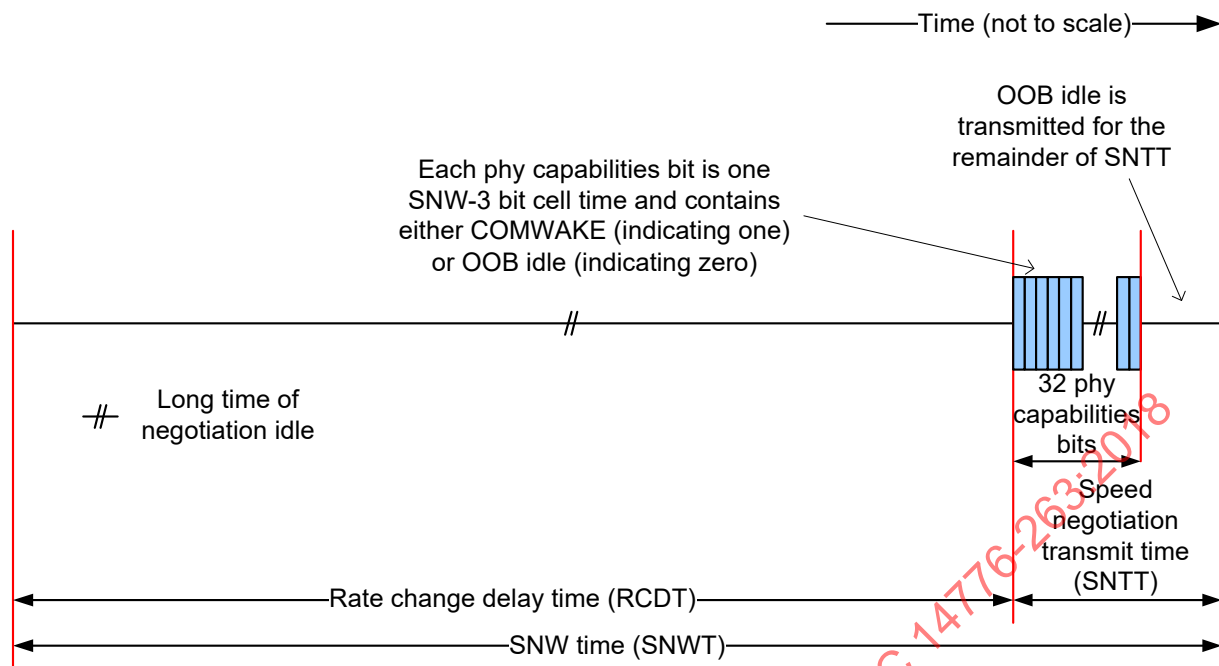


Figure 68 — SNW-3

Table 72 defines the content of each phy capabilities bit.

Table 72 — SNW-3 phy capabilities bit

| Value | Transmitted       |
|-------|-------------------|
| One   | COMWAKE (see 5.6) |
| Zero  | OOB idle          |

If the phy supports SNW-3, then:

- a) the phy shall:
  - 1) transmit negotiation idle for an RCDT;
  - 2) transmit 32 phy capabilities bits (see 5.7); and
  - 3) transmit OOB idle for the remainder of SNTT;
 and
- b) the phy shall receive a 32-bit phy capabilities value from the attached phy.

The phy receives no capabilities bits (i.e., negotiation idle) if the attached phy does not support SNW-3.

If the phy does not support SNW-3, then it shall transmit negotiation idle for the entire SNWT and ignore any phy capabilities bits received.

The first phy capabilities bit (see 5.7) is the START bit and is set to one. Each of the remaining 31 phy capabilities bits is set to one or zero. The receiver shall use the START bit to detect the beginning of the phy capabilities bits and establish the timing for subsequent bits.

The phy shall consider SNW-3 to be valid if it supports SNW-3 and receives at least one supported settings bit set to one (see table 53). If the phy does not support SNW-3 or does not receive at least one supported settings bit set to one, then it shall consider SNW-3 to be invalid.

The phy may transmit with SSC enabled or disabled (see SAS-3) during SNW-3.

#### 5.10.4.2.3.4 Train\_Tx-SNW

##### 5.10.4.2.3.4.1 Phy's transmitter initial condition

If transmitter training is enabled, then:

- if there are trained values, then that phy shall set all of its coefficients to the most recent trained values before originating a phy reset sequence (see 5.10.1); or
- if there are no trained values, then that phy shall set all of its coefficients to a default value before originating a phy reset sequence. The determination of the default value is outside the scope of this standard.

##### 5.10.4.2.3.4.2 Transmitter training

Figure 69 defines the Train\_Tx-SNW, including:

- maximum Train\_Tx-SNW window time (MTXT);
- rate change delay time (RCDT);
- maximum transmitter train time (MTTT); and
- the point at which the transmitter is trained.

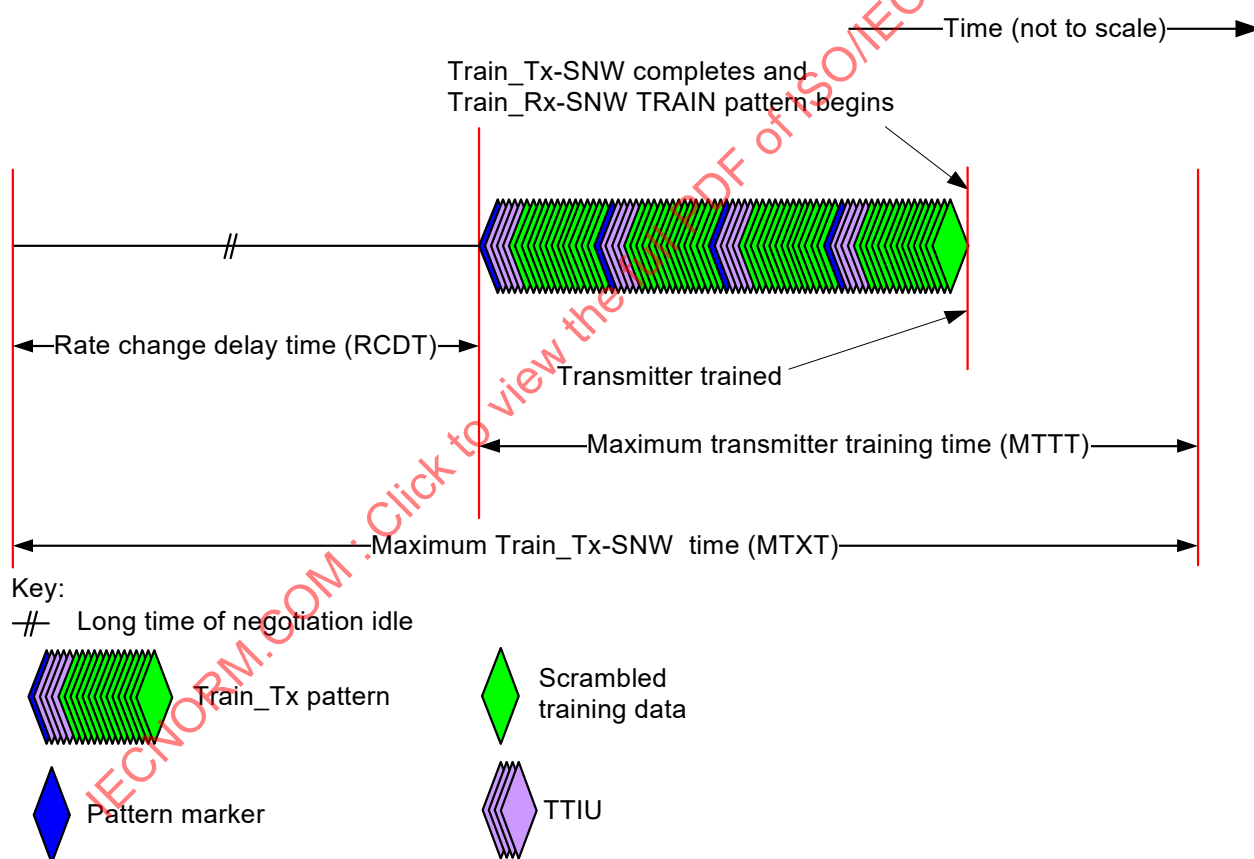


Figure 69 — Train\_Tx-SNW



The Train\_Tx-SNW contains transmitter training patterns formed by the Train\_Tx pattern as defined in table 73.

**Table 73 — Transmitter training pattern**

| Transmitter training pattern | Description                                                                                                                                                                        |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Train_Tx pattern             | Sequence of:<br>1) pattern marker (see 5.10.4.2.3.4.3);<br>2) TTIU (see 5.10.4.2.3.5); and<br>3) 58 data dwords set to 00000000h that are transmitted scrambled and 8b10b encoded. |

The scrambler is the same as that defined for the link layer (see 6.6) and shall be initialized at the end of RCDT. The scrambler shall not be reinitialized for the remainder of the Train\_Tx-SNW.

The phy shall start transmitting Train\_Tx patterns at the end of RCDT. The number of Train\_Tx patterns transmitted is determined by the time required for the phys to complete transmitter training.

After RCDT, the local phy's receiver shall attempt to train the attached phy's transmitter as follows:

- a) if the local phy and the attached phy complete transmitter training within MTTT, then the phy shall start Train\_Rx-SNW (see 5.10.4.2.3.5). At the point the phy completes transmitter training the phy shall consider the Train\_Tx-SNW to be valid; or
- b) if the local phy and the attached phy do not complete transmitter training within MTTT, then the phy shall consider the Train\_Tx-SNW to be invalid.

The phy shall not transmit primitives during Train\_Tx-SNW.

During the Train\_Tx-SNW the phy's transmitter shall transmit a pattern marker (see figure 70) at the start of each Train\_Tx pattern as defined in table 73.

#### 5.10.4.2.3.4.3 Pattern marker

The pattern marker specifies the start of a TTIU.

A pattern marker is formed by a:

- 1) 20 UI (e.g., 1.6 ns at 12 Gbit/s) differential high signal level; and
- 2) 20 UI (e.g., 1.6 ns at 12 Gbit/s) differential low signal level.

Figure 70 shows the pattern marker.

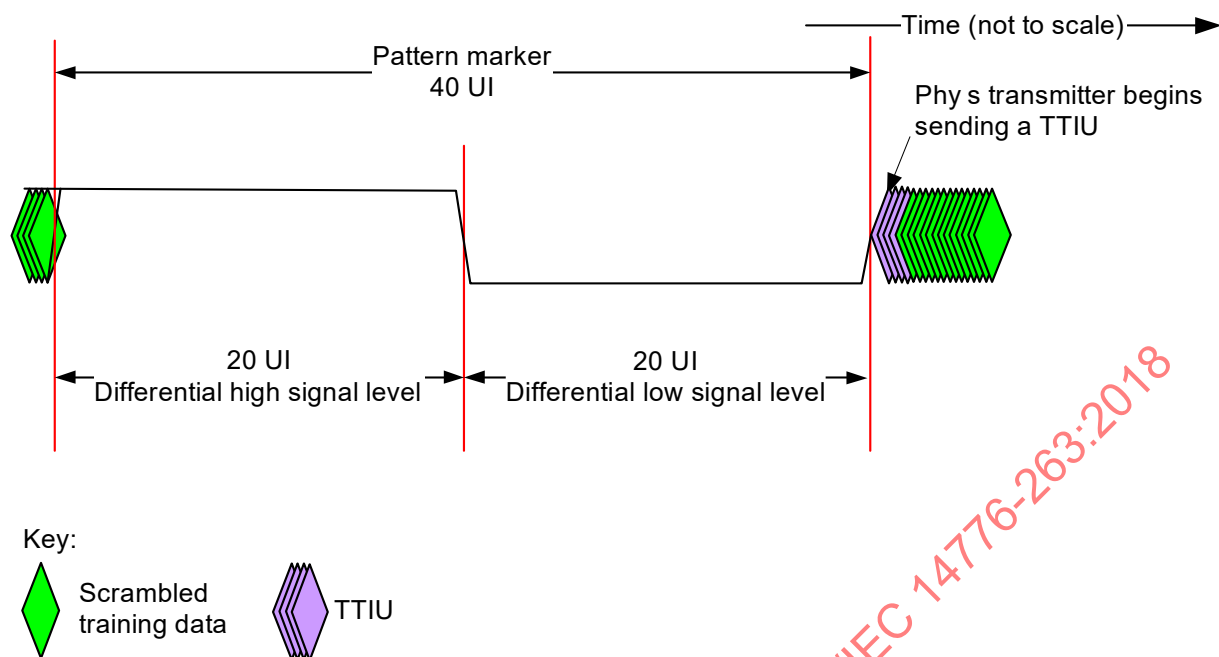


**Figure 70 — Pattern marker transmission**

During the Train\_Tx-SNW if the phy's receiver detects:

- 1) a differential high signal level for greater than or equal to 19 UIs less than or equal to 24 UIs; and
- 2) a differential low signal level for greater than or equal to 19 UIs less than or equal to 21 UIs,

then the phy's receiver shall consider the pattern marker to be valid (see figure 71).

During the Train\_Tx-SNW if the phy's receiver detects:

- a) a differential high signal level for greater than or equal to 13 UIs and less than 19 UIs;
- b) a differential high signal level for greater than 24 UIs;
- c) a differential low signal level for greater than or equal to 13 UIs and less than 19 UIs; or
- d) a differential low signal level for greater than 21 UIs,

then the phy's receiver shall consider the pattern marker to be invalid.

If the phy's receiver does not detect a pattern marker at the beginning of a Train\_Tx pattern then the pattern marker shall be invalid.

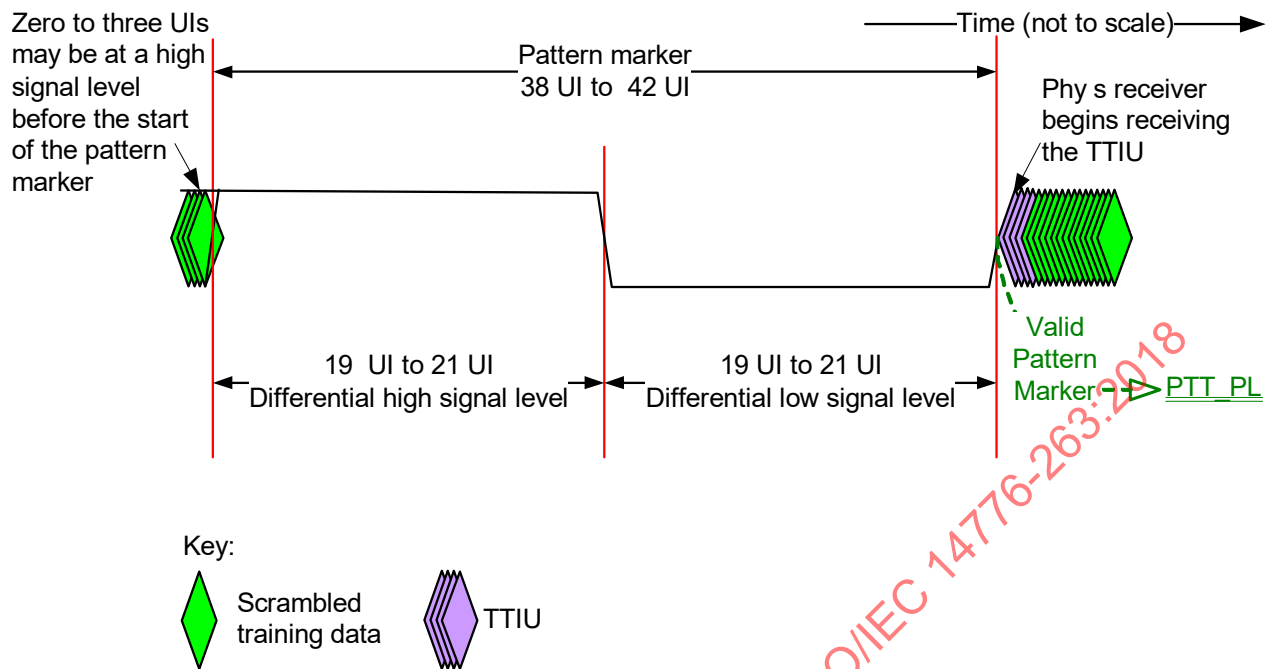


Figure 71 — Valid pattern marker detection

#### 5.10.4.2.3.5 Train\_Rx-SNW

Figure 72 defines the Train\_Rx-SNW, including:

- maximum Train\_Rx-SNW window time (MTWT);
- rate change delay time (RCDT);
- maximum receiver train time (MRTT);
- train lock time (TLT); and
- the point at which the receiver is trained and dword synchronization is acquired.

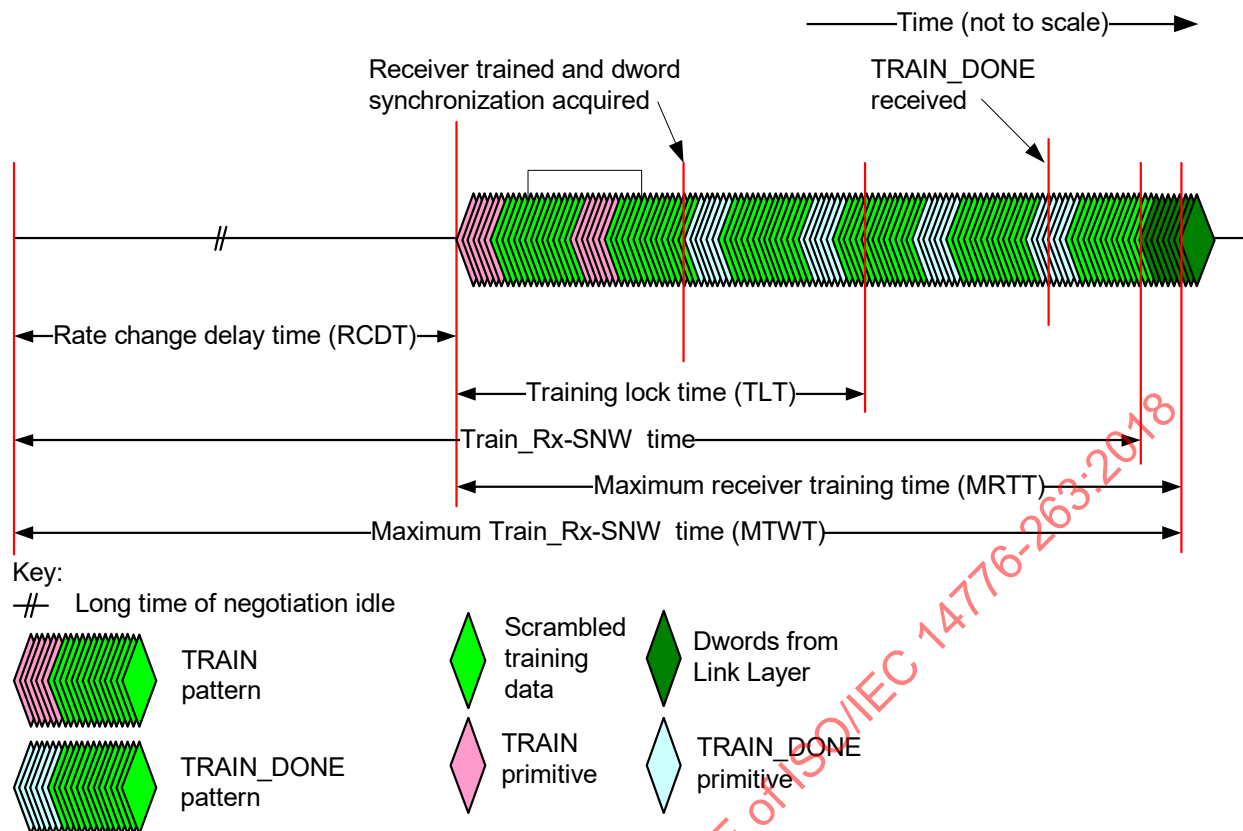


Figure 72 — Train\_Rx-SNW

The Train\_Rx-SNW contains receiver training patterns formed by TRAIN and TRAIN\_DONE (see 6.2) as defined in table 74.

Table 74 — Receiver training patterns

| Receiver training pattern | Description                                                                                                                                   |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| TRAIN pattern             | Sequence of:<br>1) TRAIN primitive sequence; and<br>2) 58 data dwords set to 00000000h that are transmitted scrambled and 8b10b encoded.      |
| TRAIN_DONE pattern        | Sequence of:<br>1) TRAIN_DONE primitive sequence; and<br>2) 58 data dwords set to 00000000h that are transmitted scrambled and 8b10b encoded. |

The scrambler is the same as that defined for the link layer (see 6.6). If there is no Train\_Tx-SNW, then the scrambler shall be initialized at the end of RCDT. If there is a Train\_Tx-SNW, then the scrambler shall be initialized at the end of Train\_Tx-SNW. The scrambler shall not be reinitialized for the remainder of the Train\_Rx-SNW.

If there is no Train\_Tx-SNW, then the phy shall start transmitting TRAIN patterns at the end of RCDT. If a Train\_Tx-SNW occurs, then the phy shall start transmitting TRAIN patterns at the end of the transmitter

training (see 5.10.4.2.3.4.2). The first TRAIN pattern may have either starting disparity. The number of TRAIN patterns transmitted is determined by the time required for the phy's receiver to complete training and acquire dword synchronization. The phy shall transmit at least one TRAIN pattern and shall transmit a minimum of four TRAIN\_DONE patterns:

- a) if the phy achieves dword synchronization within the TLT, then, after completing transmission of the current TRAIN pattern, the phy shall change from transmitting TRAIN patterns to transmitting TRAIN\_DONE patterns for the remainder of the Train\_Rx-SNW window time (i.e., the remainder of the SNW time); or
- b) if the phy does not achieve dword synchronization within the TLT, then the phy shall continue transmitting TRAIN patterns for the remainder of the MRTT (i.e., the remainder of the SNW time).

The phy shall not compare the received data characters to the expected transmitted data characters in the receiver training pattern.

If the phy:

- a) transmits four or more TRAIN\_DONE patterns; and
- b) receives a minimum of one TRAIN\_DONE primitive sequence before MRTT,

then the phy shall:

- a) after completing transmission of the current TRAIN\_DONE pattern, transmit at least one more TRAIN\_DONE pattern, stop transmitting TRAIN\_DONE patterns, and start transmitting dwords from the link layer; and
- b) consider the Train\_Rx-SNW to be valid.

If the phy does not receive a TRAIN\_DONE primitive sequence before MRTT and transmits four or more TRAIN\_DONE patterns, then it shall consider the Train\_Rx-SNW to be invalid.

#### 5.10.4.2.4 SAS speed negotiation sequence

The SAS speed negotiation sequence consists of a set of SNWs (see 5.10.4.2.3) in the order shown in figure 73.

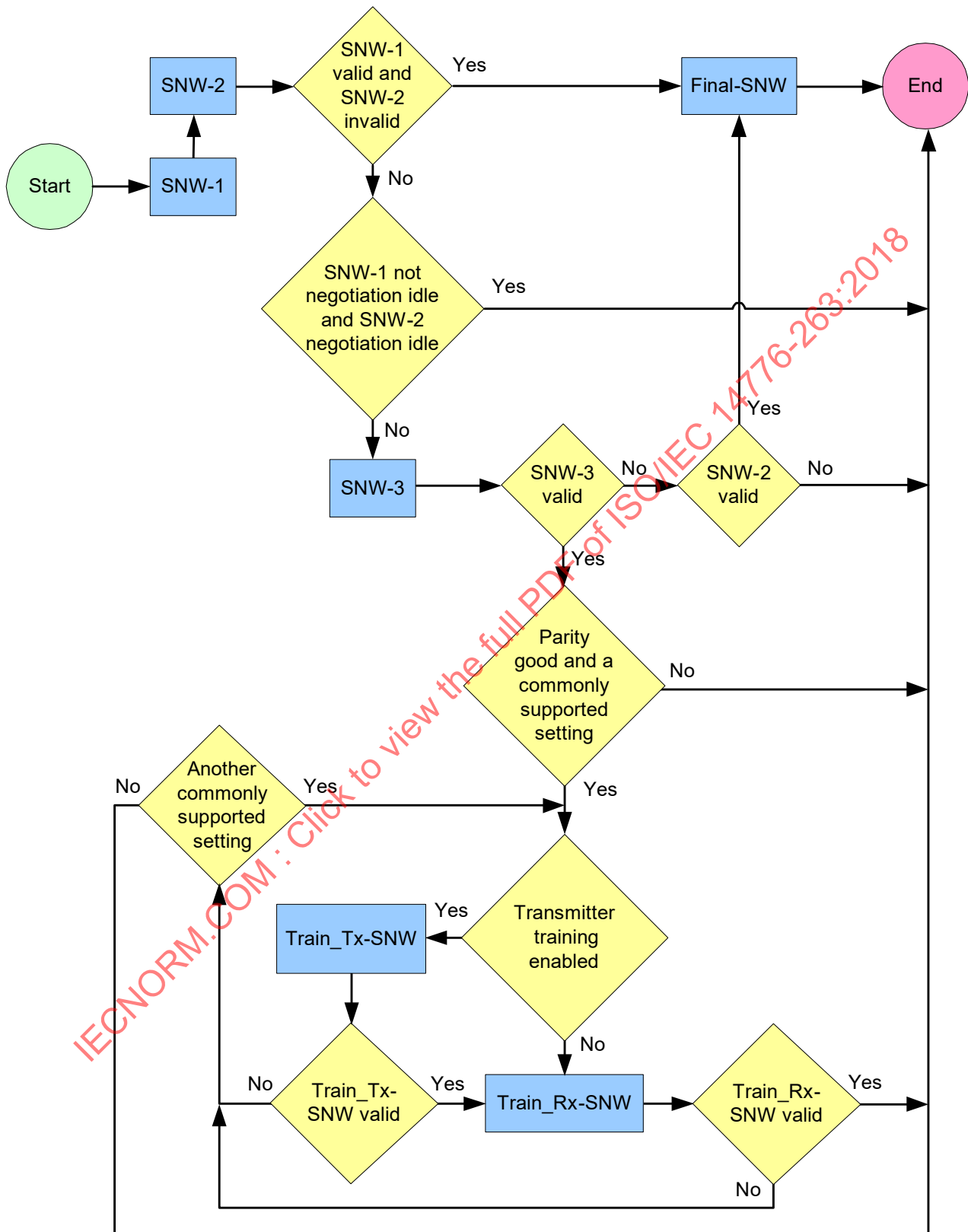


Figure 73 — SAS speed negotiation sequence SNW flowchart

A phy shall not support the following combinations of supported SNWs:

- a) no SNWs; and
- b) SNW-1 and SNW-3 only.

NOTE 11 - If SNW-1 is successful and the combination of SNW-1 and SNW-3 only is used, then the phy is not able to reach SNW-3.

A phy shall detect whether the physical link is negotiation idle during SNW-1 and SNW-2, even if the phy does not support that SNW. If the phy detects:

- a) SNW-1 is not negotiation idle; and
- b) SNW-2 is negotiation idle,

then the phy shall:

- a) end the speed negotiation sequence without progressing to SNW-3 as shown in figure 73; and
- b) transmit negotiation idle and ignore the SNW information received during SNW-3 as defined in the SP state machine (see 5.12.4.3).

NOTE 12 - This avoids causing an attached phy compliant with SAS-1.1 to misdetect a SATA port selector.

Train\_Rx-SNW and Train\_Tx-SNW are based on the highest priority commonly supported setting that has not been tried based on the outgoing and incoming SNW-3 supported settings bits (see 5.10.4.2.3).

If a Train\_Rx-SNW or Train\_Tx-SNW is invalid and there are additional, untried, commonly supported settings exchanged during SNW-3, then a new Train\_Rx-SNW and Train\_Tx-SNW, if any, shall be performed based on the next highest, untried, commonly supported settings.

A phy reset problem occurs:

- a) after Final-SNW, if Final-SNW is invalid (see 5.12.4.9);
- b) after SNW-3, if SNW-3 is valid and the parity is bad (see 5.12.4.11);
- c) during a Train\_Tx-SNW, if the MTTT timer expires or the Pattern Lock Lost Timeout timer expires and there are no additional, untried, commonly supported settings (see 5.12.4.13); or
- d) after a Train\_Rx-SNW, if the Train\_Rx-SNW is invalid and there are no additional, untried, commonly supported settings (see 5.12.4.14).

Phy reset problems terminate the SAS speed negotiation sequence and are counted and reported in the PHY RESET PROBLEM COUNT field in the SMP REPORT PHY ERROR LOG page (see 9.4.3.11) and the Protocol Specific Port log page (see 9.2.8.1).

#### 5.10.4.2.5 SAS speed negotiation sequence examples

Figure 74 shows speed negotiation between a phy A and a phy B where both phys participate in:

- 1) SNW-1, supported by both phys;
- 2) SNW-2, supported by both phys;
- 3) SNW-3, supported by both phys; and
- 4) Train\_Rx-SNW.

After phy A and phy B detect:

- a) SNW-1 valid;
- b) SNW-2 valid; and
- c) SNW-3 valid,

the phys proceed to Train\_Rx-SNW negotiating based on SNW-3 phy capabilities bits.

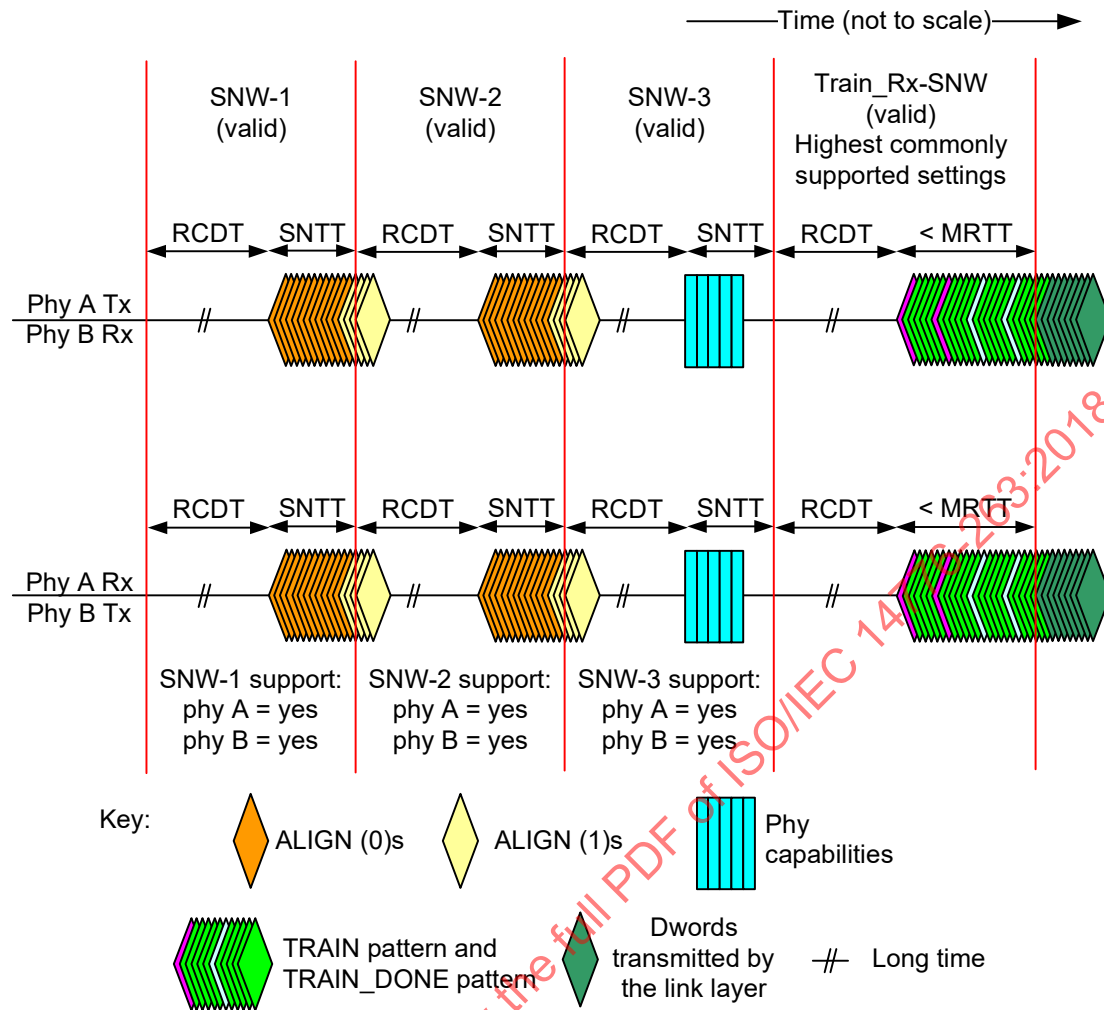


**Figure 74 — SAS speed negotiation sequence (both phys SNW-1 through Train\_Rx-SNW with no Train\_Tx-SNW)**

Figure 75 shows speed negotiation between a phy A and a phy B where both phys participate in:

- 1) SNW-1, supported by both phys;
- 2) SNW-2, supported by both phys;
- 3) SNW-3, supported by both phys;
- 4) Train\_Tx-SNW; and
- 5) Train\_Rx-SNW.

After phy A and phy B detect:

- a) SNW-1 valid;
- b) SNW-2 valid; and
- c) SNW-3 valid,

the phys proceed to Train\_Tx-SNW and Train\_Rx-SNW based on SNW-3 phy capabilities bits.



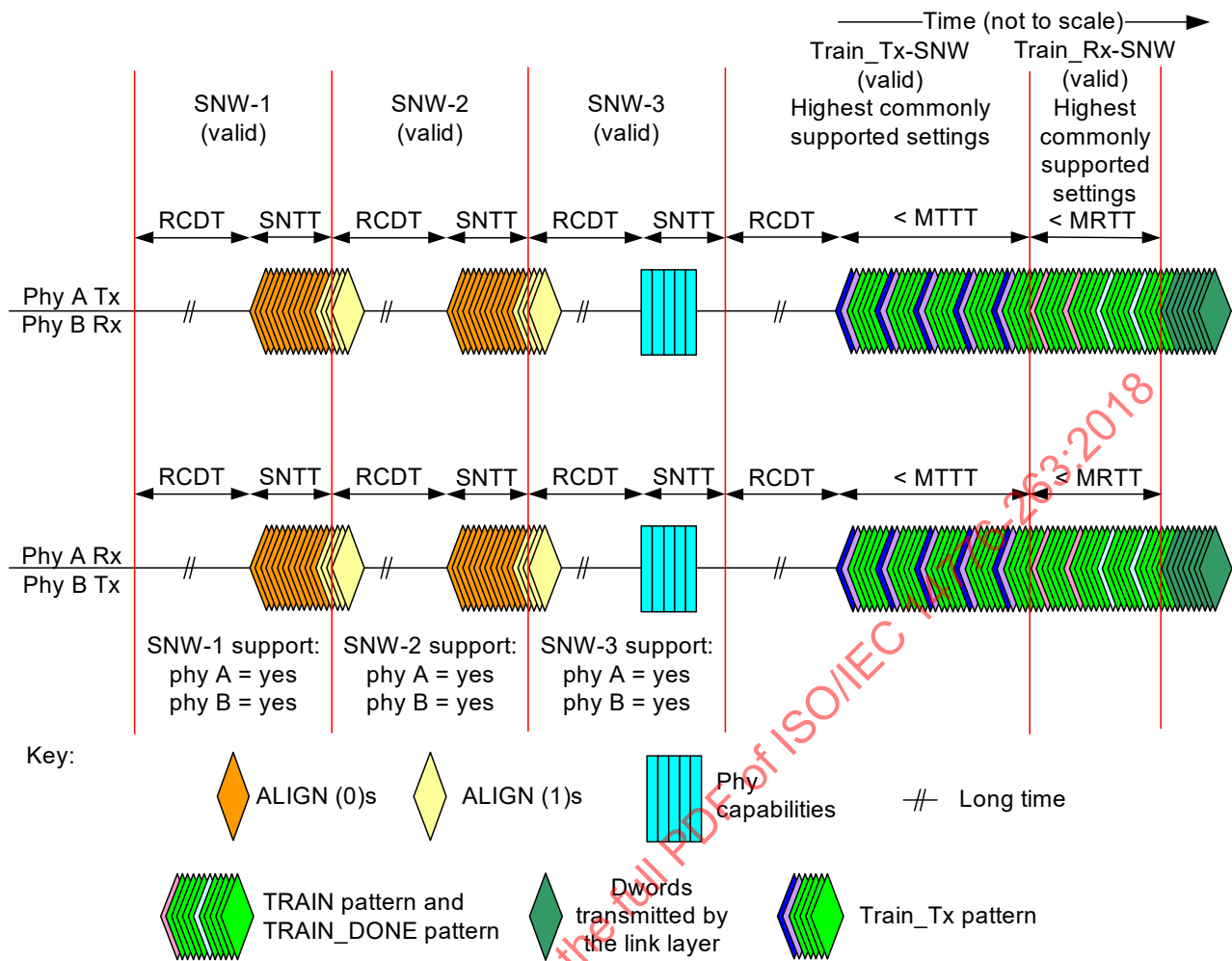


**Figure 75 — SAS speed negotiation sequence (both phys SNW-1 through Train\_Rx-SNW with Train\_Tx-SNW)**

Figure 76 shows speed negotiation between a phy A and phy B where phys participate in:

- 1) SNW-1, supported by phy A but not by phy B;
- 2) SNW-2, supported by both phys;
- 3) SNW-3, supported by phy A but not by phy B; and
- 4) Final-SNW negotiating 3 Gbit/s.

After phy A and phy B detect:

- a) SNW-1 invalid;
- b) SNW-2 valid; and
- c) SNW-3 invalid,

the phys proceed to Final-SNW negotiating 3 Gbit/s.

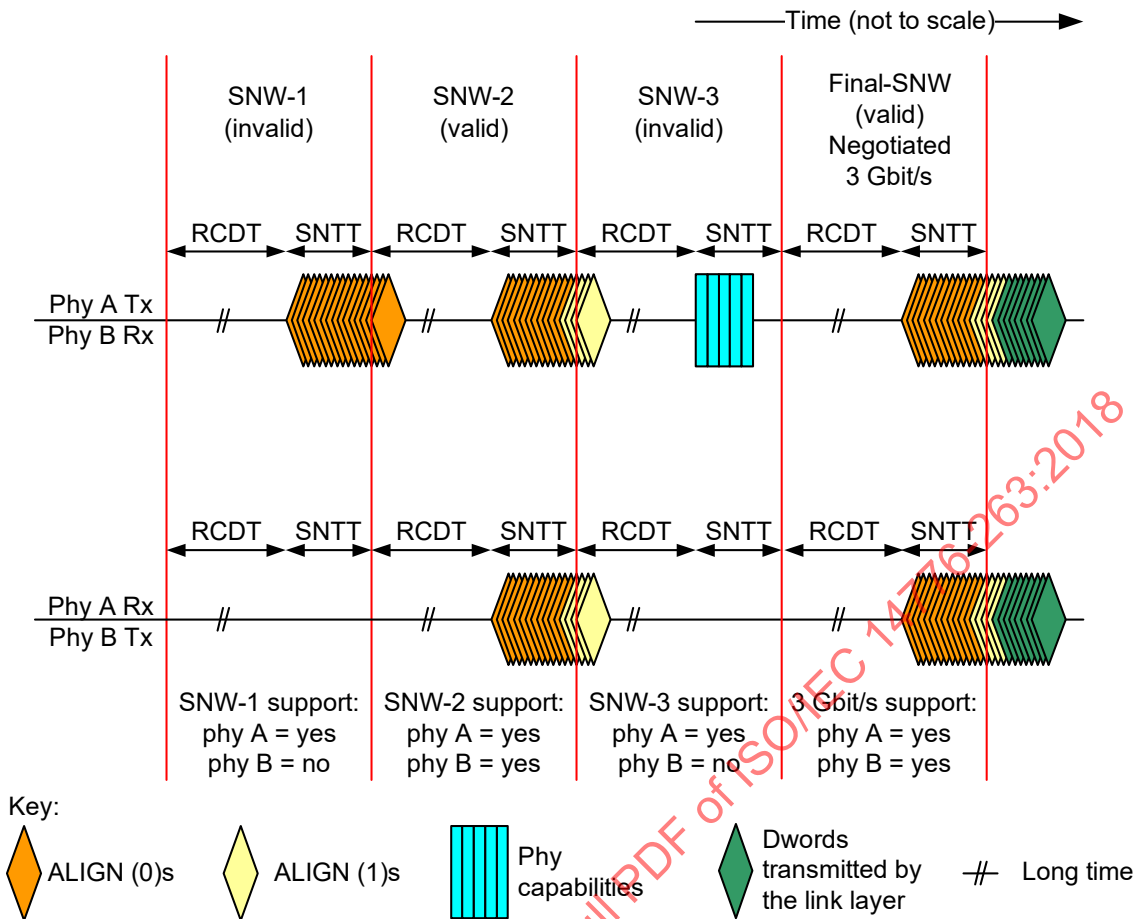


**Figure 76 — SAS speed negotiation sequence (phy A: SNW-1 through SNW-3, phy B: SNW-2 only)**

Figure 77 shows speed negotiation between a phy A and phy B where the phys participate in:

- 1) SNW-1, supported by phy B but not by phy A; and
- 2) SNW-2, supported by neither phy.

After phy A and phy B detect:

- a) SNW-1 invalid; and
- b) SNW-2 invalid,

phy A detects SNW-3 invalid.

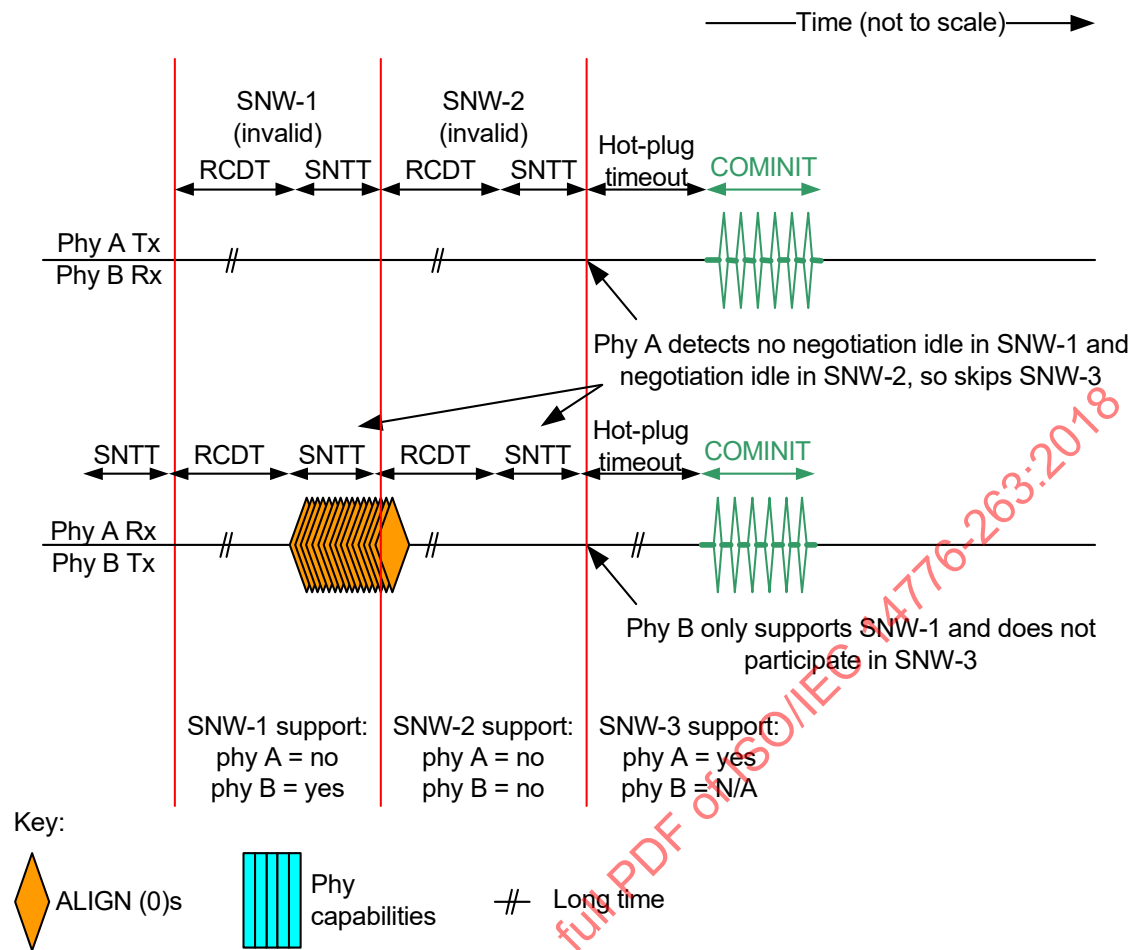


Figure 77 — SAS speed negotiation sequence (phy A: SNW-3 only, phy B: SNW-1 only)

Figure 78 shows a speed negotiation sequence where phy B does not achieve dword synchronization during Final-SNW, creating a phy reset problem. If this occurs, then the handshake is not complete and the phy reset sequence is retried.

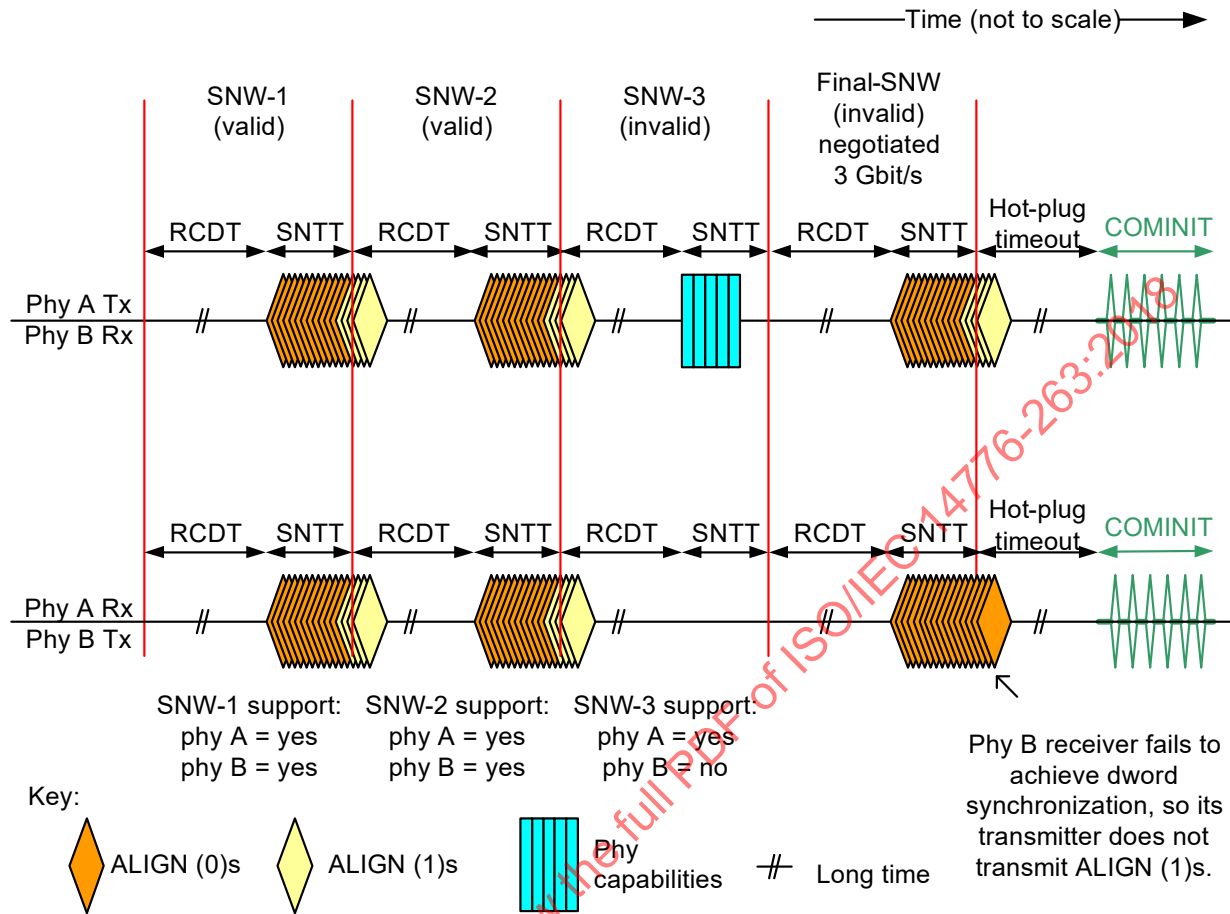


Figure 78 — SAS speed negotiation sequence - phy reset problem in Final-SNW

Figure 79 shows a speed negotiation sequence in which a phy reset problem is encountered in SNW-3 because the phys do not exchange the phy capabilities bits properly (e.g., due to a parity error).

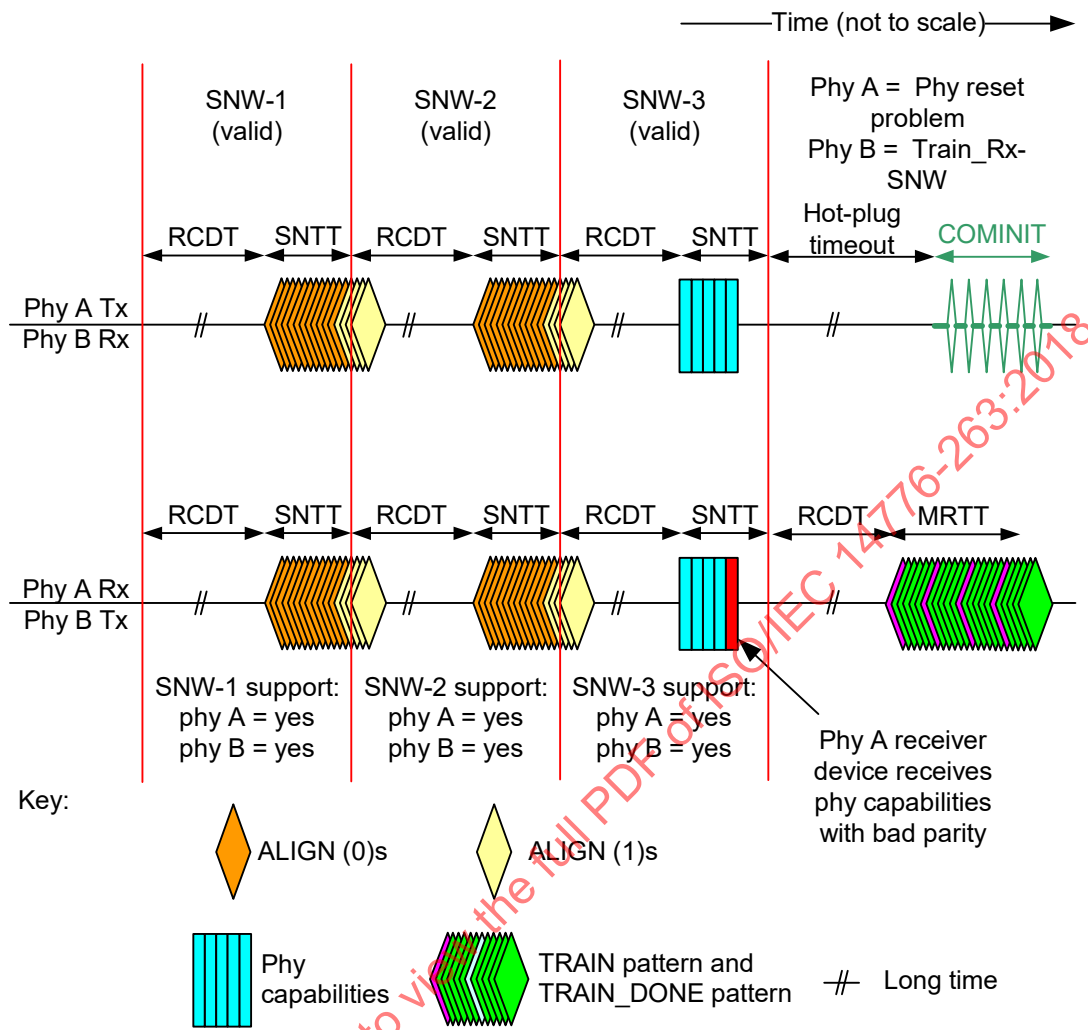


Figure 79 — SAS speed negotiation sequence - phy reset problem in SNW-3

Figure 80 shows a speed negotiation sequence in which a phy reset problem is encountered in Train\_Rx-SNW because either phy does not complete training within MRTT. This example assumes that only one commonly supported setting is exchanged in the phy capabilities bits.

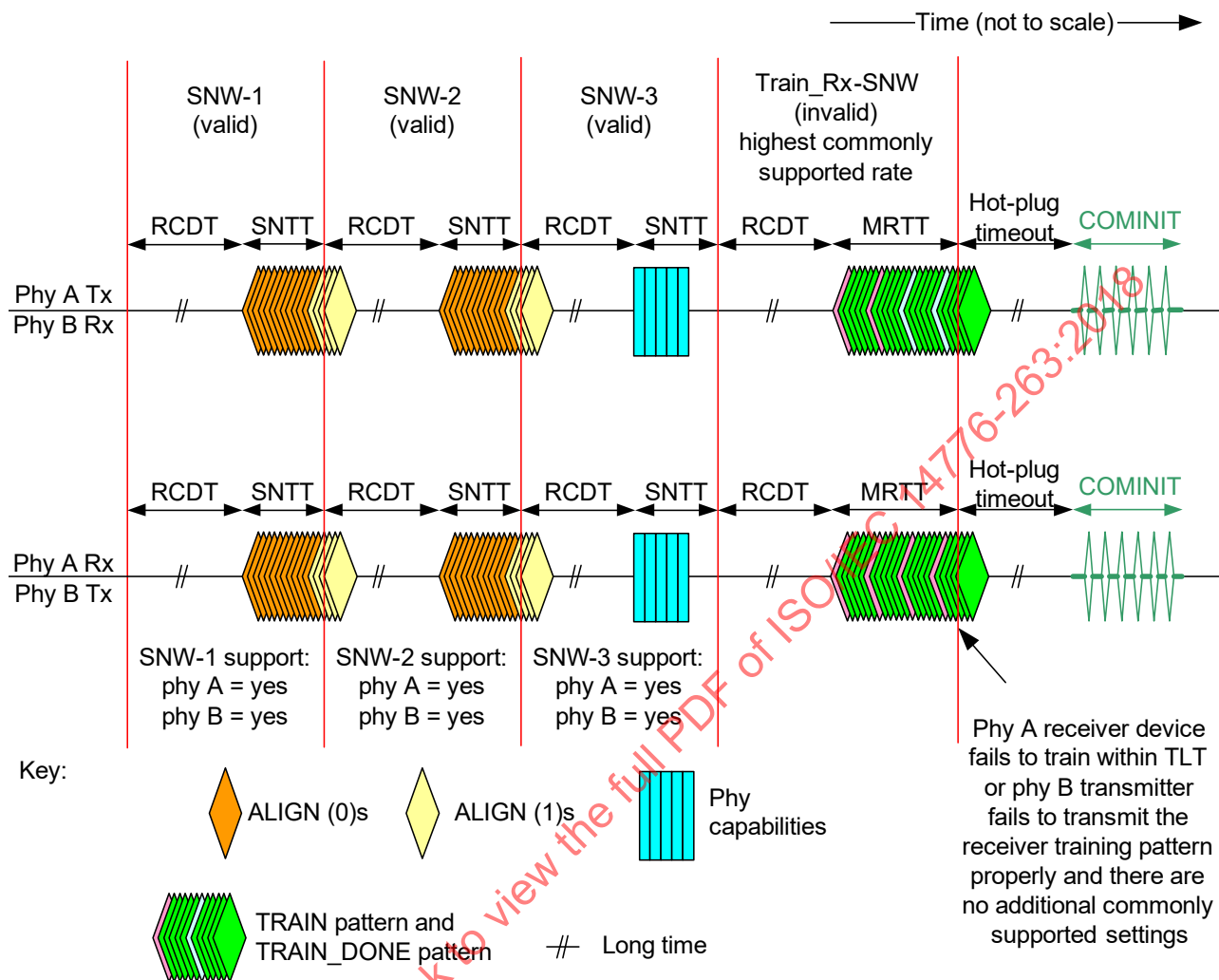


Figure 80 — SAS speed negotiation sequence - phy reset problem in Train\_Rx-SNW

Figure 81 shows two Train\_Rx-SNWs, where supported settings bits are exchanged that contain more than one commonly supported setting and the Train\_Rx-SNW using the highest commonly supported setting is invalid, so a second Train\_Rx-SNW is performed using the next highest commonly supported setting.

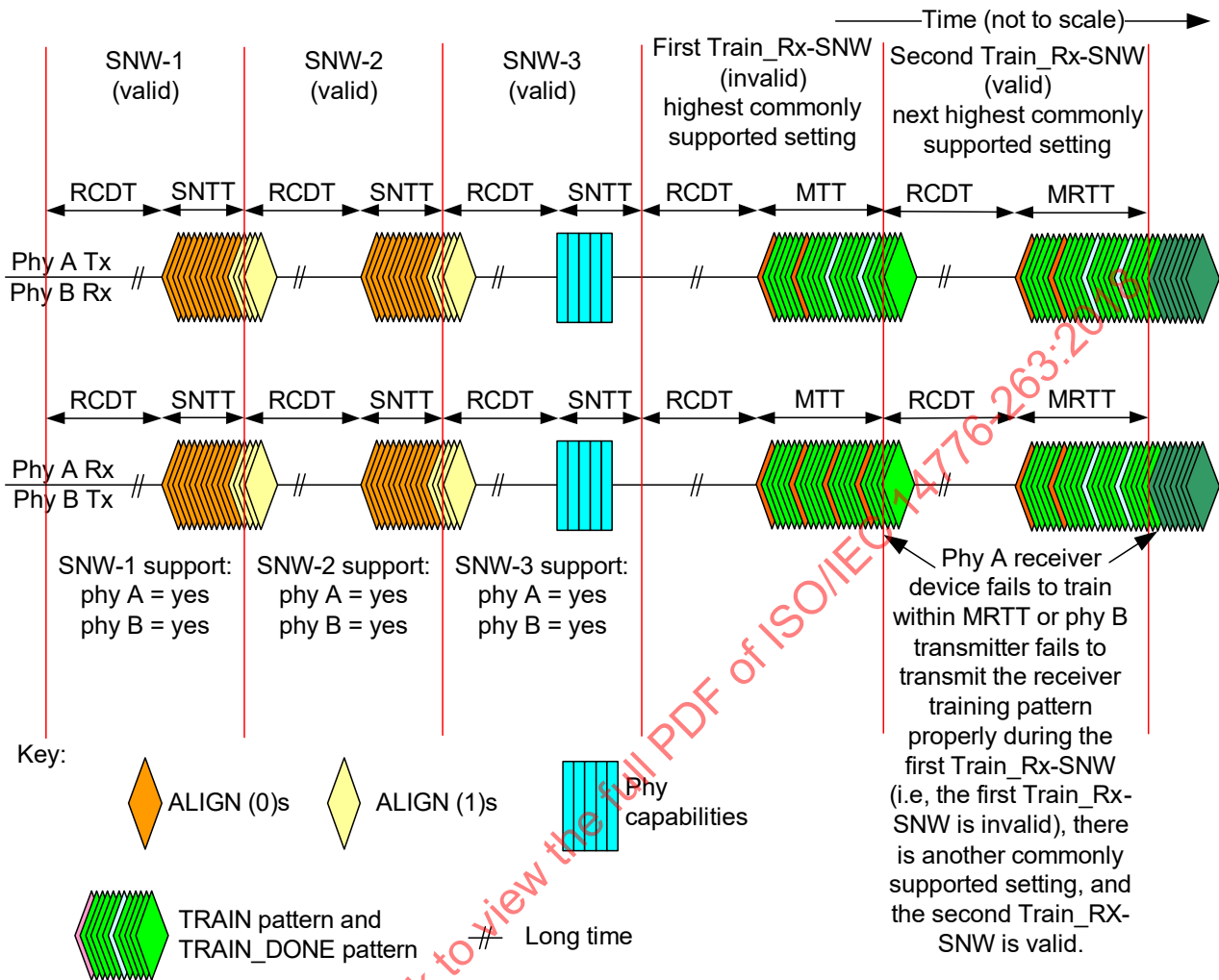


Figure 81 — SAS speed negotiation sequence - multiple Train\_Rx-SNWs

For more examples of SAS speed negotiations, see Annex B.

#### 5.10.4.2.6 Train\_Tx pattern sequence

##### 5.10.4.2.6.1 Train\_Tx pattern sequence overview

If SNW-3 indicates commonly supported settings that require transmitter training (see table 56), then the local phy and the attached phy shall exchange a sequence of Train\_Tx patterns that cause each phy's transmitter to be trained. The local phy and the attached phy exchange information in TTIUs that:

- indicate the current status of the local phy's transmitter; and
- specify adjustments to the attached phy's transmitter.

The sequencing of adjustments to the transmitter is defined in the PTT state machines (see 5.14).

#### 5.10.4.2.6.2 Train\_Tx pattern initial sequence

After RCDT during a Train\_Tx-SNW, (see 5.10.4.2.3.4) the local phy and the attached phy both begin transmitting and receiving Train\_Tx patterns. The point at which a transmitter training pattern lock occurs at the local phy's receiver may occur before or after a transmitter training pattern lock occurs at the attached phy's receiver.

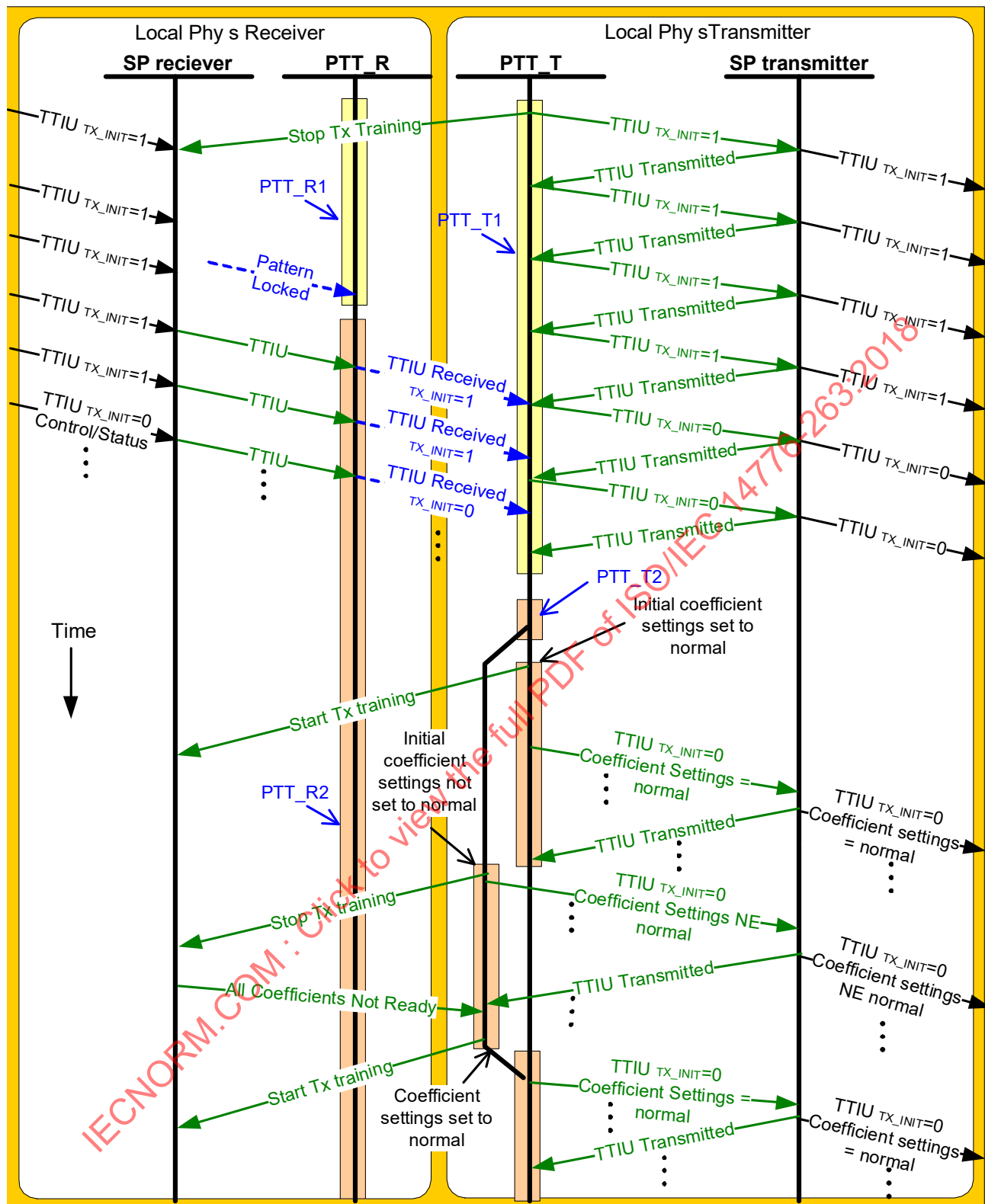
The PTT\_T state machine (see 5.14.4.1) is informed:

- a) that the local phy's receiver is receiving TTUUs when the PTT\_T1 state (see 5.14.4.3) receives a TTUU Received message from the PTT\_R2 state (see 5.14.5.4); and
- b) that the attached phy's receiver is receiving TTUUs when the PTT\_T1 state receives a TTUU Received (Attached Transmitter Initialized) message from the PTT\_R2 state.

EXAMPLE 1 - Figure 82 shows the initial sequence of a local phy in which pattern lock occurs before the attached phy achieves pattern lock.

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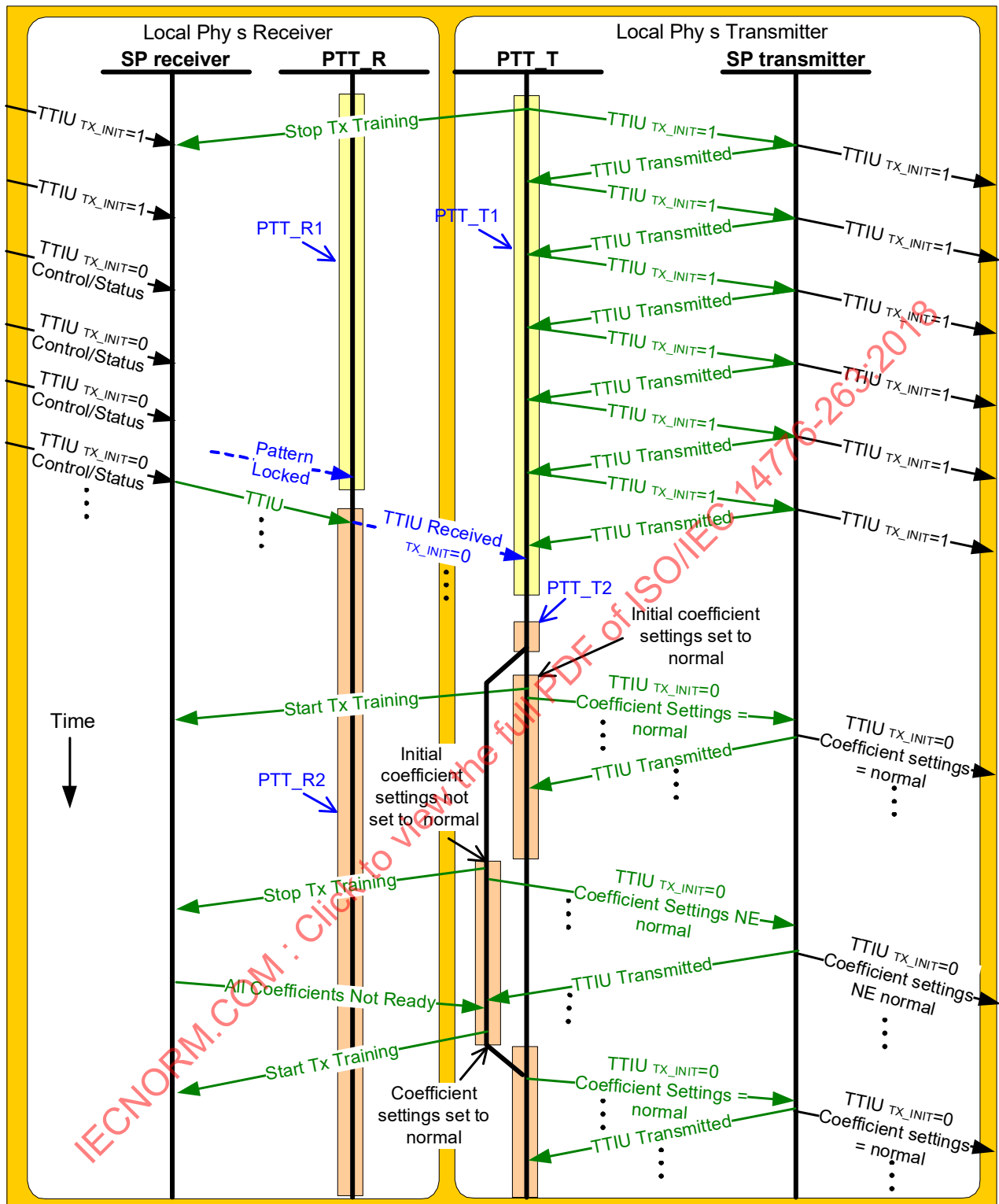
Key: Start Tx Training = Attached Physical Transmitter Training (Start) message  
Stop Tx Training = Attached Physical Transmitter Training (Stop) message

Processing PTT state name →

Information sent or received from a SP receiver or SP transmitter →

**Figure 82 — Local phy achieves pattern lock before the attached phy achieves pattern lock**

EXAMPLE 2 -Figure 83 shows the initial sequence of a local phy in which pattern lock occurs after the attached phy achieves pattern lock.



Key: Start Tx Training = Attached Physical Transmitter Training (Start) message

Stop Tx Training = Attached Physical Transmitter Training (Stop) message

Processing PTT state name  $\longrightarrow$

Information sent or received from a SP receiver or SP transmitter →

**Figure 83 — Local phy achieves pattern lock after the attached phy achieves pattern lock**

### 5.10.4.2.6.3 Train\_Tx pattern handshake sequence

#### 5.10.4.2.6.3.1 Train\_Tx pattern handshake sequence overview

During a Train\_Tx-SNW (see 5.10.4.2.3.4) after the local phy and the attached phy have both completed initialization (i.e., the local phy has received valid TTIUs and verified that the attached phy is receiving valid TTIUs) the attached phy's receiver begins training the local phy's transmitter.

The attached phy's receiver may request that the local phy's transmitter coefficients be:

- a) held at the current value;
- b) set to a no\_equalization value;
- c) set to a reference\_1 value;
- d) set to a reference\_2 value;
- e) incremented (see table 64); or
- f) decremented (see table 64).

#### 5.10.4.2.6.3.2 Attached phy's receiver increment or decrement request

The attached phy's receiver only requests changes to a local phy's transmitter coefficient if the local phy's transmitter is indicating a status of ready on all the local phy's transmitter coefficients (see 5.14.3).

The local phy's transmitter responds to the attached phy's receiver request by adjusting the specified coefficient as requested. After the specified coefficient is adjusted the local phy's transmitter indicates the completion of the coefficient adjustment by indicating to the attached phy's receiver a status of:

- a) update complete;
- b) minimum; or
- c) maximum.

After the attached phy's receiver requests one or more of the local phy's transmitter coefficients be updated, the attached phy does not attempt to do analysis of a training pattern until after it has received a status of update complete, maximum, or minimum for all the local phy's transmitter coefficients that were updated (see 5.14.3).

The processing of the attached phy's receiver coefficient adjustment requests is handled by the:

- a) PTT\_GC1 state machine (see 5.14.9);
- b) PTT\_GC2 state machine (see 5.14.10); and
- c) PTT\_GC3 state machine (see 5.14.11).

The processing of the local phy's transmitter coefficient adjustments is handled by the:

- a) PTT\_SC1 state machine (see 5.14.6);
- b) PTT\_SC2 state machine (see 5.14.7); and
- c) PTT\_SC3 state machine (see 5.14.8).

EXAMPLE 1 - Figure 84 shows a handshake sequence in which the attached phy's receiver requests two increments to coefficient 1 where the response to the first increment is an update complete and the response to the second increment is a maximum.

EXAMPLE 2 - Figure 85 shows a handshake sequence in which the attached phy's receiver requests a decrement to coefficient 1 where the response to the decrement is a minimum followed by a request for an increment where the response to the increment is an update complete.

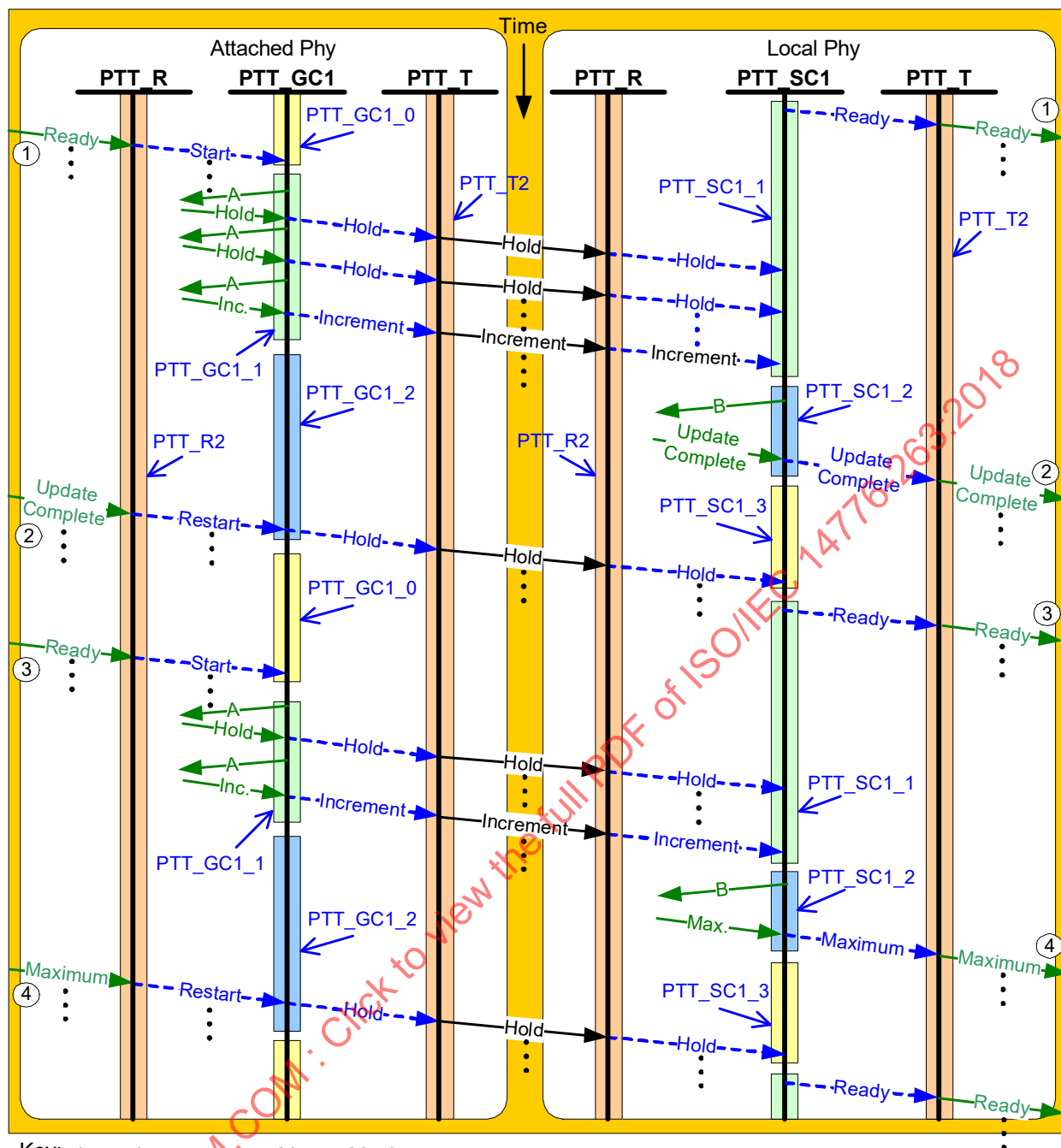
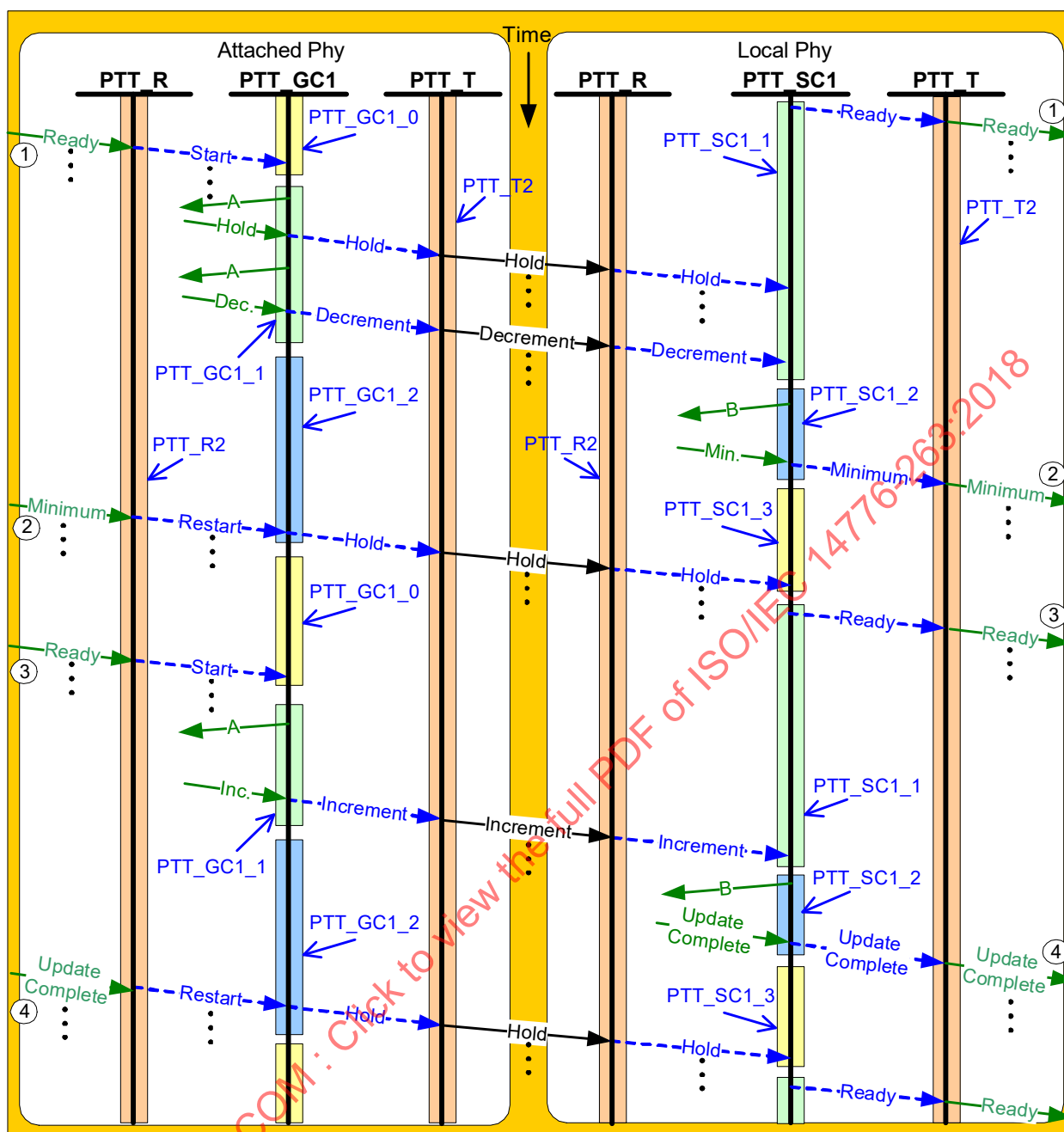


**Figure 84 — Attached receiver handshake sequence (requesting two increments to coefficient 1)**



Key: Inc. = Increment Dec. = Decrement Max. = Maximum

—A—> Get Current Coefficient 1 message to local SP receiver

—B—> Adjust Coefficient 1 message to local SP transmitter

Processing PTT state name —>

Information sent or received from a SP receiver or SP transmitter —>

Note 1 - Not shown in this figure is the attached phy's receiver PTT\_R state machine sending coefficient 1 status (i.e., ready, update complete, minimum, or maximum) to the attached SP receiver.

Note 2 - Not shown in this figure is the attached SP receiver or local SP receiver.

Note 3 - Not shown in this figure is the attached SP transmitter or local SP transmitter.

**Figure 85 — Attached receiver handshake sequence (requesting a decrement and an increment to coefficient 1)**

#### 5.10.4.2.6.3.3 Attached phy's receiver reference\_1, reference\_2, or no\_equalization request

The attached phy's receiver only requests a local phy's transmitter coefficients be set to a reference\_1 value, reference\_2 value, or no\_equalization value after the local phy's transmitter indicates a status of ready for all the local phy's transmitter coefficients (see 5.14.3).

The local phy's transmitter responds to the attached phy's receiver request by adjusting all the coefficients to the reference\_1 value, reference\_2 value, or no\_equalization value. As each coefficient is adjusted the local phy's transmitter indicates the completion of the coefficient adjustment by indicating to the attached phy's receiver a status of:

- a) update complete;
- b) minimum; or
- c) maximum.

After the attached phy's receiver requests a local phy's transmitter be set to its reference\_1 value, reference\_2 value, or no\_equalization value the attached phy does not attempt to start the analysis of a training pattern until it has received, for all the coefficients (see 5.14.3), a status of:

- a) update complete;
- b) minimum; or
- c) maximum.

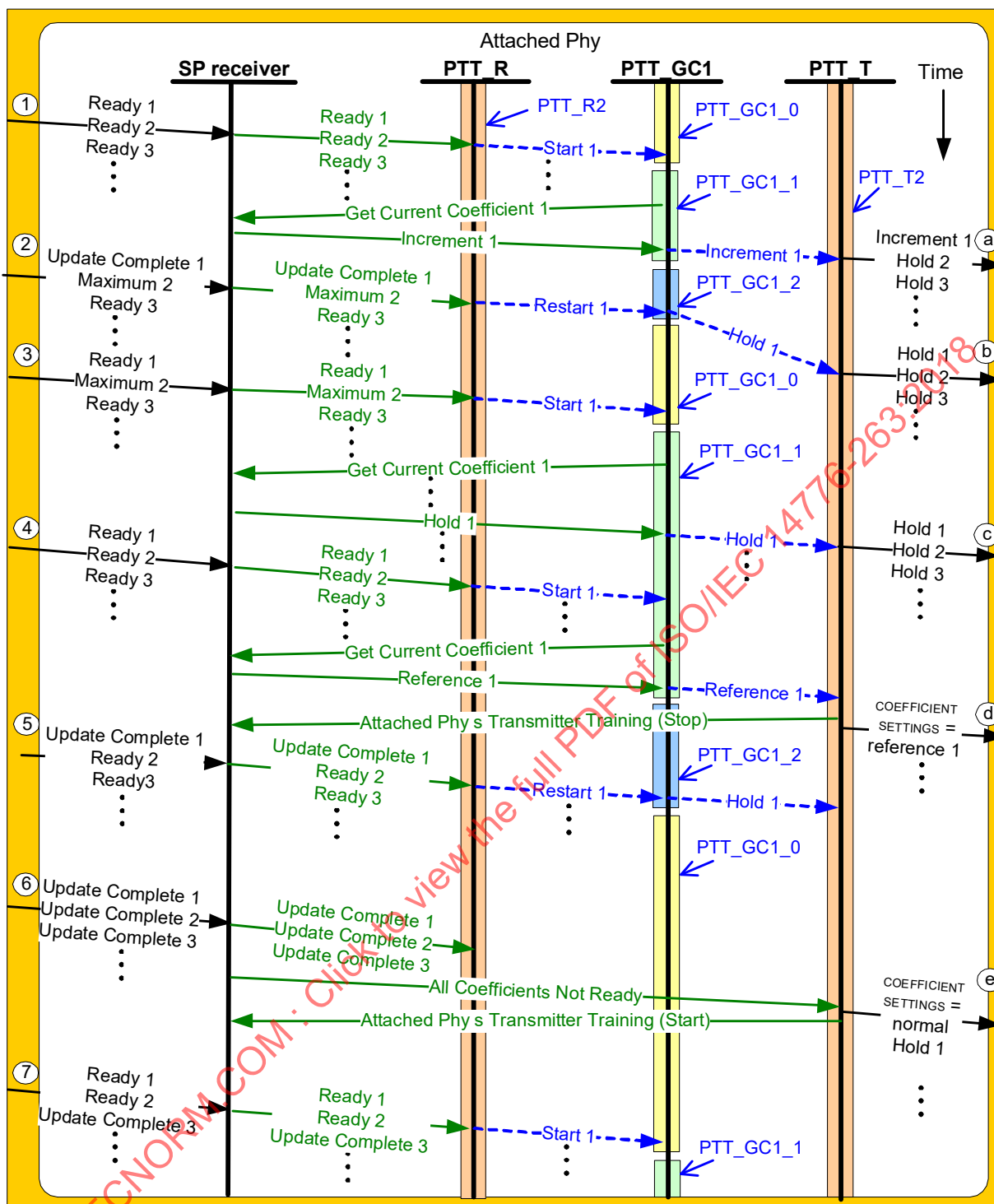
The processing of the attached phy's receiver coefficient setting requests is handled by the:

- a) PTT\_GC1 state machine (see 5.14.9);
- b) PTT\_GC2 state machine (see 5.14.10); and
- c) PTT\_GC3 state machine (see 5.14.11).

The processing of the local phy's transmitter coefficient setting is handled by the:

- a) PTT\_SC1 state machine (see 5.14.6);
- b) PTT\_SC2 state machine (see 5.14.7); and
- c) PTT\_SC3 state machine (see 5.14.8).

EXAMPLE - Figure 86 shows the attached phy's side and figure 87 shows the local phy's side of a handshake sequence in which the attached phy's receiver requests an increment to coefficient 1 followed by a request from the attached phy's receiver to set the local phy's transmitter to its no equalization value. The time sequencing between figure 86 and figure 87 is indicated using circled numbers and circled letters.



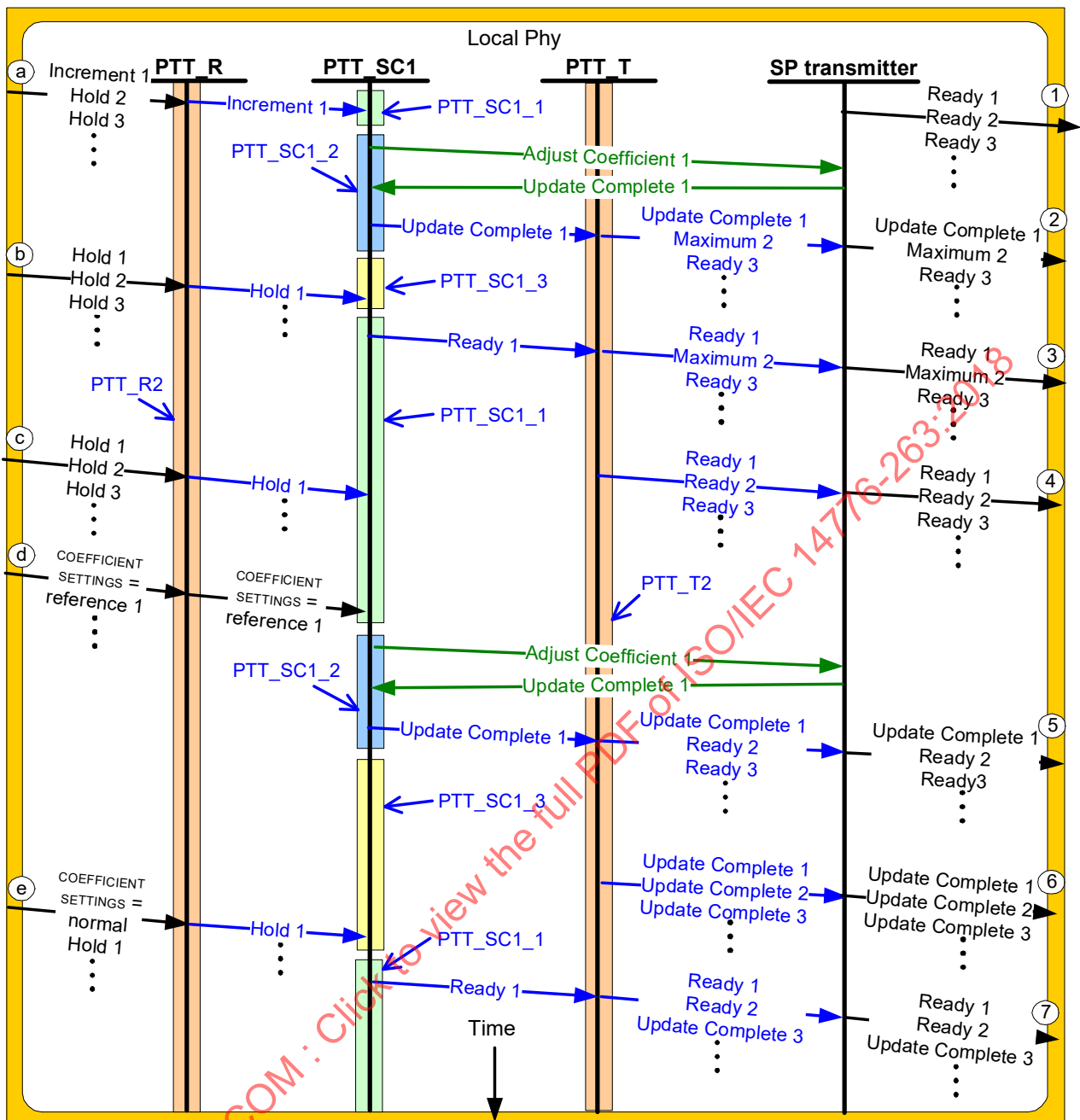
Key:  Processing PTT state name 

Information sent or received from a SP receiver or SP transmitter →

Note 1 - Not shown in this figure is the attached phy s receiver PTT\_R state machine sending coefficient 1 status (i.e., ready, update complete, minimum, or maximum) to the attached SP receiver.

Note 2 - Not shown in this figure are all the messages related to the coefficient 2 increment.

**Figure 86 — Handshake sequence to set local phy's receiver coefficients to no\_equalization values (attached phy)**



Key: Processing PTT state name →

Information sent or received from a SP receiver or SP transmitter →

Note - Not shown in this figure is the PTT\_SC2 state machine notification of coefficient 2 to PTT\_T of aa status change of maximum to ready.

**Figure 87 — Handshake sequence to set local phy's receiver coefficients to no\_equalization values (local phy)**

#### 5.10.4.2.6.4 Train\_Tx pattern completion sequence

The Train\_Tx-SNW (see 5.10.4.2.3.4) completes when:

- the local phy's receiver determines attached phy's transmitter is trained (see 5.14.3); and
- the attached phy's receiver indicates the local phy's transmitter is trained (see 5.14.5.4.1).



EXAMPLE 1 - Figure 88 shows the local phy's receiver completion of training before the attached phy's receiver indicates it has completed training.

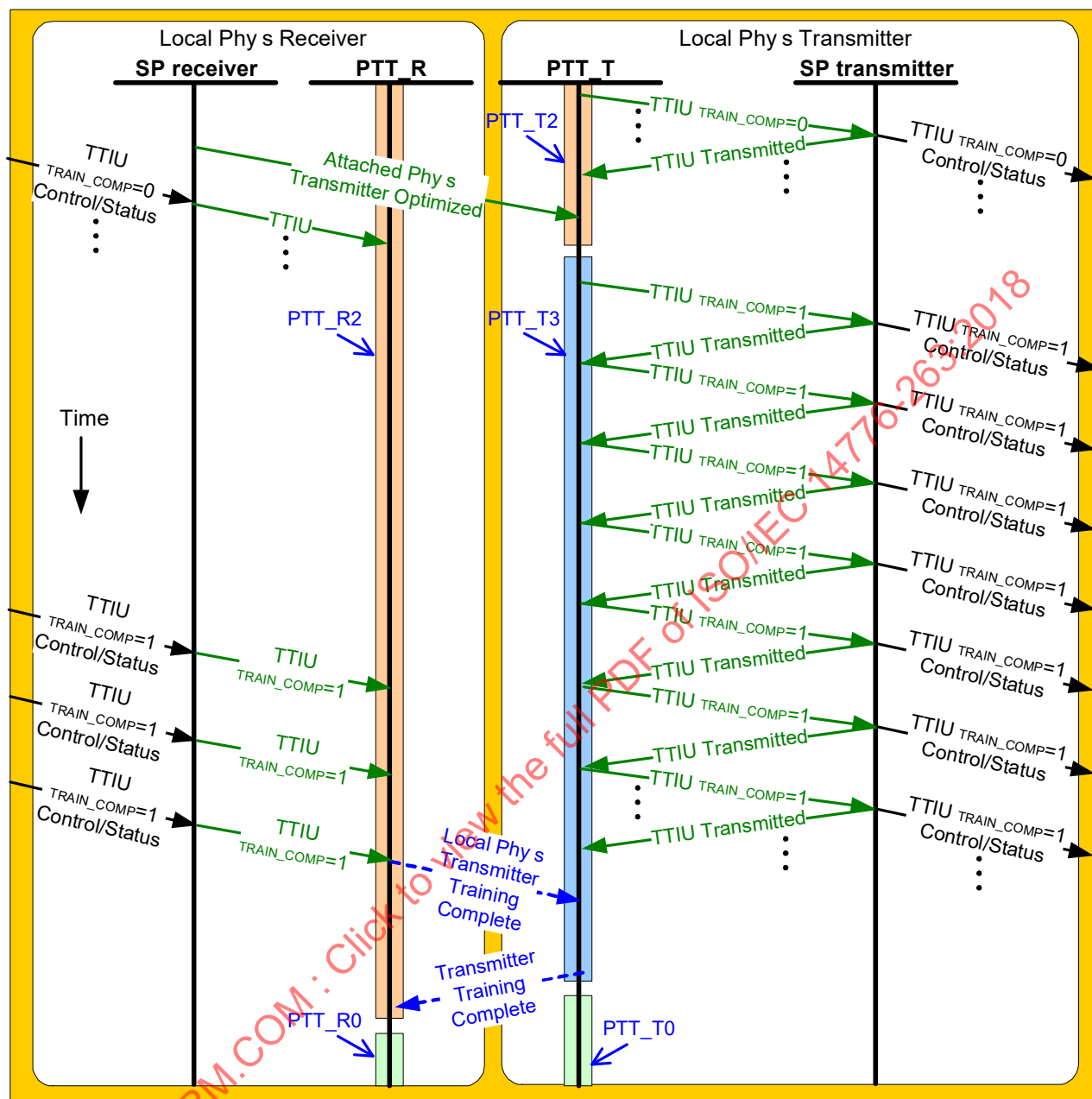


Figure 88 — Local phy's receiver indicates completion of training before the attached phy's receiver completes training

EXAMPLE 2 -Figure 89 shows the attached phy's receiver indication of completion of training before the local phy's receiver completes training.

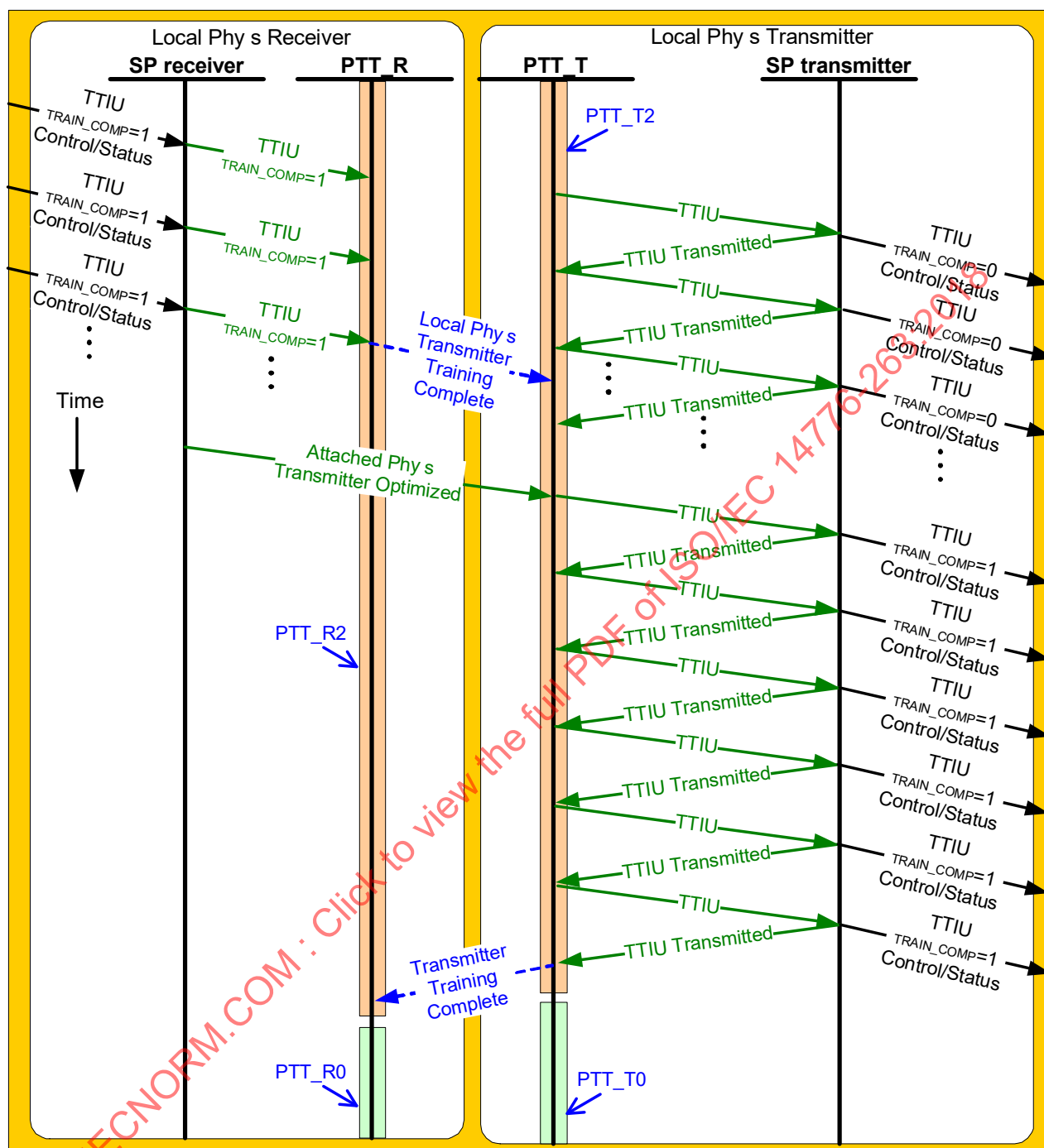


Figure 89 — Attached phy's receiver indicates completion of training before the local phy's receiver completes training

#### 5.10.4.2.6.5 Invalid TTIU sequence

If the PTT\_R state machine (see 5.14.5.4.1) detects an unsupported or reserved value in a TTIU, then the PTT\_R state machine sends a:

- a) Transmit Error Response message to the PTT\_T state machine; and
- b) Cancel message to the PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine.

If the PTT\_T2 state (see 5.14.4.4.4) or PTT\_T3 state (see 5.14.4.5.5) receives a Transmit Error Response message, then that state:

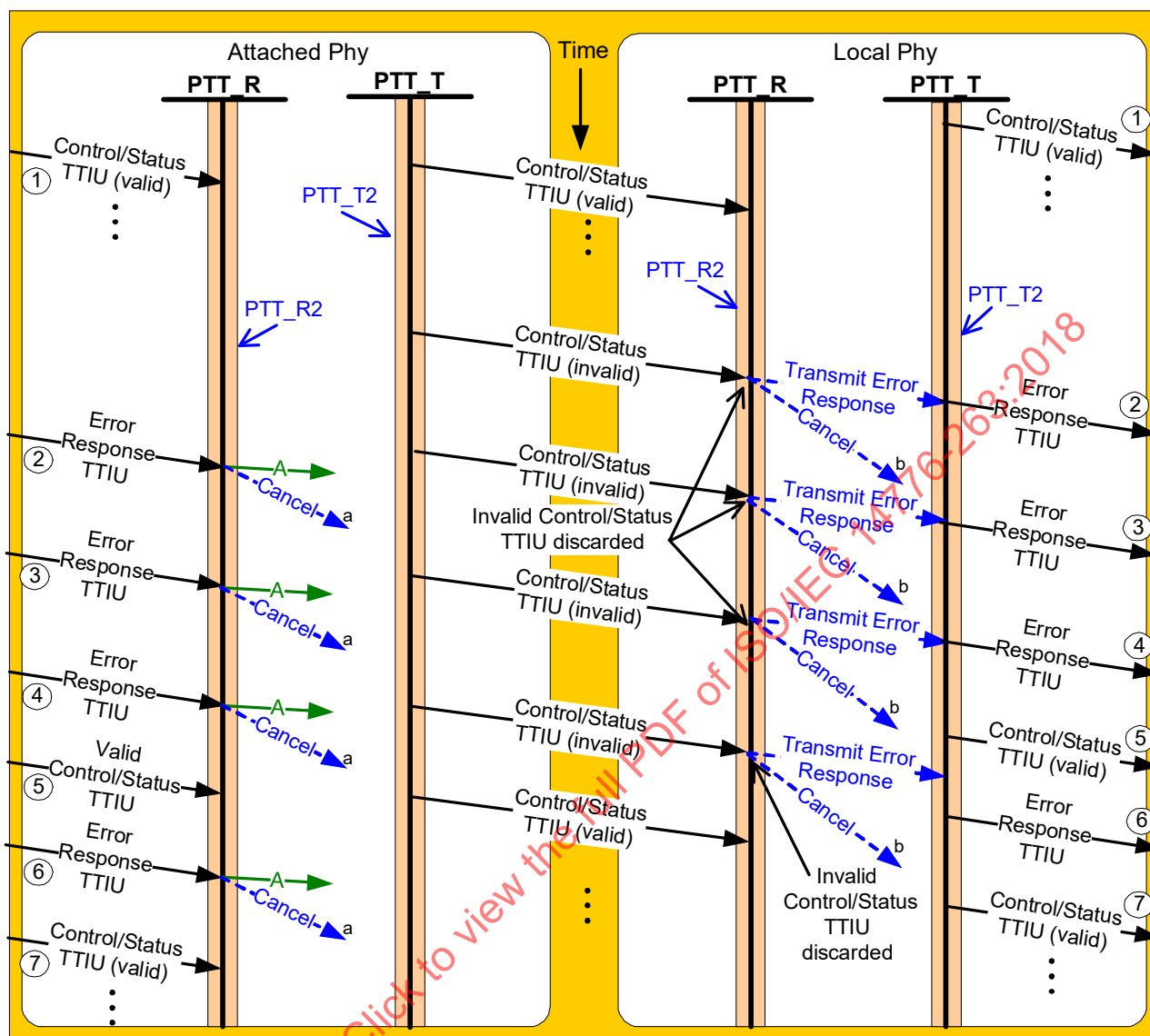
- 1) builds an Error Response TTIU;
- 2) transmits an Error Response TTIU; and
- 3) transmits a Control/Status TTIU.

If the PTT\_R2 state machine (see 5.14.5.4.1) receives an Error Response TTIU, then the PTT\_R state machine sends a:

- a) Transmitter Control Failed message to the SP receiver; and
- b) Cancel message to the PTT\_GC1 state machine, PTT\_GC2 state machine, and PTT\_GC3 state machine.

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EXAMPLE - Figure 90 shows the local phy's PTT\_R state machine processing the receipt of an invalid TTIU.



Key:

—A→ Transmitter Control Failed message to local SP receiver

Processing PTT state name →

<sup>a</sup> Cancel message to PTT GC1 state machine, PTT GC2 state machine, and PTT GC3 state machine.

<sup>b</sup> Cancel message to PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine.

### Figure 90 — Processing an invalid TTIU

#### 5.10.4.3 Multiplexing sequence

If SNW-3 indicates multiplexing (see 5.15) is enabled (see table 55), then the phy shall transmit the multiplexing sequence following the speed negotiation sequence.

The multiplexing sequence is:

- 1) MUX (LOGICAL LINK 0);
- 2) MUX (LOGICAL LINK 1);

- 3) MUX (LOGICAL LINK 0);
- 4) MUX (LOGICAL LINK 1);
- 5) MUX (LOGICAL LINK 0); and
- 6) MUX (LOGICAL LINK 1).

The phy shall not transmit deletable primitives for physical link rate tolerance management (see 6.3) during the multiplexing sequence.

If SNW-3 indicates multiplexing is not enabled, then the phy shall not transmit the multiplexing sequence.

The phy shall assign the incoming logical links to its logical phys based on the first MUX it receives:

- a) MUX (LOGICAL LINK 0) indicates the position of logical link 0 and indicates the next dword is in logical link 1; or
- b) MUX (LOGICAL LINK 1) indicates the position of logical link 1 and indicates the next dword is in logical link 0.

The phy shall handle errors during the multiplexing sequence (i.e., after receiving the first MUX) as follows:

- a) if the phy loses dword synchronization, then it shall restart the link reset sequence rather than attempt to reestablish dword synchronization;
- b) if the phy receives a dword that is not a MUX before receiving the MUX expected in that position, then it shall discard the dword;
- c) if the phy receives an invalid dword, then it shall discard the dword; or
- d) if the phy receives a MUX that does not match the MUX expected in that position (i.e., it receives MUX (LOGICAL LINK 1) on logical link 0 or receives MUX (LOGICAL LINK 0) on logical link 1), then the phy shall restart the link reset sequence.

#### 5.10.5 Phy reset sequence after devices are attached

Since SATA and SAS signal cable connectors do not include power lines, it is not possible to detect the physical insertion of the signal cable connector onto a plug. It may also not be possible to detect physical insertion of a device in non-cabled environments. As a result, every time a phy reset sequence is originated:

- a) expander phys that are enabled but not active shall originate a new phy reset sequence repeatedly, with no more than a hot-plug timeout (see table 68 in 5.10.1) between each attempt, until a speed negotiation sequence completes without error;
- b) SAS initiator phys should originate a new phy reset sequence after every hot-plug timeout; and
- c) SAS target phys should not originate a new phy reset sequence after their first attempt.

Figure 91 shows how two phys complete the phy reset sequence if the phys are not attached at power on. In this example, phy A and phy B are attached some time before phy B's second hot-plug timeout occurs. Phy B's OOB detection circuitry detects a COMINIT after the attachment, and therefore phy B transmits COMSAS,

since it has both transmitted and received a COMINIT. Upon receiving COMSAS, phy A transmits its own COMSAS. The SAS speed negotiation sequence follows.

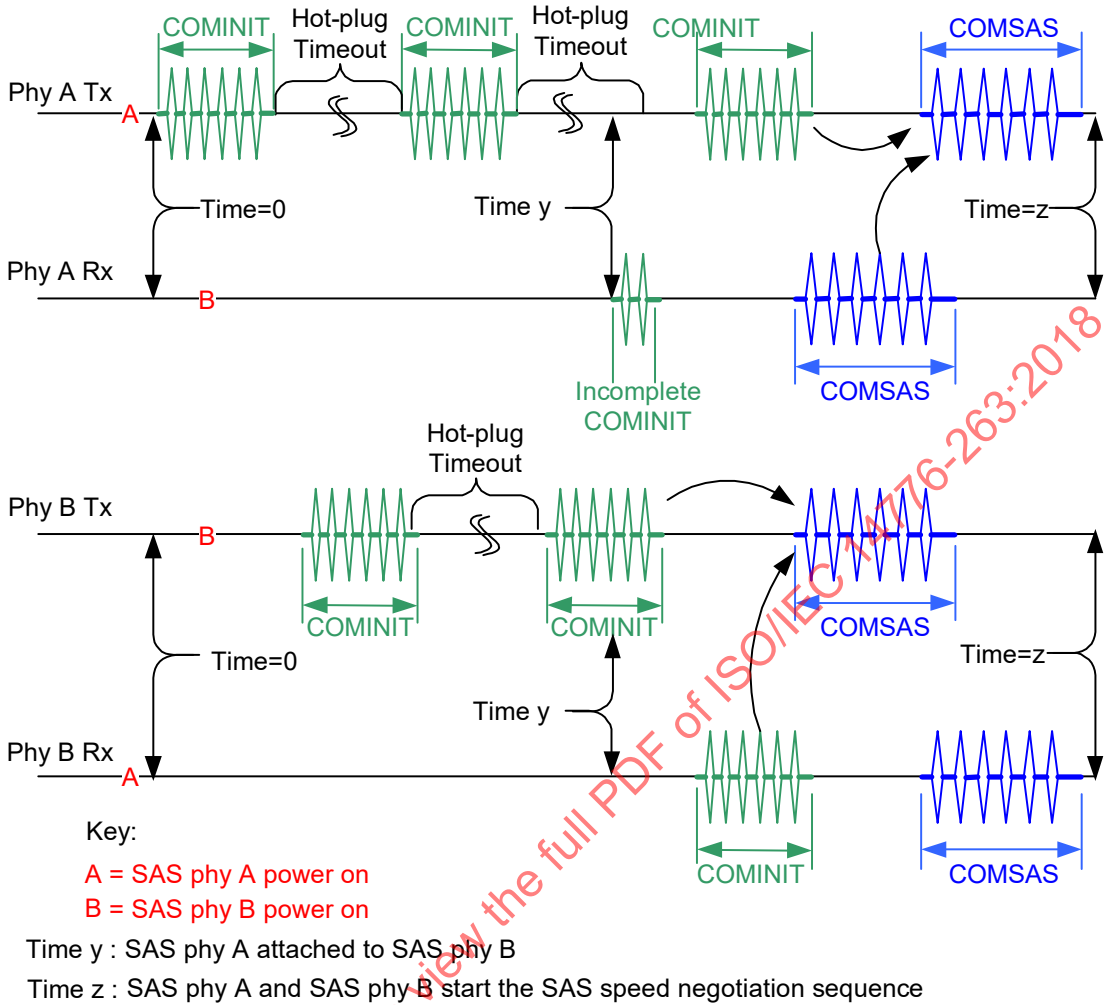


Figure 91 — Hot-plug and the phy reset sequence

## 5.11 Phy power condition sequences

### 5.11.1 Transitioning from the active phy power condition to a low phy power condition

See 6.11 for the sequence to transition from the active phy power condition to a low phy power condition.

### 5.11.2 Transitioning from a low phy power condition to the active phy power condition

Figure 92 shows the sequence to transition from a low phy power condition to the active phy power condition.

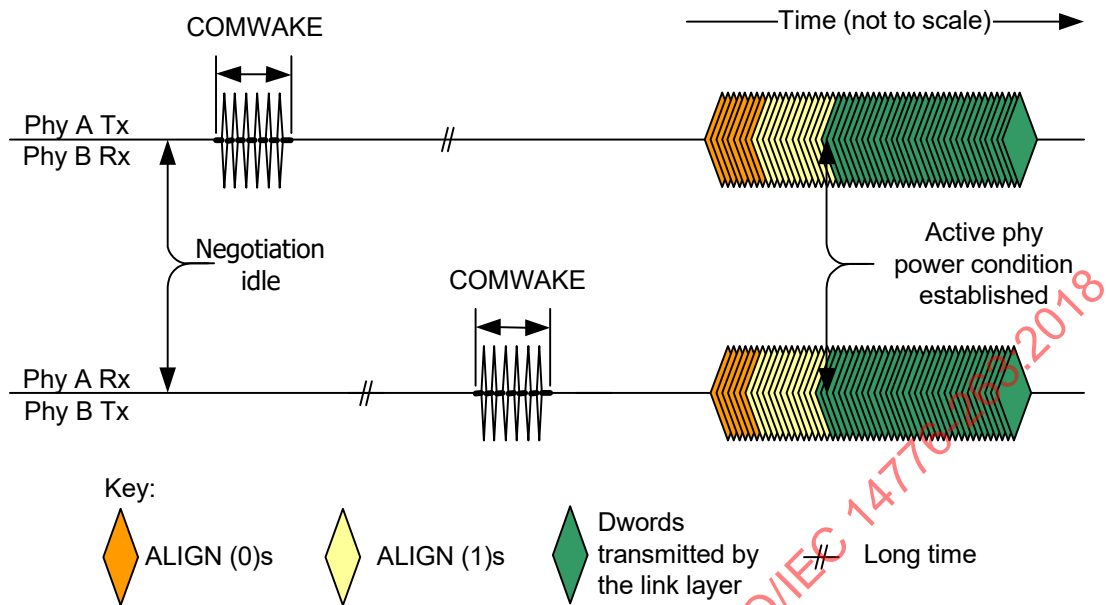


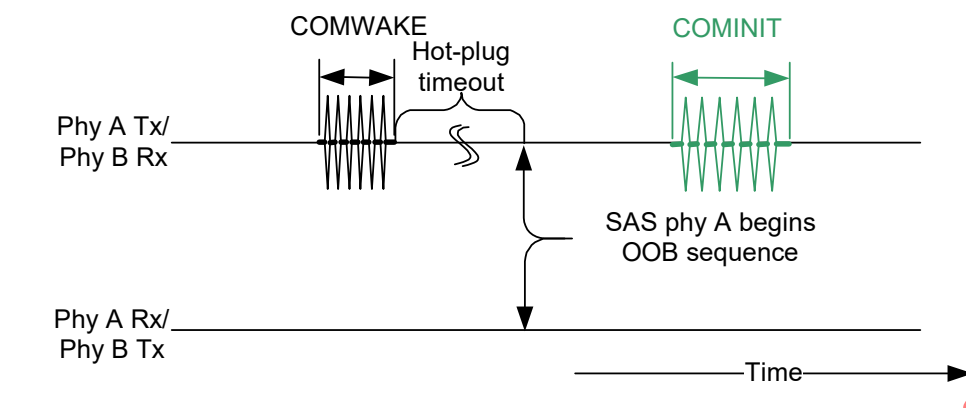
Figure 92 — Transition to active phy power condition

### 5.11.3 Events during low phy power condition

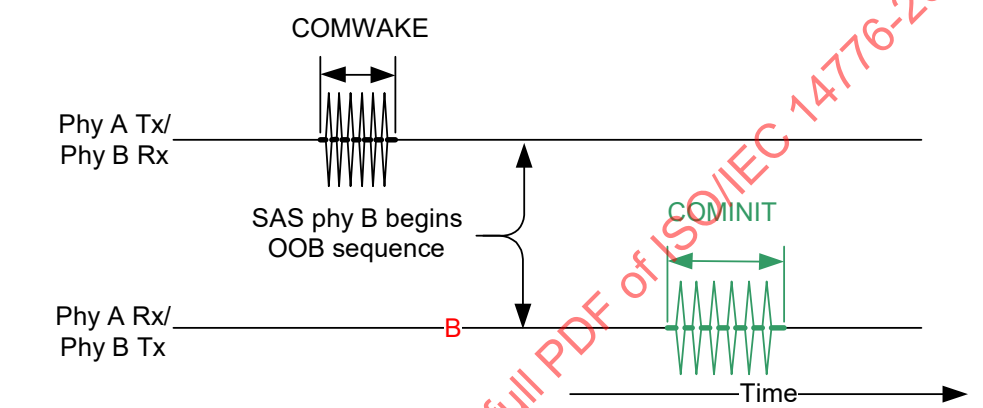
Figure 93 shows examples of responses to the following events that may occur during the transition from a low phy power condition to the active phy power condition:

- no response to COMWAKE within a hot plug timeout; and
- power on occurs after COMWAKE and before the hot plug timeout.

Sequence 1: no response to COMWAKE within a hot plug timeout



Sequence 2: power on occurs after COMWAKE and before the hot plug timeout



Key:

B = SAS phy B power on

**Figure 93 — Hot plug and low phy power condition**

The sequence for a no response to COMWAKE within a hot plug timeout depicted in sequence 1 in figure 93 proceeds as follows:

- 1) phy A transmits COMWAKE;
- 2) phy A detects no COMWAKE within a hot plug timeout; and
- 3) phy A transmits an OOB sequence.

The sequence for a power on occurs after COMWAKE and before the hot plug timeout depicted in sequence 2 in figure 93 proceeds as follows:

- 1) phy A transmits COMWAKE;
- 2) phy A detects an OOB sequence from phy B within a hot plug timeout; and
- 3) phy A transmits an OOB sequence.



## 5.12 SP (phy layer) state machine

### 5.12.1 SP state machine overview

The SP state machine controls the phy reset sequence. This state machine consists of the following sets of states:

- a) OOB sequence (OOB) states;
- b) SAS speed negotiation (SAS) states;
- c) SAS phy power condition (PS) states; and
- d) SATA host emulation (SATA) states.

This state machine consists of the following states:

- a) SP0:OOB\_COMINIT (see 5.12.3.2) (initial state);
- b) SP1:OOB\_AwaitCOMX (see 5.12.3.3);
- c) SP2:OOB\_NoCOMSASTimeout (see 5.12.3.4);
- d) SP3:OOB\_AwaitCOMINIT\_Sent (see 5.12.3.5);
- e) SP4:OOB\_COMSAS (see 5.12.3.6);
- f) SP5:OOB\_AwaitCOMSAS\_Sent (see 5.12.3.7);
- g) SP6:OOB\_AwaitNoCOMSAS (see 5.12.3.8);
- h) SP7:OOB\_AwaitCOMSAS (see 5.12.3.9);
- i) SP8:SAS\_Start (see 5.12.4.3);
- j) SP9:SAS\_WindowNotSupported (see 5.12.4.4);
- k) SP10:SAS\_AwaitALIGN (see 5.12.4.5);
- l) SP11:SAS\_AwaitALIGN1 (see 5.12.4.6);
- m) SP12:SAS\_AwaitSNW (see 5.12.4.7);
- n) SP13:SAS\_Pass (see 5.12.4.8);
- o) SP14:SAS\_Fail (see 5.12.4.9);
- p) SP15:SAS\_PHY\_Ready (see 5.12.4.10);
- q) SP16:SATA\_COMWAKE (see 5.12.6.2);
- r) SP17:SATA\_AwaitCOMWAKE (see 5.12.6.3);
- s) SP18:SATA\_AwaitNoCOMWAKE (see 5.12.6.4);
- t) SP19:SATA\_AwaitALIGN (see 5.12.6.5);
- u) SP20:SATA\_AdjustSpeed (see 5.12.6.6);
- v) SP21:SATA\_TransmitALIGN (see 5.12.6.7);
- w) SP22:SATA\_PHY\_Ready (see 5.12.6.8);
- x) SP23:SATA\_PM\_Partial (see 5.12.6.9);
- y) SP24:SATA\_PM\_Slumber (see 5.12.6.10);
- z) SP25:SATA\_PortSel (see 5.12.7.2);
- aa) SP26:SATA\_SpinupHold (see 5.12.8.2);
- ab) SP27:SAS\_Settings (see 5.12.4.11);
- ac) SP28:SAS\_TrainSetup (see 5.12.4.12);
- ad) SP29:SAS\_Train\_Rx (see 5.12.4.14);
- ae) SP30:SAS\_TrainingDone (see 5.12.4.15);
- af) SP31:SAS\_PS\_Low\_Phy\_Power (see 5.12.5.2);
- ag) SP32:SAS\_PS\_ALIGN0 (see 5.12.5.3);
- ah) SP33:SAS\_PS\_ALIGN1 (see 5.12.5.4); and
- ai) SP34:SAS\_Train\_Tx (see 5.12.4.13).

This state machine receives the following requests from the management application layer or a layer outside the scope of this standard:

- a) Management Reset from the management application layer;
- b) Disable Phy from the management application layer;
- c) Transmit SATA Port Selection Signal from the management application layer;
- d) Enter Partial request from SATA link layer, if any;
- e) Enter Slumber from the SATA link layer, if any; and
- f) Exit from the SATA link layer, if any.

This state machine sends the following confirmations to the management application layer:

- a) Transmitter Training Started.

This state machine shall start in the SP0:OOB\_COMINIT state after:

- a) a power on;
- b) a hard reset;
- c) receiving a Management Reset request (e.g., as a result of processing an SMP PHY CONTROL function requesting a phy operation of LINK RESET or HARD RESET); or
- d) receiving a Disable Phy request (e.g., as a result of processing an SMP PHY CONTROL function requesting a phy operation of DISABLE).

This state machine shall maintain a MgmtReset state machine variable to determine whether a Management Reset request has been received. Any SP state that receives a Management Reset request shall set the MgmtReset state machine variable to one before making a transition to the SP0:OOB\_COMINIT state (see 5.12.3.2). Any SP state that receives a power on or a hard reset shall set the MgmtReset state machine variable to zero before making a transition to the SP0:OOB\_COMINIT state.

This state machine shall maintain a Current SNW state machine variable to determine the current SNW (e.g., SNW-1, SNW-2, SNW-3, Final-SNW, or Unsupported Phy Attached).

If the phy status is available through any of the following:

- a) the SMP DISCOVER response (see 9.4.3.10);
- b) the SMP DISCOVER LIST response (see 9.4.3.15);
- c) the Phy Control And Discover mode page (see 9.2.7.5); or
- d) the Protocol Specific Port log page (see 9.2.8.1),

then this state machine shall maintain a ResetStatus state machine variable to determine the NEGOTIATED PHYSICAL LINK RATE field and/or the NEGOTIATED LOGICAL LINK RATE field.

If the phy supports SNW-3, then this state machine shall maintain a Commonly Supported Settings state machine variable that contains commonly supported settings.

If the phy supports SATA port selectors, then this state machine shall:

- a) maintain a COMWAKE\_Received state machine variable to indicate whether a COMWAKE Detected message was received in the SP0:OOB\_COMINIT state or the SP1:OOB\_AwaitCOMX state since the last time the SP0:OOB\_COMINIT state was entered; and
- b) transition to the SP25:SATA\_PortSel state whenever it receives a Transmit SATA Port Selection Signal request.

If the phy supports low phy power conditions, then this state machine shall maintain a SASPhyPwrCond state machine variable to determine:

- a) the current phy power condition (see 4.10 and 5.6.5); and
- b) the PHY POWER CONDITION field in the SMP DISCOVER response (see table 277).

This state machine sends the following messages to the SP\_DWS state machine (see 5.13):

- a) Start DWS; and
- b) Stop DWS.

This state machine receives the following messages from the SP\_DWS state machine:

- a) DWS Lost; and
- b) DWS Reset.

This state machine sends the following messages to the PTT state machines (see 5.14):

- a) Transmitter Training (Enable); and
- b) Transmitter Training (Disable).

This state machine receives the following message from the PTT\_T state machine (see 5.14.4):

- a) Transmitter Training Complete.

This state machine receives the following messages from the PTT\_PL state machine (see 5.14.12):

- a) Pattern Lock Lost; and
- b) Pattern Locked.

This state machine shall maintain the timers listed in table 75.

**Table 75 — SP state machine timers**

| Timer                           | Initial value                      |
|---------------------------------|------------------------------------|
| COMSAS Detect Timeout timer     | COMSAS detect timeout (see SAS-3)  |
| Await ALIGN Timeout timer       | Await ALIGN timeout (see table 69) |
| Hot-Plug Timeout timer          | Hot plug timeout (see table 68)    |
| RCDT timer                      | RCDT (see table 70)                |
| SNLT timer                      | SNLT (see table 70)                |
| SNTT timer                      | SNTT (see table 70)                |
| TLT timer                       | TLT (see table 70)                 |
| MRTT timer                      | MRTT (see table 70)                |
| MTTT timer                      | MTTT (see table 70)                |
| Pattern Lock Lost Timeout timer | 1 ms                               |

### 5.12.2 SP transmitter and SP receiver

The SP transmitter transmits OOB signals and dwords on the physical link based on messages from the SP state machine (see 5.12).

See 5.14.2 for SP transmitter requirements and see 5.14.3 for SP receiver requirements while PTT state machines are processing Train\_Tx-SNW.

The Phy Wakeup Complete message shall be sent after the SP transmitter becomes active as a result of receiving a Phy Wakeup message.

The SP transmitter receives the following messages from the SP state machine:

- a) Transmit COMINIT;
- b) Transmit COMSAS;
- c) Transmit COMWAKE;
- d) Transmit SATA Port Selection Signal;
- e) Transmit D10.2;
- f) Set Physical Link Rate with an argument specifying the physical link rate (e.g., 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, or 12 Gbit/s);
- g) Set SSC with an argument of On or Off;
- h) Transmit ALIGN with an argument indicating the specific type (e.g., Transmit ALIGN (0));
- i) Transmit Phy Capabilities Bits;
- j) Transmit TRAIN Pattern;
- k) Transmit TRAIN\_DONE Pattern;
- l) Transmit MUX Sequence;
- m) Transmit OOB Idle;
- n) Enter Partial Phy Power Condition;

- o) Enter Slumber Phy Power Condition; and
- p) Phy Wakeup.

When not otherwise instructed, the SP transmitter transmits negotiation idle.

Upon receiving a Phy Wakeup message, the SP transmitter shall become active (i.e., capable of transmitting OOB signals and dwords) within:

- a) a phy wakeup partial timeout (see table 68), if the phy is in the partial phy power condition; or
- b) a phy wakeup slumber timeout (see table 68), if the phy is in the slumber phy power condition.

Upon receiving a Transmit MUX Sequence message, the SP transmitter transmits:

- 1) MUX (LOGICAL LINK 0);
- 2) MUX (LOGICAL LINK 1);
- 3) MUX (LOGICAL LINK 0);
- 4) MUX (LOGICAL LINK 1);
- 5) MUX (LOGICAL LINK 0); and
- 6) MUX (LOGICAL LINK 1).

Upon receiving a Transmit OOB Idle message, the SP transmitter transmits OOB\_IDLE or D.C. idle as defined in SAS-3.

The SP transmitter shall complete any physical link rate change and SSC change requested with the Set Physical Link Rate message and the Set SSC message within RCDT (see table 70 in 5.10.4.2).

The SP transmitter sends the following messages to the SP state machine:

- a) COMINIT Transmitted;
- b) COMSAS Transmitted;
- c) COMWAKE Transmitted;
- d) SATA Port Selection Signal Transmitted;
- e) TRAIN\_DONE Pattern Transmitted;
- f) Phy Capabilities Bits Transmitted;
- g) MUX Sequence Transmitted; and
- h) Phy Wakeup Complete.

The SP receiver receives the following messages from the SP state machine:

- a) Set Physical Link Rate with an argument specifying the physical link rate (e.g., 1.5 Gbit/s, 3 Gbit/s, 6 Gbit/s, or 12 Gbit/s);
- b) Receive Phy Capabilities Bits;
- c) Start Rx Training;
- d) Abort Rx Training;
- e) Enable OOB Detection;
- f) Disable OOB Detection;
- g) Enter Partial Phy Power Condition; and
- h) Enter Slumber Phy Power Condition.

The SP receiver receives the following messages from the SP\_DWS state machine (see 5.13):

- a) Sync Acquired; and
- b) Sync Lost.

The SP receiver sends the following messages to the SP state machine indicating OOB signals and dwords received from the physical link:

- a) COMINIT Detected;
- b) COMSAS Detected;
- c) COMWAKE Detected;
- d) COMSAS Completed;
- e) COMWAKE Completed;
- f) ALIGN Received with an argument indicating the specific type (e.g., ALIGN Received (0));

- g) Phy Capabilities Bits Received with arguments indicating the supported settings bits received and either Good Parity or Bad Parity;
- h) Rx Training Completed;
- i) TRAIN\_DONE Received; and
- j) Dword Received.

The ALIGN Received, Dword Received, and TRAIN\_DONE Received messages are only sent after the SP\_DWS state machine has achieved dword synchronization.

For SATA speed negotiation, the ALIGN Received (0) message includes an argument containing the physical link rate at which the ALIGN (0) primitives were detected. For SAS speed negotiation, only ALIGNs at the physical link rate specified by the last Set Physical Link Rate message received by the SP receiver cause ALIGN Received messages.

The SP transmitter relationship to other transmitters is defined in 4.3.2. The SP receiver relationship to other receivers is defined in 4.3.3.

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### 5.12.3 OOB sequence states

### 5.12.3.1 OOB sequence states overview

Figure 94 shows the OOB sequence states. These states are indicated by state names with a prefix of OOB.

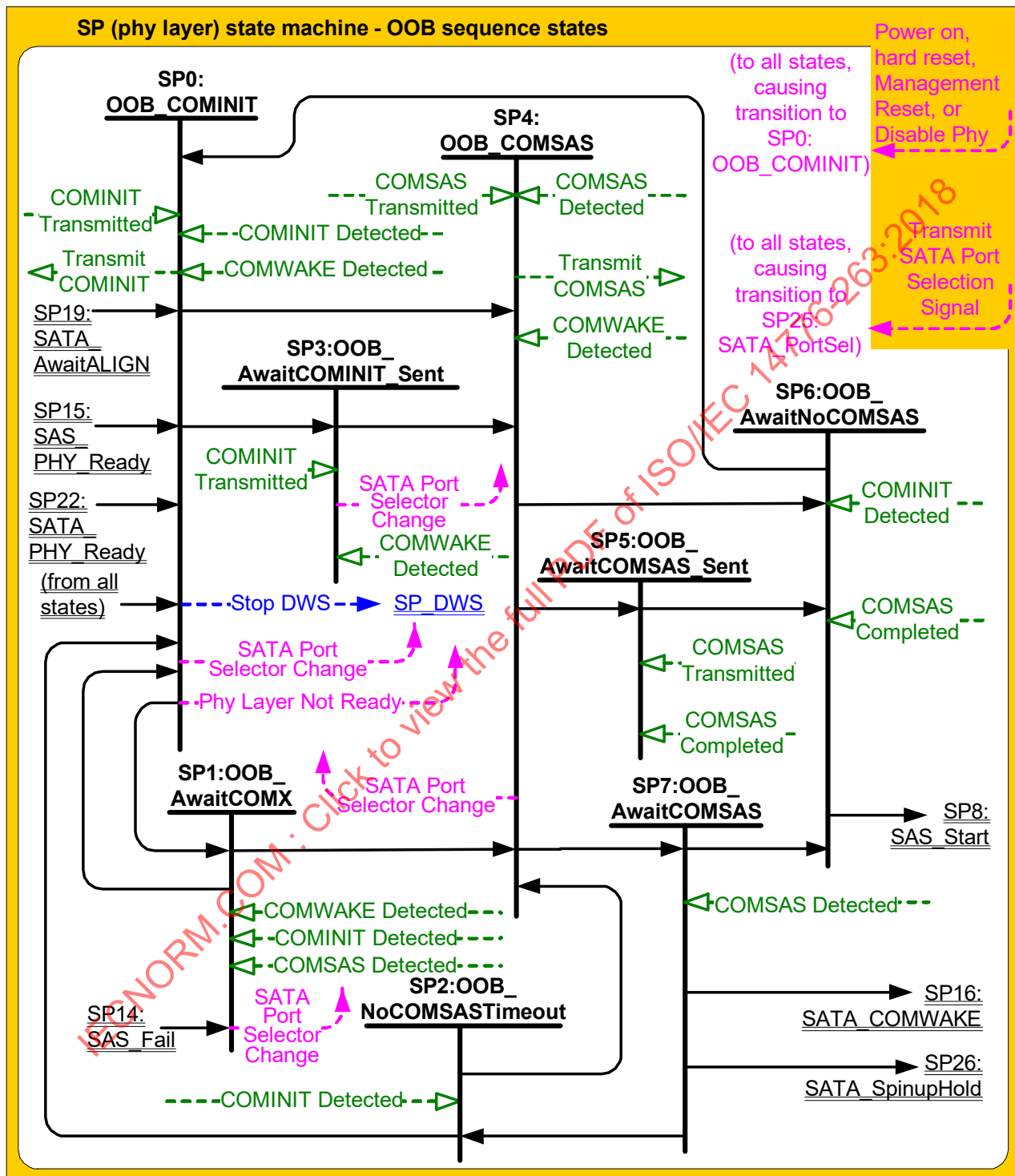


**Figure 94 — SP (phy layer) state machine - OOB sequence states**

### 5.12.3.2 SP0:OOB\_COMINIT state

#### 5.12.3.2.1 State description

This state is the initial state for this state machine.

Upon entry into this state, this state shall:

- a) set the COMWAKE\_Received state machine variable to zero;
- b) send an Enable OOB Detection message to the SP receiver;
- c) set the SASPhyPwrCond state machine variable to Active;
- d) send a Stop DWS message to the SP\_DWS state machine;
- e) send a Phy Layer Not Ready confirmation to the link layer;
- f) set the ATTACHED SATA DEVICE bit to zero in the SMP DISCOVER response (see 9.4.3.10);
- g) if this state was entered due to power on, and the phy is an SMP target phy, then set the ATTACHED SATA PORT SELECTOR bit to zero in the SMP DISCOVER response (see 9.4.3.10);
- h) if this state was not entered because of a Disable Phy request and D.C. mode is enabled, then send a Transmit COMINIT message to the SP transmitter; and
- i) if this state was not entered because of a Disable Phy request and optical mode is enabled, then:
  - 1) repeatedly send Transmit OOB Idle messages to the SP transmitter for an RCDT time; and
  - 2) send a Transmit COMINIT message to the SP transmitter.

If this state was entered because of a Disable Phy request, then upon entry into this state, this state shall:

- a) ignore COMINIT Detected messages until this state is re-entered due to a power on, hard reset, or Management Reset request; and
- b) set the ResetStatus state machine variable to DISABLED.

If this state was entered due to power on or hard reset, then upon entry into this state, this state shall set the ResetStatus state machine variable to UNKNOWN.

If this state was entered because of a Management Reset request, then upon entry into this state, this state shall:

- a) if the ResetStatus state machine variable is not set to RESET\_IN\_PROGRESS, SPINUP\_HOLD, G1, G2, G3, or G4, then set the ResetStatus state machine variable to UNKNOWN; or
- b) if the ResetStatus state machine variable is set to RESET\_IN\_PROGRESS, SPINUP\_HOLD, G1, G2, G3, or G4, then set the ResetStatus state machine variable to RESET\_IN\_PROGRESS.

If this state was not entered due to a power on, hard reset, Disable Phy, or Management Reset request, then upon entry into this state, this state shall:

- a) if the ResetStatus state machine variable is not set to PHY\_RESET\_PROBLEM, SPINUP\_HOLD, or UNSUPPORTED\_PHY\_ATTACHED, then set the ResetStatus state machine variable to UNKNOWN; or
- b) if the ResetStatus state machine variable is set to PHY\_RESET\_PROBLEM, SPINUP\_HOLD, or UNSUPPORTED\_PHY\_ATTACHED, then not change the ResetStatus state machine variable.

If the phy supports SATA port selectors and this state receives a COMWAKE Detected message, then this state shall:

- a) if the ResetStatus state machine variable is not set to PHY\_RESET\_PROBLEM, SPINUP\_HOLD, or UNSUPPORTED\_PHY\_ATTACHED, then set the ResetStatus state machine variable to PORT\_SELECTOR;
- b) set the COMWAKE\_Received state machine variable to one; and
- c) if the phy is an SMP target phy and the ATTACHED SATA PORT SELECTOR bit is set to zero in the SMP DISCOVER response (see 9.4.3.10), then:
  - A) set the ATTACHED SATA PORT SELECTOR bit to one in the SMP DISCOVER response; and
  - B) send a SATA Port Selector Change confirmation to the link layer.

This state machine waits for receipt of a COMINIT Transmitted message and/or a COMINIT Detected message.



**5.12.3.2.2 Transition SP0:OOB\_COMINIT to SP1:OOB\_AwaitCOMX**

This transition shall occur:

- a) if this state receives a COMINIT Transmitted message and has not received a COMINIT Detected message.

**5.12.3.2.3 Transition SP0:OOB\_COMINIT to SP3:OOB\_AwaitCOMINIT\_Sent**

This transition shall occur:

- a) if this state receives a COMINIT Detected message and has not received a COMINIT Transmitted message.

**5.12.3.2.4 Transition SP0:OOB\_COMINIT to SP4:OOB\_COMSAS**

This transition shall occur:

- a) if this state receives both a COMINIT Transmitted message and a COMINIT Detected message.

**5.12.3.3 SP1:OOB\_AwaitCOMX state****5.12.3.3.1 State description**

Upon entry into this state, this state shall initialize and start the Hot-Plug Timeout timer if this phy is:

- a) an expander phy; or
- b) an initiator phy or target phy implementing the Hot-Plug Timeout timer.

If the phy supports SATA port selectors and this state receives a COMWAKE Detected message, then this state shall:

- a) if the ResetStatus state machine variable is not set to PHY\_RESET\_PROBLEM, SPINUP\_HOLD, or UNSUPPORTED\_PHY\_ATTACHED, then set the ResetStatus state machine variable to PORT\_SELECTOR;
- b) set the COMWAKE\_Received state machine variable to one; and
- c) if the phy is an SMP target phy and the ATTACHED SATA PORT SELECTOR bit is set to zero in the SMP DISCOVER response (see 9.4.3.10), then:
  - A) set the ATTACHED SATA PORT SELECTOR bit to one in the SMP DISCOVER response; and
  - B) send a SATA Port Selector Change confirmation to the link layer.

**5.12.3.3.2 Transition SP1:OOB\_AwaitCOMX to SP0:OOB\_COMINIT**

This transition shall occur if the Hot-Plug Timeout timer expires.

If the COMWAKE\_Received state machine variable is set to zero and the ATTACHED SATA PORT SELECTOR bit is set to one in the SMP DISCOVER response (see 9.4.3.10), then the state machine shall, before the transition:

- a) set the ATTACHED SATA PORT SELECTOR bit to zero in the SMP DISCOVER response; and
- b) send a SATA Port Selector Change confirmation to the link layer.

Before the transition, if this state was entered from SP0:OOB\_COMINIT, then this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.3.3.3 Transition SP1:OOB\_AwaitCOMX to SP4:OOB\_COMSAS**

This transition shall occur:

- a) after receiving a COMINIT Detected message or a COMSAS Detected message.

If COMSAS Detected was received, then this transition shall include:

- a) a COMSAS Detected argument.



#### 5.12.3.4 SP2:OOB\_NoCOMSASTimeout state

##### 5.12.3.4.1 State description

Upon entry into this state, this state shall initialize and start the Hot-Plug Timeout timer if this phy is:

- a) this phy is an expander phy; or
- b) this phy is an initiator phy or target phy implementing the Hot-Plug Timeout timer.

##### 5.12.3.4.2 Transition SP2:OOB\_NoCOMSASTimeout to SP0:OOB\_COMINIT

This transition shall occur:

- a) if the Hot-Plug Timeout timer expires.

##### 5.12.3.4.3 Transition SP2:OOB\_NoCOMSASTimeout to SP4:OOB\_COMSAS

This transition shall occur:

- a) after receiving a COMINIT Detected message.

#### 5.12.3.5 SP3:OOB\_AwaitCOMINIT\_Sent state

##### 5.12.3.5.1 State description

This state waits for a COMINIT Transmitted message.

If the phy supports SATA port selectors and this state receives a COMWAKE Detected message, then this state shall:

- a) if the ResetStatus state machine variable is not set to PHY\_RESET\_PROBLEM, SPINUP\_HOLD, or UNSUPPORTED\_PHY\_ATTACHED, then set the ResetStatus state machine variable to PORT\_SELECTOR; and
- b) if the phy is an SMP target phy and the ATTACHED SATA PORT SELECTOR bit is set to zero in the SMP DISCOVER response (see 9.4.3.10), then:
  - A) set the ATTACHED SATA PORT SELECTOR bit to one in the SMP DISCOVER response; and
  - B) send a SATA Port Selector Change confirmation to the link layer.

##### 5.12.3.5.2 Transition SP3:OOB\_AwaitCOMINIT\_Sent to SP4:OOB\_COMSAS

This transition shall occur:

- a) after receiving a COMINIT Transmitted message.

#### 5.12.3.6 SP4:OOB\_COMSAS state

##### 5.12.3.6.1 State description

Upon entry into this state, this state shall send a Transmit COMSAS message to the SP transmitter.

This state waits for receipt of a COMSAS Transmitted message and/or a COMSAS Detected message.

If the phy supports SATA port selectors and this state receives a COMWAKE Detected message, then this state shall:

- a) if the ResetStatus state machine variable is not set to PHY\_RESET\_PROBLEM, SPINUP\_HOLD, or UNSUPPORTED\_PHY\_ATTACHED, then set the ResetStatus state machine variable to PORT\_SELECTOR; and
- b) if the phy is an SMP target phy and the ATTACHED SATA PORT SELECTOR bit is set to zero in the SMP DISCOVER response (see 9.4.3.10), then:
  - A) set the ATTACHED SATA PORT SELECTOR bit to one in the SMP DISCOVER response; and

B) send a SATA Port Selector Change confirmation to the link layer.

#### 5.12.3.6.2 Transition SP4:OOB\_COMSAS to SP5:OOB\_AwaitCOMSAS\_Sent

This transition shall occur:

- a) if this state receives a COMSAS Detected message or this state was entered with a COMSAS Detected argument; and
- b) this state has not received a COMSAS Transmitted message.

If the ATTACHED SATA PORT SELECTOR bit is set to one in the SMP DISCOVER response (see 9.4.3.10), then the state machine shall set the ATTACHED SATA PORT SELECTOR bit to zero in the SMP DISCOVER response and send a SATA Port Selector Change confirmation to the link layer before the transition.

#### 5.12.3.6.3 Transition SP4:OOB\_COMSAS to SP6:OOB\_AwaitNoCOMSAS

This transition shall occur if this state receives both:

- a) a COMSAS Transmitted message; and
- b) a COMSAS Detected message.

If the ATTACHED SATA PORT SELECTOR bit is set to one in the SMP DISCOVER response (see 9.4.3.10), then the state machine shall set the ATTACHED SATA PORT SELECTOR bit to zero in the SMP DISCOVER response and send a SATA Port Selector Change confirmation to the link layer before the transition.

#### 5.12.3.6.4 Transition SP4:OOB\_COMSAS to SP7:OOB\_AwaitCOMSAS

This transition shall occur if this state:

- a) receives a COMSAS Transmitted message; and
- b) has not received a COMSAS Detected message.

#### 5.12.3.7 SP5:OOB\_AwaitCOMSAS\_Sent state

##### 5.12.3.7.1 State description

This state waits for receipt of a COMSAS Transmitted message.

#### 5.12.3.7.2 Transition SP5:OOB\_AwaitCOMSAS\_Sent to SP6:OOB\_AwaitNoCOMSAS

This transition shall occur:

- a) after receiving a COMSAS Transmitted message.

If this state received a COMSAS Completed message, then it shall include:

- a) a COMSAS Completed argument with the transition.

#### 5.12.3.8 SP6:OOB\_AwaitNoCOMSAS state

##### 5.12.3.8.1 State description

This state machine waits for a COMSAS Completed message, which indicates that COMSAS has been received.

#### 5.12.3.8.2 Transition SP6:OOB\_AwaitNoCOMSAS to SP0:OOB\_COMINIT

This transition shall occur:

- a) after receiving a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.3.8.3 Transition SP6:OOB\_AwaitNoCOMSAS to SP8:SAS\_Start**

This transition shall occur:

- a) after receiving a COMSAS Completed message; or
- b) if a COMSAS Completed argument was received in the transition.

**5.12.3.9 SP7:OOB\_AwaitCOMSAS state****5.12.3.9.1 State description**

Upon entry into this state, this state shall initialize and start the COMSAS Detect Timeout timer.

**5.12.3.9.2 Transition SP7:OOB\_AwaitCOMSAS to SP2:OOB\_NoCOMSASTimeout**

This transition shall occur:

- a) if the phy does not support SATA; and
- b) the COMSAS Detect Timeout timer expires.

The state machine shall set the MgmtReset state machine variable to zero before the transition.

**5.12.3.9.3 Transition SP7:OOB\_AwaitCOMSAS to SP6:OOB\_AwaitNoCOMSAS**

This transition shall occur:

- a) after receiving a COMSAS Detected message.

The state machine shall set the MgmtReset state machine variable to zero before the transition.

The state machine shall set the ATTACHED SATA PORT SELECTOR bit to zero in the SMP DISCOVER response (see 9.4.3.10). If the ATTACHED SATA PORT SELECTOR bit in the SMP DISCOVER response was set to one before to this transition, the state machine shall send a SATA Port Selector Change confirmation to the link layer before the transition.

**5.12.3.9.4 Transition SP7:OOB\_AwaitCOMSAS to SP16:SATA\_COMWAKE**

This transition shall occur if:

- a) the phy supports SATA; and
- b) the COMSAS Detect Timeout timer expires and:
  - A) the MgmtReset state machine variable is set to one; or
  - B) the phy does not implement SATA spinup hold.

The state machine shall set the MgmtReset state machine variable to zero before the transition.

The state machine shall set the ATTACHED SATA DEVICE bit to one in the SMP DISCOVER response (see 9.4.3.10) before the transition.

**5.12.3.9.5 Transition SP7:OOB\_AwaitCOMSAS to SP26:SATA\_SpinupHold**

This transition shall occur if:

- a) the phy supports SATA;
- b) the COMSAS Detect Timeout timer expires;
- c) the phy implements SATA spinup hold; and
- d) the MgmtReset state machine variable is set to zero.

The state machine shall set the ATTACHED SATA DEVICE bit to one in the SMP DISCOVER response (see 9.4.3.10) before the transition.

## 5.12.4 SAS speed negotiation states

### 5.12.4.1 SAS speed negotiation states overview

Figure 95 shows the SAS speed negotiation states, in which the phy has detected that it is attached to a SAS phy or expander phy rather than a SATA phy, and performs the SAS speed negotiation sequence. These states are indicated by state names with a prefix of SAS.

### 5.12.4.2 Negotiation idle

SAS speed negotiation states use negotiation idle at the beginning of each SNW.

If D.C. mode is enabled, then a negotiation idle consists of the transmission of D.C. idle.

If optical mode is enabled, then see SAS-3 for the optical mode negotiation idle definition.

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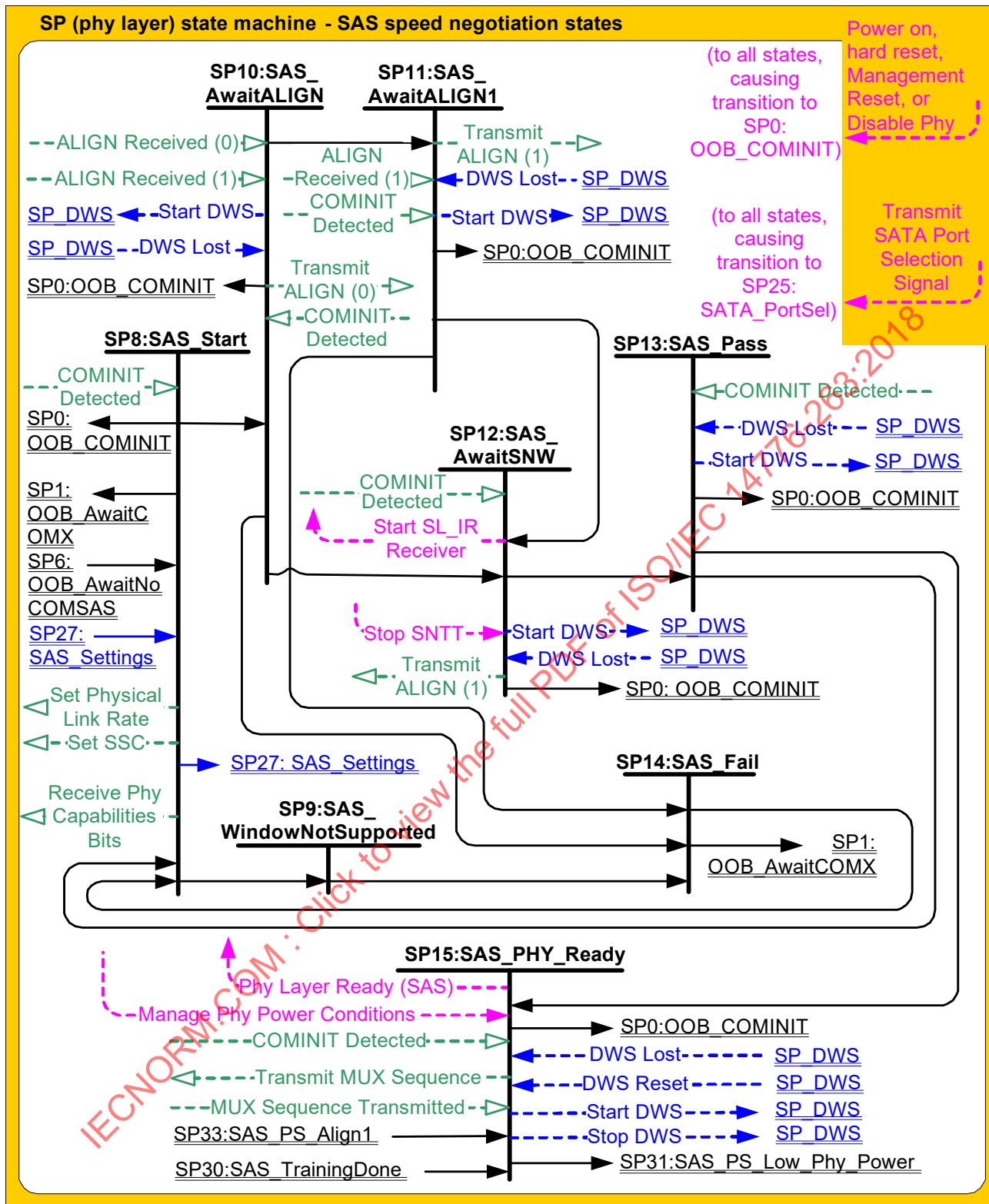


Figure 95 — SP (phy layer) state machine - SAS speed negotiation states

Figure 96 shows the SAS speed negotiation states related to SNW-3 and Train\_Rx-SNW.

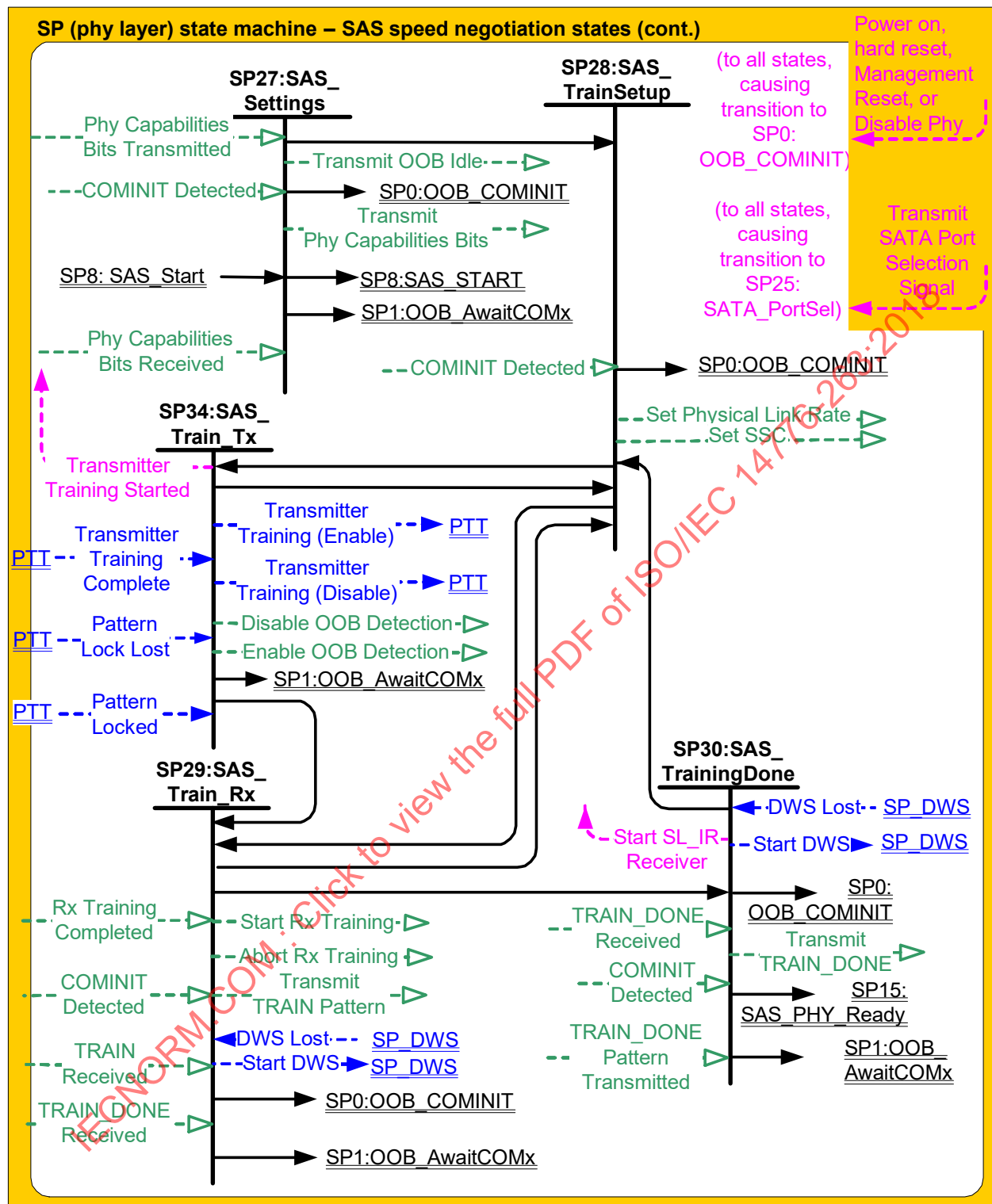


Figure 96 — SP (phy layer) state machine - SAS speed negotiation states for SNW-3 and Train\_Rx-SNW and Train\_Tx-SNW

### 5.12.4.3 SP8:SAS\_Start state

#### 5.12.4.3.1 State description

This is the state in which the SAS speed negotiation sequence begins.

Upon entry into this state, this state shall initialize and start the RCDT timer.

If this state is entered from SP6:OOB\_AwaitNoCOMSAS, then the Current SNW state machine variable shall be set to SNW-1. If this state is not entered from SP6:OOB\_AwaitNoCOMSAS, then the Current SNW state machine variable shall be set to:

- SNW-2 if the Current SNW state machine variable is set to SNW-1;
- SNW-3 if the Current SNW state machine variable is set to SNW-2, and either SNW-1 is invalid or SNW-2 is valid;
- Final-SNW if the Current SNW state machine variable is set to SNW-2, SNW-1 is valid, and SNW-2 is invalid;
- Final-SNW if the Current SNW state machine variable is set to SNW-3, SNW-3 is invalid, and SNW-2 is valid; or
- Unsupported Phy Attached if the Current SNW state machine variable is set to SNW-3, SNW-3 is invalid, and SNW-2 is invalid.

After the Current SNW state machine variable is updated, if:

- the Current SNW state machine variable is not set to Unsupported Phy Attached; and
- the SNW specified by the Current SNW state machine variable is supported,

then this state shall send the messages specified in table 76 to the SP transmitter and SP receiver.

**Table 76 — Messages to SP transmitter and SP receiver at start of RCDT**

| Current SNW state machine variable | Other conditions                      | Message(s) sent to SP transmitter                     | Message(s) sent to SP receiver      |
|------------------------------------|---------------------------------------|-------------------------------------------------------|-------------------------------------|
| SNW-1                              | none                                  | Set Physical Link Rate (1.5 Gbit/s) and Set SSC (Off) | Set Physical Link Rate (1.5 Gbit/s) |
| SNW-2                              | none                                  | Set Physical Link Rate (3 Gbit/s) and Set SSC (Off)   | Set Physical Link Rate (3 Gbit/s)   |
| SNW-3                              | none                                  | Set SSC (On) or Set SSC (Off)                         | Receive Phy Capabilities Bits       |
| Final-SNW                          | SNW-1 was valid and SNW-2 was invalid | Set Physical Link Rate (1.5 Gbit/s) and Set SSC (Off) | Set Physical Link Rate (1.5 Gbit/s) |
|                                    | SNW-2 was valid                       | Set Physical Link Rate (3 Gbit/s) and Set SSC (Off)   | Set Physical Link Rate (3 Gbit/s)   |

#### 5.12.4.3.2 Transition SP8:SAS\_Start to SP0:OOB\_COMINIT

This transition shall occur:

- after receiving a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.4.3.3 Transition SP8:SAS\_Start to SP1:OOB\_AwaitCOMX**

This transition shall occur:

- a) if the Current SNW state machine variable is set to Unsupported Phy Attached.

Before the transition, this state shall set the ResetStatus state machine variable to UNSUPPORTED\_PHY\_ATTACHED.

**5.12.4.3.4 Transition SP8:SAS\_Start to SP9:SAS\_WindowNotSupported**

This transition shall occur:

- a) after the RCDT timer expires if the SNW indicated by the Current SNW state machine variable is not supported.

**5.12.4.3.5 Transition SP8:SAS\_Start to SP10:SAS\_AwaitALIGN**

This transition shall occur after the RCDT timer expires if:

- a) the Current SNW state machine variable is not set to SNW-3; and
- b) the SNW indicated by the Current SNW state machine variable is supported.

**5.12.4.3.6 Transition SP8:SAS\_Start to SP27:SAS\_Settings**

This transition shall occur after the RCDT timer expires if:

- a) the Current SNW state machine variable is set to SNW-3; and
- b) SNW-3 is supported.

**5.12.4.4 SP9:SAS\_WindowNotSupported state****5.12.4.4.1 State description**

Upon entry into this state, this state shall initialize and start the SNTT timer.

**5.12.4.4.2 Transition SP9:SAS\_WindowNotSupported to SP0:OOB\_COMINIT**

This transition should occur:

- a) after receiving a COMINIT.Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.4.4.3 Transition SP9:SAS\_WindowNotSupported to SP14:SAS\_Fail**

This transition shall occur:

- a) after the SNTT timer expires.

**5.12.4.5 SP10:SAS\_AwaitALIGN state****5.12.4.5.1 State description**

Upon entry into this state, this state shall:

- a) initialize and start the SNTT timer and SNLT timer;
- b) send a Start DWS message to the SP\_DWS state machine; and
- c) repeatedly send Transmit ALIGN (0) messages to the SP transmitter.

Each time this state receives a DWS Lost message, this state may send a Start DWS message to the SP\_DWS state machine to re-acquire dword synchronization without running a new link reset sequence.



**5.12.4.5.2 Transition SP10:SAS\_AwaitALIGN to SP0:OOB\_COMINIT**

This transition shall occur after receiving:

- a) a DWS Lost message, if this state does not send a Start DWS message; or
- b) a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.4.5.3 Transition SP10:SAS\_AwaitALIGN to SP11:SAS\_AwaitALIGN1**

This transition shall occur:

- a) if this state receives an ALIGN Received (0) message before the SNLT timer expires.

**5.12.4.5.4 Transition SP10:SAS\_AwaitALIGN to SP12:SAS\_AwaitSNW**

This transition shall occur:

- a) if this state receives an ALIGN Received (1) message before the SNLT timer expires.

**5.12.4.5.5 Transition SP10:SAS\_AwaitALIGN to SP14:SAS\_Fail**

This transition shall occur:

- a) if the SNTT timer expires.

**5.12.4.6 SP11:SAS\_AwaitALIGN1 state****5.12.4.6.1 State description**

This state shall repeatedly send Transmit ALIGN (1) messages to the SP transmitter.

Each time this state receives a DWS Lost message, this state may send a Start DWS message to the SP\_DWS state machine to re-acquire dword synchronization without running a new link reset sequence.

**5.12.4.6.2 Transition SP11:SAS\_AwaitALIGN1 to SP0:OOB\_COMINIT**

This transition shall occur after receiving:

- a) a DWS Lost message, if this state does not send a Start DWS message; or
- b) a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.4.6.3 Transition SP11:SAS\_AwaitALIGN1 to SP12:SAS\_AwaitSNW**

This transition shall occur:

- a) if this state receives an ALIGN Received (1) message before the SNTT timer expires.

This indicates that the attached phy has been able to achieve dword synchronization in the current SNW.

**5.12.4.6.4 Transition SP11:SAS\_AwaitALIGN1 to SP14:SAS\_Fail**

This transition shall occur:

- a) if the SNTT timer expires.

This indicates that the attached phy has not been able to achieve dword synchronization in the current SNW.

#### 5.12.4.7 SP12:SAS\_AwaitSNW state

##### 5.12.4.7.1 State description

This state shall repeatedly send Transmit ALIGN (1) messages to the SP transmitter.

If the Current SNW state machine variable is set to Final-SNW, then this state shall send a Start SL\_IR Receiver confirmation to the link layer.

Each time this state receives a DWS Lost message, this state may send a Start DWS message to the SP\_DWS state machine to re-acquire dword synchronization without running a new link reset sequence.

This state waits for the SNTT timer to expire or for a Stop SNTT request.

If this state receives a Stop SNTT request, then this state shall stop the SNTT timer.

##### 5.12.4.7.2 Transition SP12:SAS\_AwaitSNW to SP0:OOB\_COMINIT

This transition shall occur after receiving:

- a) a DWS Lost message, if this state does not send a Start DWS message; or
- b) a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

##### 5.12.4.7.3 Transition SP12:SAS\_AwaitSNW to SP13:SAS\_Pass

This transition shall occur after:

- a) the SNTT timer expires; or
- b) receiving a Stop SNTT request.

#### 5.12.4.8 SP13:SAS\_Pass state

##### 5.12.4.8.1 State description

This state determines if:

- a) another SAS SNW is required; or
- b) the SAS speed negotiation sequence is complete.

Each time this state receives a DWS Lost message, this state may send a Start DWS message to the SP\_DWS state machine to re-acquire dword synchronization without running a new link reset sequence.

##### 5.12.4.8.2 Transition SP13:SAS\_Pass to SP0:OOB\_COMINIT

This transition shall occur after receiving:

- a) a DWS Lost message, if this state does not send a Start DWS message; or
- b) a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

##### 5.12.4.8.3 Transition SP13:SAS\_Pass to SP8:SAS\_Start

This transition shall occur:

- a) if the Current SNW state machine variable is not set to Final-SNW.

**5.12.4.8.4 Transition SP13:SAS\_Pass to SP15:SAS\_PHY\_Ready**

This transition shall occur:

- a) if the Current SNW state machine variable is set to Final-SNW.

**5.12.4.9 SP14:SAS\_Fail state****5.12.4.9.1 State description**

This state determines if:

- a) another SAS SNW is required; or
- b) the SAS speed negotiation sequence is complete.

**5.12.4.9.2 Transition SP14:SAS\_Fail to SP1:OOB\_AwaitCOMX**

This transition shall occur:

- a) if the Current SNW state machine variable is set to Final-SNW.

Before the transition, this state shall set the ResetStatus state machine variable to PHY\_RESET\_PROBLEM.

**5.12.4.9.3 Transition SP14:SAS\_Fail to SP8:SAS\_Start**

This transition shall occur:

- a) if the Current SNW state machine variable is not set to Final-SNW.

**5.12.4.10 SP15:SAS\_PHY\_Ready state****5.12.4.10.1 State description**

This state waits for:

- a) a COMINIT Detected message;
- b) a DWS Lost message;
- c) a DWS Reset message; or
- d) a Manage Phy Power Conditions request.

Upon entry into this state, this state shall:

- a) if multiplexing is:
  - A) enabled (see table 55), then:
    - 1) send a Transmit MUX Sequence message to the SP transmitter; and
    - 2) after receiving MUX Sequence Transmitted, send a Phy Layer Ready (SAS) confirmation to the link layer;
  - or
  - B) not enabled, then send a Phy Layer Ready (SAS) confirmation to the link layer;
- and
- b) if the SP transmitter is transmitting at:
  - A) 1.5 Gbit/s, then set the ResetStatus state machine variable to G1;
  - B) 3 Gbit/s, then set the ResetStatus state machine variable to G2;
  - C) 6 Gbit/s, then set the ResetStatus state machine variable to G3; or
  - D) 12 Gbit/s, then set the ResetStatus state machine variable to G4.

While in this state, dwords from the link layer are transmitted at the negotiated physical link rate (i.e., the rate established in the previous SNW).

If multiplexing is disabled, then each time this state receives a DWS Lost message, this state may send a Start DWS message to the SP\_DWS state machine to re-acquire dword synchronization without running a new link reset sequence.

If a Manage Phy Power Conditions (Stop DWS) request is received, then this state shall send a Stop DWS message to the SP\_DWS state machine.

#### 5.12.4.10.2 Transition SP15:SAS\_PHY\_Ready to SP0:OOB\_COMINIT

If optical mode is enabled or D.C. mode is enabled, then this transition shall occur after receiving:

- a) a DWS Lost message, if this state does not send a Start DWS message;
- b) a DWS Lost message followed by a COMINIT Detected message, if this state does not send a Start DWS message; or
- c) a DWS Reset message.

If optical mode is enabled, then this transition shall not occur after receiving a COMINIT Detected message:

- a) before receiving a DWS Lost message; or
- b) after sending a Start DWS message.

#### 5.12.4.10.3 Transition SP15:SAS\_PHY\_Ready to SP31:SAS\_PS\_Low\_Phy\_Power

This transition shall occur after this state receives:

- a) a Manage Phy Power Conditions (Enter Partial) request; or
- b) a Manage Phy Power Conditions (Enter Slumber) request.

If this transition is the result of this state receiving a Manage Phy Power Conditions (Enter Partial) request, then the transition shall include:

- a) a Partial argument.

If this transition is the result of this state receiving a Manage Phy Power Conditions (Enter Slumber) request, then the transition shall include:

- a) a Slumber argument.

#### 5.12.4.11 SP27:SAS\_Settings state

##### 5.12.4.11.1 State description

This state transmits and receives phy capabilities bits.

Upon entry to this state, this state shall:

- a) initialize and start the SNTT timer;
- b) set the Commonly Supported Settings state machine variable to indicate that there are no commonly supported settings; and
- c) send a Transmit Phy Capabilities Bits message to the SP transmitter.

If a Phy Capabilities Bits Received message is received with the argument of Good Parity, then this state shall set the Commonly Supported Settings state machine variable to the commonly supported settings.

After this state receives a Phy Capabilities Bits Transmitted message this state shall request that OOB idle be transmitted by repeatedly sending Transmit OOB Idle messages to the SP transmitter.

This state waits for the SNTT timer to expire.

##### 5.12.4.11.2 Transition SP27:SAS\_Settings to SP0:OOB\_COMINIT

This transition shall occur:

- a) after receiving a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

#### 5.12.4.11.3 Transition SP27:SAS\_Settings to SP1:OOB\_AwaitCOMX

This transition shall occur after the SNTT timer expires if:

- a) a Phy Capabilities Bits Received message is received with an argument of Bad Parity; or
- b) no commonly supported settings exist after the Commonly Supported Settings state machine variable is set as a result of receiving a Phy Capabilities Bits Received message.

Before the transition, this state shall:

- a) if a Phy Capabilities Bits Received message is received with an argument of Bad Parity, then set the ResetStatus state machine variable to PHY\_RESET\_PROBLEM; or
- b) if no commonly supported settings exist after the Commonly Supported Settings state machine variable is set, then set the ResetStatus state machine variable to UNSUPPORTED\_PHY\_ATTACHED.

#### 5.12.4.11.4 Transition SP27:SAS\_Settings to SP8:SAS\_Start

This transition shall occur if:

- a) the SNTT timer expires; and
- b) a Phy Capabilities Bits Received message is not received during this state.

#### 5.12.4.11.5 Transition SP27:SAS\_Settings to SP28:SAS\_TrainSetup

This transition shall occur:

- a) after the SNTT timer expires; and
- b) if the Commonly Supported Settings state machine variable indicates there is at least one commonly supported setting.

#### 5.12.4.12 SP28:SAS\_TrainSetup

##### 5.12.4.12.1 State description

Upon entry into this state:

- 1) this state shall set the Transmitter Training Enabled argument to:
  - A) no, if:
    - a) optical mode is enabled;
    - b) there is an active cable assembly attached to the phy; or
    - c) the highest priority commonly supported setting indicates G1, G2, or G3;
 or
  - B) yes, if optical mode is disabled, there is no active cable assembly attached to the phy, and the highest priority commonly supported setting indicates G4 or a higher priority;
- and
- 2) the phy shall:
  - A) initialize and start the RCDT timer; and
  - B) send a Set Physical Link Rate message to the SP transmitter, a Set Physical Link Rate message to the SP receiver, and a Set SSC message to the SP transmitter with the arguments set to reflect the highest priority commonly supported setting contained in the Commonly Supported Settings state machine variable.

After the Set Physical Link Rate messages and Set SSC message are sent, the Commonly Supported Settings state machine variable shall be set to indicate that the selected supported settings bit is no longer in common.

**5.12.4.12.2 Transition SP28:SAS\_TrainSetup to SP0:OOB\_COMINIT**

This transition shall occur:

- a) after receiving a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.4.12.3 Transition SP28:SAS\_TrainSetup to SP29:SAS\_Train\_Rx**

This transition shall occur:

- a) after the RCDT timer expires if the Transmitter Training Enabled argument is set to no.

**5.12.4.12.4 Transition SP28:SAS\_TrainSetup to SP34:SAS\_Train\_Tx**

This transition shall occur:

- a) after the RCDT timer expires if the Transmitter Training Enabled argument is set to yes.

**5.12.4.13 SP34:SAS\_Train\_Tx state****5.12.4.13.1 State description**

Upon entry into this state, this state shall:

- a) initialize and start the MTTT timer;
- b) initialize and start the Pattern Lock Lost Timeout timer;
- c) send a Disable OOB Detection message to the SP receiver;
- d) send a Transmitter Training (Enable) message to the PTT state machines (see 5.14); and
- e) send a Transmitter Training Started confirmation to the management application layer.

If this state receives a Pattern Lock Lost message, then this state shall initialize and start the Pattern Lock Lost Timeout timer.

If this state receives a Pattern Locked message, then this state shall stop the Pattern Lock Lost Timeout timer.

If the MTTT timer expires or the Pattern Lock Lost Timeout timer expires, then this state shall send a Transmitter Training (Disable) message to the PTT state machines.

A phy reset problem occurs if:

- a) the MTTT timer expires or the Pattern Lock Lost Timeout timer expires; and
- b) the Commonly Supported Settings state machine variable does not contain additional commonly supported settings.

**5.12.4.13.2 Transition SP34:SAS\_Train\_Tx to SP1:OOB\_AwaitCOMX**

This transition shall occur:

- a) if a phy reset problem occurs.

Before the transition, this state shall:

- a) set the ResetStatus state machine variable to PHY\_RESET\_PROBLEM;
- b) send an Enable OOB Detection message to the SP receiver;
- c) stop the MTTT timer; and
- d) stop the Pattern Lock Lost Timeout timer.

**5.12.4.13.3 Transition SP34:SAS\_Train\_Tx to SP28:SAS\_TrainSetup**

This transition shall occur if:

- a) the MTTT timer expires or the Pattern Lock Lost Timeout timer expires; and

- b) the Commonly Supported Settings state machine variable contains additional commonly supported settings.

Before the transition, this state shall:

- a) stop the MTTT timer;
- b) stop the Pattern Lock Lost Timeout timer; and
- c) send an Enable OOB Detection message to the SP receiver.

#### 5.12.4.13.4 Transition SP34:SAS\_Train\_Tx to SP29:SAS\_Train\_Rx

This transition shall occur if:

- a) the MTTT timer has not expired;
- b) the Pattern Lock Lost Timeout timer has not expired; and
- c) this state receives a Transmitter Training Complete message.

Before the transition, this state shall:

- a) stop the MTTT timer;
- b) stop the Pattern Lock Lost Timeout timer; and
- c) send an Enable OOB Detection message to the SP receiver.

#### 5.12.4.14 SP29:SAS\_Train\_Rx state

##### 5.12.4.14.1 State description

Upon entry into this state, this state shall:

- a) initialize and start the MRTT timer;
- b) initialize and start the TLT timer;
- c) send a Start Rx Training message to the SP receiver; and
- d) send a Start DWS message to the SP\_DWS state machine.

This state shall repeatedly send Transmit TRAIN Pattern messages to the SP transmitter.

Each time this state receives a DWS Lost message, this state shall send a Start DWS message to the SP\_DWS state machine to re-acquire dword synchronization.

If the MRTT timer expires, then this state shall send an Abort Rx Training message to the SP receiver.

A phy reset problem occurs if:

- a) the MRTT timer expires; and
- b) the Commonly Supported Settings state machine variable does not contain additional commonly supported settings.

##### 5.12.4.14.2 Transition SP29:SAS\_Train\_Rx to SP0:OOB\_COMINIT

This transition shall occur after receiving a COMINIT Detected message.

Before the transition, this state shall:

- a) set the ResetStatus state machine variable to UNKNOWN;
- b) stop the TLT timer; and
- c) stop the MRTT timer.

##### 5.12.4.14.3 Transition SP29:SAS\_Train\_Rx to SP1:OOB\_AwaitCOMX

This transition shall occur if a phy reset problem occurs.

Before the transition, this state shall:

- a) set the ResetStatus state machine variable to PHY\_RESET\_PROBLEM;

- b) stop the TLT timer; and
- c) stop the MRTT timer.

#### 5.12.4.14.4 Transition SP29:SAS\_Train\_Rx to SP28:SAS\_TrainSetup

This transition shall occur if:

- a) the MRTT timer expires; and
- b) the Commonly Supported Settings state machine variable contains additional commonly supported settings.

Before the transition, this state shall:

- a) stop the TLT timer; and
- b) stop the MRTT timer.

#### 5.12.4.14.5 Transition SP29:SAS\_Train\_Rx to SP30:SAS\_TrainingDone

This transition shall occur if:

- a) the TLT timer has not expired;
- b) this state receives an Rx Training Completed message;
- c) dword synchronization is acquired; and
- d) this state receives a TRAIN\_Received message or a TRAIN\_DONE\_Received message.

If a TRAIN\_DONE\_Received message was received, then the transition shall include a TRAIN\_DONE\_Received argument.

Before the transition, this state shall stop:

- a) the TLT timer; and
- b) the MRTT timer.

#### 5.12.4.15 SP30:SAS\_TrainingDone state

##### 5.12.4.15.1 State description

This state shall repeatedly send Transmit TRAIN\_DONE Pattern messages to the SP transmitter.

Each time this state receives a DWS Lost message, this state may send a Start DWS message to the SP\_DWS state machine to re-acquire dword synchronization without running a new link reset sequence.

This state waits for the MRTT timer to expire or a TRAIN\_DONE\_Received message from the receiver.

If this state receives a TRAIN\_DONE\_Received message, then this state shall stop the MRTT timer.

This state shall send a Start SL\_IR Receiver confirmation to the link layer when a TRAIN\_DONE\_Received message is received.

A phy reset problem occurs if:

- a) TRAIN\_DONE\_Received message is not received before the MRTT timer expires; and
- b) the Commonly Supported Settings state machine variable does not contain additional commonly supported settings.

##### 5.12.4.15.2 Transition SP30:SAS\_TrainingDone to SP0:OOB\_COMINIT

This transition shall occur after receiving:

- a) a DWS Lost message if this state does not send a Start DWS message; or
- b) a COMINIT Detected message.

Before the transition, this state shall:

- a) set the ResetStatus state machine variable to UNKNOWN; and



- b) stop the MRTT timer.

#### 5.12.4.15.3 Transition SP30:SAS\_TrainingDone to SP1:OOB\_AwaitCOMX

This transition shall occur:

- a) if a phy reset problem occurs.

Before the transition, this state shall set the ResetStatus state machine variable to PHY\_RESET\_PROBLEM.

#### 5.12.4.15.4 Transition SP30:SAS\_TrainingDone to SP28:SAS\_TrainSetup

This transition shall occur if:

- a) the MRTT timer expires; and
- b) the Commonly Supported Settings state machine variable contains additional commonly supported settings.

#### 5.12.4.15.5 Transition SP30:SAS\_TrainingDone to SP15:SAS\_PHY\_Ready

This transition shall occur if this state receives at least four TRAIN\_DONE Pattern Transmitted messages and either:

- a) receives:
  - 1) a TRAIN\_DONE Received message before the MRTT timer expires; and
  - 2) at least one TRAIN\_DONE Pattern Transmitted message;
- or
- b) was entered with a TRAIN\_DONE Received argument.

Before the transition, this state shall stop the MRTT timer.

### 5.12.5 SAS phy power conditions states

#### 5.12.5.1 SAS phy power conditions states overview

Figure 97 shows the SAS phy power conditions states. These states are entered when a phy is requested to enter a low phy power condition and process the actions that return a phy from a low phy power condition to the active phy power condition.

These states are indicated by state names with a prefix of SAS\_PS.

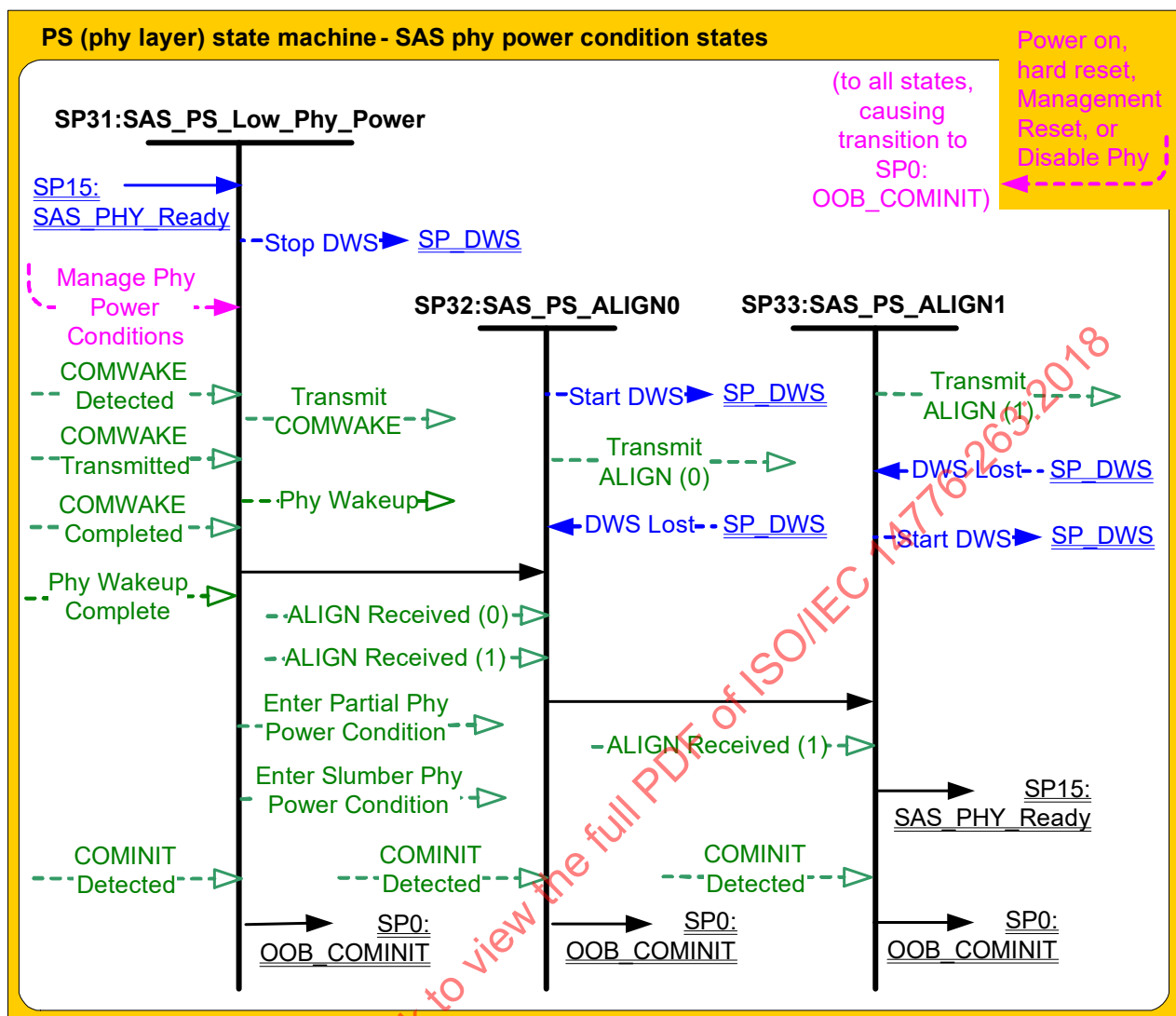


**Figure 97 — SP (phy layer) state machine - SAS phy power condition states**

#### 5.12.5.2 SP31:SAS\_PS\_Low\_Phy\_Power state

#### 5.12.5.2.1 State description

Upon entry into this state, this state shall:

- a) send a Stop DWS message to the SP\_DWS state machine; and
- b) if applicable, save any vendor specific information for the SP transmitter and SP receiver (e.g., determined from the previous Train\_Rx-SNW and Train\_Tx-SNW with the arguments set to the same values as those for the previous entry into the SP28:SAS TrainSetup state (see 5.12.4.12)).

If this state is entered with a Partial argument, then:

- a) this state shall send an Enter Partial Phy Power Condition message to the SP transmitter and SP receiver;
- b) the phy shall enter the partial phy power condition (see 4.10.1.3); and
- c) this state shall set the SASPhyPwrCond state machine variable to Partial.

If this state is entered with a Slumber argument, then:

- a) this state shall send an Enter Slumber Phy Power Condition message to the SP transmitter and SP receiver;
- b) the phy shall enter the slumber phy power condition (see 4.10.1.4); and
- c) this state shall set the SASPhyPwrCond state machine variable to Slumber.

If this state receives a Manage Phy Power Conditions (Exit) request or a COMWAKE Detected message, then this state shall:

- 1) send a Phy Wakeup message to the SP transmitter;
- 2) wait for a Phy Wakeup Completed message; and
- 3) send a Transmit COMWAKE message to the SP transmitter.

While in this state, if a Manage Phy Power Conditions (Exit) request and a COMWAKE Detected message are received, then this state shall only send one Transmit COMWAKE message to the SP transmitter.

#### 5.12.5.2.2 Transition SP31:SAS\_PS\_Low\_Phy\_Power to SP0:OOB\_COMINIT

This transition shall occur if:

- a) this state:
  - A) receives a COMWAKE Transmitted message; and
  - B) does not receive a COMWAKE Completed message within a hot-plug timeout (see table 68);
 or
- b) this state receives a COMINIT Detected message.

#### 5.12.5.2.3 Transition SP31:SAS\_PS\_Low\_Phy\_Power to SP32:SAS\_PS\_ALIGN0

This transition shall occur after this state receives:

- a) a COMWAKE Transmitted message; and
- b) a COMWAKE Completed message.

#### 5.12.5.3 SP32:SAS\_PS\_ALIGN0 state

##### 5.12.5.3.1 State description

Upon entry into this state, this state shall:

- 1) initialize and start the SNTT timer and the SNLT timer;
- 2) send a Set Physical Link Rate message to the SP transmitter and to the SP receiver and send a Set SSC message to the SP transmitter with the arguments set to those determined from the last SNW;
- 3) if applicable, restore any vendor specific information for the SP transmitter and SP receiver (see 5.12.5.2.1);
- 4) send a Start DWS message to the SP\_DWS state machine; and
- 5) repeatedly send Transmit ALIGN (0) messages to the SP transmitter.

Each time this state receives a DWS Lost message, this state may send a Start DWS message to re-acquire dword synchronization without running a new link reset sequence.

#### 5.12.5.3.2 Transition SP32:SAS\_PS\_ALIGN0 state to SP0:OOB\_COMINIT

This transition shall occur after this state:

- a) receives a DWS Lost message, if this state does not send a Start DWS message;
- b) receives a COMINIT Detected message; or
- c) the SNTT timer expires.

Before the transition, this state shall stop the SNLT timer and the SNTT timer.

**5.12.5.3.3 Transition SP32:SAS\_PS\_ALIGN0 to SP33:SAS\_PS\_ALIGN1**

This transition shall occur:

- a) if this state receives an ALIGN Received (0) message or an ALIGN Received (1) message before the SNLT timer expires; and
- b) after this state has sent at least three Transmit ALIGN (0) messages.

Before the transition, this state shall stop the SNLT timer.

**5.12.5.4 SP33:SAS\_PS\_ALIGN1 state****5.12.5.4.1 State description**

Upon entry into this state, this phy shall repeatedly send Transmit ALIGN (1) messages to the SP transmitter.

Each time this state receives a DWS Lost message, this state may send a Start DWS message to re-acquire dword synchronization without running a new link reset sequence.

If this state receives an ALIGN Received (1) message before the SNTT timer expires, then this state shall set the SASPhyPwrCond state machine variable to Active.

**5.12.5.4.2 Transition SP33:SAS\_PS\_ALIGN1 state to SP0:OOB\_COMINIT**

This transition shall occur after this state:

- a) receives a DWS Lost message, if this state does not send a Start DWS message;
- b) receives a COMINIT Detected message; or
- c) the SNTT timer expires.

Before the transition, this state shall stop the SNLT timer and the SNTT timer.

**5.12.5.4.3 Transition SP33:SAS\_PS\_ALIGN1 state to SP15:SAS\_PHY\_Ready**

This transition shall occur:

- a) if this state receives an ALIGN Received (1) message before the SNTT timer expires;
- b) after this state has sent at least three Transmit ALIGN (1) messages;
- c) after this state has set the SASPhyPwrCond state machine variable to Active; and
- d) after this state has stopped the SNLT timer and the SNTT timer.

**5.12.6 SATA host emulation states****5.12.6.1 SATA host emulation states overview**

Figure 98 shows the SATA host emulation states, in which the phy has detected that it is attached to a SATA phy and behaves as if it were a SATA host phy initiating the SATA speed negotiation sequence. These states are indicated by state names with a prefix of SATA.

The power management states defined in this standard are for SAS initiator phys or SAS expander phys that support SATA. SATA low phy power conditions may be enabled in expander phys using the SMP PHY CONTROL function (see 9.4.3.28).

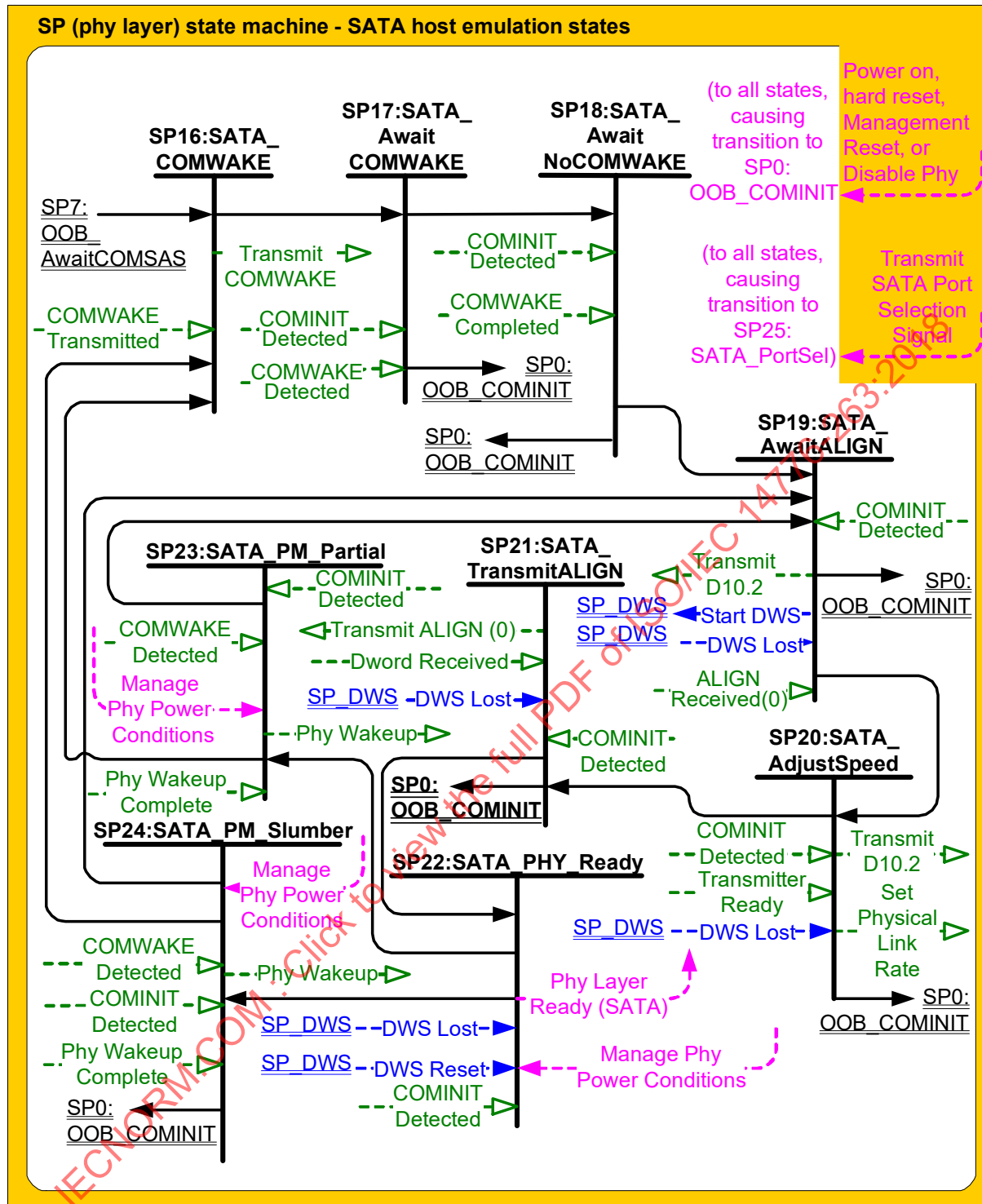


Figure 98 — SP (phy layer) state machine - SATA host emulation states

**5.12.6.2 SP16:SATA\_COMWAKE state****5.12.6.2.1 State description**

This state shall send a Transmit COMWAKE message to the SP transmitter and wait for a COMWAKE Transmitted message.

**5.12.6.2.2 Transition SP16:SATA\_COMWAKE to SP0:OOB\_COMINIT**

This transition shall occur:

- a) after receiving a COMINIT Detected message.

**5.12.6.2.3 Transition SP16:SATA\_COMWAKE to SP17:SATA\_AwaitCOMWAKE**

This transition shall occur:

- a) after receiving a COMWAKE Transmitted message.

**5.12.6.3 SP17:SATA\_AwaitCOMWAKE state****5.12.6.3.1 State description**

This state waits for a COMWAKE Detected message to be received.

**5.12.6.3.2 Transition SP17:SATA\_AwaitCOMWAKE to SP0:OOB\_COMINIT**

This transition shall occur:

- a) after receiving a COMINIT Detected message.

**5.12.6.3.3 Transition SP17:SATA\_AwaitCOMWAKE to SP18:SATA\_AwaitNoCOMWAKE**

This transition shall occur:

- a) after receiving a COMWAKE Detected message.

**5.12.6.4 SP18:SATA\_AwaitNoCOMWAKE state****5.12.6.4.1 State description**

This state waits for a COMWAKE Completed message.

**5.12.6.4.2 Transition SP18:SATA\_AwaitNoCOMWAKE to SP0:OOB\_COMINIT**

This transition shall occur:

- a) after receiving a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.6.4.3 Transition SP18:SATA\_AwaitNoCOMWAKE to SP19:SATA\_AwaitALIGN**

This transition shall occur:

- a) after receiving a COMWAKE Completed message.

### 5.12.6.5 SP19:SATA\_AwaitALIGN state

#### 5.12.6.5.1 State description

Upon entry into this state, this state shall send a Start DWS message to the SP\_DWS state machine.

This state shall:

- a) repeatedly send Transmit D10.2 messages to the SP transmitter;
- b) initialize and start the Await ALIGN Timeout timer; and
- c) wait for an ALIGN Received (0) message to be received or for the Await ALIGN Timeout timer to expire.

The phy shall start transmitting D10.2 characters no later than a COMWAKE response time (see 5.10.2.2) after entry into this state.

#### 5.12.6.5.2 Transition SP19:SATA\_AwaitALIGN to SP0:OOB\_COMINIT

This transition shall occur:

- a) if the Await ALIGN Timeout timer expires;
- b) after receiving a DWS Lost message; or
- c) after receiving a COMINIT Detected message.

Before the transition, this state shall:

- a) if the Await ALIGN Timeout timer expires, then set the ResetStatus state machine variable to UNSUPPORTED\_PHY\_ATTACHED;
- b) after receiving a DWS Lost message, set the ResetStatus state machine variable to UNKNOWN; or
- c) after receiving a COMINIT Detected message, set the ResetStatus state machine variable to UNKNOWN.

#### 5.12.6.5.3 Transition SP19:SATA\_AwaitALIGN to SP20:SATA\_AdjustSpeed

This transition shall occur:

- a) if this state receives an ALIGN Received (0) message before the Await ALIGN Timeout timer expires.

The ALIGN Received (0) message indicates an ALIGN (0) was received at any of the physical link rates supported by this phy.

### 5.12.6.6 SP20:SATA\_AdjustSpeed state

#### 5.12.6.6.1 State description

This state waits for the SP transmitter to adjust to the same physical link rate of the ALIGNs that were detected by the receiver circuitry.

This state shall:

- 1) send a Set Physical Link Rate message to the SP transmitter with an argument specifying the physical link rate of the ALIGNs that were detected by the receiver circuitry; and
- 2) repeatedly send Transmit D10.2 messages to the SP transmitter.

#### 5.12.6.6.2 Transition SP20:SATA\_AdjustSpeed to SP0:OOB\_COMINIT

This transition shall occur after receiving:

- a) a DWS Lost message; or
- b) a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.6.6.3 Transition SP20:SATA\_AdjustSpeed to SP21:SATA\_TransmitALIGN**

This transition shall occur:

- a) after receiving a Transmitter Ready message.

**5.12.6.7 SP21:SATA\_TransmitALIGN state****5.12.6.7.1 State description**

This state shall repeatedly send Transmit ALIGN (0) messages to the SP transmitter.

**5.12.6.7.2 Transition SP21:SATA\_TransmitALIGN to SP0:OOB\_COMINIT**

This transition shall occur after receiving:

- a) a DWS Lost message; or
- b) a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.6.7.3 Transition SP21:SATA\_TransmitALIGN to SP22:SATA\_PHY\_Ready**

This transition shall occur:

- a) after receiving three consecutive Dword Received messages containing primitives other than ALIGN (0).

**5.12.6.8 SP22:SATA\_PHY\_Ready state****5.12.6.8.1 State description**

While in this state dwords from the link layer are transmitted at the negotiated physical link rate (i.e., the rate established in the previous state).

Upon entry into this state, this state shall:

- a) if the SP transmitter is transmitting at 1.5 Gbit/s, then set the ResetStatus state machine variable to G1;
- b) if the SP transmitter is transmitting at 3 Gbit/s, then set the ResetStatus state machine variable to G2; or
- c) if the SP transmitter is transmitting at 6 Gbit/s, then set the ResetStatus state machine variable to G3;

This state shall send a Phy Layer Ready (SATA) confirmation to the link layer.

This state waits for a COMINIT Detected message, a DWS Lost message, or a DWS Reset message.

Each time this state receives a DWS Lost message, this state may send a Start DWS message to the SP\_DWS state machine to re-acquire dword synchronization without running a new link reset sequence.

**5.12.6.8.2 Transition SP22:SATA\_PHY\_Ready to SP0:OOB\_COMINIT**

This transition shall occur after receiving:

- a) a DWS Lost message, if this state does not send a Start DWS message;
- b) a DWS Lost message followed by a COMINIT Detected message, if this state does not send a Start DWS message; or
- c) a DWS Reset message.



**5.12.6.8.3 Transition SP22:SATA\_PHY\_Ready to SP23:SATA\_PM\_Partial**

This transition shall occur:

- a) after receiving a Manage Phy Power Conditions (Enter Partial) request.

**5.12.6.8.4 Transition SP22:SATA\_PHY\_Ready to SP24:SATA\_PM\_Slumber**

This transition shall occur:

- a) after receiving a Manage Phy Power Conditions (Enter Slumber) request.

**5.12.6.9 SP23:SATA\_PM\_Partial state****5.12.6.9.1 State description**

Upon entry into this state, this state shall set the SASPhyPwrCond state machine variable to Partial.

This state waits for a COMWAKE Detected message or a Manage Phy Power Conditions (Exit) request.

When this state receives a COMWAKE Detected message or a Manage Phy Power Conditions (Exit) request this state shall send a Phy Wakeup message to the SP transmitter.

**5.12.6.9.2 Transition SP23:SATA\_PM\_Partial to SP0:OOB\_COMINIT**

This transition shall occur:

- a) after receiving a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

**5.12.6.9.3 Transition SP23:SATA\_PM\_Partial to SP16:SATA\_COMWAKE**

This transition shall occur:

- a) if this state receives a Manage Phy Power Conditions (Exit) request; and
- b) after this state receives a Phy Wakeup Complete message.

**5.12.6.9.4 Transition SP23:SATA\_PM\_Partial to SP19:SATA\_AwaitALIGN**

This transition shall occur after this state receives a:

- a) Phy Wakeup Complete message; and
- b) COMWAKE Completed message.

**5.12.6.10 SP24:SATA\_PM\_Slumber state****5.12.6.10.1 State description**

Upon entry into this state, this state shall set the SASPhyPwrCond state machine variable to Slumber.

This state waits for a COMWAKE Detected message or a Manage Phy Power Conditions (Exit) request.

When this state receives a COMWAKE Detected message or a Manage Phy Power Conditions (Exit) request this state shall send a Phy Wakeup message to the SP transmitter.

**5.12.6.10.2 Transition SP24:SATA\_PM\_Slumber to SP0:OOB\_COMINIT**

This transition shall occur:

- a) after receiving a COMINIT Detected message.

Before the transition, this state shall set the ResetStatus state machine variable to UNKNOWN.

### 5.12.6.10.3 Transition SP24:SATA\_PM\_Slumber to SP16:SATA\_COMWAKE

This transition shall occur:

- if this state receives a Manage Phy Power Conditions (Exit) request; and
- after this state receives a Phy Wakeup Complete message.

### 5.12.6.10.4 Transition SP24:SATA\_PM\_Slumber to SP19:SATA\_AwaitALIGN

This transition shall occur after this state receives a:

- Phy Wakeup Complete message; and
- COMWAKE Completed message.

## 5.12.7 SATA port selector state SP25:SATA\_PortSel

### 5.12.7.1 State description

Figure 99 shows the SP25:SATA\_PortSel state. This state controls transmission of the SATA port selection signal when a specified phy processes a Transmit SATA Port Selection Signal request.

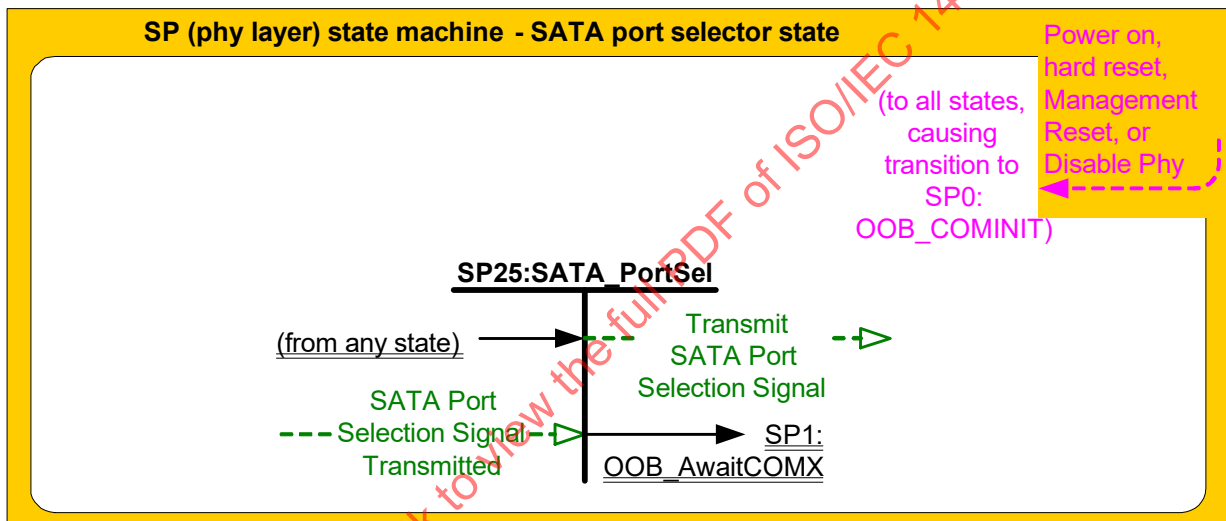


Figure 99 — SP (phy layer) state machine – SATA port selector state

Upon entry into this state, this state shall:

- set the ResetStatus state machine variable to UNKNOWN;
- send a Transmit SATA Port Selection Signal message to the SP transmitter;
- set the ATTACHED SATA PORT SELECTOR bit to zero in the SMP DISCOVER response (see 9.4.3.10); and
- set the ATTACHED SATA DEVICE bit to zero in the SMP DISCOVER response.

### 5.12.7.2 Transition SP25:SATA\_PortSel to SP1:OOB\_AwaitCOMX

This transition shall occur:

- after receiving a SATA Port Selection Signal Transmitted message.

## 5.12.8 SATA spinup hold state SP26:SATA\_SpinupHold

### 5.12.8.1 State description

Figure 100 shows the SP26:SATA\_SpinupHold state.

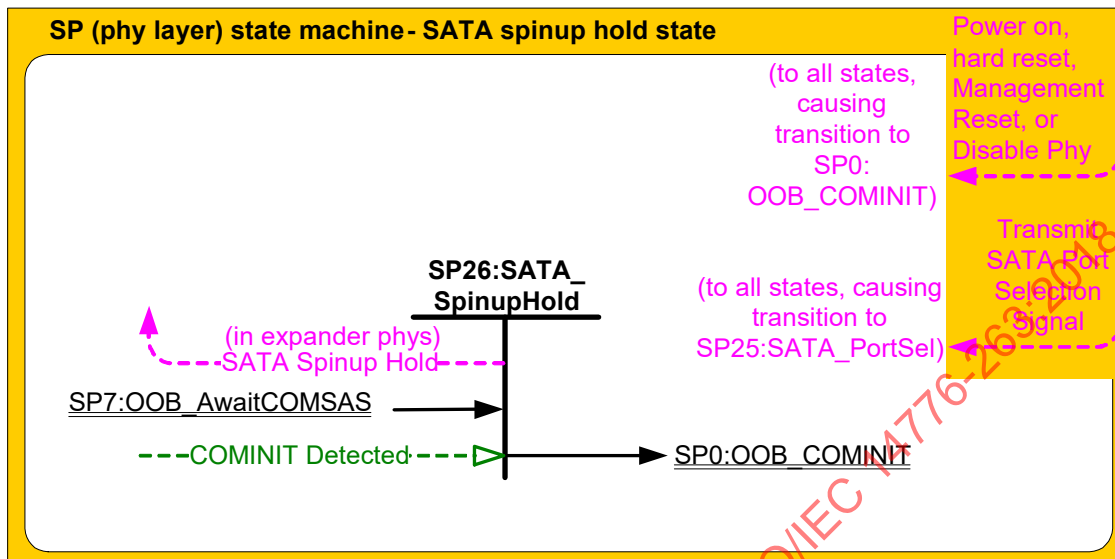


Figure 100 — SP (phy layer) state machine - SATA spinup hold state

Upon entry into this state, this state shall:

- if the ResetStatus state machine variable is set to SPINUP\_HOLD, then not change the ResetStatus state machine variable; or
- if the ResetStatus state machine variable is not set to SPINUP\_HOLD, then:
  - set the ResetStatus state machine variable to SPINUP\_HOLD; and
  - if this state machine is in an expander phy, then send a SATA Spinup Hold confirmation to the link layer.

### 5.12.8.2 Transition SP26:SATA\_SpinupHold to SP0:OOB\_COMINIT

This transition shall occur:

- if this state receives a COMINIT Detected message.

## 5.13 SP\_DWS (phy layer dword synchronization) state machine

### 5.13.1 SP\_DWS state machine overview

Each phy includes an SP\_DWS state machine and an SP\_DWS receiver.

The SP\_DWS state machine establishes the same dword boundaries at the receiver as at the attached transmitter by searching for control characters. The SP\_DWS receiver monitors and decodes the incoming data stream and forces K28.5 characters into the first character position to perform dword alignment when requested by the SP\_DWS state machine. K28.5 characters with either positive or negative disparity shall be accepted. The SP\_DWS receiver continues to reestablish dword alignment by forcing received K28.5 characters into the first character position until a K28.5-based primitive (i.e., K28.5, Dxx.y, Dxx.y, Dxx.y) with correct disparity on each data character is detected. The resultant primitives, dwords, and valid dword

indicators (e.g., encoding error indicators) are sent to this state machine to enable it to determine the dword synchronization policy.

After dword synchronization has been achieved, this state machine evaluates dwords that are received. When an invalid dword is detected, receipt of two valid dwords are required to nullify the effect of receiving the invalid dword. When four invalid dwords are detected without nullification, dword synchronization is considered lost.

While dword synchronization is lost, the data stream received is invalid and dwords shall not be passed to the link layer.

This state machine consists of the following states:

- a) SP\_DWS0:AcquireSync (see 5.13.3) (initial state);
- b) SP\_DWS1:Valid1 (see 5.13.4);
- c) SP\_DWS2:Valid2 (see 5.13.5);
- d) SP\_DWS3:SyncAcquired (see 5.13.6);
- e) SP\_DWS4:Lost1 (see 5.13.7);
- f) SP\_DWS5:Lost1Recovered (see 5.13.8);
- g) SP\_DWS6:Lost2 (see 5.13.9);
- h) SP\_DWS7:Lost2Recovered (see 5.13.10);
- i) SP\_DWS8:Lost3 (see 5.13.11); and
- j) SP\_DWS9:Lost3Recovered (see 5.13.12).

This state machine receives the following requests from the management application layer:

- a) Management Reset; and
- b) Disable Phy.

This state machine shall start in the SP\_DWS0:AcquireSync state after:

- a) power on;
- b) hard reset;
- c) receiving a Management Reset request (e.g., as a result of processing an SMP PHY CONTROL function requesting a phy operation of LINK RESET or HARD RESET);
- d) receiving a Disable Phy request (e.g., as a result of processing an SMP PHY CONTROL function requesting a phy operation of DISABLE); or
- e) receiving a Stop DWS message from the SP state machine.

This state machine receives the following messages from the SP state machine (see 5.12):

- a) Start DWS; and
- b) Stop DWS.

This state machine sends the following messages to the SP state machine:

- a) DWS Lost; and
- b) DWS Reset.

This state machine shall maintain the timers listed in table 77.

**Table 77 — SP\_DWS state machine timers**

| Timer                   | Initial value |
|-------------------------|---------------|
| DWS Reset Timeout timer | 1 ms          |

Figure 101 shows the SP\_DWS state machine.

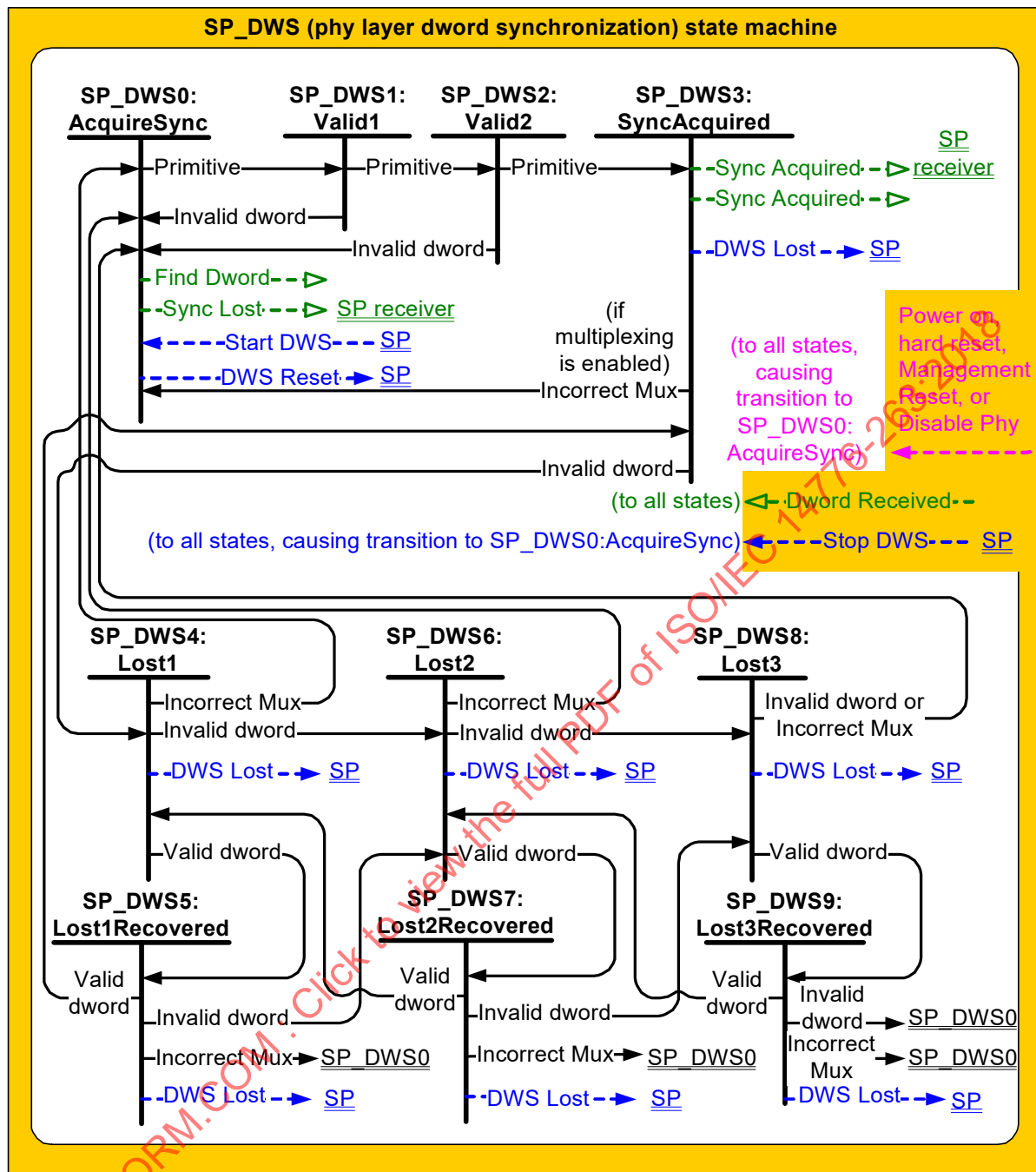


Figure 101 — SP\_DWS (phy layer dword synchronization) state machine

### 5.13.2 SP\_DWS receiver

The SP\_DWS receiver receives the following messages from the SP\_DWS state machine:

- Find Dword; and
- Sync Acquired.

The SP\_DWS receiver sends the following messages to the SP\_DWS state machine indicating dwords received from the physical link:

- a) Dword Received (Primitive);
- b) Dword Received (Data Dword);
- c) Dword Received (Invalid); and
- d) Incorrect Mux Received.

When the SP\_DWS receiver receives a Sync Acquired message, the SP\_DWS receiver shall send the most recently received primitive and all subsequent dwords to the link layer state machine receivers (e.g., SL\_IR, SL, SSP, SMP, and XL) through the elasticity buffer (see 6.3) as Dword Received confirmations. If multiplexing is enabled (see table 55), then the SP\_DWS receiver shall use the first incoming MUX to determine the logical phy to which it sends each Dword Received confirmation and shall not send an Dword Received confirmations until it receives the first incoming MUX.

Upon receiving a Find Dword message, the SP\_DWS receiver shall monitor the input data stream and force each K28.5 character detected into the first character position of a possible dword. If the next three characters are data characters with correct disparity, then the SP\_DWS receiver shall send the dword as a Dword Received (Primitive) message to the SP\_DWS state machine. Until the SP\_DWS receiver receives another Find Dword message, for every four characters that it receives the SP\_DWS receiver shall:

- a) send a Dword Received (Invalid) message to the SP\_DWS state machine if the dword is an invalid dword (see 3.1.103);
- b) send a Dword Received (Primitive) message to the SP\_DWS state machine if the dword is a primitive (i.e., the dword contains a K28.5 character in the first character position followed by three data characters); or
- c) send a Dword Received (Data Dword) message to the SP\_DWS state machine if the dword is a data dword (i.e., it is not an invalid dword or a primitive).

The SP\_DWS receiver relationship to other receivers is defined in 4.3.3.

### 5.13.3 SP\_DWS0:AcquireSync state

#### 5.13.3.1 State description

This is the initial state of this state machine.

After receiving a Start DWS message, this state shall:

- a) send a Find Dword message to the SP\_DWS receiver;
- b) send a Sync Lost message to the SP receiver; and
- c) initialize and start the DWS Reset Timeout timer.

If this state is entered from SP\_DWS1:Valid1 or SP\_DWS2:Valid2, then:

- a) this state shall send a Find Dword message to the SP\_DWS receiver;
- b) this state shall send a Sync Lost message to the SP receiver; and
- c) the DWS Reset Timeout timer shall continue running.

If the DWS Reset Timeout timer expires, then this state may send a DWS Reset message to the SP state machine (e.g., if the phy chooses to initiate a new link reset sequence because dword synchronization has been lost for too long).

This state shall not send a DWS Reset message to the SP until the DWS Reset Timeout timer expires.

#### 5.13.3.2 Transition SP\_DWS0:AcquireSync to SP\_DWS1:Valid1

This transition shall occur:

- a) after sending a Find Dword message; and
- b) after receiving a Dword Received (Primitive) message.

#### 5.13.4 SP\_DWS1:Valid1 state

##### 5.13.4.1 State description

This state is reached after one valid primitive has been received. This state waits for a second valid primitive or an invalid dword.

The DWS Reset Timeout timer shall continue running.

##### 5.13.4.2 Transition SP\_DWS1:Valid1 to SP\_DWS0:AcquireSync

This transition shall occur:

- a) after receiving a Dword Received (Invalid) message; or
- b) after the DWS Reset Timeout timer expires.

##### 5.13.4.3 Transition SP\_DWS1:Valid1 to SP\_DWS2:Valid2

This transition shall occur:

- a) after receiving a Dword Received (Primitive) message.

#### 5.13.5 SP\_DWS2:Valid2 state

##### 5.13.5.1 State description

This state is reached after two valid primitives have been received without adjusting the dword synchronization. This state waits for a third valid primitive or an invalid dword.

The DWS Reset Timeout timer shall continue running.

##### 5.13.5.2 Transition SP\_DWS2:Valid2 to SP\_DWS0:AcquireSync

This transition shall occur:

- a) after receiving a Dword Received (Invalid) message; or
- b) after the DWS Reset Timeout timer expires.

##### 5.13.5.3 Transition SP\_DWS2:Valid2 to SP\_DWS3:SyncAcquired

This transition shall occur:

- a) after receiving a Dword Received (Primitive) message.

#### 5.13.6 SP\_DWS3:SyncAcquired state

##### 5.13.6.1 State description

This state is reached after three valid primitives have been received without adjusting the dword synchronization.

Upon entry into this state, this state shall send a Sync Acquired message to the SP\_DWS receiver and the SP receiver. The most recently received primitive and all subsequent dwords shall be forwarded through the elasticity buffer (see 6.3) for processing by the link layer.

This state waits for a Dword Received (Invalid) message, which indicates a potential loss of dword synchronization, or an Incorrect Mux Received message, which indicates that dword synchronization is lost.

If an Incorrect Mux Received message is received, then this state shall send a DWS Lost message to the SP state machine.

**5.13.6.2 Transition SP\_DWS3:SyncAcquired to SP\_DWS0:AcquireSync**

This transition shall occur:

- a) after sending a DWS Lost message.

**5.13.6.3 Transition SP\_DWS3:SyncAcquired to SP\_DWS4:Lost1**

This transition shall occur:

- a) after receiving a Dword Received (Invalid) message.

**5.13.7 SP\_DWS4:Lost1 state****5.13.7.1 State description**

This state is reached when one invalid dword has been received and not nullified. This state waits for a Dword Received message or an Incorrect Mux Received message.

If an Incorrect Mux Received message is received, then this state shall send a DWS Lost message to the SP state machine.

**5.13.7.2 Transition SP\_DWS4:Lost1 to SP\_DWS0:AcquireSync**

This transition shall occur:

- a) after sending a DWS Lost message.

**5.13.7.3 Transition SP\_DWS4:Lost1 to SP\_DWS5:Lost1Recovered**

This transition shall occur after receiving:

- a) a Dword Received (Data Dword) message; or
- b) a Dword Received (Primitive) message.

**5.13.7.4 Transition SP\_DWS4:Lost1 to SP\_DWS6:Lost2**

This transition shall occur:

- a) after receiving a Dword Received (Invalid) message.

**5.13.8 SP\_DWS5:Lost1Recovered state****5.13.8.1 State description**

This state is reached when a valid dword has been received after one invalid dword had been received. This state waits for a Dword Received message or an Incorrect Mux Received message.

If an Incorrect Mux Received message is received, then this state shall send a DWS Lost message to the SP state machine.

**5.13.8.2 Transition SP\_DWS5:Lost1Recovered to SP\_DWS0:AcquireSync**

This transition shall occur:

- a) after sending a DWS Lost message.



**5.13.8.3 Transition SP\_DWS5:Lost1Recovered to SP\_DWS3:SyncAcquired**

This transition shall occur after receiving:

- a) a Dword Received (Data Dword) message; or
- b) a Dword Received (Primitive) message.

**5.13.8.4 Transition SP\_DWS5:Lost1Recovered to SP\_DWS6:Lost2**

This transition shall occur:

- a) after receiving a Dword Received (Invalid) message.

**5.13.9 SP\_DWS6:Lost2 state****5.13.9.1 State description**

This state is reached when two invalid dwords have been received and not nullified. This state waits for a Dword Received message or an Incorrect Mux Received message.

If an Incorrect Mux Received message is received, then this state shall send a DWS Lost message to the SP state machine.

**5.13.9.2 Transition SP\_DWS6:Lost2 to SP\_DWS0:AcquireSync**

This transition shall occur:

- a) after sending a DWS Lost message.

**5.13.9.3 Transition SP\_DWS6:Lost2 to SP\_DWS7:Lost2Recovered**

This transition shall occur after receiving:

- a) a Dword Received (Data Dword) message; or
- b) a Dword Received (Primitive) message.

**5.13.9.4 Transition SP\_DWS6:Lost2 to SP\_DWS8:Lost3**

This transition shall occur:

- a) after receiving a Dword Received (Invalid) message.

**5.13.10 SP\_DWS7:Lost2Recovered state****5.13.10.1 State description**

This state is reached when a valid dword has been received after two invalid dwords had been received. This state waits for a Dword Received message or an Incorrect Mux Received message.

If an Incorrect Mux Received message is received, then this state shall send a DWS Lost message to the SP state machine.

**5.13.10.2 Transition SP\_DWS7:Lost2Recovered to SP\_DWS0:AcquireSync**

This transition shall occur:

- a) after sending a DWS Lost message.

**5.13.10.3 Transition SP\_DWS7:Lost2Recovered to SP\_DWS4:Lost1**

This transition shall occur after receiving:

- a) a Dword Received (Data Dword) message; or
- b) a Dword Received (Primitive) message.

**5.13.10.4 Transition SP\_DWS7:Lost2Recovered to SP\_DWS8:Lost3**

This transition shall occur:

- a) after receiving a Dword Received (Invalid) message.

**5.13.11 SP\_DWS8:Lost3 state****5.13.11.1 State description**

This state is reached when three invalid dwords have been received and not nullified. This state waits for a Dword Received message or an Incorrect Mux Received message.

If a Dword Received (Invalid) message is received (i.e., the fourth non-nullified invalid dword is received), then this state shall send a DWS Lost message to the SP state machine.

If an Incorrect Mux Received message is received, then this state shall send a DWS Lost message to the SP state machine.

**5.13.11.2 Transition SP\_DWS8:Lost3 to SP\_DWS0:AcquireSync**

This transition shall occur:

- a) after sending a DWS Lost message.

**5.13.11.3 Transition SP\_DWS8:Lost3 to SP\_DWS9:Lost3Recovered**

This transition shall occur after receiving:

- a) a Dword Received (Data Dword) message; or
- b) a Dword Received (Primitive) message.

**5.13.12 SP\_DWS9:Lost3Recovered state****5.13.12.1 State description**

This state is reached when a valid dword has been received after three invalid dwords had been received. This state waits for a Dword Received message or an Incorrect Mux Received message.

If a Dword Received (Invalid) message is received (i.e., the fourth non-nullified invalid dword is received), then this state shall send a DWS Lost message to the SP state machine.

If an Incorrect Mux Received message is received, then this state shall send a DWS Lost message to the SP state machine.

**5.13.12.2 Transition SP\_DWS9:Lost3Recovered to SP\_DWS0:AcquireSync**

This transition shall occur:

- a) after sending a DWS Lost message.

### 5.13.12.3 Transition SP\_DWS9:Lost3Recovered to SP\_DWS6:Lost2

This transition shall occur after receiving:

- a) a Dword Received (Data Dword) message; or
- b) a Dword Received (Primitive) message.

## 5.14 PTT (phy layer transmitter training) state machines

### 5.14.1 PTT state machines overview

The PTT phy layer contains several state machines that run in parallel to control the physical link during Train\_Tx-SNW. The PTT state machines are as follows:

- a) PTT\_T (phy layer transmitter training transmit pattern) state machine (see 5.14.4);
- b) PTT\_R (phy layer transmitter training receive pattern) state machine (see 5.14.5);
- c) PTT\_SC1 (phy layer transmitter training set transmitter coefficient 1) state machine (see 5.14.6);
- d) PTT\_SC2 (phy layer transmitter training set transmitter coefficient 2) state machine (see 5.14.7);
- e) PTT\_SC3 (phy layer transmitter training set transmitter coefficient 3) state machine (see 5.14.8);
- f) PTT\_GC1 (phy layer transmitter training get transmitter coefficient 1) state machine (see 5.14.9);
- g) PTT\_GC2 (phy layer transmitter training get transmitter coefficient 2) state machine (see 5.14.10);
- h) PTT\_GC3 (phy layer transmitter training get transmitter coefficient 3) state machine (see 5.14.11);
- and
- i) PTT\_PL (phy layer transmitter training pattern lock) state machine (see 5.14.12).

All the PTT state machines shall start in the initial state after receiving a Transmitter Training (Enable) message from the SP state machine (see 5.12.4.13).

All the PTT state machines shall terminate after receiving a Transmitter Training (Disable) message from the SP state machine (see 5.12.4.13).

Each phy that supports transmitter training shall include all the PTT state machines.

If the state machine consists of multiple states, then the initial state is as indicated in the state machine description in this subclause.

Any message, request, or confirmation received by a state that is not referred to in the description of that state shall be ignored.

### 5.14.2 SP transmitter additions for transmitter training

#### 5.14.2.1 SP transmitter additions for transmitter training overview

The SP transmitter receives the following message from the PTT state machines specifying dwords to transmit:

- a) Transmit Train\_Tx Pattern (see 5.10.4.2.3.4).

The SP transmitter receives the following messages from the PTT state machines:

- a) Set Training Control;
- b) Set Training Status;
- c) Set Transmitter Failed;
- d) Adjust Coefficient 1 with arguments of:
  - A) Increment, Decrement, Set No\_Equalization, Set Reference\_1, or Set Reference\_2; and
  - B) Single or Dual;
- e) Adjust Coefficient 2 with arguments of:
  - A) Increment, Decrement, Set No\_Equalization, Set Reference\_1, or Set Reference\_2; and
  - B) Single or Dual;

and

- f) Adjust Coefficient 3 with argument of:
  - A) Increment, Decrement, Set No\_Equalization, Set Reference\_1, or Set Reference\_2; and
  - B) Single or Dual.

See 5.12.2 for SP transmitter requirements while PTT state machines are not processing Train\_Tx-SNW.

The SP transmitter relationship to other transmitters is defined in 4.3.2.

#### 5.14.2.2 TTIU transmit setup

In response to a Set Training Control message the SP transmitter shall set the Training Control word (see 5.9.2) to the contents of the received argument.

In response to a Set Training Status message the SP transmitter shall set the Training Status word (see 5.9.2) to the contents of the received argument.

In response to a Set Transmitter Failed message the SP transmitter shall set the Error Response TTIU (see 5.9.3) to the contents of the received argument.

The SP transmitter shall set the BALANCE bit (see 5.9.2 and 5.9.3) to the correct value before transmitting a Train\_Tx pattern.

The SP transmitter sends the following message to the PTT state machines based on words that have been transmitted:

- a) Train\_Tx Pattern Transmitted.

#### 5.14.2.3 No\_equalization, reference\_1, and reference\_2 coefficient settings request

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, and an Adjust Coefficient 3 message with a Set No\_Equalization argument the SP transmitter shall adjust all the coefficients to the no equalization value (see SAS-3).

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, and an Adjust Coefficient 3 message with a Set Reference\_1 argument the SP transmitter shall adjust all the coefficients to the reference\_1 value (see SAS-3).

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, and an Adjust Coefficient 3 message with a Set Reference\_2 argument the SP transmitter shall adjust all the coefficients to the reference\_2 value (see SAS-3).

#### 5.14.2.4 Coefficient limits

The individual coefficient limits and limits associated with relationships between coefficients specified in SAS-3 shall be maintained by the SP transmitter while processing coefficient adjustment requests.

#### 5.14.2.5 Coefficient request result of update complete

##### 5.14.2.5.1 Coefficient request processing

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, or an Adjust Coefficient 3 message with a Single argument, and an Increment argument or a Decrement argument the SP transmitter shall adjust the specified coefficient if that adjustment results in the specified coefficient being:

- a) less than a maximum value; and
- b) greater than a minimum value (see SAS-3).

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, or an Adjust Coefficient 3 message with a Dual argument, and an Increment argument or a Decrement argument the SP transmitter shall, after receiving the first Dual argument:

- 1) wait for a second Dual argument;
- 2) process both requests; and

- 3) for each specified coefficient, adjust that coefficient if that adjustment results in:
  - A) that coefficient being:
    - a) less than a maximum value; and
    - b) greater than a minimum value;
  - and
  - B) no coefficient being greater than a maximum value or less than a minimum value.

#### 5.14.2.5.2 Coefficient adjustment completes

If the SP transmitter adjusts a specified coefficient, then after the adjustment is complete the SP transmitter shall send to the PTT state machine state that requested the SP transmitter adjustment the message associated with the adjusted coefficient (i.e., Transmitter Adjustment 1 Complete (Update Complete) message, Transmitter Adjustment 2 Complete (Update Complete) message, or Transmitter Adjustment 3 Complete (Update Complete) message).

#### 5.14.2.5.3 No coefficient adjustment

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, or an Adjust Coefficient 3 message with a Dual argument, if the processing results in:

- a) one specified coefficient being:
  - A) less than a maximum value; and
  - B) greater than a minimum value;
- and
- b) the other specified coefficient being:
  - A) greater than a maximum value; or
  - B) less than a minimum value,

then the SP transmitter shall send the message associated with the specified coefficient (i.e., Transmitter Adjustment 1 Complete (Update Complete) message, Transmitter Adjustment 2 Complete (Update Complete) message, or Transmitter Adjustment 3 Complete (Update Complete) message) that is:

- a) less than a maximum value, and
- b) greater than a minimum value,

to the PTT state machine state that requested the SP transmitter adjustment.

#### 5.14.2.6 Coefficient request result of maximum

##### 5.14.2.6.1 Coefficient request processing

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, or an Adjust Coefficient 3 message with a Single argument and an Increment argument the SP transmitter shall adjust the specified coefficient if that adjustment results in the specified coefficient being equal to a maximum value (see SAS-3).

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, or an Adjust Coefficient 3 message with a Dual argument and an Increment argument, the SP transmitter shall, after receiving the first Dual argument:

- 1) wait for a second Dual argument;
- 2) process both requests; and
- 3) for each specified coefficient, adjust that coefficient if that adjustment results in:
  - A) that coefficient being equal to a maximum value; and
  - B) no coefficient being greater than a maximum value.

#### 5.14.2.6.2 Coefficient adjustment completes

If the SP transmitter adjusts a specified coefficient to a maximum value, then after the adjustment is complete the SP transmitter shall send to the PTT state machine state that requested the SP transmitter adjustment the message associated with the adjusted coefficient (i.e., Transmitter Adjustment 1 Complete (Maximum) message, Transmitter Adjustment 2 Complete (Maximum) message, or Transmitter Adjustment 3 Complete (Maximum) message).

#### 5.14.2.6.3 No coefficient adjustment

If the processing of the requested SP transmitter adjustment results in an adjustment that is greater than a coefficient's maximum value, then:

- a) no adjustment shall be made to any coefficient; and
- b) the SP transmitter shall send to the PTT state machine state that requested the SP transmitter adjustment the message associated with each specified coefficient that is equal to or greater than a maximum value (i.e., Transmitter Adjustment 1 Complete (Maximum) message, Transmitter Adjustment 2 Complete (Maximum) message, or Transmitter Adjustment 3 Complete (Maximum) message).

#### 5.14.2.7 Coefficient request result of minimum

##### 5.14.2.7.1 Coefficient request processing

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, or an Adjust Coefficient 3 message with a Single argument and a Decrement argument the SP transmitter shall adjust the specified coefficient if that adjustment results in the specified coefficient being equal to a minimum value (see SAS-3).

In response to an Adjust Coefficient 1 message, an Adjust Coefficient 2 message, or an Adjust Coefficient 3 message with a Dual argument and a Decrement argument, the SP transmitter shall, after receiving the first Dual argument:

- 1) wait for a second Dual argument;
- 2) process both requests; and
- 3) for each specified coefficient, adjust that coefficient if that adjustment results in:
  - A) that coefficient being equal to a minimum value; and
  - B) no coefficient being less than a minimum value.

##### 5.14.2.7.2 Coefficient adjustment completes

If the SP transmitter adjusts a specified coefficient to a minimum value, then after the adjustment is complete the SP transmitter shall send to the PTT state machine state that requested the SP transmitter adjustment the message associated with the adjusted coefficient (i.e., Transmitter Adjustment 1 Complete (Minimum) message, Transmitter Adjustment 2 Complete (Minimum) message, or Transmitter Adjustment 3 Complete (Minimum) message).

##### 5.14.2.7.3 No coefficient adjustment

If the processing of the requested SP transmitter adjustment results in an adjustment that is less than a coefficient's minimum value then:

- a) no adjustment shall be made to any coefficient; and
- b) the SP transmitter shall send to the PTT state machine state that requested the SP transmitter adjustment the message associated with each specified coefficient that is equal to or less than a minimum value (i.e., Transmitter Adjustment 1 Complete (Minimum) message, Transmitter Adjustment 2 Complete (Minimum) message, or Transmitter Adjustment 3 Complete (Minimum) message).

### 5.14.3 SP receiver additions for transmitter training

The SP receiver sends the following messages to the PTT state machines indicating dwords received by the SP receiver:

- a) Received TTIU with arguments containing the contents of the received TTIU (e.g., Training Control word and the Training Status word of the Control/Status TTIU, or error response of the Error Response TTIU);
- b) Valid Pattern Marker; and
- c) Invalid Pattern Marker.

The SP receiver sends the following messages to the PTT state machines:

- a) Current Coefficient 1 with an argument of Increment, Decrement, No\_Equalization, Reference\_1, Reference\_2, or Hold;
- b) Current Coefficient 2 with an argument of Increment, Decrement, No\_Equalization, Reference\_1, Reference\_2, or Hold;
- c) Current Coefficient 3 with an argument of Increment, Decrement, No\_Equalization, Reference\_1, Reference\_2, or Hold;
- d) All Coefficients Not Ready; and
- e) Attached Phy's Transmitter Optimized.

The SP receiver receives the following messages from the PTT state machines:

- a) Coefficient 1 Status with an argument of Maximum, Minimum, Update\_Complete, or Ready;
- b) Coefficient 2 Status with an argument of Maximum, Minimum, Update\_Complete, or Ready;
- c) Coefficient 3 Status with an argument of Maximum, Minimum, Update\_Complete, or Ready;
- d) Get Current Coefficient 1;
- e) Get Current Coefficient 2;
- f) Get Current Coefficient 3;
- g) Enable Pattern Marker Detection;
- h) Disable Pattern Marker Detection;
- i) Attached Phy's Transmitter Training with an argument of Start or Stop;
- j) Transmitter Control Failed with an argument containing information on the failure; and
- k) Coefficients Status Updated.

After the SP receiver receives an Attached Phy's Transmitter Training (Start) message, the SP receiver shall respond to a Get Current Coefficient 1 message, Get Current Coefficient 2 message, and Get Current Coefficient 3 message by sending a Current Coefficient 1 message, Current Coefficient 2 message, and Current Coefficient 3 message with an argument (i.e., Increment, Decrement, No\_Equalization, Reference\_1, Reference\_2, or Hold) to the PTT state machine after the SP receiver:

- a) completes the analysis of a transmitter training pattern; and
- b) receives a Control/Status TTIU with an even number of bits set to zero with a coefficient status of ready for all the attached phy's transmitter coefficients.

After the SP receiver sends one or more Current Coefficient 1 message, Current Coefficient 2 message, or Current Coefficient 3 message with an argument of Increment, Decrement, No\_Equalization, Reference\_1, or Reference\_2 the SP receiver shall not attempt analysis of a transmitter training pattern until after it has received a status of update complete, maximum, or minimum for all the attached phy's transmitter coefficients that were updated.

After the SP receiver receives an Attached Phy's Transmitter Training (Stop) message, the SP receiver:

- 1) shall not respond to any Get Current Coefficient 1 messages, Get Current Coefficient 2 messages, or Get Current Coefficient 3 messages;
- 2) waits until a status other than ready has been received on all coefficients; and
- 3) repeatedly send All Coefficients Not Ready messages to the PTT\_T state machine until an Attached Phy's Transmitter Training (Start) message is received.

When the SP receiver determines the attached phy's transmitter training is complete, the SP receiver shall send an Attached Phy's Transmitter Optimized message to the PTT\_T state machine.

If the SP receiver requires the attached phy's transmitter training to be restarted with the no\_equalization value, reference\_1 value, or reference\_2 value, then the SP receiver shall:

- 1) wait until the Coefficient 1 Status message, Coefficient 2 Status message, and Coefficient 3 Status message all specify a Ready argument; and
- 2) send a Current Coefficient 1 message to the PTT\_GC1 state machine, Current Coefficient 2 message to the PTT\_GC2 state machine, and Current Coefficient 3 message to the PTT\_GC3 state machines all with the same argument of No\_Equalization, Reference\_1, or Reference\_2.

The actions taken on receiving a Transmitter Control Failed message are outside the scope of this standard.

See 5.12.2 for SP receiver requirements while PTT state machines are not processing Train\_Tx-SNW.

The SP receiver relationship to other receivers is defined in 4.3.3.

#### **5.14.4 PTT\_T (phy layer transmitter training transmit pattern) state machine**

##### **5.14.4.1 PTT\_T state machine overview**

The PTT\_T state machine's function is to:

- a) transmit the status information and control information to train the attached phy's transmitter;
- b) determine when the local phy's transmitter training is complete; and
- c) determine when the attached phy's transmitter training is complete.

This state machine consists of the following states:

- a) PTT\_T0:Idle (see 5.14.4.2) (initial state);
- b) PTT\_T1:Initialize (see 5.14.4.3);
- c) PTT\_T2:Tx\_Training (see 5.14.4.4); and
- d) PTT\_T3:Local\_Tx\_Training (see 5.14.4.5).

This state machine receives the following request from the management application layer:

- a) Initial Coefficient Setting with an argument of Normal, No\_Equalization, Reference\_1, or Reference\_2.

This state machine sends the following message to the SP state machine:

- a) Transmitter Training Complete.



**PTT\_T (phy layer transmitter training) state machine**

**PTT\_T0:Idle**

Initial Coefficient Setting

SP -- Transmitter Training (Enable)

**PTT\_T1:Initialize**

SP -- Transmitter Training (Disable)

PTT\_R2 -- TTIU Received

Train\_Tx Pattern Transmitted

Set Training Status

Set Training Control

Transmit Train\_Tx Pattern

Attached Phys Transmitter Training

**PTT\_T2:Tx Training**

SP -- Transmitter Training (Disable)

PTT\_R2 -- Local Phys Transmitter Training Complete

PTT\_GC1 -- Coefficient 1 Update Request

PTT\_GC2 -- Coefficient 2 Update Request

PTT\_GC3 -- Coefficient 3 Update Request

PTT\_SC1 -- Current Coefficient 1 Status

PTT\_SC2 -- Current Coefficient 2 Status

PTT\_SC3 -- Current Coefficient 3 Status

PTT\_R2 -- Transmit Error Response

PTT\_R2 -- All Coefficients Not Ready

Attached Phys Transmitter Optimized

Train\_Tx Pattern Transmitted

Transmitter Training Complete

SP -- PTT\_R2

**PTT\_T3:Local Tx Training**

SP -- Transmitter Training (Disable)

PTT\_R2 -- Local Phys Transmitter Training Complete

Transmitter Training Complete

SP -- PTT\_R2

Set Transmitter Failed

Set Training Status

Set Training Control

Transmit Train\_Tx Pattern

**Figure 102 — PTT\_T (phy layer transmitter training transmit pattern) state machine**

#### 5.14.4.2 PTT\_T0:Idle state

##### 5.14.4.2.1 State description

This is the initial state of this state machine.

This state waits for a request to start transmitter training.

##### 5.14.4.2.2 Transition PTT\_T0:Idle to PTT\_T1:Initialize

This transition shall occur after receiving:

- a) a Transmitter Training (Enable) message; and
- b) an Initial Coefficient Setting request.

This transition shall include the coefficient setting as an argument (i.e., Normal, No\_Equalization, Reference\_1, or Reference\_2).

#### 5.14.4.3 PTT\_T1:Initialize state

##### 5.14.4.3.1 State description

This state:

- a) sets the initial values of the Training Status word and Training Control word (see 5.9.2);
- b) requests Train\_Tx patterns be transmitted; and
- c) waits for the receipt of a Control/Status TTIU.

Upon entry into this state, this state shall:

- 1) send an Attached Phy's Transmitter Training (Stop) message to the SP receiver;
- 2) set the bits and fields of the Training Status word (see 5.9.2) as follows:
  - A) set the TRAIN COMP bit to zero;
  - B) set the TX INIT bit to one;
  - C) set the COEFFICIENT 1 STATUS field to 00b (i.e., ready);
  - D) set the COEFFICIENT 2 STATUS field to 00b (i.e., ready); and
  - E) set the COEFFICIENT 3 STATUS field to 00b (i.e., ready);
- 3) set the fields of the Training Control word as follows:
  - A) set the PATTERN TYPE field set to 000b (i.e., Control/Status TTIU);
  - B) set the COEFFICIENT SETTINGS field to 00b (i.e., normal);
  - C) set the COEFFICIENT 1 REQUEST field to 00b (i.e., hold);
  - D) set the COEFFICIENT 2 REQUEST field to 00b (i.e., hold); and
  - E) set the COEFFICIENT 3 REQUEST field to 00b (i.e., hold);
- 4) send a Set Training Control message to the SP transmitter;
- 5) send a Set Training Status message to the SP transmitter;
- 6) send a Transmit Train\_Tx Pattern message to the SP transmitter;
- 7) wait for a Train\_Tx Pattern Transmitted message; and
- 8) repeat steps 6) and 7) until this state receives a TTIU Received message with an Attached Transmitter Initialized argument.

If this state receives a TTIU Received message with an Attached Transmitter Not Initialized argument, then this state shall:

- 1) set the TX INIT bit to zero; and
- 2) send a Set Training Status message to the SP transmitter.

##### 5.14.4.3.2 Transition PTT\_T1:Initialize to PTT\_T0:Idle

This transition shall occur:

- a) after receiving a Transmitter Training (Disable) message.

#### 5.14.4.3.3 Transition PTT\_T1:Initialize to PTT\_T2:Tx\_Training

This transition shall occur:

- a) after receiving a TTIU Received message with an Attached Transmitter Initialized argument.

This transition shall include the coefficient setting as an argument (i.e., Normal, No\_Equalization, Reference\_1, or Reference\_2).

#### 5.14.4.4 PTT\_T2:Tx\_Training state

##### 5.14.4.4.1 State description

This state:

- a) sets values of the Training Status word and Training Control word (see 5.9.2);
- b) requests Train\_Tx patterns be transmitted;
- c) waits for attached phy's transmitter training to complete; and
- d) transmits the local phy's transmitter status to the attached phy's receiver.

##### 5.14.4.4.2 Entry conditions

Upon entry into this state, this state shall:

- 1) set the bits and fields of the Training Status word (see 5.9.2) as follows:
  - A) set the TRAIN COMP bit to zero;
  - B) set the TX INIT bit to zero;
  - C) set the COEFFICIENT 1 STATUS field to 00b (i.e., ready);
  - D) set the COEFFICIENT 2 STATUS field to 00b (i.e., ready); and
  - E) set the COEFFICIENT 3 STATUS field to 00b (i.e., ready);
- 2) if the Coefficient Settings argument is set to No\_Equalization, Reference\_1, or Reference\_2, then process the coefficient settings as defined in 5.14.4.4.5;
- 3) send an Attached Phy's Transmitter Training (Start) message to the SP receiver;
- 4) set the fields of the Training Control word (see table 61) as follows:
  - A) set the PATTERN TYPE field to 000b (i.e., Control/Status TTIU);
  - B) set the COEFFICIENT SETTINGS field to 00b (i.e., normal);
  - C) set the COEFFICIENT 1 REQUEST field to 00b (i.e., hold);
  - D) set the COEFFICIENT 2 REQUEST field to 00b (i.e., hold); and
  - E) set the COEFFICIENT 3 REQUEST field to 00b (i.e., hold);
- 5) send a Set Training Control message to the SP transmitter;
- 6) send a Set Training Status message to the SP transmitter;
- 7) send a Transmit Train\_Tx Pattern message to the SP transmitter;
- 8) wait for a Train\_Tx Pattern Transmitted message; and
- 9) repeat steps 7) and 8) while there is no other looping occurring within this state.

#### 5.14.4.4.3 Control word and status word mappings

Table 78 defines the mapping of the messages received from the PTT\_GC state machines to the Training Control word.

**Table 78 — Mapping messages to the Training Control word**

| Message received                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Training Control word field <sup>e</sup> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| Coefficient 1 Update Request <sup>a b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | COEFFICIENT 1 REQUEST                    |
| Coefficient 2 Update Request <sup>a c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | COEFFICIENT 2 REQUEST                    |
| Coefficient 3 Update Request <sup>a d</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | COEFFICIENT 3 REQUEST                    |
| <sup>a</sup> This message contains a Decrement, Increment, Hold, No_Equalization, Reference_1, or Reference_2 argument.<br><sup>b</sup> This message is from the PTT_GC1 state machine.<br><sup>c</sup> This message is from the PTT_GC2 state machine.<br><sup>d</sup> This message is from the PTT_GC3 state machine.<br><sup>e</sup> If the message is received with an argument of Hold, Increment, or Decrement, then the Training Control word field shall be set to the argument received in the corresponding message (i.e., 00b (i.e., hold), 01b (i.e., increment), or 10b (i.e., decrement)). If the message is received with an argument of No_Equalization, Reference_1, or Reference_2, then the Training Control word field shall be set to 00b (i.e., hold). |                                          |

After this state sets the Training Control word to the argument received in the Coefficient 1 Update Request message, Coefficient 2 Update Request message, or Coefficient 3 Update Request message, this state shall send a Set Training Control message to the SP transmitter after receiving a Train\_Tx Pattern Transmitted message.

Table 79 defines the mapping of the messages received from the PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine to the Training Status word.

**Table 79 — Mapping messages from PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine to the Training Status word**

| Messages received                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Training Status word field <sup>e</sup> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| Current Coefficient 1 Status <sup>a b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | COEFFICIENT 1 STATUS                    |
| Current Coefficient 2 Status <sup>a c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | COEFFICIENT 2 STATUS                    |
| Current Coefficient 3 Status <sup>a d</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | COEFFICIENT 3 STATUS                    |
| <sup>a</sup> This message contains a Maximum, Minimum, Update_Complete, or Ready argument.<br><sup>b</sup> This message is from the PTT_SC1 state machine.<br><sup>c</sup> This message is from the PTT_SC2 state machine.<br><sup>d</sup> This message is from the PTT_SC3 state machine.<br><sup>e</sup> On receipt of the message this state shall: <ol style="list-style-type: none"> <li>1) set the Training Status word field to the argument received in the corresponding message (i.e., 00b (i.e., ready), 01b (i.e., update complete), 10b (i.e., minimum), or 11b (i.e., maximum)); and</li> <li>2) send a Set Training Status message to the SP transmitter after receiving a Train_Tx Pattern Transmitted message.</li> </ol> |                                         |

#### 5.14.4.4.4 Error message handling

If this state receives a Transmit Error Response message, then this state shall:

- 1) set the Error Response TTIU fields (see table 66) as follows:
  - A) set the PATTERN TYPE field to 111b (i.e., Error Response TTIU); and
  - B) set the Error Response TTIU fields to the arguments received in the Transmit Error Response message as defined in table 80;
- 2) send a Set Transmitter Failed message to the SP transmitter;
- 3) send a Transmit Train Tx Pattern message to the SP transmitter;
- 4) wait for a Train Tx Pattern Transmitted message;
- 5) send a Set Training Control message to the SP transmitter;
- 6) set the bits and fields of the Training Status word as follows:
  - A) set the PATTERN TYPE field set to 000b (i.e., Control/Status TTIU);
  - B) set the TRAIN COMP bit to zero;
  - C) set the TX INIT bit to zero;
  - D) set the COEFFICIENT 1 STATUS field to 00b (i.e., ready);
  - E) set the COEFFICIENT 2 STATUS field to 00b (i.e., ready); and
  - F) set the COEFFICIENT 3 STATUS field to 00b (i.e., ready);
- 7) send a Set Training Status message to the SP transmitter;
- 8) send a Transmit Train Tx Pattern message to the SP transmitter; and
- 9) wait for a Train Tx Pattern Transmitted message.

Table 80 defines that mapping of the Transmit Error Response message arguments to the Error Response TTIU fields.

**Table 80 — Mapping Transmit Error Response message arguments to Error Response TTIU fields**

| Transmit Error Response message argument | Error Response TTIU field      |
|------------------------------------------|--------------------------------|
| Coefficient Settings                     | RECEIVED COEFFICIENT SETTINGS  |
| Coefficient 1 Request                    | RECEIVED COEFFICIENT 1 REQUEST |
| Coefficient 2 Request                    | RECEIVED COEFFICIENT 2 REQUEST |
| Coefficient 3 Request                    | RECEIVED COEFFICIENT 3 REQUEST |
| Error                                    | ERROR CODE                     |

#### 5.14.4.4.5 Resetting attached phy's transmitter

If this state:

- a) receives a Coefficient 1 Update Request message, Coefficient 2 Update Request message, or Coefficient 3 Update Request message with an argument of No\_Equalization, Reference\_1, or Reference\_2; or
- b) is entered with Coefficient Settings argument set to No\_Equalization, Reference\_1, or Reference\_2 (see 5.14.4.4.2),

then this state shall:

- 1) send an Attached Phy's Transmitter Training (Stop) message to the SP receiver;
- 2) if:
  - A) this state is entered with an argument of No\_Equalization or receives an argument of No\_Equalization, then this state shall set the fields of the Training Control word (see table 61) as follows:
    - a) set the PATTERN TYPE field to 000b (i.e., Control/Status TTIU);

- b) set the COEFFICIENT SETTINGS field to 11b (i.e., no equalization);
- c) set the COEFFICIENT 1 REQUEST field to 00b (i.e., hold);
- d) set the COEFFICIENT 2 REQUEST field to 00b (i.e., hold); and
- e) set the COEFFICIENT 3 REQUEST field to 00b (i.e., hold);
- B) this state is entered with an argument of Reference\_1 or receives an argument of Reference\_1, then this state shall set the fields of the Training Control word as follows:
  - a) set the PATTERN TYPE field to 000b (i.e., Control/Status TTIU);
  - b) set the COEFFICIENT SETTINGS field to 01b (i.e., reference 1);
  - c) set the COEFFICIENT 1 REQUEST field to 00b (i.e., hold);
  - d) set the COEFFICIENT 2 REQUEST field to 00b (i.e., hold); and
  - e) set the COEFFICIENT 3 REQUEST field to 00b (i.e., hold);
- or
- C) this state is entered with an argument of Reference\_2 or receives an argument of Reference\_2, then this state shall set the fields of the Training Control word as follows:
  - a) set the PATTERN TYPE field set to 000b (i.e., Control/Status TTIU);
  - b) set the COEFFICIENT SETTINGS field to 10b (i.e., reference 2);
  - c) set the COEFFICIENT 1 REQUEST field to 00b (i.e., hold);
  - d) set the COEFFICIENT 2 REQUEST field to 00b (i.e., hold); and
  - e) set the COEFFICIENT 3 REQUEST field to 00b (i.e., hold);
- 3) send a Set Training Control message to the SP transmitter;
- 4) send a Set Training Status message to the SP transmitter;
- 5) send a Transmit Train\_Tx Pattern message to the SP transmitter;
- 6) wait for a Train\_Tx Pattern Transmitted message;
- 7) repeat steps 5) and 6) when there is no other looping occurring within this state (i.e., if a Transmit Error Response message is received, then the error as defined in 5.14.4.5.5 shall be processed) until this state receives an All Coefficients Not Ready message;
- 8) send an Attached Phy's Transmitter Training (Start) message to the SP receiver; and
- 9) set the COEFFICIENT SETTINGS field to 00b (i.e., normal).

#### 5.14.4.4.6 Local phy's transmitter and attached phy's transmitter training completed

If this state receives:

- a) a Local Phy's Transmitter Training Complete message; and
- b) an Attached Phy's Transmitter Optimized message,

then this state shall:

- 1) set the TRAIN COMP bit of the Training Status word (see table 61) to one;
- 2) set the fields of the Training Control word as follows:
  - A) set the PATTERN TYPE field set to 000b (i.e., Control/Status TTIU);
  - B) set the COEFFICIENT SETTINGS field to 00b (i.e., normal);
  - C) set the COEFFICIENT 1 REQUEST field to 00b (i.e., hold);
  - D) set the COEFFICIENT 2 REQUEST field to 00b (i.e., hold); and
  - E) set the COEFFICIENT 3 REQUEST field to 00b (i.e., hold);
- 3) send a Set Training Control message to the SP transmitter;
- 4) send a Set Training Status message to the SP transmitter;
- 5) send a Transmit Train\_Tx Pattern message to the SP transmitter;
- 6) wait for a Train\_Tx Pattern Transmitted message;
- 7) repeat steps 5) and 6) five times; and
- 8) send a Transmitter Training Complete message to the SP34:SAS\_Train\_Tx state and the PTT\_R2:Receive\_Train\_Tx\_Pattern state.

#### 5.14.4.4.7 Transition PTT\_T2:Tx\_Training to PTT\_T0:Idle

This transition shall occur after:

- a) receiving a Transmitter Training (Disable) message; or

- b) sending the Transmitter Training Complete messages.

#### 5.14.4.4.8 Transition PTT\_T2:Tx\_Training to PTT\_T3:Local\_Tx\_Training

If this state has not received a Local Phy's Transmitter Training Complete message, then this transition shall occur:

- a) after receiving an Attached Phy's Transmitter Optimized message.

This transition shall include the following from the current Training Status word as arguments:

- a) Coefficient 1 Status;
- b) Coefficient 2 Status; and
- c) Coefficient 3 Status.

#### 5.14.4.5 PTT\_T3:Local\_Tx\_Training state

##### 5.14.4.5.1 State description

This state:

- a) sets values of the Training Status word and the Training Control word (see 5.9.2);
- b) requests Train\_Tx patterns be transmitted; and
- c) waits for the local phy's transmitter training to complete.

##### 5.14.4.5.2 Entry conditions

Upon entry into this state, this state shall:

- 1) set the bits and fields of the Training Status word (see table 61) as follows:
  - A) set the TRAIN COMP bit to one;
  - B) set the TX INIT bit to zero;
  - C) set the COEFFICIENT 1 STATUS field to the Coefficient 1 Status argument;
  - D) set the COEFFICIENT 2 STATUS field to the Coefficient 2 Status argument; and
  - E) set the COEFFICIENT 3 STATUS field to the Coefficient 3 Status argument;
- 2) set the fields of the Training Control word as follows:
  - A) set the PATTERN TYPE field to 000b (i.e., Control/Status TTIU);
  - B) set the COEFFICIENT SETTINGS field to 00b (i.e., normal);
  - C) set the COEFFICIENT 1 REQUEST field to 00b (i.e., hold);
  - D) set the COEFFICIENT 2 REQUEST field to 00b (i.e., hold); and
  - E) set the COEFFICIENT 3 REQUEST field to 00b (i.e., hold);
- 3) send a Set Training Control message to the SP transmitter;
- 4) send a Set Training Status message to the SP transmitter;
- 5) send a Transmit Train\_Tx Pattern message to the SP transmitter;
- 6) wait for a Train\_Tx Pattern Transmitted message; and
- 7) repeat steps 5) and 6) while there is no other looping occurring with in this state.

##### 5.14.4.5.3 Status word mappings

Table 79 defines the mapping of the messages received from the PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine to the Training Status word.

##### 5.14.4.5.4 Local phy's transmitter and attached phy's transmitter training completed

If this state receives a Local Phy's Transmitter Training Complete message and this state has received at least six Train\_Tx Pattern Transmitted messages, then this state shall send a Transmitter Training Complete message to the SP34:SAS\_Train\_Tx state and the PTT\_R2:Receive\_Train\_Tx\_Pattern state.



#### 5.14.4.5.5 Error message handling

If this state receives a Transmit Error Response message, then this state shall;

- 1) set the Error Response TTIU fields (see table 66) as follows:
  - A) set the PATTERN TYPE field to 111b (i.e., Error Response TTIY); and
  - B) set the Error Response TTIU fields to the arguments received in the Transmit Error Response message as defined in table 80;
- 2) send a Set Transmitter Failed message to the SP transmitter;
- 3) send a Transmit Train\_Tx Pattern message to the SP transmitter;
- 4) wait for a Train\_Tx Pattern Transmitted message;
- 5) send a Set Training Control message to the SP transmitter;
- 6) set the bits and fields of the Training Status word (see table 61) as follows:
  - A) set the PATTERN TYPE field set to 000b (i.e., Control/Status TTIU);
  - B) set the TRAIN COMP bit to one;
  - C) set the TX INIT bit to zero;
  - D) set the COEFFICIENT 1 STATUS field to 00b (i.e., ready);
  - E) set the COEFFICIENT 2 STATUS field to 00b (i.e., ready); and
  - F) set the COEFFICIENT 3 STATUS field to 00b (i.e., ready);
- 7) send a Set Training Status message to the SP transmitter;
- 8) send a Transmit Train Tx Pattern message to the SP transmitter; and
- 9) wait for a Train Tx Pattern Transmitted message.

#### 5.14.4.5.6 Transition PTT\_T3:Local\_Tx\_Training to PTT\_T0:Idle

This transition shall occur after:

- a) receiving a Transmitter Training (Disable) message; or
- b) sending the Transmitter Training Complete messages.

### 5.14.5 PTT\_R (phy layer transmitter training receive pattern) state machine

#### 5.14.5.1 PTT\_R state machine overview

The PTT\_R state machine's function is to:

- a) monitor the receipt of the attached phy's Train\_Tx pattern;
- b) start pattern lock synchronization;
- c) transfer adjustment requests received from the attached phy's receiver to the local phy's transmitter; and
- d) transfer the attached phy's transmitter coefficient status to the local phy's receiver.

This state machine consists of the following states:

- a) PTT\_R0:Idle (see 5.14.5.2) (initial state);
- b) PTT\_R1:Initialize (see 5.14.5.3); and
- c) PTT\_R2:Receive\_Train\_Tx\_Pattern (see 5.14.5.4).

This state machine receives the following messages from the SP state machine:

- a) Transmitter Training (Enable); and
- b) Transmitter Training (Disable).



Figure 103 shows the PTT\_R state machine.

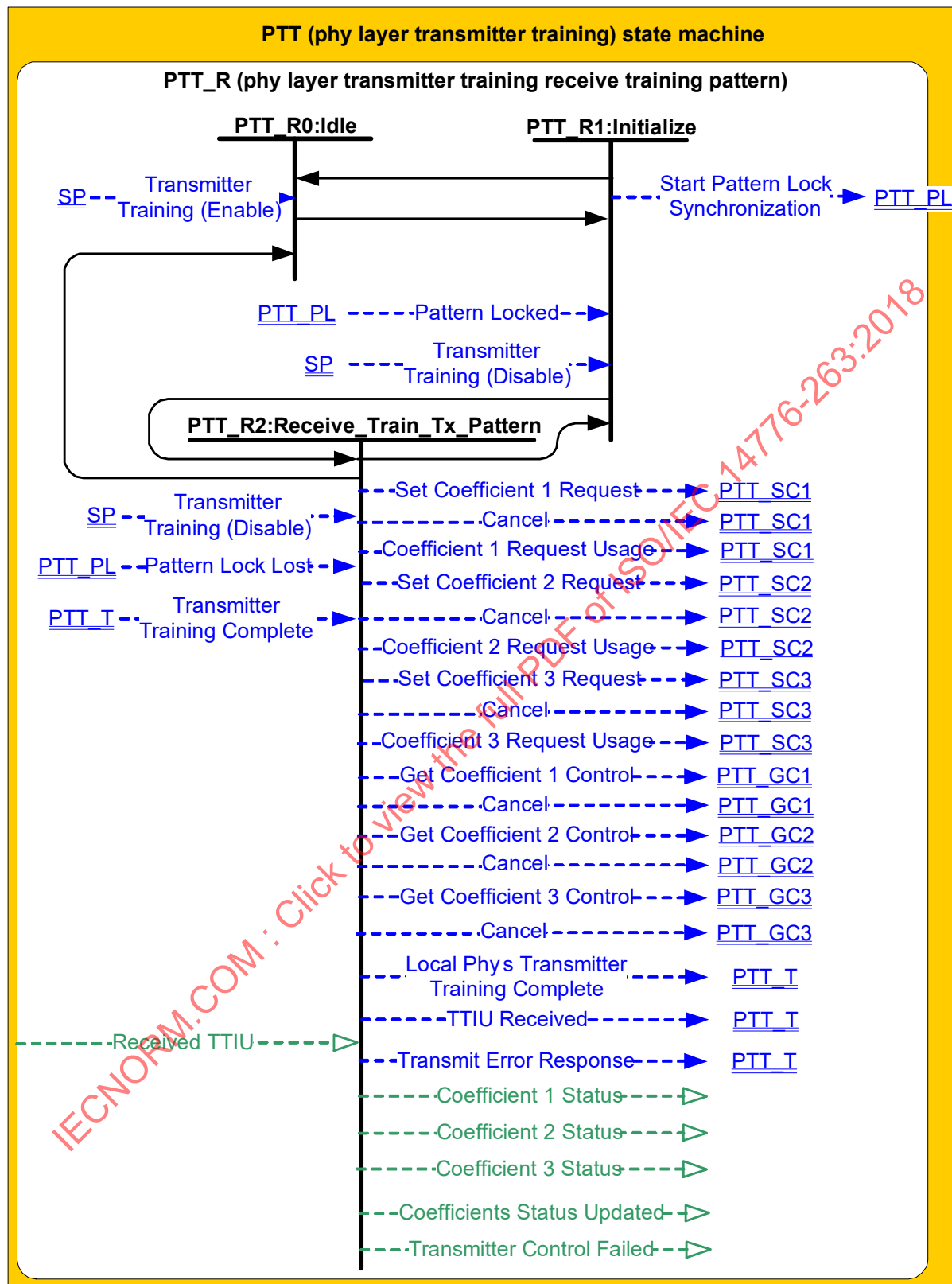


Figure 103 — PTT\_R (phy layer transmitter training receive pattern) state machine

**5.14.5.2 PTT\_R0:Idle state****5.14.5.2.1 State description**

This is the initial state of this state machine.

This state waits for a request to start transmitter training.

**5.14.5.2.2 Transition PTT\_R0:Idle to PTT\_R1:Initialize**

This transition shall occur:

- a) after receiving a Transmitter Training (Enable) message.

**5.14.5.3 PTT\_R1:Initialize state****5.14.5.3.1 State description**

This state waits for pattern lock synchronization.

Upon entry into this state, this state shall:

- a) send a Start Pattern Lock Synchronization message to the PTT\_PL phy layer state machine.

**5.14.5.3.2 Transition PTT\_R1:Initialize to PTT\_R0:Idle**

This transition shall occur:

- a) after receiving a Transmitter Training (Disable) message.

**5.14.5.3.3 Transition PTT\_R1:Initialize to PTT\_R2:Receive\_Train\_Tx\_Pattern**

This transition shall occur:

- a) after receiving a Pattern Locked message.

**5.14.5.4 PTT\_R2:Receive\_Train\_Tx\_Pattern state****5.14.5.4.1 State description**

This state:

- a) receives Training Control words and Training Status words;
- b) transfers adjustment requests received from the attached phy's receiver to the local phy's transmitter;
- c) checks the TTIU for errors; and
- d) transfers the attached phy's transmitter coefficient status to the local phy's receiver.

If this state receives a Received TTIU message with an odd number of bits set to zero in the TTIU, then this state shall discard the TTIU.

If this state receives a Received TTIU message and the TTIU is a Control/Status TTIU that contains:

- a) an unsupported value;
- b) a reserved value;
- c) a reserved bit; or
- d) a reserved combination in the Training Control word (see table 81),

then this state shall:

- 1) send a Transmit Error Response message to the PTT\_T state machine with the arguments defined in table 81;
- 2) send a Cancel message to the PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine; and

- 3) discard the TTIU.

**Table 81 — Transmit Error Response message arguments sent to PTT\_T state machine**

| Training Control word field <sup>a b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             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If this state receives:

- a) a Received TTIU message;
- b) a PATTERN TYPE field of the Training Control word set to 111b (i.e., Error Response TTIU); and
- c) an even number of bits set to zero in the TTIU,

then this state shall:

- a) send a Transmitter Control Failed message to the SP receiver with the contents of the Error Response TTIU as an argument; and
- b) send a Cancel message to the PTT\_GC1 state machine, PTT\_GC2 state machine, and PTT\_GC3 state machine.

If this state receives:

- a) a Received TTIU message;

- b) a PATTERN TYPE field of the Training Control word set to 000b (i.e., Control/Status TTIU); and
- c) an even number of bits set to zero in the TTIU,

then:

- a) if the TX INIT bit is set to zero in the received Training Status word (see table 61), then this state shall:
  - 1) send:
    - 1) the messages and arguments shown in table 82 to the SP receiver; and
    - 2) a Coefficients Status Updated message to the SP receiver;
  - 2) send to the PTT\_GC1 state machine, PTT\_GC2 state machine, and PTT\_GC3 state machine the messages and arguments shown in table 83;
  - 3) if the TRAIN COMP bit in the received Training Status word:
    - a) is set to zero, then send to the PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine the messages and arguments shown in table 84 and table 85; or
    - b) is set to one, then send a Cancel message to the PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine;
- and
- 4) send a TTIU Received (Attached Transmitter Initialized) message to the PTT\_T state machine;
- or
- b) if TX INIT bit is set to one in the received Training Status word, then this state shall send a TTIU Received (Attached Transmitter Not Initialized) message to the PTT\_T state machine.

Table 82 defines the mapping of transmitted status word fields to messages sent to the SP receiver.

**Table 82 — Mapping the Training Status word to SP receiver messages**

| Training Status word field                                                                                                                                                                                   | Message to SP receiver            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| COEFFICIENT 1 STATUS                                                                                                                                                                                         | Coefficient 1 Status <sup>a</sup> |
| COEFFICIENT 2 STATUS                                                                                                                                                                                         | Coefficient 2 Status <sup>a</sup> |
| COEFFICIENT 3 STATUS                                                                                                                                                                                         | Coefficient 3 Status <sup>a</sup> |
| <sup>a</sup> This message's argument is set to the value (i.e., Maximum, Minimum, Update_Complete, or Ready) of the corresponding Training Status word field associated with the attached phy's transmitter. |                                   |

Table 83 defines the mapping of Training Status word fields to messages sent to the PTT\_GC1 state machine, PTT\_GC2 state machine, and PTT\_GC3 state machine.

**Table 83 — Mapping the Training Status word to PTT\_GC1 state machine messages, PTT\_GC2 state machine messages, and PTT\_GC3 state machine messages**

| Training Status word                                                                                                                                                                                  |      |                 | Message                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----------------|--------------------------------------------------|
| Field name                                                                                                                                                                                            | Code | Name            |                                                  |
| COEFFICIENT 1 STATUS                                                                                                                                                                                  | 00b  | ready           | Get Coefficient 1 Control (Start) <sup>a</sup>   |
|                                                                                                                                                                                                       | 01b  | update complete | Get Coefficient 1 Control (Restart) <sup>a</sup> |
|                                                                                                                                                                                                       | 10b  | minimum         |                                                  |
|                                                                                                                                                                                                       | 11b  | maximum         |                                                  |
| COEFFICIENT 2 STATUS                                                                                                                                                                                  | 00b  | ready           | Get Coefficient 2 Control (Start) <sup>b</sup>   |
|                                                                                                                                                                                                       | 01b  | update complete | Get Coefficient 2 Control (Restart) <sup>b</sup> |
|                                                                                                                                                                                                       | 10b  | minimum         |                                                  |
|                                                                                                                                                                                                       | 11b  | maximum         |                                                  |
| COEFFICIENT 3 STATUS                                                                                                                                                                                  | 00b  | ready           | Get Coefficient 3 Control (Start) <sup>c</sup>   |
|                                                                                                                                                                                                       | 01b  | update complete | Get Coefficient 3 Control (Restart) <sup>c</sup> |
|                                                                                                                                                                                                       | 10b  | minimum         |                                                  |
|                                                                                                                                                                                                       | 11b  | maximum         |                                                  |
| <sup>a</sup> This message is sent to the PTT_GC1 state machine.<br><sup>b</sup> This message is sent to the PTT_GC2 state machine.<br><sup>c</sup> This message is sent to the PTT_GC3 state machine. |      |                 |                                                  |

Table 84 defines the mapping of transmitted control word fields to messages sent to the PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine.

**Table 84 — Mapping the Training Control word to PTT\_SC1 state machine messages, PTT\_SC2 state machine messages, and PTT\_SC3 state machine messages**

| Training Control word fields    |                              |                       | Message                                  |
|---------------------------------|------------------------------|-----------------------|------------------------------------------|
| COEFFICIENT SETTINGS field code |                              |                       |                                          |
| Code                            | Name                         |                       |                                          |
| 00b                             | normal                       | see table 85          | see table 85                             |
| 01b                             | reference_1 <sup>g</sup>     | COEFFICIENT 1 REQUEST | Set Coefficient 1 Request <sup>a d</sup> |
|                                 |                              | COEFFICIENT 2 REQUEST | Set Coefficient 2 Request <sup>a e</sup> |
|                                 |                              | COEFFICIENT 3 REQUEST | Set Coefficient 3 Request <sup>a f</sup> |
| 10b                             | reference_2 <sup>g</sup>     | COEFFICIENT 1 REQUEST | Set Coefficient 1 Request <sup>b d</sup> |
|                                 |                              | COEFFICIENT 2 REQUEST | Set Coefficient 2 Request <sup>b e</sup> |
|                                 |                              | COEFFICIENT 3 REQUEST | Set Coefficient 3 Request <sup>b f</sup> |
| 11b                             | no_equalization <sup>g</sup> | COEFFICIENT 1 REQUEST | Set Coefficient 1 Request <sup>c d</sup> |
|                                 |                              | COEFFICIENT 2 REQUEST | Set Coefficient 2 Request <sup>c e</sup> |
|                                 |                              | COEFFICIENT 3 REQUEST | Set Coefficient 3 Request <sup>c f</sup> |

<sup>a</sup> This message argument is set to Set Reference\_1 regardless of the values in the COEFFICIENT 1 REQUEST field, the COEFFICIENT 2 REQUEST field, and the COEFFICIENT 3 REQUEST field.

<sup>b</sup> This message argument is set to Set Reference\_2 regardless of the values in the COEFFICIENT 1 REQUEST field, the COEFFICIENT 2 REQUEST field, and the COEFFICIENT 3 REQUEST field.

<sup>c</sup> This message argument is set to Set No\_Equalization regardless of the values in the COEFFICIENT 1 REQUEST field, the COEFFICIENT 2 REQUEST field, and the COEFFICIENT 3 REQUEST field.

<sup>d</sup> This message is sent to the PTT\_SC1 state machine.

<sup>e</sup> This message is sent to the PTT\_SC2 state machine.

<sup>f</sup> This message is sent to the PTT\_SC3 state machine.

<sup>g</sup> The Coefficient 1 Request Usage message (see table 85), the Coefficient 2 Request Usage message (see table 85), or the Coefficient 3 Request Usage message (see table 85) shall not be sent to the PTT\_SC1 state machine, PTT\_SC 2 state machine, or PTT\_SC 3 state machine.

Table 85 defines the mapping of the Coefficient Request byte to messages sent to the PTT\_SC3 state machine, PTT\_SC2 state machine, and PTT\_SC1 state machine.

**Table 85 — Mapping Coefficient Request byte to PTT\_SC3 state machine message, PTT\_SC2 state machine message, and PTT\_SC1 state machine messages**

| Coefficient Request byte (table 64) | PTT_SC3 state machine message        |                                                     | PTT_SC2 state machine message        |                                                     | PTT_SC1 state machine message        |                                                     |
|-------------------------------------|--------------------------------------|-----------------------------------------------------|--------------------------------------|-----------------------------------------------------|--------------------------------------|-----------------------------------------------------|
|                                     | Set Coefficient 3 Request (argument) | Coefficient 3 Request Usage (argument) <sup>a</sup> | Set Coefficient 2 Request (argument) | Coefficient 2 Request Usage (argument) <sup>a</sup> | Set Coefficient 1 Request (argument) | Coefficient 1 Request Usage (argument) <sup>a</sup> |
| 00h                                 | Hold                                 | message not sent                                    | Hold                                 | message not sent                                    | Hold                                 | message not sent                                    |
| 01h                                 | Hold                                 | message not sent                                    | Hold                                 | message not sent                                    | Increment                            | Single                                              |
| 02h                                 | Hold                                 | message not sent                                    | Hold                                 | message not sent                                    | Decrement                            | Single                                              |
| 04h                                 | Hold                                 | message not sent                                    | Increment                            | Single                                              | Hold                                 | message not sent                                    |
| 05h                                 | Hold                                 | message not sent                                    | Increment                            | Dual                                                | Increment                            | Dual                                                |
| 08h                                 | Hold                                 | message not sent                                    | Decrement                            | Single                                              | Hold                                 | message not sent                                    |
| 0Ah                                 | Hold                                 | message not sent                                    | Decrement                            | Dual                                                | Decrement                            | Dual                                                |
| 10h                                 | Increment                            | Single                                              | Hold                                 | message not sent                                    | Hold                                 | message not sent                                    |
| 14h                                 | Increment                            | Dual                                                | Increment                            | Dual                                                | Hold                                 | message not sent                                    |
| 20h                                 | Decrement                            | Single                                              | Hold                                 | message not sent                                    | Hold                                 | message not sent                                    |
| 28h                                 | Decrement                            | Dual                                                | Decrement                            | Dual                                                | Hold                                 | message not sent                                    |

<sup>a</sup> If a Coefficient 1 Request Usage message is sent to the PTT\_SC1 state machine, a Coefficient 2 Request Usage message is sent to the PTT\_SC 2 state machine, or a Coefficient 3 Request Usage message is sent to the PTT\_SC 3 state machine, then PTT\_R2 shall send:

- 1) the Coefficient 1 Request Usage message, Coefficient 2 Request Usage message, or Coefficient 3 Request Usage message; and
- 2) the Set Coefficient 1 Request message, Set Coefficient 2 Request message, or Set Coefficient 3 Request message.

This state count of the number of consecutive received Training Status words in which the TRAIN COMP bit is set to one. If this number is three or greater, then this state shall send a Local Phy's Transmitter Training Complete message to the PTT\_T state machine.

#### **5.14.5.4.2 Transition PTT\_R2:Receive\_Train\_Tx\_Pattern to PTT\_R0:Idle**

This transition shall occur after receiving a:

- a) Transmitter Training (Disable) message; or
- b) Transmitter Training Complete message.

#### **5.14.5.4.3 Transition PTT\_R2:Receive\_Train\_Tx\_Pattern to PTT\_R1:Initialize**

This transition shall occur:

- a) after receiving a Pattern Lock Lost message.

### **5.14.6 PTT\_SC (phy layer transmitter training set transmitter coefficient) state machines**

#### **5.14.6.1 PTT\_SC (phy layer transmitter training set transmitter coefficient) state machines overview**

The PTT\_SC1 state machines' functions are to adjust the local phy's transmitter coefficients' and to manage those coefficients' status.

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Figure 104 shows the PTT\_SC1 state machine, PTT\_SC2 state machine, and PTT\_SC3 state machine.

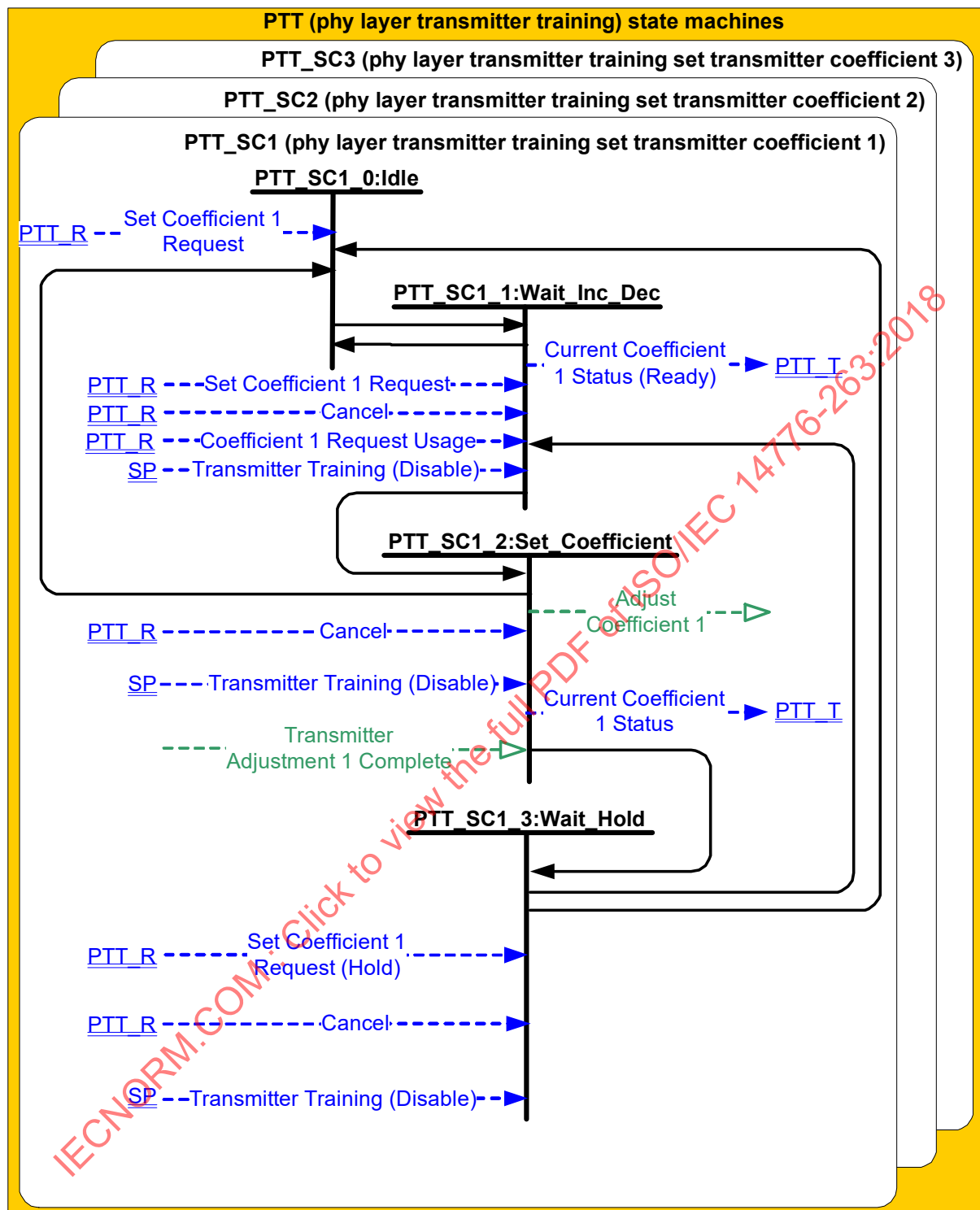


Figure 104 — PTT\_SC1, PTT\_SC2, and PTT\_SC3 (phy layer transmitter training set transmitter coefficient) state machines

#### 5.14.6.2 PTT\_SC1 state machine overview

The PTT\_SC1 state machine's function is to adjust one of the local phy's transmitter coefficients and to manage that coefficient's status. This state machine consists of the following states:

- a) PTT\_SC1\_0:Idle (see 5.14.6.3) (initial state);
- b) PTT\_SC1\_1:Wait\_Inc\_Dec (see 5.14.6.4);
- c) PTT\_SC1\_2:Set\_Coefficient (see 5.14.6.5); and
- d) PTT\_SC1\_3:Wait\_Hold (see 5.14.6.6).

This state machine receives the following message from the SP state machine:

- a) Transmitter Training (Disable).

#### 5.14.6.3 PTT\_SC1\_0:Idle state

##### 5.14.6.3.1 State description

This is the initial state of this state machine.

This state waits for a request to start setting the local phy's transmitter coefficient.

##### 5.14.6.3.2 Transition PTT\_SC1\_0:Idle to PTT\_SC1\_1:Wait\_Inc\_Dec

This transition shall occur:

- a) after receiving a Set Coefficient 1 Request message.

#### 5.14.6.4 PTT\_SC1\_1:Wait\_Inc\_Dec state

##### 5.14.6.4.1 State description

This state waits for a request to:

- a) increment or decrement the local phy's transmitter coefficient: or
- b) set the local phy's transmitter coefficient to the no equalization value, reference\_1 value, or reference\_2 value.

Upon entry into this state, this state shall:

- a) send a Current Coefficient 1 Status (Ready) message to the PTT\_T state machine.

##### 5.14.6.4.2 Transition PTT\_SC1\_1:Wait\_Inc\_Dec to PTT\_SC1\_0:Idle

This transition shall occur after receiving a:

- a) Cancel message; or
- b) Transmitter Training (Disable) message.

##### 5.14.6.4.3 Transition PTT\_SC1\_1:Wait\_Inc\_Dec to PTT\_SC1\_2:Set\_Coefficient

This transition shall occur:

- a) after receiving a Set Coefficient 1 Request message with an argument of Decrement, Increment, Set No\_Equalization, Set Reference\_1, or Set Reference\_2.

This transition shall include the argument from the:

- a) Set Coefficient 1 Request message (i.e., Increment, Decrement, Set No\_Equalization, Set Reference\_1, or Set Reference\_2); and
- b) Coefficient 1 Request Usage message (i.e., Single or Dual), if any.

### 5.14.6.5 PTT\_SC1\_2:Set\_Coefficient state

#### 5.14.6.5.1 State description

This state:

- a) requests the SP transmitter increment the coefficient, decrement the coefficient, set the coefficient to its no equalization value, set the coefficient to its reference\_1 value, or set the coefficient to its reference\_2 value;
- b) waits for the SP transmitter to complete the requested adjustment; and
- c) reports the status of the SP transmitter's coefficient to the PTT\_T state machine.

If this state was entered with an Increment argument and a Single argument, then this state shall send an Adjust Coefficient 1 message to the SP transmitter with the following arguments:

- a) Increment; and
- b) Single.

If this state was entered with an Increment argument and a Dual argument, then this state shall send an Adjust Coefficient 1 message to the SP transmitter with the following arguments:

- a) Increment; and
- b) Dual.

If this state was entered with a Decrement argument and a Single argument, then this state shall send an Adjust Coefficient 1 message to the SP transmitter with the following arguments:

- a) Decrement; and
- b) Single.

If this state was entered with a Decrement argument and a Dual argument, then this state shall send an Adjust Coefficient 1 message to the SP transmitter with the following arguments:

- a) Decrement; and
- b) Dual.

If this state was entered with a Set No\_Equalization argument, then this state shall send an Adjust Coefficient 1 (Set No\_Equalization) message to the SP transmitter.

If this state was entered with a Set Reference\_1 argument, then this state shall send an Adjust Coefficient 1 (Set Reference\_1) message to the SP transmitter.

If this state was entered with a Set Reference\_2 argument, then this state shall send an Adjust Coefficient 1 (Set Reference\_2) message to the SP transmitter.

This state shall respond to the Transmitter Adjustment 1 Complete message received from the SP transmitter with a message to the PTT\_T state machine as defined in table 86.

**Table 86 — Mapping messages to the PTT\_T state machine**

| Message from SP transmitter                         | Message sent to PTT_T state machine            |
|-----------------------------------------------------|------------------------------------------------|
| Transmitter Adjustment 1 Complete (Maximum)         | Current Coefficient 1 Status (Maximum)         |
| Transmitter Adjustment 1 Complete (Minimum)         | Current Coefficient 1 Status (Minimum)         |
| Transmitter Adjustment 1 Complete (Update_Complete) | Current Coefficient 1 Status (Update_Complete) |

**5.14.6.5.2 Transition PTT\_SC1\_2:Set\_Coefficient to PTT\_SC1\_0:Idle**

This transition shall occur after receiving a:

- a) Cancel message; or
- b) Transmitter Training (Disable) message.

**5.14.6.5.3 Transition PTT\_SC1\_2:Set\_Coefficient to PTT\_SC1\_3:Wait\_Hold**

This transition shall occur after:

- a) receiving a Transmitter Adjustment 1 Complete message; and
- b) sending a Current Coefficient 1 Status message to the PTT\_T state machine.

**5.14.6.6 PTT\_SC1\_3:Wait\_Hold state****5.14.6.6.1 State description**

This state waits for the attached phy's transmitter to request a hold.

**5.14.6.6.2 Transition PTT\_SC1\_3:Wait\_Hold to PTT\_SC1\_0:Idle**

This transition shall occur after receiving a:

- a) Cancel message; or
- b) Transmitter Training (Disable) message.

**5.14.6.6.3 Transition PTT\_SC1\_3:Wait\_Hold to PTT\_SC1\_1:Wait\_Inc\_Dec**

This transition shall occur:

- a) after receiving a Set Coefficient 1 Request (Hold) message.

**5.14.7 PTT\_SC2 (phy layer transmitter training set transmitter coefficient 2) state machine**

This state machine is identical to the PTT\_SC1 state machine (see 5.14.6) except for the messages described in table 87.

**Table 87 — PTT\_SC1 messages to substitute for PTT\_SC2 messages**

| <b>PTT_SC1 message</b>            | <b>PTT_SC2 message</b>            |
|-----------------------------------|-----------------------------------|
| Set Coefficient 1 Request         | Set Coefficient 2 Request         |
| Current Coefficient 1 Status      | Current Coefficient 2 Status      |
| Adjust Coefficient 1              | Adjust Coefficient 2              |
| Transmitter Adjustment 1 Complete | Transmitter Adjustment 2 Complete |
| Coefficient 1 Request Usage       | Coefficient 2 Request Usage       |

**5.14.8 PTT\_SC3 (phy layer transmitter training set transmitter coefficient 3) state machine**

This state machine is identical to the PTT\_SC1 state machine (see 5.14.6) except for the messages described in table 88.

**Table 88 — PTT\_SC1 messages to substitute for PTT\_SC3 messages**

| <b>PTT_SC1 message</b>            | <b>PTT_SC3 message</b>            |
|-----------------------------------|-----------------------------------|
| Set Coefficient 1 Request         | Set Coefficient 3 Request         |
| Current Coefficient 1 Status      | Current Coefficient 3 Status      |
| Adjust Coefficient 1              | Adjust Coefficient 3              |
| Transmitter Adjustment 1 Complete | Transmitter Adjustment 3 Complete |
| Coefficient 1 Request Usage       | Coefficient 3 Request Usage       |

**5.14.9 PTT\_GC (phy layer transmitter training get transmitter coefficient) state machines****5.14.9.1 PTT\_GC (phy layer transmitter training get transmitter coefficient) state machines overview**

The PTT\_GC state machines' functions are to get coefficient adjustments being requested by the local phy's SP receiver for the attached phy's transmitter and to manage those coefficients' controls.

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Figure 105 shows the PTT\_GC1 state machine, PTT\_GC2 state machine, and PTT\_GC3 state machine.

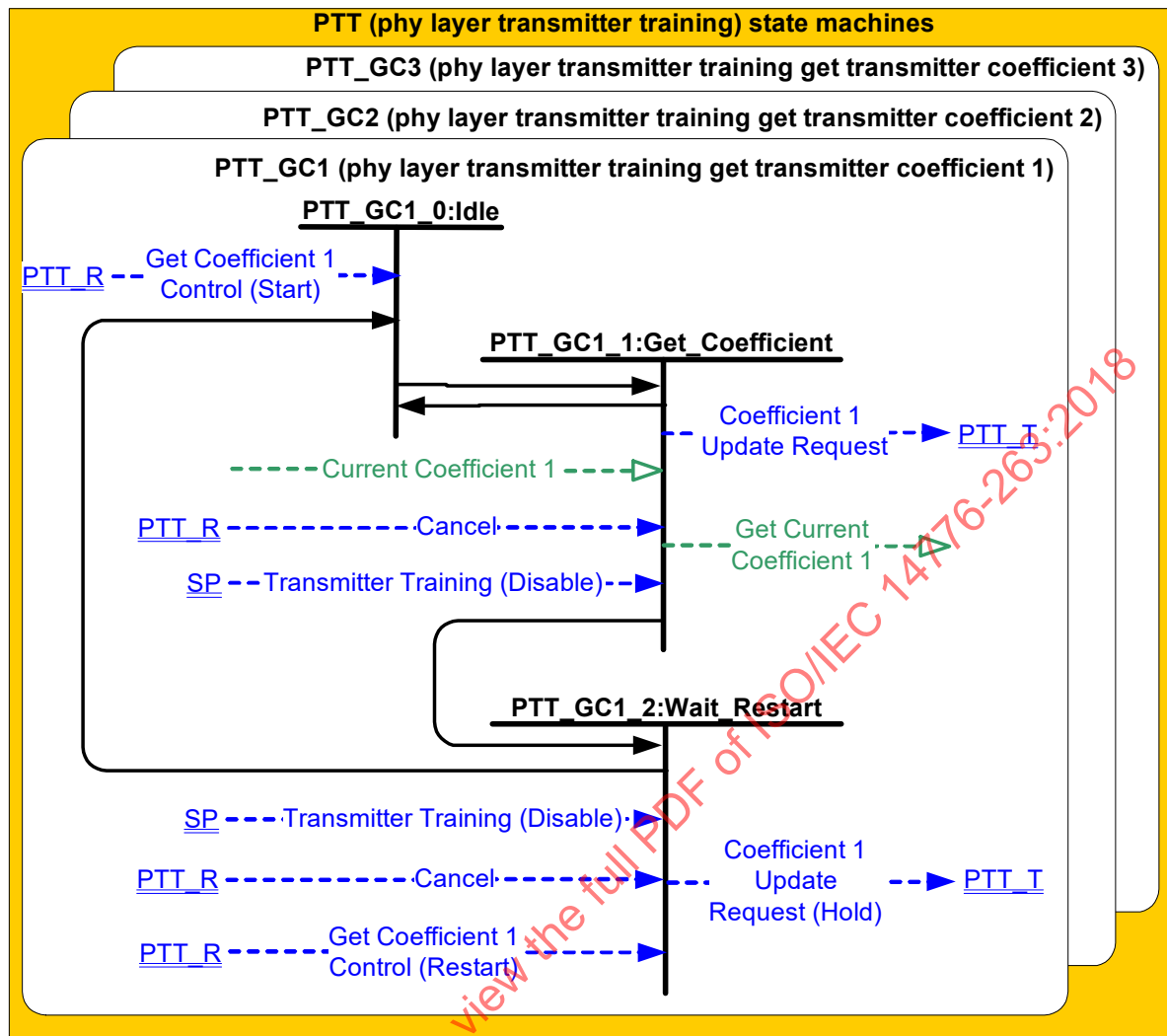


Figure 105 — PTT\_GC1, PTT\_GC2, and PTT\_GC3 (phy layer transmitter training get transmitter coefficient) state machines

#### 5.14.9.2 PTT\_GC1 state machine

The PTT\_GC1 state machine's function is to get the coefficient 1 adjustment being requested by the local phy's SP receiver for the attached phy's transmitter and to manage that coefficient's control. This state machine consists of the following states:

- PTT\_GC1\_0:Idle (see 5.14.9.3) (initial state);
- PTT\_GC1\_1:Get\_Coefficient (see 5.14.9.4); and
- PTT\_GC1\_2:Wait\_Restart (see 5.14.9.5).

This state machine receives the following messages from the SP state machine:

- Transmitter Training (Disable).

**5.14.9.3 PTT\_GC1\_0:Idle state****5.14.9.3.1 State description**

This is the initial state of this state machine.

This state waits for a request to get the coefficient.

**5.14.9.3.2 Transition PTT\_GC1\_0:Idle to PTT\_GC1\_1:Get\_Coefficient**

This transition shall occur:

- a) after receiving a Get Coefficient 1 Control (Start) message.

**5.14.9.4 PTT\_GC1\_1:Get\_Coefficient state****5.14.9.4.1 State description**

This state gets the coefficient that the local phy's receiver is requesting be sent to the attached phy's transmitter.

This state shall repeatedly:

- 1) send a Get Current Coefficient 1 message to the SP receiver;
- 2) wait for a Current Coefficient 1 message received from the SP receiver; and
- 3) respond to the Current Coefficient 1 message received from the SP receiver with a message to the PTT\_T state machine as defined in table 89.

**Table 89 — Mapping messages to the PTT\_T state machine**

| Message from the SP receiver            | Message sent to the PTT_T state machine        |
|-----------------------------------------|------------------------------------------------|
| Current Coefficient 1 (Increment)       | Coefficient 1 Update Request (Increment)       |
| Current Coefficient 1 (Decrement)       | Coefficient 1 Update Request (Decrement)       |
| Current Coefficient 1 (Hold)            | Coefficient 1 Update Request (Hold)            |
| Current Coefficient 1 (No_Equalization) | Coefficient 1 Update Request (No_Equalization) |
| Current Coefficient 1 (Reference_1)     | Coefficient 1 Update Request (Reference_1)     |
| Current Coefficient 1 (Reference_2)     | Coefficient 1 Update Request (Reference_2)     |

**5.14.9.4.2 Transition PTT\_GC1\_1:Get\_Coefficient to PTT\_GC1\_0:Idle**

This transition shall occur after receiving a:

- a) Transmitter Training (Disable) message; or
- b) Cancel message.

**5.14.9.4.3 Transition PTT\_GC1\_1:Get\_Coefficient to PTT\_GC1\_2:Wait\_Restart**

This transition shall occur after sending a:

- a) Coefficient 1 Update Request message with an argument of Increment, Decrement, No\_Equalization, Reference\_1, or Reference\_2.

### 5.14.9.5 PTT\_GC1\_2:Wait\_Restart state

#### 5.14.9.5.1 State description

This state waits for the attached phy's transmitter to indicate that the requested coefficient update is complete.

If this state receives a Get Coefficient 1 Control (Restart) message, then this state shall send a Coefficient 1 Update Request (Hold) message to the PTT\_T state machine.

#### 5.14.9.5.2 Transition PTT\_GC1\_2:Wait\_Restart to PTT\_GC1\_0:Idle

This transition shall occur after:

- a) receiving a Transmitter Training (Disable) message;
- b) receiving a Cancel message; or
- c) sending a Coefficient 1 Update Request (Hold) message.

### 5.14.10 PTT\_GC2 (phy layer transmitter training get transmitter coefficient 2) state machine

This state machine is identical to the PTT\_GC1 state machine (see 5.14.9) except for the messages described in table 90.

**Table 90 — PTT\_GC1 messages to substitute for PTT\_GC2 messages**

| PTT_GC1 message              | PTT_GC2 message              |
|------------------------------|------------------------------|
| Get Coefficient 1 Control    | Get Coefficient 2 Control    |
| Coefficient 1 Update Request | Coefficient 2 Update Request |
| Current Coefficient 1        | Current Coefficient 2        |
| Get Current Coefficient 1    | Get Current Coefficient 2    |

### 5.14.11 PTT\_GC3 (phy layer transmitter training get transmitter coefficient 3) state machine

This state machine is identical to the PTT\_GC1 state machine (see 5.14.9) except for the messages described in table 91.

**Table 91 — PTT\_GC1 messages to substitute for PTT\_GC3 messages**

| PTT_GC1 message              | PTT_GC3 message              |
|------------------------------|------------------------------|
| Get Coefficient 1 Control    | Get Coefficient 3 Control    |
| Coefficient 1 Update Request | Coefficient 3 Update Request |
| Current Coefficient 1        | Current Coefficient 3        |
| Get Current Coefficient 1    | Get Current Coefficient 3    |



#### 5.14.12 PTT\_PL (phy layer transmitter training pattern lock) state machine

##### 5.14.12.1 PTT\_PL state machine overview

The PTT\_PL state machine establishes the same transmitter training pattern lock at the local phy's receiver as was sent from the attached phy's transmitter by searching for the pattern marker (see 5.10.4.2.3.4.3). The SP receiver monitors and decodes the incoming data stream and forces the pattern marker to the first position of the Train\_Tx pattern (see 5.10.4.2.3.4) to perform pattern lock, when requested by the PTT\_PL state machine.

After pattern lock synchronization has been achieved, this state machine evaluates the pattern marker at the beginning of each Train\_Tx pattern that is received. If five consecutive invalid pattern markers (see 5.10.4.2.3.4.3) are detected, then pattern lock is considered lost. If pattern lock is lost, then receipt of two consecutive valid pattern markers (see 5.10.4.2.3.4.3) is required to reestablish pattern lock.

While pattern lock is lost, any Train\_Tx pattern received is invalid.

The state machine shall transition to the PTT\_PL0:Idle state from any other state after receiving a Transmitter Training (Disable) message from the SP state machine (see 5.12.4.13).

This state machine consists of the following states:

- a) PTT\_PL0:Idle (see 5.14.12.2) (initial state);
- b) PTT\_PL1:Acquire\_Lock (see 5.14.12.3);
- c) PTT\_PL2:Valid (see 5.14.12.4);
- d) PTT\_PL3:Lock\_Acquired (see 5.14.12.5);
- e) PTT\_PL4:Lost1 (see 5.14.12.6);
- f) PTT\_PL5:Lost2 (see 5.14.12.7);
- g) PTT\_PL6:Lost3 (see 5.14.12.8); and
- h) PTT\_PL7:Lost4 (see 5.14.12.9).

This state machine receives the following message from the SP state machine:

- a) Transmitter Training (Disable).

Figure 106 shows the PTT\_PL state machine.

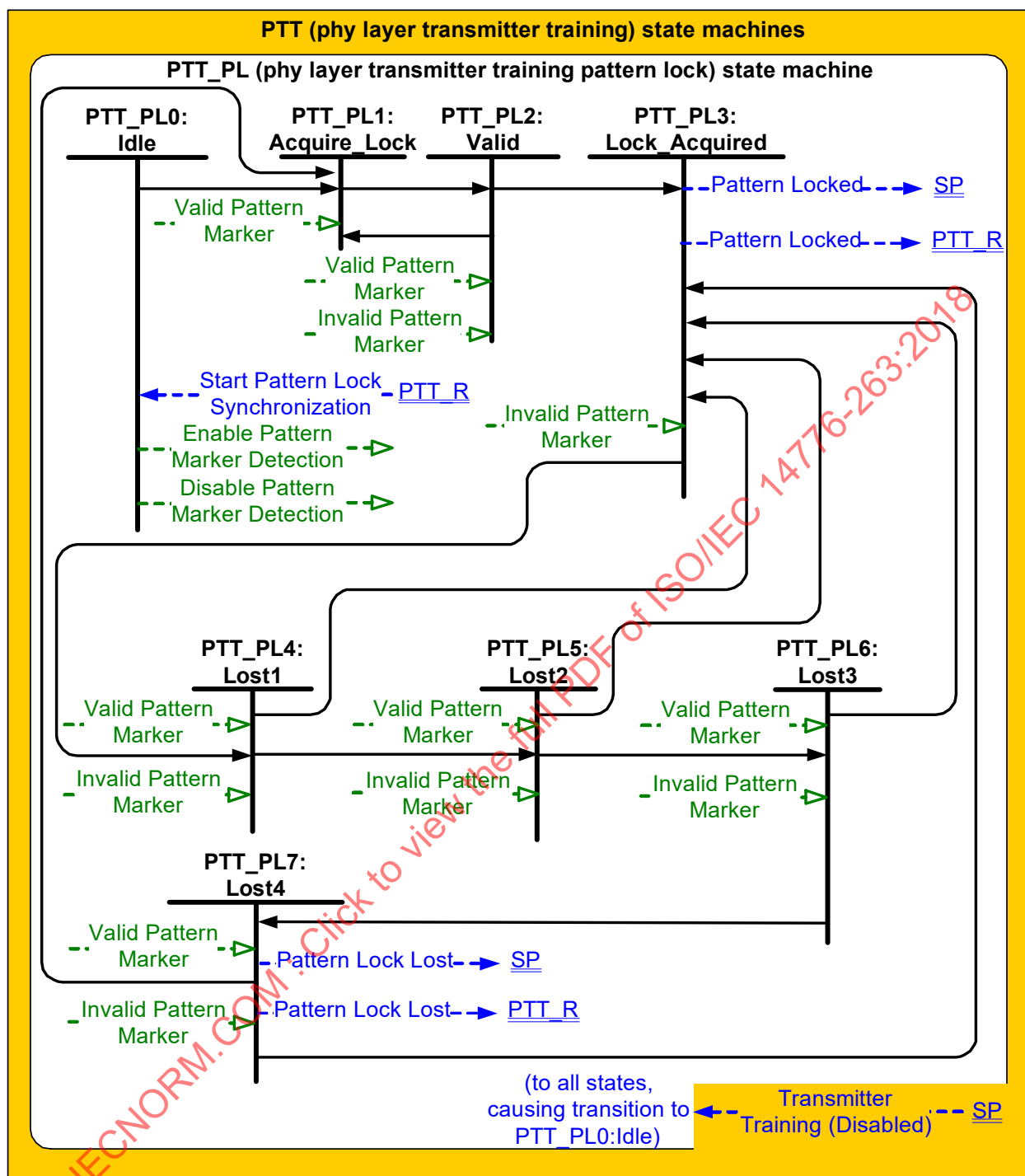


Figure 106 — PTT\_PL (phy layer transmitter training pattern lock) state machine

#### 5.14.12.2 PTT\_PL0:Idle state

##### 5.14.12.2.1 State description

This is the initial state of this state machine.

This state waits for a request to establish pattern lock.

Upon entry into this state, this state shall send a Disable Pattern Marker Detection message to the SP receiver.

If this state receives a Start Pattern Lock Synchronization message, then this state shall send an Enable Pattern Marker Detection message to the SP receiver.

#### **5.14.12.2.2 Transition PTT\_PL0:Idle to PTT\_PL1:Acquire\_Lock**

This transition shall occur:

- a) after sending an Enable Pattern Marker Detection message.

#### **5.14.12.3 PTT\_PL1:Acquire\_Lock state**

##### **5.14.12.3.1 State description**

This state waits for the SP receiver to receive a valid pattern marker.

##### **5.14.12.3.2 Transition PTT\_PL1:Acquire\_Lock to PTT\_PL2:Valid**

This transition shall occur:

- a) after receiving a Valid Pattern Marker message.

#### **5.14.12.4 PTT\_PL2:Valid state**

##### **5.14.12.4.1 State description**

This state waits for the SP receiver to receive the second pattern marker.

##### **5.14.12.4.2 Transition PTT\_PL2:Valid to PTT\_PL1:Acquire\_Lock**

This transition shall occur:

- a) after receiving an Invalid Pattern Marker message.

##### **5.14.12.4.3 Transition PTT\_PL2:Valid to PTT\_PL3:Lock\_Acquired**

This transition shall occur:

- a) after receiving a Valid Pattern Marker message.

#### **5.14.12.5 PTT\_PL3:Lock\_Acquired state**

##### **5.14.12.5.1 State description**

This state is reached after two valid pattern markers have been received without the receipt of an intervening invalid pattern marker.

If this state is entered from the PTT\_PL2:Valid state, then upon entry into this state, this state shall send a Pattern Locked message to the PTT\_R state machine (see 5.12) and the PTT\_R state machine (see 5.14.5).

This state waits for the SP receiver to receive an invalid pattern marker.

##### **5.14.12.5.2 Transition PTT\_PL3:Lock\_Acquired to PTT\_PL4:Lost1**

This transition shall occur:

- a) after receiving an Invalid Pattern Marker message.

**5.14.12.6 PTT\_PL4:Lost1 state****5.14.12.6.1 State description**

This state is reached after one invalid pattern marker has been received.

**5.14.12.6.2 Transition PTT\_PL4:Lost1 to PTT\_PL3:Lock\_Acquired**

This transition shall occur:

- a) after receiving a Valid Pattern Marker message.

**5.14.12.6.3 Transition PTT\_PL4:Lost1 to PTT\_PL5:Lost2**

This transition shall occur:

- a) after receiving an Invalid Pattern Marker message.

**5.14.12.7 PTT\_PL5:Lost2 state****5.14.12.7.1 State description**

This state is reached after two invalid pattern markers have been received.

**5.14.12.7.2 Transition PTT\_PL5:Lost2 to PTT\_PL3:Lock\_Acquired**

This transition shall occur:

- a) after receiving a Valid Pattern Marker message.

**5.14.12.7.3 Transition PTT\_PL5:Lost2 to PTT\_PL6:Lost3**

This transition shall occur:

- a) after receiving an Invalid Pattern Marker message.

**5.14.12.8 PTT\_PL6:Lost3 state****5.14.12.8.1 State description**

This state is reached after three invalid pattern markers have been received.

**5.14.12.8.2 Transition PTT\_PL6:Lost3 to PTT\_PL3:Lock\_Acquired**

This transition shall occur:

- a) after receiving a Valid Pattern Marker message.

**5.14.12.8.3 Transition PTT\_PL6:Lost3 to PTT\_PL7:Lost4**

This transition shall occur:

- a) after receiving an Invalid Pattern Marker message.

**5.14.12.9 PTT\_PL7:Lost4 state****5.14.12.9.1 State description**

This state is reached after four invalid pattern markers have been received.

If this state receives an Invalid Pattern Marker message, then this state shall send a Pattern Lock Lost message to the:

- a) PTT\_R state machine (see 5.14.5); and
- b) SP state machine (see 5.12).

**5.14.12.9.2 Transition PTT\_PL7:Lost4 to PTT\_PL3:Lock\_Acquired**

This transition shall occur:

- a) after receiving a Valid Pattern Marker message.

**5.14.12.9.3 Transition PTT\_PL7:Lost4 to PTT\_PL1:Acquire\_Lock**

This transition shall occur:

- a) after sending a Pattern Lock Lost message.

**5.15 Multiplexing**

If SNW-3 indicates multiplexing is enabled (see table 55), then the phy shall begin multiplexing immediately after the multiplexing sequence (see 5.10.4.3).

Figure 107 shows multiplexing disabled (i.e., one logical link).

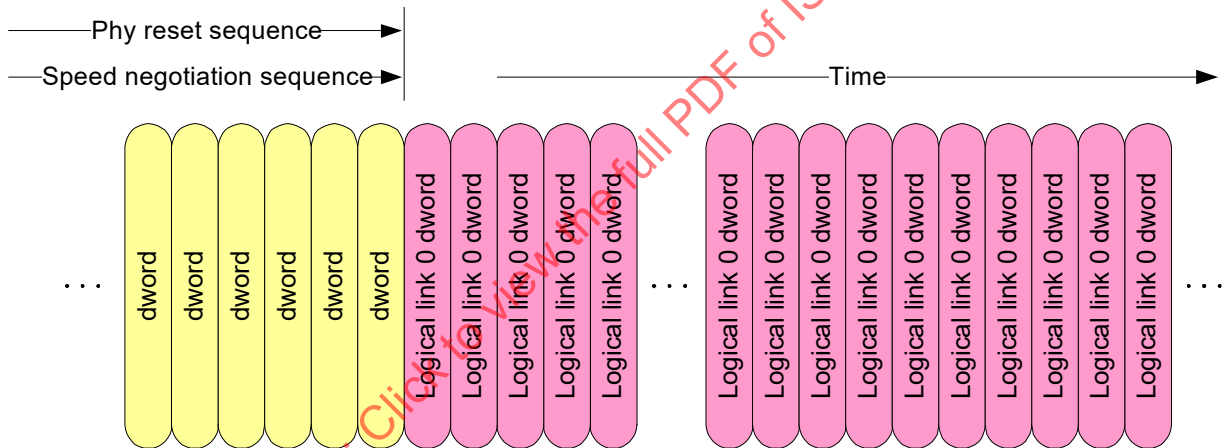


**Figure 107 — Multiplexing disabled**

Figure 108 shows multiplexing enabled (i.e., two logical links).

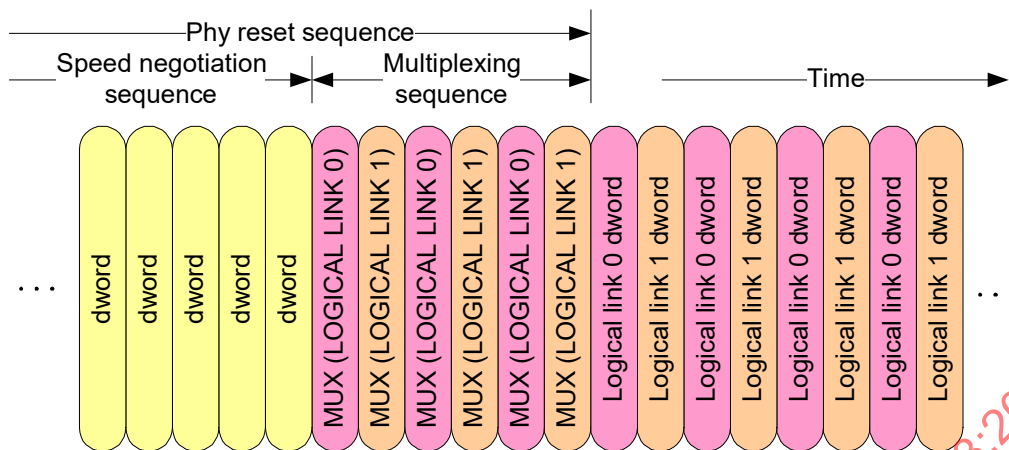


**Figure 108 — Multiplexing enabled**

After the multiplexing sequence completes, each logical phy shall honor the deletable primitive insertion requirements for physical link rate tolerance management defined in 6.3. The logical phys shall ignore MUXs.

If a phy with multiplexing enabled ever loses dword synchronization, then it shall restart the link reset sequence rather than attempt to reestablish dword synchronization.

Once the multiplexing sequence is complete, the phy shall not perform another multiplexing sequence until a new link reset sequence.

Once the multiplexing sequence is complete:

- a logical phy originating dwords shall transmit MUX as a deletable primitive (e.g., substituted in place of an ALIGN) at least once every millisecond; and
- a logical phy forwarding dwords should transmit MUX as a deletable primitive at least once every millisecond to confirm the logical link numbers.

Transmitting NOTIFY has higher priority than transmitting MUX.

NOTE 13 - Periodic MUX transmission is for the convenience of logic analyzers and to provide additional assurance that the receiving phy is in agreement with the transmitting phy.

If a phy ever receives a MUX that does not match the MUX expected in that position (i.e., it receives MUX (LOGICAL LINK 1) on logical link 0 or receives MUX (LOGICAL LINK 0) on logical link 1), then it shall perform a link reset sequence.

## 5.16 Spinup

If a SAS target device receives COMSAS during the OOB sequence, then it shall not temporarily consume additional power (e.g., to spin up rotating media) until allowed by the SA\_PC state machine (see 9.2.10).

Expander devices that detect an attached SATA phy may halt the automatic phy reset sequence after the COMSAS Detect Timeout (see 5.12) to delay temporary consumption of additional power. The resulting SATA spinup hold is reported in the NEGOTIATED PHYSICAL LINK RATE field in the SMP DISCOVER response (see 9.4.3.10) and is released with the SMP PHY CONTROL function (see 9.4.3.28).

NOTE 14 - Some enclosures supporting both SATA devices and SAS target devices sequence power to each attached device to avoid excessive power consumption during power on, since some SATA devices temporarily consume additional power automatically after power on if staggered spin-up is not implemented (see SATA).

## 6 Link layer

### 6.1 Link layer overview

The link layer defines primitives, address frames, and connections. Link layer state machines interface to the port layer and the phy layer and perform the identification and hard reset sequences, connection management, and SSP, STP, and SMP specific frame transmission and reception.

### 6.2 Primitives

#### 6.2.1 Primitives overview

Primitives are dwords whose first character is a K28.3 or K28.5. Primitives are not considered big-endian or little-endian. Primitives are interpreted as first, second, third, and last characters. Table 92 defines the primitive format.

**Table 92 — Primitive format**

| Character | Description                                                                                                                    |
|-----------|--------------------------------------------------------------------------------------------------------------------------------|
| First     | K28.5 control character (for primitives defined in this standard) or K28.3 control character (for primitives defined by SATA). |
| Second    | Constant data character.                                                                                                       |
| Third     | Constant data character.                                                                                                       |
| Last      | Constant data character.                                                                                                       |

## 6.2.2 Primitive summary

Table 93 defines the deletable primitives.

Table 93 — Deletable primitives

| Primitive                    | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|------------------------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|                              |                  | I                 | E | T | I               | E | T |                                      |
| ALIGN (0)                    | All, SpNeg       |                   |   |   |                 |   |   | Single                               |
| ALIGN (1)                    | SAS, SpNeg       | I                 | E | T | I               | E | T |                                      |
| ALIGN (2)                    | SAS              |                   |   |   |                 |   |   |                                      |
| ALIGN (3)                    |                  |                   |   |   |                 |   |   |                                      |
| MUX (LOGICAL LINK 0)         | SAS              | I                 | E | T | I               | E | T | Single                               |
| MUX (LOGICAL LINK 1)         |                  |                   |   |   |                 |   |   |                                      |
| NOTIFY (ENABLE SPINUP)       | SAS              | I                 | E |   |                 |   | T | Single                               |
| NOTIFY (POWER LOSS EXPECTED) |                  | I                 | E |   |                 |   | T |                                      |
| NOTIFY (RESERVED 1)          |                  |                   |   |   | I               | E | T |                                      |
| OOB_IDLE                     | SpNeg            | I                 | E | T | I               | E | T | Single                               |

Key:

All = SAS logical links and SATA physical links  
 SAS = SAS logical links, both outside connections or inside any type of connection  
 NoConn= SAS logical links, outside connections  
 Conn= SAS logical links, inside connections  
 STP = SAS logical links, inside STP connections  
 SpNeg = SAS physical links, during speed negotiation  
 I = SAS initiator ports  
 E = expander ports  
 T = SAS target ports

<sup>a</sup> The Use column indicates when the primitive is used.  
<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
 Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.  
<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).



**Table 94 — Primitives not specific to type of connection (part 1 of 4)**

| Primitive                         | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|-----------------------------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|                                   |                  | I                 | E | T | I               | E | T |                                      |
| AIP (NORMAL)                      | NoConn           |                   | E |   |                 |   |   | Extended                             |
| AIP (RESERVED 0)                  |                  |                   |   |   |                 |   |   |                                      |
| AIP (RESERVED 1)                  |                  |                   |   |   |                 |   |   |                                      |
| AIP (RESERVED 2)                  |                  |                   |   |   |                 |   |   |                                      |
| AIP (RESERVED WAITING ON PARTIAL) |                  |                   |   |   | I               | E | T |                                      |
| AIP (WAITING ON CONNECTION)       |                  |                   | E |   |                 |   |   |                                      |
| AIP (WAITING ON DEVICE)           |                  |                   | E |   |                 |   |   |                                      |
| AIP (WAITING ON PARTIAL)          |                  |                   | E |   |                 |   |   |                                      |
| BREAK                             | SAS              | I                 | E | T | I               | E | T | Redundant                            |
| BREAK_REPLY                       | SAS              | I                 | E | T | I               | E | T | Redundant                            |
| BROADCAST (CHANGE)                | NoConn           | I                 | E |   | I               |   |   | Redundant                            |
| BROADCAST (SES)                   |                  |                   |   | T | I               |   |   |                                      |
| BROADCAST (EXPANDER)              |                  |                   | E |   | I               |   |   |                                      |
| BROADCAST (ASYNCHRONOUS EVENT)    |                  |                   |   | T | I               |   |   |                                      |
| BROADCAST (RESERVED 3)            |                  |                   |   |   |                 |   |   |                                      |
| BROADCAST (RESERVED 4)            |                  |                   |   |   |                 |   |   |                                      |
| BROADCAST (RESERVED CHANGE 0)     |                  |                   |   |   | I               |   |   |                                      |
| BROADCAST (RESERVED CHANGE 1)     |                  |                   |   |   | I               |   |   |                                      |

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STP = SAS logical links, inside STP connections  
SpNeg = SAS physical links, during speed negotiation  
I = SAS initiator ports  
E= expander ports  
T = SAS target ports

<sup>a</sup> The Use column indicates when the primitive is used.  
<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.  
<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, an extended primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).

### Table 94 — Primitives not specific to type of connection (part 2 of 4)

| Primitive                 | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|---------------------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|                           |                  | I                 | E | T | I               | E | T |                                      |
| CLOSE (CLEAR AFFILIATION) | STP              | I                 |   |   |                 |   | T | Triple                               |
| CLOSE (NORMAL)            | Conn             | I                 |   | T | I               |   | T |                                      |
| CLOSE (RESERVED 0)        |                  |                   |   |   |                 |   |   |                                      |
| CLOSE (RESERVED 1)        |                  |                   |   |   |                 |   |   |                                      |
| EOAF                      | NoConn           | I                 | E | T | I               | E | T | Single                               |
| ERROR                     | SAS              |                   | E |   | I               | E | T | Single                               |
| HARD_RESET                | NoConn           | I                 | E |   | I               | E | T | Redundant                            |
| OPEN_ACCEPT               | NoConn           | I                 |   | T | I               |   | T | Single                               |

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I = SAS initiator ports  
E= expander ports  
T = SAS target ports

<sup>a</sup> The Use column indicates when the primitive is used.

<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.

<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, an extended primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).

### Table 94 — Primitives not specific to type of connection (part 3 of 4)

| Primitive                                   | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|---------------------------------------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|                                             |                  | I                 | E | T | I               | E | T |                                      |
| OPEN_REJECT (BAD DESTINATION)               | NoConn           |                   | E |   | I               |   | T | Single                               |
| OPEN_REJECT (CONNECTION RATE NOT SUPPORTED) |                  | I                 | E | T |                 |   |   |                                      |
| OPEN_REJECT (NO DESTINATION)                |                  |                   | E |   |                 |   |   |                                      |
| OPEN_REJECT (PATHWAY BLOCKED)               |                  |                   | E |   |                 |   |   |                                      |
| OPEN_REJECT (PROTOCOL NOT SUPPORTED)        |                  | I                 | E | T |                 |   |   |                                      |
| OPEN_REJECT (RESERVED ABANDON 1)            |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RESERVED ABANDON 2)            |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RESERVED ABANDON 3)            |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RESERVED CONTINUE 0)           |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RESERVED CONTINUE 1)           |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RESERVED INITIALIZE 0)         |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RESERVED INITIALIZE 1)         |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RESERVED STOP 0)               |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RESERVED STOP 1)               |                  |                   |   |   |                 |   |   |                                      |
| OPEN_REJECT (RETRY)                         |                  | I                 | E | T |                 |   |   |                                      |
| OPEN_REJECT (STP RESOURCES BUSY)            |                  |                   | E | T |                 |   |   |                                      |
| OPEN_REJECT (WRONG DESTINATION)             |                  | I                 |   | T |                 |   | T |                                      |
| OPEN_REJECT (ZONE VIOLATION)                |                  |                   | E |   |                 |   |   |                                      |
| PS_ACK                                      | NoConn           | I                 | E | T | I               | E | T | Redundant                            |
| PS_NAK                                      | NoConn           | I                 | E | T | I               | E | T | Redundant                            |
| PS_REQ (PARTIAL)                            | NoConn           | I                 | E | T | I               | E | T | Redundant                            |
| PS_REQ (SLUMBER)                            | NoConn           | I                 | E | T | I               | E | T | Redundant                            |

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STP = SAS logical links, inside STP connections  
SpNeg = SAS physical links, during speed negotiation  
I = SAS initiator ports  
E= expander ports  
T = SAS target ports

<sup>a</sup> The Use column indicates when the primitive is used.  
<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.  
<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, an extended primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).

Table 94 — Primitives not specific to type of connection (part 4 of 4)

| Primitive  | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|            |                  | I                 | E | T | I               | E | T |                                      |
| PWR_ACK    | NoConn           | I                 | E | T | I               | E | T | Redundant                            |
| PWR_DONE   | NoConn           |                   |   | T | I               | E |   | Redundant                            |
| PWR_GRANT  | NoConn           | I                 | E |   |                 |   | T | Redundant                            |
| PWR_REQ    | NoConn           |                   |   | T | I               | E |   | Redundant                            |
| SOAF       | NoConn           | I                 | E | T | I               | E | T | Single                               |
| TRAIN      | SpNeg            | I                 | E | T | I               | E | T | Redundant                            |
| TRAIN_DONE |                  |                   |   |   |                 |   |   |                                      |

Key:

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SAS = SAS logical links, both outside connections or inside any type of connection  
NoConn= SAS logical links, outside connections  
Conn= SAS logical links, inside connections  
STP = SAS logical links, inside STP connections  
SpNeg = SAS physical links, during speed negotiation  
I = SAS initiator ports  
E= expander ports  
T = SAS target ports

<sup>a</sup> The Use column indicates when the primitive is used.  
<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.  
<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, an extended primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).

Table 95 defines the primitives used only inside SSP and SMP connections.

**Table 95 — Primitives used inside SSP and SMP connections** (part 1 of 2)

| Primitive                  | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|----------------------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|                            |                  | I                 | E | T | I               | E | T |                                      |
| ACK                        | SSP              | I                 |   | T | I               |   | T | Single                               |
| CREDIT_BLOCKED             | SSP              | I                 |   | T | I               |   | T | Single                               |
| DONE (ACK/NAK TIMEOUT)     | SSP              | I                 |   | T | I               |   | T | Single                               |
| DONE (CREDIT TIMEOUT)      |                  | I                 |   | T |                 |   |   |                                      |
| DONE (NORMAL)              |                  | I                 |   | T |                 |   |   |                                      |
| DONE (RESERVED 0)          |                  |                   |   |   |                 |   |   |                                      |
| DONE (CLOSE)               |                  | I                 |   | T |                 |   |   |                                      |
| DONE (RESERVED TIMEOUT 0)  |                  |                   |   |   |                 |   |   |                                      |
| DONE (RESERVED TIMEOUT 1)  |                  |                   |   |   |                 |   |   |                                      |
| EOF                        | SSP, SMP         | I                 |   | T | I               |   | T | Single                               |
| EXTEND_CONNECTION (NORMAL) | SSP              | I                 |   | T | I               |   | T | Single                               |
| EXTEND_CONNECTION (CLOSE)  |                  |                   | E |   |                 |   |   |                                      |

Key:

SSP = SAS logical links, inside SSP connections  
SMP= SAS logical links, inside SMP connections  
I = SAS initiator ports and SMP initiator ports  
E= expander ports  
T = SAS target ports and SMP target ports

<sup>a</sup> The Use column indicates when the primitive is used.  
<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.  
<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, an extended primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).

### Table 95 — Primitives used inside SSP and SMP connections (part 2 of 2)

| Primitive         | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|-------------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|                   |                  | I                 | E | T | I               | E | T |                                      |
| NAK (CRC ERROR)   | SSP              | I                 |   | T | I               |   | T | Single                               |
| NAK (RESERVED 0)  |                  |                   |   |   |                 |   |   |                                      |
| NAK (RESERVED 1)  |                  |                   |   |   |                 |   |   |                                      |
| NAK (RESERVED 2)  |                  |                   |   |   |                 |   |   |                                      |
| RRDY (NORMAL)     | SSP              | I                 |   | T | I               |   | T | Single                               |
| RRDY (RESERVED 0) |                  |                   |   |   |                 |   |   |                                      |
| RRDY (CLOSE)      |                  | I                 | E | T |                 |   |   |                                      |
| SOF               | SSP, SMP         | I                 |   | T | I               |   | T | Single                               |

Key:

SSP = SAS logical links, inside SSP connections  
SMP= SAS logical links, inside SMP connections  
I = SAS initiator ports and SMP initiator ports  
E= expander ports  
T = SAS target ports and SMP target ports

<sup>a</sup> The Use column indicates when the primitive is used.  
<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.  
<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, an extended primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).

Table 96 lists the primitives used only inside STP connections and on SATA physical links.

**Table 96 — Primitives used inside STP connections and on SATA physical links (part 1 of 2)**

| Primitive               | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|-------------------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|                         |                  | I                 | E | T | I               | E | T |                                      |
| SATA_CONT               | STP, SATA        | I                 |   | T | I               |   | T | Single                               |
| SATA_DMAT               | STP, SATA        | I                 |   | T | I               |   | T | Single                               |
| SATA_EOF                | STP, SATA        | I                 |   | T | I               |   | T | Single                               |
| SATA_ERROR <sup>d</sup> | SATA             |                   | E |   |                 |   | T | Single                               |
| SATA_HOLD               | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |
| SATA_HOLDA              | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |
| SATA_PMACK              | SATA             | I                 | E |   |                 |   |   | Repeated                             |
|                         | STP              |                   |   |   |                 |   |   |                                      |
| SATA_PMNAK              | STP, SATA        | I                 | E |   |                 |   | T | Repeated                             |
| SATA_PMREQ_P            | SATA             |                   |   |   | I               | E |   | Continued                            |
|                         | STP              |                   |   |   |                 |   |   |                                      |

Key:

STP = SAS logical links, inside STP connections  
SATA= SATA physical links  
I = STP initiator ports and SATA host ports  
E= expander ports  
T = STP target ports and SATA device ports

<sup>a</sup> The Use column indicates when the primitive is used.  
<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.  
<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, an extended primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).  
<sup>d</sup> Although included in this table, SATA\_ERROR is not a primitive (see 3.1.155) since it starts with K28.6. It does not appear inside STP connections. It is an invalid dword, used by expander devices forwarding an error onto a SATA physical link (see 6.2.8.1).

**Table 96 — Primitives used inside STP connections and on SATA physical links (part 2 of 2)**

| Primitive    | Use <sup>a</sup> | From <sup>b</sup> |   |   | To <sup>b</sup> |   |   | Primitive sequence type <sup>c</sup> |
|--------------|------------------|-------------------|---|---|-----------------|---|---|--------------------------------------|
|              |                  | I                 | E | T | I               | E | T |                                      |
| SATA_PMREQ_S | SATA             |                   |   |   | I               | E |   | Continued                            |
|              | STP              |                   |   |   |                 |   |   |                                      |
| SATA_R_ERR   | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |
| SATA_R_IP    | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |
| SATA_R_OK    | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |
| SATA_R_RDY   | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |
| SATA_SOF     | STP, SATA        | I                 |   | T | I               |   | T | Single                               |
| SATA_SYNC    | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |
| SATA_WTRM    | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |
| SATA_X_RDY   | STP, SATA        | I                 |   | T | I               |   | T | Continued                            |

Key:

STP = SAS logical links, inside STP connections  
SATA= SATA physical links  
I = STP initiator ports and SATA host ports  
E= expander ports  
T = STP target ports and SATA device ports

<sup>a</sup> The Use column indicates when the primitive is used.  
<sup>b</sup> The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive.  
Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port within an expander.  
<sup>c</sup> The Primitive sequence type columns indicate whether the primitive is a single primitive sequence, a repeated primitive sequence, a continued primitive sequence, an extended primitive sequence, a triple primitive sequence, or a redundant primitive sequence (see 6.2.4).  
<sup>d</sup> Although included in this table, SATA\_ERROR is not a primitive (see 3.1.155) since it starts with K28.6. It does not appear inside STP connections. It is an invalid dword, used by expander devices forwarding an error onto a SATA physical link (see 6.2.8.1).



### 6.2.3 Primitive encodings

Table 97 defines the primitive encoding for deletable primitives.

**Table 97 — Primitive encoding for deletable primitives**

| Primitive                    | Character       |                 |                 |                        | Hexadecimal |
|------------------------------|-----------------|-----------------|-----------------|------------------------|-------------|
|                              | 1 <sup>st</sup> | 2 <sup>nd</sup> | 3 <sup>rd</sup> | 4 <sup>th</sup> (last) |             |
| ALIGN (0)                    | K28.5           | D10.2           | D10.2           | D27.3                  | BC4A4A7Bh   |
| ALIGN (1)                    | K28.5           | D07.0           | D07.0           | D07.0                  | BC070707h   |
| ALIGN (2)                    | K28.5           | D01.3           | D01.3           | D01.3                  | BC616161h   |
| ALIGN (3)                    | K28.5           | D27.3           | D27.3           | D27.3                  | BC7B7B7Bh   |
| MUX (LOGICAL LINK 0)         | K28.5           | D02.0           | D16.7           | D31.4                  | BC02F09Fh   |
| MUX (LOGICAL LINK 1)         | K28.5           | D04.7           | D31.4           | D27.4                  | BCE49F9Bh   |
| NOTIFY (ENABLE SPINUP)       | K28.5           | D31.3           | D31.3           | D31.3                  | BC7F7F7Fh   |
| NOTIFY (POWER LOSS EXPECTED) | K28.5           | D31.3           | D07.0           | D01.3                  | BC7F0761h   |
| NOTIFY (RESERVED 1)          | K28.5           | D31.3           | D01.3           | D07.0                  | BC7F6107h   |
| Obsolete                     | K28.5           | D31.3           | D10.2           | D10.2                  | BC7F4A4Ah   |
| OOB_IDLE                     | K28.5           | D07.0           | D03.4           | D13.4                  | BC07838Dh   |

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Table 98 defines the primitive encoding for primitives not specific to type of connection.

**Table 98 — Primitive encoding for primitives not specific to type of connection (part 1 of 2)**

| Primitive                                   | Character       |                 |                 |                        | Hexadecimal |
|---------------------------------------------|-----------------|-----------------|-----------------|------------------------|-------------|
|                                             | 1 <sup>st</sup> | 2 <sup>nd</sup> | 3 <sup>rd</sup> | 4 <sup>th</sup> (last) |             |
| AIP (NORMAL)                                | K28.5           | D27.4           | D27.4           | D27.4                  | BC9B9B9Bh   |
| AIP (RESERVED 0)                            | K28.5           | D27.4           | D31.4           | D16.7                  | BC9B9FF0h   |
| AIP (RESERVED 1)                            | K28.5           | D27.4           | D16.7           | D30.0                  | BC9BF01Eh   |
| AIP (RESERVED 2)                            | K28.5           | D27.4           | D29.7           | D01.4                  | BC9BFD81h   |
| AIP (RESERVED WAITING ON PARTIAL)           | K28.5           | D27.4           | D01.4           | D07.3                  | BC9B8167h   |
| AIP (WAITING ON CONNECTION)                 | K28.5           | D27.4           | D07.3           | D24.0                  | BC9B6718h   |
| AIP (WAITING ON DEVICE)                     | K28.5           | D27.4           | D30.0           | D29.7                  | BC9B1EFDh   |
| AIP (WAITING ON PARTIAL)                    | K28.5           | D27.4           | D24.0           | D04.7                  | BC9B18E4h   |
| BREAK                                       | K28.5           | D02.0           | D24.0           | D07.3                  | BC021867h   |
| BREAK_REPLY                                 | K28.5           | D02.0           | D29.7           | D16.7                  | BC02FDF0h   |
| BROADCAST (CHANGE)                          | K28.5           | D04.7           | D02.0           | D01.4                  | BCE40281h   |
| BROADCAST (SES)                             | K28.5           | D04.7           | D07.3           | D29.7                  | BCE467FDh   |
| BROADCAST (EXPANDER)                        | K28.5           | D04.7           | D01.4           | D24.0                  | BCE48118h   |
| BROADCAST (ASYNCHRONOUS EVENT)              | K28.5           | D04.7           | D04.7           | D04.7                  | BCE4E4E4h   |
| BROADCAST (RESERVED 3)                      | K28.5           | D04.7           | D16.7           | D02.0                  | BCE4F002h   |
| BROADCAST (RESERVED 4)                      | K28.5           | D04.7           | D29.7           | D30.0                  | BCE4FD1Eh   |
| BROADCAST (RESERVED CHANGE 0)               | K28.5           | D04.7           | D24.0           | D31.4                  | BCE4189Fh   |
| BROADCAST (RESERVED CHANGE 1)               | K28.5           | D04.7           | D27.4           | D07.3                  | BCE49B67h   |
| CLOSE (CLEAR AFFILIATION)                   | K28.5           | D02.0           | D07.3           | D04.7                  | BC0267E4h   |
| CLOSE (NORMAL)                              | K28.5           | D02.0           | D30.0           | D27.4                  | BC021E9Bh   |
| CLOSE (RESERVED 0)                          | K28.5           | D02.0           | D31.4           | D30.0                  | BC029F1Eh   |
| CLOSE (RESERVED 1)                          | K28.5           | D02.0           | D04.7           | D01.4                  | BC02E481h   |
| EOAF                                        | K28.5           | D24.0           | D07.3           | D31.4                  | BC18679Fh   |
| ERROR                                       | K28.5           | D02.0           | D01.4           | D29.7                  | BC0281FDh   |
| HARD_RESET                                  | K28.5           | D02.0           | D02.0           | D02.0                  | BC020202h   |
| OPEN_ACCEPT                                 | K28.5           | D16.7           | D16.7           | D16.7                  | BCF0F0F0h   |
| OPEN_REJECT (BAD DESTINATION)               | K28.5           | D31.4           | D31.4           | D31.4                  | BC9F9F9Fh   |
| OPEN_REJECT (CONNECTION RATE NOT SUPPORTED) | K28.5           | D31.4           | D04.7           | D29.7                  | BC9FE4FDh   |
| OPEN_REJECT (NO DESTINATION)                | K28.5           | D29.7           | D29.7           | D29.7                  | BCFDFDFDh   |
| OPEN_REJECT (PATHWAY BLOCKED)               | K28.5           | D29.7           | D16.7           | D04.7                  | BCFDF0E4h   |

Table 98 — Primitive encoding for primitives not specific to type of connection (part 2 of 2)

| Primitive                            | Character       |                 |                 |                        | Hexadecimal |
|--------------------------------------|-----------------|-----------------|-----------------|------------------------|-------------|
|                                      | 1 <sup>st</sup> | 2 <sup>nd</sup> | 3 <sup>rd</sup> | 4 <sup>th</sup> (last) |             |
| OPEN_REJECT (PROTOCOL NOT SUPPORTED) | K28.5           | D31.4           | D29.7           | D07.3                  | BC9FFD67h   |
| OPEN_REJECT (RESERVED ABANDON 1)     | K28.5           | D31.4           | D30.0           | D16.7                  | BC9F1EF0h   |
| OPEN_REJECT (RESERVED ABANDON 2)     | K28.5           | D31.4           | D07.3           | D02.0                  | BC9F6702h   |
| OPEN_REJECT (RESERVED ABANDON 3)     | K28.5           | D31.4           | D01.4           | D30.0                  | BC9F811Eh   |
| OPEN_REJECT (RESERVED CONTINUE 0)    | K28.5           | D29.7           | D02.0           | D30.0                  | BCFD021Eh   |
| OPEN_REJECT (RESERVED CONTINUE 1)    | K28.5           | D29.7           | D24.0           | D01.4                  | BCFD1881h   |
| OPEN_REJECT (RESERVED INITIALIZE 0)  | K28.5           | D29.7           | D30.0           | D31.4                  | BCFD1E9Fh   |
| OPEN_REJECT (RESERVED INITIALIZE 1)  | K28.5           | D29.7           | D07.3           | D16.7                  | BCFD67F0h   |
| OPEN_REJECT (RESERVED STOP 0)        | K28.5           | D29.7           | D31.4           | D07.3                  | BCFD9F67h   |
| OPEN_REJECT (RESERVED STOP 1)        | K28.5           | D29.7           | D04.7           | D27.4                  | BCFDE49Bh   |
| OPEN_REJECT (RETRY)                  | K28.5           | D29.7           | D27.4           | D24.0                  | BCFD9B18h   |
| OPEN_REJECT (STP RESOURCES BUSY)     | K28.5           | D31.4           | D27.4           | D01.4                  | BC9F9B81h   |
| OPEN_REJECT (WRONG DESTINATION)      | K28.5           | D31.4           | D16.7           | D24.0                  | BC9FF018h   |
| OPEN_REJECT (ZONE VIOLATION)         | K28.5           | D31.4           | D02.0           | D27.4                  | BC9F029Bh   |
| PS_ACK                               | K28.5           | D16.7           | D27.4           | D30.0                  | BCF09B1Eh   |
| PS_NAK                               | K28.5           | D24.0           | D27.4           | D02.0                  | BC189B02h   |
| PS_REQ (PARTIAL)                     | K28.5           | D07.3           | D02.0           | D04.7                  | BC6702E4h   |
| PS_REQ (SLUMBER)                     | K28.5           | D30.0           | D24.0           | D02.0                  | BC1E1802h   |
| PWR_ACK                              | K28.5           | D07.3           | D07.3           | D07.3                  | BC676767h   |
| PWR_DONE                             | K28.5           | D07.3           | D24.0           | D29.7                  | BC6718FDh   |
| PWR_GRANT                            | K28.5           | D07.3           | D27.4           | D16.7                  | BC679BF0h   |
| PWR_REQ                              | K28.5           | D07.3           | D29.7           | D27.4                  | BC67FD9Bh   |
| SOAF                                 | K28.5           | D24.0           | D30.0           | D01.4                  | BC181E81h   |
| TRAIN                                | K28.5           | D30.3           | D30.3           | D30.3                  | BC7E7E7Eh   |
| TRAIN_DONE                           | K28.5           | D30.3           | D30.3           | D10.2                  | BC7E7E4Ah   |

Table 99 defines the primitive encodings for primitives used only inside SSP and SMP connections.

**Table 99 — Primitive encoding for primitives used only inside SSP and SMP connections**

| Primitive                  | Character       |                 |                 |                        | Hexadecimal |
|----------------------------|-----------------|-----------------|-----------------|------------------------|-------------|
|                            | 1 <sup>st</sup> | 2 <sup>nd</sup> | 3 <sup>rd</sup> | 4 <sup>th</sup> (last) |             |
| ACK                        | K28.5           | D01.4           | D01.4           | D01.4                  | BC818181h   |
| CREDIT_BLOCKED             | K28.5           | D01.4           | D07.3           | D30.0                  | BC81671Eh   |
| DONE (ACK/NAK TIMEOUT)     | K28.5           | D30.0           | D01.4           | D04.7                  | BC1E81E4h   |
| DONE (CREDIT TIMEOUT)      | K28.5           | D30.0           | D07.3           | D27.4                  | BC1E679Bh   |
| DONE (NORMAL)              | K28.5           | D30.0           | D30.0           | D30.0                  | BC1E1E1Eh   |
| DONE (RESERVED 0)          | K28.5           | D30.0           | D16.7           | D01.4                  | BC1EF081h   |
| DONE (CLOSE)               | K28.5           | D30.0           | D29.7           | D31.4                  | BC1EFD9Fh   |
| DONE (RESERVED TIMEOUT 0)  | K28.5           | D30.0           | D27.4           | D29.7                  | BC1E9BFDh   |
| DONE (RESERVED TIMEOUT 1)  | K28.5           | D30.0           | D31.4           | D24.0                  | BC1E9F18h   |
| EOF                        | K28.5           | D24.0           | D16.7           | D27.4                  | BC18F09Bh   |
| EXTEND_CONNECTION (NORMAL) | K28.5           | D24.0           | D29.7           | D04.7                  | BC18FDE4h   |
| EXTEND_CONNECTION (CLOSE)  | K28.5           | D24.0           | D01.4           | D16.7                  | BC1881F0h   |
| NAK (CRC ERROR)            | K28.5           | D01.4           | D27.4           | D04.7                  | BC819BE4h   |
| NAK (RESERVED 0)           | K28.5           | D01.4           | D31.4           | D29.7                  | BC819FFDh   |
| NAK (RESERVED 1)           | K28.5           | D01.4           | D04.7           | D24.0                  | BC81E418h   |
| NAK (RESERVED 2)           | K28.5           | D01.4           | D16.7           | D07.3                  | BC81F067h   |
| RRDY (NORMAL)              | K28.5           | D01.4           | D24.0           | D16.7                  | BC8118F0h   |
| RRDY (RESERVED 0)          | K28.5           | D01.4           | D02.0           | D31.4                  | BC81029Fh   |
| RRDY (CLOSE)               | K28.5           | D01.4           | D30.0           | D02.0                  | BC811E02h   |
| SOF                        | K28.5           | D24.0           | D04.7           | D07.3                  | BC18E467h   |

Table 100 lists the primitive encodings for primitives used only inside STP connections and on SATA physical links.

**Table 100 — Primitive encoding for primitives used only inside STP connections and only on SATA physical links**

| Primitive                                                                                                                                                                                                                                                                                                                                             | Character       |                 |                 |                        | Hexadecimal |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------|-----------------|------------------------|-------------|
|                                                                                                                                                                                                                                                                                                                                                       | 1 <sup>st</sup> | 2 <sup>nd</sup> | 3 <sup>rd</sup> | 4 <sup>th</sup> (last) |             |
| SATA_CONT                                                                                                                                                                                                                                                                                                                                             | K28.3           | D10.5           | D25.4           | D25.4                  | 7CAA9999h   |
| SATA_DMAT                                                                                                                                                                                                                                                                                                                                             | K28.3           | D21.5           | D22.1           | D22.1                  | 7CB53636h   |
| SATA_EOF                                                                                                                                                                                                                                                                                                                                              | K28.3           | D21.5           | D21.6           | D21.6                  | 7CB5D5D5h   |
| SATA_ERROR <sup>a b</sup>                                                                                                                                                                                                                                                                                                                             | K28.6           | D02.0           | D01.4           | D29.7                  | DC0281FDh   |
| SATA_HOLD                                                                                                                                                                                                                                                                                                                                             | K28.3           | D10.5           | D21.6           | D21.6                  | 7CAAD5D5h   |
| SATA_HOLDA                                                                                                                                                                                                                                                                                                                                            | K28.3           | D10.5           | D21.4           | D21.4                  | 7CAA9595h   |
| SATA_PMACK                                                                                                                                                                                                                                                                                                                                            | K28.3           | D21.4           | D21.4           | D21.4                  | 7C959595h   |
| SATA_PMNAK                                                                                                                                                                                                                                                                                                                                            | K28.3           | D21.4           | D21.7           | D21.7                  | 7C95F5F5h   |
| SATA_PMREQ_P                                                                                                                                                                                                                                                                                                                                          | K28.3           | D21.5           | D23.0           | D23.0                  | 7CB51717h   |
| SATA_PMREQ_S                                                                                                                                                                                                                                                                                                                                          | K28.3           | D21.4           | D21.3           | D21.3                  | 7C957575h   |
| SATA_R_ERR                                                                                                                                                                                                                                                                                                                                            | K28.3           | D21.5           | D22.2           | D22.2                  | 7CB55656h   |
| SATA_R_IP                                                                                                                                                                                                                                                                                                                                             | K28.3           | D21.5           | D21.2           | D21.2                  | 7CB55555h   |
| SATA_R_OK                                                                                                                                                                                                                                                                                                                                             | K28.3           | D21.5           | D21.1           | D21.1                  | 7CB53535h   |
| SATA_R_RDY                                                                                                                                                                                                                                                                                                                                            | K28.3           | D21.4           | D10.2           | D10.2                  | 7C954A4Ah   |
| SATA_SOF                                                                                                                                                                                                                                                                                                                                              | K28.3           | D21.5           | D23.1           | D23.1                  | 7CB53737h   |
| SATA_SYNC                                                                                                                                                                                                                                                                                                                                             | K28.3           | D21.4           | D21.5           | D21.5                  | 7C95B5B5h   |
| SATA_WTRM                                                                                                                                                                                                                                                                                                                                             | K28.3           | D21.5           | D24.2           | D24.2                  | 7CB55858h   |
| SATA_X_RDY                                                                                                                                                                                                                                                                                                                                            | K28.3           | D21.5           | D23.2           | D23.2                  | 7CB55757h   |
| <sup>a</sup> Except for SATA_ERROR, all values are defined by SATA.<br><sup>b</sup> Although included in this table, SATA_ERROR is not a primitive (see 3.1.155) since it starts with K28.6. It does not appear inside STP connections. It is an invalid dword, used by expander devices forwarding an error onto a SATA physical link (see 6.2.8.1). |                 |                 |                 |                        |             |

## 6.2.4 Primitive sequences

### 6.2.4.1 Primitive sequences overview

Table 101 summarizes the types of primitive sequences.

**Table 101 — Primitive sequences**

| Primitive sequence type                                                                                                                                                                                        | Transmit <sup>a</sup>   | Receive <sup>b</sup> | Reference |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------|-----------|
| Single                                                                                                                                                                                                         | 1                       | 1                    | 6.2.4.2   |
| Repeated                                                                                                                                                                                                       | 1 or more               | 1                    | 6.2.4.3   |
| Continued                                                                                                                                                                                                      | 2 followed by SATA_CONT | 1                    | 6.2.4.4   |
| Extended                                                                                                                                                                                                       | 3                       | 1                    | 6.2.4.5   |
| Triple                                                                                                                                                                                                         | 3                       | 3                    | 6.2.4.6   |
| Redundant                                                                                                                                                                                                      | 6                       | 3                    | 6.2.4.7   |
| <sup>a</sup> Number of times the transmitter transmits the primitive to transmit the primitive sequence.<br><sup>b</sup> Number of times the receiver receives the primitive to detect the primitive sequence. |                         |                      |           |

Any number of deletable primitives may be transmitted inside primitive sequences without affecting the count or breaking the consecutiveness requirements unless prohibited by the primitives description (e.g., TRAIN, TRAIN\_DONE). Rate matching deletable primitives shall be transmitted inside primitive sequences inside of connections if rate matching is enabled (see 6.15).

#### 6.2.4.2 Single primitive sequence

Primitives labeled as single primitive sequences (e.g., RRDY, SATA\_SOF) shall be transmitted one time to form a single primitive sequence.

Receivers count each primitive received that is labeled as a single primitive sequence as a distinct single primitive sequence.

ALIGNs, NOTIFYs, and MUXs are deletable primitives (see 6.2.5 and 6.3).

#### 6.2.4.3 Repeated primitive sequence

Primitives that form repeated primitive sequences (e.g., SATA\_PMACK) shall be transmitted one or more times. Only STP primitives form repeated primitive sequences. Any number of deletable primitives may be transmitted inside repeated primitive sequences as described in 6.2.4.1.

Figure 109 shows an example of transmitting a repeated primitive sequence.

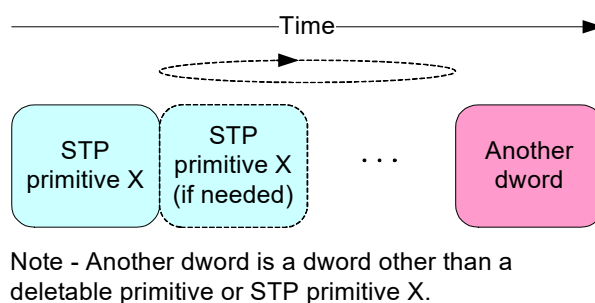


**Figure 109 — Transmitting a repeated primitive sequence**

Receivers do not count the number of times a repeated primitive is received. An expander device forwarding a repeated primitive sequence may transmit more repeated primitives than it receives (i.e., expand) or transmit fewer repeated primitives than it receives (i.e., contract). While transmitting a repeated primitive sequence, the expander device is considered to be originating (see 6.3.2) rather than forwarding (see 6.3.3) for purposes of deletable primitive insertion.

Figure 110 shows an example of receiving a repeated primitive sequence.

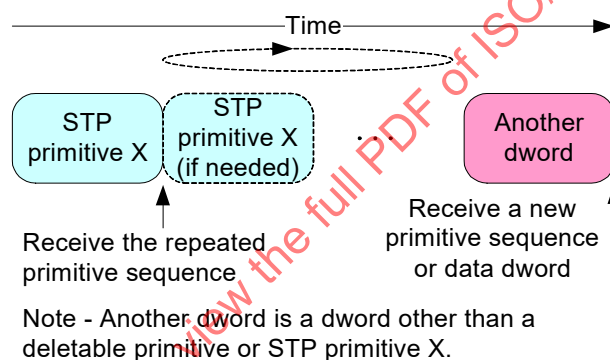


**Figure 110 — Receiving a repeated primitive sequence**

#### 6.2.4.4 Continued primitive sequence

Primitives that form continued primitive sequences (e.g., SATA\_HOLD) shall be transmitted as specified in 6.19.3. Any number of deletable primitives may be transmitted inside continued primitive sequences as described in 6.2.4.1.

#### 6.2.4.5 Extended primitive sequence

Primitives that form extended primitive sequences (e.g., AIP) shall be transmitted three times consecutively. Any number of deletable primitives may be transmitted inside extended primitive sequences as described in 6.2.4.1.

A receiver shall detect an extended primitive sequence after the primitive is received one time. The receiver shall process an extended primitive sequence the same as a single primitive sequence (see 6.2.4.2).

Figure 111 shows examples of extended primitive sequences.

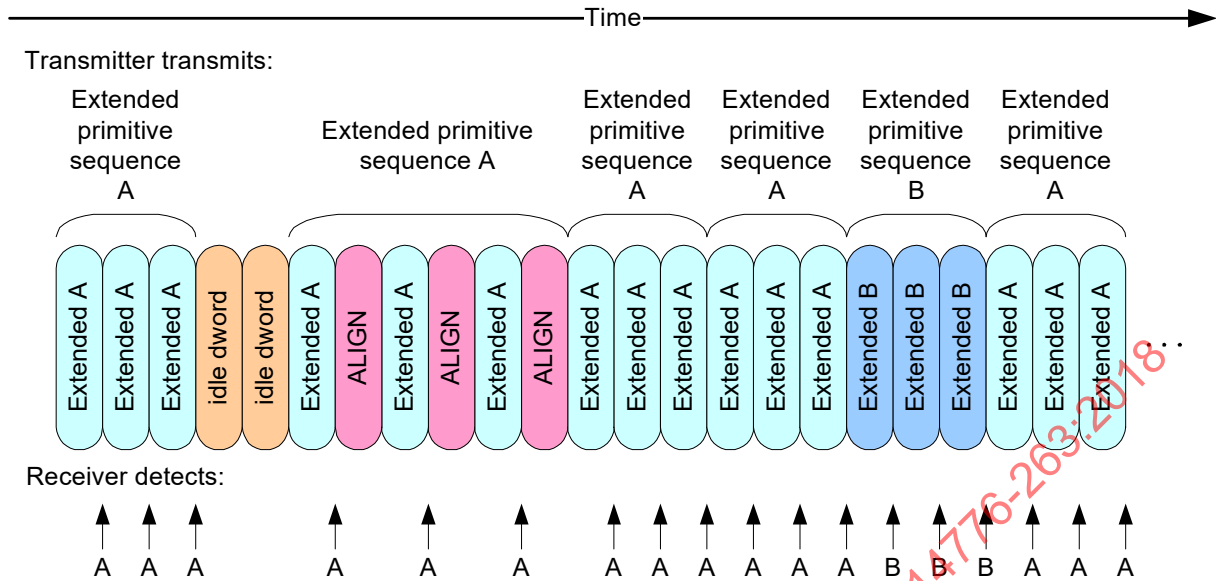


Figure 111 — Extended primitive sequences

#### 6.2.4.6 Triple primitive sequence

Primitives that form triple primitive sequences (e.g., CLOSE (NORMAL)) shall be transmitted three times consecutively. Any number of deletable primitives may be transmitted inside triple primitive sequences as described in 6.2.4.1.

Receivers shall detect a triple primitive sequence after the identical primitive is received in three consecutive dwords. After detecting a triple primitive sequence, a receiver shall not detect a second instance of the same triple primitive sequence until it has received three consecutive dwords that are not any of the following:

- the original primitive; or
- a deletable primitive.





Figure 113 shows examples of redundant primitive sequences.

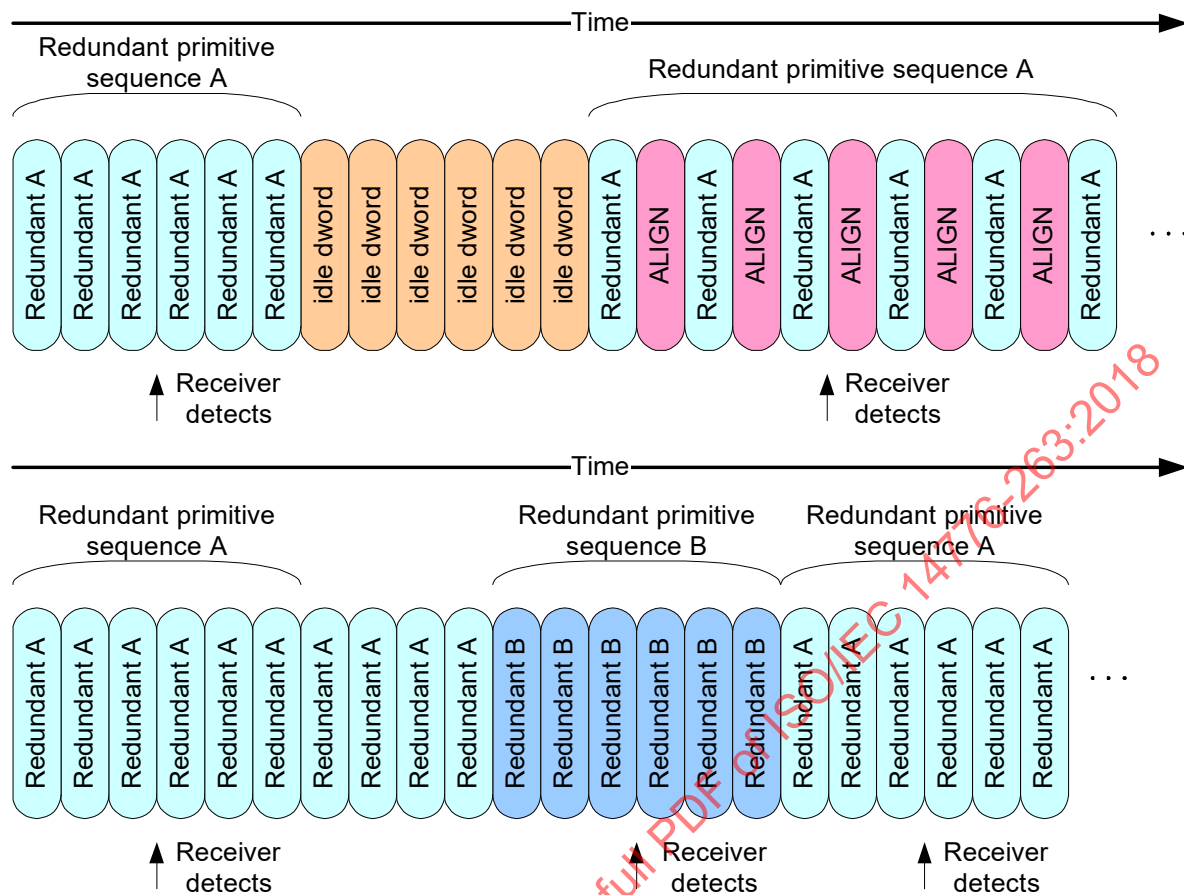


Figure 113 — Redundant primitive sequences

## 6.2.5 Deletable primitives

### 6.2.5.1 ALIGN

ALIGNs are used for:

- OOB signals (see 5.6);
- character and dword alignment during the speed negotiation sequence (see 5.10.4.2);
- physical link rate tolerance management after the phy reset sequence (see 6.3); and
- rate matching during connections (see 6.15).

ALIGNs are deletable primitives (see 6.3).

Table 102 defines the different versions of ALIGN primitives.

**Table 102 — ALIGN primitives**

| Primitive | Description                                                                                                                                                                       |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ALIGN (0) | Used for OOB signals while D.C. mode is enabled and for the speed negotiation sequence, physical link rate tolerance management, phy power condition sequence, and rate matching. |
| ALIGN (1) | Used for the speed negotiation sequence, physical link rate tolerance management, phy power condition sequence, and rate matching.                                                |
| ALIGN (2) | Used for physical link rate tolerance management and rate matching.                                                                                                               |
| ALIGN (3) | Used for OOB signals while optical mode is enabled and for physical link rate tolerance management, and rate matching.                                                            |

If D.C. mode is enabled, then phys may use ALIGN (0) to construct OOB signals (see 5.6 and SAS-3). If optical mode is enabled, then phys use ALIGN (3) to construct OOB signals (see 5.6 and SAS-3). Phys use ALIGN (0) and ALIGN (1) during the:

- a) speed negotiation sequence (see 5.10.4.2); and
- b) phy power condition sequence (see 5.11).

Phys shall rotate through transmitting ALIGN (0), ALIGN (1), ALIGN (2), and ALIGN (3) for all ALIGNs transmitted after the phy reset sequence (e.g., if the first ALIGN transmitted after the phy reset sequence is ALIGN (0), then the second transmitted is ALIGN (1), the third transmitted is ALIGN (2), the fourth transmitted is ALIGN (3), the fifth transmitted is ALIGN (0), etc.).

NOTE 15 - ALIGN rotation is performed on a physical phy basis and is used to reduce radiated emissions.

Phys receiving ALIGNs after the phy reset sequence shall not verify the rotation and shall accept any of the ALIGNs at any time.

Phys shall only detect an ALIGN after decoding all four characters in the primitive.

NOTE 16 - SATA devices are allowed to decode every dword starting with a K28.5 as an ALIGN, since ALIGN is the only primitive defined starting with K28.5.

For physical link rate tolerance management and rate matching, ALIGNs may be replaced by NOTIFYs (see 6.2.5.3) or MUXs (see 6.2.5.2). ALIGNs shall not be replaced by NOTIFYs or MUXs during OOB signals or speed negotiation.

#### **6.2.5.2 MUX (Multiplex)**

MUX is used if multiplexing (see 5.15) is enabled (see table 55) as follows:

- a) transmitted during the multiplexing sequence (see 5.10.4.3); and
- b) substituted in place of an ALIGN (see 6.2.5.1) being transmitted for physical link rate tolerance management (see 6.3) or rate matching (see 6.15) to confirm the logical link number as defined in 5.15.

Substitution of a MUX for an ALIGN may or may not affect the ALIGN rotation (i.e., the MUX may take the place of one of the ALIGNs in the rotation through ALIGN (0), ALIGN (1), ALIGN (2), and ALIGN (3), or may delay the rotation).

MUXs are deletable primitives (see 6.3). A phy supporting multiplexing shall process MUX primitives in logic running off the received clock without using an elasticity buffer rather than logic after the elasticity buffer, because they are not accompanied by additional deletable primitives (e.g., ALIGNs and/or NOTIFYs).

The versions of MUX are defined in table 103.

**Table 103 — MUX primitives**

| Primitive            | Description                                           |
|----------------------|-------------------------------------------------------|
| MUX (LOGICAL LINK 0) | Establishes the position of dwords in logical link 0. |
| MUX (LOGICAL LINK 1) | Establishes the position of dwords in logical link 1. |

See 5.15 for details on multiplexing.

### 6.2.5.3 NOTIFY

#### 6.2.5.3.1 NOTIFY overview

NOTIFY may be substituted in place of any ALIGN (see 6.2.5.1) being transmitted for physical link rate tolerance management (see 6.3) or rate matching (see 6.15). Substitution of a NOTIFY in place of an ALIGN may or may not affect the ALIGN rotation (i.e., the NOTIFY may take the place of one of the ALIGNs in the rotation through ALIGN (0), ALIGN (1), ALIGN (2), and ALIGN (3), or may delay the rotation). A specific NOTIFY shall not be transmitted in more than three consecutive dwords until at least three other dwords have been transmitted.

NOTIFYs are deletable primitives (see 6.3). If a phy supports a specific NOTIFY primitive, then the phy should decode that NOTIFY in logic running off the received clock without using an elasticity buffer rather than logic after the elasticity buffer to avoid missing detection of important information.

NOTIFY shall not be forwarded through expander devices. Expander devices shall substitute an ALIGN for a NOTIFY if necessary.

SAS target devices are not required to detect every transmitted NOTIFY.

The versions of NOTIFY representing different reasons are defined in table 104.

**Table 104 — NOTIFY primitives**

| Primitive                    | Description                                                                                                                                                            | Reference |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| NOTIFY (ENABLE SPINUP)       | Specify to a SAS target device that it may temporarily consume additional power (see 9.2.10).                                                                          | 6.2.5.3.2 |
| NOTIFY (POWER LOSS EXPECTED) | Specify to a SAS target device that power loss may occur within the time specified by the POWER LOSS TIMEOUT field in the Shared Port Control mode page (see 9.2.7.6). | 6.2.5.3.3 |
| NOTIFY (RESERVED 1)          | Reserved.                                                                                                                                                              |           |

NOTIFY (RESERVED 1) shall be ignored by all devices.

#### 6.2.5.3.2 NOTIFY (ENABLE SPINUP)

NOTIFY (ENABLE SPINUP) is transmitted by a SAS initiator port or expander port and is used to specify to a SAS target device that it may temporarily consume additional power (e.g., to spin up rotating media) (see 9.2.10). The length of time the SAS target device consumes additional power and the amount of additional power is vendor specific. NOTIFY (ENABLE SPINUP) shall interact with the device's power condition state

transitions, controlled by the Power Conditions mode page (see SPC-4) and/or the START STOP UNIT command (see SBC-3), as described in 9.2.10.

If power control is not enabled, then:

- a) SAS initiator devices and expander devices shall use NOTIFY (ENABLE SPINUP) while attached to SSP target devices (i.e., devices that report SSP target port support in their IDENTIFY address frames);
- b) SAS initiator ports and expander ports shall transmit one NOTIFY (ENABLE SPINUP) after power on when the enclosure is ready for initial temporary consumption of additional power; and
- c) after the initial NOTIFY (ENABLE SPINUP), SAS initiator ports and expander ports shall transmit NOTIFY (ENABLE SPINUP) periodically.

The selection of when and how often to transmit NOTIFY (ENABLE SPINUP) is outside the scope of this standard.

NOTE 17 - The SAS initiator device or expander device uses NOTIFY (ENABLE SPINUP) to avoid exceeding enclosure power supply capabilities during temporary consumption of additional power by multiple SAS target devices.

NOTIFY (ENABLE SPINUP) should be transmitted as frequently as possible to avoid incurring SCSI application layer timeouts.

A SAS target device with multiple SAS target ports shall process a NOTIFY (ENABLE SPINUP) received by any of its SAS target ports (e.g., if a dual-port SAS target device that powers on in the Stopped state receives a START STOP UNIT command with the START bit set to one through one SSP target port followed by a receipt of a NOTIFY (ENABLE SPINUP) on the other SSP target port, then the SAS target device may temporarily consume additional power (see 9.2.10)).

#### 6.2.5.3.3 NOTIFY (POWER LOSS EXPECTED)

NOTIFY (POWER LOSS EXPECTED) is transmitted by a SAS initiator port or expander port and is used to specify to a SAS target device that power loss may occur within the time specified in the POWER LOSS TIMEOUT field in the Shared Port Control mode page (see 9.2.7.6).

At least three NOTIFY (POWER LOSS EXPECTED) primitive sequences shall be transmitted by the SAS initiator port or expander port.

If a SAS target device supports NOTIFY (POWER LOSS EXPECTED) and receives NOTIFY (POWER LOSS EXPECTED) on an SSP target port, then:

- a) each logical unit to which the SSP target port has access shall:
  - 1) stop writing data to the medium as soon as possible without creating read errors for future reads (e.g., on a direct-access block device, when a physical block boundary is reached); and
  - 2) perform the actions for a power loss expected condition as defined in SAM-5;
 and
- b) the SAS target device shall:
  - A) on each phy that receives NOTIFY (POWER LOSS EXPECTED), if there is an SSP connection, then transmit a BREAK primitive sequence on that connection; and
  - B) on each phy that does not receive NOTIFY (POWER LOSS EXPECTED), if there is an SSP connection, then transmit a BREAK primitive sequence or a CLOSE primitive sequence on that connection.

If the SAS target device receives any frames after receiving NOTIFY (POWER LOSS EXPECTED) before a connection is closed, then it should discard the received frames.

The SCSI application layer that receives a Power Loss Expected event shall:

- a) start the power loss timer;
- b) send an Accept\_Reject OPENs (Reject SSP) request to all ST\_T state machines (i.e., all SSP connection requests result in OPEN\_REJECT (RETRY));

- c) if a SCSI Command Received transport protocol service indication is received, then the SCSI device server shall abort that command and send an Accept\_Reject OPENs (Reject SSP) request to the ST\_T state machine on which the SCSI Command Received transport protocol service indication was received; and
- d) if the power loss timeout timer expires, then the SCSI application layer shall send an Accept\_Reject OPENs (Accept SSP) request to all ST\_T state machines.

After power on, the power loss timeout timer shall be initialized and stopped until a NOTIFY (POWER LOSS EXPECTED) is received.

#### 6.2.5.4 OOB\_IDLE

OOB\_IDLE (see 5.12.4.2 and SAS-3) is used while a phy is in optical mode for:

- a) OOB signals; and
- b) speed negotiation.

#### 6.2.6 Primitives not specific to type of connections

##### 6.2.6.1 AIP (Arbitration in progress)

AIP is transmitted by an expander device after a connection request to specify that the connection request is being processed and specify the status of the connection request.

The versions of AIP representing different statuses are defined in table 105.

**Table 105 — AIP primitives**

| Primitive                         | Description                                                                                                                                                                                                                                                                       |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AIP (NORMAL)                      | Expander device has accepted the connection request. This primitive may be transmitted multiple times (see 6.14.4.3).                                                                                                                                                             |
| AIP (RESERVED 0)                  | Reserved. Processed the same as AIP (NORMAL).                                                                                                                                                                                                                                     |
| AIP (RESERVED 1)                  |                                                                                                                                                                                                                                                                                   |
| AIP (RESERVED 2)                  |                                                                                                                                                                                                                                                                                   |
| AIP (WAITING ON CONNECTION)       | Expander device has determined the routing for the connection request, but either the destination phys are all being used for connections, or there are insufficient routing resources to complete the connection request. This may be transmitted multiple times (see 6.14.4.3). |
| AIP (WAITING ON DEVICE)           | Expander device has determined the routing for the connection request and forwarded the request to the output physical link. This is transmitted one time (see 6.14.4.3).                                                                                                         |
| AIP (WAITING ON PARTIAL)          | Expander device has determined the routing for the connection request, but the destination phys are all busy with other partial pathways. This primitive may be transmitted multiple times (see 6.14.4.3).                                                                        |
| AIP (RESERVED WAITING ON PARTIAL) | Reserved. Processed the same as AIP (WAITING ON PARTIAL).                                                                                                                                                                                                                         |

See 6.14 for details on connections.

##### 6.2.6.2 BREAK

BREAK is used to abort a connection request or break a connection.

See 6.14.6 and 6.14.9 for details on breaking connections.

### 6.2.6.3 BREAK\_REPLY

BREAK\_REPLY is used to confirm the receipt of a BREAK.

See 6.14.6 and 6.14.9 for details on breaking connections.

### 6.2.6.4 BROADCAST

BROADCASTs are used to notify SAS ports and expander devices in a SAS domain about certain events.

The versions of BROADCAST representing different Broadcasts (see table 15 in 4.1.15) are defined in table 106.

**Table 106 — BROADCAST primitives**

| Primitive                      | Description                    |
|--------------------------------|--------------------------------|
| BROADCAST (CHANGE)             | Broadcast (Change)             |
| BROADCAST (RESERVED CHANGE 0)  | Broadcast (Reserved Change 0)  |
| BROADCAST (RESERVED CHANGE 1)  | Broadcast (Reserved Change 1)  |
| BROADCAST (SES)                | Broadcast (SES)                |
| BROADCAST (EXPANDER)           | Broadcast (Expander)           |
| BROADCAST (ASYNCHRONOUS EVENT) | Broadcast (Asynchronous Event) |
| BROADCAST (RESERVED 3)         | Broadcast (Reserved 3)         |
| BROADCAST (RESERVED 4)         | Broadcast (Reserved 4)         |

A phy that has not completed the link reset sequence shall not transmit a BROADCAST. A phy shall not transmit a BROADCAST inside a connection. A phy shall ignore any BROADCAST received inside a connection.

A BROADCAST received by a phy that has not completed the link reset sequence shall be ignored.

### 6.2.6.5 CLOSE

CLOSE is used to close a connection.

The versions of CLOSE representing different reasons are defined in table 107.

**Table 107 — CLOSE primitives**

| Primitive                 | Description                                                                                                                                                                                                                                                                                                                                           |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CLOSE (CLEAR AFFILIATION) | Close an open STP connection and clear the affiliation (see 6.19.4). Processed the same as CLOSE (NORMAL) if:<br>a) the connection is not an STP connection;<br>b) the connection is an STP connection, but affiliations are not implemented by the STP target port; or<br>c) the connection is an STP connection, but an affiliation is not present. |
| CLOSE (NORMAL)            | Close a connection.                                                                                                                                                                                                                                                                                                                                   |
| CLOSE (RESERVED 0)        | Reserved. Processed the same as CLOSE (NORMAL).                                                                                                                                                                                                                                                                                                       |
| CLOSE (RESERVED 1)        |                                                                                                                                                                                                                                                                                                                                                       |

See 6.14.8 for details on closing connections.

#### 6.2.6.6 EOAF (End of address frame)

EOAF specifies the end of an address frame.

See 6.8 for details on address frames.

#### 6.2.6.7 ERROR

ERROR should be transmitted by an expander device while the expander device is forwarding dwords from a SAS physical link or SATA physical link to a SAS physical link and receives an invalid dword or an ERROR.

Since an 8b10b coding error in one dword is sometimes not detected until the next dword (see table 52 in 5.3.9), expander devices should avoid deleting invalid dwords or ERRORS unless necessary (e.g., if the elasticity buffer is full) to avoid hiding evidence that an error has occurred.

See 6.17 for details on error handling by expander devices.

#### 6.2.6.8 HARD\_RESET

HARD\_RESET is used to force a phy to generate a hard reset (see 4.4.2) to its port. This primitive is only valid after the phy reset sequence without an intervening identification sequence (see 4.4) and shall be ignored at other times.

#### 6.2.6.9 OPEN\_ACCEPT

OPEN\_ACCEPT specifies the acceptance of a connection request.

See 6.14 for details on connection requests.

#### 6.2.6.10 OPEN\_REJECT

OPEN\_REJECT specifies that a connection request has been rejected and specifies the reason for the rejection. The result of some OPEN\_REJECTs is to abandon (i.e., not retry) the connection request, and the result of other OPEN\_REJECTs is to retry the connection request.



All of the OPEN\_REJECT versions defined in table 108 shall result in the originating port abandoning the connection request.

**Table 108 — Abandon-class OPEN\_REJECT primitives**

| Primitive                                   | Originator          | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| OPEN_REJECT (BAD DESTINATION)               | Expander phy        | A connection request routes to a destination expander phy in the same expander port as the source expander phy, and the expander port is using the direct routing method (see 4.5.7.1).                                                                                                                                                                                                                                                                                                                                                     |
| OPEN_REJECT (CONNECTION RATE NOT SUPPORTED) | Any phy             | <p>The requested connection rate is not supported on some physical link on the pathway between the source phy and destination phy. If a SAS initiator phy is directly attached to a SAS target phy then, the requested connection rate is not supported by the destination phy.</p> <p>If the connection rate is 1.5 Gbit/s, then this shall be considered an abandon-class OPEN_REJECT.</p> <p>If the connection rate is greater than 1.5 Gbit/s, then the connection request shall be modified and reattempted as described in 6.8.3.</p> |
| OPEN_REJECT (PROTOCOL NOT SUPPORTED)        | Any phy             | Phy with destination SAS address exists, but the destination phy does not support the requested initiator role, target role, protocol, initiator connection tag, or features (i.e., the values in the INITIATOR PORT bit, the SAS PROTOCOL field, the INITIATOR CONNECTION TAG field, and/or the FEATURES field in the OPEN address frame are not supported).                                                                                                                                                                               |
| OPEN_REJECT (RESERVED ABANDON 1)            | Unknown             | Reserved. Process the same as OPEN_REJECT (WRONG DESTINATION).                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| OPEN_REJECT (RESERVED ABANDON 2)            |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| OPEN_REJECT (RESERVED ABANDON 3)            |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| OPEN_REJECT (STP RESOURCES BUSY)            | Destination phy     | STP target port with destination SAS address exists, but the STP target port supports affiliations and is not able to establish an affiliation with this STP initiator port (e.g., because it has reached its maximum number of affiliations), or the STP target port does not support affiliations and all of the available affiliation contexts have been allocated to other STP initiator ports (see 6.19.4). Process the same as OPEN_REJECT (WRONG DESTINATION) for non-STP connection requests.                                       |
| OPEN_REJECT (WRONG DESTINATION)             | Destination phy     | The destination SAS address does not match the SAS address of the SAS port to which the connection request was delivered.                                                                                                                                                                                                                                                                                                                                                                                                                   |
| OPEN_REJECT (ZONE VIOLATION)                | Zoning expander phy | The connection request is from a zone group that does not have permission to access the zone group that contains the destination phy according to the zone permission table of an unlocked zoning expander device.                                                                                                                                                                                                                                                                                                                          |

All of the OPEN\_REJECT versions defined in table 109 shall result in the originating port retrying the connection request.

**Table 109 — Retry-class OPEN\_REJECT primitives**

| Primitive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Originator                             | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| OPEN_REJECT (NO DESTINATION) <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Expander phy                           | An expander device in the pathway is not configuring (see 4.6.4) and determines that: <ul style="list-style-type: none"> <li>a) there is no such destination phy;</li> <li>b) the connection request routes to a destination expander phy in the same expander port as the source expander phy and the expander port is using the subtractive routing method; or</li> <li>c) the SAS address is valid for an STP target port in an STP SATA bridge, but the initial Register - Device to Host FIS has been received with an error (see 9.4.3.12).</li> </ul>                                                                                                                                                                                                                                                                             |
| OPEN_REJECT (PATHWAY BLOCKED) <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Expander phy                           | An expander device determined the pathway was blocked by higher priority connection requests.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| OPEN_REJECT (RESERVED CONTINUE 0) <sup>c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Unknown                                | Reserved. Process the same as OPEN_REJECT (RETRY).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| OPEN_REJECT (RESERVED CONTINUE 1) <sup>c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| OPEN_REJECT (RESERVED INITIALIZE 0) <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Unknown                                | Reserved. Process the same as OPEN_REJECT (NO DESTINATION).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| OPEN_REJECT (RESERVED INITIALIZE 1) <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| OPEN_REJECT (RESERVED STOP 0) <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Unknown                                | Reserved. Process the same as OPEN_REJECT (PATHWAY BLOCKED).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| OPEN_REJECT (RESERVED STOP 1) <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| OPEN_REJECT (RETRY) <sup>c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Destination phy or zoning expander phy | Either: <ul style="list-style-type: none"> <li>a) a phy with the destination SAS address exists but is temporarily not able to accept connections (see 6.18.1, 6.19.5, and 6.20.3);</li> <li>b) an expander device in the pathway is configuring (see 4.6.4) and detects a connection that results in an OPEN_REJECT (NO DESTINATION) if the condition is not resolved (see 4.6.4 and 6.14.4.2.5);</li> <li>c) an expander device in the pathway is locked and detects a connection that results in an OPEN_REJECT (ZONE VIOLATION) if the condition is not resolved (see 4.8.3.5 and 6.14.4.2.5);</li> <li>d) an expander device in the pathway has reduced functionality (see 4.5.8 and 6.14.4.2.5); or</li> <li>e) a phy with the destination SAS address exists but is in the slumber phy power condition (see 4.10.1.6).</li> </ul> |
| <p><sup>a</sup> If the I_T Nexus Loss timer (see 7.2.2) is already running, it continues running. If it is not already running, it is initialized and started. Stop retrying the connection request if the I_T Nexus Loss timer expires.</p> <p><sup>b</sup> If the I_T Nexus Loss timer is already running, it continues running. Stop retrying the connection request if the I_T Nexus Loss timer expires.</p> <p><sup>c</sup> If the I_T Nexus Loss timer is already running, it is stopped.</p> |                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

NOTE 18 - Some SAS logical phys compliant with earlier versions of this standard also transmit OPEN\_REJECT (RETRY) if they receive an OPEN address frame while their SL\_CC state machines are in the SL\_CC5:BreakWait state (see 6.16.4.7).

When a SAS logical phy detects more than one reason to transmit an OPEN\_REJECT, the SL\_CC state machine determines the priority in the SL\_CC2:Selected state (see 6.16.4.4).

When an expander logical phy detects more than one reason to transmit an OPEN\_REJECT, the ECM determines the priority (see 6.14.4).

See 6.14 for details on connection requests.

#### 6.2.6.11 PS\_ACK

PS\_ACK specifies the positive acknowledgement of a PS\_REQ. See 4.10, 6.11, 6.16, and 6.17 for details on phy power conditions.

#### 6.2.6.12 PS\_NAK

PS\_NAK specifies the negative acknowledgement of a PS\_REQ. See 4.10, 6.11, 6.16, and 6.17 for details on phy power conditions.

A PS\_NAK occurs for the following reasons:

- a) a PS\_REQ is received and the requested low phy power condition is supported and disabled; or
- b) a PS\_REQ is received during an attempt to establish a connection.

#### 6.2.6.13 PS\_REQ

PS\_REQ is used to request a transition to a specific low phy power condition (see 4.10.1).

The versions of PS\_REQ representing different low phy power conditions are defined in table 110.

**Table 110 — PS\_REQ primitives**

| Primitive        | Description                                                                |
|------------------|----------------------------------------------------------------------------|
| PS_REQ (PARTIAL) | Requests a transition into the partial phy power condition (see 4.10.1.3). |
| PS_REQ (SLUMBER) | Requests a transition into the slumber phy power condition (see 4.10.1.4). |

#### 6.2.6.14 PWR\_ACK

PWR\_ACK specifies the positive acknowledgement of PWR\_DONE, PWR\_GRANT, or PWR\_REQ (see 6.12).

#### 6.2.6.15 PWR\_DONE

PWR\_DONE is used by an end device to indicate it has completed consumption of the additional power requested as a result of a PWR\_GRANT (see 6.12).

#### 6.2.6.16 PWR\_GRANT

PWR\_GRANT is used to specify that an end device may consume additional power (see 6.12).

#### 6.2.6.17 PWR\_REQ

PWR\_REQ is used by an end device to request the consumption of additional power (see 6.12).

#### **6.2.6.18 SOAF (Start of address frame)**

SOAF specifies the start of an address frame.

See 6.8 for details on address frames.

#### **6.2.6.19 TRAIN**

TRAIN is used during Train\_Rx-SNW during speed negotiation. Deletable primitives shall not be transmitted inside a TRAIN primitive sequence.

See 5.10.4.2.3.5 for details on Train\_Rx-SNW.

#### **6.2.6.20 TRAIN\_DONE**

TRAIN\_DONE is used during Train\_Rx-SNW during speed negotiation. Deletable primitives shall not be transmitted inside a TRAIN\_DONE primitive sequence.

See 5.10.4.2.3.5 for details on Train\_Rx-SNW.

### **6.2.7 Primitives used only inside SSP and SMP connections**

#### **6.2.7.1 ACK (Acknowledge)**

ACK specifies the positive acknowledgement of an SSP frame.

See 6.18.3 for details on SSP frame transmission.

ACK is not used during an SMP connection.

#### **6.2.7.2 CREDIT\_BLOCKED**

CREDIT\_BLOCKED specifies that no more RRDYs are going to be transmitted during this SSP connection (i.e., transmit SSP frame credit is not going to be increased).

See 6.18.4 for details on SSP flow control.

CREDIT\_BLOCKED is not used during an SMP connection.

#### **6.2.7.3 DONE**

DONE is used to start closing an SSP connection and specify a reason for doing so.

The versions of DONE representing different reasons are defined in table 111. The SSP state machines describe when these are used (see 6.18.9).

**Table 111 — DONE primitives**

| Primitive                 | Description                                                                                                                                                                                                                                                |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DONE (ACK/NAK TIMEOUT)    | The SSP state machines (see 6.18.9) timed out waiting for an ACK or NAK, and the phy is going to transmit BREAK primitive sequence in 1 ms unless DONE is received within 1 ms of transmitting the DONE (ACK/NAK TIMEOUT).                                 |
| DONE (RESERVED TIMEOUT 0) | Reserved. Processed the same as DONE (ACK/NAK TIMEOUT).                                                                                                                                                                                                    |
| DONE (RESERVED TIMEOUT 1) |                                                                                                                                                                                                                                                            |
| DONE (NORMAL)             | Finished transmitting all frames.                                                                                                                                                                                                                          |
| DONE (CLOSE)              | The SSP state machine (see 6.15.5) has received an RRDY (CLOSE).                                                                                                                                                                                           |
| DONE (RESERVED 0)         | Reserved. Processed the same as DONE (NORMAL).                                                                                                                                                                                                             |
| DONE (CREDIT TIMEOUT)     | The SSP state machines (see 6.18.9) timed out waiting for an RRDY or received a CREDIT BLOCKED, and the phy is going to transmit BREAK primitive sequence unless the phy receives a frame or a DONE within 1 ms of transmitting the DONE (CREDIT TIMEOUT). |

See 6.18.8 for details on closing SSP connections.

#### 6.2.7.4 EOF (End of frame)

EOF specifies the end of an SSP or SMP frame.

See 6.18.3 for details on SSP frame transmission and 6.20.1 for details on SMP frame transmission.

#### 6.2.7.5 EXTEND\_CONNECTION

EXTEND\_CONNECTION (NORMAL) is used to:

- establish a persistent connection (see 4.1.13);
- continue a persistent connection; and
- indicate that an SSP port has no SSP frames to send.

EXTEND\_CONNECTION (NORMAL) is not used during an SMP connection.

EXTEND\_CONNECTION (CLOSE) may be originated by an expander port to initiate the closing of a persistent connection. EXTEND\_CONNECTION (CLOSE) is not used during an SMP connection.

#### 6.2.7.6 NAK (Negative acknowledgement)

NAK specifies the negative acknowledgement of an SSP frame and the reason for doing so.

The versions of NAK representing different reasons are defined in table 112.

**Table 112 — NAK primitives**

| Primitive        | Description                                                                                 |
|------------------|---------------------------------------------------------------------------------------------|
| NAK (CRC ERROR)  | The frame had a bad CRC, an invalid dword, or an ERROR was received during frame reception. |
| NAK (RESERVED 0) | Reserved. Processed the same as NAK (CRC ERROR).                                            |
| NAK (RESERVED 1) |                                                                                             |
| NAK (RESERVED 2) |                                                                                             |

See 6.18.3 for details on SSP frame transmission.

NAK is not used during an SMP connection.

#### 6.2.7.7 RRDY (Receiver ready)

RRDY is used to increase SSP frame credit.

The versions of RRDY representing different reasons are defined in table 113.

**Table 113 — RRDY primitives**

| Primitive         | Description                                                            |
|-------------------|------------------------------------------------------------------------|
| RRDY (NORMAL)     | Increase transmit SSP frame credit by one.                             |
| RRDY (CLOSE)      | Increase transmit SSP frame credit by one and transmit a DONE (CLOSE). |
| RRDY (RESERVED 0) | Reserved. Processed the same as RRDY (NORMAL).                         |

A phy shall not transmit RRDY after transmitting CREDIT\_BLOCKED in a connection. See 6.18.4 for details on SSP flow control.

RRDY is not used during an SMP connection.

#### 6.2.7.8 SOF (Start of frame)

SOF specifies the start of an SSP or SMP frame.

See 6.18.3 for details on SSP frame transmission and 6.20.1 for details on SMP frame transmission.

### 6.2.8 Primitives used only inside STP connections and on SATA physical links

#### 6.2.8.1 SATA\_ERROR

SATA\_ERROR should be transmitted by an expander device when it is forwarding dwords from a SAS logical link to a SATA physical link and it receives an invalid dword or an ERROR.

Since an 8b10b coding error in one dword is sometimes not detected until the next dword (see table 52 in 5.3.9), expander devices should avoid deleting invalid dwords or ERRORS unless necessary (e.g., if the elasticity buffer is full) to avoid hiding evidence that an error has occurred.

See 5.13 for details on error handling by expander devices.

Although included in this subclause, SATA\_ERROR is not a primitive (see 3.1.155) since it starts with K28.6. SATA\_ERROR does not appear inside STP connections. SATA\_ERROR is an invalid dword.

#### 6.2.8.2 SATA\_PMACK, SATA\_PMNAK, SATA\_PMREQ\_P, and SATA\_PMREQ\_S (Power management acknowledgements and requests)

SATA\_PMREQ\_P and SATA\_PMREQ\_S request entry into the partial interface power management sequence and slumber interface power management sequence (see SATA). SATA\_PMACK is used to accept a power management request. SATA\_PMNAK is used to reject an interface power management request.

See 6.11 for rules on handling the power management primitives.

#### 6.2.8.3 SATA\_HOLD and SATA\_HOLD\_A (Hold and hold acknowledge)

See 6.19.2 for rules on STP flow control, which uses SATA\_HOLD and SATA\_HOLD\_A.

#### 6.2.8.4 SATA\_R\_RDY and SATA\_X\_RDY (Receiver ready and transmitter ready)

When a SATA port has a frame to transmit, it transmits SATA\_X\_RDY and waits for SATA\_R\_RDY before transmitting the frame.

#### 6.2.8.5 Other primitives used inside STP connections and on SATA physical links

Other primitives used in STP connections and on SATA physical links are defined in SATA.

### 6.3 Physical link rate tolerance management

#### 6.3.1 Physical link rate tolerance management overview

A phy may have three clocks:

- a) an internal clock (e.g., based on a PLL clock generator);
- b) a transmit clock (e.g., based on a PLL clock generator with SSC, if SSC is enabled). Used when transmitting dwords on the physical link; and
- c) a receive clock, derived from the input bit stream. Used when receiving dwords from the physical link.

Although the receive clock has the same nominal fixed frequency as the internal clock, the receive clock may differ from the internal clock frequency up to the physical link rate tolerance (see SAS-3). Over time:

- a) if the receive clock is faster than the internal clock, an overrun occurs if the phy's receiver receives a dword and is not able to forward it to an internal receive buffer; or
- b) if the receive clock is slower than the internal clock, an underrun occurs if the phy's receiver is not able to obtain a dword from an internal transmit buffer when needed.

To avoid overruns and underruns, the phy's transmitters insert deletable primitives (see 6.2.5) in the dword stream. The phy's receivers may pass deletable primitives through to their internal buffers, or may strip them out when an overrun occurs. The phy's receivers add deletable primitives when an underrun occurs. The internal logic shall ignore all deletable primitives that arrive in the internal buffers.

Circuitry (e.g., an elasticity buffer) is required to absorb the slight differences in frequencies between the phys. Figure 114 shows an example of an elasticity buffer. The frequency tolerance for a phy is specified in SAS-3. The depth of the elasticity buffer is vendor specific but shall accommodate the physical link rate tolerance

management deletable primitive insertion requirements in table 114 (see 6.3.2).

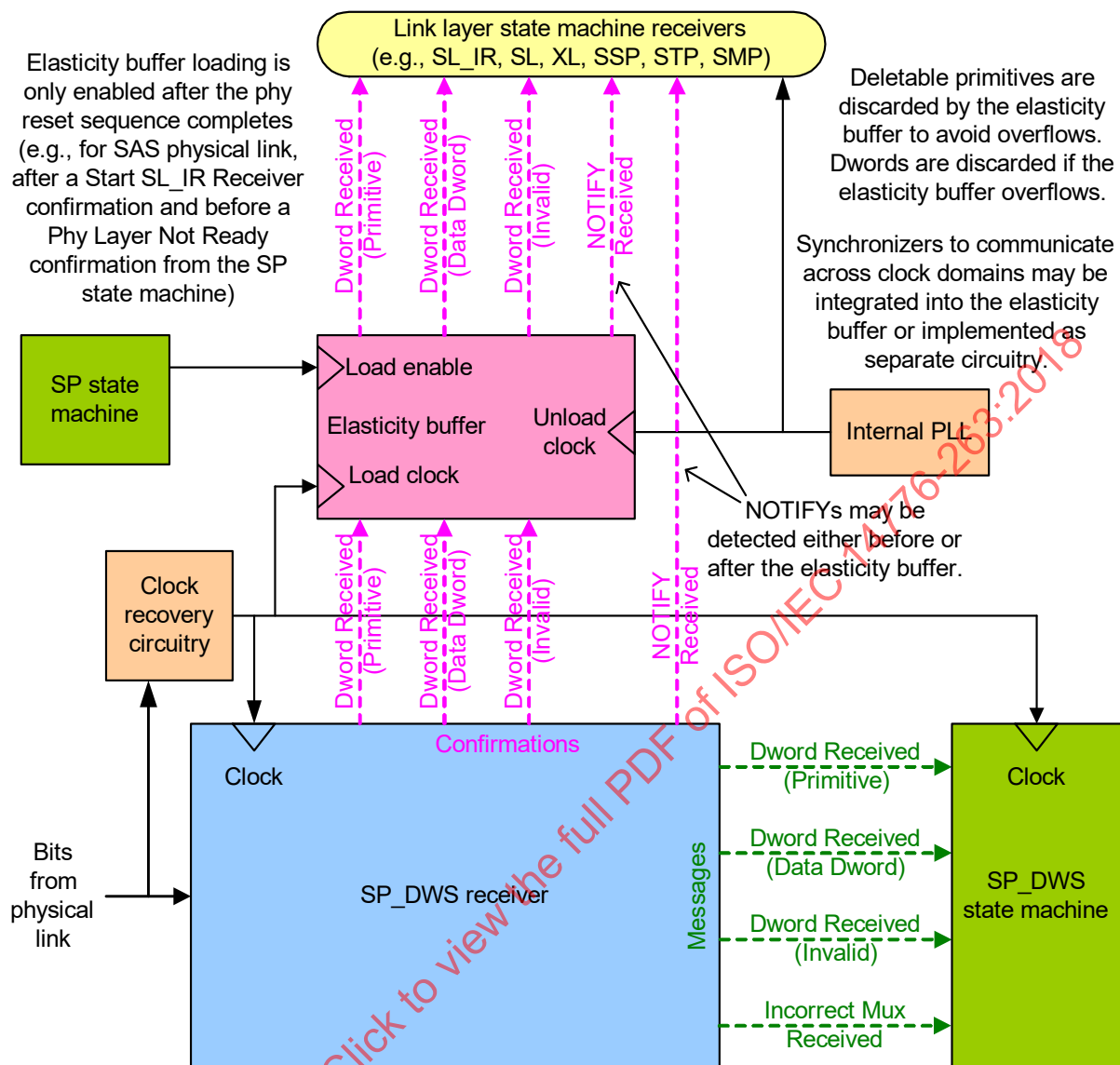


Figure 114 — Elasticity buffer

### 6.3.2 Phys originating dwords

A logical phy that is originating dwords (i.e., a logical phy that is not an expander logical phy forwarding dwords from another expander logical phy) shall only insert deletable primitives for physical link rate tolerance



management after the phy reset sequence (see 5.10) completes as described in table 114.

**Table 114 — Physical link rate tolerance management deletable primitive insertion requirement**

| Physical link rate                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Requirement <sup>a</sup>                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| 1.5 Gbit/s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | One deletable primitive within every 128 dwords <sup>b c</sup>    |
| 3 Gbit/s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Two deletable primitives within every 256 dwords <sup>b d</sup>   |
| 6 Gbit/s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Four deletable primitives within every 512 dwords <sup>b</sup>    |
| 12 Gbit/s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Eight deletable primitives within every 1 024 dwords <sup>b</sup> |
| <p><sup>a</sup> These numbers account for the worst case clock frequency differences between the fastest phy transmitter and the slowest phy receiver (e.g., a center-spreading expander phy originating dwords in an STP connection at +2 400 ppm that are forwarded to a down-spreading SATA device with an internal clock at -5 350 ppm). The difference of 7 750 ppm (i.e., 0.775 % or 1/129) is less than the deletable primitive insertion rate of 1/128 (i.e., 7 813 ppm or 0.781 25 %), ensuring there are enough deletable primitives for the phy's receiver to delete without having to buffer dwords.</p> <p><sup>b</sup> 128 dwords at 1.5 Gbit/s, 256 dwords at 3 Gbit/s, 512 dwords at 6 Gbit/s, and 1 024 dwords at 12 Gbit/s are each nominally 3 413.3 ns.</p> <p><sup>c</sup> Phys compliant with SAS-1.1 were required to insert one deletable primitive within every 2 048 dwords at 1.5 Gbit/s.</p> <p><sup>d</sup> Phys compliant with SAS-1.1 were required to insert two deletable primitives within every 4 096 dwords at 3 Gbit/s.</p> |                                                                   |

Deletable primitives inserted for physical link rate tolerance management are in addition to deletable primitives inserted for rate matching (see 6.15). See Annex G for a summary of their combined requirements.

See 6.2.5.1 for details on rotating through ALIGN (0), ALIGN (1), ALIGN (2), and ALIGN (3). NOTIFYs may also be transmitted in place of ALIGNs (see 6.2.5.3) on SAS logical links. MUXs may also be transmitted in place of ALIGNs on multiplexed SAS physical links.

### 6.3.3 Expander phys forwarding dwords

An expander device that is forwarding dwords (i.e., is not originating dwords) is allowed to insert or delete as many deletable primitives as required to match the transmit and receive connection rates. An expander device is not required to transmit the number of deletable primitives for physical link rate tolerance management described in table 114 when forwarding dwords to a SAS logical link. An expander device shall increase or reduce the number of deletable primitives based on clock frequency differences between the expander device's receiving phy and the expander device's transmitting phy (e.g., if receiving at -100 ppm and transmitting at +100 ppm, then it transmits more deletable primitives than it receives).

The expander device is also required to insert deletable primitives for rate matching (see 6.15). During an STP connection, the expander device shall:

- preserve the incoming rate of any additional deletable primitives that it receives that are not discarded because of physical link rate tolerance management or rate matching (e.g., the 1/128 deletable primitives received from an originating STP initiator phy compliant with SAS-1.1 for STP initiator phy throttling); or
- transmit one deletable primitive within every 128 dwords, without discarding any data dwords or primitives.

The expander device may reduce the length of repeated primitive sequences (i.e., primitive, SATA\_CONT, and data dword sequences).

NOTE 19 - One possible implementation for expander devices forwarding dwords is for the expander device to delete all deletable primitives received and to insert deletable primitives at the transmit phy whenever its elasticity buffer is empty.

The STP target port of an STP SATA bridge is allowed to insert or delete as many deletable primitives as required to match the transmit and receive connection rates. It is not required to transmit any particular number of deletable primitives for physical link rate tolerance management when forwarding to a SAS logical link and is not required to ensure that any deletable primitives it transmits are in pairs.

Due to physical link rate tolerance management deletable primitive removal, the STP target port may not receive a pair of deletable primitives every 256 dwords, even if the STP initiator port transmitted them in pairs. However, the rate of the dword stream allows for deletable primitive insertion by the STP SATA bridge.

EXAMPLE - The STP SATA bridge deletes all deletable primitives received by the STP target port and inserts two consecutive ALIGNs at the SATA host port when its elasticity buffer is empty or when 254 non-ALIGN dwords have been transmitted. This meets the SATA host port requirement to buffer up to two dwords concurrently while they are being received by the STP target port.

An expander device supporting the SSC modulation type of center-spreading also includes a center-spreading tolerance buffer (see SAS-3).

## 6.4 Idle physical links

Idle dwords are vendor specific data dwords that are scrambled (see 6.6).

Phys shall transmit idle dwords if there are no other dwords to transmit and:

- a) no connection is open; or
- b) an SSP connection or SMP connection is open.

SATA\_SYNC is a continued primitive sequence that may contain vendor specific data dwords (see 6.2.4.4) that are scrambled (see 6.6) during an STP connection.

## 6.5 CRC

### 6.5.1 CRC overview

All frames include cyclic redundancy check (CRC) values to help detect transmission errors.

Frames transmitted in an STP connection shall include a CRC as defined by SATA. Address frames, SSP frames, and SMP frames shall include a CRC as defined by this standard.

Annex C contains information on CRC generation/checker implementation.

Table 115 defines notation used in the following text describing CRC calculation. Arithmetic is modulo 2.

**Table 115 — CRC notation and definitions (part 1 of 2)**

| Notation | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $T(i)$   | A transformation over the non-negative integers (i.e., $Z^+$ ):<br>$T(i) = i + 7 - 2 \times (i \bmod 8)$ , $i \geq 0$ , $i \in Z^+$                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| $F(x)$   | A polynomial representing the bits covered by the CRC:<br>$F(x) = b_0x^{(k-1)} + b_1x^{(k-2)} + \dots + b_{(k-2)}x + b_{(k-1)}$<br>where:<br>$k$ is the number of bits; and<br>$b_i$ describes a bit, where the bit index $i$ denotes that bit $b_i$ is more significant than bit $b_{(i+1)}$ .<br>For example, if the frame, except for the CRC field, contains one data dword set to 516F3019h, then:<br>$F(x) = x^{30} + x^{28} + x^{24} + x^{22} + x^{21} + x^{19} + x^{18} + x^{17} + x^{16} + x^{13} + x^{12} + x^4 + x^3 + 1$<br>(i.e., in finite field notation $F(x) = 516F3019h$ ) |
| $F_t(x)$ | $F(x)$ with the bit positions of each byte transposed (i.e., bit 7 is bit 0, bit 6 is bit 1, etc.):<br>$F_t(x) = b_{T(0)}x^{(k-1)} + b_{T(1)}x^{(k-2)} + \dots + b_{T(k-2)}x + b_{T(k-1)}$<br>For example, if the frame, except for the CRC field, contains one data dword set to 516F3019h, then:<br>$F_t(x) = x^{31} + x^{27} + x^{25} + x^{23} + x^{22} + x^{21} + x^{20} + x^{18} + x^{17} + x^{11} + x^{10} + x^7 + x^4 + x^3$<br>(i.e., in finite field notation $F_t(x) = 8AF60C98h$ )                                                                                                |
| $L(x)$   | The identity polynomial of degree 31 (i.e., a polynomial with all of the coefficients set to one):<br>$L(x) = x^{31} + x^{30} + \dots + x + 1$<br>(i.e., in finite field notation $L(x) = FFFFFFFFh$ )                                                                                                                                                                                                                                                                                                                                                                                       |
| $G(x)$   | The CRC generator polynomial (i.e., the divisor polynomial):<br>$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$<br>(i.e., in finite field notation $G(x) = 1_04C11DB7h$ )                                                                                                                                                                                                                                                                                                                                               |
| $R(x)$   | The remainder polynomial, which is of degree less than 32.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| $R_t(x)$ | $R(x)$ with the bit positions of each byte transposed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| $Q(x)$   | A quotient polynomial resulting from CRC calculation by the transmitter. This value is discarded.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| $Q'(x)$  | A quotient polynomial resulting from CRC calculation by the receiver. This value is discarded.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| $M(x)$   | A polynomial representing the transmitted frame including the CRC field, which is of degree $k+31$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| $M'(x)$  | A polynomial representing the received frame including the received CRC field.<br>If the received frame has no errors, then $M'(x) = M(x)$ and $M'(x)$ is of degree $k+31$ .                                                                                                                                                                                                                                                                                                                                                                                                                 |

Table 115 — CRC notation and definitions (part 2 of 2)

| Notation  | Definition                                                                                                                                                                                                                                                                                                                                            |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $M_t'(x)$ | $M'(x)$ with the bit positions of each byte transposed.                                                                                                                                                                                                                                                                                               |
| $R'(x)$   | The result of finding the remainder of an error-free reception of $M(x)$ , and also the remainder of $x^{32}L(x) / G(x)$ , which is a unique constant polynomial:<br>$R'(x) = x^{31} + x^{30} + x^{26} + x^{25} + x^{24} + x^{18} + x^{15} + x^{14} + x^{12} + x^{11} + x^{10} + x^8 + x^6 + x^5 + x^4 + x^3 + x + 1$<br>(i.e., $R'(x) = C704DD7Bh$ ) |
| $R_t'(x)$ | $R'(x)$ with the bit positions of each byte transposed (i.e., bit 7 is bit 0, bit 6 is bit 1, etc.):<br>$R_t'(x) = x^{31} + x^{30} + x^{29} + x^{25} + x^{24} + x^{21} + x^{15} + x^{13} + x^{12} + x^{11} + x^9 + x^8 + x^7 + x^6 + x^4$<br>$+ x^3 + x^2 + x$<br>(i.e., in finite field notation $R_t'(x) = E320BBDEh$ )                             |

### 6.5.2 CRC generation

The CRC is calculated from  $F(x)$  as follows:

$$x^k \times L(x) + x^{32} \times F_t(x) = Q(x) \times G(x) + R(x)$$

That is:

- 1) the frame  $F(x)$ , not including the CRC field, is transposed into  $F_t(x)$ ;
- 2) the first 32 bits of the transposed frame are inverted (i.e.,  $x^k \times L(x)$  is added);
- 3) 32 bits of zero are appended to the end (i.e.,  $F_t(x)$  is multiplied by  $x^{32}$ ); and
- 4) this result is divided by the generator polynomial  $G(x)$  to find the remainder  $R(x)$ .

The transmitter shall present  $M(x)$  to the 8b10b encoder:

$$M(x) = x^{32} \times F(x) + L(x) + R_t(x)$$

That is, the inverted transposed remainder is appended to the end of the frame, then this result (i.e.,  $M(x)$ ) is presented to the 8b10b encoder for transmission.

For the purposes of CRC computation, inverting the first 32 bits of a frame may be performed by one of the following methods:

- a) inverting the first 32 bits of the frame  $F(x)$  and seeding the CRC remainder register with 00000000h;
- b) seeding the CRC remainder register with FFFFFFFFh; or
- c) prepending the constant 62F52692h to  $F(x)$  and seeding the CRC remainder register with 00000000h.

NOTE 20 - The bit order of  $F(x)$  used to calculate the CRC is the same order as the bit transmission order (i.e., the bits within each byte encoded into a data dword are transposed to match the implicit transposition in the 8b10b encoding process).

Figure 115 shows the CRC process for an address frame, an SSP frame and SMP frame.

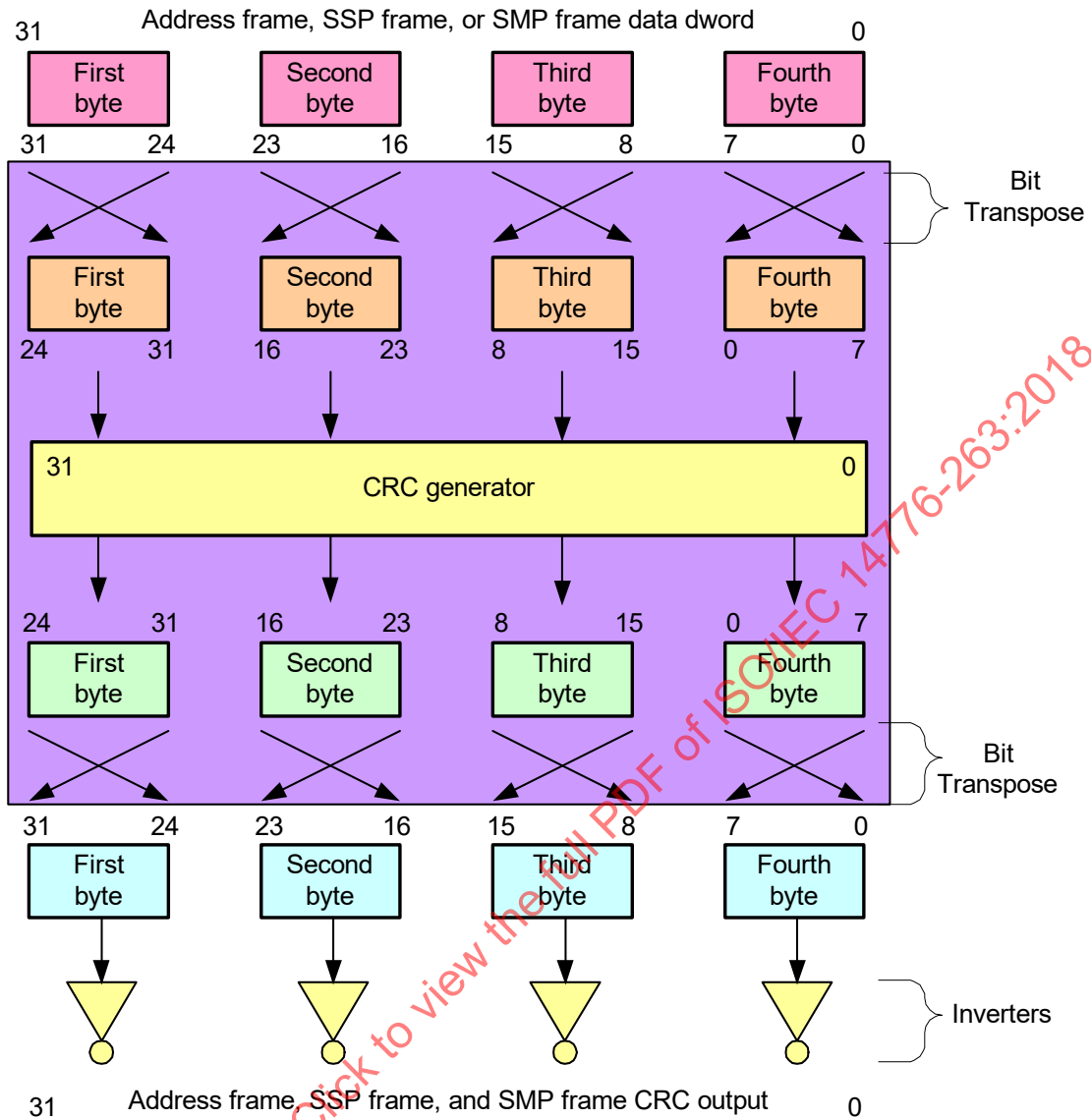


Figure 115 — Address frame, SSP frame, and SMP frame CRC bit ordering

Dwords within STP frames use little-endian. Those dwords are fed into the STP CRC generator without swapping bits within each byte and without inverting the output like the SAS CRC generator. Figure 116 shows the STP CRC bit ordering.

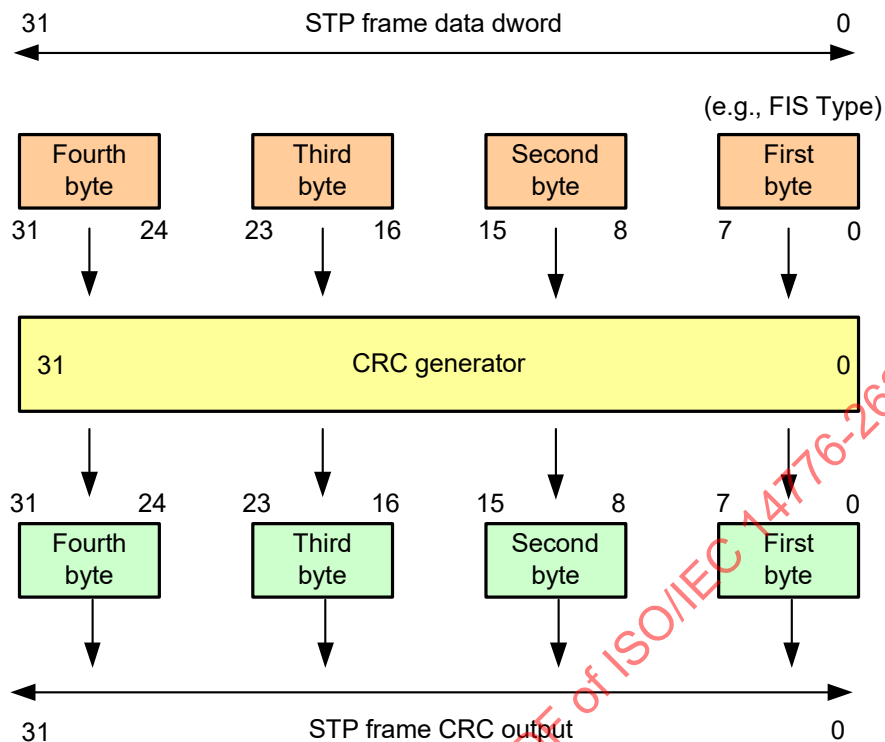


**Figure 116 — STP frame CRC bit ordering**

Since STP uses little-endian byte ordering, the first byte of a dword is in bits 7:0 rather than 31:24 as in SSP and SMP. As a result, the first byte contains the least significant bit. In SSP and SMP, the first byte contains the most significant bit.

See 6.7 for details on how the CRC generator fits into the dword flow along with the scrambler.

### 6.5.3 CRC checking

The CRC of received frame is calculated by the receiver in the same manner that it is generated by the transmitter.

That is:

- 1) the received frame  $M'(x)$ , including the CRC field, is transposed into  $M_t'(x)$ ;
- 2) the first 32 bits of the received transposed frame are inverted;
- 3) 32 bits of zero are appended to the end; and
- 4) this result is divided by the generator polynomial  $G(x)$  to find the remainder.

A received frame that has not incurred any CRC detectable errors during transmission generates a remainder equal to  $R'(x)$ .

If there were no transmission errors, then the received frame  $M'(x)$  equals  $M(x)$ :

$$\begin{aligned} M'(x) &= M(x) \\ &= x^{32} \times F(x) + L(x) + R_t(x) \end{aligned}$$

The CRC  $R'(x)$  is derived as follows:

$$\begin{aligned} x^{(k+32)} \times L(x) + x^{32} \times M_t'(x) &= x^{(k+32)} \times L(x) + x^{32} \times (x^{32} \times F_t(x) + L(x) + R(x)) \\ &= x^{32} \times Q(x) \times G(x) + x^{32} \times L(x) \end{aligned}$$

However,  $G(x)$  divides  $x^{32}L(x)$ :

$$x^{32} \times L(x) = Q'(x) \times G(x) + R'(x)$$

Since  $L(x)$  and  $G(x)$  are known and constant,  $R'(x)$  is known and constant and is expected by the receiver after calculating the CRC of a received frame.

From the previous two results:

$$x^{(k+32)} \times L(x) + x^{32} \times (x^{32} \times F_t(x) + L(x) + R(x)) = (x^{32} \times Q(x) + Q'(x)) \times G(x) + R'(x)$$

$R'(x)$  is then transposed and inverted, in the same manner as is done by the transmitter, to obtain:

$$R_t'(x) + L(x) = 1\text{CDF}4421\text{h}$$

As an alternative to this process, the receiver may check the CRC validity of the frame by stripping off the last 32 bits, leaving  $F(x)$ , and calculating the CRC as defined in 6.5.2. The frame has a valid CRC if the result  $L(x) + R_t(x)$  equals the last 32 bits of the frame that were stripped.

See 6.7 for details on where the CRC checker fits into the dword flow along with the descrambler.

## 6.6 Scrambling

Scrambling is used to reduce the probability of long strings of repeated patterns appearing on the physical link.

All data dwords are scrambled. Table 116 lists the scrambling for different types of data dwords.

**Table 116 — Scrambling for different data dword types**

| Connection state      | Data dword type     | Description of scrambling                                                                                                                        |
|-----------------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Outside connections   | SAS idle dword      | While a connection is not open and there are no other dwords to transmit, vendor specific scrambled data dwords shall be transmitted.            |
|                       | Address frame       | After an SOAF, all data dwords shall be scrambled until the EOAF.                                                                                |
| Inside SSP connection | SSP frame           | After an SOF, all data dwords shall be scrambled until the EOF.                                                                                  |
|                       | SSP idle dword      | While there are no other dwords to transmit, vendor specific scrambled data dwords shall be transmitted.                                         |
| Inside SMP connection | SMP frame           | After an SOF, all data dwords shall be scrambled until the EOF.                                                                                  |
|                       | SMP idle dword      | While there are no other dwords to transmit, vendor specific scrambled data dwords shall be transmitted.                                         |
| Inside STP connection | STP frame           | After a SATA_SOF, all data dwords shall be scrambled until the SATA_EOF.                                                                         |
|                       | Continued primitive | After a SATA_CONT, vendor specific scrambled data dwords shall be transmitted until a primitive other than a deletable primitive is transmitted. |

Data dwords being transmitted shall be XORed with a defined pattern to produce a scrambled value encoded and transmitted on the physical link. Received data dwords shall be XORed with the same pattern after decoding to produce the original data dword value, provided there are no transmission errors.

The pattern that is XORed with the data dwords is defined by the output of a linear feedback shift register implemented with the following polynomial:

$$G(x) = x^{16} + x^{15} + x^{13} + x^4 + 1.$$

The output of the pattern generator is 16 bits wide. For each data dword, two outputs of the pattern generator are used as follows:

- 1) the first output of the generator is applied to the lower 16 bits (i.e., bits 15 to 0) of the 32-bit data dword being transmitted or received; and
- 2) the second output of the generator is applied to the upper 16 bits (i.e., bits 31 to 16).

NOTE 21 - Scrambling is not based on data feedback, so the sequence of values XORed with the data being transmitted is constant.

The value of the linear feedback shift register shall be initialized at each SOF and SOAF to FFFFh.

For detailed requirements about scrambling of data dwords following SATA\_SOF and SATA\_CONT, see SATA.

NOTE 22 - STP scrambling uses two linear feedback shift registers, since continued primitive sequences are able to occur inside STP frames and the STP frame and the continued primitive sequence have independent scrambling patterns.

Annex E contains information on scrambling implementations.

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## 6.7 Bit order of CRC and scrambler

Figure 117 shows how data dwords and primitives are routed to the bit transmission logic in figure 56 (see 5.5). Data dwords go through the CRC generator and scrambler. SAS primitives go through the bit transmission logic directly.

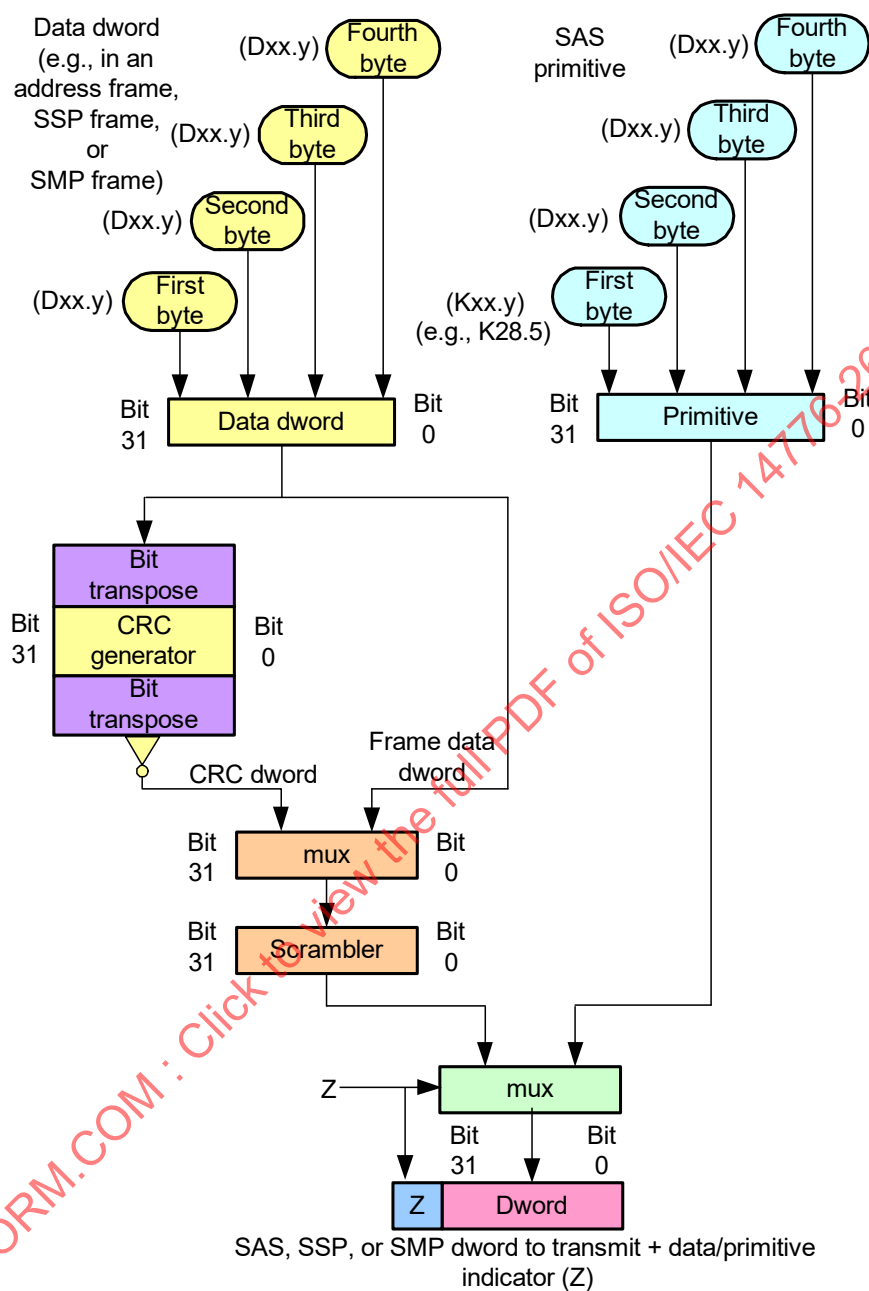


Figure 117 — Transmit path bit ordering

Figure 118 shows the routing of dwords received from the bit reception logic in figure 57 (see 5.5).

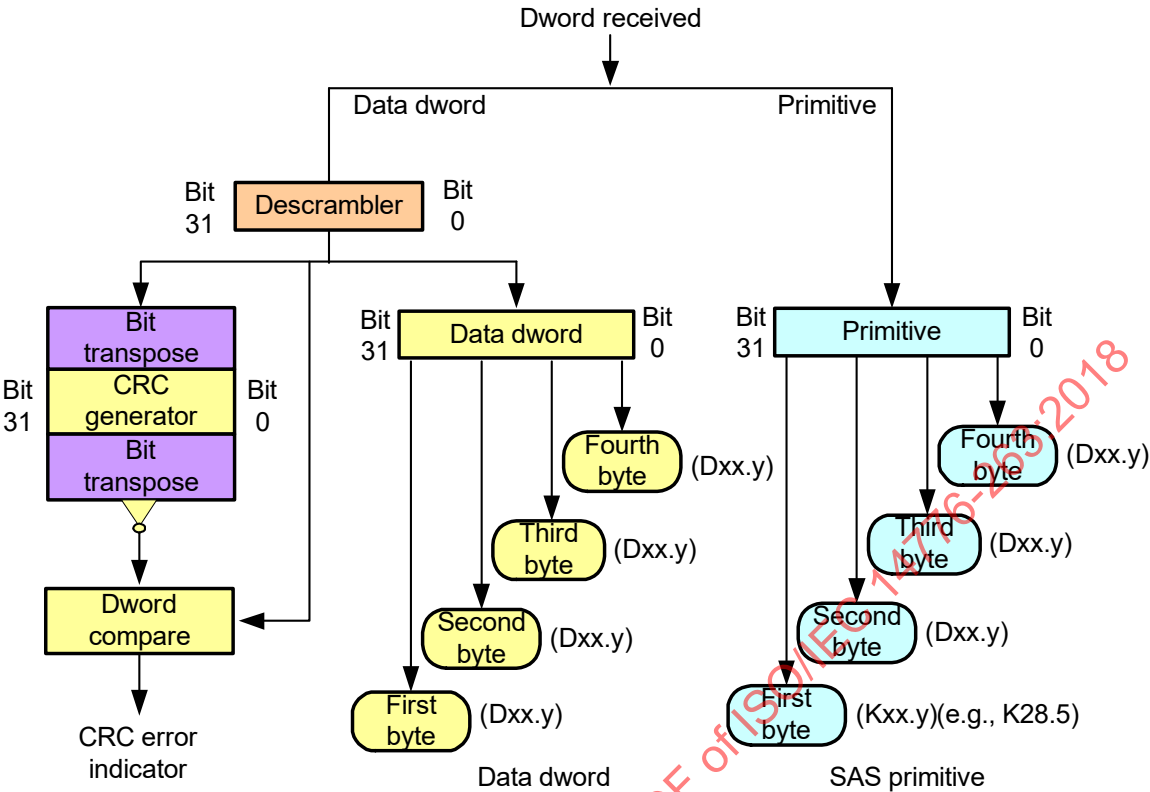


Figure 118 — Receive path bit ordering

Figure 119 shows the STP transmit path bit ordering.

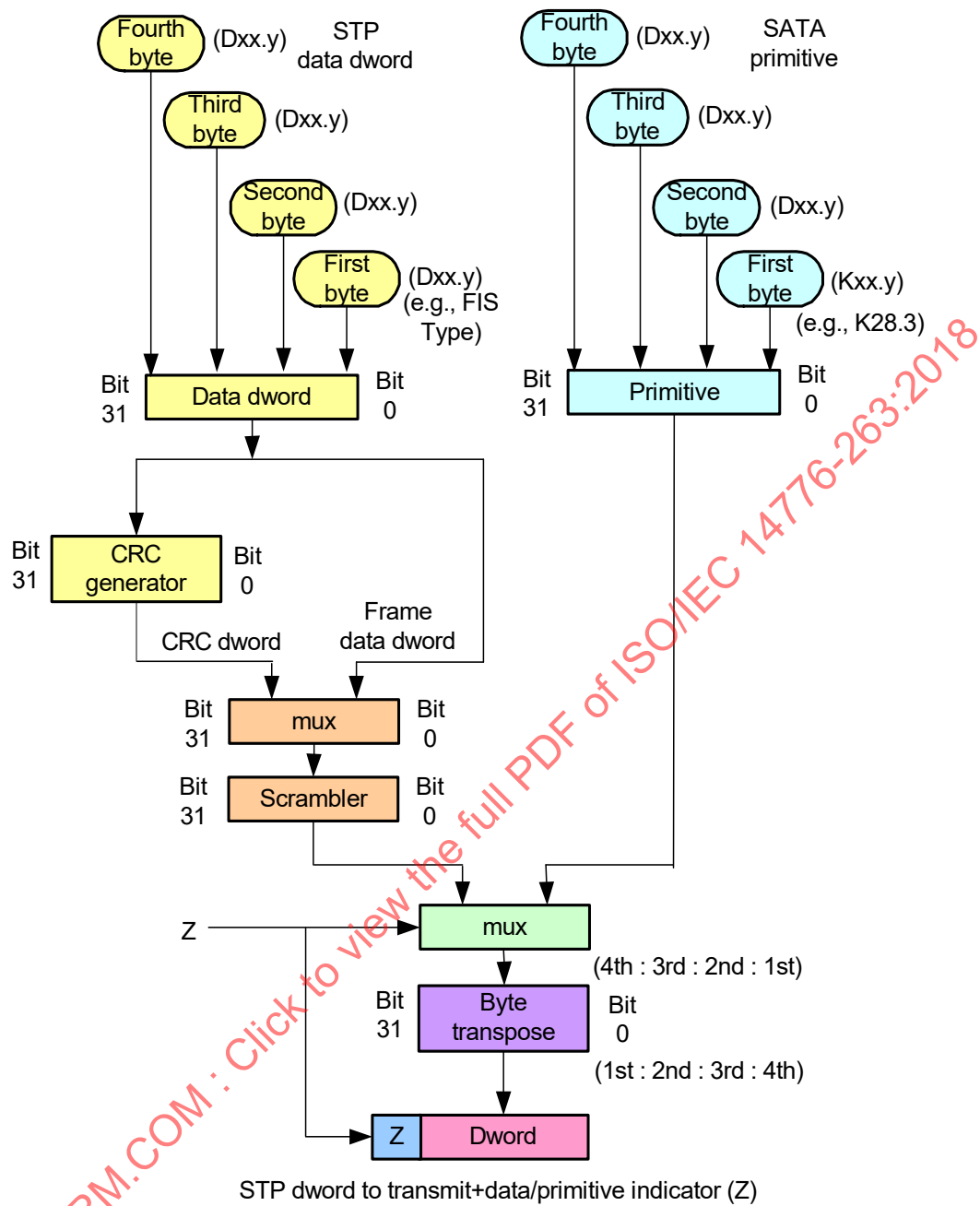


Figure 119 — STP transmit path bit ordering

Figure 120 shows the STP receive path bit ordering.

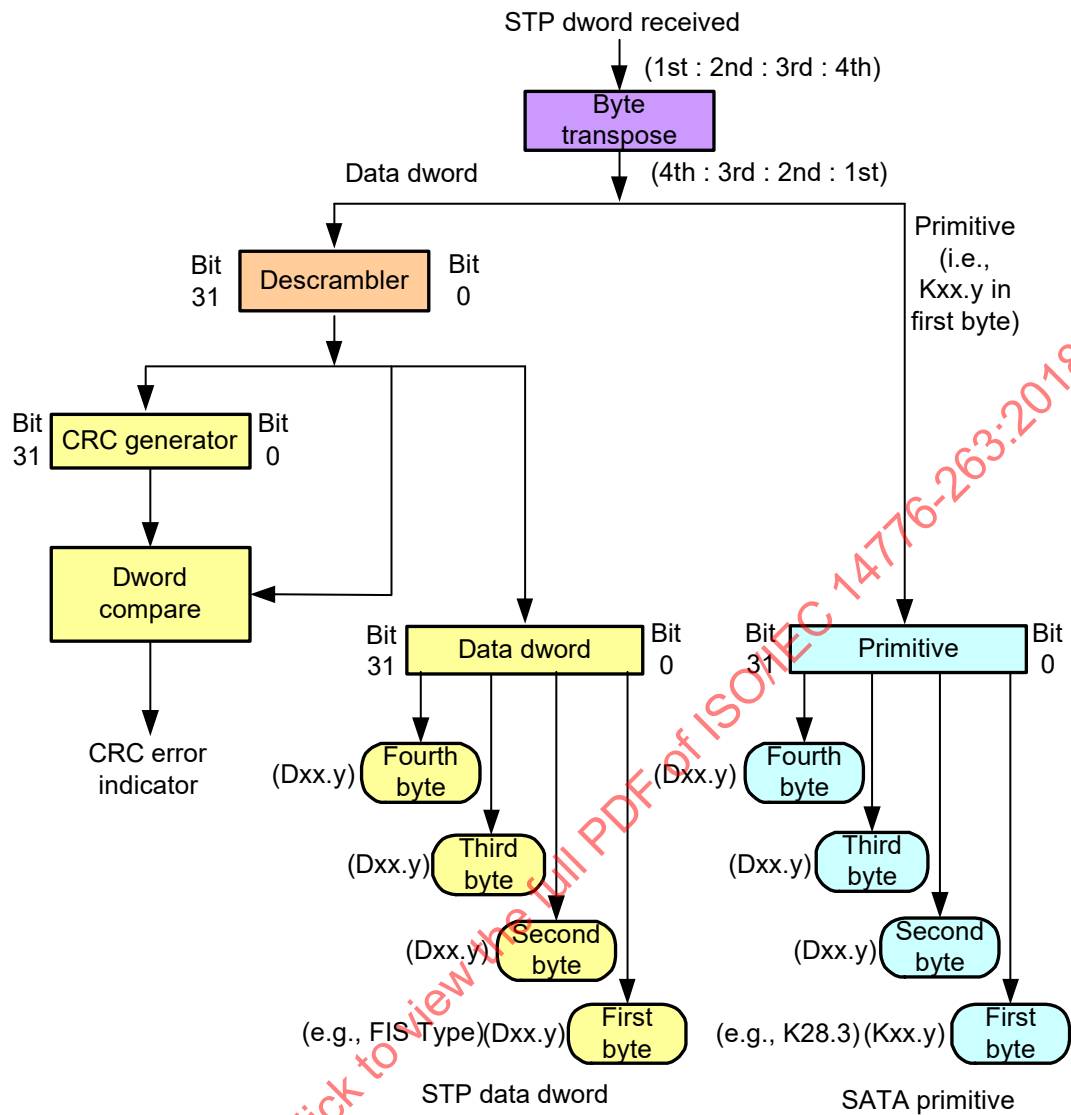


Figure 120 — STP receive path bit ordering

## 6.8 Address frames

### 6.8.1 Address frames overview

Address frames are used for the identification sequence (see 6.9) and for connection requests (see 6.14).

Address frames are preceded by SOAF and followed by EOAF as shown in figure 121.

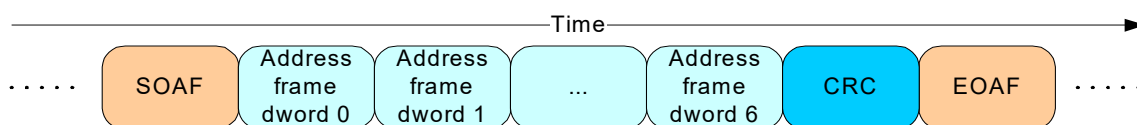


**Figure 121 — Address frame transmission**

Address frames shall only be transmitted outside connections. Partial address frames (i.e., not containing the number of data dwords defined for the frame) shall not be transmitted. All data dwords in an address frame shall be scrambled.

Table 117 defines the address frame format.

**Table 117 — Address frame format**

| Byte\Bit | 7                          | 6   | 5 | 4 | 3                  | 2 | 1 | 0 |
|----------|----------------------------|-----|---|---|--------------------|---|---|---|
| 0        |                            |     |   |   | ADDRESS FRAME TYPE |   |   |   |
| 1        | Frame type dependent bytes |     |   |   |                    |   |   |   |
| ...      |                            |     |   |   |                    |   |   |   |
| 27       |                            |     |   |   |                    |   |   |   |
| 28       | (MSB)                      | CRC |   |   |                    |   |   |   |
| ...      |                            |     |   |   |                    |   |   |   |
| 31       |                            |     |   |   |                    |   |   |   |

The ADDRESS FRAME TYPE field indicates the type of address frame and is defined in table 118. This field determines the definition of the frame type dependent bytes.

**Table 118 — ADDRESS FRAME TYPE field**

| Code       | Address frame type | Description             |
|------------|--------------------|-------------------------|
| 0h         | IDENTIFY           | Identification sequence |
| 1h         | OPEN               | Connection request      |
| All others | Reserved           |                         |

The CRC field contains a CRC value (see 6.5) that is computed over the entire address frame prior to the CRC field.

Address frames with unknown address frame types, incorrect lengths, or CRC errors shall be ignored by the recipient.

### 6.8.2 IDENTIFY address frame

Table 119 defines the IDENTIFY address frame format used for the identification sequence. The IDENTIFY address frame is transmitted by each logical phy after the phy reset sequence completes if the physical link is a SAS physical link. The IDENTIFY address frame transmitted by each logical phy in a physical phy shall be identical.

### Table 119 — IDENTIFY address frame format

| Byte\Bit | 7                  | 6             | 5               | 4               | 3                       | 2                      | 1                   | 0                                   |
|----------|--------------------|---------------|-----------------|-----------------|-------------------------|------------------------|---------------------|-------------------------------------|
| 0        | Reserved           | DEVICE TYPE   |                 |                 | ADDRESS FRAME TYPE (0h) |                        |                     |                                     |
| 1        | Reserved           |               |                 |                 | REASON                  |                        |                     |                                     |
| 2        | Reserved           |               |                 |                 | SSP INITIATOR PORT      | STP INITIATOR PORT     | SMP INITIATOR PORT  | Restricted (for OPEN address frame) |
| 3        | Reserved           |               |                 |                 | SSP TARGET PORT         | STP TARGET PORT        | SMP TARGET PORT     | Restricted (for OPEN address frame) |
| 4        | DEVICE NAME        |               |                 |                 |                         |                        |                     |                                     |
| ...      |                    |               |                 |                 |                         |                        |                     |                                     |
| 11       |                    |               |                 |                 |                         |                        |                     |                                     |
| 12       | SAS ADDRESS        |               |                 |                 |                         |                        |                     |                                     |
| ...      |                    |               |                 |                 |                         |                        |                     |                                     |
| 19       |                    |               |                 |                 |                         |                        |                     |                                     |
| 20       | PHY IDENTIFIER     |               |                 |                 |                         |                        |                     |                                     |
| 21       | PERSISTENT CAPABLE | POWER CAPABLE | SLUMBER CAPABLE | PARTIAL CAPABLE | INSIDE ZPSDS PERSISTENT | REQUESTED INSIDE ZPSDS | BREAK_REPLY CAPABLE |                                     |
| 22       | Reserved           |               |                 |                 |                         |                        |                     | PWR_DIS CAPABLE                     |
| 23       | Reserved           |               |                 |                 |                         |                        |                     |                                     |
| ...      |                    |               |                 |                 |                         |                        |                     |                                     |
| 27       |                    |               |                 |                 |                         |                        |                     |                                     |
| 28       | (MSB)              |               |                 |                 |                         |                        |                     |                                     |
| ...      | CRC                |               |                 |                 |                         |                        |                     |                                     |
| 31       |                    |               |                 |                 |                         |                        |                     |                                     |

The DEVICE TYPE field indicates the type of device containing the phy, and is defined in table 120.

**Table 120 — DEVICE TYPE field**

| Code       | Description     |
|------------|-----------------|
| 001b       | End device      |
| 010b       | Expander device |
| 011b       | Obsolete        |
| All others | Reserved        |

The ADDRESS FRAME TYPE field shall be set as shown in table 119 for the IDENTIFY address frame format.

The REASON field indicates the reason for the link reset sequence and is defined in table 121.

**Table 121 — REASON field**

| Code     | Description                                                                                                                                                                                              |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0h       | Unknown reason                                                                                                                                                                                           |
| 1h       | Power on                                                                                                                                                                                                 |
| 2h       | Hard reset (e.g., the port containing this phy received a HARD_RESET primitive sequence during the hard reset sequence) (see 4.4.2), or SMP PHY CONTROL function HARD RESET phy operation (see 9.4.3.28) |
| 3h       | SMP PHY CONTROL function LINK RESET phy operation, or TRANSMIT SATA PORT SELECTION SIGNAL phy operation (see 9.4.3.28)                                                                                   |
| 4h       | Loss of dword synchronization (see 5.13)                                                                                                                                                                 |
| 5h       | After the multiplexing sequence completes, MUX (LOGICAL LINK 0) received in logical link 1 or MUX (LOGICAL LINK 1) received in logical link 0 (see 5.15).                                                |
| 6h       | I_T nexus loss timer expired in the STP target port of an STP SATA bridge when the phy was attached to a SATA device (see 4.4.3).                                                                        |
| 7h       | Break Timeout Timer expired (see 6.14.9)                                                                                                                                                                 |
| 8h       | Phy test function stopped (see 9.4.3.29)                                                                                                                                                                 |
| 9h       | Expander device reduced functionality (see 4.5.8)                                                                                                                                                        |
| Ah to Fh | Reserved                                                                                                                                                                                                 |

An SSP INITIATOR PORT bit set to one indicates that an SSP initiator port is present. An SSP INITIATOR PORT bit set to zero indicates that an SSP initiator port is not present. Expander devices shall set the SSP INITIATOR PORT bit to zero.

An STP INITIATOR PORT bit set to one indicates that an STP initiator port is present. An STP INITIATOR PORT bit set to zero indicates that an STP initiator port is not present. Expander devices shall set the STP INITIATOR PORT bit to zero.

An SMP INITIATOR PORT bit set to one indicates that an SMP initiator port is present. An SMP INITIATOR PORT bit set to zero indicates that an SMP initiator port is not present. Expander devices may set the SMP INITIATOR PORT bit to one.

An SSP TARGET PORT bit set to one indicates that an SSP target port is present. An SSP TARGET PORT bit set to zero indicates that an SSP target port is not present. Expander devices shall set the SSP TARGET PORT bit to zero.

An STP TARGET PORT bit set to one indicates that an STP target port is present. An STP TARGET PORT bit set to zero indicates that an STP target port is not present. Expander devices shall set the STP TARGET PORT bit to zero.

An SMP TARGET PORT bit set to one indicates that an SMP target port is present. An SMP TARGET PORT bit set to zero indicates that an SMP target port is not present. Expander devices shall set the SMP TARGET PORT bit to one.

The DEVICE NAME field indicates the device name (see 4.2.6) of the SAS device or expander device transmitting the IDENTIFY address frame. A DEVICE NAME field set to 00000000 00000000h indicates the device name is not provided in this field.

NOTE 23 - In expander devices, the DEVICE NAME field, if not set to 00000000 00000000h, contains the same value as the SAS ADDRESS field.

For SAS ports, the SAS ADDRESS field indicates the port identifier (see 4.2.9) of the SAS port transmitting the IDENTIFY address frame. For expander ports, the SAS ADDRESS field indicates the device name (see 4.2.6) of the expander device transmitting the IDENTIFY address frame.

The PHY IDENTIFIER field indicates the phy identifier (see 4.2.10) of the phy transmitting the IDENTIFY address frame.

The REQUESTED INSIDE ZPSDS bit indicates the value of the REQUESTED INSIDE ZPSDS bit in the zone phy information (see 4.8.3.1) at the time the IDENTIFY address frame is transmitted. If the phy transmitting the IDENTIFY address frame is contained in an end device, a non-zoning expander device, or a zoning expander device with zoning disabled, then the REQUESTED INSIDE ZPSDS bit shall be set to zero.

The INSIDE ZPSDS PERSISTENT bit indicates the value of the INSIDE ZPSDS PERSISTENT bit in the zone phy information (see 4.8.3.1) at the time the IDENTIFY address frame is transmitted. If the phy transmitting the IDENTIFY address frame is contained in an end device, a non-zoning expander device, or a zoning expander device with zoning disabled, then the INSIDE ZPSDS PERSISTENT bit shall be set to zero.

The BREAK\_REPLY CAPABLE field indicates that the phy is capable of responding to received BREAK primitive sequences with a BREAK\_REPLY primitive sequence (see 6.14.5).

See 4.1.4 for additional requirements concerning the DEVICE TYPE field, the BREAK\_REPLY CAPABLE bit, the SSP INITIATOR PORT bit, the STP INITIATOR PORT bit, the SMP INITIATOR PORT bit, the SSP TARGET PORT bit, the STP TARGET PORT bit, the SMP TARGET PORT bit, and the SAS ADDRESS field.

A PERSISTENT CAPABLE bit set to one indicates that the phy is capable of establishing and maintaining a persistent connection (see 4.1.13). A PERSISTENT CAPABLE bit set to zero indicates that the phy is not capable of establishing or maintaining a persistent connection. If the phy transmitting the IDENTIFY address frame is contained in an expander device, then the PERSISTENT CAPABLE bit shall be set to zero.

A PARTIAL CAPABLE bit set to one indicates that the phy is capable of supporting the partial phy power condition (see 4.10.1.3). A PARTIAL CAPABLE bit set to zero indicates that the phy is not capable of supporting the partial phy power condition.

A SLUMBER CAPABLE bit set to one indicates that the phy is capable of supporting the slumber phy power condition (see 4.10.1.4). A SLUMBER CAPABLE bit set to zero indicates that the phy is not capable of supporting the slumber phy power condition.

If multiplexing is enabled (see 5.15) or optical mode is enabled, then the PARTIAL CAPABLE bit and the SLUMBER CAPABLE bit shall be set to zero.



The POWER CAPABLE field is defined in table 122.

**Table 122 — POWER CAPABLE field**

| Code | Description                                                                                                                                                                                                      |
|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00b  | The device containing the phy:<br>a) does not respond to PWR_GRANT with PWR_ACK, PWR_REQ with PWR_ACK, or PWR_DONE with PWR_ACK; and<br>b) does not issue PWR_REQ or PWR_DONE.                                   |
| 01b  | The device containing the phy is capable of allowing the management of additional consumption of power (see 6.12) by:<br>a) issuing PWR_REQ and PWR_DONE; and<br>b) responding to PWR_GRANT with PWR_ACK.        |
| 10b  | The device containing the phy is capable of managing the additional consumption of power (see 6.12) by responding to:<br>a) PWR_REQ with PWR_ACK;<br>b) PWR_REQ with PWR_GRANT; and<br>c) PWR_DONE with PWR_ACK. |
| 11b  | Reserved                                                                                                                                                                                                         |

A power disable capable (PWR\_DIS CAPABLE) bit set to one indicates that the SAS target device is a power consumer device (see 6.12.2) that is capable of using the POWER DISABLE signal (see SAS-3). A power source device (see 6.12.1) shall not set the PWR\_DIS CAPABLE bit to one. A PWR\_DIS CAPABLE bit set to zero indicates that the consumer device is not capable of using the POWER DISABLE signal.

The CRC field is defined in 6.8.1.

## 6.8.3 OPEN address frame

Table 123 defines the OPEN address frame format used for connection requests.

Table 123 — OPEN address frame format

| Byte\Bit | 7                                  | 6                        | 5 | 4 | 3                       | 2 | 1              | 0           |       |
|----------|------------------------------------|--------------------------|---|---|-------------------------|---|----------------|-------------|-------|
| 0        | INITIATOR PORT                     | SAS PROTOCOL             |   |   | ADDRESS FRAME TYPE (1h) |   |                |             |       |
| 1        | FEATURES                           |                          |   |   | CONNECTION RATE         |   |                |             |       |
| 2        | (MSB)                              | INITIATOR CONNECTION TAG |   |   |                         |   |                |             |       |
| 3        |                                    |                          |   |   |                         |   |                |             | (LSB) |
| 4        |                                    | DESTINATION SAS ADDRESS  |   |   |                         |   |                |             |       |
| ...      |                                    |                          |   |   |                         |   |                |             |       |
| 11       |                                    |                          |   |   |                         |   |                |             |       |
| 12       |                                    | SOURCE SAS ADDRESS       |   |   |                         |   |                |             |       |
| ...      |                                    |                          |   |   |                         |   |                |             |       |
| 19       |                                    |                          |   |   |                         |   |                |             |       |
| 20       | SOURCE ZONE GROUP                  |                          |   |   |                         |   |                |             |       |
| 21       | PATHWAY BLOCKED COUNT              |                          |   |   |                         |   |                |             |       |
| 22       | (MSB)                              | ARBITRATION WAIT TIME    |   |   |                         |   |                |             |       |
| 23       |                                    |                          |   |   |                         |   |                |             | (LSB) |
| 24       | COMPATIBLE FEATURES (000000b)      |                          |   |   |                         |   | CREDIT ADVANCE | SEND EXTEND |       |
| 25       | MORE COMPATIBLE FEATURES (000000h) |                          |   |   |                         |   |                |             |       |
| ...      |                                    |                          |   |   |                         |   |                |             |       |
| 27       |                                    |                          |   |   |                         |   |                |             |       |
| 28       | (MSB)                              | CRC                      |   |   |                         |   |                |             |       |
| ...      |                                    |                          |   |   |                         |   |                |             |       |
| 31       |                                    | (LSB)                    |   |   |                         |   |                |             |       |

An INITIATOR PORT bit set to one specifies that the source port is acting as a SAS initiator port. An INITIATOR PORT bit set to zero specifies that the source port is acting as a SAS target port. If a SAS port sets the INITIATOR PORT bit to one, then the SAS phy shall operate only in its initiator role during the connection. If a

SAS port sets the INITIATOR PORT bit to zero, then the SAS port shall operate only in its target role during the connection.

If a SAS port accepts an OPEN address frame with the INITIATOR PORT bit set to one, then the SAS port shall operate only in its target role during the connection. If a SAS port accepts an OPEN address frame with the INITIATOR PORT bit set to zero, then the SAS port shall operate only in its initiator role during the connection.

The SAS PROTOCOL field specifies the protocol for the connection being requested and is defined in table 124.

**Table 124 — SAS PROTOCOL field**

| Code       | Description |
|------------|-------------|
| 000b       | SMP         |
| 001b       | SSP         |
| 010b       | STP         |
| All others | Reserved    |

The ADDRESS FRAME TYPE field shall be set as shown in table 123 for the OPEN address frame format.

The FEATURES field specifies any additional features that are incompatible with SPL-2 and is defined in table 125.

**Table 125 — FEATURES field**

| Code       | Description            |
|------------|------------------------|
| 0h         | No additional features |
| All others | Reserved               |

The CONNECTION RATE field specifies the connection rate (see 4.1.12) being requested between the source and destination, and is defined in table 126.

**Table 126 — CONNECTION RATE field**

| Code       | Description                          |
|------------|--------------------------------------|
| 8h         | 1.5 Gbit/s                           |
| 9h         | 3 Gbit/s                             |
| Ah         | 6 Gbit/s                             |
| Bh         | 12 Gbit/s                            |
| Ch to Fh   | Reserved for future connection rates |
| All others | Reserved                             |

A SAS initiator port shall set the initial CONNECTION RATE field to:

- a) the highest supported connection rate supported by a potential pathway as determined during the discover process (e.g., based on the logical link rates of each logical link reported in the SMP DISCOVER responses); or

- b) the logical link rate of the logical phy used to transmit the OPEN address frame.

If a SAS initiator port selected a connection rate based on discover process information, but the connection request results in OPEN\_REJECT (CONNECTION RATE NOT SUPPORTED), then the discover process information is no longer current and the discover process should be run again.

A SAS target port shall set the initial CONNECTION RATE field to:

- a) the last known good connection rate established with the SAS initiator port; or
- b) for the first frame that it intends to transmit in the connection, the connection rate that was used by the SAS initiator port to deliver the command or task management function for that frame.

Each time that a connection request with a connection rate greater than 1.5 Gbit/s results in OPEN\_REJECT (CONNECTION RATE NOT SUPPORTED), the SAS port shall reattempt the connection request with a lower connection rate (e.g., drop from 6 Gbit/s to 3 Gbit/s or 1.5 Gbit/s) and send the same frames in the resulting connection that the SAS port intended to send at the initial connection rate.

The INITIATOR CONNECTION TAG field is used for SSP and STP connection requests to provide a SAS initiator port an alternative to using the SAS target port's SAS address for context lookup when the SAS target port originates a connection request. An SSP initiator port or STP initiator port shall set the INITIATOR CONNECTION TAG field to FFFFh if the SSP initiator port or STP initiator port does not require that this field be provided by the SAS target port. If an SSP initiator port or STP initiator port does require the field to be provided, then the SSP initiator port or STP initiator port should set the INITIATOR CONNECTION TAG field to a unique value per SAS target port. When requesting a connection to a SAS initiator port, a SAS target port shall set the INITIATOR CONNECTION TAG field to the most recent value received or the value received in one of the connection requests for one of the outstanding commands or task management functions from the SAS initiator port. A SAS initiator port shall:

- a) use the same INITIATOR CONNECTION TAG field value for all connection requests to the same SAS target port; and
- b) only change the INITIATOR CONNECTION TAG field value when it has no commands or task management functions outstanding to that SAS target port.

SAS target ports are not required to check consistency of the INITIATOR CONNECTION TAG field in different connection requests from the same SAS initiator port. SMP initiator ports shall set the INITIATOR CONNECTION TAG field to FFFFh for SMP connection requests.

The DESTINATION SAS ADDRESS field specifies the port identifier (see 4.2.9) of the SAS port to which a connection is being requested.

The SOURCE SAS ADDRESS field specifies the port identifier (see 4.2.9) of the SAS port that originated the OPEN address frame.

The SOURCE ZONE GROUP field identifies the zone group of the phy making the connection request. The SOURCE ZONE GROUP field shall be:

- a) set to 00h when transmitted by an end device;
- b) set to 00h when transmitted by an expander device on a phy with the INSIDE ZPSDS bit set to zero;
- c) set to the source zone group for the outgoing connection request as described in table 41 (see 4.8.3.5) when transmitted by an expander device on a phy with the INSIDE ZPSDS bit set to one;
- d) ignored when received by an end device;
- e) ignored when received by an expander device on a phy with the INSIDE ZPSDS bit set to zero; or
- f) used to determine the source zone group for the incoming connection request as described in table 41 (see 4.8.3.5) when received by an expander device on a phy with the INSIDE ZPSDS bit set to one.

The PATHWAY BLOCKED COUNT field specifies the number of times the port has retried this connection request due to receiving OPEN\_REJECT (PATHWAY BLOCKED), OPEN\_REJECT (RESERVED STOP 0), or OPEN\_REJECT (RESERVED STOP 1). The port shall not increment the PATHWAY BLOCKED COUNT value past FFh. If the port changes connection requests, then the port shall set the PATHWAY BLOCKED COUNT field to 00h.

The ARBITRATION WAIT TIME field specifies how long the port transmitting the OPEN address frame has been waiting for a connection request to be accepted or rejected. This time is maintained by the port layer in an Arbitration Wait Time timer (see 7.2.2). For values from 0000h to 7FFFh, the Arbitration Wait Time timer

increments in one microsecond steps. For values from 8000h to FFFFh, the Arbitration Wait Time timer increments in one millisecond steps. The maximum value represents 32 767 ms + 32 768  $\mu$ s. Table 127 describes several values of the ARBITRATION WAIT TIME field. See 6.14.3 for details on arbitration fairness.

**Table 127 — ARBITRATION WAIT TIME field**

| Code  | Description                |
|-------|----------------------------|
| 0000h | 0 $\mu$ s                  |
| 0001h | 1 $\mu$ s                  |
| ...   | ...                        |
| 7FFFh | 32 767 $\mu$ s             |
| 8000h | 0 ms + 32 768 $\mu$ s      |
| 8001h | 1 ms + 32 768 $\mu$ s      |
| ...   | ...                        |
| FFFFh | 32 767 ms + 32 768 $\mu$ s |

If the end device originating the OPEN address frame:

- a) is an initiator port (i.e., the INITIATOR PORT bit is set to one);
- b) supports persistent connections (see 4.1.13); and
- c) the SAS PROTOCOL field is set to 001b (i.e., SSP),

then a SEND EXTEND bit set to:

- a) one specifies that the source phy is requesting the establishment of a persistent connection with the destination phy (see 6.16); or
- b) zero specifies that the source phy is requesting that a persistent connection not be established (see 6.16).

If the end device transmitting the OPEN address frame is a target port (i.e., the INITIATOR PORT bit is set to zero), then the SEND EXTEND bit shall be set to zero.

If the end device receiving the OPEN address frame:

- a) does not support persistent connections; or
- b) the SAS PROTOCOL field is set to a value other than 001b,

then the SEND EXTEND bit shall be ignored.

If the SAS PROTOCOL field is set to 001b (i.e., SSP), then a CREDIT ADVANCE bit:

- a) set to one specifies that the destination SSP phy that implements credit advance, advances credit as defined in 4.1.14; or
- b) set to zero specifies that the destination SSP phy shall not advance credit (see 4.1.14).

If the SAS PROTOCOL field is not set to 001b (i.e., SSP), then the CREDIT ADVANCE bit shall be ignored.

The COMPATIBLE FEATURES field and the MORE COMPATIBLE FEATURES field shall be set as shown in table 123 for the OPEN address frame format. A phy receiving an OPEN address frame shall ignore the COMPATIBLE FEATURES field and the MORE COMPATIBLE FEATURES field.

The CRC field is defined in 6.8.1.

## 6.9 Link reset sequence

### 6.9.1 Link reset sequence overview

For SATA, a link reset sequence is a phy reset sequence (see 5.10).

For SAS, a link reset sequence is either:

- a) the following sequence:
  - 1) a phy reset sequence indicating that the physical link is using SAS rather than SATA; and
  - 2) an identification sequence;or
- b) the following sequence:
  - 1) a phy reset sequence indicating that the physical link is using SAS rather than SATA;
  - 2) a hard reset sequence;
  - 3) another phy reset sequence indicating that the physical link is using SAS rather than SATA; and
  - 4) an identification sequence.

An identification sequence occurs when a logical phy:

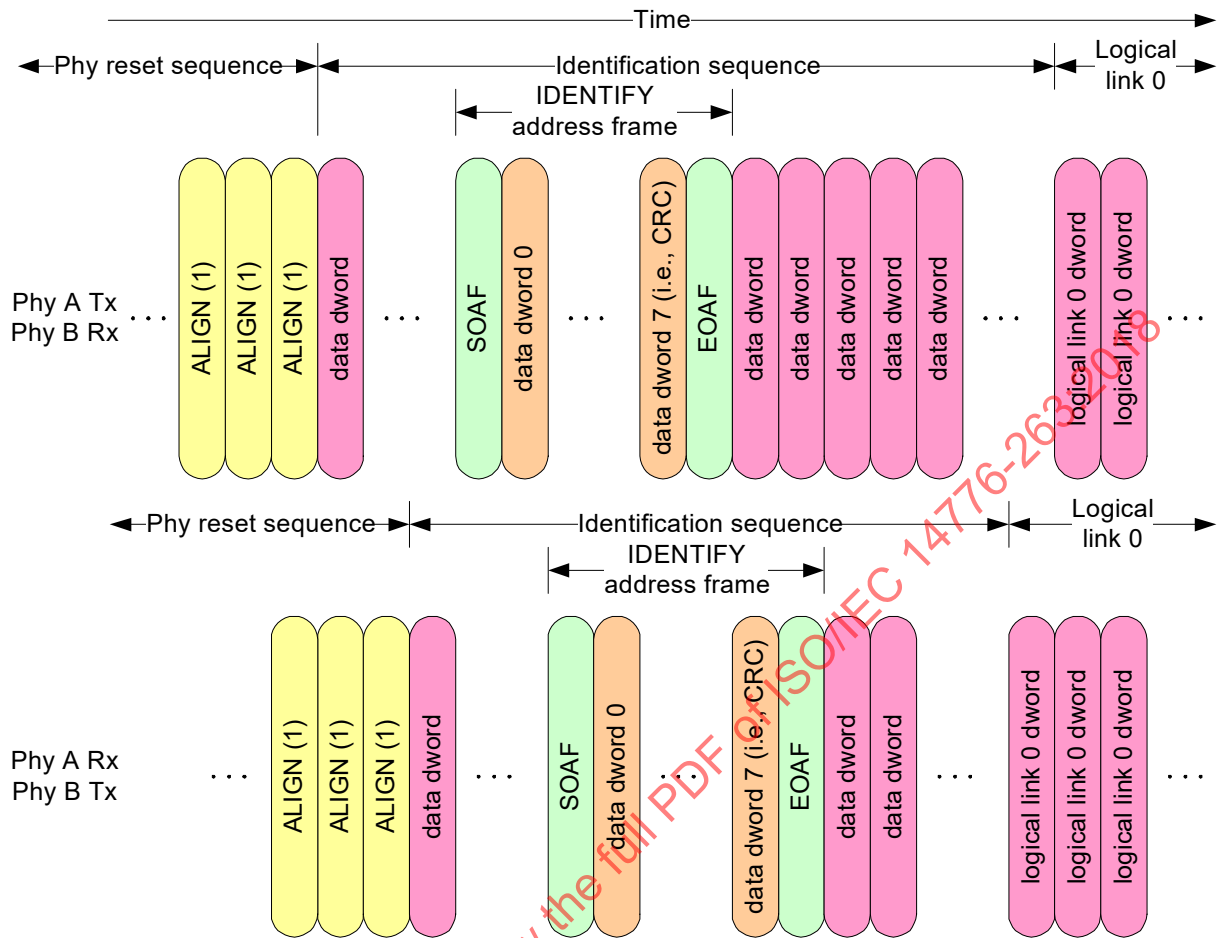
- a) transmits one or three IDENTIFY address frames (see 6.8.2); and
- b) does not receive a HARD\_RESET primitive sequence.

A hard reset sequence occurs when, after the phy reset sequence, a logical phy:

- a) transmits a HARD\_RESET primitive sequence (see 6.2.6.8); or
- b) receives a HARD\_RESET primitive sequence.

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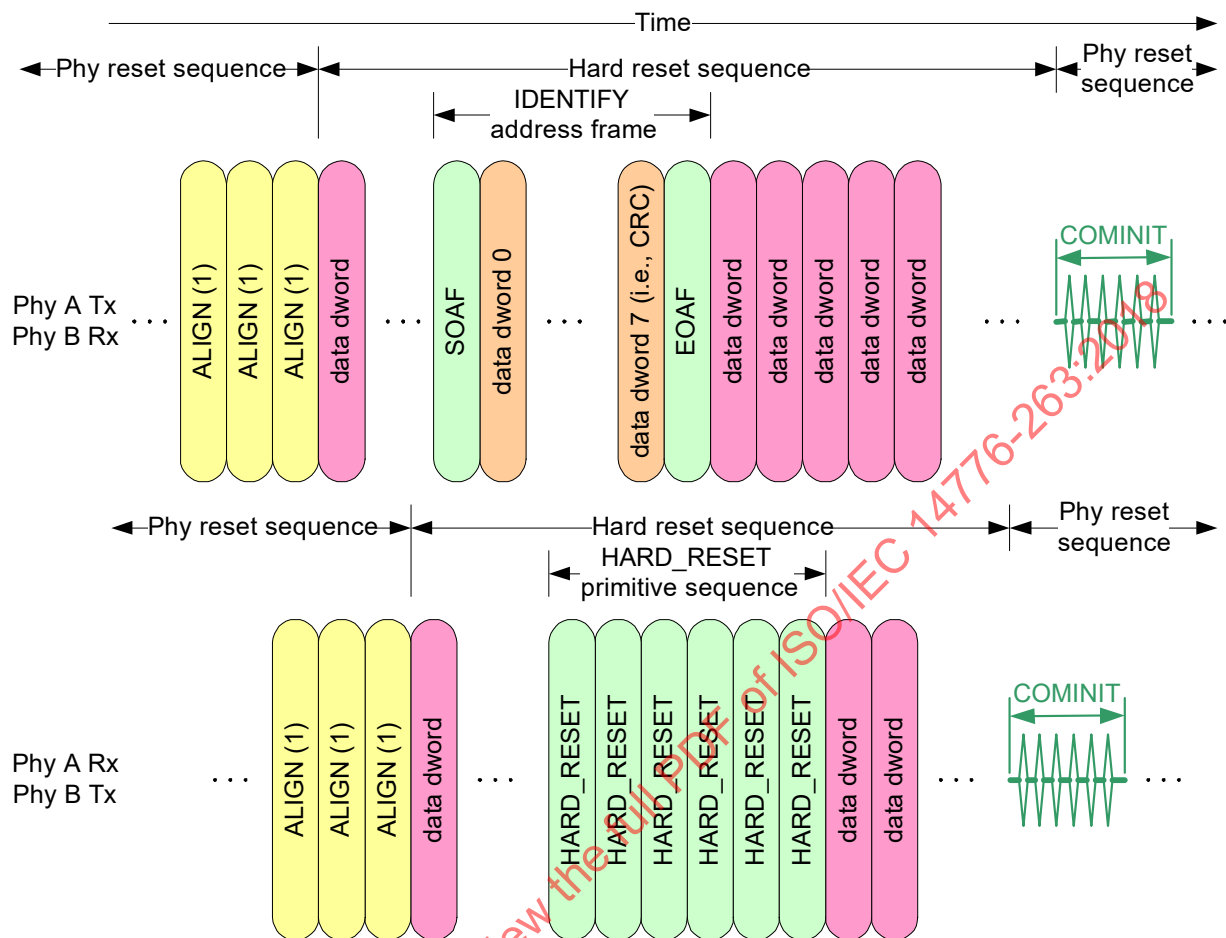
Figure 122 shows two phys with multiplexing disabled performing the identification sequence. Only one IDENTIFY address frame is shown in this example.



Note - Phys transmit deletable primitives for physical link rate tolerance management after the phy reset sequence.

Figure 122 — Identification sequence

Figure 123 shows phy A attempting to perform the identification sequence and phy B performing the hard reset sequence. Because phy A receives a HARD\_RESET primitive sequence, a hard reset sequence occurs. Multiplexing is disabled and only one IDENTIFY address frame is shown in this example.



Note - Phys transmit deletable primitives for physical link rate tolerance management after the phy reset sequence.

**Figure 123 — Hard reset sequence**

Each logical phy receives an IDENTIFY address frame or a HARD\_RESET primitive sequence from the logical phy to which it is attached.

If a logical phy receives a valid IDENTIFY address frame (see 6.10.4.3.1) within 1 ms of phy reset sequence completion, then the SAS address in the outgoing IDENTIFY address frame(s) and the SAS address in the incoming IDENTIFY address frame determine the port to which the logical phy belongs (see 4.1.4). The logical phy ignores subsequent IDENTIFY address frames and HARD\_RESETs until another phy reset sequence occurs.

If a logical phy receives a HARD\_RESET primitive sequence within 1 ms of phy reset sequence completion, then the logical phy shall consider this to be a reset event, and the port containing the logical phy shall process a hard reset (see 4.4.2).

If a logical phy does not receive a HARD\_RESET primitive sequence or a valid IDENTIFY address frame within 1 ms of phy reset sequence completion, then the physical phy containing the logical phy shall restart the phy reset sequence.



### 6.9.2 Expander device handling of link reset sequences

After completing the link reset sequence on a phy and completing internal initialization, the ECM within an expander device shall be capable of routing connection requests through that phy. The expander device may return OPEN\_REJECT (NO DESTINATION) until it is ready to process connection requests.

The ECM of an externally configurable expander device is dependent on the completion of the discover process (see 4.6) for routing connection requests using the table routing method.

## 6.10 SL\_IR (link layer identification and hard reset) state machines

### 6.10.1 SL\_IR state machines overview

The SL\_IR (link layer identification and hard reset) state machines control the flow of dwords on the physical link that are associated with the identification and hard reset sequences. The state machines are as follows:

- SL\_IR\_TIR (transmit IDENTIFY or HARD\_RESET primitive sequence) state machine (see 6.10.3);
- SL\_IR\_RIF (receive IDENTIFY address frame) state machine (see 6.10.4); and
- SL\_IR\_IRC (identification and hard reset control) state machine (see 6.10.5).

The SL\_IR state machines send the following messages to the SL state machines (see 6.16) in SAS devices or the XL (see 6.17) state machine in expander devices:

- Enable Disable SAS Link (Enable); and
- Enable Disable SAS Link (Disable).

This state machine shall maintain the timers listed in table 128.

**Table 128 — SL\_IR\_IRC state machine timers**

| Timer                          | Initial value |
|--------------------------------|---------------|
| Receive Identify Timeout timer | 1 ms          |

Figure 124 shows the SL\_IR state machines.

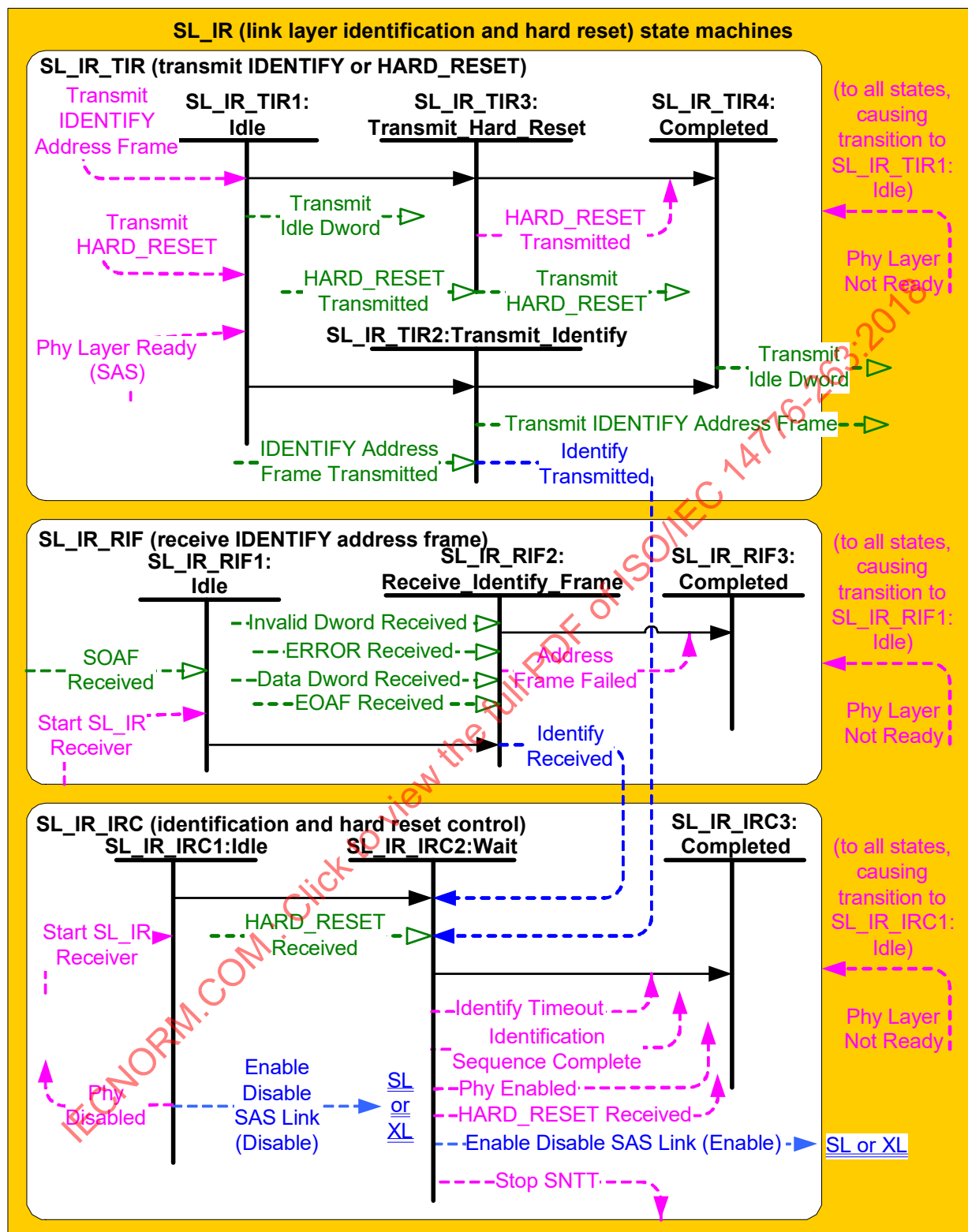


Figure 124 — SL\_IR (link layer identification and hard reset) state machines

### 6.10.2 SL\_IR transmitter and receiver

The SL\_IR transmitter receives the following messages from the SL\_IR state machines indicating primitive sequences, frames, and dwords to transmit:

- a) Transmit IDENTIFY Address Frame;
- b) Transmit HARD\_RESET; and
- c) Transmit Idle Dword.

Upon receiving a Transmit IDENTIFY Address Frame message, the SL\_IR transmitter shall transmit:

- 1) SOAF;
- 2) data dwords;
- 3) EOAF; and
- 4) at least 3 idle dwords.

NOTE 24 - Phys compliant with SAS-1.1 were not required to transmit idle dwords after EOAF.

The SL\_IR transmitter sends the following messages to the SL\_IR state machines:

- a) HARD\_RESET Transmitted; and
- b) IDENTIFY Address Frame Transmitted.

The SL\_IR receiver sends the following messages to the SL\_IR state machines indicating primitive sequences and dwords received from the SP\_DWS receiver (see 5.13.2):

- a) SOAF Received;
- b) Data Dword Received;
- c) EOAF Received;
- d) ERROR Received;
- e) Invalid Dword Received; and
- f) HARD\_RESET Received.

The SL\_IR receiver shall not require reception of any idle dwords after an IDENTIFY address frame.

The SL\_IR receiver shall ignore all other dwords.

The SL\_IR transmitter relationship to other transmitters is defined in 4.3.2. The SL\_IR receiver relationship to other receivers is defined in 4.3.3.

### 6.10.3 SL\_IR\_TIR (transmit IDENTIFY or HARD\_RESET) state machine

#### 6.10.3.1 SL\_IR\_TIR state machine overview

The SL\_IR\_TIR state machine's function is to transmit one or three IDENTIFY address frames or a HARD\_RESET primitive sequence after the phy layer enables the link layer. This state machine consists of the following states:

- a) SL\_IR\_TIR1:Idle (see 6.10.3.2) (initial state);
- b) SL\_IR\_TIR2:Transmit\_Identify (see 6.10.3.3);
- c) SL\_IR\_TIR3:Transmit\_Hard\_Reset (see 6.10.3.4); and
- d) SL\_IR\_TIR4:Completed (see 6.10.3.5).

This state machine receives the following requests from the management application layer:

- a) Transmit IDENTIFY Address Frame; and
- b) Transmit HARD\_RESET.

This state machine shall start in the SL\_IR\_TIR1:Idle state. This state machine shall transition to the SL\_IR\_TIR1:Idle state from any other state after receiving a Phy Layer Not Ready confirmation.

### 6.10.3.2 SL\_IR\_TIR1:Idle state

#### 6.10.3.2.1 State description

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SL\_IR transmitter.

#### 6.10.3.2.2 Transition SL\_IR\_TIR1:Idle to SL\_IR\_TIR2:Transmit\_Identify

This transition shall occur after both:

- a) a Phy Layer Ready (SAS) confirmation is received; and
- b) a Transmit IDENTIFY Address Frame request is received.

#### 6.10.3.2.3 Transition SL\_IR\_TIR1:Idle to SL\_IR\_TIR3:Transmit\_Hard\_Reset

This transition shall occur after both:

- a) a Phy Layer Ready (SAS) confirmation is received; and
- b) a Transmit HARD\_RESET request is received.

### 6.10.3.3 SL\_IR\_TIR2:Transmit\_Identify state

#### 6.10.3.3.1 State description

Upon entry into this state, this state shall send either one or three Transmit IDENTIFY Address Frame messages to the SL\_IR transmitter.

NOTE 25 - Phys compliant with SAS-1.1 only transmitted one Transmit IDENTIFY Address Frame message.

After this state receives an IDENTIFY Address Frame Transmitted message in response to its first Transmit IDENTIFY Address Frame message, this state shall send an Identify Transmitted message to the SL\_IR\_IRC state machine.

#### 6.10.3.3.2 Transition SL\_IR\_TIR2:Transmit\_Identify to SL\_IR\_TIR4:Completed

If this state sends one Transmit IDENTIFY Address Frame message, then this transition shall occur:

- a) after sending an Identify Transmitted message to the SL\_IR\_IRC state machine.

If this state sends three Transmit IDENTIFY Address Frame messages, then this transition shall occur:

- a) after receiving three Identify Transmitted messages.

### 6.10.3.4 SL\_IR\_TIR3:Transmit\_Hard\_Reset state

#### 6.10.3.4.1 State description

Upon entry into this state, this state shall send a Transmit HARD\_RESET message to the SL\_IR transmitter.

After this state receives a HARD\_RESET Transmitted message, this state shall send a HARD\_RESET Transmitted confirmation to the management application layer.

#### 6.10.3.4.2 Transition SL\_IR\_TIR3:Transmit\_Hard\_Reset to SL\_IR\_TIR4:Completed

This transition shall occur:

- a) after sending a HARD\_RESET Transmitted confirmation to the management application layer.

### 6.10.3.5 SL\_IR\_TIR4:Completed state

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SL\_IR transmitter.

### 6.10.4 SL\_IR\_RIF (receive IDENTIFY address frame) state machine

#### 6.10.4.1 SL\_IR\_RIF state machine overview

The SL\_IR\_RIF state machine receives an IDENTIFY address frame and checks the IDENTIFY address frame to determine if the frame should be accepted or discarded by the link layer.

This state machine consists of the following states:

- a) SL\_IR\_RIF1:Idle (see 6.10.4.2) (initial state);
- b) SL\_IR\_RIF2:Receive\_Identify\_Frame (see 6.10.4.3); and
- c) SL\_IR\_RIF3:Completed (see 6.10.4.4).

This state machine shall start in the SL\_IR\_RIF1:Idle state. This state machine shall transition to the SL\_IR\_RIF1:Idle state from any other state after receiving a Phy Layer Not Ready confirmation.

#### 6.10.4.2 SL\_IR\_RIF1:Idle state

##### 6.10.4.2.1 State description

This state waits for an SOAF to be received from the physical link, indicating an address frame is arriving.

##### 6.10.4.2.2 Transition SL\_IR\_RIF1:Idle to SL\_IR\_RIF2:Receive\_Identify\_Frame

This transition shall occur after both:

- a) a Start SL\_IR Receiver confirmation is received; and
- b) an SOAF Received message is received.

#### 6.10.4.3 SL\_IR\_RIF2:Receive\_Identify\_Frame state

##### 6.10.4.3.1 State description

This state receives the dwords of an address frame and the EOAF.

If this state receives an SOAF Received message, then this state shall discard the address frame in progress, send an Address Frame Failed confirmation to the management application layer to indicate that an invalid address frame was received, and start receiving the new address frame.

If this state receives more than eight Data Dword Received messages (i.e., 32 bytes) after an SOAF Received message and before an EOAF Received message, then this state shall discard the address frame and send an Address Frame Failed confirmation to the management application layer to indicate that an invalid address frame was received.

If this state receives an Invalid Dword Received message or an ERROR Received message after an SOAF Received message and before an EOAF Received message, then this state shall either:

- a) ignore the invalid dword or ERROR; or
- b) discard the address frame in progress and send an Address Frame Failed confirmation to the management application layer to indicate that an invalid address frame was received.

After receiving an EOAF Received message, this state shall check if the received frame is a valid IDENTIFY address frame.

This state shall accept an IDENTIFY address frame and send an Identify Received message to the SL\_IR\_IRC state machine if:

- a) the ADDRESS FRAME TYPE field is set to 0h (i.e., IDENTIFY);
- b) the number of bytes between the SOAF and EOAF is 32; and
- c) the CRC field contains a good CRC.

Otherwise, this state shall discard the address frame and send an Address Frame Failed confirmation to the management application layer to indicate that an invalid address frame was received.

#### 6.10.4.3.2 Transition SL\_IR\_RIF2:Receive\_Identify\_Frame to SL\_IR\_RIF3:Completed

This transition shall occur:

- a) after sending an Identify Received message.

#### 6.10.4.4 SL\_IR\_RIF3:Completed state

This state waits for a Phy Layer Not Ready confirmation.

### 6.10.5 SL\_IR\_IRC (identification and hard reset control) state machine

#### 6.10.5.1 SL\_IR\_IRC state machine overview

The SL\_IR\_IRC state machine ensures that IDENTIFY address frames have been both received and transmitted before enabling the rest of the link layer, and notifies the link layer if a HARD\_RESET primitive sequence is received before an IDENTIFY address frame has been received.

This state machine consists of the following states:

- a) SL\_IR\_IRC1:Idle (see 6.10.5.2) (initial state);
- b) SL\_IR\_IRC2:Wait (see 6.10.5.3); and
- c) SL\_IR\_IRC3:Completed (see 6.10.5.4).

This state machine shall start in the SL\_IR\_IRC1:Idle state. This state machine shall transition to the SL\_IR\_IRC1:Idle state from any other state after receiving a Phy Layer Not Ready confirmation.

#### 6.10.5.2 SL\_IR\_IRC1:Idle state

##### 6.10.5.2.1 State description

This state waits for the link layer to be enabled. Upon entry into this state, this state shall:

- a) send an Enable Disable SAS Link (Disable) message to the SL state machines (see 6.16) or XL state machine (see 6.17) halting any link layer activity; and
- b) send a Phy Disabled confirmation to the SL\_P\_C state machine, port layer, and the management application layer indicating that the phy is not ready for use.

##### 6.10.5.2.2 Transition SL\_IR\_IRC1:Idle to SL\_IR\_IRC2:Wait

This transition shall occur:

- a) after a Start SL\_IR Receiver confirmation is received.

#### 6.10.5.3 SL\_IR\_IRC2:Wait state

##### 6.10.5.3.1 State description

This state ensures that an IDENTIFY address frame has been received by the SL\_IR\_RIF state machine and that an IDENTIFY address frame has been transmitted by the SL\_IR\_TIR state machine before enabling the

rest of the link layer. The IDENTIFY address frames may be transmitted and received on the physical link in any order.

After this state receives an Identify Received message, this state shall send a Stop SNTT request to the phy layer.

NOTE 26 - If multiplexing is enabled, each SL\_IR\_IRC state machine sends a Stop SNTT request to the phy layer. The phy layer honors the first request and ignores the second request.

After this state receives an Identify Transmitted message, this state shall initialize and start the Receive Identify Timeout timer. If an Identify Received message is received before the Receive Identify Timeout timer expires, then this state shall:

- a) send an Identification Sequence Complete confirmation to the management application layer, with arguments carrying the contents of the incoming IDENTIFY address frame;
- b) send an Enable Disable SAS Link (Enable) message to the SL state machines (see 6.16) in a SAS logical phy or the XL state machine (see 6.17) in an expander logical phy indicating that the rest of the link layer may start operation; and
- c) send a Phy Enabled confirmation to the SL\_P\_C state machine (see 3.5.5), port layer and the management application layer indicating that the phy is ready for use.

If the Receive Identify Timeout timer expires before an Identify Received message is received, then this state shall send an Identify Timeout confirmation to the management application layer to indicate that an identify timeout occurred.

If this state receives a HARD\_RESET Received message before an Identify Received message is received, then this state shall send a HARD\_RESET Received confirmation to the port layer and the management application layer and a Stop SNTT request to the phy layer.

If this state receives a HARD\_RESET Received message after an Identify Received message is received, then the HARD\_RESET Received message shall be ignored.

#### **6.10.5.3.2 Transition SL\_IR\_IRC2:Wait to SL\_IR\_IRC3:Completed**

This transition shall occur:

- a) after sending a HARD\_RESET Received confirmation, Identify Timeout confirmation, or an Identification Sequence Complete and a Phy Enabled confirmation.

#### **6.10.5.4 SL\_IR\_IRC3:Completed state**

This state waits for a Phy Layer Not Ready confirmation.

## 6.11 Entering a low phy power condition

Figure 125 shows the sequence to transition from the active phy power condition to a low phy power condition.

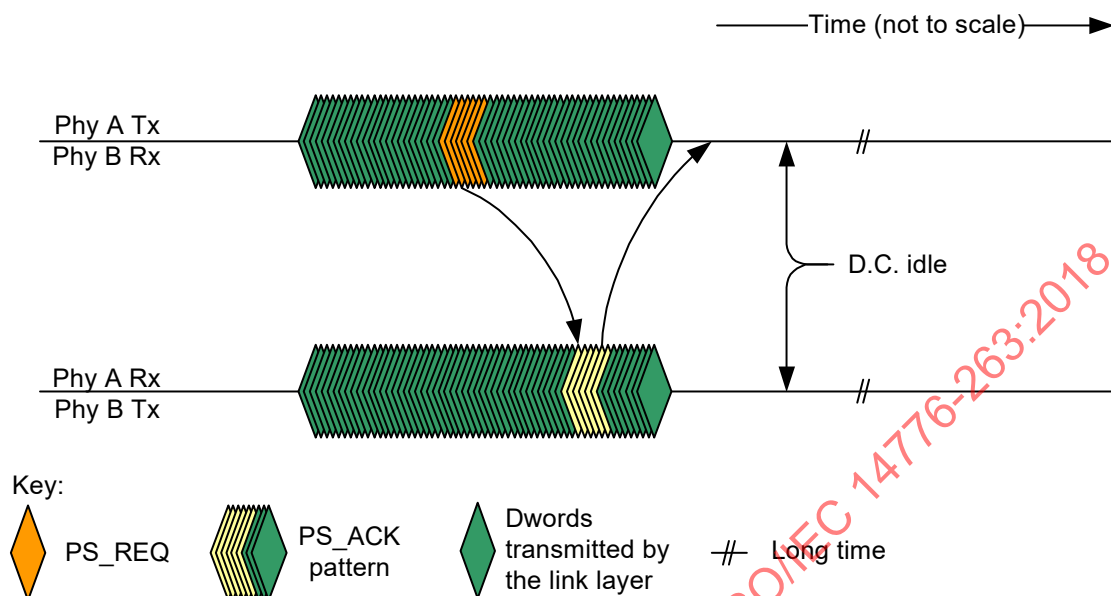


**Figure 125 — Transitioning from the active phy power condition to a low phy power condition**

The transition to a low phy power condition is acknowledged using a PS\_ACK pattern as defined in table 129.

**Table 129 — PS\_ACK pattern**

| Pattern        | Description                                                                               |
|----------------|-------------------------------------------------------------------------------------------|
| PS_ACK pattern | Sequence of:<br>1) PS_ACK primitive sequence (see 6.2.6.11); and<br>2) three idle dwords. |

After sending a PS\_ACK pattern the transmitter may continue to transmit a vendor specific number of idle dwords.

After sending a PS\_REQ primitive sequence, if no PS\_ACK primitive sequence is received before the Power Condition Request Timeout timer (see table 140 and table 143) expires, then the transition to the low phy power condition is aborted and the phy remains in the active phy power condition.

## 6.12 Power control and SL\_P (link layer power control) state machines

### 6.12.1 Power source device

An expander device or SAS initiator device that is capable of processing requests for additional consumption of power (i.e., a power source device):

- indicates support for processing requests for additional consumption of power by setting the POWER CAPABLE field to 10b in the IDENTIFY address frame (see 6.8.2);



- b) notifies the management application layer when a power consumer device is requesting the consumption of power beyond the typical peak power used while in the active power condition;
- c) manages power consumption grants sent to a power consumer device; and
- d) processes power consumption requests received from a power consumer device.

The processing of requests for additional consumption of power is enabled in a power source device that:

- a) sets the POWER CAPABLE field to 10b in the IDENTIFY address frame; and
- b) receives an IDENTIFY address frame with the POWER CAPABLE field set to 01b.

A power source device that sets the POWER CAPABLE field to 10b in the IDENTIFY address frame on any phy shall set the POWER CAPABLE field to 10b in the IDENTIFY address frame for all phys within that power source device.

A power source device uses PWR\_REQ, PWR\_GRANT, PWR\_DONE, and PWR\_ACK.

A power source device shall on a phy:

- a) only make requests to a SL\_P\_S state machine if the phy is enabled;
- b) exit any low phy power condition (see 4.10.1) before requesting a grant be sent to a power consumer device; and
- c) disable any enabled low phy power condition until the additional consumption of power is complete and then re-enable any low phy power condition that was disabled.

### 6.12.2 Power consumer device

A SAS target device that is capable of requesting additional consumption of power (i.e., a power consumer device):

- a) indicates support for requesting additional consumption of power by setting the POWER CAPABLE field to 01b in the IDENTIFY address frame (see 6.8.2);
- b) receives requests from the management application layer when consumption of power beyond the typical peak power used while in the active power condition is required;
- c) manages power consumption requests sent to a power source device; and
- d) processes power consumption grants received from a power source device.

The requesting of additional consumption of power is enabled in a power consumer device that:

- a) sets the POWER CAPABLE field to 01b in the IDENTIFY address frame; and
- b) receives an IDENTIFY address frame with the POWER CAPABLE field set to 10b.

A power consumer device that sets the POWER CAPABLE field to 01b in the IDENTIFY address frame on any phy shall set the POWER CAPABLE field to 01b in the IDENTIFY address frame for all phys within that power consumer device.

A power consumer device shall only request the additional consumption of power on one phy at a time.

A power consumer device uses PWR\_REQ, PWR\_GRANT, PWR\_DONE, and PWR\_ACK.

A power consumer device shall on a phy:

- a) exit any low phy power condition (see 4.10.1) before requesting consumption of power beyond the typical peak power; and
- b) disable any enabled low phy power conditions until consumption of power beyond the typical peak power is complete and then re-enable any low phy power condition that was disabled.

### 6.12.3 NOTIFY (ENABLE SPINUP) usage

A power source device may use NOTIFY (ENABLE SPINUP) to manage power on a SAS target device (see 6.2.5.3.2).

A power source device shall use NOTIFY (ENABLE SPINUP) to manage power on a SAS target device (see 6.2.5.3.2) if that power source device:

- a) is not capable of managing requests for additional consumption of power; or

- b) receives an IDENTIFY address frame with the POWER CAPABLE field set to 00b.

#### 6.12.4 SL\_P\_S (link layer power source device) state machine

##### 6.12.4.1 SL\_P\_S state machine overview

The SL\_P\_S state machine consists of the following states:

- a) SL\_P\_S\_1:Idle (see 6.12.4.3) (initial state);
- b) SL\_P\_S\_2:Wait\_Grant (see 6.12.4.4); and
- c) SL\_P\_S\_3:Wait\_Done (see 6.12.4.5).

This state machine shall start in the SL\_P\_S\_1:Idle state after power on.

This state machine receives the following requests from the management application layer:

- a) Transmit Notify;
- b) Cancel; and
- c) Power Use Granted.

This state machine sends the following confirmations to the management application layer:

- a) Additional Power Request;
- b) Power Done Timeout; and
- c) Power Use Complete.

This state machine receives the following messages from the SL\_CC link layer state machine and the XL link layer state machine:

- a) Idle State Condition (Active); and
- b) Idle State Condition (Inactive).

This state machine sends the following messages to the SL\_CC link layer state machine and the XL link layer state machine:

- a) Transmit Power Request (PWR\_ACK); and
- b) Transmit Power Request (PWR\_GRANT).

Any message, request, or confirmation received by a state that is not referred to in the description of that state shall be ignored.

This state machine shall maintain the timers listed in table 130.

**Table 130 — SL\_P\_S state machine timers**

| Timer             | Initial value                                                                                                                                                                                                                                                                      |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ACK Timeout timer | 1 ms                                                                                                                                                                                                                                                                               |
| Power Done timer  | Depending on the protocol used by the port: <ul style="list-style-type: none"> <li>a) for expander ports, the value in the POWER DONE TIMEOUT field in the SMP REPORT GENERAL function (see 9.4.3.4); and</li> <li>b) for SSP initiator ports, a vendor specific value.</li> </ul> |

Figure 126 shows the SL\_P\_S state machine.

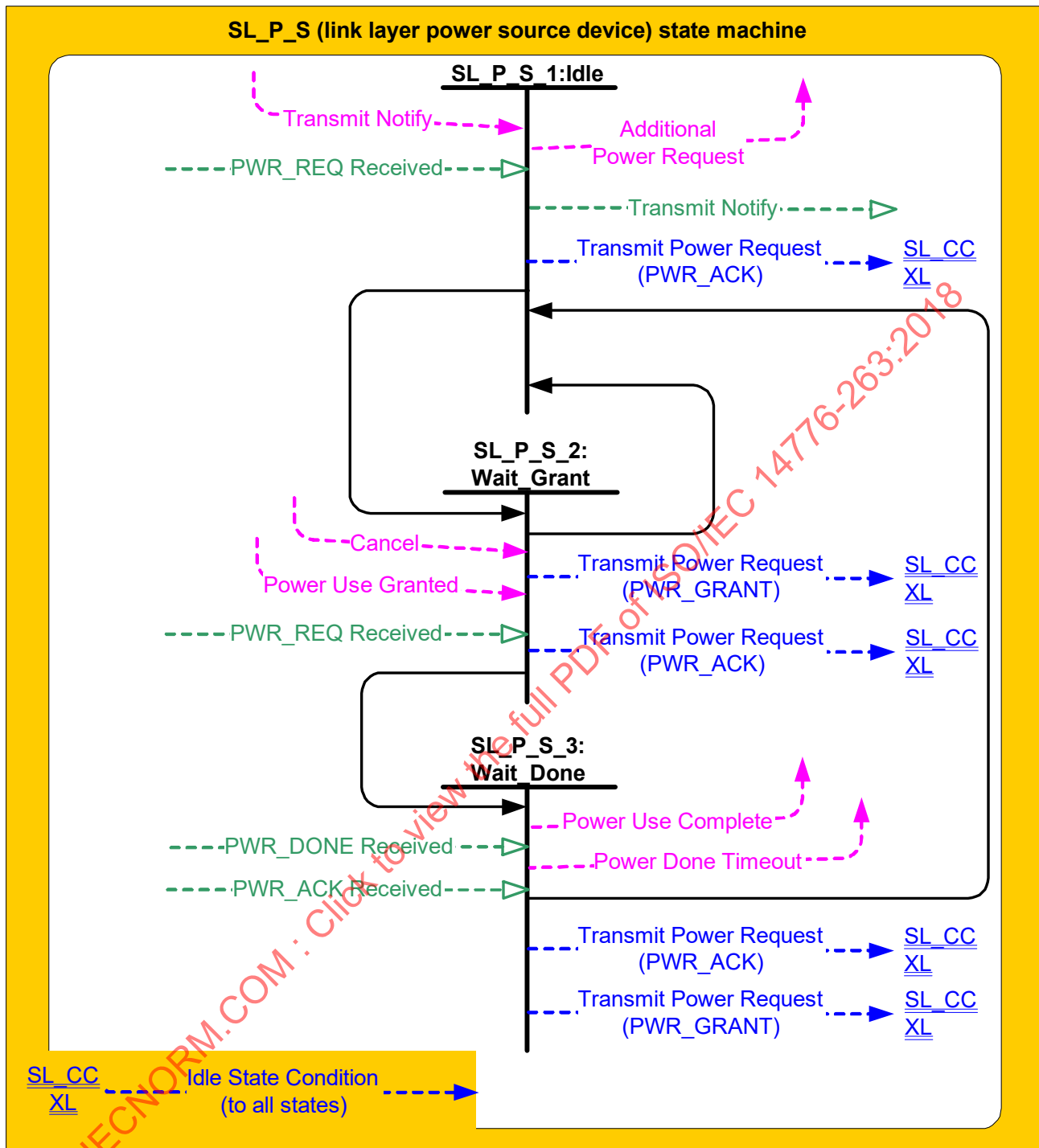


Figure 126 — SL\_P\_S (link layer power source device) state machine

#### 6.12.4.2 SL\_P\_S transmitter and SL\_P\_S receiver

The SL\_P\_S transmitter receives the following message from the SL\_P\_S state machine specifying primitive sequences to transmit:

- Transmit Notify (Enable Spinup).

The SL\_P\_S receiver sends the following messages to the SL\_P\_S state machine indicating the primitive sequence received from the SP\_DWS receiver (see 5.13.2):

- a) PWR\_REQ Received;
- b) PWR\_DONE Received; and
- c) PWR\_ACK Received.

The SL\_P\_S receiver shall ignore all other dwords.

The SL\_P\_S transmitter relationship to other transmitters is defined in 4.3.2. The SL\_P\_S receiver relationship to other receivers is defined in 4.3.3.

#### 6.12.4.3 SL\_P\_S\_1:Idle state

##### 6.12.4.3.1 State description

If this state receives a Transmit Notify request, then this state shall send a Transmit Notify (Enable Spinup) message to the SL\_P\_S transmitter.

If this state receives a PWR\_REQ Received message and the last Idle State Condition message received contained an Active argument, then this state shall send:

- a) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state or XL0:Idle state; and
- b) an Additional Power Request confirmation to the management application layer.

If this state receives a PWR\_REQ Received message and the last Idle State Condition message received contained an Inactive argument, then this state shall:

- 1) wait until receiving an Idle State Condition (Active) message; and
- 2) send:
  - A) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state or XL0:Idle state; and
  - B) an Additional Power Request confirmation to the management application layer.

##### 6.12.4.3.2 Transition SL\_P\_S\_1:Idle to SL\_P\_S\_2:Wait\_Grant

This transition shall occur after sending:

- a) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state or XL0:Idle state; and
- b) an Additional Power Request confirmation to the management application layer.

#### 6.12.4.4 SL\_P\_S\_2:Wait\_Grant state

##### 6.12.4.4.1 State description

This state waits for a Power Use Granted request from the management application layer.

If this state receives a Power Use Granted request and the last Idle State Condition message received contained an Active argument, then this state shall send a Transmit Power Request (PWR\_GRANT) message to the SL\_CC0:Idle state or XL0:Idle state.

If this state receives a Power Use Granted request and the last Idle State Condition message received contained an Inactive argument, then this state shall:

- 1) wait until receiving an Idle State Condition (Active) message; and
- 2) send a Transmit Power Request (PWR\_GRANT) message to the SL\_CC0:Idle state or XL0:Idle state.

If this state receives a PWR\_REQ Received message and the last Idle State Condition message received contained an Active argument, then this state shall send a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state or XL0:Idle state.

If this state receives a PWR\_REQ Received message and the last Idle State Condition message received contained an Inactive argument, then this state shall:

- 1) wait until receiving an Idle State Condition (Active) message; and

- 2) send a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state or XL0:Idle state.

#### 6.12.4.4.2 Transition SL\_P\_S\_2:Wait\_Grant to SL\_P\_S\_1:Idle

This transition shall occur:

- a) after receiving a Cancel request.

#### 6.12.4.4.3 Transition SL\_P\_S\_2:Wait\_Grant to SL\_P\_S\_3:Wait\_Done

This transition shall occur:

- a) after sending a Transmit Power Request (PWR\_GRANT) message to the SL\_CC0:Idle state or XL0:Idle state.

#### 6.12.4.5 SL\_P\_S\_3:Wait\_Done state

##### 6.12.4.5.1 State description

This state waits for the power consumer device to indicate the use of additional power consumption is complete.

On entry this state shall:

- a) initialize and start the Power Done timer; and
- b) initialize and start the ACK Timeout timer.

If this state receives a PWR\_ACK Received message, then this state shall stop the ACK Timeout timer.

If the ACK Timeout timer expires, and the last Idle State Condition message received contained an Active argument then this state shall:

- a) send a Transmit Power Request (PWR\_GRANT) message to the SL\_CC0:Idle state or XL0:Idle state; and
- b) initialize and start the ACK Timeout timer.

If the ACK Timeout timer expires, and the last Idle State Condition message received contained an Inactive argument then this state shall:

- 1) wait until receiving an Idle State Condition (Active) message;
- 2) send a Transmit Power Request (PWR\_GRANT) message to the SL\_CC0:Idle state or XL0:Idle state; and
- 3) initialize and start the ACK Timeout timer.

If this state receives a PWR\_DONE Received message and the last Idle State Condition message received contained an Active argument, then this state shall:

- a) send a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state or XL0:Idle state; and
- b) send a Power Use Complete confirmation to the management application layer.

If this state receives a PWR\_DONE Received message and the last Idle State Condition message received contained an Inactive argument, then this state shall:

- 1) wait until receiving an Idle State Condition (Active) message; and
- 2) send:
  - A) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state or XL0:Idle state; and
  - B) a Power Use Complete confirmation to the management application layer.

If the Power Done timer expires, then this state shall send a Power Done Timeout confirmation to the management application layer.

#### 6.12.4.5.2 Transition SL\_P\_S\_3:Wait\_Done to SL\_P\_S\_1:Idle

This transition shall occur after sending:

- a) a Power Done Timeout confirmation to the management application layer; or
- b) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state or XL0:Idle state and sending a Power Use Complete confirmation to the management application layer.

#### 6.12.5 SL\_P\_C (link layer power consumer device) state machine

##### 6.12.5.1 SL\_P\_C state machine overview

The SL\_P\_C state machine consists of the following states:

- a) SL\_P\_C\_1:Idle (see 6.12.5.3) (initial state);
- b) SL\_P\_C\_2:Request\_Power (see 6.12.5.4);
- c) SL\_P\_C\_3:Wait\_Grant (see 6.12.5.5); and
- d) SL\_P\_C\_4:Wait\_Done (see 6.12.5.6).

This state machine shall start in the SL\_P\_C\_1:Idle state after power on.

This state machine receives the following requests from the SA\_PC SCSI application layer state machine:

- a) Request Additional Power; and
- b) Power Use Complete.

This state machine sends the following confirmations to the SA\_PC SCSI application layer state machine:

- a) Power Use Granted; and
- b) Power Request Failed.

This state machine receives the following confirmations from the SL\_IR\_IRC link layer state machine:

- a) Phy Enabled; and
- b) Phy Disabled.

This state machine receives the following messages from the SL\_CC link layer state machine:

- a) Idle State Condition (Active); and
- b) Idle State Condition (Inactive).

This state machine sends the following messages to the SL\_CC link layer state machine:

- a) Transmit Power Request (PWR\_ACK);
- b) Transmit Power Request (PWR\_REQ); and
- c) Transmit Power Request (PWR\_DONE).

Any message, request, or confirmation received by a state that is not referred to in the description of that state shall be ignored.

This state machine shall maintain the timers listed in table 131.

**Table 131 — SL\_P\_C state machine timers**

| Timer             | Initial value                                                                                 |
|-------------------|-----------------------------------------------------------------------------------------------|
| ACK Timeout timer | 1 ms                                                                                          |
| Power Grant timer | The value in the POWER GRANT TIMEOUT field in the Shared Port Control mode page (see 9.2.7.6) |

Figure 127 shows the SL\_P\_C state machine.

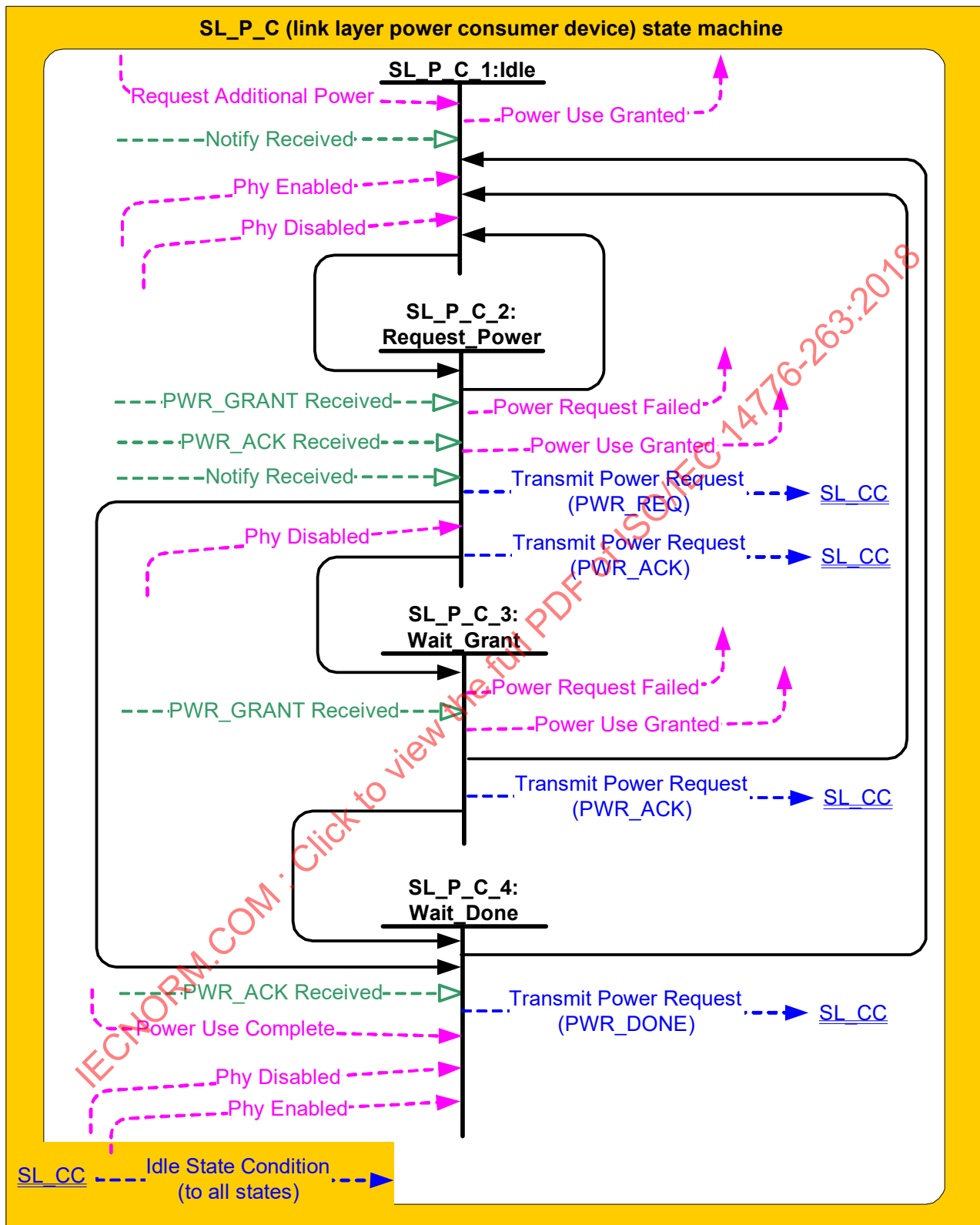


Figure 127 — SL\_P\_C (link layer power consumer device) state machine

### 6.12.5.2 SL\_P\_C receiver

The SL\_P\_C receiver sends the following messages to the SL\_P\_C state machine indicating the primitive sequence received from the SP\_DWS receiver (see 5.13.2):

- a) NOTIFY Received (Enable Spinup);
- b) PWR\_GRANT Received; and
- c) PWR\_ACK Received.

The SL\_P\_C receiver shall ignore all other dwords.

The SL\_P\_C receiver relationship to other receivers is defined in 4.3.3.

### 6.12.5.3 SL\_P\_C\_1:Idle state

#### 6.12.5.3.1 State description

If this state receives a Notify Received (Enable Spinup) message, then this state shall send a Power Use Granted confirmation to the SA\_PC state machine (see 9.2.10.2).

In this state, the phy is enabled:

- a) if no Phy Disabled confirmation has been received since this state is entered; or
- b) if a Phy Enable confirmation has been received after the last Phy Disabled confirmation was received.

In this state, the phy is disabled:

- a) if no Phy Enabled confirmation has been received since this state is entered with a Phy Disabled argument; or
- b) a Phy Disabled confirmation is received without a subsequent Phy Enabled confirmation.

In this state, requesting power is enabled when:

- a) the phy is enabled; and
- b) the last Idle State Condition message received contained an Active argument.

#### 6.12.5.3.2 Transition SL\_P\_C\_1:Idle to SL\_P\_C\_2:Request\_Power

If requesting power is enabled, then this transition shall occur:

- a) after receiving a Request Additional Power request.

If requesting power is disabled, then this transition shall occur after:

- a) requesting power is enabled; and
- b) receiving a Request Additional Power request.

### 6.12.5.4 SL\_P\_C\_2:Request\_Power state

#### 6.12.5.4.1 State description

On entry this state shall:

- a) send a Transmit Power Request (PWR\_REQ) message to the SL\_CC0:Idle state; and
- b) initialize and start the ACK Timeout timer.

If this state receives a Notify Received (Enable Spinup) message, then this state shall send a Power Use Granted confirmation to the SA\_PC state machine (see 9.2.10.2).

If this state receives a PWR\_GRANT Received message and the last Idle State Condition message received contained an Active argument, then this state shall send:

- a) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state; and
- b) a Power Use Granted confirmation to the SA\_PC state machine (see 9.2.10.2).



If this state receives a PWR\_GRANT Received message and the last Idle State Condition message received contained an Inactive argument, then this state shall:

- 1) wait until receiving an Idle State Condition (Active) message; and
- 2) send:
  - A) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state; and
  - B) a Power Use Granted confirmation to the SA\_PC state machine (see 9.2.10.2).

If the ACK Timeout timer expires, then this state shall send a Power Request Failed (ACK Timeout) confirmation to the SA\_PC state machine (see 9.2.10.2).

If this state receives a Phy Disabled confirmation, then this state shall send a Power Request Failed (Phy Disabled) confirmation to the SA\_PC state machine (see 9.2.10.2).

#### 6.12.5.4.2 Transition SL\_P\_C\_2:Request\_Power to SL\_P\_C\_1:Idle

This transition shall occur after sending:

- a) a Power Request Failed confirmation to the SA\_PC state machine; or
- b) a Power Use Granted confirmation to the SA\_PC state machine that resulted from the receipt Notify Received (Enable Spinup) message.

If a Phy Disabled confirmation is the cause of this transition, then this transition shall include a Phy Disabled argument.

#### 6.12.5.4.3 Transition SL\_P\_C\_2:Request\_Power to SL\_P\_C\_3:Wait\_Grant

This transition shall occur:

- a) after receiving a PWR\_ACK Received message.

#### 6.12.5.4.4 Transition SL\_P\_C\_2:Request\_Power to SL\_P\_C\_4:Wait\_Done

This transition shall occur after sending:

- a) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state; and
- b) a Power Use Granted confirmation to the SA\_PC state machine (see 9.2.10.2).

#### 6.12.5.5 SL\_P\_C\_3:Wait\_Grant state

##### 6.12.5.5.1 State description

This state waits for the power source device to allow additional consumption of power.

On entry this state shall initialize and start the Power Grant timer.

If this state receives a PWR\_GRANT Received message and the last Idle State Condition message received contained an Active argument, then this state shall:

- a) send a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state; and
- b) send a Power Use Granted confirmation to the SA\_PC state machine (see 9.2.10.2).

If this state receives a PWR\_GRANT Received message and the last Idle State Condition message received contained an Inactive argument, then this state shall:

- 1) wait until receiving an Idle State Condition (Active) message; and
- 2) send:
  - A) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state; and
  - B) a Power Use Granted confirmation to the SA\_PC state machine (see 9.2.10.2).

If the Power Grant timer expires, then this state shall send a Power Request Failed (Grant timeout) confirmation to the SA\_PC state machine (see 9.2.10.2).

**6.12.5.5.2 Transition SL\_P\_C\_3:Wait\_Grant to SL\_P\_C\_1:Idle**

This transition shall occur:

- a) after sending a Power Request Failed confirmation to the SA\_PC state machine (see 9.2.10.2).

**6.12.5.5.3 Transition SL\_P\_C\_3:Wait\_Grant to SL\_P\_C\_4:Wait\_Done**

This transition shall occur after sending:

- a) a Transmit Power Request (PWR\_ACK) message to the SL\_CC0:Idle state; and
- b) a Power Use Granted confirmation to the SA\_PC state machine (see 9.2.10.2).

**6.12.5.6 SL\_P\_C\_4:Wait\_Done state****6.12.5.6.1 State description**

This state waits for the management application layer to indicate that it no longer requires additional consumption of power.

In this state the phy is enabled:

- a) if no Phy Disabled confirmation has been received since this state is entered; or
- b) if a Phy Enable confirmation has been received after the last Phy Disabled confirmation was received.

If this state:

- a) receives a Power Use Complete request;
- b) the phy is enabled; and
- c) the last Idle State Condition received contained an Active argument,

then this state shall send a Transmit Power Request (PWR\_DONE) message to the SL\_CC0:Idle state.

If this state receives a Power Use Complete request and either phy is not enabled or the last Idle State Condition received contained an Inactive argument, then this state shall:

- 1) wait until:
  - A) receiving an Idle State (Active) message; and
  - B) the phy is enabled;and
- 2) send a Transmit Power Request (PWR\_DONE) message to the SL\_CC0:Idle state.

If this state sends a Transmit Power Request (PWR\_DONE) message to the SL\_CC0:Idle state, then this state shall initialize and start the ACK Timeout timer.

If the ACK Timeout timer expires, then this state shall, at least one time:

- 1) send a Transmit Power Request (PWR\_DONE) message to the SL\_CC0:Idle state after:
  - A) the phy is enabled; and
  - B) the last Idle State Condition message received contains an Active argument;and
- 2) initialize and start the ACK Timeout timer.

The number of times this state waits for an acknowledgement from the power source device is vendor specific.

**6.12.5.6.2 Transition SL\_P\_C\_4:Wait\_Done to SL\_P\_C\_1:Idle**

This transition shall occur after:

- a) the vendor specific number of failed attempts to receive a PWR\_ACK Received message; or
- b) receiving a PWR\_ACK Received message.

### 6.13 SAS domain changes (Broadcast (Change) usage)

An expander device shall originate Broadcast (Change) from at least one phy in each of its expander ports other than the expander port that is the cause for originating Broadcast (Change).

Expander devices shall originate Broadcast (Change) for the following expander phy-related reasons:

- a) after an expander phy's SP state machine transitions from the SP15:SAS\_PHY\_Ready state, SP22:SATA\_PHY\_Ready state, SP31:SAS\_PS\_Low\_Phy\_Power state, SP32:SAS\_PS\_ALIGN0 state, or SP33:SAS\_PS\_ALIGN1 state to the SP0:OoB\_COMINIT state (see 5.12);

NOTE 27 - This occurs when the expander phy is reset or disabled with the SMP PHY CONTROL function DISABLE, LINK RESET, HARD RESET, or TRANSMIT SATA PORT SELECTION SIGNAL phy operations (see 9.4.3.28) as well as when dword synchronization is lost for any other reason.

- b) after an expander phy's SP state machine reaches the SP26:SATA\_SpinupHold state and sends a SATA Spinup Hold confirmation as defined in 5.12.8 and 5.16;
- c) after an expander phy's SP state machine sends a SATA Port Selector change confirmation to the link layer (see 5.12.3);
- d) after an expander phy completes the link reset sequence (see 6.9);
- e) after a virtual phy has been enabled or completed processing a reset requested by the SMP PHY CONTROL function LINK RESET or HARD RESET phy operations (see 9.4.3.28); and
- f) after an STP SATA bridge receives an initial Register - Device to host FIS (see 8.3.1).

In zoning expander devices with zoning enabled, forwarding Broadcasts is subject to restrictions defined in 4.8.5.

In zoning expander devices with zoning enabled, a Broadcast (Change) for an expander phy-related reason shall be originated from the source zone group of the expander phy causing the Broadcast (Change) or from zone group 1.

Expander devices shall originate Broadcast (Change) for the following expander device-related reasons:

- a) after a self-configuring expander device has changed its SELF CONFIGURING bit from one to zero in the SMP REPORT GENERAL response (see 9.4.3.4) as described in 4.6.4. In zoning expander devices with zoning enabled, the source zone group shall be 01h; and
- b) after a locked expander device is unlocked (i.e., a zoning expander device has changed its ZONE CONFIGURING bit from one to zero in the SMP REPORT GENERAL response) (see 4.8.6.5, 4.8.6.6, and 9.4.3.23), with the source zone group as specified in 4.8.6.5, 4.8.6.6, and 9.4.3.23.

Expander devices shall forward Broadcast (Change) after an expander phy receives Broadcast (Change).

For a virtual phy, if there is any time after a reset is originated during which connection requests to the attached SAS address result in connection responses of OPEN\_REJECT (NO DESTINATION), then the expander device shall originate the Broadcast (Change) twice, once at the start of the reset (i.e., when the SAS address becomes unavailable) and once at its completion (i.e., when the SAS address becomes available). If there is no such time window, then the expander device shall originate the Broadcast (Change) once.

SAS initiator ports may originate Broadcast (Change) to force other SAS initiator ports and expander ports to re-run the discover process. SAS target ports should not originate Broadcast (Change).

See 9.4.3.4 for details on counting Broadcast (Change) origination in an expander device.

## 6.14 Connections

### 6.14.1 Connections overview

A connection is opened between a SAS initiator port and a SAS target port before communication begins. A connection is established between one SAS initiator phy in the SAS initiator port and one SAS target phy in the SAS target port.

SSP initiator ports open SSP connections to transmit SCSI commands, task management functions, and transfer write data. SSP target ports open SSP connections to transfer read data, request write data, and transmit service responses.

SMP initiator ports open SMP connections to transmit SMP requests and receive SMP responses.

STP initiator ports and STP target ports open STP connections to transmit SATA frames. An STP target port in an expander device opens STP connections on behalf of SATA devices.

The OPEN address frame is used to request that a connection be opened (see 6.14.2.1). AIP primitive sequences, OPEN\_ACCEPT, and OPEN\_REJECT are the responses to an OPEN address frame (see 6.14.2.2). A BREAK primitive sequence is used to abort connection requests (see 6.14.6) and to break a connection (see 6.14.9). A CLOSE primitive sequence is used for orderly closing of a connection (see 6.14.8).

Connections use a single pathway from the SAS initiator phy to the SAS target phy. While a connection is open, only one pathway shall be used for that connection.

For STP connections, connections may be between the STP initiator port and an STP target port of an STP SATA bridge in an expander device. The SATA device behind the STP SATA bridge is not aware of SAS connection management.

A wide port may have separate connections on each of its logical phys.

### 6.14.2 Opening a connection

#### 6.14.2.1 Connection request

The OPEN address frame (see 6.8.3) is used to open a connection from a source port to a destination port using one source phy (i.e., one logical phy in the source port) and one destination phy (i.e., one logical phy in the destination port).

To make a connection request, the source port shall transmit an OPEN address frame through an available logical phy (i.e., the source phy). The source phy shall transmit idle dwords after the OPEN address frame until it receives a response or aborts the connection request with a BREAK primitive sequence.

After transmitting an OPEN address frame, the source phy shall initialize and start a 1 ms Open Timeout timer. Whenever an AIP is received, the source phy shall reinitialize and restart the Open Timeout timer. Source phys are not required to enforce a limit on the number of AIPs received before aborting the connection request. When any connection response is received, the source phy shall reinitialize the Open Timeout timer. If the Open Timeout timer expires before a connection response is received, then the source phy shall transmit a BREAK primitive sequence to abort the connection request (see 6.14.6).

The OPEN address frame flows through expander devices onto intermediate logical links. If an expander device on the pathway is unable to forward the connection request, then that expander device returns OPEN\_REJECT (see 6.14.4). If the OPEN address frame reaches the destination phy, then the destination phy returns either OPEN\_ACCEPT or OPEN\_REJECT unless the OPEN address frame passed an OPEN address frame from the destination phy with higher arbitration priority (see 6.14.3). Rate matching shall be used on any logical links in the pathway with negotiated logical link rates that are faster than the requested connection rate (see 6.15).

A wide port should not attempt to establish more connections to a destination port than the number of phys in the destination port or the number of phys in the narrowest logical link on the pathway to the destination port. A wide port should not attempt to establish more connections than the number of phys in the narrowest common logical link on the pathways to the destination ports of those connections. Additional requirements for

STP connection requests are defined in 6.19.5. Additional requirements for SMP connection requests are defined in 6.20.3.

Figure 128 shows an example of the simultaneous connection recommendations for wide ports. Multiplexing is disabled in this example.

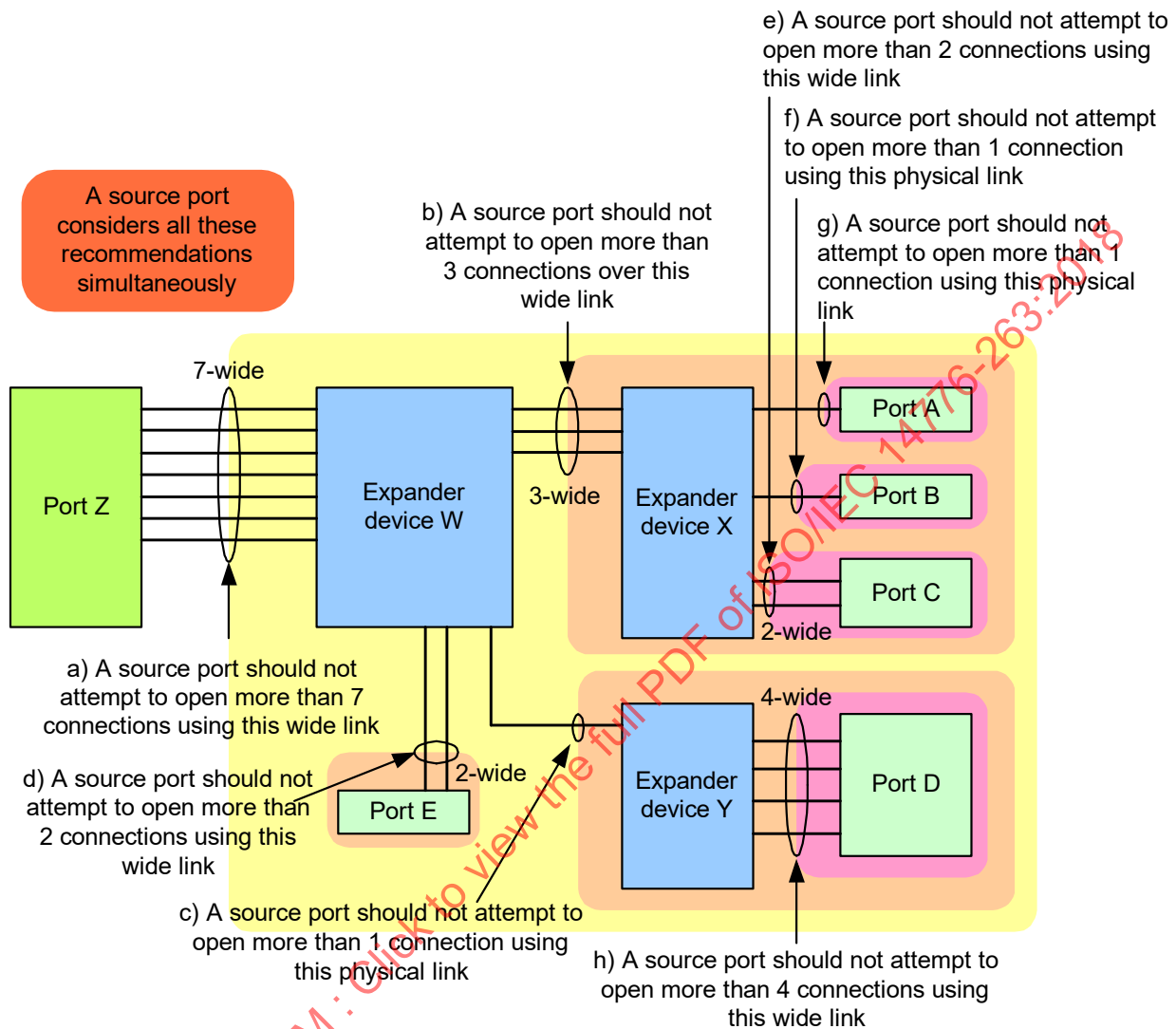


**Figure 128 — Example simultaneous connection recommendations for wide ports**

In figure 128, some of the recommendations are combined as follows:

- recommendations a), b), and e) together specify that port Z should not attempt to open more than two connections to port C;
- recommendations a), b), e), f), and g) together specify that if port Z has two connections open to ports A, B, or X, it should not attempt to open more than one connection to port C. If port Z has six connections open to ports A, B, D, E, W, X, and Y, then port Z should not attempt to open more than one connection to port C; and
- recommendations a), c), and h) together specify that port Z should not attempt to open more than one connection to port D. If port Z has a connection open to port Y, then port Z should not attempt to open another connection to port D until the first connection is closed.

### 6.14.2.2 Results of a connection request

After a logical phy transmits an OPEN address frame, it shall expect one or more of the results listed in table 132.

**Table 132 — Connection results of a connection request**

| Result                     | Description                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Receive AIP                | Arbitration in progress. While an expander device is trying to open a connection to the selected destination port (e.g., while it is internally arbitrating for access to an expander port), the expander device returns an AIP to the source phy. The source phy shall reinitialize and restart its Open Timeout timer each time the source phy receives an AIP. |
| Receive OPEN_ACCEPT        | Connection request accepted. OPEN_ACCEPT is transmitted by the destination phy.                                                                                                                                                                                                                                                                                   |
| Receive OPEN_REJECT        | Connection request rejected. OPEN_REJECT is transmitted by the destination phy or by an expander device in the partial pathway. The different versions are described in 6.2.6.10. See 4.4.3 for I_T nexus loss handling. See 6.8.3 for handling of OPEN_REJECT (CONNECTION RATE NOT SUPPORTED) for connection rates greater than 1.5 Gbit/s.                      |
| Receive OPEN address frame | If AIP has been received, then this indicates an overriding connection request.<br><br>If AIP has not yet been received, then this indicates two connection requests crossing on the logical link. Arbitration fairness determines which one wins (see 6.14.3).                                                                                                   |
| Receive BREAK              | The destination phy or an expander device in the partial pathway may reply with a BREAK primitive sequence indicating the connection is not being established. See 4.4.3 for I_T nexus loss handling.                                                                                                                                                             |
| Open Timeout timer expires | The source phy shall abort the connection request by transmitting a BREAK primitive sequence (see 6.14.6). See 4.4.3 for I_T nexus loss handling.                                                                                                                                                                                                                 |

### 6.14.3 Arbitration fairness

SAS supports least-recently used arbitration fairness for connection requests.

Each SAS port and expander port shall include an Arbitration Wait Time timer that counts the time from the moment when the port makes a connection request until the request is accepted or rejected. The Arbitration Wait Time timer is in the port layer state machine (see 7.2.2). The Arbitration Wait Time timer shall count in microseconds from 0  $\mu$ s to 32 767  $\mu$ s and in milliseconds from 32 768  $\mu$ s to 32 767 ms + 32 768  $\mu$ s. The Arbitration Wait Time timer shall stop incrementing when its value reaches 32 767 ms + 32 768  $\mu$ s.

A SAS port (i.e., a SAS initiator port or a SAS target port) shall start the Arbitration Wait Time timer when it transmits the first OPEN address frame (see 6.8.3) for the connection request. When the SAS port retransmits the OPEN address frame (e.g., after losing arbitration and handling an inbound OPEN address frame), it shall set the ARBITRATION WAIT TIME field to the current value of the Arbitration Wait Time timer.

A SAS port should set the Arbitration Wait Time timer to zero when it transmits the first OPEN address frame for the connection request. A SAS initiator port or SAS target port may be unfair by setting the ARBITRATION WAIT TIME field in the OPEN address frame (see 6.8.3) to a higher value than its Arbitration Wait Time timer indicates. However, an unfair SAS port shall not set the ARBITRATION WAIT TIME field to a value greater than or equal to 8000h.



The expander port that receives an OPEN address frame shall set the Arbitration Wait Time timer to the value of the incoming ARBITRATION WAIT TIME field and start the Arbitration Wait Time timer as the expander port arbitrates for internal access to the outgoing expander port. When the expander device transmits the OPEN address frame out another expander port, it shall set the outgoing ARBITRATION WAIT TIME field to the current value of the Arbitration Wait Time timer maintained by the incoming expander port.

A SAS port shall stop the Arbitration Wait Time timer and set the Arbitration Wait Time timer to zero when the SAS port has no more frames to send.

A SAS port shall stop the Arbitration Wait Time timer and set the Arbitration Wait Time timer to zero when the SAS port receives one of the following connection responses:

- a) OPEN\_ACCEPT;
- b) OPEN\_REJECT (PROTOCOL NOT SUPPORTED);
- c) OPEN\_REJECT (ZONE VIOLATION);
- d) OPEN\_REJECT (RESERVED ABANDON 1);
- e) OPEN\_REJECT (RESERVED ABANDON 2);
- f) OPEN\_REJECT (RESERVED ABANDON 3);
- g) OPEN\_REJECT (STP RESOURCES BUSY); or
- h) OPEN\_REJECT (WRONG DESTINATION).

When an OPEN\_REJECT (RETRY), OPEN\_REJECT (RESERVED CONTINUE 0), or OPEN\_REJECT (RESERVED CONTINUE 1) is received:

- a) if the CONTINUE AWT bit is set to one in the Protocol Specific Port mode page (see 9.2.7.4), then a connection response of OPEN\_REJECT (RETRY), OPEN\_REJECT (RESERVED CONTINUE 0), or OPEN\_REJECT (RESERVED CONTINUE 1) shall not stop the Arbitration Wait Time timer and shall not set the Arbitration Wait Time timer to zero; or
- b) If the CONTINUE AWT bit is set to zero, then a SAS port shall stop the Arbitration Wait Time timer and set the Arbitration Wait Time timer to zero.

A SAS port should not stop the Arbitration Wait Time timer and set the Arbitration Wait Time timer to zero when the SAS port receives an incoming OPEN address frame that has priority over the outgoing OPEN address frame according to table 133, regardless of whether the SAS port replies with an OPEN\_ACCEPT or an OPEN\_REJECT.

When arbitrating for access to an outgoing expander port, the expander device shall select the connection request based on the rules described in 6.14.4.

If two connection requests pass on a logical link, then the logical phy shall determine the winner by comparing OPEN address frame field contents using the arbitration priority described in table 133.

**Table 133 — Arbitration priority for OPEN address frames passing on a logical link**

| Bits 79 to 64 (79 is MSB)         | Bits 63 to 0 (0 is LSB)        |
|-----------------------------------|--------------------------------|
| ARBITRATION WAIT TIME field value | SOURCE SAS ADDRESS field value |

See 6.8.3 for details on the OPEN address frame and the ARBITRATION WAIT TIME field.

#### 6.14.4 Arbitration inside an expander device

##### 6.14.4.1 Expander logical phy arbitration requirements

An expander logical phy shall set its Request Path request High Priority argument to one when the expander logical phy requests a path after:

- a) the expander logical phy has forwarded an OPEN address frame to the logical link;

- b) the expander logical phy receives an OPEN address frame with higher arbitration priority (see 6.14.3); and
- c) the destination SAS address and connection rate of the received OPEN address frame are not equal to the source SAS address and connection rate of the transmitted OPEN address frame (see 6.17.4 and 6.17.9).

Otherwise, the expander logical phy shall set the High Priority argument to zero.

See the XL state machine (see 6.17) for detailed expander logical phy requirements.

#### 6.14.4.2 ECM arbitration requirements

##### 6.14.4.2.1 ECM arbitration requirements overview

The ECM shall arbitrate and assign or deny path resources for Request Path requests (see 4.5.6.3) from each expander logical phy.

Arbitration includes adherence to the SAS arbitration fairness algorithm and path recovery. Path recovery is used to avoid potential deadlock scenarios within the SAS topology by deterministically choosing which partial pathway(s) to tear down to allow at least one connection to complete.

The ECM shall maintain an Arbitration Wait Time state machine variable for each Request Path request that the ECM is processing. The ECM shall initialize the Arbitration Wait Time state machine variable to the Arbitration Wait Time argument upon receiving the Request Path request and shall repeatedly increment the Arbitration Wait Time state machine variable until the ECM completes responding to the Request Path request.

The Source SAS Address argument, and Connection Rate argument are filled in from the received OPEN address frame and are used with the High Priority argument and the Arbitration Wait Time state machine variable by the ECM to compare Request Path requests. The High Priority argument is used to increase the priority of a Request Path request after a Backoff Retry response is sent by an expander logical phy (see 6.17.4).

When the ECM in an expander device receives a connection request:

- 1) if the destination SAS address is that of the expander device itself, then the ECM shall arbitrate for access to its SMP target port;
- 2) if the destination SAS address matches the SAS address attached to one or more of the expander logical phys, then the ECM shall arbitrate for access to those expander logical phys;
- 3) if the destination SAS address matches an enabled SAS address in the expander route table for one or more expander logical phys that is using the table routing method, then the ECM shall arbitrate for access to those expander logical phys; and
- 4) if at least one expander logical phy is using the subtractive routing method and the request did not come from one of those expander logical phys, then the ECM shall arbitrate for access to one of those expander logical phys.

The ECM shall respond to each Request Path request by returning the following confirmations to the requesting expander logical phy while processing the Request Path request:

- a) Arbitrating (Normal) (see 6.14.4.2.2);
- b) Arbitrating (Waiting On Partial) (see 6.14.4.2.2);
- c) Arbitrating (Blocked On Partial) (see 6.14.4.2.2); and
- d) Arbitrating (Waiting On Connection) (see 6.14.4.2.2).

The ECM shall complete responding to each Request Path request by returning one of the following confirmations to the requesting expander logical phy:

- a) Arb Won (see 6.14.4.2.3);
- b) Arb Lost (see 6.14.4.2.4); or
- c) Arb Reject (see 6.14.4.2.5).



If the ECM receives an Idle request from a phy that is involved in a connection before it has received a Forward Close request from that phy and sent a Forward Close indication to that phy, then the ECM shall send a Forward Break indication to the destination phy.

#### 6.14.4.2.2 Arbitrating confirmations

The ECM shall send an Arbitrating (Normal) confirmation after it has received a Request Path request.

The ECM shall send an Arbitrating (Waiting On Partial) confirmation if it is waiting on a partial pathway (see 4.1.11). The ECM is waiting on a partial pathway if:

- a) there is a destination port capable of routing to the requested destination SAS address;
- b) at least one expander logical phy within the destination port supports the requested connection rate;
- c) each of the expander logical phys within the destination port is returning a Phy Status (Partial Pathway) or Phy Status (Blocked Partial Pathway) response; and
- d) at least one of the expander logical phys within the destination port is returning a Phy Status (Partial Pathway) response.

The ECM shall send an Arbitrating (Blocked On Partial) confirmation if it is waiting on a blocked partial pathway (see 4.1.11). The ECM is waiting on a blocked partial pathway if:

- a) there is a destination port capable of routing to the requested destination SAS address;
- b) at least one expander logical phy within the destination port supports the requested connection rate; and
- c) each of the expander logical phys within the destination port is returning a Phy Status (Blocked Partial Pathway) response.

The ECM shall send an Arbitrating (Waiting On Connection) confirmation if it is waiting on a connection to complete (see 4.1.12). The ECM is waiting on a connection to complete if:

- a) the connection request is blocked by an active connection; or
- b) there are insufficient routing resources within the expander to complete the connection request.

A connection request shall be considered blocked by an active connection when:

- a) there is a destination port capable of routing to the requested destination SAS address;
- b) at least one expander logical phy within the destination port supports the requested connection rate;
- c) each of the expander logical phys within the destination port is returning a Phy Status (Partial Pathway) response, a Phy Status (Blocked Partial Pathway) response, a Phy Status (Breaking Connection) response, or a Phy Status (Connection) response; and
- d) at least one of the expander logical phys within the destination port is returning a Phy Status (Connection) response.

#### 6.14.4.2.3 Arb Won confirmation

The ECM shall generate the Arb Won confirmation when all of the following conditions are met:

- a) the Request Path request maps to a destination expander logical phy that:
  - A) supports the connection rate; and
  - B) is not reporting a Phy Status (Partial Pathway) response, a Phy Status (Blocked Partial Pathway) response, a Phy Status (Breaking Connection) response, or a Phy Status (Connection) response unless that expander logical phy is arbitrating for the requesting expander logical phy;
- b) there are sufficient routing resources to complete the connection request;
- c) no higher priority Request Path requests are present with the requesting expander logical phy as the destination; and
- d) the Request Path request is the highest priority Request Path request (see table 134) mapping to the destination expander logical phy (i.e., only send one Arb Won confirmation for Request Path requests to the same destination phy).

If two or more Request Path requests contend, then the ECM shall select the request with the highest arbitration priority. The arbitration priority for a Request Path request (see table 134) consists of the following:

- a) High Priority argument;
- b) SMP Open Priority argument;
- c) Arbitration Wait Time state machine variable;
- d) Source SAS Address argument; and
- e) Connection Rate argument.

**Table 134 — Arbitration priority for a Request Path request in the ECM**

| Bit 85 (85 is MSB)     | Bit 84                     | Bits 83 to 68                                | Bits 67 to 4                | Bits 3 to 0 (0 is LSB)   |
|------------------------|----------------------------|----------------------------------------------|-----------------------------|--------------------------|
| High Priority argument | SMP Open Priority argument | Arbitration Wait Time state machine variable | Source SAS Address argument | Connection Rate argument |

#### 6.14.4.2.4 Arb Lost confirmation

The ECM shall generate the Arb Lost confirmation when all of the following conditions are met:

- a) the Request Path request maps to a destination expander logical phy that:
  - A) supports the connection rate; and
  - B) is not reporting a Phy Status (Partial Pathway) response, a Phy Status (Blocked Partial Pathway) response, a Phy Status (Breaking Connection) response, or a Phy Status (Connection) response unless that expander logical phy is arbitrating for the requesting expander logical phy;
- b) there are sufficient routing resources to complete the connection request; and
- c) one of the following conditions are met:
  - A) the destination expander logical phy is making a Request Path request with the requesting expander logical phy as its destination (i.e., when two expander logical phys both receive an OPEN address frame destined for each other, the ECM provides the Arb Lost confirmation to the expander logical phy that received the lowest priority OPEN address frame); or
  - B) the ECM is sending an Arb Won confirmation to another expander logical phy that is using the requesting expander logical phy as the destination.

#### 6.14.4.2.5 Arb Reject confirmation

The ECM shall generate one of the following Arb Reject confirmations when any of the following conditions are met and all the Arb Won conditions (see 6.14.4.2.3) are not met:

- 1) an Arb Reject (Bad Destination) confirmation if the source expander logical phy and destination expander logical phy(s) are in the same expander port and are using the direct routing method;
- 2) an Arb Reject (Retry) confirmation if the expander device is unable to process the connection request because it has reduced functionality (see 4.5.8);
- 3) if the source expander logical phy and destination expander logical phy(s) are in the same expander port and are using the table routing method or the subtractive routing method, then:
  - A) an Arb Reject (No Destination) confirmation if the expander device is not configuring (see 4.6.4); or
  - B) an Arb Reject (Retry) confirmation if the expander device is configuring;
- 4) if there are no destination expander logical phys (i.e., there is no direct routing or table routing match and there is no subtractive phy), then:
  - A) an Arb Reject (No Destination) confirmation if the expander device is not configuring; or
  - B) an Arb Reject (Retry) confirmation if the expander device is configuring;
- 5) if access to the destination expander logical phy(s) is prohibited by zoning (see 4.8.3), then:
  - A) an Arb Reject (Zone Violation) confirmation if the zoning expander device is unlocked; or
  - B) an Arb Reject (Retry) confirmation if the zoning expander device is locked;

- 6) an Arb Reject (Connection Rate Not Supported) confirmation if none of the destination expander logical phys supports the connection rate; and
- 7) an Arb Reject (Pathway Blocked) confirmation if all the destination expander logical phys that support the connection rate contain blocked partial pathways (i.e., are all returning Phy Status (Blocked Partial Pathway) confirmations) and pathway recovery rules require this Request Path request be rejected to release path resources (see 6.14.4.5).

#### 6.14.4.3 Arbitration status

Arbitration status shall be conveyed between expander devices and by expander devices to SAS endpoints using AIP primitive sequences (see 6.2.6.1). This status is used to monitor the progress of connection attempts and to facilitate pathway recovery as part of deadlock recovery.

The arbitration status of an expander logical phy is set to the last type of AIP received.

Before an expander device transmits an AIP primitive sequence, the expander device may have transmitted an OPEN address frame on the same physical link. Arbitration fairness dictates which OPEN address frame wins (see 6.14.3).

After an expander device transmits an AIP, the expander device shall not transmit an OPEN address frame unless that OPEN address frame has higher arbitration priority than the OPEN address frame for which the AIP was transmitted.

After transmitting an AIP primitive sequence, an expander device shall transmit at least one other dword (e.g., an idle dword) before transmitting another AIP primitive sequence.

Expander devices shall transmit at least one AIP primitive sequence every 128 dwords while originating AIP (NORMAL) primitive sequences, AIP (WAITING ON PARTIAL) primitive sequences, or AIP (WAITING ON CONNECTION) primitive sequence.

NOTE 28 - Expander devices compliant with SAS-1.1 were not required to transmit three consecutive AIP primitives, as AIP was defined as a single primitive sequence (see 6.2.4.2) rather than as an extended primitive sequence (see 6.2.4.5).

Expander devices shall transmit an AIP primitive sequence (e.g., an AIP (NORMAL)) within 128 dwords of receiving an OPEN address frame.

#### 6.14.4.4 Partial Pathway Timeout timer

Each expander logical phy shall maintain a Partial Pathway Timeout timer. This timer is used to identify potential deadlock conditions and to request resolution by the ECM. An expander logical phy shall initialize the Partial Pathway Timeout timer to the time reported in the PARTIAL PATHWAY TIMEOUT VALUE field in the SMP DISCOVER response (see 9.4.3.10) and run the Partial Pathway Timeout timer whenever the ECM provides confirmation to the expander logical phy that all expander logical phys within the requested destination port are blocked waiting on partial pathways.

NOTE 29 - The partial pathway timeout value allows flexibility in specifying how long an expander device waits before attempting pathway recovery. The recommended default value (see 9.4.3.10) was chosen to cover a wide range of topologies. Selecting small partial pathway timeout value values within a large topology compromises performance as a result of the time a device waits after receiving OPEN\_REJECT (PATHWAY BLOCKED) before retrying the connection request. Similarly, selecting large partial pathway timeout value values within a small topology compromises performance due to waiting longer than necessary to detect pathway blockage.

When the Partial Pathway Timeout timer is not running, an expander logical phy shall initialize and start the Partial Pathway Timeout timer when all expander logical phys within the requested destination port contain a blocked partial pathway (i.e., are returning Phy Status (Blocked Partial Pathway)).

NOTE 30 - The Partial Pathway Timeout timer is not initialized and started if one or more of the expander logical phys within a requested destination port are being used for a connection.

When one of the conditions above is not met, the expander logical phy shall stop the Partial Pathway Timeout timer. If the timer expires, then pathway recovery shall occur (see 6.14.4.5).

#### 6.14.4.5 Pathway recovery

Pathway recovery provides a means to abort connection requests in order to prevent deadlock using pathway recovery priority comparisons. Pathway recovery priority comparisons compare the PATHWAY BLOCKED COUNT fields and SOURCE SAS ADDRESS fields of the OPEN address frames of the blocked connection requests as described in table 135.

**Table 135 — Pathway recovery priority**

| Bits 71 to 64 (71 is MSB)         | Bits 63 to 0 (0 is LSB)        |
|-----------------------------------|--------------------------------|
| PATHWAY BLOCKED COUNT field value | SOURCE SAS ADDRESS field value |

When the Partial Pathway Timeout timer for an arbitrating expander logical phy expires (i.e., reaches a value of zero), the ECM shall determine whether to continue the connection request or to abort the connection request.

The ECM shall reply to a connection request with Arb Reject (Pathway Blocked) when:

- the Partial Pathway Timeout timer expires; and
- the pathway recovery priority of the arbitrating expander logical phy (i.e., the expander logical phy requesting the connection) is less than or equal to the pathway recovery priority of any of the expander logical phys within the destination port that are sending Phy Status (Blocked Partial Pathway) responses to the ECM.

The pathway blocked count and source SAS address values used to form the pathway recovery priority of a destination phy are those of the Request Path request if the expander logical phy sent a Request Path request to the ECM or those of the Forward Open indication if the expander logical phy received a Forward Open indication from the ECR.

#### 6.14.5 BREAK handling

A logical phy aborts a connection request (see 6.14.6) and breaks a connection (see 6.14.9) by transmitting a BREAK primitive sequence.

Logical phys shall enable the BREAK\_REPLY method of responding to received BREAK primitive sequences when:

- the BREAK\_REPLY CAPABLE bit transmitted by the logical phy in the outgoing IDENTIFY address frame is set to one; and
- the BREAK\_REPLY CAPABLE bit received by the logical phy in the incoming IDENTIFY address frame is set to one.

Logical phys shall disable the BREAK\_REPLY method of responding to received BREAK primitive sequences if the BREAK\_REPLY CAPABLE bit received by the logical phy in the incoming IDENTIFY address frame is set to zero.

Logical phys contained within SAS devices or expander devices that are compliant with this standard shall set the BREAK\_REPLY CAPABLE bit to one in their outgoing IDENTIFY address frame.

If the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled, then the logical phy shall transmit a BREAK\_REPLY primitive sequence in response to a received BREAK primitive sequence.

If the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled, then the logical phy shall transmit a BREAK primitive sequence in response to a received BREAK primitive sequence.

NOTE 31 - Phys compliant with SAS-1.1 do not set the BREAK\_REPLY CAPABLE bit to one in their outgoing IDENTIFY address frames.

#### 6.14.6 Aborting a connection request

BREAK may be used to abort a connection request. The source phy shall transmit a BREAK primitive sequence after the Open Timeout timer expires or if the source phy chooses to abort its request for any other reason before a connection is established.

After transmitting a BREAK primitive sequence, the source phy shall initialize a Break Timeout timer to 1 ms and start the Break Timeout timer.

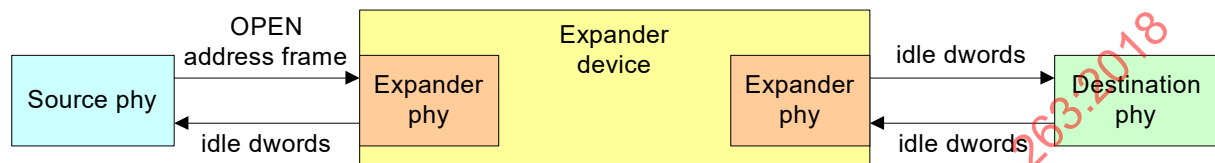
After a source phy transmits a BREAK primitive sequence to abort a connection request, the source phy shall expect one of the results listed in table 136.

**Table 136 — Results of aborting a connection request**

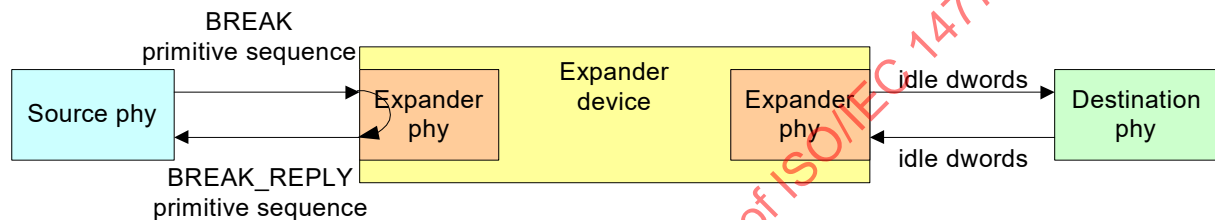
| <b>BREAK_REPLY<br/>method of<br/>responding to<br/>received BREAK<br/>primitive<br/>sequences</b> | <b>Result</b>                            | <b>Description</b>                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Disabled                                                                                          | Receive a BREAK primitive sequence       | This confirms that the connection request has been aborted.                                                                                                        |
|                                                                                                   | Receive a BREAK_REPLY primitive sequence | Ignore the BREAK_REPLY primitive sequence.                                                                                                                         |
| Enabled                                                                                           | Receive a BREAK primitive sequence       | The originating phy shall transmit a BREAK_REPLY primitive sequence and wait to receive a BREAK_REPLY primitive sequence or for the BREAK Timeout timer to expire. |
|                                                                                                   | Receive a BREAK_REPLY primitive sequence | This confirms that the connection request has been aborted.                                                                                                        |
| Enabled or disabled                                                                               | Break Timeout timer expires              | The originating phy shall assume the connection request has been aborted.                                                                                          |

When a logical phy transmitting a BREAK primitive sequence is attached to an expander device, the BREAK or BREAK\_REPLY response to the logical phy is generated by the expander logical phy to which the logical phy is attached, not the other SAS logical phy in the connection. If the expander device has transmitted a connection request to the destination, then the expander device shall also transmit a BREAK primitive sequence to the destination. If the expander device has not transmitted a connection request to the destination, then the expander device shall not transmit a BREAK primitive sequence to the destination. After transmitting a BREAK primitive sequence or BREAK\_REPLY primitive sequence back to the source phy, the expander device shall ensure that a connection response does not occur (i.e., the expander device shall no longer forward dwords from the destination). Figure 129 shows an example of BREAK usage. Multiplexing is disabled on all phys in the example.

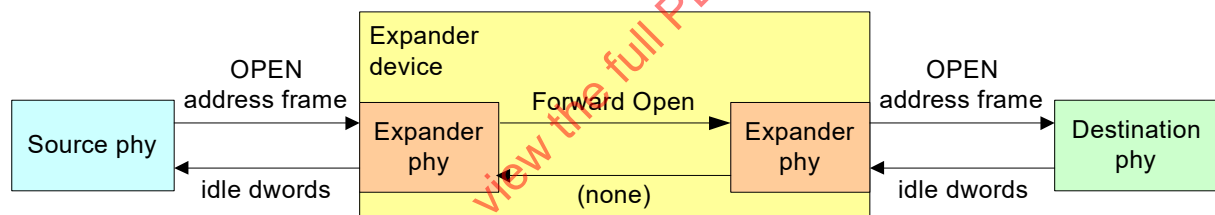
Case 1: OPEN address frame has not propagated through the expander device:



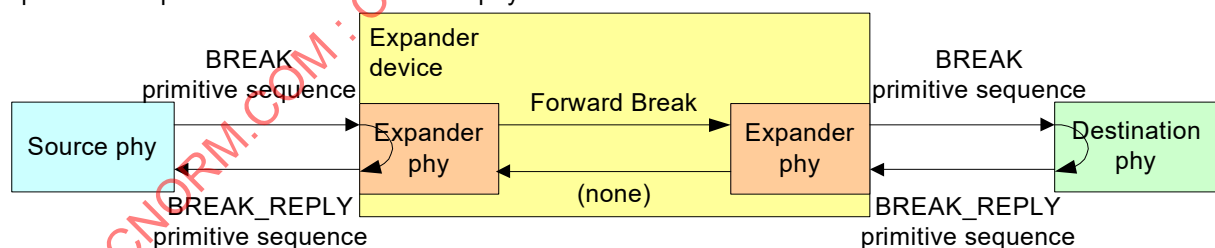
Case 1 result: Expander device transmits a BREAK\_REPLY primitive sequence to the source phy.



Case 2: OPEN address frame has propagated through the expander device:



Case 2 result: Expander device transmits a BREAK\_REPLY primitive sequence to the source phy and a BREAK primitive sequence to the destination phy, then waits for a BREAK\_REPLY primitive sequence from the destination phy.



Note - If the BREAK\_REPLY method of responding to BREAK primitive sequences is disabled, phys transmit a BREAK primitive sequence rather than a BREAK\_REPLY primitive sequence in response to a BREAK primitive sequence.

**Figure 129 — Aborting a connection request with a BREAK primitive sequence**

Figure 130 shows the sequence for a connection request where the Open Timeout timer expires.

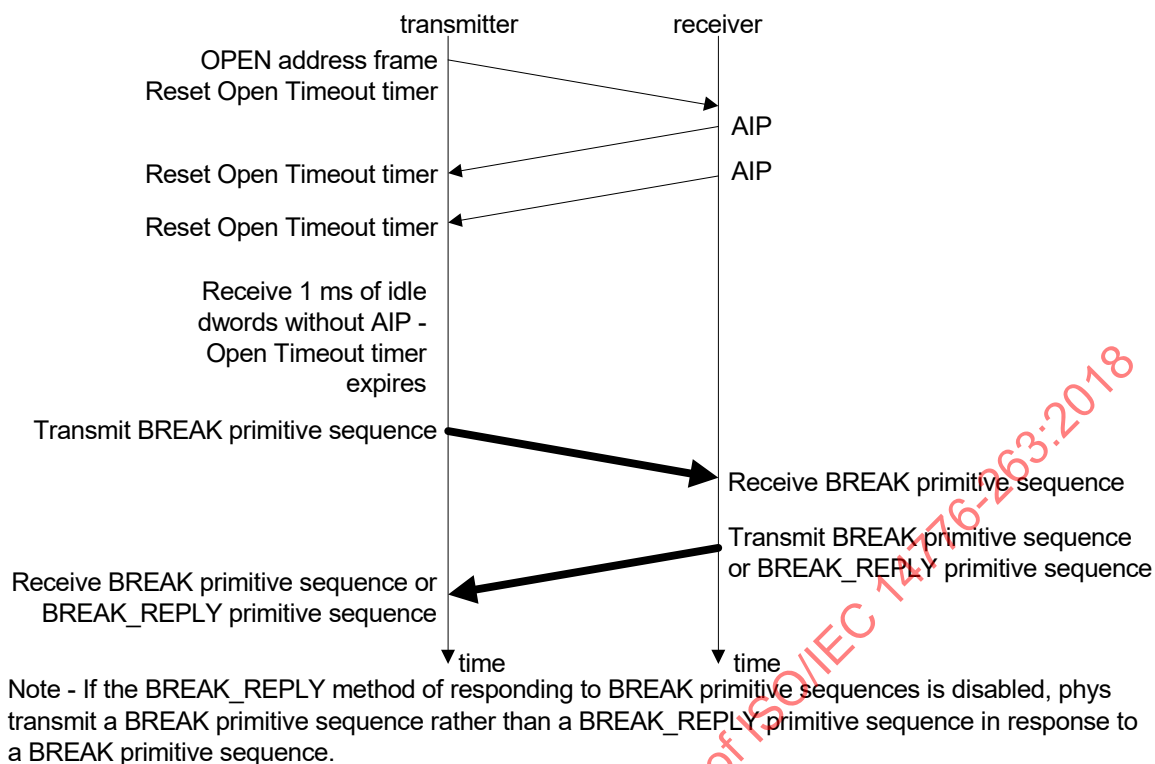


**Figure 130 — Connection request timeout example**

#### 6.14.7 Expander device request for an SSP connection close

An expander device's expander function initiates the closing of an SSP connection by sending a Begin SSP Connection Close confirmation to the XL state machine (see 6.17.10) for each expander phy being used by the SSP connection. Upon receipt of a Begin SSP Connection Close confirmation each expander phy associated with the SSP connection being closed replaces the transmission of any:

- RRDY (NORMAL) with an RRDY (CLOSE) (see 6.17.2); and
- EXTEND\_CONNECTION (NORMAL) with an EXTEND\_CONNECTION (CLOSE) (see 6.17.2).

#### 6.14.8 Closing a connection

CLOSE is used to close a connection of any protocol. See 6.18.8 for details on closing SSP connections, 6.19.6 for details on closing STP connections, and 6.20.4 for details on closing SMP connections.

After transmitting a CLOSE primitive sequence, the originating phy shall initialize a Close Timeout timer to 1 ms and start the Close Timeout timer.



After the logical phy transmits a CLOSE primitive sequence to close a connection, logical phy shall expect one of the results listed in table 137.

**Table 137 — Results of closing a connection**

| Result                             | Description                                                             |
|------------------------------------|-------------------------------------------------------------------------|
| Receive a CLOSE primitive sequence | This confirms that the connection has been closed.                      |
| Close Timeout timer expires        | The originating phy shall attempt to break the connection (see 6.14.9). |

No additional dwords for the connection shall follow the CLOSE primitive sequence. Expander devices shall close the full-duplex connection upon forwarding a CLOSE primitive sequence in each direction.

When a logical phy has both transmitted and received a CLOSE primitive sequence, the logical phy shall consider the connection closed.

Figure 131 shows example sequences for closing a connection.

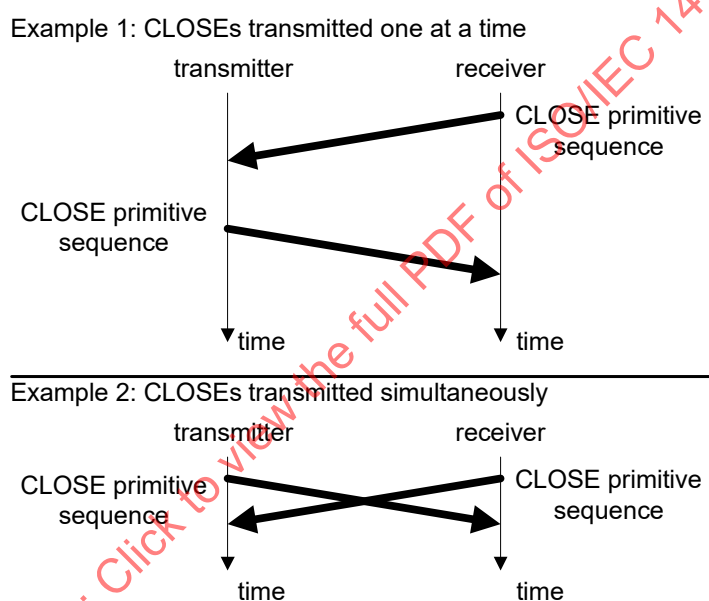


**Figure 131 — Closing a connection example**

#### 6.14.9 Breaking a connection

In addition to aborting a connection request, a BREAK primitive sequence may also be used to break a connection in cases where CLOSE is not available. After transmitting a BREAK primitive sequence, the originating phy shall ignore all incoming dwords except for BREAKs, BREAK\_REPLYs, and deletable primitives.

After transmitting a BREAK primitive sequence, the originating phy shall initialize a Break Timeout timer to 1 ms and start the Break Timeout timer.



After a logical phy transmits a BREAK primitive sequence to break a connection, the logical phy shall expect one of the results listed in table 138.

**Table 138 — Results of breaking a connection**

| <b>BREAK_REPLY<br/>method of<br/>responding to<br/>received BREAK<br/>primitive<br/>sequences</b> | <b>Result</b>                            | <b>Description</b>                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Disabled                                                                                          | Receive a BREAK primitive sequence       | This confirms that the connection has been broken.                                                                                                                 |
|                                                                                                   | Receive BREAK_REPLY primitive sequence   | Ignore the BREAK_REPLY primitive sequence.                                                                                                                         |
| Enabled                                                                                           | Receive a BREAK primitive sequence       | The originating phy shall transmit a BREAK_REPLY primitive sequence and wait to receive a BREAK_REPLY primitive sequence or for the BREAK Timeout timer to expire. |
|                                                                                                   | Receive a BREAK_REPLY primitive sequence | This confirms that the connection has been broken.                                                                                                                 |
| Enabled or disabled                                                                               | Break Timeout timer expires              | The originating phy shall assume the connection has been broken. The originating phy may perform a link reset sequence.                                            |

In addition to a BREAK, a connection is considered broken if a link reset sequence starts (i.e., the SP state machine transitions from SP15:SAS\_PHY\_Ready or SP22:SATA\_PHY\_Ready to SP0:OOB\_COMINIT (see 5.12)).

See 6.18.7 for additional rules on breaking an SSP connection.

## 6.15 Rate matching

Each successful connection request contains the connection rate (see 4.1.12) of the pathway.

Each logical phy in the pathway shall insert deletable primitives between dwords if the logical phy's logical link rate is faster than the connection rate as described in table 139.

**Table 139 — Rate matching deletable primitive insertion requirements**

| Logical link rate | Connection rate | Requirement                                                                                                                                                                                                                                                                                                             |
|-------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.5 Gbit/s        | 1.5 Gbit/s      | None                                                                                                                                                                                                                                                                                                                    |
| 3 Gbit/s          | 1.5 Gbit/s      | One deletable primitive within every two dwords that are not physical link rate tolerance management deletable primitives (i.e., every overlapping window of two dwords) (e.g., a repeating pattern of a deletable primitive followed by a dword, or a repeating pattern of a dword followed by an deletable primitive) |
|                   | 3 Gbit/s        | None                                                                                                                                                                                                                                                                                                                    |
| 6 Gbit/s          | 1.5 Gbit/s      | Three deletable primitives within every four dwords that are not physical link rate tolerance management deletable primitives (i.e., 3 in every overlapping window of four dwords)                                                                                                                                      |
|                   | 3 Gbit/s        | One deletable primitive within every two dwords that are not physical link rate tolerance management deletable primitives (i.e., every overlapping window of two dwords) (e.g., a repeating pattern of a deletable primitive followed by a dword, or a repeating pattern of a dword followed by an deletable primitive) |
|                   | 6 Gbit/s        | None                                                                                                                                                                                                                                                                                                                    |
| 12 Gbit/s         | 1.5 Gbit/s      | Seven deletable primitives within every eight dwords that are not physical link rate tolerance management deletable primitives (i.e., seven in every overlapping window of eight dwords)                                                                                                                                |
|                   | 3 Gbit/s        | Three deletable primitives within every four dwords that are not physical link rate tolerance management deletable primitives (i.e., three in every overlapping window of four dwords)                                                                                                                                  |
|                   | 6 Gbit/s        | One deletable primitive within every two dwords that are not physical link rate tolerance management deletable primitives (i.e., every overlapping window of two dwords) (e.g., a repeating pattern of a deletable primitive followed by a dword, or a repeating pattern of a dword followed by an deletable primitive) |
|                   | 12 Gbit/s       | None                                                                                                                                                                                                                                                                                                                    |

Deletable primitives inserted for rate matching are in addition to deletable primitives inserted for physical link rate tolerance management (see 6.3). See Annex G for a summary of their combined requirements.

Figure 132 shows an example of rate matching between a 3 Gbit/s originating phy and a 3 Gbit/s receiving phy, with an intermediate 1.5 Gbit/s physical link in between them. Multiplexing is disabled in this example.

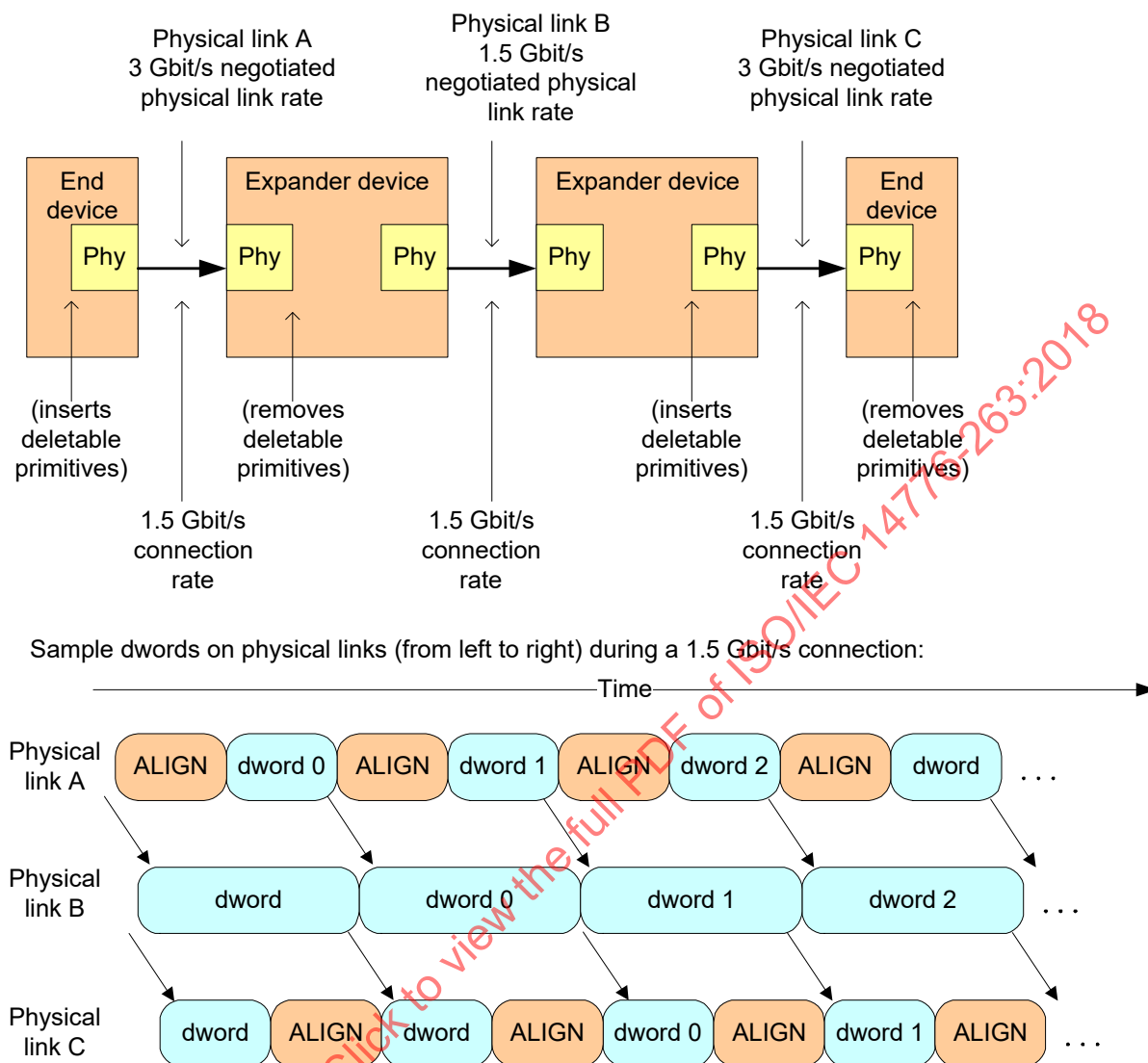


**Figure 132 — Rate matching example**

A logical phy originating dwords shall start rate matching at the selected connection rate starting with the first dword that is not a deletable primitive inserted for physical link rate tolerance management following:

- transmitting the EOAF for an OPEN address frame; or
- transmitting an OPEN\_ACCEPT.

An expander logical phy forwarding dwords shall not insert deletable primitives for rate matching based on counting dwords transmitted, and shall insert deletable primitives whenever it underflows.

The source phy transmits idle dwords including deletable primitives at the selected connection rate while waiting for the connection response. This enables each expander device to start forwarding dwords from the source phy to the destination phy after forwarding an OPEN\_ACCEPT.

A logical phy shall stop inserting deletable primitives for rate matching after:

- transmitting the first dword in a CLOSE primitive sequence;
- transmitting the first dword in a BREAK primitive sequence;

- c) transmitting the first dword in a BREAK\_REPLY primitive sequence;
- d) receiving an OPEN\_REJECT for a connection request; or
- e) losing arbitration to a received OPEN address frame.

## 6.16 SL (link layer for SAS logical phys) state machines

### 6.16.1 SL state machines overview

The SL (link layer for SAS logical phys) state machines control connections, handles connection requests (i.e., OPEN address frames), CLOSEs, and BREAKs. The SL state machines are as follows:

- a) SL\_RA (receive OPEN address frame) state machine (see 6.16.3); and
- b) SL\_CC (connection control) state machine (see 6.16.4).

All the SL state machines shall begin after receiving an Enable Disable SAS Link (Enable) message from the SL\_IR state machines.

If a state machine consists of multiple states, then the initial state is as indicated in the state machine description.

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The diagram illustrates the state machine for the SL (link layer for SAS logical phys) connection control, specifically part 1 of 3. The states and transitions are as follows:

- SL\_CC0:Idle** (Initial State):
  - Transitions to **SL\_CC1:ArbSel** on **OPEN Address Frame Received** (RA).
  - Transitions to **SL\_CC2:Selected** on **Enable SAS Link (Enable)** (IR).
  - Transitions to **SL\_CC6:Break** on **Transmit Broadcast** (IR).
  - Transitions to **SL\_CC7:CloseSTP** on **Open Failed** (IR).
  - Transitions to **SL\_CC0:Idle** on **Retry Transmit Broadcast** (IR).
  - Transitions to **SL\_CC0:Idle** on **Enable Disable SAS Link (Disable)** (IR).
  - Transitions to **SL\_CC0:Idle** on **Idle State Condition** (SL\_P C, SL\_P S).
- SL\_CC1:ArbSel**:
  - Transitions to **SL\_CC2:Selected** on **Phy Power Condition Status** (SL\_CC8).
  - Transitions to **SL\_CC3:Connected** on **Connection Opened** (SL\_CC9).
  - Transitions to **SL\_CC0:Idle** on **Stop Arb** (SL\_CC9).
  - Transitions to **SL\_CC0:Idle** on **Open Failed** (SL\_CC9).
  - Transitions to **SL\_CC0:Idle** on **Change Received** (SL\_CC9).
- SL\_CC2:Selected**:
  - Transitions to **SL\_CC3:Connected** on **Connection Opened** (SL\_CC8).
  - Transitions to **SL\_CC6:Break** on **Request Break** (SSP, SMP, or STP).
  - Transitions to **SL\_CC7:CloseSTP** on **Request Close** (SSP, SMP, or STP).
  - Transitions to **SL\_CC0:Idle** on **Enable Disable SSP (Disable)** (SSP).
  - Transitions to **SL\_CC0:Idle** on **Enable Disable SMP (Disable)** (SMP).
  - Transitions to **SL\_CC0:Idle** on **Enable Disable STP (Disable)** (STP).
- SL\_CC3:Connected**:
  - Transitions to **SL\_CC4:DisconnectWait** on **Persistent Connection Established** (SSP\_EM).
  - Transitions to **SL\_CC4:DisconnectWait** on **Enable Disable SSP (Enable)** (SSP).
  - Transitions to **SL\_CC4:DisconnectWait** on **Enable Disable SMP (Enable)** (SMP).
  - Transitions to **SL\_CC4:DisconnectWait** on **Enable Disable STP (Enable)** (STP).
  - Transitions to **SL\_CC4:DisconnectWait** on **Advance Credit** (SSP\_TCM).
  - Transitions to **SL\_CC4:DisconnectWait** on **Connection Closed** (SL\_CC9).
  - Transitions to **SL\_CC6:Break** on **Inbound Connection Rejected** (SL\_CC8).
- SL\_CC4:DisconnectWait**:
  - Transitions to **SL\_CC0:Idle** on **Connection Closed** (SL\_CC9).
- SL\_CC5:BreakWait**:
  - Transitions to **SL\_CC6:Break** on **NOTIFY Received** (SL\_CC9).
- SL\_CC6:Break**:
  - Transitions to **SL\_CC7:CloseSTP** on **Connection Closed** (SL\_CC9).
- SL\_CC7:CloseSTP**:
  - Transitions to **SL\_CC0:Idle** on **Connection Closed** (SL\_CC9).

The diagram also includes various inputs and outputs that trigger state transitions, such as **RA** (Request Address), **IR** (Initiate Request), **SSP** (SAS Sense Protocol), **SMP** (SAS Management Protocol), **STP** (SAS Transport Protocol), **SL\_CC8**, **SL\_CC9**, **SL\_P C**, **SL\_P S**, **PHY Power Condition Status**, **NOTIFY Received**, **Connection Opened**, **Connection Closed**, **Open Failed**, **Change Received**, **Stop Arb**, **Request Break**, **Request Close**, **Persistent Connection Established**, **Enable Disable SSP (Enable/Disable)**, **Enable Disable SMP (Enable/Disable)**, **Enable Disable STP (Enable/Disable)**, **Advance Credit**, **Inbound Connection Rejected**, **Manage Power Conditions (to all states)**, and **Accept/Reject Opens (to all states)**.

**Figure 133 — SL (link layer for SAS logical phys) state machines (part 1)**

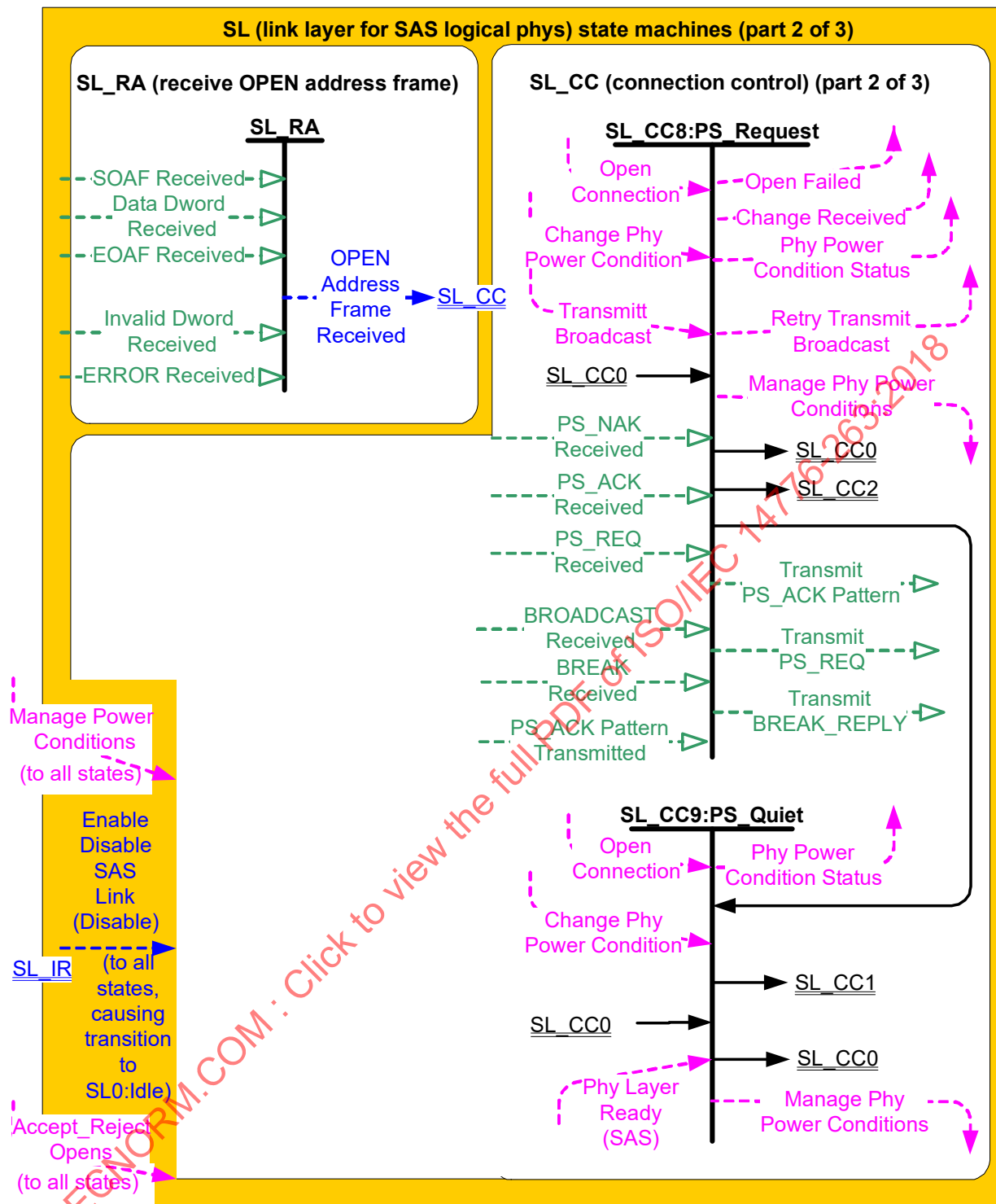


Figure 134 — SL (link layer for SAS logical phys) state machines (part 2)

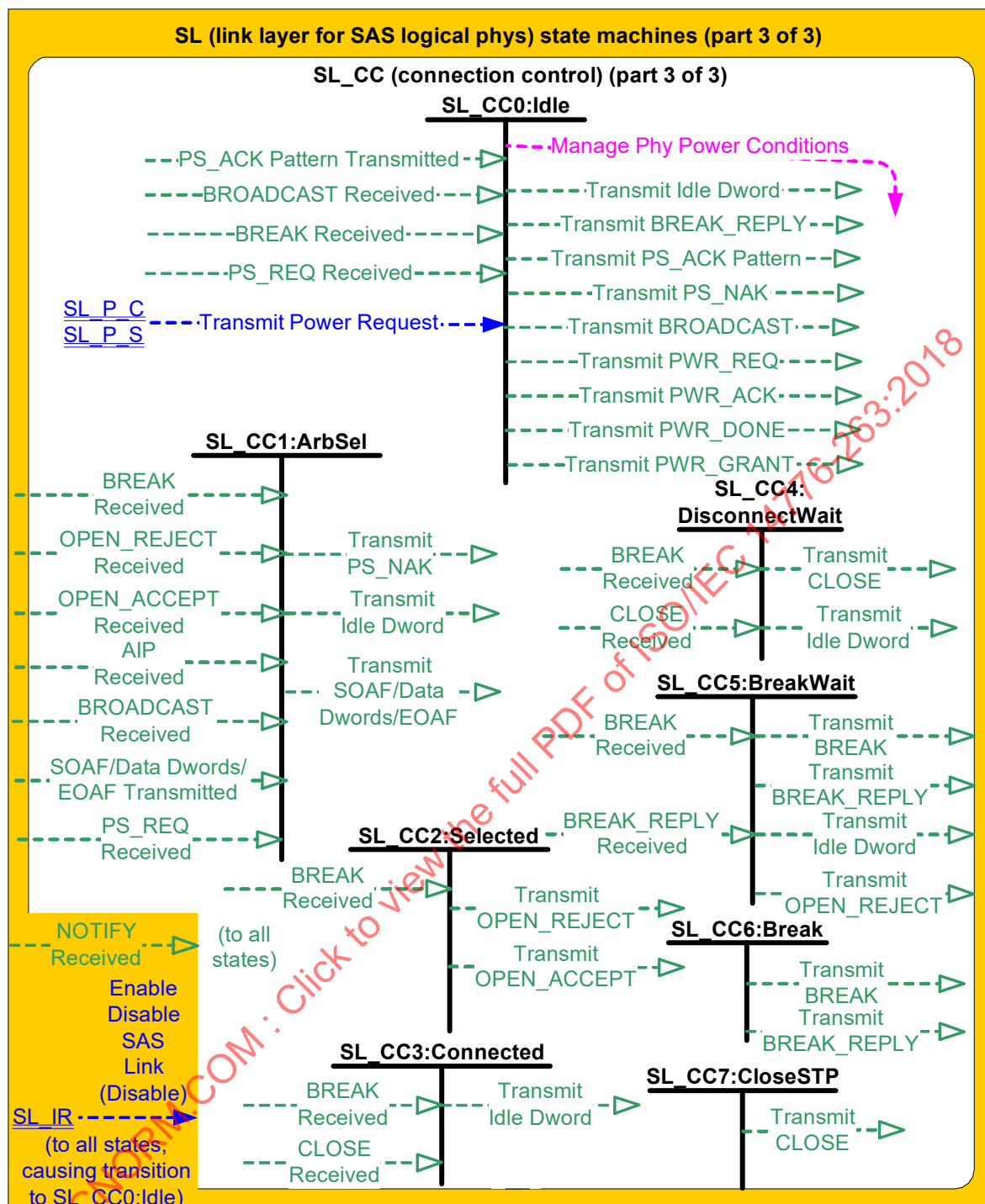


Figure 135 — SL (link layer for SAS logical phys) state machines (part 3)

### 6.16.2 SL transmitter and receiver

The SL transmitter receives the following messages from the SL state machines specifying primitive sequences, frames, and dwords to transmit:

- Transmit Idle Dword;
- Transmit SOAF/Data Dwords/EOAF;

- c) Transmit OPEN\_ACCEPT;
- d) Transmit OPEN\_REJECT with an argument indicating the specific type (e.g., Transmit OPEN\_REJECT (Retry));
- e) Transmit BREAK;
- f) Transmit BREAK\_REPLY;
- g) Transmit PS\_REQ with an argument indicating the specific type (e.g., Transmit PS\_REQ (Partial) or Transmit PS\_REQ (Slumber));
- h) Transmit PS\_ACK Pattern (see 6.11);
- i) Transmit PS\_NAK;
- j) Transmit BROADCAST;
- k) Transmit PWR\_REQ;
- l) Transmit PWR\_ACK;
- m) Transmit PWR\_DONE;
- n) Transmit PWR\_GRANT; and
- o) Transmit CLOSE with an argument indicating the specific type (e.g., Transmit CLOSE (Normal)).

When the SL transmitter is requested to transmit a dword from any state within any of the SL state machines, the SL transmitter shall transmit that dword. If there are multiple requests to transmit, then the following priority should be followed when selecting the dword to transmit:

- 1) BREAK\_REPLY;
- 2) BREAK;
- 3) CLOSE;
- 4) OPEN\_ACCEPT or OPEN\_REJECT;
- 5) SOAF, data dword, or EOAF;
- 6) PWR\_REQ, PWR\_ACK, PWR\_DONE, or PWR\_GRANT;
- 7) PS\_REQ, PS\_ACK Pattern, or PS\_NAK; and
- 8) idle dword.

When there is no outstanding message specifying a dword to transmit, the SL transmitter shall transmit idle dwords.

The SL transmitter sends the following messages to the SL state machines based on dwords that have been transmitted:

- a) SOAF/Data Dwords/EOAF Transmitted; and
- b) PS\_ACK Pattern Transmitted.

The SL receiver sends the following messages to the SL state machines indicating primitive sequences and dwords received from the SP\_DWS receiver (see 5.13.2):

- a) SOAF Received;
- b) Data Dword Received;
- c) EOAF Received;
- d) BROADCAST Received with an argument indicating the specific type (e.g., BROADCAST Received (Change));
- e) BREAK Received;
- f) BREAK\_REPLY Received;
- g) OPEN\_ACCEPT Received;
- h) OPEN\_REJECT Received with an argument indicating the specific type (e.g., OPEN\_REJECT Received (No Destination));
- i) AIP Received;
- j) CLOSE Received with an argument indicating the specific type (e.g., CLOSE Received (Normal));
- k) NOTIFY Received (Power Loss Expected);
- l) PS\_REQ Received with an argument indicated the specific type (e.g., PS\_REQ Received (Partial) or PS\_REQ Received (Slumber));
- m) PS\_ACK Received;
- n) PS\_NAK Received;
- o) ERROR Received; and
- p) Invalid Dword Received.



The SL receiver shall ignore all other dwords.

The SL transmitter relationship to other transmitters is defined in 4.3.2. The SL receiver relationship to other receivers is defined in 4.3.3.

### 6.16.3 SL\_RA (receive OPEN address frame) state machine

The SL\_RA state machine's function is to receive address frames and determine if each received address frame is a valid OPEN address frame. This state machine consists of one state.

This state machine receives SOAFs, dwords of an OPEN address frames, and EOAFs.

This state machine shall ignore all messages except SOAF Received, Data Dword Received, and EOAF Received.

If this state machine receives a subsequent SOAF Received message after receiving an SOAF Received message but before receiving an EOAF Received message, then this state machine shall discard the address frame in progress.

If this state machine receives more than eight Data Dword Received messages (i.e., 32 bytes) after an SOAF Received message and before an EOAF Received message, then this state machine shall discard the address frame.

If this state machine receives an Invalid Dword Received message or an ERROR Received message after an SOAF Received message and before an EOAF Received message, then this state machine shall either:

- a) ignore the invalid dword or ERROR; or
- b) discard the address frame.

After receiving an EOAF Received message, this state machine shall check if the address frame is a valid OPEN address frame.

This state machine shall accept an address frame if:

- a) the ADDRESS FRAME TYPE field is set to 1h (i.e., OPEN);
- b) the number of data dwords between the SOAF and EOAF is eight; and
- c) the CRC field contains a good CRC.

Otherwise, this state machine shall discard the address frame. If the frame is not discarded then this state machine shall send an OPEN Address Frame Received message to the SL\_CC0:Idle state and the SL\_CC1:ArbSel state with an argument that contains all the data dwords received in the OPEN address frame.

### 6.16.4 SL\_CC (connection control) state machine

#### 6.16.4.1 SL\_CC state machine overview

The SL\_CC state machine consists of the following states:

- a) SL\_CC0:Idle (see 6.16.4.2) (initial state);
- b) SL\_CC1:ArbSel (see 6.16.4.3);
- c) SL\_CC2:Selected (see 6.16.4.4);
- d) SL\_CC3:Connected (see 6.16.4.5);
- e) SL\_CC4:DisconnectWait (see 6.16.4.6);
- f) SL\_CC5:BreakWait (see 6.16.4.7);
- g) SL\_CC6:Break (see 6.16.4.8);
- h) SL\_CC7:CloseSTP (see 6.16.4.9);
- i) SL\_CC8:PS\_Request (see 6.16.4.10); and
- j) SL\_CC9:PS\_Quiet (see 6.16.4.11).

This state machine receives the following requests from the management application layer:

- a) Transmit Broadcast.

This state machine shall start in the SL\_CC0:Idle state. The state machine shall transition to the SL\_CC0:Idle state from any other state after receiving an Enable Disable SAS Link (Disable) message from the SL\_IR state machines (see 6.10).

This machine receives the following messages from the SSP link layer state machine (see 6.18.9), the STP link layer state machine, and SMP link layer state machine (see 6.20.5):

- a) Request Break; and
- b) Request Close.

This state machine sends the following messages to the SL\_P\_S link layer state machine (see 6.12.4) and SL\_P\_C link layer state machine (see 6.12.5):

- a) Idle State Condition (Active); and
- b) Idle State Condition (Inactive).

This state machine sends the following messages to the SSP link layer state machine, the STP link layer state machine, and SMP link layer state machine:

- a) Enable Disable SSP (Enable);
- b) Enable Disable SSP (Disable);
- c) Enable Disable STP (Enable);
- d) Enable Disable STP (Disable);
- e) Enable Disable SMP (Enable); and
- f) Enable Disable SMP (Disable).

This state machine receives the following messages from the SL\_IR state machines (see 6.10):

- a) Enable Disable SAS Link (Enable); and
- b) Enable Disable SAS Link (Disable).

Any message received by a state that is not referred to in the description of that state or in this subclause shall be ignored.

If this state machine receives an Accept\_Reject OPENs (Accept SSP) request, then this state machine shall set the Reject SSP Opens state machine variable (see table 141) to NO. If this state machine receives an Accept\_Reject OPENs (Reject SSP) request, then this state machine shall set the Reject SSP Opens state machine variable to YES.

If this state machine receives an Accept\_Reject OPENs (Accept SMP) request, then this state machine shall set the Reject SMP Opens state machine variable (see table 141) to NO. If this state machine receives an Accept\_Reject OPENs (Reject SMP) request, then this state machine shall set the Reject SMP Opens state machine variable to YES.

If this state machine receives an Accept\_Reject OPENs (Accept STP) request, then this state machine shall set the Reject STP Opens state machine variable (see table 141) to NO. If this state machine receives an Accept\_Reject OPENs (Reject STP) request, then this state machine shall set the Reject STP Opens state machine variable to YES.

If this state machine receives a Manage Power Conditions (Accept Partial) request from the management application layer, then this state machine shall set the Accept Partial state machine variable (see table 141) to YES. If this state machine receives a Manage Power Conditions (Accept Slumber) request from the management application layer, then this state machine shall set the Accept Slumber state machine variable (see table 141) to YES.

If this state machine receives a Manage Power Conditions (Reject Partial) request from the management application layer, then this state machine shall set the Accept Partial state machine variable to NO. If this state machine receives a Manage Power Conditions (Reject Slumber) request from the management application layer, then this state machine shall set the Accept Slumber state machine variable to NO.

The default value of the Accept Partial state machine variable shall be set to NO and default value of the Accept Slumber state machine variable shall be set to NO.

Any detection of an internal error shall cause the SL\_CC state machine to transition to the SL\_CC5:BreakWait state.

This state machine shall maintain the timers listed in table 140.

**Table 140 — SL\_CC state machine timers**

| Timer                                 | Initial value |
|---------------------------------------|---------------|
| Open Timeout timer                    | 1 ms          |
| Close Timeout timer                   | 1 ms          |
| Break Timeout timer                   | 1 ms          |
| Power Condition Request Timeout timer | 1 ms          |
| Idle timer                            | 1 ms          |

This state machine shall maintain the state machine variables listed in table 141.

**Table 141 — SL\_CC state machine variables**

| State machine variable | Description                                                                                                                     |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Reject SSP Opens       | Used to determine if the SCSI application layer is permitting SSP connection requests to be accepted on this logical phy.       |
| Reject SMP Opens       | Used to determine if the management application layer is permitting SMP connection requests to be accepted on this logical phy. |
| Reject STP Opens       | Used to determine if the ATA application layer is permitting STP connection requests to be accepted on this logical phy.        |
| Accept Partial         | Used to determine if the management application layer is permitting this phy to enter a partial phy power condition.            |
| Accept Slumber         | Used to determine if the management application layer is permitting this phy to enter a slumber phy power condition.            |

#### 6.16.4.2 SL\_CC:Idle state

##### 6.16.4.2.1 State description

This state is the initial state and is the state that is used while there is no connection pending or established.

Upon entry into this state, this state shall:

- send an Enable Disable SSP (Disable) message to the SSP link layer state machines;
- send an Enable Disable SMP (Disable) message to the SMP link layer state machines;
- send an Enable Disable STP (Disable) message to the STP link layer state machines;
- send an Idle State Condition (Active) message to the SL\_P\_S link layer state machine (see 6.12.4) and SL\_P\_C link layer state machine (see 6.12.5);
- initialize and start the Idle timer; and
- send a Connection Closed (Transition to Idle) confirmation to the port layer.

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SL transmitter (see 6.4).

If a BROADCAST Received (Change) message, BROADCAST Received (Reserved Change 0) message, or BROADCAST Received (Reserved Change 1) message is received, then this state shall send a Change Received confirmation to the management application layer.

If a Transmit Broadcast request is received with any argument and this state has not sent a Transmit PS\_ACK Pattern message, then this state shall send a Transmit BROADCAST message with the same argument to the SL transmitter. If a Transmit Broadcast request is received and this state has sent a Transmit PS\_ACK Pattern message to the SL transmitter, then this state shall send a Retry Transmit Broadcast confirmation to the management application layer.

If the Transmit Broadcast request is received coincident with receiving either an Open Connection request or an OPEN Address Frame Received message, then this state shall send a Transmit BROADCAST message with the same argument to the SL transmitter before transitioning to another state.

If a BREAK Received message is received and the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5), then this state shall send a Transmit BREAK\_REPLY message to the SL transmitter.

After this state receives an Enable Disable SAS Link (Enable) message, this state shall:

- a) set the Reject SSP Opens state machine variable to a vendor specific default value (i.e., YES or NO);
- b) set the Reject SMP Opens state machine variable to a vendor specific default value (i.e., YES or NO); and
- c) set the Reject STP Opens state machine variable to a vendor specific default value (i.e., YES or NO).

If this state receives a NOTIFY Received (Power Loss Expected) message and the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port), then this state shall send a Notify Received (Power Loss Expected) confirmation to the port layer.

If a PS\_REQ Received (Partial) message is received and the Accept Partial state machine variable is set to YES, then this state shall send:

- a) a Transmit PS\_ACK Pattern message to the SL transmitter; and
- b) a Manage Phy Power Conditions (Stop DWS) request to the phy layer.

If a PS\_REQ Received (Slumber) message is received and the Accept Slumber state machine variable is set to YES, then this state shall send:

- a) a Transmit PS\_ACK Pattern message to the SL transmitter; and
- b) a Manage Phy Power Conditions (Stop DWS) request to the phy layer.

If a PS\_REQ Received (Partial) message is received and the Accept Partial state machine variable is set to NO, then this state shall send a Transmit PS\_NAK message to the SL transmitter. If a PS\_REQ Received (Slumber) message is received and the Accept Slumber state machine variable is set to NO, then this state shall send a Transmit PS\_NAK message to the SL transmitter.

If this state receives an Open Connection request and this state has sent a Transmit PS\_ACK Pattern message to the SL transmitter, then this state shall send an Open Failed (Low Phy Power Condition) confirmation to the port layer.

If this state receives a Change Phy Power Condition request and this state has sent a Transmit PS\_ACK Pattern message to the SL transmitter, then this state shall send a Phy Power Condition Status (Retry Change Phy Power Condition Request) confirmation to the management application layer.

This state shall ignore any Change Phy Power Condition (Exit Power Condition) requests.

If this state receives a:

- a) Transmit Power Request (PWR\_REQ) message, then this state shall send a Transmit PWR\_REQ message to the SL transmitter;
- b) Transmit Power Request (PWR\_ACK) message, then this state shall send a Transmit PWR\_ACK message to the SL transmitter;
- c) Transmit Power Request (PWR\_DONE) message, then this state shall send a Transmit PWR\_DONE message to the SL transmitter; or
- d) Transmit Power Request (PWR\_GRANT) message, then this state shall send a Transmit PWR\_GRANT message to the SL transmitter.

If the Idle timer expires, then this state shall:

- a) send an Idle State Condition (Active) message to the SL\_P\_S link layer state machine (see 6.12.4) and SL\_P\_C link layer state machine (see 6.12.5); and
- b) initialize and start the Idle timer.

#### 6.16.4.2.2 Transition SL\_CC0:Idle to SL\_CC1:ArbSel

If this state has not sent a Transmit PS\_ACK Pattern message to the SL transmitter, then this transition shall occur after receiving:

- a) an Enable Disable SAS Link (Enable) message; and
- b) an Open Connection request.

The Open Connection request includes these arguments:

- a) Initiator Port Bit;
- b) Protocol;
- c) Connection Rate;
- d) Initiator Connection Tag;
- e) Destination SAS Address;
- f) Source SAS Address;
- g) Pathway Blocked Count; and
- h) Arbitration Wait Time.

If persistent connections are supported (see 4.1.13.2), then the Open Connection request includes the following argument:

- a) Send Extend Bit.

If credit advance is implemented (see 4.1.14), then the Open Connection request includes the following argument:

- a) Credit Advance Bit.

Before this transition, this state shall send an Idle State Condition (Inactive) message to the SL\_P\_S link layer state machine (see 6.12.4) and SL\_P\_C link layer state machine (see 6.12.5).

#### 6.16.4.2.3 Transition SL\_CC0:Idle to SL\_CC2:Selected

This transition shall occur:

- a) after receiving both an Enable Disable SAS Link (Enable) message and an OPEN Address Frame Received message.

Before this transition, this state shall send an Idle State Condition (Inactive) message to the SL\_P\_S link layer state machine (see 6.12.4) and SL\_P\_C link layer state machine (see 6.12.5).

If persistent connections are supported (see 4.1.13.2) and:

- a) the SEND EXTEND bit is set to one in the received OPEN address frame and the INITIATOR PORT bit is set to one in the received OPEN address frame, then this transition shall include an Extend Connection (Transmit) argument;
- b) the SEND EXTEND bit is set to zero in the received OPEN address frame, then this transition shall include an Extend Connection (Off) argument; or
- c) the INITIATOR PORT bit is set to zero in the received OPEN address frame, then this transition shall include an Extend Connection (Off) argument.

If credit advance is implemented (see 4.1.14) and:

- a) the CREDIT ADVANCE bit is set to one in the received OPEN address frame; and
- b) the SAS PROTOCOL field is set to 001b (i.e., SSP) in the received OPEN address frame,

then this transition shall include an Advance Credit argument.

#### 6.16.4.2.4 Transition SL\_CC0:Idle to SL\_CC8:PS\_Request

If this state has not sent a Transmit PS\_ACK Pattern message to the SL transmitter, then this transition shall occur after receiving:

- a) an Enable Disable SAS Link (Enable) message; and
- b) a Change Phy Power Condition (Enter Slumber) or Change Phy Power Condition (Enter Partial) request from the management application layer.

This transition shall include the Phy Power Condition (Enter Partial) argument or Phy Power Condition (Enter Slumber) argument that corresponds to the Change Phy Power Condition request.

Before this transition, this state shall send an Idle State Condition (Inactive) message to the SL\_P\_S link layer state machine (see 6.12.4) and SL\_P\_C link layer state machine (see 6.12.5).

#### 6.16.4.2.5 Transition SL\_CC0:Idle to SL\_CC9:PS\_Quiet

This transition shall occur:

- a) after receiving a PS\_ACK Pattern Transmitted message from the SL transmitter.

This transition shall include the Phy Power Condition (Enter Partial) argument or Phy Power Condition (Enter Slumber) argument that corresponds to the PS\_REQ Received message.

Before this transition, this state shall send an Idle State Condition (Inactive) message to the SL\_P\_S link layer state machine (see 6.12.4) and SL\_P\_C link layer state machine (see 6.12.5).

#### 6.16.4.3 SL\_CC1:ArbSel state

##### 6.16.4.3.1 State description

This state is used to make a connection request.

Upon entry into this state, this state shall:

- 1) request an OPEN address frame be transmitted by sending a Transmit SOAF/Data Dwords/EOAF message to the SL transmitter with the dwords containing the OPEN address frame with its fields set to the arguments received with the Open Connection request;
- 2) initialize and start the Open Timeout timer; and
- 3) request idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SL transmitter.

See 6.14 for details on rate matching when opening a connection.

If this state receives an SOAF/Data Dwords/EOAF Transmitted message followed by an OPEN\_ACCEPT Received message and the SAS PROTOCOL field in the transmitted OPEN address frame was set to:

- a) STP, then this state shall send a Connection Opened (STP, Source Opened) confirmation to the port layer;
- b) SSP, then this state shall send a Connection Opened (SSP, Source Opened) confirmation to the port layer; or
- c) SMP, then this state shall send a Connection Opened (SMP, Source Opened) confirmation to the port layer.

After this state sends the Connection Opened confirmation the SMP connection, SSP connection, or SMP connection has been opened between the source phy and the destination phy.

This state shall ignore OPEN\_REJECT Received and OPEN\_ACCEPT Received messages from the time a Transmit SOAF/Data Dwords/EOAF message is sent to the SL transmitter until an SOAF/Data Dwords/EOAF Transmitted message is received from the SL transmitter.

If a BROADCAST Received (Change) message, BROADCAST Received (Reserved Change 0) message, or BROADCAST Received (Reserved Change 1) message is received, then this state shall send a Change Received confirmation to the management application layer.

If a PS\_REQ Received message is received, then this state shall send a Transmit PS\_NAK to the SL transmitter.

If an AIP Received message is received after requesting the OPEN address frame be transmitted, then this state shall reinitialize and restart the Open Timeout timer. The state machine shall not enforce a limit on the number of AIPs received.

If a Stop Arb request is received, then this state shall send an Open Failed (Arb Stopped) confirmation to the port layer.

If there is no response to the OPEN address frame before the Open Timeout timer expires, then this state shall send an Open Failed (Open Timeout Occurred) confirmation to the port layer.

If a BREAK Received message is received, then this state shall send an Open Failed (Break Received) confirmation to the port layer.

If this state receives an OPEN\_REJECT Received message listed in table 142 after transmitting the OPEN address frame, then this state shall send the corresponding Open Failed confirmation listed in table 142 to the port layer.

**Table 142 — OPEN\_REJECT Received message to Open Failed confirmation mapping**

| <b>OPEN_REJECT Received message</b>                  | <b>Open Failed confirmation</b>             |
|------------------------------------------------------|---------------------------------------------|
| OPEN_REJECT Received (Bad Destination)               | Open Failed (Bad Destination)               |
| OPEN_REJECT Received (Connection Rate Not Supported) | Open Failed (Connection Rate Not Supported) |
| OPEN_REJECT Received (Protocol Not Supported)        | Open Failed (Protocol Not Supported)        |
| OPEN_REJECT Received (Reserved Abandon 1)            | Open Failed (Reserved Abandon 1)            |
| OPEN_REJECT Received (Reserved Abandon 2)            | Open Failed (Reserved Abandon 2)            |
| OPEN_REJECT Received (Reserved Abandon 3)            | Open Failed (Reserved Abandon 3)            |
| OPEN_REJECT Received (STP Resources Busy)            | Open Failed (STP Resources Busy)            |
| OPEN_REJECT Received (Wrong Destination)             | Open Failed (Wrong Destination)             |
| OPEN_REJECT Received (Zone Violation)                | Open Failed (Zone Violation)                |
| OPEN_REJECT Received (No Destination)                | Open Failed (No Destination)                |
| OPEN_REJECT Received (Pathway Blocked)               | Open Failed (Pathway Blocked)               |
| OPEN_REJECT Received (Reserved Continue 0)           | Open Failed (Reserved Continue 0)           |
| OPEN_REJECT Received (Reserved Continue 1)           | Open Failed (Reserved Continue 1)           |
| OPEN_REJECT Received (Reserved Initialize 0)         | Open Failed (Reserved Initialize 0)         |



**Table 142 — OPEN\_REJECT Received message to Open Failed confirmation mapping**

| <b>OPEN_REJECT Received message</b>          | <b>Open Failed confirmation</b>     |
|----------------------------------------------|-------------------------------------|
| OPEN_REJECT Received (Reserved Initialize 1) | Open Failed (Reserved Initialize 1) |
| OPEN_REJECT Received (Reserved Stop 0)       | Open Failed (Reserved Stop 0)       |
| OPEN_REJECT Received (Reserved Stop 1)       | Open Failed (Reserved Stop 1)       |
| OPEN_REJECT Received (Retry)                 | Open Failed (Retry)                 |

**6.16.4.3.2 Transition SL\_CC1:ArbSel to SL\_CC0:Idle**

This transition shall occur:

- a) after sending an Open Failed confirmation.

**6.16.4.3.3 Transition SL\_CC1:ArbSel to SL\_CC2:Selected**

This transition shall occur after receiving a SOAF/Data Dwords/EOAF Transmitted message if:

- a) one or more AIP Received messages have been received before an OPEN Address Frame Received message is received (i.e., the incoming OPEN address frame overrides the outgoing OPEN address frame); or
- b) no AIP Received messages have been received before an OPEN Address Frame Received message is received, and the arbitration fairness rules (see 6.14.3) indicate the received OPEN address frame overrides the outgoing OPEN address frame. The arbitration fairness comparison shall compare:
  - A) the value of the arbitration wait time argument in the Open Connection request for the outgoing OPEN address frame; and
  - B) the value of the ARBITRATION WAIT TIME field received in the incoming OPEN address frame.

If persistent connections are supported (see 4.1.13.2) and:

- a) the SEND EXTEND bit is set to one in the received OPEN address frame and the INITIATOR PORT bit is set to one in the received OPEN address frame, then this transition shall include an Extend Connection (Transmit) argument;
- b) the SEND EXTEND bit is set to zero in the received OPEN address frame, then this transition shall include an Extend Connection (Off) argument; or
- c) the INITIATOR PORT bit is set to zero in the received OPEN address frame, then this transition shall include an Extend Connection (Off) argument.

If credit advance is implemented (see 4.1.14) and:

- a) the CREDIT ADVANCE bit is set to one in the received OPEN address frame; and
- b) the SAS PROTOCOL field is set to 001b (i.e., SSP) in the received OPEN address frame,

then this transition shall include an Advance Credit argument.

**6.16.4.3.4 Transition SL\_CC1:ArbSel to SL\_CC3:Connected**

This transition shall occur:

- a) after sending a Connection Opened confirmation.

If the SAS PROTOCOL field in the transmitted OPEN address frame was set to:

- a) STP, then this transition shall include an Open STP Connection argument;
- b) SSP, then this transition shall include an Open SSP Connection argument; or
- c) SMP, then this transition shall include an Open SMP Connection argument.



If persistent connections are supported (see 4.1.13.2), and:

- a) the SEND EXTEND bit is set to one in the transmitted OPEN address frame and the INITIATOR PORT bit was set to one in the transmitted OPEN address frame, then this transition shall include an Extend Connection (Wait) argument;
- b) the SEND EXTEND bit is set to zero in the transmitted OPEN address frame, then this transition shall include an Extend Connection (Off) argument; or
- c) the INITIATOR PORT bit was set to zero in the transmitted OPEN address frame, then this transition shall include an Extend Connection (Off) argument.

If credit advance is implemented (see 4.1.14) and:

- a) the CREDIT ADVANCE bit is set to one in the transmitted OPEN address frame; and
- b) the SAS PROTOCOL field is set to 001b (i.e., SSP) in the transmitted OPEN address frame,

then this transition shall include an Advance Credit argument.

#### 6.16.4.3.5 Transition SL\_CC1:ArbSel to SL\_CC5:BreakWait

This transition shall occur after receiving a SOAF/Data Dwords/EOAF Transmitted message if a BREAK Received message has not been received and after:

- a) sending an Open Failed (Arb Stopped) confirmation to the port layer;
- b) sending an Open Failed (Open Timeout Occurred) confirmation to the port layer; or
- c) a NOTIFY Received (Power Loss Expected) message is received.

If a NOTIFY Received (Power Loss Expected) message was received and the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port), then this transition shall include a Power Loss Expected argument.

#### 6.16.4.3.6 Transition SL\_CC1:ArbSel to SL\_CC6:Break

This transition shall occur after:

- a) receiving a SOAF/Data Dwords/EOAF Transmitted message;
- b) receiving a BREAK Received message; and
- c) sending an Open Failed (Break Received) confirmation to the port layer.

If a NOTIFY Received (Power Loss Expected) message was received and the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port), then this transition shall include a Power Loss Expected argument.

#### 6.16.4.4 SL\_CC2:Selected state

##### 6.16.4.4.1 State description

This state completes the establishment of an SSP, SMP, or STP connection when an incoming connection request has won arbitration by sending a Transmit OPEN\_ACCEPT message, or rejects opening a connection by sending a Transmit OPEN\_REJECT message to the SL transmitter.

This state shall respond to an incoming OPEN address frame using the following rules:

- 1) if the OPEN address frame DESTINATION SAS ADDRESS field does not match the SAS address of this port, then this state shall send a Transmit OPEN\_REJECT (Wrong Destination) message to the SL transmitter (see 6.16.4.4.2);
- 2) if the OPEN address frame INITIATOR PORT bit, SAS PROTOCOL field, FEATURES field, and/or INITIATOR CONNECTION TAG field are set to values that are not supported (e.g., a connection request from an SMP target port), then this state shall send a Transmit OPEN\_REJECT (Protocol Not Supported) message to the SL transmitter (see 6.16.4.4.2);
- 3) if the OPEN address frame CONNECTION RATE field is set to a connection rate that is not supported, then this state shall send a Transmit OPEN\_REJECT (Connection Rate Not Supported) message to the SL transmitter (see 6.16.4.4.2);

- 4) if the OPEN address frame SAS PROTOCOL field is set to STP, the STP target port supports affiliations, and the source SAS address is not that of an STP initiator port with an affiliation established (see 6.19.4), then this state shall send a Transmit OPEN\_REJECT (STP Resources Busy) message to the SL transmitter (see 6.16.4.4.2);
- 5) if the OPEN address frame SAS PROTOCOL field is set to SSP and the Reject SSP Opens state machine variable is set to YES, then this state shall send a Transmit OPEN\_REJECT (Retry) message to the SL transmitter (see 6.16.4.4.2);
- 6) if the OPEN address frame SAS PROTOCOL field is set to SMP and the Reject SMP Opens state machine variable is set to YES, then this state shall send a Transmit OPEN\_REJECT (Retry) message to the SL transmitter (see 6.16.4.4.2);
- 7) if the OPEN address frame SAS PROTOCOL field is set to STP and the Reject STP Opens state machine variable is set to YES, then this state shall send a Transmit OPEN\_REJECT (Retry) message to the SL transmitter (see 6.16.4.4.2);
- 8) if the OPEN address frame SAS PROTOCOL field is set to SSP and the Reject SSP Opens state machine variable is set to NO, then this state shall send a Transmit OPEN\_ACCEPT message to the SL transmitter and send a Connection Opened (SSP, Destination Opened) confirmation to the port layer (see 6.16.4.4.3);
- 9) if the OPEN address frame SAS PROTOCOL field is set to SMP and the Reject SMP Opens state machine variable is set to NO, then this state shall send a Transmit OPEN\_ACCEPT message to the SL transmitter and send a Connection Opened (SMP, Destination Opened) confirmation to the port layer (see 6.16.4.4.3); or
- 10) if the OPEN address frame SAS PROTOCOL field is set to STP and the Reject STP Opens state machine variable is set to NO, then this state shall send a Transmit OPEN\_ACCEPT message to the SL transmitter and send a Connection Opened (STP, Destination Opened) confirmation to the port layer (see 6.16.4.4.3).

If this state sends a Transmit OPEN\_REJECT message to the SL transmitter, then it shall also send an Inbound Connection Rejected confirmation to the port layer.

NOTE 32 - Possible livelock scenarios occur if the BREAK\_REPLY method of responding to BREAK primitive sequences is disabled and a SAS logical phy transmits a BREAK primitive sequence to abort a connection request (e.g., if its Open Timeout timer expires). SAS logical phys responding to OPEN Address frames faster than 1 ms reduce susceptibility to this problem.

#### 6.16.4.4.2 Transition SL\_CC2:Selected to SL\_CC0:Idle

This transition shall occur after sending a Transmit OPEN\_REJECT message to the SL transmitter.

#### 6.16.4.4.3 Transition SL\_CC2:Selected to SL\_CC3:Connected

This transition shall occur after sending a Connection Opened confirmation to the port layer.

This transition shall include:

- a) an Open SSP Connection, Open STP Connection, or Open SMP Connection argument based on the requested protocol;
- b) the received OPEN address frame;
- c) the Extend Connection argument, if persistent connections are supported (see 4.1.13.2); and
- d) the Advance Credit argument, if the transition into this state included an Advance Credit argument.

#### 6.16.4.4.4 Transition SL\_CC2:Selected to SL\_CC5:BreakWait

If the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port), then this transition shall occur:

- a) after receiving a NOTIFY Received (Power Loss Expected) message and shall include a Power Loss Expected argument.

#### 6.16.4.4.5 Transition SL\_CC2:Selected to SL\_CC6:Break

This transition shall occur:

- a) after a BREAK Received message is received.

#### 6.16.4.5 SL\_CC3:Connected state

##### 6.16.4.5.1 State description

This state enables the SSP, STP, or SMP link layer state machine to transmit dwords during a connection. See 6.15 for details on rate matching during the connection.

If this state is entered from SL\_CC1:ArbSel state or the SL\_CC2:Selected state with an argument of Open SMP Connection, then:

- 1) this state shall send an Enable Disable SMP (Enable) message to the SMP link layer state machines (see 6.20.5); and
- 2) if this state is entered with an Advance Credit argument, then this state shall send an Advance Credit message to the SSP link layer state machines (see 6.18.9).

If this state is entered from SL\_CC1:ArbSel state or the SL\_CC2:Selected state with an argument of Open SSP Connection, then this state shall send an Enable Disable SSP (Enable) message to the SSP link layer state machines (see 6.18.9).

If this state is entered from SL\_CC1:ArbSel state or the SL\_CC2:Selected state with an argument of Open STP Connection, then this state shall send an Enable Disable STP (Enable) message to the STP link layer state machines (see 6.19.8).

If this state is entered from SL\_CC1:ArbSel state or the SL\_CC2:Selected state with an argument of Open SSP Connection and persistent connections are supported (see 4.1.13.2), then this state if entered with:

- a) an Extend Connection (Transmit) argument, shall:
  - A) send a Persistent Connection (Transmit) message to the SSP\_EM link layer state machine (see 6.18.9.12); and
  - B) send a Persistent Connection Established (Disabled) confirmation to the port layer;
- b) an Extend Connection (Wait) argument, shall:
  - A) send a Persistent Connection (Wait) message to the SSP\_EM link layer state machine (see 6.18.9.12); and
  - B) send a Persistent Connection Established (Disabled) confirmation to the port layer;
- or
- c) an Extend Connection (Off) argument, send a Persistent Connection (Off) message to the SSP\_EM link layer state machine (see 6.18.9.12).

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SL transmitter until the SSP, SMP, or STP link layer state machine starts transmitting.

A CLOSE Received message may be received at any time while in this state, but shall be ignored during SSP and SMP connections. If a CLOSE Received (Clear Affiliation) message is received during an STP connection, then this state shall clear any affiliation (see 6.19.4).

If a Request Break message is received and a BREAK Received message has not been received, then this state shall send a Connection Closed (Break Requested) confirmation to the port layer.

If a BREAK Received message is received, then this state shall send a Connection Closed (Break Received) confirmation to the port layer.

##### 6.16.4.5.2 Transition SL\_CC3:Connected to SL\_CC4:DisconnectWait

This transition shall occur:

- a) if a Request Close message is received.

**6.16.4.5.3 Transition SL\_CC3:Connected to SL\_CC5:BreakWait**

This transition shall occur after:

- a) sending a Connection Closed (Break Requested) confirmation to the port layer; or
- b) receiving a NOTIFY Received (Power Loss Expected) message, if the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port).

If a NOTIFY Received (Power Loss Expected) message was received and the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port), then this state shall include:

- a) a Power Loss Expected argument.

**6.16.4.5.4 Transition SL\_CC3:Connected to SL\_CC6:Break**

This transition shall occur:

- a) after sending a Connection Closed (Break Received) confirmation to the port layer.

**6.16.4.5.5 Transition SL\_CC3:Connected to SL\_CC7:CloseSTP**

This transition shall occur:

- a) if a CLOSE Received message is received during an STP connection.

**6.16.4.6 SL\_CC4:DisconnectWait state****6.16.4.6.1 State description**

This state closes the connection and releases all resources associated with the connection.

Upon entry into this state, this state shall:

- 1) send a Transmit CLOSE (Normal) message or Transmit CLOSE (Clear Affiliation) message to the SL transmitter (see 6.19.6); and
- 2) initialize and start the Close Timeout timer.

A CLOSE Received message may be received at any time while in this state. If a CLOSE Received (Clear Affiliation) message is received during an STP connection, then this state shall clear any affiliation (see 6.19.4).

NOTE 33 - Possible livelock scenarios occur if the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled and a SAS logical phy transmits a BREAK primitive sequence to break a connection (e.g., if its Close Timeout timer expires). SAS logical phys responding to CLOSE faster than 1 ms reduce susceptibility to this problem.

If a CLOSE Received message is received, then this state shall send a Connection Closed (Normal) confirmation to the port layer.

If a BREAK Received message is received, then this state shall send a Connection Closed (Break Received) confirmation to the port layer.

If a BREAK Received message has not been received and no CLOSE Received message is received in response to a Transmit CLOSE message before the Close Timeout timer expires then this state shall send a Connection Closed (Close Timeout) confirmation to the port layer.

**6.16.4.6.2 Transition SL\_CC4:DisconnectWait to SL\_CC0:Idle**

This transition shall occur:

- a) after sending a Connection Closed (Normal) confirmation to the port layer.

**6.16.4.6.3 Transition SL\_CC4:DisconnectWait to SL\_CC5:BreakWait**

This transition shall occur after:

- a) receiving a NOTIFY Received (Power Loss Expected) message; or
- b) sending a Connection Closed (Close Timeout) confirmation to the port layer.

If a NOTIFY Received (Power Loss Expected) message was received and the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port), then this state shall include:

- a) a Power Loss Expected argument.

**6.16.4.6.4 Transition SL\_CC4:DisconnectWait to SL\_CC6:Break**

This transition shall occur:

- A) after sending a Connection Closed (Break Received) confirmation to the port layer.

**6.16.4.7 SL\_CC5:BreakWait state****6.16.4.7.1 State description**

This state closes the connection if one is established and releases all resources associated with the connection.

Upon entry into this state, this state shall:

- 1) send a Transmit BREAK message to the SL transmitter; and
- 2) initialize and start the Break Timeout timer.

If this state:

- a) is entered with a Power Loss Expected argument; or
- b) receives a NOTIFY Received (Power Loss Expected) message and the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port),

then this state shall send a Notify Received (Power Loss Expected) confirmation to the port layer.

If a BREAK Received message is received and the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5), then this state shall send a Transmit BREAK\_REPLY message to the SL transmitter.

NOTE 34 - Some SAS logical phys compliant with SAS-1.1 send a Transmit OPEN\_REJECT (Retry) message to the SL transmitter in response to each OPEN Address Frame Received message received while in this state.

**6.16.4.7.2 Transition SL\_CC5:BreakWait to SL\_CC0:Idle**

This transition shall occur after:

- a) receiving a BREAK\_REPLY Received message if the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5);
- b) receiving a BREAK Received message if the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled (see 6.14.5); or
- c) the Break Timeout timer expires.

**6.16.4.8 SL\_CC6:Break state****6.16.4.8.1 State description**

This state closes any connection and releases all resources associated with this connection.

Upon entry into this state:

- a) if the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5), then this state shall send a Transmit BREAK\_REPLY message to the SL transmitter (see 6.16.4.8.2); and
- b) if the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled (see 6.14.5), then this state shall send a Transmit BREAK message to the SL transmitter.

If this state:

- a) is entered with a Power Loss Expected argument; or
- b) receives a NOTIFY Received (Power Loss Expected) message and the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port),

then this state shall send a Notify Received (Power Loss Expected) confirmation to the port layer.

#### 6.16.4.8.2 Transition SL\_CC6:Break to SL\_CC0:Idle

This transition shall occur:

- a) after sending a Transmit BREAK message or a Transmit BREAK\_REPLY message to the SL transmitter.

#### 6.16.4.9 SL\_CC7:CloseSTP state

##### 6.16.4.9.1 State description

This state closes an STP connection and releases all resources associated with the connection.

Upon entry into this state, this state shall:

- 1) send a Transmit CLOSE (Normal) message or Transmit CLOSE (Clear Affiliation) message to the SL transmitter (see 6.19.6); and
- 2) send a Connection Closed (Normal) confirmation to the port layer (see 6.16.4.9.2).

NOTE 35 - Possible livelock scenarios occur if the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled and a SAS logical phy transmits a BREAK primitive sequence to break a connection (e.g., if its Close Timeout timer expires). SAS logical phys responding to a CLOSE primitive sequence faster than 1 ms reduce susceptibility to this problem.

##### 6.16.4.9.2 Transition SL\_CC7:CloseSTP to SL\_CC0:Idle

This transition shall occur:

- a) after sending a Connection Closed (Normal) confirmation to the port layer.

#### 6.16.4.10 SL\_CC8:PS\_Request state

##### 6.16.4.10.1 State description

This state requests the attached phy change to a low phy power condition.

Upon entry into this state, this state shall:

- a) if entered with the Phy Power Condition (Enter Partial) argument, then send a Transmit PS\_REQ (Partial) message to the SL transmitter;
- b) if entered with the Phy Power Condition (Enter Slumber) argument, then send a Transmit PS\_REQ (Slumber) message to the SL transmitter; and
- c) initialize and start the Power Condition Request Timeout timer.

If this state:

- a) is entered with the Phy Power Condition (Enter Partial) argument; and



- b) receives a PS\_REQ Received (Slumber) message,

then this state shall set the Phy Power Condition argument to Enter Partial.

If this state:

- a) is entered with the Phy Power Condition (Enter Slumber) argument; and
- b) receives a PS\_REQ Received (Partial) message,

then this state shall:

- a) set the Phy Power Condition argument to Enter Partial; and
- b) if the Accept Partial state machine variable is set to:
  - A) YES, then send a Transmit PS\_ACK Pattern message to the SL transmitter; or
  - B) NO, then send a Transmit PS\_NAK message to the SL transmitter.

If this state:

- a) receives a PS\_REQ Received message;
- b) the PS\_REQ Received message argument is requesting the same power condition as the Phy Power Condition argument; and
- c) the attached SAS address is greater than the port identifier (i.e., SAS address),

then this state shall send:

- a) a Transmit PS\_ACK Pattern message to the SL transmitter; and
- b) a Manage Phy Power Conditions (Stop DWS) request to the phy layer.

If a Change Phy Power Condition request is received, then this state shall send a Phy Power Condition Status (Retry Change Phy Power Condition Request) confirmation to the management application layer.

If an Open Connection request is received, then this state shall send an Open Failed (Low Phy Power Condition) confirmation to the port layer.

If a BROADCAST Received (Change) message, BROADCAST Received (Reserved Change 0) message, or BROADCAST Received (Reserved Change 1) message is received, then this state shall send a Change Received confirmation to the management application layer.

If a Transmit Broadcast request is received, then this state shall send a Retry Transmit Broadcast confirmation to the management application layer.

If a BREAK Received message is received and the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5), then this state shall send a Transmit BREAK\_REPLY message to the SL transmitter.

#### 6.16.4.10.2 Transition SL\_CC8:PS\_Request to SL\_CC9:PS\_Quiet

This transition shall occur after:

- a) receiving a PS\_ACK Pattern Transmitted message from the SL transmitter; or
- b) receiving a PS\_ACK Received message.

This transition shall include the:

- a) Phy Power Condition argument.

#### 6.16.4.10.3 Transition SL\_CC8:PS\_Request to SL\_CC0:Idle

This transition shall occur after:

- a) sending a Transmit PS\_NAK message to the SL transmitter;
- b) receiving a PS\_NAK Received message;
- c) sending a Transmit BREAK\_REPLY message to the SL transmitter;
- d) a BREAK Received message is received and the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled; or
- e) the Power Condition Request Timeout timer expires.

**6.16.4.10.4 Transition SL\_CC8:PS\_Request to SL\_CC2:Selected**

This transition shall occur:

- a) after receiving an OPEN Address Frame Received message.

**6.16.4.11 SL\_CC9:PS\_Quiet state****6.16.4.11.1 State description**

This state requests the phy be placed into a low phy power condition.

If this state is entered with a Phy Power Condition (Enter Partial) argument, then this state shall send:

- a) a Manage Phy Power Conditions (Enter Partial) request to the phy layer; and
- b) a Phy Power Condition Status (In Partial) confirmation to the management application layer.

If this state is entered with Phy Power Condition (Enter Slumber) argument, then this state shall send:

- a) a Manage Phy Power Conditions (Enter Slumber) request to the phy layer; and
- b) a Phy Power Condition Status (In Slumber) confirmation to the management application layer.

If this state receives a:

- a) Change Phy Power Condition (Enter Slumber) request and the current phy power condition is partial; or
- b) Change Phy Power Condition (Enter Partial) request and the current phy power condition is slumber,

then this state shall send a Phy Power Condition Status (Request Exit Power Condition) confirmation to the management application layer.

If a Transmit Broadcast request is received, then this state shall send a Retry Transmit Broadcast confirmation to the management application layer.

If this state receives an Open Connection request or a Change Phy Power Condition (Exit Power Condition) request, then this state shall send a Manage Phy Power Conditions (Exit) request to the phy layer.

**6.16.4.11.2 Transition SL\_CC9:PS\_Quiet to SL\_CC0:Idle**

This transition shall occur:

- a) after a Phy Layer Ready (SAS) confirmation is received; and
- b) an Open Connection request has not been received.

**6.16.4.11.3 Transition SL\_CC9:PS\_Quiet to SL\_CC1:ArbSel**

This transition shall occur after receiving both a Phy Layer Ready (SAS) confirmation and an Open Connection request. The Open Connection request includes these arguments:

- a) Initiator Port Bit;
- b) Protocol;
- c) Connection Rate;
- d) Initiator Connection Tag;
- e) Destination SAS Address;
- f) Source SAS Address;
- g) Pathway Blocked Count; and
- h) Arbitration Wait Time.

If persistent connections are supported (see 4.1.13.2), then the Open Connection request includes the following argument:

- a) Send Extend Bit.



If credit advance is implemented (see 4.1.14), then the Open Connection request includes the following argument:

- a) Credit Advance Bit.

## 6.17 XL (link layer for expander logical phys) state machine

### 6.17.1 XL state machine overview

The XL state machine controls the flow of dwords on the logical link and establishes and maintains connections with another XL state machine as facilitated by the expander function (e.g., the ECM and ECR).

This state machine consists of the following states:

- a) XL0:Idle (see 6.17.3) (initial state);
- b) XL1:Request\_Path (see 6.17.4);
- c) XL2:Request\_Open (see 6.17.5);
- d) XL3:Open\_Confirm\_Wait (see 6.17.6);
- e) XL4:Open\_Reject (see 6.17.7);
- f) XL5:Forward\_Open (see 6.17.8);
- g) XL6:Open\_Response\_Wait (see 6.17.9);
- h) XL7:Connected (see 6.17.10);
- i) XL8:Close\_Wait (see 6.17.11);
- j) XL9:Break (see 6.17.12);
- k) XL10:Break\_Wait (see 6.17.13);
- l) XL11:PS\_Request (see 6.17.14); and
- m) XL12:PS\_Quiet (see 6.17.15).

This state machine shall start in the XL0:Idle state. The XL state machine shall transition to the XL0:Idle state from any other state after receiving an Enable Disable SAS Link (Disable) message from the SL\_IR state machines (see 6.10).

This state machine receives the following messages from the SL\_IR state machines:

- a) Enable Disable SAS Link (Enable); and
- b) Enable Disable SAS Link (Disable).

This state machine sends the following messages to the SL\_P\_S link layer state machine (see 6.12.4):

- a) Idle State Condition (Active); and
- b) Idle State Condition (Inactive).

Any message received by a state that is not referred to in the description of that state shall be ignored.

If this state machine receives a Manage Power Conditions (Accept Partial) request from the ECM, then this state machine shall set the Accept Partial state machine variable (see table 144) to YES. If this state machine receives a Manage Power Conditions (Accept Slumber) request from the ECM, then this state machine shall set the Accept Slumber state machine variable (see table 144) to YES.

If this state machine receives a Manage Power Conditions (Reject Partial) request from the ECM, then this state machine shall set the Accept Partial state machine variable to NO. If this state machine receives a Manage Power Conditions (Reject Slumber) request from the ECM, then this state machine shall set the Accept Slumber state machine variable to NO.

The default value of the Accept Partial state machine variable and Accept Slumber state machine variable shall be NO.

This state machine shall maintain the timers listed in table 143.

**Table 143 — XL state machine timers**

| Timer                                   | Initial value                                                                                                                                                                        |
|-----------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Partial Pathway Timeout timer           | Partial pathway timeout value (see 6.14.4.4)                                                                                                                                         |
| Break Timeout timer                     | 1 ms                                                                                                                                                                                 |
| Power Condition Request Timeout timer   | 1 ms                                                                                                                                                                                 |
| Idle timer                              | 1 ms                                                                                                                                                                                 |
| SSP Maximum Connection Time Limit timer | For SSP connections, the value in the SSP CONNECT TIME LIMIT field in the SMP REPORT GENERAL response (see 9.4.3.4). For SMP connections and STP connections this timer is not used. |
| Wait For Frame Timeout timer            | 1 ms                                                                                                                                                                                 |

The XL state machine shall maintain the state machine variables listed in table 144.

**Table 144 — XL state machine variable**

| State machine variable | Description                                                                                 |
|------------------------|---------------------------------------------------------------------------------------------|
| Accept Partial         | Used to determine if the ECM is permitting this phy to enter a partial phy power condition. |
| Accept Slumber         | Used to determine if the ECM is permitting this phy to enter a slumber phy power condition. |

**XL (link layer for expander logical phys) state machine (part 1 of 4)**

**States:** XL0:Idle, XL9:Break, XL3:Open\_Confirm\_Wait, XL6:Open\_Response\_Wait, XL4:Open\_Reject, XL5:Forward\_Open, XL1:Request\_Path, XL7:Connected, XL8:Close\_Wait, XL2:Request\_Open, XL10:Break\_Wait, XL11:PS\_Request, XL12:PS\_Quiet.

**Transitions and Events:**

- XL0:Idle to XL4:Open\_Reject:** Phy Power Condition (Manage Phy Power Conditions), Transmit Broadcast (Broadcast Event Notify).
- XL4:Open\_Reject to XL0:Idle:** Phy Layer Not Ready (Phy Layer Not Ready), Retry (Transmit Broadcast).
- XL4:Open\_Reject to XL5:Forward\_Open:** Transmit OPEN\_REJECT.
- XL4:Open\_Reject to XL1:Request\_Path:** Transmit AIP.
- XL5:Forward\_Open to XL0:Idle:** SATA Spinup Hold (SATA Spinup Hold), SATA Port Selector Change (SATA Port Selector Change), Idle State Condition (SL\_P\_S).
- XL5:Forward\_Open to XL1:Request\_Path:** Manage Phy Power Conditions, Forward Open (Forward Open), Open Reject (Open Reject), Backoff Retry (Backoff Retry), Arb Won (Arb Won), Arb Lost (Arb Lost).
- XL1:Request\_Path to XL2:Request\_Open:** Request Path.
- XL2:Request\_Open to XL5:Forward\_Open:** Transmit AIP.
- XL5:Forward\_Open to XL3:Open\_Confirm\_Wait:** Transmit OPEN\_REJECT.
- XL3:Open\_Confirm\_Wait to XL6:Open\_Response\_Wait:** Transmit OPEN\_REJECT.
- XL6:Open\_Response\_Wait to XL0:Idle:** Transmit OPEN\_REJECT.
- XL6:Open\_Response\_Wait to XL8:Close\_Wait:** Transmit OPEN\_REJECT.
- XL8:Close\_Wait to XL0:Idle:** Transmit OPEN\_REJECT.
- XL8:Close\_Wait to XL10:Break\_Wait:** Transmit OPEN\_REJECT.
- XL10:Break\_Wait to XL11:PS\_Request:** Transmit OPEN\_REJECT.
- XL11:PS\_Request to XL12:PS\_Quiet:** Transmit OPEN\_REJECT.
- XL12:PS\_Quiet to XL11:PS\_Request:** Transmit OPEN\_REJECT.
- XL11:PS\_Request to XL12:PS\_Quiet:** Transmit OPEN\_REJECT.
- XL12:PS\_Quiet to XL0:Idle:** Transmit OPEN\_REJECT.
- XL0:Idle to XL9:Break:** Manage Phy Power Conditions (to all states, causing transition to XL0:Idle), SL\_IR (SL\_IR), Enable Disable SAS Link (Disable).
- XL9:Break to XL0:Idle:** Manage Phy Power Conditions (to all states, causing transition to XL0:Idle), SL\_IR (SL\_IR), Enable Disable SAS Link (Disable).
- XL9:Break to XL0:Idle:** Transmit BREAK, Transmit BREAK\_REPLY.

**Figure 136 — XL (link layer for expander logical phys) state machine (part 1)**



Figure 138 shows additional states in the XL state machine.

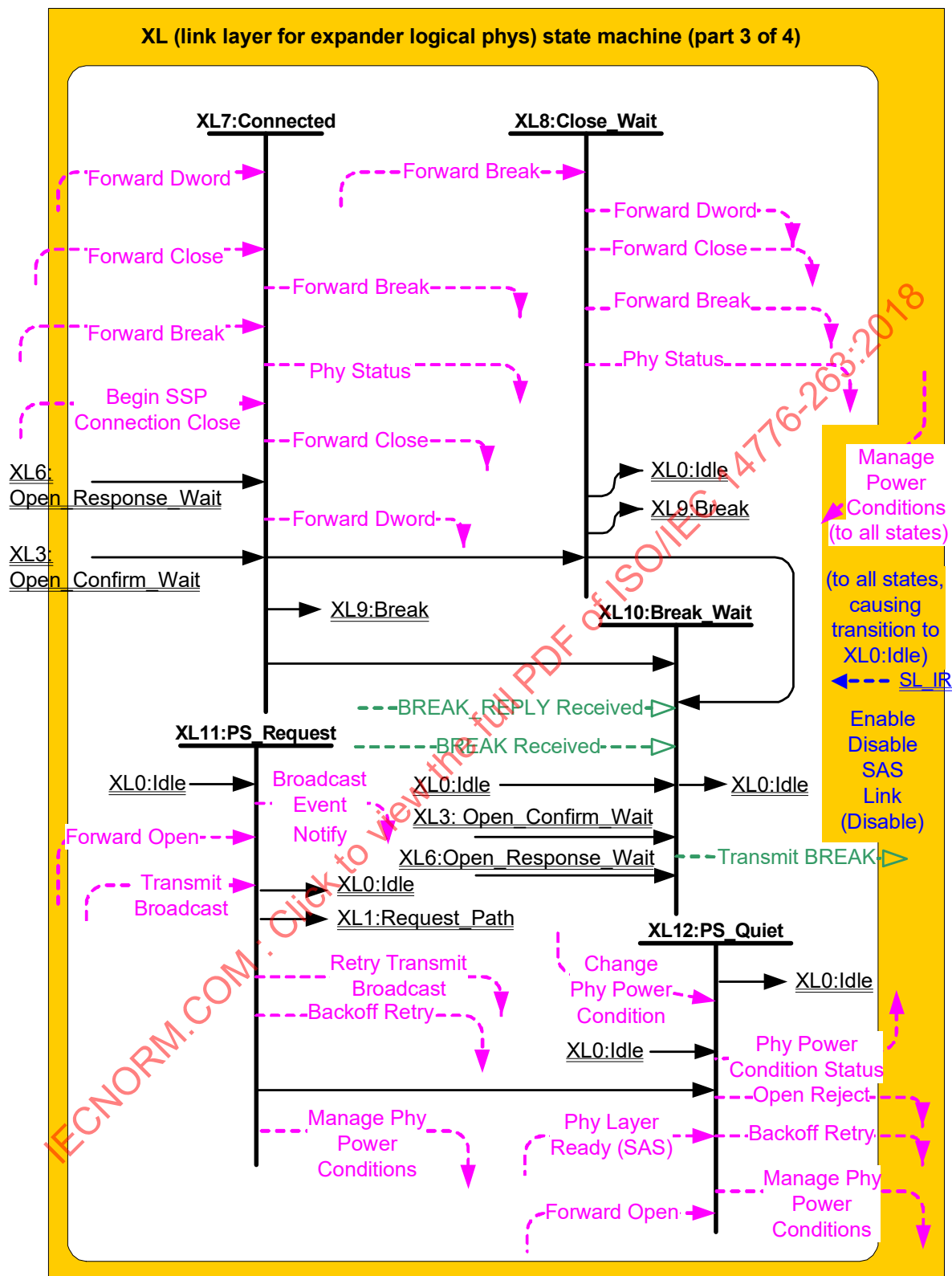


Figure 138 — XL (link layer for expander logical phys) state machine (part 3)

Figure 139 shows additional states in the XL state machine.

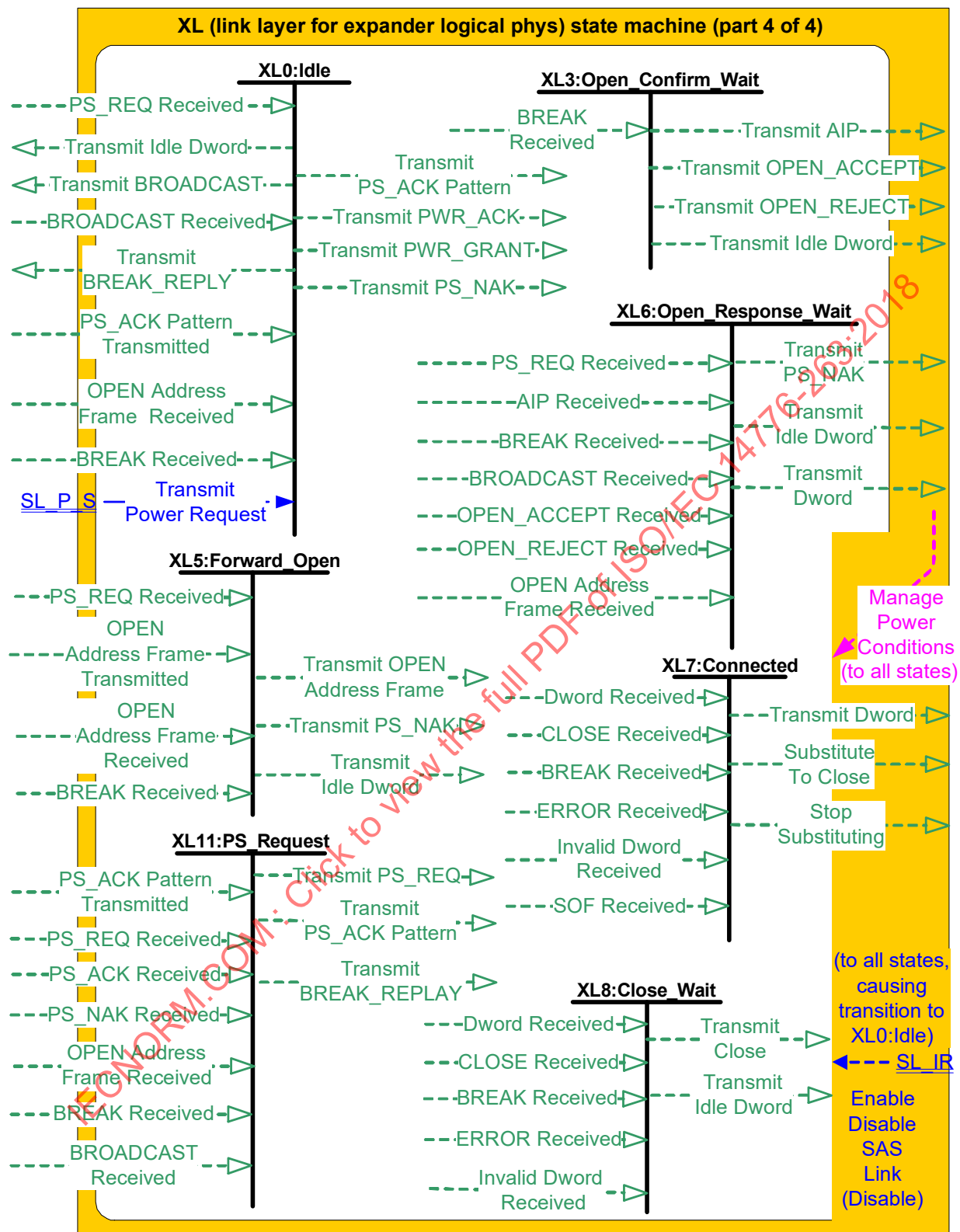


Figure 139 — XL (link layer for expander logical phys) state machine (part 4)

### 6.17.2 XL transmitter and receiver

The XL transmitter receives the following messages from the XL state machine specifying primitive sequences, frames, and dwords to transmit:

- a) Transmit Idle Dword;
- b) Transmit AIP with an argument indicating the specific type (e.g., Transmit AIP (Normal));
- c) Transmit BREAK;
- d) Transmit BREAK\_REPLY;
- e) Transmit BROADCAST with an argument indicating the specific type (e.g., Transmit BROADCAST (Change));
- f) Transmit CLOSE with an argument indicating the specific type (e.g., Transmit CLOSE (Normal));
- g) Transmit OPEN\_ACCEPT;
- h) Transmit OPEN\_REJECT, with an argument indicating the specific type (e.g., Transmit OPEN\_REJECT (No Destination));
- i) Transmit PS\_REQ with an argument indicating the specific type (e.g., Transmit PS\_REQ (Partial) or Transmit PS\_REQ (Slumber));
- j) Transmit PS\_ACK Pattern (see 6.11);
- k) Transmit PS\_NAK;
- l) Transmit PWR\_ACK;
- m) Transmit PWR\_GRANT;
- n) Substitute to Close;
- o) Stop Substituting;
- p) Transmit OPEN Address Frame; and
- q) Transmit Dword.

The XL transmitter sends the following messages to the XL state machine based on dwords that have been transmitted:

- a) OPEN Address Frame Transmitted; and
- b) PS\_ACK Pattern Transmitted.

The XL transmitter shall ensure physical link rate tolerance management requirements are met (see 6.3) while originating dwords.

The XL transmitter shall ensure physical link rate tolerance management requirements are met while forwarding dwords (i.e., during a connection) by inserting or deleting as many deletable primitives as required to match the transmit and receive connection rates (see 6.3.2).

The XL transmitter shall ensure physical link rate tolerance management requirements are met (see 6.3) during and after switching from forwarding dwords to originating dwords, including, for example:

- a) when transmitting a BREAK primitive sequence;
- b) when transmitting a BREAK\_REPLY primitive sequence;
- c) when transmitting a CLOSE primitive sequence;
- d) when transmitting an idle dword after closing a connection (i.e., after receiving a BREAK primitive sequence, BREAK\_REPLY primitive sequence, or CLOSE primitive sequence);
- e) while transmitting a SATA frame to a SAS logical link during an STP connection, when transmitting the first SATA\_HOLD in response to detection of SATA\_HOLD; and
- f) while receiving dwords of a SATA frame from a SAS logical link during an STP connection, when transmitting SATA\_HOLD.

The XL transmitter may insert a deletable primitive before transmitting a BREAK, BREAK\_REPLY, CLOSE, or SATA\_HOLD to meet physical link rate tolerance management requirements.

The XL transmitter shall insert a deletable primitive before switching from originating dwords to forwarding dwords, including, for example:

- a) when transmitting OPEN\_ACCEPT;
- b) when transmitting the last idle dword before a connection is established (i.e., after receiving OPEN\_ACCEPT);

- c) while transmitting a SATA frame to a SAS logical link during an STP connection, when transmitting the last dword from the STP flow control buffer in response to release of SATA\_HOLD;
- d) while transmitting a SATA frame to a SAS logical link during an STP connection, when transmitting the last SATA\_HOLD in response to release of SATA\_HOLD (e.g., if the STP flow control buffer is empty); and
- e) while receiving dwords of a SATA frame from a SAS logical link during an STP connection, when transmitting the last SATA\_HOLD.

NOTE 36 - This ensures that physical link rate tolerance management requirements are met, even if the forwarded dword stream does not include a deletable primitive until the last possible dword.

The XL transmitter shall ensure rate matching requirements are met during a connection (see 6.15).

After receiving a Substitute To Close message the XL transmitter shall transmit:

- a) an RRDY (CLOSE) in place of each received RRDY (NORMAL); and
- b) an EXTEND\_CONNECTION (CLOSE) in place of each received EXTEND\_CONNECTION (NORMAL).

If the XL transmitter receives a Stop Substituting message after receiving a Substitute To Close message, then the XL transmitter shall cancel the replacement:

- a) of RRDY (NORMAL) with RRDY (CLOSE); and
- b) of EXTEND\_CONNECTION (NORMAL) with EXTEND\_CONNECTION (CLOSE).

When there is no outstanding message specifying a dword to transmit, the XL transmitter shall transmit idle dwords.

The XL receiver sends the following messages to the XL state machine indicating primitive sequences, frames, and dwords received from the SP\_DWS receiver (see 5.13.2):

- a) AIP Received with an argument indicating the specific type (e.g., AIP Received (Normal));
- b) BREAK Received;
- c) BREAK\_REPLY Received;
- d) BROADCAST Received;
- e) CLOSE Received;
- f) OPEN\_ACCEPT Received;
- g) OPEN\_REJECT Received;
- h) OPEN Address Frame Received;
- i) PS\_REQ Received with an argument indicated the specific type (e.g., PS\_REQ Received (Partial)) or PS\_REQ Received (Slumber);
- j) PS\_ACK Received;
- k) PS\_NAK Received;
- l) SOF Received;
- m) Dword Received with an argument indicating the data dword or primitive received. Deletable primitives are not included; and
- n) Invalid Dword Received.

The XL receiver shall ignore all other dwords.

While receiving an address frame, if the XL receiver receives an invalid dword or ERROR, then the XL receiver shall either:

- a) ignore the invalid dword or ERROR; or
- b) discard the address frame.

The XL transmitter relationship to other transmitters is defined in 4.3.2. The XL receiver relationship to other receivers is defined in 4.3.3.



### 6.17.3 XL0:Idle state

#### 6.17.3.1 State description

This state is the initial state and is the state that is used when there is no connection pending or established.

Upon entry into this state, this state shall:

- a) send an Idle State Condition (Active) message to the SL\_P\_S link layer state machine; and
- b) initialize and start the Idle timer.

This state shall repeatedly send Idle requests to the ECM.

If a Phy Layer Not Ready confirmation is received, then this state shall send a Broadcast Event Notify (Phy Not Ready) request to the BPP.

If a SATA Spinup Hold confirmation is received, then this state shall send a Broadcast Event Notify (SATA Spinup Hold) request to the BPP.

If an Enable Disable SAS Link (Enable) message is received, then this state shall send a Broadcast Event Notify (Identification Sequence Complete) request to the BPP.

If a SATA Port Selector Change confirmation is received, then this state shall send a Broadcast Event Notify (SATA Port Selector Change) request to the BPP.

If a BROADCAST Received message is received, then this state shall send a Broadcast Event Notify request to the BPP with the argument indicating the specific BROADCAST primitive sequence received (e.g., Change Received).

If a Transmit Broadcast indication is received and this state has not sent a Transmit PS\_ACK Pattern message, then this state shall send a Transmit BROADCAST message to the XL transmitter with an argument specifying the specific type from the Transmit Broadcast indication. Otherwise, this state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the XL transmitter. If a Transmit Broadcast indication is received and this state has sent a Transmit PS\_ACK Pattern message to the XL transmitter, then this state shall send a Retry Transmit Broadcast request to the BPP.

If a Transmit Broadcast indication is received coincident with receiving either a Forward Open indication or an OPEN Address Frame Received message, then this state shall send a Transmit BROADCAST message with the same argument to the XL transmitter before transitioning to another state.

If a BREAK Received message is received and the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5), then this state shall send a Transmit BREAK\_REPLY message to the XL transmitter.

If a PS\_REQ Received (Partial) message is received and the Accept Partial state machine variable is set to YES, then this state shall send:

- a) a Transmit PS\_ACK Pattern message to the XL transmitter; and
- b) a Manage Phy Power Conditions (Stop DWS) request to the phy layer.

If a PS\_REQ Received (Slumber) message is received and the Accept Slumber state machine variable is set to YES, then this state shall send:

- a) a Transmit PS\_ACK Pattern message to the XL transmitter; and
- b) a Manage Phy Power Conditions (Stop DWS) request to the phy layer.

If a PS\_REQ Received (Partial) message is received and the Accept Partial state machine variable is set to NO, then this state shall send a Transmit PS\_NAK message to the XL transmitter. If a PS\_REQ Received (Slumber) message is received and the Accept Slumber state machine variable is set to NO, then this state shall send a Transmit PS\_NAK message to the XL transmitter.

If a Forward Open indication is received from the ECM and this state has sent a Transmit PS\_ACK Pattern message to the XL transmitter, then this state shall send a Backoff Retry response to the ECR.

If a Change Phy Power Condition request is received and this state has sent a Transmit PS\_ACK Pattern message to the XL transmitter, then this state shall send a Phy Power Condition Status (Retry Change Phy Power Condition Request) confirmation to the management application layer.

This state shall ignore any Change Phy Power Condition (Exit Power Condition) requests.

If this state receives a:

- a) Transmit Power Request (PWR\_ACK) message, then this state shall send a Transmit PWR\_ACK message to the SL transmitter; or
- b) Transmit Power Request (PWR\_GRANT) message, then this state shall send a Transmit PWR\_GRANT message to the SL transmitter.

If the Idle timer expires, then this state shall:

- a) send an Idle State Condition (Active) message to the SL\_P\_S link layer state machine; and
- b) initialize and start the Idle timer.

#### 6.17.3.2 Transition XL0:Idle to XL1:Request\_Path

This transition shall occur if:

- a) an Enable Disable SAS Link (Enable) message has been received;
- b) a Forward Open indication is not being received; and
- c) an OPEN Address Frame Received message is received.

This state shall include an OPEN Address Frame Received argument with the transition.

Before this transition, this state shall send an Idle State Condition (Inactive) message to the SL\_P\_S link layer state machine (see 6.12.4).

#### 6.17.3.3 Transition XL0:Idle to XL5:Forward\_Open

If this state has not sent a Transmit PS\_ACK Pattern message to the XL transmitter, then this transition shall occur after receiving:

- a) an Enable Disable SAS Link (Enable) message; and
- b) a Forward Open indication.

This transition shall include a set of arguments containing the arguments received in the Forward Open indication.

If an OPEN Address Frame Received message is received, then this state shall include:

- a) an OPEN Address Frame Received argument with the transition.

Before this transition, this state shall send an Idle State Condition (Inactive) message to the SL\_P\_S link layer state machine (see 6.12.4).

#### 6.17.3.3.1 Transition XL0:Idle to XL11:PS\_Request

If this state has not sent a Transmit PS\_ACK Pattern message to the XL transmitter, then this transition shall occur after receiving:

- a) an Enable Disable SAS Link (Enable) message; and
- b) a Change Phy Power Condition request.

This transition shall include the following argument that corresponds to the Change Phy Power Condition request:

- a) Phy Power Condition argument (Enter Partial); or
- b) Phy Power Condition (Enter Slumber).

Before this transition, this state shall send an Idle State Condition (Inactive) message to the SL\_P\_S link layer state machine (see 6.12.4).

### 6.17.3.3.2 Transition XL0:Idle to XL12:PS\_Quiet

This transition shall occur:

- a) after receiving a PS\_ACK Pattern Transmitted message from the XL transmitter.

This transition shall include the following argument that corresponds to the PS\_REQ Received message:

- a) Phy Power Condition (Enter Partial) argument; or
- b) Phy Power Condition (Enter Slumber).

Before this transition, this state shall send an Idle State Condition (Inactive) message to the SL\_P\_S link layer state machine (see 6.12.4).

### 6.17.4 XL1:Request\_Path state

#### 6.17.4.1 State description

This state is used to arbitrate for connection resources and to specify the destination of the connection.

If an Arbitrating (Normal) confirmation is received, then this state shall repeatedly send Transmit AIP (Normal) messages and Transmit Idle Dword messages to the XL transmitter in accordance with AIP transmission rules (see 6.14.4.3).

If an Arbitrating (Waiting On Partial) confirmation or an Arbitrating (Blocked On Partial) confirmation is received, then this state shall repeatedly send Transmit AIP (Waiting On Partial) messages and Transmit Idle Dword messages to the XL transmitter in accordance with AIP transmission rules (see 6.14.4.3).

If an Arbitrating (Waiting On Partial) confirmation is received, then this state shall repeatedly send a Phy Status (Partial Pathway) response to the ECM.

If an Arbitrating (Blocked On Partial) confirmation is received, then this state shall repeatedly send a Phy Status (Blocked Partial Pathway) response to the ECM.

If an Arbitrating (Waiting On Connection) confirmation is received, then this state shall repeatedly send Transmit AIP (Waiting On Connection) messages and Transmit Idle Dword messages to the XL transmitter in accordance with AIP transmission rules (see 6.14.4.3).

If an Arbitrating (Waiting On Connection) confirmation is received, then this state shall repeatedly send a Phy Status (Connection) response to the ECM.

If this state is entered from the XL6:Open\_Response\_Wait state, then the High Priority argument shall be set to one. If this state is entered from any other state, then the High Priority argument shall be set to zero.

If the protocol argument is set to SMP, then the SMP Open Priority argument shall be set to one. If the protocol argument is set to SSP or STP, then the SMP Open Priority argument shall be set to zero.

Upon entry into this state, this state shall send a Request Path request to the ECM with the following arguments:

- a) Initiator Port Bit;
- b) Protocol;
- c) Connection Rate;
- d) Initiator Connection Tag;
- e) Destination SAS Address;
- f) Source SAS Address;
- g) Pathway Blocked Count;
- h) Arbitration Wait Time;
- i) SMP Open Priority; and
- j) High Priority.

This state maintains the Partial Pathway Timeout timer.

If the Partial Pathway Timeout timer is not already running, then the Partial Pathway Timeout timer shall be initialized and started when an Arbitrating (Blocked On Partial) confirmation is received.

If the Partial Pathway Timeout timer is already running, then the Partial Pathway Timeout timer shall continue to run if an Arbitrating (Blocked On Partial) confirmation is received.

The Partial Pathway Timeout timer shall be stopped when one of the following confirmations is received:

- a) Arbitrating (Waiting On Partial); or
- b) Arbitrating (Waiting On Connection).

If the Partial Pathway Timeout timer expires, then this state shall send a Partial Pathway Timeout Timer Expired request to the ECM.

#### 6.17.4.2 Transition XL1:Request\_Path to XL0:Idle

This transition shall occur if:

- a) a BREAK Received message has not been received; and
- b) an Arb Lost confirmation is received.

#### 6.17.4.3 Transition XL1:Request\_Path to XL2:Request\_Open

This transition shall occur if:

- a) a BREAK Received message has not been received; and
- b) an Arb Won confirmation is received.

#### 6.17.4.4 Transition XL1:Request\_Path to XL4:Open\_Reject

This transition shall occur if:

- a) a BREAK Received message has not been received; and
- b) an Arb Reject confirmation is received.

This transition shall include:

- a) an Arb Reject argument corresponding to the Arb Reject confirmation.

#### 6.17.4.5 Transition XL1:Request\_Path to XL5:Forward\_Open

This transition shall occur if a Forward Open indication is received and none of the following confirmations have been received:

- a) Arbitrating (Normal);
- b) Arbitrating (Waiting On Partial);
- c) Arbitrating (Blocked On Partial);
- d) Arbitrating (Waiting On Connection);
- e) Arb Won;
- f) Arb Lost;
- g) Arb Reject (No Destination);
- h) Arb Reject (Bad Destination);
- i) Arb Reject (Connection Rate Not Supported);
- j) Arb Reject (Zone Violation);
- k) Arb Reject (Pathway Blocked); or
- l) Arb Reject (Retry).

This transition shall include:

- a) an OPEN Address Frame Received argument containing the arguments received in the Forward Open indication; and
- b) a BREAK Received argument if a BREAK Received message was received.

#### 6.17.4.6 Transition XL1:Request\_Path to XL9:Break

This transition shall occur:

- a) after receiving a BREAK Received message if a Forward Open indication has not been received.

#### 6.17.5 XL2:Request\_Open state

##### 6.17.5.1 State description

This state is used to forward an OPEN address frame through the ECR to a destination phy.

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the XL transmitter.

Upon entry into this state, this state shall send a Forward Open request to the ECR, received by the destination phy as a Forward Open indication (see 6.17.5.2). The arguments to the Forward Open request are:

- a) initiator port bit;
- b) protocol;
- c) features;
- d) connection rate;
- e) initiator connection tag;
- f) Destination SAS Address;
- g) source SAS address;
- h) source zone group;
- i) pathway blocked count;
- j) arbitration wait time;
- k) compatible features; and
- l) more compatible features.

##### 6.17.5.2 Transition XL2:Request\_Open to XL3:Open\_Confirm\_Wait

This transition shall occur:

- a) after sending a Forward Open request to the ECR.

If a BREAK Received message is received, then this state shall include:

- a) a BREAK Received argument with the transition.

#### 6.17.6 XL3:Open\_Confirm\_Wait state

##### 6.17.6.1 State description

This state waits for confirmation for an OPEN address frame sent on a destination phy.

This state shall send the following messages to the XL transmitter:

- a) a Transmit AIP (Normal) message when an Arb Status (Normal) confirmation is received;
- b) a Transmit AIP (Waiting On Partial) message when an Arb Status (Waiting On Partial) confirmation is received;
- c) a Transmit AIP (Waiting On Connection) message when an Arb Status (Waiting On Connection) confirmation is received;
- d) a Transmit AIP (Waiting On Device) message when an Arb Status (Waiting On Device) confirmation is received;
- e) a Transmit OPEN\_ACCEPT message when an Open Accept confirmation is received (see 6.17.6.5);
- f) a Transmit OPEN\_REJECT message when an Open Reject confirmation is received with the argument from the Open Reject confirmation, after releasing path resources (see 6.17.6.2); or

- g) request idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages when none of the previous conditions are present.

If a Backoff Retry confirmation is received, then this state shall release path resources.

If a BREAK Received message is received or a BREAK Received argument is included in the transition into this state, then this state shall send a Forward Break request to the ECR (see 6.17.6.6).

This state shall repeatedly send a Phy Status (Partial Pathway) response to the ECM until an Arb Status (Waiting On Partial) confirmation is received. After an Arb Status (Waiting on Partial) confirmation is received, this state shall repeatedly send a Phy Status (Blocked Partial Pathway) response to the ECM.

If a Dword Received message is received containing a valid dword except a BREAK, then this state shall send a Forward Dword request to the ECR containing that dword.

If:

- a) an Invalid Dword Received message is received; and
- b) the expander logical phy is forwarding to an expander logical phy attached to a SAS logical link,

then the expander logical phy shall:

- a) send an ERROR with the Forward Dword request instead of the invalid dword; or
- b) delete the invalid dword.

If:

- a) an ERROR is received with the Dword Received message or an Invalid Dword Received message is received; and
- b) the expander logical phy is forwarding to an expander phy attached to a SATA physical link,

then the expander logical phy shall:

- a) send a SATA\_ERROR with the Forward Dword request instead of the invalid dword or ERROR primitive; or
- b) delete the ERROR or invalid dword.

#### 6.17.6.2 Transition XL3:Open\_Confirm\_Wait to XL0:Idle

This transition shall occur after sending a Transmit OPEN\_REJECT message to the XL transmitter if:

- a) a BREAK Received message has not been received; and
- b) a BREAK Received argument was not included in the transition into this state.

#### 6.17.6.3 Transition XL3:Open\_Confirm\_Wait to XL1:Request\_Path

This transition shall occur after receiving a Backoff Retry confirmation, after releasing path resources if:

- a) a BREAK Received message has not been received; and
- b) a BREAK Received argument was not included in the transition into this state.

#### 6.17.6.4 Transition XL3:Open\_Confirm\_Wait to XL5:Forward\_Open

This transition shall occur after receiving a Backoff Reverse Path confirmation if:

- a) a BREAK Received message has not been received; and
- b) a BREAK Received argument was not included in the transition into this state.

The transition shall include:

- a) the Backoff Reverse Path arguments (i.e., the OPEN address frame).

**6.17.6.5 Transition XL3:Open\_Confirm\_Wait to XL7:Connected**

This transition shall occur after sending a Transmit OPEN\_ACCEPT message to the XL transmitter if:

- a) a BREAK Received message has not been received; and
- b) a BREAK Received argument was not included in the transition into this state.

**6.17.6.6 Transition XL3:Open\_Confirm\_Wait to XL9:Break**

This transition shall occur:

- a) after sending a Forward Break request to the ECR.

**6.17.6.7 Transition XL3:Open\_Confirm\_Wait to XL10:Break\_Wait**

This transition shall occur after receiving a Forward Break indication if:

- a) a BREAK Received message has not been received; and
- b) a BREAK Received argument was not included in the transition into this state.

**6.17.7 XL4:Open\_Reject state****6.17.7.1 State description**

This state is used to reject a connection request.

This state shall send one of the following messages to the XL transmitter (see 6.17.7.2):

- a) a Transmit OPEN\_REJECT (No Destination) message when an Arb Reject (No Destination) argument is received with the transition into this state;
- b) a Transmit OPEN\_REJECT (Bad Destination) message when an Arb Reject (Bad Destination) argument is received with the transition into this state;
- c) a Transmit OPEN\_REJECT (Connection Rate Not Supported) message when an Arb Reject (Connection Rate Not Supported) argument is received with the transition into this state;
- d) a Transmit OPEN\_REJECT (Zone Violation) message when an Arb Reject (Zone Violation) argument is received with the transition into this state;
- e) a Transmit OPEN\_REJECT (Pathway Blocked) message when an Arb Reject (Pathway Blocked) argument is received with the transition into this state; or
- f) a Transmit OPEN\_REJECT (Retry) message when an Arb Reject (Retry) argument is received with the transition into this state.

**6.17.7.2 Transition XL4:Open\_Reject to XL0:Idle**

This transition shall occur:

- a) after sending a Transmit OPEN\_REJECT message to the XL transmitter.

**6.17.7.3 Transition XL4:Open\_Reject to XL5:Forward\_Open**

This transition shall occur:

- a) if a Forward Open indication is received.

This transition shall include an OPEN Address Frame Received argument containing the arguments received in the Forward Open indication.

**6.17.8 XL5:Forward\_Open state****6.17.8.1 State description**

This state is used to transmit an OPEN address frame passed with the transition into this state.



If a BROADCAST Received message is received, then this state shall send a Broadcast Event Notify request to the BPP with the argument indicating the specific BROADCAST primitive sequence received (e.g., Change Received).

Upon entry into this state, this state shall send a Transmit OPEN Address Frame message to the XL transmitter with the fields set to the values specified with the transition into this state.

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the XL transmitter.

If a PS\_REQ Received message is received, then this state shall send a Transmit PS\_NAK to the XL transmitter.

#### 6.17.8.2 Transition XL5:Forward\_Open to XL6:Open\_Response\_Wait

This transition shall occur:

- a) after receiving an OPEN Address Frame Transmitted message.

If an OPEN Address Frame Received message or argument is received, then this state shall include:

- a) an OPEN Address Frame Received argument with the transition.

If a BREAK Received message or argument is received, then this state shall include:

- a) a BREAK Received argument with the transition.

#### 6.17.9 XL6:Open\_Response\_Wait state

##### 6.17.9.1 State description

This state waits for a response to a transmitted OPEN address frame and determines the appropriate action to take based on the response.

This state shall either:

- a) request idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the XL transmitter, honoring ALIGN insertion rules for rate matching and physical link rate tolerance management; or
- b) send Transmit Dword messages to the XL transmitter to transmit all dwords received with Forward Dword indications.

If a BROADCAST Received message is received before an AIP Received message is received, then this state shall send a Broadcast Event Notify request to the BPP with the argument indicating the specific BROADCAST primitive sequence received (e.g., Broadcast Event Notify (Change Received)).

This state shall send the following responses to the ECR, which are received by the source phy as confirmations:

- a) an Open Accept response when an OPEN\_ACCEPT Received message is received (see 6.17.9.5);
- b) an Open Reject response when an OPEN\_REJECT Received message is received, after releasing any path resources (see 6.17.9.2);
- c) a Backoff Retry response, after releasing path resources (see 6.17.9.3), when:
  - A) an AIP Received message has not been received;
  - B) an OPEN Address Frame Received message is received or an OPEN Address Frame Received argument is included in the transition into this state containing a higher priority OPEN address frame according to the arbitration fairness comparison (see 6.14.3); and
  - C) the destination SAS address and connection rate of the received OPEN address frame are not equal to the source SAS address and connection rate of the transmitted OPEN address frame;
- d) a Backoff Retry response, after releasing path resources (see 6.17.9.3), when:
  - A) an AIP Received message has been received;
  - B) an OPEN Address Frame Received message is received or an OPEN Address Frame Received argument is included in the transition into this state; and



- C) the destination SAS address and connection rate of the received OPEN address frame are not equal to the source SAS address and connection rate of the transmitted OPEN address frame;
- e) a Backoff Reverse Path response (see 6.17.9.4) when:
  - A) an AIP Received message has not been received,
  - B) an OPEN Address Frame Received message is received or an OPEN Address Frame Received argument is included in the transition into this state containing a higher priority OPEN address frame according to the arbitration fairness comparison (see 6.14.3); and
  - C) the destination SAS address and connection rate of the received OPEN address frame are equal to the source SAS address and connection rate of the transmitted OPEN address frame;
- and
- f) a Backoff Reverse Path response (see 6.17.9.4) when:
  - A) an AIP Received message has been received;
  - B) an OPEN Address Frame Received message is received or an OPEN Address Frame Received argument is included in the transition into this state; and
  - C) the destination SAS address and connection rate of the received OPEN address frame are equal to the source SAS address and connection rate of the transmitted OPEN address frame.

A Backoff Reverse Path response shall include the contents of the OPEN Address Frame Received message or argument.

This state shall send the following responses to the ECR, which are received by the source phy as confirmations:

- a) an Arb Status (Waiting On Device) response upon entry into this state;
- b) an Arb Status (Normal) response when an AIP Received (Normal) message is received;
- c) an Arb Status (Waiting On Partial) response when an AIP Received (Waiting On Partial) message is received;
- d) an Arb Status (Waiting On Connection) response when an AIP Received (Waiting On Connection) message is received; and
- e) an Arb Status (Waiting On Device) response when an AIP Received (Waiting On Device) message is received.

If a BREAK Received message is received or a BREAK Received argument is included in the transition into this state, then this state shall send a Forward Break request to the ECR (see 6.17.9.6).

This state shall repeatedly send a Phy Status (Partial Pathway) response to the ECM until an AIP Received (Waiting On Partial) message is received. After an AIP Received (Waiting On Partial) message is received, this state shall repeatedly send a Phy Status (Blocked Partial Pathway) response to the ECM.

If a PS\_REQ Received message is received this state shall send a Transmit PS\_NAK to the XL transmitter.

#### **6.17.9.2 Transition XL6:Open\_Response\_Wait to XL0:Idle**

This transition shall occur:

- a) after sending an Open Reject response to the ECR.

#### **6.17.9.3 Transition XL6:Open\_Response\_Wait to XL1:Request\_Path**

This transition shall occur:

- a) after sending a Backoff Retry response to the ECR.

#### **6.17.9.4 Transition XL6:Open\_Response\_Wait to XL2:Request\_Open**

This transition shall occur:

- a) after sending a Backoff Reverse Path response to the ECR.

**6.17.9.5 Transition XL6:Open\_Response\_Wait to XL7:Connected**

This transition shall occur:

- a) after sending an Open Accept response to the ECR.

**6.17.9.6 Transition XL6:Open\_Response\_Wait to XL9:Break**

This transition shall occur:

- a) after sending a Forward Break response to the ECR.

**6.17.9.7 Transition XL6:Open\_Response\_Wait to XL10:Break\_Wait**

This transition shall occur after receiving a Forward Break indication if:

- a) a BREAK Received message has not been received; and
- b) a BREAK Received argument was not included in the transition into this state.

**6.17.10 XL7:Connected state****6.17.10.1 State description**

This state provides a full-duplex path between two phys within an expander device.

If the connection is an SSP connection, then upon entry into this state, this state shall initialize and start the Wait For Frame Timeout timer.

If the connection is an SSP connection, then this state shall initialize and start the SSP Maximum Connection Time Limit timer when:

- a) the Wait For Frame Timeout timer expires; or
- b) an SOF Received message is received.

This state shall send Transmit Dword messages to the XL transmitter to transmit all dwords received with Forward Dword indications. During an STP connection, the expander device may expand or contract a repeated or continued primitive sequence (see 6.2.4).

If this state has not sent a Forward Close request to the ECR, then this state shall send Forward Dword requests to the ECR containing each valid dword except BREAK and CLOSE received with Dword Received messages. During an STP connection, the expander device may expand or contract a repeated or continued primitive sequence (see 6.2.4).

If:

- a) an Invalid Dword Received message is received; and
- b) the expander phy is forwarding to an expander logical phy attached to a SAS logical link,

then the expander logical phy shall:

- a) send an ERROR with the Forward Dword request instead of the invalid dword; or
- b) delete the invalid dword.

If:

- a) an ERROR is received with the Dword Received message or an Invalid Dword Received message is received; and
- b) the expander phy is forwarding to an expander logical phy attached to a SATA phy,

then the expander logical phy shall:

- a) send a SATA\_ERROR with the Forward Dword request instead of the invalid dword or ERROR primitive; or
- b) delete the ERROR or invalid dword.

If:

- a) this state receives a Begin SSP Connection Close confirmation and:
  - A) the Wait For Frame Timeout timer has expired; or
  - B) an SOF Received message was received;
- or
- b) the SSP Maximum Connection Time Limit timer expires,

then this state shall send a Substitute To Close message to the XL transmitter.

If this state receives a Begin SSP Connection Close confirmation and:

- a) the Wait For Frame Timeout timer has not expired; and
- b) an SOF Received message has not been received,

then this state shall:

- 1) wait until:
  - A) the Wait For Frame Timeout timer expires; or
  - B) an SOF Received message is received;
- and
- 2) send a Substitute To Close message to the XL transmitter.

If a CLOSE Received message is received, then this state shall:

- 1) stop the SSP Maximum Connection Time Limit timer;
- 2) send a Stop Substituting message to the XL transmitter; and
- 3) send a Forward Close request to the ECR with the argument from the CLOSE Received message.

If a BREAK Received message is received, then this state shall:

- 1) stop the SSP Maximum Connection Time Limit timer;
- 2) send a Stop Substituting message to the XL transmitter; and
- 3) send a Forward Break request to the ECR (see 6.17.10.3).

This state shall repeatedly send a Phy Status (Connection) response to the ECM.

#### **6.17.10.2 Transition XL7:Connected to XL8:Close\_Wait**

This transition shall occur:

- a) after receiving a Forward Close indication if a BREAK Received message has not been received.

#### **6.17.10.3 Transition XL7:Connected to XL9:Break**

This transition shall occur:

- a) after sending a Forward Break request to the ECR.

#### **6.17.10.4 Transition XL7:Connected to XL10:Break\_Wait**

This transition shall occur after receiving a Forward Break indication if a BREAK Received message has not been received. If this state has sent a Forward Close request to the ECR, then this transition shall include a Close Forwarded argument.

This transition shall occur after:

- a) stopping the SSP Maximum Connection Time Limit timer; and
- b) sending a Stop Substituting message to the XL transmitter.

### 6.17.11 XL8:Close\_Wait state

#### 6.17.11.1 State description

This state closes a connection and releases path resources.

Upon entry into this state, this state shall send a Transmit CLOSE message to the XL transmitter with the argument from the Forward Close indication, then shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the XL transmitter.

NOTE 37 - Possible livelock scenarios occur if the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled and a phy transmits a BREAK primitive sequence to break a connection (e.g., if its Close Timeout timer expires). Phys responding to a CLOSE primitive sequence faster than 1 ms reduce susceptibility to this problem.

If a Dword Received message is received containing a valid dword except a BREAK or CLOSE, then this state shall send a Forward Dword request to the ECR containing that dword. During an STP connection, the expander device may expand or contract a repeated or continued primitive sequence (see 6.2.4).

If:

- a) an Invalid Dword Received message is received; and
- b) the expander logical phy is forwarding to an expander logical phy attached to a SAS logical link,

then the expander logical phy shall:

- a) send an ERROR with the Forward Dword request instead of the invalid dword; or
- b) delete the invalid dword.

If:

- a) an ERROR is received with the Dword Received message or an Invalid Dword Received message is received; and
- b) the expander logical phy is forwarding to an expander phy attached to a SATA physical link,

then the expander logical phy shall:

- a) send a SATA\_ERROR with the Forward Dword request instead of the invalid dword or ERROR primitive; or
- b) delete the ERROR or invalid dword.

If a CLOSE Received message is received, then this state shall release path resources and send a Forward Close request to the ECR with the argument from the CLOSE Received message (see 6.17.11.2).

If this state was entered with an argument of Close Forwarded, then this state shall release path resources.

If a BREAK Received message is received, then this state shall send a Forward Break request to the ECR (see 6.17.11.3).

This state shall repeatedly send a Phy Status (Connection) response to the ECM.

#### 6.17.11.2 Transition XL8:Close\_Wait to XL0:Idle

This transition shall occur after:

- a) sending a Forward Close request to the ECR; or
- b) sending a Transmit CLOSE message to the XL transmitter if this state was entered with an argument of Close Forwarded.

#### 6.17.11.3 Transition XL8:Close\_Wait to XL9:Break

This transition shall occur:

- a) after sending a Forward Break request to the ECR.

**6.17.11.4 Transition XL8:Close\_Wait to XL10:Break\_Wait**

This transition shall occur:

- a) after receiving a Forward Break indication if a BREAK Received message has not been received.

**6.17.12 XL9:Break state****6.17.12.1 State description**

This state closes the connection, if there is one, and releases all path resources associated with the connection.

This state shall:

- a) send a Transmit BREAK\_REPLY message to the XL transmitter if the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5); and
- b) send a Transmit BREAK message to the XL transmitter if the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled (see 6.14.5).

**6.17.12.2 Transition XL9:Break to XL0:Idle**

This transition shall occur:

- a) after sending a Transmit BREAK message or a Transmit BREAK\_REPLY message to the XL transmitter.

**6.17.13 XL10:Break\_Wait state****6.17.13.1 State description**

This state closes the connection, if there is one, and releases path resources associated with the connection.

Upon entry into this state, this state shall:

- 1) send a Transmit BREAK message to the XL transmitter;
- 2) initialize and start the Break Timeout timer; and
- 3) repeatedly send a Phy Status (Breaking Connection) request to the ECM.

If a BREAK Received message is received and the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5), then this state shall send a Transmit BREAK\_REPLY message to the XL transmitter.

**6.17.13.2 Transition XL10:Break\_Wait to XL0:Idle**

This transition shall occur after:

- a) a BREAK\_REPLY Received message is received if the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5);
- b) a BREAK Received message is received if the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled (see 6.14.5); or
- c) the Break Timeout timer expires.

**6.17.14 XL11:PS\_Request state****6.17.14.1 State description**

This state requests the attached phy change to a low phy power condition.

Upon entry into this state, this state shall:

- a) if entered with the Phy Power Condition (Enter Partial) argument, then send a Transmit PS\_REQ (Partial) message to the XL transmitter;
- b) if entered with the Phy Power Condition (Enter Slumber) argument, then send a Transmit PS\_REQ (Slumber) message to the XL transmitter; and
- c) initialize and start the Power Condition Request Timeout timer.

If this state:

- a) is entered with the Phy Power Condition (Enter Partial) argument; and
- b) receives a PS\_REQ Received (Slumber) message.

then this state shall set the Phy Power Condition argument to Partial.

If this state:

- a) is entered with the Phy Power Condition (Enter Slumber) argument; and
- b) receives a PS\_REQ Received (Partial) message.

then this state shall:

- a) set the Phy Power Condition argument to Partial; and
- b) if the Accept Partial state machine variable is set to:
  - A) YES, then send a Transmit PS\_ACK Pattern message to the XL transmitter; or
  - B) NO, then send a Transmit PS\_NAK message to the XL transmitter.

If this state:

- a) receives a PS\_REQ Received message;
- b) the PS\_REQ Received message argument is requesting the same power condition as the Phy Power Condition argument; and
- c) the attached SAS address is greater than the port identifier (i.e., SAS Address),

then this state shall send:

- a) a Transmit PS\_ACK Pattern message to the XL transmitter; and
- b) a Manage Phy Power Conditions (Stop DWS) request to the phy layer.

If this state receives a Forward Open indication, this state shall send a Backoff Retry response to the ECR.

If a BROADCAST Received message is received, this state shall send a Broadcast Event Notify request to the BPP with the argument indicating the specific BROADCAST primitive sequence received (e.g., Change Received).

If a Transmit Broadcast indication is received, then this state shall send a Retry Transmit Broadcast request to the BPP.

If a BREAK Received message is received and the BREAK\_REPLY method of responding to received BREAK primitive sequences is enabled (see 6.14.5), then this state shall send a Transmit BREAK\_REPLY message to the XL transmitter.

#### 6.17.14.2 Transition XL11:PS\_Request to XL12:PS\_Quiet

This transition shall occur after receiving:

- a) a PS\_ACK Pattern Transmitted message from the XL transmitter; or
- b) a PS\_ACK Received message.

This transition shall include:

- a) the Phy Power Condition argument.

**6.17.14.3 Transition XL11:PS\_Request to XL0:Idle**

This transition shall occur after:

- a) sending a Transmit PS\_NAK message to the XL transmitter;
- b) a PS\_NAK Received message is received;
- c) sending a Transmit BREAK\_REPLY message to the XL transmitter;
- d) a BREAK Received message is received and the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled (see 6.14.5); or
- e) the Power Condition Request Timeout timer expires.

**6.17.14.4 Transition XL11:PS\_Request to XL1:Request\_Path**

This transition shall occur:

- a) after receiving an OPEN Address Frame Received message.

**6.17.15 XL12:PS\_Quiet state****6.17.15.1 State description**

This state requests the phy be placed into a low phy power condition.

If this state is entered with a Phy Power Condition (Enter Partial) argument, then this state shall send:

- a) a Manage Phy Power Conditions (Enter Partial) request to the phy layer; and
- b) a Phy Power Condition Status (In Partial) confirmation to the ECM.

If this state is entered with a Phy Power Condition (Enter Slumber) argument, then this state shall send:

- a) a Manage Phy Power Conditions (Enter Slumber) request to the phy layer; and
- b) a Phy Power Condition Status (In Slumber) confirmation to the ECM.

If this state receives a:

- a) Change Phy Power Condition (Enter Slumber) request and the current phy power condition is partial;  
or
- b) Change Phy Power Condition (Enter Partial) request and the current phy power condition is slumber,

then this state shall send a Phy Power Condition Status (Request Exit Power Condition) confirmation to the application client layer.

If a Transmit Broadcast indication is received, then this state shall send a Retry Transmit Broadcast request to the BPP.

If this state receives a Change Phy Power Condition (Exit Power Condition) request, then this state shall send a Manage Phy Power Conditions (Exit) request to the phy layer.

If this state receives a Forward Open indication from the ECM, then this state shall send a Manage Phy Power Conditions (Exit) request to the phy layer and if the phy is in:

- a) a slumber phy power condition, send an Open Reject (Retry) response to the ECR; or
- b) a partial phy power condition, send a Backoff Retry response to the ECR.

**6.17.15.2 Transition XL12:PS\_Quiet to XL0:Idle**

This transition shall occur:

- a) after a Phy Layer Ready (SAS) confirmation is received.



## 6.18 SSP link layer

### 6.18.1 Opening an SSP connection

An SSP phy that accepts a connection request (i.e., an OPEN address frame) shall:

- a) transmit at least one RRDY in that connection within 1 ms of transmitting an OPEN\_ACCEPT; and
- b) if persistent connections are supported (see 4.1.13.2), the SEND\_EXTEND bit is set to one in the received OPEN address frame, and the INITIATOR\_PORT bit is set to one in the received OPEN address frame, then transmit an EXTEND\_CONNECTION (NORMAL).

If the SSP phy is not able to grant SSP frame credit, then it shall respond with OPEN\_REJECT (RETRY) and not accept the connection request.

To prevent livelocks (e.g., where ports are waiting on each other to accept a connection request):

- a) a SAS phy shall not reject an incoming connection request to an SSP initiator port with OPEN\_REJECT (RETRY) because the SAS port containing that SAS phy is waiting for an outgoing connection request to be accepted (e.g., if the SAS phy is used by an SSP initiator port and an SSP target port, they share a buffer, that buffer is being used by the SSP target port, and the SSP target port is waiting to transmit a frame to another SSP initiator port before it is able to free that buffer);
- b) a SAS phy may reject an incoming connection request to an SSP initiator port with OPEN\_REJECT (RETRY) for any reason that is not dependent on the SAS port containing that SAS phy having an outgoing connection request accepted (e.g., a temporary buffer full condition); and
- c) a SAS phy may reject an incoming connection request to an SSP target port with OPEN\_REJECT (RETRY) for any reason, including because the SAS port containing that SAS phy is waiting for an outgoing connection request to be accepted (e.g., to transmit a frame and empty a buffer).

### 6.18.2 Full duplex

SSP is a full duplex protocol. An SSP phy may receive an SSP frame or primitive in a connection while the SSP phy is transmitting an SSP frame or primitive in the same connection. A wide SSP port may send and/or receive SSP frames or primitives concurrently on different connections (i.e., on different phys).

If:

- a) a connection is open;
- b) a persistent connection has:
  - A) not been requested (i.e., the SEND\_EXTEND bit was set to zero in the OPEN address frame); or
  - B) been:
    - 1) requested (i.e., the SEND\_EXTEND bit was set to one in the OPEN address frame);
    - 2) established (see 4.1.13); and
    - 3) disabled (see 6.18.9.12.4);

and

- c) an SSP phy has no more SSP frames to transmit on that connection,

then the SSP phy transmits a DONE to start closing the connection (see 7.2.2.3.9). The other direction may still be active, so the DONE may be followed by one or more of the following primitives:

- a) CREDIT\_BLOCKED;
- b) RRDY;
- c) ACK; or
- d) NAK.



### 6.18.3 SSP frame transmission and reception

During an SSP connection, SSP frames are preceded by SOF and followed by EOF as shown in figure 140.

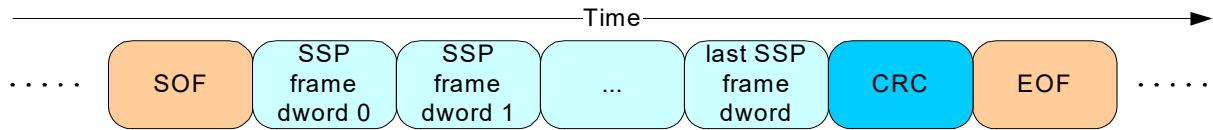


**Figure 140 — SSP frame transmission**

The last data dword after the SOF prior to the EOF always contains a CRC (see 6.5). The SSP link layer state machine checks that the frame is a valid length and that the CRC is valid (see 6.18.9.7). Other primitives (e.g., CREDIT\_BLOCKED, RRDY, ACK, and NAK) may be interspersed between the SOF, data dwords, and EOF.

Receiving SSP phys shall acknowledge SSP frames within 1 ms, if not discarded as described in 6.18.9.7, with either:

- a) ACK (i.e., positive acknowledgement) if the SSP frame was received into a frame buffer without errors; or
- b) NAK (CRC ERROR) (i.e., negative acknowledgement) if the SSP frame was received with a CRC error (i.e., a bad CRC), an invalid dword, or an ERROR.

NOTE 38 - It is not required that frame recipients generate NAK (CRC ERROR) from invalid dwords and ERRORS (see 6.18.9.2).

If an SSP frame results in a link layer error (e.g., is NAKed or creates an ACK/NAK timeout), then:

- a) the transport layer (see 8.2.4) retries sending the SSP frame; or
- b) the SCSI application layer aborts the SCSI command associated with that SSP frame.

### 6.18.4 SSP flow control

An SSP phy uses the CREDIT ADVANCE bit in the OPEN address frame and RRDY to grant SSP frame credit for permission for the other SSP phy in the connection to transmit frames.

If credit advance is implemented (see 4.1.14) and an OPEN address frame with the CREDIT ADVANCE bit set to one is received, then:

- 1) at the beginning of each connection a transmit SSP frame credit of zero is established;
- 2) the transmit SSP frame credit is incremented by one (see 6.18.9.4);
- 3) the first RRDY received does not increment transmit SSP frame credit (see 6.18.9.4); and
- 4) each subsequent RRDY increments transmit SSP frame credit by one frame.

If credit advance is not implemented (see 4.1.14) or an OPEN address frame with the CREDIT ADVANCE bit set to zero is received, then:

- a) at the beginning of each connection a transmit SSP frame credit of zero is established; and
- b) each RRDY increments transmit SSP frame credit by one frame.

Frame transmission decrements transmit SSP frame credit by one frame.

SSP phys shall not grant more than 255 SSP frame credits (i.e., outstanding received SSP frame credits shall not exceed 255).

To prevent deadlocks where an SSP initiator port and SSP target port are both waiting on each other to provide SSP frame credit, an SSP initiator port shall not refuse to provide SSP frame credit by withholding RRDY because the SSP initiator port is waiting to transmit a frame. An SSP initiator port may refuse to provide SSP frame credit for other reasons (e.g., temporary buffer full conditions).

An SSP target port may refuse to provide SSP frame credit for any reason, including because the SSP target port is waiting to transmit a frame.

If SSP frame credit is zero and a persistent connection:

- a) has not been established;
- b) was established and has been disabled (see 6.18.9.12.4); or
- c) has been established and the Persistent Connection Timeout timer (see table 147) has expired,

then SSP phys that are going to be unable to provide SSP frame credit for 1 ms may send CREDIT\_BLOCKED. The other phy may use this to avoid waiting 1 ms to transmit DONE (CREDIT\_TIMEOUT) (see 6.18.9).

If SSP frame credit is nonzero and a persistent connection:

- a) has not been established;
- b) was established and has been disabled (see 6.18.9.12.4); or
- c) has been established and the Persistent Connection Timeout timer (see table 147) has expired,

then SSP phys that are going to be unable to provide additional SSP frame credit for 1 ms, even if they receive frames per the existing SSP frame credit, may transmit CREDIT\_BLOCKED.

After sending CREDIT\_BLOCKED, an SSP phy shall not transmit any additional RRDYs in the connection.

### 6.18.5 Extending an SSP connection with persistent connections

If a persistent connection has been established (see 4.1.13), then to maintain the persistent connection an SSP phy shall transmit an EXTEND\_CONNECTION within the interval specified by the Transmit Extend Connection timer (see table 147) while the SSP phy has no SSP frame to transmit.

An EXTEND\_CONNECTION is not transmitted within an SSP frame.

The management application layer initiates the closing of a persistent connection by sending a Close Persistent Connection request for the SSP\_EM state machine (see 6.18.9.12).

### 6.18.6 Interlocked frames

Table 145 shows which SSP frames shall be interlocked and which are non-interlocked.

**Table 145 — SSP frame interlock requirements**

| SSP frame type                                 | Interlock requirement |
|------------------------------------------------|-----------------------|
| COMMAND                                        | Interlocked           |
| TASK                                           | Interlocked           |
| XFER_RDY                                       | Interlocked           |
| DATA                                           | Non-interlocked       |
| RESPONSE                                       | Interlocked           |
| Note - See 8.2 for SSP frame type definitions. |                       |

Before transmitting an interlocked frame, an SSP phy shall wait for all SSP frames to be acknowledged with ACK or NAK, even if transmit SSP frame credit is available. After transmitting an interlocked frame, an SSP phy shall not transmit another SSP frame until that interlocked frame has been acknowledged with ACK or NAK, even if transmit SSP frame credit is available.

Before transmitting a non-interlocked frame, an SSP phy shall wait for:

- a) all non-interlocked frames with different initiator port transfer tags; and

- b) all interlocked frames,

to be acknowledged with ACK or NAK, even if transmit SSP frame credit is available.

After transmitting a non-interlocked frame, an SSP phy may transmit another non-interlocked frame with the same initiator port transfer tag if transmit SSP frame credit is available. The phy shall not transmit:

- a) a non-interlocked frame with a different initiator port transfer tag; or
- b) an interlocked frame,

until all SSP frames have been acknowledged with ACK or NAK, even if transmit SSP frame credit is available.

Transmitting an interlocked frame does not prevent the transmitting phy from receiving frames at the same time (e.g., it is possible for an SSP initiator phy to transmit a COMMAND frame while receiving XFER\_RDY, DATA, or RESPONSE frames).

An SSP phy may transmit primitives responding to traffic that it is receiving (e.g., an ACK or NAK to acknowledge an SSP frame, an RRDY to grant more transmit SSP frame credit, or a CREDIT\_BLOCKED to specify that no more RRDYs are going to be transmitted in the connection) while waiting for an interlocked frame that it transmitted to be acknowledged. These primitives may also be interspersed within an SSP frame.

Figure 141 shows an example of interlocked frame transmission.

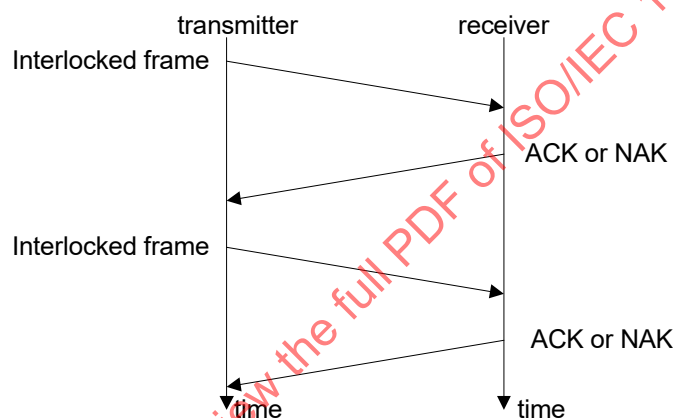


Figure 141 — Interlocked frames

Figure 142 shows an example of non-interlocked frame transmission with the same initiator port transfer tags.

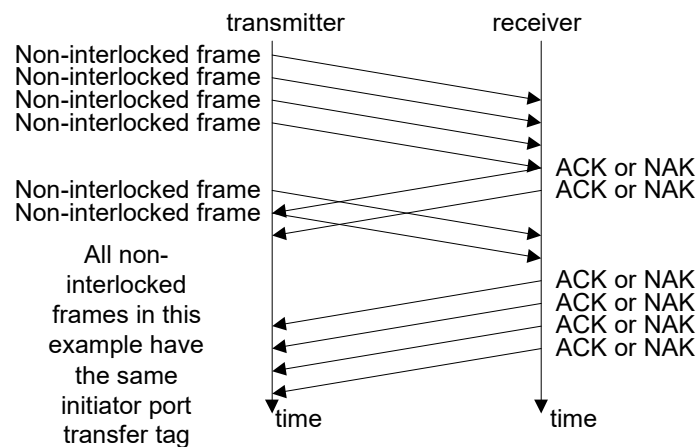


**Figure 142 — Non-interlocked frames with the same initiator port transfer tags**

Figure 143 shows an example of non-interlocked frame transmission with different initiator port transfer tags.

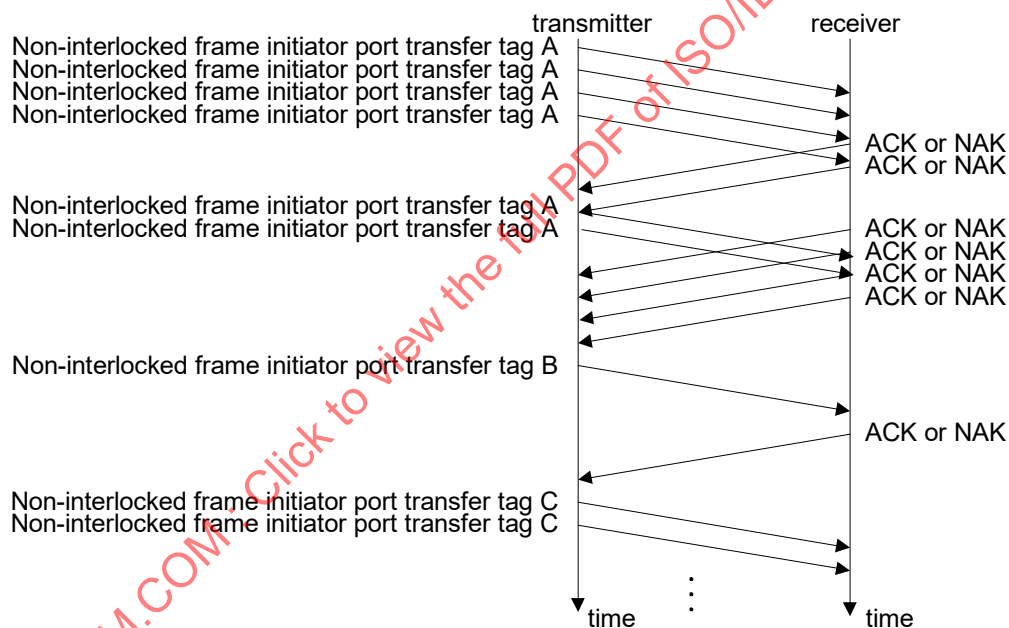


**Figure 143 — Non-interlocked frames with different initiator port transfer tags**

### 6.18.7 Breaking an SSP connection

In addition to the actions described in 6.14.9, the following shall be the responses by an SSP phy to a broken connection:

- received frames having no CRC error may be considered valid regardless of whether an ACK has been transmitted in response to the frame prior to the broken connection;
- transmitted frames for which an ACK has been received prior to a broken connection shall be considered transmitted without error; and

- c) transmitted frames for which an ACK or NAK has not been received prior to a broken connection shall be considered to have been transmitted with an error.

#### 6.18.8 Closing an SSP connection

DONE shall be exchanged prior to closing an SSP connection (see 7.2.2.3.9). The type of DONE indicates additional information about why the SSP connection is being closed as follows:

- a) DONE (NORMAL) specifies that the transmitter has no more SSP frames to transmit (i.e., normal completion);
- b) DONE (CLOSE) specifies that an end device has received an RRDY (CLOSE) (i.e, forced normal completion);
- c) DONE (CREDIT TIMEOUT) specifies that the transmitter still has SSP frames to transmit but did not receive an RRDY granting transmit SSP frame credit within 1 ms, or the transmitter has received a CREDIT\_BLOCKED and has consumed all RRDYs received; and
- d) DONE (ACK/NAK TIMEOUT) specifies that the transmitter transmitted an SSP frame but did not receive the corresponding ACK or NAK within 1 ms. As a result, the ACK/NAK count is not balanced and the transmitter is going to transmit a BREAK primitive sequence in 1 ms unless the recipient replies with DONE and the connection is closed,

A DONE exchange may be requested as follows:

- a) RRDY (CLOSE) specifies that an expander device or an end device has requested that the SSP connection or the SSP persistent connection be closed (i.e., requested forced normal completion); and
- b) EXTEND\_CONNECTION (CLOSE) specifies that an expander device has requested that the SSP persistent connection be closed (i.e., requested forced normal completion).

If the transmitter has no more SSP frames to transmit and receives a CREDIT\_BLOCKED, then it may transmit either DONE (NORMAL) or DONE (CREDIT TIMEOUT).

After transmitting DONE, the transmitting phy initializes and starts a 1 ms DONE Timeout timer (see 6.18.9.5).

After transmitting DONE, the transmitting phy shall not transmit any more SSP frames during this connection. However, the phy may transmit ACK, NAK, RRDY, and CREDIT\_BLOCKED as needed after transmitting DONE if the other phy is still transmitting SSP frames in the reverse direction. Once an SSP phy has both transmitted and received DONE, it shall close the connection by transmitting a CLOSE (NORMAL) primitive sequence (see 6.14.8).

Figure 144 shows the sequence for a closing an SSP connection.

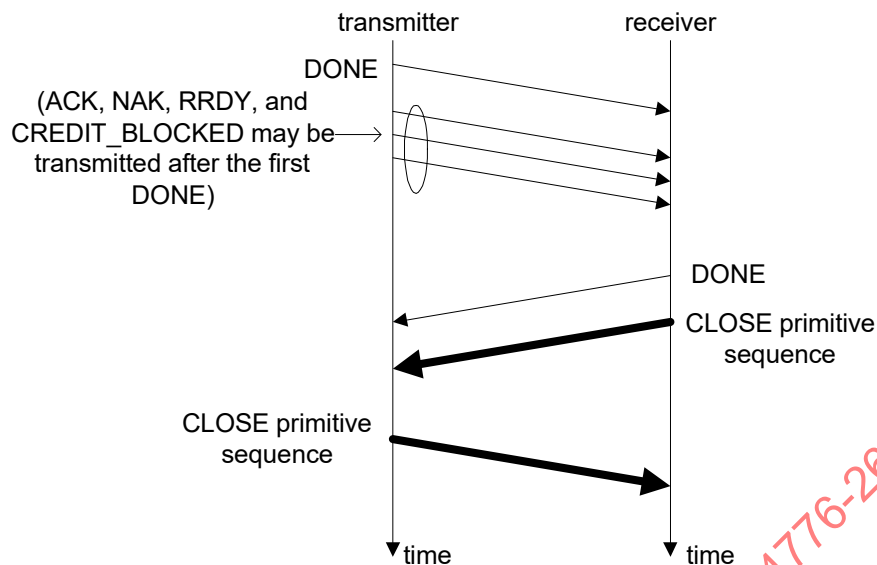


**Figure 144 — Closing an SSP connection example**

A Force Completion request sent to the SSP link layer (see 6.18.9.10) by a management application layer in an end device requests an RRDY (CLOSE) be substituted (i.e., forced normal completion of a connection). After a Force Completion request is received by the SSP link layer, the SSP link layer substitutes RRDY (CLOSE) when granting more transmit SSP frame credit instead of transmitting RRDY (NORMAL) until the connection is closed.

By sending a Begin SSP Connection Close confirmation to the XL link layer (see 6.17.10) a management application layer in an expander device may request:

- a) an RRDY (CLOSE) be substituted for an RRDY (NORMAL); and
- b) an EXTEND\_CONNECTION (CLOSE) be substituted for an EXTEND\_CONNECTION (NORMAL).

In response to receiving an RRDY (CLOSE) or an EXTEND\_CONNECTION (CLOSE) the SSP link layer requests the transmission of a DONE (CLOSE). The transmission of a DONE (CLOSE) occurs:

- a) if there are no SSP frames waiting to be transmitted by the SSP link layer (see 6.18.9.6.3);
- b) if there are no SSP frames being transmitted by the SSP link layer (see 6.18.9.6.4); and
- c) ACK/NAK count is balanced (see 6.18.9.3).

## 6.18.9 SSP (link layer for SSP phys) state machines

### 6.18.9.1 SSP state machines overview

The SSP link layer contains several state machines that run in parallel to control the flow of dwords on the physical link during an SSP connection. The SSP state machines are as follows:

- a) SSP\_TIM (transmit interlocked frame monitor) state machine (see 6.18.9.3);
- b) SSP\_TCM (transmit frame credit monitor) state machine (see 6.18.9.4);
- c) SSP\_D (DONE control) state machine (see 6.18.9.5);
- d) SSP\_TF (transmit frame control) state machine (see 6.18.9.6);
- e) SSP\_RF (receive frame control) state machine (see 6.18.9.7);
- f) SSP\_RCM (receive frame credit monitor) state machine (see 6.18.9.8);
- g) SSP\_RIM (receive interlocked frame monitor) state machine (see 6.18.9.9);
- h) SSP\_TC (transmit credit control) state machine (see 6.18.9.10);
- i) SSP\_TAN (transmit ACK/NAK control) state machine (see 6.18.9.11); and

j) SSP\_EM (establish and manage persistent connection) state machine (see 6.18.9.12).

All the SSP state machines, except SSP\_EM, shall start after receiving an Enable Disable SSP (Enable) message from the SL state machines (see 6.16).

If persistent connections are supported (see 4.1.13.2), then the SSP\_EM state machine shall start after receiving an Enable Disable SSP (Enable) message from the SL state machines.

All the SSP state machines shall terminate after:

- a) receiving an Enable Disable SSP (Disable) message from the SL state machines;
- b) receiving a Request Close message from the SSP\_D state machine indicating that the connection has been closed;
- c) receiving a Request Break message from the SSP\_D state machine indicating that a BREAK primitive sequence has been transmitted; or
- d) receiving a NOTIFY Received (Power Loss Expected) message from the SP\_DWS receiver if the SAS port that contains this state machine supports NOTIFY (Power Loss Expected) (e.g., the SAS port is an SSP target port).

If a state machine consists of multiple states, then the initial state is as indicated in the state machine description in this subclause.

The SSP state machines shall maintain the timers listed in table 146.

**Table 146 — SSP state machines timers**

| Timer                 | Initial value | State machine | Reference |
|-----------------------|---------------|---------------|-----------|
| ACK/NAK Timeout timer | 1 ms          | SSP_TIM       | 6.18.9.3  |
| DONE Timeout timer    | 1 ms          | SSP_D         | 6.18.9.5  |
| Credit Timeout timer  | 1 ms          | SSP_TF        | 6.18.9.6  |

If persistent connections are supported (see 4.1.13.2), then the SSP state machines shall maintain the timers listed in table 147.

**Table 147 — SSP state machines timers for persistent connections**

| Timer                               | Initial value | State machine | Reference |
|-------------------------------------|---------------|---------------|-----------|
| Persistent Connection Timeout timer | 1 ms          | SSP_EM        | 6.18.9.12 |
| Transmit Extend Connection timer    | 100 $\mu$ s   | SSP_EM        | 6.18.9.12 |

Figure 145 shows the SSP state machines and states related to frame transmission.

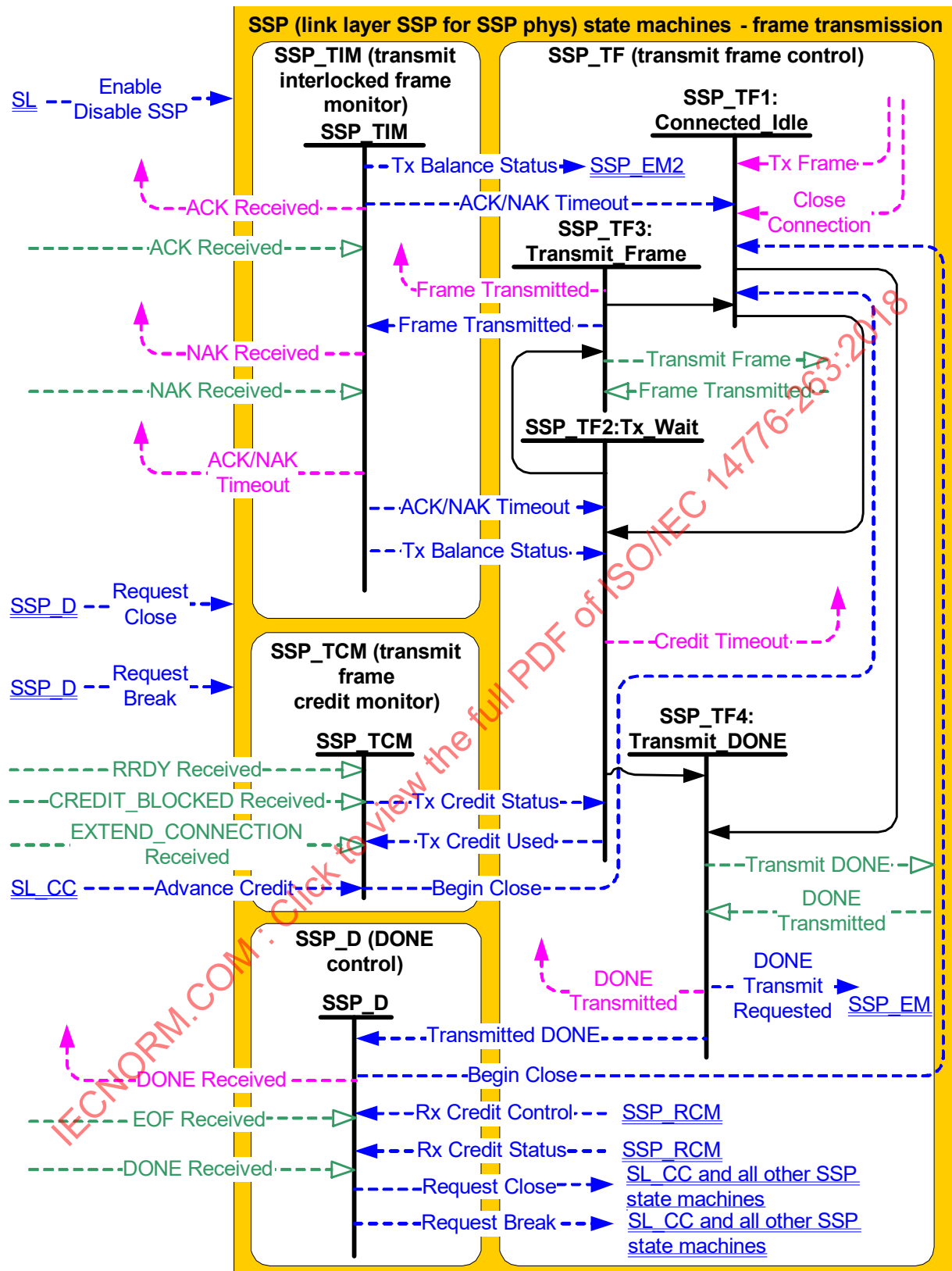


Figure 145 — SSP (link layer for SSP phys) state machines (part 1 - frame transmission)



Figure 146 shows the SSP state machines and states related to frame reception.

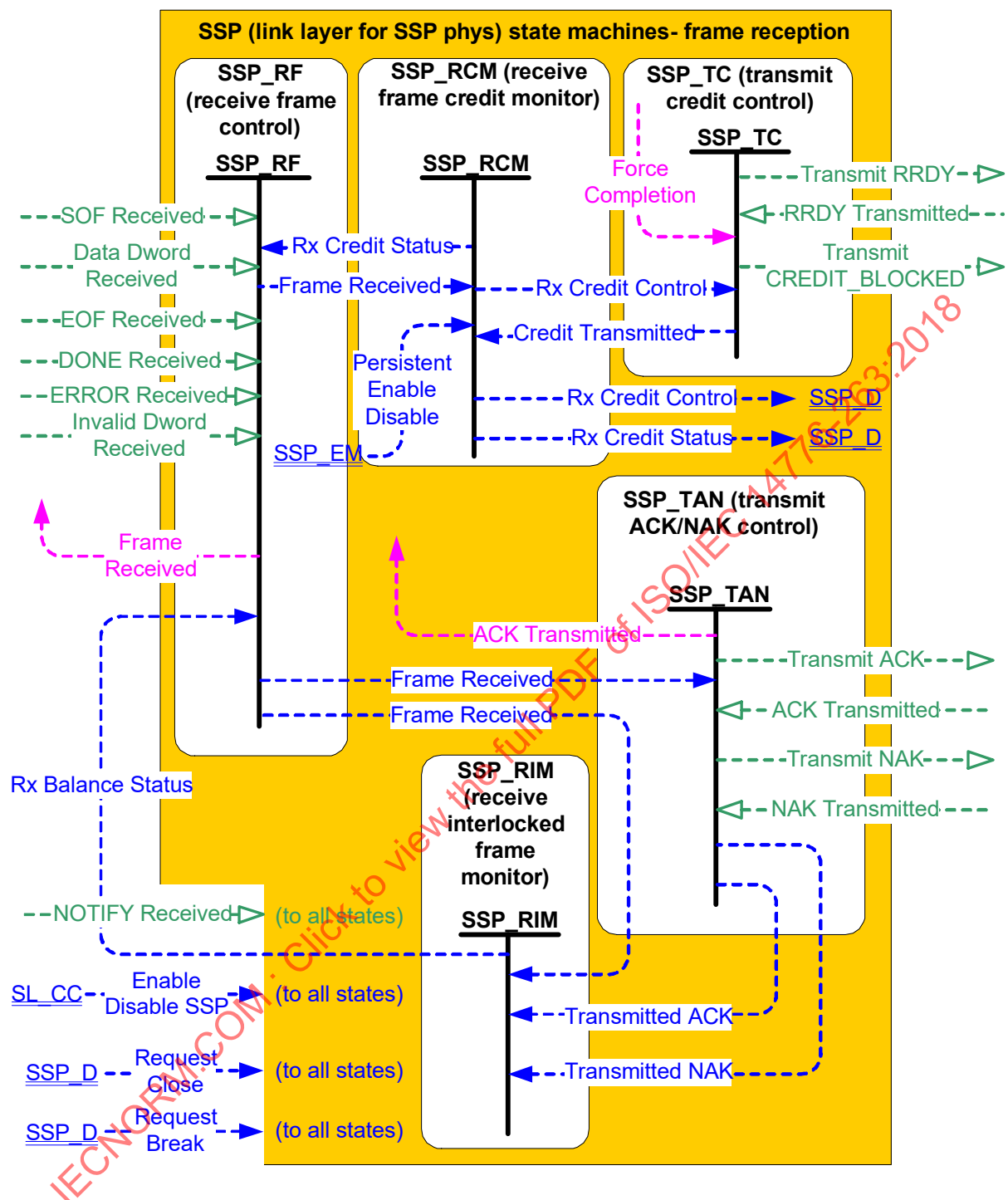


Figure 146 — SSP (link layer for SSP phys) state machines (part 2 - frame reception)

Figure 147 shows the SSP state machine and states related to persistent connections.

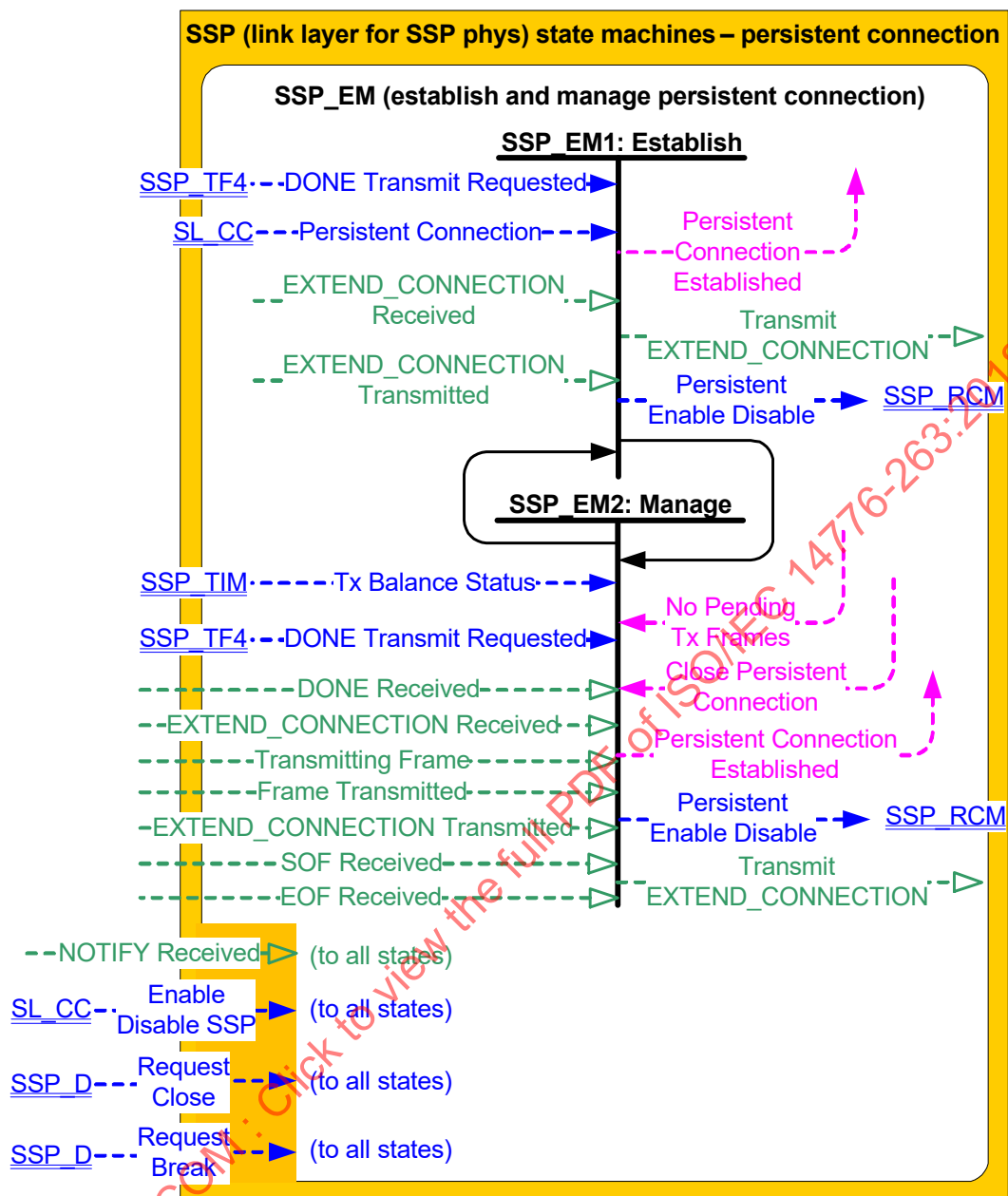


Figure 147 — SSP (link layer for SSP phys) state machines (part 3 - persistent connection)

#### 6.18.9.2 SSP transmitter and receiver

The SSP transmitter receives the following messages from the SSP state machines specifying primitive sequences and frames to transmit:

- Transmit RRDY with an argument indicating the specific type (e.g., Transmit RRDY (Normal));
- Transmit CREDIT\_BLOCKED;
- Transmit ACK;
- Transmit NAK with an argument indicating the specific type (e.g., Transmit NAK (CRC Error));
- Transmit Frame with an argument containing the frame contents;
- Transmit DONE with an argument indicating the specific type (e.g., Transmit DONE (Normal)); and

- g) Transmit EXTEND\_CONNECTION with an argument indicating the specific type (e.g., Transmit EXTEND\_CONNECTION (Normal)).

In response to the Transmit Frame message, the SSP transmitter transmits:

- 1) SOF;
- 2) the frame contents;
- 3) CRC; and
- 4) EOF.

If persistent connections are supported (see 4.1.13.2), then in response to the Transmit Frame message, the SSP transmitter shall send a Transmitting Frame message to the SSP state machines before transmitting an SOF.

The SSP transmitter shall not transmit an EXTEND\_CONNECTION while processing a Transmit Frame message (i.e., the EXTEND\_CONNECTION shall only be transmitted outside an SSP frame).

When the SSP transmitter is requested to transmit a dword from any state within any of the SSP state machines, the SSP transmitter shall transmit that dword. If there are multiple requests to transmit, then the following priority should be followed when selecting the dwords to transmit:

- 1) RRDY, CREDIT\_BLOCKED, ACK, NAK, or DONE;
- 2) SOF, the frame contents, CRC, and EOF;
- 3) EXTEND\_CONNECTION; and
- 4) idle dword.

The SSP transmitter sends the following messages to the SSP state machines based on dwords that have been transmitted:

- a) DONE Transmitted;
- b) RRDY Transmitted;
- c) CREDIT\_BLOCKED Transmitted;
- d) EXTEND\_CONNECTION Transmitted;
- e) ACK Transmitted;
- f) NAK Transmitted;
- g) Transmitting Frame; and
- h) Frame Transmitted.

While there is no outstanding message specifying a dword to transmit, the SSP transmitter shall transmit idle dwords.

The SSP receiver sends the following messages to the SSP state machines indicating primitive sequences and dwords received from the SP\_DWS receiver (see 5.13.2):

- a) ACK Received;
- b) NAK Received;
- c) RRDY Received with an argument indicating the specific type (e.g., RRDY Received (Normal));
- d) CREDIT\_BLOCKED Received;
- e) DONE Received with an argument indicating the specific type (e.g., DONE Received (Normal));
- f) SOF Received;
- g) Data Dword Received;
- h) EOF Received;
- i) NOTIFY Received (Power Loss Expected);
- j) ERROR Received;
- k) EXTEND\_CONNECTION Received with an argument indicating the specific type (e.g., EXTEND\_CONNECTION Received (Normal)); and
- l) Invalid Dword Received.

The SSP receiver shall ignore all other dwords.

The SSP transmitter relationship to other transmitters is defined in 4.3.2. The SSP receiver relationship to other receivers is defined in 4.3.3.

### 6.18.9.3 SSP\_TIM (transmit interlocked frame monitor) state machine

The SSP\_TIM state machine's function is to ensure that ACKs or NAKs are received for each transmitted frame before the ACK/NAK timeout. This state machine consists of one state.

This state machine monitors the number of frames transmitted with a Number Of Frames Transmitted counter and monitors the number of ACKs and NAKs received with a Number Of ACKs/NAKs Received counter. This state machine ensures that an ACK or NAK is received for each frame transmitted and reports an ACK/NAK timeout if they are not.

When the Number Of Frames Transmitted counter equals the Number Of ACKs/NAKs Received counter, the ACK/NAK count is balanced and this state machine shall repeatedly send the Tx Balance Status (Balanced) message to the SSP\_TF2:Tx\_Wait state and the SSP\_EM state machine. When the Number Of Frames Transmitted counter does not equal the Number Of ACKs/NAKs Received counter, the ACK/NAK count is not balanced and this state machine shall send the Tx Balance Status (Not Balanced) message to the SSP\_TF2:Tx\_Wait state and the SSP\_EM state machine.

Each time a Frame Transmitted message is received, this state machine shall increment the Number Of Frames Transmitted counter.

If the ACK/NAK count is not balanced, then each time an ACK Received message is received, this state machine shall:

- a) increment the Number Of ACKs/NAKs Received counter; and
- b) send an ACK Received confirmation to the port layer.

If the ACK/NAK count is not balanced, then each time a NAK Received message is received, this state machine shall:

- a) increment the Number Of ACKs/NAKs Received counter; and
- b) send a NAK Received confirmation to the port layer.

If the ACK/NAK count is balanced, then the ACK Received message and NAK Received message shall be ignored and the ACK/NAK Timeout timer shall be stopped.

Each time the ACK/NAK count is not balanced, the ACK/NAK Timeout timer shall be initialized and started. The ACK/NAK Timeout timer shall be reinitialized each time the Number Of ACKs/NAKs Received counter is incremented. If the ACK/NAK Timeout timer expires, then this state machine shall send the ACK/NAK Timeout confirmation to the port layer and to the following states:

- a) SSP\_TF1:Connected\_Idle; and
- b) SSP\_TF2:Tx\_Wait state.

When this state machine receives an Enable Disable SSP (Enable) message, Request Close message, or Request Break message, the Number Of Frames Transmitted counter shall be set to zero and the Number Of ACKs/NAKs Received counter shall be set to zero.

### 6.18.9.4 SSP\_TCM (transmit frame credit monitor) state machine

The SSP\_TCM state machine's function is to ensure that transmit SSP frame credit is available before a frame is transmitted. This state machine consists of one state.

This state machine shall keep track of the number of transmit SSP frame credits available.

If an Advance Credit message is received, then this state machine shall:

- 1) increment transmit SSP frame credit by one frame;
- 2) ignore the first RRDY Received message received; and
- 3) add one transmit SSP frame credit for each subsequent RRDY Received message received.

If an Advance Credit message is not received, then this state machine shall add one transmit SSP frame credit for each RRDY Received message received.

This state machine shall subtract one transmit SSP frame credit for each Tx Credit Used message received.

Upon starting this state machine, the number of transmit SSP frame credits available value shall be set to zero.

The CREDIT\_BLOCKED Received message indicates that transmit SSP frame credit is blocked. After receiving a CREDIT\_BLOCKED Received message, this state machine may ignore additional RRDY Received messages until it receives a Request Close message or a Request Break message.

This state machine shall handle an EXTEND\_CONNECTION Received (Close) message as if a CREDIT\_BLOCKED Received message was received.

The RRDY Received (Close) message indicates:

- a) that transmit SSP frame credit is available; and
- b) this state machine shall handle that RRDY Received (Close) message as if a CREDIT\_BLOCKED Received message was received.

After receiving an RRDY Received (Close) message, this state machine may ignore additional RRDY Received messages until it receives a Request Close message or a Request Break message.

If this state receives an RRDY Received (Close) message or an EXTEND\_CONNECTION Received (Close) message, then this state shall repeatedly send a Begin Close message to the SSP\_TF1:Connected\_Idle state.

While transmit SSP frame credit is available, this state machine repeatedly shall send the Tx Credit Status (Available) message to the SSP\_TF2:Tx\_Wait state.

While transmit SSP frame credit is not available and transmit SSP frame credit is not blocked, this state machine shall repeatedly send the Tx Credit Status (Not Available) message to the SSP\_TF2:Tx\_Wait state.

While transmit SSP frame credit is not available and transmit SSP frame credit is blocked, this state machine shall repeatedly send the Tx Credit Status (Blocked) message to the SSP\_TF2:Tx\_Wait state.

When this state machine receives an Enable Disable SSP (Enable) message, a Request Close message, or a Request Break message, this state shall set transmit SSP frame credit to not available and transmit SSP frame credit shall be set to not blocked.

#### 6.18.9.5 SSP\_D (DONE control) state machine

The SSP\_D state machine's function is to ensure a DONE has been received and transmitted before the SL\_CC state machine disables the SSP state machines. This state machine consists of one state.

This state machine ensures that a DONE is received and transmitted before the connection is closed. The DONE may be transmitted and received in any order.

If a DONE (Close) Received message is received, then this state shall repeatedly send a Begin Close message to the SSP\_TF1:Connected\_Idle state.

If a DONE Received message has been received before a Transmitted DONE message is received, then this state machine shall send a Request Close message to the SL\_CC state machine (see 6.16) and all the SSP state machines after receiving the Transmitted DONE message.

If a DONE Received message, a Transmitted DONE (Normal) message, or a Transmitted DONE (Credit Timeout) message has not been received and an Rx Credit Status (Extended) message or an Rx Credit Control (Blocked) message has been received, then this state shall initialize and start the DONE Timeout timer after receiving a Transmitted DONE (Normal) message or a Transmitted DONE (Credit Timeout) message.

If a DONE Received message has not been received and a Transmitted DONE (Normal) message or a Transmitted DONE (Credit Timeout) message has been received, then this state machine shall initialize and start the DONE Timeout timer each time:

- a) an Rx Credit Status (Extended) message is received; or
- b) an Rx Credit Control (Blocked) message is received.

If a Transmitted DONE (Normal) message or a Transmitted DONE (Credit Timeout) message has been received, then the DONE Timeout timer shall be reinitialized each time an EOF Received message is received.

If a Transmitted DONE (Normal) message or a Transmitted DONE (Credit Timeout) message has been received, then the DONE Timeout timer shall be stopped after:

- a) an Rx Credit Status (Exhausted) message is received; and
- b) an Rx Credit Control (Blocked) message has not been received.

NOTE 39 - Stopping the timer ensures that, if SSP frame credit remains exhausted long enough that the Credit Timeout timer of the other phy in the connection expires, the other phy is able to transmit a DONE (CREDIT TIMEOUT).

If a DONE Received message has not been received and a Transmitted DONE (ACK/NAK Timeout) message has been received, then:

- a) this state machine shall initialize and start the DONE Timeout timer; and
- b) this state shall not reinitialize the DONE Timeout timer if an EOF Received message is received.

If a DONE Received message is received before the DONE Timeout timer expires, then this state machine shall send a Request Close message to the SL\_CC state machine and all the SSP state machines.

If a DONE Received message is not received before the DONE Timeout timer expires, then this state machine shall send a Request Break message to the SL\_CC state machine and all the SSP state machines.

If a DONE Received message is received, then this state machine shall send a DONE Received confirmation to the port layer. A DONE Received (ACK/NAK Timeout) confirmation informs the port layer that the SSP transmitter is going to close the connection within 1 ms. Other DONE Received confirmations (e.g., DONE Received (Normal), DONE Received (Close), and DONE Received (Credit Timeout)) may be used by the SCSI application layer to decide when to reuse initiator port transfer tags (see 9.2.2).

It is possible for the DONE Timeout timer in one phy (e.g., phy A) may expire concurrently with the ACK/NAK Timeout timer in the other phy (e.g., phy B) in a connection.

EXAMPLE - If phy A receives DONE (NORMAL) indicating phy B has no more frames to transmit, and phy A then transmits a series of non-interlocked frames where one or more of the SOFs is corrupted, then phy A waits to receive all the ACKs and/or NAKs after transmitting the series of non-interlocked frames. However, since phy B did not receive the full number of SOFs, it does not transmit as many ACKs and/or NAKs as phy A is expecting. The ACK/NAK Timeout timer in phy A expires and phy A transmits DONE (ACK/NAK TIMEOUT). Meanwhile, despite having transmitted DONE, phy B stops receiving frames while phy A is waiting for the final ACKs and/or NAKs. Since phy B does not receive DONE or any more frames, its DONE Timeout timer expires and phy B transmits a BREAK primitive sequence.

Since the timers may expire at different times (e.g., due to timer resolution differences), the DONE (ACK/NAK TIMEOUT) may be transmitted before, concurrently with, or after the BREAK primitive sequence.

Nevertheless, the phys handle the link layer error (i.e., the ACK/NAK timeout or the DONE timeout) the same way (see 8.2.4.5 and 8.2.4.6).

#### 6.18.9.6 SSP\_TF (transmit frame control) state machine

##### 6.18.9.6.1 SSP\_TF state machine overview

The SSP\_TF state machine's function is to control when the SSP transmitter transmits SOF, frame dwords, EOF, and DONE. This state machine consists of the following states:

- a) SSP\_TF1:Connected\_Idle (see 6.18.9.6.2) (initial state);
- b) SSP\_TF2:Tx\_Wait (see 6.18.9.6.3);
- c) SSP\_TF3:Transmit\_Frame (see 6.18.9.6.4); and
- d) SSP\_TF4:Transmit\_DONE (see 6.18.9.6.5).

This state machine shall start in the SSP\_TF1:Connected\_Idle state.

**6.18.9.6.2 SSP\_TF1:Connected\_Idle state****6.18.9.6.2.1 State description**

This state waits for a request to transmit a frame or to close the connection.

**6.18.9.6.2.2 Transition SSP\_TF1:Connected\_Idle to SSP\_TF2:Tx\_Wait**

This transition shall occur after:

- a) a Tx Frame request is received;
- b) a Close Connection request is received; or
- c) a Begin Close message is received.

If:

- a) a Tx Frame (Balance Required) request was received; and
- b) no Begin Close message has been received,

then this transition shall include a Transmit Frame Balance Required argument.

If:

- a) a Tx Frame (Balance Not Required) request was received; and
- b) no Begin Close message has been received,

then this transition shall include a Transmit Frame Balance Not Required argument.

If a Close Connection request was received, then this transition shall include a Close Connection argument.

If a Begin Close message was received, then this transition shall include a Full Duplex Close argument.

If a Begin Close message and a Close Connection request were received, then this transition:

- a) shall include a Full Duplex Close argument; and
- b) shall not include a Close Connection argument.

If a Begin Close message and a Tx Frame request were received, then this transition:

- a) shall include a Full Duplex Close argument; and
- b) shall not include a Transmit Frame Balance Required argument or a Transmit Frame Balance Not Required argument.

**6.18.9.6.2.3 Transition SSP\_TF1:Connected\_Idle to SSP\_TF4:Transmit\_DONE**

This transition shall occur:

- a) if an ACK/NAK Timeout message is received. This transition shall include an ACK/NAK Timeout argument.

**6.18.9.6.3 SSP\_TF2:Tx\_Wait state****6.18.9.6.3.1 State description**

This state monitors the Tx Balance Status message and the Tx Credit Status message to ensure that frames are transmitted and connections are closed at the proper time.

If this state is entered from the SSP\_TF1:Connected\_Idle state with a Transmit Frame Balance Required argument or a Transmit Frame Balance Not Required argument, and if the last Tx Credit Status message:

- a) received had an argument of Not Available, then this state shall initialize and start the Credit Timeout timer; or
- b) had an argument other than Not Available, then this state shall stop the Credit Timeout timer.



**6.18.9.6.3.2 Transition SSP\_TF2:Tx\_Wait to SSP\_TF3:Transmit\_Frame**

This transition shall occur if this state was entered from the SSP\_TF1:Connected\_Idle state with an argument of Transmit Frame Balance Required if the last:

- a) Tx Balance Status message received had an argument of Balanced; and
- b) Tx Credit Status message received had an argument of Available.

This transition shall occur if this state was entered from the SSP\_TF1:Connected\_Idle state with an argument of Transmit Frame Balance Not Required and if the last Tx Credit Status message received had an argument of Available.

This transition shall occur:

- a) after sending a Tx Credit Used message to the SSP\_TCM state machine.

**6.18.9.6.3.3 Transition SSP\_TF2:Tx\_Wait to SSP\_TF4:Transmit\_DONE**

This transition shall occur and include:

- a) an ACK/NAK Timeout argument if an ACK/NAK Timeout message is received.

This transition shall occur and include a Close Connection argument if:

- a) this state was entered from the SSP\_TF1:Connected\_Idle state with an argument of Close Connection; and
- b) the last Tx Balance Status message received had an argument of Balanced.

This transition shall occur and include a Full Duplex Close argument if:

- a) this state was entered from the SSP\_TF1:Connected\_Idle state with an argument of Full Duplex Close; and
- b) the last Tx Balance Status message received had an argument of Balanced.

This transition shall occur after sending a Credit Timeout confirmation and include a Credit Timeout argument if:

- a) this state was entered from the SSP\_TF1:Connected\_Idle state with a Transmit Frame Balance Required argument or a Transmit Frame Balance Not Required argument;
- b) the Credit Timeout timer expired before a Tx Credit Status message was received with an argument of Available, or the last Tx Credit Status message received had an argument of Blocked;
- c) a Tx Balance Status message was received with an argument of Balanced (i.e., the Credit Timeout argument shall not be included in this transition for this reason unless the ACK/NAK count is balanced); and
- d) an ACK/NAK Timeout message was not received.

**6.18.9.6.4 SSP\_TF3:Transmit\_Frame state****6.18.9.6.4.1 State description**

This state shall request a frame transmission by sending a Transmit Frame message to the SSP transmitter with an argument containing the frame contents. Each time a Transmit Frame message is sent to the SSP transmitter, one SSP frame (i.e., SOF, frame contents, CRC, and EOF) is transmitted.

In this state receiving a Frame Transmitted message indicates that the frame has been transmitted.

**6.18.9.6.4.2 Transition SSP\_TF3:Transmit\_Frame to SSP\_TF1:Connected\_Idle**

This transition shall occur after:

- a) receiving a Frame Transmitted message;
- b) sending a Frame Transmitted message to the SSP\_TIM state machine; and
- c) sending a Frame Transmitted confirmation to the port layer.



**6.18.9.6.5 SSP\_TF4:Transmit\_DONE state**

This state shall send one of the following messages to an SSP transmitter:

- a) a Transmit DONE (Normal) message if this state was entered from the SSP\_TF2:Tx\_Wait state with an argument of Close Connection;
- b) a Transmit DONE (Close) message if this state was entered from the SSP\_TF2:Tx\_Wait state with an argument of Full Duplex Close;
- c) a Transmit DONE (ACK/NAK Timeout) message if this state was entered from the SSP\_TF2:Tx\_Wait state or the SSP\_TF1:Connected\_Idle state with an argument of ACK/NAK Timeout; or
- d) a Transmit DONE (Credit Timeout) message if this state was entered from the SSP\_TF2:Tx\_Wait state with an argument of Credit Timeout.

NOTE 40 - Possible livelock scenarios occur if the BREAK\_REPLY method of responding to received BREAK primitive sequences is disabled and a SAS logical phy transmits a BREAK primitive sequence to break a connection (e.g., if its Done Timeout timer expires). SAS logical phys responding to DONE faster than 1 ms reduce susceptibility to this problem.

This state shall send a DONE Transmit Requested message to the SSP\_EM1:Establish state and the SSP\_EM2:Manage state.

After a DONE Transmitted message is received, this state shall send the DONE Transmitted confirmation to the port layer and send one of the following messages to the SSP\_D state machine:

- a) a Transmitted DONE (Normal) message if this state was entered from the SSP\_TF2:Tx\_Wait state with an argument of Close Connection or Full Duplex Close;
- b) a Transmitted DONE (ACK/NAK Timeout) message if this state was entered from the SSP\_TF2:Tx\_Wait state or the SSP\_TF1:Connected\_Idle state with an argument of ACK/NAK Timeout; or
- c) a Transmitted DONE (Credit Timeout) message if this state was entered from the SSP\_TF2:Tx\_Wait state with an argument of Credit Timeout.

**6.18.9.7 SSP\_RF (receive frame control) state machine**

The SSP\_RF state machine's function is to receive frames and determine whether or not those frames were received without error. This state machine consists of one state.

This state machine:

- a) checks the frame to determine if the frame should be accepted or discarded;
- b) checks the frame to determine if an ACK or NAK should be transmitted; and
- c) sends a Frame Received confirmation to the port layer.

If this state receives a subsequent SOF Received message after receiving an SOF Received message but before receiving an EOF Received message (i.e., SOF, data dwords, SOF, data dwords, and EOF instead of SOF, data dwords, EOF, SOF, data dwords, and EOF), then this state shall discard the frame in progress.

This state shall discard the frame if this state receives:

- a) more than 263 Data Dword Received messages (i.e., 1 052 bytes) after an SOF Received message and before an EOF Received message;
- b) fewer than 7 Data Dword Received messages (i.e., 28 bytes) after an SOF Received message and before an EOF Received message;
- c) an Rx Credit Status (Credit Exhausted) message; or
- d) a DONE Received message.

If this state receives an Invalid Dword Received message or an ERROR Received message after receiving an SOF Received message and before receiving an EOF Received message, then this state machine shall either:

- a) ignore the invalid dword or ERROR; or

- b) discard the frame, send a Frame Received message to the SSP\_RCM state machine, send a Frame Received message to the SSP\_RIM state machine, and send a Frame Received (Unsuccessful) message to the SSP\_TAN state machine.

If the frame is not discarded and the frame CRC is bad, then this state machine shall send:

- a) a Frame Received message to the SSP\_RCM state machine;
- b) a Frame Received message to the SSP\_RIM state machine; and
- c) a Frame Received (Unsuccessful) message to the SSP\_TAN state machine.

If the frame is not discarded and the frame CRC is good, then this state machine shall send:

- a) a Frame Received message to the SSP\_RCM state machine;
- b) a Frame Received message to the SSP\_RIM state machine; and
- c) a Frame Received (Successful) message to the SSP\_TAN state machine, and if the last Rx Balance Status message received had an argument of:
  - A) Balanced, then send a Frame Received (ACK/NAK Balanced) confirmation to the port layer; or
  - B) Not Balanced, then send a Frame Received (ACK/NAK Not Balanced) confirmation to the port layer.

#### 6.18.9.8 SSP\_RCM (receive frame credit monitor) state machine

The SSP\_RCM state machine's function is to ensure that there was transmit SSP frame credit given to the originator for every frame that is received. This state machine consists of one state.

This state machine monitors the receiver's resources and keeps track of the number of RRDYs transmitted versus the number of frames received.

Upon starting this state machine, the following values shall be set to zero:

- a) the number of RRDYs transmitted; and
- b) the number of frames received.

If:

- a) resources are released or become available; and
- b) this state machine has not sent the Rx Credit Control (Blocked) message to the SSP\_TC state machine and the SSP\_D state machine,

then this state machine shall send the Rx Credit Control (Available) message to the SSP\_TC state machine. This state machine shall only send the Rx Credit Control (Available) message to the SSP\_TC state machine after frame receive resources become available. The specifications for when or how resources become available is outside the scope of this standard.

If this state machine has:

- a) not received a Persistent Enable Disable (Enabled) message; or
- b) received a Persistent Enable Disable (Enabled) message followed by a Persistent Enable Disable (Disabled) message,

then this state machine may send the Rx Credit Control (Blocked) message to the SSP\_TC state machine and the SSP\_D state machine when no further receive frame credit is going to become available within a credit timeout (i.e., less than 1 ms), even if frames are received per the existing receive frame credit. After sending the Rx Credit Control (Blocked) message to the SSP\_TC state machine and the SSP\_D state machine, this state machine shall not send the Rx Credit Control (Available) message to the SSP\_TC state machine or the SSP\_D state machine for the duration of the current connection.

This state machine shall indicate through the Rx Credit Control message only the amount of resources available to handle received frames (e.g., if this state machine has resources for five frames, then the maximum number of Rx Credit Control requests with the Available argument outstanding is five).

This state machine shall use the Credit Transmitted message to keep track of the number of RRDYs transmitted. This state machine shall use the Frame Received message to keep a track of the number of frames received.

If the number of Credit Transmitted messages received exceeds the number of Frame Received messages received, then this state machine shall send an Rx Credit Status (Extended) message to the SSP\_RF state machine and the SSP\_D state machine.

If the number of Credit Transmitted messages received equals the number of Frame Received messages received, then this state machine shall send an Rx Credit Status (Exhausted) message to the SSP\_RF state machine and the SSP\_D state machine.

If this state machine receives an Enable Disable SSP (Enable) message, Request Close message, or Request Break message, then the frame receive resources shall be initialized to the no SSP frame credit value for the current connection.

#### 6.18.9.9 SSP\_RIM (receive interlocked frame monitor) state machine

The SSP\_RIM state machine's function is to inform the SSP\_RF state machine when the number of ACKs and NAKs transmitted equals the number of the EOFs received. This state machine consists of one state.

This state machine monitors the number of frames received with a Number Of Frames Received counter and monitors the number of ACKs and NAKs transmitted with a Number Of ACKs/NAKs Transmitted counter.

Each time a Frame Received message is received, this state machine shall increment the Number Of Frames Received counter.

Each time an ACK Transmitted message or a NAK Transmitted message is received, this state machine shall increment the Number Of ACKs/NAKs Transmitted counter.

While the Number Of Frames Received counter equals the Number Of ACKs/NAKs Transmitted counter, this state machine shall repeatedly send an Rx Balance Status (Balanced) message to the SSP\_RF state machine.

While the Number Of Frames Received counter does not equal the Number Of ACKs/NAKs Transmitted counter, this state machine shall repeatedly send an Rx Balance Status (Not Balanced) message to the SSP\_RF state machine.

When this state machine receives an Enable Disable SSP (Enable) message, Request Close message, or Request Break message, the Number Of Frames Received counter shall be set to zero and the Number Of ACKs/NAKs Transmitted counter shall be set to zero.

#### 6.18.9.10 SSP\_TC (transmit credit control) state machine

The SSP\_TC state machine's function is to control the sending of requests to transmit an RRDY or CREDIT\_BLOCKED. This state machine consists of one state.

If this state machine receives an Rx Credit Control (Available) message, then this state machine shall send to the SSP transmitter the indicated amount of resources available to handle received frames (e.g., if the Available argument indicates five RRDYs are to be transmitted, then this state machine sends five Transmit RRDY (Normal) messages to the SSP transmitter) and if this state has:

- a) not received a Force Completion request, then this state machine shall send that number of Transmit RRDY (Normal) messages; or
- b) received a Force Completion request, then this state machine shall send that number of Transmit RRDY (Close) messages.

If this state machine receives an RRDY Transmitted message, then this state machine shall send a Credit Transmitted message to the SSP\_RCM state machine.

If this state machine receives an Rx Credit Control (Blocked) message, then this state machine shall send a Transmit CREDIT\_BLOCKED message to the SSP transmitter.

#### 6.18.9.11 SSP\_TAN (transmit ACK/NAK control) state machine

The SSP\_TAN state machine's function is to control the sending of requests to transmit an ACK or NAK to the SSP transmitter. This state machine consists of one state.

If this state machine receives a Frame Received (Successful) message, then this state machine shall send a Transmit ACK message to the SSP transmitter.

If this state machine receives a Frame Received (Unsuccessful) message, then this state machine shall send a Transmit NAK (CRC Error) message to the SSP transmitter.

If multiple Frame Received (Unsuccessful) messages and Frame Received (Successful) messages are received, then the order in which the Transmit ACK messages and Transmit NAK messages are sent to the SSP transmitter shall be the same order as the Frame Received (Unsuccessful) messages and Frame Received (Successful) messages were received.

If this state machine receives an ACK Transmitted message, then this state machine shall send:

- a) a Transmitted ACK message to the SSP\_RIM state machine; and
- b) an ACK Transmitted confirmation to the port layer.

If this state machine receives a NAK Transmitted argument, then this state machine shall send a Transmitted NAK message to the SSP\_RIM state machine.

#### 6.18.9.12 SSP\_EM (establish and manage persistent connection) state machine

##### 6.18.9.12.1 SSP\_EM state machine overview

The SSP\_EM state machine's function is to establish a persistent connection and manage the sending and receiving of EXTEND\_CONNECTIONs. This state machine consists of the following states:

- a) SSP\_EM1:Establish (see 6.18.9.12.2) (initial state); and
- b) SSP\_EM2:Manage (see 6.18.9.12.4).

This state machine shall start in the SSP\_EM1:Establish state.

##### 6.18.9.12.2 SSP\_EM1:Establish state

This state establishes a persistent connection (see 6.18.1).

If this state receives a Persistent Connection (Transmit) message, then:

- a) this state shall send a Transmit EXTEND\_CONNECTION (Normal) message to the SSP transmitter;
- b) this state shall initialize and start the Transmit Extend Connection timer; and
- c) if this state receives an EXTEND\_CONNECTION Received message and this state has not received a DONE Transmit Requested message, then this state shall send:
  - A) a Persistent Connection Established (Enabled) confirmation to the port layer; and
  - B) a Persistent Enable Disable (Enable) message to the SSP\_RCM state machine.

If this state receives a Persistent Connection (Wait) message, has not received a DONE Transmit Requested message, and receives an EXTEND\_CONNECTION Received message, then this state shall send:

- a) a Transmit EXTEND\_CONNECTION (Normal) message to the SSP transmitter; a Persistent Connection Established (Enabled) confirmation to the port layer; and
- b) a Persistent Enable Disable (Enable) message to the SSP\_RCM state machine.

If this state receives a Persistent Connection (Off) message, then this state shall:

- a) ignore EXTEND\_CONNECTION Received messages; and
- b) send a Persistent Connection Established (Disabled) confirmation to the port layer.

If the Transmit Extend Connection timer expires and this state has not received a DONE Transmit Requested message, then this state shall:

- 1) wait for a Tx Balance Status (Balanced) message;
- 2) send a Transmit EXTEND\_CONNECTION (Normal) message to the SSP transmitter; and
- 3) after receiving an EXTEND\_CONNECTION Transmitted message, initialize and start the Transmit Extend Connection timer.

**6.18.9.12.3 Transition SSP\_EM1:Establish to SSP\_EM2:Manage**

This transition shall occur after:

- a) sending a Persistent Connection Established (Enabled) confirmation to the port layer; and
- b) receiving an EXTEND\_CONNECTION Transmitted message.

**6.18.9.12.4 SSP\_EM2:Manage**

This state:

- a) requests the SSP transmitter transmit EXTEND\_CONNECTION; and
- b) monitors the receipt of EXTEND\_CONNECTION.

Upon entry into this state, this state shall initialize and start:

- a) the Transmit Extend Connection timer; and
- b) the Persistent Connection Timeout timer.

If this state receives:

- a) a Frame Transmitted message, then this state shall initialize and start the Transmit Extend Connection timer; or
- b) a Transmitting Frame message, then this state shall stop the Transmit Extend Connection timer.

If the Transmit Extend Connection timer expires, then this state shall:

- 1) wait for a Tx Balance Status (Balanced) message;
- 2) send a Transmit EXTEND\_CONNECTION (Normal) message to the SSP transmitter; and
- 3) after receiving an EXTEND\_CONNECTION Transmitted message, initialize and start the Transmit Extend Connection timer.

If this state receives an EXTEND\_CONNECTION Received message, then this state shall initialize and start the Persistent Connection Timeout timer.

If this state receives:

- a) an SOF Received message, then this state shall stop the Persistent Connection Timeout timer; or
- b) an EOF Received message and the Persistent Connection Timeout timer is currently stopped, then this state shall initialize and start the Persistent Connection Timeout timer.

If:

- a) the Persistent Connection Timeout timer expires;
- b) this state receives a DONE Received message;
- c) this state receives a Close Persistent Connection request or
- d) this state receives a DONE Transmit Requested message,

then this state shall send:

- a) a Persistent Connection Established (Disabled) confirmation to the port layer; and
- b) a Persistent Enable Disable (Disable) message to the SSP\_RCM state machine.

If this state receives a No Pending Tx Frames request, then this state shall:

- 1) wait for a Tx Balance Status (Balanced) message; and
- 2) send a Transmit EXTEND\_CONNECTION (Normal) message to the SSP transmitter.

**6.18.9.12.5 Transition SSP\_EM2:Manage to SSP\_EM1:Establish**

This transition shall occur:

- a) after a Persistent Connection Established (Disabled) confirmation is sent to the port layer.

## 6.19 STP link layer

### 6.19.1 STP frame transmission and reception

STP frame transmission is defined by SATA. During an STP connection, frames are preceded by SATA\_SOF and followed by SATA\_EOF as shown in figure 148.

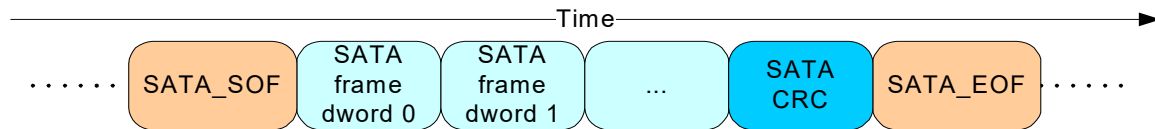


**Figure 148 — STP frame transmission**

The last data dword after the SOF prior to the EOF always contains a CRC (see 6.5).

Other primitives may be interspersed during the connection as defined by SATA.

STP encapsulates SATA with connection management. Table 148 summarizes STP link layer differences from the SATA link layer (see SATA) that affect behavior during an STP connection.

**Table 148 — STP link layer differences from SATA link layer during an STP connection**

| Feature                      | Description                                                                                                                                                                                                                                                                | Reference |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| STP flow control             | Flow control through an STP connection is point-to-point, not end-to-end. Expander devices accept dwords in an STP flow control buffer after transmitting SATA_HOLD to avoid losing data en-route before the transmitting phy acknowledges the SATA_HOLD with SATA_HOLD_A. | 6.19.2    |
| Continued primitive sequence | Sustain the continued primitive sequence if a SATA_CONT appears after the continued primitive sequence has begun.                                                                                                                                                          | 6.19.3    |

### 6.19.2 STP flow control

#### 6.19.2.1 STP flow control overview

Each STP phy (i.e., STP initiator phy and STP target phy) and expander logical phy through which the STP connection is routed shall implement the SATA flow control protocol on each logical link in the pathway. The flow control primitives are not forwarded through expander devices like other dwords.

#### 6.19.2.2 SATA frame buffering

When an STP phy or expander phy during an STP connection is receiving a SATA frame and its STP flow control buffer begins to fill up, that STP phy or expander phy shall transmit SATA\_HOLD. After transmitting SATA\_HOLD, the STP phy or expander phy shall accept at least the number of data dwords or SATA\_EOFs for the SATA frame defined in 6.19.2.3 into its STP flow control buffer and receives SATA\_HOLD\_A within that number of data dwords or SATA\_EOFs. While receiving SATA\_HOLD\_A, the STP phy or expander phy does not place any data dwords into the STP flow control buffer. The STP phy or expander phy shall stop transmitting SATA\_HOLD when the STP flow control buffer empties enough to hold at least that number of data dwords or SATA\_EOFs.



When an STP phy or expander phy during an STP connection is transmitting a SATA frame and receives SATA\_HOLD, that STP phy or expander phy shall transmit no more than 20 data dwords or SATA\_EOFs for the SATA frame and respond with SATA\_HOLDA.

When a SATA host phy in an STP SATA bridge is receiving a SATA frame from a SATA physical link, that SATA host phy shall transmit a SATA\_HOLD when it is only capable of receiving 21 more data dwords for Gen1 and Gen2 or 25 more data dwords for Gen3 (see SATA). The SATA host phy shall stop transmitting SATA\_HOLD (e.g., return to transmitting SATA\_R\_IP) when it is capable of receiving at least 21 more data dwords for Gen1 and Gen2 or 24 more data dwords for Gen3.

NOTE 41 - SATA requires that frame transmission cease and SATA\_HOLDA be transmitted within 20 data dwords of receiving SATA\_HOLD. Since the SATA physical link has non-zero propagation time for Gen1 or Gen2, one dword of margin is included.

When a SATA host phy in an STP SATA bridge is transmitting a SATA frame to a SATA physical link, that SATA host phy shall transmit no more than 19 dwords for Gen1 and Gen2 or 20 dwords for Gen3 (see SATA) (e.g., including data dwords, deletable primitives, SATA\_EOF, and SATA\_HOLDs followed by data dwords) after receiving SATA\_HOLD before responding with SATA\_HOLDA.

NOTE 42 - SATA assumes that once a SATA\_HOLD is transmitted, frame transmission ceases and SATA\_HOLDA arrives within 20 dwords for Gen1 or Gen2. Since the SATA physical link has non-zero propagation time for Gen1 or Gen2, one dword of margin is included.

While transmitting SATA\_HOLD or SATA\_HOLDA, the expander device is considered to be originating (see 6.3.2) rather than forwarding (see 6.3.3) for purposes of deletable primitive insertion.

### 6.19.2.3 STP flow control buffer size

All logical phys in a port shall support the same STP flow control buffer size. The STP flow control buffer size is determined for each connector category (see SAS-3) to which the phy is attached as follows:

- a) for the unmanaged passive connector category (see SAS-3) the STP flow control buffer size shall be at least:
  - A) 24 data dwords or SATA\_EOFs at the 1.5 Gbit/s logical link rate;
  - B) 28 data dwords or SATA\_EOFs at the 3 Gbit/s logical link rate; or
  - C) 36 data dwords or SATA\_EOFs at the 6 Gbit/s logical link rate;

NOTE 43 - For connectors in the unmanaged connector category the STP flow control buffer requirements are based on  $(20 + (4 \times 2^n))$  where  $n$  is zero for 1.5 Gbit/s, one for 3Gbit/s, and two for 6 Gbit/s. The 20 portion of this equation is based on the frame transmitter requirements (see SATA). The  $(4 \times 2^n)$  portion of this equation is based on:

- a) one-way propagation time on a 10 m cable = 53 ns (see SAS-3);
- b) round-trip propagation time on a 10 m cable = 106 ns (e.g., time to send SATA\_HOLD and receive SATA\_HOLD A);
- c) time to transmit a 1.5 Gbit/s dword =  $(0.6 \text{ ns/bit unit interval (see SAS-3)}) \times (40 \text{ bits/dword}) = 26.6 \text{ ns}$ ;
- d) number of 1.5 Gbit/s dwords on the wire during round-trip propagation time =  $(106 \text{ ns} / 26.6 \text{ ns}) = 3.98$  data dwords; and
- e) rounding to 4 data dwords.

- b) for the unmanaged active connector category (see SAS-3) the STP flow control buffer size shall be at least:
  - A) 30 data dwords or SATA\_EOFs at the 1.5 Gbit/s logical link rate;
  - B) 40 data dwords or SATA\_EOFs at the 3 Gbit/s logical link rate; or
  - C) 60 data dwords or SATA\_EOFs at the 6 Gbit/s logical link rate;

NOTE 44 - For connectors in the unmanaged active connector category the STP flow control buffer requirements are based on  $(20 + (9.375 \times 2^n))$  where  $n$  is zero for 1.5 Gbit/s, one for 3 Gbit/s, and two for 6 Gbit/s. The 20 portion of this equation is based on the frame transmitter requirements (see SATA). The  $(9.375 \times 2^n)$  portion of this equation is based on:

- a) one-way propagation time on a 25 m cable = 133 ns (see SAS-3);

- b) round-trip propagation time on a 25 m cable = 266 ns (e.g., time to send SATA\_HOLD and receive SATA\_HOLD\_A);
- c) time to transmit a 1.5 Gbit/s dword =  $(0.6 \text{ ns/bit unit interval (see SAS-3)}) \times (40 \text{ bits/dword}) = 26.6 \text{ ns}$ ; and
- d) number of 1.5 Gbit/s dwords on the wire during round-trip propagation time =  $(266 \text{ ns} / 26.6 \text{ ns}) = 10$  data dwords.

or

- c) for the managed connector category (see SAS-3) the total cable assembly propagation delay is reported through the management protocol (see SAS-3). If the propagation delay is less than or equal to 53 ns, then the STP flow control buffer size is 24 data dwords, 28 data dwords, or 36 data dwords depending on the logical link rate (see a)). If the propagation delay exceeds 53 ns then the minimum STP flow control buffer size in dwords shall be calculated using the following equation:

$$\text{Minimum STP flow control buffer size} = (20 + ((2 \times P_d \times R) / 40))$$

where:

- $P_d$  is the propagation delay of cable assembly (e.g., in ns) (see SAS-3); and
- $R$  is the nominal logical link rate (e.g., in Gbit/s).

If the minimum buffer size is not an integer, then the minimum buffer size value shall be rounded to the next highest integer value.

NOTE 45 - For connectors in the managed active connector category where the cable reports total propagation delay of 250 ns and connection rate at 6 Gbit/s then the STP flow control buffer requirements are based on Minimum buffer size =  $[20 + ((2 \times P_d \times R) / 40)]$ . The 20 portion of this equation is based on the frame transmitter requirements (see SATA). The  $[(2 \times P_d \times R) / 40]$  portion of this equation is the number of dwords on the wire during a round trip:  $2 \times P_d$  is the round trip propagation time, and  $40 / R$  is the time to transmit a dword. For example, for a 100 m optical cable:

- a) one-way propagation time = 500 ns;
- b) round-trip propagation time = 1 000 ns (e.g., time to send SATA\_HOLD and receive SATA\_HOLD\_A);
- c) time to transmit a 6 Gbit/s dword =  $(0.16 \text{ ns/bit unit interval}) \times (40 \text{ bits/dword}) = 6.6 \text{ ns}$ ;
- d) number of 6 Gbit/s dwords on the wire during round-trip propagation time =  $(1\,000 \text{ ns} / 6.6 \text{ ns}) = 150$  data dwords; and
- e) 20 is the buffer size required by SATA, resulting in a minimum STP flow control buffer size = 170 data dwords.

#### 6.19.2.4 STP flow control example

Figure 149 shows STP flow control between:

- a) an STP initiator phy receiving a frame;
- b) an expander device (the first expander device);
- c) an expander device with an STP SATA bridge (the second expander device); and
- d) a SATA device phy transmitting a frame.



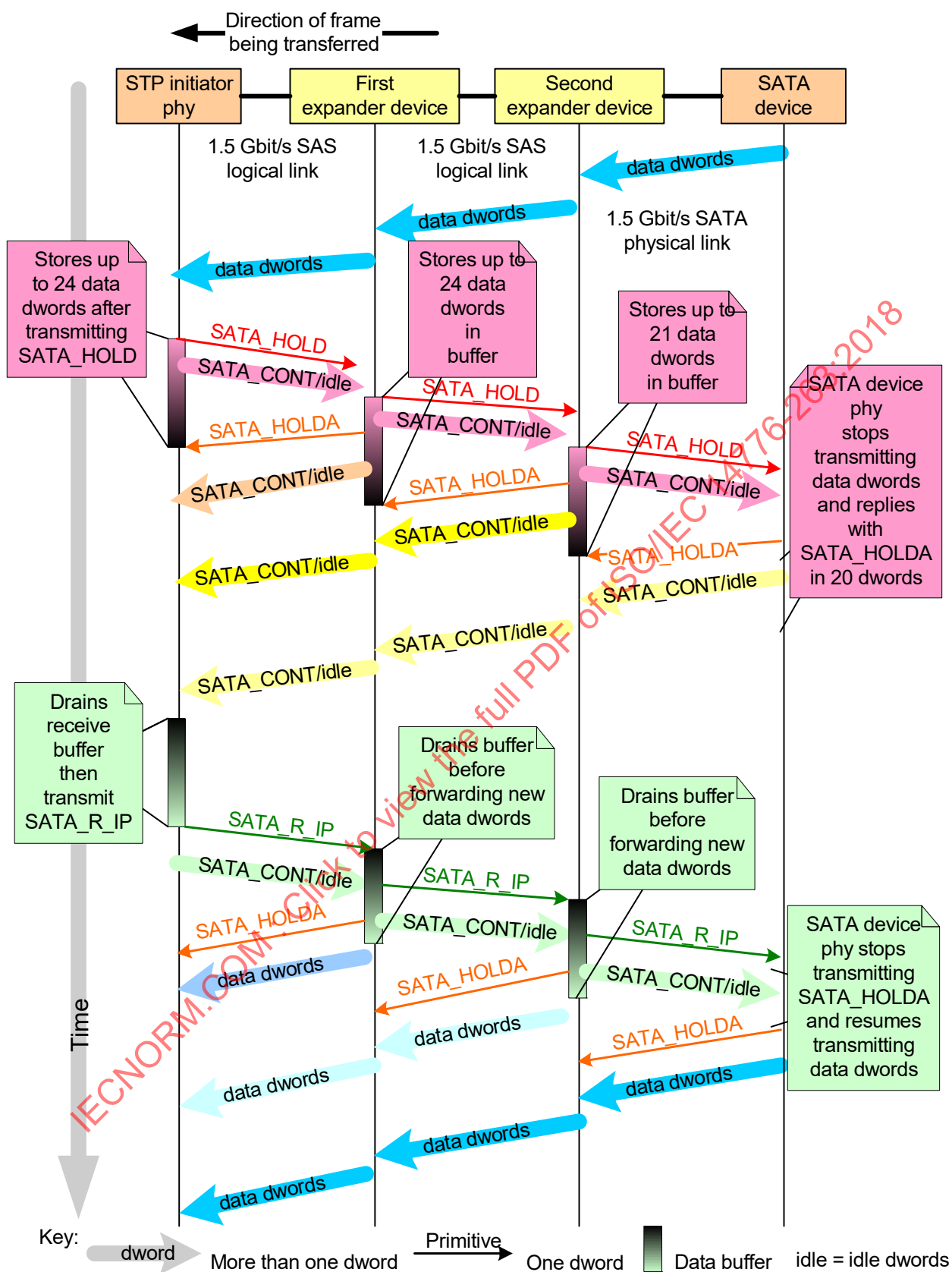


Figure 149 — STP flow control

After the STP initiator phy transmits SATA\_HOLD, it receives a SATA\_HOLD\_A reply from the first expander device within 24 dwords. The first expander device transmits SATA\_HOLD to the second expander device and receives SATA\_HOLD\_A within 24 dwords, buffering data dwords in the STP flow control buffer that the first expander device is no longer able to forward to the STP initiator phy. The second expander device transmits SATA\_HOLD to the SATA device phy and receives SATA\_HOLD\_A within 21 dwords, buffering data dwords in the STP flow control buffer that it is no longer able to forward to the first expander device. When the SATA device phy stops transmitting data dwords, its previous data dwords are stored in the STP flow control buffers in both expander devices and the STP initiator phy.

After the STP initiator phy drains its STP flow control buffer and transmits SATA\_R\_IP, it receives data dwords from the first expander device's STP flow control buffer, followed by data dwords from the second expander device's STP flow control buffer, followed by data dwords from the SATA device phy.

#### 6.19.2.5 STP insufficient buffer support

If an STP phy is attached to a connector in the managed connector category (see SAS-3) and that STP phy does not support the minimum buffer size for the logical link rate, then all phys in the STP port shall perform a link reset sequence indicating the STP protocol is not supported with:

- a) the STP\_INITIATOR\_PORT bit set to zero in the IDENTIFY address frame (see 6.8.2); and
- b) the STP\_TARGET\_PORT bit set to zero in the IDENTIFY address frame (see 6.8.2).

An STP initiator port shall not originate an STP connection request to a destination STP target port on a pathway that contains an expander device reporting insufficient buffer for STP support.

If an expander phy is attached to a connector in the managed connector category (see SAS-3) and that expander phy does not support the minimum buffer size for the logical link rate, then all phys in the expander port shall perform a link reset sequence indicating the STP protocol is not supported with the STP\_BUFFER\_TOO\_SMALL bit set to one in:

- a) the SMP\_DISCOVER response (see 9.4.3.10); and
- b) the SMP\_DISCOVER\_LIST response (see 9.4.3.15).

If an expander phy does not support the minimum buffer size for the logical link rate, then that expander phy shall respond to an STP connection request with OPEN\_REJECT (PROTOCOL NOT SUPPORTED).

#### 6.19.3 Continued primitive sequence

Primitives that form continued primitive sequences (e.g., SATA\_HOLD) shall be:

- 1) transmitted two times;
- 2) be followed by SATA\_CONT, if needed; and
- 3) be followed by vendor specific scrambled data dwords, if needed.

Deletable primitives may be transmitted inside continued primitive sequences as described in 6.2.4.1.

After the SATA\_CONT, during the vendor specific scrambled data dwords:

- a) a SATA\_CONT continues the continued primitive sequence; and
- b) any other STP primitive, including the primitive that is being continued, ends the continued primitive sequence.

Figure 150 shows an example of transmitting a continued primitive sequence.

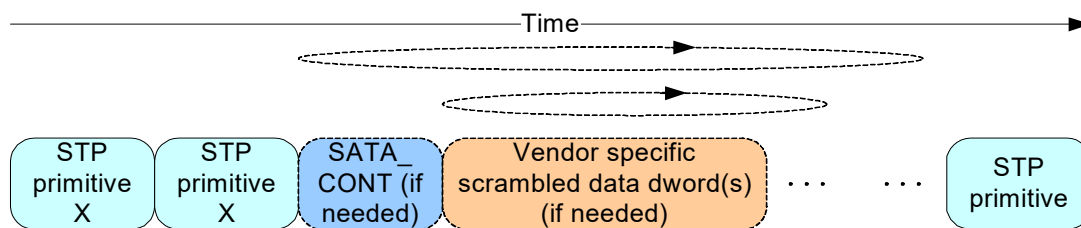


**Figure 150 — Transmitting a continued primitive sequence**

Receivers shall detect a continued primitive sequence after at least one primitive is received. The primitive may be followed by one or more of the same primitive. The primitive may be followed by one or more SATA\_CONTs, each of which may be followed by vendor specific data dwords. Receivers shall ignore invalid dwords before, during, or after the SATA\_CONT(s). Receivers do not count the number of times the continued primitive, the SATA\_CONTs, or the vendor specific data dwords are received (i.e., receivers are in the state of receiving the primitive).

Expanders forwarding dwords may or may not detect an incoming sequence of the same primitive and convert the incoming sequence into a continued primitive sequence.

Figure 151 shows an example of receiving a continued primitive sequence.

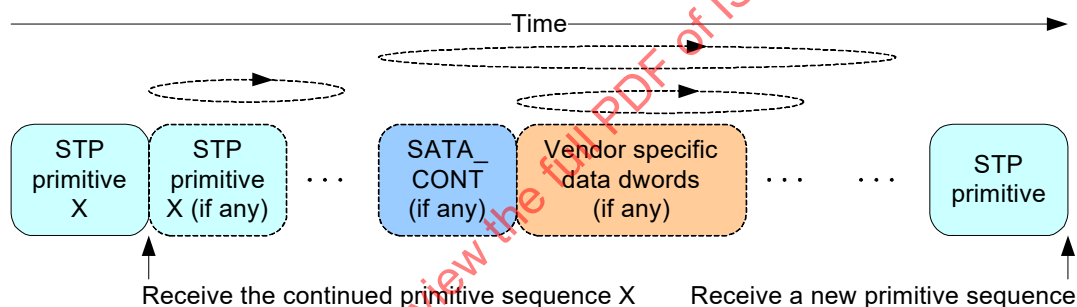


**Figure 151 — Receiving a continued primitive sequence**

An expander device forwarding a continued primitive sequence may transmit more dwords in the continued primitive sequence than it receives (i.e., expand) or transmit fewer dwords in the continued primitive sequence than it receives (i.e., contract). While transmitting a continued primitive sequence, the expander device is considered to be originating (see 6.3.2) rather than forwarding (see 6.3.3) for purposes of deletable primitive insertion.

#### 6.19.4 Affiliations

The STP target port shall provide coherent access to a set of registers called an affiliation context for each STP initiator port from which the STP target port accepts connections. An affiliation is a state entered by an STP target port in which the STP target port refuses to accept connection requests from STP initiator ports other than those that have established an affiliation.

An STP target port shall implement one of the affiliation policies defined in table 149.

**Table 149 — Affiliation policies**

| Affiliation policy    | Description                                                                                                                                                                                                                                              |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| No affiliations       | An unlimited number of STP initiator ports are allowed to access the STP target port concurrently. The STP target port is cognizant of the SAS address of the STP initiator port that sends each ATA command.                                            |
| Multiple affiliations | The STP target port implements more than one affiliation, so a limited number of STP initiator ports are allowed to access the STP target port concurrently. The STP target port implements no more than one affiliation context per STP initiator port. |
| Single affiliation    | The STP target port implements one affiliation, so one STP initiator port is allowed to access the STP target port at a time.                                                                                                                            |

An STP SATA bridge that supports either no affiliations or multiple affiliations shall:

- ensure that the SATA NCQ tags in commands issued to the SATA device are unique across all affiliations;
- ensure that a non-queued command received in one affiliation context is not issued to the SATA device while another affiliation context has a queued command outstanding to the SATA device (e.g., the STP target port shall allow all queued commands in the SATA device to complete prior to issuing the non-queued command);
- ensure that a non-queued command received in one affiliation context is not issued to the SATA device while another affiliation context has a non-queued command outstanding to the SATA device (e.g., the STP target port shall allow the non-queued command in the SATA device to complete prior to issuing the new non-queued command); and
- ensure that a queued command received in one affiliation context is not issued to the SATA device while another affiliation context has a non-queued command outstanding to the SATA device (e.g., the STP target port shall allow any non-queued command in the SATA device to complete prior to issuing the queued commands).

An STP SATA bridge that supports multiple affiliations may modify the queue depth reported in the ATA IDENTIFY DEVICE data (see ACS-2) to each STP initiator port to ensure that all the STP initiator ports with affiliations do not send more commands than the SATA device supports.

An STP target port that supports affiliations shall establish an affiliation whenever it accepts a connection request from an STP initiator port that does not already have an affiliation. While all affiliation contexts are in use, the STP target port shall reject all subsequent connection requests from other STP initiator ports with OPEN\_REJECT (STP RESOURCES BUSY).

An STP target port shall maintain an affiliation until any of the following occurs:

- power on;
- the management device server receives an SMP PHY CONTROL request specifying the phy with the affiliation and specifying a phy operation of HARD RESET (see 9.4.3.28) from any SMP initiator port;
- the management device server receives an SMP PHY CONTROL request specifying the phy with the affiliation and specifying a phy operation of TRANSMIT SATA PORT SELECTION SIGNAL (see 9.4.3.28) from any SMP initiator port;
- the management device server receives an SMP PHY CONTROL request specifying the phy with the affiliation and specifying a phy operation of CLEAR AFFILIATION (see 9.4.3.28) from the same SAS initiator port that has the affiliation;
- an STP connection to a phy in the STP target port is closed with a CLOSE (CLEAR AFFILIATION) primitive sequence; or
- the STP target port encounters an I\_T nexus loss.

The STP initiator port shall maintain an affiliation starting with the connection in which a command is transmitted until all frames for the command have been delivered. An STP initiator port implementing command queuing (see ACS-2 and SATA) shall maintain an affiliation while any commands are outstanding. STP initiator ports should not keep affiliations while commands are not outstanding.

An STP target port that implements affiliations shall implement at least one affiliation context per STP target port. Multiple phys on the same STP target port shall use the same set of affiliation contexts. Support for affiliations is indicated in the SMP REPORT PHY SATA response (see 9.4.3.12).

An STP target port implementing multiple affiliations shall sort the affiliation contexts in a vendor specific order. In the SMP REPORT PHY SATA response, if the SMP initiator port has the same SAS address as an affiliated STP initiator port, then the management device server shall report the affiliation for that SAS address as relative identifier 0 and shall report all additional affiliations with incrementing relative identifiers following the sorted order. If the SMP initiator port does not have the same SAS address as an affiliated STP initiator port, the management device server shall report the affiliation contexts in the vendor specific order.

For example, if the STP target port supports four affiliation contexts sorted in order A, B, C, and D, when returning the SMP REPORT PHY SATA response to an SMP initiator port, then the management device server reports the affiliation contexts as described in table 150.

**Table 150 — Affiliation context relative identifier example**

| Affiliation context containing the SAS address of the SMP initiator port | Affiliation context relative identifier assignment |   |   |   |
|--------------------------------------------------------------------------|----------------------------------------------------|---|---|---|
|                                                                          | 0                                                  | 1 | 2 | 3 |
| A                                                                        | A                                                  | B | C | D |
| B                                                                        | B                                                  | C | D | A |
| C                                                                        | C                                                  | D | A | B |
| D                                                                        | D                                                  | A | B | C |
| None                                                                     | A                                                  | B | C | D |

### 6.19.5 Opening an STP connection

When the SATA host port in an STP SATA bridge receives a SATA\_X\_RDY from the attached SATA device, the STP target port in the STP SATA bridge shall establish an STP connection to the appropriate STP initiator port. If there is no affiliation, the SATA host port may either:

- perform a link reset on the SATA physical link; or
- wait for an affiliation to be established.

If an STP SATA bridge receives a connection request for a SATA device that has delivered the initial Register – Device to Host FIS in error, then it shall return an OPEN\_REJECT (NO DESTINATION).

If there is a problem receiving the expected initial Register - Device to Host FIS, then the STP SATA bridge should use SATA\_R\_ERR to retry until the FIS is received without error. In the DISCOVER response, the ATTACHED SATA DEVICE bit is set to one and the ATTACHED SAS ADDRESS field is valid, but the ATTACHED DEVICE TYPE field is set to 000b (i.e., no device attached) during this time.

If an STP SATA bridge that retrieves IDENTIFY (PACKET) DEVICE data receives a connection request for a SATA device before it has retrieved the IDENTIFY (PACKET) DEVICE data, then it shall return an OPEN\_REJECT (NO DESTINATION). If the STP SATA bridge has a problem retrieving the IDENTIFY (PACKET) DEVICE data (e.g., word 255 (i.e., the Integrity Word) is not correct), then it shall set the ATTACHED DEVICE NAME field to zero, set the ATTACHED DEVICE TYPE field to 001b (i.e., end device), and start accepting connections.

A wide STP initiator port shall not request more than one connection at a time to a specific STP target port.

While a wide STP initiator port is waiting for a response to a connection request to an STP target port, a SAS phy in the STP initiator port shall not reject an incoming connection request from that STP target port with OPEN\_REJECT (RETRY) because the SAS port containing that SAS phy is waiting for an outgoing connection request to be accepted. The SAS phy may reject an incoming connection request from that STP target port with OPEN\_REJECT (RETRY) for any reason that is not dependent on the SAS port containing that SAS phy having an outgoing connection request accepted (e.g., because of a temporary buffer full condition).

If a wide STP initiator port receives an incoming connection request from an STP target port while it has a connection established with that STP target port, then the wide STP initiator port shall reject the request with OPEN\_REJECT (RETRY).

A wide STP target port shall not request more than one connection at a time to a specific STP initiator port.

While a wide STP target port is waiting for a response to a connection request or has established a connection to an STP initiator port, the wide STP target port shall:

- a) reject incoming connection requests from that STP initiator port with OPEN\_REJECT (RETRY); and
- b) if affiliations are supported and the maximum number of affiliations has been established (i.e., all affiliation contexts are in use), reject incoming connection requests from other STP initiator ports that do not have affiliations with OPEN\_REJECT (STP RESOURCES BUSY).

A SAS phy may reject an incoming connection request (i.e., an OPEN address frame) to an STP target port with OPEN\_REJECT (RETRY) for any reason, including because the SAS port containing that SAS phy is waiting for an outgoing connection request to be accepted (e.g., to transmit a frame and empty a buffer).

An expander device should not allow its STP ports (e.g., the STP target ports in STP SATA bridges and any STP initiator ports in the expander device) to attempt to establish more connections to a specific destination port than the destination port width or the width of the narrowest physical link on the pathway to the destination port. This does not apply to connection requests being forwarded by the expander device.

An expander device should not allow its STP ports (e.g., the STP target ports in STP SATA bridges and any STP initiator ports in the expander device) to attempt to establish more connections than the width of the narrowest common physical link on the pathways to the destination ports of those connections. This does not apply to connection requests being forwarded by the expander device.

Figure 152 shows an example of the simultaneous connection recommendations for an expander device containing STP ports. Multiplexing is disabled in this example.

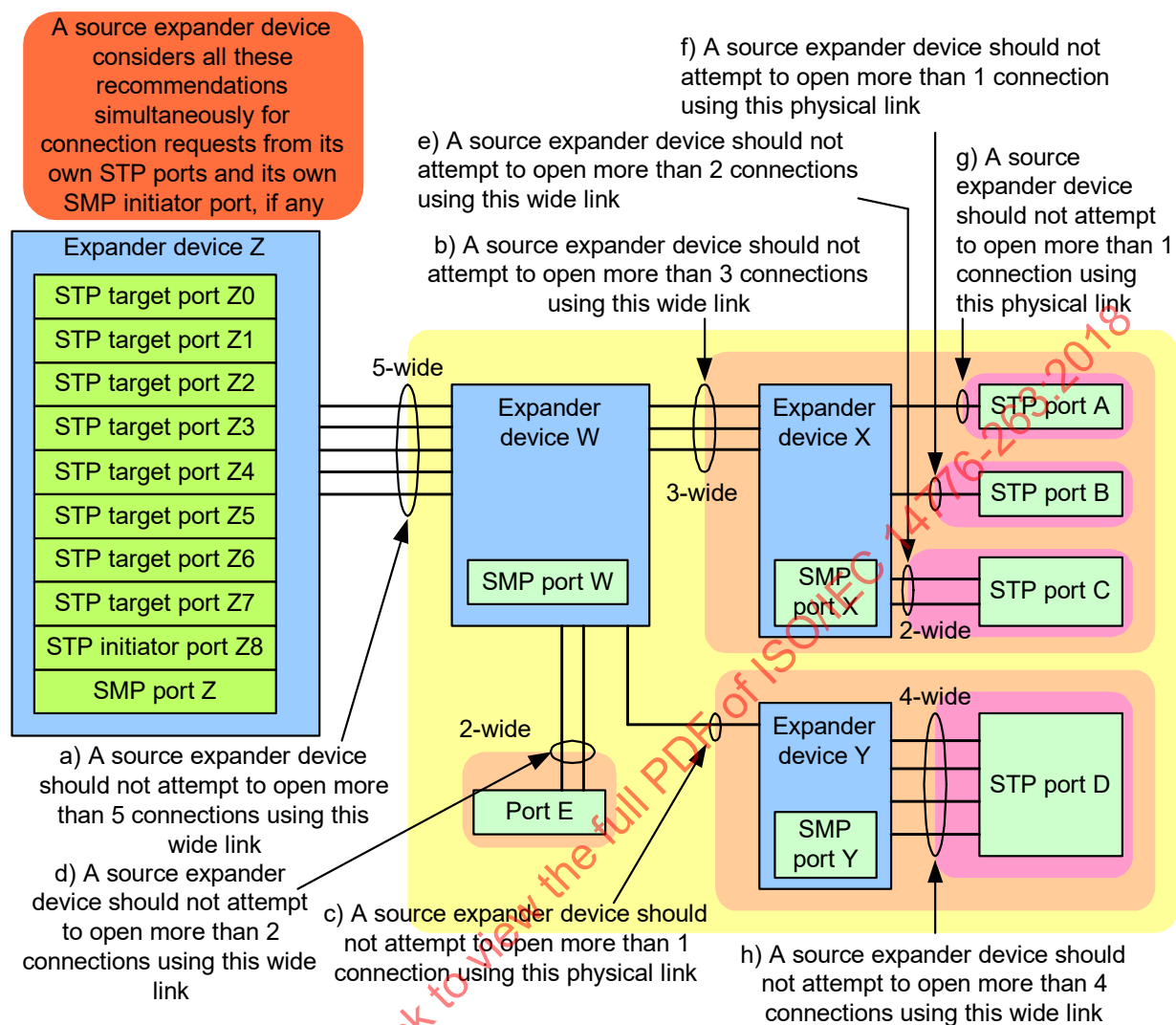


**Figure 152 — Example simultaneous connection recommendations for an expander device**

In figure 152, some of the recommendations are combined as follows:

- a) recommendations a), b), and e) together specify that expander device Z should not attempt to open more than 2 connections to port C;
- b) recommendations a), b), e), f), and g) together specify that if expander device Z has two connections open to ports A, B, and X, expander device Z should not attempt to open more than one connection to port C. If expander device Z has four connections open to ports A, B, D, E, W, X, and Y, expander device Z should not attempt to open more than one connection to port C; and
- c) recommendations a), c), and h) together specify that expander device Z should not attempt to open more than one connection to port D. If expander device Z has a connection open to port Y, expander device Z should not attempt to open another connection to port D until the first connection is closed.

The first dword that an STP phy sends inside an STP connection after OPEN\_ACCEPT that is not a deletable primitive shall be an STP primitive (e.g., SATA\_SYNC).



### 6.19.6 Closing an STP connection

Either STP port (i.e., either the STP initiator port or the STP target port) may originate closing an STP connection. An STP port shall not originate closing an STP connection after sending a SATA\_X\_RDY or SATA\_R\_RDY until after both sending and receiving SATA\_SYNC. An STP port shall transmit a CLOSE primitive sequence after receiving a CLOSE primitive sequence if it has not already transmitted a CLOSE primitive sequence.

If an STP port receives a CLOSE primitive sequence after transmitting a SATA\_X\_RDY but before receiving a SATA\_R\_RDY, then the STP port shall complete closing the connection (i.e., transmit a CLOSE primitive sequence) and retransmit the SATA\_X\_RDY in a new connection.

When an STP initiator port closes an STP connection, it shall transmit a CLOSE (NORMAL) primitive sequence or CLOSE (CLEAR AFFILIATION) primitive sequence. When an STP target port closes an STP connection, it shall transmit a CLOSE (NORMAL) primitive sequence.

An STP initiator port may issue a CLOSE (CLEAR AFFILIATION) primitive sequence in place of a CLOSE (NORMAL) primitive sequence to cause the STP target port to clear the affiliation (see 6.19.4) along with closing the connection. If an STP target port receives a CLOSE (CLEAR AFFILIATION) primitive sequence, then the STP target port shall clear the affiliation for the STP initiator port from which the a CLOSE (CLEAR AFFILIATION) primitive sequence was received.

See 6.14.8 for additional details on closing connections.

An STP SATA bridge shall break an STP connection if its SATA host phy loses dword synchronization (see 6.14.9).

### 6.19.7 STP connection management examples

The STP SATA bridge adds the outgoing OPEN address frames and CLOSEs so the STP initiator port sees an STP target port. The STP SATA bridge removes incoming OPEN address frame and CLOSEs so the SATA device port sees only a SATA host port. While the connection is open, the STP SATA bridge passes through all dwords without modification. Both STP initiator port and STP target port use SATA, with SATA flow control (see 6.19.2), while the connection is open.



Figure 153 shows an STP initiator port opening a connection, transmitting a single SATA frame, and closing the connection.

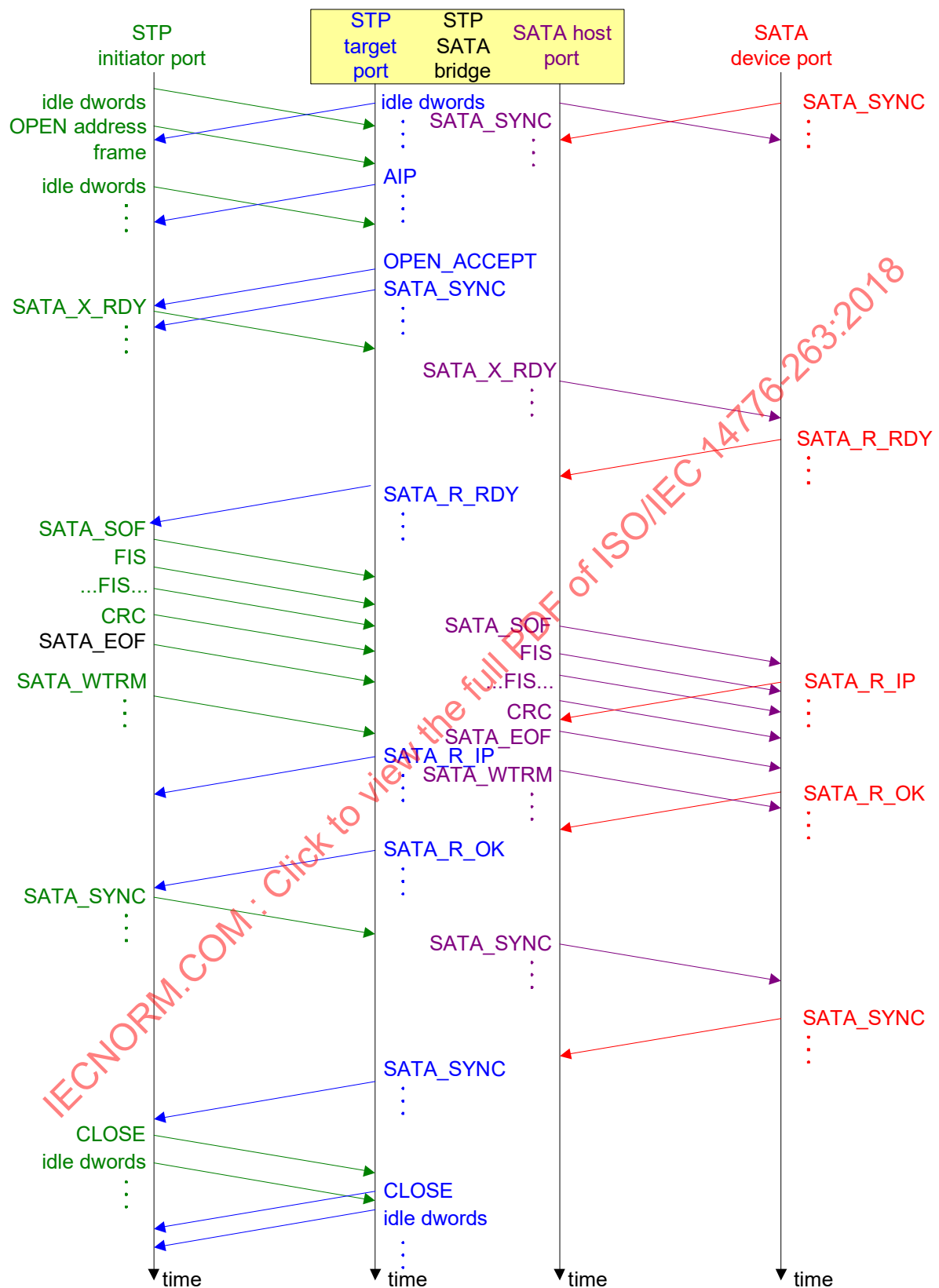


**Figure 153 — STP initiator port opening an STP connection**



### 6.19.8 STP (link layer for STP phys) state machines

The STP link layer uses the SATA link layer state machines (see SATA), modified to:

- a) communicate with the port layer rather than directly with the transport layer;
- b) interface with the SL state machines for connection management (e.g., to select when to open and close STP connections, and to tolerate idle dwords between an OPEN address frame and the first SATA primitive);
- c) communicate with an STP transmitter and receiver; and
- d) support an affiliation policy (see 6.19.4).

These modifications are not described in this standard.

The STP transmitter relationship to other transmitters is defined in 4.3.2. The STP receiver relationship to other receivers is defined in 4.3.3.

### 6.19.9 SMP target port support

A SAS device that contains an STP target port shall also contain an SMP target port.

## 6.20 SMP link layer

### 6.20.1 SMP frame transmission and reception

Inside an SMP connection, the SMP initiator phy transmits a single SMP\_REQUEST frame within 100 µs and the SMP target phy responds with a single SMP\_RESPONSE frame (see 8.4) within 1 900 µs.

Frames are surrounded by SOF and EOF as shown in figure 155. See 6.20.5 for error handling details.

NOTE 46 - Unlike SSP, there is no acknowledgement of SMP frames with ACK and NAK and there is no frame credit exchange with RRDY.

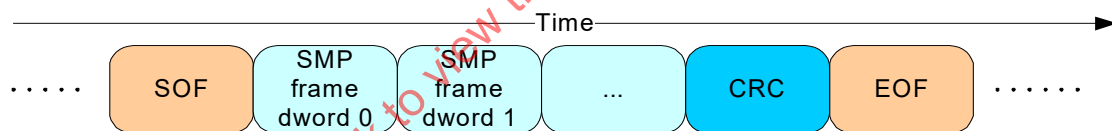


Figure 155 — SMP frame transmission

The last data dword after the SOF prior to the EOF always contains a CRC (see 6.5). The SMP link layer state machine checks that the frame is not too short and that the CRC is valid (see 6.20.5).

### 6.20.2 SMP flow control

By accepting an SMP connection, the SMP target phy indicates it is ready to receive one SMP\_REQUEST frame.

After the SMP initiator phy transmits one SMP\_REQUEST frame, it shall be ready to receive one SMP\_RESPONSE frame.

### 6.20.3 Opening an SMP connection

An SMP target port shall not attempt to establish an SMP connection.

A SAS phy may reject an incoming connection request (i.e., OPEN address frame) to an SMP target port with OPEN\_REJECT (RETRY) for any reason, including because the SAS port containing that SAS phy is waiting for an outgoing connection request to be accepted (e.g., to transmit a frame and empty a buffer).

#### 6.20.4 Closing an SMP connection

After receiving the SMP\_RESPONSE frame, the SMP initiator phy shall transmit a CLOSE (NORMAL) primitive sequence to close the connection.

After transmitting the SMP\_RESPONSE frame, the SMP target phy shall reply with a CLOSE (NORMAL) primitive sequence.

See 6.14.8 for additional details on closing connections.

#### 6.20.5 SMP (link layer for SMP phys) state machines

##### 6.20.5.1 SMP state machines overview

The SMP state machines control the flow of dwords on the physical link during an SMP connection. The SMP state machines are as follows:

- a) SMP\_IP (link layer for SMP initiator phys) state machine (see 6.20.5.3); and
- b) SMP\_TP (link layer for SMP target phys) state machine (see 6.20.5.4).

##### 6.20.5.2 SMP transmitter and receiver

The SMP transmitter receives the following messages from the SMP state machines specifying dwords and frames to transmit:

- a) Transmit Idle Dword; and
- b) Transmit Frame with an argument containing the frame contents.

In response to the Transmit Frame message, the SMP transmitter transmits:

- 1) SOF;
- 2) the frame contents;
- 3) CRC; and
- 4) EOF.

The SMP transmitter sends the following message to the SMP state machines based on dwords that have been transmitted:

- a) Frame Transmitted.

While there is no outstanding message specifying a dword to transmit, the SMP transmitter shall transmit idle dwords.

The SMP receiver sends the following messages to the SMP state machines indicating primitive sequences and dwords received from the SP\_DWS receiver (see 5.13.2):

- a) SOF Received;
- b) Data Dword Received;
- c) EOF Received;
- d) ERROR Received; and
- e) Invalid Dword Received.

The SMP receiver shall ignore all other dwords.

The SMP transmitter relationship to other transmitters is defined in 4.3.2. The SMP receiver relationship to other receivers is defined in 4.3.3.

### 6.20.5.3 SMP\_IP (link layer for SMP initiator phys) state machine

#### 6.20.5.3.1 SMP\_IP state machine overview

The SMP\_IP state machine's function is to transmit an SMP request frame and then receive the corresponding response frame. This state machine consists of the following states:

- SMP\_IP1:Idle (see 6.20.5.3.2) (initial state);
- SMP\_IP2:Transmit\_Frame (see 6.20.5.3.3); and
- SMP\_IP3:Receive\_Frame (see 6.20.5.3.4).

This state machine shall start in the SMP\_IP1:Idle state on receipt of an Enable Disable SMP (Enable) message from the SL state machines (see 6.16).

The SMP\_IP state machine shall terminate after receiving an Enable Disable SMP (Disable) message from the SL state machines.

Figure 156 shows the SMP\_IP state machine.

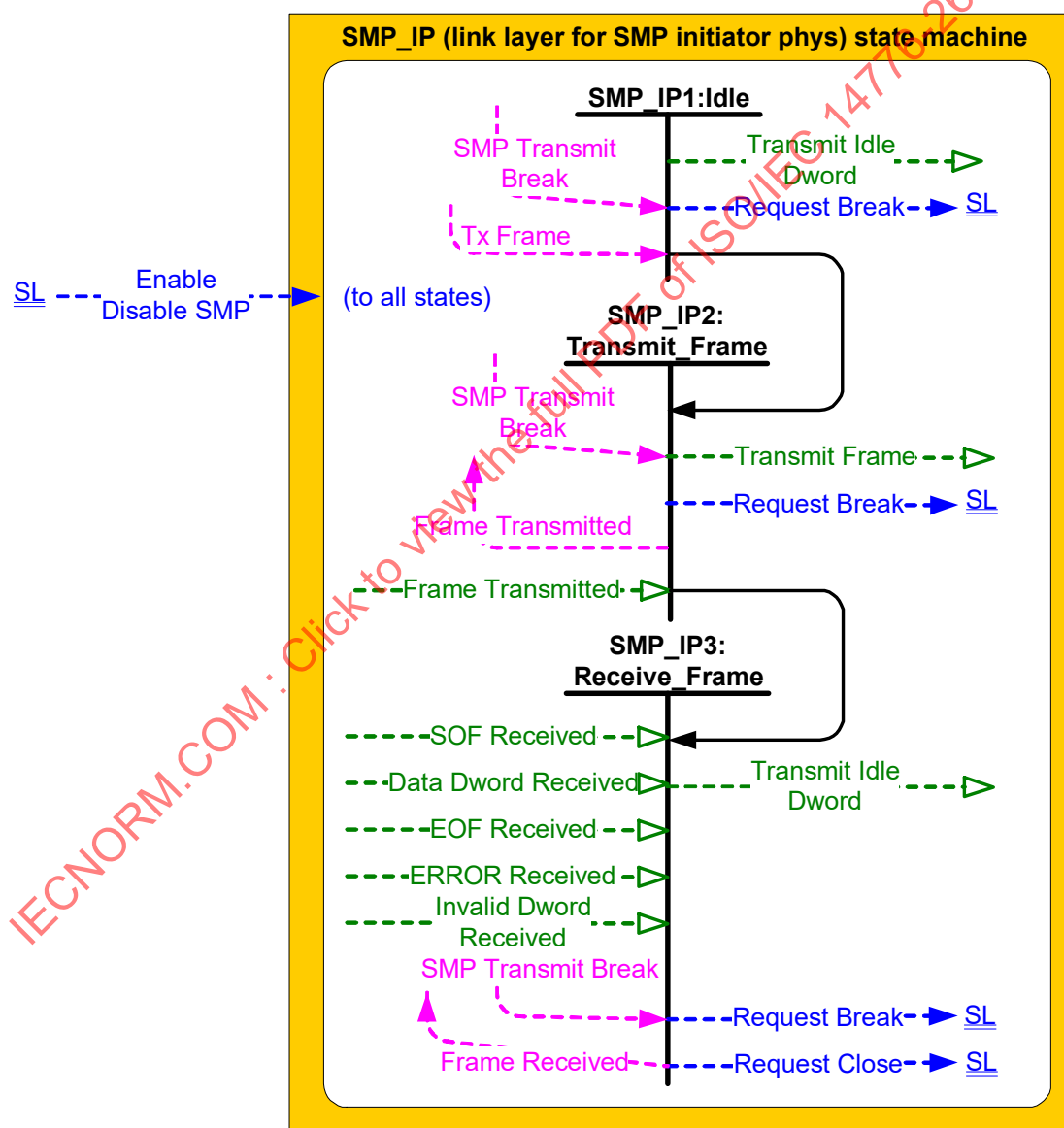


Figure 156 — SMP\_IP (link layer for SMP initiator phys) state machine

### 6.20.5.3.2 SMP\_IP1:Idle state

#### 6.20.5.3.2.1 State description

This state is the initial state.

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SMP transmitter.

If an SMP Transmit Break request is received, then this state shall send a Request Break message to the SL state machines (see 6.16).

#### 6.20.5.3.2.2 Transition SMP\_IP1:Idle to SMP\_IP2:Transmit\_Frame

This transition shall occur:

- a) after a Tx Frame request is received.

### 6.20.5.3.3 SMP\_IP2:Transmit\_Frame state

#### 6.20.5.3.3.1 State description

This state shall send a Transmit Frame message to the SMP transmitter with an argument containing the frame contents.

If an SMP Transmit Break request is received, then this state shall send a Request Break message to the SL state machines (see 6.16) and terminate this state machine.

After the Frame Transmitted message is received, this state shall send a Frame Transmitted confirmation to the port layer.

#### 6.20.5.3.3.2 Transition SMP\_IP2:Transmit\_Frame to SMP\_IP3:Receive\_Frame

This transition shall occur:

- a) after sending a Frame Transmitted confirmation to the port layer.

### 6.20.5.3.4 SMP\_IP3:Receive\_Frame state

This state checks the SMP response frame and determines if the SMP response frame was received without error (e.g., no CRC error).

If this state receives a subsequent SOF Received message after receiving an SOF Received message but before receiving an EOF Received message (i.e., SOF, data dwords, SOF, data dwords, and EOF instead of SOF, data dwords, EOF, SOF, data dwords, and EOF), then this state shall discard the frame in progress.

This state shall discard the frame, send a Frame Received (SMP Unsuccessful) confirmation to the port layer, send a Request Break message to the SL state machines, and terminate this state machine if:

- a) this state receives more than 257 Data Dword Received messages (i.e., 1 028 bytes) after an SOF Received message and before an EOF Received message; or

NOTE 47 - SMP target phys compliant with SAS 1.1 may send vendor specific SMP frames containing 258 data dwords (i.e., 1 032 bytes).

- b) this state receives fewer than two Data Dword Received messages (i.e., 8 bytes) after an SOF Received message and before an EOF Received message.

If this state receives an Invalid Dword Received message or an ERROR Received message after an SOF Received message and before an EOF Received message, then this state machine shall either:

- a) ignore the invalid dword or ERROR; or

- b) discard the frame, send a Frame Received (SMP Unsuccessful) confirmation to the port layer, send a Request Break message to the SL state machines, and terminate this state machine.

If the SMP response frame is received with a CRC error, then this state shall discard the frame, send a Frame Received (SMP Unsuccessful) confirmation to the port layer, send a Request Break message to the SL state machines, and terminate this state machine.

If the SMP response frame is received with no CRC error and the SMP response frame is valid, then this state shall send:

- a) a Frame Received (SMP Successful) confirmation to the port layer; and
- b) a Request Close message to the SL state machines (see 6.16).

If an SMP Transmit Break request is received, then this state shall send a Request Break message to the SL state machines and terminate this state machine.

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SMP transmitter.

#### **6.20.5.4 SMP\_TP (link layer for SMP target phys) state machine**

##### **6.20.5.4.1 SMP\_TP state machine overview**

The SMP\_TP state machine's function is to receive an SMP request frame and then transmit the corresponding SMP response frame. The SMP\_TP state machine consists of the following states:

- a) SMP\_TP1:Receive\_Frame (see 6.20.5.4.2) (initial state); and
- b) SMP\_TP2:Transmit\_Frame (see 6.20.5.4.3).

This state machine shall start in the SMP\_TP1:Receive\_Frame state after receiving an Enable Disable SMP (Enable) message from the SL state machines (see 6.16).

This state machine shall terminate after receiving an Enable Disable SMP (Disable) message from the SL state machines.

Figure 157 shows the SMP\_TP state machine.

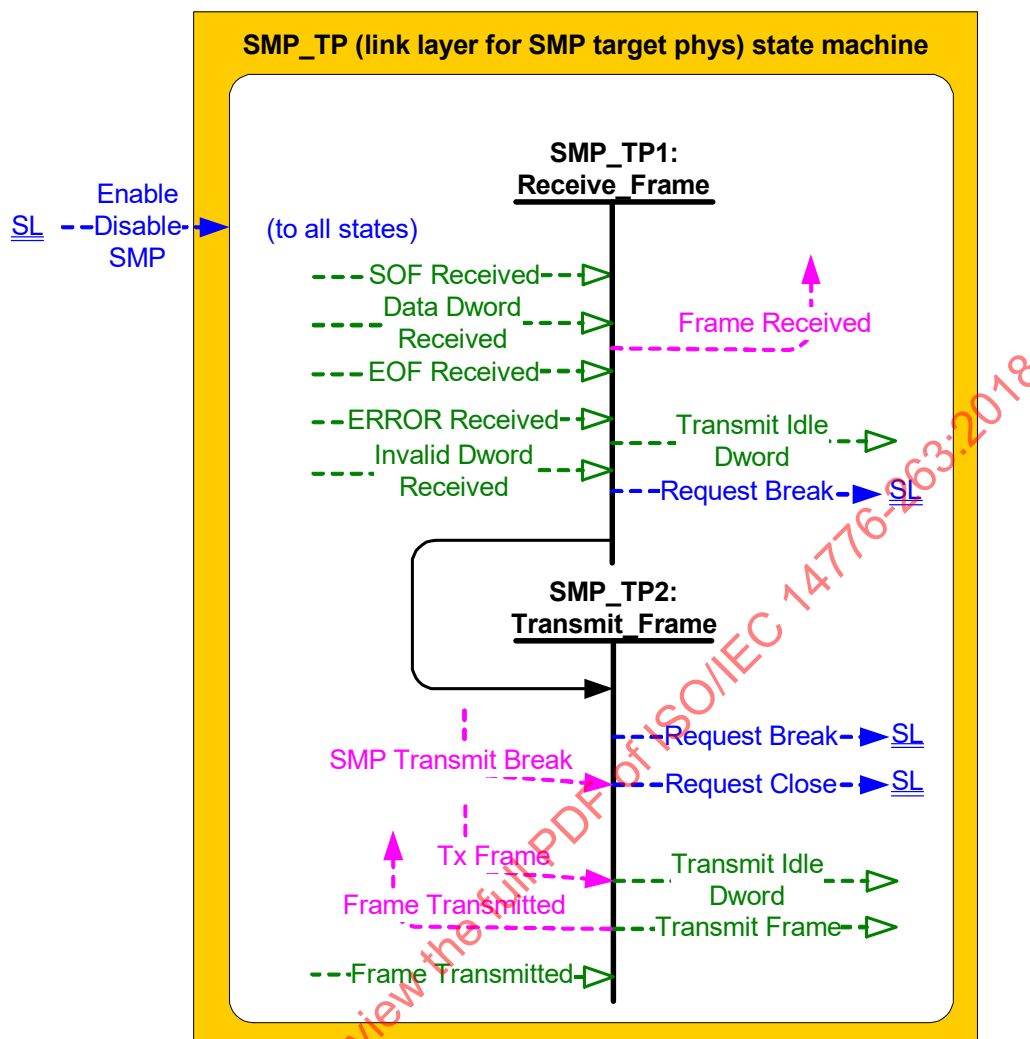


Figure 157 — SMP\_TP (link layer for SMP target phys) state machine

#### 6.20.5.4.2 SMP\_TP1:Receive\_Frame state

##### 6.20.5.4.2.1 State description

This state waits for an SMP frame and determines if the SMP frame was received without error (e.g., no CRC error).

If this state receives a subsequent SOF Received message after receiving an SOF Received message but before receiving an EOF Received message (i.e., SOF, data dwords, SOF, data dwords, and EOF instead of SOF, data dwords, EOF, SOF, data dwords, and EOF), then this state shall discard the frame in progress.

This state shall discard the frame, send a Request Break message to the SL state machines (see 6.16) and shall terminate this state machine if:

- this state receives more than 257 Data Dword Received messages (i.e., 1 028 bytes) after an SOF Received message and before an EOF Received message; or

NOTE 48 - SMP initiator phys compliant with SAS 1.1 may send vendor specific SMP frames containing 258 data dwords (i.e., 1 032 bytes).



- b) this state receives fewer than two Data Dword Received messages (i.e., 8 bytes) after an SOF Received message and before an EOF Received message.

If this state receives an Invalid Dword Received message or an ERROR Received message after an SOF Received message and before an EOF Received message, then this state machine shall either:

- a) ignore the invalid dword or ERROR; or
- b) discard the frame, send a Request Break message to the SL state machines (see 6.16) and shall terminate this state machine.

If the SMP request frame is received with a CRC error, then this state shall discard the frame, send a Request Break message to the SL state machines (see 6.16) and shall terminate this state machine.

Otherwise, this state shall send a Frame Received (SMP Successful) confirmation to the port layer.

This state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SMP transmitter.

#### **6.20.5.4.2.2 Transition SMP\_TP1:Receive\_Frame to SMP\_TP2:Transmit\_Frame**

This transition shall occur after sending a Frame Received (SMP Successful) confirmation to the port layer.

#### **6.20.5.4.3 SMP\_TP2:Transmit\_Frame state**

If this state receives an SMP Transmit Break request, then this state shall send a Request Break message to the SL state machines and terminate this state machine.

If this state receives a Tx Frame request, then this state shall send a Transmit Frame message to the SMP transmitter with an argument containing the frame contents, then wait for a Frame Transmitted message. After receiving a Frame Transmitted message, this state shall send a Frame Transmitted confirmation to the port layer, send a Request Close message to the SL state machines (see 6.16) and terminate this state machine.

After sending Transmit Frame message to the SMP transmitter, this state shall request that idle dwords be transmitted by repeatedly sending Transmit Idle Dword messages to the SMP transmitter.

## 7 Port layer

### 7.1 Port layer overview

The port layer (PL) state machines interface with one or more SAS link layer state machines and one or more SSP, SMP, and STP transport layer state machines to establish port connections and disconnections. The port layer state machines also interpret or pass transmit data, receive data, commands, and confirmations between the link layer, transport layer, and the management application layer.

### 7.2 PL (port layer) state machines

#### 7.2.1 PL state machines overview

The PL (port layer) consists of state machines that run in parallel and perform the following functions:

- a) receive requests from the SSP, SMP, and STP transport layer state machines for connection management (e.g., requests to open or close connections) and frame transmission;
- b) receive requests from the management application layer;
- c) send requests to the SAS link layer state machines for connection management and frame transmission;
- d) receive confirmation from the SAS link layer state machines;
- e) send confirmations to the SSP, SMP, and STP transport layer state machines; and
- f) send confirmations to the management application layer.

The port layer state machines are as follows:

- a) PL\_OC (port layer overall control) state machines (see 7.2.2); and
- b) PL\_PM (port layer phy manager) state machines (see 7.2.3).

There is one PL\_OC state machine per port (see 4.1.4). There is one PL\_PM state machine for each phy contained in the port. Phys are assigned to ports by the management application layer. More than one port in a SAS device may have the same SAS address if the ports are in different SAS domains (see 4.2.9).

Figure 158 shows examples of the port layer state machines and their interaction with the transport and link layers.

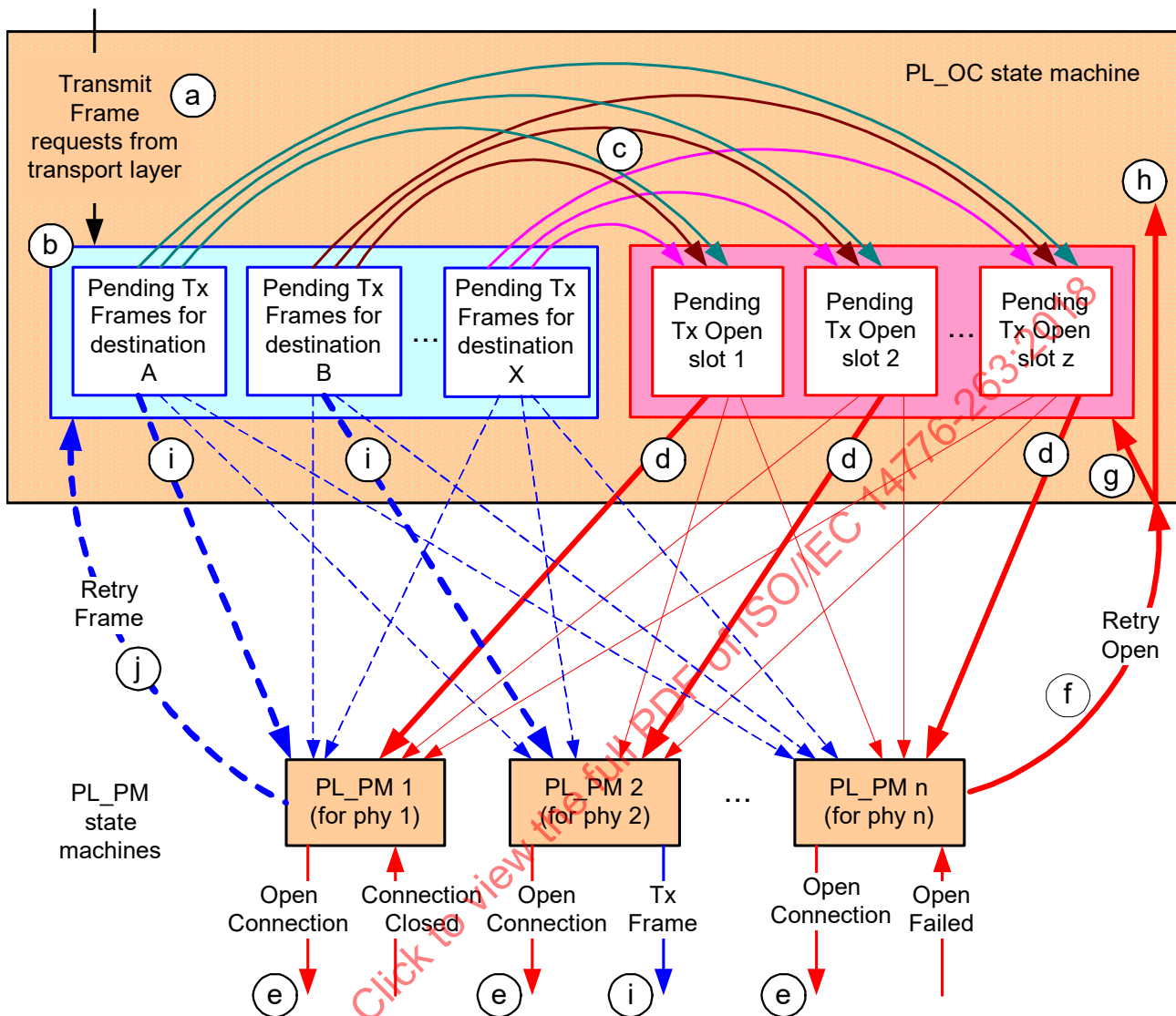


Figure 158 — Port layer examples

The following is a description of the example processes in figure 158. These example processes do not describe all of the possible condition or actions:

- Transmit Frame requests are received by the PL\_OC state machine;
- the PL\_OC state machine converts Transmit Frame requests into pending Tx Frame messages associated with the destination SAS address;
- the PL\_OC state machine generates a pending Tx Open message for a pending Tx Frame message when there is a pending Tx Open slot available (i.e., the number of pending Tx Open messages is less than or equal to the number of destination SAS addresses);
- the PL\_OC state machine sends a pending Tx Open message as a Tx Open message to a PL\_PM state machine when a PL\_PM machine is available, a slot is then available for a new pending Tx Open message;
- when a PL\_PM state machine receives a Tx Open message, the PL\_PM state machine attempts to establish a connection with the destination SAS address through the link layer;

- f) if a PL\_PM state machine is unable to establish a connection with the destination SAS address, then the PL\_PM state machine sends a Retry Open message to the PL\_OC state machine;
- g) if there is a pending Tx Open slot available, then the PL\_OC state machine converts a Retry Open message to a pending Tx Open message with the pathway blocked count and arbitration wait time context from the Retry Open message applied to the pending Tx Open message, and may start the Reject To Open Limit timer;
- h) if the PL\_OC state machine does not convert a Retry Open to a pending Tx Open message, then the PL\_OC discards the Retry Open message. The PL\_OC state machine may create a new Tx Open message for the same pending Tx Frame at a later time or send the appropriate Transmission Status confirmation to the transport layer. If the PL\_OC state machine discards a Retry Open message, then the pathway blocked count and arbitration wait time context from the Retry Open message are also discarded;
- i) after the Reject To Open Limit timer, if any, has expired and after a PL\_PM state machine establishes a connection with a destination SAS address, the PL\_OC state machine sends pending Tx Frame messages for the destination to the PL\_PM state machine as Tx Frame messages;
- j) if a PL\_PM state machine is unable to send a Tx Frame message to the link layer as a Tx Frame request (e.g., due to an SSP frame credit timeout), then the PL\_PM state machine sends a Retry Frame message to the PL\_OC state machine, and the PL\_OC state machine converts the Retry Frame message into a pending Tx Frame message; and
- k) if the PL\_PM state machine is able to send a Tx Frame message as a Tx Frame request to the link layer, then the PL\_PM state machine sends a Transmission Status confirmation to the transport layer.

The Transmission Status confirmation from either the PL\_OC state machine or a PL\_PM state machine shall include the following as arguments:

- a) initiator port transfer tag;
- b) Destination SAS Address; and
- c) Source SAS Address.

## 7.2.2 PL\_OC (port layer overall control) state machine

### 7.2.2.1 PL\_OC state machine overview

The PL\_OC state machine:

- a) receives requests from the SSP, SMP, and STP transport layers;
- b) sends messages to the PL\_PM state machine;
- c) receives messages from the PL\_PM state machine;
- d) receives requests from the management application layer;
- e) selects frames to transmit;
- f) selects phys on which to transmit frames;
- g) receives confirmations from the link layer;
- h) sends confirmations to the transport layer;
- i) sends confirmations to the management application layer;
- j) has Arbitration Wait Time timers;
- k) has I\_T Nexus Loss timers; and
- l) may have Reject To Open Limit timers.

This state machine consists of the following states:

- a) PL\_OC1:Idle (see 7.2.2.2) (initial state); and
- b) PL\_OC2:Overall\_Control (see 7.2.2.3).

This state machine shall start in the PL\_OC1:Idle state after power on.

This state machine shall maintain a pool of pending:

- a) Tx Frame messages for each destination SAS address; and
- b) Tx Open message slots. There shall only be at most a single pending Tx Open message slot for each destination SAS address. There may be fewer total pending Tx Open message slots than the total number of destination SAS addresses.

This state machine shall maintain the timers listed in table 151.

**Table 151 — PL\_OC state machine timers**

| Timer                       | Maximum number of timers        | Initial value                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|-----------------------------|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T Nexus Loss timer        | One per destination SAS address | Depending on the protocol used by the port:<br>a) for SSP target ports, the value in the I_T NEXUS LOSS TIME field in the Protocol Specific Port mode page (see 9.2.7.4);<br>b) for SSP initiator ports, the value in the I_T NEXUS LOSS TIME field in the Protocol Specific Port mode page for the SSP target port with that destination SAS address (see 9.2.7.4);<br>c) for STP target ports, the value in the STP SMP I_T NEXUS LOSS TIME field in the SMP CONFIGURE GENERAL function (see 9.4.3.18);<br>d) for STP initiator ports, the value in the STP SMP I_T NEXUS LOSS TIME field in the SMP REPORT GENERAL function (see 9.4.3.4) for the STP target port with that destination SAS address;<br>e) for SMP initiator ports managed by a management device server, the value in the STP SMP I_T NEXUS LOSS TIME field in the SMP CONFIGURE GENERAL function (see 9.4.3.18); or<br>f) for SMP initiator ports not managed by a management device server, the value in the STP SMP I_T NEXUS LOSS TIME field in the SMP REPORT GENERAL function (see 9.4.3.4) for the SMP target port with that destination SAS address. |
| Arbitration Wait Time timer | One per pending Tx Open message | 0000h, a vendor specific value less than 8000h (see 6.14.3), or the value received with a Retry Open message.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Reject To Open Limit timer  | One per Retry Open message      | Depending on the protocol used by the port:<br>a) for SSP target ports, the value in the REJECT TO OPEN LIMIT field in the Protocol Specific Port mode page (see 9.2.7.4);<br>b) for SSP initiator ports, a vendor specific value;<br>c) for STP target ports, the value in the STP REJECT TO OPEN LIMIT field in the SMP CONFIGURE GENERAL function (see 9.4.3.18); or<br>d) for STP initiator ports, a vendor specific value.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

Figure 159 shows the PL\_OC state machine.

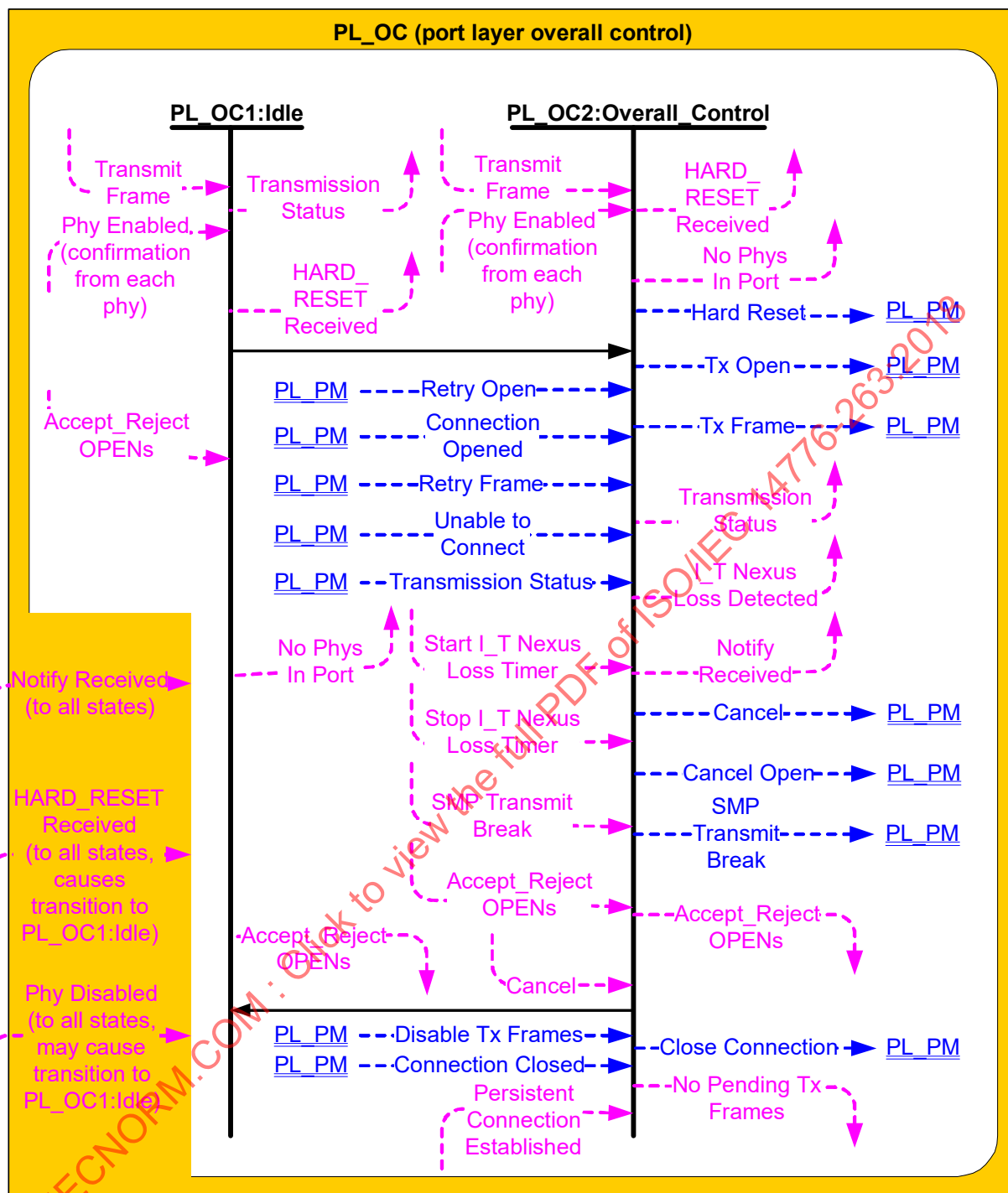


Figure 159 — PL\_OC (port layer overall control) state machine

#### 7.2.2.2 PL\_OC1:Idle state

##### 7.2.2.2.1 PL\_OC1:Idle state description

This state is the initial state of the PL\_OC state machine.

If this state receives a HARD\_RESET Received confirmation, then this state shall send a HARD\_RESET Received confirmation to the transport layer.

If this state receives a Notify Received (Power Loss Expected) confirmation, then this state shall send a Notify Received (Power Loss Expected) confirmation to the transport layer.

If this state receives an Accept\_Reject OPENs request, then this state shall send an Accept\_Reject OPENs request with the same arguments to all link layers in the port.

If this state receives a Transmit Frame request, then this state shall send a No Phys In Port confirmation to the transport layer.

If the port is an STP target port or an STP initiator port, then the port shall handle all pending commands as described in 4.4.3.

#### 7.2.2.2.2 Transition PL\_OC1:Idle to PL\_OC2:Overall\_Control

This transition shall occur after a Phy Enabled confirmation is received for at least one phy assigned to the port.

#### 7.2.2.3 PL\_OC2:Overall\_Control state

##### 7.2.2.3.1 PL\_OC2:Overall\_Control state overview

This state may receive Transmit Frame requests from the transport layers (i.e., SSP and SMP) and Retry Frame messages from PL\_PM state machines. This state shall create a pending Tx Frame message for each received Transmit Frame request and Retry Frame message. There may be more than one pending Tx Frame message at a time for each SSP transport layer. There shall be only one pending Tx Frame message at a time for each SMP transport layer.

This state selects PL\_PM state machines through which connections are established. This state shall only attempt to establish connections through PL\_PM state machines whose phys are enabled. In a vendor specific manner, this state selects PL\_PM state machines on which connections are established to transmit frames. This state shall receive a response to a message from a PL\_PM state machine before sending another message to that PL\_PM state machine.

This state also:

- a) receives connection management requests from the transport layers;
- b) sends connection management messages to PL\_PM state machines;
- c) receives connection management messages from PL\_PM state machines; and
- d) sends connection management confirmations to the transport layers
- e) receives requests from the management application layer; and
- f) sends confirmations to the management application layer.

##### 7.2.2.3.2 PL\_OC2: Non-connection specific confirmations and requests

###### 7.2.2.3.2.1 PL\_OC2: Transmit Frame request

After receiving a Transmit Frame request for a destination SAS address for which there is no connection established and for which no I\_T Nexus Loss timer has been created, this state shall create an I\_T Nexus Loss timer for that SAS address if the protocol is:

- a) SSP, the port is an SSP target port, the Protocol Specific Port mode page is implemented, and the I\_T NEXUS LOSS TIME field in the Protocol Specific Port mode page (see 9.2.7.4) is not set to 0000h;
- b) STP, the port is an STP target port, and the STP SMP I\_T NEXUS LOSS TIME field in the SMP CONFIGURE GENERAL function is not set to 0000h; or
- c) SMP, the port is an SMP initiator port, and the STP SMP I\_T NEXUS LOSS TIME field in the SMP CONFIGURE GENERAL function is not set to 0000h.

After receiving a Transmit Frame request for a destination SAS address for which there is no connection established and for which no I\_T Nexus Loss timer has been created this state may create an I\_T Nexus Loss timer for that SAS address if the protocol is:

- a) SSP and the port is an SSP initiator port; or
- b) STP and the port is an STP initiator port.

If this state creates an I\_T Nexus Loss timer after receiving a Transmit Frame request for a destination SAS address, then this state shall:

- 1) initialize that I\_T Nexus Loss timer as specified in table 151 (see 7.2.2.1); and
- 2) not start that I\_T Nexus Loss timer.

If there are no pending Tx Frame messages for a destination SAS address and an I\_T Nexus Loss timer has been created for that destination SAS address, then this state shall delete the I\_T Nexus Loss timer for that destination SAS address.

#### 7.2.2.3.2.2 PL\_OC2: HARD\_RESET Received confirmation

If this state receives a HARD\_RESET Received confirmation, then this state shall:

- a) discard all pending Tx Frame messages;
- b) discard all pending Tx Open messages;
- c) delete all timers (e.g., I\_T Nexus Loss timers, Arbitration Wait Time timers, and Reject To Open Limit timers);
- d) send a Hard Reset message to each PL\_PM state machine; and
- e) send a HARD\_RESET Received confirmation to the transport layer.

#### 7.2.2.3.2.3 PL\_OC2: Notify Received (Power Loss Expected) confirmation

If this state receives a Notify Received (Power Loss Expected) confirmation, then this state shall:

- a) discard all pending Tx Frame messages;
- b) discard all pending Tx Open messages;
- c) delete all timers (e.g., I\_T Nexus Loss timers, Arbitration Wait Time timers, and Reject To Open Limit timers);
- d) send a Close Connection message to each of the PL\_PM state machines;
- e) send a Cancel Open message to each of the PL\_PM state machines; and
- f) send a Notify Received (Power Loss Expected) confirmation to the transport layer.

#### 7.2.2.3.2.4 PL\_OC2: Phy Disabled confirmation

If this state receives a Phy Disabled confirmation from all the link layers in the port, then for each destination SAS address accessible through this port for which no I\_T Nexus Loss timer has been created, this state should create an I\_T Nexus Loss timer for that SAS address if the protocol is:

- a) SSP, the port is an SSP target port, the Protocol-Specific Port mode page is implemented, and the I\_T NEXUS LOSS TIME field is not set to 0000h in the Protocol-Specific Port mode page (see 9.2.7.4);
- b) STP, the port is an STP target port, and the STP SMP I\_T NEXUS LOSS TIME field is not set to 0000h in the SMP CONFIGURE GENERAL function; or
- c) SMP, the port is an SMP initiator port, and the STP SMP I\_T NEXUS LOSS TIME field is not set to 0000h in the SMP CONFIGURE GENERAL function.

If this state receives a Phy Disabled confirmation from all the link layers in the port, then, for each destination SAS address accessible through this port, this state may create an I\_T Nexus Loss timer for that SAS address if the protocol is:

- a) SSP and the port is an SSP initiator port; or
- b) STP and the port is an STP initiator port.



If this state receives a Phy Disabled confirmation from all the link layers in the port, an I\_T Nexus Loss timer has been created for a destination SAS address, and that I\_T Nexus Loss timer is not running, then this state shall:

- 1) initialize that I\_T Nexus Loss timer; and
- 2) start that I\_T Nexus Loss timer.

If this state receives a Phy Disabled confirmation from all the link layers in the port and an I\_T Nexus Loss timer has not been created for the destination SAS address (e.g., the destination port is an SSP target port does not support the I\_T NEXUS LOSS TIME field in the Protocol Specific Port mode page), then this state shall, for the destination SAS address:

- a) discard all pending Tx Frame messages;
- b) discard all pending Tx Open messages;
- c) delete all timers (e.g., Arbitration Wait Time timers, and Reject To Open Limit timers); and
- d) send a No Phys In Port confirmation to the transport layer.

After this state receives a Phy Disabled confirmation from all the link layers in the port, if a Phy Enabled confirmation is not received from any phy in the port before the I\_T Nexus Loss timer for a destination SAS address has expired, then this state shall, for the destination SAS address:

- a) discard all pending Tx Frame messages;
- b) discard all pending Tx Open messages;
- c) delete all timers (e.g., I\_T Nexus Loss timers, Arbitration Wait Time timers, and Reject To Open Limit timers); and
- d) send a No Phys In Port confirmation to the transport layer.

#### 7.2.2.3.2.5 PL\_OC2: Start I\_T Nexus Loss Timer request

If this state receives a Start I\_T Nexus Loss Timer request from the management application layer for a destination SAS Address accessible through this port for which no I\_T Nexus Loss timer has been created, this state shall create an I\_T Nexus Loss timer for the specified SAS address if the protocol is:

- a) SSP, the port is an SSP target port, the Protocol-Specific Port mode page is implemented, and the I\_T NEXUS LOSS TIME field is not set to 0000h in the Protocol-Specific Port mode page (see 9.2.7.4);
- b) STP, the port is an STP target port, and the STP SMP I\_T NEXUS LOSS TIME field is not set to 0000h in the SMP CONFIGURE GENERAL function; or
- c) SMP, the port is an SMP initiator port, and the STP SMP I\_T NEXUS LOSS TIME field is not set to 0000h in the SMP CONFIGURE GENERAL function.

If this state receives a Start I\_T Nexus Loss Timer request from the management application layer, then this state may create an I\_T Nexus Loss timer for the specified SAS address if the protocol is:

- a) SSP and the port is an SSP initiator port; or
- b) STP and the port is an STP initiator port.

If this state receives a Start I\_T Nexus Loss Timer request from the management application layer, an I\_T Nexus Loss timer has been created for the specified destination SAS address, and that I\_T Nexus Loss timer is not running, then this state shall:

- 1) initialize that I\_T Nexus Loss timer; and
- 2) start that I\_T Nexus Loss timer.

#### 7.2.2.3.3 PL\_OC2:Overall\_Control state establishing connections

This state receives Phy Enabled confirmations indicating when a phy is available.

This state receives Retry Open messages from a PL\_PM state machine.

This state creates pending Tx Open messages based on pending Tx Frame messages and Retry Open messages. Pending Tx Open messages are sent to a PL\_PM state machine as Tx Open messages. This state shall discard a pending Tx Open message if there are no pending Tx Frame messages for that

destination (e.g., after accepting an incoming connection in which the other phy provides transmit SSP frame credit).

See 6.14.2.1 for additional requirements and recommendations on how this state decides to create pending Tx Open messages.

If this state receives a Retry Open (Retry) message or a Retry Open (Low Phy Power Condition) message, then this state shall process the Retry Open message.

If this state receives a Retry Open (No Destination) message or a Retry Open (Open Timeout Occurred) message and an I\_T Nexus Loss timer has not been created for the destination SAS address (e.g., the destination port is an SSP target port does not support the I\_T NEXUS LOSS TIME field in the Protocol Specific Port mode page), then this state shall process the Retry Open message as either a Retry Open message or an Unable To Connect message. This selection is vendor specific.

If this state receives a Retry Open (Pathway Blocked) message or Retry Open (Break Received) message, and an I\_T Nexus Loss timer has not been created for the destination SAS address, then this state shall process the Retry Open message.

If this state receives a Retry Open (No Destination) message, a Retry Open (Open Timeout Occurred) message, Retry Open (Break Received) message, or a Retry Open (Pathway Blocked) message, and an I\_T Nexus Loss timer has been created for the destination SAS address with an initial value of FFFFh, then this state shall process the Retry Open message (i.e., the Retry Open message is never processed as an Unable To Connect message).

If:

- a) this state receives a Retry Open (No Destination) message, a Retry Open (Break Received) message, or a Retry Open (Open Timeout Occurred) message;
- b) an I\_T Nexus Loss timer has been created for the destination SAS address; and
- c) there is no connection established with the destination SAS address,

then this state shall check the I\_T Nexus Loss timer, and:

- a) if the I\_T Nexus Loss timer is not running, the I\_T nexus loss time is not set to FFFFh, and the CONFIGURING bit is set to zero in the REPORT GENERAL response (see 9.4.3.4) for each expander device between this port and the destination port that is two or more levels away from this port, then this state shall start the I\_T Nexus Loss timer;
- b) if the I\_T Nexus Loss timer is running, then this state shall not stop the timer; and
- c) if the I\_T Nexus Loss timer has expired, then this state shall process the Retry Open message as if it were an Unable To Connect message (see 7.2.2.3.6).

If this state:

- a) receives a Retry Open (Pathway Blocked) message or Retry Open (Low Phy Power Condition) message;
- b) an I\_T Nexus Loss timer has been created for the destination SAS address; and
- c) there is no connection established with the destination SAS address,

then this state shall check the I\_T Nexus Loss timer, and if the I\_T Nexus Loss timer:

- a) is running, then this state shall not stop the timer; or
- b) has expired, then this state shall process the Retry Open message as if it were an Unable To Connect message (see 7.2.2.3.6).

If this state receives a Retry Open (Retry) message and an I\_T Nexus Loss timer is running for the destination SAS address, then this state shall:

- a) stop the I\_T Nexus Loss timer; and
- b) initialize the I\_T Nexus Loss timer (see table 151).

This state shall create a pending Tx Open message if:

- a) this state has a pending Tx Frame message or has received a Retry Open message;
- b) there is a pending Tx Open message slot available for the destination SAS address;

- c) there is no pending Tx Open message for the destination SAS address; and
- d) there is no connection established with the destination SAS address.

This state may create a pending Tx Open message if:

- a) this state has a pending Tx Frame message, or this state has received a Retry Open message and has not processed the message by sending a confirmation; and
- b) there is a pending Tx Open message slot available for the destination SAS address.

If this state receives a Retry Open message and there are pending Tx Frame messages for which pending Tx Open messages have not been created, then this state should create a pending Tx Open message from the Retry Open message.

If this state does not create a pending Tx Open message from a Retry Open message (e.g., there is not an available pending Tx Open message slot for the destination SAS address), then this state shall discard the Retry Open message. This state may create a new pending Tx Open message at a later time for the pending Tx Frame message that resulted in the Retry Open message.

If this state receives a Retry Open (Opened By Destination) message, and the initiator port bit and protocol arguments match those in the Tx Open messages that resulted in the Retry Open message, then this state may discard the Retry Open message and use the established connection to send pending Tx Frame messages as Tx Frame messages to the destination SAS address. If this state receives a Retry Open (Opened By Destination) message and state has a pending Tx Open slot available, then this state may create a pending Tx Open message from the Retry Open message.

If a connection is established by another port as indicated by a Retry Open (Opened By Destination) message, then transmit SSP frame credit may not be granted for frame transmission. In this case this state may create a pending Tx Open message from a Retry Open message in order to establish a connection where transmit SSP frame credit is granted.

This state shall send a pending Tx Open message as a Tx Open message to a PL\_PM state machine that has an enabled phy and does not have a connection established. If there is more than one pending Tx Open message, then this state should send a Tx Open message for the pending Tx Open message that has been pending for the longest time first.

If low phy power conditions (see 4.10.1) are enabled, then this state should use the following precedence in selecting the PL\_PM state machine to which a pending Tx Open message is to be sent:

- 1) PL\_PM state machine with its phy in the active phy power condition (see 4.10.1.2);
- 2) PL\_PM state machine with its phy in the partial phy power condition (see 4.10.1.3); and
- 3) PL\_PM state machine with its phy in the slumber phy power condition (see 4.10.1.4).

If this state creates a pending Tx Open message from one of the following messages:

- a) Retry Open (Opened By Destination);
- b) Retry Open (Opened By Other);
- c) Retry Open (Collided);
- d) Retry Open (Pathway Blocked);
- e) Retry Open (Low Phy Power Condition); or
- f) Retry Open (Retry) if the CONTINUE AWT bit is set to one in the Protocol specific Port mode page (see 9.2.7.4).

then this state shall:

- 1) create an Arbitration Wait Time timer for the pending Tx Open message;
- 2) set the Arbitration Wait Time timer for the pending Tx Open message to the arbitration wait time argument from the Retry Open message; and
- 3) start the Arbitration Wait Time timer for the pending Tx Open message.

When a pending Tx Open message is sent to a PL\_PM state machine as a Tx Open message, the Tx Open message shall contain the following arguments to be used in an OPEN address frame:

- a) Initiator Port Bit from the Transmit Frame request;
- b) Protocol from the Transmit Frame request;

- c) Connection Rate from the Transmit Frame request;
- d) Initiator Connection Tag from the Transmit Frame request;
- e) Destination SAS Address from the Transmit Frame request;
- f) Source SAS Address from the Transmit Frame request;
- g) Pathway Blocked Count; and
- h) Arbitration Wait Time.

If persistent connections are supported (see 4.1.13.2), then the Tx Open message sent to a PL\_PM state machine shall contain the following additional argument to be used in an OPEN address frame:

- a) Send Extend Bit from the Transmit Frame request.

If credit advance is implemented (see 4.1.14), then the Tx Open message sent to a PL\_PM state machine shall contain the following additional argument to be used in an OPEN address frame:

- a) Credit Advance Bit from the Transmit Frame request.

If this state creates a pending Tx Open message from one of the following:

- a) a Transmit Frame request;
- b) a Retry Open (No Destination) message;
- c) a Retry Open (Open Timeout Occurred) message;
- d) a Retry Open (Break Received) message; or
- e) a Retry Open (Retry) message if the CONTINUE AWT bit is set to zero in the Protocol Specific Port mode page (see 9.2.7.4),

then this state shall set:

- a) the pathway blocked count argument in the Tx Open message to zero; and
- b) the arbitration wait time argument in the Tx Open message to zero or a vendor specific value less than 8000h (see 6.14.3).

If a pending Tx Open message was created as the result of this state receiving a Retry Open (Retry) message and the protocol for the connection is:

- a) SSP, the Protocol Specific Port mode page is implemented, and the REJECT TO OPEN LIMIT field in the Protocol Specific Port mode page (see 9.2.7.4) is not set to zero; or
- b) STP and the STP REJECT TO OPEN LIMIT field is not set to zero in the SMP REPORT GENERAL response (see 9.4.3.4),

then this state shall:

- 1) create a Reject To Open Limit timer associated with the pending Tx Open message that received the Retry Open (Retry) message;
- 2) initialize the Reject To Open Limit timer as specified in table 151 (see 7.2.2.1);
- 3) start the Reject To Open Limit timer; and
- 4) wait at least until the Reject To Open Limit timer expires before sending a Tx Open message.

If a pending Tx Open message was created as the result this state receiving a Retry Open (Pathway Blocked) message and the Retry Open pathway blocked count argument is:

- a) FFh, then this state shall set the Tx Open pathway blocked count argument to FFh; or
- b) less than FFh, then this state shall set the Tx Open pathway blocked count argument to the Retry Open pathway blocked count argument plus 01h.

If a pending Tx Open message was created as the result of this state receiving one of the following:

- a) a Retry Open (Opened By Destination) message;
- b) a Retry Open (Opened By Other) message;
- c) a Retry Open (Collided) message;
- d) a Retry Open (Pathway Blocked) message;
- e) a Retry Open (Low Phy Power Condition) message; or
- f) a Retry Open (Retry) message if the CONTINUE AWT bit is set to one in the Protocol Specific Port mode page (see 9.2.7.4),

then this state shall set the arbitration wait time argument in the Tx Open message to be the value from the Arbitration Wait Time timer created as a result of the Retry Open message.

After this state sends a Tx Open message, this state shall discard the pending Tx Open message from which the Tx Open message was created. After this state discards a pending Tx Open message, this state may create a new pending Tx Open message.

If this state receives a Connection Opened message and the initiator port bit and protocol arguments match those in a pending Tx Open message, then any Reject To Open Limit timer associated with that pending Tx Open message shall be discarded.

If this state receives a Connection Opened message and the initiator port bit and protocol arguments match those in any pending Tx Frame messages, then this state may use the established connection to send pending Tx Frame messages as Tx Frame messages to the destination SAS address.

#### 7.2.2.3.4 PL\_OC2:Overall\_Control state connection established

If this state receives a Connection Opened message or a Retry Open (Opened By Destination) message for a SAS address, and an I\_T Nexus Loss timer has been created for the SAS address, then this state shall:

- a) if the I\_T Nexus Loss timer for the SAS address has been running, then stop the timer; and
- b) initialize the I\_T Nexus Loss timer (see table 151).

#### 7.2.2.3.5 PL\_OC2:Overall\_Control state unable to establish a connection — Unable To Connect message

If this state receives an Unable To Connect message shown in table 152, then this state shall establish an I\_T nexus loss event (see 7.2.2.3.8).

Table 152 defines the confirmation to be sent to the transport layer for each Unable To Connect message received.

**Table 152 — Confirmations from Unable To Connect messages**

| Message received                                  | Confirmation sent to the transport layer |
|---------------------------------------------------|------------------------------------------|
| Unable To Connect (Bad Destination)               | Transmission Status (I_T Nexus Loss)     |
| Unable To Connect (Connection Rate Not Supported) | Transmission Status (I_T Nexus Loss)     |
| Unable To Connect (Protocol Not Supported)        | Transmission Status (I_T Nexus Loss)     |
| Unable To Connect (Reserved Abandon 1)            | Transmission Status (I_T Nexus Loss)     |
| Unable To Connect (Reserved Abandon 2)            | Transmission Status (I_T Nexus Loss)     |
| Unable To Connect (Reserved Abandon 3)            | Transmission Status (I_T Nexus Loss)     |
| Unable To Connect (STP Resources Busy)            | Transmission Status (I_T Nexus Loss)     |
| Unable To Connect (Wrong Destination)             | Transmission Status (I_T Nexus Loss)     |
| Unable To Connect (Zone Violation)                | Transmission Status (I_T Nexus Loss)     |

#### 7.2.2.3.6 PL\_OC2:Overall\_Control state unable to establish a connection — Unable To Connect message - Retry Open message processed as an Unable To Connect message

If this state receives a Retry Open (No Destination) message, a Retry Open (Open Timeout Occurred) message, Retry Open (Low Phy Power Condition), or a Retry Open (Pathway Blocked) message and

processes it as an Unable To Connect message, then this state shall establish an I\_T nexus loss event (see 7.2.2.3.8).

#### **7.2.2.3.7 PL\_OC2:Overall\_Control state unable to establish a connection — I\_T Nexus Loss timer expires**

If this state receives a Retry Open (No Destination) message, a Retry Open (Open Timeout Occurred) message, Retry Open (Break Received), Retry Open (Low Phy Power Condition), or a Retry Open (Pathway Blocked) message and the I\_T Nexus Loss timer for the SAS address has expired, then this state shall establish an I\_T nexus loss event (see 7.2.2.3.8).

#### **7.2.2.3.8 PL\_OC2:Overall\_Control state - I\_T nexus loss event**

If an I\_T nexus loss event occurs, then this state shall perform the following:

- a) delete the I\_T Nexus Loss timer for the SAS address;
- b) discard the Retry Open message;
- c) send a Transmission Status (I\_T Nexus Loss) confirmation for the pending Tx Frame message from which the Retry Open message resulted;
- d) discard the pending Tx Frame message from which the Retry Open message resulted;
- e) send an I\_T Nexus Loss Detected confirmation to the management application layer;
- f) if this state has any pending Tx Frame messages with the same destination SAS address and protocol as the Retry Open message, and this state has not sent a Tx Open message to a PL\_PM state machine for the messages, then this state shall send a Transmission Status (I\_T Nexus Loss) confirmation for each pending Tx Frame message and discard the pending Tx Frame messages and any corresponding pending Tx Open messages; and
- g) if this state has any pending Tx Frame messages with the same destination SAS address and protocol as the Retry Open message, and this state has sent a Tx Open message to a PL\_PM state machine for a message, then this state shall send a Cancel Open message to each PL\_PM state machine to which it has sent a Tx Open message. After receiving an Unable To Connect (Arb Stopped) message from a PL\_PM state machine in response to the Cancel Open message, this state shall send a Transmission Status (I\_T Nexus Loss) confirmation for each pending Tx Frame message and discard the pending Tx Frame messages and any corresponding pending Tx Open messages.

#### **7.2.2.3.9 PL\_OC2:Overall\_Control state connection management**

If this state receives an Accept\_Reject OPENs request, then this state shall send an Accept\_Reject OPENs request with the same arguments to all phys in the port.

If this state receives an SMP Transmit Break request, then this state shall send an SMP Transmit Break message to the PL\_PM state machine associated with the corresponding SMP transport state machine. If there is no PL\_PM state machine associated with the request, then the PL\_OC state machine shall ignore the request.

If this state receives one of the following:

- a) a Connection Closed (Close Timeout) message;
- b) a Connection Closed (Break Requested) message; or
- c) a Connection Closed (Break Received) message,

then this state shall not send a Tx Open or Tx Frame message to the PL\_PM state machine that sent the message until this state receives a Connection Closed (Transition to Idle) message from that PL\_PM state machine.

If this state receives a Connection Closed (Normal) message or a Connection Closed (Transition to Idle) message indicating that a connection with a destination SAS address is no longer open and this state has pending Tx Open messages, then this state may send a Tx Open message to the PL\_PM state machine that sent the Connection Closed message.



If this port is a wide SSP port, then this state shall not reject an incoming connection request on one phy because this state has an outgoing connection request on another phy.

If:

- a) persistent connections are not supported (see 4.1.13.2);
- b) this port is an SSP port;
- c) there are no pending Tx Frame messages for a destination SAS address with which a PL\_PM state machine has established a connection; and
- d) the connection was established by a message from this state,

then this state should send a Close Connection message to the PL\_PM state machine.

If:

- a) persistent connections are not supported (see 4.1.13.2);
- b) this port is an SSP port;
- c) has no pending Tx Frame messages for a destination SAS address with which a PL\_PM state machine has established a connection; and
- d) the connection was established by the destination,

then this state may wait a vendor specific time and then shall send a Close Connection message to the PL\_PM state machine.

If:

- a) persistent connections are supported (see 4.1.13.2);
- b) this port is an SSP port;
- c) Transmission Status (Frame Transmitted) message is received;
- d) there are no pending Tx Frame messages for a destination SAS address with which a PL\_PM state machine has established a connection; and
- e) the last Persistent Connection Established confirmation received from the link layer associated with the PL\_PM state machine contained an Enabled argument,

then this state shall send a No Pending Tx Frames request to the link layer:

- a) associated with the PL\_PM state machine; and
- b) from which the last Persistent Connection Established (Enabled) confirmation was received.

If:

- a) persistent connections are supported (see 4.1.13.2);
- b) this port is an SSP port;
- c) there are no pending Tx Frame messages for a destination SAS address with which a PL\_PM state machine has established a connection;
- d) the connection was established by a message from this state; and
- e) the last Persistent Connection Established confirmation received contained a Disabled argument (i.e., a Persistent Connection Established (Disabled) confirmation was received from the PL\_PM state machine that established the connection),

then this state should send a Close Connection message to the PL\_PM state machine.

If:

- a) persistent connections are supported (see 4.1.13.2);
- b) this port is an SSP port;
- c) has no pending Tx Frame messages for a destination SAS address with which a PL\_PM state machine has established a connection;
- d) the connection was established by the destination; and
- e) the last Persistent Connection Established confirmation received contained a Disabled argument (i.e., a Persistent Connection Established (Disabled) confirmation was received from the PL\_PM state machine that established the connection),

then this state:

- 1) may wait a vendor specific time: and
- 2) shall send a Close Connection message to the PL\_PM state machine, if the last Persistent Connection Established confirmation received did not contain an Enabled argument.

If this state has received a Disable Tx Frames message from a PL\_PM state machine, then this state should send a Close Connection message to the PL\_PM state machine.

NOTE 49 - The PL\_PM state machine sends a Close Connection request to the link layer upon receipt of a Close Connection message or on expiration of the Bus Inactivity Time Limit timer (see 7.2.3.4.1).

#### 7.2.2.3.10 PL\_OC2:Overall\_Control state frame transmission

In order to prevent livelocks, if this port is a wide SSP port, has multiple connections established, and has a pending Tx Frame message, then this state shall send at least one Tx Frame message to a PL\_PM state machine before sending a Close Connection message to the PL\_PM state machine.

After this state receives a Connection Opened message from a PL\_PM state machine, this state selects pending Tx Frame messages for the destination SAS address with the same initiator port bit and protocol arguments, and, as an option, the same connection rate argument, and sends the messages to the PL\_PM state machine as Tx Frame messages.

This state may send a Tx Frame message to any PL\_PM state machine that has established a connection with the destination SAS address when the initiator port bit and protocol arguments match those in the Tx Frame message.

After this state sends a Tx Frame message to a PL\_PM state machine, this state shall not send another Tx Frame message to that PL\_PM state machine until this state receives a Transmission Status (Frame Transmitted) message.

This state shall not send a Tx Frame message containing a Request Fence argument or Response Fence argument to any PL\_PM state machine until this state has received one of the following messages for each Tx Frame message with the same nexus as specified by that Request Fence argument or Response Fence argument:

- a) Transmission Status (ACK Received);
- b) Transmission Status (NAK Received);
- c) Transmission Status (ACK/NAK Timeout); or
- d) Transmission Status (Connection Lost Without ACK/NAK).

After this state sends a Tx Frame message containing a Request Fence argument or Response Fence argument, this state shall not send another Tx Frame message with the same nexus as specified by that Request Fence argument or Response Fence argument until this state has received one of the following messages:

- a) Transmission Status (ACK Received);
- b) Transmission Status (NAK Received);
- c) Transmission Status (ACK/NAK Timeout); or
- d) Transmission Status (Connection Lost Without ACK/NAK).

Once this state has sent a Tx Frame message containing a Non-Interlocked argument to a PL\_PM state machine, this state shall not send a Tx Frame message containing a Non-Interlocked argument with the same I\_T\_L\_Q nexus to another PL\_PM state machine until this state has received one of the following messages for each Tx Frame message containing a Non-Interlocked argument for the same I\_T\_L\_Q nexus:

- a) Transmission Status (ACK Received);
- b) Transmission Status (NAK Received);
- c) Transmission Status (ACK/NAK Timeout); or
- d) Transmission Status (Connection Lost Without ACK/NAK).



For a bidirectional command, frames with the Non-Interlocked argument for an I\_T\_L\_Q nexus may be transmitted on one phy at the same time as frames with the Non-Interlocked argument for the same I\_T\_L\_Q nexus are received on the same phy or on a different phy.

If this port is an SMP initiator port, then this state shall send the Tx Frame message containing the SMP REQUEST frame to the PL\_PM state machine on which the connection was established for the Tx Open message. If this port is an SMP target port, then this state shall send the Tx Frame message containing the SMP\_RESPONSE frame to the PL\_PM state machine on which the connection was established for the Tx Open message. See 6.20 for additional information about SMP connections.

Characteristics of STP connections are defined by SATA (also see 6.19).

The following arguments shall be included with the Tx Frame message:

- a) the frame to be transmitted; and
- b) Balance Required or Balance Not Required.

A Balance Not Required argument shall only be included if:

- a) the request was a Transmit Frame (Non-Interlocked) request (i.e., the request included a DATA frame); and
- b) the last Tx Frame message sent to this PL\_PM state machine while this connection has been established was for a DATA frame having the same logical unit number and initiator port transfer tag as the DATA frame in this Tx Frame message.

If a Balance Not Required argument is not included in the Tx Frame message, then a Balance Required argument shall be included.

If this state receives a Disable Tx Frames message from a PL\_PM state machine, then this state should send no more Tx Frame messages to that state machine until a new connection is established.

#### 7.2.2.3.11 PL\_OC2:Overall\_Control state frame transmission cancellations

Cancel requests cause this state to cancel previous Transmit Frame requests. A Cancel request includes the following arguments:

- a) Destination SAS Address; and
- b) Initiator Port Transfer Tag.

If this state receives a Cancel request and has not already sent a Tx Frame message for the Transmit Frame request to a PL\_PM state machine for the Transmit Frame request specified by the Cancel request, then this state shall:

- a) discard all Transmit Frame requests for the specified destination SAS address and initiator port transfer tag; and
- b) send a Transmission Status (Cancel Acknowledge) confirmation to the transport layer.

If this state receives a Cancel request and has already sent a Tx Frame message to a PL\_PM state machine for the Transmit Frame request specified by the Cancel request, then this state shall send a Cancel message to the PL\_PM state machine to which the Tx Frame message was sent. The Cancel message shall include the initiator port transfer tag.

#### 7.2.2.3.12 Transition PL\_OC2:Overall\_Control to PL\_OC1:Idle

This transition shall occur after:

- a) sending a HARD\_RESET Received confirmation to the transport layer;
- b) a No Phys In Port confirmation is sent to the transport layer; or
- c) sending a Notify Received (Power Loss Expected) confirmation to the transport layer.

### 7.2.3 PL\_PM (port layer phy manager) state machine

#### 7.2.3.1 PL\_PM state machine overview

A PL\_PM state machine:

- a) receives messages from the PL\_OC state machine;
- b) sends requests to the link layer;
- c) receives confirmations from the link layer;
- d) sends confirmations to the transport layer;
- e) sends messages to PL\_OC state machine;
- f) has an Arbitration Wait Time timer;
- g) may have a Bus Inactivity Time Limit timer; and
- h) may have Maximum Connect Time Limit timer.

This state machine consist of the following states:

- a) PL\_PM1:Idle (see 7.2.3.2) (initial state);
- b) PL\_PM2:Req\_Wait (see 7.2.3.3);
- c) PL\_PM3:Connected (see 7.2.3.4); and
- d) PL\_PM4:Wait\_For\_Close (see 7.2.3.5).

This state machine shall start in the PL\_PM1:Idle state after power on.

This state machine shall maintain the timers listed in table 153.

**Table 153 — PL\_PM state machine timers**

| Timer                            | Initial value                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Arbitration Wait Time timer      | The arbitration wait time argument from a Retry Open message (see 7.2.2.3.1).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Bus Inactivity Time Limit timer  | Depending on the protocol used by the port: <ul style="list-style-type: none"> <li>a) for SSP target ports, the value in the BUS INACTIVITY LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2);</li> <li>b) for STP target ports, the value in the STP BUS INACTIVITY LIMIT field in the SMP REPORT GENERAL response (see 9.4.3.4);</li> <li>c) for SSP initiator ports, the value in the BUS INACTIVITY LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2) of the destination SSP target port; or</li> <li>d) for STP initiator ports, the value in the STP BUS INACTIVITY LIMIT field in the SMP REPORT GENERAL response (see 9.4.3.4) of the destination STP target port.</li> </ul>               |
| Maximum Connect Time Limit timer | Depending on the protocol used by the port: <ul style="list-style-type: none"> <li>a) for an SSP target port, the value in the CONNECT TIME LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2);</li> <li>b) for an STP target port, the value in the STP CONNECT TIME LIMIT field in the SMP REPORT GENERAL response;</li> <li>c) for an SMP target port, 2 ms;</li> <li>d) for an SSP initiator port, the value in the CONNECT TIME LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2) of the destination SSP target port; or</li> <li>e) for an STP initiator port, the value in the STP CONNECT TIME LIMIT field in the SMP REPORT GENERAL response of the destination STP target port.</li> </ul> |

Figure 160 shows part 1 of the PL\_PM state machine.

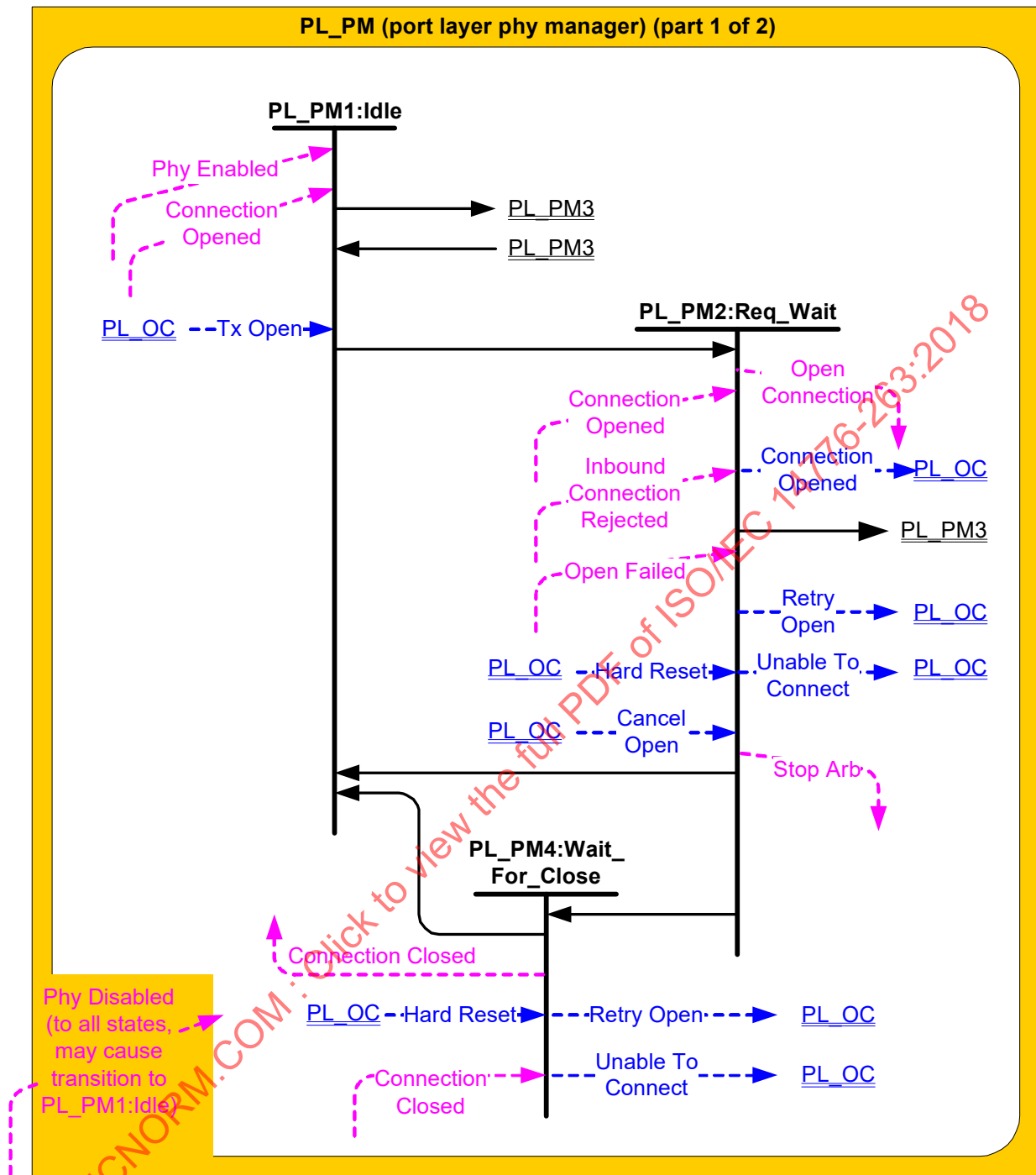


Figure 160 — PL\_PM (port layer phy manager) state machine (part 1)

[illegible]

**Figure 161 — PL\_PM (port layer phy manager) state machine (part 2)**

### 7.2.3.2 PL\_PM1:Idle state

#### 7.2.3.2.1 PL\_PM1:Idle state description

This is the initial state of the PL\_PM state machine.

#### 7.2.3.2.2 Transition PL\_PM1:Idle to PL\_PM2:Req\_Wait

This transition shall occur after:

- a) a Phy Enabled confirmation is received; and
- b) a Tx Open message is received.

#### 7.2.3.2.3 Transition PL\_PM1:Idle to PL\_PM3:Connected

This transition shall occur after a Connection Opened confirmation is received. The transition shall include the received OPEN address frame.

### 7.2.3.3 PL\_PM2:Req\_Wait state

#### 7.2.3.3.1 PL\_PM2:Req\_Wait state overview

This state sends an Open Connection request to the link layer and waits for a confirmation. This state sends and receives connection management messages to and from the PL\_OC state machine.

If this state receives a Hard Reset message, then this state shall terminate all operations.

#### 7.2.3.3.2 PL\_PM2:Req\_Wait establishing a connection

Upon entry into this state, this state shall:

- 1) create an Arbitration Wait Time timer;
- 2) initialize the Arbitration Wait Time timer to the arbitration wait time argument received with the Tx Open message;
- 3) start the Arbitration Wait Time timer; and
- 4) send an Open Connection request to the link layer.

The Open Connection request shall contain the following arguments from the Tx Open message to be used in an OPEN address frame:

- a) Initiator Port Bit;
- b) Protocol;
- c) Connection Rate;
- d) Initiator Connection Tag;
- e) Destination SAS Address;
- f) Source SAS Address;
- g) Pathway Blocked Count; and
- h) Arbitration Wait Time.

If persistent connections are supported (see 4.1.13.2), then the Open Connection request shall contain the following additional argument from the Tx Open message to be used in an OPEN address frame:

- a) Send Extend Bit.

If credit advance is implemented (see 4.1.14), then the Open Connection request shall contain the following additional argument from the Tx Open message to be used in an OPEN address frame:

- a) Credit Advance Bit.

### 7.2.3.3.3 PL\_PM2:Req\_Wait connection established

If this state receives a Connection Opened confirmation, then this state shall send a Connection Opened message to the PL\_OC state machine.

If this state receives a Connection Opened confirmation and the confirmation was not in response to an Open Connection request from this state (i.e., the connection was established in response to an OPEN address frame from another device), then this state shall discard any Open Connection request and send a Retry Open message to the PL\_OC state machine. If the Connection Opened confirmation was from the destination of the Open Connection request, then this state shall send a Retry Open (Opened By Destination) message to the PL\_OC state machine. If the Connection Opened confirmation was from a destination other than the destination of the Open Connection request, then this state shall send a Retry Open (Opened By Other) message to the PL\_OC state machine.

A Retry Open (Opened By Destination) or Retry Open (Opened By Other) message shall contain the following arguments:

- a) Initiator Port Bit set to the value received with the Tx Open message;
- b) Protocol set to the value received with the Tx Open message;
- c) Connection Rate set to the value received with the Tx Open message;
- d) Initiator Connection Tag set to the value received with the Tx Open message;
- e) Destination SAS Address set to the value received with the Tx Open message;
- f) Source SAS Address set to the value received with the Tx Open message;
- g) Pathway Blocked Count set to the value received with the Tx Open message; and
- h) Arbitration Wait Time set to the value of the Arbitration Wait Time timer.

If persistent connections are supported (see 4.1.13.2), then a Retry Open (Opened By Destination) or Retry Open (Opened By Other) message shall contain the following additional argument:

- a) Send Extend Bit set to the value received with the Tx Open message.

If credit advance is implemented (see 4.1.14), then a Retry Open (Opened By Destination) or Retry Open (Opened By Other) message shall contain the following additional argument:

- a) Credit Advance Bit set to the value received with the Tx Open message.

### 7.2.3.3.4 PL\_PM2:Req\_Wait unable to establish a connection

If this state receives one of the Open Failed confirmations listed in table 154, then this state shall send either a Retry Open message or an Unable To Connect message to the PL\_OC state machine.

Table 154 defines the message to be sent to the PL\_OC state machine for each Open Failed confirmation.

**Table 154 — Messages from Open Failed confirmations**

| Confirmation received               | Message sent to the PL_OC state machine |
|-------------------------------------|-----------------------------------------|
| Open Failed (No Destination)        | Retry Open (No Destination)             |
| Open Failed (Pathway Blocked)       | Retry Open (Pathway Blocked)            |
| Open Failed (Reserved Continue 0)   | Retry Open (Retry)                      |
| Open Failed (Reserved Continue 1)   | Retry Open (Retry)                      |
| Open Failed (Reserved Initialize 0) | Retry Open (No Destination)             |
| Open Failed (Reserved Initialize 1) | Retry Open (No Destination)             |
| Open Failed (Reserved Stop 0)       | Retry Open (Pathway Blocked)            |

Table 154 — Messages from Open Failed confirmations

| Confirmation received                       | Message sent to the PL_OC state machine           |
|---------------------------------------------|---------------------------------------------------|
| Open Failed (Reserved Stop 1)               | Retry Open (Pathway Blocked)                      |
| Open Failed (Retry)                         | Retry Open (Retry)                                |
| Open Failed (Low Phy Power Condition)       | Retry Open (Low Phy Power Condition)              |
| Open Failed (Bad Destination)               | Unable To Connect (Bad Destination)               |
| Open Failed (Connection Rate Not Supported) | Unable To Connect (Connection Rate Not Supported) |
| Open Failed (Protocol Not Supported)        | Unable To Connect (Protocol Not Supported)        |
| Open Failed (Reserved Abandon 1)            | Unable To Connect (Reserved Abandon 1)            |
| Open Failed (Reserved Abandon 2)            | Unable To Connect (Reserved Abandon 2)            |
| Open Failed (Reserved Abandon 3)            | Unable To Connect (Reserved Abandon 3)            |
| Open Failed (STP Resources Busy)            | Unable To Connect (STP Resources Busy)            |
| Open Failed (Wrong Destination)             | Unable To Connect (Wrong Destination)             |
| Open Failed (Zone Violation)                | Unable To Connect (Zone Violation)                |

If this state receives an Inbound Connection Rejected confirmation after sending an Open Connection request, then this state shall discard the Open Connection request and send a Retry Open (Collided) message to the PL\_OC state machine.

A Retry Open message shall include the following arguments:

- Initiator Port Bit set to the value received with the Tx Open message;
- Protocol set to the value received with the Tx Open message;
- Connection Rate set to the value received with the Tx Open message;
- Initiator Connection Tag set to the value received with the Tx Open message;
- Destination SAS Address set to the value received with the Tx Open message;
- Source SAS Address set to the value received with the Tx Open message;
- Pathway Blocked Count argument set to the value received with the Tx Open message; and
- Arbitration Wait Time set to the value of the Arbitration Wait Time timer.

If persistent connections are supported (see 4.1.13.2), then the Retry Open message shall include the following additional argument:

- Send Extend Bit set to the value received with the Tx Open message.

If credit advance is implemented (see 4.1.14), then a Retry Open message shall include the following additional argument:

- Credit Advance Bit set to the value received with the Tx Open message.

An Unable To Connect message shall include the following arguments:

- Initiator Connection Tag set to the value received with the Tx Open message;
- Destination SAS Address set to the value received with the Tx Open message; and
- Source SAS Address set to the value received with the Tx Open message.

### 7.2.3.3.5 PL\_PM2:Req\_Wait connection management

If this state receives a Cancel Open message and a Connection Opened confirmation has not been received, then this state shall send a Stop Arb request to the link layer.

### 7.2.3.3.6 Transition PL\_PM2:Req\_Wait to PL\_PM1:Idle

This transition shall occur after:

- a) a Retry Open message is sent to the PL\_OC state machine;
- b) an Unable To Connect message is sent to the PL\_OC state machine;
- c) all operations have been terminated after receiving a Hard Reset message; or
- d) a Phy Disabled confirmation is received.

### 7.2.3.3.7 Transition PL\_PM2:Req\_Wait to PL\_PM3:Connected

This transition shall occur:

- a) after a Connection Opened confirmation is received.

### 7.2.3.3.8 Transition PL\_PM2:Req\_Wait to PL\_PM4:Wait\_For\_Close

This transition shall occur after one of the following confirmations is received:

- a) an Open Failed (Open Timeout Occurred);
- b) an Open Failed (Break Received); or
- c) an Open Failed (Arb Stopped).

## 7.2.3.4 PL\_PM3:Connected state

### 7.2.3.4.1 PL\_PM3:Connected state description

If this state was entered from the PL\_PM1:Idle state, then this state shall send a Connection Opened message to the PL\_OC state machine that includes as an argument the received OPEN address frame.

If:

- a) the protocol for the connection is SSP, the port is an SSP target port, the Disconnect-Reconnect mode page is implemented, and the CONNECT TIME LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2) is not set to zero;
- b) the protocol for the connection is SMP and the port is an SMP target port; or
- c) the protocol for the connection is STP, the port is an STP target port, and the STP CONNECT TIME LIMIT field is not set to zero in the SMP REPORT GENERAL response (see 9.4.3.4),

then, upon entry into this state, this state shall:

- 1) create a Maximum Connect Time Limit timer;
- 2) initialize the Maximum Connect Time Limit timer as specified in table 153 (see 7.2.3.1); and
- 3) start the Maximum Connect Time Limit timer.

If:

- a) the protocol for the connection is SSP, the port is an SSP initiator port, and the CONNECT TIME LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2) for the destination SSP target port is not set to zero; or
- b) the protocol for the connection is STP, the port is an STP initiator port, and the STP CONNECT TIME LIMIT field is not set to zero in the SMP REPORT GENERAL response (see 9.4.3.4) for the destination STP target port,

then, upon entry into this state, this state may:

- 1) create a Maximum Connect Time Limit timer;



- 2) initialize the Maximum Connect Time Limit timer as specified in table 153 (see 7.2.3.1); and
- 3) start the Maximum Connect Time Limit timer.

If:

- a) the protocol for the connection is SSP, the port is an SSP target port, and the BUS INACTIVITY LIMIT field is set to a non-zero value in the Disconnect-Reconnect mode page (see 9.2.7.2); or
- b) the protocol for the connection is STP, the port is an STP initiator port, and the STP BUS INACTIVITY LIMIT field is not set to zero in the SMP REPORT GENERAL response for the destination STP target port,

then, upon entry into this state, this state shall:

- 1) create a Bus Inactivity Time Limit timer;
- 2) initialize the Bus Inactivity Time Limit timer as specified in table 153; and
- 3) start the Bus Inactivity Time Limit timer.

If a Bus Inactivity Time Limit timer has been created and the connection is:

- a) SSP and this state receives a Tx Frame message; or
- b) STP and the phy is not both transmitting and receiving SATA\_SYNC,

then this state shall:

- 1) stop the Bus Inactivity Time Limit timer, if it is running;
- 2) initialize the Bus Inactivity Time Limit timer as specified in table 153; and
- 3) start the Bus Inactivity Time Limit timer.

If this state receives a Tx Frame message, then this state shall send a Tx Frame request to the link layer. The following arguments from the Tx Frame message shall be included with the Tx Frame request:

- a) the frame to be transmitted; and
- b) if this port is an SSP port, Balance Required or Balance Not Required.

For STP connections, this state connects the STP transport layer to the STP link layer.

If a Bus Inactivity Time Limit timer expires, then:

- a) if persistent connections are not supported (see 4.1.13) and the connection is SSP and there is no Tx Frame request outstanding (i.e., this state is not waiting for an ACK Received or NAK Received confirmation), then this state shall send a Close Connection request to the link layer;
- b) if persistent connections are not supported and the connection is SSP and there is a Tx Frame request outstanding (i.e., this state is waiting for an ACK Received or NAK Received confirmation), then this state shall send a Close Connection request to the link layer after receiving an ACK Received or NAK Received confirmation; or
- c) if the connection is STP, then this state shall send a Close Connection request to the link layer.

If:

- a) the connection is SSP;
- b) persistent connections are supported (see 4.1.13.2);
- c) the Bus Inactivity Time Limit timer expires; and
- d) the last Persistent Connection Established confirmation received contained a Disabled argument then:
  - A) if there is no Tx Frame request outstanding (i.e., this state is not waiting for an ACK Received or NAK Received confirmation), then this state shall send a Close Connection request to the link layer; or
  - B) if there is a Tx Frame request outstanding (i.e., this state is waiting for an ACK Received or NAK Received confirmation), then this state shall send a Close Connection request to the link layer after receiving an ACK Received or NAK Received confirmation.

If:

- a) the connection is SSP;
- b) persistent connections are supported;

- c) the Bus Inactivity Time Limit timer expires; and
- d) the last Persistent Connection Established confirmation received contained an Enabled argument, then this state shall:
  - 1) initialize the Bus Inactivity Time Limit timer as specified in table 153; and
  - 2) start the Bus Inactivity Time Limit timer.

If a Maximum Connect Time Limit timer (see table 153) expires, then:

- a) if persistent connections are not supported (see 4.1.13) and the connection is SSP and there is no Tx Frame request outstanding (i.e., this state is not waiting for an ACK Received or NAK Received confirmation), then this state shall send a Close Connection request to the link layer;
- b) if persistent connections are not supported and the connection is SSP and there is a Tx Frame request outstanding (i.e., this state is waiting for an ACK Received or NAK Received confirmation), then this state shall send a Close Connection request to the link layer after receiving an ACK Received or NAK Received confirmation;
- c) if the connection is SMP, then this state shall send an SMP Transmit Break request to the link layer; or
- d) if the connection is STP, then this state shall send a Close Connection request to the link layer after the phy is both transmitting and receiving SATA\_SYNC.

If:

- a) the connection is SSP;
- b) persistent connections are supported (see 4.1.13.2);
- c) the Maximum Connect Time Limit timer (see table 153) expires; and
- d) the last Persistent Connection Established confirmation received contained a Disabled argument then:
  - A) if there is no Tx Frame request outstanding (i.e., this state is not waiting for an ACK Received or NAK Received confirmation), then this state shall send a Close Connection request to the link layer; or
  - B) if there is a Tx Frame request outstanding (i.e., this state is waiting for an ACK Received or NAK Received confirmation), then this state shall send a Close Connection request to the link layer after receiving an ACK Received or NAK Received confirmation.

If:

- a) the connection is SSP;
- b) persistent connections are supported;
- c) the Maximum Connect Time Limit timer expires; and
- d) the last Persistent Connection Established confirmation received contained an Enabled argument, then this state shall:
  - 1) initialize the Maximum Connect Time Limit timer as specified in table 153; and
  - 2) start the Maximum Connect Time Limit timer.

If this state receives a Tx Frame message after sending a Close Connection request but before receiving a Connection Closed confirmation, then this state shall send a Retry Frame message to the PL\_OC state machine.

If this state receives a Frame Received confirmation, then this state shall send a Frame Received confirmation to the transport layer. The confirmation shall include the arguments received with the confirmation (e.g., the frame).

If this state receives an ACK Transmitted confirmation, then this state shall send an ACK Transmitted confirmation to the transport layer including the initiator port transfer tag of the frame that was ACKed.

If this state receives a Frame Transmitted confirmation, then this state shall send:

- a) a Transmission Status (Frame Transmitted) confirmation to the transport layer; and
- b) a Transmission Status (Frame Transmitted) message to the PL\_OC state machine.

If this state receives an ACK Received confirmation, then this state shall send:

- a) a Transmission Status (ACK Received) confirmation to the transport layer; and
- b) a Transmission Status (ACK Received) message to the PL\_OC state machine.

If this state receives a NAK Received confirmation, then this state shall send:

- a) a Transmission Status (NAK Received) confirmation to the transport layer; and
- b) a Transmission Status (NAK Received) message to the PL\_OC state machine.

If this state receives an ACK/NAK Timeout confirmation, then this state shall send:

- a) a Transmission Status (ACK/NAK Timeout) confirmation to the transport layer; and
- b) a Transmission Status (ACK/NAK Timeout) message to the PL\_OC state machine.

If this state receives a Cancel message, then this state shall:

- a) discard all Tx Frame requests for the specified initiator port transfer tag;
- b) send a Transmission Status (Cancel Acknowledge) confirmation to the transport layer including the destination SAS address and the initiator port transfer tag as arguments; and
- c) discard any subsequent confirmations for previous Tx Frame requests sent for the initiator port transfer tag.

If this state receives a Close Connection message from the PL\_OC state machine, then this state shall send a Close Connection request to the link layer.

If this state receives one of the following:

- a) a Connection Closed (Normal) confirmation;
- b) a Connection Closed (Close Timeout) confirmation;
- c) a Connection Closed (Break Requested) confirmation;
- d) a Connection Closed (Break Received) confirmation; or
- e) a Connection Closed (Transition to Idle) confirmation,

then this state shall send a Connection Closed message to the PL\_OC state machine including the argument received with the confirmation.

If this state receives a Connection Closed (Transition to Idle) confirmation after receiving one of the following:

- a) a Connection Closed (Break Received) confirmation; or
- b) a Connection Closed (Break Requested) confirmation,

then this state shall send a Transmission Status (Break Received) confirmation to the transport layer.

If this state receives a Connection Closed (Normal) confirmation, a Connection Closed (Transition to Idle) confirmation, or a Phy Disabled confirmation after sending a Transmission Status (Frame Transmitted) confirmation, but before this state receives an ACK Received or NAK Received confirmation, then this state shall send:

- a) a Transmission Status (Connection Lost Without ACK/NAK) confirmation to the transport layer; and
- b) a Transmission Status (Connection Lost Without ACK/NAK) message to the PL\_OC state machine.

If this state receives a Connection Closed (Normal) confirmation, a Connection Closed (Transition to Idle) confirmation, or a Phy Disabled confirmation after sending a Tx Frame request but before receiving a Frame Transmitted confirmation, then this state shall send a Retry Frame message to the PL\_OC state machine.

If this state receives a Connection Closed confirmation during an SMP connection, then this state shall send a Connection Closed confirmation to the transport layer.

If this state receives a Credit Timeout confirmation, then this state shall send a Retry Frame message to the PL\_OC state machine.

A Retry Frame message shall include the following arguments from the Tx Frame message:

- a) Initiator Port Bit;
- b) Protocol;
- c) Connection Rate;
- d) Initiator Connection Tag;
- e) Destination SAS Address;
- f) Source SAS Address; and
- g) Frame.

After this state receives a DONE Received (Normal) confirmation or DONE Received (Credit Timeout) confirmation, if this state does not receive a Tx Frame message within 1 ms, then this state shall send a Disable Tx Frames message to the PL\_OC state machine.

If this state receives a DONE Received (ACK/NAK Timeout) confirmation or DONE Transmitted confirmation, then this state shall send a Disable Tx Frames message to the PL\_OC state machine.

If this state receives an SMP Transmit Break message, then this state shall send an SMP Transmit Break request to the link layer.

If this state receives a Hard Reset message, then this state shall terminate all operations.

#### 7.2.3.4.2 Transition PL\_PM3:Connected to PL\_PM1:Idle

This transition shall occur after:

- a) a Connection Closed (Transition to Idle) message is sent to the PL\_OC state machine; or
- b) all operations are terminated after receiving a Hard Reset message.

#### 7.2.3.5 PL\_PM4:Wait\_For\_Close state

##### 7.2.3.5.1 PL\_PM4:Wait\_For\_Close state description

After receiving a Connection Closed (Transition to Idle) confirmation, if this state was entered as the result of the PL\_PM2:Req\_Wait state receiving:

- a) an Open Failed (Open Timeout Occurred) confirmation, then this state shall send a Retry Open (Open Timeout Occurred) message to the PL\_OC state machine; or
- b) an Open Failed (Break Received) confirmation, then this state shall send a Retry Open (Break Received) message to the PL\_OC state machine.

The Retry Open message shall include the following arguments:

- a) Initiator Port Bit set to the value received with the Tx Open message;
- b) Protocol set to the value received with the Tx Open message;
- c) Connection Rate set to the value received with the Tx Open message;
- d) Initiator Connection Tag set to the value received with the Tx Open message;
- e) Destination SAS Address set to the value received with the Tx Open message;
- f) Source SAS Address set to the value received with the Tx Open message;
- g) Pathway Blocked Count set to the value received with the Tx Open message; and
- h) Arbitration Wait Time set to the value of the Arbitration Wait Time timer.

If persistent connections are supported (see 4.1.13.2), then the Retry Open message shall include the following additional argument:

- a) Send Extend Bit set to the value received with the Tx Open message.

If this state receives a Connection Closed confirmation and the connection request was for an SMP connection, then this state shall send a Connection Closed confirmation to the transport layer.

After receiving a Connection Closed (Transition to Idle) confirmation, if this state was entered after the PL\_PM2:Req\_Wait state received an Open Failed (Arb Stopped) confirmation (i.e., as the result of the PL\_PM2:Req\_Wait state sending a Stop Arb request), then this state shall send an Unable To Connect (Arb Stopped) message to the PL\_OC state machine.

If this state receives a Hard Reset message, then this state shall terminate all operations.

##### 7.2.3.5.2 Transition PL\_PM4:Wait\_For\_Close to PL\_PM1:Idle

This transition shall occur after:

- a) a Retry Open or Unable To Connect message is sent to the PL\_OC state machine; or
- b) all operations are terminated after receiving a Hard Reset message.

## 8 Transport layer

### 8.1 Transport layer overview

The transport layer defines frame formats and how frames are processed by this layer. Transport layer state machines interface to the application layer and port layer and construct and parse frame contents. For SSP, the transport layer only receives frames from the port layer for which an ACK is going to be transmitted by the link layer.

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## 8.2 SSP transport layer

### 8.2.1 SSP frame format

Table 155 defines the SSP frame format.

### Table 155 — SSP frame format

| Byte\Bit | 7                                                                    | 6                              | 5 | 4           | 3 | 2                 | 1                    | 0                     |       |
|----------|----------------------------------------------------------------------|--------------------------------|---|-------------|---|-------------------|----------------------|-----------------------|-------|
| 0        | FRAME TYPE                                                           |                                |   |             |   |                   |                      |                       |       |
| 1        | (MSB)                                                                | HASHED DESTINATION SAS ADDRESS |   |             |   |                   |                      |                       |       |
| ...      |                                                                      |                                |   |             |   |                   |                      |                       |       |
| 3        |                                                                      |                                |   |             |   |                   |                      |                       | (LSB) |
| 4        | Reserved                                                             |                                |   |             |   |                   |                      |                       |       |
| 5        | (MSB)                                                                | HASHED SOURCE SAS ADDRESS      |   |             |   |                   |                      |                       |       |
| ...      |                                                                      |                                |   |             |   |                   |                      |                       |       |
| 7        |                                                                      |                                |   |             |   |                   |                      |                       | (LSB) |
| 8        | Reserved                                                             |                                |   |             |   |                   |                      |                       |       |
| 9        | Reserved                                                             |                                |   |             |   |                   |                      |                       |       |
| 10       | Reserved                                                             |                                |   | TLR CONTROL |   | RETRY DATA FRAMES | RETRANSMIT           | CHANGING DATA POINTER |       |
| 11       | Reserved                                                             |                                |   |             |   |                   | NUMBER OF FILL BYTES |                       |       |
| 12       | Reserved                                                             |                                |   |             |   |                   |                      |                       |       |
| 13       | Reserved                                                             |                                |   |             |   |                   |                      |                       |       |
| ...      |                                                                      |                                |   |             |   |                   |                      |                       |       |
| 15       |                                                                      |                                |   |             |   |                   |                      |                       |       |
| 16       | (MSB)                                                                | INITIATOR PORT TRANSFER TAG    |   |             |   |                   |                      |                       |       |
| 17       |                                                                      |                                |   |             |   |                   |                      |                       | (LSB) |
| 18       | (MSB)                                                                | TARGET PORT TRANSFER TAG       |   |             |   |                   |                      |                       |       |
| 19       |                                                                      |                                |   |             |   |                   |                      |                       | (LSB) |
| 20       | (MSB)                                                                | DATA OFFSET                    |   |             |   |                   |                      |                       |       |
| ...      |                                                                      |                                |   |             |   |                   |                      |                       |       |
| 23       |                                                                      |                                |   |             |   |                   |                      |                       | (LSB) |
| 24       | INFORMATION UNIT                                                     |                                |   |             |   |                   |                      |                       |       |
| ...      | (e.g., see table 158, table 160, table 162, table 163, or table 164) |                                |   |             |   |                   |                      |                       |       |
| m        |                                                                      |                                |   |             |   |                   |                      |                       |       |
|          | Fill bytes, if needed                                                |                                |   |             |   |                   |                      |                       |       |
| n - 3    | (MSB)                                                                | CRC                            |   |             |   |                   |                      |                       |       |
| ...      |                                                                      |                                |   |             |   |                   |                      |                       |       |
| n        |                                                                      |                                |   |             |   |                   |                      |                       | (LSB) |

Table 156 defines the FRAME TYPE field, which defines the format of the INFORMATION UNIT field.

**Table 156 — FRAME TYPE field**

| Code       | Name of frame                                          | Type of information unit                                                                | Originator                            | Information unit size (bytes) | Reference |
|------------|--------------------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------|-------------------------------|-----------|
| 01h        | DATA frame (i.e., write DATA frame or read DATA frame) | Data information unit (i.e., write Data information unit or read Data information unit) | SSP initiator port or SSP target port | 1 to 1 024                    | 8.2.2.4   |
| 05h        | XFER_RDY frame                                         | Transfer Ready information unit                                                         | SSP target port                       | 12                            | 8.2.2.3   |
| 06h        | COMMAND frame                                          | Command information unit                                                                | SSP initiator port                    | 28 to 280                     | 8.2.2.1   |
| 07h        | RESPONSE frame                                         | Response information unit                                                               | SSP target port                       | 24 to 1 024                   | 8.2.2.5   |
| 16h        | TASK frame                                             | Task Management Function information unit                                               | SSP initiator port                    | 28                            | 8.2.2.2   |
| F0h to FFh | Vendor specific                                        |                                                                                         |                                       |                               |           |
| All others | Reserved                                               |                                                                                         |                                       |                               |           |

The HASHED DESTINATION SAS ADDRESS field contains the hashed value of the destination SAS address (see 4.2.5). See 8.2.6.2.2 and 8.2.6.3.2 for transport layer requirements on checking this field.

The HASHED SOURCE SAS ADDRESS field contains the hashed value of the source SAS address (see 4.2.5). See 8.2.6.2.2 and 8.2.6.3.2 for transport layer requirements on checking this field.

Table 157 defines the TLR CONTROL field for COMMAND frames. The TLR CONTROL field is reserved for all other frame types.

**Table 157 — TLR CONTROL field for COMMAND frames**

| Code <sup>a</sup>                                                                                                                                                                                                                                                                                                           | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00b or 11b                                                                                                                                                                                                                                                                                                                  | The SSP target port shall use the TRANSPORT LAYER RETRIES bit in the Protocol Specific Logical Unit mode page (see 9.2.7.3) to enable or disable transport layer retries for this command as follows if the TRANSPORT LAYER RETRIES bit is set to:<br>a) one, then the SSP target port shall set the RETRY DATA FRAMES bit to one in any XFER_RDY frames that the SSP target port transmits for this command; or<br>b) zero, then the SSP target port shall set the RETRY DATA FRAMES bit to zero in any XFER_RDY frames that the SSP target port transmits for this command. |
| 01b                                                                                                                                                                                                                                                                                                                         | The SSP target port may enable transport layer retries for this command.<br><br>If the SSP target port enables transport layer retries, then it shall set the RETRY DATA FRAMES bit to one in any XFER_RDY frames that it transmits for this command.<br><br>If the SSP target port does not enable transport layer retries, then it shall set the RETRY DATA FRAMES bit to zero in any XFER_RDY frames that it transmits for this command.                                                                                                                                   |
| 10b                                                                                                                                                                                                                                                                                                                         | The SSP target port shall:<br>a) disable transport layer retries for this command; and<br>b) set the RETRY DATA FRAMES bit to zero in any XFER_RDY frames that it transmits for this command.                                                                                                                                                                                                                                                                                                                                                                                 |
| <sup>a</sup> If the SSP target port receives a non-zero value in the TLR CONTROL field and does not support non-zero values in the TLR CONTROL field, then the SSP target port shall reply with a RESPONSE frame with the DATAPRES field set to RESPONSE_DATA and the RESPONSE CODE field set to 02h (i.e., INVALID FRAME). |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

If an SSP initiator port supports transport layer retries, then it shall set the TLR CONTROL field to 01b in each COMMAND frame that it sends unless it has determined that the I\_T\_L nexus does not support the TLR CONTROL field.

If an SSP initiator port does not support transport layer retries, then it shall set the TLR CONTROL field to 10b in each COMMAND frame that it sends unless it has determined that the I\_T\_L nexus does not support the TLR CONTROL field.

An SSP initiator port determines that an I\_T\_L nexus does not support the TLR CONTROL field if the SSP initiator port sends a COMMAND frame with the TLR CONTROL field set to 01b or 10b and receives a RESPONSE frame with the DATAPRES field set to RESPONSE\_DATA and the RESPONSE CODE field set to 02h (i.e., INVALID FRAME). After determining that an I\_T\_L nexus does not support the TLR CONTROL field, the SSP initiator port shall set the TLR CONTROL field to 00b for subsequent COMMAND frames for that I\_T\_L nexus.

NOTE 50 – Initiator ports compliant with SAS-1.1 always set the TLR CONTROL field to 00b.

NOTE 51 - The TLR CONTROL SUPPORTED field in the Protocol Specific Logical Unit Information VPD page (see 9.2.11.3) indicates if the SSP target port supports the TLR CONTROL field set to a non-zero value.

An SSP target port sets the RETRY DATA FRAMES bit in an XFER\_RDY frame based on the TLR CONTROL field received in the COMMAND frame for the command (see table 157) and the TRANSPORT LAYER RETRIES bit in the Protocol Specific Logical Unit mode page (see 9.2.7.3).

A RETRY DATA FRAMES bit set to one in an XFER\_RDY frame specifies that the SSP initiator port shall enable transport layer retries for write DATA transfers related to this XFER\_RDY.



A RETRY DATA FRAMES bit set to zero in an XFER\_RDY frame specifies that the SSP initiator port shall disable transport layer retries for write DATA transfers related to this XFER\_RDY.

The RETRY DATA FRAMES bit is reserved for frames other than XFER\_RDY frames.

A RETRANSMIT bit set to one specifies that the frame is a retransmission after the SSP port failed in its previous attempt to transmit the frame (e.g., the SSP port received a NAK for the frame transmitted in the previous attempt). The RETRANSMIT bit is set to one for TASK frames, RESPONSE frames, and XFER\_RDY frames under the conditions defined in 8.2.4 and shall be set to zero for all other frame types.

A CHANGING DATA POINTER bit set to one specifies that the frame is a retransmission after the SSP port failed in its previous attempt to transmit the frame or a subsequent frame and the DATA OFFSET field of the frame may not be sequentially increased from that of the previous frame. The CHANGING DATA POINTER bit is set to one for DATA frames under the conditions defined in 8.2.4.5 and shall be set to zero for all other frame types.

The NUMBER OF FILL BYTES field specifies the number of fill bytes between the INFORMATION UNIT field and the CRC field. The NUMBER OF FILL BYTES field shall be set to 00b for all frame types except DATA frames as specified in 8.2.2.4 and RESPONSE frames as specified in 8.2.2.5 (i.e., all other frame types are four-byte aligned).

The INITIATOR PORT TRANSFER TAG field contains a value that allows the SSP initiator port to establish a context for commands and task management functions.

For COMMAND frames and TASK frames, the SSP initiator port shall set the INITIATOR PORT TRANSFER TAG field to a value that is unique for the I\_T nexus established by the connection (see 6.14). An SSP initiator port shall not reuse the same initiator port transfer tag when transmitting COMMAND frames or TASK frames to different LUNs in the same SSP target port. An SSP initiator port may reuse an initiator port transfer tag when transmitting frames to different SSP target ports. An SSP initiator port does not reuse an initiator port transfer tag until it receives indication from the SSP target port that the initiator port transfer tag is no longer in use (see 8.2.4, 8.2.5, and 9.2.2).

The INITIATOR PORT TRANSFER TAG field in a COMMAND frame contains the command identifier defined in SAM-5. The INITIATOR PORT TRANSFER TAG field in a TASK frame is the association between a Send Task Management Request (see 9.2.1.12) and a Received Task Management Function Executed (see 9.2.1.15). The number space used in the INITIATOR PORT TRANSFER TAG fields is shared across COMMAND frames and TASK frames (e.g., if an initiator port transfer tag is used for a COMMAND frame, then it is not also used for a concurrent TASK frame).

For DATA, XFER\_RDY, and RESPONSE frames, the SSP target port shall set the INITIATOR PORT TRANSFER TAG field to the initiator port transfer tag of the command or task management function to which the frame pertains.

The TARGET PORT TRANSFER TAG field provides an optional method for an SSP target port to establish the write data context when receiving a write DATA frame (i.e., determine the command to which the write data corresponds). Unlike the INITIATOR PORT TRANSFER TAG field, which was assigned by the SSP initiator port, the TARGET PORT TRANSFER TAG field in a write DATA frame contains a value assigned by the SSP target port that was delivered to the SSP initiator port in the XFER\_RDY frame requesting the write data.

NOTE 52 - The TARGET PORT TRANSFER TAG field is useful if an SSP target port has more than one XFER\_RDY frame outstanding (i.e., the SSP target port has transmitted an XFER\_RDY frame for each of two or more commands and has not yet received all the write data for them).

SSP target ports may set the TARGET PORT TRANSFER TAG field to any value when transmitting any SSP frame. SSP target ports that use this field should set the TARGET PORT TRANSFER TAG field in every XFER\_RDY frame to a value that is unique for the L\_Q portion of the I\_T\_L\_Q nexus (i.e., that is unique for every XFER\_RDY that is outstanding from the SSP target port).

SSP initiator ports shall set the TARGET PORT TRANSFER TAG field as follows:

- a) for each write DATA frame that is sent in response to an XFER\_RDY frame, the SSP initiator port shall set the TARGET PORT TRANSFER TAG field to the value that was in the corresponding XFER\_RDY frame;

- b) for each write DATA frame that is sent containing first burst data (see 8.2.2.4), the SSP initiator port shall set the TARGET PORT TRANSFER TAG field to FFFFh; and
- c) for frames other than write DATA frames, the SSP initiator port shall set the TARGET PORT TRANSFER TAG field to FFFFh.

For DATA frames, the DATA OFFSET field is described in 8.2.2.4. For all other frame types, the DATA OFFSET field shall be ignored.

The INFORMATION UNIT field contains the information unit, the format of which is defined by the FRAME TYPE field (see table 156). The maximum size of the INFORMATION UNIT field is 1 024 bytes, making the maximum size of the frame 1 052 bytes (i.e., 24 bytes of header + 1 024 bytes of data + 4 bytes of CRC).

Fill bytes shall be included after the INFORMATION UNIT field so the CRC field is aligned on a four byte boundary. The number of fill bytes are specified by the NUMBER OF FILL BYTES field. The contents of the fill bytes are vendor specific.

The CRC field contains a CRC value (see 6.5) that is computed over the entire SSP frame prior to the CRC field including the fill bytes (i.e., all data dwords between the SOF and the CRC field). The CRC field is checked by the link layer (see 6.18), not the transport layer.

## 8.2.2 Information units

### 8.2.2.1 COMMAND frame - Command information unit

A COMMAND frame is sent by an SSP initiator port to request that a command be processed by the SCSI device server in a logical unit (see 8.2.3.3, 8.2.3.4, 8.2.3.5, and 8.2.3.6).

Table 158 defines the Command information unit used in a COMMAND frame.

**Table 158 — COMMAND frame - Command information unit**

| Byte\Bit | 7                                | 6                | 5 | 4 | 3 | 2              | 1        | 0 |
|----------|----------------------------------|------------------|---|---|---|----------------|----------|---|
| 0        | LOGICAL UNIT NUMBER              |                  |   |   |   |                |          |   |
| ...      |                                  |                  |   |   |   |                |          |   |
| 7        |                                  |                  |   |   |   |                |          |   |
| 8        | Reserved                         |                  |   |   |   |                |          |   |
| 9        | ENABLE<br>FIRST<br>BURST         | COMMAND PRIORITY |   |   |   | TASK ATTRIBUTE |          |   |
| 10       | Reserved                         |                  |   |   |   |                |          |   |
| 11       | ADDITIONAL CDB LENGTH (n dwords) |                  |   |   |   |                | Reserved |   |
| 12       | CDB                              |                  |   |   |   |                |          |   |
| ...      |                                  |                  |   |   |   |                |          |   |
| 27       |                                  |                  |   |   |   |                |          |   |
| 28       | ADDITIONAL CDB BYTES             |                  |   |   |   |                |          |   |
| ...      |                                  |                  |   |   |   |                |          |   |
| 27+n×4   |                                  |                  |   |   |   |                |          |   |

The LOGICAL UNIT NUMBER field specifies the logical unit number of the logical unit to which the task router shall route the command. The structure of the LOGICAL UNIT NUMBER field shall be as defined in SAM-5. If the addressed logical unit does not exist, then the task router shall follow the rules for selection of incorrect logical units defined in SAM-5.

An ENABLE FIRST BURST bit set to one specifies that the SSP target port shall expect first burst data for the command as defined by the FIRST BURST SIZE field in the Disconnect-Reconnect mode page (see 9.2.7.2). An ENABLE FIRST BURST bit set to zero specifies that the SSP target port shall not expect first burst data for the command (i.e., the FIRST BURST SIZE field in the Disconnect-Reconnect mode page shall be ignored). SCSI application clients shall only set the ENABLE FIRST BURST bit to one if:

- a) the FIRST BURST SIZE field in the Disconnect-Reconnect mode page is set to a value other than 0000h; and
- b) the logical unit and SSP target port comply with this standard (e.g., as reported in the standard INQUIRY data version descriptors (see SPC-4)).

The COMMAND PRIORITY field specifies the relative scheduling importance of a command with the TASK ATTRIBUTE field set to 000b (i.e., SIMPLE) in relation to other commands already in the task set with SIMPLE task attributes (see SAM-5).

The TASK ATTRIBUTE field is defined in table 159.

**Table 159 — TASK ATTRIBUTE field**

| Code         | Task attribute | Description                                                                                                  |
|--------------|----------------|--------------------------------------------------------------------------------------------------------------|
| 000b         | SIMPLE         | Specifies that the command be managed according to the rules for a SIMPLE task attribute (see SAM-5).        |
| 001b         | HEAD OF QUEUE  | Specifies that the command be managed according to the rules for a HEAD OF QUEUE task attribute (see SAM-5). |
| 010b         | ORDERED        | Specifies that the command be managed according to the rules for an ORDERED task attribute (see SAM-5).      |
| 011b         | Reserved       |                                                                                                              |
| 100b         | ACA            | Specifies that the command be managed according to the rules for an ACA task attribute (see SAM-5).          |
| 101b to 111b | Reserved       |                                                                                                              |

The ADDITIONAL CDB LENGTH field contains the length in dwords (i.e., four bytes) of the ADDITIONAL CDB BYTES field.

The CDB and ADDITIONAL CDB BYTES fields together contain the CDB to be interpreted by the addressed logical unit. Any bytes after the end of the actual CDB within the two fields shall be ignored (e.g., a six-byte CDB occupies the first six bytes of the CDB field, the remaining ten bytes of the CDB field are ignored, and the ADDITIONAL CDB BYTES field is not present).

The contents of the CDB are defined in the SCSI command standards (e.g., SPC-4).

#### 8.2.2.2 TASK frame - Task Management Function information unit

A TASK frame is sent by an SSP initiator port to request that a task management function be processed by the task manager in a logical unit (see 8.2.3.2).

Table 160 defines the Task Management Function information unit used in a TASK frame.

**Table 160 — TASK frame - Task Management Function information unit**

| Byte\Bit | 7                        | 6                                     | 5 | 4 | 3 | 2 | 1 | 0     |  |  |  |  |  |  |  |
|----------|--------------------------|---------------------------------------|---|---|---|---|---|-------|--|--|--|--|--|--|--|
| 0        | LOGICAL UNIT NUMBER      |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| ...      |                          |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| 7        |                          |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| 8        | Reserved                 |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| 9        | Reserved                 |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| 10       | TASK MANAGEMENT FUNCTION |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| 11       | Reserved                 |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| 12       | (MSB)                    | INITIATOR PORT TRANSFER TAG TO MANAGE |   |   |   |   |   | (LSB) |  |  |  |  |  |  |  |
| 13       |                          |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| 14       | Reserved                 |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| ...      |                          |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |
| 27       |                          |                                       |   |   |   |   |   |       |  |  |  |  |  |  |  |

The LOGICAL UNIT NUMBER field specifies the logical unit number of the logical unit, if any, to which the task router shall route the task management function. The structure of the LOGICAL UNIT NUMBER field shall be as defined in SAM-5. If the addressed logical unit does not exist, then the task router shall return a RESPONSE frame with the DATAPRES field set to RESPONSE\_DATA and its RESPONSE CODE field set to INCORRECT LOGICAL UNIT NUMBER.

Table 161 defines the TASK MANAGEMENT FUNCTION field.

**Table 161 — TASK MANAGEMENT FUNCTION field (part 1 of 2)**

| Code                                                                                                                                                                                                                                                                                                                                                                    | Task management function | Support <sup>a</sup> | Uses LOGICAL UNIT NUMBER field | Uses INITIATOR PORT TRANSFER TAG TO MANAGE field | Description <sup>b</sup>                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|----------------------|--------------------------------|--------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 01h                                                                                                                                                                                                                                                                                                                                                                     | ABORT TASK               | M                    | yes                            | yes                                              | The task manager shall perform the ABORT TASK task management function with the L of the I_T_L_Q nexus set to the value of the LOGICAL UNIT NUMBER field and the Q of the I_T_L_Q nexus set to the value of the INITIATOR PORT TRANSFER TAG TO MANAGE field (see SAM-5). |
| 02h                                                                                                                                                                                                                                                                                                                                                                     | ABORT TASK SET           | M                    | yes                            | no                                               | The task manager shall perform the ABORT TASK SET task management function with the L of the I_T_L nexus set to the value of the LOGICAL UNIT NUMBER field (see SAM-5).                                                                                                  |
| 04h                                                                                                                                                                                                                                                                                                                                                                     | CLEAR TASK SET           | M                    | yes                            | no                                               | The task manager shall perform the CLEAR TASK SET task management function with the L of the I_T_L nexus set to the value of the LOGICAL UNIT NUMBER field (see SAM-5).                                                                                                  |
| 08h                                                                                                                                                                                                                                                                                                                                                                     | LOGICAL UNIT RESET       | M                    | yes                            | no                                               | The logical unit shall perform the LOGICAL UNIT RESET task management function with the L of the I_T_L nexus set to the value of the LOGICAL UNIT NUMBER field (see SAM-5).                                                                                              |
| 10h                                                                                                                                                                                                                                                                                                                                                                     | I_T NEXUS RESET          | M                    | no                             | no                                               | The SSP target device shall perform the I_T NEXUS RESET task management function (see SAM-5).                                                                                                                                                                            |
| 20h                                                                                                                                                                                                                                                                                                                                                                     | Reserved                 |                      |                                |                                                  |                                                                                                                                                                                                                                                                          |
| 40h                                                                                                                                                                                                                                                                                                                                                                     | CLEAR ACA                | X                    | yes                            | no                                               | The task manager shall perform the CLEAR ACA task management function with the L of the I_T_L nexus set to the value of the LOGICAL UNIT NUMBER field (see SAM-5).                                                                                                       |
| <sup>a</sup> M = implementation is mandatory, X = implementation requirements are specified by SAM-5.<br><sup>b</sup> The task manager, logical unit, or SSP target device shall perform the specified task management function with the I and T arguments set to the SSP initiator port and SSP target port involved in the connection used to deliver the TASK frame. |                          |                      |                                |                                                  |                                                                                                                                                                                                                                                                          |

Table 161 — TASK MANAGEMENT FUNCTION field (part 2 of 2)

| Code       | Task management function | Support <sup>a</sup> | Uses LOGICAL UNIT NUMBER field | Uses INITIATOR PORT TRANSFER TAG TO MANAGE field | Description <sup>b</sup>                                                                                                                                                                                               |
|------------|--------------------------|----------------------|--------------------------------|--------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 80h        | QUERY TASK               | M                    | yes                            | yes                                              | The task manager shall perform the QUERY TASK task management function with L set to the value of the LOGICAL UNIT NUMBER field and Q set to the value of the INITIATOR PORT TRANSFER TAG TO MANAGE field (see SAM-5). |
| 81h        | QUERY TASK SET           | M                    | yes                            | no                                               | The task manager shall perform the QUERY TASK SET task management function with L set to the value of the LOGICAL UNIT NUMBER field (see SAM-5).                                                                       |
| 82h        | QUERY ASYNCHRONOUS EVENT | M                    | yes                            | no                                               | The task manager shall perform the QUERY ASYNCHRONOUS EVENT task management function with L set to the value of the LOGICAL UNIT NUMBER field (see SAM-5).                                                             |
| All others | Reserved                 |                      |                                |                                                  |                                                                                                                                                                                                                        |

<sup>a</sup> M = implementation is mandatory, X = implementation requirements are specified by SAM-5.

<sup>b</sup> The task manager, logical unit, or SSP target device shall perform the specified task management function with the I and T arguments set to the SSP initiator port and SSP target port involved in the connection used to deliver the TASK frame.

If the TASK MANAGEMENT FUNCTION field contains a reserved or unsupported value, then the task manager shall return a RESPONSE frame with the DATAPRES field set to RESPONSE\_DATA and its RESPONSE CODE field set to TASK MANAGEMENT FUNCTION NOT SUPPORTED.

If the TASK MANAGEMENT FUNCTION field is set to ABORT TASK or QUERY TASK, then the INITIATOR PORT TRANSFER TAG TO MANAGE field specifies the INITIATOR PORT TRANSFER TAG value from the COMMAND frame that contained the command to be aborted or checked. For all other task management functions, the INITIATOR PORT TRANSFER TAG TO MANAGE field shall be ignored.

### 8.2.2.3 XFER\_RDY frame - Transfer Ready information unit

An XFER\_RDY frame is sent by an SSP target port to request write data from the SSP initiator port during a write command or a bidirectional command (see 8.2.3.4 and 8.2.3.6).

Table 162 defines the Transfer Ready information unit used in an XFER\_RDY frame.

**Table 162 — XFER\_RDY frame - Transfer Ready information unit**

| Byte\Bit | 7                             | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|-------------------------------|---|---|---|---|---|---|---|
| 0        | (MSB) REQUESTED OFFSET (LSB)  |   |   |   |   |   |   |   |
| ...      |                               |   |   |   |   |   |   |   |
| 3        |                               |   |   |   |   |   |   |   |
| 4        | (MSB) WRITE DATA LENGTH (LSB) |   |   |   |   |   |   |   |
| ...      |                               |   |   |   |   |   |   |   |
| 7        |                               |   |   |   |   |   |   |   |
| 8        | Reserved                      |   |   |   |   |   |   |   |
| ...      |                               |   |   |   |   |   |   |   |
| 11       |                               |   |   |   |   |   |   |   |

The REQUESTED OFFSET field contains the application client buffer offset of the segment of write data in the data-out buffer that the SSP initiator port may transmit to the logical unit using write DATA frames. The requested offset shall be a multiple of four (i.e., each write DATA frame shall begin transferring data on a dword boundary).

The REQUESTED OFFSET field shall be set to 00000000h for the first XFER\_RDY frame of a command unless:

- a) the ENABLE FIRST BURST bit was set to one in the COMMAND frame (see 8.2.2.1); and
- b) the FIRST BURST SIZE field is set to a value other than 0000h in the Disconnect-Reconnect mode page (see 9.2.7.2.5).

If the ENABLE FIRST BURST bit was set to one in the COMMAND frame (see 8.2.2.1), then in the initial XFER\_RDY frame for the command, the SSP target port shall set the REQUESTED OFFSET field to the application client buffer offset of the segment of write data following the first burst data defined by the FIRST BURST SIZE field in the Disconnect-Reconnect mode page (see 9.2.7.2.5).

If any additional XFER\_RDY frames are required for the command and transport layer retries are not being used, then the REQUESTED OFFSET field shall be set to the sum of the requested offset and write data length of the previous XFER\_RDY frame.

The WRITE DATA LENGTH field contains the number of bytes of write data the SSP initiator port may transmit to the logical unit using write DATA frames from the application client data-out buffer starting at the requested offset. The SSP target port shall set the WRITE DATA LENGTH field to a value greater than or equal to 00000001h. If the MAXIMUM BURST SIZE field is not set to 0000h in the Disconnect-Reconnect mode page, and a persistent connection has not been established (see 4.1.13), then the SSP target port shall set the WRITE DATA LENGTH field to a value less than or equal to the number of bytes specified by the MAXIMUM BURST SIZE field (see 9.2.7.2.5).

If an SSP target port transmits an XFER\_RDY frame containing a WRITE DATA LENGTH field set to a value that is not divisible by four, then the SSP target port shall not transmit any subsequent XFER\_RDY frames for that command (i.e., only the last XFER\_RDY for a command may request a non-dword multiple write data length).

The value in the REQUESTED OFFSET field plus the value of the WRITE DATA LENGTH field shall not be greater than 1\_00000000h (i.e., a SCSI command shall not transfer more than  $2^{32}$  bytes of write data).

#### 8.2.2.4 DATA frame - Data information unit

During a write command or a bidirectional command (see 8.2.3.4 and 8.2.3.6), one or more write DATA frames are sent by an SSP initiator port to deliver write data.



During a read command or a bidirectional command (see 8.2.3.5 and 8.2.3.6), one or more read DATA frames are sent by an SSP target port to deliver read data.

Table 163 defines the Data information unit used in a DATA frame.

**Table 163 — DATA frame - Data information unit**

| Byte\Bit | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|------|---|---|---|---|---|---|---|
| 0        | DATA |   |   |   |   |   |   |   |
| ...      |      |   |   |   |   |   |   |   |
| n        |      |   |   |   |   |   |   |   |

The DATA field contains the read data (i.e., data to the application client's data-in buffer) or write data (i.e., data from the application client's data-out buffer).

The size of the DATA field (i.e., the data length) is determined by subtracting the following values from the DATA frame size (i.e., the number of bytes between SOF and EOF (see 6.18.3)):

- a) the number of bytes in frame header (i.e., 24);
- b) the number of bytes in the CRC field (i.e., 4); and
- c) the number of fill bytes, specified by the NUMBER OF FILL BYTES field in the frame header (see 8.2.1).

The maximum size of the Data information unit (i.e., the DATA field) is the maximum size of any information unit in an SSP frame (see 8.2.1). The minimum size of the Data information unit is one byte.

An SSP initiator port shall only transmit a write DATA frame:

- a) in response to an XFER\_RDY frame; or
- b) after transmitting a COMMAND frame if the ENABLE FIRST BURST bit was set to one in the COMMAND frame (see 8.2.2.1) and the FIRST BURST SIZE field in the Disconnect-Reconnect mode page is set to a value other than 0000h (see 9.2.7.2.5).

If the MAXIMUM BURST SIZE field is not set to 0000h in the Disconnect-Reconnect mode page, and a persistent connection has not been established (see 4.1.13), then, the maximum amount of data that is transferred at one time by an SSP target port per I\_T\_L\_Q nexus is limited by the value in the MAXIMUM BURST SIZE field (see 9.2.7.2.5).

A write DATA frame shall only contain write data for a single XFER\_RDY frame.

An SSP initiator port shall set the NUMBER OF FILL BYTES field to 00b in the frame header (see 8.2.1) in all write DATA frames that it transmits in response to an XFER\_RDY frame except the last write DATA frame for that XFER\_RDY frame. An SSP initiator port may set the NUMBER OF FILL BYTES field to a non-zero value in the last DATA frame that it transmits in response to an XFER\_RDY.

An SSP target port shall set the NUMBER OF FILL BYTES field to 00b in the frame header (see 8.2.1) in all read DATA frames for a command except the last read DATA frame for that command. The SSP target port may set the NUMBER OF FILL BYTES field to a non-zero value in the last read DATA frame for a command (i.e., only the last read DATA frame for a command may contain data with a length that is not a multiple of four).

An SSP initiator port shall not transmit a write DATA frame for a given I\_T\_L\_Q nexus after the SSP initiator port has sent a TASK frame that terminates that command (e.g., an ABORT TASK).

The DATA OFFSET field in the frame header (see 8.2.1) contains the application client buffer offset as described by SAM-5. For read DATA frames, this is the offset into the application client's data-in buffer. For write DATA frames, this is the offset into the application client's data-out buffer. The data offset shall be a multiple of four (i.e., each DATA frame shall transfer data beginning on a dword boundary).

The DATA OFFSET field shall be set to 00000000h in the initial read DATA frame for a command. If any additional read DATA frames are required for the command and transport layer retries are not being used, then the DATA OFFSET field shall be set to the sum of the data offset and data length of the previous read DATA frame.





Table 165 defines the DATAPRES field, which specifies the format and content of the STATUS field, the STATUS QUALIFIER field, the SENSE DATA LENGTH field, the RESPONSE DATA LENGTH field, the RESPONSE DATA field, and the SENSE DATA field.

**Table 165 — DATAPRES field**

| Code | Name          | Description                            | Reference |
|------|---------------|----------------------------------------|-----------|
| 00b  | NO_DATA       | No response data or sense data present | 8.2.2.5.2 |
| 01b  | RESPONSE_DATA | Response data present                  | 8.2.2.5.3 |
| 10b  | SENSE_DATA    | Sense data present                     | 8.2.2.5.4 |
| 11b  | Reserved      |                                        |           |

An SSP target port shall set the DATAPRES field to NO\_DATA in a RESPONSE frame sent for a command that completes without response data or sense data.

An SSP target port shall set the DATAPRES field to RESPONSE\_DATA in a RESPONSE frame sent for:

- every TASK frame; and
- every COMMAND frame for which errors occur while the transport layer is processing the frame (see 8.2.5.3).

An SSP target port shall set the DATAPRES field to SENSE\_DATA in a RESPONSE frame sent for a command that completes with sense data to return (e.g., CHECK CONDITION status).

If the DATAPRES field is set to a reserved value, then the SSP initiator port shall discard the RESPONSE frame.

#### 8.2.2.5.2 Response information unit - NO\_DATA format

If the DATAPRES field is set to NO\_DATA, then:

- the SSP target port shall set the STATUS field to the status code for a completed command (see SAM-5 for a list of status codes);
- the SSP target port shall set the STATUS QUALIFIER field to the status qualifier for the command (see SAM-5);
- the SSP target port shall set the SENSE DATA LENGTH field to 00000000h and the RESPONSE DATA LENGTH field to 00000000h;
- the SSP initiator port shall ignore the SENSE DATA LENGTH field and the RESPONSE DATA LENGTH field; and
- the SSP target port shall not include the SENSE DATA field and the RESPONSE DATA field.

#### 8.2.2.5.3 Response information unit - RESPONSE\_DATA format

If the DATAPRES field is set to RESPONSE\_DATA, then:

- the SSP target port shall set the STATUS field to 00h, the STATUS QUALIFIER field to 0000h, and the SENSE DATA LENGTH field to 00000000h;
- the SSP initiator port shall ignore the STATUS field, the STATUS QUALIFIER field, and the SENSE DATA LENGTH field;
- the SSP target port shall not include the SENSE DATA field;
- the SSP target port shall set the RESPONSE DATA LENGTH field to 00000004h; and
- the SSP target port shall include the RESPONSE DATA field.

Table 166 defines the RESPONSE DATA field. The RESPONSE DATA field shall be present if the SSP target port detects any of the conditions described by a non-zero value in the RESPONSE CODE field and shall be present for a RESPONSE frame sent in response to a TASK frame.

**Table 166 — RESPONSE DATA field**

| Byte\Bit | 7                               | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|---------------------------------|---|---|---|---|---|---|---|
| 0        | ADDITIONAL RESPONSE INFORMATION |   |   |   |   |   |   |   |
| ...      |                                 |   |   |   |   |   |   |   |
| 2        |                                 |   |   |   |   |   |   |   |
| 3        | RESPONSE CODE                   |   |   |   |   |   |   |   |

The ADDITIONAL RESPONSE INFORMATION field contains additional response information for certain task management functions (e.g., QUERY ASYNCHRONOUS EVENT) as defined in SAM-5. If the task management function does not define additional response information or the logical unit does not support additional response information, then the SSP target port shall set the ADDITIONAL RESPONSE INFORMATION field to 000000h.

Table 167 defines the RESPONSE CODE field, which specifies the error condition or the completion status of a task management function. See 9.2.1.5 and 9.2.1.15 for the mapping of these response codes to SCSI service responses.

**Table 167 — RESPONSE CODE field**

| Code                                                                                                                                                                                                                      | Description                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| 00h                                                                                                                                                                                                                       | TASK MANAGEMENT FUNCTION COMPLETE <sup>a</sup>                |
| 02h                                                                                                                                                                                                                       | INVALID FRAME                                                 |
| 04h                                                                                                                                                                                                                       | TASK MANAGEMENT FUNCTION NOT SUPPORTED <sup>a</sup>           |
| 05h                                                                                                                                                                                                                       | TASK MANAGEMENT FUNCTION FAILED <sup>a</sup>                  |
| 08h                                                                                                                                                                                                                       | TASK MANAGEMENT FUNCTION SUCCEEDED <sup>a</sup>               |
| 09h                                                                                                                                                                                                                       | INCORRECT LOGICAL UNIT NUMBER <sup>a</sup>                    |
| 0Ah                                                                                                                                                                                                                       | OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED <sup>b</sup> |
| All others                                                                                                                                                                                                                | Reserved                                                      |
| <sup>a</sup> Only valid when responding to a TASK frame.<br><sup>b</sup> Returned in case of command/task management function or task management function/task management function initiator port transfer tag conflicts. |                                                               |

#### 8.2.2.5.4 Response information unit - SENSE\_DATA format

If the DATAPRES field is set to SENSE\_DATA, then:

- the SSP target port shall set the STATUS field to the status code for a completed command (see SAM-5 for a list of status codes);
- the SSP target port shall set the STATUS QUALIFIER field to the status qualifier for the command (see SAM-5);
- the SSP target port shall set the RESPONSE DATA LENGTH field to 00000000h;
- the SSP initiator port shall ignore the RESPONSE DATA LENGTH field;

- e) the SSP target port shall not include the RESPONSE DATA field;
- f) the SSP target port shall set the SENSE DATA LENGTH field to a non-zero value indicating the number of bytes in the SENSE DATA field. The value in the SENSE DATA LENGTH field shall not be greater than 1 000 (see table 156 in 8.2.1); and
- g) the SSP target port shall set the SENSE DATA field to the sense data (see SAM-5).

The value in the SENSE DATA LENGTH field is not required to be a multiple of four. If the value is not a multiple of four, then the value in the NUMBER OF FILL BYTES field in the SSP frame header is non-zero and fill bytes are present.

### 8.2.3 Sequences of SSP frames

#### 8.2.3.1 Sequences of SSP frames overview

Table 168 lists the sequences of SSP frames supporting the SCSI transport protocol services described in 9.2.1.

**Table 168 — Sequences of SSP frames**

| Sequence                 | Reference |
|--------------------------|-----------|
| Task management function | 8.2.3.2   |
| Non-data command         | 8.2.3.3   |
| Write command            | 8.2.3.4   |
| Read command             | 8.2.3.5   |
| Bidirectional command    | 8.2.3.6   |

When multiple commands and/or task management functions are outstanding, frames from each of the individual sequences may be interleaved in any order. RESPONSE frames may be returned in any order (i.e., the order in which TASK frames and COMMAND frames are sent has no effect on the order that RESPONSE frames are returned).

Frames in a sequence may be transmitted during one or more connections (see 6.14) (e.g., for a write command using a single XFER\_RDY frame, the COMMAND frame may be transmitted in a connection originated by the SSP initiator port, the XFER\_RDY frame in a connection originated by the SSP target port, the DATA frames in one or more connections originated by the SSP initiator port, and the RESPONSE frame in a connection originated by the SSP target port. Alternatively, all the frames may be transmitted in one connection).

8.2.3.2 Task management function sequence of SSP frames

Figure 162 shows the sequence of SSP frames for a task management function (e.g., ABORT TASK (see SAM-5)), including the transport protocol services (see 9.2.1) invoked by the SCSI application layer.

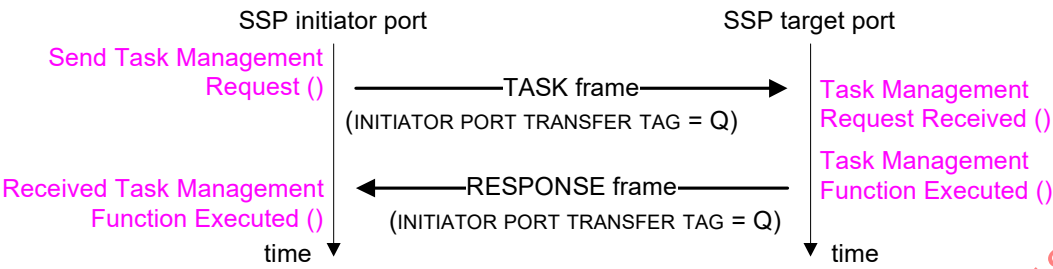


Figure 162 — Task management function sequence of SSP frames

8.2.3.3 Non-data command sequence of SSP frames

Figure 163 shows the sequence of SSP frames for a non-data command (e.g., TEST UNIT READY (see SPC-4)), including the transport protocol services (see 9.2.1) invoked by the SCSI application layer.

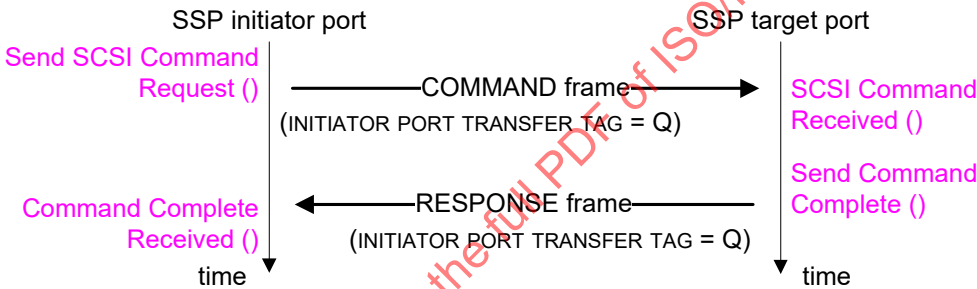


Figure 163 — Non-data command sequence of SSP frames

### 8.2.3.4 Write command sequence of SSP frames

Figure 164 shows the sequence of SSP frames for a write command (e.g., MODE SELECT (see SPC-4)), including the transport protocol services (see 9.2.1) invoked by the SCSI application layer.

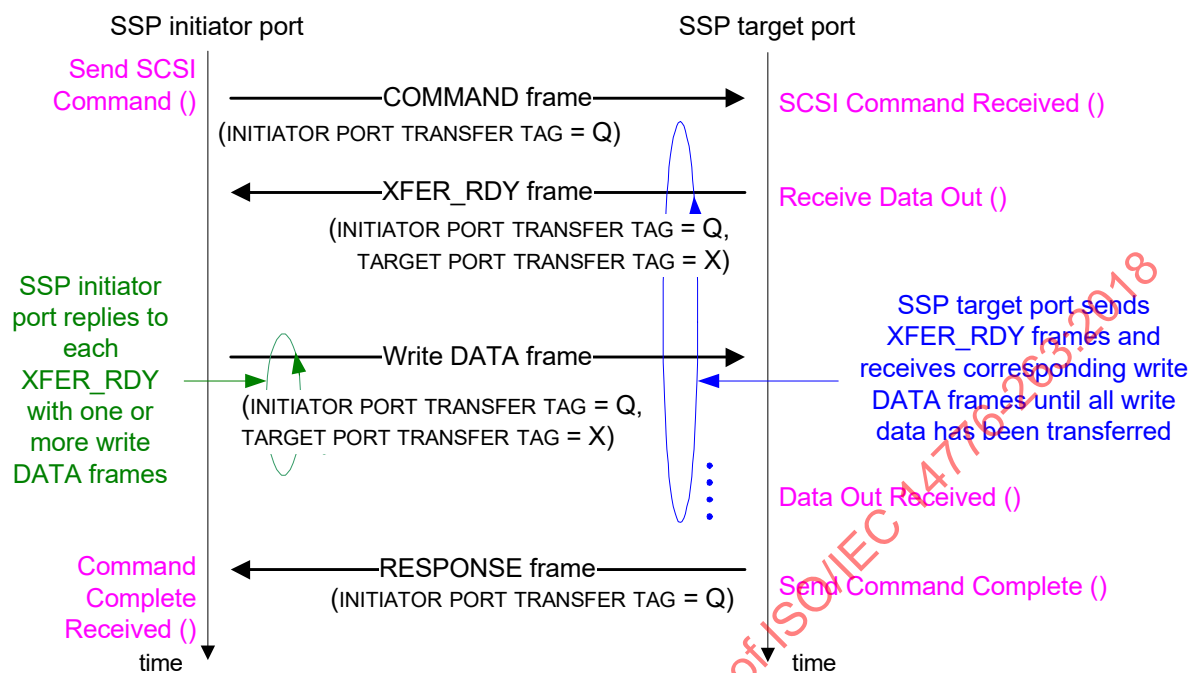


Figure 164 — Write command sequence of SSP frames

### 8.2.3.5 Read command sequence of SSP frames

Figure 165 shows the sequence of SSP frames for a read command (e.g., INQUIRY, REPORT LUNS, or MODE SENSE (see SPC-4)), including the transport protocol services (see 9.2.1) invoked by the SCSI application layer.

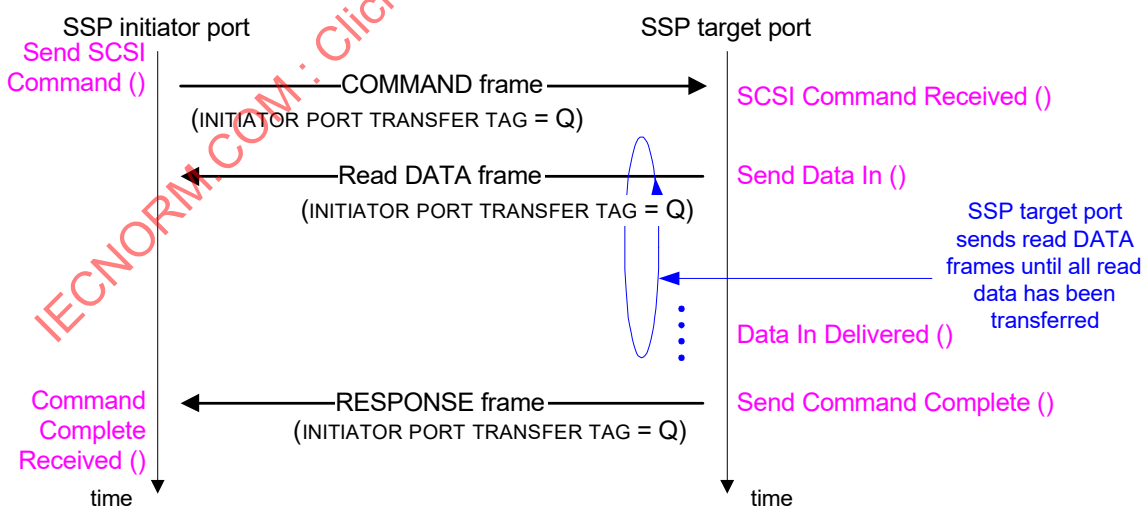


Figure 165 — Read command sequence of SSP frames

### 8.2.3.6 Bidirectional command sequence of SSP frames

Figure 166 shows the sequence of SSP frames for a bidirectional command (e.g., XDWRITEREAD (see SBC-3)), including the transport protocol services (see 9.2.1) invoked by the SCSI application layer.

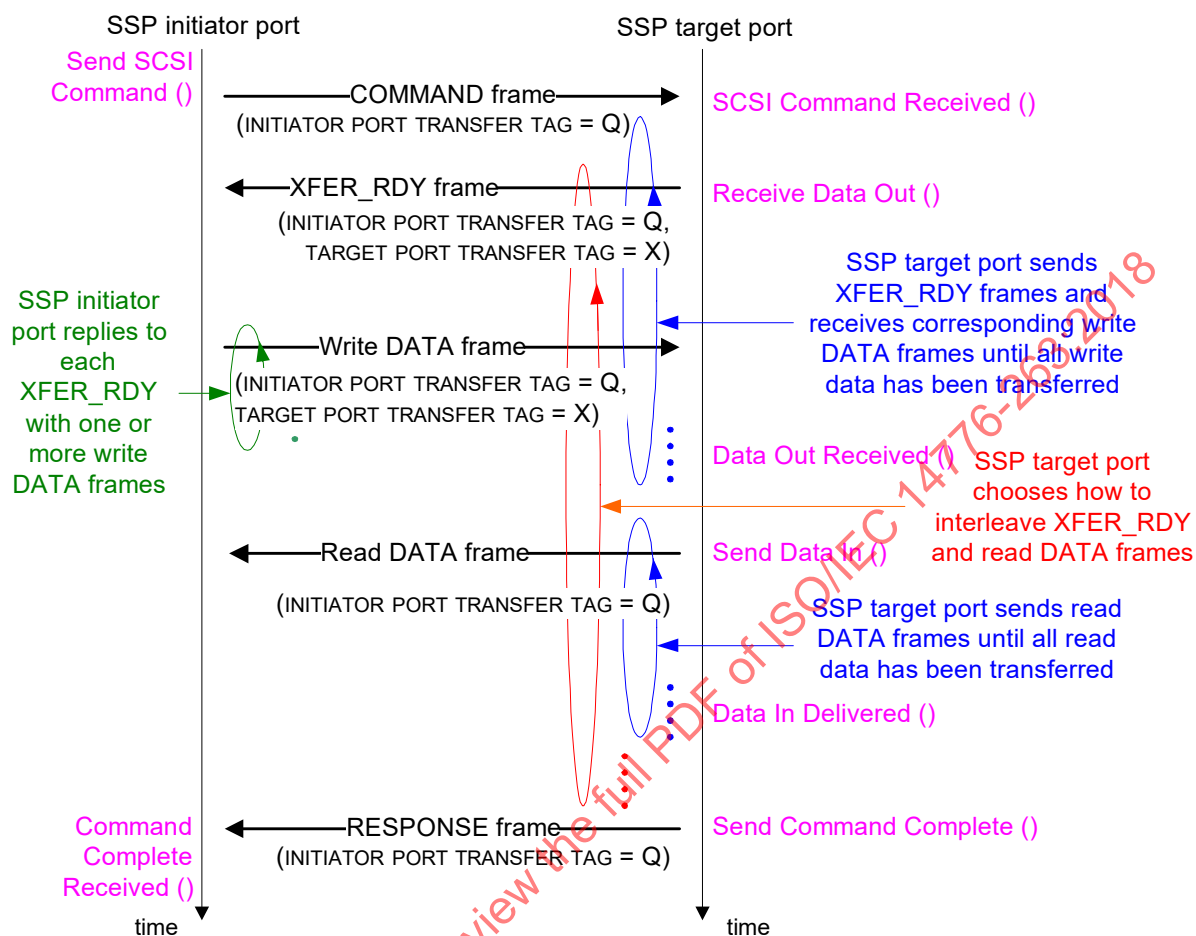


**Figure 166 — Bidirectional command sequence of SSP frames**

An SSP target port may transmit read DATA frames for a bidirectional command at the same time it is receiving write DATA frames for the same bidirectional command.

### 8.2.4 SSP transport layer handling of link layer errors

#### 8.2.4.1 SSP transport layer handling of link layer errors overview

The transport layer, sometimes assisted by the SCSI application layer, handles some link layer errors (e.g., NAKs and ACK/NAK timeouts). See 8.2.5 for transport layer handling of transport layer errors (e.g., invalid frame contents).

Link layer errors that occur when transmitting XFER\_RDY and DATA frames are processed based on the values in the TLR CONTROL field in the COMMAND frame header (see 8.2.1) and the TRANSPORT LAYER RETRIES bit in the Protocol Specific Logical Unit mode page (see 9.2.7.3) of the logical unit that is the source of the frame.

If transport layer retries are disabled, then the logical unit:

- sets the RETRY DATA FRAMES bit to zero in each XFER\_RDY frame;

- b) may or may not select a different value for the TARGET PORT TRANSFER TAG field in each XFER\_RDY frame than that used in the previous XFER\_RDY frame for that I\_T\_L\_Q nexus;
- c) processes XFER\_RDY frame link layer errors as described in 8.2.4.4.3;
- d) processes read DATA frame link layer errors as described in 8.2.4.5.3; and
- e) processes write DATA frame link layer errors as described in 8.2.4.6.3.

If transport layer retries are enabled, then the logical unit:

- a) sets the RETRY DATA FRAMES bit to one in each XFER\_RDY frame;
- b) selects a different value for the TARGET PORT TRANSFER TAG field in each XFER\_RDY frame than that used in the previous XFER\_RDY frame for that I\_T\_L\_Q nexus;
- c) processes XFER\_RDY frame link layer errors as described in 8.2.4.4.2;
- d) processes read DATA frame link layer errors as described in 8.2.4.5.2; and
- e) processes write DATA frame link layer errors as described in 8.2.4.6.2.

#### 8.2.4.2 COMMAND frame - handling of link layer errors

If an SSP initiator port transmits a COMMAND frame and receives a NAK for that frame, then the COMMAND frame was not received. The SSP initiator port should retransmit, in the same or in a new connection, the COMMAND frame at least one time (see 8.2.6.2.3.3). The SSP initiator port may reuse the initiator port transfer tag from the frame for which the NAK was received.

If an SSP initiator port transmits a COMMAND frame and does not receive an ACK or NAK for that frame (e.g., times out, or the connection is broken), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5);
- 2) to determine whether the command was received, the SCSI application client calls Send Task Management Function Request () (see 9.2.2) with:
  - A) Nexus set to the I\_T\_L\_Q nexus of the COMMAND frame; and
  - B) Function Identifier set to QUERY TASK;
 and
- 3) the SSP initiator port transmits the TASK frame in a new connection to the SSP target port.

If the command is a write command or a bidirectional command and the SSP initiator port receives an XFER\_RDY frame for the I\_T\_L\_Q nexus of the command before the RESPONSE frame for the QUERY TASK, then the COMMAND frame was received and is being processed by the SSP target port, and the XFER\_RDY frame is valid.

If the command is a read command or a bidirectional command and the SSP initiator port receives a read DATA frame for the I\_T\_L\_Q nexus of the command before the RESPONSE frame for the QUERY TASK, then the COMMAND frame was received and is being processed by the SSP target port, and the read DATA frame is valid.

If the SSP initiator port receives a RESPONSE frame for the I\_T\_L\_Q nexus of the command before the RESPONSE frame for the QUERY TASK, then the COMMAND frame was received by the SSP target port, the RESPONSE frame is valid, and the command processing is complete. The SSP initiator port may reuse the initiator port transfer tag of the COMMAND frame.

If the SSP initiator port receives a RESPONSE frame for the QUERY TASK with a response code of TASK MANAGEMENT FUNCTION SUCCEEDED, then the COMMAND frame was received by the SSP target port (i.e., an ACK was transmitted by the SSP target port for the COMMAND frame) and the command is being processed.

If the SSP initiator port receives a RESPONSE frame for the QUERY TASK with a response code of TASK MANAGEMENT FUNCTION COMPLETE, then the COMMAND frame is not being processed. If neither an XFER\_RDY frame, a read DATA frame, nor a RESPONSE frame has been received for the I\_T\_L\_Q nexus of the command, then the COMMAND frame was not received. The SSP initiator port should retransmit the COMMAND frame at least one time. The SSP initiator port may reuse the initiator port transfer tag of the COMMAND frame.



### 8.2.4.3 TASK frame - handling of link layer errors

If an SSP initiator port transmits a TASK frame and receives a NAK for that frame, then the TASK frame was not received. The SSP initiator port should retransmit, in the same or in a new connection, the TASK frame at least one time with the RETRANSMIT bit set to one (see 8.2.6.2.2.2). The SSP initiator port may reuse the initiator port transfer tag from the frame for which the NAK was received.

If an SSP initiator port transmits a TASK frame and does not receive an ACK or NAK for that frame (e.g., an ACK/NAK timeout occurs, or the connection is broken), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5);
- 2) the SCSI application client calls Send Task Management Request () using the same initiator port transfer tag (see 9.2.2); and
- 3) the SSP initiator port transmits the TASK frame with the RETRANSMIT bit set to one in a new connection to the SSP target port (see 8.2.6.2.2.2).

If the SSP initiator port receives a RESPONSE frame for the TASK frame that arrives before the ACK or NAK for the TASK frame, then the TASK frame was received by the SSP target port (i.e., an ACK was transmitted by the SSP target port for the TASK frame), the RESPONSE frame is valid, and the task management function is complete (see 8.2.6.2.2.3). The initiator port may reuse the initiator port transfer tag of the TASK frame.

### 8.2.4.4 XFER\_RDY frame - handling of link layer errors

#### 8.2.4.4.1 XFER\_RDY frame overview

If transport layer retries are enabled, then the SSP target port processes link layer errors that occur while transmitting XFER\_RDY frames as described in 8.2.4.4.2.

If transport layer retries are disabled, then the SSP target port processes link layer errors that occur while transmitting XFER\_RDY frames as described in 8.2.4.4.3.

#### 8.2.4.4.2 XFER\_RDY frame with transport layer retries enabled

If an SSP target port transmits an XFER\_RDY frame and receives a NAK for that frame, then the SSP target port retransmits, in the same or a new connection, the XFER\_RDY frame at least one time with:

- a) the TARGET PORT TRANSFER TAG field set to a different value than in the original XFER\_RDY frame;
- b) the RETRANSMIT bit set to one; and
- c) the other fields set to the same values as in the original XFER\_RDY frame (see 8.2.6.3.3.3).

If an SSP target port transmits an XFER\_RDY frame and does not receive an ACK or NAK for that frame (e.g., times out, or the connection is broken), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5); and
- 2) the SSP target port retransmits, in a new connection, the XFER\_RDY frame with:
  - A) the TARGET PORT TRANSFER TAG field set to a different value than in the original XFER\_RDY frame;
  - B) the RETRANSMIT bit set to one; and
  - C) the other fields set to the same values as in the original XFER\_RDY frame (see 8.2.6.3.3.3).

If an SSP initiator port is processing an XFER\_RDY frame for an I\_T\_L\_Q nexus (e.g., transmitting write DATA frames for the nexus), and the SSP initiator port receives a new XFER\_RDY frame for that I\_T\_L\_Q nexus with the RETRANSMIT bit set to one in the frame, then the ST\_ITS state machine stops processing the original XFER\_RDY frame (i.e., stops transmitting write DATA frames) and starts servicing the new XFER\_RDY frame (see 8.2.6.2.3). The ST\_ITS state machine does not transmit any write DATA frames for the original XFER\_RDY frame after transmitting a write DATA frame for the new XFER\_RDY frame.

An SSP target port may reuse the value in the TARGET PORT TRANSFER TAG field from an XFER\_RDY frame for an I\_T\_L\_Q nexus after the SSP target port receives a write DATA frame for a subsequent XFER\_RDY frame for that I\_T\_L\_Q nexus.

An SSP target port retransmits each XFER\_RDY frame that does not receive an ACK or NAK at least one time.

The number of times an SSP target port retransmits each XFER\_RDY frame is vendor specific. When the SSP target port reaches its vendor specific limit, the SSP target port follows the procedure for transport layer retries disabled described in 8.2.4.4.3.

#### 8.2.4.4.3 XFER\_RDY frame with transport layer retries disabled

If an SSP target port transmits an XFER\_RDY frame and receives a NAK for that frame, then:

- 1) the SCSI device server calls Send Command Complete () to return CHECK CONDITION status for that command with the sense key set to ABORTED COMMAND and the additional sense code set to NAK RECEIVED (see 9.2.3); and
- 2) the SSP target port transmits the RESPONSE frame in the same or a new connection.

If an SSP target port transmits an XFER\_RDY frame and does not receive an ACK or NAK for that frame (e.g., times out, or the connection is broken), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5);
- 2) the SCSI device server calls Send Command Complete () to return CHECK CONDITION status for that command with the sense key set to ABORTED COMMAND and the additional sense code set to ACK/NAK TIMEOUT or CONNECTION LOST (see 9.2.3); and
- 3) the SSP target port transmits the RESPONSE frame in a new connection.

#### 8.2.4.5 Read DATA frame - handling of link layer errors

##### 8.2.4.5.1 Read DATA frame overview

If an SSP target port transmits a read DATA frame for a command with transport layer retries enabled, then the SSP target port processes link layer errors that occur while transmitting read DATA frames as described in 8.2.4.5.2.

If an SSP target port transmits a read DATA frame for a command with transport layer retries disabled, then the SSP target port processes link layer errors that occur while transmitting read DATA frames as described in 8.2.4.5.3.

##### 8.2.4.5.2 Read DATA frame with transport layer retries enabled

If an SSP target port transmits a read DATA frame and receives a NAK for that frame, then the read DATA frame was not received. The SSP target port retransmits, in the same or in a new connection, all the read DATA frames for that I\_T\_L\_Q nexus since a previous time when ACK/NAK balance occurred at least one time (see 8.2.6.3.3.4).

If an SSP target port transmits a read DATA frame and does not receive an ACK or NAK for that frame (e.g., an ACK/NAK timeout occurs, or the connection is broken), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5); and
- 2) the ST\_TTS state machine retransmits, in a new connection, all the read DATA frames for that I\_T\_L\_Q nexus since a previous time when ACK/NAK balance occurred at least one time (see 8.2.6.3.3.4).

The CHANGING DATA POINTER bit is set to one in the first retransmitted read DATA frame and the CHANGING DATA POINTER bit is set to zero in subsequent read DATA frames.

The ST\_TTS state machine retransmits each read DATA frame that does not receive an ACK at least one time (see 8.2.6.3.3).

The number of times an SSP target port retransmits each read DATA frame is vendor specific. When an SSP target port reaches its vendor specific limit for retransmitting read DATA frames, the SSP target port follows the procedure for transport layer retries disabled described in 8.2.4.5.3.

#### 8.2.4.5.3 Read DATA frame with transport layer retries disabled

If an SSP target port transmits a read DATA frame and receives a NAK for that frame, then:

- 1) the SCSI device server calls Send Command Complete () to return CHECK CONDITION status for that command with the sense key set to ABORTED COMMAND and the additional sense code set to NAK RECEIVED (see 9.2.3); and
- 2) the SSP target port transmits the RESPONSE frame in the same or a new connection.

If an SSP target port transmits a read DATA frame and does not receive an ACK or NAK for that frame (e.g., an ACK/NAK timeout occurs), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5);
- 2) the SCSI device server calls Send Command Complete () to return CHECK CONDITION status for that command with the sense key set to ABORTED COMMAND and the additional sense code set to ACK/NAK TIMEOUT (see 9.2.3); and
- 3) the SSP target port transmits the RESPONSE frame in a new connection.

#### 8.2.4.6 Write DATA frame - handling of link layer errors

##### 8.2.4.6.1 Write DATA frame overview

An SSP initiator port processes link layer errors that occur while transmitting write DATA frames transmitted in response to an XFER\_RDY frame that has its RETRY DATA FRAMES bit set to one as described in 8.2.4.6.2.

An SSP initiator port processes link layer errors that occur while transmitting write DATA frames in response to an XFER\_RDY frame that has its RETRY DATA FRAMES bit set to zero as described in 8.2.4.6.3.

##### 8.2.4.6.2 Write DATA frame with transport layer retries enabled

If an SSP initiator port transmits a write DATA frame and receives a NAK for that frame, then the write DATA frame was not received. The SSP\_ITS state machine retransmits, in the same or in a new connection, all the write DATA frames for the previous XFER\_RDY frame (see 8.2.6.2.3.3.2).

If an SSP initiator port transmits a write DATA frame and does not receive an ACK or NAK for that frame (e.g., an ACK/NAK timeout occurs, or the connection is broken), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5); and
- 2) the ST\_ITS state machine retransmits, in a new connection, all the write DATA frames for the previous XFER\_RDY frame (see 8.2.6.2.3.3.2).

If that SSP initiator port receives a new XFER\_RDY frame or a RESPONSE frame for the command while retransmitting or preparing to retransmit the write DATA frames, then the ST\_IFR state machine and ST\_ITS state machine process the XFER\_RDY frame or RESPONSE frame and stop retransmitting the write DATA frames (see 8.2.6.2.2 and 8.2.6.2.3). The ST\_ITS state machine does not transmit a write DATA frame for the previous XFER\_RDY frame after transmitting a write DATA frame in response to the new XFER\_RDY frame.

The CHANGING DATA POINTER bit is set to one in the first retransmitted write DATA frame and the CHANGING DATA POINTER bit is set to zero in subsequent write DATA frames.

The ST\_ITS state machine retransmits each write DATA frame that does not receive an ACK at least one time (see 8.2.6.2.3).

The number of times an SSP initiator port retransmits each write DATA frame is vendor specific. When an SSP initiator port reaches its vendor specific limit for retransmitting write DATA frames, the SSP initiator port follows the procedure for transport layer retries disabled described in 8.2.4.6.3.

#### 8.2.4.6.3 Write DATA frame with transport layer retries disabled

If an SSP initiator port transmits a write DATA frame and does not receive an ACK or NAK for that frame (e.g., an ACK/NAK timeout occurs, or the connection is broken), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5); and
- 2) the SCSI application client aborts the command (see 9.2.2).

If an SSP initiator port transmits a write DATA frame and receives a NAK for that frame, then the SCSI application client aborts the command (see 9.2.2).

#### 8.2.4.7 RESPONSE frame - handling of link layer errors

If an SSP target port transmits a RESPONSE frame and receives a NAK for that frame, then the SSP target port retransmits, in the same or a new connection, the RESPONSE frame at least one time with the RETRANSMIT bit set to one and with the other fields set to the same values as in the original RESPONSE frame (see 8.2.6.3.3.3).

If an SSP target port transmits a RESPONSE frame and does not receive an ACK or NAK for that frame (e.g., an ACK/NAK timeout occurs, or the connection is broken), then:

- 1) the SSP\_TF state machine closes the connection with DONE (ACK/NAK TIMEOUT) (see 6.18.9.6.5); and
- 2) the SSP target port retransmits, in a new connection, the RESPONSE frame with:
  - A) the RETRANSMIT bit set to one; and
  - B) the other fields set to the same values as in the original RESPONSE frame (see 8.2.6.3.3.3).

The ST\_TTS state machine retransmits each RESPONSE frame that does not receive an ACK at least one time (see 8.2.6.3.3). The number of times an SSP target port retransmits each RESPONSE frame is vendor specific.

If an SSP initiator port receives a RESPONSE frame with a RETRANSMIT bit set to one, and the SSP initiator port has previously received a RESPONSE frame for the same I\_T\_L\_Q nexus, then the ST\_IFR state machine discards the extra RESPONSE frame (see 8.2.6.2.2.3). If the ST\_IFR state machine has not previously received a RESPONSE frame for the I\_T\_L\_Q nexus, then the state machine processes the RESPONSE frame.

### 8.2.5 SSP transport layer error handling summary

#### 8.2.5.1 SSP transport layer error handling summary introduction

This subclause contains a summary of how SSP ports process transport layer errors. This summary does not include every error case. See 8.2.4 for transport layer handling of link layer errors (e.g., using transport layer retries).

#### 8.2.5.2 SSP initiator port transport layer error handling summary

If an SSP initiator port receives a COMMAND or TASK frame or an unsupported frame type, then the ST\_IFR state machine discards the frame (see 8.2.6.2.2.3).

If an SSP initiator port receives an XFER\_RDY, read DATA, or RESPONSE frame with an unknown INITIATOR PORT TRANSFER TAG field value, then the ST\_IFR state machine discards the frame (see 8.2.6.2.3.7). The SCSI application client may then abort the command with that initiator port transfer tag.

If an SSP initiator port receives an XFER\_RDY frame with a Transfer Ready information unit that is not 12 bytes long, then the ST\_IFR state machine discards the frame (see 8.2.6.2.3.7). The SCSI application client may then abort the command.

If an SSP initiator port receives an XFER\_RDY frame in response to a command that does not specify write data, then the ST\_IFR state machine discards the frame (see 8.2.6.2.2.3), and the SCSI application client

aborts the command (see 9.2.2).

If an SSP initiator port receives an XFER\_RDY frame requesting more write data than expected, then the ST\_ITS state machine discards the frame (see 8.2.6.2.3.3), and the SCSI application client aborts the command (see 9.2.2).

If an SSP initiator port receives an XFER\_RDY frame requesting zero bytes, then the ST\_ITS state machine discards the frame (see 8.2.6.2.3.3), and the SCSI application client aborts the command (see 9.2.2).

If transport layer retries are disabled and an SSP initiator port receives an XFER\_RDY frame with a requested offset that was not expected, then the ST\_ITS state machine discards the frame (see 8.2.6.2.3.3), and the SCSI application client aborts the command (see 9.2.2).

If an SSP initiator port receives a read DATA frame in response to a command with no read data, then the ST\_IFR state machine discards the frame (see 8.2.6.2.2.3), and the SCSI application client aborts the command (see 9.2.2).

If an SSP initiator port receives a read DATA frame with more read data than expected, then the ST\_ITS state machine discards the frame (see 8.2.6.2.3.3), and the SCSI application client aborts the command (see 9.2.2). The SSP initiator port may receive a RESPONSE for the command before being able to abort the command.

If an SSP initiator port receives a read DATA frame with zero bytes, then the ST\_ITS state machine discards the frame (see 8.2.6.2.3.3), and the SCSI application client aborts the command (see 9.2.2). The SSP initiator port may receive a RESPONSE for the command before being able to abort the command.

If transport layer retries are disabled and an SSP initiator port receives a read DATA frame with a data offset that was not expected, then the ST\_ITS state machine discards that frame and any subsequent read DATA frames received for that command (see 8.2.6.2.3.7), and the SCSI application client aborts the command (see 9.2.2). The SSP initiator port may receive a RESPONSE for the command before being able to abort the command.

If an SSP initiator port receives a RESPONSE frame that is not the correct length, then the ST\_IFR state machine considers the command or task management function completed with an error and discards the frame (see 8.2.6.2.2.3).

### 8.2.5.3 SSP target port transport layer error handling summary

If an SSP target port receives an XFER\_RDY or RESPONSE frame or another unsupported frame type, then the ST\_TFR state machine discards the frame (see 8.2.6.3.2.2).

If an SSP target port receives a COMMAND frame and:

- a) the frame is too short to contain a LOGICAL UNIT NUMBER field;
- b) the frame is too short to contain a CDB;
- c) the ADDITIONAL CDB LENGTH field specifies that the frame should be a different length; or
- d) the TLR CONTROL field is set to a non-zero value and non-zero values are not supported,

then the ST\_TTS state machine returns a RESPONSE frame with the DATAPRES field set to RESPONSE\_DATA and the RESPONSE CODE field set to INVALID FRAME (see 8.2.6.3.2.2).

If an SSP target port receives a TASK frame that is too short, then the ST\_TTS state machine returns a RESPONSE frame with the DATAPRES field set to RESPONSE\_DATA and the RESPONSE CODE field set to INVALID FRAME (see 8.2.6.3.2.2).

If an SSP target port receives a COMMAND frame with an initiator port transfer tag that is already in use for another command and the SSP target device implements initiator port transfer tag checking, then the task router and task manager(s) return CHECK CONDITION status with the sense key set to ABORTED COMMAND and the additional sense code set to OVERLAPPED COMMANDS ATTEMPTED (see 9.2.4).

If an SSP target port receives:

- a) a COMMAND frame with an initiator port transfer tag that is already in use for a task management function; or



- b) a TASK frame with an initiator port transfer tag that is already in use for a command or another task management function,

then the task router and task manager(s) return a RESPONSE frame with the RESPONSE CODE field set to OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED (see 9.2.4).

If an SSP target port receives a write DATA frame with an unknown initiator port transfer tag, then the ST\_TFR state machine discards the frame (see 8.2.6.3.2).

If an SSP target port receives a write DATA frame that does not contain first burst data and for which there is no XFER\_RDY frame outstanding (i.e., it has received all requested write data), then the ST\_TFR state machine discards the frame (see 8.2.6.3.2.2).

If an SSP target port receives a TASK frame with an unknown logical unit number, then the ST\_TFR state machine returns a RESPONSE frame with the DATAPRES field set to RESPONSE\_DATA and the RESPONSE CODE field set to INCORRECT LOGICAL UNIT NUMBER (see 8.2.6.3.2.2).

If an SSP target port receives a COMMAND frame or TASK frame with a TARGET PORT TRANSFER TAG field set to a value other than FFFFh, then the ST\_TFR state machine may return a RESPONSE frame with the DATAPRES field set to RESPONSE\_DATA and the RESPONSE CODE field set to INVALID FRAME (see 8.2.6.3.2.2).

If an SSP target port is using target port transfer tags and receives a write DATA frame with an unknown target port transfer tag, then the ST\_TFR state machine discards the frame (see 8.2.6.3.3).

If transport layer retries are disabled and an SSP target port receives a write DATA frame with a data offset that was not expected, then the ST\_TTS state machine discards the frame (see 8.2.6.3.3.6.1), and the SCSI device server terminates the command with CHECK CONDITION status with the sense key set to ABORTED COMMAND and the additional sense code set to DATA OFFSET ERROR (see 9.2.3).

If an SSP target port receives a write DATA frame with more write data than expected (i.e., the write DATA frame contains data in excess of that requested by an XFER\_RDY frame or, for first burst data, indicated by the FIRST BURST LENGTH field in the Disconnect-Reconnect mode page), then the ST\_TTS state machine discards the frame (see 8.2.6.3.3.6.1), and the SCSI device server terminates the command with CHECK CONDITION status with the sense key set to ABORTED COMMAND and the additional sense code set to TOO MUCH WRITE DATA (see 9.2.3).

If an SSP target port receives a write DATA frame with zero bytes, then the ST\_TTS state machine discards the frame (see 8.2.6.3.3.6.1), and the SCSI device server terminates the command with CHECK CONDITION status with the sense key set to ABORTED COMMAND and the additional sense code set to INFORMATION UNIT TOO SHORT (see 9.2.3).

## 8.2.6 ST (transport layer for SSP ports) state machines

### 8.2.6.1 ST state machines overview

The ST state machines perform the following functions:

- a) receive and process transport protocol service requests and transport protocol service responses from the SCSI application layer;
- b) receive and process other SAS connection management requests from the SCSI application layer;
- c) send transport protocol service indications and transport protocol service confirmations to the SCSI application layer;
- d) send requests to the port layer to transmit frames and manage SAS connections; and
- e) receive confirmations from the port layer.

The following confirmations between the ST state machines and the port layer:

- a) Transmission Status; and
- b) Frame Received,

include the following as arguments:

- a) initiator port transfer tag;

- b) Destination SAS Address; and
- c) Source SAS Address,

and are used to route the confirmations to the correct ST state machines.

NOTE 53 - Although allowed by this standard, the ST state machines do not handle bidirectional commands that result in concurrent write DATA frames and read DATA frames.

### 8.2.6.2 ST\_I (transport layer for SSP initiator ports) state machines

#### 8.2.6.2.1 ST\_I state machines overview

The ST\_I state machines are as follows:

- a) ST\_IFR (initiator frame router) state machine (see 8.2.6.2.2); and
- b) ST\_ITS (initiator transport server) state machine (see 8.2.6.2.3).

Each SAS initiator port includes:

- a) one ST\_IFR state machine; and
- b) one ST\_ITS state machine for each possible command and task management function (i.e., for each initiator port transfer tag).

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Figure 167 shows the ST\_I state machines.

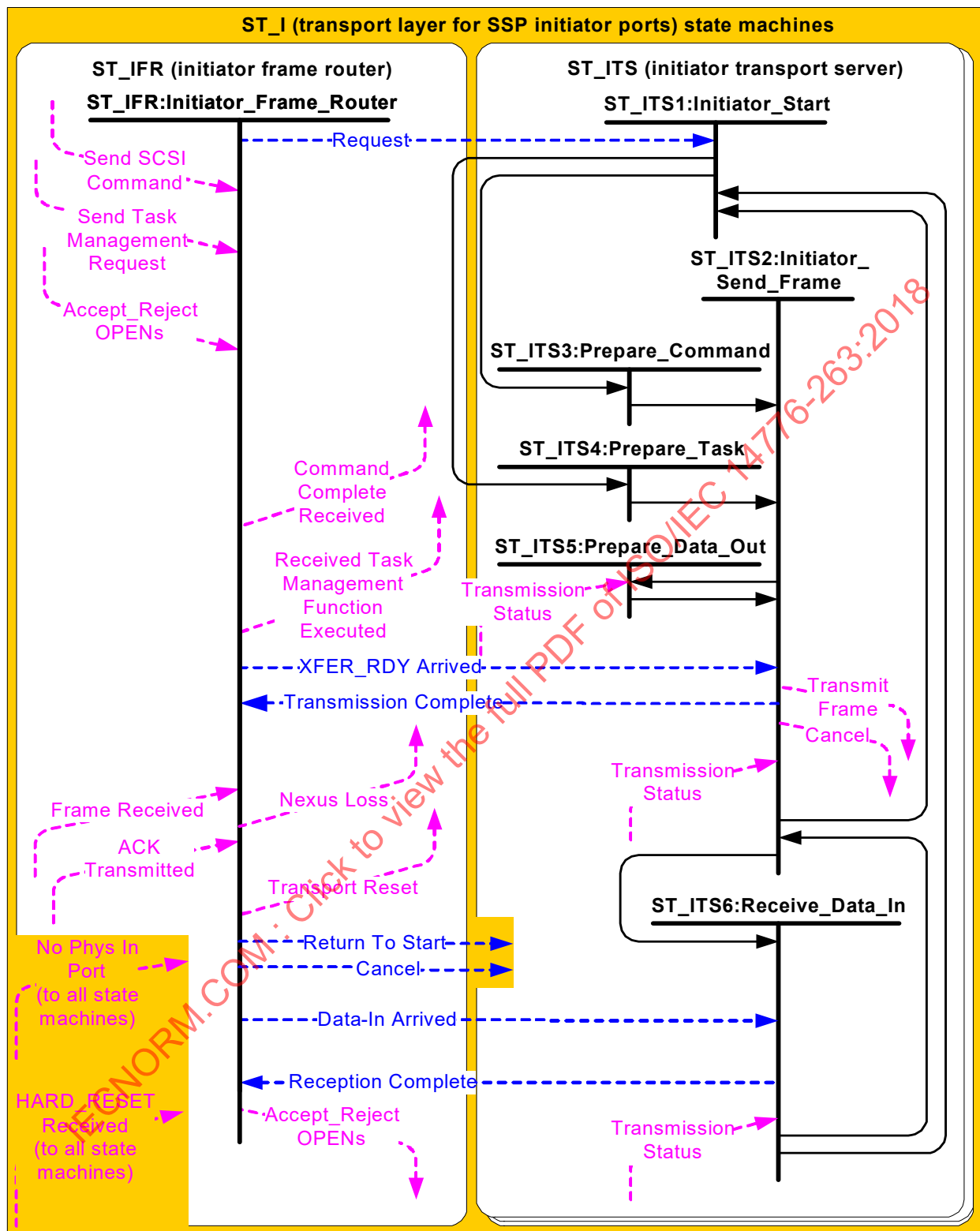


Figure 167 — ST\_I (transport layer for SSP initiator ports) state machines



### 8.2.6.2.2 ST\_IFR (initiator frame router) state machine

#### 8.2.6.2.2.1 ST\_IFR state machine overview

The ST\_IFR state machine performs the following functions:

- a) receives Send SCSI Command and Send Task Management transport protocol service requests from the SCSI application layer;
- b) sends messages to the ST\_ITS state machine;
- c) receives messages from the ST\_ITS state machine;
- d) receives confirmations from the port layer;
- e) sends transport protocol service confirmations to the SCSI application layer;
- f) receives vendor specific requests from the SCSI application layer;
- g) sends vendor specific confirmations to the SCSI application layer;
- h) receives Accept\_Reject OPENs requests from the SCSI application layer;
- i) sends Accept\_Reject OPENs requests to the port layer;
- j) sends Nexus Loss event notifications to the SCSI application layer; and
- k) sends Transport Reset event notifications to the SCSI application layer.

This state machine consists of one state.

This state machine shall be started after power on.

#### 8.2.6.2.2.2 Processing transport protocol service requests

If this state machine receives a Send SCSI Command transport protocol service request then this state machine shall send a Request (Send Command) message with Command arguments and Application Client Buffer arguments to the ST\_ITS state machine for the specified initiator port transfer tag.

The following is the list of Command arguments:

- a) connection rate;
- b) initiator connection tag;
- c) Destination SAS Address;
- d) Source SAS Address set to the SAS address of the SSP initiator port;
- e) initiator port transfer tag;
- f) logical unit number;
- g) command priority;
- h) task attribute;
- i) additional CDB length;
- j) CDB;
- k) additional CDB bytes, if any;
- l) first burst enabled; and
- m) request fence.

The following is the list of Application Client Buffer arguments:

- a) data-in buffer size;
- b) data-out buffer; and
- c) data-out buffer size.

If the command specifies a write operation and the Send SCSI Command transport service request contains a First Burst Enabled argument, then the Request (Send Command) message shall also include the Enable First Burst argument and the number of bytes for the First Burst Size argument.

If this state machine receives a Send Task Management Request transport protocol service request, then this state machine shall send a Request (Send Task) message with the Task arguments to the ST\_ITS state machine for the specified initiator port transfer tag.

The following is the list of Task arguments:

- a) connection rate;

- b) initiator connection tag;
- c) Source SAS Address set to the SAS address of the SSP initiator port;
- d) Destination SAS Address;
- e) retransmit bit;
- f) initiator port transfer tag;
- g) logical unit number;
- h) task management function;
- i) initiator port transfer tag to manage; and
- j) request fence.

If the ST\_ITS state machine for the initiator port transfer tag specified in the Send Task Management Request is currently in use, then this state machine shall set the retransmit bit argument to one. If the ST\_ITS state machine for the initiator port transfer tag specified in the Send Task Management Request is not currently in use, then this state machine shall set the retransmit bit argument to zero.

#### 8.2.6.2.2.3 Processing Frame Received confirmations

If this state machine receives a Frame Received (ACK/NAK Balanced) confirmation or Frame Received (ACK/NAK Not Balanced) confirmation, then this state machine shall compare the frame type of the frame received with the received confirmation (see table 156 in 8.2.1). If the confirmation was Frame Received (ACK/NAK Balanced) and the frame type is not XFER\_RDY, RESPONSE, or DATA, then this state machine shall discard the frame. If the confirmation was Frame Received (ACK/NAK Not Balanced) and the frame type is not DATA, then this state machine shall discard the frame.

If the frame type is correct relative to the Frame Received confirmation, then this state machine may check that the hashed source SAS address matches the SAS address of the SAS port that transmitted the frame and that the hashed destination SAS address matches the SAS address of the SAS port that received the frame based on the connection information. If this state machine checks these SAS addresses, and they do not match, then this state machine:

- a) shall discard the frame; and
- b) may send a vendor specific confirmation to the SCSI application layer to cause the command using that initiator port transfer tag to be aborted.

If the frame type is XFER\_RDY, then this state machine shall check the length of the information unit. If the length of the information unit is not correct, then this state machine:

- a) shall discard the frame; and
- b) may send a vendor specific confirmation to the SCSI application layer to cause the command using that initiator port transfer tag to be aborted.

If the frame type is XFER\_RDY and the initiator port transfer tag is for a command with no write data, then this state machine shall:

- a) discard the frame;
- b) send a Command Complete Received transport protocol service confirmation with the Service Response argument set to Service Delivery or Target Failure - XFER\_RDY Not Expected to the SCSI application layer; and
- c) if there is an ST\_ITS state machine for the initiator port transfer tag, then send a Return To Start message to that state machine.

If the frame type is DATA and the initiator port transfer tag is for a command with no read data, then this state machine shall:

- a) discard the frame;
- b) send a Command Complete Received transport protocol service confirmation with the Service Response argument set to Service Delivery or Target Failure - DATA Not Expected to the SCSI application layer; and
- c) if there is an ST\_ITS state machine for the initiator port transfer tag, then send a Return To Start message to that state machine.

If the frame type is RESPONSE, then this state machine shall check the length of the information unit. If the length of the information unit is not correct and the RESPONSE frame was for a command, then this state machine shall discard the frame and send a Command Complete Received transport protocol service confirmation to the SCSI application layer with the Service Response argument set to Service Delivery or Target Failure - RESPONSE Incorrect Length. If the length of the information unit is not correct and the RESPONSE frame was for a task management function, then this state machine shall discard the frame and send a Received Task Management Function Executed transport protocol service confirmation to the SCSI application layer with the Service Response argument set to Service Delivery or Target Failure - RESPONSE Incorrect Length.

If the frame type is correct relative to the Frame Received confirmation, then this state machine shall check the initiator port transfer tag. If the initiator port transfer tag does not specify a valid ST\_ITS state machine, then this state machine shall discard the frame and may send a vendor specific confirmation to the SCSI application layer to cause the command using that initiator port transfer tag to be aborted.

If the frame type is RESPONSE and this state machine has previously received a RESPONSE frame for the I\_T\_L\_Q nexus, then this state machine shall discard the frame.

If the frame type is RESPONSE, the fields checked in the frame are correct, and this state machine has not previously received a RESPONSE frame for this I\_T\_L\_Q nexus, then this state machine shall send a Return To Start message to the ST\_ITS state machine for the specified initiator port transfer tag and:

- a) if the RESPONSE frame was for a command, then this state machine shall send a Command Complete Received transport protocol service confirmation to the SCSI application layer with the arguments set as specified in table 194; or
- b) if the RESPONSE frame was for a task management request, then this state machine shall send a Received Task Management Function Executed transport protocol service confirmation to the SCSI application layer with the arguments set as specified in table 204.

If the frame type is XFER\_RDY and the fields checked in the frame are correct, then this state machine shall wait to receive an ACK Transmitted confirmation.

If this state machine receives an ACK Transmitted confirmation for an XFER\_RDY frame, then it shall send an XFER\_RDY Arrived message to the ST\_ITS state machine specified by the initiator port transfer tag. The message shall include the following Xfer\_Rdy arguments:

- a) retry data frames;
- b) retransmit bit;
- c) target port transfer tag;
- d) requested offset; and
- e) write data length.

If the frame type is DATA and the fields checked in the frame are correct, then this state machine shall send a Data-In Arrived message to the ST\_ITS state machine specified by the initiator port transfer tag. The message shall include the following Read Data arguments:

- a) changing data pointer;
- b) number of fill bytes;
- c) data offset; and
- d) data.

#### 8.2.6.2.2.4 Processing Transmission Complete and Reception Complete messages

If this state machine receives a Transmission Complete (I\_T Nexus Loss) message, then this state machine shall send a Nexus Loss event notification to the SCSI application layer.

Table 169 defines the transport protocol service confirmation and Delivery Result argument generated as a result of receiving a Transmission Complete message or a Reception Complete message indicating that an error occurred during the transmission or reception of a frame.

**Table 169 — Confirmations sent to the SCSI application layer if a frame transmission error or reception error occurs**

| Message received from ST_ITS state machine                      | Transport protocol service confirmation and Delivery Result argument sent to the SCSI application layer |
|-----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Transmission Complete<br>(Command Failed, ACK/NAK Timeout)      | Command Complete Received (Service Delivery or Target Failure - ACK/NAK Timeout)                        |
| Transmission Complete<br>(Command Failed, Connection Failed)    | Command Complete Received (Service Delivery or Target Failure - Connection Failed)                      |
| Transmission Complete<br>(Command Failed, NAK Received)         | Command Complete Received (Service Delivery or Target Failure - NAK Received)                           |
| Transmission Complete<br>(Task Failed, ACK/NAK Timeout)         | Received Task Management Function Executed (Service Delivery or Target Failure - ACK/NAK Timeout)       |
| Transmission Complete<br>(Task Failed, Connection Failed)       | Received Task Management Function Executed (Service Delivery or Target Failure - Connection Failed)     |
| Transmission Complete<br>(Task Failed, NAK Received)            | Received Task Management Function Executed (Service Delivery or Target Failure - NAK Received)          |
| Transmission Complete<br>(XFER_RDY Incorrect Write Data Length) | Command Complete Received (Service Delivery or Target Failure - XFER_RDY Incorrect Write Data Length)   |
| Transmission Complete<br>(XFER_RDY Requested Offset Error)      | Command Complete Received (Service Delivery or Target Failure - XFER_RDY Requested Offset Error)        |
| Transmission Complete<br>(Cancel Acknowledged)                  | Command Complete Received (Service Delivery or Target Failure - Cancel Acknowledged)                    |
| Reception Complete<br>(Command Failed, ACK/NAK Timeout)         | Command Complete Received (Service Delivery or Target Failure - ACK/NAK Timeout)                        |
| Reception Complete<br>(Data Offset Error)                       | Command Complete Received (Service Delivery or Target Failure - DATA Data Offset Error)                 |
| Reception Complete<br>(Too Much Read Data)                      | Command Complete Received (Service Delivery or Target Failure - DATA Too Much Read Data)                |
| Reception Complete<br>(Incorrect Data Length)                   | Command Complete Received (Service Delivery or Target Failure - DATA Incorrect Data Length)             |
| Reception Complete<br>(Cancel Acknowledged)                     | Command Complete Received (Service Delivery or Target Failure - Cancel Acknowledged)                    |

The transport protocol service confirmation shall include the initiator port transfer tag as an argument.

#### 8.2.6.2.2.5 Processing miscellaneous requests

If this state machine receives an Accept\_Reject OPENs (Accept SSP) request or an Accept\_Reject OPENs (Reject SSP) request, then this state machine shall send an Accept\_Reject OPENs request with the same arguments to the port layer.

If this state machine receives a HARD\_RESET Received confirmation, then this state machine shall send a Transport Reset event notification to the SCSI application layer.

If this state machine receives a No Phys In Port confirmation, then this state machine shall send a Command Complete Received (Service Delivery or Target Failure - Connection Failed) or Received Task Management

Function Executed (Service Delivery or Target Failure - Connection Failed) confirmation to the SCSI application layer for each ST\_ITS state machine that is not in the ST\_ITS1:Initiator\_Start state.

This state machine may receive vendor specific requests from the SCSI application layer that cause this state machine to send a Cancel message to an ST\_ITS state machine.

### 8.2.6.2.3 ST\_ITS (initiator transport server) state machine

#### 8.2.6.2.3.1 ST\_ITS state machine overview

The ST\_ITS state machine performs the following functions:

- a) receives and processes messages from the ST\_IFR state machine;
- b) sends messages to the ST\_IFR state machine;
- c) sends request to the port layer regarding frame transmission;
- d) receives confirmations from the port layer regarding frame transmission; and
- e) receives HARD\_RESET Received confirmations and No Phys In Port confirmations from the port layer.

This state machine consists of the following states:

- a) ST\_ITS1:Initiator\_Start state (see 8.2.6.2.3.2) (initial state);
- b) ST\_ITS2:Initiator\_Send\_Frame state (see 8.2.6.2.3.3);
- c) ST\_ITS3:Prepare\_Command state (see 8.2.6.2.3.4);
- d) ST\_ITS4:Prepare\_Task state (see 8.2.6.2.3.5);
- e) ST\_ITS5:Prepare\_Data\_Out state (see 8.2.6.2.3.6); and
- f) ST\_ITS6:Receive\_Data\_In state (see 8.2.6.2.3.7).

This state machine shall start in the ST\_ITS1:Initiator\_Start state after power on.

If this state machine receives a HARD\_RESET Received confirmation or a No Phys In Port confirmation, then this state machine shall transition to the ST\_ITS1:Initiator\_Start state.

This state machine shall maintain the state machine variables defined in table 170.

**Table 170 — ST\_ITS state machine variables**

| State machine variable     | Description                                                                                                                                   |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Data-In Buffer Offset      | Current offset in the application client's data-in buffer (i.e., the application client buffer for read data)                                 |
| Data-Out Buffer Offset     | Current offset in the application client's data-out buffer (i.e., the application client buffer for write data)                               |
| Previous Requested Offset  | Offset in the application client's data-out buffer (i.e., the application client buffer for write data) from the last XFER_RDY frame received |
| Previous Write Data Length | Write data length from the last XFER_RDY frame received                                                                                       |

This state machine shall maintain the state machine arguments defined in table 171.

**Table 171 — ST\_ITS state machine arguments**

| State machine argument | Description                                                                                                        |
|------------------------|--------------------------------------------------------------------------------------------------------------------|
| Command                | Consists of the Command arguments received in the Request (Send Command) message                                   |
| Task                   | Consists of the arguments received in the Request (Send Task) message                                              |
| Xfer_Rdy               | Consists of the arguments received in the XFER_RDY Arrived message                                                 |
| Data-Out Buffer        | The location of the application client's data-out buffer (i.e., the application client buffer for write data)      |
| Data-Out Buffer Size   | The size in bytes of the application client's data-out buffer (i.e., the application client buffer for write data) |
| Data-In Buffer Size    | The size in bytes of the application client's data-in buffer (i.e., the application client buffer for read data)   |

#### **8.2.6.2.3.2 ST\_ITS1:Initiator\_Start state**

##### **8.2.6.2.3.2.1 State description**

This state is the initial state of the ST\_ITS state machine.

Upon entry into this state, this state shall set the Data-In Buffer Offset state machine variable to zero.

Upon entry into this state, this state shall set the Data-Out Buffer Offset state machine variable to zero.

##### **8.2.6.2.3.2.2 Transition ST\_ITS1:Initiator\_Start to ST\_ITS3:Prepare\_Command**

This transition shall occur after receiving a Request (Send Command) message.

##### **8.2.6.2.3.2.3 Transition ST\_ITS1:Initiator\_Start to ST\_ITS4:Prepare\_Task**

This transition shall occur after receiving a Request (Send Task) message.

##### **8.2.6.2.3.3 ST\_ITS2:Initiator\_Send\_Frame state**

If this state is entered from the ST\_ITS3:Prepare\_Command state for transmission of a COMMAND frame, then this state shall send a Transmit Frame (Interlocked) request to the port layer.

If this state is entered from the ST\_ITS6:Receive\_Data\_In state, and the vendor specific number of retries has not been reached for the COMMAND frame requesting a read operation, then this state shall send a Transmit Frame (Interlocked) request to the port layer.

If this state is entered from the ST\_ITS4:Prepare\_Task state for transmission of an TASK frame, then this state shall send a Transmit Frame (Interlocked) request to the port layer.

If this state is entered from the ST\_ITS5:Prepare\_Data\_Out state for transmission of a write DATA frame, then this state shall send a Transmit Frame (Non-Interlocked) request to the port layer after this state has received an XFER\_RDY Arrived message.

If this state is entered from the ST\_ITS5:Prepare\_Data\_Out state for transmission of a write DATA frame and first burst is enabled, then this state shall send a Transmit Frame (Non-Interlocked) request to the port layer after this state has received a Transmission Status (Frame Transmitted) confirmation and a Transmission Status (ACK Received) confirmation for the COMMAND frame.



A Transmit Frame request shall include the COMMAND frame from the ST\_ITS3:Prepare\_Command state or from the ST\_ITS6:Receive\_Data\_In state, the TASK frame from the ST\_ITS4:Prepare\_Task state, or the write DATA frame from the ST\_ITS5:Prepare\_Data\_Out state and the following arguments to be used for any OPEN address frame:

- a) Initiator Port Bit set to one;
- b) Protocol set to SSP;
- c) Connection Rate;
- d) Initiator Connection Tag;
- e) Destination SAS Address; and
- f) Source SAS Address.

If persistent connections are supported (see 4.1.13.2), then the Transmit Frame request shall include the following additional argument to be used for any OPEN address frame:

- a) Send Extend Bit.

If credit advance is implemented (see 4.1.14), then the Transmit Frame request shall include the following additional argument to be used for an OPEN address frame:

- a) Credit Advance Bit.

After sending a Transmit Frame request this state shall wait to receive a Transmission Status confirmation.

If the confirmation is Transmission Status (I\_T Nexus Loss), then this state shall send a Transmission Complete (I\_T Nexus Loss) message to the ST\_IFR state machine. This Transmission Complete message shall include the initiator port transfer tag as an argument.

If the confirmation is not Transmission Status (Frame Transmitted) or Transmission Status (I\_T Nexus Loss) (see table 152), and the Transmit Frame request was for a COMMAND frame or a DATA frame, then this state shall send a Transmission Complete (Command Failed, Connection Failed) message to the ST\_IFR state machine. The message shall include the initiator port transfer tag.

If the confirmation is not Transmission Status (Frame Transmitted) or Transmission Status (I\_T Nexus Loss) (see table 152), and the Transmit Frame request was for a TASK frame, then this state shall send a Transmission Complete (Task Failed, Connection Failed) message to the ST\_IFR state machine. The message shall include the initiator port transfer tag.

If the confirmation is Transmission Status (Frame Transmitted), and the Transmit Frame request was for a COMMAND frame not requesting a read operation, a COMMAND frame not requesting a write operation, a TASK frame, or a write DATA frame where the number of data bytes that have been transmitted equal the Data-Out Buffer Size state machine argument, then this state shall wait to receive one of the following confirmations:

- a) Transmission Status (ACK Received);
- b) Transmission Status (NAK Received);
- c) Transmission Status (ACK/NAK Timeout); or
- d) Transmission Status (Connection Lost Without ACK/NAK).

If the confirmation is Transmission Status (Frame Transmitted), and the Transmit Frame request was for a COMMAND frame requesting a write operation, or a write DATA frame where the number of data bytes that have been transmitted is less than the Data-Out Buffer Size state machine argument and the write data length from the previous XFER\_RDY frame, then this state shall wait to receive one of the following:

- a) a Transmission Status (ACK Received) confirmation;
- b) a Transmission Status (NAK Received) confirmation;
- c) a Transmission Status (ACK/NAK Timeout) confirmation;
- d) a Transmission Status (Connection Lost Without ACK/NAK) confirmation; or
- e) an XFER\_RDY Arrived message.

If an XFER\_RDY Arrived message is received, then the ST\_ITS shall respond to the XFER\_RDY frame as if a Transmission Status (ACK Received) confirmation was received.

If the number of data bytes requested to be transmitted for the Send SCSI Command transport protocol service request are fewer than the number of bytes in the service request, then this state may send additional Transmit Frame requests for write DATA frames for the transport protocol service request before receiving a Transmission Status (ACK Received), Transmission Status (NAK Received), Transmission Status (ACK/NAK Timeout), or Transmission Status (Connection Lost Without ACK/NAK) confirmation for Transmit Frame requests for previous write DATA frames sent for the I\_T\_L\_Q nexus.

After a Transmission Status (Frame Transmitted) confirmation is received, if a Transmission Status (NAK Received) confirmation is received, the Transmit Frame request was for a COMMAND frame, and the vendor specific number of retries has not been reached, then this state shall send a Transmit Frame (Interlocked) request to the port layer (i.e., the last COMMAND frame is retransmitted).

After a Transmission Status (Frame Transmitted) confirmation is received, if a Transmission Status (NAK Received) confirmation is received, the Transmit Frame request was for a TASK frame, and the vendor specific number of retries has not been reached, then this state shall send a Transmit Frame (Interlocked) request to the port layer (i.e., the last TASK frame is retransmitted).

Table 172 defines the messages that this state shall send to the ST\_IFR state machine upon receipt of the listed confirmations, based on the conditions under which each confirmation was received.

**Table 172 — Messages sent to the ST\_IFR state machine**

| Confirmation received from the port layer                                                      | Conditions under which confirmation was received                                                                                                                                                                                                                                                               | Message sent to the ST_IFR state machine                 |
|------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| Transmission Status (ACK/NAK Timeout) or Transmission Status (Connection Lost Without ACK/NAK) | The Transmit Frame request was for a COMMAND frame.                                                                                                                                                                                                                                                            | Transmission Complete (Command Failed, ACK/NAK Timeout)  |
|                                                                                                | The Transmit Frame request was for a TASK frame.                                                                                                                                                                                                                                                               | Transmission Complete (Task Failed, ACK/NAK Timeout)     |
| Transmission Status (NAK Received)                                                             | The Transmit Frame request was for a COMMAND frame and the vendor specific number of retries has been reached.                                                                                                                                                                                                 | Transmission Complete (Command Failed, NAK Received)     |
|                                                                                                | The Transmit Frame request was for a TASK frame and the vendor specific number of retries has been reached.                                                                                                                                                                                                    | Transmission Complete (Task Failed, NAK Received)        |
| Transmission Status (NAK Received)                                                             | The Transmit Frame request was for a write DATA frame and:<br>a) the RETRY DATA FRAMES bit was set to zero in the XFER_RDY frame requesting the data; or<br>b) the RETRY DATA FRAMES bit was set to one in the XFER_RDY frame requesting the data, and the vendor specific number of retries has been reached. | Transmission Complete (Data-Out Failed, NAK Received)    |
| Transmission Status (ACK/NAK Timeout) or Transmission Status (Connection Lost Without ACK/NAK) |                                                                                                                                                                                                                                                                                                                | Transmission Complete (Data-Out Failed, ACK/NAK Timeout) |

After this state sends a Transmission Complete (Command Failed, ACK/NAK Timeout) message this state shall continue processing messages and confirmations.

If this state receives a Return to Start message or a Return to Start argument, and this state has not received confirmations for all Transmit Frame requests sent to the port layer, then this state shall send a Cancel request to the port layer. This state may also send a Cancel request to the port layer to cancel a previous Transmit Frame request.



If this state receives a Cancel message or a Cancel argument, and this state has received confirmations for all Transmit Frame requests sent to the port layer, then this state shall send a Transmission Complete (Cancel Acknowledged) message to the ST\_IFR state machine.

If this state receives a Cancel message or a Cancel argument, and this state has not received confirmations for all Transmit Frame requests sent to the port layer, then this state shall send a Cancel request to the port layer. This state may also send a Cancel request to the port layer to cancel a previous Transmit Frame request. The Cancel request shall include the following arguments:

- a) Destination SAS Address; and
- b) Initiator Port Transfer Tag.

NOTE 54 - The Cancel message results from a vendor specific request from the SCSI application layer after the SCSI application layer has used a task management function to determine that the SSP target port did not receive the COMMAND frame.

If this state receives a Transmission Status (Cancel Acknowledged) confirmation, then this state shall send a Transmission Complete (Cancel Acknowledged) message to the ST\_IFR state machine.

If this state receives an XFER\_RDY Arrived message, then this state shall verify the Xfer\_Rdy state machine argument as specified in table 173. If the verification fails, then this state shall send the Transmission Complete message specified in table 173 to the ST\_IFR state machine.

**Table 173 — Transmission Complete messages for XFER\_RDY frame verification failures**

| Message sent to the ST_IFR state machine <sup>a</sup>                                                                                                                             | Condition                                                                                                                                                                                                                                                                                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Transmission Complete (XFER_RDY Incorrect Write Data Length)                                                                                                                      | The Write Data Length Xfer_Rdy state machine argument is zero.                                                                                                                                                                                                                                    |
|                                                                                                                                                                                   | The Requested Offset Xfer_Rdy state machine argument plus the Write Data Length Xfer_Rdy state machine argument is greater than the Data-Out Buffer Size state machine argument.                                                                                                                  |
| Transmission Complete (XFER_RDY Requested Offset Error)                                                                                                                           | First burst is disabled, this is the first XFER_RDY frame for a command, and the value in the Requested Offset Xfer_Rdy state machine argument is not set to zero.                                                                                                                                |
|                                                                                                                                                                                   | First burst is enabled, this is the first XFER_RDY frame for a command, and the value in the Requested Offset Xfer_Rdy state machine argument is not equal to the value indicated by the FIRST BURST SIZE field in the Disconnect-Reconnect mode page (see 9.2.7.2.5).                            |
|                                                                                                                                                                                   | Transport layer retries are disabled and the Requested Offset Xfer_Rdy state machine argument is not equal to the Previous Requested Offset state machine variable plus the Previous Write Data Length Field state machine variable.                                                              |
|                                                                                                                                                                                   | Transport layer retries are enabled, the Retransmit Bit Xfer_Rdy state machine argument is set to zero, and the Requested Offset Xfer_Rdy state machine argument is not equal to the Previous Requested Offset state machine variable plus the Previous Write Data Length state machine variable. |
|                                                                                                                                                                                   | Transport layer retries are enabled, this is not the first XFER_RDY frame for the command, the Retransmit Bit Xfer_Rdy state machine argument is set to one, and the Requested Offset Xfer_Rdy state machine argument is not equal to the Previous Requested Offset state machine variable.       |
| <sup>a</sup> If more than one condition is true, then this state shall send the Transmission Complete (XFER_RDY Incorrect Write Data Length) message to the ST_IFR state machine. |                                                                                                                                                                                                                                                                                                   |

After this state verifies an XFER\_RDY frame, this state shall:

- a) set the Data-Out Buffer Offset state machine variable to the Requested Offset Xfer\_Rdy state machine argument;
- b) set the Previous Requested Offset state machine variable to the Requested Offset Xfer\_Rdy state machine argument; and
- c) set the Previous Write Data Length state machine variable to the Write Data Length Xfer\_Rdy state machine argument.

#### 8.2.6.2.3.3.1 Transition ST\_ITS2:Initiator\_Send\_Frame to ST\_ITS1:Initiator\_Start

This transition shall occur after:

- a) this state has sent one of the following to the ST\_IFR state machine:
  - A) a Transmission Complete (Command Failed, ACK/NAK Timeout) message and the command was for a non-data operation;
  - B) a Transmission Complete (Command Failed, Connection Failed) message;
  - C) a Transmission Complete (Command Failed, NAK Received) message;
  - D) a Transmission Complete (Task Failed, ACK/NAK Timeout) message;
  - E) a Transmission Complete (Task Failed, Connection Failed) message;
  - F) a Transmission Complete (Task Failed, NAK Received) message;
  - G) a Transmission Complete (Data-Out Failed, ACK/NAK Timeout) message;
  - H) a Transmission Complete (Data-Out Failed, NAK Received) message;
  - I) a Transmission Complete (XFER\_RDY Incorrect Write Data Length) message;
  - J) a Transmission Complete (XFER\_RDY Requested Offset Error) message; or
  - K) a Transmission Complete (Cancel Acknowledged) message;
- or
- b) this state has received a Return To Start message or Return To Start argument, and has received:
  - A) confirmations for all Transmit Frame requests sent to the port layer; or
  - B) a Transmission Status (Cancel Acknowledged) confirmation.

#### 8.2.6.2.3.3.2 Transition ST\_ITS2:Initiator\_Send\_Frame to ST\_ITS5:Prepare\_Data\_Out

If first burst is enabled, then this transition shall occur and include the First Burst argument after receiving a Transmission Status (Frame Transmitted) confirmation:

- a) followed by a Transmission Status (ACK Received) confirmation for a COMMAND frame requesting a write operation; or
- b) for a Transmit Frame (Non-interlocked) request if the Data-Out Buffer Offset state machine variable is less than the first burst size.

This transition shall occur after receiving:

- a) an XFER\_RDY Arrived message; or
- b) a Transmission Status (Frame Transmitted) confirmation for a Transmit Frame (Non-interlocked) request if the Data-Out Buffer Offset state machine variable is less than the Requested Offset Xfer\_Rdy state machine argument plus the Write Data Length Xfer\_Rdy state machine argument.

NOTE 55 - This transition occurs even if this state has not received a Transmission Status (ACK Received) confirmation for the write DATA frame.

This transition shall include a Retry argument and occur after:

- a) this state receives one of the following confirmations or arguments for a write DATA frame:
  - A) Transmission Status (NAK Received);
  - B) Transmission Status (ACK/NAK Timeout); or
  - C) Transmission Status (Connection Lost without ACK/NAK);
- b) the RETRY DATA FRAMES bit is set to one in the XFER\_RDY frame for the write operation;

- c) the Data-Out Buffer Offset state machine variable is set to the Requested Offset Xfer\_Rdy state machine argument;
- d) all write DATA frames that have received a Transmission Status (Frame Transmitted) confirmation have received a Transmission Status confirmation; and
- e) the vendor specific number of retries, if any, for the write DATA frame has not been reached.

#### 8.2.6.2.3.3.3 Transition ST\_ITS2:Initiator\_Send\_Frame to ST\_ITS6:Receive\_Data\_In

This transition shall occur:

- a) after receiving a Transmission Status (Frame Transmitted) confirmation for a COMMAND frame for a command requesting a read operation.

NOTE 56 - This transition occurs even if this state has not received a Transmission Status (ACK Received) for the COMMAND frame.

#### 8.2.6.2.3.4 ST\_ITS3:Prepare\_Command state

##### 8.2.6.2.3.4.1 State description

This state shall construct a COMMAND frame using the Command arguments:

- a) set the FRAME TYPE field to 06h (i.e., COMMAND frame);
- b) set the HASHED DESTINATION SAS ADDRESS field to the hashed value of the Destination SAS Address Commands argument;
- c) set the HASHED SOURCE SAS ADDRESS field to the hashed value of the SSP initiator port's SAS address;
- d) set the RETRY DATA FRAMES bit to zero;
- e) set the RETRANSMIT bit to zero;
- f) set the CHANGING DATA POINTER bit to zero;
- g) set the NUMBER OF FILL BYTES field to 00b;
- h) set the INITIATOR PORT TRANSFER TAG field to the Initiator Port Transfer Tag Command argument;
- i) TARGET PORT TRANSFER TAG field to FFFFh;
- j) set the DATA OFFSET field to 00000000h;
- k) in the information unit, set the LOGICAL UNIT NUMBER field to the Logical Unit Number Command argument;
- l) in the information unit, set the ENABLE FIRST BURST bit to the Enable First Burst Command argument;
- m) in the information unit, set the COMMAND PRIORITY field to the Command Priority Command argument;
- n) in the information unit, set the TASK ATTRIBUTE field to the Task Attribute Command argument;
- o) in the information unit, set the ADDITIONAL CDB LENGTH field to the Additional CDB Length Command argument;
- p) in the information unit, set the CDB field to the CDB Command argument;
- q) in the information unit, set the ADDITIONAL CDB BYTES field to the Additional CDB Bytes Command argument, if any; and
- r) no fill bytes.

##### 8.2.6.2.3.4.2 Transition ST\_ITS3:Prepare\_Command to ST\_ITS2:Initiator\_Send\_Frame

This transition shall occur after this state:

- a) constructs a COMMAND frame;
- b) receives a Cancel message; or
- c) receives a Return To Start message.

This transition shall include:

- a) if neither a Cancel message nor a Return to Start message was received, then the COMMAND frame as an argument;
- b) if a Cancel message was received, then a Cancel argument; or

- c) if a Return To Start message was received, then a Return To Start argument.

#### 8.2.6.2.3.5 ST\_ITS4:Prepare\_Task state

##### 8.2.6.2.3.5.1 State description

This state shall construct a TASK frame using the Task arguments:

- a) set the FRAME TYPE field to 16h (i.e., TASK frame);
- b) set the HASHED DESTINATION SAS ADDRESS field to the hashed value of the Destination SAS Address Task argument;
- c) set the HASHED SOURCE SAS ADDRESS field to the hashed value of the SSP initiator port's SAS address;
- d) set the RETRY DATA FRAMES bit to zero;
- e) set the RETRANSMIT bit to the Retransmit Bit Task argument;
- f) set the CHANGING DATA POINTER bit to zero;
- g) set the NUMBER OF FILL BYTES field to 00b;
- h) set the INITIATOR PORT TRANSFER TAG field to the Initiator Port Transfer Tag Task argument;
- i) set the TARGET PORT TRANSFER TAG field to FFFFh;
- j) set the DATA OFFSET field to 00000000h;
- k) in the information unit, set the LOGICAL UNIT NUMBER field to the Logical Unit Number Task argument;
- l) in the information unit, set the TASK MANAGEMENT FUNCTION field to the Task Management Function Task argument;
- m) in the information unit, set the INITIATOR PORT TRANSFER TAG TO MANAGE field to the Initiator Port Transfer Tag Task argument of the command to be managed; and
- n) no fill bytes.

##### 8.2.6.2.3.5.2 Transition ST\_ITS4:Prepare\_Task to ST\_ITS2:Initiator\_Send\_Frame

This transition shall occur after this state:

- a) constructs a TASK frame;
- b) receives a Cancel message; or
- c) receives a Return To Start message.

This transition shall include:

- a) if neither a Cancel message nor a Return to Start message was received, then the TASK frame as an argument;
- b) if a Cancel message was received, then a Cancel argument; or
- c) if a Return To Start message was received, then a Return To Start argument.

#### 8.2.6.2.3.6 ST\_ITS5:Prepare\_Data\_Out state

##### 8.2.6.2.3.6.1 State description

This state shall construct a write DATA frame using the following Xfer\_Rdy state machine arguments and Command state machine arguments:

- a) set the FRAME TYPE field to 01h (i.e., DATA frame);
- b) set the HASHED DESTINATION SAS ADDRESS field to the hashed value of the Destination SAS Address Command argument;
- c) set the HASHED SOURCE SAS ADDRESS field to the hashed value of the SSP initiator port's SAS address;
- d) set the RETRY DATA FRAMES bit to zero;
- e) set the RETRANSMIT bit to zero;
- f) set the CHANGING DATA POINTER bit as specified in this subclause;
- g) set the NUMBER OF FILL BYTES field to the number of fill bytes, based on the length of the specified data;

- h) set the INITIATOR PORT TRANSFER TAG field to the Initiator Port Transfer Tag Command argument;
- i) set the TARGET PORT TRANSFER TAG field to FFFFh if this state received a First Burst argument or the Target Port Transfer Tag Xfer\_Rdy argument if this state did not receive a First Burst argument;
- j) set the DATA OFFSET field to the Data-Out Buffer Offset state machine variable;
- k) in the information unit, set the DATA field to the information that starts at the location in the Data-Out Buffer state machine argument pointed to by the Data-Out Buffer Offset state machine variable. If the number of bytes remaining to be transferred as defined by the following calculation:

bytes remaining to be transferred = Write Data Length Xfer\_Rdy state machine argument - (Data-Out Buffer Offset state machine argument - Requested Offset Xfer\_Rdy state machine argument)

is equal to the maximum size of the write Data information unit, then the amount of data shall be the maximum size of the write Data information unit. Otherwise, the amount of data shall be the lesser of:

- A) the bytes remaining to be transferred; and
- B) the maximum size of the Write information unit;

and

- l) fill bytes, if any.

If this state is entered without a Retry argument, then this state shall set the CHANGING DATA POINTER bit to zero.

If this state is entered with a Retry argument, then this state shall set the CHANGING DATA POINTER bit to one.

After constructing the write DATA frame, this state shall set the Data-Out Buffer Offset state machine variable to the value of the DATA OFFSET field plus the number of bytes in the DATA field in the write Data information unit.

#### 8.2.6.2.3.6.2 Transition ST\_ITS5:Prepare\_Data\_Out to ST\_ITS2:Initiator\_Send\_Frame

This transition shall occur after this state:

- a) constructs a write DATA frame;
- b) receives a Cancel message; or
- c) receives a Return To Start message.

This transition shall include the received Transmission Status, if any, as an argument and:

- a) if neither a Cancel message nor a Return to Start message was received, then the write DATA frame as an argument;
- b) if a Cancel message was received, then a Cancel argument; or
- c) if a Return To Start message was received, then a Return To Start argument.

#### 8.2.6.2.3.7 ST\_ITS6:Receive\_Data\_In state

##### 8.2.6.2.3.7.1 State description

If this state receives a Data-In Arrived message, then this state shall verify the values in the read DATA frame received with the message as defined in table 174.

If the verification fails, then this state sends the Reception Complete message specified in table 174 to the ST\_IFR state machine.

**Table 174 — Reception Complete messages for read DATA frame verification failures**

| Message sent to the ST_IFR state machine <sup>a</sup>                                                                                                                                                                                                                                                             | Condition                                                                                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Reception Complete (Data Offset Error)                                                                                                                                                                                                                                                                            | Transport layer retries are disabled, and the DATA OFFSET field in the read DATA frame is not equal to the Data-In Buffer Offset state machine variable.                                                           |
|                                                                                                                                                                                                                                                                                                                   | The DATA OFFSET field in the read DATA frame is greater than the Data-In Buffer Size state machine argument.                                                                                                       |
| Reception Complete (Too Much Read Data)                                                                                                                                                                                                                                                                           | The number of bytes in the DATA field in the read Data information unit plus the Data-In Buffer Offset state machine variable is greater than the Data-In Buffer Size state machine argument.                      |
| Reception Complete (Information Unit Too Short)                                                                                                                                                                                                                                                                   | Either:<br>a) the number of bytes in the DATA field in the read Data information unit is zero; or<br>b) this is not the last read DATA frame for the command and the NUMBER OF FILL BYTES field is not set to 00b. |
| <sup>a</sup> If more than one condition is true, then this state shall select which message to send to the ST_IFR state machine using the following order:<br>1) Reception Complete (Data Offset Error);<br>2) Reception Complete (Too Much Read Data); or<br>3) Reception Complete (Information Unit Too Short). |                                                                                                                                                                                                                    |

If:

- a) transport layer retries are enabled;
- b) the CHANGING DATA POINTER bit is set to zero;
- c) the DATA OFFSET field is not set to the Data-In Buffer Offset state machine variable;
- d) the DATA OFFSET field is less than the Data-In Buffer Size state machine argument; and
- e) the DATA OFFSET field plus the number of bytes in the DATA field in the read Data information unit is less than or equal to the Data-In Buffer Size state machine argument,

then this state should discard all Data-In Arrived messages until a read DATA frame is received in which the CHANGING DATA POINTER bit is set to one. This state shall resume processing additional Data-In Arrived messages when it receives a Data-In Arrived message with the CHANGING DATA POINTER bit set to one.

If the read DATA frame verification is successful or after this state resumes processing Data-In Arrived messages, then this state shall process the data received in the read DATA frame and set the Data-In Buffer Offset state machine variable to the DATA OFFSET field plus the number of bytes in the DATA field in the read Data information unit.

If data received in the read DATA frame overlaps data previously received and verified as having no errors, then this state may either discard the overlapping data, or replace the previously received data with the new data.

If this state receives a Transmission Status (ACK/NAK Timeout) confirmation or a Transmission Status (Connection Lost Without ACK/NAK) confirmation, then this state shall send a Reception Complete (Command Failed, ACK/NAK Timeout) message to the ST\_IFR state machine.

After this state sends a Reception Complete (Command Failed, ACK/NAK Timeout) message, this state shall continue processing messages and confirmations.

If this state receives a Cancel message, then this state shall send a Reception Complete (Cancel Acknowledged) message to the ST\_IFR state machine. The Reception Complete message shall include the initiator port transfer tag as an argument.

NOTE 57 - The Cancel message results from a vendor specific request from the SCSI application layer after the SCSI application layer has used a task management function to determine that the SSP target port did not receive the COMMAND frame.

#### 8.2.6.2.3.7.2 Transition ST\_ITS6:Receive\_Data\_In to ST\_ITS1:Initiator\_Start

This transition shall occur after this state:

- a) sends one of the following to the ST\_IFR state machine:
  - A) a Reception Complete (Data Offset Error) message;
  - B) a Reception Complete (Too Much Read Data) message;
  - C) a Reception Complete (Incorrect Data Length) message; or
  - D) a Reception Complete (Cancel Acknowledged) message;
- or
- b) receives a Return To Start message.

#### 8.2.6.2.3.7.3 Transition ST\_ITS6:Receive\_Data\_In to ST\_ITS2:Initiator\_Send\_Frame

This transition shall occur:

- a) after this state receives a Transmission Status (NAK Received) confirmation for a COMMAND frame for a command requesting a read operation.

### 8.2.6.3 ST\_T (transport layer for SSP target ports) state machines

#### 8.2.6.3.1 ST\_T state machines overview

The ST\_T state machines are as follows:

- a) ST\_TFR (target frame router) state machine (see 8.2.6.3.2); and
- b) ST\_TTS (target transport server) state machine (see 8.2.6.3.3).

The SAS target port includes:

- a) one ST\_TFR state machine; and
- b) one ST\_TTS state machine for each possible command and task management function (i.e., for each initiator port transfer tag).

This state machine may maintain the timers listed in table 175.

**Table 175 — ST\_T state machine timers**

| Timer                      | Initial value                                                                                            |
|----------------------------|----------------------------------------------------------------------------------------------------------|
| Initiator Response Timeout | The value in the INITIATOR RESPONSE TIMEOUT field in the Protocol Specific Port mode page (see 9.2.7.4). |



Figure 168 shows the ST\_T state machines.

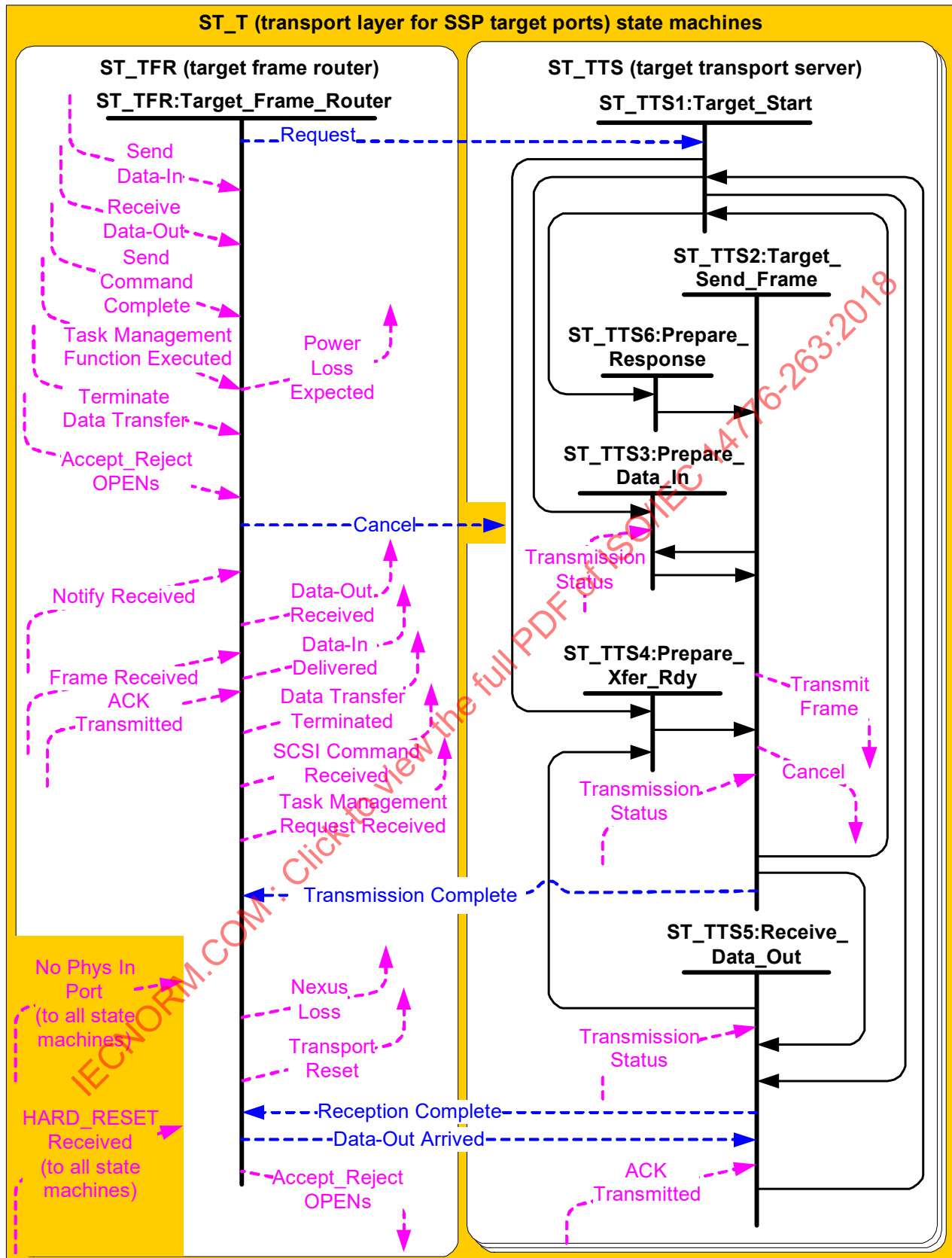


Figure 168 — ST\_T (transport layer for SSP target ports) state machines



### 8.2.6.3.2 ST\_TFR (target frame router) state machine

#### 8.2.6.3.2.1 ST\_TFR state machine overview

The ST\_TFR state machine performs the following functions:

- a) receives confirmations from the port layer;
- b) receives transport protocol service requests from the SCSI application layer;
- c) sends transport protocol service indications to the SCSI application layer;
- d) sends messages to the ST\_TTS state machine;
- e) receives messages from the ST\_TTS state machine;
- f) receives Accept\_Reject OPENs requests from the SCSI application layer;
- g) sends Accept\_Reject OPENs requests to the port layer;
- h) sends Nexus Loss event notifications to the SCSI application layer;
- i) sends Transport Reset event notifications to the SCSI application layer; and
- j) sends Power Loss Expected event notifications to the SCSI application layer.

This state machine consists of one state.

This state machine shall be started after power on.

If this state receives a Notify Received (Power Loss Expected) confirmation, then this state shall:

- a) send a Cancel message to all the ST\_TTS state machines; and
- b) send a Power Loss Expected confirmation to the SCSI application layer.

#### 8.2.6.3.2.2 Processing Frame Received confirmations

If this state machine receives a Frame Received (ACK/NAK Balanced) or Frame Received (ACK/NAK Not Balanced) confirmation, then this state machine shall check the frame type in the received frame (see table 156 in 8.2.1). If the frame type is not COMMAND, TASK, or DATA, then this state machine shall discard the frame. If the confirmation was Frame Received (ACK/NAK Not Balanced) and the frame type is not DATA, then this state machine shall discard the frame.

This state machine may check that reserved fields in the received frame are zero. If non-zero values are not supported in the TLR CONTROL field in a COMMAND frame, then the TLR CONTROL field shall be treated as a reserved field. If any reserved fields are checked and they are not set to zero, then this state machine shall send the following to an ST\_TTS state machine that does not have an active command or task management function and discard the frame:

- a) a Request (Send Transport Response) message with the Transport Response arguments;
- b) the Destination SAS Address argument set to the SAS address from which the invalid frame was received; and
- c) the Service Response argument set to Invalid Frame.

The check of reserved fields within the frame shall not apply to the reserved fields within the CDB in a COMMAND frame. Checking of reserved fields in a CDB is described in SPC-4.

The following is the list of Transport Response arguments:

- a) Connection Rate;
- b) Initiator Connection Tag;
- c) Destination SAS Address (i.e., the SAS address to which the RESPONSE frame is to be transmitted);
- d) Source SAS Address set to the SAS address of the SAS port containing the state machine;
- e) Initiator Port Transfer Tag; and
- f) Service Response.

The Response Fence argument is not included in the Transport Response arguments.

If the frame type is correct relative to the Frame Received confirmation, then this state machine may check that the hashed source SAS address matches the SAS address of the SAS port that transmitted the frame and that the hashed destination SAS address matches the SAS address of the SAS port that received the

frame based on the connection information. If this state machine checks these SAS addresses, and they do not match, then this state machine shall discard the frame.

If the frame type is COMMAND or TASK then this state machine shall check the length of the information unit. If the length of the information unit is not correct, then this state machine shall send the following to an ST\_TTS state machine that does not have an active command or task management function and discard the frame:

- a) a Request (Send Transport Response) message with the Transport Response arguments;
- b) the Destination SAS Address argument set to the SAS address from which the invalid frame was received; and
- c) the Service Response argument set to Invalid Frame.

If the frame type is TASK, this state machine checks initiator port transfer tags, the RETRANSMIT bit is set to one in the new TASK frame, and the initiator port transfer tag for the new TASK frame is the same as the initiator port transfer tag for a previous TASK frame where the task management function for the previous TASK frame is not complete, then this state machine shall discard the new TASK frame and not send a Task Management Request Received confirmation to the SCSI application layer.

If the frame type is TASK and this state machine does not check initiator port transfer tags, then this state machine shall ignore the RETRANSMIT bit.

If the frame type is COMMAND or TASK, then this state machine may check the target port transfer tag. If this state checks the target port transfer tag and it is set to a value other than FFFFh, then this state machine shall send the following to an ST\_TTS state machine that does not have an active command or task management function and discard the frame:

- a) a Request (Send Transport Response) message with the Transport Response arguments;
- b) the Destination SAS Address argument set to the SAS address from which the invalid frame was received; and
- c) the Service Response argument set to Invalid Frame.

If the frame type is TASK, then this state machine shall check the logical unit number. If the logical unit number is unknown, then this state machine shall send the following to an ST\_TTS state machine that does not have an active command or task management function and discard the frame:

- a) a Request (Send Transport Response) message with the Transport Response arguments;
- b) the Destination SAS Address argument set to the SAS address from which the invalid frame was received; and
- c) the Service Response argument set to Incorrect Logical Unit Number.

If:

- a) the frame type is DATA and this frame is for first burst data; or
- b) this state machine did not assign a target port transfer tag for the data transfer,

then this state machine may check the target port transfer tag. If the target port transfer tag is set to a value other than FFFFh, then this state machine shall send the following to an ST\_TTS state machine that does not have an active command or task management function and discard the frame:

- a) a Request (Send Transport Response) message with the Transport Response arguments;
- b) the Destination SAS Address argument set to the SAS address from which the invalid frame was received; and
- c) the Service Response argument set to Invalid Frame.

If the frame type is COMMAND or TASK and the fields checked in the frame are correct, then this state machine shall wait to receive an ACK Transmitted confirmation.

If the frame type is COMMAND, the fields checked in the frame are correct, and this state machine receives an ACK Transmitted confirmation, then this state machine shall send a SCSI Command Received transport protocol service indication with the following arguments to the SCSI application layer:

- a) Source SAS Address (i.e., the SAS address that transmitted the COMMAND frame);
- b) Initiator Port Transfer Tag;

- c) Logical Unit Number;
- d) Task Attribute;
- e) Command Priority;
- f) CDB; and
- g) Additional CDB Bytes, if any.

If the frame type is TASK, the fields checked in the frame are correct, and this state machine receives an ACK Transmitted confirmation, then this state machine shall send a Task Management Request Received transport protocol service indication with the following arguments to the SCSI application layer:

- a) Source SAS Address (i.e., the SAS address that transmitted the TASK frame);
- b) Initiator Port Transfer Tag;
- c) Logical Unit Number;
- d) Task Management Function; and
- e) Initiator Port Transfer Tag To Manage.

If the frame type is DATA, and the initiator port transfer tag does not match an initiator port transfer tag for an outstanding command performing write operations, then this state machine shall discard the frame.

If the frame type is DATA, and the initiator port transfer tag matches an initiator port transfer tag for an outstanding command performing write operations when first burst is disabled or for which no Transmission Complete (Xfer\_Rdy Delivered) message has been received from an ST\_TTS state machine, then this state machine shall discard the frame.

If the frame type is DATA and a target port transfer tag was received in a Transmission Complete (Xfer\_Rdy Delivered) message, then this state machine shall check the target port transfer tag. If the target port transfer tag received in the DATA frame does not match the Target Port Transfer Tag argument in the Transmission Complete (Xfer\_Rdy Delivered) message, then this state machine shall discard the frame.

If the frame type is DATA and the fields checked in the frame are correct, and first burst is enabled or this state machine has received a Transmission Complete (Xfer\_Rdy Delivered) from the ST\_TTS state machine for the request, then this state machine shall send a Data-Out Arrived message to the ST\_TTS state machine specified by the initiator port transfer tag in the frame. The message shall include the content of the write DATA frame.

#### 8.2.6.3.2.3 Processing transport protocol service requests and responses

If this state machine receives a Send Data-In transport protocol service request from the SCSI application layer, then this state machine shall send a Request (Send Data-In) message to an ST\_TTS state machine that does not have an active command or task management function. The message shall include the following Data-In arguments:

- a) Connection Rate;
- b) Initiator Connection Tag;
- c) Destination SAS Address (i.e., the SAS address to which the read DATA frame is to be transmitted);
- d) Source SAS Address set to the SAS address of the SSP target port;
- e) Initiator Port Transfer Tag;
- f) Device Server Buffer;
- g) Request Byte Count; and
- h) Application Client Buffer Offset.

If this state machine receives a Receive Data-Out transport protocol service request from the SCSI application layer, then this state machine shall send a Request (Receive Data-Out) message to an ST\_TTS state machine that does not have an active command or task management function. The message shall include the following Data-Out state machine arguments:

- a) Connection Rate;
- b) Initiator Connection Tag;
- c) Destination SAS Address (i.e., the SAS address to which the XFER\_RDY frame is to be transmitted);
- d) Source SAS Address set to the SAS address of the SSP target port;
- e) Initiator Port Transfer Tag;

- f) Device Server Buffer;
- g) Request Byte Count;
- h) Application Client Buffer Offset; and
- i) Target Port Transfer Tag.

If first burst is enabled, then the Request (Receive Data\_Out) message shall also include the Enable First Burst argument and First Burst Size argument. The First Burst Size argument shall be set to the first burst size from the Disconnect-Reconnect mode page (see 9.2.7.2.5).

If this state machine receives a Send Command Complete transport protocol service response from the SCSI application layer with the Service Response argument set to TASK COMPLETE, then this state machine shall send a Request (Send Application Response) message to the ST\_TTS state machine specified by the initiator port transfer tag. The message shall include the following Application Response arguments:

- a) Connection Rate;
- b) Initiator Connection Tag;
- c) Destination SAS Address (i.e., the SAS address to which the RESPONSE frame is to be transmitted);
- d) Source SAS Address set to the SAS address of the SSP target port;
- e) Initiator Port Transfer Tag;
- f) Status;
- g) Status Qualifier, if any;
- h) Sense Data, if any; and
- i) Response Fence.

If this state machine receives a Task Management Function Executed transport protocol service response from the SCSI application layer, then this state machine shall send the following to the ST\_TTS state machine specified by the initiator port transfer tag:

- a) a Request (Send Transport Response) message with the Transport Response arguments;
- b) the Service Response argument set as specified in table 176; and
- c) the Response Fence argument set to the Task Management Function Executed transport protocol service response Response Fence argument.

Table 176 specifies which argument to send with the Request (Send Transport Response) message based on the Service Response argument that was received.

**Table 176 — Task Management Function Executed Service Response argument mapping to Request (Send Transport Response) Service Response argument**

| <b>Task Management Function Executed transport protocol service response Service Response argument received</b> | <b>Request (Send Transport Response) message Service Response argument</b> |
|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| FUNCTION COMPLETE                                                                                               | Task Management Function Complete                                          |
| FUNCTION SUCCEEDED                                                                                              | Task Management Function Succeeded                                         |
| FUNCTION REJECTED                                                                                               | Task Management Function Not Supported                                     |
| INCORRECT LOGICAL UNIT NUMBER                                                                                   | Incorrect Logical Unit Number                                              |
| SERVICE DELIVERY OR TARGET FAILURE - Overlapped Initiator Port Transfer Tag Attempted                           | Overlapped Initiator Port Transfer Tag Attempted                           |

If this state machine receives a Terminate Data Transfer transport protocol service request from the SCSI application layer and this state machine has not sent a Request message to a ST\_TTS state machine for the Send Data-In or Receive Data-Out transport protocol service request to which the Terminate Data Transfer request applies, then this state machine shall:

- 1) discard the Terminate Data Transfer transport protocol service request and any corresponding Send Data-In or Receive Data-Out transport protocol service request; and

- 2) send a Data Transfer Terminated transport protocol service confirmation to the SCSI application layer.

If this state machine receives a Terminate Data Transfer transport protocol service request from the SCSI application layer and this state machine has sent a Request message to a ST\_TTS state machine for the Send Data-In transport protocol service request to which the Terminate Data Transfer request applies, then this state machine shall send a Cancel message to the ST\_TTS state machine specified by the initiator port transfer tag and the Send Data-In transport protocol service request.

If this state machine receives a Terminate Data Transfer transport protocol service request from the SCSI application layer and this state machine has sent a Request message to a ST\_TTS state machine for the Receive Data-Out transport protocol service request to which the Terminate Data Transfer request applies, then this state machine shall send a Cancel message to the ST\_TTS state machine specified by the initiator port transfer tag and the Receive Data-Out transport protocol service request.

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This state machine receives Transmission Complete and Reception Complete messages that may result in this state machine sending a Nexus Loss event notification or a transport protocol service confirmation to the SCSI application layer. If this state machine receives a Transmission Complete (I\_T Nexus Loss) message, then this state machine shall send a Nexus Loss event notification to the SCSI application layer. Table 177 defines messages received from ST\_TTS state machines and the corresponding transport protocol service confirmations, if any, that shall be sent upon receipt of the message.

**Table 177 — Confirmations sent to the SCSI application layer**

| Message received from ST_TTS state machine                                                                                                                                                                      | Transport protocol service confirmation sent to SCSI application layer                                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Transmission Complete (Xfer_Rdy Delivered)                                                                                                                                                                      | None                                                                                                     |
| Transmission Complete (Response Delivered)                                                                                                                                                                      | None                                                                                                     |
| Transmission Complete (Response Failed) <sup>a</sup>                                                                                                                                                            | None                                                                                                     |
| Transmission Complete (Data Transfer Terminated)                                                                                                                                                                | Data Transfer Terminated                                                                                 |
| Transmission Complete (Data-In Delivered)                                                                                                                                                                       | Data-In Delivered with the Delivery Result argument set to DELIVERY SUCCESSFUL                           |
| Transmission Complete (Xfer_Rdy Failed, NAK Received)                                                                                                                                                           | Data-Out Received with the Delivery Result argument set to DELIVERY FAILURE - NAK RECEIVED               |
| Transmission Complete (Xfer_Rdy Failed, Connection Failed)                                                                                                                                                      | Data-Out Received with the Delivery Result argument set to DELIVERY FAILURE - CONNECTION FAILED          |
| Transmission Complete (Data-In Failed, NAK Received)                                                                                                                                                            | Data-In Delivered with the Delivery Result argument set to DELIVERY FAILURE - NAK RECEIVED               |
| Transmission Complete (Data-In Failed, ACK/NAK Timeout)                                                                                                                                                         | Data-In Delivered with the Delivery Result argument set to DELIVERY FAILURE - ACK/NAK TIMEOUT            |
| Transmission Complete (Data-In Failed, Connection Lost without ACK/NAK)                                                                                                                                         | Data-In Delivered with the Delivery Result argument set to DELIVERY FAILURE - CONNECTION FAILED          |
| Reception Complete (Data-Out Received)                                                                                                                                                                          | Data-Out Received with the Delivery Result argument set to DELIVERY SUCCESSFUL                           |
| Reception Complete (Data Offset Error)                                                                                                                                                                          | Data-Out Received with the Delivery Result argument set to DELIVERY FAILURE - DATA OFFSET ERROR          |
| Reception Complete (Too Much Write Data)                                                                                                                                                                        | Data-Out Received with the Delivery Result argument set to DELIVERY FAILURE - TOO MUCH WRITE DATA        |
| Reception Complete (Information Unit Too Short)                                                                                                                                                                 | Data-Out Received with the Delivery Result argument set to DELIVERY FAILURE - INFORMATION UNIT TOO SHORT |
| Reception Complete (Initiator Response Timeout)                                                                                                                                                                 | Data-Out Received with the Delivery Result argument set to DELIVERY FAILURE - INITIATOR RESPONSE TIMEOUT |
| Reception Complete (Data Transfer Terminated)                                                                                                                                                                   | Data Transfer Terminated                                                                                 |
| <sup>a</sup> SAM-5 does not define a mechanism for the SCSI device server to determine the result of its Send Command Complete and Task Management Function Executed transport protocol service response calls. |                                                                                                          |

Each transport protocol service confirmation shall include the initiator port transfer tag as an argument.

#### 8.2.6.3.2.4 Processing miscellaneous requests and confirmations

If this state machine receives an Accept\_Reject OPENs (Accept SSP) request or an Accept\_Reject OPENs (Reject SSP) request, then this state machine shall send an Accept\_Reject OPENs request with the same arguments to the port layer.

If this state machine receives a HARD\_RESET Received confirmation, then this state shall send a Transport Reset event notification to the SCSI application layer.

If this state machine receives a No Phys In Port confirmation, then this state shall send a Nexus Loss event notification to the SCSI application layer.

#### 8.2.6.3.3 ST\_TTS (target transport server) state machine

##### 8.2.6.3.3.1 ST\_TTS state machine overview

The ST\_TTS state machine performs the following functions:

- a) receives and processes messages from the ST\_TFR state machine;
- b) sends messages to the ST\_TFR state machine;
- c) communicates with the port layer using requests and confirmations regarding frame transmission; and
- d) receives HARD\_RESET Received confirmations and No Phys In Port confirmations from the port layer.

This state machine consists of the following states:

- a) ST\_TTS1:Target\_Start (see 8.2.6.3.3.2) (initial state);
- b) ST\_TTS2:Target\_Send\_Frame (see 8.2.6.3.3.3);
- c) ST\_TTS3:Prepare\_Data\_In (see 8.2.6.3.3.4);
- d) ST\_TTS4:Prepare\_Xfer\_Rdy (see 8.2.6.3.3.5);
- e) ST\_TTS5:Receive\_Data\_Out (see 8.2.6.3.3.6); and
- f) ST\_TTS6:Prepare\_Response (see 8.2.6.3.3.7).

This state machine shall start in the ST\_TTS1:Target\_Start state after power on.

If this state machine receives a HARD\_RESET Received confirmation or a No Phys In Port confirmation, then this state machine shall transition to the ST\_TTS1:Target\_Start state.



The state machine shall maintain the state machine variables defined in table 178.

**Table 178 — ST\_TTS state machine variables**

| State machine variable         | Description                                                                                                                                                                                                                                                        |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Read Data Offset               | Offset into the application client's data-in buffer (i.e., the application client buffer for read data)                                                                                                                                                            |
| Balance Point Read Data Offset | Offset into the application client's data-in buffer (i.e., the application client buffer for read data) of last point at which the number of Transmission Status (ACK Received) confirmations or arguments was equal to the number of transmitted read DATA frames |
| Read Data Frames Transmitted   | The number of Transmission Status (Frame Transmitted) confirmations received for read DATA frames                                                                                                                                                                  |
| Read Data Frames ACKed         | The number of Transmission Status (ACK Received) confirmations received for read DATA frames                                                                                                                                                                       |
| Read Data Buffer End           | One greater than the offset into the application client's data-in buffer (i.e., the application client buffer for read data) of the last location into which read data is to be placed.                                                                            |
| Requested Write Data Offset    | SCSI device server requested offset in the application client buffer for write data                                                                                                                                                                                |
| Requested Write Data Length    | Amount of write data requested by the SCSI device server from the application client buffer                                                                                                                                                                        |
| Write Data Offset              | Offset into the application client's data-out buffer (i.e., the application client buffer containing write data)                                                                                                                                                   |

This state machine shall maintain the state machine arguments defined in table 179.

**Table 179 — ST\_TTS state machine arguments**

| State machine argument | Description                                                                                 |
|------------------------|---------------------------------------------------------------------------------------------|
| Data-In                | The Data-In arguments received in the Request (Send Data-In) message (see 8.2.6.3.2.3)      |
| Data-Out               | The Data-Out arguments received in the Request (Receive Data-Out) message (see 8.2.6.3.2.3) |

#### 8.2.6.3.3.2 ST\_TTS1:Target\_Start state

##### 8.2.6.3.3.2.1 State description

This state is the initial state of the ST\_TTS state machine.

Upon entry into this state, this state shall:

- set the Read Data Offset state machine variable to the Application Client Buffer Offset Data-In state machine argument;
- set the Balance Point Read Data Offset state machine variable to the Application Client Buffer Offset Data-In state machine argument;
- set the Read Data Frames Transmitted state machine variable to zero;



- d) set the Read Data Frames ACKed state machine variable to zero;
- e) set the Read Data Buffer End state machine variable to the Application Client Buffer Offset Data-In state machine argument plus the Request Byte Count Data-In state machine argument; and
- f) set the Requested Write Data Offset state machine variable to the Application Client Buffer Offset Data-Out state machine argument.

If this state was entered without an Enable First Burst Data-Out state machine argument, then the Requested Write Data Length state machine variable shall be set to the Request Byte Count Data-Out state machine argument.

If this state was entered with an Enable First Burst Data-Out state machine argument, then the Requested Write Data Length state machine variable shall be set to the First Burst Size Data-Out state machine argument.

#### 8.2.6.3.3.2.2 Transition ST\_TTS1:Target\_Start to ST\_TTS3:Prepare\_Data\_In

This transition shall occur:

- a) after receiving a Request (Send Data-In) message.

#### 8.2.6.3.3.2.3 Transition ST\_TTS1:Target\_Start to ST\_TTS4:Prepare\_Xfer\_Rdy

If this state was entered without an Enable First Burst Data-Out state machine argument, then this transition shall occur:

- a) after a Request (Receive Data-Out) message is received.

#### 8.2.6.3.3.2.4 Transition ST\_TTS1:Target\_Start to ST\_TTS5:Receive\_Data\_Out

If this state was entered with an Enable First Burst Data-Out state machine argument, then this transition shall occur:

- a) after a Request (Receive Data-Out) message is received.

#### 8.2.6.3.3.2.5 Transition ST\_TTS1:Target\_Start to ST\_TTS7:Prepare\_Response

This transition shall occur:

- a) after receiving a Request (Send Transport Response) message.

The transition shall include:

- a) the Transport Response arguments.

#### 8.2.6.3.3.3 ST\_TTS2:Target\_Send\_Frame state

##### 8.2.6.3.3.3.1 State description

If this state is entered from the ST\_TTS3:Prepare\_Data\_In state for transmission of a read DATA frame, then this state shall send a Transmit Frame (Non-Interlocked) request to the port layer.

If this state is entered from the ST\_TTS4:Prepare\_Xfer\_Rdy state for transmission of an XFER\_RDY frame, then this state shall send a Transmit Frame (Interlocked) request to the port layer.

If this state is entered from the ST\_TTS6:Prepare\_Response state for transmission of a RESPONSE frame, then this state shall send a Transmit Frame (Interlocked) request to the port layer.

All Transmit Frame requests from this state shall include the read DATA frame from the ST\_TTS3:Prepare\_Data\_In state, the XFER\_RDY frame from the ST\_TTS4:Prepare\_Xfer\_Rdy state, or the RESPONSE frame from the ST\_TTS6:Prepare\_Response state and the following arguments to be used for any OPEN address frame:

- a) Initiator Port Bit set to zero;

- b) Protocol set to SSP;
- c) Connection Rate;
- d) Initiator Connection Tag;
- e) Destination SAS Address; and
- f) Source SAS Address.

If persistent connections are supported (see 4.1.13.2), then the Transmit Frame request shall include the following additional argument to be used for any OPEN address frame:

- a) Send Extend Bit set to zero.

If credit advance is implemented (see 4.1.14), then the Transmit Frame request shall include the following additional argument to be used for an OPEN address frame:

- a) Credit Advance Bit.

After sending a Transmit Frame request, this state shall wait to receive a Transmission Status confirmation.

If the confirmation or argument is Transmission Status (I\_T Nexus Loss), then this state shall send a Transmission Complete (I\_T Nexus Loss) message to the ST\_TFR state machine. The Transmission Complete message shall include the initiator port transfer tag as an argument.

If the confirmation or argument is not Transmission Status (Frame Transmitted) or Transmission Status (I\_T Nexus Loss), then this state shall send the Transmission Complete message defined in table 180 to the ST\_TFR state machine. The message shall include the following arguments:

- a) Initiator Port Transfer Tag; and
- b) arguments received with the Transmission Status confirmation.

If the confirmation is Transmission Status (Frame Transmitted) and the Transmit Frame request was for:

- a) an XFER\_RDY frame; or
- b) a RESPONSE frame,

then this state shall wait to receive one of the following confirmations:

- a) Transmission Status (ACK Received);
- b) Transmission Status (NAK Received);
- c) Transmission Status (ACK/NAK Timeout); or
- d) Transmission Status (Connection Lost Without ACK/NAK).

If the confirmation is Transmission Status (Frame Transmitted) and the Transmit Frame request was for a read DATA frame, then this state shall:

- a) increment the Read Data Frames Transmitted state machine variable by one; and
- b) set the Read Data Offset state machine variable to the current Read Data Offset state machine variable plus the number of read data bytes transmitted in the DATA frame associated with the Transmission Status (Frame Transmitted) confirmation.

If the confirmation is Transmission Status (ACK Received) and the Transmit Frame request was for a read DATA frame, then this state shall increment the Read Data Frames ACKed state machine variable by one.

If the confirmation is Transmission Status (Frame Transmitted), the Transmit Frame request was for a read DATA frame, and the Read Data Offset state machine variable is equal to the Read Data Buffer End state machine variable, then this state shall wait to receive:

- a) Transmission Status (ACK Received) confirmations or arguments for each outstanding read DATA frame (i.e., Read Data Frames Transmitted state machine variable equals the Read Data Frames ACKed state machine variable); or
- b) one of the following confirmations:
  - A) Transmission Status (NAK Received);
  - B) Transmission Status (ACK/NAK Timeout); or
  - C) Transmission Status (Connection Lost Without ACK/NAK).

NOTE 58 - If the number of data bytes that have been transmitted for a Request (Send Data-In) message are fewer than the Request Byte Count Data-In state machine argument, then this state transitions to the ST\_TTS3:Prepare\_Data\_In state to construct the additional read DATA frames for the request before receiving a Transmission Status (ACK Received), Transmission Status (NAK Received), Transmission Status (ACK/NAK Timeout), or Transmission Status (Connection Lost Without ACK/NAK) confirmation.

When the Read Data Frames Transmitted state machine variable equals the Read Data Frames ACKed state machine variable and the Transmit Frame request was for a read DATA frame, this state shall:

- a) not modify the Balance Point Read Data Offset state machine variable (i.e., the balance point remains at the last point at which balance occurred); or
- b) set the Balance Point Read Data Offset state machine variable to the current Read Data Offset state machine variable.

If the Transmit Frame request was for a RESPONSE frame, the vendor specific number of retries has not been reached, and this state receives one of the following confirmations:

- a) Transmission Status (NAK Received);
- b) Transmission Status (ACK/NAK Timeout); or
- c) Transmission Status (Connection Lost Without ACK/NAK),

then this state shall:

- a) set the RETRANSMIT bit to one;
- b) set the other fields to the same values as contained in the failed RESPONSE frame; and
- c) resend a Transmit Frame (Interlocked) request to the port layer for the failed RESPONSE frame.

If transport layer retries are enabled, the Transmit Frame request was for an XFER\_RDY frame, the vendor specific number of retries has not been reached, and this state receives one of the following confirmations:

- a) Transmission Status (NAK Received);
- b) Transmission Status (ACK/NAK Timeout); or
- c) Transmission Status (Connection Lost Without ACK/NAK),

then this state shall:

- a) set the RETRANSMIT bit to one;
- b) set the TARGET PORT TRANSFER TAG field to a value that is different than the target port transfer tag in the previous XFER\_RDY frame associated with the Data-Out state machine arguments and is different than any other target port transfer tag currently in use. If write data is received for a subsequent XFER\_RDY frame for a command, then all target port transfer tags used for previous XFER\_RDY frames for the command are no longer in use;
- c) set the other fields to the same values contained in the failed XFER\_RDY frame; and
- d) resend a Transmit Frame (Interlocked) request to the port layer for the failed XFER\_RDY frame.

Table 180 defines messages that this state shall send to the ST\_TFR state machine upon receipt of the listed confirmations and arguments, based on the conditions under which each confirmation or argument was received.

**Table 180 — Messages sent to the ST\_TFR state machine**

| Confirmation received from the port layer or argument received from ST_TTS3:Prepare_Data_In                                         | Conditions under which confirmation was received                                                                                                                                                                                              | Message sent to the ST_TFR state machine                                            |
|-------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Transmission Status (ACK Received)                                                                                                  | The Transmit Frame request was for an XFER_RDY frame.                                                                                                                                                                                         | Transmission Complete (Xfer_Rdy Delivered) with a Target Port Transfer Tag argument |
|                                                                                                                                     | The Transmit Frame request was for a RESPONSE frame.                                                                                                                                                                                          | Transmission Complete (Response Delivered)                                          |
|                                                                                                                                     | The Transmit Frame request was for a read DATA frame and the Read Data Offset state machine variable is equal to:<br>a) the Read Data Buffer End state machine variable; and<br>b) the Balance Point Read Data Offset state machine variable. | Transmission Complete (Data-In Delivered)                                           |
| Transmission Status (NAK Received), Transmission Status (ACK/NAK Timeout), or Transmission Status (Connection Lost Without ACK/NAK) | The Transmit Frame request was for a RESPONSE frame and the vendor specific number of retries has been reached.                                                                                                                               | Transmission Complete (Response Failed)                                             |
| Transmission Status (NAK Received)                                                                                                  | The Transmit Frame request was for an XFER_RDY frame and if transport layer retries are:<br>a) disabled; or<br>b) enabled and the vendor specific number of retries has been reached.                                                         | Transmission Complete (Xfer_Rdy Failed, NAK Received)                               |
| Transmission Status (ACK/NAK Timeout) or Transmission Status (Connection Lost Without ACK/NAK)                                      |                                                                                                                                                                                                                                               | Transmission Complete (Xfer_Rdy Failed, Connection Failed)                          |
| Transmission Status (NAK Received)                                                                                                  | The Transmit Frame request was for a read DATA frame and if transport layer retries are:<br>a) disabled; or<br>b) enabled and the vendor specific number of retries has been reached.                                                         | Transmission Complete (Data-In Failed, NAK Received)                                |
| Transmission Status (ACK/NAK Timeout)                                                                                               |                                                                                                                                                                                                                                               | Transmission Complete (Data-In Failed, ACK/NAK Timeout)                             |
| Transmission Status (Connection Lost Without ACK/NAK)                                                                               |                                                                                                                                                                                                                                               | Transmission Complete (Data-In Failed, Connection Lost Without ACK/NAK)             |

Table 181 defines messages that this state shall send to the ST\_TFR state machine upon receipt of the listed confirmations and arguments.

**Table 181 — Additional messages sent to the ST\_TFR state machine**

| Confirmation received from the port layer or argument received from ST_TTS3:Prepare_Data_In | Message sent to the ST_TFR state machine         |
|---------------------------------------------------------------------------------------------|--------------------------------------------------|
| Transmission Status (Break Received)                                                        | Transmission Complete (Data Transfer Terminated) |

If this state receives a Cancel message or a Cancel argument and this state has received confirmations for all Transmit Frame requests sent to the port layer, then this state shall send a Transmission Complete (Data Transfer Terminated) message to the ST\_TFR state machine.

If this state receives a Cancel message or a Cancel argument and this state has not received confirmations for all Transmit Frame requests sent to the port layer, then this state shall send a Cancel request to the port layer to cancel previous Transmit Frame requests. The Cancel request shall include the following arguments:

- a) Destination SAS Address; and
- b) Initiator Port Transfer Tag.

Upon receipt of a Transmission Status (Cancel Acknowledged) confirmation or argument this state shall send a Transmission Complete (Data Transfer Terminated) message to the ST\_TFR state machine.

A Transmission Complete message to the ST\_TFR state machine shall include the following arguments:

- a) Destination SAS Address; and
- b) Initiator Port Transfer Tag.

#### 8.2.6.3.3.3.2 Transition ST\_TTS2:Target\_Send\_Frame to ST\_TTS1:Target\_Start

This transition shall occur:

- a) after sending a Transmission Complete message other than the Transmission Complete (Xfer\_Rdy Delivered) message to the ST\_TFR state machine.

#### 8.2.6.3.3.3.3 Transition ST\_TTS2:Target\_Send\_Frame to ST\_TTS3:Prepare\_Data\_In

This transition shall occur:

- a) after receiving a Transmission Status (Frame Transmitted) confirmation for a read DATA frame if the Read Data Offset state machine variable is less than the Read Data Buffer End state machine variable (i.e., there is more read data to transfer).

If transport layer retries are enabled and the vendor specific number of retries, if any, for the read DATA frame has not been reached, then this transition shall occur and include a Retry argument after receiving one of the following confirmations for a read DATA frame:

- a) Transmission Status (NAK Received);
- b) Transmission Status (ACK/NAK Timeout); or
- c) Transmission Status (Connection Lost Without ACK/NAK).

#### 8.2.6.3.3.3.4 Transition ST\_TTS2:Target\_Send\_Frame to ST\_TTS5:Receive\_Data\_Out

This transition shall occur:

- a) after sending a Transmission Complete (Xfer\_Rdy Delivered) message to the ST\_TFR state machine.

#### 8.2.6.3.3.4 ST\_TTS3:Prepare\_Data\_In state

##### 8.2.6.3.3.4.1 State description

This state retrieves the data from the Device Server Buffer Data-In state machine argument and constructs a read DATA frame.

This state shall construct a read DATA frame using the Data-In state machine arguments as follows:

- a) set the FRAME TYPE field to 01h (i.e., DATA frame);
- b) set the HASHED DESTINATION SAS ADDRESS field to the hashed value of the Destination SAS Address Data-In state machine argument;
- c) set the HASHED SOURCE SAS ADDRESS field to the hashed value of the SSP target port's SAS address;
- d) set the RETRY DATA FRAMES bit to zero;
- e) set the RETRANSMIT bit to zero;
- f) set the CHANGING DATA POINTER as specified in this subclause;
- g) set the NUMBER OF FILL BYTES field to the number of fill bytes to be used in the DATA frame for the specified read data;
- h) set the INITIATOR PORT TRANSFER TAG field to the Initiator Port Transfer Tag Data-In state machine argument;
- i) set the TARGET PORT TRANSFER TAG field to a vendor specific value;
- j) set the DATA OFFSET field as specified in this subclause;
- k) in the information unit, set the DATA field as specified in this subclause; and
- l) fill bytes, if required.

If this state is entered without a Retry argument, then this state shall:

- a) set the CHANGING DATA POINTER bit to zero;
- b) set the DATA OFFSET field to the Read Data Offset state machine variable; and
- c) in the information unit, set the DATA field to the information in the Device Server Buffer argument that corresponds to the read data to be transferred. If the Read Data Buffer End state machine variable minus the Read Data Offset state machine variable is equal to the maximum size of the read Data information unit, then the amount of data shall be the maximum size of the read Data information unit. Otherwise, the amount of data shall be the lesser of:
  - A) the Read Data Buffer End state machine variable minus the Read Data Offset state machine variable; and
  - B) the maximum size of the read Data information unit for this Send Data-In request.

If this state is entered with a Retry argument, then this state shall either:

- a) set the CHANGING DATA POINTER bit to one;
- b) set the DATA OFFSET field to the Balance Point Read Data Offset state machine variable;
- c) set the Read Data Offset state machine variable to the Balance Point Read Data Offset state machine variable;
- d) set the Read Data Frames Transmitted state machine variable to zero;
- e) set the Read Data Frames ACKed state machine variable to zero; and
- f) in the information unit, set the DATA field to the information in the Device Server Buffer argument that corresponds to the read data to be transferred. If the Read Data Buffer End state machine variable minus the Read Data Offset state machine variable is equal to the maximum size of the read Data information unit, then the amount of data shall be the maximum size of the read Data information unit. Otherwise, the amount of data shall be the lesser of:
  - A) the Read Data Buffer End state machine variable minus the Balance Point Read Data Offset state machine variable; and
  - B) the maximum size of the read Data information unit for this Send Data-In request;

or:

- a) set the CHANGING DATA POINTER bit to one;
- b) set the DATA OFFSET field to the Application Client Buffer Offset Data-In state machine argument;
- c) set the Read Data Offset state machine variable to the Application Client Buffer Offset Data-In state machine argument;
- d) set the Read Data Frames Transmitted state machine variable to zero;

- e) set the Read Data Frames ACKed state machine variable to zero; and
- f) in the information unit, set the DATA field to the information in the Device Server Buffer argument that corresponds to the read data to be transferred. If the Request Byte Count Data-In state machine argument is equal to the maximum size of the read Data information unit, then the amount of data shall be the maximum size of the read Data information unit. Otherwise, the amount of data shall be the lesser of:
  - A) the Request Byte Count Data-In state machine argument; and
  - B) the maximum size of the read Data information unit for this Send Data-In request.

#### 8.2.6.3.3.4.2 Transition ST\_TTS3:Prepare\_Data\_In to ST\_TTS2:Target\_Send\_Frame

This transition shall occur after this state:

- a) constructs a read DATA frame; or
- b) receives a Cancel message.

This transition shall include the received Transmission Status, if any, as an argument and if a Cancel message was:

- a) not received, then the read DATA frame as an argument; or
- b) received, then a Cancel argument.

#### 8.2.6.3.3.5 ST\_TTS4:Prepare\_Xfer\_Rdy state

##### 8.2.6.3.3.5.1 State description

This state shall construct an XFER\_RDY frame using the Data-Out state machine arguments:

- a) set the FRAME TYPE field to 05h (i.e., XFER\_RDY frame);
- b) set the HASHED DESTINATION SAS ADDRESS field to the hashed value of the Destination SAS Address Data-Out state machine argument;
- c) set the HASHED SOURCE SAS ADDRESS field to the hashed value of the SSP target port's SAS address;
- d) set the RETRY DATA FRAMES bit to one if transport layer retries are enabled and zero if transport layer retries are disabled;
- e) set the RETRANSMIT bit to zero;
- f) set the CHANGING DATA POINTER bit to zero;
- g) set the NUMBER OF FILL BYTES field to 00b;
- h) set the INITIATOR PORT TRANSFER TAG field to the Initiator Port Transfer Tag Data-Out state machine argument;
- i) if transport layer retries are disabled, set the TARGET PORT TRANSFER TAG field to a vendor specific value;
- j) if transport layer retries are enabled, set the TARGET PORT TRANSFER TAG field to a vendor specific value that is different from:
  - A) the target port transfer tag in the previous XFER\_RDY frame associated with the Data-Out state machine arguments; and
  - B) any other target port transfer tag currently in use.

If write data is received for a subsequent XFER\_RDY frame for a command, then all target port transfer tags used for previous XFER\_RDY frames for the command are no longer in use;

- k) set the DATA OFFSET field to 00000000h;
- l) in the information unit, set the REQUESTED OFFSET field to the Requested Write Data Offset state machine variable;
- m) in the information unit, set the WRITE DATA LENGTH field as specified in this subclause; and
- n) no fill bytes.

If the SSP target port has the resources available to receive all of the write data as indicated by the Requested Write Data Length state machine variable, then this state shall set the WRITE DATA LENGTH field in the XFER\_RDY information unit to the Requested Write Data Length state machine variable.



If the SSP target port does not have the resources available to receive all of the write data as indicated by the Requested Write Data Length state machine variable (e.g., the SSP target port has a vendor specific limit as to how much write data may be received during one operation), then this state shall set the WRITE DATA LENGTH field in the XFER\_RDY information unit and the Requested Write Data Length state machine variable to a value representing the amount of write data for which the SSP target port has available resources to receive.

#### 8.2.6.3.3.5.2 Transition ST\_TTS4:Prepare\_Xfer\_Rdy to ST\_TTS2:Target\_Send\_Frame

This transition shall occur after this state:

- a) constructs an XFER\_RDY frame; or
- b) receives a Cancel message.

This transition shall include if a Cancel message was:

- a) not received, then the XFER\_RDY frame as an argument; or
- b) received, then a Cancel argument.

#### 8.2.6.3.3.6 ST\_TTS5:Receive\_Data\_Out state

##### 8.2.6.3.3.6.1 State description

Upon entry into this state, the Write Data Offset state machine variable is set to the Requested Write Data Offset state machine variable.

If this state receives a Data-Out Arrived message, then this state shall verify the write DATA frame received with the Data-Out Arrived values as specified in table 182. If the verification test fails, then this state sends the message specified in table 182 to the ST\_TFR state machine.

**Table 182 — Reception Complete message for write DATA frame verification failures**

| Message sent to the ST_TFR state machine <sup>a</sup>                                                                                                                                                                                                                                                              | Condition                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Reception Complete (Data Offset Error)                                                                                                                                                                                                                                                                             | Transport layer retries are disabled, and the DATA OFFSET field is not equal to the Write Data Offset state machine variable.                                                                                                                           |
|                                                                                                                                                                                                                                                                                                                    | The DATA OFFSET field is:<br>a) less than the Requested Write Data Offset state machine variable; or<br>b) greater than or equal to the Requested Write Data Offset state machine variable plus the Requested Write Data Length state machine variable. |
| Reception Complete (Too Much Write Data)                                                                                                                                                                                                                                                                           | The number of bytes in the DATA field in the write Data information unit plus the Write Data Offset state machine variable is greater than the Request Byte Count Data-Out state machine argument.                                                      |
| Reception Complete (Information Unit Too Short)                                                                                                                                                                                                                                                                    | Either:<br>a) the number of bytes in the DATA field in the write Data information unit is zero; or<br>b) this is not the last write DATA frame for the command and the NUMBER OF FILL BYTES field for the frame is not set to 00b.                      |
| <sup>a</sup> If more than one condition is true, then this state shall select which message to send to the ST_TFR state machine using the following order:<br>1) Reception Complete (Data Offset Error);<br>2) Reception Complete (Too Much Write Data); or<br>3) Reception Complete (Information Unit Too Short). |                                                                                                                                                                                                                                                         |



If:

- a) transport layer retries are enabled;
- b) the CHANGING DATA POINTER bit is set to zero; and
- c) the value in the DATA OFFSET field is not equal to the Write Data Offset state machine variable,

then this state should discard all Data-Out Arrived messages until the CHANGING DATA POINTER bit is set to one. This state shall resume processing additional Data-Out Arrived messages when it receives a Data-Out Arrived message with the CHANGING DATA POINTER bit set to one.

If the WRITE data frame verification is successful and the Data-Out Arrived message is not discarded, then this state shall:

- a) process the write data as indicated in the Data-Out state machine arguments using the Device Server Buffer (e.g., logical block address) to which the write data is to be transferred; and
- b) set the Write Data Offset state machine variable to the current Write Data Offset state machine variable plus the number of bytes received in the DATA field of the write Data information unit.

If the WRITE data frame verification is successful and the CHANGING DATA POINTER bit set to one, then this state shall:

- a) set the Write Data Offset state machine variable to the Requested Write Data Offset state machine variable plus the number of bytes received in the DATA field of the write Data information unit; and
- b) process the write data as indicated in the Data-Out state machine arguments using the Device Server Buffer (e.g., logical block address) to which the write data is to be transferred.

If data received in the write DATA frame overlaps data previously received and verified to have no errors, then this state may either discard the overlapping data or replace the previously received data with the new data.

If the Initiator Response Timeout timer is implemented, then this state shall initialize and start the Initiator Response Timeout timer:

- a) upon entry into this state; and
- b) when this state receives and verifies the write DATA frame received with the Data-Out Arrived values (i.e., Data-Out data was received and processed).

If the Initiator Response Timeout timer is running, then this state shall stop the timer before transitioning from this state.

If the Initiator Response Timeout timer expires, then this state shall send a Reception Complete (Initiator Response Timeout) message to the ST\_TFR state machine.

If the Write Data Offset state machine variable equals the Request Byte Count Data-Out state machine argument plus the Application Client Buffer Offset Data-Out state machine argument, then this state shall send a Reception Complete (Data-Out Received) message to the ST\_TFR state machine after an ACK Transmitted confirmation is received for each write DATA frame received.

If this state receives a Cancel message, then this state shall send a Reception Complete (Data Transfer Terminated) message to the ST\_TFR state machine.

If this state receives Transmission Status (Break Received) confirmation, then this state shall send a Reception Complete (Data Transfer Terminated) message to the ST\_TFR state machine.

The Reception Complete message, if any, shall include the initiator port transfer tag as an argument.

#### 8.2.6.3.3.6.2 Transition ST\_TTS5:Receive\_Data\_Out to ST\_TTS1:Target\_Start

This transition shall occur after sending a Reception Complete message to the ST\_TFR state machine.

#### 8.2.6.3.3.6.3 Transition ST\_TTS5:Receive\_Data\_Out to ST\_TTS4:Prepare\_Xfer\_Rdy

This transition shall occur:

- 1) if the Write Data Offset state machine variable is less than Request Byte Count Data-Out state machine argument plus the Application Client Buffer Offset Data-Out state machine argument and

- equal to the Requested Write Data Offset state machine variable plus the Requested Write Data Length state machine variable;
- 2) after an ACK Transmitted confirmation is received for each write DATA frame received;
- 3) after determining the amount of write data already transferred by subtracting the Application Client Buffer Offset Data-Out state machine argument from the Write Data Offset state machine variable;
- 4) after setting the Requested Write Data Length state machine variable to the Request Byte Count Data-Out state machine argument minus the amount of write data already transferred; and
- 5) after setting the Requested Write Data Offset state machine variable to the Write Data Offset state machine variable.

#### 8.2.6.3.3.7 ST\_TTS6:Prepare\_Response state

##### 8.2.6.3.3.7.1 State description

This state shall construct a RESPONSE frame using the received Application Response arguments or the received Transport Response arguments as follows:

- a) set the FRAME TYPE field to 07h (i.e., RESPONSE frame);
- b) set the HASHED DESTINATION SAS ADDRESS field to the hashed value of the Application Response or Transport Response Destination SAS Address argument;
- c) set the HASHED SOURCE SAS ADDRESS field to the hashed value of the SSP target port's SAS address;
- d) set the RETRY DATA FRAMES set to zero;
- e) set the RETRANSMIT bit to zero;
- f) set the CHANGING DATA POINTER bit to zero;
- g) set the INITIATOR PORT TRANSFER TAG field to the Initiator Port Transfer Tag Application Response argument or the Initiator Port Transfer Tag Transport Response argument;
- h) set the TARGET PORT TRANSFER TAG field to a vendor specific value;
- i) set the DATA OFFSET field to 00000000h;
- j) set the information unit as specified in this subclause; and
- k) fill bytes, if needed as specified in this subclause.

If this state was entered with the Transport Response arguments, then this state shall set the fields as follows:

- a) set the NUMBER OF FILL BYTES field to the number of fill bytes, based on the length of the response data, if any;
- b) in the information unit, set the DATAPRES field to RESPONSE DATA;
- c) in the information unit, set the STATUS field to 00h;
- d) in the information unit, set the STATUS QUALIFIER field to 0000h;
- e) in the information unit, set the SENSE DATA LENGTH field to 00000000h;
- f) in the information unit, set the RESPONSE DATA LENGTH field to 00000004h;
- g) in the information unit, set the RESPONSE DATA field as specified in table 183; and
- h) in the information unit, do not include the SENSE DATA field.

Table 183 defines how the RESPONSE DATA field shall be set based on the arguments received with the Request (Send Transport Response) message.

**Table 183 — Request (Send Transport Response) message Service Response argument to RESPONSE frame RESPONSE DATA field mapping**

| Request (Send Transport Response) message Service Response argument | RESPONSE frame RESPONSE DATA field               |
|---------------------------------------------------------------------|--------------------------------------------------|
| Invalid Frame                                                       | INVALID FRAME                                    |
| Task Management Function Complete                                   | TASK MANAGEMENT FUNCTION COMPLETE                |
| Task Management Function Succeeded                                  | TASK MANAGEMENT FUNCTION SUCCEEDED               |
| Task Management Function Not Supported                              | TASK MANAGEMENT FUNCTION NOT SUPPORTED           |
| Task Management Function Failed                                     | TASK MANAGEMENT FUNCTION FAILED                  |
| Incorrect Logical Unit Number                                       | INCORRECT LOGICAL UNIT NUMBER                    |
| Overlapped Initiator Port Transfer Tag Attempted                    | OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED |

If this state was entered with the Application Response arguments, then this state shall set the fields as follows:

- in the information unit, set the DATAPRES field to SENSE\_DATA if sense data is to be included in the information unit or NO\_DATA if sense data is not to be included in the information unit;
- in the information unit, set the STATUS field to the status;
- in the information unit, set the STATUS QUALIFIER field to the status qualifier, if any;
- in the information unit, set the SENSE DATA LENGTH field to the length of the sense data, if any;
- in the information unit, set the RESPONSE DATA LENGTH field to 00000000h;
- in the information unit, do not include the RESPONSE DATA field;
- in the information unit, set the SENSE DATA field to the sense data, if any; and
- NUMBER OF FILL BYTES field set to the number of fill bytes, based on the length of the sense data, if needed.

#### 8.2.6.3.3.7.2 Transition ST\_TTS6:Prepare\_Response to ST\_TTS2:Target\_Send\_Frame

This transition shall occur:

- after this state constructs a RESPONSE frame.

This transition shall include if a Cancel message was:

- not received, then the RESPONSE frame as an argument; or
- received, then a Cancel argument.

### 8.3 STP transport layer

#### 8.3.1 Initial FIS

A SATA device phy transmits a Register - Device to Host FIS after completing the link reset sequence, except for the case described in F.5. The expander device shall update a set of shadow registers with the contents of this FIS and shall not deliver this FIS to any STP initiator port. SMP initiator ports may read the shadow register contents using the SMP REPORT PHY SATA function (see 9.4.3.12). The expander device originates a Broadcast (Change) after receiving the Register - Device to Host FIS (see 6.13).

### 8.3.2 BIST Activate FIS

STP initiator ports and STP target ports shall not generate BIST Activate FISes and shall process any BIST Activate FISes received as frames having invalid FIS types (i.e., have the link layer generate SATA\_R\_ERR in response).

### 8.3.3 TT (transport layer for STP ports) state machines

The STP transport layer uses the transport layer state machines defined in SATA, modified to communicate with the port layer rather than directly with the link layer. These modifications are not described in this standard.

## 8.4 SMP transport layer

### 8.4.1 SMP transport layer overview

Table 184 defines the SMP frame format.

**Table 184 — SMP frame format**

| Byte\Bit | 7                          | 6   | 5 | 4 | 3 | 2 | 1 | 0     |
|----------|----------------------------|-----|---|---|---|---|---|-------|
| 0        | SMP FRAME TYPE             |     |   |   |   |   |   |       |
| 1        | Frame-type dependent bytes |     |   |   |   |   |   |       |
| ...      |                            |     |   |   |   |   |   |       |
| n - 4    |                            |     |   |   |   |   |   |       |
| n - 3    | (MSB)                      | CRC |   |   |   |   |   | (LSB) |
| ...      |                            |     |   |   |   |   |   |       |
| n        |                            |     |   |   |   |   |   |       |

Table 185 defines the SMP FRAME TYPE field, which defines the format of the frame-type dependent bytes.

**Table 185 — SMP FRAME TYPE field**

| Code       | Name         | Frame type            | Originator         | Reference |
|------------|--------------|-----------------------|--------------------|-----------|
| 40h        | SMP_REQUEST  | SMP function request  | SMP initiator port | 8.4.2     |
| 41h        | SMP_RESPONSE | SMP function response | SMP target port    | 8.4.3     |
| All others | Reserved     |                       |                    |           |

The number of frame-type dependent bytes shall be either:

- three bytes; or
- three bytes plus an integer multiple of four bytes,

so the CRC field is aligned on a four byte boundary.

The CRC field contains a CRC value (see 6.5) that is computed over the entire SMP frame prior to the CRC field, and shall begin on a four-byte boundary. The CRC field is checked by the SMP link layer (see 6.20).

### 8.4.2 SMP\_REQUEST frame

The SMP\_REQUEST frame is sent by an SMP initiator port to request an SMP function be performed by a management device server. Table 186 defines the SMP\_REQUEST frame format.

### Table 186 — SMP\_REQUEST frame format

| Byte\Bit | 7                    | 6   | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|----------------------|-----|---|---|---|---|---|---|
| 0        | SMP FRAME TYPE (40h) |     |   |   |   |   |   |   |
| 1        | Request bytes        |     |   |   |   |   |   |   |
| ...      |                      |     |   |   |   |   |   |   |
| n - 4    |                      |     |   |   |   |   |   |   |
| n - 3    | (MSB)                | CRC |   |   |   |   |   |   |
| ...      |                      |     |   |   |   |   |   |   |
| n        |                      |     |   |   |   |   |   |   |

The SMP FRAME TYPE field shall be set as shown in table 186 for the SMP\_REQUEST frame format.

The format and length of the request bytes is defined by the SMP function description (see 9.4.3.2).

The number of request bytes are either:

- a) three bytes; or
- b) three bytes plus an integer multiple of four bytes,

so the CRC field is aligned on a four byte boundary.

The maximum number of request bytes is 1 023, making the maximum size of the frame 1 028 bytes (i.e., 1 byte header + 1 023 request bytes + 4 bytes of CRC).

NOTE 59 - If a management application client compliant with SAS-1.1 sends a vendor specific SMP request frame containing 1 027 request bytes, then the SMP\_TP state machine discards that SMP request frame as it exceeds the maximum allowed request size of 1 023 bytes (see 6.20.5.4.2.2). SMP request frames defined in SAS-1.1 do not have more than 39 request bytes.

The CRC field is defined in 8.4.1.

### 8.4.3 SMP\_RESPONSE frame

The SMP\_RESPONSE frame is sent by an SMP target port in response to an SMP\_REQUEST frame. Table 187 defines the SMP\_RESPONSE frame format.

### Table 187 — SMP\_RESPONSE frame format

| Byte\Bit | 7                    | 6   | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|----------------------|-----|---|---|---|---|---|---|
| 0        | SMP FRAME TYPE (41h) |     |   |   |   |   |   |   |
| 1        | Response bytes       |     |   |   |   |   |   |   |
| ...      |                      |     |   |   |   |   |   |   |
| n - 4    |                      |     |   |   |   |   |   |   |
| n - 3    | (MSB)                | CRC |   |   |   |   |   |   |
| ...      |                      |     |   |   |   |   |   |   |
| n        | (LSB)                |     |   |   |   |   |   |   |

The SMP FRAME TYPE field shall be set as shown in table 187 for the SMP\_RESPONSE frame format.

The format and length of the request bytes is defined by the SMP function description (see 9.4.3.3).

The number of response bytes are either:

- a) three bytes; or
- b) three bytes plus an integer multiple of four bytes,

so the CRC field is aligned on a four byte boundary.

The maximum number of response bytes is 1 023, making the maximum size of the frame 1 028 bytes (i.e., 1 byte header + 1 023 request bytes + 4 bytes of CRC).

NOTE 60 - If a management device server compliant with SAS-1.1 sends a vendor specific SMP response frame containing 1 027 response bytes, then the SMP\_IP state machine discards that SMP response frame as it exceeds the maximum allowed request size of 1 023 bytes (see 6.20.5.3.4). SMP response frames defined SAS-1.1 do not have more than 59 request bytes.

The CRC field is defined in 8.4.1.

#### 8.4.4 Sequence of SMP frames

Inside an SMP connection, the SMP initiator port transmits a single SMP\_REQUEST frame and the SMP target port replies with a single SMP\_RESPONSE frame.

Figure 169 shows the sequence of SMP frames.

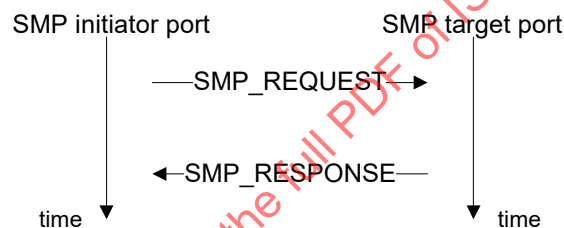


Figure 169 — Sequence of SMP frames

#### 8.4.5 MT (transport layer for SMP ports) state machines

##### 8.4.5.1 SMP transport layer state machines overview

The SMP transport layer contains state machines that process requests from the management application layer and return confirmations to the management application layer. The SMP transport state machines are as follows:

- a) MT\_IP (transport layer for SMP initiator ports) state machine (see 8.4.5.2); and
- b) MT\_TP (transport layer for SMP target ports) state machine (see 8.4.5.3).

##### 8.4.5.2 MT\_IP (transport layer for SMP initiator ports) state machine

###### 8.4.5.2.1 MT\_IP state machine overview

The MT\_IP state machine processes requests from the management application layer. These management requests are sent to the port layer, and the resulting SMP frame or error condition is sent to the management application layer as a confirmation.

This state machine consists of the following states:

- a) MT\_IP1:Idle (see 8.4.5.2.2) (initial state);

- b) MT\_IP2:Send (see 8.4.5.2.3); and
- c) MT\_IP3:Receive (see 8.4.5.2.4).

This state machine shall start in the MT\_IP1:Idle state.

Figure 170 shows the MT\_IP state machine.

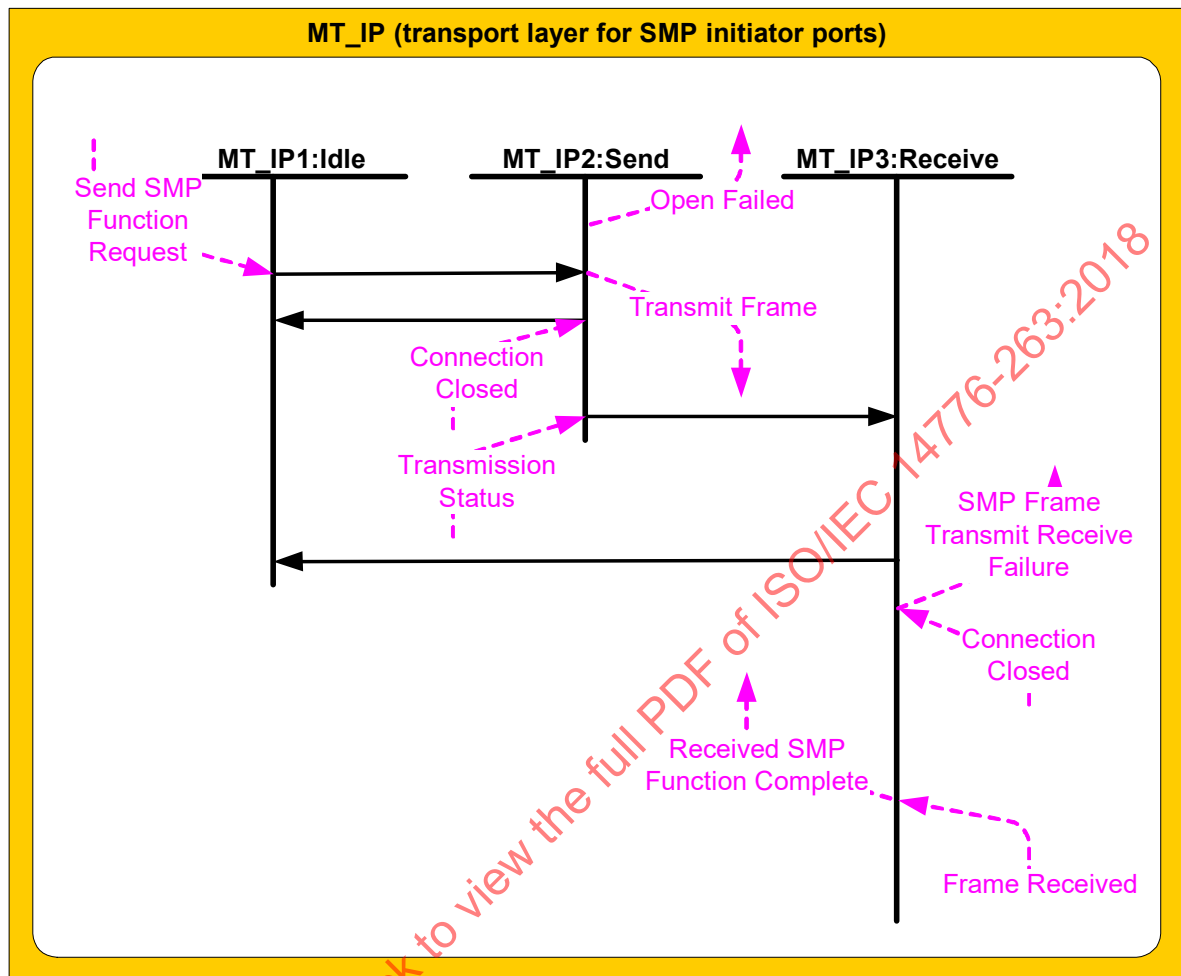


Figure 170 — MT\_IP (transport layer for SMP initiator ports) state machine

#### 8.4.5.2.2 MT\_IP1:Idle state

##### 8.4.5.2.2.1 State description

This state is the initial state of the MT\_IP state machine.

This state waits for a Send SMP Function Request request, which includes the following arguments:

- a) Connection Rate;
- b) Destination SAS Address; and
- c) Request Bytes.

##### 8.4.5.2.2.2 Transition MT\_IP1:Idle to MT\_IP2:Send

This transition shall occur:

- a) after a Send SMP Function Request request is received.

This transition shall include the following arguments:

- a) Connection Rate;
- b) Destination SAS Address; and
- c) Request Bytes.

#### 8.4.5.2.3 MT\_IP2:Send state

##### 8.4.5.2.3.1 State description

This state constructs an SMP\_REQUEST frame using the following arguments received in the transition into this state:

- a) Request Bytes;

and sends a Transmit Frame request to the port layer with the following arguments:

- a) Initiator Port bit set to one;
- b) Protocol set to SMP;
- c) Connection Rate;
- d) Initiator Connection Tag set to FFFFh;
- e) Destination SAS Address;
- f) Source SAS Address set to the SAS address of the SMP initiator port; and
- g) Request Bytes.

##### 8.4.5.2.3.2 Transition MT\_IP2:Send to MT\_IP1:Idle

This transition shall occur after:

- a) receiving either a Connection Closed confirmation or a Transmission Status confirmation other than a Transmission Status (Frame Transmitted) confirmation; and
- b) sending an Open Failed confirmation to the management application layer.

##### 8.4.5.2.3.3 Transition MT\_IP2:Send to MT\_IP3:Receive

This transition shall occur:

- a) after receiving a Transmission Status (Frame Transmitted) confirmation.

#### 8.4.5.2.4 MT\_IP3:Receive state

##### 8.4.5.2.4.1 State description

This state waits for a confirmation from the port layer that either an SMP frame has been received or a failure occurred.

If a Frame Received (SMP Successful) confirmation is received and the SMP frame type is equal to 41h, then this state shall send a Received SMP Function Complete confirmation to the management application layer.

If a Frame Received (SMP Successful) confirmation is received and the SMP frame type is not equal to 41h, then this state shall send an SMP Frame Transmit Receive Failure confirmation to the management application layer.

If a Connection Closed or Frame Received (SMP Unsuccessful) confirmation is received, then this state shall send an SMP Frame Transmit Receive Failure confirmation to the management application layer.

##### 8.4.5.2.4.2 Transition MT\_IP3:Receive to MT\_IP1:Idle

This transition shall occur after one of the following:

- a) sending a Received SMP Function Complete confirmation; or
- b) sending an SMP Frame Transmit Receive Failure confirmation.



### 8.4.5.3 MT\_TP (transport layer for SMP target ports) state machine

#### 8.4.5.3.1 MT\_TP state machine overview

The MT\_TP state machine informs the management application layer of the receipt of an SMP frame, and sends the resulting SMP frame to the port layer.

This state machine consists of the following states:

- MT\_TP1:Idle (see 8.4.5.3.2) (initial state); and
- MT\_TP2:Respond (see 8.4.5.3.3).

This state machine shall start in the MT\_TP1:Idle state.

Figure 171 shows the MT\_TP state machine.

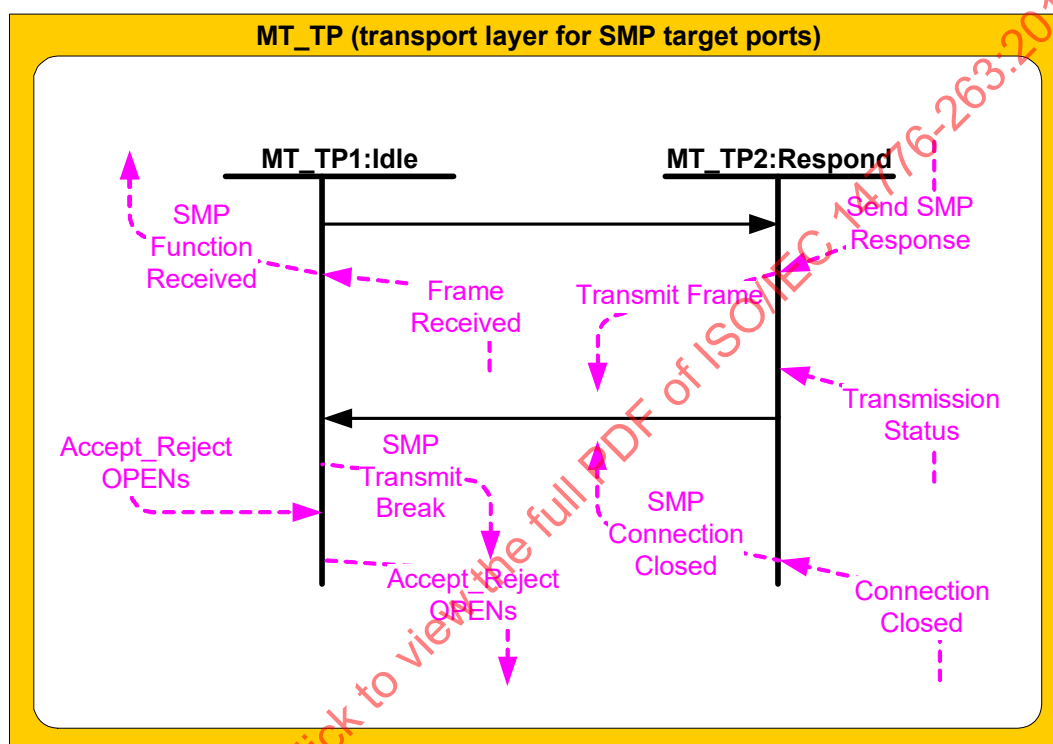


Figure 171 — MT\_TP (transport layer for SMP target ports) state machine

The MT\_TP state machine shall comply with the time limits listed in table 188.

Table 188 — MT\_TP time limits

| Time limit              | Value    | Description                                                                            |
|-------------------------|----------|----------------------------------------------------------------------------------------|
| SMP Response time limit | 1 900 µs | Maximum time from receiving an SMP_REQUEST frame to transmitting an SMP_RESPONSE frame |

#### 8.4.5.3.2 MT\_TP1:Idle state

##### 8.4.5.3.2.1 State description

This state is the initial state of the MT\_TP state machine.

This state waits for a Frame Received (SMP Successful) confirmation. If the SMP frame type is not equal to 40h, then this state shall discard the frame and send an SMP Transmit Break request to the port layer. Otherwise, this state shall send an SMP Function Received confirmation to the management application layer.

If an Accept\_Reject OPENs (Accept SMP) request or an Accept\_Reject OPENs (Reject SMP) request is received, then this state shall send an Accept\_Reject OPENs request with the same arguments to the port layer.

#### **8.4.5.3.2.2 Transition MT\_TP1:Idle to MT\_TP2:Respond**

This transition shall occur:

- a) after sending an SMP Function Received confirmation.

#### **8.4.5.3.3 MT\_TP2:Respond state**

##### **8.4.5.3.3.1 State description**

This state waits for a Send SMP Response request, which includes the following argument:

- a) Response Bytes.

After receiving a Send SMP Response request, this state shall construct an SMP\_RESPONSE frame using the arguments from the Send SMP Response request and send a Transmit Frame request to the port layer within the SMP Response time limit specified in table 188 (see 8.4.5.3.1).

If this state receives a Connection Closed confirmation, then this state shall send an SMP Connection Closed confirmation to the management application layer.

##### **8.4.5.3.3.2 Transition MT\_TP2:Respond to MT\_TP1:Idle**

This transition shall occur after one of the following:

- a) receiving a Transmission Status (Frame Transmitted) confirmation; or
- b) sending an SMP Connection Closed confirmation.

## 9 Application layer

### 9.1 Application layer overview

The application layer defines SCSI, ATA, and management specific features.

### 9.2 SCSI application layer

#### 9.2.1 SCSI transport protocol services

##### 9.2.1.1 SCSI transport protocol services overview

A SCSI application client requests the processing of a SCSI command by invoking SCSI transport protocol services, the collective operation of which is conceptually modeled in the following procedure call (see SAM-5):

**Service response = Execute Command (IN (I\_T\_L\_Q Nexus, CDB, Task Attribute, [Data-In Buffer Size], [Data-Out Buffer], [Data-Out Buffer Size], [Command Priority]), OUT ([Data-In Buffer], [Sense Data], [Sense Data Length], Status, [Status Qualifier]))**

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This standard defines the transport protocol services required by SAM-5 in support of this procedure call. Table 189 describes the mapping of the **Execute Command** procedure call to transport protocol services and the SSP implementation of each transport protocol service.

**Table 189 — Execute Command procedure call transport protocol services**

| Transport protocol service                                                                                                                                                                                                                         | I/T <sup>a</sup> | SSP implementation                                                      | Reference |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------------------------------------------------------------------------|-----------|
| <b>Command and status</b>                                                                                                                                                                                                                          |                  |                                                                         |           |
| Send SCSI Command request                                                                                                                                                                                                                          | I                | COMMAND frame                                                           | 9.2.1.2   |
| SCSI Command Received indication                                                                                                                                                                                                                   | T                | Receipt of the COMMAND frame                                            | 9.2.1.3   |
| Send Command Complete response                                                                                                                                                                                                                     | T                | RESPONSE frame                                                          | 9.2.1.4   |
| Command Complete Received confirmation                                                                                                                                                                                                             | I                | Receipt of the RESPONSE frame or problem transmitting the COMMAND frame | 9.2.1.5   |
| <b>Data-In delivery <sup>b</sup></b>                                                                                                                                                                                                               |                  |                                                                         |           |
| Send Data-In request                                                                                                                                                                                                                               | T                | Read DATA frames                                                        | 9.2.1.6   |
| Data-In Delivered confirmation                                                                                                                                                                                                                     | T                | Receipt of ACKs for the read DATA frames                                | 9.2.1.7   |
| <b>Data-Out delivery <sup>b</sup></b>                                                                                                                                                                                                              |                  |                                                                         |           |
| Receive Data-Out request                                                                                                                                                                                                                           | T                | XFER_RDY frame                                                          | 9.2.1.8   |
| Data-Out Received confirmation                                                                                                                                                                                                                     | T                | Receipt of write DATA frames                                            | 9.2.1.9   |
| <b>Terminate Data Transfer <sup>b</sup></b>                                                                                                                                                                                                        |                  |                                                                         |           |
| Terminate Data Transfer request                                                                                                                                                                                                                    | T                |                                                                         | 9.2.1.10  |
| Data Transfer Terminated confirmation                                                                                                                                                                                                              | T                |                                                                         | 9.2.1.11  |
| <sup>a</sup> I/T indicates whether the SSP initiator port (I) or the SSP target port (T) implements the transport protocol service.<br><sup>b</sup> Data transfer transport protocol services for SCSI initiator ports are not specified by SAM-5. |                  |                                                                         |           |

A SCSI application client requests the processing of a SCSI task management function by invoking SCSI transport protocol services, the collective operation of which is conceptually modeled in the following procedure calls (see SAM-5):

- a) **Service Response = ABORT TASK (IN (Nexus));**
- b) **Service Response = ABORT TASK SET (IN (Nexus));**
- c) **Service Response = CLEAR ACA (IN (Nexus));**
- d) **Service Response = CLEAR TASK SET (IN (Nexus));**
- e) **Service Response = I\_T NEXUS RESET (IN (Nexus));**
- f) **Service Response = LOGICAL UNIT RESET (IN (Nexus));**
- g) **Service Response = QUERY TASK (IN (Nexus));**
- h) **Service Response = QUERY TASK SET (IN (Nexus), OUT ([Additional Response Information]));**  
and
- i) **Service Response = QUERY ASYNCHRONOUS EVENT (IN (Nexus), OUT ([Additional Response Information]));**

This standard defines the transport protocol services required by SAM-5 in support of these procedure calls. Table 190 describes the mapping of these procedure calls to transport protocol services and the SSP implementation of each transport protocol service.

**Table 190 — Task management function procedure call transport protocol services**

| Transport protocol service                                                                                                          | I/T <sup>a</sup> | SSP implementation                                                   | Reference |
|-------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------------------------------------------------|-----------|
| Task management                                                                                                                     |                  |                                                                      |           |
| Send Task Management Request request                                                                                                | I                | TASK frame                                                           | 9.2.1.12  |
| Task Management Request Received indication                                                                                         | T                | Receipt of the TASK frame                                            | 9.2.1.13  |
| Task Management Function Executed response                                                                                          | T                | RESPONSE frame                                                       | 9.2.1.14  |
| Received Task Management Function Executed confirmation                                                                             | I                | Receipt of the RESPONSE frame or problem transmitting the TASK frame | 9.2.1.15  |
| <sup>a</sup> I/T indicates whether the SSP initiator port (I) or the SSP target port (T) implements the transport protocol service. |                  |                                                                      |           |

Transport protocol services are used as the requests and confirmations to the SSP transport layer state machines (see 8.2.6) from the SCSI application layer.

#### 9.2.1.2 Send SCSI Command transport protocol service

A SCSI application client uses the Send SCSI Command transport protocol service request to request that an SSP initiator port transmit a COMMAND frame.

**Send SCSI Command (IN (I\_T\_L\_Q Nexus, CDB, Task Attribute, [Data-In Buffer Size], [Data-Out Buffer], [Data-Out Buffer Size], [Command Priority], [CRN], [First Burst Enabled], [Request Fence]))**

Table 191 shows how the arguments to the Send SCSI Command transport protocol service are used.

**Table 191 — Send SCSI Command transport protocol service arguments**

| Argument                                                                                                                                                                                             | SAS SSP implementation                                                                                                                                                                                                                                                                                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T_L_Q nexus                                                                                                                                                                                        | I_T_L_Q nexus, where:<br>a) I specifies the SSP initiator port to send the COMMAND frame;<br>b) T specifies the SSP target port to which the COMMAND frame is to be sent;<br>c) L specifies the LOGICAL UNIT NUMBER field in the COMMAND frame header;<br>and<br>d) Q specifies the INITIATOR PORT TRANSFER TAG field in the COMMAND frame header. |
| CDB                                                                                                                                                                                                  | Specifies the CDB field in the COMMAND frame.                                                                                                                                                                                                                                                                                                      |
| Task Attribute                                                                                                                                                                                       | Specifies the TASK ATTRIBUTE field in the COMMAND frame.                                                                                                                                                                                                                                                                                           |
| [Data-In Buffer Size]                                                                                                                                                                                | Maximum of $2^{32}$ bytes. <sup>a</sup>                                                                                                                                                                                                                                                                                                            |
| [Data-Out Buffer]                                                                                                                                                                                    | Internal to the SSP initiator port.                                                                                                                                                                                                                                                                                                                |
| [Data-Out Buffer Size]                                                                                                                                                                               | Maximum of $2^{32}$ bytes. <sup>a</sup>                                                                                                                                                                                                                                                                                                            |
| [CRN]                                                                                                                                                                                                | Ignored                                                                                                                                                                                                                                                                                                                                            |
| [Command Priority]                                                                                                                                                                                   | Specifies the COMMAND PRIORITY field in the COMMAND frame.                                                                                                                                                                                                                                                                                         |
| [First Burst Enabled]                                                                                                                                                                                | Specifies the ENABLE FIRST BURST bit in the COMMAND frame and causes the SSP initiator port to transmit the number of bytes indicated by the FIRST BURST SIZE field in the Disconnect-Reconnect mode page (see 9.2.7.2.5) for the SSP target port without waiting for an XFER_RDY frame.                                                           |
| [Request Fence]                                                                                                                                                                                      | If included, specifies an I_T nexus, I_T_L nexus, or I_T_L_Q nexus for which the COMMAND frame is fenced.                                                                                                                                                                                                                                          |
| <sup>a</sup> See the restrictions on the REQUESTED OFFSET field and the WRITE DATA LENGTH field in the SSP XFER_RDY frame (see 8.2.2.3) and the DATA OFFSET field in the SSP DATA frame (see 8.2.1). |                                                                                                                                                                                                                                                                                                                                                    |

A SCSI application client shall set the Request Fence argument to the nexus containing any commands or task management functions that the command affects (e.g., for a PERSISTENT RESERVE OUT command with a PREEMPT AND ABORT service action, the SCSI application client sets the Response Fence argument to the I\_T\_L nexus) or upon which the command depends (e.g., when the Task Attribute argument is set to Ordered, the SCSI application client sets the Response Fence argument to the I\_T\_L\_Q nexus of the previous command). If the SCSI application client is not able to determine the nexus affected by the command or upon which the command depends, then the SCSI application client should set the Request Fence argument to the I\_T nexus.

### 9.2.1.3 SCSI Command Received transport protocol service

An SSP target port uses the SCSI Command Received transport protocol service indication to notify a task manager that the SSP target port has received a COMMAND frame.

**SCSI Command Received (IN (I\_T\_L\_Q Nexus, CDB, Task Attribute, [Command Priority], [CRN], [First Burst Enabled]))**

Table 192 shows how the arguments to the SCSI Command Received transport protocol service are determined.

**Table 192 — SCSI Command Received transport protocol service arguments**

| Argument              | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                             |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T_L_Q nexus         | I_T_L_Q nexus, where:<br>a) I indicates the SSP initiator port that sent the COMMAND frame;<br>b) T indicates the SSP target port that received the COMMAND frame;<br>c) L indicates the value of the LOGICAL UNIT NUMBER field in the COMMAND frame header; and<br>d) Q indicates the value of the INITIATOR PORT TRANSFER TAG field in the COMMAND frame header. |
| CDB                   | Indicates the value of the CDB field and the ADDITIONAL CDB BYTES field, if any, in the COMMAND frame.                                                                                                                                                                                                                                                             |
| Task Attribute        | Indicates the value of the TASK ATTRIBUTE field in the COMMAND frame.                                                                                                                                                                                                                                                                                              |
| [CRN]                 | Ignored                                                                                                                                                                                                                                                                                                                                                            |
| [Command Priority]    | Indicates the value of the COMMAND PRIORITY field in the COMMAND frame.                                                                                                                                                                                                                                                                                            |
| [First Burst Enabled] | Indicates that first burst data is being delivered based on the ENABLE FIRST BURST bit in the COMMAND frame and the FIRST BURST SIZE field in the Disconnect-Reconnect mode page (see 9.2.7.2.5).                                                                                                                                                                  |

#### 9.2.1.4 Send Command Complete transport protocol service

A SCSI device server uses the Send Command Complete transport protocol service response to request that an SSP target port transmit a RESPONSE frame.

**Send Command Complete (IN (I\_T\_L\_Q Nexus, [Sense Data], [Sense Data Length], Status, [Status Qualifier], Service Response, [Response Fence]))**

A SCSI device server shall only call Send Command Complete () after receiving SCSI Command Received ().

A SCSI device server shall not call Send Command Complete () for a given I\_T\_L\_Q nexus until the SCSI device server has:

- responded to all outstanding Receive Data-Out () calls for that I\_T\_L\_Q nexus with Data-Out Received (), and
- responded to all outstanding Send Data-In () calls for that I\_T\_L\_Q nexus with Data-In Delivered ().

Table 193 shows how the arguments to the Send Command Complete transport protocol service are used.

**Table 193 — Send Command Complete transport protocol service arguments**

| Argument            | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                                              |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T_L_Q nexus       | I_T_L_Q nexus, where:<br>a) I specifies the SSP initiator port to which the RESPONSE frame is to be sent;<br>b) T specifies the SSP target port to send the RESPONSE frame;<br>c) L specifies the LOGICAL UNIT NUMBER field in the RESPONSE frame header;<br>and<br>d) Q specifies the INITIATOR PORT TRANSFER TAG field in the RESPONSE frame header.                              |
| [Sense Data]        | Specifies the SENSE DATA field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                               |
| [Sense Data Length] | Specifies the SENSE DATA LENGTH field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                        |
| Status              | Specifies the STATUS field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                                   |
| [Status Qualifier]  | Specifies the STATUS QUALIFIER field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                         |
| Service Response    | Specifies the DATAPRES field and STATUS field in the RESPONSE frame:<br>a) COMMAND COMPLETE: The DATAPRES field is set to NO_DATA or SENSE_DATA; or<br>b) SERVICE DELIVERY OR TARGET FAILURE - Overlapped Initiator Port Transfer Tag Attempted: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED. |
| [Response Fence]    | If included, specifies an I_T nexus, I_T_L nexus, or I_T_L_Q nexus for which the RESPONSE frame is fenced.                                                                                                                                                                                                                                                                          |

A SCSI device server shall set the Response Fence argument to the nexus containing any commands or task management functions that the command affects (e.g., for a PERSISTENT RESERVE OUT command with a PREEMPT AND ABORT service action, the SCSI device server sets the Response Fence argument to the I\_T\_L nexus) or upon which the command completion depends (e.g., when returning a unit attention condition with the additional sense code set to COMMANDS CLEARED BY ANOTHER INITIATOR, the SCSI device server sets the Response Fence argument to the I\_T\_L nexus). If the SCSI device server is not able to determine the nexus affected by the command or upon which the command depends, then the SCSI device server should set the Response Fence argument to the I\_T nexus.

#### 9.2.1.5 Command Complete Received transport protocol service

An SSP initiator port uses the Command Complete Received transport protocol service confirmation to notify a SCSI application client that the SSP initiator port has received a response for its COMMAND frame (e.g., a RESPONSE frame or a NAK) or terminated a command because of an error.

**Command Complete Received (IN (I\_T\_L\_Q Nexus, [Data-In Buffer], [Sense Data], [Sense Data Length], Status, [Status Qualifier], Service Response))**



Table 194 shows how the arguments to the Command Complete Received transport protocol service are determined.

**Table 194 — Command Complete Received transport protocol service arguments**

| Argument            | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T_L_Q nexus       | I_T_L_Q nexus, where:<br>a) I indicates the SSP initiator port that received the RESPONSE frame;<br>b) T indicates the SSP target port that sent the RESPONSE frame;<br>c) L indicates the value of the LOGICAL UNIT NUMBER field in the RESPONSE frame header or COMMAND frame header; and<br>d) Q indicates the value of the INITIATOR PORT TRANSFER TAG field in the RESPONSE frame header or COMMAND frame header.                                                                                                                        |
| [Data-In Buffer]    | Internal to the SSP initiator port.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| [Sense Data]        | Indicates the value of the SENSE DATA field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| [Sense Data Length] | The smaller of the value of the SENSE DATA LENGTH field in the RESPONSE frame and the actual number of sense data bytes received by the SSP initiator port.                                                                                                                                                                                                                                                                                                                                                                                   |
| Status              | Indicates the value of the STATUS field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| [Status Qualifier]  | Indicates the value of the STATUS QUALIFIER field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Service Response    | Either:<br>a) COMMAND COMPLETE: The RESPONSE frame contains a DATAPRES field set to NO_DATA or SENSE_DATA; or<br>b) SERVICE DELIVERY OR TARGET FAILURE: Either:<br>A) the RESPONSE frame contains a DATAPRES field set to RESPONSE_DATA and a RESPONSE CODE field set to INVALID FRAME or OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED; or<br>B) the ST_IFR state machine detects an error as described in 8.2.6.2.2.3 and 8.2.6.2.2.4 (e.g., a NAK was received for the COMMAND frame or the length of the RESPONSE frame is incorrect). |

#### 9.2.1.6 Send Data-In transport protocol service

A SCSI device server uses the Send Data-In transport protocol service request to request that an SSP target port transmit a read DATA frame.

**Send Data-In (IN (I\_T\_L\_Q Nexus, Device Server Buffer, Application Client Buffer Offset, Request Byte Count))**

A SCSI device server shall only call Send Data-In () during a read command or bidirectional command.

A SCSI device server shall not call Send Data-In () for a given I\_T\_L\_Q nexus after the SCSI device server has called Send Command Complete () for that I\_T\_L\_Q nexus (e.g., a RESPONSE frame for that I\_T\_L\_Q nexus has been transmitted) or called Task Management Function Executed () for a task management function that terminates that command (e.g., an ABORT TASK).

Table 195 shows how the arguments to the Send Data-In transport protocol service are used.

**Table 195 — Send Data-In transport protocol service arguments**

| Argument                         | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                  |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T_L_Q nexus                    | I_T_L_Q nexus, where:<br>a) I specifies the SSP initiator port to which the read DATA frame is to be sent;<br>b) T specifies the SSP target port to send the read DATA frame;<br>c) L specifies the LOGICAL UNIT NUMBER field in the read DATA frame header; and<br>d) Q specifies the INITIATOR PORT TRANSFER TAG field in the read DATA frame header. |
| Device Server Buffer             | Internal to the SCSI device server.                                                                                                                                                                                                                                                                                                                     |
| Application Client Buffer Offset | Specifies the DATA OFFSET field in the read DATA frame.                                                                                                                                                                                                                                                                                                 |
| Request Byte Count               | Specifies the size of the read DATA frame.                                                                                                                                                                                                                                                                                                              |

#### 9.2.1.7 Data-In Delivered transport protocol service

An SSP target port uses the Data-In Delivered transport protocol service indication to notify a SCSI device server of the results of transmitting a read DATA frame.

##### **Data-In Delivered (IN (I\_T\_L\_Q Nexus, Delivery Result))**

Table 196 shows how the arguments to the Data-In Delivered transport protocol service are determined.

**Table 196 — Data-In Delivered transport protocol service arguments**

| Argument        | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                                     |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T_L_Q nexus   | I_T_L_Q nexus, where:<br>a) I indicates the SSP initiator port that sent the read DATA frame;<br>b) T indicates the SSP target port that received the read DATA frame;<br>c) L indicates the value of the LOGICAL UNIT NUMBER field in the read DATA frame header; and<br>d) Q indicates the value of the INITIATOR PORT TRANSFER TAG field in the read DATA frame header. |
| Delivery Result | From the response to the outgoing read DATA frame:<br>a) DELIVERY SUCCESSFUL: The read DATA frame received an ACK; or<br>b) DELIVERY FAILURE: The read DATA frame received a NAK or no response.                                                                                                                                                                           |

#### 9.2.1.8 Receive Data-Out transport protocol service

A SCSI device server uses the Receive Data-Out transport protocol service request to request that an SSP target port transmit an XFER\_RDY frame.

##### **Receive Data-Out (IN (I\_T\_L\_Q Nexus, Application Client Buffer Offset, Request Byte Count, Device Server Buffer))**

A SCSI device server shall only call Receive Data-Out () during a write command or bidirectional command.

A SCSI device server shall not call Receive Data-Out () for a given I\_T\_L\_Q nexus until the Data-Out Received () has completed without error for the previous Receive Data-Out () call for that I\_T\_L\_Q nexus (i.e., no XFER\_RDY frame shall be transmitted until all write DATA frames for the previous XFER\_RDY frame, if any, have been received, and the link layer has provided acknowledgement for all of the previous write DATA frames for that I\_T\_L\_Q nexus).

A SCSI device server shall not call Receive Data-Out () for a given I\_T\_L\_Q nexus after a Send Command Complete () has been called for that I\_T\_L\_Q nexus or after a Task Management Function Executed () has been called for a task management function that terminates that command (e.g., an ABORT TASK).

Table 197 shows how the arguments to the Receive Data-Out transport protocol service are used.

**Table 197 — Receive Data-Out transport protocol service arguments**

| Argument                         | SAS SSP implementation                                                                                                                                                                                                                                                                                                                              |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T_L_Q nexus                    | I_T_L_Q nexus, where:<br>a) I specifies the SSP initiator port to which the XFER_RDY frame is to be sent;<br>b) T specifies the SSP target port to send the XFER_RDY frame;<br>c) L specifies the LOGICAL UNIT NUMBER field in the XFER_RDY frame header; and<br>d) Q specifies the INITIATOR PORT TRANSFER TAG field in the XFER_RDY frame header. |
| Application Client Buffer Offset | Specifies the REQUESTED OFFSET field in the XFER_RDY frame.                                                                                                                                                                                                                                                                                         |
| Request Byte Count               | Specifies WRITE DATA LENGTH field in the XFER_RDY frame.                                                                                                                                                                                                                                                                                            |
| Device Server Buffer             | Internal to the SCSI device server.                                                                                                                                                                                                                                                                                                                 |

#### 9.2.1.9 Data-Out Received transport protocol service

An SSP target port uses the Data-Out Received transport protocol service indication to notify a SCSI device server of the result of transmitting an XFER\_RDY frame (e.g., receiving write DATA frames in response).

##### **Data-Out Received (IN (I\_T\_L\_Q Nexus, Delivery Result))**

Table 198 shows how the arguments to the Data-Out Received transport protocol service are determined.

**Table 198 — Data-Out Received transport protocol service arguments**

| Argument        | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                                     |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I_T_L_Q nexus   | I_T_L_Q nexus, where:<br>a) I indicates the SSP initiator port to which the XFER_RDY frame was sent;<br>b) T indicates the SSP target port that sent the XFER_RDY frame;<br>c) L indicates the value of the LOGICAL UNIT NUMBER field in the XFER_RDY frame header; and<br>d) Q indicates the value of the INITIATOR PORT TRANSFER TAG field in the XFER_RDY frame header. |
| Delivery Result | From the response to the XFER_RDY:<br>a) DELIVERY SUCCESSFUL: The XFER_RDY frame was transmitted without error and all the write DATA frames for the requested write data were received; or<br>b) DELIVERY FAILURE: The XFER_RDY frame received a NAK or no response.                                                                                                      |

### 9.2.1.10 Terminate Data Transfer transport protocol service

A SCSI device server uses the Terminate Data Transfer transport protocol service request to request that an SSP target port terminate any Send Data-In () or Receive Data-Out () transport protocol services, if any, being processed using the specified nexus.

#### Terminate Data Transfer (IN (Nexus))

Table 199 shows how the arguments to the Terminate Data Transfer transport protocol service are used.

**Table 199 — Terminate Data Transfer transport protocol service arguments**

| Argument | SAS SSP implementation                                                                               |
|----------|------------------------------------------------------------------------------------------------------|
| Nexus    | I_T nexus, I_T_L nexus, or I_T_L_Q nexus, specifying the scope of the data transfer(s) to terminate. |

### 9.2.1.11 Data Transfer Terminated transport protocol service

An SSP target port uses the Data Transfer Terminated transport protocol service indication to notify a SCSI device server that all data transfers for the indicated nexus have been terminated.

#### Data Transfer Terminated (IN (Nexus))

Table 200 shows how the arguments to the Data Transfer Terminated transport protocol service are determined.

**Table 200 — Data Transfer Terminated transport protocol service arguments**

| Argument | SAS SSP implementation                                                                               |
|----------|------------------------------------------------------------------------------------------------------|
| Nexus    | I_T nexus, I_T_L nexus, or I_T_L_Q nexus indicated by the preceding Terminate Data Transfer () call. |

### 9.2.1.12 Send Task Management Request transport protocol service

A SCSI application client uses the Send Task Management Request transport protocol service request to request that an SSP initiator port transmit a TASK frame.

#### Send Task Management Request (IN (Nexus, Function Identifier, Task Management Tag, [Request Fence]))

Table 201 shows how the arguments to the Send Task Management Request transport protocol service are used.

**Table 201 — Send Task Management Request transport protocol service arguments**

| Argument            | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Nexus               | <p>I_T nexus, I_T_L nexus, or I_T_L_Q nexus (depending on the Function Identifier), where:</p> <ul style="list-style-type: none"> <li>a) I specifies the SSP initiator port to send the TASK frame;</li> <li>b) T specifies the SSP target port to which the TASK frame is sent;</li> <li>c) L (for an I_T_L nexus or an I_T_L_Q nexus) specifies the LOGICAL UNIT NUMBER field in the TASK frame header; and</li> <li>d) Q (for an I_T_L_Q nexus) specifies the INITIATOR PORT TRANSFER TAG TO MANAGE field in the TASK frame header.</li> </ul>                                                                                                                                                                                                                                                                                 |
| Function Identifier | <p>Specifies the TASK MANAGEMENT FUNCTION field in the TASK frame. Only these task management functions are supported:</p> <ul style="list-style-type: none"> <li>a) ABORT TASK (Nexus argument specifies an I_T_L_Q Nexus);</li> <li>b) ABORT TASK SET (Nexus argument specifies an I_T_L Nexus);</li> <li>c) CLEAR ACA (Nexus argument specifies an I_T_L Nexus);</li> <li>d) CLEAR TASK SET (Nexus argument specifies an I_T_L Nexus);</li> <li>e) I_T NEXUS RESET (Nexus argument specifies an I_T Nexus);</li> <li>f) LOGICAL UNIT RESET (Nexus argument specifies an I_T_L Nexus);</li> <li>g) QUERY TASK (Nexus argument specifies an I_T_L_Q Nexus);</li> <li>h) QUERY TASK SET (Nexus argument specifies an I_T_L Nexus); and</li> <li>i) QUERY ASYNCHRONOUS EVENT (Nexus argument specifies an I_T_L Nexus).</li> </ul> |
| Task Management Tag | Specifies the INITIATOR PORT TRANSFER TAG field in the TASK frame header.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| [Request Fence]     | If included, specifies an I_T nexus, I_T_L nexus, or I_T_L_Q nexus for which the TASK frame is fenced.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

A SCSI application client shall set the Request Fence argument to the Nexus argument.

#### 9.2.1.13 Task Management Request Received transport protocol service

An SSP target port uses the Task Management Request Received transport protocol service indication to notify a task manager that the SSP target port has received a TASK frame.

**Task Management Request Received (IN (Nexus, Function Identifier, Task Management Tag))**

Table 202 shows how the arguments to the Task Management Request Received transport protocol service are determined.

**Table 202 — Task Management Request Received transport protocol service arguments**

| Argument            | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Nexus               | <p>I_T nexus, I_T_L nexus, or I_T_L_Q nexus (depending on the Function Identifier), where:</p> <ul style="list-style-type: none"> <li>a) I indicates the SSP initiator port that sent the TASK frame;</li> <li>b) T indicates the SSP target port that received the TASK frame;</li> <li>c) L (for an I_T_L nexus or an I_T_L_Q nexus) indicates the LOGICAL UNIT NUMBER field in the TASK frame header; and</li> <li>d) Q (for an I_T_L_Q nexus) indicates the INITIATOR PORT TRANSFER TAG TO MANAGE field in the TASK frame header.</li> </ul>                                                                                                                                                                                                                                                                                  |
| Function Identifier | <p>Indicates the TASK MANAGEMENT FUNCTION field in the TASK frame. Only these task management functions are supported:</p> <ul style="list-style-type: none"> <li>a) ABORT TASK (Nexus argument indicates an I_T_L_Q Nexus);</li> <li>b) ABORT TASK SET (Nexus argument indicates an I_T_L Nexus);</li> <li>c) CLEAR ACA (Nexus argument indicates an I_T_L Nexus);</li> <li>d) CLEAR TASK SET (Nexus argument indicates an I_T_L Nexus);</li> <li>e) I_T NEXUS RESET (Nexus argument indicates an I_T Nexus);</li> <li>f) LOGICAL UNIT RESET (Nexus argument indicates an I_T_L Nexus);</li> <li>g) QUERY TASK (Nexus argument indicates an I_T_L_Q Nexus);</li> <li>h) QUERY TASK SET (Nexus argument indicates an I_T_L Nexus); and</li> <li>i) QUERY ASYNCHRONOUS EVENT (Nexus argument indicates an I_T_L Nexus).</li> </ul> |
| Task Management Tag | Indicates the INITIATOR PORT TRANSFER TAG field in the TASK frame header.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

#### 9.2.1.14 Task Management Function Executed transport protocol service

A task manager uses the Task Management Function Executed transport protocol service response to request that an SSP target port transmit a RESPONSE frame.

**Task Management Function Executed (IN (Nexus, Service Response, [Additional Response Information], Task Management Tag, [Response Fence]))**

A task manager shall only call Task Management Function Executed () after receiving Task Management Request Received ().

Table 203 shows how the arguments to the Task Management Function Executed transport protocol service are used.

**Table 203 — Task Management Function Executed transport protocol service arguments**

| Argument                          | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Nexus                             | I_T_L nexus or I_T_L_Q nexus (depending on the function), where:<br>a) I specifies the SSP initiator port to which the RESPONSE frame is sent;<br>b) T specifies the SSP target port to send the RESPONSE frame;<br>c) L (for an I_T_L nexus or an I_T_L_Q nexus) specifies the logical unit that is sending the response frame; and<br>d) Q (for an I_T_L_Q nexus) specifies the command that was managed by the task management function.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Service Response                  | Specifies the DATAPRES field and RESPONSE CODE field in the RESPONSE frame:<br>a) FUNCTION COMPLETE: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to TASK MANAGEMENT FUNCTION COMPLETE;<br>b) FUNCTION SUCCEEDED: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to TASK MANAGEMENT FUNCTION SUCCEEDED;<br>c) FUNCTION REJECTED: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to TASK MANAGEMENT FUNCTION NOT SUPPORTED;<br>d) INCORRECT LOGICAL UNIT NUMBER: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to INCORRECT LOGICAL UNIT NUMBER;<br>e) SERVICE DELIVERY OR TARGET FAILURE: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to TASK MANAGEMENT FUNCTION FAILED; or<br>f) SERVICE DELIVERY OR TARGET FAILURE - Overlapped Initiator Port Transfer Tag Attempted: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED. |
| [Additional Response Information] | Specifies the ADDITIONAL RESPONSE INFORMATION field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Task Management Tag               | Specifies the INITIATOR PORT TRANSFER TAG field in the RESPONSE frame header.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| [Response Fence]                  | If included, specifies an I_T nexus, I_T_L nexus, or I_T_L_Q nexus for which the RESPONSE frame is fenced.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

A SCSI device server shall set the Response Fence argument to the Nexus argument.

#### 9.2.1.15 Received Task Management Function Executed transport protocol service

An SSP initiator port uses the Received Task Management Function Executed transport protocol service confirmation to notify a SCSI application client that the SSP initiator port has received a response to a TASK frame (e.g., received a RESPONSE frame or a NAK).

**Received Task Management Function Executed (IN (Nexus, Service Response, [Additional Response Information], Task Management Tag))**



Table 204 shows how the arguments to the Received Task Management Function Executed transport protocol service are determined.

**Table 204 — Received Task Management Function Executed transport protocol service arguments**

| Argument                          | SAS SSP implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Nexus                             | <p>I_T nexus, I_T_L nexus, or I_T_L_Q nexus (depending on the function), where:</p> <ul style="list-style-type: none"> <li>a) I indicates the SSP initiator port that received the RESPONSE frame;</li> <li>b) T indicates the SSP target port that sent the RESPONSE frame;</li> <li>c) L (for an I_T_L nexus or an I_T_L_Q nexus) indicates the logical unit that sent the response frame, and is indicated by the LOGICAL UNIT NUMBER field of the TASK frame with an INITIATOR PORT TRANSFER TAG field equal to the INITIATOR PORT TRANSFER TAG field in the RESPONSE frame header; and</li> <li>d) Q (for an I_T_L_Q nexus) indicates the command that was managed by the task management function, and is indicated by the INITIATOR PORT TRANSFER TAG field of the COMMAND frame with an INITIATOR PORT TRANSFER TAG field equal to the INITIATOR PORT TRANSFER TAG TO MANAGE field in the TASK frame with an INITIATOR PORT TRANSFER TAG field equal to the INITIATOR PORT TRANSFER TAG field in the RESPONSE frame header.</li> </ul>                                                                                                                                                                                                                                                                                     |
| Service Response                  | <p>Indicates the response to the TASK frame:</p> <ul style="list-style-type: none"> <li>a) FUNCTION COMPLETE: The RESPONSE frame contains a DATAPRES field set to RESPONSE_DATA and a RESPONSE CODE field set to TASK MANAGEMENT FUNCTION COMPLETE;</li> <li>b) FUNCTION SUCCEEDED: The RESPONSE frame contains a DATAPRES field set to RESPONSE_DATA and a RESPONSE CODE field set to TASK MANAGEMENT FUNCTION SUCCEEDED;</li> <li>c) FUNCTION REJECTED: The RESPONSE frame contains a DATAPRES field set to RESPONSE_DATA and a RESPONSE CODE field set to TASK MANAGEMENT FUNCTION NOT SUPPORTED;</li> <li>d) INCORRECT LOGICAL UNIT NUMBER: The RESPONSE frame contains a DATAPRES field set to RESPONSE_DATA and a RESPONSE CODE field set to INCORRECT LOGICAL UNIT NUMBER; or</li> <li>e) SERVICE DELIVERY OR TARGET FAILURE: The ST_IFR state machine detects an error as described in 8.2.6.2.2.3 and 8.2.6.2.2.4 (e.g., a NAK was received for the COMMAND frame or the length of the RESPONSE frame is incorrect), or the RESPONSE frame contains a DATAPRES field set to RESPONSE_DATA and a RESPONSE CODE field set to: <ul style="list-style-type: none"> <li>A) INVALID FRAME;</li> <li>B) TASK MANAGEMENT FUNCTION FAILED; or</li> <li>C) OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED.</li> </ul> </li> </ul> |
| [Additional Response Information] | Indicates the ADDITIONAL RESPONSE INFORMATION field in the RESPONSE frame.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Task Management Tag               | Indicates the INITIATOR PORT TRANSFER TAG field in the RESPONSE frame header or the TASK frame header.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

### 9.2.2 SCSI application client error handling

If a SCSI application client processes Command Complete Received () with a Service Response of:

- a) Service Delivery or Target Failure - XFER\_RDY Incorrect Write Data Length;
- b) Service Delivery or Target Failure - XFER\_RDY Requested Offset Error;



- c) Service Delivery or Target Failure - XFER\_RDY Not Expected;
- d) Service Delivery or Target Failure - DATA Incorrect Data Length;
- e) Service Delivery or Target Failure - DATA Too Much Read Data;
- f) Service Delivery or Target Failure - DATA Data Offset Error;
- g) Service Delivery or Target Failure - DATA Not Expected;
- h) Service Delivery or Target Failure - RESPONSE Incorrect Length;
- i) Service Delivery or Target Failure - NAK Received; or
- j) Service Delivery or Target Failure - Connection Failed,

then the SCSI application client shall abort the command (e.g., by sending an ABORT TASK task management function).

After a SCSI application client calls Send SCSI Command (), if Command Complete Received () returns a Service Response of Service Delivery or Target Failure - ACK/NAK Timeout, then the SCSI application client shall send a QUERY TASK task management function with Send Task Management Request () to determine whether the command was received with no error. If Received Task Management Function Executed () returns a Service Response of:

- a) FUNCTION SUCCEEDED, then the SCSI application client shall assume the command was delivered with no error; or
- b) FUNCTION COMPLETE, and Command Complete Received () has not yet been invoked a second time for the command in question (e.g., indicating a RESPONSE frame arrived for the command before the QUERY TASK was processed), then the SCSI application client shall assume the command was not delivered and may reuse the initiator port transfer tag. The SCSI application client should call Send SCSI Command () again with identical arguments.

After a Received Task Management Function Executed () call with a Service Response of Service Delivery or Target Failure - ACK/NAK Timeout, a SCSI application client should call Send Task Management Request () with identical arguments, including the same initiator port transfer tag.

After a Command Complete Received () or Received Task Management Function Executed () call returns a Service Response other than Service Delivery or Target Failure - ACK/NAK Timeout, a SCSI application client shall not reuse the initiator port transfer tag until it determines the initiator port transfer tag is no longer in use by the logical unit (e.g., the ACK for the RESPONSE frame was seen by the SSP target port). Examples of ways the SCSI application client may determine that an initiator port transfer tag may be reused are:

- a) receiving another frame in the same connection;
- b) receiving a DONE (NORMAL) or DONE (CREDIT TIMEOUT) in the same connection; or
- c) receiving a DONE (ACK/NAK TIMEOUT) in the same connection, then running a QUERY TASK task management function to confirm that the initiator port transfer tag is no longer active in the logical unit.

### 9.2.3 SCSI device server error handling

#### 9.2.3.1 SCSI Command Received () error handling

If a SCSI device server processes SCSI Command Received () and the CDB argument does not contain all the bytes of the CDB (see SPC-4), then the SCSI device server shall terminate the command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN COMMAND INFORMATION UNIT.

#### 9.2.3.2 Data-Out Received () error handling

If a SCSI device server processes Data-Out Received () with a Delivery Result set to a value in table 205, then the SCSI device server shall terminate the command with CHECK CONDITION status with the sense

key set to ABORTED COMMAND and the additional sense code set as indicated in table 205.

**Table 205 — Delivery Result to additional sense code mapping**

| Delivery Result                               | Additional sense code                               |
|-----------------------------------------------|-----------------------------------------------------|
| DELIVERY FAILURE - DATA OFFSET ERROR          | DATA OFFSET ERROR                                   |
| DELIVERY FAILURE - TOO MUCH WRITE DATA        | TOO MUCH WRITE DATA                                 |
| DELIVERY FAILURE - INFORMATION UNIT TOO SHORT | INFORMATION UNIT TOO SHORT                          |
| DELIVERY FAILURE - ACK/NAK TIMEOUT            | ACK/NAK TIMEOUT                                     |
| DELIVERY FAILURE - CONNECTION FAILED          | Should be CONNECTION LOST<br>May be ACK/NAK TIMEOUT |
| DELIVERY FAILURE - NAK RECEIVED               | NAK RECEIVED                                        |
| DELIVERY FAILURE - INITIATOR RESPONSE TIMEOUT | INITIATOR RESPONSE TIMEOUT                          |

#### 9.2.4 Task router and task manager error handling

If a SCSI target device performs initiator port transfer tag checking and a task router or task manager processes SCSI Command Received () with an initiator port transfer tag already in use by another command (i.e., an overlapped command (see SAM-5)) in any logical unit, then the task router or task manager(s) shall:

- a) abort all task management functions received on that I\_T nexus; and
- b) respond to the overlapped command as defined in SAM-5.

If a SCSI target device performs initiator port transfer tag checking and:

- a) a task router or task manager processes SCSI Command Received () with an initiator port transfer tag already in use by a task management function in any logical unit; or
- b) a task router or task manager processes Task Management Request Received () with an initiator port transfer tag already in use by a command or task management function in any logical unit,

then the task router or task manager shall:

- a) abort all commands received on that I\_T nexus;
- b) abort all task management functions received on that I\_T nexus; and
- c) call Task Management Function Executed () with the Service Response set to SERVICE DELIVERY OR TARGET FAILURE - Overlapped Initiator Port Transfer Tag Attempted (i.e., requesting that the SSP target port set the DATAPRES field to RESPONSE\_DATA and the RESPONSE CODE field to OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED).

#### 9.2.5 SCSI transport protocol services for event notifications

The SCSI transport protocol services are used by:

- a) an SSP initiator port to deliver an indication of an event to a SCSI application client; and
- b) an SSP target port to deliver an indication of an event to a task manager and a SCSI device server.

Table 206 lists the SCSI transport protocol services for event notifications supported by this standard.

**Table 206 — SCSI transport protocol events**

| Delivered transport protocol service indication                                                                                                                                                                                                                                                                                                                                                                      | I/T <sup>a</sup> | SSP implementation  | Reference |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------------------|-----------|
| Transport Reset (IN ( SCSI Port )) <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                      | I/T              | Transport Reset     | 4.4.2     |
| Nexus Loss (IN ( I_T Nexus )) <sup>c</sup>                                                                                                                                                                                                                                                                                                                                                                           | I/T              | Nexus Loss          | 4.4.3     |
| Power Loss Expected (IN ( SCSI Port )) <sup>d</sup>                                                                                                                                                                                                                                                                                                                                                                  | T                | Power Loss Expected | 6.2.5.3.3 |
| <sup>a</sup> I/T indicates whether the SSP initiator port (I) or the SSP target port (T) implements the transport protocol service.<br><sup>b</sup> The specific SCSI port in the SCSI device for which a transport reset was detected.<br><sup>c</sup> The specific I_T nexus that has been detected as lost.<br><sup>d</sup> The specific SCSI port in the SCSI device for which power loss expected was detected. |                  |                     |           |

## 9.2.6 SCSI commands

### 9.2.6.1 INQUIRY command

SAS-specific vital product data accessed with the INQUIRY command (see SPC-4) is described in 9.2.11.

### 9.2.6.2 LOG SELECT and LOG SENSE commands

SAS-specific log pages accessed with the LOG SELECT command and LOG SENSE command (see SPC-4) are described in 9.2.8.

### 9.2.6.3 MODE SELECT and MODE SENSE commands

SAS-specific mode pages accessed with the MODE SELECT command and MODE SENSE command (see SPC-4) are described in 9.2.7.

### 9.2.6.4 SEND DIAGNOSTIC and RECEIVE DIAGNOSTIC RESULTS commands

SAS-specific diagnostic pages accessed with the SEND DIAGNOSTIC command and RECEIVE DIAGNOSTIC RESULTS command (see SPC-4) are described in 9.2.9.

Zoning (see 4.8) is applied to SES-3 diagnostic pages as described in 9.2.9.

### 9.2.6.5 START STOP UNIT command

The power condition states controlled by the START STOP UNIT command (see SBC-3) for a SAS device are described in 9.2.10.

## 9.2.7 SCSI mode parameters

### 9.2.7.1 SCSI mode parameters overview

Table 207 defines mode pages supported by logical units in SCSI target devices in SAS domains (i.e., with SSP target ports) that support the MODE SELECT command or MODE SENSE command.

**Table 207 — SSP target port mode pages**

| Mode page code | Subpage code | Description                                 | Reference |
|----------------|--------------|---------------------------------------------|-----------|
| 02h            | 00h          | Disconnect-Reconnect mode page              | 9.2.7.2   |
| 18h            | 00h          | Protocol Specific Logical Unit mode page    | 9.2.7.3   |
|                | 01h to DFh   | Reserved                                    |           |
|                | E0h to FEh   | Vendor specific                             |           |
|                | FFh          | Return all subpages for this mode page code | SPC-4     |
| 19h            | 00h          | Protocol Specific Port mode page            | 9.2.7.4   |
|                | 01h          | Phy Control And Discover mode page          | 9.2.7.5   |
|                | 02h          | Shared Port Control mode page               | 9.2.7.6   |
|                | 03h          | Enhanced Phy Control mode page              | 9.2.7.7   |
|                | 04h to DFh   | Reserved                                    |           |
|                | E0h to FEh   | Vendor specific                             |           |
|                | FFh          | Return all subpages for this mode page code | SPC-4     |

If any field in an implemented mode page is not implemented, then the value of the field shall be assumed to be zero (i.e., as if the field is set to zero) (see SPC-4).

If a mode page defined by this standard is not implemented, then the value of each field in that mode page that is:

- a) allowed by this standard to be changeable (e.g., not defined as a read only field); and
- b) not used solely to define the mode page structure (e.g., the NUMBER OF PHYS field in the Phy Control And Discover mode page) or coordinate access to the mode page (e.g., the GENERATION CODE field in the Phy Control And Discover mode page),

shall be assumed to be zero (i.e., as if the mode page is implemented and the field is set to zero).

### 9.2.7.2 Disconnect-Reconnect mode page

#### 9.2.7.2.1 Disconnect-Reconnect mode page overview

The Disconnect-Reconnect mode page (see SPC-4) provides the SCSI application client the means to tune the performance of a service delivery subsystem. Table 208 defines the parameters that are applicable to SAS SSP.

The SCSI application client sends the values in the fields to be used by the SCSI device server to control the SSP connections by means of a MODE SELECT command. The SCSI device server shall then communicate

the field values to the SSP target port. The field values are communicated from the SCSI device server to the SSP target port in a vendor specific manner.

SAS devices shall only use the parameter fields defined in table 208. If any other fields within the Disconnect-Reconnect mode page of the MODE SELECT command contain a non-zero value, then the SCSI device server shall terminate the MODE SELECT command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

**Table 208 — Disconnect-Reconnect mode page for SAS SSP**

| Byte\Bit | 7                 | 6                    | 5               | 4 | 3 | 2 | 1 | 0     |
|----------|-------------------|----------------------|-----------------|---|---|---|---|-------|
| 0        | PS                | SPF (0b)             | PAGE CODE (02h) |   |   |   |   |       |
| 1        | PAGE LENGTH (0Eh) |                      |                 |   |   |   |   |       |
| 2        | Reserved          |                      |                 |   |   |   |   |       |
| 3        | Reserved          |                      |                 |   |   |   |   |       |
| 4        | (MSB)             | BUS INACTIVITY LIMIT |                 |   |   |   |   |       |
| 5        |                   |                      |                 |   |   |   |   | (LSB) |
| 6        |                   | Reserved             |                 |   |   |   |   |       |
| 7        |                   |                      |                 |   |   |   |   |       |
| 8        | (MSB)             | CONNECT TIME LIMIT   |                 |   |   |   |   |       |
| 9        |                   |                      |                 |   |   |   |   | (LSB) |
| 10       | (MSB)             | MAXIMUM BURST SIZE   |                 |   |   |   |   |       |
| 11       |                   |                      |                 |   |   |   |   | (LSB) |
| 12       |                   | Reserved             |                 |   |   |   |   |       |
| 13       |                   |                      |                 |   |   |   |   |       |
| 14       | (MSB)             | FIRST BURST SIZE     |                 |   |   |   |   |       |
| 15       |                   |                      |                 |   |   |   |   | (LSB) |

The PARAMETERS SAVEABLE (PS) bit is defined in SPC-4.

The SUBPAGE FORMAT (SPF) bit is defined in SPC-4 and shall be set as shown in table 208 for the Disconnect-Reconnect mode page for SAS SSP.

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 208 for the Disconnect-Reconnect mode page for SAS SSP.

The PAGE LENGTH field is defined in SPC-4 and shall be set as shown in table 208 for the Disconnect-Reconnect mode page for SAS SSP.

The BUS INACTIVITY LIMIT field is defined in SPC-4 and 9.2.7.2.2.

The CONNECT TIME LIMIT field is defined in SPC-4 and 9.2.7.2.3.

The MAXIMUM BURST SIZE field is defined in SPC-4 and 9.2.7.2.4.

The FIRST BURST SIZE field is defined in SPC-4 and 9.2.7.2.5.

#### 9.2.7.2.2 BUS INACTIVITY LIMIT field

The BUS INACTIVITY LIMIT field contains the maximum time, in 100  $\mu$ s increments, that an SSP target port is permitted to maintain a connection (see 4.1.12) without transferring a frame to the SSP initiator port. If this time is exceeded and a persistent connection has not been established (see 4.1.13), then, the SSP target port shall prepare to close the connection (i.e., by requesting to have the link layer transmit DONE). This value may be rounded as defined in SPC-4. A value of 0000h in this field specifies that there is no bus inactivity time limit. The bus inactivity time limit is enforced by the port layer (see 7.2.3).

#### 9.2.7.2.3 CONNECT TIME LIMIT field

The CONNECT TIME LIMIT field contains the maximum duration of a connection (see 4.1.12) in 100  $\mu$ s increments (e.g., a value of 0001h in this field means that the time is less than or equal to 100  $\mu$ s and a value of 0002h in this field means that the time is less than or equal to 200  $\mu$ s). If this time is exceeded and a persistent connection has not been established (see 4.1.13), then, the SSP target port shall prepare to close the connection. If an SSP target port is transferring a frame when the maximum connection time limit is exceeded, then the SSP target port shall complete transfer of the frame before preparing to close the connection. This value may be rounded as defined in SPC-4. A value of 0000h in this field specifies that there is no maximum connection time limit. The maximum connection time limit is enforced by the port layer (see 7.2.3).

#### 9.2.7.2.4 MAXIMUM BURST SIZE field

If a persistent connection has been established (see 4.1.13), then the MAXIMUM BURST SIZE field shall be ignored.

If a persistent connection has not been established (see 4.1.13), then:

- a) for read data, the MAXIMUM BURST SIZE field contains the maximum amount of data in 512-byte increments that is transferred during a connection by an SSP target port per I\_T\_L\_Q nexus without transferring at least one frame for a different I\_T\_L\_Q nexus;

If the SSP target port:

- A) has read data to transfer for only one I\_T\_L\_Q nexus; and
- B) has no requests to transfer write data for any I\_T\_L\_Q nexus,

then the SSP target port shall prepare to close the connection after the amount of data specified by the MAXIMUM BURST SIZE field is transferred to the SSP initiator port; and

- b) for write data, the MAXIMUM BURST SIZE field shall specify the maximum amount of data that an SSP target port requests via a single XFER\_RDY frame (see 8.2.2.3).

If a persistent connection has not been established (see 4.1.13), then:

- a) the MAXIMUM BURST SIZE field is specified in 512-byte increments (e.g., a value of 0001h in this field means that the number of bytes transferred to the SSP initiator port for the nexus is less than or equal to 512, and a value of 0002h in this field means that the number of bytes transferred to the SSP initiator port for the nexus is less than or equal to 1 024). A value of 0000h in this field specifies that there is no maximum burst size; and
- b) in terms of the SCSI transport protocol services (see 9.2.1), the SCSI device server shall limit the Request Byte Count argument to the Receive Data-Out transport protocol service and the Send Data-In transport protocol service to the amount specified in this field.

### 9.2.7.2.5 FIRST BURST SIZE field

If the ENABLE FIRST BURST bit is set to zero in the COMMAND frame, then the FIRST BURST SIZE field is ignored.

If the ENABLE FIRST BURST bit is set to one in the COMMAND frame, then the FIRST BURST SIZE field contains the maximum amount of write data in 512-byte increments that may be sent by the SSP initiator port to the SSP target port without having to receive an XFER\_RDY frame (see 8.2.2.3) from the SSP target port (e.g., a value of 0001h in this field means that the number of bytes transferred by the SSP initiator port is less than or equal to 512 and a value of 0002h in this field means that the number of bytes transferred by the SSP initiator port is less than or equal to 1 024).

Specifying a non-zero value in the FIRST BURST SIZE field is equivalent to an implicit XFER\_RDY frame for each command requiring write data where the WRITE DATA LENGTH field of the XFER\_RDY frame is set to 512 times the value of the FIRST BURST SIZE field.

The rules for data transferred using the value in the FIRST BURST SIZE field are the same as those used for data transferred for an XFER\_RDY frame (i.e., the number of bytes transferred using the value in the FIRST BURST SIZE field is as if that number of bytes was requested by an XFER\_RDY frame).

If the amount of data to be transferred for the command is less than the amount of data specified by the FIRST BURST SIZE field, then the SSP target port shall not transmit an XFER\_RDY frame for the command. If the amount of data to be transferred for the command is greater than the amount of data specified by the FIRST BURST SIZE field, then the SSP target port shall transmit an XFER\_RDY frame after it has received all of the data specified by the FIRST BURST SIZE field from the SSP initiator port. All data for the command is not required to be transferred during the same connection in which the command is transferred.

A value of 0000h in this field specifies that there is no first burst size (i.e., an SSP initiator port transmits no write DATA frames to the SSP target port before receiving an XFER\_RDY frame).

The first burst size is handled by the SCSI transport protocol services (see 9.2.1) and the SSP transport layer (see 8.2.6).

### 9.2.7.3 Protocol Specific Logical Unit mode page

The Protocol Specific Logical Unit mode page (see SPC-4) contains parameters that affect SSP target port operation on behalf of the logical unit.

The mode page policy (see SPC-4) for this mode page shall be either shared or per target port. If the SAS target device has multiple SSP target ports, then the mode page policy should be per target port.

Parameters in this mode page shall affect all phys in:

- a) the SSP target port if the mode page policy is per target port; or
- b) all SSP target ports in the SAS target device if the mode page policy is shared.



Table 209 defines the format of the page for SAS SSP.

**Table 209 — Protocol Specific Logical Unit mode page for SAS SSP**

| Byte\Bit | 7                 | 6        | 5               | 4                             | 3                        | 2 | 1 | 0 |
|----------|-------------------|----------|-----------------|-------------------------------|--------------------------|---|---|---|
| 0        | PS                | SPF (0b) | PAGE CODE (18h) |                               |                          |   |   |   |
| 1        | PAGE LENGTH (06h) |          |                 |                               |                          |   |   |   |
| 2        | Reserved          |          |                 | TRANSPORT<br>LAYER<br>RETRIES | PROTOCOL IDENTIFIER (6h) |   |   |   |
| 3        | Reserved          |          |                 |                               |                          |   |   |   |
| ...      |                   |          |                 |                               |                          |   |   |   |
| 7        |                   |          |                 |                               |                          |   |   |   |

The PARAMETERS SAVEABLE (PS) bit is defined in SPC-4.

The SUBPAGE FORMAT (SPF) bit is defined in SPC-4 and shall be set as shown in table 209 for the Protocol Specific Logical Unit mode page for SAS SSP.

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 209 for the Protocol Specific Logical Unit mode page for SAS SSP.

The PAGE LENGTH field is defined in SPC-4 and shall be set as shown in table 209 for the Protocol Specific Logical Unit mode page for SAS SSP.

A TRANSPORT LAYER RETRIES bit set to one specifies that, for commands received in COMMAND frames with the TLR CONTROL field set to 00b or 11b (see 8.2.1), the SSP target port shall support transport layer retries for XFER\_RDY and DATA frames for the logical unit as described in 8.2.4 (i.e., transport layer retries are enabled). A TRANSPORT LAYER RETRIES bit set to zero specifies that, for commands received in COMMAND frames with the TLR CONTROL field set to 00b or 11b (see 8.2.1), transport layer retries shall not be used (i.e., transport layer retries are disabled).

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 209 for the Protocol Specific Logical Unit mode page for SAS SSP indicating that this is a SAS SSP specific mode page.

#### 9.2.7.4 Protocol Specific Port mode page

The Protocol Specific Port mode page (see SPC-4) contains parameters that affect SSP target port operation. If the mode page is implemented by one logical unit in a SCSI target device, then it shall be implemented by all logical units in the SCSI target device that support the MODE SELECT or MODE SENSE commands.

The mode page policy (see SPC-4) for this mode page shall be either shared or per target port. If a SAS target device has multiple SSP target ports, then the mode page policy should be per target port.

Parameters in this mode page shall affect all phys in:

- the SSP target port if the mode page policy is per target port; or
- all SSP target ports in the SAS target device if the mode page policy is shared.



Table 210 defines the format of the page for SAS SSP.

**Table 210 — Protocol Specific Port mode page for SAS SSP**

| Byte\Bit | 7                          | 6            | 5                            | 4                 | 3                        | 2 | 1 | 0 |  |
|----------|----------------------------|--------------|------------------------------|-------------------|--------------------------|---|---|---|--|
| 0        | PS                         | SPF (0b)     | PAGE CODE (19h)              |                   |                          |   |   |   |  |
| 1        | PAGE LENGTH (0Eh)          |              |                              |                   |                          |   |   |   |  |
| 2        | Reserved                   | CONTINUE AWT | BROADCAST ASYNCHRONOUS EVENT | READY LED MEANING | PROTOCOL IDENTIFIER (6h) |   |   |   |  |
| 3        | Reserved                   |              |                              |                   |                          |   |   |   |  |
| 4        | I_T NEXUS LOSS TIME        |              |                              |                   |                          |   |   |   |  |
| 5        |                            |              |                              |                   |                          |   |   |   |  |
| 6        | INITIATOR RESPONSE TIMEOUT |              |                              |                   |                          |   |   |   |  |
| 7        |                            |              |                              |                   |                          |   |   |   |  |
| 8        | REJECT TO OPEN LIMIT       |              |                              |                   |                          |   |   |   |  |
| 9        |                            |              |                              |                   |                          |   |   |   |  |
| 10       | Reserved                   |              |                              |                   |                          |   |   |   |  |
| ...      |                            |              |                              |                   |                          |   |   |   |  |
| 15       |                            |              |                              |                   |                          |   |   |   |  |

The PARAMETERS SAVEABLE (PS) bit is defined in SPC-4.

The SUBPAGE FORMAT (SPF) bit is defined in SPC-4 and shall be set as shown in table 210 for the Protocol Specific Port mode page for SAS SSP.

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 210 for the Protocol Specific Port mode page for SAS SSP.

The PAGE LENGTH field is defined in SPC-4 and shall be set as shown in table 210 for the Protocol Specific Port mode page for SAS SSP.

A CONTINUE AWT bit set to one specifies that the SAS port shall not stop the Arbitration Wait Time timer and shall not set the Arbitration Wait Time timer to zero when the SAS port receives an OPEN\_REJECT (RETRY). A CONTINUE AWT bit set to zero specifies that the SAS port shall stop the Arbitration Wait Time timer and set the Arbitration Wait Time timer to zero when the SAS port receives an OPEN\_REJECT (RETRY).

A BROADCAST ASYNCHRONOUS EVENT bit set to one specifies that the SCSI device server shall enable origination of Broadcast (Asynchronous Event) (see 4.1.15). A BROADCAST ASYNCHRONOUS EVENT bit set to zero specifies that the SCSI device server shall disable origination of Broadcast (Asynchronous Event).

The READY LED MEANING bit specifies the READY LED signal behavior (see 9.4.1). Regardless of the mode page policy (see SPC-4) for this mode page, the shared mode page policy shall be applied to the READY LED MEANING bit.

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 210 for the Protocol Specific Port mode page for SAS SSP indicating that this is a SAS SSP specific mode page.

The I\_T NEXUS LOSS TIME field contains the minimum time that the SSP target port shall retry connection requests to an SSP initiator port that are rejected with certain responses indicating that the SSP initiator port may no longer be present (see 7.2.2) before recognizing an I\_T nexus loss (see 4.4.3).

An SSP initiator port should retry connection requests for at least the time indicated by the I\_T NEXUS LOSS TIME field in the Protocol Specific Port mode page for the SSP target port to which it is trying to establish a connection (see 4.4.3).

Table 211 defines the values of the I\_T NEXUS LOSS TIME field. This value is enforced by the port layer (see 7.2.2).

**Table 211 — I\_T NEXUS LOSS TIME field**

| Code <sup>a</sup>                                                                                                                                                                       | Description                                                                                                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| 0000h                                                                                                                                                                                   | Vendor specific amount of time.                                                                                     |
| 0001h to FFFEh                                                                                                                                                                          | Time in one millisecond increments.                                                                                 |
| FFFFh                                                                                                                                                                                   | The SSP target port shall never recognize an I_T nexus loss (i.e., it shall retry the connection requests forever). |
| <sup>a</sup> If this mode page is implemented, then the default value of the I_T NEXUS LOSS TIME field should be non-zero. It is recommended that this value be 07D0h (i.e., 2 000 ms). |                                                                                                                     |

The INITIATOR RESPONSE TIMEOUT field contains the minimum time in one millisecond increments that the SSP target port shall wait for the receipt of a frame (e.g., a write DATA frame) before aborting the command associated with that frame. An INITIATOR RESPONSE TIMEOUT field set to 0000h indicates that the SSP target port shall disable the initiator response timeout timer. This value is enforced by the transport layer (see 8.2.6.3).

The REJECT TO OPEN LIMIT field contains the minimum time, in 10  $\mu$ s increments, that the SSP target port shall wait to establish a connection request with an initiator port on an I\_T nexus after receiving an OPEN\_REJECT (RETRY), OPEN\_REJECT (RESERVED CONTINUE 0), or OPEN\_REJECT (RESERVED CONTINUE 1). This value may be rounded as defined in SPC-4. A REJECT TO OPEN LIMIT field set to 0000h indicates that the minimum time is vendor specific. This minimum time is enforced by the port layer (see 7.2.3).

#### 9.2.7.5 Phy Control And Discover mode page

The Phy Control And Discover mode page contains parameters that affect SSP target phy operation. If the mode page is implemented by one logical unit in a SCSI target device, then it shall be implemented by all logical units in the SCSI target device that support the MODE SELECT command or MODE SENSE command.

The mode page policy (see SPC-4) for this mode page shall be shared. Parameters in this mode page shall affect only the referenced phy.

Table 212 defines the format of this mode page.

**Table 212 — Phy Control And Discover mode page**

| Byte\Bit                     | 7                                               | 6        | 5               | 4 | 3                        | 2 | 1 | 0 |
|------------------------------|-------------------------------------------------|----------|-----------------|---|--------------------------|---|---|---|
| 0                            | PS                                              | SPF (1b) | PAGE CODE (19h) |   |                          |   |   |   |
| 1                            | SUBPAGE CODE (01h)                              |          |                 |   |                          |   |   |   |
| 2                            | (MSB)                                           |          |                 |   |                          |   |   |   |
| 3                            | PAGE LENGTH (n - 3)                             |          |                 |   |                          |   |   |   |
| 4                            | (LSB)                                           |          |                 |   |                          |   |   |   |
| 4                            | Reserved                                        |          |                 |   |                          |   |   |   |
| 5                            | Reserved                                        |          |                 |   | PROTOCOL IDENTIFIER (6h) |   |   |   |
| 6                            | GENERATION CODE                                 |          |                 |   |                          |   |   |   |
| 7                            | NUMBER OF PHYS                                  |          |                 |   |                          |   |   |   |
| SAS phy mode descriptor list |                                                 |          |                 |   |                          |   |   |   |
| 8                            | SAS phy mode descriptor (first) (see table 213) |          |                 |   |                          |   |   |   |
| ...                          |                                                 |          |                 |   |                          |   |   |   |
| 55                           |                                                 |          |                 |   |                          |   |   |   |
| ...                          | ...                                             |          |                 |   |                          |   |   |   |
| n - 47                       | SAS phy mode descriptor (last) (see table 213)  |          |                 |   |                          |   |   |   |
| ...                          |                                                 |          |                 |   |                          |   |   |   |
| n                            |                                                 |          |                 |   |                          |   |   |   |

The PARAMETERS SAVEABLE (PS) bit is defined in SPC-4.

The SUBPAGE FORMAT (SPF) bit is defined in SPC-4 and shall be set as shown in table 212 for the Phy Control And Discover mode page.

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 212 for the Phy Control And Discover mode page.

The SUBPAGE CODE field is defined in SPC-4 and shall be set as shown in table 212 for the Phy Control And Discover mode page.

The PAGE LENGTH field is defined in SPC-4 and shall be set as shown in table 212 for the Phy Control And Discover mode page (i.e.,  $4 + ((\text{the value of the NUMBER OF PHYS field}) \times (\text{the length in bytes of the SAS phy mode descriptor}))$ ).

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 212 for the Phy Control And Discover mode page indicating that this is a SAS SSP specific mode page.

The GENERATION CODE field is a one-byte counter that shall be incremented by one by the SCSI device server every time the values in this mode page or the Enhanced Phy Control mode page (see 9.2.7.7) are changed.

A GENERATION CODE field set to 00h indicates the generation code is unknown. The SCSI device server shall wrap this field to 01h as the next increment after the generation code reaches its maximum value (i.e., FFh). The GENERATION CODE field is also contained in the Enhanced Phy Control mode page (see 9.2.7.7) and the Protocol Specific Port log page (see 9.2.8.1) and may be used to correlate phy settings across mode page and log page accesses.

NOTE 61 - SCSI device servers compliant with SAS-1.1 set the GENERATION CODE field to 00h.

The NUMBER OF PHYS field contains the number of phys in the SAS target device and indicates the number of SAS phy mode descriptors in the SAS phy mode descriptor list. This field shall not be changeable with the MODE SELECT command.

The SAS phy mode descriptor list contains a SAS phy mode descriptor for each phy in the SAS target device, not just the SAS target port, starting with the lowest numbered phy and ending with the highest numbered phy as determined by the value in the PHY IDENTIFIER field in the SAS phy mode descriptor.

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Table 213 defines the SAS phy mode descriptor.

**Table 213 — SAS phy mode descriptor**

| Byte\Bit | 7                                          | 6                      | 5                        | 4                        | 3                                   | 2                               | 1                            | 0        |
|----------|--------------------------------------------|------------------------|--------------------------|--------------------------|-------------------------------------|---------------------------------|------------------------------|----------|
| 0        | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 1        | PHY IDENTIFIER                             |                        |                          |                          |                                     |                                 |                              |          |
| 2        | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 3        | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 4        | Reserved                                   | ATTACHED DEVICE TYPE   |                          |                          | ATTACHED REASON                     |                                 |                              |          |
| 5        | REASON                                     |                        |                          |                          | NEGOTIATED LOGICAL LINK RATE        |                                 |                              |          |
| 6        | Reserved                                   |                        |                          |                          | ATTACHED SSP INITIATOR PORT         | ATTACHED STP INITIATOR PORT     | ATTACHED SMP INITIATOR PORT  | Reserved |
| 7        | Reserved                                   |                        |                          |                          | ATTACHED SSP TARGET PORT            | ATTACHED STP TARGET PORT        | ATTACHED SMP TARGET PORT     | Reserved |
| 8        | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| ...      | SAS ADDRESS                                |                        |                          |                          |                                     |                                 |                              |          |
| 15       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 16       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| ...      | ATTACHED SAS ADDRESS                       |                        |                          |                          |                                     |                                 |                              |          |
| 23       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 24       | ATTACHED PHY IDENTIFIER                    |                        |                          |                          |                                     |                                 |                              |          |
| 25       | Reserved                                   | ATTACHED POWER CAPABLE | ATTACHED SLUMBER CAPABLE | ATTACHED PARTIAL CAPABLE | ATTACHED INSIDE ZPSDS PERSISTENT    | ATTACHED REQUESTED INSIDE ZPSDS | ATTACHED BREAK_REPLY CAPABLE |          |
| 26       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| ...      | Reserved for IDENTIFY frame related fields |                        |                          |                          |                                     |                                 |                              |          |
| 31       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 32       | PROGRAMMED MINIMUM PHYSICAL LINK RATE      |                        |                          |                          | HARDWARE MINIMUM PHYSICAL LINK RATE |                                 |                              |          |
| 33       | PROGRAMMED MAXIMUM PHYSICAL LINK RATE      |                        |                          |                          | HARDWARE MAXIMUM PHYSICAL LINK RATE |                                 |                              |          |
| 34       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| ...      | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 41       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 42       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| ...      | Vendor specific                            |                        |                          |                          |                                     |                                 |                              |          |
| 43       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 44       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| ...      | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |
| 47       | Reserved                                   |                        |                          |                          |                                     |                                 |                              |          |

The PROGRAMMED MINIMUM PHYSICAL LINK RATE field and PROGRAMMED MAXIMUM PHYSICAL LINK RATE field are defined in the SMP PHY CONTROL function (see 9.4.3.28) for accesses with MODE SELECT commands and in the SMP DISCOVER function (see 9.4.3.10) for accesses with MODE SENSE commands.

The fields in the SAS phy mode descriptor not defined in this subclause are defined in the SMP DISCOVER response (see 9.4.3.10). These fields shall not be changeable with the MODE SELECT command.

### 9.2.7.6 Shared Port Control mode page

The Shared Port Control mode page contains parameters that affect SSP target port operation. If the mode page is implemented by one logical unit in a SCSI target device, then it shall be implemented by all logical units in the SCSI target device that support the MODE SELECT command or MODE SENSE command.

The mode page policy (see SPC-4) for this mode page shall be shared.

Table 214 defines the format of this mode page.

**Table 214 — Shared Port Control mode page**

| Byte\Bit | 7                   | 6                   | 5               | 4 | 3                        | 2 | 1 | 0     |
|----------|---------------------|---------------------|-----------------|---|--------------------------|---|---|-------|
| 0        | PS                  | SPF (1b)            | PAGE CODE (19h) |   |                          |   |   |       |
| 1        | SUBPAGE CODE (02h)  |                     |                 |   |                          |   |   |       |
| 2        | (MSB)               | PAGE LENGTH (000Ch) |                 |   |                          |   |   | (LSB) |
| 3        |                     |                     |                 |   |                          |   |   |       |
| 4        | Reserved            |                     |                 |   |                          |   |   |       |
| 5        | Reserved            |                     |                 |   | PROTOCOL IDENTIFIER (6h) |   |   |       |
| 6        | (MSB)               | POWER LOSS TIMEOUT  |                 |   |                          |   |   | (LSB) |
| 7        |                     |                     |                 |   |                          |   |   |       |
| 8        | Reserved            |                     |                 |   |                          |   |   |       |
| 9        | POWER GRANT TIMEOUT |                     |                 |   |                          |   |   |       |
| 10       | Reserved            |                     |                 |   |                          |   |   |       |
| ...      |                     |                     |                 |   |                          |   |   |       |
| 15       |                     |                     |                 |   |                          |   |   |       |

The PARAMETERS SAVEABLE (PS) bit is defined in SPC-4.

The SUBPAGE FORMAT (SPF) bit is defined in SPC-4 and shall be set as shown in table 214 for the Shared Port Control mode page.

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 214 for the Shared Port Control mode page.

The SUBPAGE CODE field is defined in SPC-4 and shall be set as shown in table 214 for the Shared Port Control mode page.

The PAGE LENGTH field is defined in SPC-4 and shall be set as shown in table 214 for the Shared Port Control mode page.

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 214 for the Shared Port Control mode page indicating that this is a SAS SSP specific mode page.

The POWER LOSS TIMEOUT field contains the maximum time, in one millisecond increments, that a target port shall respond to connection requests with OPEN\_REJECT (RETRY) after receiving NOTIFY (POWER LOSS EXPECTED) (see 6.2.5.3.3). A POWER LOSS TIMEOUT field set to 0000h specifies that the maximum time is vendor specific. The power loss timeout shall be restarted on each NOTIFY (POWER LOSS EXPECTED) that is received.

The POWER GRANT TIMEOUT field contains the minimum time, in one second increments, that a SAS target device shall wait to receive a PWR\_GRANT (see 6.12.5.4) from a power source device (see 6.12.1). A POWER GRANT TIMEOUT field set to 00h specifies that the time limit is vendor specific.

#### 9.2.7.7 Enhanced Phy Control mode page

The Enhanced Phy Control mode page contains parameters that affect SSP target phy operation. If the mode page is implemented by one logical unit in a SCSI target device, then it shall be implemented by all logical units in the SCSI target device that support the MODE SELECT command or MODE SENSE command.

The mode page policy (see SPC-4) for this mode page shall be shared.

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Table 215 defines the format of this mode page.

**Table 215 — Enhanced Phy Control mode page**

| Byte\Bit                                  | 7                                                            | 6        | 5               | 4 | 3 | 2 | 1 | 0 |
|-------------------------------------------|--------------------------------------------------------------|----------|-----------------|---|---|---|---|---|
| 0                                         | PS                                                           | SPF (1b) | PAGE CODE (19h) |   |   |   |   |   |
| 1                                         | SUBPAGE CODE (03h)                                           |          |                 |   |   |   |   |   |
| 2                                         | (MSB)                                                        |          |                 |   |   |   |   |   |
| 3                                         | PAGE LENGTH (n - 3)                                          |          |                 |   |   |   |   |   |
| 4                                         | (LSB)                                                        |          |                 |   |   |   |   |   |
| 5                                         | Reserved                                                     |          |                 |   |   |   |   |   |
| 6                                         | PROTOCOL IDENTIFIER (6h)                                     |          |                 |   |   |   |   |   |
| 7                                         | GENERATION CODE                                              |          |                 |   |   |   |   |   |
| 8                                         | NUMBER OF PHYS                                               |          |                 |   |   |   |   |   |
| Enhanced phy control mode descriptor list |                                                              |          |                 |   |   |   |   |   |
| 8                                         | Enhanced phy control mode descriptor (first) (see table 216) |          |                 |   |   |   |   |   |
| ...                                       |                                                              |          |                 |   |   |   |   |   |
| 27                                        |                                                              |          |                 |   |   |   |   |   |
| ...                                       | ...                                                          |          |                 |   |   |   |   |   |
| n - 19                                    | Enhanced phy control mode descriptor (last) (see table 216)  |          |                 |   |   |   |   |   |
| ...                                       |                                                              |          |                 |   |   |   |   |   |
| n                                         |                                                              |          |                 |   |   |   |   |   |

The PARAMETERS SAVEABLE (PS) bit is defined in SPC-4.

The SUBPAGE FORMAT (SPF) bit is defined in SPC-4 and shall be set as shown in table 215 for the Enhanced Phy Control mode page.

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 215 for the Enhanced Phy Control mode page.

The SUBPAGE CODE field is defined in SPC-4 and shall be set as shown in table 215 for the Enhanced Phy Control mode page.

The PAGE LENGTH field is defined in SPC-4 and shall be set as shown in table 215 for the Enhanced Phy Control mode page (i.e.,  $4 + ((\text{the value of the NUMBER OF PHYS field}) \times (\text{the length in bytes of the SAS phy mode descriptor}))$ ).

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 215 for the Enhanced Phy Control mode page indicating that this is a SAS SSP specific mode page.

The GENERATION CODE field is defined in the Phy Control and Discover mode page (see 9.2.7.5).



The NUMBER OF PHYS field contains the number of phys in the SAS target device and indicates the number of enhanced phy control mode descriptors in the enhanced phy control mode descriptor list. This field shall not be changeable with the MODE SELECT command.

The enhanced phy control mode descriptor list contains an enhanced phy control mode descriptor for each phy in the SAS target device, not just the SAS target port, starting with the lowest numbered phy and ending with the highest numbered phy as determined by the value in the PHY IDENTIFIER field in the enhanced phy control mode descriptor.

Table 216 defines the enhanced phy control mode descriptor.

**Table 216 — Enhanced phy control mode descriptor**

| Byte\Bit | 7                           | 6                          | 5                 | 4                             | 3 | 2                 | 1                 | 0                               |  |
|----------|-----------------------------|----------------------------|-------------------|-------------------------------|---|-------------------|-------------------|---------------------------------|--|
| 0        | Reserved                    |                            |                   |                               |   |                   |                   |                                 |  |
| 1        | PHY IDENTIFIER              |                            |                   |                               |   |                   |                   |                                 |  |
| 2        | (MSB)                       | DESCRIPTOR LENGTH (0010h)  |                   |                               |   |                   |                   |                                 |  |
| 3        |                             |                            |                   |                               |   |                   |                   |                                 |  |
| 4        | PROGRAMMED PHY CAPABILITIES |                            |                   |                               |   |                   |                   |                                 |  |
| ...      |                             |                            |                   |                               |   |                   |                   |                                 |  |
| 7        |                             |                            |                   |                               |   |                   |                   |                                 |  |
| 8        | CURRENT PHY CAPABILITIES    |                            |                   |                               |   |                   |                   |                                 |  |
| ...      |                             |                            |                   |                               |   |                   |                   |                                 |  |
| 11       |                             |                            |                   |                               |   |                   |                   |                                 |  |
| 12       | ATTACHED PHY CAPABILITIES   |                            |                   |                               |   |                   |                   |                                 |  |
| ...      |                             |                            |                   |                               |   |                   |                   |                                 |  |
| 15       |                             |                            |                   |                               |   |                   |                   |                                 |  |
| 16       | Reserved                    |                            |                   |                               |   |                   |                   |                                 |  |
| 17       |                             |                            |                   |                               |   |                   |                   |                                 |  |
| 18       | Reserved                    | OPTICAL<br>MODE<br>ENABLED | NEGOTIATED<br>SSC | NEGOTIATED PHYSICAL LINK RATE |   |                   |                   |                                 |  |
| 19       | Reserved                    |                            |                   |                               |   | ENABLE<br>SLUMBER | ENABLE<br>PARTIAL | HARDWARE<br>MUXING<br>SUPPORTED |  |

The DESCRIPTOR LENGTH field contains the length in bytes that follow in the descriptor and shall be set as shown in table 216 for the enhanced phy control mode descriptor.

An ENABLE SLUMBER bit set to one specifies that the SCSI device server shall enable the management application layer to control the slumber phy power condition (see 4.10.1.4) on the phy specified by the PHY IDENTIFIER field. An ENABLE SLUMBER bit set to zero specifies that the SCSI device server shall disable control of the slumber phy power condition by the management application layer on the phy specified by the PHY IDENTIFIER field.

An ENABLE PARTIAL bit set to one specifies that the SCSI device server shall enable the management application layer to control the partial phy power condition (see 4.10.1.3) on the phy specified by the PHY IDENTIFIER field. An ENABLE PARTIAL bit set to zero specifies that the SCSI device server shall disable control of the partial phy power condition by the management application layer on the phy specified by the PHY IDENTIFIER field.

The fields in the enhanced phy control mode descriptor not defined in this subclause are defined in the SMP DISCOVER response (see 9.4.3.10). These fields shall not be changeable with the MODE SELECT command.

## 9.2.8 SCSI log parameters

### 9.2.8.1 Protocol Specific Port log page

The Protocol Specific Port log page for SAS SSP defined in table 218 provides the SCSI application client a means to determine information about phy events concerning the SAS target device's phy(s). The parameter codes for the Protocol Specific Port log page are listed in table 217.

**Table 217 — Protocol Specific Port log parameters**

| Parameter code                                                                                   | Description                                               | Resettable or Changeable <sup>a</sup> | Reference | Support Required |
|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------|-----------|------------------|
| 0000h                                                                                            | Reserved                                                  |                                       |           |                  |
| 0001h to FFFFh                                                                                   | Protocol Specific Port log parameter for SAS target ports | Never                                 | 9.2.8.2   | Optional         |
| <sup>a</sup> The keywords in this column – Always, Reset Only, and Never – are defined in SPC-4. |                                                           |                                       |           |                  |

The Protocol Specific Port log page for SAS SSP has the format shown in table 218.

**Table 218 — Protocol Specific Port log page for SAS SSP**

| Byte\Bit                                  | 7                                                            | 6        | 5               | 4 | 3 | 2 | 1 | 0 |
|-------------------------------------------|--------------------------------------------------------------|----------|-----------------|---|---|---|---|---|
| 0                                         | DS                                                           | SPF (0b) | PAGE CODE (18h) |   |   |   |   |   |
| 1                                         | SUBPAGE CODE (00h)                                           |          |                 |   |   |   |   |   |
| 2                                         | (MSB)                                                        |          |                 |   |   |   |   |   |
| 3                                         | PAGE LENGTH (n - 3)                                          |          |                 |   |   |   |   |   |
|                                           | (LSB)                                                        |          |                 |   |   |   |   |   |
| Protocol Specific Port log parameter list |                                                              |          |                 |   |   |   |   |   |
| 4                                         | Protocol Specific Port log parameter (first) (see table 219) |          |                 |   |   |   |   |   |
| ...                                       |                                                              |          |                 |   |   |   |   |   |
|                                           |                                                              |          |                 |   |   |   |   |   |
| ...                                       | ...                                                          |          |                 |   |   |   |   |   |
|                                           | Protocol Specific Port log parameter (last) (see table 219)  |          |                 |   |   |   |   |   |
| ...                                       |                                                              |          |                 |   |   |   |   |   |
| n                                         |                                                              |          |                 |   |   |   |   |   |

The disable save (DS) bit, subpage format (SPF) bit, PAGE CODE field, SUBPAGE CODE field, and PAGE LENGTH field are described in SPC-4. The SPF bit, PAGE CODE field, and SUBPAGE CODE field shall be set as shown in table 218 for the Protocol Specific Port log page for SAS SSP.

The Protocol Specific Port log parameter list contains a Protocol Specific Port log parameter for each SCSI port in the SAS target device.

### 9.2.8.2 Protocol Specific Port log parameter for SAS target ports

Table 219 defines the format for the Protocol Specific Port log parameter for SAS target ports. The SAS log parameter is a list parameter (i.e., not a data counter) and only has cumulative (i.e., not threshold) values (see SPC-4).

**Table 219 — Protocol Specific Port log parameter for SAS target ports**

| Byte\Bit                    | 7                                                                     | 6        | 5   | 4   | 3                        | 2                  | 1 | 0 |
|-----------------------------|-----------------------------------------------------------------------|----------|-----|-----|--------------------------|--------------------|---|---|
| 0                           | (MSB)                                                                 |          |     |     |                          |                    |   |   |
| 1                           | PARAMETER CODE (relative target port identifier)                      |          |     |     |                          |                    |   |   |
| 2                           | Parameter control byte - binary format list log parameter (see SPC-4) |          |     |     |                          |                    |   |   |
|                             | DU                                                                    | Obsolete | TSD | ETC | TMC                      | FORMAT AND LINKING |   |   |
| 3                           | PARAMETER LENGTH (y - 3)                                              |          |     |     |                          |                    |   |   |
| 4                           | Reserved                                                              |          |     |     | PROTOCOL IDENTIFIER (6h) |                    |   |   |
| 5                           | Reserved                                                              |          |     |     |                          |                    |   |   |
| 6                           | GENERATION CODE                                                       |          |     |     |                          |                    |   |   |
| 7                           | NUMBER OF PHYS                                                        |          |     |     |                          |                    |   |   |
| SAS phy log descriptor list |                                                                       |          |     |     |                          |                    |   |   |
| 8                           | SAS phy log descriptor (first) (see table 220)                        |          |     |     |                          |                    |   |   |
| ...                         |                                                                       |          |     |     |                          |                    |   |   |
| 8 + m                       |                                                                       |          |     |     |                          |                    |   |   |
| ...                         | ...                                                                   |          |     |     |                          |                    |   |   |
| y - m                       | SAS phy log descriptor (last) (see table 220)                         |          |     |     |                          |                    |   |   |
| ...                         |                                                                       |          |     |     |                          |                    |   |   |
| y                           |                                                                       |          |     |     |                          |                    |   |   |

The PARAMETER CODE field is defined in SPC-4 and contains the relative target port identifier (see SPC-4) of the SSP target port that the log parameter describes.

The DU bit, TSD bit, ETC bit, TMC field, and FORMAT AND LINKING field are described in SPC-4. These fields shall be set as described for a binary format list log parameter (see SPC-4) for the Protocol Specific Port log parameter for SAS target ports.

The PARAMETER LENGTH field is defined in SPC-4.

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 219 for the Protocol Specific Port log page parameter for SAS target ports.

The GENERATION CODE field is defined in the Phy Control and Discover mode page (see 9.2.7.5).

The NUMBER OF PHYS field contains the number of phys in the SAS target port (not in the entire SAS target device) and indicates the number of SAS phy log descriptors in the SAS phy log descriptor list.

The SAS phy log descriptor list contains SAS phy log descriptors.

Table 220 defines the SAS phy log descriptor.

**Table 220 — SAS phy log descriptor** (part 1 of 2)

| Byte\Bit | 7                                     | 6                    | 5 | 4 | 3                            | 2                           | 1                           | 0        |
|----------|---------------------------------------|----------------------|---|---|------------------------------|-----------------------------|-----------------------------|----------|
| 0        | Reserved                              |                      |   |   |                              |                             |                             |          |
| 1        | PHY IDENTIFIER                        |                      |   |   |                              |                             |                             |          |
| 2        | Reserved                              |                      |   |   |                              |                             |                             |          |
| 3        | SAS PHY LOG DESCRIPTOR LENGTH (m - 3) |                      |   |   |                              |                             |                             |          |
| 4        | Reserved                              | ATTACHED DEVICE TYPE |   |   | ATTACHED REASON              |                             |                             |          |
| 5        | REASON                                |                      |   |   | NEGOTIATED LOGICAL LINK RATE |                             |                             |          |
| 6        | Reserved                              |                      |   |   | ATTACHED SSP INITIATOR PORT  | ATTACHED STP INITIATOR PORT | ATTACHED SMP INITIATOR PORT | Reserved |
| 7        | Reserved                              |                      |   |   | ATTACHED SSP TARGET PORT     | ATTACHED STP TARGET PORT    | ATTACHED SMP TARGET PORT    | Reserved |
| 8        | SAS ADDRESS                           |                      |   |   |                              |                             |                             |          |
| ...      |                                       |                      |   |   |                              |                             |                             |          |
| 15       |                                       |                      |   |   |                              |                             |                             |          |
| 16       | ATTACHED SAS ADDRESS                  |                      |   |   |                              |                             |                             |          |
| ...      |                                       |                      |   |   |                              |                             |                             |          |
| 23       |                                       |                      |   |   |                              |                             |                             |          |
| 24       | ATTACHED PHY IDENTIFIER               |                      |   |   |                              |                             |                             |          |
| 25       | Reserved                              |                      |   |   |                              |                             |                             |          |
| ...      |                                       |                      |   |   |                              |                             |                             |          |
| 31       |                                       |                      |   |   |                              |                             |                             |          |

Table 220 — SAS phy log descriptor (part 2 of 2)

| Byte\Bit                  | 7                                                          | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------------------------|------------------------------------------------------------|---|---|---|---|---|---|---|
| 32                        | (MSB)                                                      |   |   |   |   |   |   |   |
| ...                       | INVALID DWORD COUNT                                        |   |   |   |   |   |   |   |
| 35                        | (LSB)                                                      |   |   |   |   |   |   |   |
| 36                        | (MSB)                                                      |   |   |   |   |   |   |   |
| ...                       | RUNNING DISPARITY ERROR COUNT                              |   |   |   |   |   |   |   |
| 39                        | (LSB)                                                      |   |   |   |   |   |   |   |
| 40                        | (MSB)                                                      |   |   |   |   |   |   |   |
| ...                       | LOSS OF DWORD SYNCHRONIZATION                              |   |   |   |   |   |   |   |
| 43                        | (LSB)                                                      |   |   |   |   |   |   |   |
| 44                        | (MSB)                                                      |   |   |   |   |   |   |   |
| ...                       | PHY RESET PROBLEM                                          |   |   |   |   |   |   |   |
| 47                        | (LSB)                                                      |   |   |   |   |   |   |   |
| 48                        | Reserved                                                   |   |   |   |   |   |   |   |
| 49                        |                                                            |   |   |   |   |   |   |   |
| 50                        | PHY EVENT DESCRIPTOR LENGTH                                |   |   |   |   |   |   |   |
| 51                        | NUMBER OF PHY EVENT DESCRIPTORS                            |   |   |   |   |   |   |   |
| Phy event descriptor list |                                                            |   |   |   |   |   |   |   |
| 52                        |                                                            |   |   |   |   |   |   |   |
| ...                       | Phy event descriptor (first) (see table 292 in 9.4.3.14.4) |   |   |   |   |   |   |   |
| 63                        |                                                            |   |   |   |   |   |   |   |
| ...                       | ...                                                        |   |   |   |   |   |   |   |
| m - 11                    |                                                            |   |   |   |   |   |   |   |
| ...                       | Phy event descriptor (last) (see table 292 in 9.4.3.14.4)  |   |   |   |   |   |   |   |
| m                         |                                                            |   |   |   |   |   |   |   |

The SAS PHY LOG DESCRIPTOR LENGTH field indicates the number of bytes that follow in the SAS phy log descriptor. A SAS PHY LOG DESCRIPTOR LENGTH field set to 00h indicates that there are 44 additional bytes.

NOTE 62 - Logical units compliant with SAS and SAS-1.1 only support a 48 byte SAS phy log descriptor.

The INVALID DWORD COUNT field, RUNNING DISPARITY ERROR COUNT field, LOSS OF DWORD SYNCHRONIZATION field, and PHY RESET PROBLEM COUNT field are defined in the SMP REPORT PHY ERROR LOG response (see 9.4.3.11).

For the INVALID DWORD COUNT field, RUNNING DISPARITY ERROR COUNT field, LOSS OF DWORD SYNCHRONIZATION COUNT field, and PHY RESET PROBLEM COUNT field, the phy may maintain any size counter but should maintain a 32-bit counter. If it reaches its maximum value, then the counter shall stop and the SCSI device server shall set the field to FFFFFFFFh in the SAS phy log descriptor.

The PHY EVENT DESCRIPTOR LENGTH field indicates the number of bytes in the phy event descriptor (see 9.4.3.14.4).

The NUMBER OF PHY EVENT DESCRIPTORS field indicates the number of phy event descriptors in the phy event descriptor list.

Each phy event descriptor uses the format defined for the SMP REPORT PHY EVENT function in table 292 (see 9.4.3.14.4).

The fields in the SAS phy log descriptor not defined in this subclause are defined in the SMP DISCOVER response (see 9.4.3.10). These fields shall not be changeable with the LOG SELECT command.

## 9.2.9 SCSI diagnostic parameters

### 9.2.9.1 SCSI diagnostic parameters overview

Table 221 defines diagnostic pages supported by logical units in SCSI target devices in SAS domains (i.e., with SSP target ports) that support the SEND DIAGNOSTIC or RECEIVE DIAGNOSTIC RESULTS commands.

**Table 221 — SSP target port diagnostic pages**

| Diagnostic page code | Description                       | Reference |
|----------------------|-----------------------------------|-----------|
| 3Fh                  | Protocol Specific diagnostic page | 9.2.9.2   |

An enclosure services process (see SES-3) describing elements in a SAS domain that are attached to a zoning expander device with zoning enabled (see 4.8) shall apply the zone permission table when providing access to those elements. Element types that may be subject to zoning include:

- a) Device Slot element;
- b) Array Device Slot element;
- c) Enclosure Services Controller Electronics element;
- d) SCC Controller Electronics element;
- e) SCSI Port/Transceiver element;
- f) SCSI Target Port element;
- g) SCSI Initiator Port element;
- h) SAS Expander element; and
- i) SAS Connector element.

Table 222 defines SCSI enclosure services diagnostic pages supported by logical units in SCSI target devices in SAS domains (e.g., with SSP target ports) that are affected by zoning.

**Table 222 — Diagnostic pages affected by zoning**

| Diagnostic page code | Description                               | Reference         |
|----------------------|-------------------------------------------|-------------------|
| 02h                  | Enclosure Control diagnostic page         | SES-3 and 9.2.9.3 |
|                      | Enclosure Status diagnostic page          | SES-3 and 9.2.9.4 |
| 0Ah                  | Additional Element Status diagnostic page | SES-3 and 9.2.9.5 |

#### 9.2.9.2 Protocol Specific diagnostic page

The Protocol Specific diagnostic page provides a method for a SCSI application client to enable and disable phy test functions (see 4.11) for selected phys. The diagnostic page format is specified in SPC-4.

The Protocol Specific diagnostic page is sent by a SCSI application client using the SEND DIAGNOSTIC command. If the SCSI device server receives a RECEIVE DIAGNOSTIC RESULTS command with the PAGE CODE field set to 3Fh, then the SCSI device server shall terminate the command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN CDB.

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Table 223 defines the Protocol Specific diagnostic page for SAS SSP.

**Table 223 — Protocol Specific diagnostic page for SAS SSP**

| Byte\Bit | 7                               | 6                         | 5                        | 4 | 3                                    | 2 | 1 | 0 |
|----------|---------------------------------|---------------------------|--------------------------|---|--------------------------------------|---|---|---|
| 0        | PAGE CODE (3Fh)                 |                           |                          |   |                                      |   |   |   |
| 1        | Reserved                        |                           |                          |   | PROTOCOL IDENTIFIER (6h)             |   |   |   |
| 2        | (MSB) PAGE LENGTH (001Ch)       |                           |                          |   |                                      |   |   |   |
| 3        | (LSB)                           |                           |                          |   |                                      |   |   |   |
| 4        | PHY IDENTIFIER                  |                           |                          |   |                                      |   |   |   |
| 5        | PHY TEST FUNCTION               |                           |                          |   |                                      |   |   |   |
| 6        | PHY TEST PATTERN                |                           |                          |   |                                      |   |   |   |
| 7        | Reserved                        | PHY TEST FUNCTION<br>SATA | PHY TEST FUNCTION<br>SSC |   | PHY TEST FUNCTION PHYSICAL LINK RATE |   |   |   |
| 8        | Reserved                        |                           |                          |   |                                      |   |   |   |
| ...      |                                 |                           |                          |   |                                      |   |   |   |
| 10       |                                 |                           |                          |   |                                      |   |   |   |
| 11       | PHY TEST PATTERN DWORDS CONTROL |                           |                          |   |                                      |   |   |   |
| 12       | PHY TEST PATTERN DWORDS         |                           |                          |   |                                      |   |   |   |
| ...      |                                 |                           |                          |   |                                      |   |   |   |
| 19       |                                 |                           |                          |   |                                      |   |   |   |
| 20       | Reserved                        |                           |                          |   |                                      |   |   |   |
| ...      |                                 |                           |                          |   |                                      |   |   |   |
| 31       |                                 |                           |                          |   |                                      |   |   |   |

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 223 for the Protocol Specific diagnostic page for SAS SSP.

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 223 for the Protocol Specific diagnostic page for SAS SSP indicating this is a SAS SSP specific diagnostic page.

The PAGE LENGTH field is defined in SPC-4 and shall be set as shown in table 223 for the Protocol Specific diagnostic page for SAS SSP.

The PHY IDENTIFIER field specifies the phy identifier (see 4.2.10) of the phy that is to perform or to stop performing a phy test function (i.e., the selected phy). If the PHY IDENTIFIER field specifies a phy that does not exist, then the SCSI device server shall terminate the SEND DIAGNOSTIC command with CHECK

CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

The PHY TEST FUNCTION field specifies the phy test function to be performed and is defined in table 224. If the PHY TEST FUNCTION field specifies a phy test function that is not supported, then the SCSI device server shall terminate the SEND DIAGNOSTIC command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

**Table 224 — PHY TEST FUNCTION field**

| Code                                                                                                                                                                                                                                                               | Name             | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h                                                                                                                                                                                                                                                                | STOP             | <p>If the selected phy is performing a phy test function, then the selected phy shall stop performing the phy test function and originate a link reset sequence.</p> <p>If the selected phy is not performing a phy test function, then this function has no effect on the selected phy.<sup>a</sup></p>                                                                                                                                                                                                                                                                                                         |
| 01h                                                                                                                                                                                                                                                                | TRANSMIT PATTERN | <p>If the selected phy is not performing a phy test function, then the selected phy shall perform the transmit pattern phy test function (see 4.11.2) using the phy test pattern specified by the PHY TEST PATTERN field and the physical link rate specified by the PHY TEST FUNCTION PHYSICAL LINK RATE field.</p> <p>If the selected phy is performing a phy test function, then the SCSI device server shall terminate the SEND DIAGNOSTIC command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to PHY TEST FUNCTION IN PROGRESS.<sup>a</sup></p> |
| 02h to EFh                                                                                                                                                                                                                                                         | Reserved         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| F0h to FFh                                                                                                                                                                                                                                                         | Vendor specific  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <sup>a</sup> If there is no SSP target port available to receive a SEND DIAGNOSTIC command to stop a phy from performing a phy test function, then a power on may be required to cause the phy to stop performing the function and originate a phy reset sequence. |                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

If the PHY TEST FUNCTION field is set to 01h (i.e., TRANSMIT\_PATTERN), then the PHY TEST PATTERN field specifies the phy test pattern to be transmitted as defined by table 225. If the PHY TEST PATTERN field specifies a phy test pattern that is not supported by the specified SAS phy, then the SCSI device server shall terminate

the SEND DIAGNOSTIC command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

**Table 225 — PHY TEST PATTERN field**

| Code       | Name            | Description                                                                                                                                                                                                                                                                                                                                                         |
|------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h        | Reserved        |                                                                                                                                                                                                                                                                                                                                                                     |
| 01h        | JTPAT           | The selected phy shall repeatedly transmit JTPAT for RD+ and RD- (see A.1).                                                                                                                                                                                                                                                                                         |
| 02h        | CJTPAT          | The selected phy shall repeatedly transmit CJTPAT (see A.2).                                                                                                                                                                                                                                                                                                        |
| 03h to 0Fh | Reserved        |                                                                                                                                                                                                                                                                                                                                                                     |
| 10h        | TRAIN           | The selected phy shall repeatedly transmit the TRAIN pattern (see 5.10.4.2.3.5).                                                                                                                                                                                                                                                                                    |
| 11h        | TRAIN_DONE      | The selected phy shall repeatedly transmit the TRAIN_DONE pattern (see 5.10.4.2.3.5).                                                                                                                                                                                                                                                                               |
| 12h        | IDLE            | The selected phy shall repeatedly transmit idle dwords (see 6.4).                                                                                                                                                                                                                                                                                                   |
| 13h        | SCRAMBLED_0     | The selected phy shall repeatedly transmit a repeating pattern of at least 58 dwords (i.e., 2 320 bits on the physical link) set to 00000000h that are transmitted scrambled and 8b10b encoded (see 6.4). The scrambler shall be reinitialized at the beginning of each pattern. See table E.2 in E.4.                                                              |
| 14h to 3Fh | Reserved        |                                                                                                                                                                                                                                                                                                                                                                     |
| 40h        | TWO_DWORDS      | <p>The selected phy shall repeatedly transmit the dwords specified by the PHY TEST PATTERN DWORDS CONTROL field and the PHY TEST PATTERN DWORDS field without scrambling.</p> <p>This pattern is only for use for characterization of the transmitter device and the passive interconnect. Phys are not required to support all patterns that may be specified.</p> |
| 41h to EFh | Reserved        |                                                                                                                                                                                                                                                                                                                                                                     |
| F0h to FFh | Vendor specific |                                                                                                                                                                                                                                                                                                                                                                     |

A PHY TEST FUNCTION SATA bit set to one specifies that the phy shall transmit as a SATA phy during the phy test function. A PHY TEST FUNCTION SATA bit set to zero specifies that the phy shall transmit as a SAS phy during the phy test function. If the PHY TEST FUNCTION SATA bit is set to one and the phy does not support SATA, then the SCSI device server shall terminate the SEND DIAGNOSTIC command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

The PHY TEST FUNCTION SSC field specifies the SSC modulation type (see SAS-3) that the phy shall use during transmission during the phy test function and is defined in table 226. If the SSC modulation type specified by the PHY TEST FUNCTION SSC field is not supported (e.g., if the phy is a SAS phy, then it only supports no-spreading and down-spreading SSC), then the SCSI device server shall terminate the SEND

DIAGNOSTIC command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

**Table 226 — PHY TEST FUNCTION SSC field**

| Code                                                                                                                                                                                                                                                                                                                                           | Description                       |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| 00b                                                                                                                                                                                                                                                                                                                                            | No-spreading                      |
| 01b                                                                                                                                                                                                                                                                                                                                            | Center-spreading SSC <sup>a</sup> |
| 10b                                                                                                                                                                                                                                                                                                                                            | Down-spreading SSC                |
| 11b                                                                                                                                                                                                                                                                                                                                            | Reserved                          |
| <sup>a</sup> If the PHY TEST FUNCTION SATA bit is set to one (i.e., a SATA phy is requested to transmit center-spreading), then the SCSI device server shall terminate the SEND DIAGNOSTIC command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST. |                                   |

The PHY TEST FUNCTION PHYSICAL LINK RATE field specifies the physical link rate at which the phy test function shall be performed and is defined in table 227. If the physical link rate specified by the PHY TEST FUNCTION PHYSICAL LINK RATE field is less than the hardware minimum physical link rate or greater than the hardware maximum physical link rate, then the SCSI device server shall terminate the SEND DIAGNOSTIC command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

**Table 227 — PHY TEST FUNCTION PHYSICAL LINK RATE field**

| Code     | Description                             |
|----------|-----------------------------------------|
| 0h to 7h | Reserved                                |
| 8h       | 1.5 Gbit/s                              |
| 9h       | 3 Gbit/s                                |
| Ah       | 6 Gbit/s                                |
| Bh       | 12 Gbit/s                               |
| Ch to Fh | Reserved for future physical link rates |

The PHY TEST PATTERN DWORDS CONTROL field and PHY TEST PATTERN DWORDS field are only used if the PHY TEST PATTERN field is set to 40h (i.e., TWO\_DWORDS) (see table 225).

The PHY TEST PATTERN DWORDS CONTROL field defined in table 228 controls whether the bytes in the PHY TEST PATTERN DWORDS field are sent as control characters or data characters.

**Table 228 — PHY TEST PATTERN DWORDS CONTROL field**

| Code       | Description                                                                                                                                                                               |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h        | Each byte in the PHY TEST PATTERN DWORDS field shall be sent as a data character (i.e., Dxx.y) (see 5.3.6) without scrambling.                                                            |
| 08h        | The fifth byte in the PHY TEST PATTERN DWORDS field shall be sent as a control character (i.e., Kxx.y) (see 5.3.7). Each other byte shall be sent as a data character without scrambling. |
| 80h        | The first byte in the PHY TEST PATTERN DWORDS field shall be sent as a control character. Each other byte shall be sent as a data character without scrambling.                           |
| 88h        | The first and fifth bytes in the PHY TEST PATTERN DWORDS field shall each be sent as a control character. Each other byte shall be sent as a data character without scrambling.           |
| All others | Reserved                                                                                                                                                                                  |

The PHY TEST PATTERN DWORDS field contains the two dwords that are sent during a TWO\_DWORDS test pattern. Whether each byte in the dwords is sent as a control character or a data character is specified by the PHY TEST PATTERN DWORDS CONTROL field. A byte specifying a control character shall only specify a control character that is used in this standard (see table 51 in 5.3.7) and is supported by the phy (i.e., all phys support K28.5 (i.e., BCh), but only phys supporting STP support K28.3 (i.e., 7Ch) or K28.6 (i.e., DCh)).

The SCSI device server shall terminate a SEND DIAGNOSTIC command specifying any unsupported combination with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

Table 229 lists some examples of TWO\_DWORDS phy test patterns.

**Table 229 — TWO\_DWORDS phy test pattern examples**

| PHY TEST<br>PATTERN<br>DWORDS<br>CONTROL<br>field | PHY TEST<br>PATTERN<br>DWORDS field | Description                                                                                                                                                                                                                                                                                                                               |
|---------------------------------------------------|-------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h                                               | 4A4A4A4A<br>4A4A4A4Ah               | D10.2 characters (see table 49 in 5.3.6). This pattern contains 01b repeating and has the highest possible frequency. This pattern may be used for measuring intra-pair skew, rise time, fall time, and RJ (see SAS-3).                                                                                                                   |
| 00h                                               | B5B5B5B5<br>B5B5B5B5h               | D21.5 characters (see table 49 in 5.3.6). This pattern contains 10b repeating and has the highest possible frequency. This pattern may be used for measuring intra-pair skew, rise time, fall time, and RJ (see SAS-3).                                                                                                                   |
| 00h                                               | 78787878<br>78787878h               | D24.3 characters (see table 49 in 5.3.6). This pattern contains 0011b or 1100b repeating (depending on starting disparity) and has half the highest possible frequency. This pattern may be used for calibrating the JTF, calibrating the reference transmitter test load, and measuring transmitter device S-parameters (see SAS-3).     |
| 00h                                               | D926D926<br>D926D926h               | Pairs of D25.6 and D6.1 characters (see table 49 in 5.3.6). This pattern contains 1001b repeating and has half the highest possible frequency.                                                                                                                                                                                            |
| 00h                                               | 7E7E7E7E<br>7E7E7E7Eh               | D30.3 characters (see table 49 in 5.3.6). This pattern contains four bits of one polarity, three bits of the other polarity, and three bits of the first polarity (e.g., 11 11000111b), followed by the inverse (e.g., 00 00111000b). This pattern may be used for measuring transmitter equalization and SSC-induced jitter (see SAS-3). |
| 88h                                               | BC4A4A7B<br>BC4A4A7Bh               | ALIGN (0) primitives (see table 98 in 6.2.3). This pattern appears during OOB bursts (SAS-3), the SATA speed negotiation sequence (see 5.10.2.2), and the SAS speed negotiation sequence (see 5.10.4.2).                                                                                                                                  |
| 88h                                               | BC070707<br>BC070707h               | ALIGN (1) primitives (see table 98 in 6.2.3). This pattern appears during the SAS speed negotiation sequences (see 5.10.4.2).                                                                                                                                                                                                             |
| 80h                                               | BC4A4A7B<br>4A787E7Eh               | Pairs of an ALIGN (0) (see table 98 in 6.2.3) and a dword containing D10.2, D24.3, D30.3, and D30.3 characters (see table 49 in 5.3.6).                                                                                                                                                                                                   |

### 9.2.9.3 Enclosure Control diagnostic page

If the SELECT bit is set to one for any element that represents a device attached to an expander phy for which the SAS initiator port performing the SEND DIAGNOSTIC command does not have access according to the zone permission table, then the enclosure services process shall terminate the SEND DIAGNOSTIC command with CHECK CONDITION status with the sense key set to ILLEGAL REQUEST and the additional sense code set to INVALID FIELD IN PARAMETER LIST.

### 9.2.9.4 Enclosure Status diagnostic page

The enclosure services process shall set the ELEMENT STATUS CODE field to 8h (i.e., No Access Allowed) for each element that represents a device attached to an expander phy for which the SAS initiator port performing

the RECEIVE DIAGNOSTIC RESULTS command does not have access according to the zone permission table.

#### 9.2.9.5 Additional Element Status diagnostic page

The enclosure services process shall set the INVALID bit to one in the Additional Element Status descriptor (see SES-3) for each element that represents a device attached to an expander phy for which the SAS initiator port performing the RECEIVE DIAGNOSTIC RESULTS command does not have access according to the zone permission table.

#### 9.2.10 SCSI power conditions

##### 9.2.10.1 SCSI power conditions overview

The logical unit power condition states from the Power Condition mode page (see SPC-4) and START STOP UNIT command (see SBC-3), if implemented, shall interact with the SL\_P\_C state machine (see 6.12.5) to control temporary consumption of additional power (e.g., to spin up rotating media) as described in this subclause.

The logical unit sends requests to the SL\_P\_C state machine and receives confirmations from the SL\_P\_C state machine to delay:

- a) initial temporary consumption of additional power after power on;
- b) temporary consumption of additional power requested by START STOP UNIT commands; and
- c) temporary consumption of additional power while making a change from a standby power condition to a higher power condition.

##### 9.2.10.2 SA\_PC (SCSI application layer power condition) state machine

###### 9.2.10.2.1 SA\_PC state machine overview

The SA\_PC (SCSI application layer power condition) state machine describes how the SAS target device processes logical unit power condition state change requests.

Logical units with peripheral device types other than direct-access block device (e.g., sequential-access devices) that implement an additional power condition, not defined by this standard, that consumes more peak power during a change from that additional power condition to a higher power condition than the typical peak power consumption in the active power condition shall use the SL\_P\_C state machine (see 6.12.5) to delay consumption of additional power when making the change to a higher power condition.

NOTE 63 - This state machine is an enhanced version of the logical unit power condition state machines described in SPC-4 and SBC-3 that adds the interactions with the SL\_P\_C state machine.

This state machine consists of the states shown in table 230.

**Table 230 — Summary of states in the SA\_PC state machine**

| State                                                                                                                                                                                                                                       | Reference   | Modified <sup>a</sup> | States that contribute to definition |                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------------|--------------------------------------|-----------------------|
|                                                                                                                                                                                                                                             |             |                       | SPC-4                                | SBC-3                 |
| SA_PC_0:Powered_On <sup>b</sup>                                                                                                                                                                                                             | 9.2.10.2.2  | No                    | PC0:Powered_On                       | SSU_PC0:Powered_On    |
| SA_PC_1:Active                                                                                                                                                                                                                              | 9.2.10.2.3  | No                    | PC1:Active                           | SSU_PC1:Active        |
| SA_PC_2:Idle                                                                                                                                                                                                                                | 9.2.10.2.4  | No                    | PC2:Idle                             | SSU_PC2:Idle          |
| SA_PC_3:Standby                                                                                                                                                                                                                             | 9.2.10.2.5  | No                    | PC3:Standby                          | SSU_PC3:Standby       |
| SA_PC_4:Active_Wait                                                                                                                                                                                                                         | 9.2.10.2.6  | Yes                   | PC4:Active_Wait                      | SSU_PC4:Active_Wait   |
| SA_PC_5:Wait_Idle                                                                                                                                                                                                                           | 9.2.10.2.7  | No                    | PC5:Wait_Idle                        | SSU_PC5:Wait_Idle     |
| SA_PC_6:Wait_Standby                                                                                                                                                                                                                        | 9.2.10.2.8  | No                    | PC6:Wait_Standby                     | SSU_PC6:Wait_Standby  |
| SA_PC_7:Idle_Wait                                                                                                                                                                                                                           | 9.2.10.2.9  | Yes                   |                                      | SSU_PC7:Idle_Wait     |
| SA_PC_8:Stopped                                                                                                                                                                                                                             | 9.2.10.2.10 | No                    |                                      | SSU_PC8:Stopped       |
| SA_PC_9:Standby_Wait                                                                                                                                                                                                                        | 9.2.10.2.11 | No                    |                                      | SSU_PC9:Standby_Wait  |
| SA_PC_10:Wait_Stopped                                                                                                                                                                                                                       | 9.2.10.2.12 | No                    |                                      | SSU_PC10:Wait_Stopped |
| <sup>a</sup> Yes indicates that this standard adds requirements to a state. No indicates that this standard does not alter or enhance the requirements defined in SPC-4 and SBC-3.<br><sup>b</sup> SA_PC_0:Powered_On is the initial state. |             |                       |                                      |                       |

While in the following SA\_PC states the logical unit may be increasing power usage to enter a higher power condition:

- a) SA\_PC\_4:Active\_Wait;
- b) SA\_PC\_7:Idle\_Wait; or
- c) SA\_PC\_9:Standby\_Wait.

While in the following SA\_PC states the logical unit may be decreasing power usage to enter a lower power condition:

- a) SA\_PC\_5:Wait\_Idle;
- b) SA\_PC\_6:Wait\_Standby; or
- c) SA\_PC\_10:Wait\_Stopped.

Any command causing a state machine transition (e.g., a START STOP UNIT command with the IMMED bit set to zero) shall not complete with GOOD status until this state machine reaches the state (i.e., power condition) required by the command.

This state machine shall start in the SA\_PC\_0:Powered\_On state after power on. For direct-access block devices, the SA\_PC state machine shall be configured to transition to the SA\_PC\_8:Stopped state or the SA\_PC\_4:Active\_Wait state after power on by a mechanism outside the scope of this standard.

This state machine receives the following confirmations from the SL\_P\_C link layer state machine:

- a) Power Use Granted; and
- b) Power Request Failed.



This state machine sends the following requests to the SL\_P\_C link layer state machine:

- a) Request Additional Power; and
- b) Power Use Complete.

This state machine sends the following message to the management application layer:

- a) Phy Power Condition Status.

This state machine uses the following timers that are controlled by the Power Condition mode page (see SPC-4):

- a) the idle condition timers; and
- b) the standby condition timers.

If the SCSI device server processes a START STOP UNIT command with the IMMED bit set to one, then the SCSI device server shall complete the command before completing the transition, if any, specified by a START STOP UNIT command.

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Figure 172 shows the SA\_PC state machine.

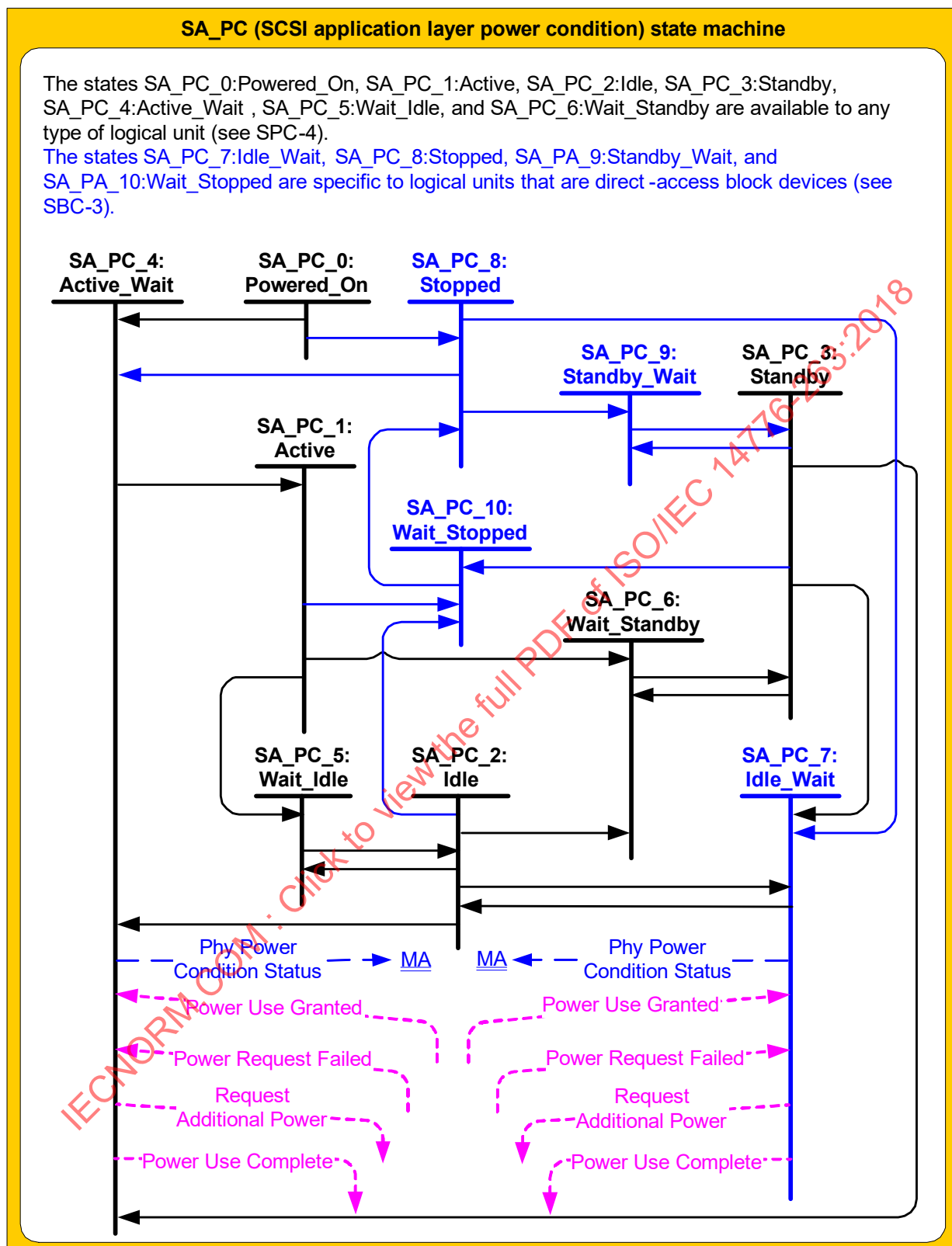


Figure 172 — SA\_PC (SCSI application layer power condition) state machine for SAS

### 9.2.10.2.2 SA\_PC\_0:Powered\_On state

#### 9.2.10.2.2.1 State description

See the PC0:Power\_On state in SPC-4 for details about this state.

#### 9.2.10.2.2.2 Transition SA\_PC\_0:Powered\_On to SA\_PC\_4:Active\_Wait

For devices that are not direct-access block devices, see the PC0:Power\_On to PC4:Active\_Wait transition in SPC-4 for details about this transition.

For direct-access block devices, see the SSU\_PC0:Power\_On to SSU\_PC4:Active\_Wait transition in SBC-3 for details about this transition.

#### 9.2.10.2.2.3 Transition SA\_PC\_0:Powered\_On to SA\_PC\_8:Stopped

This transition is only implemented in logical units that are direct-access block devices. See the SSU\_PC0:Power\_On to SSU\_PC8:Stopped transition in SBC-3 for details about this transition.

### 9.2.10.2.3 SA\_PC\_1:Active state

#### 9.2.10.2.3.1 State description

See the PC1:Active state in SPC-4 for details about this state.

#### 9.2.10.2.3.2 Transition SA\_PC\_1:Active to SA\_PC\_5:Wait\_Idle

For devices that are not direct-access block devices, see the PC1:Active to PC5:Wait\_Idle transition in SPC-4 for details about this transition.

For direct-access block devices, see the SSU\_PC1:Active to SSU\_PC5:Wait\_Idle transition in SBC-3 for details about this transition.

#### 9.2.10.2.3.3 Transition SA\_PC\_1:Active to SA\_PC\_6:Wait\_Standby

For devices that are not direct-access block devices, see the PC1:Active to PC6:Wait\_Standby transition in SPC-4 for details about this transition.

For direct-access block devices, see the SSU\_PC1:Active to SSU\_PC6:Wait\_Standby transition in SBC-3 for details about this transition.

#### 9.2.10.2.3.4 Transition SA\_PC\_1:Active to SA\_PC\_10:Wait\_Stopped

This transition is only implemented in logical units that are direct-access block devices. See the SSU\_PC1:Active to SSU\_PC10:Wait\_Stopped transition in SBC-3 for details about this transition.

### 9.2.10.2.4 SA\_PC\_2:Idle state

#### 9.2.10.2.4.1 State description

See the PC2:Idle state in SPC-4 for details about this state.

#### 9.2.10.2.4.2 Transition SA\_PC\_2:Idle to SA\_PC\_4:Active\_Wait

For devices that are not direct-access block devices, see the PC2:Idle to PC4:Active\_Wait transition in SPC-4 for details about this transition.

For direct access block devices, see the SSU\_PC2:Idle to SSU\_PC4:Active\_Wait transition in SBC-3 for details about this transition.

**9.2.10.2.4.3 Transition SA\_PC\_2:Idle to SA\_PC\_5:Wait\_Idle**

For devices that are not direct-access block devices, see the PC2:Idle to PC5:Wait\_Idle transition in SPC-4 for details about this transition.

For direct-access block devices, see the SSU\_PC2:Idle to SSU\_PC5:Wait\_Idle transition in SBC-3 for details about this transition.

**9.2.10.2.4.4 Transition SA\_PC\_2:Idle to SA\_PC\_6:Wait\_Standby**

For devices that are not direct-access block device, see the PC2:Idle to PC6:Wait\_Standby transition in SPC-4 for details about this transition.

For direct-access block devices, see the SSU\_PC2:Idles to SSU\_PC6:Wait\_Standby transition in SBC-3 for details about this transition.

**9.2.10.2.4.5 Transition SA\_PC\_2:Idle to SA\_PC\_7:Idle\_Wait**

This transition is only implemented in logical units that are direct-access block devices. See the SSU\_PC2:Idle to SSU\_PC7:Idle\_Wait transition in SBC-3 for details about this transition.

**9.2.10.2.4.6 Transition SA\_PC\_2:Idle to SA\_PC\_10:Wait\_Stopped**

This transition is only implemented in logical units that are direct-access block devices. See the SSU\_PC2:Idle to SSU\_PC10:Wait\_Stopped transition in SBC-3 for details about this transition.

**9.2.10.2.5 SA\_PC\_3:Standby state****9.2.10.2.5.1 State description**

See the PC3:Standby state in SPC-4 for details about this state.

**9.2.10.2.5.2 Transition SA\_PC\_3:Standby to SA\_PC\_4:Active\_Wait**

For devices that are not direct-access block devices, see the PC3:Standby to PC4:Active\_Wait transition in SPC-4 for details about this transition.

For direct-access block devices, see the SSU\_PC3:Standby to SSU\_PC4:Active\_Wait transition in SBC-3 for details about this transition.

**9.2.10.2.5.3 Transition SA\_PC\_3:Standby to SA\_PC\_6:Wait\_Standby**

For devices that are not direct-access block devices, see the PC3:Standby to PC6:Wait\_Standby transition in SPC-4 for details about this transition.

For direct-access block devices, see the SSU\_PC3:Standby to SSU\_PC6:Wait\_Standby transition in SBC-3 for details about this transition.

**9.2.10.2.5.4 Transition SA\_PC\_3:Standby to SA\_PC\_7:Idle\_Wait**

This transition is only implemented in logical units that are direct-access block devices. See the SSU\_PC3:Standby to SSU\_PC7:Idle\_Wait transition in SBC-3 for details about this transition.

**9.2.10.2.5.5 Transition SA\_PC\_3:Standby to SA\_PC\_9: Standby\_Wait**

This transition is only implemented in logical units that are direct-access block devices. See the SSU\_PC3:Standby to SSU\_PC9:Standby\_Wait transition in SBC-3 for details about this transition.

### 9.2.10.2.5.6 Transition SA\_PC\_3:Standby to SA\_PC\_10:Wait\_Stopped

This transition is only implemented in logical units that are direct-access block devices. See the SSU\_PC3:Standby to SSU\_PC10:Wait\_Stopped transition in SBC-3 for details about this transition.

### 9.2.10.2.6 SA\_PC\_4:Active\_Wait state

#### 9.2.10.2.6.1 State description

If this state was entered with a Transitioning From Power On argument, Transitioning From Standby argument, or Transitioning From Stopped argument, then this state shall:

- 1) send a Phy Power Condition Status (Disable Low Phy Power Conditions) message to the management application layer; and
- 2) if power control is enabled and the consumption of additional power is required, then send a Request Additional Power request to the SL\_P\_C state machine (see 3.5.5).

While in this state:

- a) each idle condition timer that is enabled and not expired is running;
- b) each standby condition timer that is enabled and not expired is running;
- c) the SCSI device server shall provide pollable sense data (see SPC-4) with the sense key set to NO SENSE and the additional sense code set to LOGICAL UNIT TRANSITIONING TO ANOTHER POWER CONDITION;
- d) if a Power Request Failed (Grant Timeout) confirmation is received, then this state shall send a Request Additional Power request to the SL\_P\_C state machine on any phy;
- e) if a Power Request Failed (ACK Timeout) confirmation or a Power Request Failed (Phy Disabled) confirmation is received, then this state should send a Request Additional Power request to the SL\_P\_C state machine on a different phy from the one that Power Request Failed confirmation was received; and
- f) the logical unit is performing the operations required for it to be in the SA\_PC\_1:Active state (e.g., a hard disk drive spins up its media).

If this state was entered with a Transitioning From Idle argument, then:

- a) the SCSI device server is capable of processing and completing the same commands, except a START STOP UNIT command with the IMMED bit set to zero (see SBC-3), that the SCSI device server is able to process and complete while in the SA\_PC\_2:Idle state;
- b) the peak power consumed in this state shall be no more than the typical peak power consumed in the SA\_PC\_1: Active state; and
- c) if:
  - A) this state was entered with a Transitioning From Idle\_c argument; and
  - B) the CCF IDLE field in the Power Conditions mode page (see SPC-4) is set to 10b (i.e., enabled),
 then the SCSI device server shall terminate any command, except START STOP UNIT command, that requires the logical unit be in the SA\_PC\_1:Active state to continue processing, with CHECK CONDITION status, with the sense key set to NOT READY and the additional sense code set to LOGICAL UNIT IS IN PROCESS OF BECOMING READY.

If this state was entered with a Transitioning From Standby argument, then:

- a) the SCSI device server is capable of processing and completing the same commands, except a START STOP UNIT command with the IMMED bit set to zero, that the SCSI device server is able to process and complete while in the SA\_PC\_3:Standby state;
- b) if the CCF STANDBY field in the Power Conditions mode page (see SPC-4) is set to 10b (i.e., enabled), then the SCSI device server shall terminate any command, except a START STOP UNIT command, that requires the logical unit be in the SA\_PC\_1:Active state or SA\_PC\_2:Idle state to continue processing, with CHECK CONDITION status, with the sense key set to NOT READY and:
  - A) if power control is enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, ADDITIONAL POWER USE NOT YET GRANTED;

- B) if power control is not enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, NOTIFY (ENABLE SPINUP) REQUIRED; or
- C) if the Power Use Granted confirmation has been received, then the additional sense code set to LOGICAL UNIT IN THE PROCESS OF BECOMING READY;
- c) if a Power Use Granted confirmation has not been received, then the peak power consumption shall be no more than the typical peak power consumed in the SA\_PC\_1: Active state; and
- d) if a Power Use Granted confirmation has been received, then the peak power consumption is not limited by this standard.

If this state was entered with a Transitioning From Stopped argument, then:

- a) the SCSI device server is capable of processing and completing the same commands, except a START STOP UNIT command with the IMMED bit set to zero, that the SCSI device server is able to process and complete while in the SA\_PC\_8: Stopped state;
- b) if the CCF STOPPED field in the Power Conditions mode page (see SPC-4) is set to 10b (i.e., enabled), then the SCSI device server shall terminate any TEST UNIT READY command or media access command, with CHECK CONDITION status, with the sense key set to NOT READY and:
  - A) if power control is enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, ADDITIONAL POWER USE NOT YET GRANTED;
  - B) if power control is not enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, NOTIFY (ENABLE SPINUP) REQUIRED; or
  - C) if the Power Use Granted confirmation has been received, then the additional sense code set to LOGICAL UNIT IN THE PROCESS OF BECOMING READY;
- c) if a Power Use Granted confirmation has not been received, then the peak power consumption shall be no more than the typical peak power consumed in the SA\_PC\_1: Active state; and
- d) if a Power Use Granted confirmation has been received, then the peak power consumption is not limited by this standard.

If this state was entered with a Transitioning From Powered On argument, then:

- a) the SCSI device server is capable of processing and completing the same commands, except a START STOP UNIT command with the IMMED bit set to zero, that the SCSI device server is able to process and complete while in the SA\_PC\_8: Stopped state for direct-access devices;
- b) the SCSI device server shall terminate any TEST UNIT READY command or media access command with CHECK CONDITION status with the sense key set to NOT READY and:
  - A) if power control is enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, ADDITIONAL POWER USE NOT YET GRANTED;
  - B) if power control is not enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, NOTIFY (ENABLE SPINUP) REQUIRED; or
  - C) if the Power Use Granted confirmation has been received, then the additional sense code shall be set to LOGICAL UNIT IN THE PROCESS OF BECOMING READY;
- c) if a Power Use Granted confirmation has not been received, then the peak power consumption shall be no more than the typical peak power consumed in the SA\_PC\_1: Active state; and
- d) if a Power Use Granted confirmation has been received, then the peak power consumption is not limited by this standard.

If an idle condition timer or a standby condition timer is enabled and expires, then that timer shall be ignored.

When the SCSI device server meets the requirements for the logical unit being in the SA\_PC\_1: Active state this state shall:

- 1) if this state sent a Request Additional Power request to the SL\_P\_C state machine (see 6.12.5), then send a Power Use Complete request to the SL\_P\_C state machine (see 6.12.5); and
- 2) send a Phy Power Condition Status (Enable Low Phy Power Conditions) message to the management application layer.

**9.2.10.2.6.2 Transition SA\_PC\_4:Active\_Wait to SA\_PC\_1:Active**

This transition shall occur:

- a) after sending a Phy Power Condition Status (Enable Low Phy Power Conditions) message to the management application layer.

**9.2.10.2.7 SA\_PC\_5:Wait\_Idle state****9.2.10.2.7.1 SA\_PC\_5:Wait\_Idle state description**

See the PC5:Wait\_Idle state in SPC-4 for details about this state.

**9.2.10.2.7.2 Transition SA\_PC\_5:Wait\_Idle to SA\_PC\_2:Idle**

See the PC5:Wait\_Idle to PC2:Idle transition in SPC-4 for details about this transition.

**9.2.10.2.8 SA\_PC\_6:Wait\_Standby state****9.2.10.2.8.1 SA\_PC\_6:Wait\_Standby state description**

See the PC6:Wait\_Standby state in SPC-4 for details about this state.

**9.2.10.2.8.2 Transition SA\_PC\_6:Wait\_Standby to SA\_PC\_3:Standby**

See the PC6:Wait\_Standby to PC3:Standby transition in SPC-4 for details about this transition.

**9.2.10.2.9 SA\_PC\_7:Idle\_Wait state****9.2.10.2.9.1 State description**

If this state was entered with a Transitioning From Standby argument or Transitioning From Stopped argument, then this state shall:

- 1) send a Phy Power Condition Status (Disable Low Phy Power Conditions) message to the management application layer; and
- 2) if power control is enabled and the consumption of additional power is required, then send a Request Additional Power request to the SL\_P\_C state machine (see 6.12.5).

While in this state:

- a) each idle condition timer that is enabled and not expired is running;
- b) each standby condition timer that is enabled and not expired is running;
- c) the SCSI device server shall provide pollable sense data (see SPC-4) with the sense key set to NO SENSE and the additional sense code set to LOGICAL UNIT TRANSITIONING TO ANOTHER POWER CONDITION;
- d) if a Power Request Failed (Grant Timeout) confirmation is received, then this state shall send a Request Additional Power request to the SL\_P\_C state machine on any phy;
- e) if a Power Request Failed (ACK Timeout) confirmation or a Power Request Failed (Phy Disabled) confirmation is received, then this state should send a Request Additional Power request to the SL\_P\_C state machine on a different phy from the one that Power Request Failed confirmation was received; and
- f) the logical unit is performing the operations required for it to be in the SA\_PC\_2:Idle state (e.g., a hard disk drive spinning up its media).

If this state was entered with a Transitioning From Idle argument, then:

- a) the SCSI device server is capable of processing and completing the same commands, except a START STOP UNIT command with the IMMED bit set to zero (see SBC-3), that the SCSI device server is able to process and complete while in the SA\_PC\_2:Idle state; and



- b) the peak power consumed in this state shall be no more than the typical peak power consumed in the SA\_PC\_1: Active state.

If this state was entered with a Transitioning From Standby argument, then:

- a) the SCSI device server is capable of processing and completing the same commands, except a START STOP UNIT command with the IMMED bit set to zero, that the SCSI device server is able to process and complete while in the SA\_PC\_3: Standby state;
- b) if the CCF STANDBY field in the Power Conditions mode page (see SPC-4) is set to 10b (i.e., enabled), then the SCSI device server shall terminate any command, except a START STOP UNIT command, that requires the logical unit be in the SA\_PC\_1: Active state or SA\_PC\_2: Idle state to continue processing, with CHECK CONDITION status, with the sense key set to NOT READY and:
  - A) if power control is enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, ADDITIONAL POWER USE NOT YET GRANTED;
  - B) if power control is not enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, NOTIFY (ENABLE SPINUP) REQUIRED; or
  - C) if the Power Use Granted confirmation has been received, the additional sense code set to LOGICAL UNIT IN THE PROCESS OF BECOMING READY;
- c) if a Power Use Granted confirmation has not been received, then the peak power consumption shall be no more than the typical peak power consumed in the SA\_PC\_1: Active state; and
- d) if a Power Use Granted confirmation has been received, then the peak power consumption is not limited by this standard.

If this state was entered with a Transitioning From Stopped argument, then:

- a) the SCSI device server is capable of processing and completing the same commands, except a START STOP UNIT command with the IMMED bit set to zero, that the SCSI device server is able to process and complete while in the SA\_PC\_8: Stopped state;
- b) if the CCF STOPPED field in the Power Conditions mode page (see SPC-4) is set to 10b (i.e., enabled), then the SCSI device server shall terminate any TEST UNIT READY command or media access command, with CHECK CONDITION status, with the sense key set to NOT READY and:
  - A) if power control is enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, ADDITIONAL POWER USE NOT YET GRANTED;
  - B) if power control is not enabled (see 6.12) and the Power Use Granted confirmation has not been received, then the additional sense code set to LOGICAL UNIT NOT READY, NOTIFY (ENABLE SPINUP) REQUIRED; or
  - C) if the Power Use Granted confirmation has been received, then the additional sense code set to LOGICAL UNIT IN THE PROCESS OF BECOMING READY;
- c) if a Power Use Granted confirmation has not been received, then the peak power consumption shall be no more than the typical peak power consumed in the SA\_PC\_1: Active state; and
- d) if a Power Use Granted confirmation has been received, then the peak power consumption is not limited.

If an idle condition timer or a standby condition timer is enabled and expires, then that timer shall be ignored.

When the SCSI device server meets the requirements for the logical unit being in the:

- a) idle\_a power condition, if this state was entered with a Transitioning To Idle\_a argument;
- b) idle\_b power condition, if this state was entered with a Transitioning To Idle\_b argument; or
- c) idle\_c power condition, if this state was entered with a Transitioning To Idle\_c argument,

this state shall:

- 1) if this state sent a Request Additional Power request to the SL\_P\_C state machine (see 6.12.5), then send a Power Use Complete request to the SL\_P\_C state machine (see 6.12.5); and
- 2) send a Phy Power Condition Status (Enable Low Phy Power Conditions) message to the management application layer.



**9.2.10.2.9.2 Transition SA\_PC\_7:Idle\_Wait to SA\_PC\_2:Idle**

This transition shall occur:

- a) after sending a Phy Power Condition Status (Enable Low Phy Power Conditions) message to the management application layer.

**9.2.10.2.10 SA\_PC\_8:Stopped state****9.2.10.2.10.1 State description**

This state is only implemented in logical units that are direct-access block devices.

See the SSU\_PC8:Stopped state in SBC-3 for details about this state.

**9.2.10.2.10.2 Transition SA\_PC\_8:Stopped to SA\_PC\_4:Active\_Wait**

See the SSU\_PC8:Stopped to SSU\_PC4:Active\_Wait transition in SBC-3 for details about this transition.

The transition shall include:

- a) a From Stopped argument.

**9.2.10.2.10.3 Transition SA\_PC\_8:Stopped to SA\_PC\_7:Idle\_Wait**

See the SSU\_PC8:Stopped to SSU\_PC7:Idle\_Wait transition in SBC-3 for details about this transition.

**9.2.10.2.10.4 Transition SA\_PC\_8:Stopped to SA\_PC\_9:Standby\_Wait**

See the SSU\_PC8:Stopped to SSU\_PC9:Standby\_Wait transition in SBC-3 for details about this transition.

**9.2.10.2.11 SA\_PC\_9:Standby\_Wait state****9.2.10.2.11.1 SA\_PC\_9:Standby\_Wait state description**

This state is only implemented in logical units that are direct-access block devices.

See the SSU\_PC9:Standby\_Wait state in SBC-3 for details about this state.

**9.2.10.2.11.2 Transition SA\_PC\_9:Standby\_Wait to SA\_PC\_3:Standby**

See the SSU\_PC9:Standby\_Wait to SSU\_PC3:Standby transition in SBC-3 for details about this transition.

**9.2.10.2.12 SA\_PC\_10:Wait\_Stopped state****9.2.10.2.12.1 SA\_PC\_10:Wait\_Stopped state description**

This state is only implemented in logical units that are direct-access block devices.

See the SSU\_PC10:Standby\_Wait state in SBC-3 for details about this state.

**9.2.10.2.12.2 Transition SA\_PC\_10:Wait\_Stopped to SA\_PC\_8:Stopped**

See the SSU\_PC10:Wait\_Stopped to SSU\_PC8:Stopped transition in SBC-3 for details about this transition.

## 9.2.11 SCSI vital product data (VPD)

### 9.2.11.1 SCSI vital product data (VPD) overview

Table 231 lists VPD pages for which this standard defines special requirements.

**Table 231 — VPD pages with special requirements for SAS SSP**

| Page code | VPD page name                                       | Reference          | Support requirements |
|-----------|-----------------------------------------------------|--------------------|----------------------|
| 83h       | Device Identification VPD page                      | 9.2.11.2 and SPC-4 | Mandatory            |
| 90h       | Protocol Specific Logical Unit Information VPD page | 9.2.11.3 and SPC-4 | Mandatory            |
| 91h       | Protocol Specific Port Information VPD page         | 9.2.11.4 and SPC-4 | Mandatory            |

### 9.2.11.2 Device Identification VPD page

In the Device Identification VPD page (83h) returned in response to an INQUIRY command (see SPC-4), each logical unit in a SAS target device shall include the designation descriptors for the target port identifier (see 4.2.9) and the relative target port identifier (see SAM-5 and SPC-4) listed in table 232.

**Table 232 — Device Identification VPD page designation descriptors for the SAS target port**

| Field in designation descriptor                                                                                                                                                                                                                                                     | Designation descriptor               |                                                                       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-----------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                     | Target port identifier               | Relative target port identifier                                       |
| DESIGNATOR TYPE                                                                                                                                                                                                                                                                     | 3h (i.e., NAA)                       | 4h (i.e., relative target port identifier)                            |
| ASSOCIATION                                                                                                                                                                                                                                                                         | 01b (i.e., SCSI target port)         | 01b (i.e., SCSI target port)                                          |
| CODE SET                                                                                                                                                                                                                                                                            | 1h (i.e., binary)                    | 1h (i.e., binary)                                                     |
| DESIGNATOR LENGTH                                                                                                                                                                                                                                                                   | 8                                    | 4                                                                     |
| PIV (protocol identifier valid)                                                                                                                                                                                                                                                     | 1                                    | 1                                                                     |
| PROTOCOL IDENTIFIER                                                                                                                                                                                                                                                                 | 6h (i.e., SAS)                       | 6h (i.e., SAS)                                                        |
| DESIGNATOR                                                                                                                                                                                                                                                                          | SAS address <sup>a</sup> (see 4.2.4) | Relative port identifier <sup>b</sup> as described in SAM-5 and SPC-4 |
| <sup>a</sup> The DESIGNATOR field contains the SAS address of the SSP target port through which the INQUIRY command was received.<br><sup>b</sup> The DESIGNATOR field contains the relative port identifier of the SSP target port through which the INQUIRY command was received. |                                      |                                                                       |

In the Device Identification VPD page (83h) returned in response to an INQUIRY command (see SPC-4), each logical unit in a SAS target device shall include a designation descriptor for the SAS target device name (see 4.2.6) using NAA format and may include a designation descriptor for the SAS target device name using

the SCSI name string format as listed in table 233.

**Table 233 — Device Identification VPD page designation descriptors for the SAS target device**

| Field in designation descriptor                                                       | Designation descriptor                                                 |                                                                                                                                                      |
|---------------------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                       | NAA format (required)                                                  | SCSI name string format (optional)                                                                                                                   |
| DESIGNATOR TYPE                                                                       | 3h (i.e., NAA)                                                         | 8h (i.e., SCSI name string)                                                                                                                          |
| ASSOCIATION                                                                           | 10b (i.e., SCSI target device)                                         | 10b (i.e., SCSI target device)                                                                                                                       |
| CODE SET                                                                              | 1h (i.e., binary)                                                      | 3h (i.e., UTF-8)                                                                                                                                     |
| DESIGNATOR LENGTH                                                                     | 8                                                                      | 24                                                                                                                                                   |
| PIV (protocol identifier valid)                                                       | 1                                                                      | 0                                                                                                                                                    |
| PROTOCOL IDENTIFIER                                                                   | 6h (i.e., SAS)                                                         | 0h <sup>a</sup>                                                                                                                                      |
| DESIGNATOR                                                                            | Device name of the SAS target device in SAS address format (see 4.2.4) | Device name of the SAS target device in SCSI name string format (e.g., "naa," followed by 16 hexadecimal digits followed by 4 ASCII null characters) |
| <sup>a</sup> The PROTOCOL IDENTIFIER field is reserved if the PIV bit is set to zero. |                                                                        |                                                                                                                                                      |

Logical units may include designation descriptors in addition to those required by this standard (e.g., SCSI target devices with SCSI target ports using other SCSI transport protocols may return additional SCSI target device names for those other SCSI transport protocols).

### 9.2.11.3 Protocol Specific Logical Unit Information VPD page

The Protocol Specific Logical Unit Information VPD page (see SPC-4) contains parameters for the logical unit that are protocol specific based on the I\_T nexus being used to access the logical unit.

The Protocol Specific Logical Unit Information VPD page shall only return information relating to SAS target ports.

Table 234 defines the Protocol Specific Logical Unit Information VPD page for logical units with SAS ports.

**Table 234 — Protocol Specific Logical Unit Information VPD page for SAS SSP**

| Byte\Bit                                 | 7                                                           | 6 | 5 | 4                      | 3 | 2 | 1 | 0 |
|------------------------------------------|-------------------------------------------------------------|---|---|------------------------|---|---|---|---|
| 0                                        | PERIPHERAL QUALIFIER                                        |   |   | PERIPHERAL DEVICE TYPE |   |   |   |   |
| 1                                        | PAGE CODE (90h)                                             |   |   |                        |   |   |   |   |
| 2                                        | (MSB)                                                       |   |   |                        |   |   |   |   |
| 3                                        | PAGE LENGTH (n - 3)                                         |   |   |                        |   |   |   |   |
|                                          | (LSB)                                                       |   |   |                        |   |   |   |   |
| Logical unit information descriptor list |                                                             |   |   |                        |   |   |   |   |
| 4                                        | Logical unit information descriptor (first) (see table 235) |   |   |                        |   |   |   |   |
| ...                                      |                                                             |   |   |                        |   |   |   |   |
| ...                                      | ...                                                         |   |   |                        |   |   |   |   |
| ...                                      | Logical unit information descriptor (last) (see table 235)  |   |   |                        |   |   |   |   |
| n                                        |                                                             |   |   |                        |   |   |   |   |

The PERIPHERAL QUALIFIER field and the PERIPHERAL DEVICE TYPE field are defined in SPC-4.

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 234 for the Protocol Specific Logical Unit Information VPD page for SAS SSP.

The PAGE LENGTH field is defined in SPC-4.

The logical unit information descriptor list is defined in SPC-4 and shall contain a logical unit information descriptor for each SAS target port known to the SCSI device server.

Table 235 defines the logical unit information descriptor for logical units with SAS target ports.

**Table 235 — Logical unit information descriptor for SAS SSP**

| Byte\Bit                                      | 7                                     | 6 | 5 | 4 | 3                        | 2 | 1 | 0                           |
|-----------------------------------------------|---------------------------------------|---|---|---|--------------------------|---|---|-----------------------------|
| 0                                             | (MSB) _____                           |   |   |   |                          |   |   |                             |
| 1                                             | RELATIVE PORT IDENTIFIER _____ (LSB)  |   |   |   |                          |   |   |                             |
| 2                                             | Reserved                              |   |   |   | PROTOCOL IDENTIFIER (6h) |   |   |                             |
| 3                                             | Reserved                              |   |   |   |                          |   |   |                             |
| ...                                           |                                       |   |   |   |                          |   |   |                             |
| 5                                             |                                       |   |   |   |                          |   |   |                             |
| 6                                             | (MSB) _____                           |   |   |   |                          |   |   |                             |
| 7                                             | DESCRIPTOR LENGTH (0004h) _____ (LSB) |   |   |   |                          |   |   |                             |
| Per logical unit SCSI transport specific data |                                       |   |   |   |                          |   |   |                             |
| 8                                             | Reserved                              |   |   |   |                          |   |   | TLR<br>CONTROL<br>SUPPORTED |
| 9                                             | Reserved                              |   |   |   |                          |   |   |                             |
| ...                                           |                                       |   |   |   |                          |   |   |                             |
| 11                                            |                                       |   |   |   |                          |   |   |                             |

The RELATIVE PORT IDENTIFIER field is defined in SPC-4.

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 235 for the logical unit information descriptor for SAS SSP indicating that this is a SAS SSP specific descriptor.

The DESCRIPTOR LENGTH field is defined in SPC-4 and shall be set as shown in table 235 for the logical unit information descriptor for SAS SSP.

A TLR CONTROL SUPPORTED bit set to one indicates that the combination of the SSP target port and logical unit support the TLR CONTROL field in the SSP frame header (see 8.2.1). A TLR CONTROL SUPPORTED bit set to zero indicates that the combination of the SSP target port and logical unit do not support the TLR CONTROL field in the SSP frame header.

#### 9.2.11.4 Protocol Specific Port Information VPD page

The Protocol Specific Port Information VPD page (see SPC-4) contains parameters for the SAS target ports that are protocol specific and are the same for all logical units in the SCSI target device.

Table 236 defines the Protocol Specific Port Information VPD page for the SAS target ports.

**Table 236 — Protocol Specific Port Information VPD page for SAS SSP**

| Byte\Bit                         | 7                                                   | 6 | 5 | 4                      | 3 | 2 | 1 | 0 |
|----------------------------------|-----------------------------------------------------|---|---|------------------------|---|---|---|---|
| 0                                | PERIPHERAL QUALIFIER                                |   |   | PERIPHERAL DEVICE TYPE |   |   |   |   |
| 1                                | PAGE CODE (91h)                                     |   |   |                        |   |   |   |   |
| 2                                | (MSB)                                               |   |   |                        |   |   |   |   |
| 3                                | PAGE LENGTH (n - 3)                                 |   |   |                        |   |   |   |   |
|                                  | (LSB)                                               |   |   |                        |   |   |   |   |
| Port information descriptor list |                                                     |   |   |                        |   |   |   |   |
| 4                                | Port information descriptor (first) (see table 237) |   |   |                        |   |   |   |   |
| ...                              |                                                     |   |   |                        |   |   |   |   |
| ...                              | ...                                                 |   |   |                        |   |   |   |   |
| ...                              | Port information descriptor (last) (see table 237)  |   |   |                        |   |   |   |   |
| n                                |                                                     |   |   |                        |   |   |   |   |

The PERIPHERAL QUALIFIER field and the PERIPHERAL DEVICE TYPE field are defined in SPC-4.

The PAGE CODE field is defined in SPC-4 and shall be set as shown in table 236 for the Protocol Specific Port Information VPD page for SAS SSP.

The PAGE LENGTH field is defined in SPC-4.

The port information descriptor list is defined in SPC-4 and shall contain a port information descriptor for each SAS target port known to the SCSI device server.

Table 237 defines the port information descriptor for the SAS target ports.

**Table 237 — Port information descriptor for SAS SSP**

| Byte\Bit                            | 7                                                      | 6 | 5 | 4 | 3                        | 2 | 1 | 0       |
|-------------------------------------|--------------------------------------------------------|---|---|---|--------------------------|---|---|---------|
| 0                                   | (MSB) _____                                            |   |   |   |                          |   |   |         |
| 1                                   | RELATIVE PORT IDENTIFIER _____ (LSB)                   |   |   |   |                          |   |   |         |
| 2                                   | Reserved                                               |   |   |   | PROTOCOL IDENTIFIER (6h) |   |   |         |
| 3                                   | Reserved                                               |   |   |   |                          |   |   | PWR_D_S |
| 4                                   | Reserved                                               |   |   |   |                          |   |   |         |
| 5                                   |                                                        |   |   |   |                          |   |   |         |
| 6                                   | (MSB) _____                                            |   |   |   |                          |   |   |         |
| 7                                   | DESCRIPTOR LENGTH (n-7) _____ (LSB)                    |   |   |   |                          |   |   |         |
| SAS phy information descriptor list |                                                        |   |   |   |                          |   |   |         |
| 8                                   |                                                        |   |   |   |                          |   |   |         |
| ...                                 | SAS phy information descriptor (first) (see table 238) |   |   |   |                          |   |   |         |
| 11                                  |                                                        |   |   |   |                          |   |   |         |
| ...                                 | ...                                                    |   |   |   |                          |   |   |         |
| n - 3                               |                                                        |   |   |   |                          |   |   |         |
| ...                                 | SAS phy information descriptor (last) (see table 238)  |   |   |   |                          |   |   |         |
| n                                   |                                                        |   |   |   |                          |   |   |         |

The RELATIVE PORT IDENTIFIER field is defined in SPC-4.

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set as shown in table 237 for the port information descriptor for SAS SSP indicating that this is a port information descriptor for SAS SSP.

A power disable supported (PWR\_D\_S) bit set to one indicates that the POWER DISABLE signal (see SAS-3) is supported. A PWR\_D\_S bit set to zero indicates that the POWER DISABLE signal is not supported.

The DESCRIPTOR LENGTH field is defined in SPC-4.

The SAS phy information descriptor list contains a SAS phy information descriptor for each SAS phy in the SAS target port.

Table 238 defines the SAS phy information descriptor.

**Table 238 — SAS phy information descriptor for SAS SSP**

| Byte\Bit | 7              | 6 | 5 | 4 | 3 | 2 | 1 | 0                            |
|----------|----------------|---|---|---|---|---|---|------------------------------|
| 0        | Reserved       |   |   |   |   |   |   |                              |
| 1        | PHY IDENTIFIER |   |   |   |   |   |   |                              |
| 2        | Reserved       |   |   |   |   |   |   | SSP<br>PERSISTENT<br>CAPABLE |
| 3        | Reserved       |   |   |   |   |   |   |                              |

The PHY IDENTIFIER field is defined in the SMP DISCOVER response (see 9.4.3.10).

An SSP PERSISTENT CAPABLE bit set to one indicates that the phy supports a persistent connection (see 4.1.13).  
An SSP PERSISTENT CAPABLE bit set to zero indicates that the phy does not support persistent connections.

### 9.3 ATA application layer

No SAS-specific ATA features are defined by this standard.

### 9.4 Management application layer

#### 9.4.1 READY LED signal behavior

A SAS target device uses the READY LED signal to activate an externally visible LED that indicates the state of readiness and activity of the SAS target device. The READY LED signal electrical characteristics are described in SAS-3.

The system is not required to generate any visual output when the READY LED signal is asserted. Additional vendor specific flashing patterns may be used to signal vendor specific conditions.

SAS target devices without SSP target ports may transmit the READY LED signal using vendor specific methods and patterns.



SAS target devices with SSP target ports shall follow the behavior indicated by the READY LED MEANING bit in the Protocol Specific Port mode page (see 9.2.7.4) as described in table 239.

**Table 239 — READY LED signal behavior**

| Power condition <sup>a</sup><br>(see 9.2.10) or activity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | READY LED MEANING <b>bit set to zero</b> <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | READY LED MEANING <b>bit set to one</b>                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| active power condition or an idle power condition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <p>The SAS target device shall:</p> <p>a) while not processing a command, assert the READY LED signal continuously; or</p> <p>b) while processing a command, toggle the READY LED signal between the asserted and negated states in a vendor-specified manner.</p> <p>(i.e., the LED is usually on, but flashes on and off while commands are processed)</p>                                                                                                                                                                           | <p>The SAS target device shall:</p> <p>a) while not processing a command, negate the READY LED signal continuously; or</p> <p>b) while processing a command, toggle the READY LED signal between the asserted and negated states in a vendor-specified manner.</p> <p>(i.e., The LED is usually off, but flashes on and off while commands are processed)</p> |
| a standby power condition or stopped power condition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <p>The SAS target device shall:</p> <p>a) while not processing a command, negate the READY LED signal continuously; or</p> <p>b) while processing a command, toggle the READY LED signal between the asserted and negated states in a vendor-specified manner.</p> <p>(i.e., the LED is usually off, but flashes on and off while commands are processed)</p> <p>After a vendor specific amount of time in this state, SAS target devices with rotating media may be removed with minimum risk of mechanical or electrical damage.</p> |                                                                                                                                                                                                                                                                                                                                                               |
| spinup/spindown                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <p>If the SAS target device has rotating media and is in the process of performing a spinup or spindown, then the SAS target device shall toggle the READY LED signal between the asserted and negated states with a 1 s ± 0.1 s cycle using a 50 % ± 10 % duty cycle (e.g., the LED is on for 0.5 s and off for 0.5 s).</p>                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                               |
| formatting media                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <p>If the SAS target device is in the process of formatting media, then the SAS target device shall toggle the READY LED signal between the asserted and negated states in a vendor-specified manner (e.g., with each cylinder change on a disk drive).</p>                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                               |
| <p><sup>a</sup> If the SAS target device has more than one logical unit and any logical unit is active or idle, then the power condition of that logical unit should be used to control the READY LED signal.</p> <p><sup>b</sup> If the target device has rotating media, a READY LED MEANING bit set to zero results in a READY LED signal behavior that provides an indication of the target device's readiness for removal. A target device with rotating media that is not in a state for safe removal shall either toggle the READY LED signal at a significant rate during spinup, during spindown, and while formatting media, or assert the READY LED signal continuously. When removal is safe from a mechanical standpoint, the READY LED signal shall be negated.</p> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                               |

## 9.4.2 Management protocol services

The management application client and management device server use the following four-step process to perform SMP functions:

- 1) the management application client invokes Send SMP Function;
- 2) the SMP target port invokes SMP Function Received;
- 3) the management device server invokes Send SMP Function Response; and
- 4) the SMP initiator port invokes Received SMP Function Complete.

## 9.4.3 SMP functions

### 9.4.3.1 SMP functions overview

Table 240 defines the SMP functions.

**Table 240 — SMP functions (FUNCTION field) (part 1 of 3)**

| Function code                              | SMP function                             | Description                                                                 | Reference |
|--------------------------------------------|------------------------------------------|-----------------------------------------------------------------------------|-----------|
| SMP input functions (00h to 7Fh)           |                                          |                                                                             |           |
| General SMP input functions (00h to 0Fh)   |                                          |                                                                             |           |
| 00h                                        | REPORT GENERAL                           | Return general information about the device                                 | 9.4.3.4   |
| 01h                                        | REPORT MANUFACTURER INFORMATION          | Return vendor and product identification                                    | 9.4.3.5   |
| 02h                                        | Obsolete                                 |                                                                             |           |
| 03h                                        | REPORT SELF-CONFIGURATION STATUS         | Return status of the discover process in a self-configuring expander device | 9.4.3.6   |
| 04h                                        | REPORT ZONE PERMISSION TABLE             | Return zone permission table values                                         | 9.4.3.7   |
| 05h                                        | REPORT ZONE MANAGER PASSWORD             | Return the zone manager password                                            | 9.4.3.8   |
| 06h                                        | REPORT BROADCAST                         | Return information about Broadcast counters                                 | 9.4.3.9   |
| 07h                                        | Restricted for SFF                       |                                                                             |           |
| 08h to 0Fh                                 | Reserved for general SMP input functions |                                                                             |           |
| Phy-based SMP input functions (10h to 1Fh) |                                          |                                                                             |           |
| 10h                                        | DISCOVER                                 | Return information about the specified phy                                  | 9.4.3.10  |
| 11h                                        | REPORT PHY ERROR LOG                     | Return error logging information about the specified phy                    | 9.4.3.11  |
| 12h                                        | REPORT PHY SATA                          | Return information about a phy currently attached to a SATA phy             | 9.4.3.12  |

Table 240 — SMP functions (FUNCTION field) (part 2 of 3)

| Function code                                          | SMP function                                           | Description                                                                           | Reference |
|--------------------------------------------------------|--------------------------------------------------------|---------------------------------------------------------------------------------------|-----------|
| 13h                                                    | REPORT ROUTE INFORMATION                               | Return phy-based expander route table information                                     | 9.4.3.13  |
| 14h                                                    | REPORT PHY EVENT                                       | Return phy events for the specified phy                                               | 9.4.3.14  |
| 15h to 1Fh                                             | Reserved for phy-based SMP input functions             |                                                                                       |           |
| Descriptor list-based SMP input functions (20h to 2Fh) |                                                        |                                                                                       |           |
| 20h                                                    | DISCOVER LIST                                          | Return information about the specified phys                                           | 9.4.3.15  |
| 21h                                                    | REPORT PHY EVENT LIST                                  | Return phy events                                                                     | 9.4.3.16  |
| 22h                                                    | REPORT EXPANDER ROUTE TABLE LIST                       | Return contents of the expander-based expander route table                            | 9.4.3.17  |
| 23h to 2Fh                                             | Reserved for descriptor list-based SMP input functions |                                                                                       |           |
| Other SMP input functions (30h to 7Fh)                 |                                                        |                                                                                       |           |
| 30h to 3Fh                                             | Reserved for SMP input functions                       |                                                                                       |           |
| 40h to 7Fh                                             | Vendor specific                                        |                                                                                       |           |
| SMP output functions (80h to FFh)                      |                                                        |                                                                                       |           |
| General SMP output functions (80h to 8Fh)              |                                                        |                                                                                       |           |
| 80h                                                    | CONFIGURE GENERAL                                      | Configure the device                                                                  | 9.4.3.18  |
| 81h                                                    | ENABLE DISABLE ZONING                                  | Enable or disable zoning                                                              | 9.4.3.19  |
| 82h                                                    | Obsolete                                               |                                                                                       |           |
| 83h                                                    | Restricted for SFF                                     |                                                                                       |           |
| 84h                                                    | Reserved for general SMP output functions              |                                                                                       |           |
| 85h                                                    | ZONED BROADCAST                                        | Transmit the specified Broadcast on the expander ports in the specified zone group(s) | 9.4.3.20  |
| 86h                                                    | ZONE LOCK                                              | Lock a zoning expander device                                                         | 9.4.3.21  |
| 87h                                                    | ZONE ACTIVATE                                          | Set the zoning expander current values equal to the zoning expander shadow values     | 9.4.3.22  |
| 88h                                                    | ZONE UNLOCK                                            | Unlock a zoning expander device                                                       | 9.4.3.23  |
| 89h                                                    | CONFIGURE ZONE MANAGER PASSWORD                        | Configure the zone manager password                                                   | 9.4.3.24  |
| 8Ah                                                    | CONFIGURE ZONE PHY INFORMATION                         | Configure zone phy information                                                        | 9.4.3.25  |

Table 240 — SMP functions (FUNCTION field) (part 3 of 3)

| Function code                               | SMP function                                | Description                                       | Reference |
|---------------------------------------------|---------------------------------------------|---------------------------------------------------|-----------|
| 8Bh                                         | CONFIGURE ZONE PERMISSION TABLE             | Configure the zone permission table               | 9.4.3.26  |
| 8Ch to 8Fh                                  | Reserved for general SMP output functions   |                                                   |           |
| Phy-based SMP output functions (90h to 9Fh) |                                             |                                                   |           |
| 90h                                         | CONFIGURE ROUTE INFORMATION                 | Change phy-based expander route table information | 9.4.3.27  |
| 91h                                         | PHY CONTROL                                 | Request actions by the specified phy              | 9.4.3.28  |
| 92h                                         | PHY TEST FUNCTION                           | Request a test function by the specified phy      | 9.4.3.29  |
| 93h                                         | CONFIGURE PHY EVENT                         | Configure phy events for the specified phy        | 9.4.3.30  |
| 94h to 9Fh                                  | Reserved for phy-based SMP output functions |                                                   |           |
| Other SMP output functions (A0h to FFh)     |                                             |                                                   |           |
| A0h to BFh                                  | Reserved for SMP output functions           |                                                   |           |
| C0h to FFh                                  | Vendor specific                             |                                                   |           |

### 9.4.3.2 SMP function request frame format

#### 9.4.3.2.1 SMP function request frame format overview

An SMP request frame is sent by a management application client via an SMP initiator port to request an SMP function be performed by a management device server. Table 241 defines the SMP request frame format.

**Table 241 — SMP request frame format**

| Byte <sup>a</sup> \ Bit | 7                                      | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------------------|----------------------------------------|---|---|---|---|---|---|---|
| 0                       | SMP FRAME TYPE (40h)                   |   |   |   |   |   |   |   |
| 1                       | FUNCTION                               |   |   |   |   |   |   |   |
| 2                       | ALLOCATED RESPONSE LENGTH              |   |   |   |   |   |   |   |
| 3                       | REQUEST LENGTH ((00h or ((n - 7) / 4)) |   |   |   |   |   |   |   |
| 4                       | Additional request bytes               |   |   |   |   |   |   |   |
| ...                     |                                        |   |   |   |   |   |   |   |
| n - 4                   |                                        |   |   |   |   |   |   |   |
| n - 3                   | (MSB)                                  |   |   |   |   |   |   |   |
| ...                     | CRC                                    |   |   |   |   |   |   |   |
| n                       |                                        |   |   |   |   |   |   |   |

<sup>a</sup> Shaded byte numbers (e.g., bytes 0 to 3 and (n - 3) to n) show the bytes that are included in the request frame if the REQUEST LENGTH field is set to 00h. Functions defined in SAS-1.1 may be defined as containing more than eight bytes if the REQUEST LENGTH field is set to 00h.

#### 9.4.3.2.2 SMP FRAME TYPE field

The SMP FRAME TYPE field is defined by the SMP transport layer (see 8.4.1) and parsed by the SMP transport layer state machines (see 8.4.5). The SMP FRAME TYPE field shall be set as shown in table 241 for the SMP request frame format.

#### 9.4.3.2.3 FUNCTION field

The FUNCTION field specifies which SMP function is being requested and is defined in table 240 (see 9.4.3.1). If the management device server does not support the value in the FUNCTION field, then the management device server shall return a function result of UNKNOWN SMP FUNCTION as described in table 243 (see 9.4.3.3.4).

#### 9.4.3.2.4 ALLOCATED RESPONSE LENGTH field

The ALLOCATED RESPONSE LENGTH field specifies the maximum number of dwords that the management application client has allocated in the data-in buffer for the additional response bytes in the response frame (see 9.4.3.3).

For compatibility with SAS-1.1, an ALLOCATED RESPONSE LENGTH field set to 00h specifies that a specific number of dwords are to be transferred as defined in the SMP function description. If the SMP function

description does not specify a specific number of dwords, then the number of dwords to be transferred is zero. This condition shall not be considered as an error.

If the LONG RESPONSE bit is set to one in the REPORT GENERAL response (see 9.4.3.4), then the management application client may set the ALLOCATED RESPONSE LENGTH field to a non-zero value in all SMP request frames. If the LONG RESPONSE bit is set to zero in the REPORT GENERAL response, then the management application client shall set the ALLOCATED RESPONSE LENGTH field to 00h in all SMP request frames.

If the ALLOCATED RESPONSE LENGTH field is set to a non-zero value, then the management device server shall truncate the additional response bytes to the number of dwords specified by the ALLOCATED RESPONSE LENGTH field.

If the ALLOCATED RESPONSE LENGTH field is set to 00h, then the management device server shall truncate the additional response bytes to the number of dwords specified by the SMP function description.

The allocated response length is used to limit the maximum amount of variable length data returned to the management application client. Fields in the additional response bytes (e.g., fields containing counts of the number of dwords in some or all of the data) shall not be altered to reflect the truncation, if any, that results from an insufficient allocated response length.

#### 9.4.3.2.5 REQUEST LENGTH field

A REQUEST LENGTH field set to 00h specifies that either:

- a) no dwords follow the REQUEST LENGTH field before the CRC field; or
- b) a non-zero number of dwords follow the REQUEST LENGTH field before the CRC field. This is for compatibility with SAS-1.1.

The function description defines the interpretation of a REQUEST LENGTH field set to 00h.

A REQUEST LENGTH field set to a non-zero value (i.e., the non-zero value defined in table 241 (see 9.4.3.2.1)) specifies the number of dwords that follow the REQUEST LENGTH field before the CRC field (i.e., the length of the entire request frame minus two).

If the LONG RESPONSE bit is set to one in the REPORT GENERAL response (see 9.4.3.4), then the management application client may set the REQUEST LENGTH field to a non-zero value in the SMP request frame for any SMP function. If the LONG RESPONSE bit is set to zero in the REPORT GENERAL response, then the management application client shall set the REQUEST LENGTH field to 00h in the SMP request frame for every SMP function.

If the request frame size including the CRC field is less than 8 bytes, or the REQUEST LENGTH field does not match the request frame size, then the management device server shall return a function result of INVALID REQUEST FRAME LENGTH.

The management device server shall consider any fields not included in the request frame to be set to zero.

#### 9.4.3.2.6 Additional request bytes

The additional request bytes definition and length are based on the SMP function.

The number of additional request bytes are an integer multiple of four, so the CRC field is aligned on a four byte boundary.

The maximum number of additional request bytes is 1 020, making the maximum size of the frame 1 028 bytes (i.e., 4 bytes of header + 1 020 bytes of data + 4 bytes of CRC).

NOTE 64 - If a management application clients compliant with SAS-1.1 sends a vendor specific SMP request frame containing 1 024 additional request bytes, then the SMP\_TP state machine discards that SMP request frame at it exceeds the maximum allowed request size of 1 023 bytes (see 6.20.5.4.2.2). SMP request frames defined in SAS 1.1 do not have more than 36 additional request bytes.

If the management device server receives more additional request bytes than it expects (e.g., the management device server complies with a previous version of this standard (i.e., SAS-1.1) defining 24 additional request bytes, but receives a request frame containing 36 additional request bytes), then the management device server shall return a function result of INVALID REQUEST FRAME LENGTH.

For additional request bytes containing a DESCRIPTOR LENGTH field and a descriptor list, if the management device server receives more bytes in each descriptor than it expects (e.g., the management device server complies with a previous version of this standard (i.e., SAS-1.1) defining that a descriptor is 12 bytes, but receives a request frame containing a descriptor list with 16 byte descriptors), then the management device server shall return a function result of INVALID REQUEST FRAME LENGTH.

#### 9.4.3.2.7 CRC field

The CRC field is defined by the SMP transport layer (see 8.4.1) and parsed by the SMP link layer state machines (see 6.20.5).

#### 9.4.3.3 SMP function response frame format

#### 9.4.3.3.1 SMP function response frame format overview

An SMP response frame is sent by a management device server via an SMP target port in response to an SMP request frame. Table 242 defines the SMP response frame format.

### Table 242 — SMP response frame format

| Byte <sup>a</sup> \ Bit | 7                                      | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------------------|----------------------------------------|---|---|---|---|---|---|---|
| 0                       | SMP FRAME TYPE (41h)                   |   |   |   |   |   |   |   |
| 1                       | FUNCTION                               |   |   |   |   |   |   |   |
| 2                       | FUNCTION RESULT                        |   |   |   |   |   |   |   |
| 3                       | RESPONSE LENGTH (00h or ((n - 7) / 4)) |   |   |   |   |   |   |   |
| 4                       | Additional response bytes              |   |   |   |   |   |   |   |
| ...                     |                                        |   |   |   |   |   |   |   |
| n - 4                   |                                        |   |   |   |   |   |   |   |
| n - 3                   | (MSB)                                  |   |   |   |   |   |   |   |
| ...                     | CRC                                    |   |   |   |   |   |   |   |
| n                       |                                        |   |   |   |   |   |   |   |

<sup>a</sup> Shaded byte numbers (e.g., bytes 0 to 3 and (n - 3) to n) show the bytes that are included in the response frame if the ALLOCATED RESPONSE LENGTH field is set to 00h in the request frame. Functions defined in SAS-1.1 may be defined as returning more than eight bytes if the ALLOCATED RESPONSE LENGTH field is set to 00h.

**9.4.3.3.2 SMP FRAME TYPE field**

The SMP FRAME TYPE field is defined by the SMP transport layer (see 8.4.1) and parsed by the MT state machines (see 8.4.5). The SMP FRAME TYPE field shall be set as shown in table 242 for the SMP response frame format.

**9.4.3.3.3 FUNCTION field**

The FUNCTION field indicates the SMP function to which this frame is a response, and is defined in table 240 (see 9.4.3.1).

**9.4.3.3.4 FUNCTION RESULT field**

The FUNCTION RESULT field is defined in table 243.

**Table 243 — FUNCTION RESULT field (part 1 of 4)**

| Code | Name                          | SMP function(s)                                                                                                                                                                                                                                        | Description                                                                                                                                            |
|------|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 00h  | SMP FUNCTION ACCEPTED         | All                                                                                                                                                                                                                                                    | The management device server supports the SMP function and processed the SMP function.                                                                 |
| 01h  | UNKNOWN SMP FUNCTION          | Unknown                                                                                                                                                                                                                                                | The management device server does not support the requested SMP function.                                                                              |
| 02h  | SMP FUNCTION FAILED           | All                                                                                                                                                                                                                                                    | The requested SMP function failed.                                                                                                                     |
| 03h  | INVALID REQUEST FRAME LENGTH  | All                                                                                                                                                                                                                                                    | The SMP request frame length was invalid (see 9.4.3.2).                                                                                                |
| 04h  | INVALID EXPANDER CHANGE COUNT | CONFIGURE GENERAL, ENABLE DISABLE ZONING, ZONE LOCK, ZONE ACTIVATE, CONFIGURE ZONE MANAGER PASSWORD, CONFIGURE ZONE PHY INFORMATION, CONFIGURE ZONE PERMISSION TABLE, CONFIGURE ROUTE INFORMATION, PHY CONTROL, PHY TEST FUNCTION, CONFIGURE PHY EVENT | The management device server supports the SMP function, but the EXPECTED EXPANDER CHANGE COUNT field does not match the current expander change count. |



**Table 243** — FUNCTION RESULT field (part 2 of 4)

| Code | Name                             | SMP function(s)                                                                                                                                                                                                                                                           | Description                                                                                                                                                                                                                                                                                                                                                                                                                         |
|------|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 05h  | BUSY                             | ZONE UNLOCK,<br>ENABLE DISABLE<br>ZONING,<br>CONFIGURE ZONE<br>MANAGER<br>PASSWORD,<br>CONFIGURE ZONE<br>PHY INFORMATION,<br>CONFIGURE ZONE<br>PERMISSION TABLE                                                                                                           | For ZONE UNLOCK, the locked zoning expander device is processing the activate step.<br><br>For the other functions, the management device server is currently saving zoning values.                                                                                                                                                                                                                                                 |
| 06h  | INCOMPLETE<br>DESCRIPTOR<br>LIST | ZONED BROADCAST,<br>CONFIGURE ZONE<br>PHY INFORMATION,<br>CONFIGURE ZONE<br>PERMISSION TABLE,<br>CONFIGURE PHY<br>EVENT                                                                                                                                                   | The request frame length results in the truncation of a multi-byte field or descriptor list (e.g., in the ZONED BROADCAST request (see table 311), the request frame is not large enough to contain the number of Broadcast source zone groups specified by the NUMBER OF BROADCAST SOURCE ZONE GROUPS field).                                                                                                                      |
| 10h  | PHY DOES NOT<br>EXIST            | DISCOVER, REPORT<br>PHY ERROR LOG,<br>REPORT PHY SATA,<br>REPORT ROUTE<br>INFORMATION,<br>REPORT PHY<br>EVENT, DISCOVER<br>LIST, CONFIGURE<br>ZONE PHY<br>INFORMATION,<br>CONFIGURE ROUTE<br>INFORMATION, PHY<br>CONTROL, PHY<br>TEST FUNCTION,<br>CONFIGURE PHY<br>EVENT | The phy specified by the PHY IDENTIFIER field or the STARTING PHY IDENTIFIER field in the SMP request frame does not exist (e.g., the value is not less than the value indicated in the NUMBER OF PHYs field in the SMP REPORT GENERAL response).                                                                                                                                                                                   |
| 11h  | INDEX DOES NOT<br>EXIST          | REPORT ROUTE<br>INFORMATION,<br>CONFIGURE ROUTE<br>INFORMATION                                                                                                                                                                                                            | The phy specified by the PHY IDENTIFIER field in the SMP request frame does not have the table routing attribute (see 4.5.7.1), or the expander route index specified by the EXPANDER ROUTE INDEX field does not exist (i.e., the value is not in the range of 0000h to the value of the EXPANDER ROUTE INDEXES field in the SMP REPORT GENERAL response). The ADDITIONAL RESPONSE BYTES field may be present but shall be ignored. |
| 12h  | PHY DOES NOT<br>SUPPORT SATA     | REPORT PHY SATA,<br>PHY CONTROL                                                                                                                                                                                                                                           | See 9.4.3.12 and 9.4.3.28                                                                                                                                                                                                                                                                                                                                                                                                           |
| 13h  | UNKNOWN PHY<br>OPERATION         | PHY CONTROL                                                                                                                                                                                                                                                               | See 9.4.3.28                                                                                                                                                                                                                                                                                                                                                                                                                        |

**Table 243** — FUNCTION RESULT field (part 3 of 4)

| Code | Name                                | SMP function(s)                                                                                                                                                                                               | Description                                                                                                                                                                                                                                                                     |
|------|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14h  | UNKNOWN PHY TEST FUNCTION           | PHY TEST FUNCTION                                                                                                                                                                                             | See 9.4.3.29                                                                                                                                                                                                                                                                    |
| 15h  | PHY TEST FUNCTION IN PROGRESS       | PHY TEST FUNCTION                                                                                                                                                                                             | See 9.4.3.29                                                                                                                                                                                                                                                                    |
| 16h  | PHY VACANT                          | DISCOVER, REPORT PHY ERROR LOG, REPORT PHY SATA, REPORT ROUTE INFORMATION, REPORT PHY EVENT, CONFIGURE ZONE PHY INFORMATION, CONFIGURE ROUTE INFORMATION, PHY CONTROL, PHY TEST FUNCTION, CONFIGURE PHY EVENT | The management device server processing the SMP request frame does not have access to a specified phy (e.g., because of zoning or vendor specific reasons), although the value is less than the value indicated in the NUMBER OF PHYS field in the SMP REPORT GENERAL response. |
| 17h  | UNKNOWN PHY EVENT SOURCE            | CONFIGURE PHY EVENT                                                                                                                                                                                           | See 9.4.3.30.3                                                                                                                                                                                                                                                                  |
| 18h  | UNKNOWN DESCRIPTOR TYPE             | DISCOVER LIST                                                                                                                                                                                                 | The descriptor type specified by the DESCRIPTOR TYPE field is not supported.                                                                                                                                                                                                    |
| 19h  | UNKNOWN PHY FILTER                  | DISCOVER LIST                                                                                                                                                                                                 | The phy filter specified by the PHY FILTER field is not supported.                                                                                                                                                                                                              |
| 1Ah  | AFFILIATION VIOLATION               | PHY CONTROL                                                                                                                                                                                                   | The specified phy operation is not allowed due to the current state of affiliations.                                                                                                                                                                                            |
| 20h  | SMP ZONE VIOLATION                  | CONFIGURE GENERAL, ZONED BROADCAST, PHY CONTROL, PHY TEST FUNCTION, CONFIGURE PHY EVENT                                                                                                                       | Zoning is enabled and the SMP initiator port does not have access to a necessary zone group according to the zone permission table (see 4.8.3.2).                                                                                                                               |
| 21h  | NO MANAGEMENT ACCESS RIGHTS         | REPORT ZONE MANAGER PASSWORD, ZONE LOCK, CONFIGURE ZONE MANAGER PASSWORD                                                                                                                                      | For ZONE LOCK see 9.4.3.21. For REPORT ZONE MANAGER PASSWORD, see 9.4.3.8. For CONFIGURE ZONE MANAGER PASSWORD, see 9.4.3.24.                                                                                                                                                   |
| 22h  | UNKNOWN ENABLE DISABLE ZONING VALUE | ENABLE DISABLE ZONING                                                                                                                                                                                         | See 9.4.3.19                                                                                                                                                                                                                                                                    |

Table 243 — FUNCTION RESULT field (part 4 of 4)

| Code       | Name                             | SMP function(s)                                                                                                                                                                     | Description                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 23h        | ZONE LOCK VIOLATION              | ENABLE DISABLE ZONING, ZONE LOCK, ZONE ACTIVATE, ZONE UNLOCK, CONFIGURE ZONE PHY INFORMATION, CONFIGURE ZONE PERMISSION TABLE                                                       | Zoning is enabled and:<br>a) an unlocked zoning expander device receives an SMP zone configuration function request, a ZONE ACTIVATE request, or a ZONE UNLOCK request; or<br>b) a locked zoning expander device receives an SMP zone configuration function request, a ZONE ACTIVATE request, or a ZONE UNLOCK request from an SMP initiator port that is not the active zone manager.                                  |
| 24h        | NOT ACTIVATED                    | ZONE UNLOCK                                                                                                                                                                         | The following conditions are true:<br>a) the ACTIVATE REQUIRED bit is set to one in the request; and<br>b) the locked zoning expander device has not processed the activate step.                                                                                                                                                                                                                                        |
| 25h        | ZONE GROUP OUT OF RANGE          | CONFIGURE ZONE PHY INFORMATION, CONFIGURE ZONE PERMISSION TABLE                                                                                                                     | The ZONE GROUP field or NUMBER OF ZONE GROUPS field contains a value that is not supported.                                                                                                                                                                                                                                                                                                                              |
| 26h        | NO PHYSICAL PRESENCE             | CONFIGURE ZONE MANAGER PASSWORD                                                                                                                                                     | The following conditions are true:<br>a) the NEW ZONE MANAGER PASSWORD field is set to DISABLED (see table 35 in 4.8.1); and<br>b) physical presence is not asserted.                                                                                                                                                                                                                                                    |
| 27h        | SAVING NOT SUPPORTED             | REPORT ZONE PERMISSION TABLE, REPORT ZONE MANAGER PASSWORD, ENABLE DISABLE ZONING, CONFIGURE ZONE MANAGER PASSWORD, CONFIGURE ZONE PHY INFORMATION, CONFIGURE ZONE PERMISSION TABLE | For REPORT ZONE PERMISSION TABLE, see 9.4.3.7<br><br>For REPORT ZONE MANAGER PASSWORD, see 9.4.3.8<br><br>For ENABLE DISABLE ZONING, CONFIGURE ZONE MANAGER PASSWORD, CONFIGURE ZONE PHY INFORMATION, and CONFIGURE ZONE PERMISSION TABLE, the following conditions are true the:<br>a) SAVE field is set to 01b or 11b; and<br>b) management device server does not support saved values for the specified information. |
| 28h        | SOURCE ZONE GROUP DOES NOT EXIST | REPORT ZONE PERMISSION TABLE                                                                                                                                                        | See 9.4.3.7                                                                                                                                                                                                                                                                                                                                                                                                              |
| 29h        | DISABLED PASSWORD NOT SUPPORTED  | CONFIGURE ZONE MANAGER PASSWORD                                                                                                                                                     | See 9.4.3.24                                                                                                                                                                                                                                                                                                                                                                                                             |
| 2Ah        | INVALID FIELD IN SMP REQUEST     | All                                                                                                                                                                                 | The management device server does not support a field in the requested SMP function.                                                                                                                                                                                                                                                                                                                                     |
| All others | Reserved                         |                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                          |

Table 244 defines the priority of the SMP function results defined in table 243.

**Table 244 — Function result priority** (part 1 of 5)

| SMP function                                         | SMP function result priority is as follows:                                                                                                                                                          |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| REPORT GENERAL<br>(see 9.4.3.4)                      | 1) INVALID REQUEST FRAME LENGTH;<br>2) SMP FUNCTION FAILED;<br>3) INVALID FIELD IN SMP REQUEST; and<br>4) SMP FUNCTION ACCEPTED.                                                                     |
| REPORT MANUFACTURER<br>INFORMATION<br>(see 9.4.3.5)  | 1) INVALID REQUEST FRAME LENGTH;<br>2) SMP FUNCTION FAILED;<br>3) INVALID FIELD IN SMP REQUEST; and<br>4) SMP FUNCTION ACCEPTED.                                                                     |
| REPORT<br>SELF-CONFIGURATION<br>STATUS (see 9.4.3.6) | 1) INVALID REQUEST FRAME LENGTH;<br>2) SMP FUNCTION FAILED;<br>3) INVALID FIELD IN SMP REQUEST; and<br>4) SMP FUNCTION ACCEPTED.                                                                     |
| REPORT ZONE PERMISSION<br>TABLE<br>(see 9.4.3.7)     | 1) INVALID REQUEST FRAME LENGTH;<br>2) SOURCE ZONE GROUP DOES NOT EXIST;<br>3) SAVING NOT SUPPORTED;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED. |
| REPORT ZONE MANAGER<br>PASSWORD<br>(see 9.4.3.8)     | 1) INVALID REQUEST FRAME LENGTH;<br>2) NO MANAGEMENT ACCESS RIGHTS;<br>3) SAVING NOT SUPPORTED;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED.      |
| REPORT BROADCAST<br>(see 9.4.3.9)                    | 1) INVALID REQUEST FRAME LENGTH;<br>2) SMP FUNCTION FAILED;<br>3) INVALID FIELD IN SMP REQUEST; and<br>4) SMP FUNCTION ACCEPTED.                                                                     |
| DISCOVER<br>(see 9.4.3.10)                           | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) PHY VACANT;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED.                         |
| REPORT PHY ERROR LOG<br>(see 9.4.3.11)               | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) PHY VACANT;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED.                         |

Table 244 — Function result priority (part 2 of 5)

| SMP function                                       | SMP function result priority is as follows:                                                                                                                                                                         |
|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| REPORT PHY SATA<br>(see 9.4.3.12)                  | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) PHY VACANT;<br>4) PHY DOES NOT SUPPORT SATA;<br>5) SMP FUNCTION FAILED;<br>6) INVALID FIELD IN SMP REQUEST; and<br>7) SMP FUNCTION ACCEPTED.       |
| REPORT ROUTE INFORMATION<br>(see 9.4.3.13)         | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) PHY VACANT;<br>4) INDEX DOES NOT EXIST;<br>5) SMP FUNCTION FAILED;<br>6) INVALID FIELD IN SMP REQUEST; and<br>7) SMP FUNCTION ACCEPTED.            |
| REPORT PHY EVENT<br>(see 9.4.3.14)                 | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) PHY VACANT;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED.                                        |
| DISCOVER LIST<br>(see 9.4.3.15)                    | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) UNKNOWN DESCRIPTOR TYPE;<br>4) UNKNOWN PHY FILTER;<br>5) SMP FUNCTION FAILED;<br>6) INVALID FIELD IN SMP REQUEST; and<br>7) SMP FUNCTION ACCEPTED. |
| REPORT PHY EVENT LIST<br>(see 9.4.3.16)            | 1) INVALID REQUEST FRAME LENGTH;<br>2) SMP FUNCTION FAILED;<br>3) INVALID FIELD IN SMP REQUEST; and<br>4) SMP FUNCTION ACCEPTED.                                                                                    |
| REPORT EXPANDER ROUTE TABLE LIST<br>(see 9.4.3.17) | 1) INVALID REQUEST FRAME LENGTH;<br>2) SMP FUNCTION FAILED;<br>3) INVALID FIELD IN SMP REQUEST; and<br>4) SMP FUNCTION ACCEPTED.                                                                                    |
| CONFIGURE GENERAL<br>(see 9.4.3.18)                | 1) INVALID REQUEST FRAME LENGTH;<br>2) SMP ZONE VIOLATION;<br>3) INVALID EXPANDER CHANGE COUNT;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED.                     |

Table 244 — Function result priority (part 3 of 5)

| SMP function                                         | SMP function result priority is as follows:                                                                                                                                                                                                                                                             |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ENABLE DISABLE ZONING<br>(see 9.4.3.19)              | 1) INVALID REQUEST FRAME LENGTH;<br>2) ZONE LOCK VIOLATION;<br>3) UNKNOWN ENABLE DISABLE ZONING VALUE;<br>4) INVALID EXPANDER CHANGE COUNT;<br>5) SAVING NOT SUPPORTED;<br>6) SMP FUNCTION FAILED;<br>7) INVALID FIELD IN SMP REQUEST; and<br>8) SMP FUNCTION ACCEPTED.                                 |
| ZONED BROADCAST<br>(see 9.4.3.20)                    | 1) INVALID REQUEST FRAME LENGTH;<br>2) INCOMPLETE DESCRIPTOR LIST;<br>3) SMP ZONE VIOLATION;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED.                                                                                                            |
| ZONE LOCK<br>(see 9.4.3.21)                          | 1) INVALID REQUEST FRAME LENGTH;<br>2) NO MANAGEMENT ACCESS RIGHTS;<br>3) INVALID EXPANDER CHANGE COUNT;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED.                                                                                                |
| ZONE ACTIVATE<br>(see 9.4.3.22)                      | 1) INVALID REQUEST FRAME LENGTH;<br>2) ZONE LOCK VIOLATION;<br>3) INVALID EXPANDER CHANGE COUNT;<br>4) SMP FUNCTION FAILED;<br>5) INVALID FIELD IN SMP REQUEST; and<br>6) SMP FUNCTION ACCEPTED.                                                                                                        |
| ZONE UNLOCK<br>(see 9.4.3.23)                        | 1) INVALID REQUEST FRAME LENGTH;<br>2) ZONE LOCK VIOLATION;<br>3) NOT ACTIVATED;<br>4) BUSY;<br>5) SMP FUNCTION FAILED;<br>6) INVALID FIELD IN SMP REQUEST; and<br>7) SMP FUNCTION ACCEPTED.                                                                                                            |
| CONFIGURE ZONE<br>MANAGER PASSWORD<br>(see 9.4.3.24) | 1) INVALID REQUEST FRAME LENGTH;<br>2) INVALID EXPANDER CHANGE COUNT;<br>3) NO MANAGEMENT ACCESS RIGHTS;<br>4) NO PHYSICAL PRESENCE;<br>5) SAVING NOT SUPPORTED;<br>6) DISABLED PASSWORD NOT SUPPORTED;<br>7) SMP FUNCTION FAILED;<br>8) INVALID FIELD IN SMP REQUEST; and<br>9) SMP FUNCTION ACCEPTED. |

Table 244 — Function result priority (part 4 of 5)

| SMP function                                         | SMP function result priority is as follows:                                                                                                                                                                                                                                                                                                 |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CONFIGURE ZONE PHY<br>INFORMATION<br>(see 9.4.3.25)  | 1) INVALID REQUEST FRAME LENGTH;<br>2) INCOMPLETE DESCRIPTOR LIST;<br>3) PHY DOES NOT EXIST;<br>4) PHY VACANT;<br>5) ZONE LOCK VIOLATION;<br>6) INVALID EXPANDER CHANGE COUNT;<br>7) SAVING NOT SUPPORTED;<br>8) ZONE GROUP OUT OF RANGE;<br>9) SMP FUNCTION FAILED;<br>10) INVALID FIELD IN SMP REQUEST; and<br>11) SMP FUNCTION ACCEPTED. |
| CONFIGURE ZONE<br>PERMISSION TABLE<br>(see 9.4.3.26) | 1) INVALID REQUEST FRAME LENGTH;<br>2) INCOMPLETE DESCRIPTOR LIST;<br>3) ZONE LOCK VIOLATION;<br>4) INVALID EXPANDER CHANGE COUNT;<br>5) SAVING NOT SUPPORTED;<br>6) ZONE GROUP OUT OF RANGE;<br>7) SMP FUNCTION FAILED;<br>8) INVALID FIELD IN SMP REQUEST; and<br>9) SMP FUNCTION ACCEPTED.                                               |
| CONFIGURE ROUTE<br>INFORMATION<br>(see 9.4.3.27)     | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) PHY VACANT;<br>4) INVALID EXPANDER CHANGE COUNT;<br>5) INDEX DOES NOT EXIST;<br>6) SMP FUNCTION FAILED;<br>7) INVALID FIELD IN SMP REQUEST; and<br>8) SMP FUNCTION ACCEPTED.                                                                                               |
| PHY CONTROL<br>(see 9.4.3.28)                        | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) PHY VACANT;<br>4) SMP ZONE VIOLATION;<br>5) INVALID EXPANDER CHANGE COUNT;<br>6) UNKNOWN PHY OPERATION;<br>7) PHY DOES NOT SUPPORT SATA;<br>8) AFFILIATION VIOLATION;<br>9) SMP FUNCTION FAILED;<br>10) INVALID FIELD IN SMP REQUEST; and<br>11) SMP FUNCTION ACCEPTED.    |

Table 244 — Function result priority (part 5 of 5)

| SMP function                          | SMP function result priority is as follows:                                                                                                                                                                                                                                                                        |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PHY TEST FUNCTION<br>(see 9.4.3.29)   | 1) INVALID REQUEST FRAME LENGTH;<br>2) PHY DOES NOT EXIST;<br>3) PHY VACANT;<br>4) SMP ZONE VIOLATION;<br>5) INVALID EXPANDER CHANGE COUNT;<br>6) UNKNOWN PHY TEST FUNCTION;<br>7) PHY TEST FUNCTION IN PROGRESS;<br>8) SMP FUNCTION FAILED;<br>9) INVALID FIELD IN SMP REQUEST; and<br>10) SMP FUNCTION ACCEPTED. |
| CONFIGURE PHY EVENT<br>(see 9.4.3.30) | 1) INVALID REQUEST FRAME LENGTH;<br>2) INCOMPLETE DESCRIPTOR LIST;<br>3) PHY DOES NOT EXIST;<br>4) PHY VACANT;<br>5) SMP ZONE VIOLATION;<br>6) INVALID EXPANDER CHANGE COUNT;<br>7) UNKNOWN PHY EVENT SOURCE;<br>8) SMP FUNCTION FAILED;<br>9) INVALID FIELD IN SMP REQUEST; and<br>10) SMP FUNCTION ACCEPTED.     |

#### 9.4.3.3.5 RESPONSE LENGTH field

A RESPONSE LENGTH field set to 00h indicates that either:

- no dwords follow the RESPONSE LENGTH field before the CRC field; or
- a non-zero number of dwords follow the RESPONSE LENGTH field before the CRC field. This is for compatibility with SAS-1.1.

The function description defines the interpretation of a RESPONSE LENGTH field set to 00h.

A RESPONSE LENGTH field set to a non-zero value (i.e., the non-zero value defined in table 242 (see 9.4.3.3.1)) indicates the number of dwords that follow the RESPONSE LENGTH field before the CRC field (i.e., the length of the entire response frame minus two).

#### 9.4.3.3.6 Additional response bytes

If the FUNCTION RESULT field is set to 00h, then the additional response bytes definition depends on the SMP function requested. If the FUNCTION RESULT field is set to a value other than 00h, then the additional response bytes may be present but shall be ignored.

The number of additional response bytes are an integer multiple of four, so the CRC field is aligned on a four byte boundary.

The maximum number of additional response bytes is 1 020, making the maximum size of the frame 1 028 bytes (i.e., 4 bytes of header + 1 020 bytes of data + 4 bytes of CRC).

NOTE 65 - If a management device server compliant with SAS-1.1 sends a vendor specific SMP response frame containing 1 024 additional response bytes, then the SMP\_IP state machine discards that SMP response frame as it exceeds the maximum allowed request size of 1 023 bytes (see 6.20.5.3.4). SMP response frames defined in SAS-1.1 do not have more than 56 additional response bytes.

The management application client should ignore any additional response bytes beyond those that it expects (e.g., if the management application client complies with a version of this standard defining 24 additional



response bytes, but receives a response frame containing 36 additional response bytes, then it should ignore the last 12 additional response bytes).

For additional response bytes containing a DESCRIPTOR LENGTH field and a descriptor list, the management application client should ignore any bytes in each descriptor beyond those that it expects (e.g., if the management application client complies with a version of this standard defining that a descriptor has 24 bytes, but receives a response frame containing a descriptor list with 36 byte descriptors, then it should ignore the last 12 bytes of each descriptor).

#### 9.4.3.3.7 CRC field

The CRC field is defined by the SMP transport layer (see 8.4.1) and parsed by the SMP link layer state machines (see 6.20.5).

#### 9.4.3.4 REPORT GENERAL function

The REPORT GENERAL function returns general information about the SAS device (e.g., a SAS device contained in an expander device). This SMP function shall be implemented by all management device servers.

Table 245 defines the REPORT GENERAL request format.

**Table 245 — REPORT GENERAL request**

| Byte\Bit | 7                                 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|-----------------------------------|---|---|---|---|---|---|---|
| 0        | SMP FRAME TYPE (40h)              |   |   |   |   |   |   |   |
| 1        | FUNCTION (00h)                    |   |   |   |   |   |   |   |
| 2        | ALLOCATED RESPONSE LENGTH         |   |   |   |   |   |   |   |
| 3        | REQUEST LENGTH (00h)              |   |   |   |   |   |   |   |
| 4        | (MSB) _____<br>CRC<br>_____ (LSB) |   |   |   |   |   |   |   |
| ...      |                                   |   |   |   |   |   |   |   |
| 7        |                                   |   |   |   |   |   |   |   |
|          |                                   |   |   |   |   |   |   |   |

The SMP FRAME TYPE field is defined in 9.4.3.2.2 and shall be set as shown in table 245 for the REPORT GENERAL request.

The FUNCTION field is defined in 9.4.3.2.3 and shall be set as shown in table 245 for the REPORT GENERAL request.

The ALLOCATED RESPONSE LENGTH field is defined in 9.4.3.2.4.

If the ALLOCATED RESPONSE LENGTH field is set to 00h, then the management device server shall:

- set the RESPONSE LENGTH field to 00h in the response frame; and
- return the first 28 bytes defined in table 246 plus the CRC field as the response frame.

If the ALLOCATED RESPONSE LENGTH field is not set to 00h, then the management device server shall:

- set the RESPONSE LENGTH field in the response frame to the non-zero value defined in table 246; and
- return the response frame as defined in 9.4.3.2.4.

The REQUEST LENGTH field is defined in 9.4.3.2.5 and shall be set as shown in table 245 for the REPORT GENERAL request.

The CRC field is defined in 9.4.3.2.7.

Table 246 defines the response format.

**Table 246 — REPORT GENERAL response (part 1 of 3)**

| Byte\Bit | 7                                          | 6                | 5                | 4                | 3                           | 2                 | 1           | 0                                   |
|----------|--------------------------------------------|------------------|------------------|------------------|-----------------------------|-------------------|-------------|-------------------------------------|
| 0        | SMP FRAME TYPE (41h)                       |                  |                  |                  |                             |                   |             |                                     |
| 1        | FUNCTION (00h)                             |                  |                  |                  |                             |                   |             |                                     |
| 2        | FUNCTION RESULT                            |                  |                  |                  |                             |                   |             |                                     |
| 3        | RESPONSE LENGTH (00h or 11h)               |                  |                  |                  |                             |                   |             |                                     |
| 4        | (MSB) _____                                |                  |                  |                  |                             |                   |             |                                     |
| 5        | EXPANDER CHANGE COUNT _____ (LSB)          |                  |                  |                  |                             |                   |             |                                     |
| 6        | (MSB) _____                                |                  |                  |                  |                             |                   |             |                                     |
| 7        | EXPANDER ROUTE INDEXES _____ (LSB)         |                  |                  |                  |                             |                   |             |                                     |
| 8        | LONG RESPONSE                              | Reserved         |                  |                  |                             |                   |             |                                     |
| 9        | NUMBER OF PHYS                             |                  |                  |                  |                             |                   |             |                                     |
| 10       | TABLE TO TABLE SUPPORTED                   | ZONE CONFIGURING | SELF CONFIGURING | STP CONTINUE AWT | OPEN REJECT RETRY SUPPORTED | CONFIGURES OTHERS | CONFIGURING | EXTERNALLY CONFIGURABLE ROUTE TABLE |
| 11       | Reserved                                   |                  |                  |                  |                             |                   |             |                                     |
| 12       | ENCLOSURE LOGICAL IDENTIFIER _____         |                  |                  |                  |                             |                   |             |                                     |
| ...      |                                            |                  |                  |                  |                             |                   |             |                                     |
| 19       |                                            |                  |                  |                  |                             |                   |             |                                     |
| 20       | Reserved _____                             |                  |                  |                  |                             |                   |             |                                     |
| ...      |                                            |                  |                  |                  |                             |                   |             |                                     |
| 27       |                                            |                  |                  |                  |                             |                   |             |                                     |
| 28       | (MSB) _____                                |                  |                  |                  |                             |                   |             |                                     |
| 29       | SSP MAXIMUM CONNECT TIME LIMIT _____ (LSB) |                  |                  |                  |                             |                   |             |                                     |
| 30       | (MSB) _____                                |                  |                  |                  |                             |                   |             |                                     |
| 31       | STP BUS INACTIVITY TIME LIMIT _____ (LSB)  |                  |                  |                  |                             |                   |             |                                     |

**Table 246 — REPORT GENERAL response (part 2 of 3)**

| Byte\Bit | 7                                               | 6        | 5           | 4                           | 3                                      | 2                                     | 1                                      | 0                               |
|----------|-------------------------------------------------|----------|-------------|-----------------------------|----------------------------------------|---------------------------------------|----------------------------------------|---------------------------------|
| 32       | (MSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 33       | STP MAXIMUM CONNECT TIME LIMIT                  |          |             |                             |                                        |                                       |                                        |                                 |
| 34       | (LSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 35       | (MSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 36       | STP SMP I_T NEXUS LOSS TIME                     |          |             |                             |                                        |                                       |                                        |                                 |
| 37       | (LSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 38       | NUMBER OF ZONE GROUPS                           | Reserved | ZONE LOCKED | PHYSICAL PRESENCE SUPPORTED | PHYSICAL PRESENCE ASSERTED             | ZONING SUPPORTED                      | ZONING ENABLED                         |                                 |
| 39       | Reserved                                        |          |             | SAVING                      | SAVING ZONE MANAGER PASSWORD SUPPORTED | SAVING ZONE PHY INFORMATION SUPPORTED | SAVING ZONE PERMISSION TABLE SUPPORTED | SAVING ZONING ENABLED SUPPORTED |
| 40       | (MSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 41       | MAXIMUM NUMBER OF ROUTED SAS ADDRESSES          |          |             |                             |                                        |                                       |                                        |                                 |
| 42       | (LSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 43       | ACTIVE ZONE MANAGER SAS ADDRESS                 |          |             |                             |                                        |                                       |                                        |                                 |
| 44       | ...                                             |          |             |                             |                                        |                                       |                                        |                                 |
| 45       | ...                                             |          |             |                             |                                        |                                       |                                        |                                 |
| 46       | ...                                             |          |             |                             |                                        |                                       |                                        |                                 |
| 47       | (MSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 48       | ZONE LOCK INACTIVITY TIME LIMIT                 |          |             |                             |                                        |                                       |                                        |                                 |
| 49       | (LSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 50       | Reserved                                        |          |             |                             |                                        |                                       |                                        |                                 |
| 51       | Reserved                                        |          |             |                             |                                        |                                       |                                        |                                 |
| 52       | POWER DONE TIMEOUT                              |          |             |                             |                                        |                                       |                                        |                                 |
| 53       | FIRST ENCLOSURE CONNECTOR ELEMENT INDEX         |          |             |                             |                                        |                                       |                                        |                                 |
| 54       | NUMBER OF ENCLOSURE CONNECTOR ELEMENT INDEXES   |          |             |                             |                                        |                                       |                                        |                                 |
| 55       | Reserved                                        |          |             |                             |                                        |                                       |                                        |                                 |
| 56       | REDUCED FUNCTIONALITY                           | Reserved |             |                             |                                        |                                       |                                        |                                 |
| 57       | TIME TO REDUCED FUNCTIONALITY                   |          |             |                             |                                        |                                       |                                        |                                 |
| 58       | INITIAL TIME TO REDUCED FUNCTIONALITY           |          |             |                             |                                        |                                       |                                        |                                 |
| 59       | MAXIMUM REDUCED FUNCTIONALITY TIME              |          |             |                             |                                        |                                       |                                        |                                 |
| 60       | (MSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |
| 61       | LAST SELF-CONFIGURATION STATUS DESCRIPTOR INDEX |          |             |                             |                                        |                                       |                                        |                                 |
| 62       | (LSB)                                           |          |             |                             |                                        |                                       |                                        |                                 |

Table 246 — REPORT GENERAL response (part 3 of 3)

| Byte\Bit | 7                                                                                | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|----------------------------------------------------------------------------------|---|---|---|---|---|---|---|
| 62       | (MSB) _____                                                                      |   |   |   |   |   |   |   |
| 63       | _____ MAXIMUM NUMBER OF STORED SELF-CONFIGURATION STATUS DESCRIPTORS _____ (LSB) |   |   |   |   |   |   |   |
| 64       | (MSB) _____                                                                      |   |   |   |   |   |   |   |
| 65       | _____ LAST PHY EVENT LIST DESCRIPTOR INDEX _____ (LSB)                           |   |   |   |   |   |   |   |
| 66       | (MSB) _____                                                                      |   |   |   |   |   |   |   |
| 67       | _____ MAXIMUM NUMBER OF STORED PHY EVENT LIST DESCRIPTORS _____ (LSB)            |   |   |   |   |   |   |   |
| 68       | (MSB) _____                                                                      |   |   |   |   |   |   |   |
| 69       | _____ STP REJECT TO OPEN LIMIT _____ (LSB)                                       |   |   |   |   |   |   |   |
| 70       | _____                                                                            |   |   |   |   |   |   |   |
| 71       | _____ Reserved _____                                                             |   |   |   |   |   |   |   |
| 72       | (MSB) _____                                                                      |   |   |   |   |   |   |   |
| ...      | _____ CRC _____                                                                  |   |   |   |   |   |   |   |
| 75       | _____ (LSB)                                                                      |   |   |   |   |   |   |   |

The SMP FRAME TYPE field is defined in 9.4.3.3.2 and shall be set as shown in table 246 for the REPORT GENERAL response.

The FUNCTION field is defined in 9.4.3.3.3 and shall be set as shown in table 246 for the REPORT GENERAL response.

The FUNCTION RESULT field is defined in 9.4.3.3.4.

The RESPONSE LENGTH field is defined in 9.4.3.3.5 and shall be set to one of the values defined in table 246 based on the ALLOCATED RESPONSE LENGTH field in the request frame.

The EXPANDER CHANGE COUNT field indicates the number of Broadcast (Change)s originated by an expander device (see 6.13). Management device servers in expander devices shall support this field. Management device servers in other device types (e.g., end devices) shall set this field to 0000h. This field shall be set to at least 0001h at power on. If the expander device has originated Broadcast (Change) for any reason described in 6.13 since transmitting any SMP response frame containing an EXPANDER CHANGE COUNT field, then it:

- shall increment this field at least once from the value in the previous REPORT GENERAL response; and
- shall not increment this field when forwarding a Broadcast (Change).

This field shall wrap to at least 0001h after reaching the maximum value (i.e., FFFFh).

NOTE 66 - If a management application client uses the EXPANDER CHANGE COUNT field, then reading that field often ensures that the field does not increment a multiple of 65 535 times between reading the field in an expander device compliant with this standard or a multiple of 65 536 times between reading the field in an expander device compliant with SAS-1.1.

NOTE 67 - Management device servers in expander devices compliant with SAS-1.1 wrap the EXPANDER CHANGE COUNT field to 0000h.

NOTE 68 - The originated Broadcast (Change) count is also reported in the REPORT BROADCAST response (see 9.4.3.9).

The EXPANDER ROUTE INDEXES field indicates the maximum number of expander route indexes per phy for the expander device (see 4.5.7.4). Management device servers in externally configurable expander devices containing phy-based expander route tables shall support this field. Management device servers in other device types (e.g., end devices, externally configurable expander devices with expander-based expander route tables, and self-configuring expander devices) shall set the EXPANDER ROUTE INDEXES field to 0000h. Not all phys in an externally configurable expander device are required to support the maximum number indicated by this field.

A LONG RESPONSE bit set to one indicates that the management device server supports returning non-zero values in the RESPONSE LENGTH field of the response frame for any SMP function if the ALLOCATED RESPONSE LENGTH field in the request frame for that SMP function is set to a non-zero value. The LONG RESPONSE bit shall be set to one.

NOTE 69 - Devices compliant with SAS-1.1 set the LONG RESPONSE bit to zero in the REPORT GENERAL response and set the RESPONSE LENGTH field to 00h in all SMP response frames.

The NUMBER OF PHYS field indicates the number of phys in the device, including any virtual phys and any vacant phys.

A TABLE TO TABLE SUPPORTED bit set to one indicates that the expander device is a self-configuring expander device that supports its table routing phys being attached to table routing phys in other expander devices (i.e., table-to-table attachment). The TABLE TO TABLE SUPPORTED bit shall only be set to one if the EXTERNALLY CONFIGURABLE ROUTE TABLE bit is set to zero. A TABLE TO TABLE SUPPORTED bit set to zero indicates that the expander device is not a self-configuring expander device that supports its table routing phys being attached to table routing phys in other expander devices.

A ZONE CONFIGURING bit set to one indicates that the zoning expander device is locked and the zoning expander shadow values differ from the zoning expander current values. A ZONE CONFIGURING bit set to zero indicates that is not true. Management device servers in zoning expander devices shall support this bit. Management device servers in non-zoning expander devices and in other device types shall set this bit to zero.

A SELF CONFIGURING bit set to one indicates that the management device server is in a self-configuring expander device, the self-configuring expander device's management application client is currently performing the discover process (see 4.6), and that management application client has identified at least one change to its expander routing table. Management device servers in self-configuring expander devices shall support this bit. Management device servers in externally configurable expander devices and in other device types shall set this bit to zero.

An STP CONTINUE AWT bit set to one specifies that the STP port shall not stop the Arbitration Wait Time timer and shall not set the Arbitration Wait Time timer to zero when the STP port receives an OPEN\_REJECT (RETRY). An STP CONTINUE AWT bit set to zero specifies that the STP port shall stop the Arbitration Wait Time timer and shall set the Arbitration Wait Time timer to zero when the STP port receives an OPEN\_REJECT (RETRY).

An OPEN REJECT RETRY SUPPORTED bit set to one indicates that the expander device returns OPEN\_REJECT (RETRY) for any connection requests that detects a condition that results in OPEN\_REJECT (NO DESTINATION) while the SELF CONFIGURING bit is set to one (see 4.6.4) or the ZONE CONFIGURING bit is set to one (see 4.8.6.3). An OPEN REJECT RETRY SUPPORTED set to zero indicates that the expander device complies with SAS-1.1 (i.e., it returns OPEN\_REJECT (NO DESTINATION) while the CONFIGURING bit is set to one). Self-configuring expander devices compliant with this standard shall set the OPEN REJECT RETRY SUPPORTED bit to one.

A CONFIGURES OTHERS bit set to one indicates that the expander device is a self-configuring expander device that performs the configuration subprocess defined in 4.7. A CONFIGURES OTHERS bit set to zero indicates that the expander device may or may not perform the configuration subprocess. Self-configuring expander devices compliant with this standard shall set the CONFIGURES OTHERS bit to one.

The CONFIGURING bit indicates the logical OR of the ZONE CONFIGURING bit and the SELF CONFIGURING bit. Changes in this bit from one to zero result in a Broadcast (Change) being originated (see 6.13). Management device servers that support the ZONE CONFIGURING bit or the SELF CONFIGURING bit shall support this bit.

An EXTERNALLY CONFIGURABLE ROUTE TABLE bit set to one indicates that the management device server is in an externally configurable expander device that has a phy-based expander route table that is required to be configured with the SMP CONFIGURE ROUTE INFORMATION function (see 4.5.7.4). An EXTERNALLY CONFIGURABLE ROUTE TABLE bit set to zero indicates that the management device server is not in an externally configurable expander device (e.g., the management device server is in an end device, in a self-configuring expander device, or in an expander device with no phys with table routing attributes).

The INITIATES SSP CLOSE bit set to one indicates that the expander device is capable of initiating the closing of SSP connections (see 6.14.8). An INITIATES SSP CLOSE bit set to zero indicates that the expander device is not capable of initiating closing of SSP connections.

The ENCLOSURE LOGICAL IDENTIFIER field identifies the enclosure, if any, in which the device is located, and is defined in SES-3. The ENCLOSURE LOGICAL IDENTIFIER field shall be set to the same value reported by the enclosure services process, if any, for the enclosure. An ENCLOSURE LOGICAL IDENTIFIER field set to 00000000 00000000h indicates no enclosure information is available.

The SSP CONNECT TIME LIMIT field indicates the maximum connect time limit for expander device SSP connections. The maximum time limit is specified by the CONFIGURE GENERAL function (see 9.4.3.18).

The STP BUS INACTIVITY LIMIT field indicates the bus inactivity time limit for STP connections. The STP bus inactivity limit is specified by the CONFIGURE GENERAL function (see 9.4.3.18).

The STP CONNECT TIME LIMIT field indicates the maximum connect time limit for STP connections. The STP maximum connect time limit is specified by the CONFIGURE GENERAL function (see 9.4.3.18).

The STP SMP I\_T NEXUS LOSS TIME field indicates the minimum time that an STP target port and an SMP initiator port retry certain connection requests. The STP SMP I\_T nexus loss time timer is specified by the CONFIGURE GENERAL function (see 9.4.3.18).

The NUMBER OF ZONE GROUPS field indicates the number of zone groups (e.g., the number of entries in the zone group permission table) supported by the expander device and is defined in table 247.

**Table 247 — NUMBER OF ZONE GROUPS field**

| Code       | Description     |
|------------|-----------------|
| 00b        | 128 zone groups |
| 01b        | 256 zone groups |
| All others | Reserved        |

A ZONE LOCKED bit set to one indicates that the zoning expander device is locked (see 4.8.6.2). A ZONE LOCKED bit set to zero indicates that the zoning expander device is not locked.

A PHYSICAL PRESENCE SUPPORTED bit set to one indicates that the expander device supports physical presence as a mechanism for allowing locking from phys in zone groups without access to zone group 2. A PHYSICAL PRESENCE SUPPORTED bit set to zero indicates that the expander device does not support physical presence as a mechanism for allowing locking.

A PHYSICAL PRESENCE ASSERTED bit set to one indicates that the expander device is currently detecting physical presence. A PHYSICAL PRESENCE ASSERTED bit set to zero indicates that the expander device is not currently detecting physical presence. The PHYSICAL PRESENCE ASSERTED bit shall be set to zero if the PHYSICAL PRESENCE SUPPORTED bit is set to zero.

A ZONING SUPPORTED bit set to one indicates that zoning is supported by the expander device (i.e., it is a zoning expander device). A ZONING SUPPORTED bit set to zero indicates that zoning is not supported by the expander device.

A ZONING ENABLED bit set to one indicates that zoning is enabled in the expander device. A ZONING ENABLED bit set to zero indicates that zoning is disabled in the expander device. The ZONING ENABLED bit shall be set to zero if the ZONING SUPPORTED bit is set to zero.

A SAVING bit set to one indicates that the management device server is currently saving zoning values to non-volatile storage and may return a function result of BUSY for SMP zone management functions that access saved zoning values. A SAVING bit set to zero indicates that the management device server is not currently saving zoning values to non-volatile storage.

A SAVING ZONE MANAGER PASSWORD SUPPORTED bit set to one indicates that saving the zone manager password is supported. A SAVING ZONE MANAGER PASSWORD SUPPORTED bit set to zero indicates that saving the zone manager password is not supported.

A SAVING ZONE PHY INFORMATION SUPPORTED bit set to one indicates that saving the zone phy information is supported. A SAVING ZONE PHY INFORMATION SUPPORTED bit set to zero indicates that saving the zone phy information is not supported.

A SAVING ZONE PERMISSION TABLE SUPPORTED bit set to one indicates that saving the zone permission table is supported. A SAVING ZONE PERMISSION TABLE SUPPORTED bit set to zero indicates that saving the zone permission table is not supported.

A SAVING ZONING ENABLE SUPPORTED bit set to one indicates that saving the ZONING ENABLED bit is supported. A SAVING ZONING ENABLE SUPPORTED bit set to zero indicates that saving the ZONING ENABLED bit is not supported.

The MAXIMUM NUMBER OF ROUTED SAS ADDRESSES field indicates the number of routed SAS addresses in an expander-based expander route table (see 4.5.7.4 and 4.8.3.4). Management device servers in expander devices containing expander-based expander route tables shall support this field. Management device servers in other device types (e.g., end devices and expander devices with phy-based expander route tables) shall set this field to 0000h.

The ACTIVE ZONE MANAGER SAS ADDRESS field indicates the SAS address (see 4.2.4) of the zone manager that last locked the zoning expander device. If the zoning expander device is currently being configured by a vendor specific sideband method then the ACTIVE ZONE MANAGER SAS ADDRESS field shall be set to 00000000 00000000h. This field shall be set to 00000000 00000000h at power on.

The ZONE LOCK INACTIVITY TIME LIMIT field indicates the minimum time between any SMP ZONE LOCK requests, SMP zone configuration function requests, or SMP ZONE ACTIVATE requests from the active zone manager that the locked expander device allows and is set in the SMP ZONE LOCK request (see 9.4.3.21).

The POWER DONE TIMEOUT field indicates the maximum time the management application layer allows a power consumer device (see 6.12.2) to consume additional power. The power done timeout is specified by the CONFIGURE GENERAL function (see 9.4.3.18). A POWER DONE TIMEOUT field set to 00h or FFh indicates that the maximum time is vendor specific.

The FIRST ENCLOSURE CONNECTOR ELEMENT INDEX field indicates the lowest CONNECTOR ELEMENT INDEX field of all the expander phys in all the expander devices in the enclosure that have CONNECTOR TYPE fields set to 20h to 2Fh (i.e., an internal connector to an end device) in their SMP DISCOVER responses.

The NUMBER OF ENCLOSURE CONNECTOR ELEMENT INDEXES field indicates the number of expander phys in all the expander devices in the enclosure that have CONNECTOR TYPE fields set to 20h to 2Fh (i.e., an internal connector to an end device) in their SMP DISCOVER responses.

NOTE 70 - The NUMBER OF ENCLOSURE CONNECTOR ELEMENT INDEXES field assumes that all internal connectors to end devices are assigned to a contiguous range of CONNECTOR ELEMENT INDEX field values.

A REDUCED FUNCTIONALITY bit set to one indicates that:

- a) the expander device is scheduled to reduce its functionality (see 4.5.8) in the time indicated in the TIME TO REDUCED FUNCTIONALITY field; or
- b) the expander device is currently operating with reduced functionality (see 4.5.8).

A REDUCED FUNCTIONALITY bit set to zero indicates that the expander device is not scheduled to reduce functionality and that the contents of the TIME TO REDUCED FUNCTIONALITY field shall be ignored.



If the REDUCED FUNCTIONALITY bit is set to one, then the TIME TO REDUCED FUNCTIONALITY field indicates the time, in 100 ms increments, remaining until the expander device is scheduled to reduce functionality. The expander device starts the reduced functionality delay timer after originating a Broadcast (Expander) (see 4.5.8).

The INITIAL TIME TO REDUCED FUNCTIONALITY field indicates the minimum time, in 100 ms increments, that an expander device waits from originating a Broadcast (Expander) to reducing functionality. The expander device should set the default value for the INITIAL TIME TO REDUCED FUNCTIONALITY field to at least 2 000 ms (i.e., 14h).

The MAXIMUM REDUCED FUNCTIONALITY TIME field indicates the maximum time, in one second increments, that the expander device responds with OPEN\_REJECT (RETRY) to connection requests that map to an expander phy or an SMP target port that is not accessible during expander device reduced functionality. This timer starts after the reduced functionality delay timer expires.

The LAST SELF-CONFIGURATION STATUS DESCRIPTOR INDEX field is defined in the REPORT SELF-CONFIGURATION STATUS response (see 9.4.3.6).

The MAXIMUM NUMBER OF STORED SELF-CONFIGURATION STATUS DESCRIPTORS field indicates the maximum number of self-configuration status descriptors (see 9.4.3.6.4) that the management device server supports.

The LAST PHY EVENT LIST DESCRIPTOR INDEX field is defined in the REPORT PHY EVENT LIST response (see 9.4.3.16).

The MAXIMUM NUMBER OF STORED PHY EVENT LIST DESCRIPTORS field indicates the maximum number of phy event list descriptors (see 9.4.3.14.4) that the management device server supports.

The STP REJECT TO OPEN LIMIT field indicates the minimum time, in 10  $\mu$ s increments, that an STP port waits to establish a connection request with an initiator port on an I\_T nexus after receiving an OPEN\_REJECT (RETRY), OPEN\_REJECT (RESERVED CONTINUE 0), or OPEN\_REJECT (RESERVED CONTINUE 1). An STP REJECT TO OPEN LIMIT field set to 0000h indicates that the time limit is vendor specific.

The CRC field is defined in 9.4.3.3.7.

#### 9.4.3.5 REPORT MANUFACTURER INFORMATION function

The REPORT MANUFACTURER INFORMATION function returns vendor and product identification. This SMP function may be implemented by any management device server.

Table 248 defines the request format.

**Table 248 — REPORT MANUFACTURER INFORMATION request**

| Byte\Bit | 7                         | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|---------------------------|---|---|---|---|---|---|---|
| 0        | SMP FRAME TYPE (40h)      |   |   |   |   |   |   |   |
| 1        | FUNCTION (01h)            |   |   |   |   |   |   |   |
| 2        | ALLOCATED RESPONSE LENGTH |   |   |   |   |   |   |   |
| 3        | REQUEST LENGTH (00h)      |   |   |   |   |   |   |   |
| 4        | (MSB)                     |   |   |   |   |   |   |   |
| ...      | CRC                       |   |   |   |   |   |   |   |
| 7        | (LSB)                     |   |   |   |   |   |   |   |



The SMP FRAME TYPE field is defined in 9.4.3.2.2 and shall be set as shown in table 248 for the REPORT MANUFACTURER INFORMATION request.

The FUNCTION field is defined in 9.4.3.2.3 and shall be set as shown in table 248 for the REPORT MANUFACTURER INFORMATION request.

The ALLOCATED RESPONSE LENGTH field is defined in 9.4.3.2.4.

If the ALLOCATED RESPONSE LENGTH field is set to 00h, then the management device server shall:

- a) set the RESPONSE LENGTH field to 00h in the response frame; and
- b) return the first 60 bytes defined in table 249 plus the CRC field as the response frame.

If the ALLOCATED RESPONSE LENGTH field is not set to 00h, then the management device server shall:

- a) set the RESPONSE LENGTH field in the response frame to the non-zero value defined in table 249; and
- b) return the response frame as defined in 9.4.3.2.4.

The REQUEST LENGTH field is defined in 9.4.3.2.5 and shall be set as shown in table 248 for the REPORT MANUFACTURER INFORMATION request.

The CRC field is defined in 9.4.3.2.7.

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Table 249 defines the response format.

**Table 249 — REPORT MANUFACTURER INFORMATION response**

| Byte\Bit | 7                            | 6                               | 5 | 4 | 3 | 2 | 1 | 0                 |
|----------|------------------------------|---------------------------------|---|---|---|---|---|-------------------|
| 0        | SMP FRAME TYPE (41h)         |                                 |   |   |   |   |   |                   |
| 1        | FUNCTION (01h)               |                                 |   |   |   |   |   |                   |
| 2        | FUNCTION RESULT              |                                 |   |   |   |   |   |                   |
| 3        | RESPONSE LENGTH (00h or 0Eh) |                                 |   |   |   |   |   |                   |
| 4        | (MSB)                        | EXPANDER CHANGE COUNT           |   |   |   |   |   | (LSB)             |
| 5        |                              |                                 |   |   |   |   |   |                   |
| 6        |                              | Reserved                        |   |   |   |   |   |                   |
| 7        |                              |                                 |   |   |   |   |   |                   |
| 8        |                              | Reserved                        |   |   |   |   |   | SAS-1.1<br>FORMAT |
| 9        |                              | Reserved                        |   |   |   |   |   |                   |
| ...      |                              |                                 |   |   |   |   |   |                   |
| 11       |                              | VENDOR IDENTIFICATION           |   |   |   |   |   | (LSB)             |
| 12       | (MSB)                        |                                 |   |   |   |   |   |                   |
| ...      |                              | PRODUCT IDENTIFICATION          |   |   |   |   |   | (LSB)             |
| 19       |                              |                                 |   |   |   |   |   |                   |
| 20       | (MSB)                        | PRODUCT REVISION LEVEL          |   |   |   |   |   | (LSB)             |
| ...      |                              |                                 |   |   |   |   |   |                   |
| 35       |                              | COMPONENT VENDOR IDENTIFICATION |   |   |   |   |   | (LSB)             |
| 36       | (MSB)                        |                                 |   |   |   |   |   |                   |
| ...      |                              | COMPONENT ID                    |   |   |   |   |   | (LSB)             |
| 39       |                              |                                 |   |   |   |   |   |                   |
| 40       | (MSB)                        | COMPONENT REVISION LEVEL        |   |   |   |   |   | (LSB)             |
| ...      |                              |                                 |   |   |   |   |   |                   |
| 47       |                              | Reserved                        |   |   |   |   |   |                   |
| 48       | (MSB)                        |                                 |   |   |   |   |   |                   |
| ...      |                              | Vendor specific                 |   |   |   |   |   |                   |
| 59       |                              |                                 |   |   |   |   |   |                   |
| 60       | (MSB)                        | CRC                             |   |   |   |   |   | (LSB)             |
| ...      |                              |                                 |   |   |   |   |   |                   |
| 63       |                              |                                 |   |   |   |   |   |                   |

The SMP FRAME TYPE field is defined in 9.4.3.3.2 and shall be set as shown in table 249 for the REPORT MANUFACTURER INFORMATION response.

The FUNCTION field is defined in 9.4.3.3.3 and shall be set as shown in table 249 for the REPORT MANUFACTURER INFORMATION response.

The FUNCTION RESULT field is defined in 9.4.3.3.4.

The RESPONSE LENGTH field is defined in 9.4.3.3.5 and shall be set to one of the values defined in table 249 based on the ALLOCATED RESPONSE LENGTH field in the request frame.

The EXPANDER CHANGE COUNT field is defined in the SMP REPORT GENERAL response (see 9.4.3.4).

A SAS-1.1 FORMAT bit set to one indicates that bytes 40 to 59 are as defined in this standard. A SAS-1.1 FORMAT bit set to zero indicates that bytes 40 to 59 are vendor specific as defined in the original version of this standard.

ASCII data fields (e.g., the VENDOR IDENTIFICATION field, the PRODUCT IDENTIFICATION field, and PRODUCT REVISION LEVEL field, and the COMPONENT VENDOR IDENTIFICATION field) shall contain only graphic codes (i.e., code values 20h to 7Eh). Left-aligned fields shall place any unused bytes at the end of the field (i.e., at the highest offset) and the unused bytes shall be filled with space characters (i.e., 20h).

The VENDOR IDENTIFICATION field contains eight bytes of ASCII data identifying the vendor of the subsystem (e.g., the board or enclosure) containing the component. The data shall be left-aligned within the field. The vendor identification string shall be one assigned by INCITS for use in the standard INQUIRY data VENDOR IDENTIFICATION field. A list of assigned vendor identification strings is in SPC-4 and on the T10 web site (see <http://www.t10.org>).

The PRODUCT IDENTIFICATION field contains 16 bytes of ASCII data identifying the type of the subsystem (e.g., the board or enclosure model number) containing the component, as defined by the vendor of the subsystem. The data shall be left-aligned within the field. The PRODUCT IDENTIFICATION field should be changed whenever the subsystem design changes in a way noticeable to a user (e.g., a different stock-keeping unit (SKU)).

The PRODUCT REVISION LEVEL field contains four bytes of ASCII data identifying the revision level of the subsystem (e.g., the board or enclosure) containing the component, as defined by the vendor of the subsystem. The data shall be left-aligned within the field. The PRODUCT REVISION LEVEL field should be changed whenever the subsystem design changes (e.g., any component change, even including resistor values).

All components on a subsystem should have the same values for their VENDOR IDENTIFICATION fields, PRODUCT IDENTIFICATION fields, and PRODUCT REVISION LEVEL fields.

NOTE 71 - A use of the VENDOR IDENTIFICATION field and PRODUCT IDENTIFICATION field is for the management application client to identify the subsystem (e.g., for a user interface). Another use of the VENDOR IDENTIFICATION field, PRODUCT IDENTIFICATION field, and PRODUCT REVISION LEVEL field is for a management application client to perform workarounds for problems in a specific revision of a subsystem.

The COMPONENT VENDOR IDENTIFICATION field contains eight bytes of ASCII data identifying the vendor of the component (e.g., the expander device) containing the management device server. The data shall be left-aligned within the field. The component vendor identification string shall be one assigned by INCITS for use in the standard INQUIRY data VENDOR IDENTIFICATION field. A list of assigned vendor identification strings is in SPC-4 and on the T10 web site (see <http://www.t10.org>).

The COMPONENT ID field contains a 16-bit identifier identifying the type of the component (e.g., the expander device model number) containing the management device server, as defined by the vendor of the component. The COMPONENT ID field should be changed whenever the component's programming interface (e.g., the management device server definition) changes.

The COMPONENT REVISION LEVEL field contains an 8-bit identifier identifying the revision level of the component (e.g., the expander device) containing the management device server, as defined by the vendor of the component. The COMPONENT REVISION LEVEL field should be changed whenever the component changes but its programming interface does not change.

NOTE 72 - A use of COMPONENT VENDOR IDENTIFICATION field and the COMPONENT ID field is for the management application client to interpret vendor specific information (e.g., vendor specific SMP functions) correctly for that component. Another use of the COMPONENT VENDOR IDENTIFICATION field, the COMPONENT ID field, and the COMPONENT REVISION LEVEL field is for a management application client to perform workarounds for problems in a specific revision of a component.

The vendor specific bytes are defined by the vendor of the subsystem (e.g., the board or enclosure) containing the component.

The CRC field is defined in 9.4.3.3.7.

#### 9.4.3.6 REPORT SELF-CONFIGURATION STATUS function

##### 9.4.3.6.1 REPORT SELF-CONFIGURATION STATUS function overview

The REPORT SELF-CONFIGURATION STATUS function returns self-configuration expander device status. This SMP function shall be implemented by the management device server in self-configuring expander devices and shall not be implemented by any other management device servers.

##### 9.4.3.6.2 REPORT SELF-CONFIGURATION STATUS request

Table 250 defines the request format.

**Table 250 — REPORT SELF-CONFIGURATION STATUS request**

| Byte\Bit | 7                         | 6                                                   | 5 | 4 | 3 | 2 | 1 | 0     |
|----------|---------------------------|-----------------------------------------------------|---|---|---|---|---|-------|
| 0        | SMP FRAME TYPE (40h)      |                                                     |   |   |   |   |   |       |
| 1        | FUNCTION (03h)            |                                                     |   |   |   |   |   |       |
| 2        | ALLOCATED RESPONSE LENGTH |                                                     |   |   |   |   |   |       |
| 3        | REQUEST LENGTH (01h)      |                                                     |   |   |   |   |   |       |
| 4        | Reserved                  |                                                     |   |   |   |   |   |       |
| 5        |                           |                                                     |   |   |   |   |   |       |
| 6        | (MSB)                     | STARTING SELF-CONFIGURATION STATUS DESCRIPTOR INDEX |   |   |   |   |   |       |
| 7        |                           |                                                     |   |   |   |   |   | (LSB) |
| 8        | (MSB)                     | CRC                                                 |   |   |   |   |   |       |
| ...      |                           |                                                     |   |   |   |   |   |       |
| 11       |                           |                                                     |   |   |   |   |   | (LSB) |

The SMP FRAME TYPE field is defined in 9.4.3.2.2 and shall be set as shown in table 250 for the REPORT SELF-CONFIGURATION STATUS request.

The FUNCTION field is defined in 9.4.3.2.3 and shall be set as shown in table 250 for the REPORT SELF-CONFIGURATION STATUS request.

The ALLOCATED RESPONSE LENGTH field is defined in 9.4.3.2.4.

The REQUEST LENGTH field is defined in 9.4.3.2.5 and shall be set as shown in table 250 for the REPORT SELF-CONFIGURATION STATUS request.

The STARTING SELF-CONFIGURATION STATUS DESCRIPTOR INDEX field specifies the first self-configuration status descriptor that the management device server shall return in the SMP response frame. If the specified index does not contain a valid self-configuration status descriptor, then the STARTING SELF-CONFIGURATION STATUS DESCRIPTOR INDEX field in the response may differ from the specified index. A STARTING SELF-CONFIGURATION STATUS DESCRIPTOR INDEX field set to 0000h specifies that the management device server shall return no self-configuration status descriptors.

The CRC field is defined in 9.4.3.2.7.

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