

INTERNATIONAL STANDARD



**Information technology – Small Computer System Interface (SCSI) –
Part 262: SAS Protocol Layer – 2 (SPL-2)**

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2017 ISO/IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about ISO/IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-23:2017

INTERNATIONAL STANDARD



**Information technology – Small Computer System Interface (SCSI) –
Part 262: SAS Protocol Layer – 2 (SPL-2)**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 35.200

ISBN 978-2-8322-3952-0

Warning! Make sure that you obtained this publication from an authorized distributor.

FOREWORD.....	37
INTRODUCTION.....	38
General	38
SCSI standards family.....	39
1 Scope	40
2 Normative references	41
3 Terms, definitions, symbols, abbreviations, keywords, and conventions.....	42
3.1 Terms and definitions	42
3.2 Symbols and abbreviations	71
3.3 Keywords.....	74
3.4 Editorial conventions	75
3.5 UML notation conventions	76
3.5.1 Notation conventions overview	76
3.5.2 Constraint and note conventions	77
3.5.3 Class diagram conventions.....	77
3.5.4 Object diagram conventions	81
3.6 State machine conventions	83
3.6.1 State machine conventions overview.....	83
3.6.2 Transitions	84
3.6.3 Messages, requests, indications, confirmations, responses, and event notifications	84
3.6.4 State machine counters, timers, and variables	84
3.6.5 State machine arguments	85
3.7 Bit and byte ordering	85
3.8 Notation for procedures and functions.....	85
4 General	87
4.1 Architecture	87
4.1.1 Architecture overview.....	87
4.1.2 Physical links and phys.....	88
4.1.3 Logical links	93
4.1.4 Narrow ports and wide ports	93
4.1.5 Application clients and device servers	96
4.1.6 SAS devices.....	97
4.1.7 Expander devices	98
4.1.8 Service delivery subsystem	99
4.1.9 Domains.....	99
4.1.10 Expander device topologies.....	102
4.1.10.1 Expander device topology overview.....	102
4.1.10.2 Expander device topologies	102
4.1.11 Pathways	104
4.1.12 Connections	104
4.1.13 Broadcasts	106
4.2 Names and identifiers.....	109
4.2.1 Names and identifiers overview.....	109
4.2.2 NAA IEEE Registered format identifier	109
4.2.3 NAA Locally Assigned format identifier.....	110
4.2.4 SAS address	111
4.2.5 Hashed SAS addresses.....	111
4.2.6 Device names and expander device SAS addresses.....	112
4.2.7 Device names for SATA devices with world wide names	112
4.2.8 Port names.....	113
4.2.9 Port identifiers and SAS port SAS addresses.....	113
4.2.10 Phy identifiers	114
4.3 State machines.....	115
4.3.1 State machine overview.....	115

4.3.2 Transmit data path	116
4.3.3 Receive data path	121
4.3.4 State machines and SAS Device, SAS Port, and SAS Phy classes	125
4.4 Events	126
4.4.1 Reset sequences	126
4.4.2 Hard reset	128
4.4.2.1 Hard reset overview	128
4.4.2.2 Additional hard reset processing by SAS ports	128
4.4.2.3 Additional hard reset processing by expander ports	128
4.4.3 I_T nexus loss	128
4.4.4 Power loss expected	129
4.5 Expander device model	129
4.5.1 Expander device model overview	129
4.5.2 Expander ports	131
4.5.3 Expander connection manager (ECM)	131
4.5.4 Expander connection router (ECR)	131
4.5.5 Broadcast propagation processor (BPP)	132
4.5.6 Expander device interfaces	132
4.5.6.1 Expander device interface overview	132
4.5.6.2 Expander device interfaces detail	134
4.5.6.3 ECM interface	135
4.5.6.4 ECR interface	137
4.5.6.5 BPP interface	138
4.5.7 Expander device routing	140
4.5.7.1 Routing attributes and routing methods	140
4.5.7.2 Expander device topology routing attribute restrictions	140
4.5.7.3 Connection request routing	141
4.5.7.4 Expander route table	141
4.5.7.4.1 Expander route table overview	141
4.5.7.4.2 Phy-based expander route table	142
4.5.7.4.3 Expander-based expander route table	143
4.5.8 Expander device reduced functionality	143
4.5.9 Broadcast (Expander) handling	144
4.6 Discover process	144
4.6.1 Discover process overview	144
4.6.2 Starting the discover process (Broadcast (Change) handling)	144
4.6.3 Discover process traversal	144
4.6.4 Discover process in a self-configuring expander device	146
4.6.5 Enabling multiplexing	147
4.7 Configuration subprocess	147
4.7.1 Configuration subprocess overview	147
4.7.2 Allowed expander device topologies	148
4.7.3 Externally configurable expander device route table optimization	149
4.7.4 Externally configurable expander device expander route index order	150
4.8 Zoning	157
4.8.1 Zoning overview	157
4.8.2 Zoning expander device requirements	161
4.8.3 Zoning operation	164
4.8.3.1 Zone phy information	164
4.8.3.2 Zone groups	166
4.8.3.3 Zone permission table	166
4.8.3.4 Zoning expander route table	168
4.8.3.5 Source zone group and destination zone group determination	169
4.8.4 Zone phy information and link reset sequences	169
4.8.5 Broadcast processing in a zoning expander device with zoning enabled	172
4.8.6 Zone configuration	172
4.8.6.1 Zone configuration overview	172
4.8.6.2 Lock step	173

4.8.6.3 Load step.....	173
4.8.6.4 Activate step.....	174
4.8.6.5 Unlock step.....	174
4.8.6.6 Zone lock inactivity timer.....	175
4.8.6.7 Enable a zoning expander device.....	175
4.9 SAS device and expander device power conditions.....	176
4.10 Phy power conditions.....	176
4.10.1 Low phy power conditions.....	176
4.10.1.1 Low phy power conditions overview.....	176
4.10.1.2 Active phy power condition.....	176
4.10.1.3 Partial phy power condition.....	176
4.10.1.4 Slumber phy power condition.....	177
4.10.1.5 End device low phy power conditions.....	177
4.10.1.6 Expander device low phy power conditions.....	177
4.10.2 SATA phy power conditions.....	178
4.11 Phy test functions.....	178
4.11.1 Phy test functions overview.....	178
4.11.2 Transmit pattern phy test function.....	179
4.12 Phy events.....	179
5 Phy layer.....	184
5.1 Phy layer overview.....	184
5.2 8b10b coding.....	184
5.2.1 8b10b coding overview.....	184
5.2.2 8b10b coding notation conventions.....	184
5.3 Character encoding and decoding.....	185
5.3.1 Introduction.....	185
5.3.2 Bit transmission order.....	185
5.3.3 Character transmission order.....	185
5.3.4 Frame transmission order.....	185
5.3.5 Running disparity (RD).....	186
5.3.6 Data characters.....	186
5.3.7 Control characters.....	191
5.3.8 Encoding characters in the transmitter.....	192
5.3.9 Decoding characters in the receiver.....	193
5.4 Dwords, primitives, data dwords, and invalid dwords.....	193
5.5 Bit order.....	193
5.6 Out of band (OOB) signals.....	195
5.6.1 OOB signals overview.....	195
5.6.2 SP Transmission of OOB signals.....	195
5.6.3 Receiver detection of OOB signals.....	196
5.6.4 SATA port selection signal.....	198
5.6.5 Phy power conditions.....	199
5.7 Phy capabilities bits.....	199
5.8 BMC coding.....	203
5.8.1 BMC coding overview.....	203
5.8.2 TTIU bit cell encoding in the transmitter.....	204
5.8.3 TTIU bit transmission order.....	205
5.8.4 TTIU bit cell decoding in the receiver.....	205
5.9 Train_Tx-SNW TTIUs.....	206
5.9.1 Train_Tx-SNW TTIU format.....	206
5.9.2 Control/Status TTIU.....	207
5.9.3 Error Response TTIU.....	211
5.10 Phy reset sequences.....	213
5.10.1 Phy reset sequences overview.....	213
5.10.2 SATA phy reset sequence.....	214
5.10.2.1 SATA OOB sequence.....	214
5.10.2.2 SATA speed negotiation sequence.....	215

5.10.3 SAS to SATA phy reset sequence	216
5.10.4 SAS to SAS phy reset sequence	217
5.10.4.1 SAS OOB sequence	217
5.10.4.2 SAS speed negotiation sequence	219
5.10.4.2.1 SAS speed negotiation sequence overview	219
5.10.4.2.2 SAS speed negotiation sequence timing specifications	219
5.10.4.2.3 Speed negotiation window (SNW) definitions	221
5.10.4.2.3.1 SNW definitions overview	221
5.10.4.2.3.2 SNW-1, SNW-2, and Final-SNW	221
5.10.4.2.3.3 SNW-3	223
5.10.4.2.3.4 Train_Tx-SNW	224
5.10.4.2.3.4.1 Phy's transmitter initial condition	224
5.10.4.2.3.4.2 Transmitter training	224
5.10.4.2.3.4.3 Pattern marker	226
5.10.4.2.3.5 Train_Rx-SNW	227
5.10.4.2.4 SAS speed negotiation sequence	230
5.10.4.2.5 SAS speed negotiation sequence examples	231
5.10.4.2.6 Train_Tx pattern sequence	239
5.10.4.2.6.1 Train_Tx pattern sequence overview	239
5.10.4.2.6.2 Train_Tx pattern initial sequence	239
5.10.4.2.6.3 Train_Tx pattern handshake sequence	243
5.10.4.2.6.3.1 Train_Tx pattern handshake sequence overview	243
5.10.4.2.6.3.2 Attached phy's receiver increment or decrement request	243
5.10.4.2.6.3.3 Attached phy's receiver reference_1, reference_2, or no_equalization request	246
5.10.4.2.6.4 Train_Tx pattern completion sequence	248
5.10.4.2.6.5 Invalid TTIU sequence	251
5.10.4.3 Multiplexing sequence	252
5.10.5 Phy reset sequence after devices are attached	253
5.11 Phy power condition sequences	254
5.11.1 Transitioning from the active phy power condition to a low phy power condition	254
5.11.2 Transitioning from a low phy power condition to the active phy power condition	254
5.11.3 Events during low phy power condition	255
5.12 SP (phy layer) state machine	256
5.12.1 SP state machine overview	256
5.12.2 SP transmitter and SP receiver	259
5.12.3 OOB sequence states	262
5.12.3.1 OOB sequence states overview	262
5.12.3.2 SP0:OOB_COMINIT state	263
5.12.3.2.1 State description	263
5.12.3.2.2 Transition SP0:OOB_COMINIT to SP1:OOB_AwaitCOMX	264
5.12.3.2.3 Transition SP0:OOB_COMINIT to SP3:OOB_AwaitCOMINIT_Sent	264
5.12.3.2.4 Transition SP0:OOB_COMINIT to SP4:OOB_COMSAS	264
5.12.3.3 SP1:OOB_AwaitCOMX state	264
5.12.3.3.1 State description	264
5.12.3.3.2 Transition SP1:OOB_AwaitCOMX to SP0:OOB_COMINIT	264
5.12.3.3.3 Transition SP1:OOB_AwaitCOMX to SP4:OOB_COMSAS	264
5.12.3.4 SP2:OOB_NoCOMSASTimeout state	264
5.12.3.4.1 State description	264
5.12.3.4.2 Transition SP2:OOB_NoCOMSASTimeout to SP0:OOB_COMINIT	265
5.12.3.4.3 Transition SP2:OOB_NoCOMSASTimeout to SP4:OOB_COMSAS	265
5.12.3.5 SP3:OOB_AwaitCOMINIT_Sent state	265
5.12.3.5.1 State description	265
5.12.3.5.2 Transition SP3:OOB_AwaitCOMINIT_Sent to SP4:OOB_COMSAS	265
5.12.3.6 SP4:OOB_COMSAS state	265
5.12.3.6.1 State description	265
5.12.3.6.2 Transition SP4:OOB_COMSAS to SP5:OOB_AwaitCOMSAS_Sent	265
5.12.3.6.3 Transition SP4:OOB_COMSAS to SP6:OOB_AwaitNoCOMSAS	265
5.12.3.6.4 Transition SP4:OOB_COMSAS to SP7:OOB_AwaitCOMSAS	266

5.12.3.7 SP5:OOB_AwaitCOMSAS_Sent state	266
5.12.3.7.1 State description	266
5.12.3.7.2 Transition SP5:OOB_AwaitCOMSAS_Sent to SP6:OOB_AwaitNoCOMSAS	266
5.12.3.8 SP6:OOB_AwaitNoCOMSAS state	266
5.12.3.8.1 State description	266
5.12.3.8.2 Transition SP6:OOB_AwaitNoCOMSAS to SP0:OOB_COMINIT	266
5.12.3.8.3 Transition SP6:OOB_AwaitNoCOMSAS to SP8:SAS_Start	266
5.12.3.9 SP7:OOB_AwaitCOMSAS state	266
5.12.3.9.1 State description	266
5.12.3.9.2 Transition SP7:OOB_AwaitCOMSAS to SP2:OOB_NoCOMSASTimeout	266
5.12.3.9.3 Transition SP7:OOB_AwaitCOMSAS to SP6:OOB_AwaitNoCOMSAS	266
5.12.3.9.4 Transition SP7:OOB_AwaitCOMSAS to SP16:SATA_COMWAKE	266
5.12.3.9.5 Transition SP7:OOB_AwaitCOMSAS to SP26:SATA_SpinupHold	267
5.12.4 SAS speed negotiation states	267
5.12.4.1 SAS speed negotiation states overview	267
5.12.4.2 Negotiation idle	267
5.12.4.3 SP8:SAS_Start state	270
5.12.4.3.1 State description	270
5.12.4.3.2 Transition SP8:SAS_Start to SP0:OOB_COMINIT	270
5.12.4.3.3 Transition SP8:SAS_Start to SP1:OOB_AwaitCOMX	270
5.12.4.3.4 Transition SP8:SAS_Start to SP9:SAS_WindowNotSupported	271
5.12.4.3.5 Transition SP8:SAS_Start to SP10:SAS_AwaitALIGN	271
5.12.4.3.6 Transition SP8:SAS_Start to SP27:SAS_Settings	271
5.12.4.4 SP9:SAS_WindowNotSupported state	271
5.12.4.4.1 State description	271
5.12.4.4.2 Transition SP9:SAS_WindowNotSupported to SP0:OOB_COMINIT	271
5.12.4.4.3 Transition SP9:SAS_WindowNotSupported to SP14:SAS_Fail	271
5.12.4.5 SP10:SAS_AwaitALIGN state	271
5.12.4.5.1 State description	271
5.12.4.5.2 Transition SP10:SAS_AwaitALIGN to SP0:OOB_COMINIT	271
5.12.4.5.3 Transition SP10:SAS_AwaitALIGN to SP11:SAS_AwaitALIGN1	271
5.12.4.5.4 Transition SP10:SAS_AwaitALIGN to SP12:SAS_AwaitSNW	272
5.12.4.5.5 Transition SP10:SAS_AwaitALIGN to SP14:SAS_Fail	272
5.12.4.6 SP11:SAS_AwaitALIGN1 state	272
5.12.4.6.1 State description	272
5.12.4.6.2 Transition SP11:SAS_AwaitALIGN1 to SP0:OOB_COMINIT	272
5.12.4.6.3 Transition SP11:SAS_AwaitALIGN1 to SP12:SAS_AwaitSNW	272
5.12.4.6.4 Transition SP11:SAS_AwaitALIGN1 to SP14:SAS_Fail	272
5.12.4.7 SP12:SAS_AwaitSNW state	272
5.12.4.7.1 State description	272
5.12.4.7.2 Transition SP12:SAS_AwaitSNW to SP0:OOB_COMINIT	272
5.12.4.7.3 Transition SP12:SAS_AwaitSNW to SP13:SAS_Pass	272
5.12.4.8 SP13:SAS_Pass state	273
5.12.4.8.1 State description	273
5.12.4.8.2 Transition SP13:SAS_Pass to SP0:OOB_COMINIT	273
5.12.4.8.3 Transition SP13:SAS_Pass to SP8:SAS_Start	273
5.12.4.8.4 Transition SP13:SAS_Pass to SP15:SAS_PHY_Ready	273
5.12.4.9 SP14:SAS_Fail state	273
5.12.4.9.1 State description	273
5.12.4.9.2 Transition SP14:SAS_Fail to SP1:OOB_AwaitCOMX	273
5.12.4.9.3 Transition SP14:SAS_Fail to SP8:SAS_Start	273
5.12.4.10 SP15:SAS_PHY_Ready state	273
5.12.4.10.1 State description	273
5.12.4.10.2 Transition SP15:SAS_PHY_Ready to SP0:OOB_COMINIT	274
5.12.4.10.3 Transition SP15:SAS_PHY_Ready to SP31:SAS_PS_Low_Phy_Power	274
5.12.4.11 SP27:SAS_Settings state	274
5.12.4.11.1 State description	274
5.12.4.11.2 Transition SP27:SAS_Settings to SP0:OOB_COMINIT	274

5.12.4.11.3 Transition SP27:SAS_Settings to SP1:OOB_AwaitCOMX.....	275
5.12.4.11.4 Transition SP27:SAS_Settings to SP8:SAS_Start	275
5.12.4.11.5 Transition SP27:SAS_Settings to SP28:SAS_TrainSetup	275
5.12.4.12 SP28:SAS_TrainSetup.....	275
5.12.4.12.1 State description	275
5.12.4.12.2 Transition SP28:SAS_TrainSetup to SP0:OOB_COMINIT	275
5.12.4.12.3 Transition SP28:SAS_TrainSetup to SP29:SAS_Train_Rx.....	276
5.12.4.12.4 Transition SP28:SAS_TrainSetup to SP34:SAS_Train_Tx	276
5.12.4.13 SP34:SAS_Train_Tx state	276
5.12.4.13.1 State description	276
5.12.4.13.2 Transition SP34:SAS_Train_Tx to SP1:OOB_AwaitCOMX	276
5.12.4.13.3 Transition SP34:SAS_Train_Tx to SP28:SAS_TrainSetup	276
5.12.4.13.4 Transition SP34:SAS_Train_Tx to SP29:SAS_Train_Rx	277
5.12.4.14 SP29:SAS_Train_Rx state	277
5.12.4.14.1 State description	277
5.12.4.14.2 Transition SP29:SAS_Train_Rx to SP0:OOB_COMINIT	277
5.12.4.14.3 Transition SP29:SAS_Train_Rx to SP1:OOB_AwaitCOMX.....	277
5.12.4.14.4 Transition SP29:SAS_Train_Rx to SP28:SAS_TrainSetup.....	277
5.12.4.14.5 Transition SP29:SAS_Train_Rx to SP30:SAS_TrainingDone.....	278
5.12.4.15 SP30:SAS_TrainingDone state	278
5.12.4.15.1 State description	278
5.12.4.15.2 Transition SP30:SAS_TrainingDone to SP0:OOB_COMINIT	278
5.12.4.15.3 Transition SP30:SAS_TrainingDone to SP1:OOB_AwaitCOMX	278
5.12.4.15.4 Transition SP30:SAS_TrainingDone to SP28:SAS_TrainSetup.....	278
5.12.4.15.5 Transition SP30:SAS_TrainingDone to SP15:SAS_PHY_Ready.....	279
5.12.5 SAS phy power conditions states	279
5.12.5.1 SAS phy power conditions states overview.....	279
5.12.5.2 SP31:SAS_PS_Low_Phy_Power state.....	280
5.12.5.2.1 State description	280
5.12.5.2.2 Transition SP31:SAS_PS_Low_Phy_Power to SP0:OOB_COMINIT	281
5.12.5.2.3 Transition SP31:SAS_PS_Low_Phy_Power to SP32:SAS_PS_ALIGN0.....	281
5.12.5.3 SP32:SAS_PS_ALIGN0 state.....	281
5.12.5.3.1 State description	281
5.12.5.3.2 Transition SP32:SAS_PS_ALIGN0 state to SP0:OOB_COMINIT.....	281
5.12.5.3.3 Transition SP32:SAS_PS_ALIGN0 to SP33:SAS_PS_ALIGN1.....	281
5.12.5.4 SP33:SAS_PS_ALIGN1 state	282
5.12.5.4.1 State description	282
5.12.5.4.2 Transition SP33:SAS_PS_ALIGN1 state to SP0:OOB_COMINIT.....	282
5.12.5.4.3 Transition SP33:SAS_PS_ALIGN1 state to SP15:SAS_PHY_Ready.....	282
5.12.6 SATA host emulation states.....	282
5.12.6.1 SATA host emulation states overview.....	282
5.12.6.2 SP16:SATA_COMWAKE state	283
5.12.6.2.1 State description	283
5.12.6.2.2 Transition SP16:SATA_COMWAKE to SP0:OOB_COMINIT.....	284
5.12.6.2.3 Transition SP16:SATA_COMWAKE to SP17:SATA_AwaitCOMWAKE.....	284
5.12.6.3 SP17:SATA_AwaitCOMWAKE state.....	284
5.12.6.3.1 State description	284
5.12.6.3.2 Transition SP17:SATA_AwaitCOMWAKE to SP0:OOB_COMINIT	284
5.12.6.3.3 Transition SP17:SATA_AwaitCOMWAKE to SP18:SATA_AwaitNoCOMWAKE	284
5.12.6.4 SP18:SATA_AwaitNoCOMWAKE state	284
5.12.6.4.1 State description	284
5.12.6.4.2 Transition SP18:SATA_AwaitNoCOMWAKE to SP0:OOB_COMINIT	284
5.12.6.4.3 Transition SP18:SATA_AwaitNoCOMWAKE to SP19:SATA_AwaitALIGN.....	284
5.12.6.5 SP19:SATA_AwaitALIGN state.....	284
5.12.6.5.1 State description	284
5.12.6.5.2 Transition SP19:SATA_AwaitALIGN to SP0:OOB_COMINIT	284
5.12.6.5.3 Transition SP19:SATA_AwaitALIGN to SP20:SATA_AdjustSpeed.....	285
5.12.6.6 SP20:SATA_AdjustSpeed state	285

5.12.6.6.1 State description	285
5.12.6.6.2 Transition SP20:SATA_AdjustSpeed to SP0:OOB_COMINIT	285
5.12.6.6.3 Transition SP20:SATA_AdjustSpeed to SP21:SATA_TransmitALIGN	285
5.12.6.7 SP21:SATA_TransmitALIGN state	285
5.12.6.7.1 State description	285
5.12.6.7.2 Transition SP21:SATA_TransmitALIGN to SP0:OOB_COMINIT	285
5.12.6.7.3 Transition SP21:SATA_TransmitALIGN to SP22:SATA_PHY_Ready	285
5.12.6.8 SP22:SATA_PHY_Ready state	286
5.12.6.8.1 State description	286
5.12.6.8.2 Transition SP22:SATA_PHY_Ready to SP0:OOB_COMINIT	286
5.12.6.8.3 Transition SP22:SATA_PHY_Ready to SP23:SATA_PM_Partial	286
5.12.6.8.4 Transition SP22:SATA_PHY_Ready to SP24:SATA_PM_Slumber	286
5.12.6.9 SP23:SATA_PM_Partial state	286
5.12.6.9.1 State description	286
5.12.6.9.2 Transition SP23:SATA_PM_Partial to SP0:OOB_COMINIT	286
5.12.6.9.3 Transition SP23:SATA_PM_Partial to SP16:SATA_COMWAKE	286
5.12.6.9.4 Transition SP23:SATA_PM_Partial to SP19:SATA_AwaitALIGN	287
5.12.6.10 SP24:SATA_PM_Slumber state	287
5.12.6.10.1 State description	287
5.12.6.10.2 Transition SP24:SATA_PM_Slumber to SP0:OOB_COMINIT	287
5.12.6.10.3 Transition SP24:SATA_PM_Slumber to SP16:SATA_COMWAKE	287
5.12.6.10.4 Transition SP24:SATA_PM_Slumber to SP19:SATA_AwaitALIGN	287
5.12.7 SATA port selector state SP25:SATA_PortSel	288
5.12.7.1 State description	288
5.12.7.2 Transition SP25:SATA_PortSel to SP1:OOB_AwaitCOMX	288
5.12.8 SATA spinup hold state SP26:SATA_SpinupHold	289
5.12.8.1 State description	289
5.12.8.2 Transition SP26:SATA_SpinupHold to SP0:OOB_COMINIT	289
5.13 SP_DWS (phy layer dword synchronization) state machine	289
5.13.1 SP_DWS state machine overview	289
5.13.2 SP_DWS receiver	291
5.13.3 SP_DWS0:AcquireSync state	292
5.13.3.1 State description	292
5.13.3.2 Transition SP_DWS0:AcquireSync to SP_DWS1:Valid1	292
5.13.4 SP_DWS1:Valid1 state	292
5.13.4.1 State description	292
5.13.4.2 Transition SP_DWS1:Valid1 to SP_DWS0:AcquireSync	293
5.13.4.3 Transition SP_DWS1:Valid1 to SP_DWS2:Valid2	293
5.13.5 SP_DWS2:Valid2 state	293
5.13.5.1 State description	293
5.13.5.2 Transition SP_DWS2:Valid2 to SP_DWS0:AcquireSync	293
5.13.5.3 Transition SP_DWS2:Valid2 to SP_DWS3:SyncAcquired	293
5.13.6 SP_DWS3:SyncAcquired state	293
5.13.6.1 State description	293
5.13.6.2 Transition SP_DWS3:SyncAcquired to SP_DWS0:AcquireSync	293
5.13.6.3 Transition SP_DWS3:SyncAcquired to SP_DWS4:Lost1	293
5.13.7 SP_DWS4:Lost1 state	293
5.13.7.1 State description	293
5.13.7.2 Transition SP_DWS4:Lost1 to SP_DWS0:AcquireSync	293
5.13.7.3 Transition SP_DWS4:Lost1 to SP_DWS5:Lost1Recovered	294
5.13.7.4 Transition SP_DWS4:Lost1 to SP_DWS6:Lost2	294
5.13.8 SP_DWS5:Lost1Recovered state	294
5.13.8.1 State description	294
5.13.8.2 Transition SP_DWS5:Lost1Recovered to SP_DWS0:AcquireSync	294
5.13.8.3 Transition SP_DWS5:Lost1Recovered to SP_DWS3:SyncAcquired	294
5.13.8.4 Transition SP_DWS5:Lost1Recovered to SP_DWS6:Lost2	294
5.13.9 SP_DWS6:Lost2 state	294
5.13.9.1 State description	294

5.13.9.2 Transition SP_DWS6:Lost2 to SP_DWS0:AcquireSync	294
5.13.9.3 Transition SP_DWS6:Lost2 to SP_DWS7:Lost2Recovered	294
5.13.9.4 Transition SP_DWS6:Lost2 to SP_DWS8:Lost3	294
5.13.10 SP_DWS7:Lost2Recovered state	294
5.13.10.1 State description	294
5.13.10.2 Transition SP_DWS7:Lost2Recovered to SP_DWS0:AcquireSync	295
5.13.10.3 Transition SP_DWS7:Lost2Recovered to SP_DWS4:Lost1	295
5.13.10.4 Transition SP_DWS7:Lost2Recovered to SP_DWS8:Lost3	295
5.13.11 SP_DWS8:Lost3 state	295
5.13.11.1 State description	295
5.13.11.2 Transition SP_DWS8:Lost3 to SP_DWS0:AcquireSync	295
5.13.11.3 Transition SP_DWS8:Lost3 to SP_DWS9:Lost3Recovered	295
5.13.12 SP_DWS9:Lost3Recovered state	295
5.13.12.1 State description	295
5.13.12.2 Transition SP_DWS9:Lost3Recovered to SP_DWS0:AcquireSync	295
5.13.12.3 Transition SP_DWS9:Lost3Recovered to SP_DWS6:Lost2	295
5.14 PTT (phy layer transmitter training) state machines	295
5.14.1 PTT state machines overview	295
5.14.2 SP transmitter additions for transmitter training	296
5.14.2.1 SP transmitter additions for transmitter training overview	296
5.14.2.2 TTIU transmit setup	296
5.14.2.3 No_equalization, reference_1, and reference_2 coefficient settings request	297
5.14.2.4 Coefficient limits	297
5.14.2.5 Coefficient request result of update complete	297
5.14.2.5.1 Coefficient request processing	297
5.14.2.5.2 Coefficient adjustment completes	297
5.14.2.5.3 No coefficient adjustment	298
5.14.2.6 Coefficient request result of maximum	298
5.14.2.6.1 Coefficient request processing	298
5.14.2.6.2 Coefficient adjustment completes	298
5.14.2.6.3 No coefficient adjustment	298
5.14.2.7 Coefficient request result of minimum	299
5.14.2.7.1 Coefficient request processing	299
5.14.2.7.2 Coefficient adjustment completes	299
5.14.2.7.3 No coefficient adjustment	299
5.14.3 SP receiver additions for transmitter training	299
5.14.4 PTT_T (phy layer transmitter training transmit pattern) state machine	300
5.14.4.1 PTT_T state machine overview	300
5.14.4.2 PTT_T0:Idle state	303
5.14.4.2.1 State description	303
5.14.4.2.2 Transition PTT_T0:Idle to PTT_T1:Initialize	303
5.14.4.3 PTT_T1:Initialize state	303
5.14.4.3.1 State description	303
5.14.4.3.2 Transition PTT_T1:Initialize to PTT_T0:Idle	303
5.14.4.3.3 Transition PTT_T1:Initialize to PTT_T2:Tx_Training	304
5.14.4.4 PTT_T2:Tx_Training state	304
5.14.4.4.1 State description	304
5.14.4.4.2 Entry conditions	304
5.14.4.4.3 Control word and status word mappings	304
5.14.4.4.4 Error message handling	305
5.14.4.4.5 Resetting attached phy's transmitter	306
5.14.4.4.6 Local phy's transmitter and attached phy's transmitter training completed	307
5.14.4.4.7 Transition PTT_T2:Tx_Training to PTT_T0:Idle	307
5.14.4.4.8 Transition PTT_T2:Tx_Training to PTT_T3:Local_Tx_Training	307
5.14.4.5 PTT_T3:Local_Tx_Training state	308
5.14.4.5.1 State description	308
5.14.4.5.2 Entry conditions	308
5.14.4.5.3 Status word mappings	308

5.14.4.5.4 Local phy's transmitter and attached phy's transmitter training completed	308
5.14.4.5.5 Error message handling.....	308
5.14.4.5.6 Transition PTT_T3:Local_Tx_Training to PTT_T0:Idle.....	309
5.14.5 PTT_R (phy layer transmitter training receive pattern) state machine.....	309
5.14.5.1 PTT_R0:Idle state	311
5.14.5.1.1 State description	311
5.14.5.1.2 Transition PTT_R0:Idle to PTT_R1:Initialize	311
5.14.5.2 PTT_R1:Initialize state	311
5.14.5.2.1 State description	311
5.14.5.2.2 Transition PTT_R1:Initialize to PTT_R0:Idle	311
5.14.5.2.3 Transition PTT_R1:Initialize to PTT_R2:Receive_Train_Tx_Pattern	311
5.14.5.3 PTT_R2:Receive_Train_Tx_Pattern state	311
5.14.5.3.1 State description	311
5.14.5.3.2 Transition PTT_R2:Receive_Train_Tx_Pattern to PTT_R0:Idle.....	317
5.14.5.3.3 Transition PTT_R2:Receive_Train_Tx_Pattern to PTT_R1:Initialize	317
5.14.6 PTT_SC (phy layer transmitter training set transmitter coefficient) state machines	317
5.14.6.1 PTT_SC (phy layer transmitter training set transmitter coefficient) state machines overview	317
5.14.6.2 PTT_SC1 state machine overview	319
5.14.6.3 PTT_SC1_0:Idle state	319
5.14.6.3.1 State description	319
5.14.6.3.2 Transition PTT_SC1_0:Idle to PTT_SC1_1:Wait_Inc_Dec	319
5.14.6.4 PTT_SC1_1:Wait_Inc_Dec state	319
5.14.6.4.1 State description	319
5.14.6.4.2 Transition PTT_SC1_1:Wait_Inc_Dec to PTT_SC1_0:Idle	319
5.14.6.4.3 Transition PTT_SC1_1:Wait_Inc_Dec to PTT_SC1_2:Set_Coefficient.....	319
5.14.6.5 PTT_SC1_2:Set_Coefficient state	320
5.14.6.5.1 State description	320
5.14.6.5.2 Transition PTT_SC1_2:Set_Coefficient to PTT_SC1_0:Idle	320
5.14.6.5.3 Transition PTT_SC1_2:Set_Coefficient to PTT_SC1_3:Wait_Hold	321
5.14.6.6 PTT_SC1_3:Wait_Hold state	321
5.14.6.6.1 State description	321
5.14.6.6.2 Transition PTT_SC1_3:Wait_Hold to PTT_SC1_0:Idle	321
5.14.6.6.3 Transition PTT_SC1_3:Wait_Hold to PTT_SC1_1:Wait_Inc_Dec	321
5.14.7 PTT_SC2 (phy layer transmitter training set transmitter coefficient 2) state machine	321
5.14.8 PTT_SC3 (phy layer transmitter training set transmitter coefficient 3) state machine	321
5.14.9 PTT_GC (phy layer transmitter training get transmitter coefficient) state machines.....	322
5.14.9.1 PTT_GC (phy layer transmitter training get transmitter coefficient) state machines overview	322
5.14.9.2 PTT_GC1 state machine.....	323
5.14.9.3 PTT_GC1_0:Idle state.....	323
5.14.9.3.1 State description	323
5.14.9.3.2 Transition PTT_GC1_0:Idle to PTT_GC1_1:Get_Coefficient.....	324
5.14.9.4 PTT_GC1_1:Get_Coefficient state.....	324
5.14.9.4.1 State description	324
5.14.9.4.2 Transition PTT_GC1_1:Get_Coefficient to PTT_GC1_0:Idle	324
5.14.9.4.3 Transition PTT_GC1_1:Get_Coefficient to PTT_GC1_2:Wait_Restart.....	324
5.14.9.5 PTT_GC1_2:Wait_Restart state.....	324
5.14.9.5.1 State description	324
5.14.9.5.2 Transition PTT_GC1_2:Wait_Restart to PTT_GC1_0:Idle	325
5.14.10 PTT_GC2 (phy layer transmitter training get transmitter coefficient 2) state machine	325
5.14.11 PTT_GC3 (phy layer transmitter training get transmitter coefficient 3) state machine	325
5.14.12 PTT_PL (phy layer transmitter training pattern lock) state machine	325
5.14.12.1 PTT_PL state machine overview.....	325
5.14.12.2 PTT_PL0:Idle state.....	327
5.14.12.2.1 State description	327
5.14.12.2.2 Transition PTT_PL0:Idle to PTT_PL1:Acquire_Lock	328
5.14.12.3 PTT_PL1:Acquire_Lock state.....	328
5.14.12.3.1 State description	328
5.14.12.3.2 Transition PTT_PL1:Acquire_Lock to PTT_PL2:Valid.....	328

5.14.12.4 PTT_PL2:Valid state	328
5.14.12.4.1 State description	328
5.14.12.4.2 Transition PTT_PL2:Valid to PTT_PL1:Acquire_Lock	328
5.14.12.4.3 Transition PTT_PL2:Valid to PTT_PL3:Lock_Acquired	328
5.14.12.5 PTT_PL3:Lock_Acquired state	328
5.14.12.5.1 State description	328
5.14.12.5.2 Transition PTT_PL3:Lock_Acquired to PTT_PL4:Lost1	328
5.14.12.6 PTT_PL4:Lost1 state	328
5.14.12.6.1 State description	328
5.14.12.6.2 Transition PTT_PL4:Lost1 to PTT_PL3:Lock_Acquired	329
5.14.12.6.3 Transition PTT_PL4:Lost1 to PTT_PL5:Lost2	329
5.14.12.7 PTT_PL5:Lost2 state	329
5.14.12.7.1 State description	329
5.14.12.7.2 Transition PTT_PL5:Lost2 to PTT_PL3:Lock_Acquired	329
5.14.12.7.3 Transition PTT_PL5:Lost2 to PTT_PL6:Lost3	329
5.14.12.8 PTT_PL6:Lost3 state	329
5.14.12.8.1 State description	329
5.14.12.8.2 Transition PTT_PL6:Lost3 to PTT_PL3:Lock_Acquired	329
5.14.12.8.3 Transition PTT_PL6:Lost3 to PTT_PL7:Lost4	329
5.14.12.9 PTT_PL7:Lost4 state	329
5.14.12.9.1 State description	329
5.14.12.9.2 Transition PTT_PL7:Lost4 to PTT_PL3:Lock_Acquired	329
5.14.12.9.3 Transition PTT_PL7:Lost4 to PTT_PL1:Acquire_Lock	330
5.15 Multiplexing	330
5.16 Spinup	331
6 Link layer	332
6.1 Link layer overview	332
6.2 Primitives	332
6.2.1 Primitives overview	332
6.2.2 Primitive summary	333
6.2.3 Primitive encodings	338
6.2.4 Primitive sequences	343
6.2.4.1 Primitive sequences overview	343
6.2.4.2 Single primitive sequence	343
6.2.4.3 Repeated primitive sequence	343
6.2.4.4 Continued primitive sequence	344
6.2.4.5 Extended primitive sequence	344
6.2.4.6 Triple primitive sequence	345
6.2.4.7 Redundant primitive sequence	346
6.2.5 Deletable primitives	347
6.2.5.1 ALIGN	347
6.2.5.2 MUX (Multiplex)	348
6.2.5.3 NOTIFY	349
6.2.5.3.1 NOTIFY overview	349
6.2.5.3.2 NOTIFY (ENABLE SPINUP)	349
6.2.5.3.3 NOTIFY (POWER LOSS EXPECTED)	350
6.2.5.4 OOB_IDLE	351
6.2.6 Primitives not specific to type of connections	351
6.2.6.1 AIP (Arbitration in progress)	351
6.2.6.2 BREAK	351
6.2.6.3 BREAK_REPLY	351
6.2.6.4 BROADCAST	352
6.2.6.5 CLOSE	352
6.2.6.6 EOAF (End of address frame)	352
6.2.6.7 ERROR	353
6.2.6.8 HARD_RESET	353
6.2.6.9 OPEN_ACCEPT	353

6.2.6.10 OPEN_REJECT	353
6.2.6.11 PS_ACK	356
6.2.6.12 PS_NAK	356
6.2.6.13 PS_REQ	356
6.2.6.14 PWR_ACK	356
6.2.6.15 PWR_DONE	356
6.2.6.16 PWR_GRANT	356
6.2.6.17 PWR_REQ	356
6.2.6.18 SOAF (Start of address frame)	356
6.2.6.19 TRAIN	357
6.2.6.20 TRAIN_DONE	357
6.2.7 Primitives used only inside SSP and SMP connections	357
6.2.7.1 ACK (Acknowledge)	357
6.2.7.2 CREDIT_BLOCKED	357
6.2.7.3 DONE	357
6.2.7.4 EOF (End of frame)	358
6.2.7.5 NAK (Negative acknowledgement)	358
6.2.7.6 RRDY (Receiver ready)	358
6.2.7.7 SOF (Start of frame)	358
6.2.8 Primitives used only inside STP connections and on SATA physical links	358
6.2.8.1 SATA_ERROR	358
6.2.8.2 SATA_PMACK, SATA_PMNAK, SATA_PMREQ_P, and SATA_PMREQ_S (Power management acknowledgements and requests)	359
6.2.8.3 SATA_HOLD and SATA_HOLD_A (Hold and hold acknowledge)	359
6.2.8.4 SATA_R_RDY and SATA_X_RDY (Receiver ready and transmitter ready)	359
6.2.8.5 Other primitives used inside STP connections and on SATA physical links	359
6.3 Physical link rate tolerance management	359
6.3.1 Physical link rate tolerance management overview	359
6.3.2 Phys originating dwords	360
6.3.3 Expander phys forwarding dwords	361
6.4 Idle physical links	362
6.5 CRC	362
6.5.1 CRC overview	362
6.5.2 CRC generation	364
6.5.3 CRC checking	366
6.6 Scrambling	367
6.7 Bit order of CRC and scrambler	369
6.8 Address frames	372
6.8.1 Address frames overview	372
6.8.2 IDENTIFY address frame	374
6.8.3 OPEN address frame	378
6.9 Link reset sequence	381
6.9.1 Link reset sequence overview	381
6.9.2 Expander device handling of link reset sequences	384
6.10 SL_IR (link layer identification and hard reset) state machines	384
6.10.1 SL_IR state machines overview	384
6.10.2 SL_IR transmitter and receiver	386
6.10.3 SL_IR_TIR (transmit IDENTIFY or HARD_RESET) state machine	386
6.10.3.1 SL_IR_TIR state machine overview	386
6.10.3.2 SL_IR_TIR1:Idle state	387
6.10.3.2.1 State description	387
6.10.3.2.2 Transition SL_IR_TIR1:Idle to SL_IR_TIR2:Transmit_Identify	387
6.10.3.2.3 Transition SL_IR_TIR1:Idle to SL_IR_TIR3:Transmit_Hard_Reset	387
6.10.3.3 SL_IR_TIR2:Transmit_Identify state	387
6.10.3.3.1 State description	387
6.10.3.3.2 Transition SL_IR_TIR2:Transmit_Identify to SL_IR_TIR4:Completed	387
6.10.3.4 SL_IR_TIR3:Transmit_Hard_Reset state	387
6.10.3.4.1 State description	387

6.10.3.4.2 Transition SL_IR_TIR3:Transmit_Hard_Reset to SL_IR_TIR4:Completed	387
6.10.3.5 SL_IR_TIR4:Completed state	387
6.10.4 SL_IR_RIF (receive IDENTIFY address frame) state machine	388
6.10.4.1 SL_IR_RIF state machine overview	388
6.10.4.2 SL_IR_RIF1:Idle state	388
6.10.4.2.1 State description	388
6.10.4.2.2 Transition SL_IR_RIF1:Idle to SL_IR_RIF2:Receive_Identify_Frame	388
6.10.4.3 SL_IR_RIF2:Receive_Identify_Frame state	388
6.10.4.3.1 State description	388
6.10.4.3.2 Transition SL_IR_RIF2:Receive_Identify_Frame to SL_IR_RIF3:Completed	389
6.10.4.4 SL_IR_RIF3:Completed state	389
6.10.5 SL_IR_IRC (identification and hard reset control) state machine	389
6.10.5.1 SL_IR_IRC state machine overview	389
6.10.5.2 SL_IR_IRC1:Idle state	389
6.10.5.2.1 State description	389
6.10.5.2.2 Transition SL_IR_IRC1:Idle to SL_IR_IRC2:Wait	389
6.10.5.3 SL_IR_IRC2:Wait state	389
6.10.5.3.1 State description	389
6.10.5.3.2 Transition SL_IR_IRC2:Wait to SL_IR_IRC3:Completed	390
6.10.5.4 SL_IR_IRC3:Completed state	390
6.11 Entering a low phy power condition	390
6.12 Power control and SL_P (link layer power control) state machines	391
6.12.1 Power source device	391
6.12.2 Power consumer device	391
6.12.3 NOTIFY (ENABLE SPINUP) usage	392
6.12.4 SL_P_S (link layer power source device) state machine	392
6.12.4.1 SL_P_S state machine overview	392
6.12.4.2 SL_P_S transmitter and SL_P_S receiver	394
6.12.4.3 SL_P_S_1:Idle state	395
6.12.4.3.1 State description	395
6.12.4.3.2 Transition SL_P_S_1:Idle to SL_P_S_2:Wait_Grant	395
6.12.4.4 SL_P_S_2:Wait_Grant state	395
6.12.4.4.1 State description	395
6.12.4.4.2 Transition SL_P_S_2:Wait_Grant to SL_P_S_1:Idle	396
6.12.4.4.3 Transition SL_P_S_2:Wait_Grant to SL_P_S_3:Wait_Done	396
6.12.4.5 SL_P_S_3:Wait_Done state	396
6.12.4.5.1 State description	396
6.12.4.5.2 Transition SL_P_S_3:Wait_Done to SL_P_S_1:Idle	396
6.12.5 SL_P_C (link layer power consumer device) state machine	396
6.12.5.1 SL_P_C state machine overview	396
6.12.5.2 SL_P_C receiver	399
6.12.5.3 SL_P_C_1:Idle state	399
6.12.5.3.1 State description	399
6.12.5.3.2 Transition SL_P_C_1:Idle to SL_P_C_2:Request_Power	399
6.12.5.4 SL_P_C_2:Request_Power state	399
6.12.5.4.1 State description	399
6.12.5.4.2 Transition SL_P_C_2:Request_Power to SL_P_C_1:Idle	400
6.12.5.4.3 Transition SL_P_C_2:Request_Power to SL_P_C_3:Wait_Grant	400
6.12.5.4.4 Transition SL_P_C_2:Request_Power to SL_P_C_4:Wait_Done	400
6.12.5.5 SL_P_C_3:Wait_Grant state	400
6.12.5.5.1 State description	400
6.12.5.5.2 Transition SL_P_C_3:Wait_Grant to SL_P_C_1:Idle	400
6.12.5.5.3 Transition SL_P_C_3:Wait_Grant to SL_P_C_4:Wait_Done	401
6.12.5.6 SL_P_C_4:Wait_Done state	401
6.12.5.6.1 State description	401
6.12.5.6.2 Transition SL_P_C_4:Wait_Done to SL_P_C_1:Idle	401
6.13 SAS domain changes (Broadcast (Change) usage)	401
6.14 Connections	402

6.14.1 Connections overview	402
6.14.2 Opening a connection	403
6.14.2.1 Connection request	403
6.14.2.2 Results of a connection request	405
6.14.3 Arbitration fairness	405
6.14.4 Arbitration inside an expander device	406
6.14.4.1 Expander logical phy arbitration requirements	406
6.14.4.2 ECM arbitration requirements	407
6.14.4.2.1 ECM arbitration requirements overview	407
6.14.4.2.2 Arbitrating confirmations	407
6.14.4.2.3 Arb Won confirmation	408
6.14.4.2.4 Arb Lost confirmation	409
6.14.4.2.5 Arb Reject confirmation	409
6.14.4.3 Arbitration status	409
6.14.4.4 Partial Pathway Timeout timer	410
6.14.4.5 Pathway recovery	410
6.14.5 BREAK handling	411
6.14.6 Aborting a connection request	411
6.14.7 Closing a connection	414
6.14.8 Breaking a connection	415
6.15 Rate matching	416
6.16 SL (link layer for SAS logical phys) state machines	419
6.16.1 SL state machines overview	419
6.16.2 SL transmitter and receiver	422
6.16.3 SL_RA (receive OPEN address frame) state machine	424
6.16.4 SL_CC (connection control) state machine	424
6.16.4.1 SL_CC state machine overview	424
6.16.4.2 SL_CC0:Idle state	426
6.16.4.2.1 State description	426
6.16.4.2.2 Transition SL_CC0:Idle to SL_CC1:ArbSel	427
6.16.4.2.3 Transition SL_CC0:Idle to SL_CC2:Selected	428
6.16.4.2.4 Transition SL_CC0:Idle to SL_CC8:PS_Request	428
6.16.4.2.5 Transition SL_CC0:Idle to SL_CC9:PS_Quiet	428
6.16.4.3 SL_CC1:ArbSel state	428
6.16.4.3.1 State description	428
6.16.4.3.2 Transition SL_CC1:ArbSel to SL_CC0:Idle	430
6.16.4.3.3 Transition SL_CC1:ArbSel to SL_CC2:Selected	430
6.16.4.3.4 Transition SL_CC1:ArbSel to SL_CC3:Connected	430
6.16.4.3.5 Transition SL_CC1:ArbSel to SL_CC5:BreakWait	431
6.16.4.3.6 Transition SL_CC1:ArbSel to SL_CC6:Break	431
6.16.4.4 SL_CC2:Selected state	431
6.16.4.4.1 State description	431
6.16.4.4.2 Transition SL_CC2:Selected to SL_CC0:Idle	432
6.16.4.4.3 Transition SL_CC2:Selected to SL_CC3:Connected	432
6.16.4.4.4 Transition SL_CC2:Selected to SL_CC5:BreakWait	432
6.16.4.4.5 Transition SL_CC2:Selected to SL_CC6:Break	432
6.16.4.5 SL_CC3:Connected state	432
6.16.4.5.1 State description	432
6.16.4.5.2 Transition SL_CC3:Connected to SL_CC4:DisconnectWait	433
6.16.4.5.3 Transition SL_CC3:Connected to SL_CC5:BreakWait	433
6.16.4.5.4 Transition SL_CC3:Connected to SL_CC6:Break	433
6.16.4.5.5 Transition SL_CC3:Connected to SL_CC7:CloseSTP	433
6.16.4.6 SL_CC4:DisconnectWait state	433
6.16.4.6.1 State description	433
6.16.4.6.2 Transition SL_CC4:DisconnectWait to SL_CC0:Idle	434
6.16.4.6.3 Transition SL_CC4:DisconnectWait to SL_CC5:BreakWait	434
6.16.4.6.4 Transition SL_CC4:DisconnectWait to SL_CC6:Break	434
6.16.4.7 SL_CC5:BreakWait state	434

6.16.4.7.1 State description	434
6.16.4.7.2 Transition SL_CC5:BreakWait to SL_CC0:Idle	434
6.16.4.8 SL_CC6:Break state	434
6.16.4.8.1 State description	434
6.16.4.8.2 Transition SL_CC6:Break to SL_CC0:Idle	435
6.16.4.9 SL_CC7:CloseSTP state	435
6.16.4.9.1 State description	435
6.16.4.9.2 Transition SL_CC7:CloseSTP to SL_CC0:Idle	435
6.16.4.10 SL_CC8:PS_Request state	435
6.16.4.10.1 State description	435
6.16.4.10.2 Transition SL_CC8:PS_Request to SL_CC9:PS_Quiet	436
6.16.4.10.3 Transition SL_CC8:PS_Request to SL_CC0:Idle	436
6.16.4.10.4 Transition SL_CC8:PS_Request to SL_CC2:Selected	436
6.16.4.11 SL_CC9:PS_Quiet state	436
6.16.4.11.1 State description	436
6.16.4.11.2 Transition SL_CC9:PS_Quiet to SL_CC0:Idle	437
6.16.4.11.3 Transition SL_CC9:PS_Quiet to SL_CC1:ArbSel	437
6.17 XL (link layer for expander logical phys) state machine	437
6.17.1 XL state machine overview	437
6.17.2 XL transmitter and receiver	443
6.17.3 XL0:Idle state	444
6.17.3.1 State description	444
6.17.3.2 Transition XL0:Idle to XL1:Request_Path	445
6.17.3.3 Transition XL0:Idle to XL5:Forward_Open	446
6.17.3.3.1 Transition XL0:Idle to XL11:PS_Request	446
6.17.3.3.2 Transition XL0:Idle to XL12:PS_Quiet	446
6.17.4 XL1:Request_Path state	446
6.17.4.1 State description	446
6.17.4.2 Transition XL1:Request_Path to XL0:Idle	447
6.17.4.3 Transition XL1:Request_Path to XL2:Request_Open	447
6.17.4.4 Transition XL1:Request_Path to XL4:Open_Reject	447
6.17.4.5 Transition XL1:Request_Path to XL5:Forward_Open	448
6.17.4.6 Transition XL1:Request_Path to XL9:Break	448
6.17.5 XL2:Request_Open state	448
6.17.5.1 State description	448
6.17.5.2 Transition XL2:Request_Open to XL3:Open_Confirm_Wait	448
6.17.6 XL3:Open_Confirm_Wait state	449
6.17.6.1 State description	449
6.17.6.2 Transition XL3:Open_Confirm_Wait to XL0:Idle	449
6.17.6.3 Transition XL3:Open_Confirm_Wait to XL1:Request_Path	449
6.17.6.4 Transition XL3:Open_Confirm_Wait to XL5:Forward_Open	450
6.17.6.5 Transition XL3:Open_Confirm_Wait to XL7:Connected	450
6.17.6.6 Transition XL3:Open_Confirm_Wait to XL9:Break	450
6.17.6.7 Transition XL3:Open_Confirm_Wait to XL10:Break_Wait	450
6.17.7 XL4:Open_Reject state	450
6.17.7.1 State description	450
6.17.7.2 Transition XL4:Open_Reject to XL0:Idle	450
6.17.7.3 Transition XL4:Open_Reject to XL5:Forward_Open	450
6.17.8 XL5:Forward_Open state	451
6.17.8.1 State description	451
6.17.8.2 Transition XL5:Forward_Open to XL6:Open_Response_Wait	451
6.17.9 XL6:Open_Response_Wait state	451
6.17.9.1 State description	451
6.17.9.2 Transition XL6:Open_Response_Wait to XL0:Idle	452
6.17.9.3 Transition XL6:Open_Response_Wait to XL1:Request_Path	452
6.17.9.4 Transition XL6:Open_Response_Wait to XL2:Request_Open	452
6.17.9.5 Transition XL6:Open_Response_Wait to XL7:Connected	452
6.17.9.6 Transition XL6:Open_Response_Wait to XL9:Break	452

6.17.9.7 Transition XL6:Open_Response_Wait to XL10:Break_Wait	453
6.17.10 XL7:Connected state	453
6.17.10.1 State description.....	453
6.17.10.2 Transition XL7:Connected to XL8:Close_Wait.....	453
6.17.10.3 Transition XL7:Connected to XL9:Break.....	453
6.17.10.4 Transition XL7:Connected to XL10:Break_Wait.....	453
6.17.11 XL8:Close_Wait state	454
6.17.11.1 State description.....	454
6.17.11.2 Transition XL8:Close_Wait to XL0:Idle.....	454
6.17.11.3 Transition XL8:Close_Wait to XL9:Break.....	454
6.17.11.4 Transition XL8:Close_Wait to XL10:Break_Wait.....	454
6.17.12 XL9:Break state	455
6.17.12.1 State description.....	455
6.17.12.2 Transition XL9:Break to XL0:Idle.....	455
6.17.13 XL10:Break_Wait state	455
6.17.13.1 State description.....	455
6.17.13.2 Transition XL10:Break_Wait to XL0:Idle	455
6.17.14 XL11:PS_Request state.....	455
6.17.14.1 State description.....	455
6.17.14.2 Transition XL11:PS_Request to XL12:PS_Quiet	456
6.17.14.3 Transition XL11:PS_Request to XL0:Idle.....	456
6.17.14.4 Transition XL11:PS_Request to XL1:Request_Path.....	456
6.17.15 XL12:PS_Quiet state	456
6.17.15.1 State description.....	456
6.17.15.2 Transition XL12:PS_Quiet to XL0:Idle.....	457
6.18 SSP link layer	457
6.18.1 Opening an SSP connection.....	457
6.18.2 Full duplex.....	457
6.18.3 SSP frame transmission and reception.....	458
6.18.4 SSP flow control.....	458
6.18.5 Interlocked frames	459
6.18.6 Breaking an SSP connection	461
6.18.7 Closing an SSP connection	461
6.18.8 SSP (link layer for SSP phys) state machines	462
6.18.8.1 SSP state machines overview	462
6.18.8.2 SSP transmitter and receiver	465
6.18.8.3 SSP_TIM (transmit interlocked frame monitor) state machine	466
6.18.8.4 SSP_TCM (transmit frame credit monitor) state machine.....	467
6.18.8.5 SSP_D (DONE control) state machine.....	467
6.18.8.6 SSP_TF (transmit frame control) state machine	468
6.18.8.6.1 SSP_TF state machine overview.....	468
6.18.8.6.2 SSP_TF1:Connected_Idle state	469
6.18.8.6.2.1 State description	469
6.18.8.6.2.2 Transition SSP_TF1:Connected_Idle to SSP_TF2:Tx_Wait.....	469
6.18.8.6.2.3 Transition SSP_TF1:Connected_Idle to SSP_TF4:Transmit_DONE.....	469
6.18.8.6.3 SSP_TF2:Tx_Wait state	469
6.18.8.6.3.1 State description	469
6.18.8.6.3.2 Transition SSP_TF2:Tx_Wait to SSP_TF3:Transmit_Frame.....	469
6.18.8.6.3.3 Transition SSP_TF2:Tx_Wait to SSP_TF4:Transmit_DONE.....	469
6.18.8.6.4 SSP_TF3:Transmit_Frame state	470
6.18.8.6.4.1 State description	470
6.18.8.6.4.2 Transition SSP_TF3:Transmit_Frame to SSP_TF1:Connected_Idle.....	470
6.18.8.6.5 SSP_TF4:Transmit_DONE state.....	470
6.18.8.7 SSP_RF (receive frame control) state machine	471
6.18.8.8 SSP_RCM (receive frame credit monitor) state machine.....	471
6.18.8.9 SSP_RIM (receive interlocked frame monitor) state machine.....	472
6.18.8.10 SSP_TC (transmit credit control) state machine	472
6.18.8.11 SSP_TAN (transmit ACK/NAK control) state machine.....	473

6.19 STP link layer	473
6.19.1 STP frame transmission and reception.....	473
6.19.2 STP flow control.....	474
6.19.2.1 STP flow control overview	474
6.19.2.2 SATA frame buffering.....	474
6.19.2.3 STP flow control buffer size.....	475
6.19.2.4 STP flow control example.....	476
6.19.2.5 STP insufficient buffer support	478
6.19.3 Continued primitive sequence.....	478
6.19.4 Affiliations.....	479
6.19.5 Opening an STP connection	481
6.19.6 Closing an STP connection.....	483
6.19.7 STP connection management examples	483
6.19.8 STP (link layer for STP phys) state machines	486
6.19.9 SMP target port support.....	486
6.20 SMP link layer.....	486
6.20.1 SMP frame transmission and reception	486
6.20.2 SMP flow control.....	486
6.20.3 Opening an SMP connection	486
6.20.4 Closing an SMP connection.....	486
6.20.5 SMP (link layer for SMP phys) state machines.....	487
6.20.5.1 SMP state machines overview	487
6.20.5.2 SMP transmitter and receiver.....	487
6.20.5.3 SMP_IP (link layer for SMP initiator phys) state machine	487
6.20.5.3.1 SMP_IP state machine overview.....	487
6.20.5.3.2 SMP_IP1:Idle state	488
6.20.5.3.2.1 State description	488
6.20.5.3.2.2 Transition SMP_IP1:Idle to SMP_IP2:Transmit_Frame.....	488
6.20.5.3.3 SMP_IP2:Transmit_Frame state	489
6.20.5.3.3.1 State description	489
6.20.5.3.3.2 Transition SMP_IP2:Transmit_Frame to SMP_IP3:Receive_Frame	489
6.20.5.3.4 SMP_IP3:Receive_Frame state	489
6.20.5.4 SMP_TP (link layer for SMP target phys) state machine	490
6.20.5.4.1 SMP_TP state machine overview.....	490
6.20.5.4.2 SMP_TP1:Receive_Frame state	490
6.20.5.4.2.1 State description	490
6.20.5.4.2.2 Transition SMP_TP1:Receive_Frame to SMP_TP2:Transmit_Frame.....	491
6.20.5.4.3 SMP_TP2:Transmit_Frame state	491
7 Port layer.....	492
7.1 Port layer overview.....	492
7.2 PL (port layer) state machines.....	492
7.2.1 PL state machines overview	492
7.2.2 PL_OC (port layer overall control) state machine	494
7.2.2.1 PL_OC state machine overview	494
7.2.2.2 PL_OC1:Idle state.....	496
7.2.2.2.1 PL_OC1:Idle state description	496
7.2.2.2.2 Transition PL_OC1:Idle to PL_OC2:Overall_Control.....	497
7.2.2.3 PL_OC2:Overall_Control state.....	497
7.2.2.3.1 PL_OC2:Overall_Control state overview	497
7.2.2.3.2 PL_OC2:Overall_Control state establishing connections.....	498
7.2.2.3.3 PL_OC2:Overall_Control state connection established.....	501
7.2.2.3.4 PL_OC2:Overall_Control state unable to establish a connection — Unable To Connect message.....	502
7.2.2.3.5 PL_OC2:Overall_Control state unable to establish a connection — Unable To Connect message - Retry Open message processed as an Unable To Connect message	502
7.2.2.3.6 PL_OC2:Overall_Control state unable to establish a connection — I_T Nexus Loss timer expires	502

7.2.2.3.7 PL_OC2:Overall_Control state - I_T nexus loss	502
7.2.2.3.8 PL_OC2:Overall_Control state connection management	503
7.2.2.3.9 PL_OC2:Overall_Control state frame transmission	503
7.2.2.3.10 PL_OC2:Overall_Control state frame transmission cancellations	505
7.2.2.3.11 Transition PL_OC2:Overall_Control to PL_OC1:Idle	505
7.2.3 PL_PM (port layer phy manager) state machine	505
7.2.3.1 PL_PM state machine overview	505
7.2.3.2 PL_PM1:Idle state	508
7.2.3.2.1 PL_PM1:Idle state description	508
7.2.3.2.2 Transition PL_PM1:Idle to PL_PM2:Req_Wait	509
7.2.3.2.3 Transition PL_PM1:Idle to PL_PM3:Connected	509
7.2.3.3 PL_PM2:Req_Wait state	509
7.2.3.3.1 PL_PM2:Req_Wait state overview	509
7.2.3.3.2 PL_PM2:Req_Wait establishing a connection	509
7.2.3.3.3 PL_PM2:Req_Wait connection established	509
7.2.3.3.4 PL_PM2:Req_Wait unable to establish a connection	510
7.2.3.3.5 PL_PM2:Req_Wait connection management	511
7.2.3.3.6 Transition PL_PM2:Req_Wait to PL_PM1:Idle	511
7.2.3.3.7 Transition PL_PM2:Req_Wait to PL_PM3:Connected	511
7.2.3.3.8 Transition PL_PM2:Req_Wait to PL_PM4:Wait_For_Close	511
7.2.3.4 PL_PM3:Connected state	511
7.2.3.4.1 PL_PM3:Connected state description	511
7.2.3.4.2 Transition PL_PM3:Connected to PL_PM1:Idle	514
7.2.3.5 PL_PM4:Wait_For_Close state	514
7.2.3.5.1 PL_PM4:Wait_For_Close state description	514
7.2.3.5.2 Transition PL_PM4:Wait_For_Close to PL_PM1:Idle	515
8 Transport layer	516
8.1 Transport layer overview	516
8.2 SSP transport layer	517
8.2.1 SSP frame format	517
8.2.2 Information units	521
8.2.2.1 COMMAND frame - Command information unit	521
8.2.2.2 TASK frame - Task Management Function information unit	522
8.2.2.3 XFER_RDY frame - Transfer Ready information unit	525
8.2.2.4 DATA frame - Data information unit	526
8.2.2.5 RESPONSE frame - Response information unit	528
8.2.2.5.1 RESPONSE frame - Response information unit overview	528
8.2.2.5.2 Response information unit - NO_DATA format	530
8.2.2.5.3 Response information unit - RESPONSE_DATA format	530
8.2.2.5.4 Response information unit - SENSE_DATA format	531
8.2.3 Sequences of SSP frames	532
8.2.3.1 Sequences of SSP frames overview	532
8.2.3.2 Task management function sequence of SSP frames	532
8.2.3.3 Non-data command sequence of SSP frames	533
8.2.3.4 Write command sequence of SSP frames	533
8.2.3.5 Read command sequence of SSP frames	534
8.2.3.6 Bidirectional command sequence of SSP frames	535
8.2.4 SSP transport layer handling of link layer errors	535
8.2.4.1 SSP transport layer handling of link layer errors overview	535
8.2.4.2 COMMAND frame - handling of link layer errors	536
8.2.4.3 TASK frame - handling of link layer errors	536
8.2.4.4 XFER_RDY frame - handling of link layer errors	537
8.2.4.4.1 XFER_RDY frame overview	537
8.2.4.4.2 XFER_RDY frame with transport layer retries enabled	537
8.2.4.4.3 XFER_RDY frame with transport layer retries disabled	538
8.2.4.5 Read DATA frame - handling of link layer errors	538
8.2.4.5.1 Read DATA frame overview	538

8.2.4.5.2 Read DATA frame with transport layer retries enabled	538
8.2.4.5.3 Read DATA frame with transport layer retries disabled.....	538
8.2.4.6 Write DATA frame - handling of link layer errors.....	539
8.2.4.6.1 Write DATA frame overview	539
8.2.4.6.2 Write DATA frame with transport layer retries enabled	539
8.2.4.6.3 Write DATA frame with transport layer retries disabled.....	539
8.2.4.7 RESPONSE frame - handling of link layer errors.....	540
8.2.5 SSP transport layer error handling summary.....	540
8.2.5.1 SSP transport layer error handling summary introduction.....	540
8.2.5.2 SSP initiator port transport layer error handling summary	540
8.2.5.3 SSP target port transport layer error handling summary.....	541
8.2.6 ST (transport layer for SSP ports) state machines	542
8.2.6.1 ST state machines overview	542
8.2.6.2 ST_I (transport layer for SSP initiator ports) state machines	542
8.2.6.2.1 ST_I state machines overview.....	542
8.2.6.2.2 ST_IFR (initiator frame router) state machine	544
8.2.6.2.2.1 ST_IFR state machine overview	544
8.2.6.2.2.2 Processing transport protocol service requests	544
8.2.6.2.2.3 Processing Frame Received confirmations.....	545
8.2.6.2.2.4 Processing Transmission Complete and Reception Complete messages.....	546
8.2.6.2.2.5 Processing miscellaneous requests.....	547
8.2.6.2.3 ST_ITS (initiator transport server) state machine	548
8.2.6.2.3.1 ST_ITS state machine overview	548
8.2.6.2.3.2 ST_ITS1:Initiator_Start state.....	549
8.2.6.2.3.2.1 State description.....	549
8.2.6.2.3.2.2 Transition ST_ITS1:Initiator_Start to ST_ITS3:Prepare_Command.....	549
8.2.6.2.3.2.3 Transition ST_ITS1:Initiator_Start to ST_ITS4:Prepare_Task	549
8.2.6.2.3.3 ST_ITS2:Initiator_Send_Frame state.....	549
8.2.6.2.3.3.1 Transition ST_ITS2:Initiator_Send_Frame to ST_ITS1:Initiator_Start	553
8.2.6.2.3.3.2 Transition ST_ITS2:Initiator_Send_Frame to ST_ITS5:Prepare_Data_Out.....	553
8.2.6.2.3.3.3 Transition ST_ITS2:Initiator_Send_Frame to ST_ITS6:Process_Data_In	553
8.2.6.2.3.4 ST_ITS3:Prepare_Command state.....	554
8.2.6.2.3.4.1 State description.....	554
8.2.6.2.3.4.2 Transition ST_ITS3:Prepare_Command to ST_ITS2:Initiator_Send_Frame	554
8.2.6.2.3.5 ST_ITS4:Prepare_Task state.....	554
8.2.6.2.3.5.1 State description.....	554
8.2.6.2.3.5.2 Transition ST_ITS4:Prepare_Task to ST_ITS2:Initiator_Send_Frame	555
8.2.6.2.3.6 ST_ITS5:Prepare_Data_Out state.....	555
8.2.6.2.3.6.1 State description.....	555
8.2.6.2.3.6.2 Transition ST_ITS5:Prepare_Data_Out to ST_ITS2:Initiator_Send_Frame	556
8.2.6.2.3.7 ST_ITS6:Receive_Data_In state.....	556
8.2.6.2.3.7.1 State description.....	556
8.2.6.2.3.7.2 Transition ST_ITS6:Receive_Data_In to ST_ITS1:Initiator_Start	557
8.2.6.2.3.7.3 Transition ST_ITS6:Receive_Data_In to ST_ITS2:Initiator_Send_Frame	557
8.2.6.3 ST_T (transport layer for SSP target ports) state machines	557
8.2.6.3.1 ST_T state machines overview.....	557
8.2.6.3.2 ST_TFR (target frame router) state machine.....	560
8.2.6.3.2.1 ST_TFR state machine overview	560
8.2.6.3.2.2 Processing Frame Received confirmations.....	560
8.2.6.3.2.3 Processing transport protocol service requests and responses.....	562
8.2.6.3.2.4 Processing miscellaneous requests and confirmations	566
8.2.6.3.3 ST_TTS (target transport server) state machine	566
8.2.6.3.3.1 ST_TTS state machine overview	566
8.2.6.3.3.2 ST_TTS1:Target_Start state	567
8.2.6.3.3.2.1 State description.....	567
8.2.6.3.3.2.2 Transition ST_TTS1:Target_Start to ST_TTS3:Prepare_Data_In.....	568
8.2.6.3.3.2.3 Transition ST_TTS1:Target_Start to ST_TTS4:Prepare_Xfer_Rdy	568
8.2.6.3.3.2.4 Transition ST_TTS1:Target_Start to ST_TTS5:Receive_Data_Out.....	568

8.2.6.3.3.2.5 Transition ST_TTS1:Target_Start to ST_TTS7:Prepare_Response	568
8.2.6.3.3.3 ST_TTS2:Target_Send_Frame state	568
8.2.6.3.3.3.1 State description	568
8.2.6.3.3.3.2 Transition ST_TTS2:Target_Send_Frame to ST_TTS1:Target_Start	572
8.2.6.3.3.3.3 Transition ST_TTS2:Target_Send_Frame to ST_TTS3:Prepare_Data_In	572
8.2.6.3.3.3.4 Transition ST_TTS2:Target_Send_Frame to ST_TTS5:Receive_Data_Out	572
8.2.6.3.3.4 ST_TTS3:Prepare_Data_In state	572
8.2.6.3.3.4.1 State description	572
8.2.6.3.3.4.2 Transition ST_TTS3:Prepare_Data_In to ST_TTS2:Target_Send_Frame	574
8.2.6.3.3.5 ST_TTS4:Prepare_Xfer_Rdy state	574
8.2.6.3.3.5.1 State description	574
8.2.6.3.3.5.2 Transition ST_TTS4:Prepare_Xfer_Rdy to ST_TTS2:Target_Send_Frame	574
8.2.6.3.3.6 ST_TTS5:Receive_Data_Out state	575
8.2.6.3.3.6.1 State description	575
8.2.6.3.3.6.2 Transition ST_TTS5:Receive_Data_Out to ST_TTS1:Target_Start	576
8.2.6.3.3.6.3 Transition ST_TTS5:Receive_Data_Out to ST_TTS4:Prepare_Xfer_Rdy	576
8.2.6.3.3.7 ST_TTS6:Prepare_Response state	577
8.2.6.3.3.7.1 State description	577
8.2.6.3.3.7.2 Transition ST_TTS6:Prepare_Response to ST_TTS2:Target_Send_Frame	578
8.3 STP transport layer	578
8.3.1 Initial FIS	578
8.3.2 BIST Activate FIS	578
8.3.3 TT (transport layer for STP ports) state machines	578
8.4 SMP transport layer	579
8.4.1 SMP transport layer overview	579
8.4.2 SMP_REQUEST frame	580
8.4.3 SMP_RESPONSE frame	581
8.4.4 Sequence of SMP frames	581
8.4.5 MT (transport layer for SMP ports) state machines	582
8.4.5.1 SMP transport layer state machines overview	582
8.4.5.2 MT_IP (transport layer for SMP initiator ports) state machine	582
8.4.5.2.1 MT_IP state machine overview	582
8.4.5.2.2 MT_IP1:Idle state	583
8.4.5.2.2.1 State description	583
8.4.5.2.2.2 Transition MT_IP1:Idle to MT_IP2:Send	583
8.4.5.2.3 MT_IP2:Send state	584
8.4.5.2.3.1 State description	584
8.4.5.2.3.2 Transition MT_IP2:Send to MT_IP1:Idle	584
8.4.5.2.3.3 Transition MT_IP2:Send to MT_IP3:Receive	584
8.4.5.2.4 MT_IP3:Receive state	584
8.4.5.2.4.1 State description	584
8.4.5.2.4.2 Transition MT_IP3:Receive to MT_IP1:Idle	584
8.4.5.3 MT_TP (transport layer for SMP target ports) state machine	584
8.4.5.3.1 MT_TP state machine overview	584
8.4.5.3.2 MT_TP1:Idle state	585
8.4.5.3.2.1 State description	585
8.4.5.3.2.2 Transition MT_TP1:Idle to MT_TP2:Respond	585
8.4.5.3.3 MT_TP2:Respond state	586
8.4.5.3.3.1 State description	586
8.4.5.3.3.2 Transition MT_TP2:Respond to MT_TP1:Idle	586
9 Application layer	587
9.1 Application layer overview	587
9.2 SCSI application layer	587
9.2.1 SCSI transport protocol services	587
9.2.1.1 SCSI transport protocol services overview	587
9.2.1.2 Send SCSI Command transport protocol service	588
9.2.1.3 SCSI Command Received transport protocol service	589

9.2.1.4 Send Command Complete transport protocol service	590
9.2.1.5 Command Complete Received transport protocol service	591
9.2.1.6 Send Data-In transport protocol service	592
9.2.1.7 Data-In Delivered transport protocol service	593
9.2.1.8 Receive Data-Out transport protocol service	593
9.2.1.9 Data-Out Received transport protocol service	594
9.2.1.10 Terminate Data Transfer transport protocol service	594
9.2.1.11 Data Transfer Terminated transport protocol service	595
9.2.1.12 Send Task Management Request transport protocol service	595
9.2.1.13 Task Management Request Received transport protocol service	596
9.2.1.14 Task Management Function Executed transport protocol service	597
9.2.1.15 Received Task Management Function Executed transport protocol service	598
9.2.2 SCSI application client error handling	599
9.2.3 SCSI device server error handling	600
9.2.3.1 SCSI Command Received () error handling	600
9.2.3.2 Data-Out Received () error handling	600
9.2.4 Task router and task manager error handling	601
9.2.5 SCSI transport protocol services for event notifications	601
9.2.6 SCSI commands	602
9.2.6.1 INQUIRY command	602
9.2.6.2 LOG SELECT and LOG SENSE commands	602
9.2.6.3 MODE SELECT and MODE SENSE commands	602
9.2.6.4 SEND DIAGNOSTIC and RECEIVE DIAGNOSTIC RESULTS commands	602
9.2.6.5 START STOP UNIT command	602
9.2.7 SCSI mode parameters	602
9.2.7.1 SCSI mode parameters overview	602
9.2.7.2 Disconnect-Reconnect mode page	603
9.2.7.2.1 Disconnect-Reconnect mode page overview	603
9.2.7.2.2 BUS INACTIVITY TIME LIMIT field	604
9.2.7.2.3 MAXIMUM CONNECT TIME LIMIT field	605
9.2.7.2.4 MAXIMUM BURST SIZE field	605
9.2.7.2.5 FIRST BURST SIZE field	605
9.2.7.3 Protocol Specific Logical Unit mode page	606
9.2.7.4 Protocol Specific Port mode page	606
9.2.7.5 Phy Control And Discover mode page	608
9.2.7.6 Shared Port Control mode page	612
9.2.7.7 Enhanced Phy Control mode page	613
9.2.8 SCSI log parameters	615
9.2.8.1 Protocol Specific Port log page	615
9.2.8.2 Protocol Specific Port log parameter for SAS target ports	616
9.2.9 SCSI diagnostic parameters	619
9.2.9.1 SCSI diagnostic parameters overview	619
9.2.9.2 Protocol Specific diagnostic page	619
9.2.9.3 Enclosure Control diagnostic page	625
9.2.9.4 Enclosure Status diagnostic page	625
9.2.9.5 Additional Element Status diagnostic page	625
9.2.10 SCSI power conditions	626
9.2.10.1 SCSI power conditions overview	626
9.2.10.2 SA_PC (SCSI application layer power condition) state machine	626
9.2.10.2.1 SA_PC state machine overview	626
9.2.10.2.2 SA_PC_0:Powered_On state	630
9.2.10.2.2.1 State description	630
9.2.10.2.2.2 Transition SA_PC_0:Powered_On to SA_PC_4:Active_Wait	630
9.2.10.2.2.3 Transition SA_PC_0:Powered_On to SA_PC_8:Stopped	630
9.2.10.2.3 SA_PC_1:Active state	630
9.2.10.2.3.1 State description	630
9.2.10.2.3.2 Transition SA_PC_1:Active to SA_PC_5:Wait_Idle	630
9.2.10.2.3.3 Transition SA_PC_1:Active to SA_PC_6:Wait_Standby	630

9.2.10.2.3.4 Transition SA_PC_1:Active to SA_PC_10:Wait_Stopped	630
9.2.10.2.4 SA_PC_2:Idle state	630
9.2.10.2.4.1 State description	630
9.2.10.2.4.2 Transition SA_PC_2:Idle to SA_PC_4:Active_Wait	630
9.2.10.2.4.3 Transition SA_PC_2:Idle to SA_PC_5:Wait_Idle	630
9.2.10.2.4.4 Transition SA_PC_2:Idle to SA_PC_6:Wait_Standby	631
9.2.10.2.4.5 Transition SA_PC_2:Idle to SA_PC_7:Idle_Wait	631
9.2.10.2.4.6 Transition SA_PC_2:Idle to SA_PC_10:Wait_Stopped	631
9.2.10.2.5 SA_PC_3:Standby state	631
9.2.10.2.5.1 State description	631
9.2.10.2.5.2 Transition SA_PC_3:Standby to SA_PC_4:Active_Wait	631
9.2.10.2.5.3 Transition SA_PC_3:Standby to SA_PC_6:Wait_Standby	631
9.2.10.2.5.4 Transition SA_PC_3:Standby to SA_PC_7:Idle_Wait	631
9.2.10.2.5.5 Transition SA_PC_3:Standby to SA_PC_9: Standby_Wait	631
9.2.10.2.5.6 Transition SA_PC_3:Standby to SA_PC_10:Wait_Stopped	631
9.2.10.2.6 SA_PC_4:Active_Wait state	632
9.2.10.2.6.1 State description	632
9.2.10.2.6.2 Transition SA_PC_4:Active_Wait to SA_PC_1:Active	633
9.2.10.2.7 SA_PC_5:Wait_Idle state	634
9.2.10.2.7.1 SA_PC_5:Wait_Idle state description	634
9.2.10.2.7.2 Transition SA_PC_5:Wait_Idle to SA_PC_2:Idle	634
9.2.10.2.8 SA_PC_6:Wait_Standby state	634
9.2.10.2.8.1 SA_PC_6:Wait_Standby state description	634
9.2.10.2.8.2 Transition SA_PC_6:Wait_Standby to SA_PC_3:Standby	634
9.2.10.2.9 SA_PC_7:Idle_Wait state	634
9.2.10.2.9.1 State description	634
9.2.10.2.9.2 Transition SA_PC_7:Idle_Wait to SA_PC_2:Idle	635
9.2.10.2.10 SA_PC_8:Stopped state	635
9.2.10.2.10.1 State description	635
9.2.10.2.10.2 Transition SA_PC_8:Stopped to SA_PC_4:Active_Wait	636
9.2.10.2.10.3 Transition SA_PC_8:Stopped to SA_PC_7:Idle_Wait	636
9.2.10.2.10.4 Transition SA_PC_8:Stopped to SA_PC_9:Standby_Wait	636
9.2.10.2.11 SA_PC_9:Standby_Wait state	636
9.2.10.2.11.1 SA_PC_9:Standby_Wait state description	636
9.2.10.2.11.2 Transition SA_PC_9:Standby_Wait to SA_PC_3:Standby	636
9.2.10.2.12 SA_PC_10:Wait_Stopped state	636
9.2.10.2.12.1 SA_PC_10:Wait_Stopped state description	636
9.2.10.2.12.2 Transition SA_PC_10:Wait_Stopped to SA_PC_8:Stopped	636
9.2.11 SCSI vital product data (VPD)	636
9.2.11.1 SCSI vital product data (VPD) overview	636
9.2.11.2 Device Identification VPD page	636
9.2.11.3 Protocol Specific Logical Unit Information VPD page	638
9.3 ATA application layer	640
9.4 Management application layer	640
9.4.1 READY LED signal behavior	640
9.4.2 Management protocol services	641
9.4.3 SMP functions	642
9.4.3.1 SMP functions overview	642
9.4.3.2 SMP function request frame format	644
9.4.3.2.1 SMP function request frame format overview	644
9.4.3.2.2 SMP FRAME TYPE field	644
9.4.3.2.3 FUNCTION field	644
9.4.3.2.4 ALLOCATED RESPONSE LENGTH field	644
9.4.3.2.5 REQUEST LENGTH field	645
9.4.3.2.6 Additional request bytes	645
9.4.3.2.7 CRC field	646
9.4.3.3 SMP function response frame format	646
9.4.3.3.1 SMP function response frame format overview	646

9.4.3.3.2 SMP FRAME TYPE field	646
9.4.3.3.3 FUNCTION field	646
9.4.3.3.4 FUNCTION RESULT field	647
9.4.3.3.5 RESPONSE LENGTH field	654
9.4.3.3.6 Additional response bytes	655
9.4.3.3.7 CRC field	655
9.4.3.4 REPORT GENERAL function	655
9.4.3.5 REPORT MANUFACTURER INFORMATION function	662
9.4.3.6 REPORT SELF-CONFIGURATION STATUS function	665
9.4.3.6.1 REPORT SELF-CONFIGURATION STATUS function overview	665
9.4.3.6.2 REPORT SELF-CONFIGURATION STATUS request	665
9.4.3.6.3 REPORT SELF-CONFIGURATION STATUS response	666
9.4.3.6.4 Self-configuration status descriptor	668
9.4.3.7 REPORT ZONE PERMISSION TABLE function	670
9.4.3.7.1 REPORT ZONE PERMISSION TABLE function overview	670
9.4.3.7.2 REPORT ZONE PERMISSION TABLE request	670
9.4.3.7.3 REPORT ZONE PERMISSION TABLE response	672
9.4.3.7.4 Zone permission descriptor	673
9.4.3.8 REPORT ZONE MANAGER PASSWORD function	674
9.4.3.9 REPORT BROADCAST function	676
9.4.3.9.1 REPORT BROADCAST function overview	676
9.4.3.9.2 REPORT BROADCAST request	677
9.4.3.9.3 REPORT BROADCAST response	678
9.4.3.9.4 Broadcast descriptor	679
9.4.3.10 DISCOVER function	680
9.4.3.11 REPORT PHY ERROR LOG function	697
9.4.3.12 REPORT PHY SATA function	700
9.4.3.13 REPORT ROUTE INFORMATION function	704
9.4.3.14 REPORT PHY EVENT function	707
9.4.3.14.1 REPORT PHY EVENT function overview	707
9.4.3.14.2 REPORT PHY EVENT request	707
9.4.3.14.3 REPORT PHY EVENT response	709
9.4.3.14.4 Phy event descriptor	710
9.4.3.15 DISCOVER LIST function	710
9.4.3.15.1 DISCOVER LIST function overview	710
9.4.3.15.2 DISCOVER LIST request	711
9.4.3.15.3 DISCOVER LIST response	713
9.4.3.15.4 DISCOVER LIST response SHORT FORMAT descriptor	715
9.4.3.16 REPORT PHY EVENT LIST function	716
9.4.3.16.1 REPORT PHY EVENT LIST function overview	716
9.4.3.16.2 REPORT PHY EVENT LIST request	716
9.4.3.16.3 REPORT PHY EVENT LIST response	717
9.4.3.16.4 Phy event list descriptor	719
9.4.3.17 REPORT EXPANDER ROUTE TABLE LIST function	719
9.4.3.17.1 REPORT EXPANDER ROUTE TABLE LIST function overview	719
9.4.3.17.2 REPORT EXPANDER ROUTE TABLE LIST request	720
9.4.3.17.3 REPORT EXPANDER ROUTE TABLE LIST response	722
9.4.3.17.4 Expander route table descriptor	724
9.4.3.18 CONFIGURE GENERAL function	724
9.4.3.19 ENABLE DISABLE ZONING function	728
9.4.3.20 ZONED BROADCAST function	730
9.4.3.21 ZONE LOCK function	732
9.4.3.22 ZONE ACTIVATE function	734
9.4.3.23 ZONE UNLOCK function	736
9.4.3.24 CONFIGURE ZONE MANAGER PASSWORD function	737
9.4.3.25 CONFIGURE ZONE PHY INFORMATION function	740
9.4.3.25.1 CONFIGURE ZONE PHY INFORMATION function overview	740
9.4.3.25.2 CONFIGURE ZONE PHY INFORMATION request	740

9.4.3.25.3 Zone phy configuration descriptor	741
9.4.3.25.4 CONFIGURE ZONE PHY INFORMATION response	742
9.4.3.26 CONFIGURE ZONE PERMISSION TABLE function	742
9.4.3.26.1 CONFIGURE ZONE PERMISSION TABLE function overview	742
9.4.3.26.2 CONFIGURE ZONE PERMISSION TABLE request	743
9.4.3.26.3 Zone permission configuration descriptor	745
9.4.3.26.4 CONFIGURE ZONE PERMISSION TABLE response	746
9.4.3.27 CONFIGURE ROUTE INFORMATION function	747
9.4.3.28 PHY CONTROL function	749
9.4.3.29 PHY TEST FUNCTION function	757
9.4.3.30 CONFIGURE PHY EVENT function	761
9.4.3.30.1 CONFIGURE PHY EVENT function overview	761
9.4.3.30.2 CONFIGURE PHY EVENT request	761
9.4.3.30.3 Phy event configuration descriptor	762
9.4.3.30.4 CONFIGURE PHY EVENT response	763
Annex A (normative) Jitter tolerance patterns	764
A.1 Jitter tolerance pattern (JTPAT)	764
A.2 Compliant jitter tolerance pattern (CJTPAT)	764
A.3 Considerations for a phy transmitting JTPAT and CJTPAT	770
A.4 Considerations for a phy receiving JTPAT and CJTPAT	770
Annex B (informative) SAS to SAS phy reset sequence examples	772
Annex C (informative) CRC	777
C.1 CRC generator and checker implementation examples	777
C.2 CRC implementation in C	777
C.3 CRC implementation with XORs	778
C.4 CRC examples	780
Annex D (informative) SAS address hashing	781
D.1 SAS address hashing overview	781
D.2 Hash collision probability	781
D.3 Hash generation	782
D.4 Hash implementation in C	782
D.5 Hash implementation with XORs	783
D.6 Hash examples	784
Annex E (informative) Scrambling	787
E.1 Scrambler implementation example	787
E.2 Scrambler implementation in C	787
E.3 Scrambler implementation with XORs	788
E.4 Scrambler examples	789
Annex F (informative) ATA architectural notes	791
F.1 STP differences from Serial ATA (SATA)	791
F.2 STP differences from Serial ATA II	791
F.3 Affiliation policies	791
F.3.1 Affiliation policies overview	791
F.3.2 Affiliation policy for static STP initiator port to STP target port mapping	792
F.3.3 Affiliation policy with SATA queued commands and multiple STP initiator ports	792
F.3.4 Applicability of affiliation for STP target ports	792
F.4 SATA port selector considerations	792
F.5 SATA device not transmitting initial Register Device-to-Host FIS	792
Annex G (informative) Minimum deletable primitive insertion rate summary	794
Annex H (informative) Zone permission configuration descriptor examples	795

Annex I (informative) SAS addressing	798
I.1 SAS addressing in SAS domains	798
I.2 Expander device SAS addresses	798
Annex J (informative) Expander device handling of connections.....	799
J.1 Expander device handling of connections overview	799
J.2 Connection request - OPEN_ACCEPT	801
J.3 Connection request - OPEN_REJECT by end device	802
J.4 Connection request - OPEN_REJECT by expander device	803
J.5 Connection request - arbitration lost.....	804
J.6 Connection request - backoff and retry.....	805
J.7 Connection request - backoff and reverse path.....	806
J.8 Connection close - single step.....	807
J.9 Connection close - simultaneous.....	808
J.10 BREAK handling during path arbitration when the BREAK_REPLY method is disabled.....	809
J.11 BREAK handling during connection when the BREAK_REPLY method is disabled.....	810
J.12 BREAK handling during path arbitration when the BREAK_REPLY method is enabled	811
J.13 BREAK handling during connection when BREAK_REPLY method is enabled	812
J.14 STP connection - originated by STP initiator port.....	813
J.15 STP connection - originated by STP target port in an STP SATA bridge.....	814
J.16 STP connection close - originated by STP initiator port	815
J.17 STP connection close - originated by STP target port in an STP SATA bridge.....	816
J.18 Connection request - XL1:Request_Path to XL5:Forward_Open transition	817
J.19 Pathway blocked and pathway recovery example.....	818
Annex K (informative) Primitive encoding	820
Annex L (informative) Standards bodies contact information.....	823
Bibliography	824

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 1 — Organization of this standard	38
Figure 2 — SCSI document relationships	39
Figure 3 — ATA document relationships	39
Figure 4 — Examples of association relationships in class diagrams	79
Figure 5 — Examples of aggregation relationships in class diagrams	80
Figure 6 — Example of generalization relationships in class diagrams	81
Figure 7 — Example of a dependency relationship in class diagrams	81
Figure 8 — Examples of link relationships for object diagrams	82
Figure 9 — State machine conventions	83
Figure 10 — SAS Domain class diagram	88
Figure 11 — Phy class diagram	90
Figure 12 — SAS phy object diagram	91
Figure 13 — Expander phy object diagram	92
Figure 14 — Ports (narrow ports and wide ports)	94
Figure 15 — Port class diagram	95
Figure 16 — Port object diagram	96
Figure 17 — SAS devices	97
Figure 18 — Expander device	98
Figure 19 — Domains	99
Figure 20 — SAS domain bridging to ATA domains	100
Figure 21 — SAS domains bridging to ATA domains with SATA port selectors	101
Figure 22 — Devices spanning SAS domains	102
Figure 23 — Single expander device topology example	102
Figure 24 — Multiple expander device topologies	103
Figure 25 — Potential pathways	104
Figure 26 — Multiple connections on wide ports	106
Figure 27 — State machines for SAS devices	115
Figure 28 — State machines for expander devices	116
Figure 29 — Transmit data path in a SAS phy	117
Figure 30 — SSP link, port, SSP transport, and SCSI application layer state machines	118
Figure 31 — SMP link, port, SMP transport, and management application layer state machines	119
Figure 32 — STP link, port, STP transport, and ATA application layer state machines	120
Figure 33 — Transmit data path and state machines in an expander phy	121
Figure 34 — Receive data path in a SAS phy	123
Figure 35 — Receive data path in an expander phy	124
Figure 36 — State machines and SAS Device classes	125
Figure 37 — State machines and Expander Device classes	126
Figure 38 — Reset terminology	127
Figure 39 — Expander device model	130
Figure 40 — Expander device interfaces	133
Figure 41 — Expander device interface detail	134
Figure 42 — Phy-based expander route table	142
Figure 43 — Expander-based expander route table	143
Figure 44 — Level-order traversal example	145
Figure 45 — Examples of invalid topologies	149
Figure 46 — Externally configurable expander device and table-to-table attachment	152
Figure 47 — Expander route index levels example	153
Figure 48 — Expander route index order example	155
Figure 49 — Zoning example	157
Figure 50 — One ZPSDS example	158
Figure 51 — Zone manager location examples	159
Figure 52 — Three ZPSDSes example	160
Figure 53 — Extending a ZPSDS example	162
Figure 54 — Overtaking a ZPSDS example	163
Figure 55 — Zoning expander route table	168
Figure 56 — SAS bit transmission logic	194
Figure 57 — SAS bit reception logic	195
Figure 58 — OOB signal transmission	196

Figure 59 – OOB signal detection	198
Figure 60 – TTIU transmitter BMC encoding	204
Figure 61 – TTIU bit cell transmitter encoding	205
Figure 62 – TTIU bit cell receiver decoding	206
Figure 63 – SATA OOB sequence	215
Figure 64 – SATA speed negotiation sequence	215
Figure 65 – SAS to SATA OOB sequence	217
Figure 66 – SAS to SAS OOB sequence	218
Figure 67 – SNW-1, SNW-2, and Final-SNW	222
Figure 68 – SNW-3	223
Figure 69 – Train_Tx-SNW	225
Figure 70 – Pattern marker transmission	226
Figure 71 – Valid pattern marker detection	227
Figure 72 – Train_Rx-SNW	228
Figure 73 – SAS speed negotiation sequence SNW flowchart	230
Figure 74 – SAS speed negotiation sequence (both phys SNW-1 through Train_Rx-SNW with no Train_Tx-SNW)	232
Figure 75 – SAS speed negotiation sequence (both phys SNW-1 through Train_Rx-SNW with Train_Tx-SNW)	233
Figure 76 – SAS speed negotiation sequence (phy A: SNW-1 through SNW-3, phy B: SNW-2 only)	234
Figure 77 – SAS speed negotiation sequence (phy A: SNW-3 only, phy B: SNW-1 only)	235
Figure 78 – SAS speed negotiation sequence - phy reset problem in Final-SNW	236
Figure 79 – SAS speed negotiation sequence - phy reset problem in SNW-3	237
Figure 80 – SAS speed negotiation sequence - phy reset problem in Train_Rx-SNW	238
Figure 81 – SAS speed negotiation sequence - multiple Train_Rx-SNWs	239
Figure 82 – Local phy achieves pattern lock before the attached phy achieves pattern lock	241
Figure 83 – Local phy achieves pattern lock after the attached phy achieves pattern lock	242
Figure 84 – Attached receiver handshake sequence (requesting two increments to coefficient 1)	244
Figure 85 – Attached receiver handshake sequence (requesting a decrement and an increment to coefficient 1)	245
Figure 86 – Handshake sequence to set local phy's receiver coefficients to no_equalization values (attached phy)	247
Figure 87 – Handshake sequence to set local phy's receiver coefficients to no_equalization values (local phy)	248
Figure 88 – Local phy's receiver indicates completion of training before the attached phy's receiver completes training	249
Figure 89 – Attached phy's receiver indicates completion of training before the local phy's receiver completes training	250
Figure 90 – Processing an invalid TTIU	252
Figure 91 – Hot-plug and the phy reset sequence	254
Figure 92 – Transition to active phy power condition	255
Figure 93 – Hot plug and low phy power condition	256
Figure 94 – SP (phy layer) state machine - OOB sequence states	262
Figure 95 – SP (phy layer) state machine - SAS speed negotiation states	268
Figure 96 – SP (phy layer) state machine - SAS speed negotiation states for SNW-3 and Train_Rx-SNW and Train_Tx-SNW	269
Figure 97 – SP (phy layer) state machine - SAS phy power condition states	280
Figure 98 – SP (phy layer) state machine - SATA host emulation states	283
Figure 99 – SP (phy layer) state machine – SATA port selector state	288
Figure 100 – SP (phy layer) state machine - SATA spinup hold state	289
Figure 101 – SP_DWS (phy layer dword synchronization) state machine	291
Figure 102 – PTT_T (phy layer transmitter training transmit pattern) state machine	302
Figure 103 – PTT_R (phy layer transmitter training receive pattern) state machine	310
Figure 104 – PTT_SC1, PTT_SC2, and PTT_SC3 (phy layer transmitter training set transmitter coefficient) state machines	318
Figure 105 – PTT_GC1, PTT_GC2, and PTT_GC3 (phy layer transmitter training get transmitter coefficient) state machines	323
Figure 106 – PTT_PL (phy layer transmitter training pattern lock) state machine	327

Figure 107 – Multiplexing disabled	330
Figure 108 – Multiplexing enabled	330
Figure 109 – Transmitting a repeated primitive sequence	343
Figure 110 – Receiving a repeated primitive sequence	344
Figure 111 – Extended primitive sequences	345
Figure 112 – Triple primitive sequences	346
Figure 113 – Redundant primitive sequences	347
Figure 114 – Elasticity buffer	360
Figure 115 – Address frame, SSP frame, and SMP frame CRC bit ordering	365
Figure 116 – STP frame CRC bit ordering	366
Figure 117 – Transmit path bit ordering	369
Figure 118 – Receive path bit ordering	370
Figure 119 – STP transmit path bit ordering	371
Figure 120 – STP receive path bit ordering	372
Figure 121 – Address frame transmission	372
Figure 122 – Identification sequence	382
Figure 123 – Hard reset sequence	383
Figure 124 – SL_IR (link layer identification and hard reset) state machines	385
Figure 125 – Transitioning from the active phy power condition to a low phy power condition	390
Figure 126 – SL_P_S (link layer power source device) state machine	394
Figure 127 – SL_P_C (link layer power consumer device) state machine	398
Figure 128 – Example simultaneous connection recommendations for wide ports	404
Figure 129 – Aborting a connection request with a BREAK primitive sequence	413
Figure 130 – Connection request timeout example	414
Figure 131 – Closing a connection example	415
Figure 132 – Rate matching example	418
Figure 133 – SL (link layer for SAS logical phys) state machines (part 1)	420
Figure 134 – SL (link layer for SAS logical phys) state machines (part 2)	421
Figure 135 – SL (link layer for SAS logical phys) state machines (part 3)	422
Figure 136 – XL (link layer for expander logical phys) state machine (part 1)	439
Figure 137 – XL (link layer for expander logical phys) state machine (part 2)	440
Figure 138 – XL (link layer for expander logical phys) state machine (part 3)	441
Figure 139 – XL (link layer for expander logical phys) state machine (part 4)	442
Figure 140 – SSP frame transmission	458
Figure 141 – Interlocked frames	460
Figure 142 – Non-interlocked frames with the same initiator port transfer tags	460
Figure 143 – Non-interlocked frames with different initiator port transfer tags	461
Figure 144 – Closing an SSP connection example	462
Figure 145 – SSP (link layer for SSP phys) state machines (part 1 - frame transmission)	464
Figure 146 – SSP (link layer for SSP phys) state machines (part 2 - frame reception)	465
Figure 147 – STP frame transmission	473
Figure 148 – STP flow control	477
Figure 149 – Transmitting a continued primitive sequence	478
Figure 150 – Receiving a continued primitive sequence	479
Figure 151 – Example simultaneous connection recommendations for an expander device	482
Figure 152 – STP initiator port opening an STP connection	484
Figure 153 – STP target port opening an STP connection	485
Figure 154 – SMP frame transmission	486
Figure 155 – SMP_IP (link layer for SMP initiator phys) state machine	488
Figure 156 – SMP_TP (link layer for SMP target phys) state machine	490
Figure 157 – Port layer examples	493
Figure 158 – PL_OC (port layer overall control) state machine	496
Figure 159 – PL_PM (port layer phy manager) state machine (part 1)	507
Figure 160 – PL_PM (port layer phy manager) state machine (part 2)	508
Figure 161 – Task management function sequence of SSP frames	532
Figure 162 – Non-data command sequence of SSP frames	533
Figure 163 – Write command sequence of SSP frames	533
Figure 164 – Read command sequence of SSP frames	534

Figure 165 – Bidirectional command sequence of SSP frames	535
Figure 166 – ST_I (transport layer for SSP initiator ports) state machines	543
Figure 167 – ST_T (transport layer for SSP target ports) state machines	559
Figure 168 – Sequence of SMP frames	581
Figure 169 – MT_IP (transport layer for SMP initiator ports) state machine	583
Figure 170 – MT_TP (transport layer for SMP target ports) state machine	585
Figure 171 – SA_PC (SCSI application layer power condition) state machine for SAS	629
Figure A.1 – CJTPAT pre-scrambling	765
Figure B.1 – SAS speed negotiation sequence (phy A: SNW-1 only, phy B: SNW-1 only)	772
Figure B.2 – SAS speed negotiation sequence (phy A: SNW-1, SNW-2, phy B: SNW-1, SNW-2)	773
Figure B.3 – SAS speed negotiation sequence (phy A: SNW-1, SNW-2, and SNW-3, phy B: SNW-1 and SNW-2)	774
Figure B.4 – SAS speed negotiation sequence (phy A: SNW-2, SNW-3, phy B: SNW-1, SNW-2)	775
Figure B.5 – SAS speed negotiation sequence (phy A: SNW-1 only, phy B: SNW-2 only)	776
Figure C.1 – CRC generator example	777
Figure C.2 – CRC checker example	777
Figure D.1 – BCH(69, 39, 9) code generator	782
Figure E.1 – Scrambler	787
Figure J.1 – Example topology	799
Figure J.2 – Connection request - OPEN_ACCEPT	801
Figure J.3 – Connection request - OPEN_REJECT by end device	802
Figure J.4 – Connection request - OPEN_REJECT by expander device	803
Figure J.5 – Connection request - arbitration lost	804
Figure J.6 – Connection request - backoff and retry	805
Figure J.7 – Connection request - backoff and reverse path	806
Figure J.8 – Connection close - single step	807
Figure J.9 – Connection close - simultaneous	808
Figure J.10 – BREAK handling during path arbitration when the BREAK_REPLY method is disabled	809
Figure J.11 – BREAK handling during a connection when the BREAK_REPLY method is disabled	810
Figure J.12 – BREAK handling during path arbitration when the BREAK_REPLY method is enabled	811
Figure J.13 – BREAK handling during a connection when the BREAK_REPLY method is enabled	812
Figure J.14 – STP connection - originated by STP initiator port	813
Figure J.15 – STP connection - originated by STP target port in an STP SATA bridge	814
Figure J.16 – STP connection close - originated by STP initiator port	815
Figure J.17 – STP connection close - originated by STP target port in an STP SATA bridge	816
Figure J.18 – XL1:Request_Path to XL5:Forward_Open transition	817
Figure J.19 – Partial pathway recovery	818

Table 1 – Numbering conventions	76
Table 2 – Constraint and note notation	77
Table 3 – Class diagram notation for classes	78
Table 4 – Multiplicity notation	78
Table 5 – Class diagram notation for associations	79
Table 6 – Class diagram notation for aggregations	80
Table 7 – Class diagram notation for generalizations	80
Table 8 – Class diagram notation for dependency	81
Table 9 – Object diagram notation for objects	82
Table 10 – Object diagram notation for link	82
Table 11 – Data dword containing a value	85
Table 12 – Data dword containing four one-byte fields	85
Table 13 – Logical links	93
Table 14 – Broadcast types	107
Table 15 – Names and identifiers	109
Table 16 – SCSI architecture model object attribute mapping	109
Table 17 – NAA IEEE Registered format	110
Table 18 – NAA Locally Assigned format	111
Table 19 – Hashed SAS address code parameters	111
Table 20 – Device name created from the IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device world wide name	113
Table 21 – Expander logical phy to ECM requests	135
Table 22 – Expander logical phy to ECM responses	135
Table 23 – ECM to expander logical phy confirmations	136
Table 24 – Expander logical phy to ECR to expander logical phy requests and indications	137
Table 25 – Expander logical phy to ECR to expander logical phy responses and confirmations	138
Table 26 – Expander logical phy to BPP requests	139
Table 27 – BPP to expander logical phy indications	139
Table 28 – Routing attributes and routing methods	140
Table 29 – Expander route table types	141
Table 30 – Expander route table levels for externally configurable expander device R phy A	154
Table 31 – Expander route table levels for externally configurable expander device N	154
Table 32 – Expander route entries for externally configurable expander device E0 phy 1	156
Table 33 – Expander route entries for externally configurable expander device F phy 0	156
Table 34 – Zone manager password	161
Table 35 – Zone phy information	164
Table 36 – Zone phy information usage	164
Table 37 – Zone groups	166
Table 38 – Zone permission table	167
Table 39 – Zone permission table granting minimal permissions	167
Table 40 – Source zone group determination	169
Table 41 – Destination zone group determination	169
Table 42 – REQUESTED INSIDE ZPSDS bit and INSIDE ZPSDS PERSISTENT bit changes after a link reset sequence	170
Table 43 – ZONE GROUP field values if the ZONE GROUP PERSISTENT bit is set to one	171
Table 44 – Conditions that cause the ZONE GROUP field to be reset if the ZONE GROUP PERSISTENT bit is set to zero	171
Table 45 – PHY EVENT SOURCE field	180
Table 46 – Bit designations	184
Table 47 – Conversion from byte notation to character name example	185
Table 48 – Data characters	187
Table 49 – Control characters	192
Table 50 – Control character usage	192
Table 51 – Delayed code violation example	193
Table 52 – SNW-3 phy capabilities	199
Table 53 – Requested logical link rate	200
Table 54 – Multiplexing negotiation	201
Table 55 – Supported settings bit priorities	202

Table 56 – Example SNW-3 phy capabilities values.....	203
Table 57 – Train_Tx-SNW TTIU bit.....	206
Table 58 – Train_Tx-SNW TTIU	206
Table 59 – PATTERN TYPE field.....	207
Table 60 – Control/Status TTIU	207
Table 61 – COEFFICIENT SETTINGS field	208
Table 62 – COEFFICIENT 1 REQUEST field, COEFFICIENT 2 REQUEST field, and COEFFICIENT 3 REQUEST field ..	209
Table 63 – Valid coefficient requests	210
Table 64 – COEFFICIENT 1 STATUS field, COEFFICIENT 2 STATUS field, and COEFFICIENT 3 STATUS field	211
Table 65 – Error Response TTIU	211
Table 66 – ERROR CODE field.....	213
Table 67 – Phy reset sequence timing specifications	214
Table 68 – SATA speed negotiation sequence timing specifications.....	216
Table 69 – SAS speed negotiation sequence timing specifications.....	220
Table 70 – SNW rates used in SNW-1, SNW-2, and Final-SNW.....	222
Table 71 – SNW-3 phy capabilities bit	223
Table 72 – Transmitter training pattern	225
Table 73 – Receiver training patterns	228
Table 74 – SP state machine timers	259
Table 75 – Messages to SP transmitter and SP receiver at start of RCDT	270
Table 76 – SP_DWS state machine timers.....	290
Table 77 – Mapping messages to the Training Control word.....	305
Table 78 – Mapping messages from PTT_SC1 state machine, PTT_SC2 state machine, and PTT_SC3 state machine to the Training Status word.....	305
Table 79 – Mapping Transmit Error Response message arguments to Error Response TTIU fields	306
Table 80 – Transmit Error Response message arguments sent to PTT_T state machine	312
Table 81 – Mapping the Training Status word to SP receiver messages	313
Table 82 – Mapping the Training Status word to PTT_GC1 state machine messages, PTT_GC2 state machine messages, and PTT_GC3 state machine messages.....	314
Table 83 – Mapping the Training Control word to PTT_SC1 state machine messages, PTT_SC2 state machine messages, and PTT_SC3 state machine messages	315
Table 84 – Mapping Coefficient Request byte to PTT_SC3 state machine message, PTT_SC2 state machine message, and PTT_SC1 state machine messages	316
Table 85 – Mapping messages to the PTT_T state machine.....	320
Table 86 – PTT_SC1 messages to substitute for PTT_SC2 messages	321
Table 87 – PTT_SC1 messages to substitute for PTT_SC3 messages	322
Table 88 – Mapping messages to the PTT_T state machine.....	324
Table 89 – PTT_GC1 messages to substitute for PTT_GC2 messages	325
Table 90 – PTT_GC1 messages to substitute for PTT_GC2 messages	325
Table 91 – Primitive format	332
Table 92 – Deletable primitives.....	333
Table 93 – Primitives not specific to type of connection	334
Table 94 – Primitives used inside SSP and SMP connections	336
Table 95 – Primitives used inside STP connections and on SATA physical links.....	337
Table 96 – Primitive encoding for deletable primitives.....	338
Table 97 – Primitive encoding for primitives not specific to type of connection	339
Table 98 – Primitive encoding for primitives used only inside SSP and SMP connections	341
Table 99 – Primitive encoding for primitives that are used only inside STP connections and only on SATA physical links	342
Table 100 – Primitive sequences.....	343
Table 101 – ALIGN primitives	348
Table 102 – MUX primitives	349
Table 103 – NOTIFY primitives.....	349
Table 104 – AIP primitives	351
Table 105 – BROADCAST primitives.....	352
Table 106 – CLOSE primitives.....	352
Table 107 – Abandon-class OPEN_REJECT primitives.....	354
Table 108 – Retry-class OPEN_REJECT primitives.....	355

Table 109 – PS_REQ primitives	356
Table 110 – DONE primitives.....	357
Table 111 – NAK primitives.....	358
Table 112 – RRDY primitives.....	358
Table 113 – Physical link rate tolerance management deletable primitive insertion requirement.....	361
Table 114 – CRC notation and definitions	363
Table 115 – Scrambling for different data dword types.....	367
Table 116 – Address frame format.....	373
Table 117 – ADDRESS FRAME TYPE field	373
Table 118 – IDENTIFY address frame format.....	374
Table 119 – DEVICE TYPE field	375
Table 120 – REASON field	375
Table 121 – POWER CAPABLE field	377
Table 122 – OPEN address frame format.....	378
Table 123 – SAS PROTOCOL field.....	379
Table 124 – FEATURES field	379
Table 125 – CONNECTION RATE field	379
Table 126 – ARBITRATION WAIT TIME field	381
Table 127 – SL_IR_IRC state machine timers.....	384
Table 128 – PS_ACK pattern.....	391
Table 129 – SL_P_S state machine timers.....	393
Table 130 – SL_P_C state machine timers.....	397
Table 131 – Connection results of a connection request.....	405
Table 132 – Arbitration priority for OPEN address frames passing on a logical link.....	406
Table 133 – Arbitration priority for a Request Path request in the ECM	409
Table 134 – Pathway recovery priority.....	411
Table 135 – Results of aborting a connection request.....	412
Table 136 – Results of closing a connection.....	414
Table 137 – Results of breaking a connection.....	416
Table 138 – Rate matching deletable primitive insertion requirements	417
Table 139 – SL_CC state machine timers	426
Table 140 – SL_CC state machine variables.....	426
Table 141 – OPEN_REJECT Received message to Open Failed confirmation mapping	430
Table 142 – XL state machine timers.....	438
Table 143 – XL state machine variable.....	438
Table 144 – SSP frame interlock requirements	459
Table 145 – SSP state machines timers.....	463
Table 146 – STP link layer differences from SATA link layer during an STP connection	474
Table 147 – Affiliation policies.....	479
Table 148 – Affiliation context relative identifier example	481
Table 149 – PL_OC state machine timers	495
Table 150 – Confirmations from Unable To Connect messages	502
Table 151 – PL_PM state machine timers	506
Table 152 – Messages from Open Failed confirmations.....	510
Table 153 – SSP frame format.....	517
Table 154 – FRAME TYPE field	518
Table 155 – TLR CONTROL field for COMMAND frames.....	519
Table 156 – COMMAND frame - Command information unit.....	521
Table 157 – TASK ATTRIBUTE field	522
Table 158 – TASK frame - Task Management Function information unit	523
Table 159 – TASK MANAGEMENT FUNCTION field	524
Table 160 – XFER_RDY frame - Transfer Ready information unit	526
Table 161 – DATA frame - Data information unit.....	527
Table 162 – RESPONSE frame - Response information unit.....	529
Table 163 – DATAPRES field	530
Table 164 – RESPONSE DATA field.....	531
Table 165 – RESPONSE CODE field	531
Table 166 – Sequences of SSP frames.....	532

Table 167 – Confirmations sent to the SCSI application layer if a frame transmission error or reception error occurs.....	547
Table 168 – ST_ITS state machine variables	548
Table 169 – ST_ITS state machine arguments.....	549
Table 170 – Messages sent to the ST_IFR state machine	551
Table 171 – Transmission Complete messages for XFER_RDY frame verification failures.....	552
Table 172 – Reception Complete messages for read DATA frame verification failures	556
Table 173 – ST_T state machine timers	558
Table 174 – Task Management Function Executed Service Response argument mapping to Request (Send Transport Response) Service Response argument.....	563
Table 175 – Confirmations sent to the SCSI application layer.....	565
Table 176 – ST_TTS state machine variables	567
Table 177 – ST_TTS state machine arguments	567
Table 178 – Messages sent to the ST_TFR state machine	571
Table 179 – Additional messages sent to the ST_TFR state machine	572
Table 180 – Reception Complete message for write DATA frame verification failures.....	575
Table 181 – Request (Send Transport Response) message Service Response argument to RESPONSE frame RESPONSE DATA field mapping.....	577
Table 182 – SMP frame format.....	579
Table 183 – SMP FRAME TYPE field.....	579
Table 184 – SMP_REQUEST frame format.....	580
Table 185 – SMP_RESPONSE frame format	581
Table 186 – MT_TP time limits	585
Table 187 – Execute Command procedure call transport protocol services.....	587
Table 188 – Task management function procedure call transport protocol services	588
Table 189 – Send SCSI Command transport protocol service arguments	589
Table 190 – SCSI Command Received transport protocol service arguments.....	590
Table 191 – Send Command Complete transport protocol service arguments	591
Table 192 – Command Complete Received transport protocol service arguments.....	592
Table 193 – Send Data-In transport protocol service arguments.....	593
Table 194 – Data-In Delivered transport protocol service arguments.....	593
Table 195 – Receive Data-Out transport protocol service arguments	594
Table 196 – Data-Out Received transport protocol service arguments	594
Table 197 – Terminate Data Transfer transport protocol service arguments.....	595
Table 198 – Data Transfer Terminated transport protocol service arguments.....	595
Table 199 – Send Task Management Request transport protocol service arguments	596
Table 200 – Task Management Request Received transport protocol service arguments.....	597
Table 201 – Task Management Function Executed transport protocol service arguments	598
Table 202 – Received Task Management Function Executed transport protocol service arguments	599
Table 203 – Delivery Result to additional sense code mapping	601
Table 204 – SCSI transport protocol events	602
Table 205 – SSP target port mode pages.....	603
Table 206 – Disconnect-Reconnect mode page for SAS SSP	604
Table 207 – Protocol Specific Logical Unit mode page for SAS SSP	606
Table 208 – Protocol Specific Port mode page for SAS SSP	607
Table 209 – I_T NEXUS LOSS TIME field	608
Table 210 – Phy Control And Discover mode page	609
Table 211 – SAS phy mode descriptor	611
Table 212 – Shared Port Control mode page	612
Table 213 – Enhanced Phy Control mode page	613
Table 214 – Enhanced phy control mode descriptor.....	614
Table 215 – Protocol Specific Port log parameters.....	615
Table 216 – Protocol Specific Port log page for SAS SSP	615
Table 217 – Protocol Specific Port log parameter for SAS target ports.....	616
Table 218 – SAS phy log descriptor.....	617
Table 219 – SSP target port diagnostic pages.....	619
Table 220 – Diagnostic pages affected by zoning	619
Table 221 – Protocol Specific diagnostic page for SAS SSP.....	620

Table 222 – PHY TEST FUNCTION field	621
Table 223 – PHY TEST PATTERN field	622
Table 224 – PHY TEST FUNCTION SSC field	623
Table 225 – PHY TEST FUNCTION PHYSICAL LINK RATE field	623
Table 226 – PHY TEST PATTERN DWORDS CONTROL field	624
Table 227 – TWO_DWORDS phy test pattern examples	625
Table 228 – Summary of states in the SA_PC state machine	627
Table 229 – VPD pages with special requirements for SAS SSP	636
Table 230 – Device Identification VPD page designation descriptors for the SAS target port	637
Table 231 – Device Identification VPD page designation descriptors for the SAS target device	638
Table 232 – Protocol Specific Logical Unit Information VPD page for SAS SSP	639
Table 233 – Logical unit information descriptor for SAS SSP	640
Table 234 – READY LED signal behavior	641
Table 235 – SMP functions (FUNCTION field)	642
Table 236 – SMP request frame format	644
Table 237 – SMP response frame format	646
Table 238 – FUNCTION RESULT field	647
Table 239 – Function result priority	651
Table 240 – REPORT GENERAL request	655
Table 241 – REPORT GENERAL response	656
Table 242 – NUMBER OF ZONE GROUPS field	660
Table 243 – REPORT MANUFACTURER INFORMATION request	662
Table 244 – REPORT MANUFACTURER INFORMATION response	663
Table 245 – REPORT SELF-CONFIGURATION STATUS request	665
Table 246 – REPORT SELF-CONFIGURATION STATUS response	666
Table 247 – Self-configuration status descriptor	668
Table 248 – STATUS TYPE field	668
Table 249 – REPORT ZONE PERMISSION TABLE request	670
Table 250 – REPORT TYPE field	671
Table 251 – REPORT ZONE PERMISSION TABLE response	672
Table 252 – Zone permission descriptors	673
Table 253 – Zone permission descriptor for a source zone group (i.e., s) with 128 zone groups	673
Table 254 – Zone permission descriptor for a source zone group (i.e., s) with 256 zone groups	674
Table 255 – Zone permission descriptor bit requirements	674
Table 256 – REPORT ZONE MANAGER PASSWORD request	675
Table 257 – REPORT TYPE field	675
Table 258 – REPORT ZONE MANAGER PASSWORD response	676
Table 259 – REPORT BROADCAST request	677
Table 260 – REPORT BROADCAST response	678
Table 261 – Broadcast descriptor	679
Table 262 – BROADCAST REASON field for originated Broadcasts	680
Table 263 – DISCOVER request	681
Table 264 – DISCOVER response	682
Table 265 – ATTACHED DEVICE TYPE field	685
Table 266 – NEGOTIATED LOGICAL LINK RATE field and NEGOTIATED PHYSICAL LINK RATE field	686
Table 267 – NEGOTIATED LOGICAL LINK RATE field	687
Table 268 – ATTACHED SATA PORT SELECTOR and ATTACHED SATA DEVICE bits	688
Table 269 – PROGRAMMED MINIMUM PHYSICAL LINK RATE field and PROGRAMMED MAXIMUM PHYSICAL LINK RATE field	691
Table 270 – The HARDWARE MINIMUM PHYSICAL LINK RATE field and the HARDWARE MAXIMUM PHYSICAL LINK RATE field	691
Table 271 – ROUTING ATTRIBUTE field	692
Table 272 – PHY POWER CONDITION field	692
Table 273 – SAS POWER CAPABLE field	693
Table 274 – ATTACHED DEVICE NAME field	694
Table 275 – SELF-CONFIGURATION STATUS field	695
Table 276 – SELF-CONFIGURATION LEVELS COMPLETED field	695
Table 277 – REPORT PHY ERROR LOG request	698

Table 278 – REPORT PHY ERROR LOG response	699
Table 279 – REPORT PHY SATA request	700
Table 280 – REPORT PHY SATA response.....	702
Table 281 – REPORT ROUTE INFORMATION request	704
Table 282 – REPORT ROUTE INFORMATION response.....	706
Table 283 – REPORT PHY EVENT request.....	707
Table 284 – REPORT PHY EVENT response	709
Table 285 – Phy event descriptor	710
Table 286 – DISCOVER LIST request.....	711
Table 287 – PHY FILTER field.....	712
Table 288 – DESCRIPTOR TYPE field	712
Table 289 – DISCOVER LIST response	713
Table 290 – SHORT FORMAT descriptor.....	715
Table 291 – REPORT PHY EVENT LIST request	716
Table 292 – REPORT PHY EVENT LIST response	717
Table 293 – Phy event list descriptor	719
Table 294 – REPORT EXPANDER ROUTE TABLE LIST request.....	720
Table 295 – REPORT EXPANDER ROUTE TABLE LIST response	722
Table 296 – Expander route table descriptor	724
Table 297 – CONFIGURE GENERAL request	725
Table 298 – STP SMP I_T NEXUS LOSS TIME field.....	727
Table 299 – CONFIGURE GENERAL response.....	727
Table 300 – ENABLE DISABLE ZONING request.....	728
Table 301 – SAVE field	729
Table 302 – ENABLE DISABLE ZONING field.....	729
Table 303 – ENABLE DISABLE ZONING response	729
Table 304 – ZONED BROADCAST request	730
Table 305 – BROADCAST TYPE field	731
Table 306 – ZONED BROADCAST response	731
Table 307 – ZONE LOCK request	733
Table 308 – ZONE LOCK response.....	734
Table 309 – ZONE ACTIVATE request.....	735
Table 310 – ZONE ACTIVATE response.....	735
Table 311 – ZONE UNLOCK request	736
Table 312 – ZONE UNLOCK response	737
Table 313 – CONFIGURE ZONE MANAGER PASSWORD request	738
Table 314 – SAVE field.....	739
Table 315 – CONFIGURE ZONE MANAGER PASSWORD response.....	739
Table 316 – CONFIGURE ZONE PHY INFORMATION request.....	740
Table 317 – SAVE field.....	741
Table 318 – Zone phy configuration descriptor.....	741
Table 319 – CONFIGURE ZONE PHY INFORMATION response	742
Table 320 – CONFIGURE ZONE PERMISSION TABLE request.....	743
Table 321 – NUMBER OF ZONE GROUPS field.....	744
Table 322 – SAVE field.....	744
Table 323 – Zone permission configuration descriptors	745
Table 324 – Zone permission configuration descriptor for source zone group for 128 zone groups	745
Table 325 – Zone permission configuration descriptor for source zone group for 256 zone groups	745
Table 326 – Zone permission configuration descriptor bit requirements	746
Table 327 – CONFIGURE ZONE PERMISSION TABLE response.....	746
Table 328 – CONFIGURE ROUTE INFORMATION request.....	747
Table 329 – CONFIGURE ROUTE INFORMATION response	748
Table 330 – PHY CONTROL request	750
Table 331 – PHY OPERATION field.....	752
Table 332 – PROGRAMMED MINIMUM PHYSICAL LINK RATE field and PROGRAMMED MAXIMUM PHYSICAL LINK RATE field	754
Table 333 – ENABLE SAS SLUMBER field	755
Table 334 – ENABLE SAS PARTIAL field	755

Table 335 – ENABLE SATA SLUMBER field	755
Table 336 – ENABLE SATA PARTIAL field	756
Table 337 – PHY CONTROL response	756
Table 338 – PHY TEST FUNCTION request	758
Table 339 – PHY TEST FUNCTION field	759
Table 340 – PHY TEST FUNCTION PHYSICAL LINK RATE field	760
Table 341 – PHY TEST FUNCTION response	760
Table 342 – CONFIGURE PHY EVENT request	761
Table 343 – Phy event configuration descriptor	762
Table 344 – CONFIGURE PHY EVENT response	763
Table A.1 – JTPAT for RD+ and RD-	764
Table A.2 – CJTPAT	766
Table A.3 – CJTPAT with fixed content	770
Table C.1 – CRC examples	780
Table D.1 – Monte-Carlo simulation results	781
Table D.2 – Hash results for simple SAS addresses	784
Table D.3 – Hash results for realistic SAS addresses	784
Table D.4 – Hash results for a walking ones pattern	785
Table D.5 – Hash results for a walking zeros pattern	786
Table E.1 – Scrambler examples	789
Table E.2 – Initial scrambler output	790
Table G.1 – Minimum deletable primitive insertion rate examples	794
Table H.1 – Zone permission table example initial value	795
Table H.2 – CONFIGURE ZONE PERMISSION TABLE request example	796
Table H.3 – Zone permission table after processing first zone permission configuration descriptor	797
Table H.4 – Zone permission table after processing second zone permission configuration descriptor	797
Table J.1 – Column descriptions for connection examples	800
Table K.1 – Primitives with Hamming distance of at least 7	820
Table K.2 – Primitives without Hamming distance of 7	822
Table L.1 – Standards bodies	823

INFORMATION TECHNOLOGY – SMALL COMPUTER SYSTEM INTERFACE (SCSI) –

Part 262: SAS PROTOCOL LAYER - 2 (SPL-2)

FOREWORD

- 1) ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.
- 2) The formal decisions or agreements of IEC and ISO on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees and ISO member bodies.
- 3) IEC, ISO and ISO/IEC publications have the form of recommendations for international use and are accepted by IEC National Committees and ISO member bodies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC, ISO and ISO/IEC publications is accurate, IEC or ISO cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees and ISO member bodies undertake to apply IEC, ISO and ISO/IEC publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any ISO, IEC or ISO/IEC publication and the corresponding national or regional publication should be clearly indicated in the latter.
- 5) ISO and IEC do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. ISO or IEC are not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or ISO or its directors, employees, servants or agents including individual experts and members of their technical committees and IEC National Committees or ISO member bodies for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication of, use of, or reliance upon, this ISO/IEC publication or any other IEC, ISO or ISO/IEC publications.
- 8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this ISO/IEC publication may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

International Standard ISO/IEC 14776-262 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

The list of all currently available parts of the ISO/IEC 14776 series, under the general title *Information technology – Small computer system interface (SCSI)*, can be found on the IEC web site.

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.

INFORMATION TECHNOLOGY – SMALL COMPUTER SYSTEM INTERFACE (SCSI) –

Part 262: SAS PROTOCOL LAYER - 2 (SPL-2)

INTRODUCTION

General

The SCSI family of standards provides for many different transport protocols that define the rules for exchanging information between different SCSI devices. This standard 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.

The following figure shows the organization of the layers of this standard.

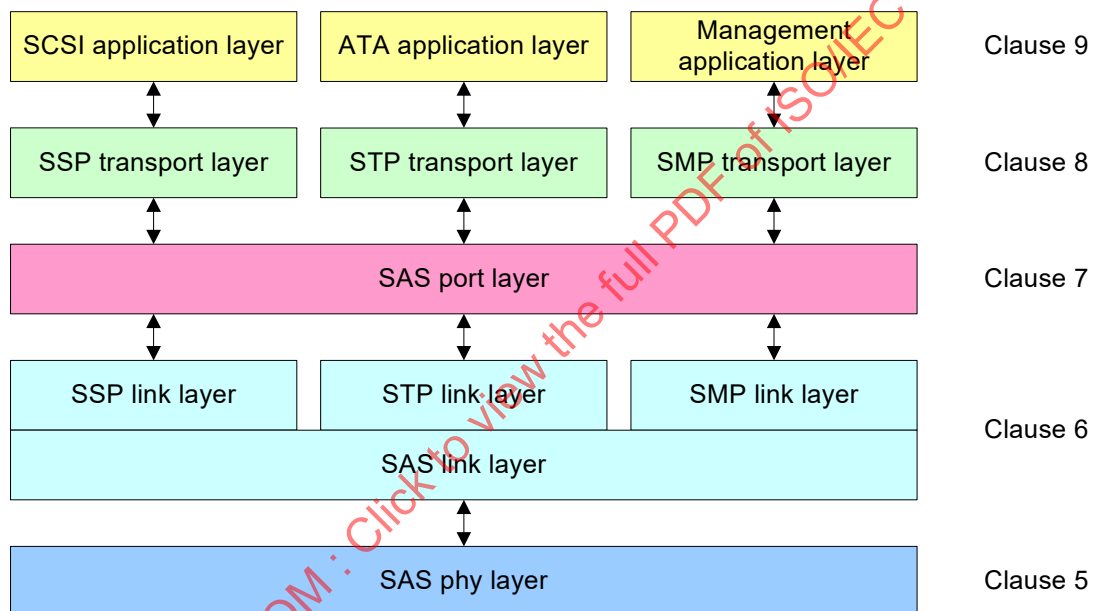


Figure 1 – Organization of this standard

SCSI standards family

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

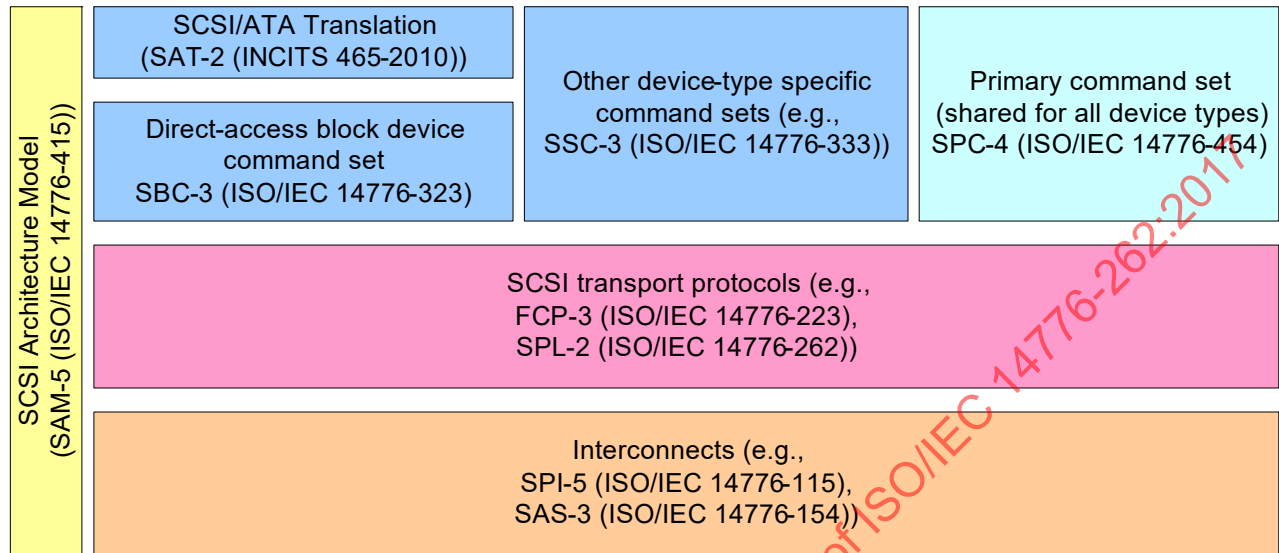


Figure 2 – SCSI document relationships

This standard 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 standard to other standards and related projects in the ATA family of standards.

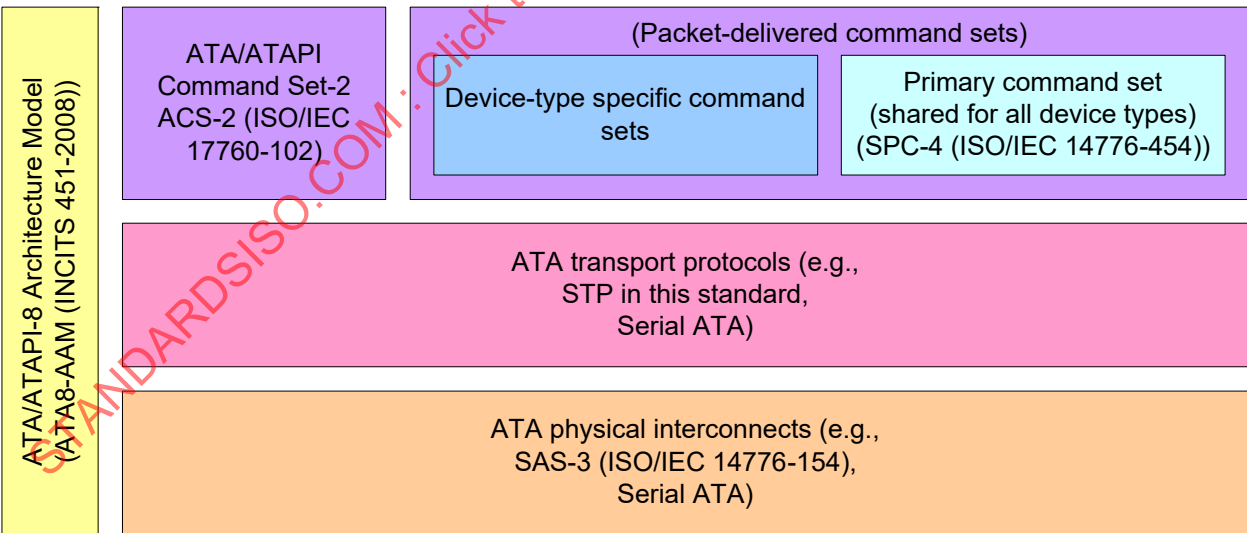


Figure 3 – ATA document relationships

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 standard is a functional description. Conforming implementations may employ any design technique that does not violate interoperability.

INFORMATION TECHNOLOGY – SMALL COMPUTER SYSTEM INTERFACE (SCSI) –

Part 262: SAS Protocol Layer - 2 (SPL-2)

1 Scope

This standard 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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

ISO/IEC 14776-372, *Information technology – Small Computer System Interface (SCSI) – Part 372: SCSI Enclosure Services - 2 (SES-2)*

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

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

INCITS 465-2010, *SCSI/ATA Translation - 2 (SAT-2)*

INCITS 514-2014, *SCSI Block Commands - 3 (SBC-3)*

INCITS 515-2016, *SCSI Architecture Model - 5 (SAM-5)*

INCITS 513-2015, *SCSI Primary Commands - 4 (SPC-4)*

INCITS 519-2014, *Serial Attached SCSI - 3 (SAS-3)*

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

Serial AT Attachment Revision 3.1 (SATA). 18-July-2011¹

SFF-8485, *Serial GPIO (SGPIO) Bus*²

1. For information on the current status of Serial ATA documents, contact the Serial ATA International Organization (see <http://www.sata-io.org>).

2. For more information on the current status of SFF documents, contact the SFF Committee at 408-867-6630 (phone), or 408-867-2115 (fax). To obtain copies of these documents, contact the SFF Committee at 14426 Black Walnut Court, Saratoga, CA 95070 at 408-867-6630 (phone) or 408-741-1600 (fax) or see <http://www.sffcommittee.org>.

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 3.1.253) that locks a zoning expander device (see 3.1.257)

Note 1 to entry: See 4.8.6.

3.1.7

affiliation

STP target port (see 3.1.224) state of limiting acceptance of connection requests to those from one or more STP initiator ports (see 3.1.219)

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 3.5.

3.1.10

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 3.5.

3.1.11

attached

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

3.1.12

attached SAS address

SAS address (see 3.1.164) 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),

3.1.13

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 3.5.

3.1.14

AT Attachment

ATA

standard for the internal attachment of storage devices to hosts

Note 1 to entry: See ATA8-AAM.

3.1.15

ATA device

storage peripheral that processes ATA commands and device management functions

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

Note 2 to entry: See ATA8-AAM.

3.1.16**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 3.1.199)

Note 1 to entry: Analogous to a SCSI domain (see 3.1.187).

Note 2 to entry: See ATA8-AAM.

3.1.17**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 3.1.188).

Note 2 to entry: See ATA8-AAM.

3.1.18**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).

3.1.19**bi-phase mark code****BMC**

encoding in which a transition occurs at the beginning of each TTIU bit cell (see 3.1.242), 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.

3.1.20**bit cell time**

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

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 4.1.13.

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

object within an expander function (see 3.1.66) 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 an unit

3.1.25

character

sequence of ten contiguous bits considered as an unit

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

3.1.26

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.

3.1.27

class diagram

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

Note 1 to entry: See 3.5.

3.1.28

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.

3.1.29

commonly supported setting

supported settings bit (see table 52) with a value set to one by both the phy and the attached phy as transmitted during the most recent SNW-3

3.1.30

compliant jitter tolerance pattern

CJTPAT

test pattern for jitter testing

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

3.1.31

configuration subprocess

subprocess invoked from the discover process (see 3.1.55) to configure an externally configurable expander device (see 3.1.73)

Note 1 to entry: See 4.7.

3.1.32

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 3.6.

3.1.33**connection**

temporary association between a SAS initiator port and a SAS target port using a pathway (see 3.1.136)

Note 1 to entry: See 4.1.12 and 6.14.

3.1.34**connection rate**

effective rate of dwords through the pathway (see 3.1.136) between a SAS initiator phy and a SAS target phy, established through the connection request

3.1.35**connection request**

request to establish a connection originated by a SAS phy (see 3.1.170) using an OPEN address frame (see 6.8.3)

Note 1 to entry: See 6.14.2.1.

3.1.36**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 3.5.

3.1.37**control byte**

byte containing control information defined in table 49

Note 1 to entry: See 5.3.7.

3.1.38**control character****Kxx.y**

character containing control information defined in table 49

Note 1 to entry: See 5.3.7.

3.1.39**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.

3.1.40**D.C. idle**

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

Note 1 to entry: See SAS-3.

3.1.41**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)

3.1.42

data byte

byte containing data information defined in table 48

Note 1 to entry: See 5.3.6.

3.1.43

data character

Dxx.y

character containing data information defined in table 48 (see 5.2)

Note 1 to entry: See 5.3.6.

3.1.44

data dword

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

3.1.45

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

3.1.46

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.

3.1.47

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 3.5.

3.1.48

device name

worldwide unique name for a device within a transport protocol

Note 1 to entry: See 4.2.6.

3.1.49

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.

3.1.50

differential high signal level

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

3.1.51

differential low signal level

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

3.1.52**direct current****D.C.**

non-A.C. component of a signal

Note 1 to entry: See SAS-3.

3.1.53**direct routing attribute**

attribute of an expander phy that indicates that the expander phy may be used by the ECM (see 3.1.63) to route a connection request to an end device

Note 1 to entry: See 4.5.7.1.

3.1.54**direct routing method**

method the ECM (see 3.1.63) uses to route connection requests to an attached end device or an attached expander device

Note 1 to entry: See 4.5.7.1.

3.1.55**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 3.1.31) as needed.

Note 2 to entry: See 4.6.

3.1.56**disparity**

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

3.1.57**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 3.1.166), a SCSI domain (see 3.1.187), or an ATA domain (see 3.1.16).

Note 2 to entry: See 4.1.9.

3.1.58**dword**

sequence of four contiguous bytes or four contiguous characters considered as an 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)).

3.1.59**dword synchronization**

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

Note 1 to entry: See 5.13.

3.1.60

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 3.1.61) and/or expander device(s) (see 3.1.65)

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 standard.

3.1.61

end device

SAS device (see 3.1.165) or SATA device (see 3.1.176) that is not contained within an expander device (see 3.1.65)

3.1.62

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.

3.1.63

expander connection manager

ECM

object within an expander function (see 3.1.66) that manages routing

Note 1 to entry: See 4.5.3.

3.1.64

expander connection router

ECR

portion of an expander function (see 3.1.66) that routes messages between expander phys

Note 1 to entry: See 4.5.4.

3.1.65

expander device

device that is part of a service delivery subsystem (see 3.1.199), facilitates communication between SAS devices (see 3.1.165) and SATA devices (see 3.1.176), and is either an externally configurable expander device (see 3.1.73) or a self-configuring expander device (see 3.1.193)

Note 1 to entry: See 4.1.7.

3.1.66

expander function

object within an expander device (see 3.1.65) that contains an expander connection manager (see 3.1.63), expander connection router (see 3.1.64), and Broadcast propagation processor (see 3.1.22)

Note 1 to entry: See 4.5.1.

3.1.67

expander logical phy

expander phy (see 3.1.68) or a multiplexed portion of an expander phy

Note 1 to entry: See 4.1.2.

3.1.68

expander phy

phy in an expander device (see 3.1.65) that interfaces to a service delivery subsystem (see 3.1.199)

3.1.69**expander port**

expander device object that interfaces to a service delivery subsystem (see 3.1.199) and to SAS ports in other devices

Note 1 to entry: See 4.5.2.

3.1.70**expander route entry**

SAS address and an enable/disable bit in an expander route table (see 3.1.72)

3.1.71**expander route index**

value used in combination with a phy identifier to select an expander route entry in an expander route table (see 3.1.72) in an externally configurable expander device (see 3.1.73)

Note 1 to entry: See 4.5.7.4.

3.1.72**expander route table**

table of expander route entries (see 3.1.70) within an expander device (see 3.1.65)

Note 1 to entry: The table is used by the expander function (see 3.1.66) to resolve connection requests.

Note 2 to entry: See 4.5.7.4.

3.1.73**externally configurable expander device**

non-self-configuring expander device (see 3.1.65) containing an expander route table (see 3.1.72)

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.

3.1.74**field**

group of one or more contiguous bits

3.1.75**Final-SNW**

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

3.1.76**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.

3.1.77**frame information structure****FIS**

SATA frame format

Note 1 to entry: See SATA.

3.1.78

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 3.5.

3.1.79

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

3.1.80

hard reset sequence

sequence that causes a hard reset (see 3.1.79)

Note 1 to entry: See 4.4 and 6.9.

3.1.81

hardware maximum physical link rate

maximum physical link rate capability of a phy

3.1.82

hardware minimum physical link rate

minimum physical link rate capability of a phy

3.1.83

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

3.1.84

highest priority commonly supported setting

commonly supported setting based on the priority defined in table 55

3.1.85

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.

3.1.86**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 3.1.172), 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 3.1.190) (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.

3.1.87**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.

3.1.88**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.

3.1.89**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.

3.1.90**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.

3.1.91**identification sequence**

sequence where phys exchange IDENTIFY address frames

Note 1 to entry: See 4.4 and 6.9.

3.1.92**idle dword**

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

Note 1 to entry: See 6.4.

3.1.93**idle time**

part of an OOB signal (see 3.1.131) where OOB idle (see 3.1.129) is being transmitted

Note 1 to entry: See 5.6.

3.1.94

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 3.6.

3.1.95

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.

3.1.96

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.

3.1.97

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.

3.1.98

invalid character

character that is not a control character (see 3.1.38) or a data character (see 3.1.43)

3.1.99

invalid dword

dword that is not a data dword (see 3.1.44) or a primitive (see 3.1.150)

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.

3.1.100

jitter tolerance pattern

JTPAT

test pattern for jitter testing

Note 1 to entry: See SAS-3.

3.1.101

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.

3.1.102**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.

3.1.103**link reset sequence**

phy reset sequence

Note 1 to entry: For SATA a link reset sequence is only a phy reset sequence (see 3.1.141).

Note 2 to entry: For SAS a link reset sequence is a phy reset sequence followed by an identification sequence (see 3.1.91), or a phy reset sequence followed by a hard reset sequence (see 3.1.80), another phy reset sequence, and an identification sequence.

Note 3 to entry: See 4.4 and 6.9.

3.1.104**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).

3.1.105**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

3.1.106**local**

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

3.1.107**locked zoning expander device**

zoning expander device (see 3.1.257) that has been locked by a zone manager (see 3.1.253)

Note 1 to entry: See 4.8.6.2.

3.1.108**logical link**

physical link or a multiplexed portion of a physical link

Note 1 to entry: See 4.1.3.

3.1.109**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

3.1.110

logical phy

phy (see 3.1.138) or a multiplexed portion of a phy

Note 1 to entry: See 4.1.2.

3.1.111

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.

3.1.112

logical unit number

LUN

identifier for a logical unit (see 3.1.111)

Note 1 to entry: See SAM-5.

3.1.113

low phy power condition

partial phy power condition or the slumber phy power condition

Note 1 to entry: See 4.10.1.

3.1.114

media

material on which data is stored

Note 1 to entry: Media is the plural of medium.

Note 2 to entry: An example of media on which data is stored are magnetic disks.

3.1.115

message

information sent between state machines

Note 1 to entry: See 3.6.

3.1.116

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.

3.1.117

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.

3.1.118**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 3.5.

3.1.119**narrow link**

physical link that attaches a narrow port to another narrow port

Note 1 to entry: See 4.1.4.

3.1.120**narrow port**

port that contains exactly one phy

Note 1 to entry: See 4.1.4.

3.1.121**negation time**

part of an OOB signal (see 3.1.131) during which OOB idle (see 3.1.129) is transmitted after the last OOB burst (see 3.1.128)

Note 1 to entry: See 5.6.

3.1.122**negotiation idle**

transmission of OOB idle (see 3.1.129)

Note 1 to entry: See 5.12.4.2.

3.1.123**negotiated logical link rate**

current operational logical link rate (see 3.1.109)

3.1.124**negotiated physical link rate**

current operational physical link rate (see 3.1.143)

3.1.125**nexus**

relationship between two SAS devices or two SCSI devices

Note 1 to entry: When referring to SAS devices (see 3.1.165), 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 3.1.186), 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.

3.1.126**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).

3.1.127

object diagram

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

Note 1 to entry: See 3.5.

3.1.128

OOB burst

transmission of signal transitions for a burst time

Note 1 to entry: See SAS-3.

3.1.129

OOB idle

transmission of D.C. idle when D.C. mode (see 3.1.41) is enabled, or a defined sequence of dwords when optical mode (see 3.1.133) is enabled

Note 1 to entry: See SAS-3.

3.1.130

OOB sequence

sequence where two phys exchange OOB signals (see 3.1.131)

Note 1 to entry: See 5.10.2.1 and 5.10.4.1.

3.1.131

OOB signal

pattern of idle time (see 3.1.93), burst time, and negation time (see 3.1.121) used during the link reset sequence

Note 1 to entry: See 5.6.

3.1.132

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 3.5.

3.1.133

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)

3.1.134

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.

3.1.135**partial phy power condition**

low phy power condition for a SAS phy or expander phy

Note 1 to entry: See 4.10.1.3.

3.1.136**pathway**

set of logical links between a SAS initiator phy and a SAS target phy being used by a connection (see 3.1.33)

Note 1 to entry: See 4.1.11.

3.1.137**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)

3.1.138**phy**

object in a device that is used to interface to other devices (e.g., an expander phy (see 3.1.68) or a SAS phy (see 3.1.170))

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

3.1.139**phy identifier**

value by which a phy is identified within a device

Note 1 to entry: See 4.2.10.

3.1.140**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)

3.1.141**phy reset sequence**

OOB sequence (see 3.1.130) followed by a speed negotiation sequence (see 3.1.208)

Note 1 to entry: See 4.4 and 5.10.

3.1.142**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.

3.1.143**physical link rate**

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

3.1.144**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.

3.1.145

port

SAS port (see 3.1.172) or an expander port (see 3.1.69)

Note 1 to entry: Each port contains one or more phys (see 3.1.138).

Note 2 to entry: See 4.1.4.

3.1.146

port identifier

value by which a port is identified within a domain

Note 1 to entry: See 4.2.9.

3.1.147

port name

worldwide unique name for a port within a transport protocol

Note 1 to entry: See 4.2.8.

3.1.148

potential pathway

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

Note 1 to entry: See 4.1.11.

3.1.149

power on

power being applied

3.1.150

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.

3.1.151

primitive sequence

set of primitives treated as a single entity

Note 1 to entry: See 6.2.4.

3.1.152

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).

3.1.153**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 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).

3.1.154**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.

3.1.155**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)

3.1.156**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.

3.1.157**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 3.6.

3.1.158**reset event**

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

3.1.159**response**

information passed from a higher layer state machine to a lower layer state machine, usually in response to an indication (see 3.1.94)

Note 1 to entry: See 3.6.

3.1.160**role**

label at the end of an association (see 3.1.10) 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 3.5.

3.1.161

route table optimization

configuration subprocess (see 3.1.31) algorithm that reduces the number of entries required in an expander route table (see 3.1.72) in an externally configurable expander device (see 3.1.73)

Note 1 to entry: See 4.7.3.

3.1.162

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.

3.1.163

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.

3.1.164

SAS address

identifier assigned to a SAS port (see 3.1.172) or expander device (see 3.1.65)

Note 1 to entry: See 4.2.4.

3.1.165

SAS device

SAS initiator device and/or a SAS target device

Note 1 to entry: See 4.1.6.

3.1.166

SAS domain

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

Note 1 to entry: See 4.1.9.

3.1.167

SAS initiator device

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

Note 1 to entry: See 4.1.6.

3.1.168

SAS initiator phy

logical phy (see 3.1.110) in a SAS initiator device

3.1.169

SAS initiator port

SSP initiator port (see 3.1.212), STP initiator port (see 3.1.219), and/or SMP initiator port (see 3.1.202) in a SAS domain

3.1.170

SAS phy

phy in a SAS device that interfaces to a service delivery subsystem (see 3.1.199)

3.1.171**SAS logical phy**

SAS phy (see 3.1.170) or a multiplexed portion of a SAS phy

Note 1 to entry: See 4.1.2.

3.1.172**SAS port**

SAS initiator port (see 3.1.169) and/or a SAS target port (see 3.1.175)

3.1.173**SAS target device**

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

Note 1 to entry: See 4.1.6.

3.1.174**SAS target phy**

logical phy (see 3.1.110) in a SAS target device

3.1.175**SAS target port**

SSP target port (see 3.1.216), STP target port (see 3.1.224), and/or SMP target port (see 3.1.206) in a SAS domain

3.1.176**SATA device**

ATA device that contains a SATA device port in an ATA domain; analogous to a SAS target device (see 3.1.173)

3.1.177**SATA device port**

ATA device object that interfaces to a service delivery subsystem (see 3.1.199) with SATA

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

3.1.178**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 3.1.167).

3.1.179**SATA host port**

ATA host object that interfaces to a service delivery subsystem (see 3.1.199) with SATA

Note 1 to entry: Analogous to a SAS initiator port (see 3.1.169).

3.1.180**SATA phy**

phy in a SATA device or SATA port selector that interfaces to a service delivery subsystem (see 3.1.199)

Note 1 to entry: Analogous to a SAS phy (see 3.1.170).

3.1.181**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)

3.1.182

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.

3.1.183

saturating counter

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

3.1.184

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.

3.1.185

SCSI 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.

3.1.186

SCSI device

device that contains one or more SCSI ports that are connected to a service delivery subsystem (see 3.1.199) and supports a SCSI application protocol

Note 1 to entry: See SAM-5.

3.1.187

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 3.1.199)

Note 1 to entry: See SAM-5.

3.1.188

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.

3.1.189

SCSI initiator port

SCSI initiator device object that acts as the connection between SCSI application clients and a service delivery subsystem (see 3.1.199) through which requests and confirmations are routed

Note 1 to entry: See SAM-5.

3.1.190**SCSI port**

SCSI initiator port and/or a SCSI target port

Note 1 to entry: See SAM-5.

3.1.191**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.

3.1.192**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 3.1.199) through which requests, indications, responses, and confirmations are routed

Note 1 to entry: See SAM-5.

3.1.193**self-configuring expander device**

expander device (see 3.1.65) containing an SMP initiator port and a management application client to perform the discover process (see 3.1.55) to configure its own expander route table (see 3.1.72)

Note 1 to entry: See 4.6.4.

3.1.194**Serial ATA****SATA**

protocol defined by SATA (see clause 2)

3.1.195**Serial ATA Tunneled Protocol****STP**

protocol defined in this standard used by STP initiator ports (see 3.1.219) to communicate with STP target ports (see 3.1.224) in a SAS domain

Note 1 to entry: See 6.19 and 8.3.

3.1.196**Serial Attached SCSI****SAS**

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

3.1.197**Serial Management Protocol****SMP**

protocol defined in this standard used by SMP initiator ports (see 3.1.202) to communicate with SMP target ports (see 3.1.206) in a SAS domain

Note 1 to entry: See 6.20 and 8.4.

3.1.198

Serial SCSI Protocol

SSP

protocol defined in this standard used by SSP initiator ports (see 3.1.212) to communicate with SSP target ports (see 3.1.216) in a SAS domain

Note 1 to entry: See 6.18 and 8.2.

3.1.199

service delivery subsystem

part of the domain that transmits information

Note 1 to entry: A service delivery subsystem is the part of:

- a) a SCSI I/O system that transmits information between a SCSI initiator port and a SCSI target port;
- b) an ATA I/O system that transmits information between an ATA host and an ATA device; or
- c) a SAS I/O system that transmits information between a SAS initiator port and a SAS target port.

Note 2 to entry: See 4.1.8.

3.1.200

slumber phy power condition

low phy power condition for a SAS phy or expander phy

Note 1 to entry: See 4.10.1.4.

3.1.201

SMP initiator phy

SAS initiator phy (see 3.1.168) in an SMP initiator port (see 3.1.202)

3.1.202

SMP initiator port

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

3.1.203

SMP phy

SAS logical phy (see 3.1.171) in an SMP port

3.1.204

SMP port

SMP initiator port (see 3.1.202) and/or an SMP target port (see 3.1.206)

3.1.205

SMP target phy

SAS target phy (see 3.1.174) in an SMP target port (see 3.1.206)

3.1.206

SMP target port

SAS target device object in a SAS domain that interfaces to a service delivery subsystem (see 3.1.199) with SMP

3.1.207

SMP zone configuration function

SMP function that configures zoning expander shadow values (see 3.1.259) and is only accepted by a locked zoning expander device

Note 1 to entry: See 4.8.6.3.

3.1.208**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.

3.1.209**speed negotiation window****SNW**

portion of the SAS speed negotiation sequence

Note 1 to entry: See 5.10.4.2.3.

3.1.210**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.

3.1.211**SSP initiator phy**

SAS initiator phy (see 3.1.168) in an SSP initiator port (see 3.1.212)

3.1.212**SSP initiator port**

SCSI initiator port in a SAS domain that implements SSP

3.1.213**SSP phy**

SAS logical phy (see 3.1.171) in an SSP port

3.1.214**SSP port**

SSP initiator port (see 3.1.212) and/or an SSP target port (see 3.1.216)

3.1.215**SSP target phy**

SAS target phy (see 3.1.174) in an SSP target port (see 3.1.216)

3.1.216**SSP target port**

SCSI target port in a SAS domain that implements SSP

3.1.217**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.

3.1.218**STP initiator phy**

SAS initiator phy (see 3.1.168) in an STP initiator port (see 3.1.219)

3.1.219

STP initiator port

SAS initiator device object in a SAS domain that interfaces to a service delivery subsystem (see 3.1.199) with STP

3.1.220

STP phy

SAS logical phy (see 3.1.171) in an STP port

3.1.221

STP port

STP initiator port (see 3.1.219) and/or an STP target port (see 3.1.224)

3.1.222

STP primitive

primitive used only inside STP connections and on SATA physical links

Note 1 to entry: See 6.2.2.

3.1.223

STP target phy

SAS target phy (see 3.1.174) in an STP target port (see 3.1.224)

3.1.224

STP target port

SAS target device object in a SAS domain that interfaces to a service delivery subsystem (see 3.1.199) with STP

3.1.225

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

3.1.226

subtractive routing attribute

attribute of an expander phy that indicates that the expander phy may be used by the ECM (see 3.1.63) 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.

3.1.227

subtractive routing method

method the ECM (see 3.1.63) uses to route connection requests not resolved using the direct routing method or table routing method to an attached expander device (see 3.1.65)

Note 1 to entry: See 4.5.7.1.

3.1.228

table routing attribute

attribute of an expander phy that indicates that the expander phy may be used by the ECM (see 3.1.63) to route connection requests using an expander route table (see 3.1.72)

Note 1 to entry: See 4.5.7.1.

3.1.229**table routing method**

method the ECM (see 3.1.63) uses to route connection requests to an attached expander device (see 3.1.65) using an expander route table (see 3.1.72)

Note 1 to entry: See 4.5.7.1.

3.1.230**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.

3.1.231**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.

3.1.232**task manager**

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

Note 1 to entry: See SAM-5.

3.1.233**Train_Rx-SNW**

speed negotiation window with receiver training

Note 1 to entry: See 5.10.4.2.3.5.

3.1.234**Train_Rx-SNW window time**

actual duration of Train_Rx-SNW

3.1.235**Train_Tx-SNW**

speed negotiation window with transmitter training

Note 1 to entry: See 5.10.4.2.3.4.

3.1.236**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)

3.1.237**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

3.1.238

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

3.1.239

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

3.1.240

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

3.1.241

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.

3.1.242

TTIU bit cell

group of ten UIs that encode a single bit of BMC (see 3.1.19) information

3.1.243

unit interval

UI

time period that has the normalized, dimensionless, nominal duration of a symbol (see SAS-3) (e.g., $666.\bar{6}$ ps at 1.5 Gbit/s, $333.\bar{3}$ ps at 3 Gbit/s, $166.\bar{6}$ ps at 6 Gbit/s, and $83.\bar{3}$ ps at 12 Gbit/s)

Note 1 to entry: See SAS-3.

3.1.244

valid character

character that is a control character (see 3.1.38) or a data character (see 3.1.43)

3.1.245

valid dword

dword that is a data dword (see 3.1.44) or a primitive (see 3.1.150)

3.1.246

virtual phy

phy (see 3.1.138) that interfaces with a vendor specific interface to another virtual phy inside the same device

Note 1 to entry: See 4.1.2.

3.1.247

wide link

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

Note 1 to entry: See 4.1.4.

3.1.248**wide port**

port that contains more than one phy

Note 1 to entry: See 4.1.4.

3.1.249**word**

sequence of 16 contiguous bits considered as an unit

3.1.250**wrapping counter**

counter that wraps back to zero after reaching its maximum value

3.1.251**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)

3.1.252**zone group**

set of phys in a ZPSDS (see 3.1.255) that all have the same access permission

Note 1 to entry: See 4.8.

3.1.253**zone manager**

entity responsible for configuring a ZPSDS (see 3.1.255)

Note 1 to entry: See 4.8.

3.1.254**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.

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

group of zoning expander devices (see 3.1.257) that cooperate to control access between phys; the ZPSDS may include all or part of a service delivery subsystem (see 3.1.199)

Note 1 to entry: See 4.8.

3.1.256**zoning expander current values**

current zone permission table (see 3.1.254) and zone phy information in a zoning expander device (see 3.1.257)

Note 1 to entry: See 4.8.6.

3.1.257**zoning expander device**

expander device (see 3.1.65) that supports zoning

Note 1 to entry: See 4.8.

3.1.258

zoning expander phy

expander phy in a zoning expander device (see 3.1.257)

3.1.259

zoning expander shadow values

shadow zone permission table (see 3.1.254) and zone phy information in a zoning expander device, which are changed by SMP zone configuration functions (see 3.1.207) 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

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

Units and abbreviations used in this standard:

Abbreviation	Meaning
AA	ATA application layer (see 9.3)
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 3.1.14)
ATAPI	AT attachment packet interface
ATA8-AAM	AT Attachment - 8 ATA/ATAPI Architecture Model standard (see clause 2)
A.C.	alternating current
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 3.1.19)
BPP	Broadcast propagation processor (see 3.1.22)
CDB	command descriptor block (see 3.1.28)
CJTPAT	compliant jitter tolerance pattern (see 3.1.30)
CRC	cyclic redundancy check (see 3.1.39)
CRN	command reference number (see SAM-5)
D.C.	direct current
Dxx.y	data character (see 3.1.43)
ECM	expander connection manager (see 3.1.63)
ECR	expander connection router (see 3.1.64)
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 3.1.77)
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)

Abbreviation	Meaning
Gbit/s	gigabits per second (i.e., 10^9 bits per second)
ID	identifier
JTPAT	jitter tolerance pattern (see 3.1.100)
Kxx.y	control character (see 3.1.38)
LED	light-emitting diode
LSB	least significant bit (see 3.1.101)
LUN	logical unit number (see 3.1.112)
μ s	microsecond (i.e., 10^{-6} seconds)
m	meter
MA	management application layer (see 9.4)
MRTT	maximum receiver training time (see table 69)
MSB	most significant bit (see 3.1.116)
ms	millisecond (i.e., 10^{-3} seconds)
MT	SMP transport layer state machines (see 8.4.5)
MTTT	maximum transmitter training time (see table 69)
MTWT	maximum Train_Rx-SNW window time (see table 69)
MTXT	maximum Train_Tx-SNW window time (see table 69)
N/A	not applicable
NAA	name address authority (see 4.2)
NAK	negative acknowledge (see 6.2.7.5)
NE	not equal
ns	nanosecond (i.e., 10^{-9} seconds)
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 69)
RD	running disparity (see 3.1.163)
RRDY	receiver ready (see 6.2.7.6)
Rx	receiver device (see 3.1.156)
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 3.1.196)
SAS-1,1	Serial Attached SCSI - 1.1 (see clause 2)
SAS-3	Serial Attached SCSI - 3 (see clause 2)
SAT-2	SCSI/ATA Translation - 2 (see clause 2)
SATA	Serial ATA (see 3.1.194) or the Serial ATA 3.1 specification
SBC-3	SCSI Block Commands - 3 standard (see clause 2)
SCSI	Small Computer System Interface family of standards

Abbreviation	Meaning
SES-2	SCSI Enclosure Services - 2 (see clause 2)
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 3.1.197), or link layer for SMP phys state machines (see 6.20.5)
SNLT	speed negotiation lock time (see table 69)
SNTT	speed negotiation transmit time (see table 69)
SNW	speed negotiation window (see 3.1.209)
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 69)
SOAF	start of address frame (see 6.2.6.18)
SOF	start of frame (see 6.2.7.7)
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 3.1.198), or link layer for SSP phys state machines (see 6.18.8)
ST	SSP transport layer state machines (see 8.2.6)
STP	Serial ATA Tunneled Protocol (see 3.1.195), or link layer for STP phys state machines (see 6.19.8)
s	second (unit of time)
TLT	training lock time (see table 69)
TT	STP transport layer state machines (see 8.3.3)
TTIU	transmitter training information unit (see 3.1.241)
Tx	transmitter device (see 3.1.236)
UI	unit interval (see 3.1.243)
V	volt
VPD	vital product data (see 9.2.11)
XL	link layer for expander phys state machine (see 6.17)
XOR	exclusive logical OR
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)
ZPSDS	zoned portion of a service delivery subsystem (see 3.1.255)
^	exclusive logical OR
<	less than

Abbreviation	Meaning
$\leq$	less than or equal to
$>$	greater than
$\geq$	greater than or equal to
$+$	plus
$-$	minus
$\pm$	plus or minus
$\times$	multiplied by
$/$	divided by
$ v $	the absolute value (i.e., magnitude) of v
$\sim$	approximately equal to
$\in$	set membership
$\textcircled{R}$	registered trademark

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.

Normal case is used for words having the normal English meaning.

A binary number is represented in this standard by any sequence of digits consisting of only the Western-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., 0 0101 1010b or 0_0101_1010b).

A hexadecimal number is represented in this standard by any sequence of digits consisting of only the Western-Arabic numerals 0 through 9 and/or the upper-case English letters A through 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 through 9 not immediately followed by a lower-case b or lower-case h (e.g., 25).

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; and
- c) the thousands separator is used in both the integer portion and the fraction portion of a number.

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., $\overline{666}.6$ means $666.\overline{666}$ or $666 \frac{2}{3}$, and $12.\overline{142\ 857}$ means $12.\overline{142\ 857}$ or $12 \frac{1}{7}$).

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

3.5 UML notation conventions

3.5.1 Notation conventions overview

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

See 3.5.3 for the conventions used for class diagrams.

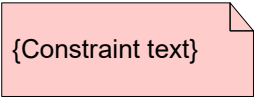
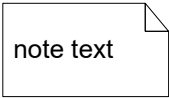
See 3.5.4 for the conventions used for object diagrams.

3.5.2 Constraint and note conventions

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

Table 2 shows the notation used for constraints and notes.

Table 2 – 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.

3.5.3 Class diagram conventions

Table 3 shows the notation used for classes in class diagrams.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Table 3 – Class diagram notation for classes

Notation			Description
Class Name	Class Name	Class Name	A class with no attributes or operations.
Class Name Attribute01[1] Attribute02[1]	Class Name Attribute01[1] Attribute02[1]		A class with attributes and no operations.
	Class Name Operation01() Operation02()		A class with operations and no attributes.
	Class Name Attribute01[1] Attribute02[1] Operation01() Operation02()		A class with attributes and operations.
	Class Name Attribute01[1..*] Attribute02[1] Operation01() Operation02()		A class with attributes that have a specified multiplicity (see table 4) and operations.

Table 4 shows the notation used to indicate multiplicity in class diagrams.

Table 4 – Multiplicity notation

Notation	Description
not specified	The number of instances of an 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).
^a See figure 4 and figure 5 for examples of multiplicity notation.	

Table 5 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 4) at each end of the relationship line.

Table 5 – Class diagram notation for associations

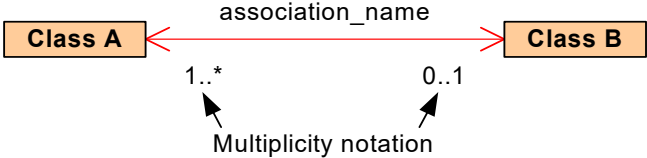
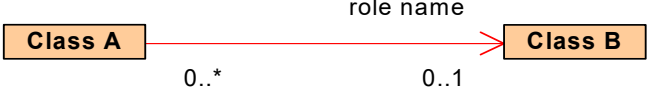
Notation	Description
	Class A knows about Class B (i.e., read as “Class A association_name Class B”) and Class B knows about Class A (i.e., read as “Class B association name Class A”).
	Class B knows about Class A (i.e., read as “Class B knows about Class A”) but Class A does not know about Class B.
	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.

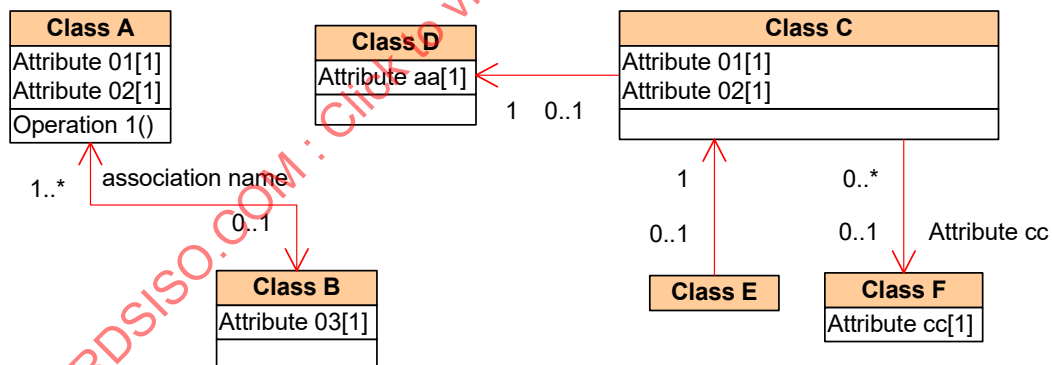


Figure 4 – Examples of association relationships in class diagrams

Table 6 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 and always include multiplicity notation (see table 4) at each end of the relationship line.

Table 6 – Class diagram notation for aggregations

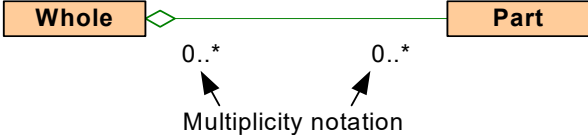
Notation	Description
	The Part class is part of the Whole class and may continue to exist even if the Whole class is removed (i.e., read as “the whole contains the part”).
	The Part class is part of the Whole class, shall only belong to one Whole class, and shall not continue to exist if the Whole class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

Figure 5 shows examples of aggregation relationships between classes.

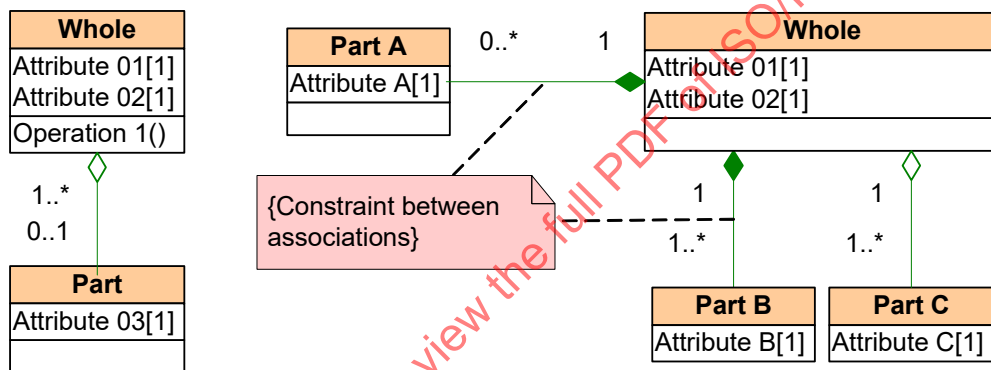


Figure 5 – Examples of aggregation relationships in class diagrams

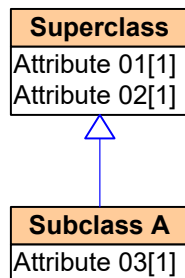
Table 7 shows the notation used to denote generalization (i.e., “is a kind of”) relationships between classes.

Table 7 – Class diagram notation for generalizations

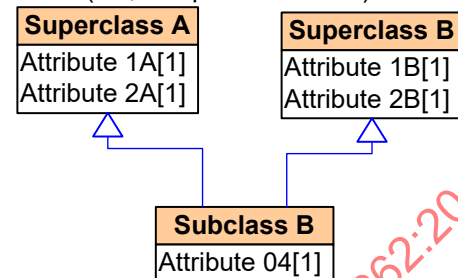
Notation	Description
	Subclass is a kind of superclass. A subclass shares all the attributes and operations of the superclass (i.e., the subclass inherits from the superclass).

Figure 6 shows examples of generalization relationships between classes.

Single superclass/single subclass:



Multiple superclasses/single subclass (i.e., multiple inheritance):



Single superclass/multiple subclasses:

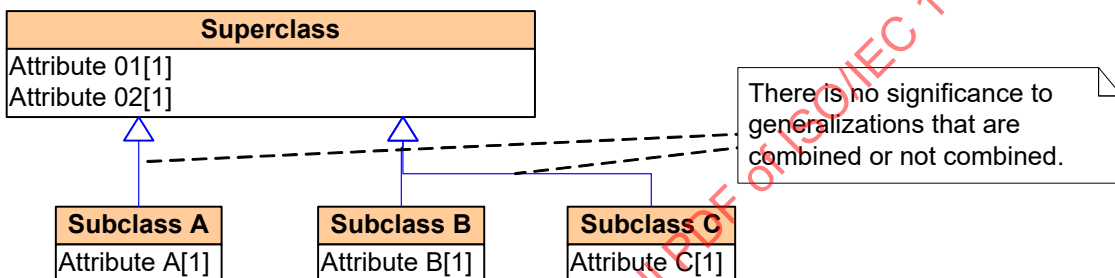


Figure 6 – Example of generalization relationships in class diagrams

Table 8 shows the notation used to denote dependency (i.e., “depends on”) relationships between classes.

Table 8 – Class diagram notation for dependency

Notation	Description
	Class A depends on class B. A change in class B may cause a change in class A.

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



Figure 7 – Example of a dependency relationship in class diagrams

3.5.4 Object diagram conventions

Table 9 shows the notation used for objects in object diagrams.

Table 9 – Object diagram notation for objects

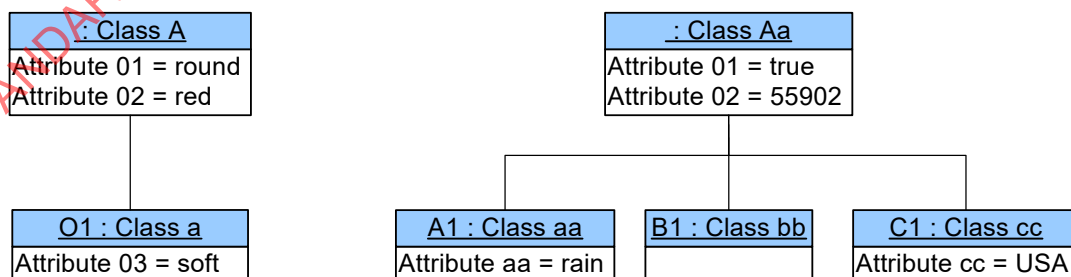
Notation	Description
<u>label</u> : Class Name	Notation for a named object with no attributes.
<u>label</u> : Class Name Attribute01 = x Attribute02 = y	Notation for a named object with attributes.
<u>: Class Name</u>	Notation for a anonymous object with no attributes.
<u>: Class Name</u> Attribute01 = x Attribute02 = y	Notation for a anonymous object with attributes.

Table 10 shows the notation used to denote link relationships between objects.

Table 10 – Object diagram notation for link

Notation	Description
<u>: Object A</u> — <u>: Object B</u>	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**

3.6 State machine conventions

3.6.1 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.

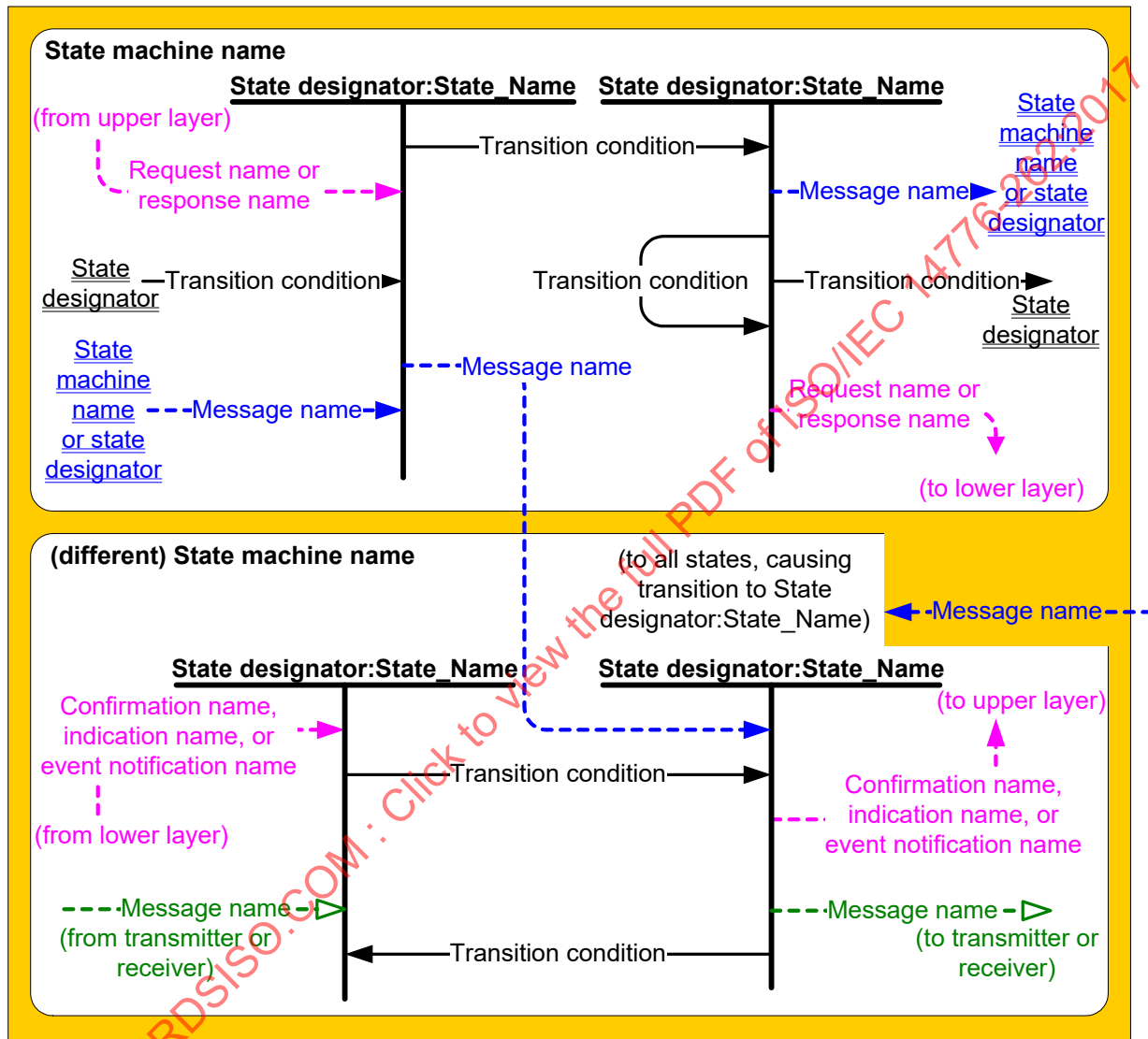


Figure 9 – State machine conventions

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.

3.6.2 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.

3.6.3 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.

3.6.4 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 with 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).

3.6.5 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.

3.7 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; 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 11 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 11 – 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 12 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 12 – 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 (First byte)				LSB				MSB				Byte 1 (Second byte)				LSB				MSB				Byte 2 (Third byte)				LSB				MSB				Byte 3 (Fourth byte)				LSB			

3.8 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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.

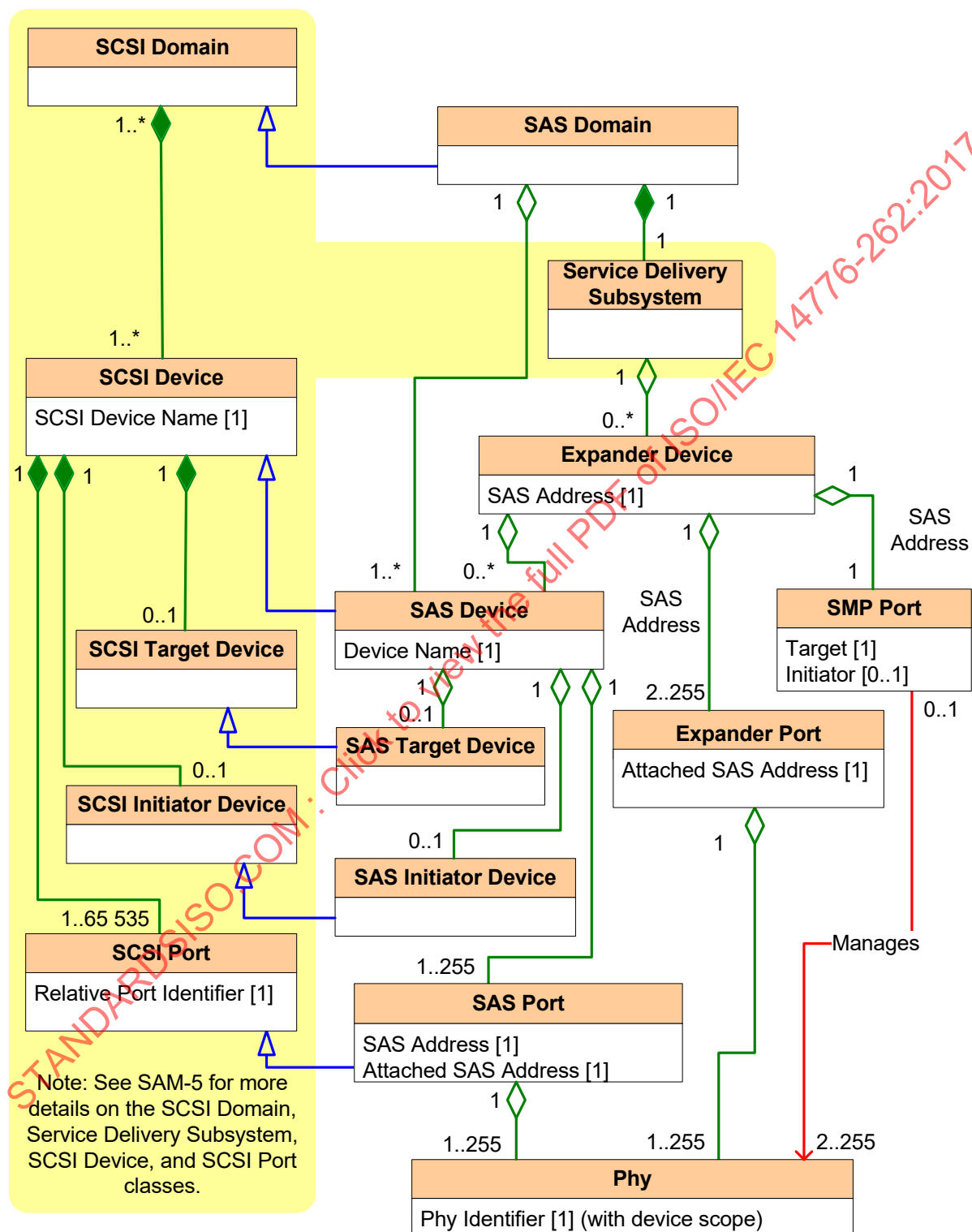


Figure 10 – SAS Domain class diagram

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) which 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) Logical SAS Phy;
- e) Expander Phy;
- f) Logical Expander 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.

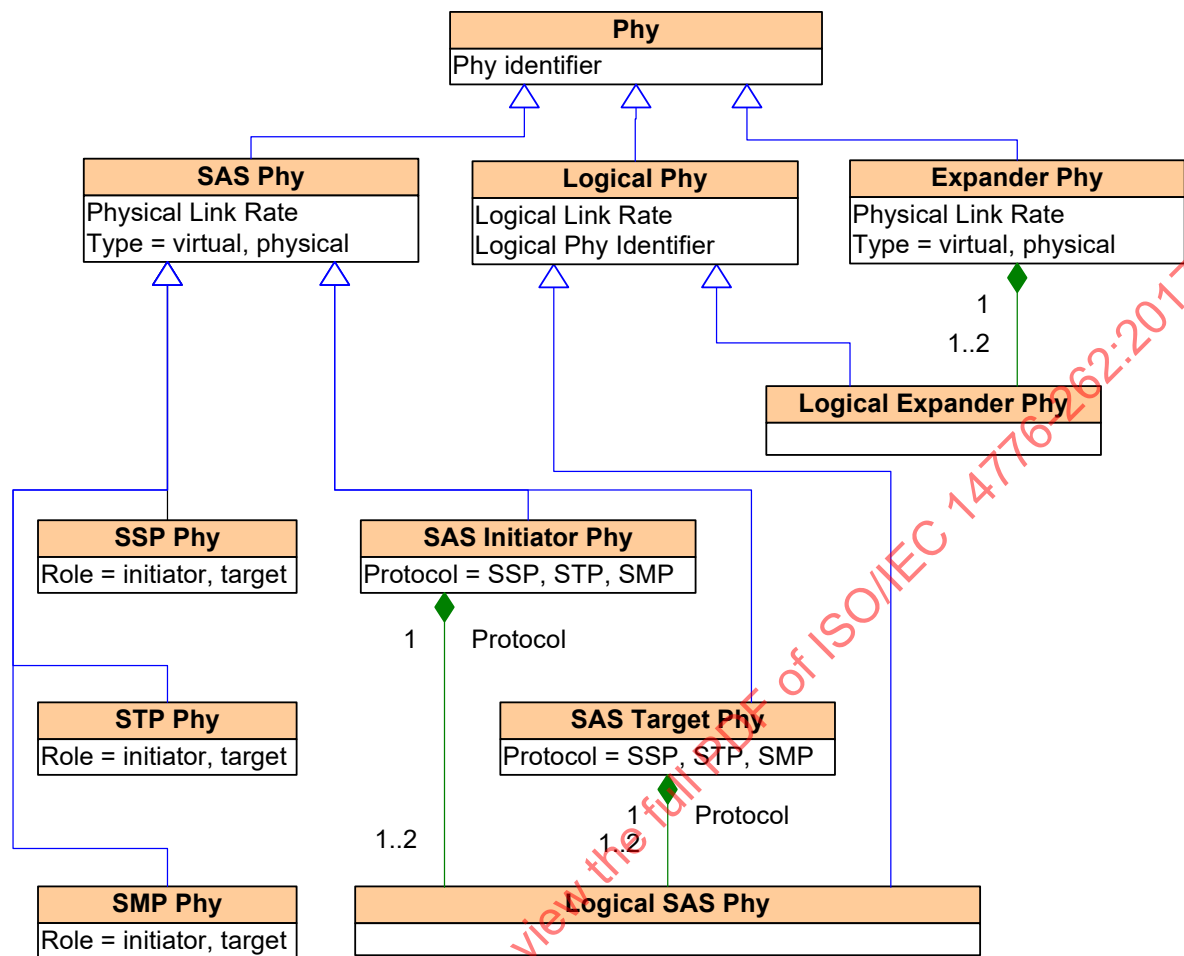


Figure 11 – Phy class diagram

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

- a) SSP initiator phy;
- b) SSP target phy;
- c) virtual SMP initiator phy;
- d) virtual SMP target phy;
- e) STP initiator phy; and
- f) logical SAS 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.

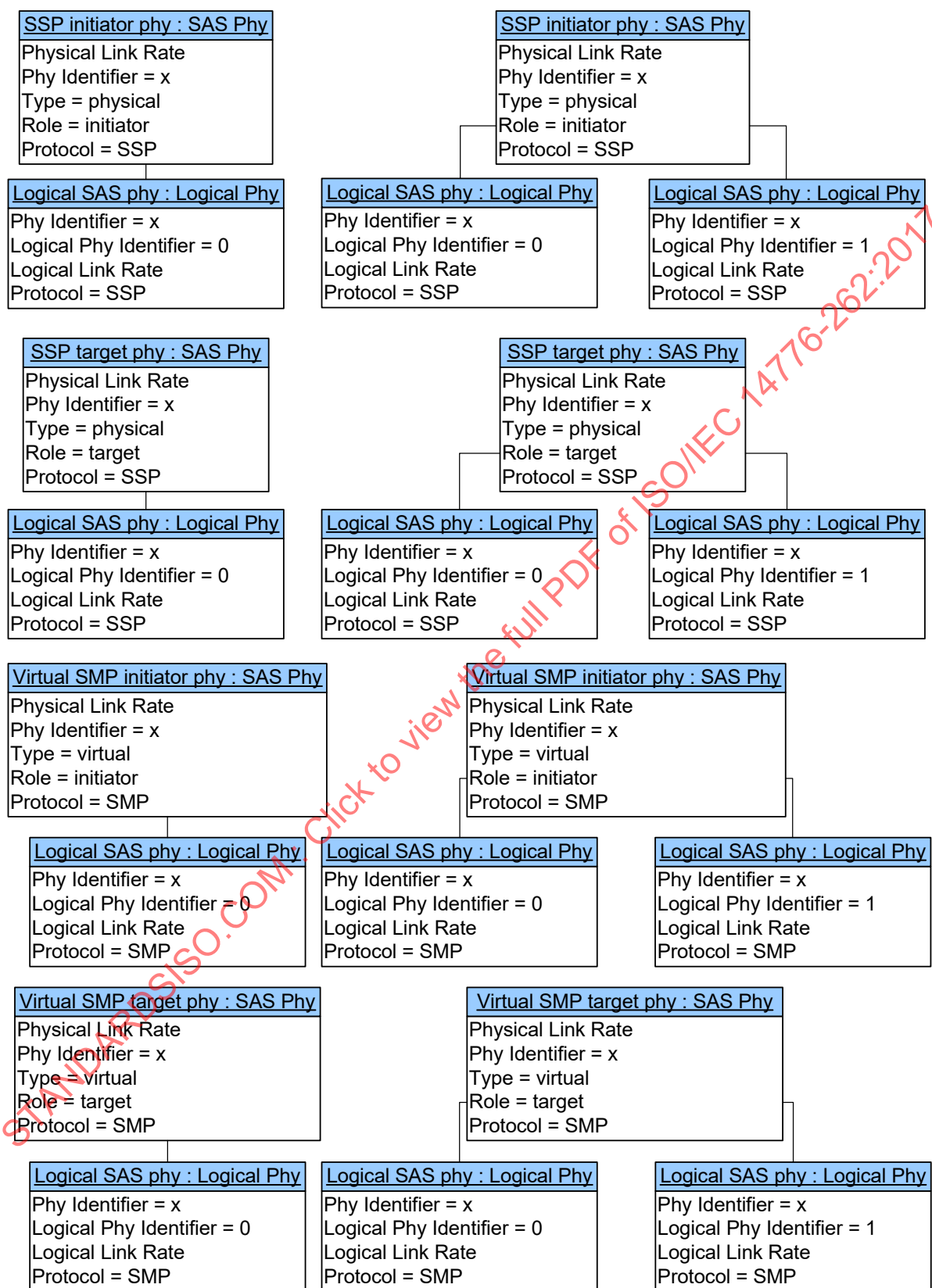


Figure 12 – SAS phy object diagram

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

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

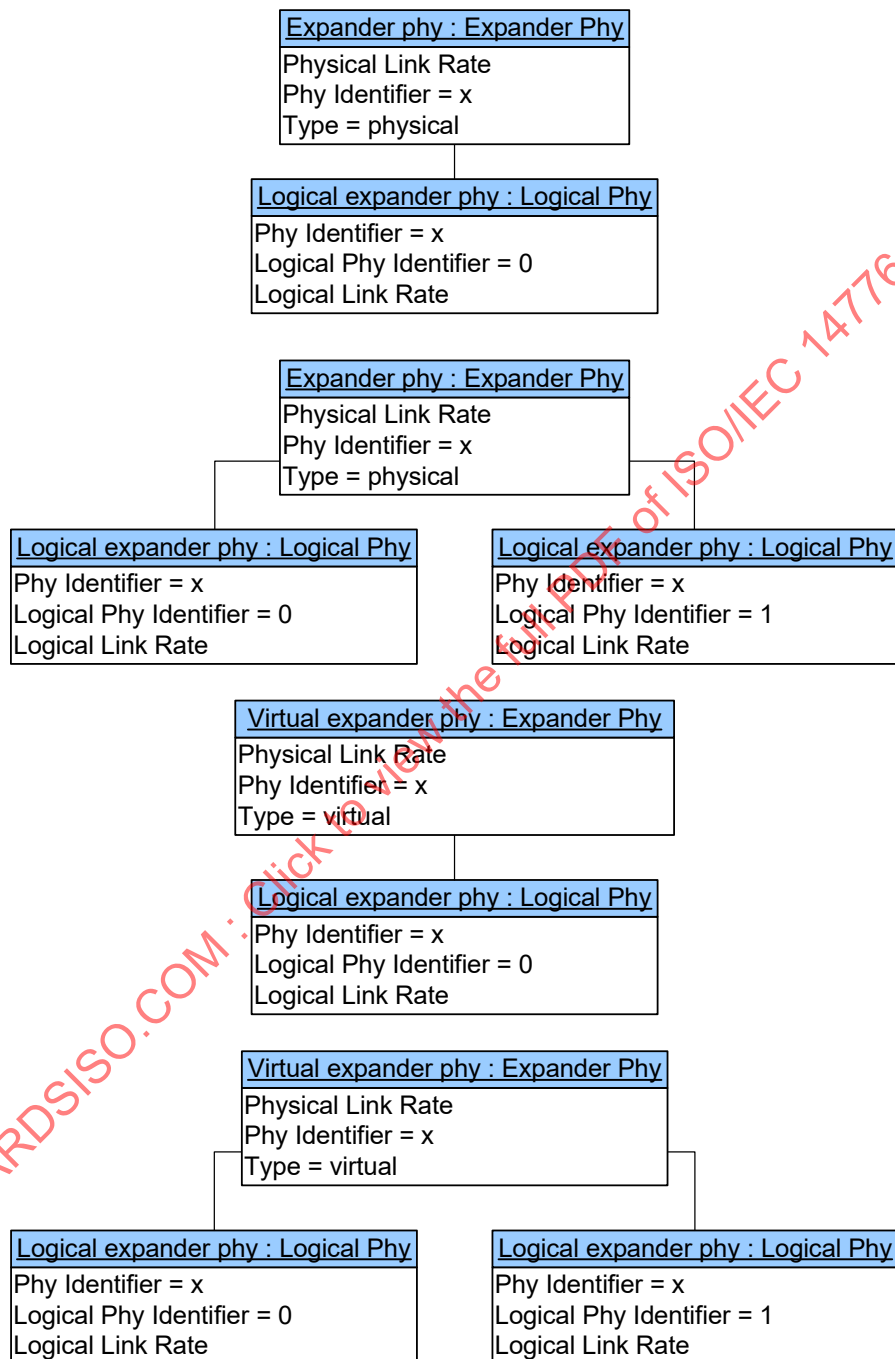


Figure 13 – Expander phy object diagram

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 13.

Table 13 – 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;
- SSP TARGET PORT bit;
- STP TARGET PORT bit;
- SMP TARGET PORT bit;
- SAS ADDRESS field;
- INSIDE ZPSDS PERSISTENT bit;

- k) REQUESTED INSIDE ZPSDS bit;
- l) SLUMBER CAPABLE bit; and
- m) PARTIAL 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.

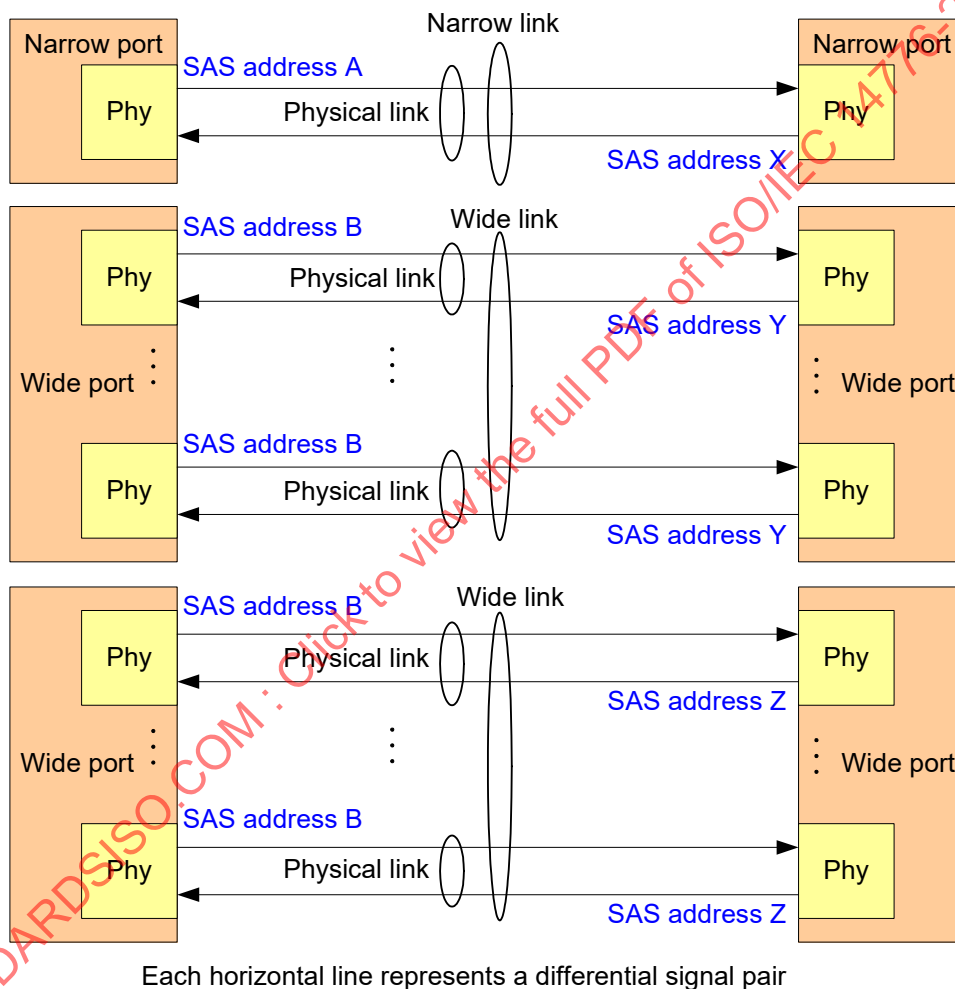


Figure 14 – Ports (narrow ports and wide ports)

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.

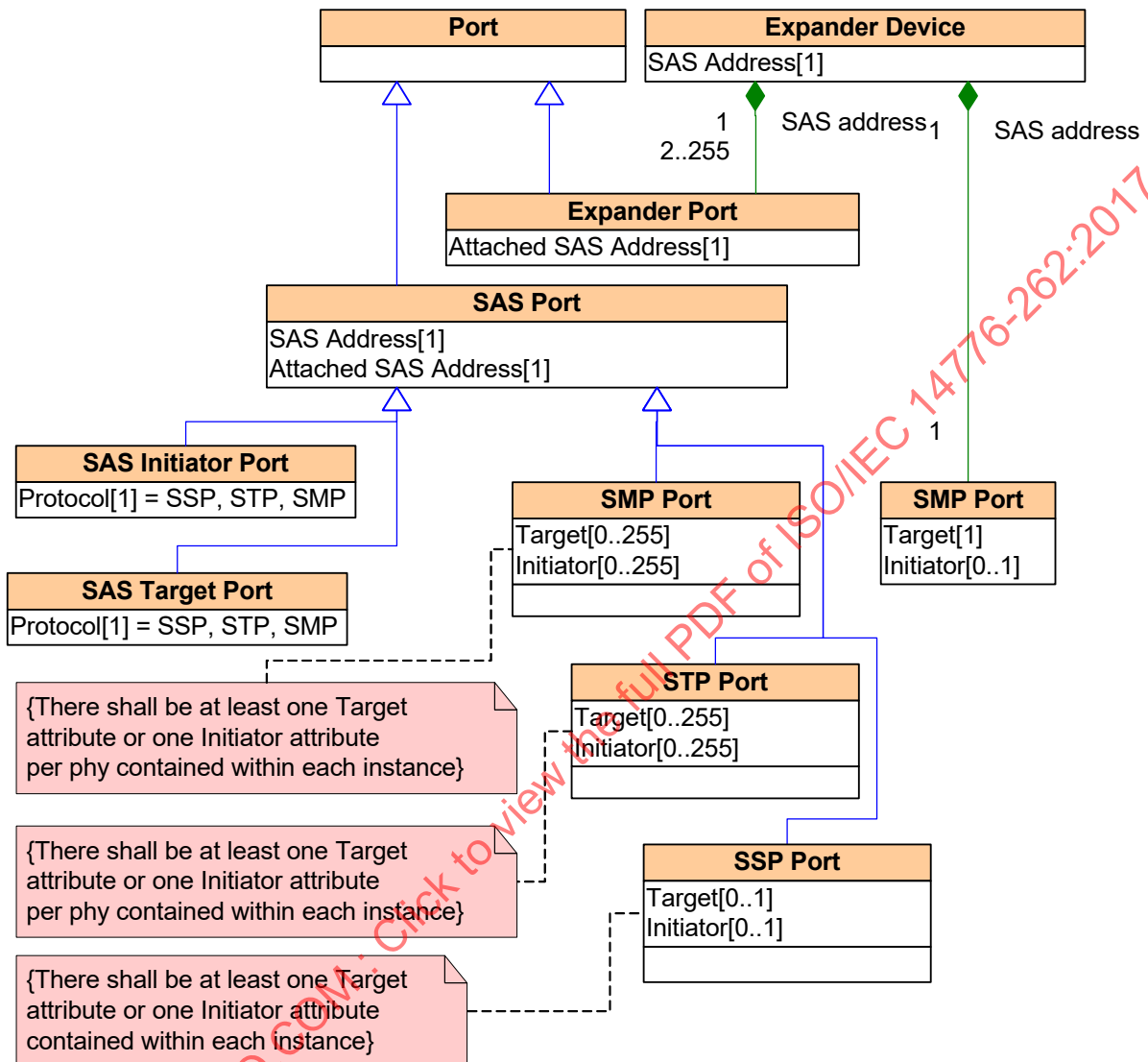


Figure 15 – Port class diagram

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.

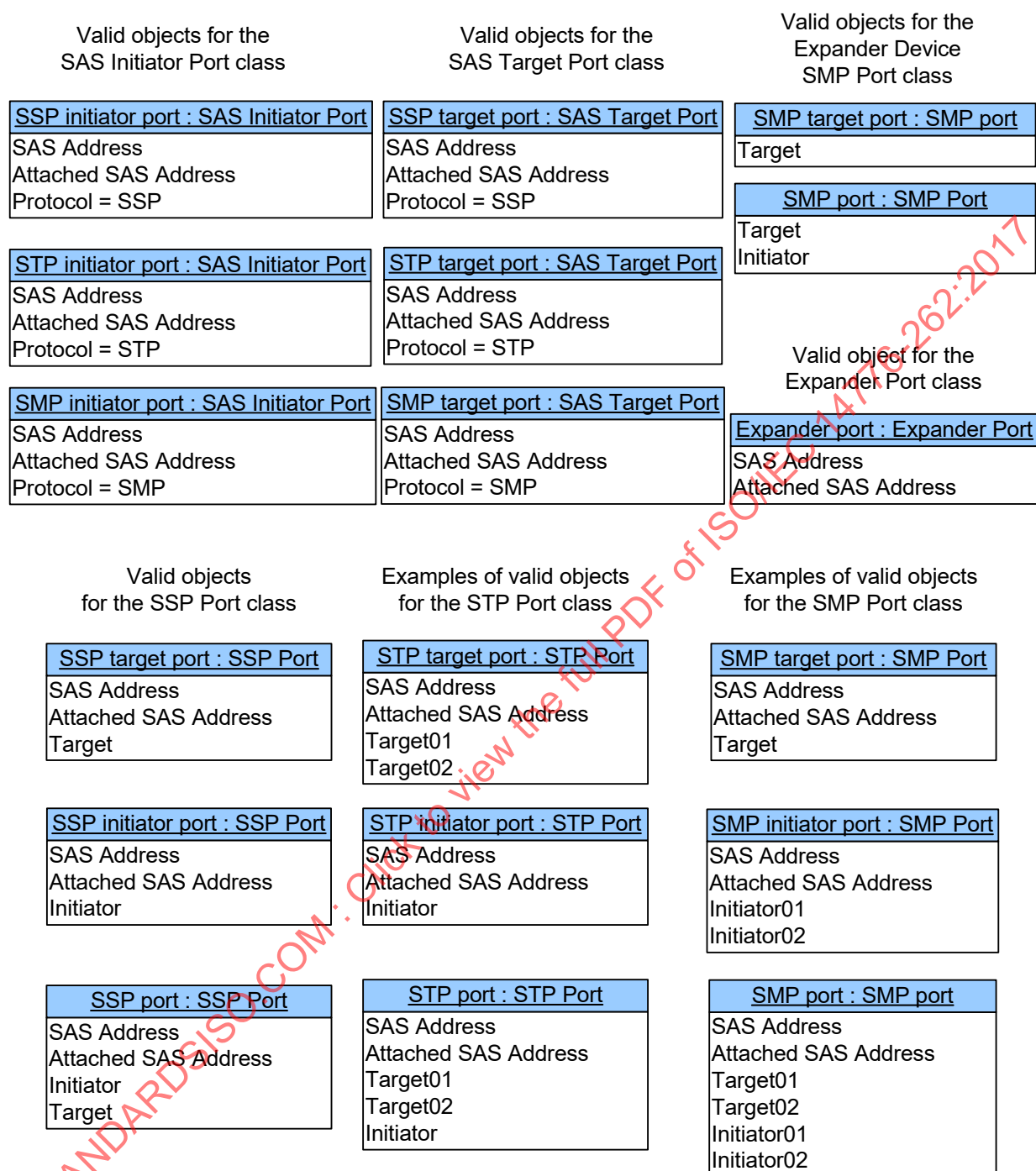


Figure 16 – Port object diagram

4.1.5 Application clients and device servers

This standard defines the following application clients:

- a 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;
- 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:

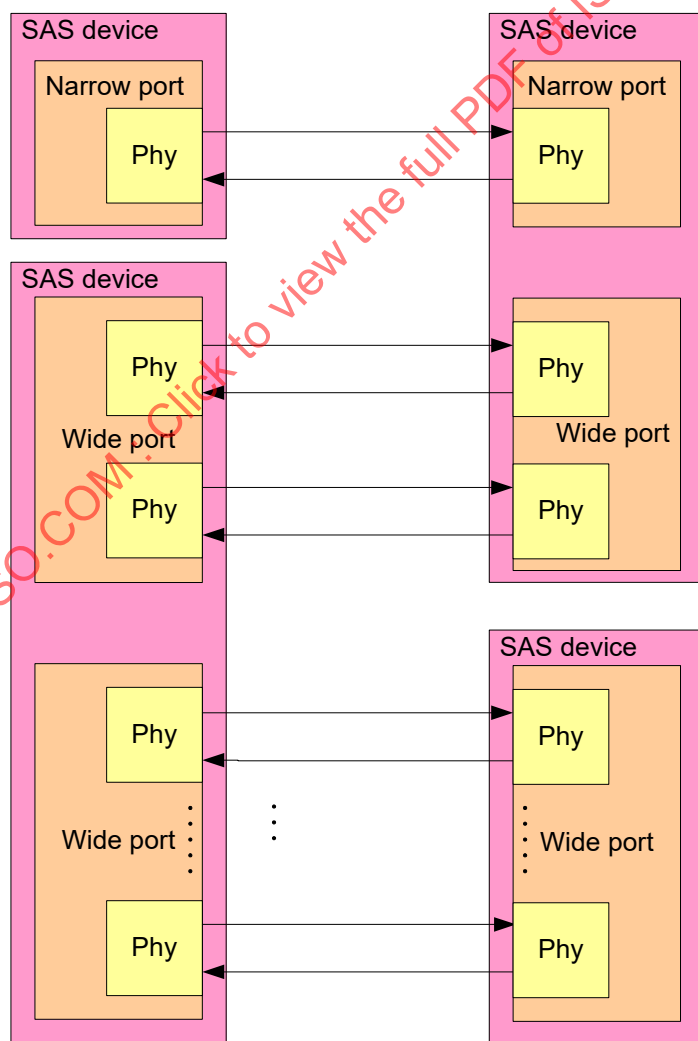
- a) a SCSI device server (see SAM-5) processes SCSI commands. A SCSI device server uses an SSP target port to interface to a service delivery subsystem;
- b) an ATA device server (see ATA8-AAM) processes ATA commands and device management functions. An ATA device server uses an STP target port to interface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



Each horizontal line represents a differential signal pair

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-2)).

Figure 18 shows an expander device.

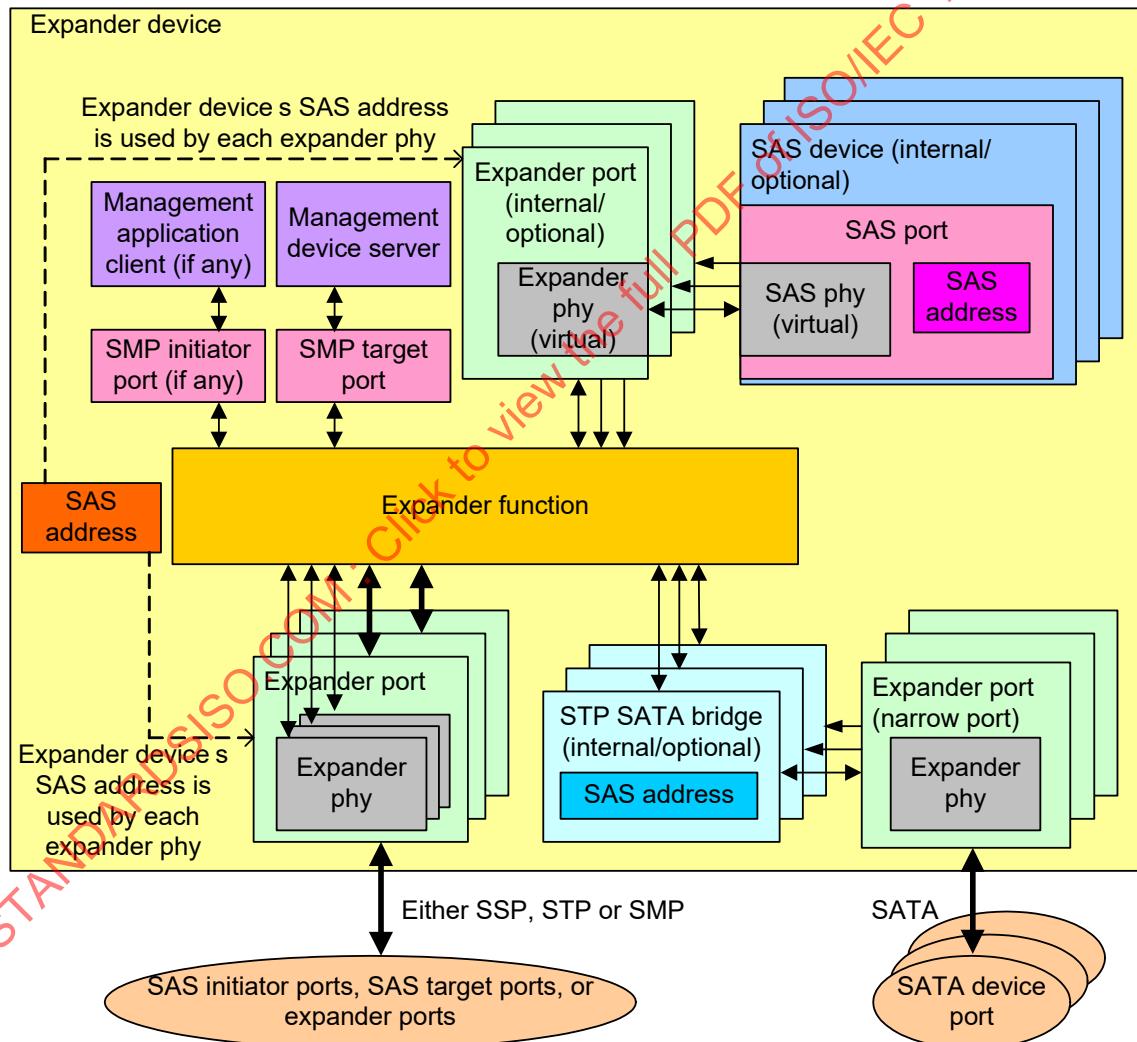


Figure 18 – Expander device

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):

- 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

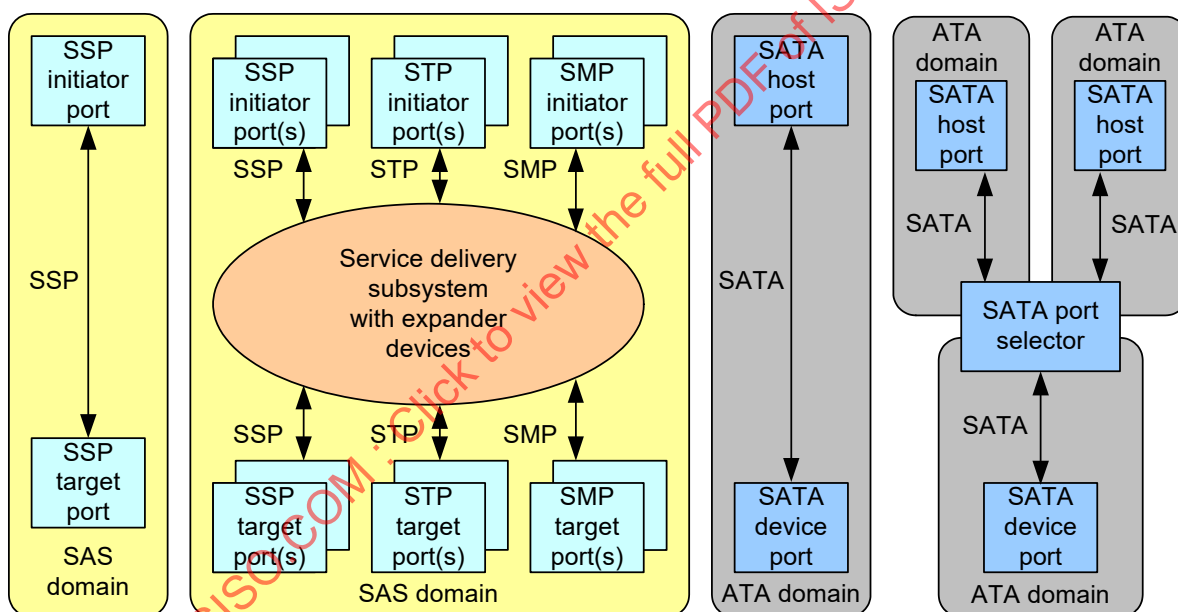
A service delivery subsystem is either:

- 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: When 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.

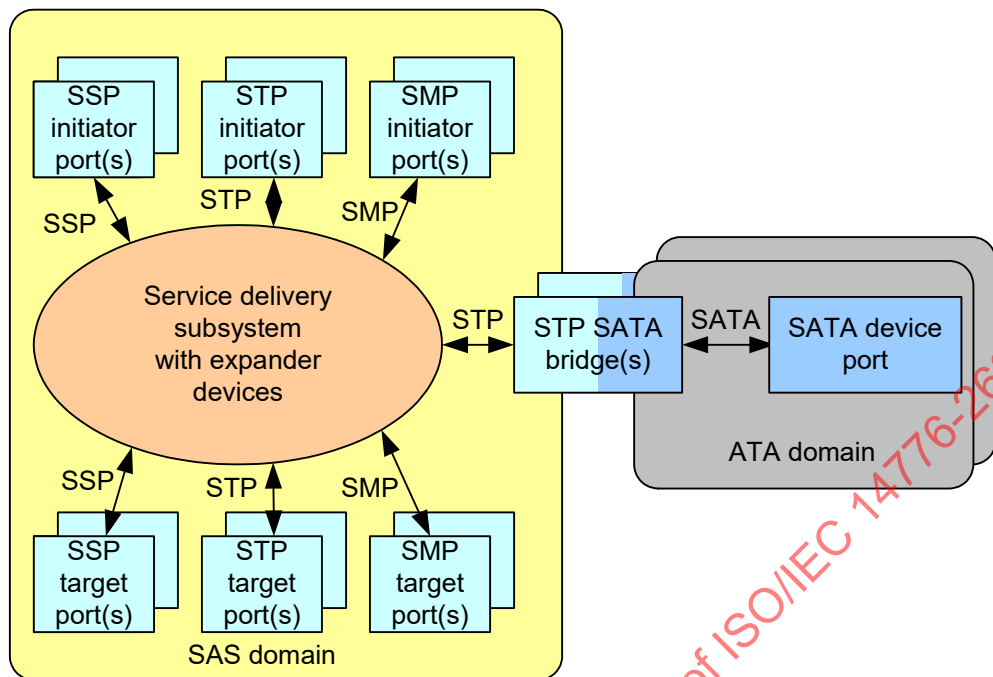


Figure 20 – SAS domain bridging to ATA domains

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

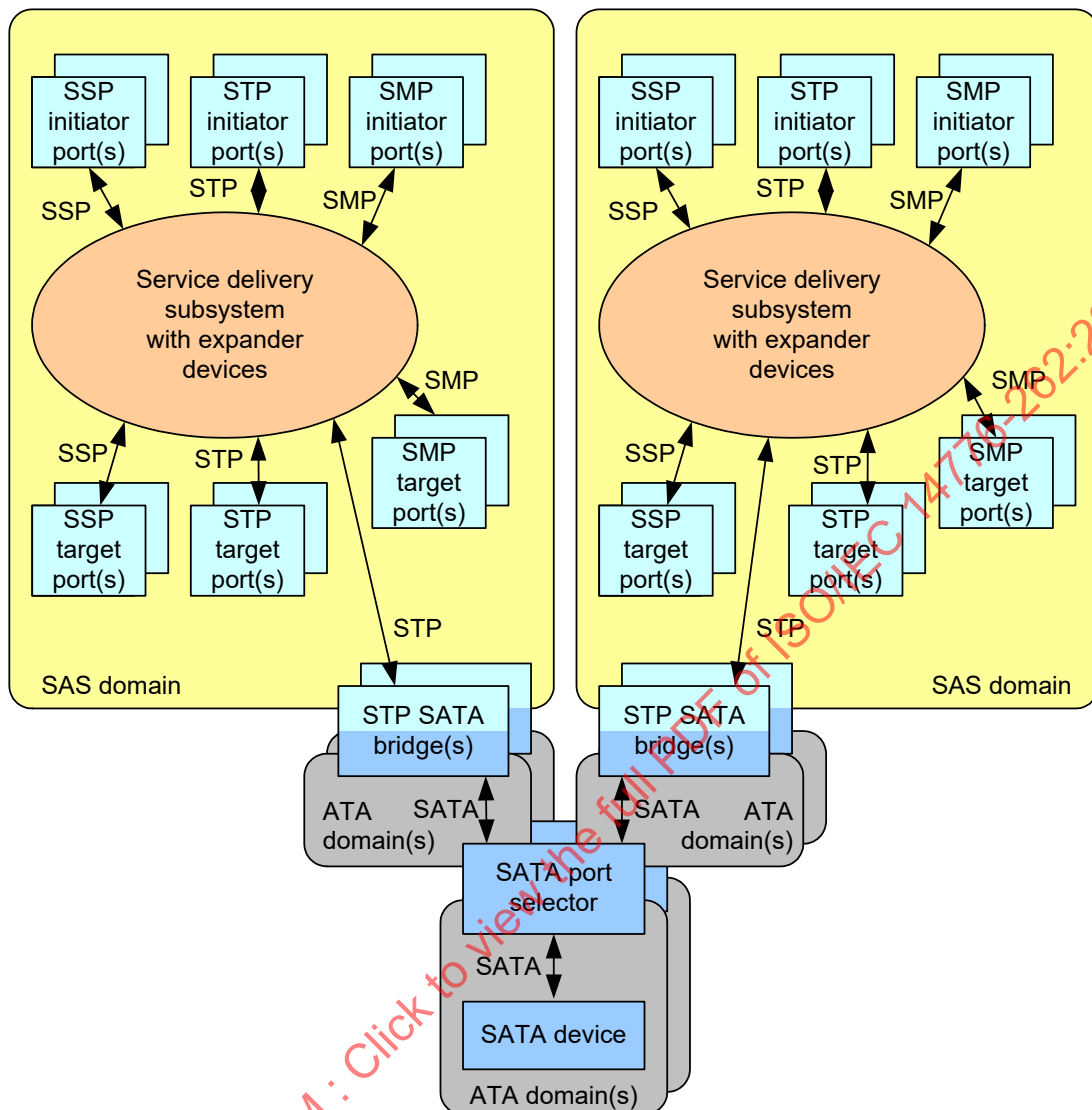


Figure 21 – SAS domains bridging to ATA domains with SATA port selectors

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

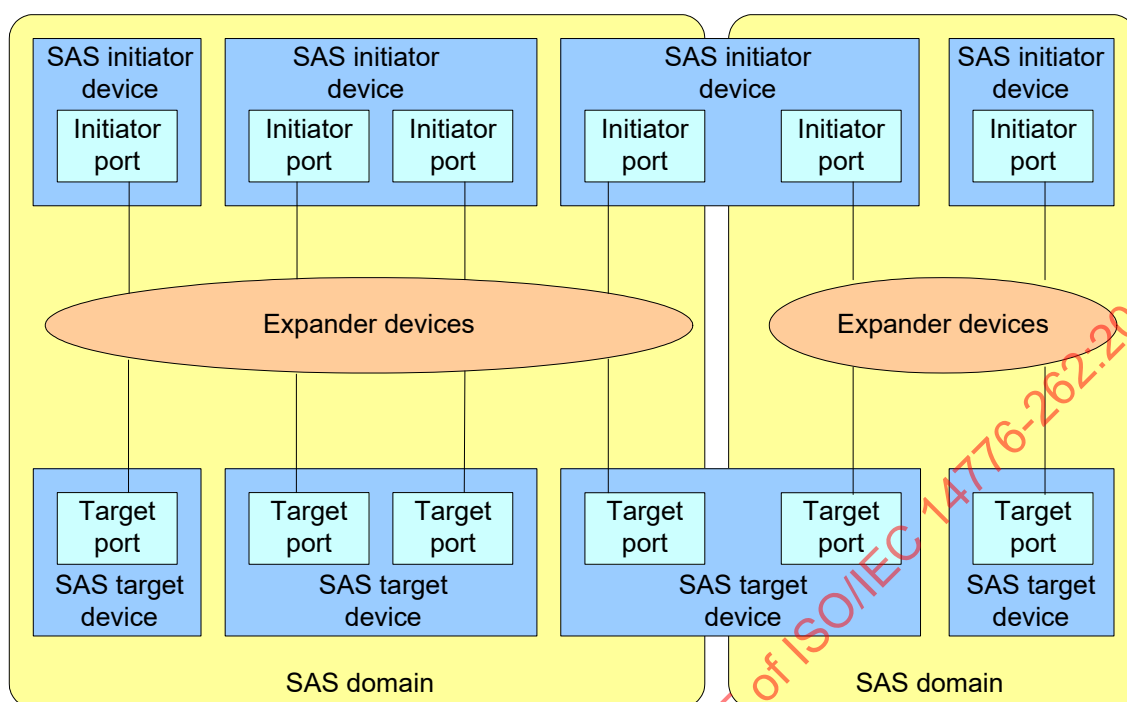


Figure 22 – Devices spanning SAS domains

4.1.10 Expander device topologies

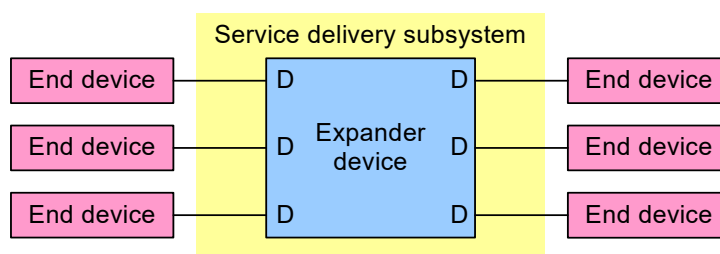
4.1.10.1 Expander device topology overview

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.



D = direct routing method

Figure 23 – Single expander device topology example

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

4.1.11 Pathways

A potential pathway is a set of logical links between a SAS initiator phy and a SAS target phy. When a SAS initiator phy is directly attached to a SAS target phy with a non-multiplexed physical link, there is one potential pathway. When the physical link is multiplexed or there are expander devices between a SAS initiator phy and a SAS target phy, 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.

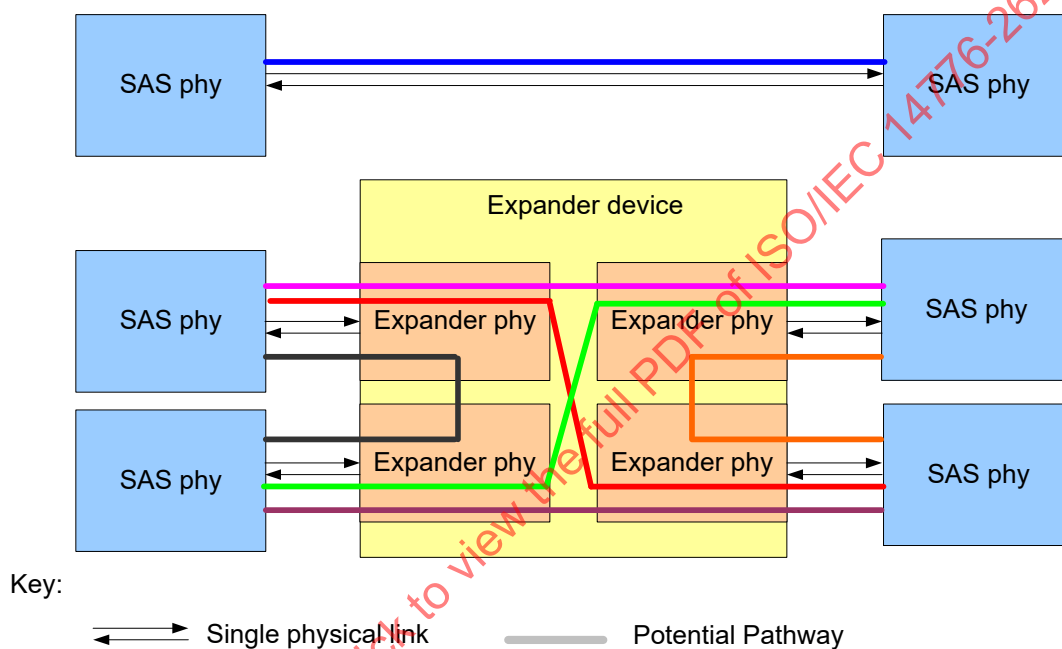


Figure 25 – Potential pathways

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 when 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: SSP, STP, or 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.

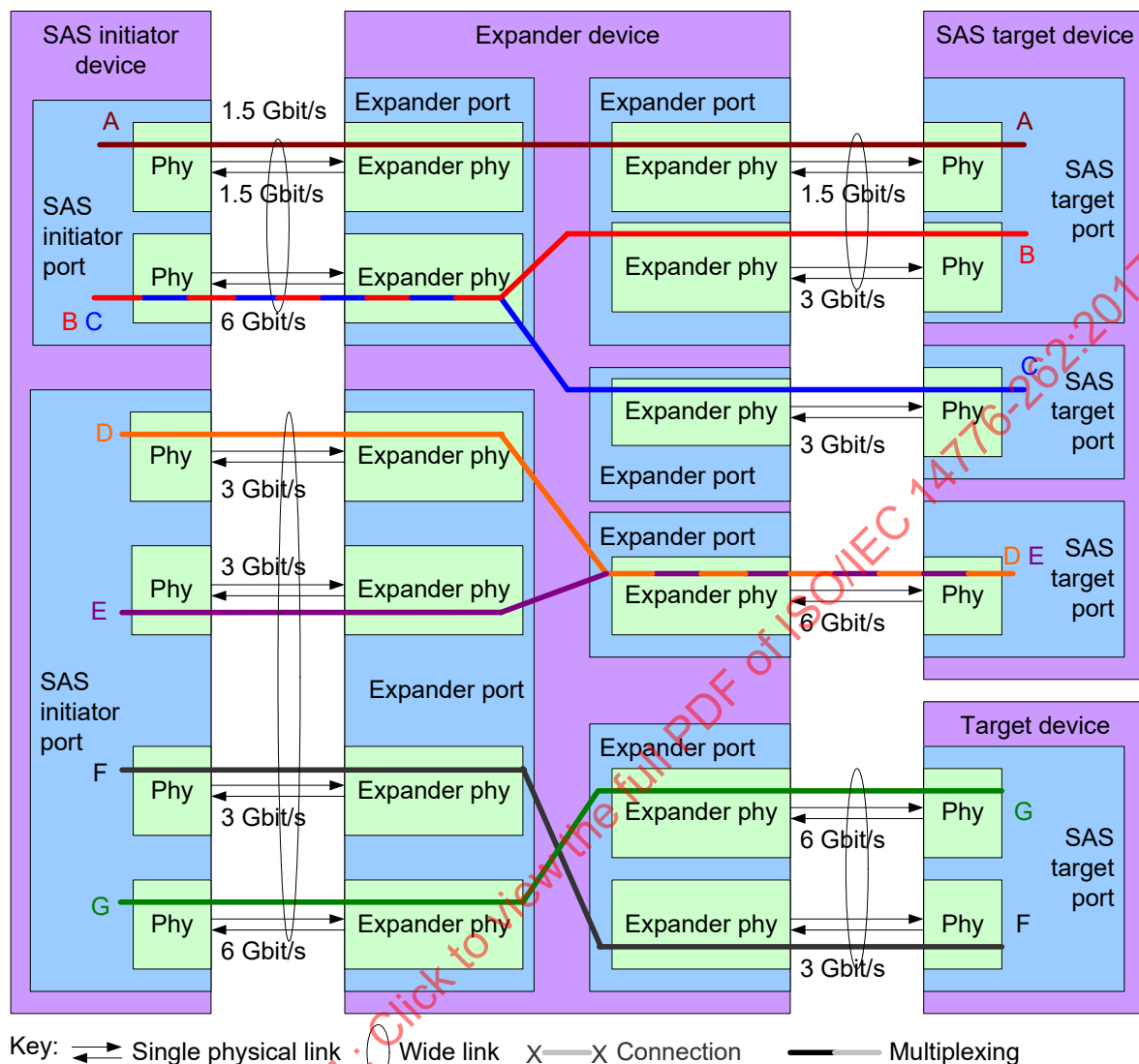
If multiple potential pathways exist between the SAS initiator port(s) and the SAS target port(s), multiple connections may be established by a SAS port between the following:

- 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 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 14 defines the Broadcast types.

Table 14 – Broadcast types (part 1 of 2)

Broadcast	Primitive ^a	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. 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).
Broadcast (SES)	yes	Originated by a logical unit with a peripheral device type set to 0Dh (i.e., enclosure services device) (see SPC-4 and SES-2) accessible through a SAS target port in the SAS domain to notify SAS initiator ports of an asynchronous event. 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. SAS target ports shall ignore this Broadcast.
Broadcast (Expander)	yes	Originated by an expander device to notify SAS initiator ports that an expander event has occurred, including: a) the expander device is going to have reduced functionality for a period of time (see 4.5.8); b) a phy event peak value detector has reached its threshold value; or c) a phy event peak value detector has been cleared by an SMP CONFIGURE PHY EVENT function (see 9.4.3.30). Expander events do not include SAS domain changes, which are communicated with Broadcast (Change). SAS target ports shall ignore this Broadcast. See 4.5.9 for management application client handling of Broadcast (Expander).
^a 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 14 – Broadcast types (part 2 of 2)

Broadcast	Primitive ^a	Description
Broadcast (Asynchronous Event)	yes	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. 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). SAS ports other than SSP initiator ports shall ignore this Broadcast.
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	Initiates the zone activate step (see 4.8.6.4). Devices that are not locked zoning expander devices shall ignore this Broadcast.
^a 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 15 describes the definitions of names and identifiers for SAS.

Table 15 – Names and identifiers

Attribute	Format	SAS usage	Reference(s)
Device name	SAS address (see 4.2.4) for SAS devices and expander devices. NAA IEEE Registered format (see 4.2.2) for SATA devices with worldwide names. ^a	Reported in: a) the IDENTIFY address frame (see 6.8.2) DEVICE NAME field; b) the Device Identification VPD page (see 9.2.11.2); and 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: a) the IDENTIFY address frame (see 6.8.2) for SAS ports; and b) the Device Identification VPD page (see 9.2.11.2).	4.2.9
Phy identifier	8-bit value	Phy identifier	4.2.10
^a 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 16 describes the identifier attributes and name attributes for SCSI architecture model objects (see SAM-5) using SAS SSP.

Table 16 – 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 17 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 17 – 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 is set to the value defined in table 17.

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

Bit 5 of byte 1, which serves as the UNIVERSALLY/LOCALLY ADMINISTERED ADDRESS bit, shall be set to zero.

Bit 4 of byte 1, which serves as the INDIVIDUAL/GROUP ADDRESS bit, shall be set to zero.

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 18 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 18 – NAA Locally Assigned format

Byte\Bit	7	6	5	4	3	2	1	0
0	NAA (3h)							
1								
2								
3								
4					LOCALLY ADMINISTERED VALUE			
5								
6								
7								

The NAA field is set to the value defined in table 18.

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:

- a) the NAA IEEE Registered format (see 4.2.2); or
- b) 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 19 lists the parameters for the code.

Table 19 – Hashed SAS address code parameters

Parameter	Value
Number of bits per codeword	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 20 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 DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data (See ACS-2).

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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

Table 20 – Device name created from the IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device world wide name

Subformat field name ^a	Specific bits in	Contents ^b
NAA	Byte 0 bits 7:4	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 108 bits 15:12 ^c
IEEE COMPANY_ID	Byte 0 bits 3:0	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 108 bits 11:8
	Byte 1	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 108 bits 7:0
	Byte 2	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 109 bits 15:8
	Byte 3 bits 7:4	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 109 bits 7:4
VENDOR SPECIFIC IDENTIFIER	Byte 3 bits 3:0	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 109 bits 3:0
	Byte 4	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 110 bits 15:8
	Byte 5	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 110 bits 7:0
	Byte 6	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 111 bits 15:8
	Byte 7	IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data word 111 bits 7:0
^a See table 17. ^b IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data words 108-111 contain the world wide name field (see ACS-2). ^c 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

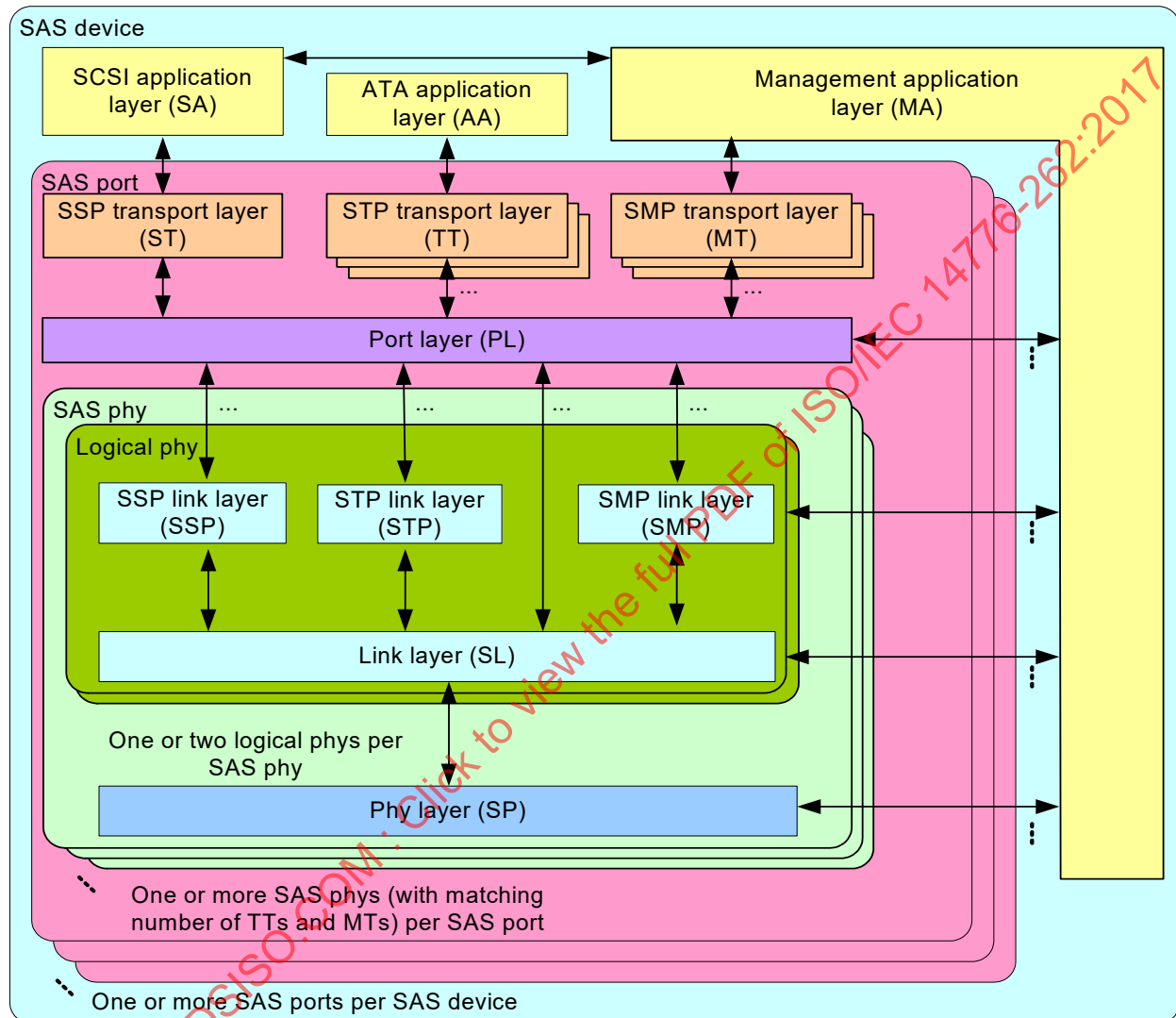
Each SAS phy and expander phy shall be assigned an identifier called a phy identifier that is unique within the SAS device and/or expander device. Each SAS logical phy within a SAS phy shall use the same phy identifier. Each expander logical phy within an expander phy shall use the same phy identifier. 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).

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.



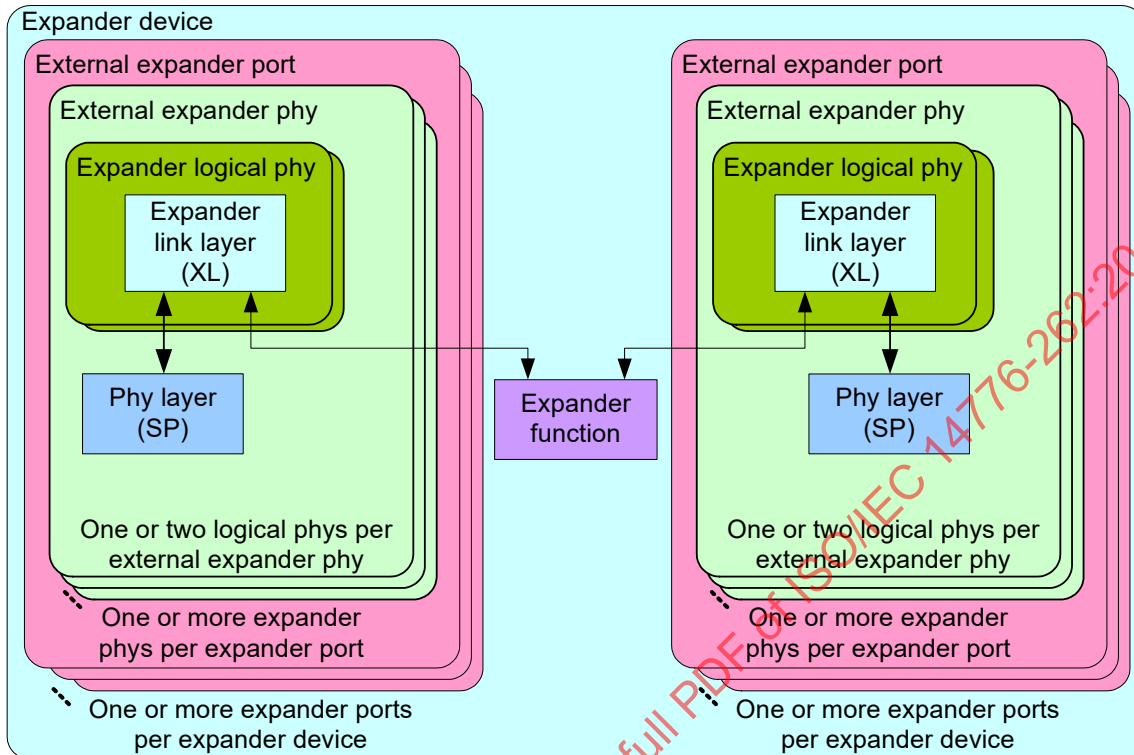
Note 1 - The link layer includes the SL_IR state machines.

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.



Note: The expander link layer includes the SL_IR state machines.

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).

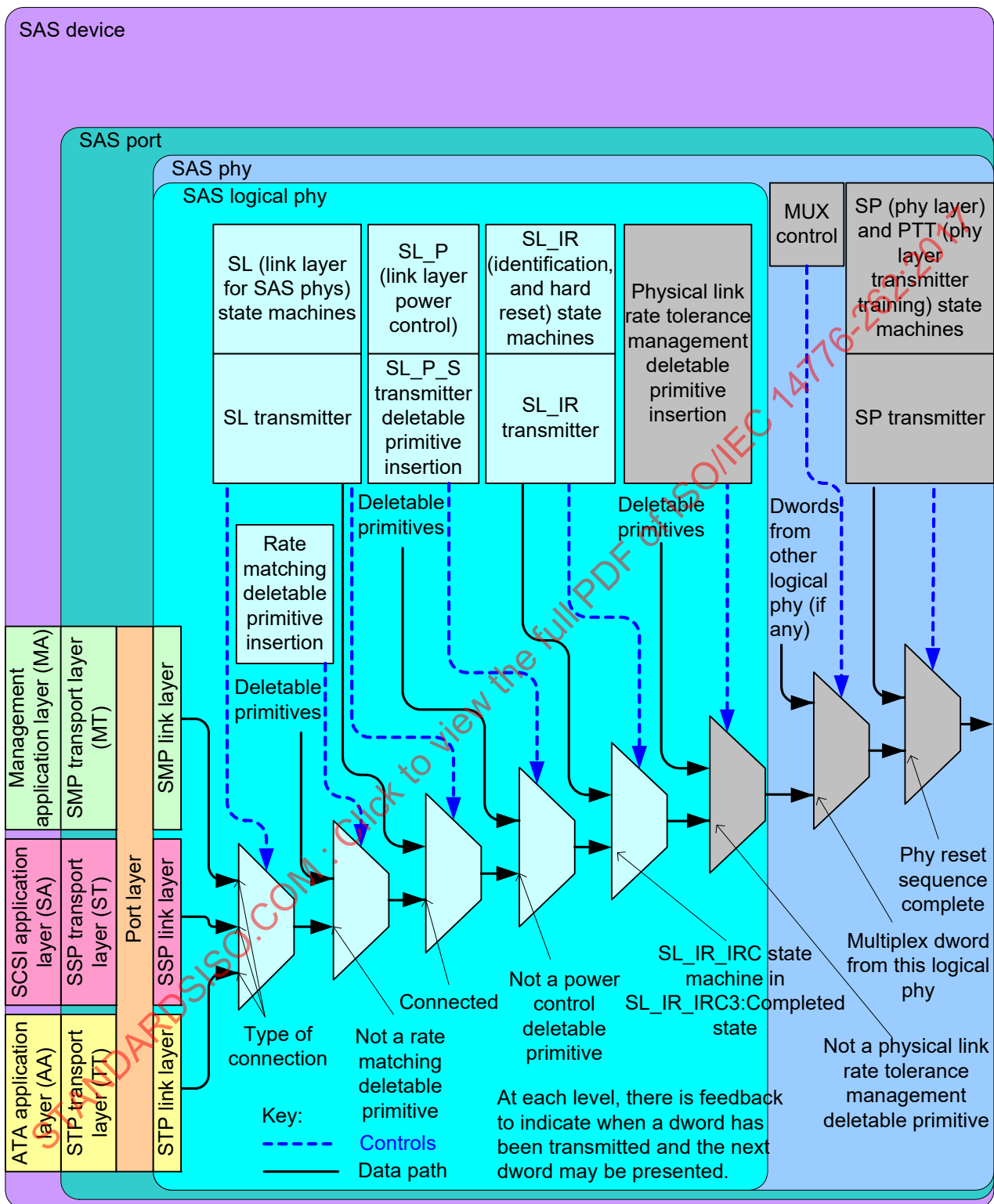


Figure 29 – Transmit data path in a SAS phy

Figure 30 shows the transmit data path for the SSP link layer, including the SSP state machines and the SSP transmitter (see 6.18.8 and 6.18.8.2), 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.

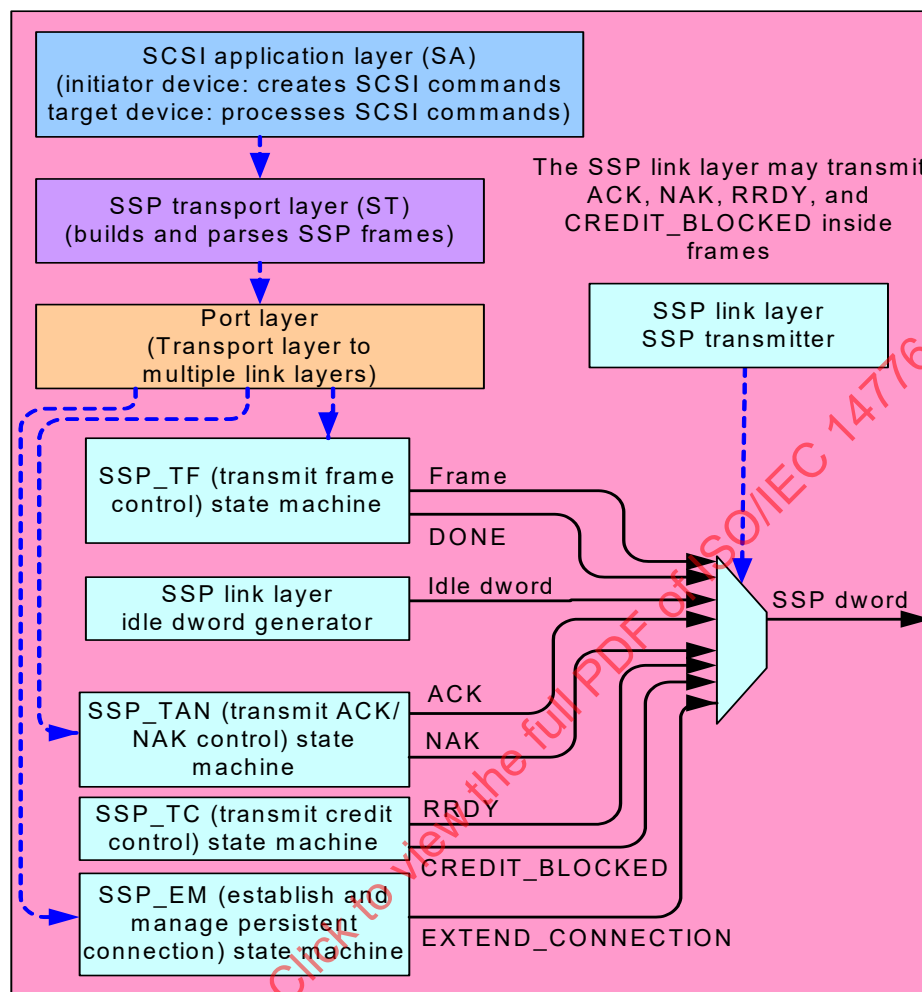


Figure 30 – SSP link, port, SSP transport, and SCSI application layer state machines

Figure 31 shows the transmit data path for the SMP link layer, including the SMP state machines and the SMP transmitter (see 6.20.5 and 6.20.5.2), and 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.

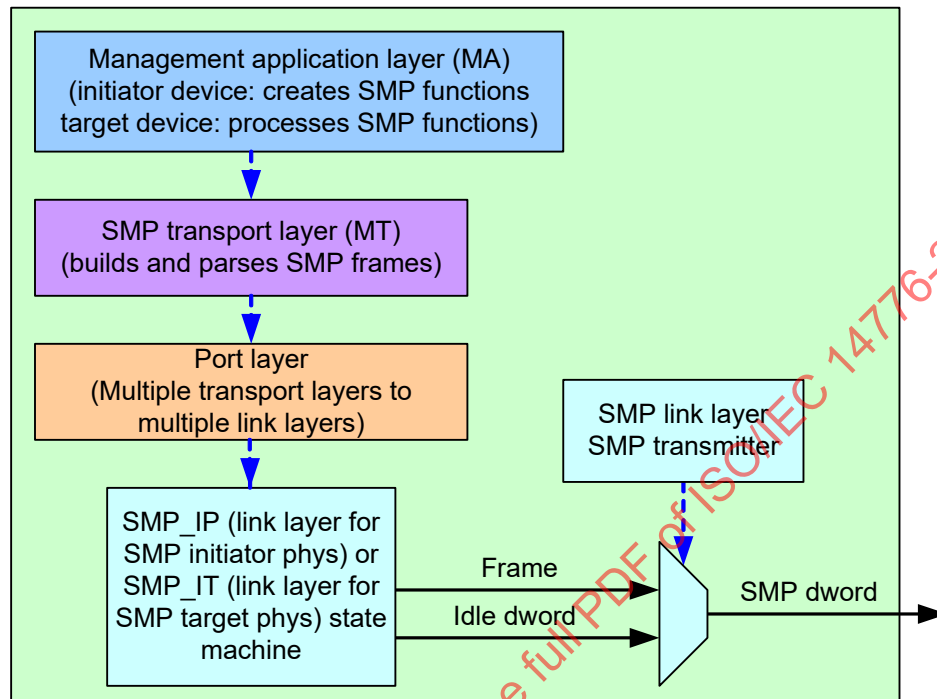


Figure 31 – SMP link, port, SMP transport, and management application layer state machines

Figure 32 shows the transmit data path for the STP link layer, including the STP state machines (see 6.19.8), and communication to the port layer, STP transport layer, and ATA application layer. Only the STP link layer (i.e., not the port layer, STP transport layer, or ATA application layer) transmits dwords.

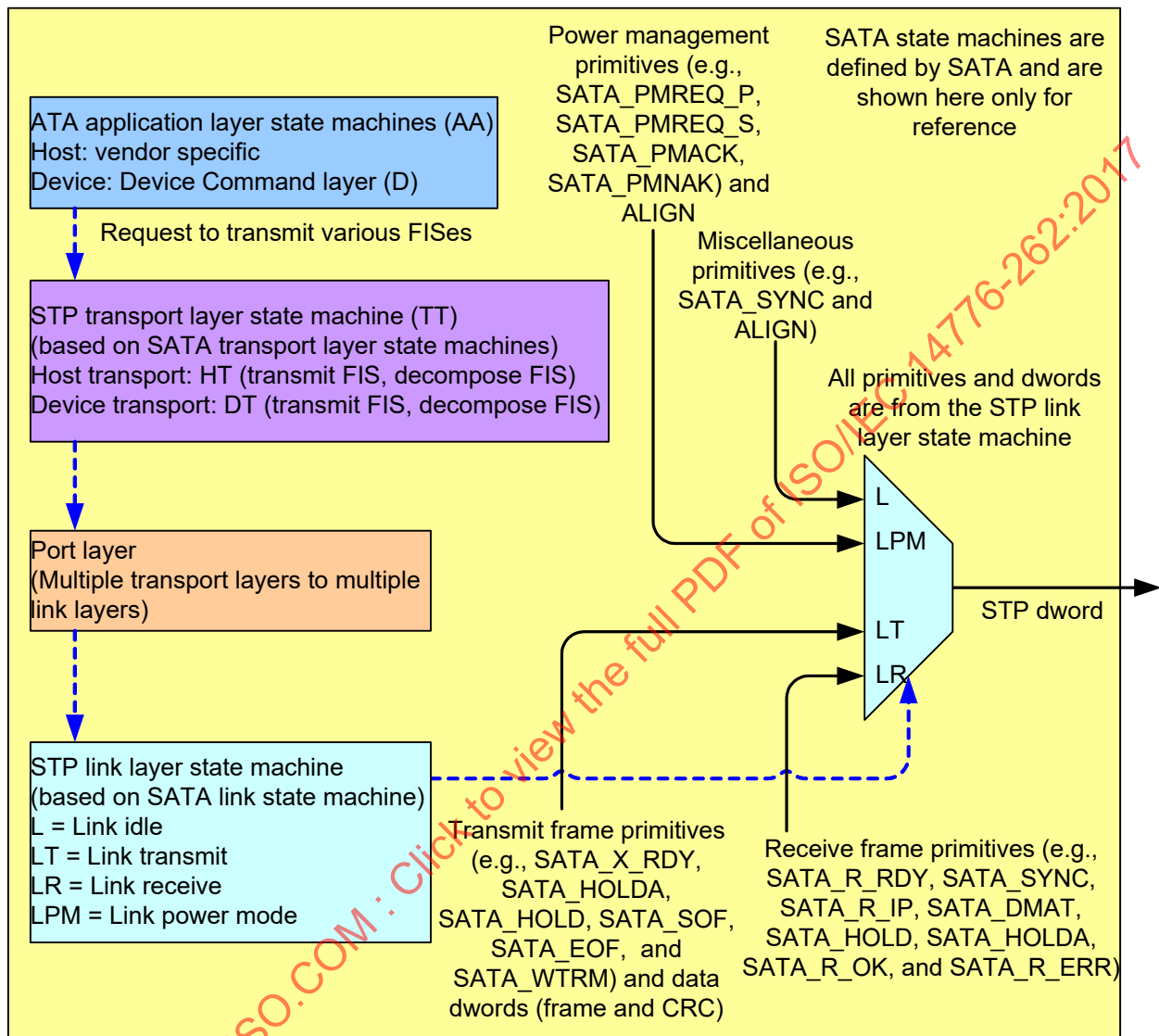


Figure 32 – STP link, port, STP transport, and ATA application layer state machines

Figure 33 shows the transmit data path in an expander 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);
- 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);
- power control (see 6.12) and the SL_P_S transmitter (see 6.12.4.2); and
- the XL state machines (see 6.17) and the XL transmitter (see 6.17.2).

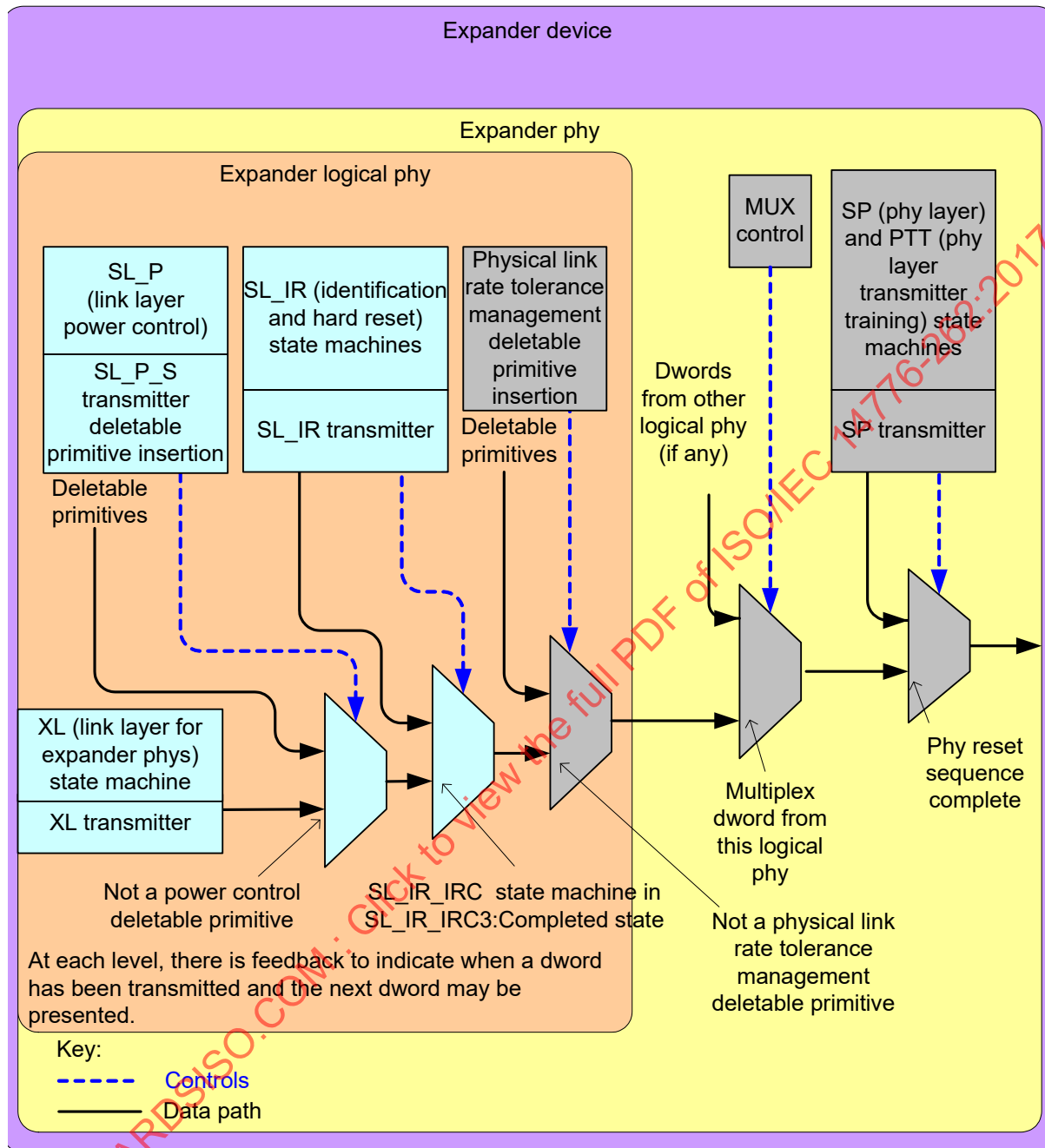


Figure 33 – Transmit data path and state machines in an expander phy

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 to the link layer state machine receivers.

If multiplexing (see 5.15) is enabled (see table 54), 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);
- the SP_DWS state machine (see 5.13) and the SP_DWS receiver (see 5.13.2);
- the SL_IR state machines (see 6.10) and the SL_IR receiver (see 6.10.2);
- 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); and
- g) the SSP state machines (see 6.18.8) and the SSP receiver (see 6.18.8.2);
- 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).

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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

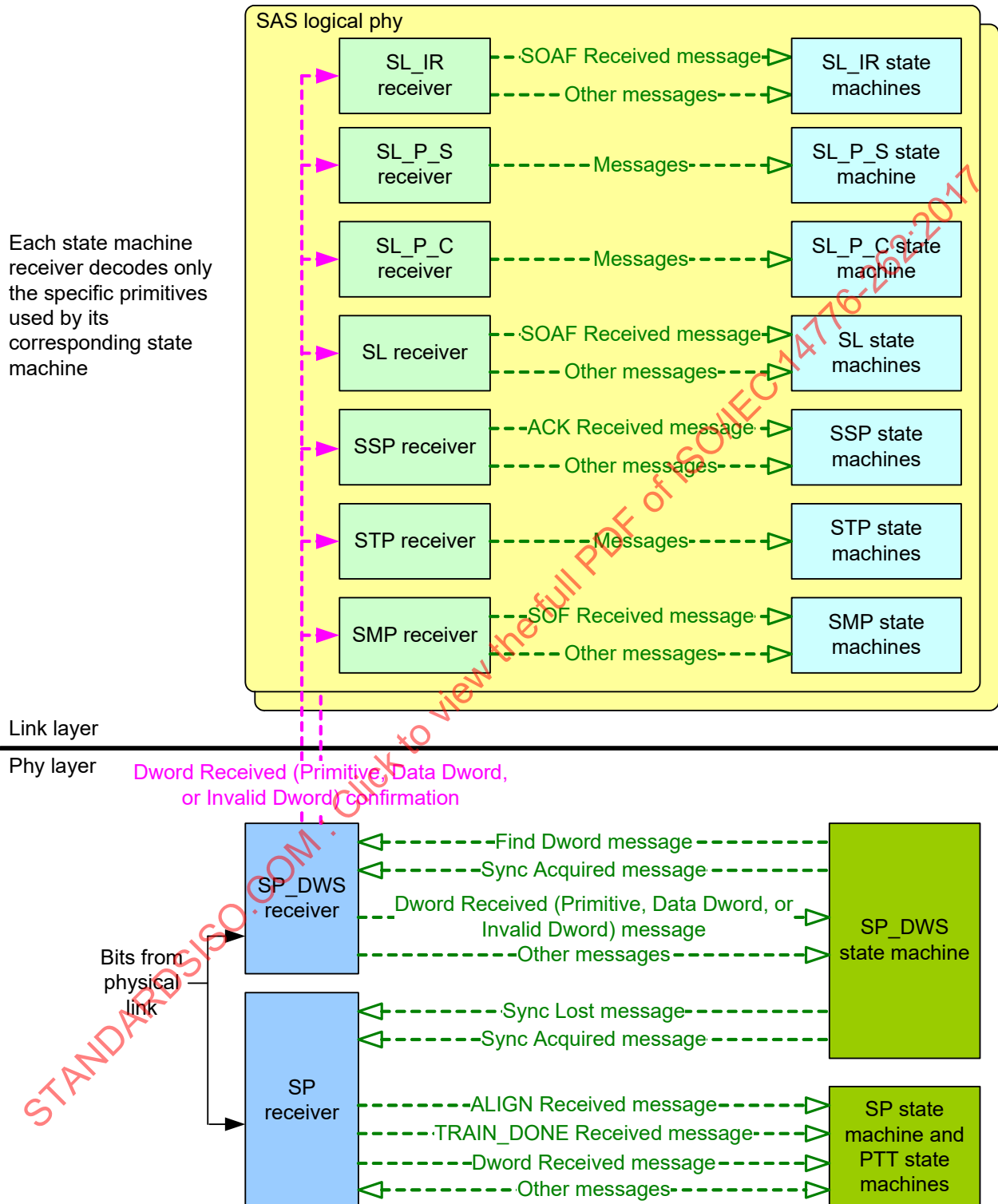


Figure 34 – Receive data path in a SAS phy

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.

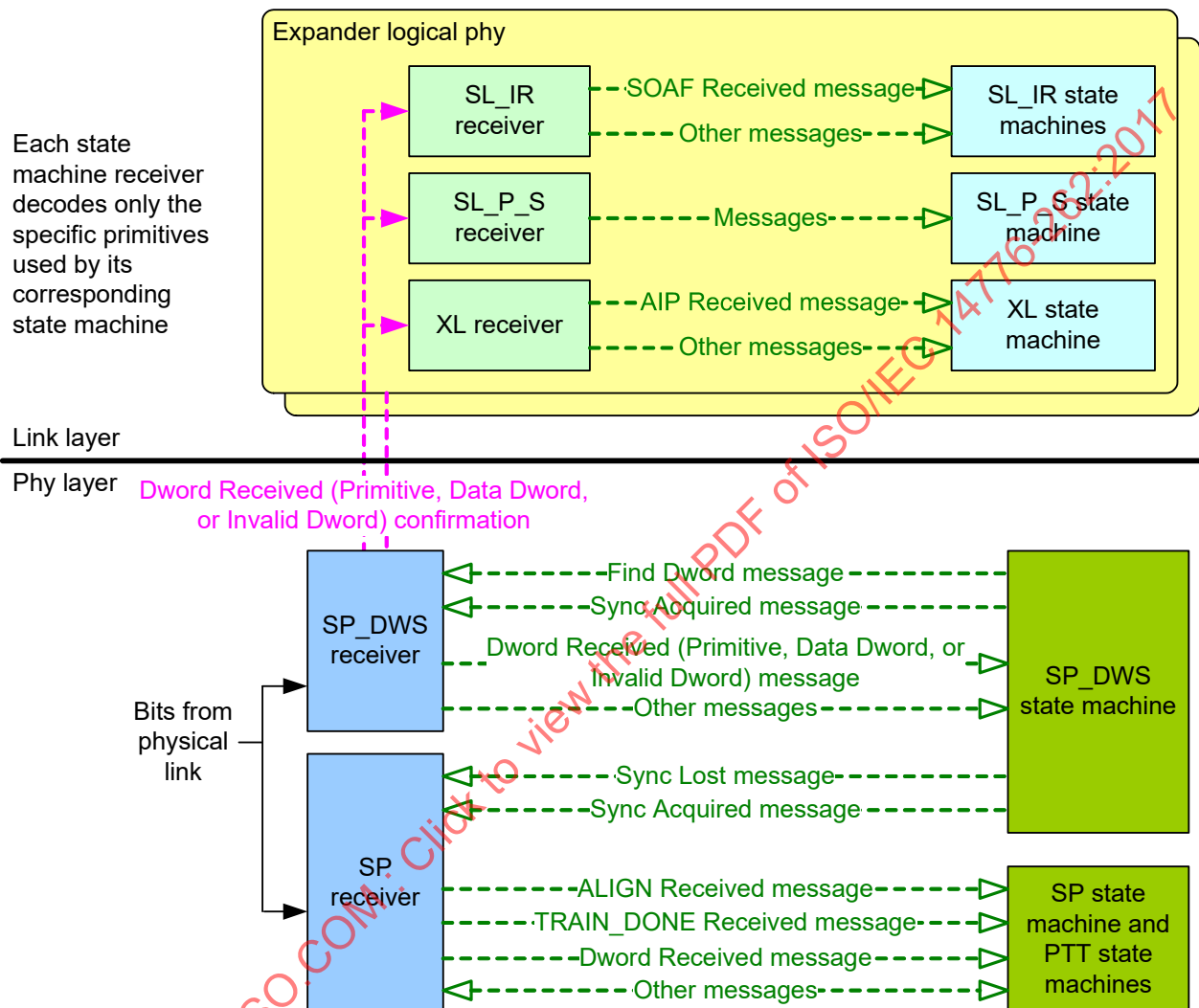


Figure 35 – Receive data path in an expander phy

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.

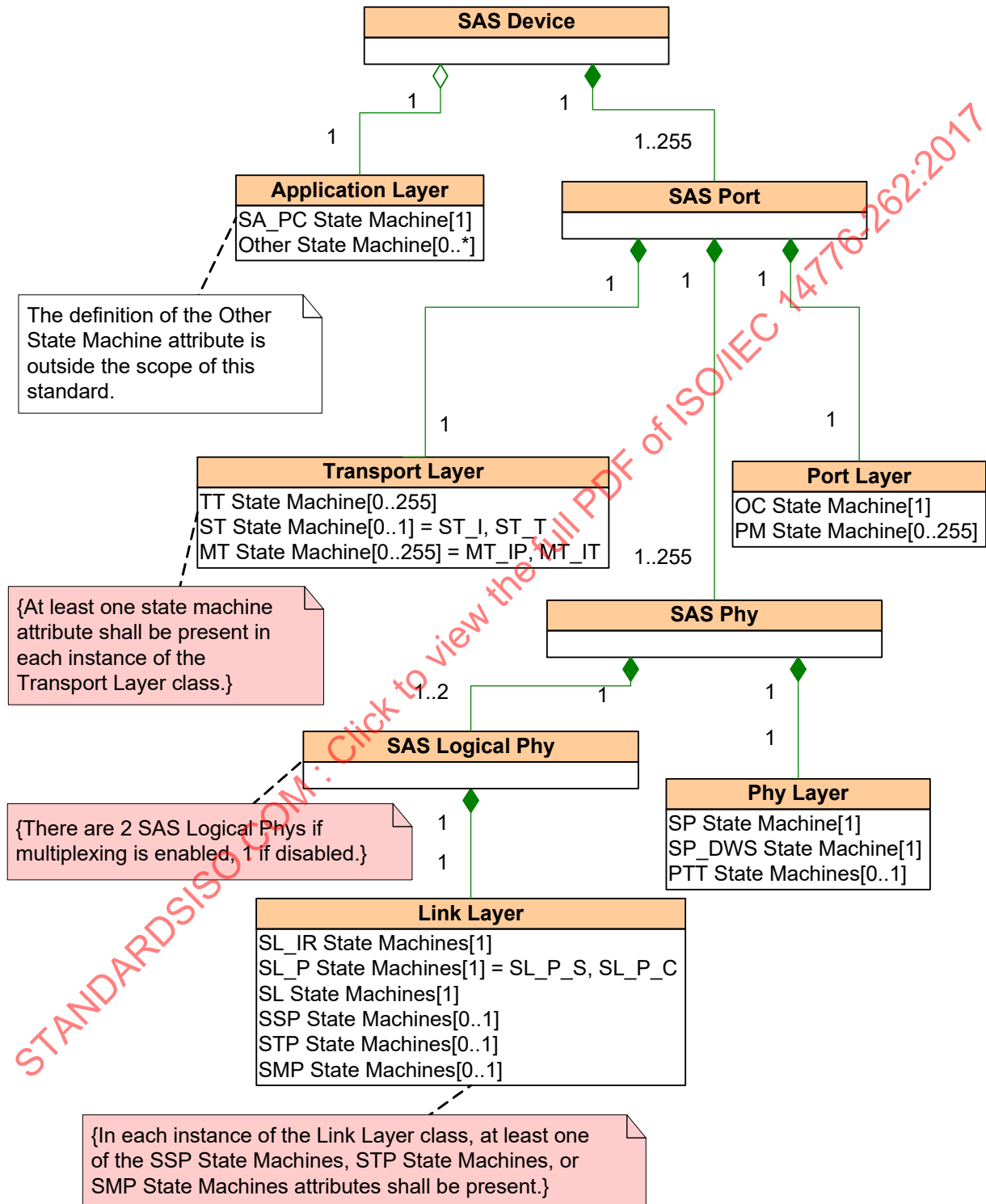


Figure 36 – State machines and SAS Device classes

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.

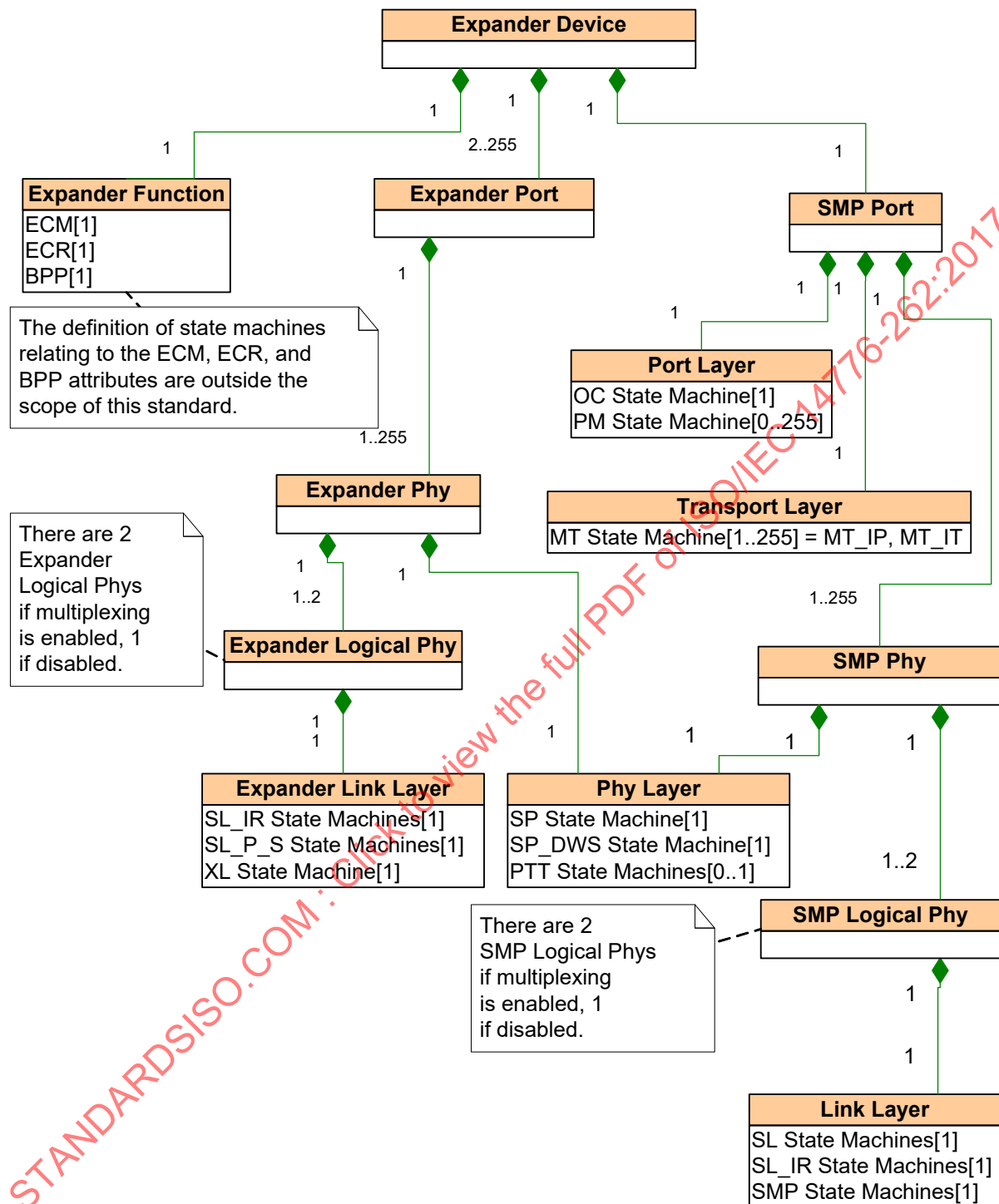


Figure 37 – State machines and Expander Device classes

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).

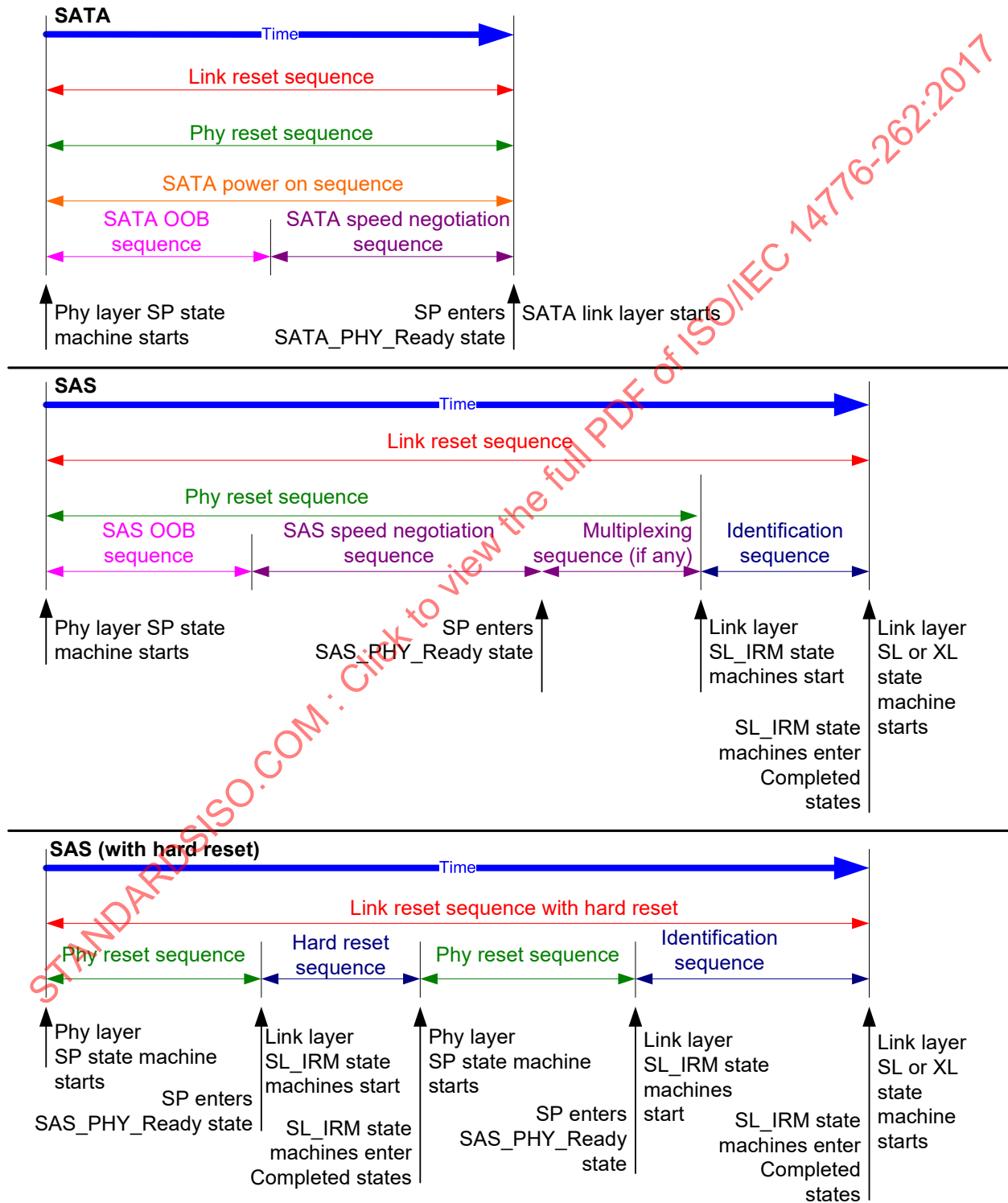


Figure 38 – Reset terminology

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 an 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 7.2.2.3.2) 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 108);
- b) a connection request to the destination port results in the Open Timeout timer expiring (see 6.14.2); or
- c) 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 108); or
- b) a connection to the destination port is established.

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 107); 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:

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

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

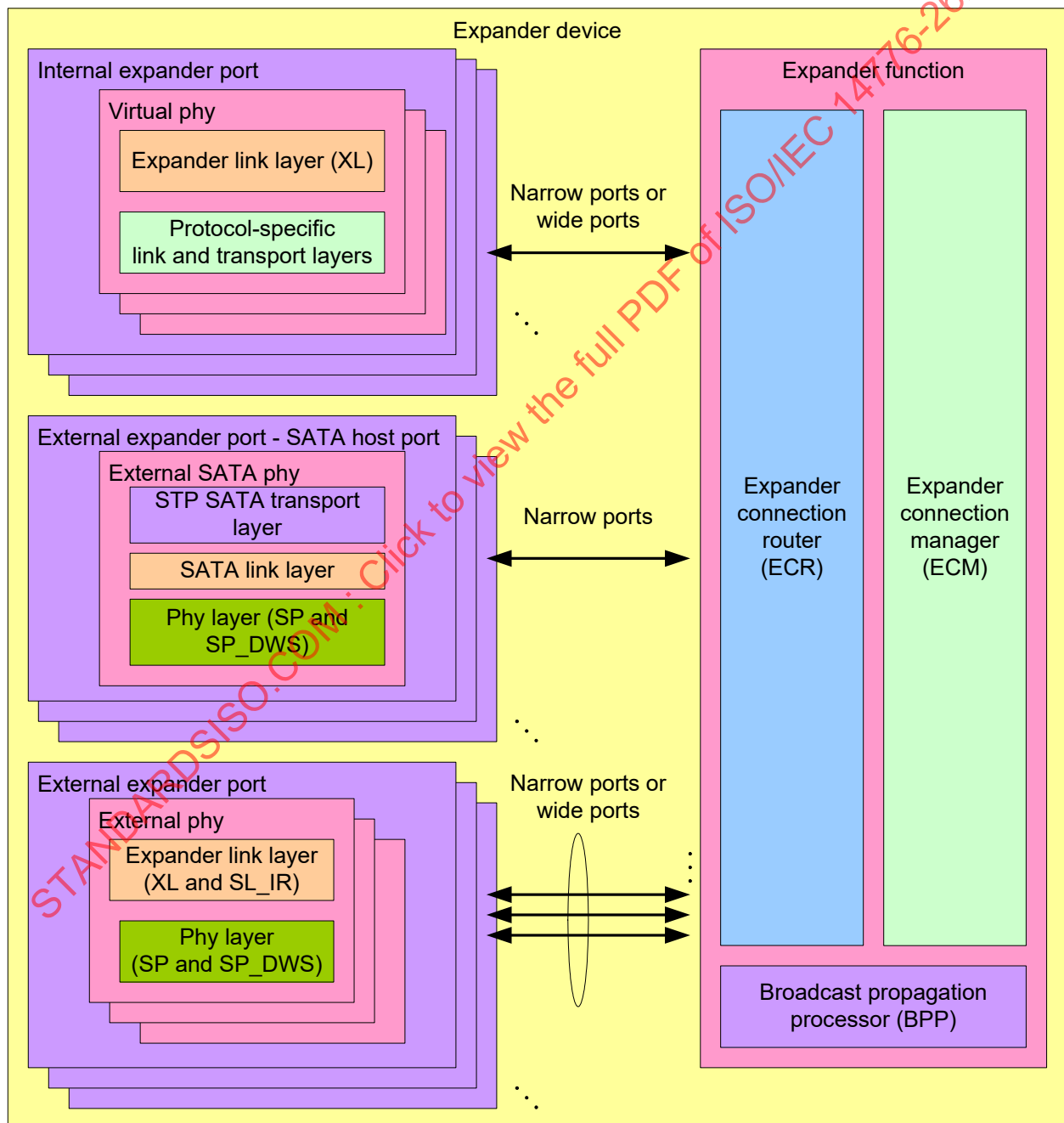


Figure 39 – Expander device model

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-2)).

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.

When 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).

When 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 - The receiver may send up to 20 data dwords after detection of SATA_HOLD. Therefore, the transmitter of SATA_HOLD may receive up to 21+n data dwords (see 6.19.2). SATA_HOLD does not affect primitives (see SATA). The STP SATA bridge may expand or contract 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.

Figure 40 describes the interfaces present within an expander device.

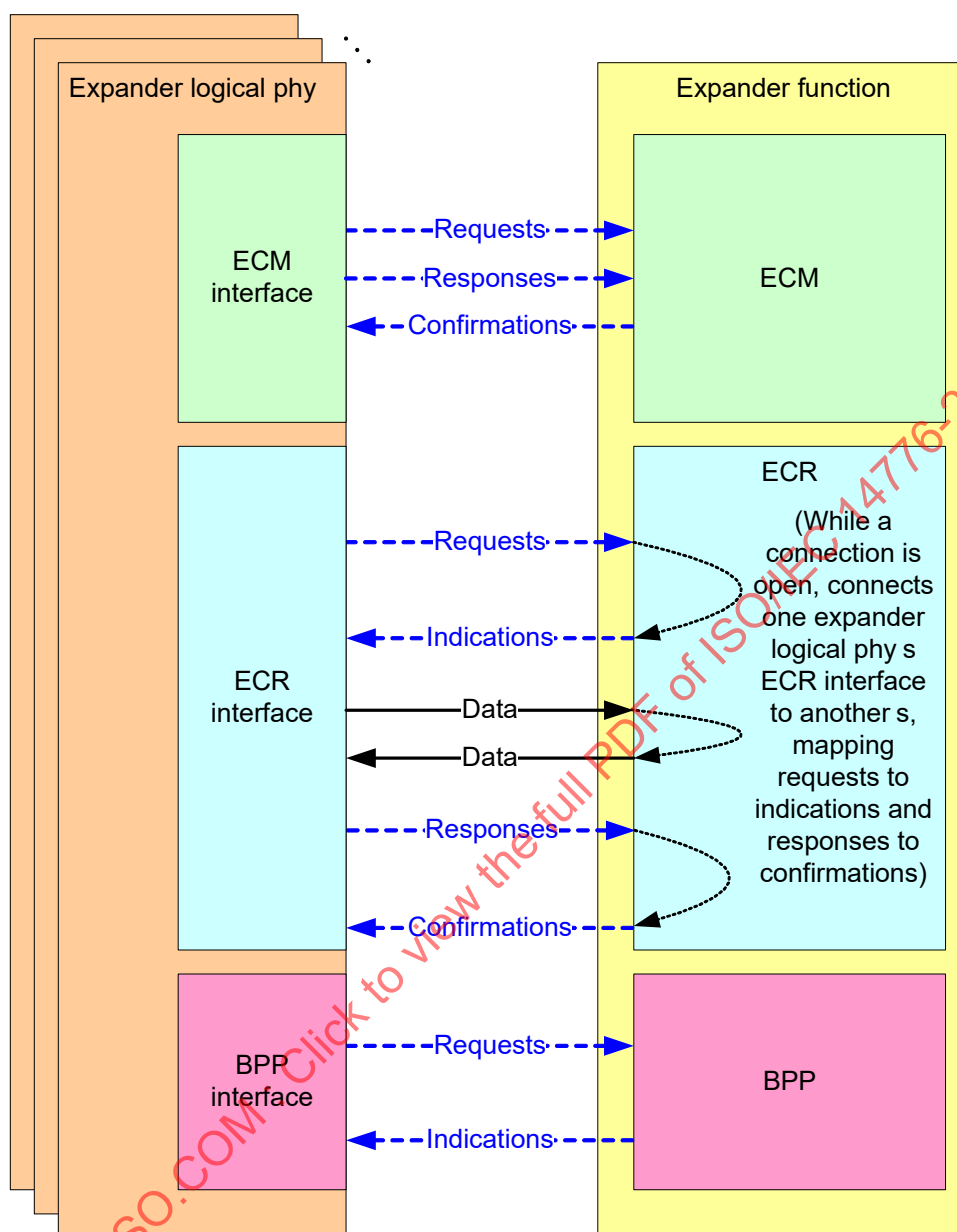


Figure 40 – Expander device interfaces

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.

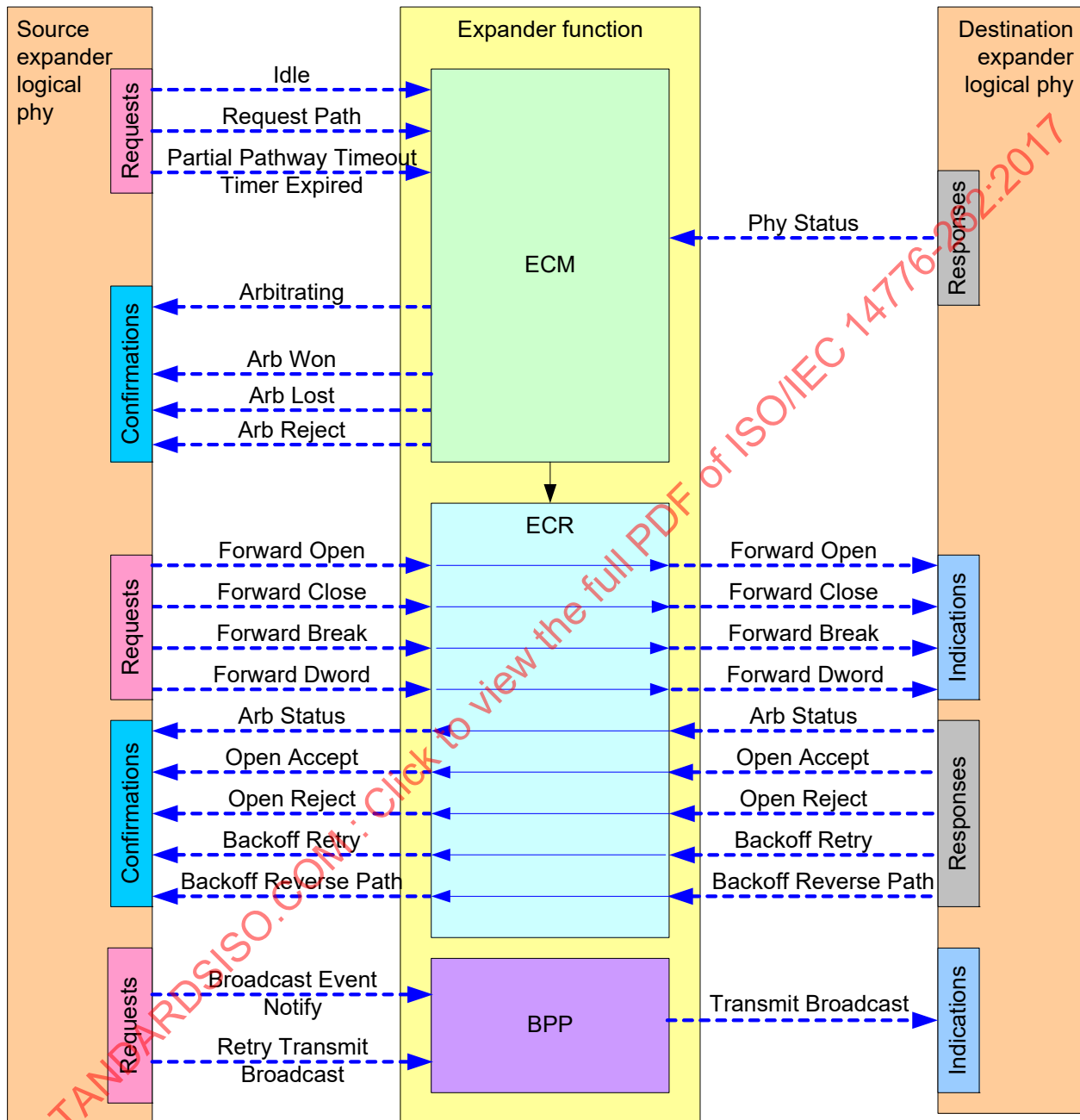


Figure 41 – Expander device interface detail

4.5.6.3 ECM interface

Table 21 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 21 – 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 22 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 22 – Expander logical phy to ECM responses

Response	Description
Phy Status (Partial Pathway)	Response meaning that an expander logical phy: a) is being used for an unblocked partial pathway; or 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: a) is being used for a blocked partial pathway; or 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: a) is being used for a connection; or 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 23 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 23 – 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: a) the expander device is configuring (see 4.6.4) and the ECM would otherwise have returned Arb Reject (No Destination); b) the expander device is locked (see 4.8.6.2) and the ECM would otherwise have returned Arb Reject (Zone Violation); or c) the expander device has reduced functionality (see 4.5.8 and 6.14.4.2.5).

4.5.6.4 ECR interface

Table 24 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 24 – 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 25 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Table 25 – Expander logical phy to ECR to expander logical phy responses and confirmations

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: a) AIP (WAITING ON DEVICE) has been received; or b) the expander logical phy has completed the forwarding of an OPEN address frame and has entered the XL6:Open_Response_Wait state.
Open Accept	Confirmation/response that OPEN_ACCEPT has been received.
Open Reject	Confirmation/response that either: a) OPEN_REJECT has been received; or 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: a) a higher priority OPEN address frame has been received (see 6.14.3); and 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: a) a higher priority OPEN address frame has been received (see 6.14.3); and 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 26 describes the requests from an expander logical phy to the BPP. Requests from the management device server about SMP ZONED BROADCAST requests (see table 304) 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 26 – 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 27 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 27 – 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 28 describes the routing methods that the ECM uses based on the routing attributes of an expander phy.

Table 28 – 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 ^a	
Table	Direct	Direct for the SAS address of the expander device. Table for SAS addresses beyond the expander device.
Subtractive	Direct	Subtractive
^a 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 SAS 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 29 defines the types of expander route tables.

Table 29 – 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.

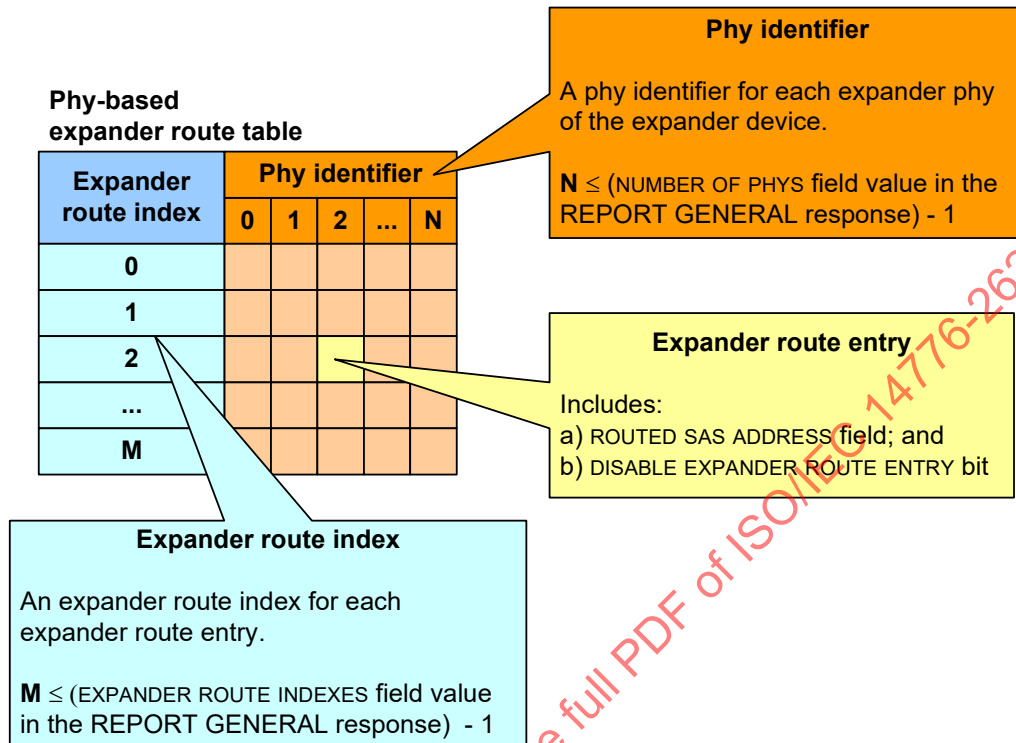


Figure 42 – Phy-based expander route table

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.

Routed SAS address	Phy bit map				
	0	1	2	...	N
SAS address A					
SAS address B		1			
SAS address C					
...					

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 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.

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.

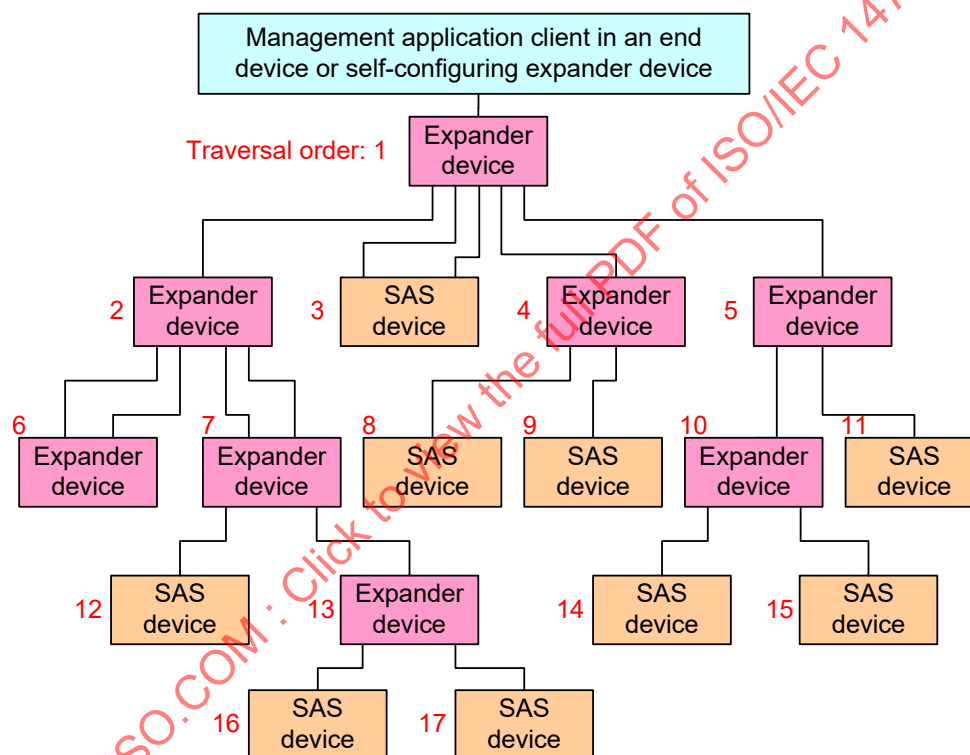
The discover process completes when all expander devices have been traversed. If the management application client discovers an externally configurable expander device that is not located beyond a

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.

While a self-configuring expander device's CONFIGURING bit is set to one in the SMP REPORT GENERAL response, connection requests for destination ports two or more levels beyond the self-configuring expander device that would otherwise have returned OPEN_REJECT (NO DESTINATION) return OPEN_REJECT (RETRY) instead (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.

While the SELF CONFIGURING bit is set to one, the expander device shall return OPEN_REJECT (RETRY) for any connection requests that would otherwise have resulted in 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), when the management application client discovers an externally configurable expander device, 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 illegal topologies.

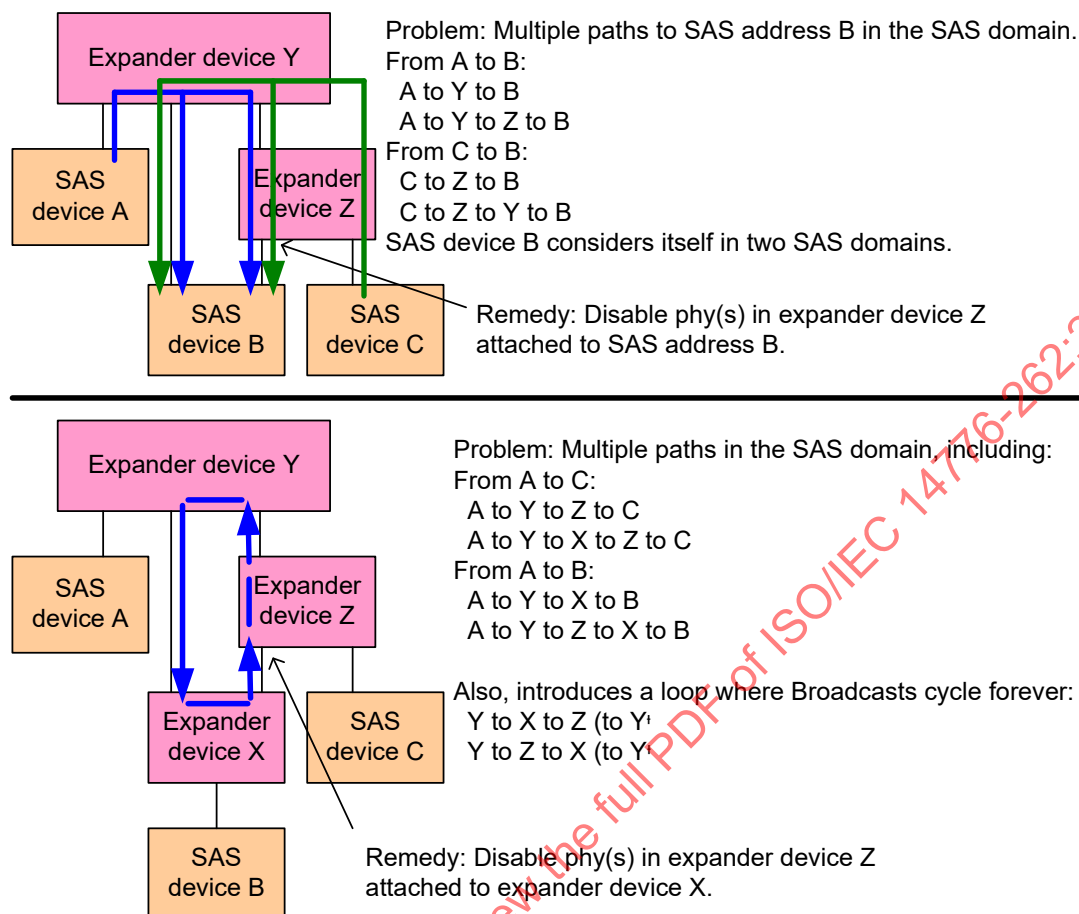


Figure 45 – Examples of invalid topologies

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 ROUTE 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

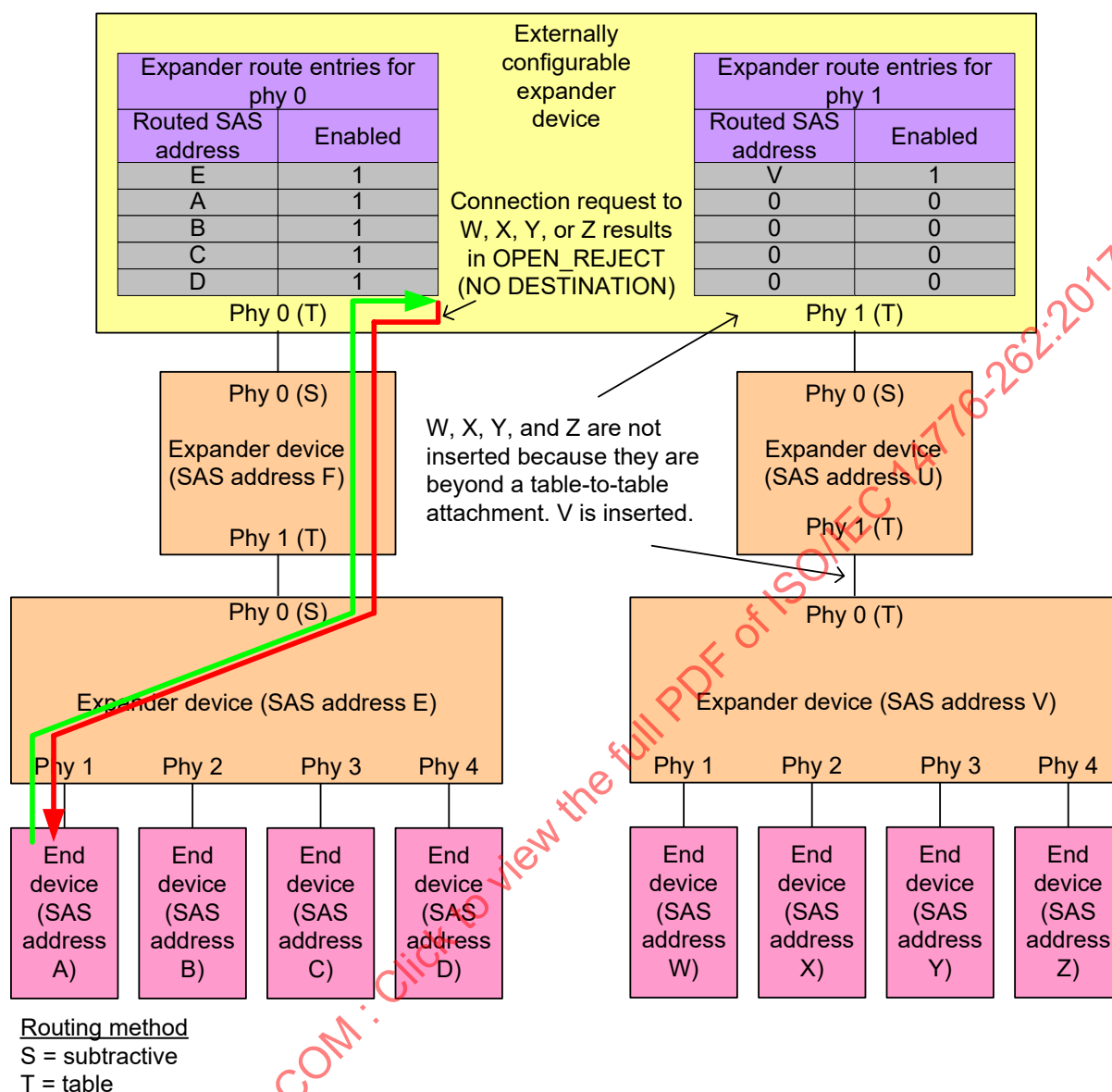


Figure 46 – Externally configurable expander device and table-to-table attachment

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.

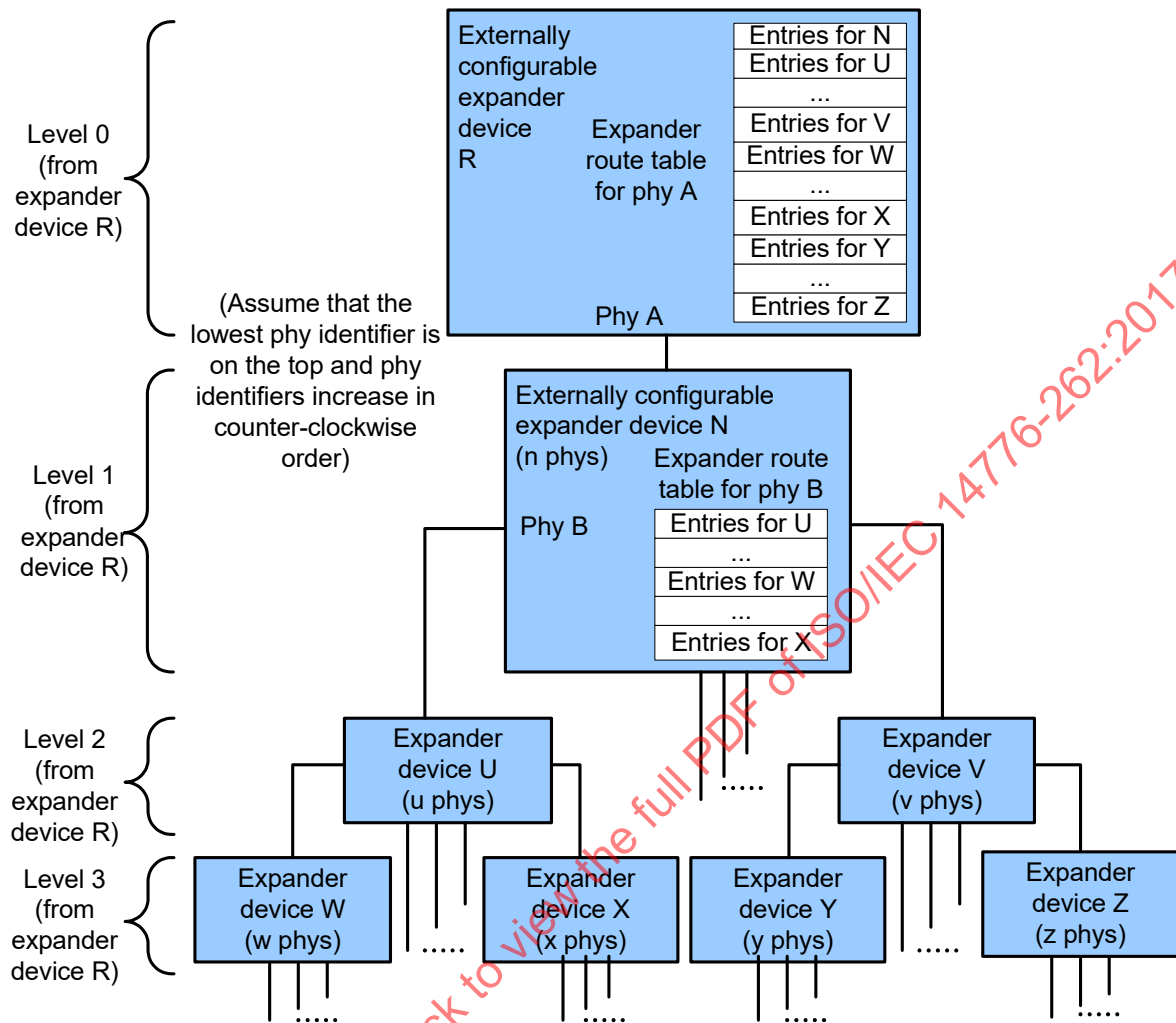


Figure 47 – Expander route index levels example

Table 30 shows how the expander route table is configured for externally configurable expander device R phy A in figure 47.

Table 30 – 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
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 31 shows how the expander route table is configured for externally configurable expander device N phy B in figure 47.

Table 31 – 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.

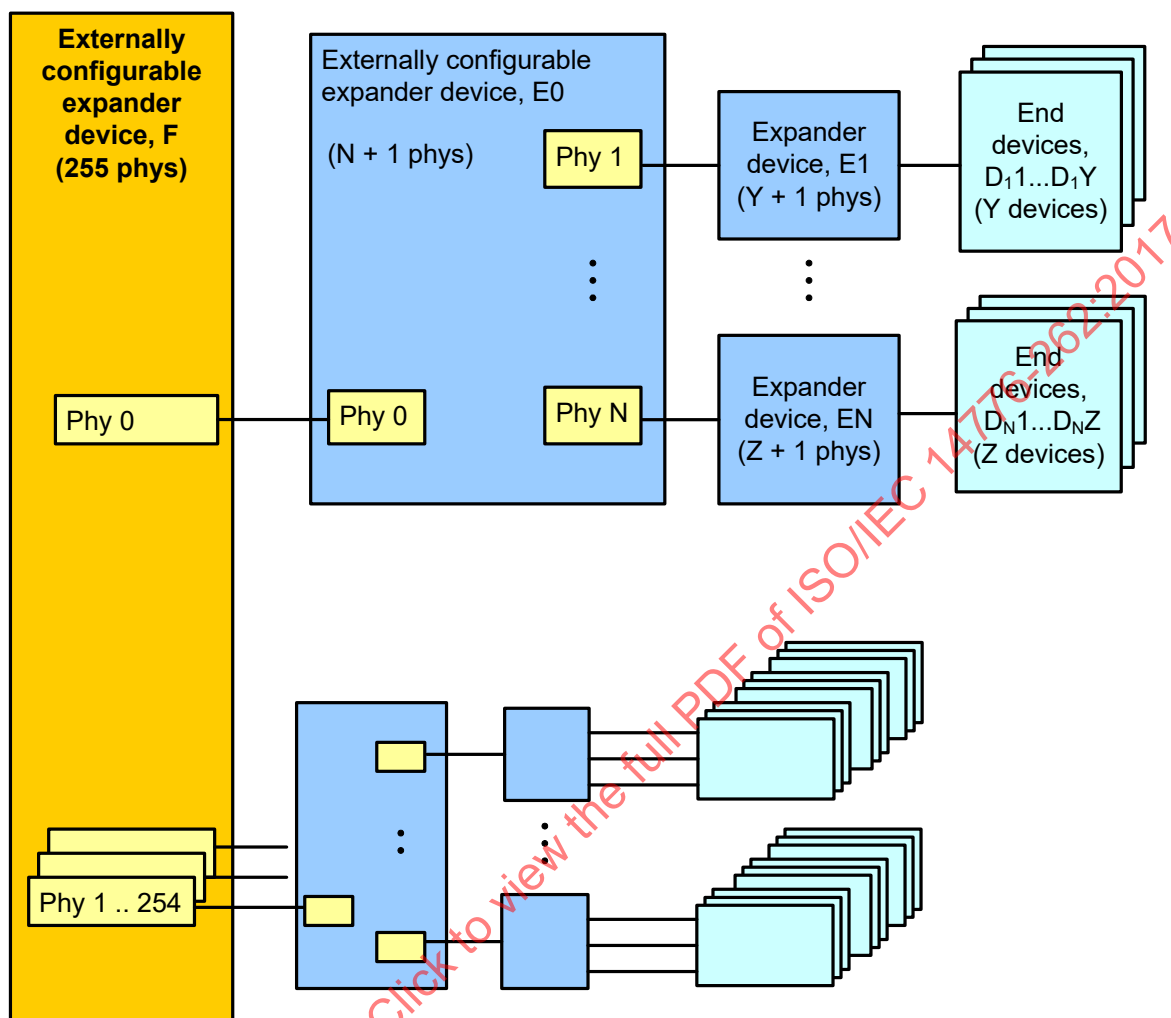


Figure 48 – Expander route index order example

Table 32 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 32 – 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 ₁ 1) of the device attached to phy 1 of expander device E1
1	SAS address (e.g., D ₁ 2) of the device attached to phy 2 of expander device E1
...	...
Y - 1	SAS address (e.g., D ₁ Y) of the device attached to phy Y of expander device E1
Level 2 and beyond	
	No entries
Disabled entries	
	Any remaining entries are disabled

Table 33 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 33 – 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 ₁ 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 ₁ Y) of the device attached to phy Y of expander device E1
...	...additional qualified SAS addresses for expander devices E2 through EN-1...
	SAS address (e.g., D _N 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 _N Z) of the device attached to phy Z of expander device EN
Level 3 and beyond	
	No entries since all devices attached to E1 through EN, except for E0, are end devices
Disabled entries	
	Any remaining entries are disabled

4.8 Zoning

4.8.1 Zoning overview

SAS zoning is implemented by a set of zoning expander devices with zoning enabled that define a zoned portion of a service delivery subsystem (ZPSDS). The zoning expander devices control whether a phy is permitted to participate in a connection to another phy.

Figure 49 shows an example of zoning.

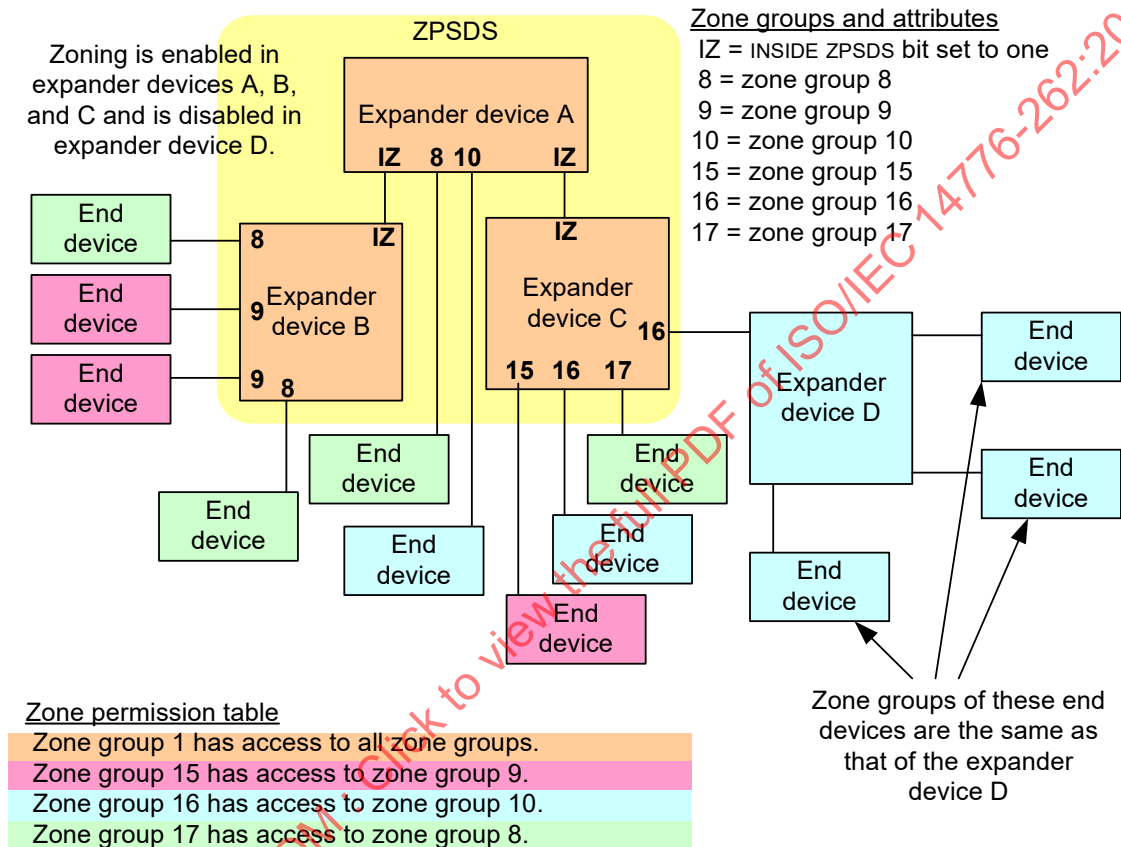
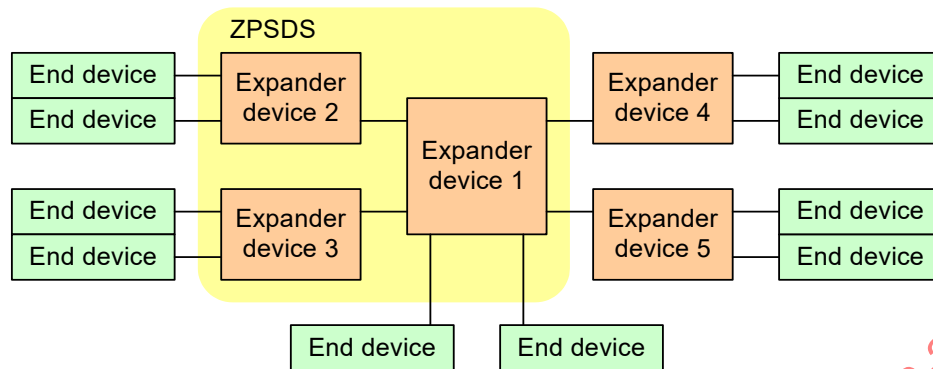


Figure 49 – Zoning example

Figure 50 shows an example of one ZPSDS in a SAS domain.



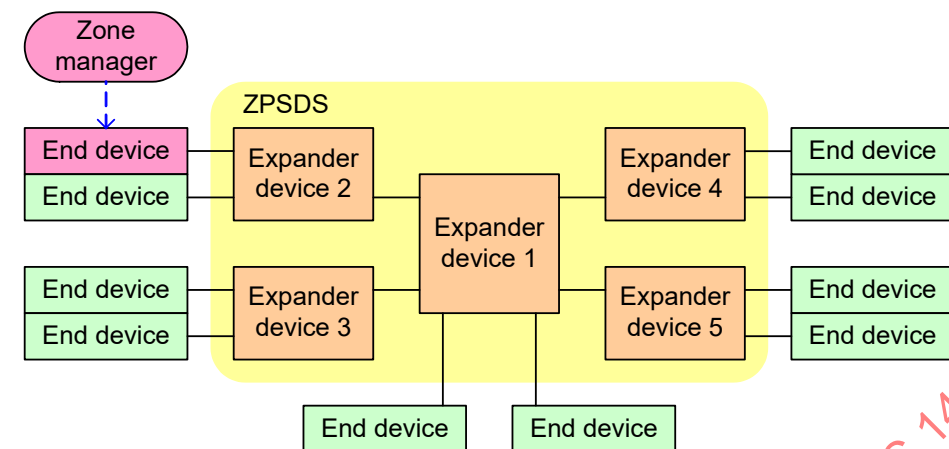
Expander devices 1, 2, and 3 have zoning enabled.
Expander devices 4 and 5 have zoning disabled.

Figure 50 – One ZPSDS example

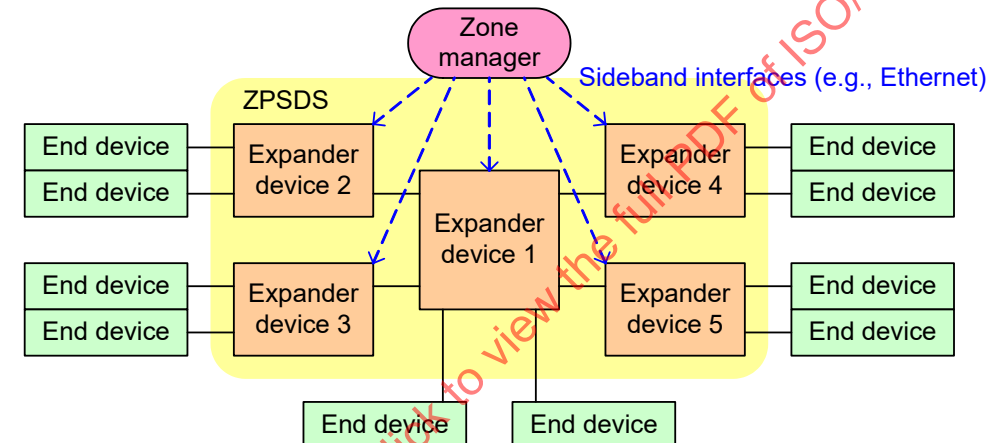
A ZPSDS has a zone manager responsible for its configuration. The zone manager may have access to an end device with a SAS port whose zone group (see 4.8.3.2) has access to zone group 2, or may have access to one or more zoning expander devices through a sideband interface (e.g., Ethernet) outside the 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

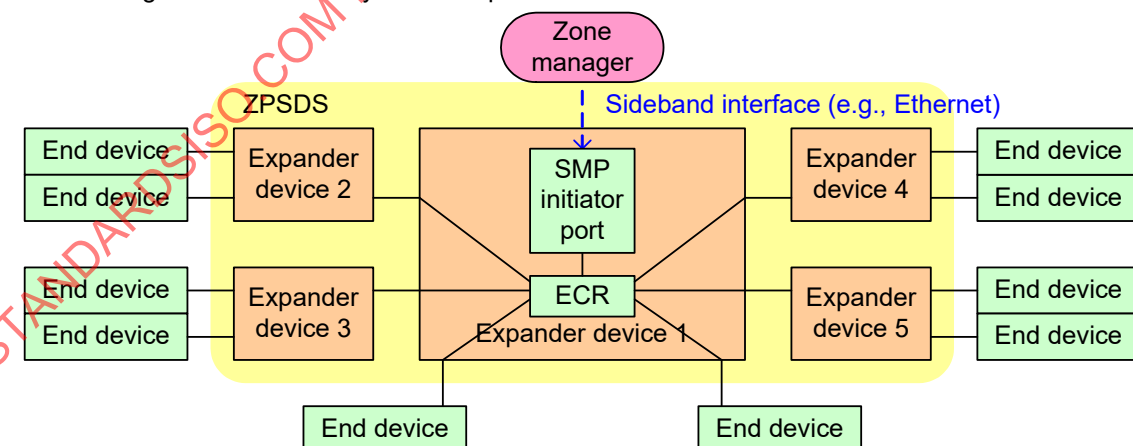


Figure 51 – Zone manager location examples

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.

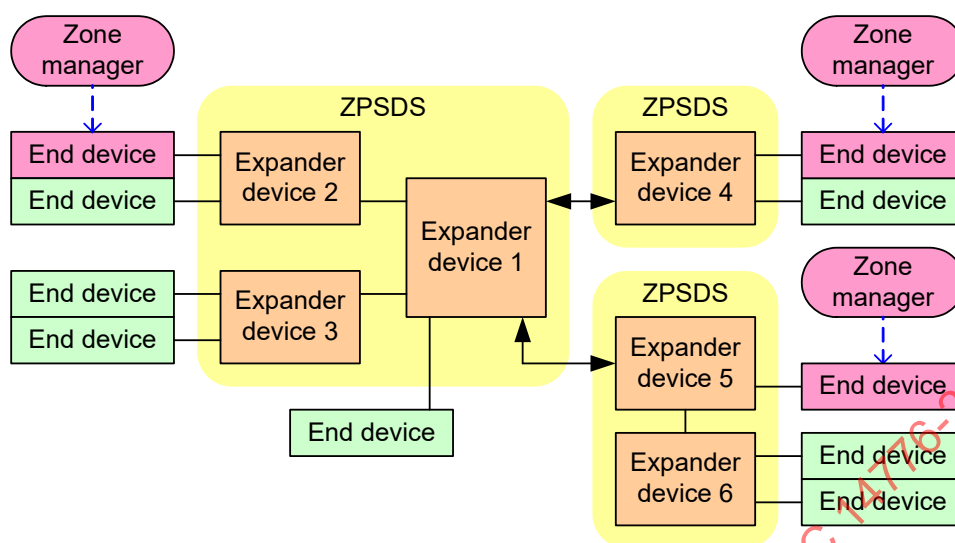


Figure 52 – Three ZPSDSes example

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 through 127 or 0 through 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 34.

Table 34 – Zone manager password

Code	Name	Description
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000h	ZERO	Well-known value that provides access to any zone manager that presents it.
FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF 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.

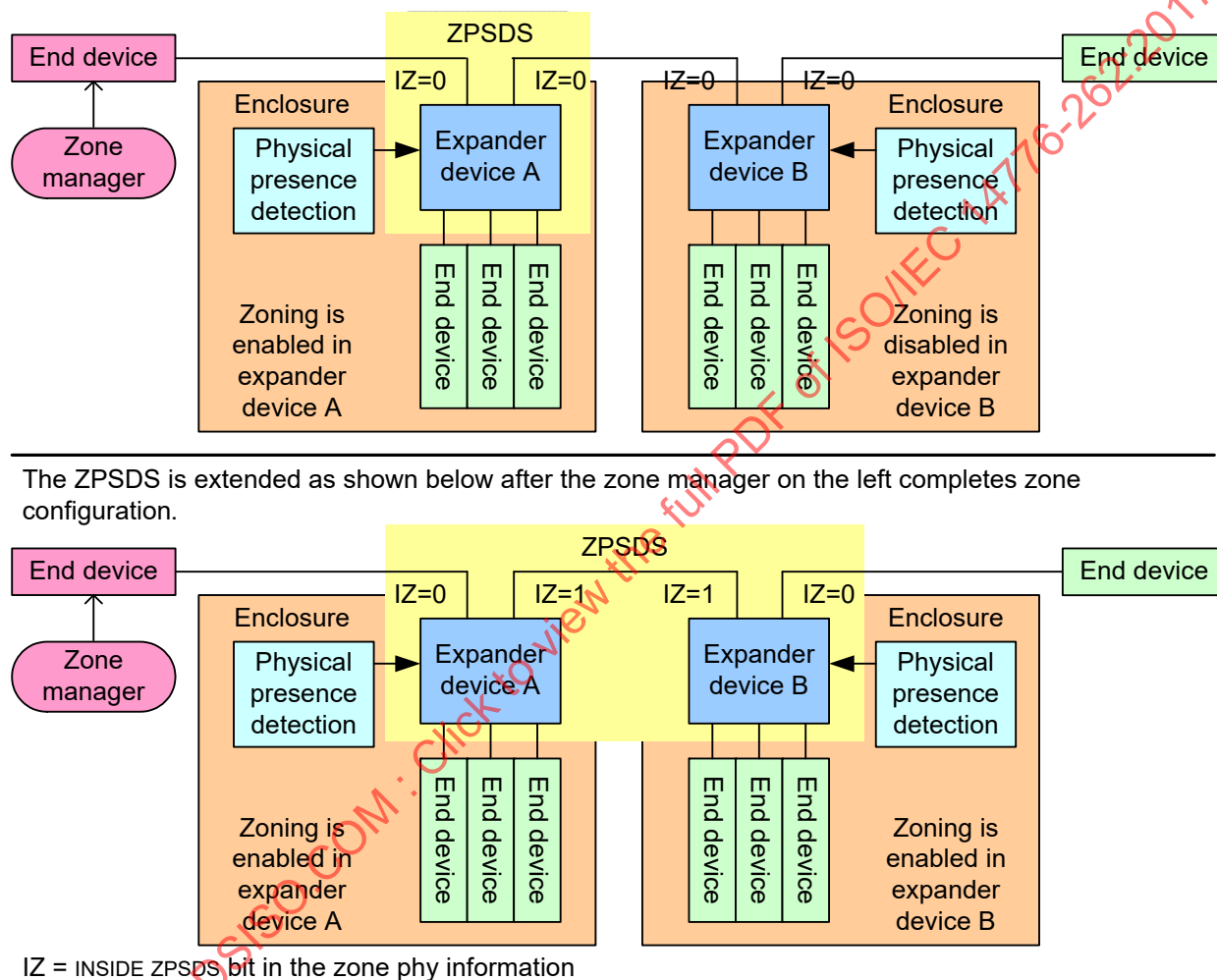
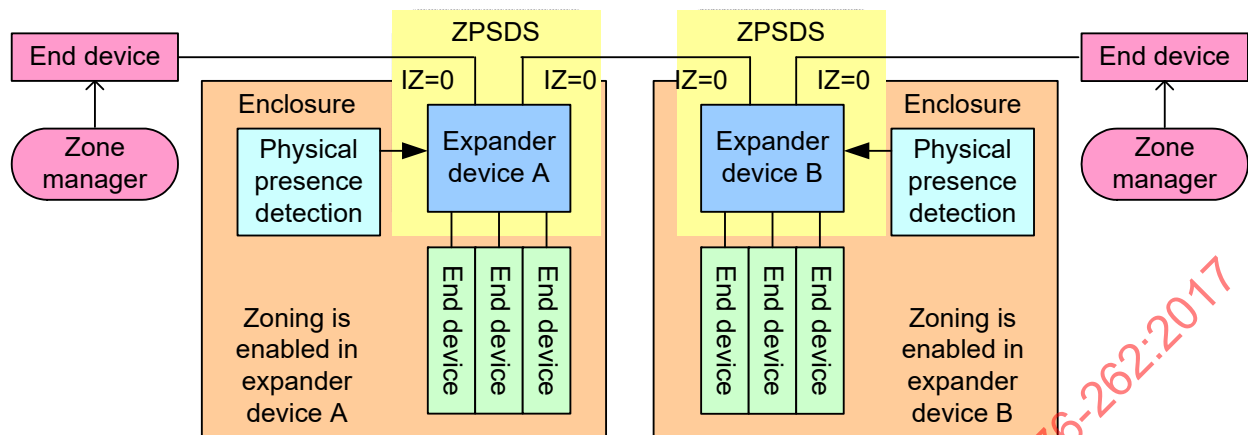
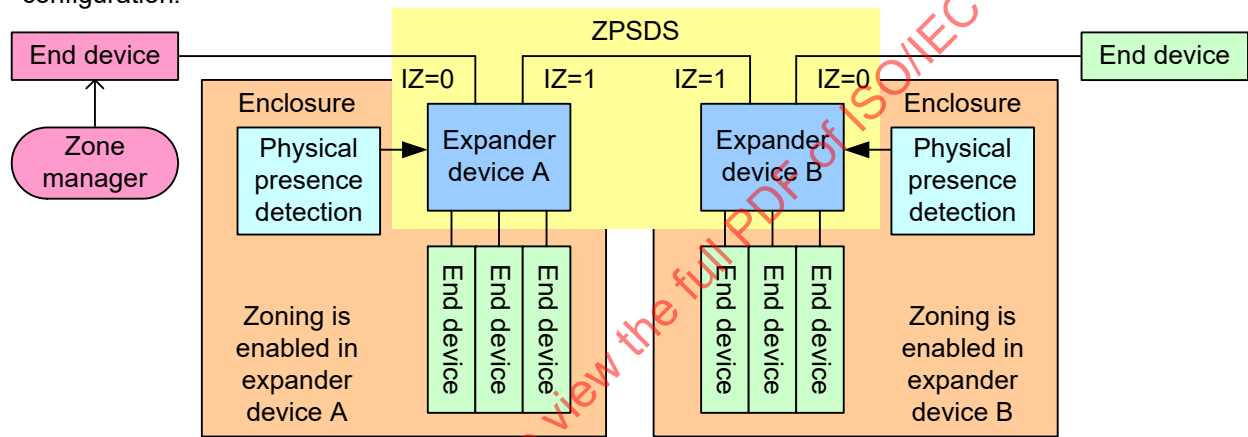


Figure 53 – Extending a ZPSDS example

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.



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 35.

Table 35 – 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 ^a
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
^a The INSIDE ZPSDS bit is determined from the values exchanged during the link reset sequence.		

Table 36 lists the usage of the current values of the zone phy information fields.

Table 36 – Zone phy information usage

Field	Transmitted in IDENTIFY address frame ^a	Indicated in DISCOVER function and DISCOVER LIST function ^b	Attached value indicated in DISCOVER function ^c	Programmable with the CONFIGURE ZONE PHY INFORMATION function ^d	Changeable by the expander device after a link reset sequence ^e
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 ^f
^a Defined in the IDENTIFY address frame (see 6.8.2). ^b Defined in the DISCOVER response (see 9.4.3.10) and the DISCOVER LIST response SHORT FORMAT descriptor (see 9.4.3.15.4). ^c Defined in the DISCOVER response (see 9.4.3.10). ^d 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. ^e See 4.8.4. ^f 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 determine 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 determine 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. The zone group of the SMP initiator port and SMP target port in a zoning expander device shall be 01h. 4.8.3.2 defines more about zone groups.

The ZONE GROUP PERSISTENT bit is used to determine 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 37.

Table 37 – Zone groups

Zone group	Configurable in the zone permission table ^a	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.
2	Yes	Phys in zone group 2 have access to phys in the zone groups indicated by the zone permission table. 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: a) CONFIGURE GENERAL (see 9.4.3.18); b) ZONE LOCK (see 9.4.3.21); and c) SMP zone configuration functions (see 4.8.6.1) performed while the zoning expander device is locked. 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.
3	Yes	Phys in zone group 3 have access to phys in the zone groups indicated by the zone permission table. 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)).
4 to 7	Reserved	
8 to 255	Yes	Phys in zone groups 8 through 255 have access to phys in the zone groups indicated by the zone permission table.
^a 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 38.

Table 38 – Zone permission table

Destination zone group (i.e., d)	Source zone group (i.e., s) ^{a b}				
	0	1	2 to 3	4 to 7	8 to (z-1) ^c
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) ^c	0	1	ZP[s = 2 to 3, d = 8 to (z-1)]	Reserved	ZP[s = 8 to (z-1), d = 8 to (z-1)]
^a Shading identifies configurable zone groups. ^b All reserved ZP bits shall be set to zero (e.g., bits ZP[4 to 7, 4 to (z-1)] are set to zero). ^c 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:

- a) shall preserve the zone permission table while zoning is disabled; and
- b) 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 39.

Table 39 – Zone permission table granting minimal permissions

Destination zone group (i.e., d)	Source zone group (i.e., s) ^{a b}				
	0	1	2 to 3	4 to 7	8 to (z-1) ^c
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) ^c	0	1	0	Reserved	0
^a Shading identifies configurable zone groups. ^b All reserved ZP bits shall be set to zero (e.g., bits ZP[4 to 7, 4 to (z-1)] are set to zero). ^c 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.

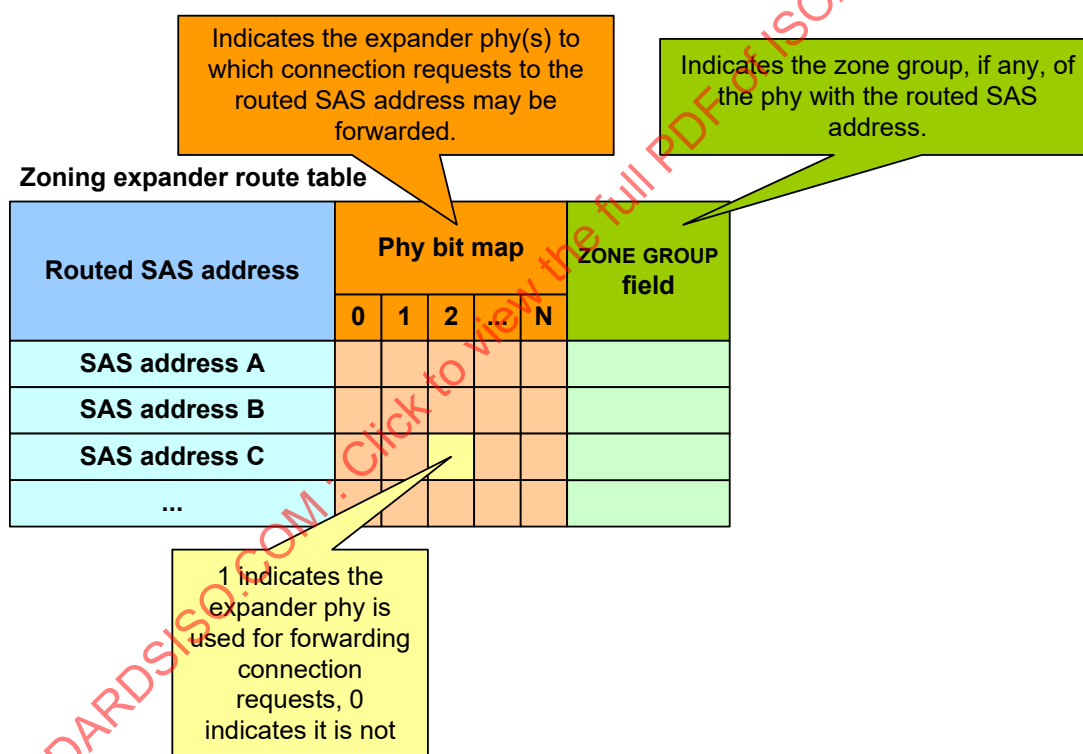


Figure 55 – Zoning expander route table

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):

- a) the zone group of the source port (i.e., s) is identified as defined in table 40; and
- b) the zone group of the destination port (i.e., d) is identified as defined in table 41.

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:

- a) OPEN_REJECT (RETRY) if the zoning expander device is locked; and
- b) OPEN_REJECT (ZONE VIOLATION) if the zoning expander device is unlocked.

Zoning expander devices with zoning enabled shall follow the rules in table 40 to determine the zone group of the source port.

Table 40 – 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 41 to determine the zone group of the destination port.

Table 41 – Destination zone group determination

Routing method of the destination expander phy	Destination zone group
Direct	Zone group of the destination expander phy
Subtractive	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. 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).
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 42 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 42 – 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	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:
		0	1	
		1	0	a) set the REQUESTED INSIDE ZPSDS bit to zero; and b) set the INSIDE ZPSDS bit to zero.
		1	1	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.
		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 43. If the ZONE GROUP PERSISTENT bit is set to zero, then table 44 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 43 – ZONE GROUP field values if the ZONE GROUP PERSISTENT bit is set to one

Current INSIDE ZPSDS Bit ^a	New INSIDE ZPSDS Bit ^b	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.
^a Current INSIDE ZPSDS bit is the value before the link reset sequence. ^b New INSIDE ZPSDS bit is the computed value based upon table 42.		

Table 44 – Conditions that cause the ZONE GROUP field to be reset 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	A subsequent link reset sequence completes and: 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: A) SAS ADDRESS field; or B) REQUESTED INSIDE ZPSDS field; or b) a SATA device is attached.
Completed link reset sequence with a SATA device attached	Either: a) a subsequent link reset sequence completes and: 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; 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-2), or a change in the WORLD WIDE NAME field in the attached SATA device's IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data (see ACS-2); or C) a SAS phy or expander phy is attached; or b) the expander phy is disabled with the SMP PHY CONTROL function (see 9.4.3.28) DISABLE phy operation.

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:

- a) 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
- b) 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 304) 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:

- a) 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;
- b) 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
- c) 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
- B) 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).

While the ZONE CONFIGURING bit is set to one, the expander device shall return OPEN_REJECT (RETRY) for any connection requests that would otherwise have resulted in 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 4.1.13); 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 67) 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 67) 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 67) 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 SAS 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 SAS 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 45, 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 45 – PHY EVENT SOURCE field (part 1 of 4)

Code	Name	Type ^a	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 ^b	WC	Number of invalid dwords (see 3.1.99) 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 ^b	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 ^b	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 ^b	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).
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.

^a The Type column indicates the source type:

- a) WC = wrapping counter;
- b) PVD = peak value detector; and
- c) N/A = not applicable.

^b This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11).

Table 45 – PHY EVENT SOURCE field (part 2 of 4)

Code	Name	Type ^a	Description
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.
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.

^a The Type column indicates the source type:

- a) WC = wrapping counter;
- b) PVD = peak value detector; and
- c) N/A = not applicable.

^b This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11).

Table 45 – PHY EVENT SOURCE field (part 3 of 4)

Code	Name	Type ^a	Description
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 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.
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.

^a The Type column indicates the source type:

- a) WC = wrapping counter;
- b) PVD = peak value detector; and
- c) N/A = not applicable.

^b This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11).

Table 45 – PHY EVENT SOURCE field (part 4 of 4)

Code	Name	Type ^a	Description
52h	SATA flow control buffer overflow count	WC	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). 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.
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		
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		
^a The Type column indicates the source type: a) WC = wrapping counter; b) PVD = peak value detector; and c) N/A = not applicable. ^b This standard also defines a saturating counter that counts this event (see 9.2.8.1 and 9.4.3.11).			

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 1024 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 46. Bit H is the most significant bit of the byte and bit A is the least significant bit of the byte.

Table 46 – 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 47 shows the conversion from byte notation to the character naming convention.

Table 47 – 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 49 (see 5.3.7) are considered valid.

5.3 Character encoding and decoding

5.3.1 Introduction

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 48 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 48 defines the data characters.

Table 48 – Data characters (part 1 of 5)

Name	Data byte		Data character (binary representation)	
	Binary representation (HGF EDCBA)	Hexadecimal representation	Current RD - abcdei fghj	Current RD + 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
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

Table 48 – Data characters (part 2 of 5)

Name	Data byte		Data character (binary representation)	
	Binary representation (HGF EDCBA)	Hexadecimal representation	Current RD - abcdei fghj	Current RD + abcdei fghj
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
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

Table 48 – Data characters (part 3 of 5)

Name	Data byte		Data character (binary representation)	
	Binary representation (HGF EDCBA)	Hexadecimal representation	Current RD - abcdei fghj	Current RD + abcdei fghj
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
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

Table 48 – Data characters (part 4 of 5)

Name	Data byte		Data character (binary representation)	
	Binary representation (HGF EDCBA)	Hexadecimal representation	Current RD - abcdei fghj	Current RD + abcdei fghj
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	Aeh	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
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

Table 48 – Data characters (part 5 of 5)

Name	Data byte		Data character (binary representation)	
	Binary representation (HGF EDCBA)	Hexadecimal representation	Current RD - abcdei fghj	Current RD + abcdei fghj
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 49 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 49 – Control characters

Name	Control byte		Control character (binary representation) ^a	
	Binary representation (HGF EDCBA)	Hexadecimal representation	Current RD - abcdei fghj	Current RD + abcdei fghj
K28.0	000 11100	1Ch	001111 0100	110000 1011
K28.1 ^b	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 ^b	101 11100	BCh	<u>001111</u> 1010	<u>110000</u> 0101
K28.6	110 11100	DCh	001111 0110	110000 1001
K28.7 ^{b, c}	111 11100	FCh	<u>001111</u> 1000	<u>110000</u> 0111
K23.7	111 10111	F7h	11010 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
^a Comma patterns, which are two bits of one polarity followed by five bits of the opposite polarity (i.e., 0011111b or 1100000b), are underlined. ^b K28.1, K28.5, and K28.7 are the only characters which contain comma patterns. Comma patterns do not appear in any data characters and do not appear across any adjacent data characters. ^c 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 50.

Table 50 – 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 48 based on the current value of the transmitter's RD. To transmit a control byte, the transmitter shall select the appropriate

character from table 49 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 48 and table 49 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 51 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 51 – 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 1011 (error in second to last bit)	+	010101 0101	+	111010 1010	+
Decoded character stream	-	D21.0 (rather than D21.1) (not detected as an error)	+	D10.2 (no error)	+	Code violation (although D23.5 was received without 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.

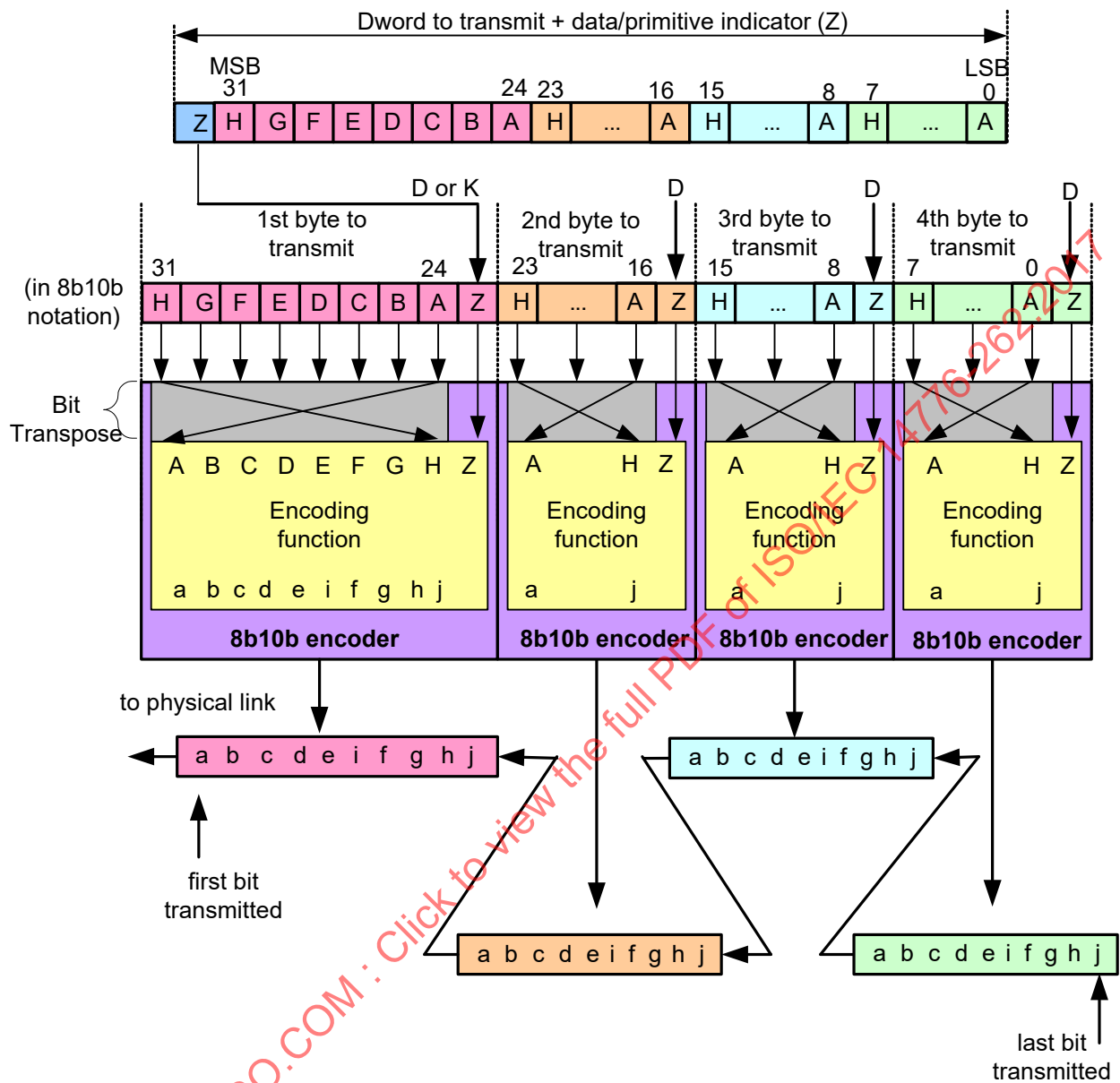


Figure 56 – SAS bit transmission logic

Figure 57 shows the SAS bit reception order.

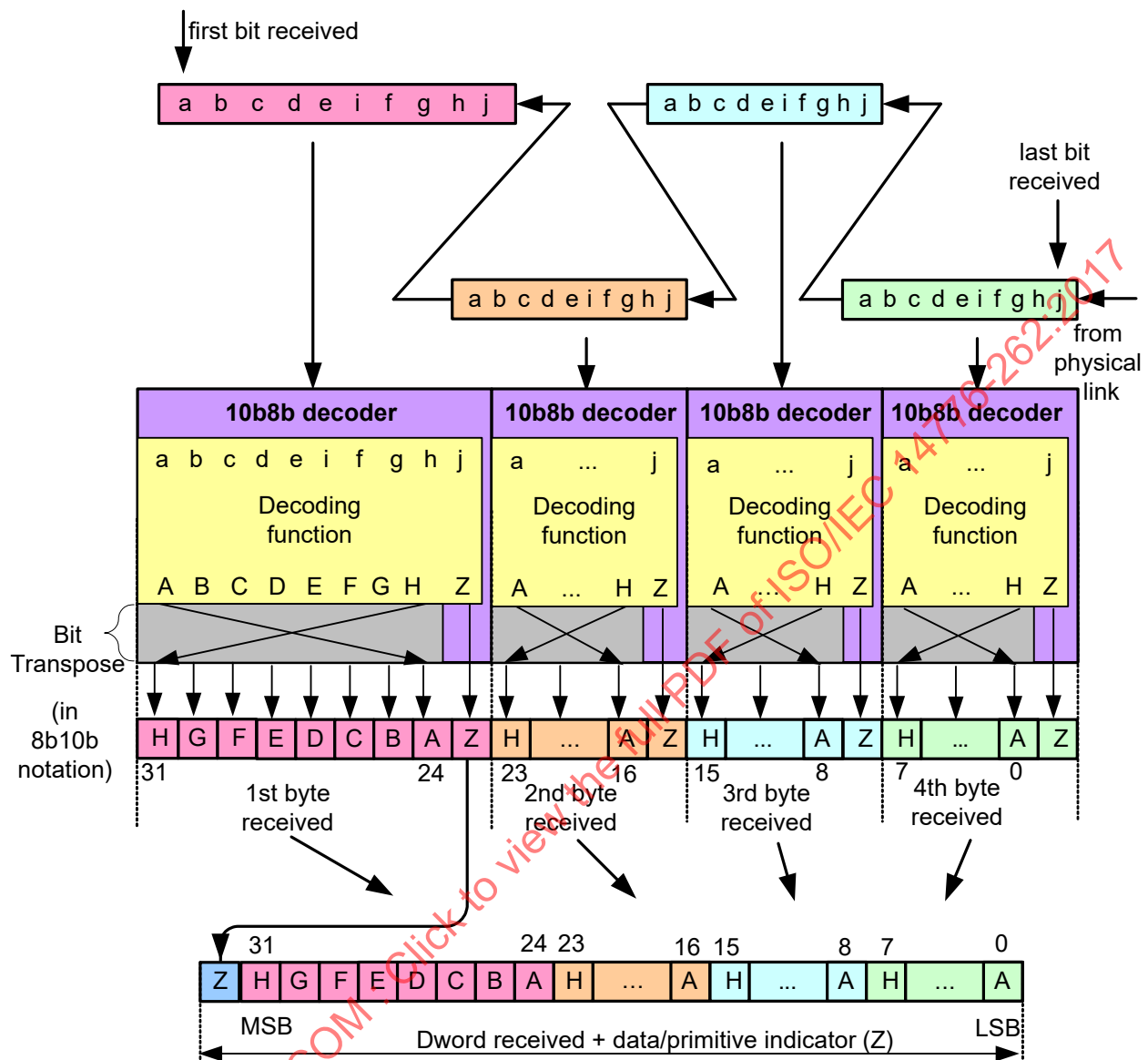


Figure 57 – SAS bit reception logic

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 SP 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).

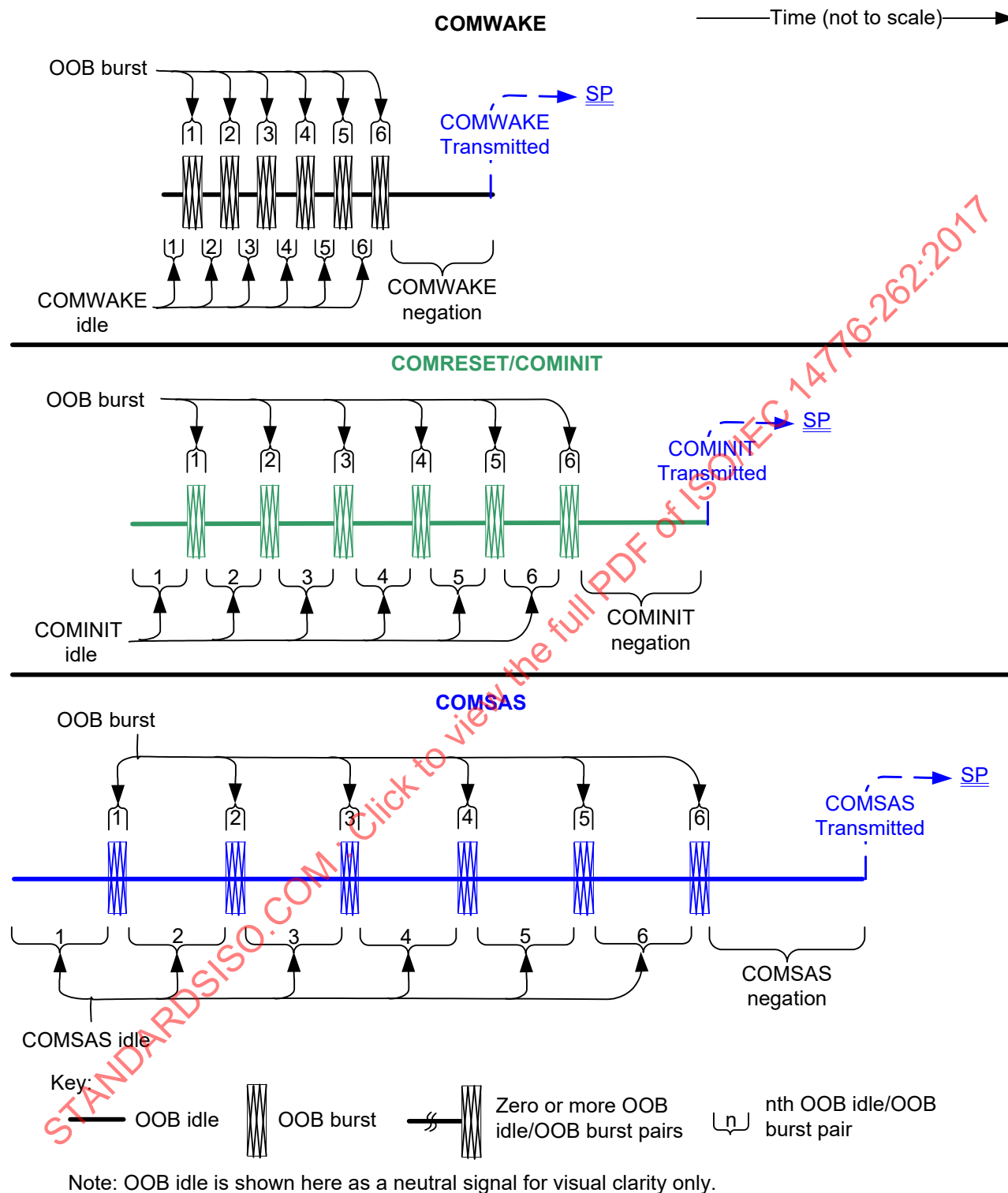


Figure 58 – OOB signal transmission

5.6.3 Receiver detection of OOB signals

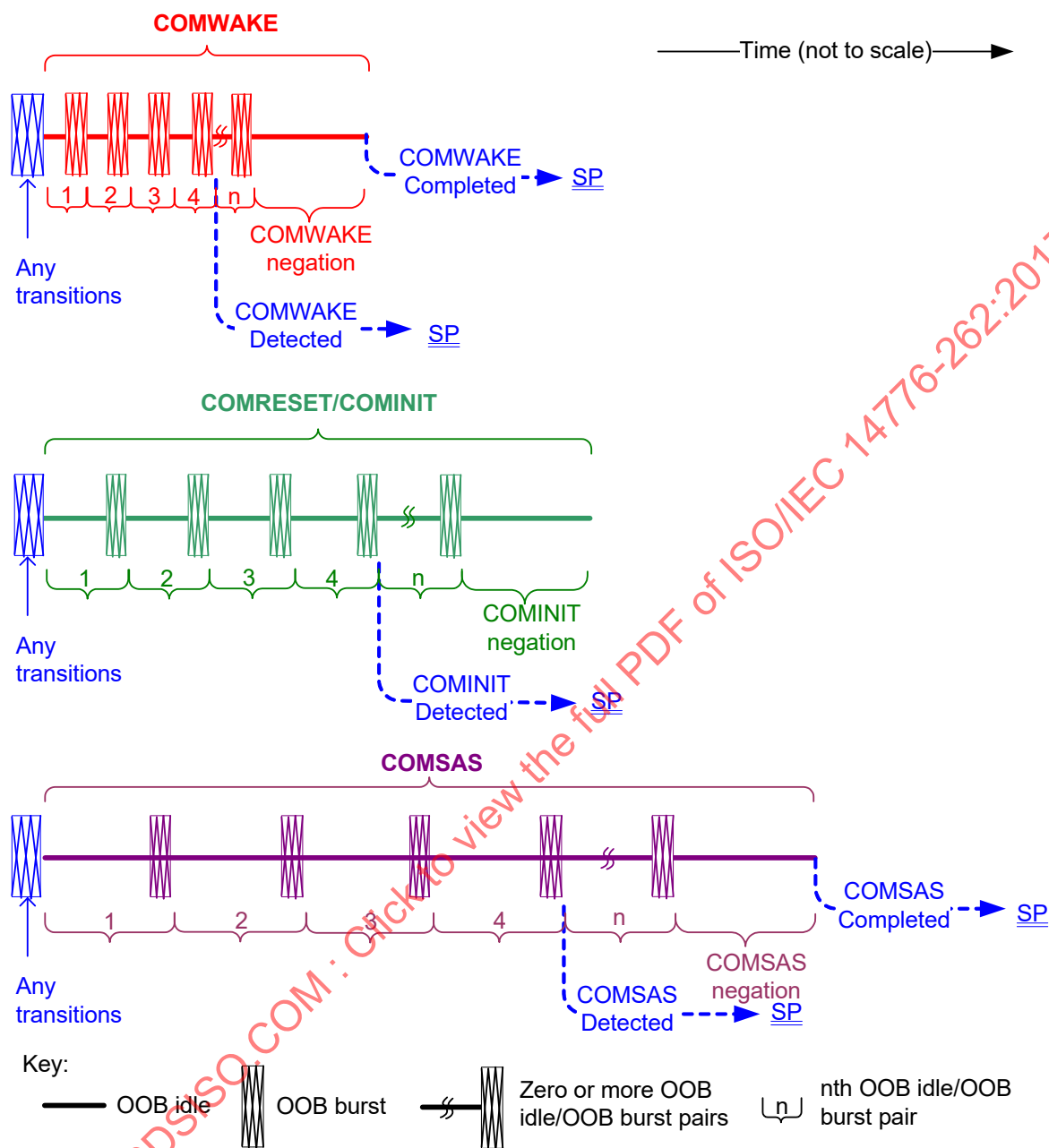
The detection of OOB signals is disabled and enabled by the SP state machine (see 5.9.4.5).

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).

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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017



Note: OOB idle is shown here as a neutral signal for visual clarity only.

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 67.

5.7 Phy capabilities bits

Table 52 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 52 – 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 to the value defined in table 52.

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 53 defines the requested logical link rate based on the transmitted and received REQUESTED LOGICAL LINK RATE fields.

Table 53 – 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 54 defines whether or not multiplexing is enabled and defines the negotiated logical link rate based on the requested logical link rate (see table 53) and the negotiated physical link rate (see 5.10.4.2.4).

Table 54 – Multiplexing negotiation

Requested logical link rate (see table 53)	Negotiated physical link rate	Multiplexing	Negotiated 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	Enabled	3 Gbit/s
	6 Gbit/s		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		12 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 55 defines the priority of the supported settings bits.

Table 55 – Supported settings bit priorities

Priority	Bit
Highest	G4 WITH SSC bit ^a
...	G4 WITHOUT SSC bit ^a
...	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
^a 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 56 lists some example SNW-3 phy capabilities values.

Table 56 – Example SNW-3 phy capabilities values

Code ^a	Description
80540000h	Down-spreading SSC G1, G2, and G3 with SSC supported
80550001h	Down-spreading SSC G1, G2, G3, and G4 with SCC supported
80FC0001h	Down-spreading SSC G1, G2, and G3 with and without SSC supported
80FF0001h	Down-spreading SSC 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 G1, G2, and G3 with and without SSC supported
C0FF0000h	Center-spreading SSC G1, G2, G3, and G4 with and without SSC supported
C9FC0000h	Center-spreading SSC Requested 3 Gbit/s logical link rate G1, G2, and G3 with and without SSC supported
C8F00001h	Center-spreading SSC Requested 1.5 Gbit/s logical link rate G1 and G2 with and without SSC supported
^a 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.

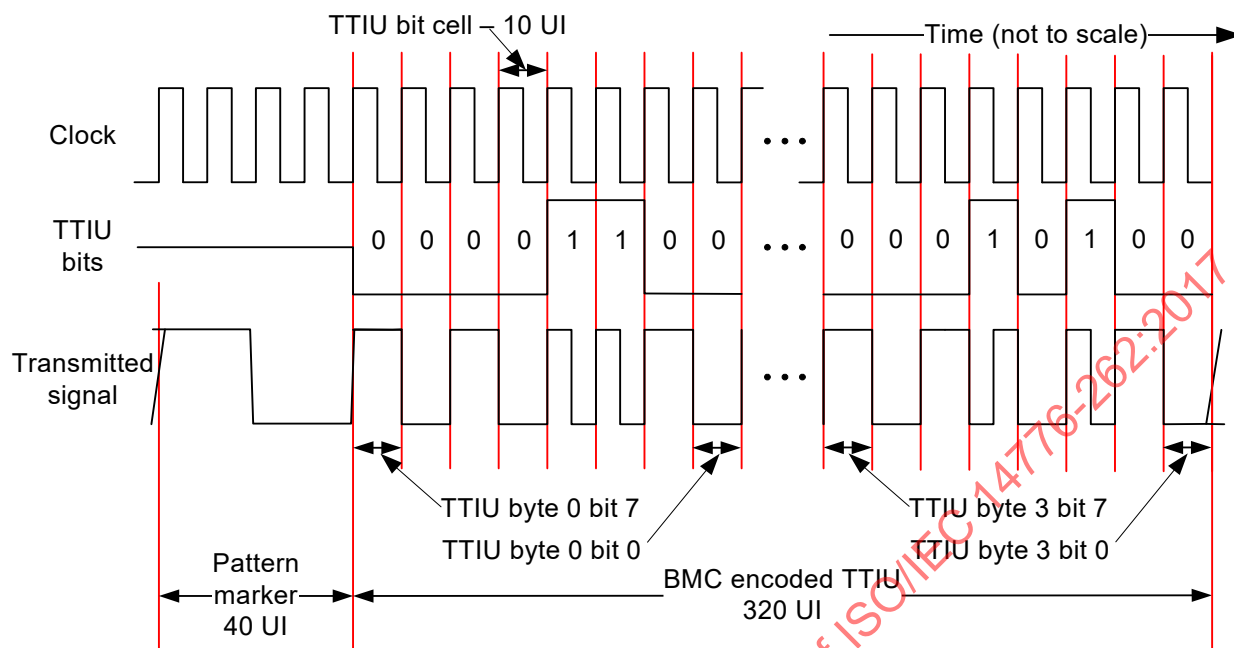


Figure 60 – TTIU transmitter BMC encoding

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., $833.\bar{3}$ 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.

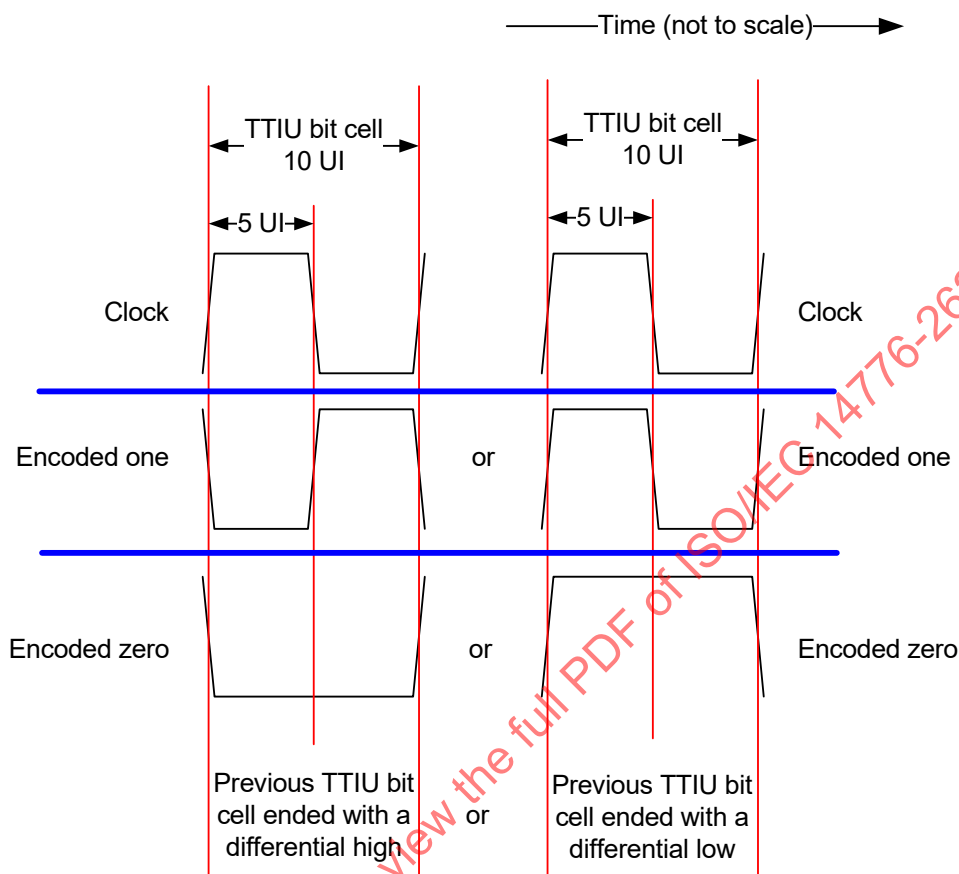


Figure 61 – TTIU bit cell transmitter encoding

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 16th TTIU bit cell transmitted contains byte 1 bit 0 of the TTIU;
- 5) the 17th TTIU bit cell transmitted contains byte 2 bit 7 of the TTIU;
- 6) the 24th TTIU bit cell transmitted contains byte 2 bit 0 of the TTIU;
- 7) the 25th TTIU bit cell transmitted contains byte 3 bit 7 of the TTIU; and
- 8) the 32nd 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.

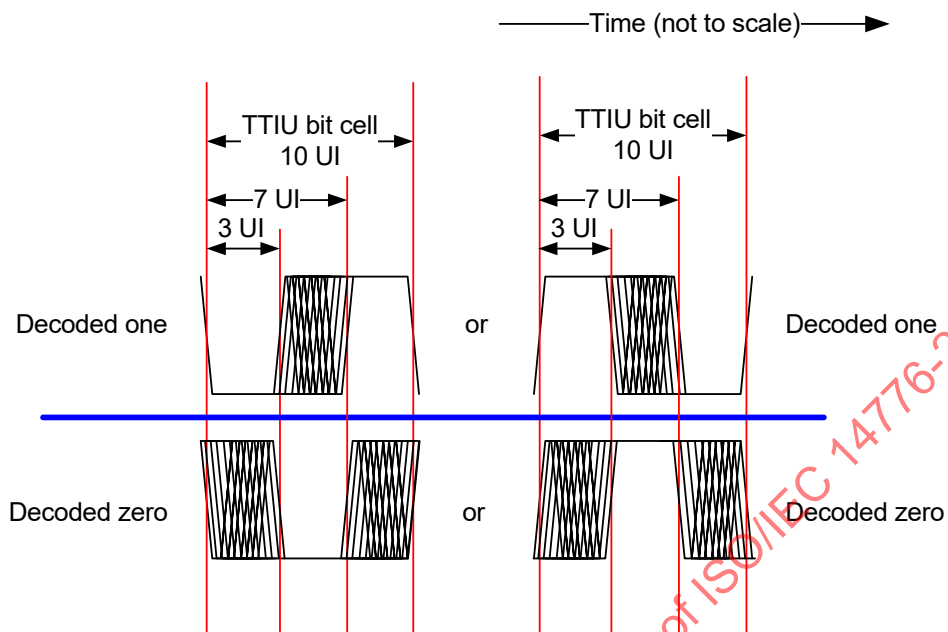


Figure 62 – TTIU bit cell receiver decoding

5.9 Train_Tx-SNW TTIUs

5.9.1 Train_Tx-SNW TTIU format

Table 57 defines the content of each Train_Tx-SNW TTIU bit.

Table 57 – Train_Tx-SNW TTIU bit

Value	Transmitted
One	BMC encoded one (see 5.8.2)
Zero	BMC encoded zero (see 5.8.2)

Table 58 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 58 – Train_Tx-SNW TTIU

Byte\Bit	7	6	5	4	3	2	1	0
0	PATTERN TYPE							
1								
2				PATTERN TYPE SPECIFIC				
3								

Table 59 defines the PATTERN TYPE field, which defines the format of the PATTERN TYPE SPECIFIC field.

Table 59 – PATTERN TYPE field

Code	Name of TTIU	Type	Reference
000b	Control/Status TTIU	M	5.9.2
001b to 110b	Reserved ^a		
111b	Error Response TTIU	M	5.9.3
Key: M = TTIU implementation is mandatory.			
^a 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 5.14.5.3).			

The PATTERN TYPE SPECIFIC field contains the transmitter training information, the form of which is defined by the PATTERN TYPE field (see table 59).

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 60 – 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 5.14.5.3).

The PATTERN TYPE field shall be set to the value shown in table 59.

Table 61 defines the COEFFICIENT SETTINGS field.

Table 61 – COEFFICIENT SETTINGS field

Code	Name	Description	Type
00b	normal	If a coefficient change is specified (see table 62) and the TRAIN COMP bit is set to zero, then the local phy's transmitter coefficients shall be changed as specified in the: a) COEFFICIENT 1 REQUEST field; b) COEFFICIENT 2 REQUEST field; and 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: 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 62) 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 62) 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 62) 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 62 – 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. ^a	M
10b	decrement	The local phy shall adjust the specified coefficient by one decrement. ^a	M
11b	Reserved ^b		
Key: M = Coefficient request implementation is mandatory.			
^a See SAS-3 for the amount of adjustment represented by one increment and one decrement to the coefficient. ^b If a phy receives one coefficient request that is reserved, then that phy shall transmit an Error Response TTIU (see 5.14.5.3) that indicates the coefficient request that was reserved with the ERROR CODE field set to: a) RESERVED COEFFICIENT 1 REQUEST; b) RESERVED COEFFICIENT 2 REQUEST; or c) RESERVED COEFFICIENT 3 REQUEST. If a phy receives more than one coefficient request that is reserved, then that phy shall transmit an Error Response TTIU (see 5.14.5.3) with the ERROR CODE field set to MULTIPLE RESERVED COEFFICIENTS REQUESTED.			

See table 63 for the combinations of coefficient requests that are mandatory or reserved.

Table 63 – 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 ^a						
Key: M = Coefficient Request byte's coefficient request combination implementation is mandatory.							
^a 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 62).							

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 5.14.5.3.1).

The COEFFICIENT 3 STATUS field indicates the status (see table 64) of the local phy's transmitter coefficient 3 (see SAS-3).

The COEFFICIENT 2 STATUS field indicates the status (see table 64) of the local phy's transmitter coefficient 2 (see SAS-3).

The COEFFICIENT 1 STATUS field indicates the status (see table 64) of the local phy's transmitter coefficient 1 (see SAS-3).

Table 64 – 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). ^a	M
11b	maximum	The indicated local phy's transmitter coefficient is at a maximum value (see 5.14.2.6). ^a	M
Key: M = Coefficient status value implementation is mandatory.			
^a 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 65 – 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 to the value defined in table 65.

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.

The ERROR CODE field is defined in table 66.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Table 66 – ERROR CODE field

Code	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 59).
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 59).
03h	RESERVED TTIU BIT SET TO ONE	Reserved TTIU bit set to one (e.g., reserved bits in table 60).
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 62).
11h	RESERVED COEFFICIENT 1 REQUEST	Coefficient 1 is set to a reserved value (see table 62).
13h	RESERVED COEFFICIENT 2 REQUEST	Coefficient 2 is set to a reserved value (see table 62).
15h	RESERVED COEFFICIENT 3 REQUEST	Coefficient 3 is set to a reserved value (see table 62).
1Ah	RESERVED COEFFICIENT REQUEST COMBINATION	One of the following occurs: a) none of the coefficient requests are set 11b (i.e., reserved) (see table 62); b) the combination of the coefficient 3 request, coefficient 2 request, and coefficient 1 request is reserved (see table 63).
1Bh to 1Fh	Reserved	
Reserved error codes		
20h to FFh	Reserved	
^a If more than one error condition is true, then the phy shall use the following priority determine which error condition to report in the ERROR CODE field: 1) UNSUPPORTED PATTERN TYPE or RESERVED PATTERN TYPE; 2) RESERVED TTIU BIT SET TO ONE; 3) MULTIPLE RESERVED COEFFICIENTS REQUESTED; 4) RESERVED COEFFICIENT 1 REQUEST, RESERVED COEFFICIENT 2 REQUEST, or RESERVED COEFFICIENT 3 REQUEST; 5) RESERVED COEFFICIENT REQUEST COMBINATION; and 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 62), 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 67 defines phy reset sequence timing parameters used by the SP state machine (see 5.12).

Table 67 – Phy reset sequence timing specifications

Parameter	Minimum	Maximum	Comments
Hot-plug timeout	10 ms	500 ms	The time after which: a) an expander phy shall retry an unsuccessful phy reset sequence; b) a SAS initiator phy should retry an unsuccessful phy reset sequence (see 5.10.5); and 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).
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.

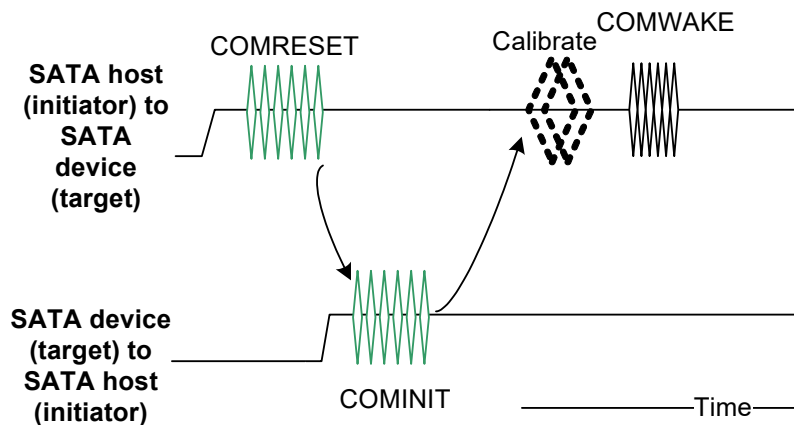


Figure 63 – SATA OOB sequence

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).

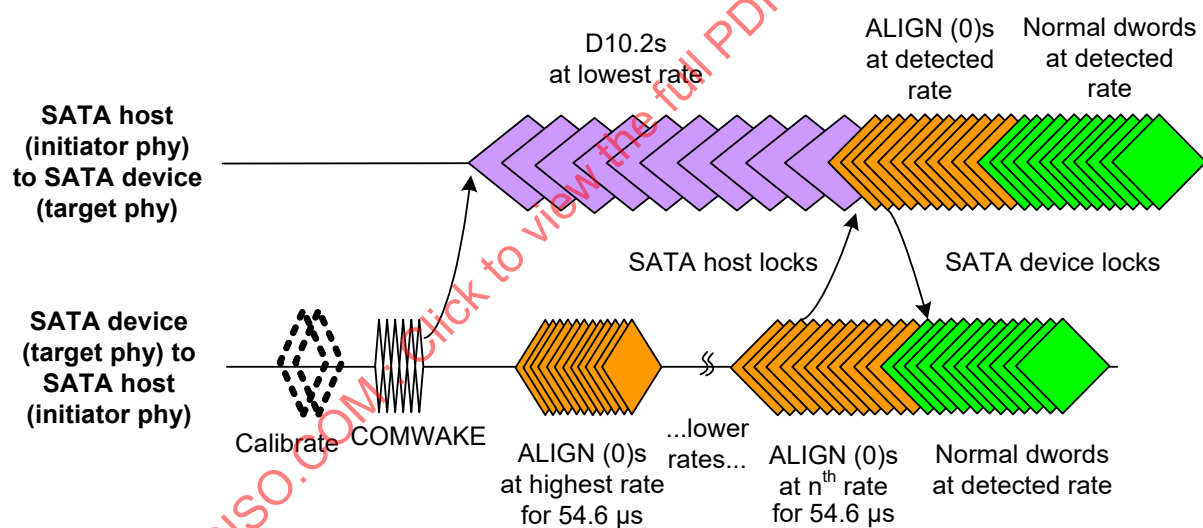


Figure 64 – SATA speed negotiation sequence

Table 68 defines SATA speed negotiation sequence timing parameters used by the SP state machine (see 5.12).

Table 68 – 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 ns ^b	The maximum time during SATA speed negotiation after detecting COMWAKE Completed before which a phy shall start transmitting D10.2 characters.
^a $873.813 \bar{\mu}\text{s}$ is $32\,768 \times 40 \times \text{nominal OOB}$ (see SAS-3 and SATA). ^b 533 ns is $200 \times 40 \times \text{nominal OOB}$ (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 transmit deletable primitives 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.

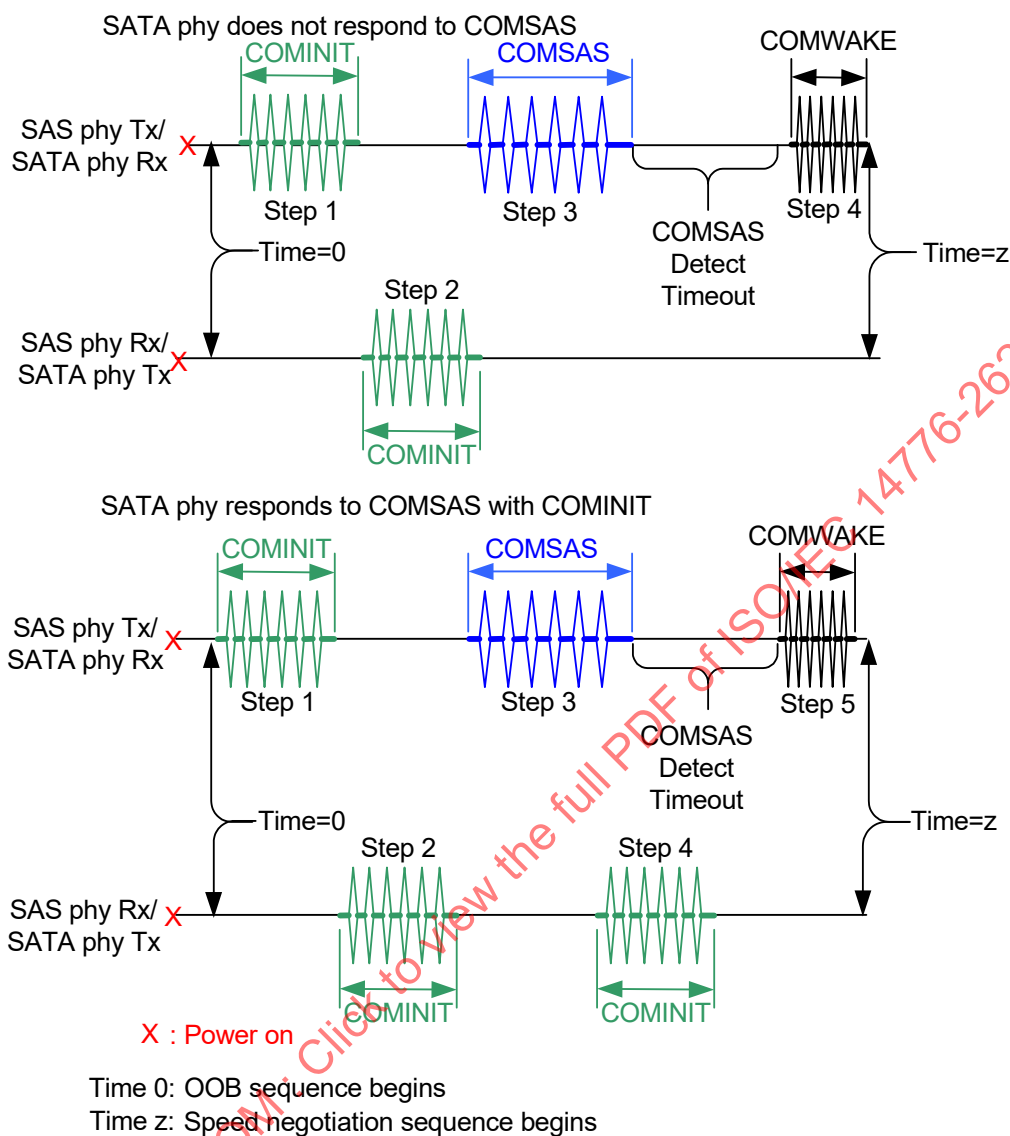


Figure 65 – SAS to SATA OOB sequence

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:

- if the phy has not yet transmitted a COMINIT, transmit a COMINIT followed by a COMSAS; or
- 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.

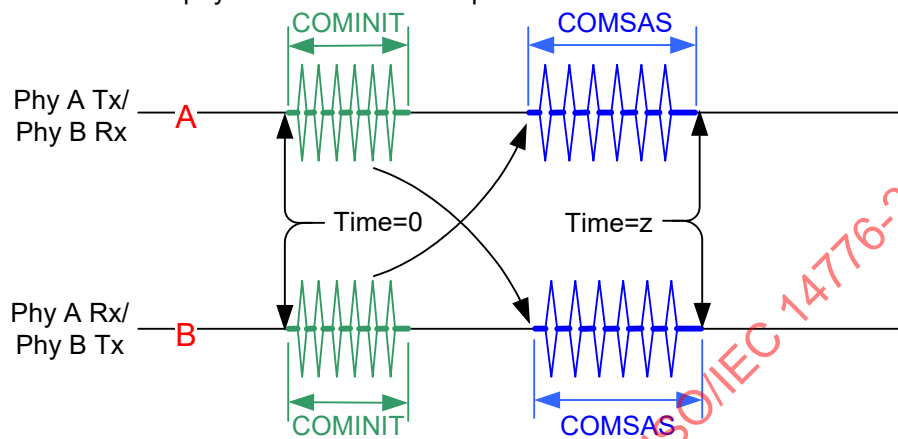
On receipt of a COMSAS, if the receiving phy has not yet transmitted a COMSAS, then the phy transmits a COMSAS.

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.

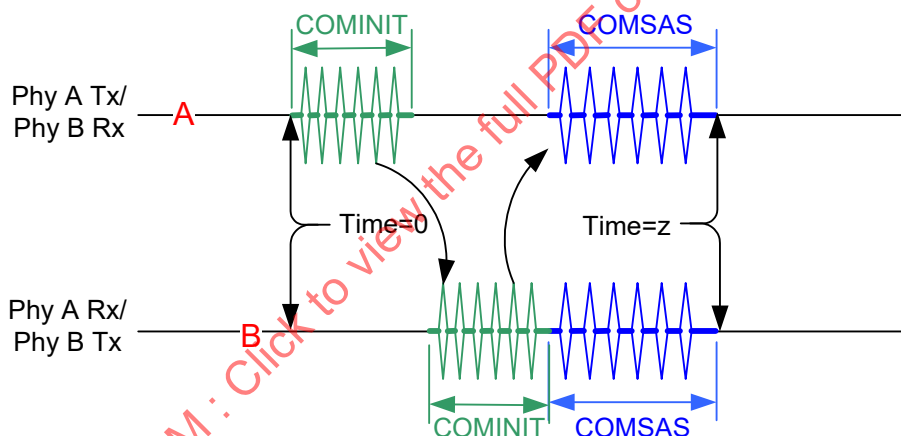
A phy distinguishes between COMINIT and COMSAS and continues with a SAS speed negotiation sequence (see 5.10.4.2) after completing the SAS OOB sequence.

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.

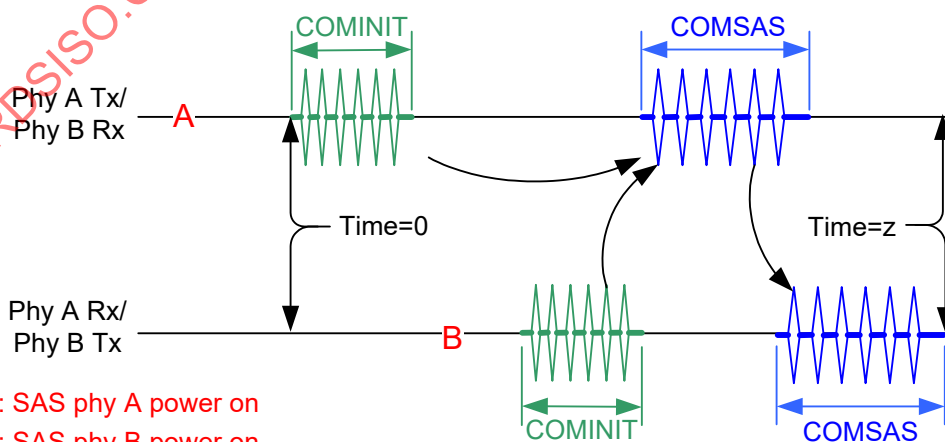
Scenario 1: Both SAS phys start SAS OOB sequence at same time



Scenario 2: SAS phy A starts SAS OOB sequence



Scenario 3: SAS phy B misses SAS phy A's COMINIT



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: SNW-1, SNW-2 and Final-SNW (see 5.10.4.2.3.2);
- b) phy capabilities exchange: SNW-3 (see 5.10.4.2.3.3);
- c) phy receiver training: Train_Rx-SNW (see 5.10.4.2.3.5); and
- d) phy transmitter training: 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 transmit deletable primitives for 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 69 defines the timing specifications for the SAS speed negotiation sequence.

Table 69 – SAS speed negotiation sequence timing specifications (part 1 of 2)

Parameter	Acronym	Time ^a	Comments
Rate change delay time	RCDT	750 000 OOB ^b	The time the transmitter device shall transmit negotiation idle at the beginning of: a) SNW-1; b) SNW-2; c) SNW-3; d) Final-SNW; and e) Train_Rx-SNW or Train_Tx-SNW.
Speed negotiation transmit time	SNTT	163 840 OOB ^c	During SNW-1, SNW-2, and Final-SNW, the time after RCDT during which ALIGN (0) or ALIGN (1) is transmitted. During SNW-3, the time after RCDT in which bit cells and OOB idle are transmitted. 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 ^d	The maximum time for a phy to reply with ALIGN (1) during SNW-1, SNW-2, and Final-SNW. 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).
SNW time	SNWT	913 840 OOB ^e	The duration of SNW-1, SNW-2, SNW-3, or Final-SNW.
Bit cell time	none	2 200 OOB ^f	The time to transmit a COMWAKE or OOB idle during SNW-3.

^a OOB is defined in SAS-3.

^b 750 000 OOB (e.g., RCDT) is nominally 500 μ s. Equal to: $18\,750 \times 40$ OOB.

^c 163 840 OOB (e.g., SNTT) is nominally 109.226 μ s. Equal to: $4\,096 \times 40$ OOB.

^d 153 600 OOB (e.g., SNLT) is nominally 102.4 μ s. Equal to: $(4\,096 - 256) \times 40$ OOB.

^e 913 840 OOB (e.g., SNWT) is nominally 609.226 μ s. Equal to: RCDT + SNTT.

^f 2 200 OOB is nominally 1 466.6 ns. Equal to the COMWAKE signal time (see SAS-3).

^g 29 998 080 OOB (e.g., MRTT) is nominally 19.998 72 ms. Equal to: $11\,718 \times 64 \times 40$ OOB. This is the time of the maximum number of complete receiver training patterns that fit into 20 ms.

^h 28 497 920 OOB (e.g., TLT) is nominally 18.998 613 ms. Equal to: $11\,132 \times 64 \times 40$ OOB. This is the time of the maximum number of complete receiver training patterns that fit into 19 ms.

ⁱ 30 748 080 OOB (e.g., MTWT) is nominally 20.498 72 ms. Equal to: RCDT + MRTT.

^j 750 000 000 OOB (e.g., MTTT) is nominally 500 ms.

^k 750 750 000 OOB (e.g., MTXT) is nominally 500.5 ms. Equal to: MTTT + RCDT.

Table 69 – SAS speed negotiation sequence timing specifications (part 2 of 2)

Parameter	Acronym	Time ^a	Comments
Maximum receiver training time	MRTT	29 998 080 OOB ⁱ	The maximum time for receiver training to complete during Train_Rx-SNW.
Training lock time	TLT	28 497 920 OOB ^h	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	The maximum duration of Train_Rx-SNW.
Maximum transmitter training time	MTTT	750 000 000 OOB ^j	The maximum time for transmitter training to complete during Train_Tx-SNW.
Maximum Train_Tx time	MTXT	750 750 000 OOB ^k	The maximum duration of Train_Tx-SNW.
^a OOB ⁱ is defined in SAS-3. ^b 750 000 OOB ⁱ (e.g., RCDT) is nominally 500 µs. Equal to: 18 750 × 40 OOB ⁱ . ^c 163 840 OOB ⁱ (e.g., SNTT) is nominally 109.226 µs. Equal to: 4 096 × 40 OOB ⁱ . ^d 153 600 OOB ⁱ (e.g., SNLT) is nominally 102.4 µs. Equal to: (4 096 - 256) × 40 OOB ⁱ . ^e 913 840 OOB ⁱ (e.g., SNWT) is nominally 609.226 µs. Equal to: RCDT + SNTT. ^f 2 200 OOB ⁱ is nominally 1 466.6 ns. Equal to the COMWAKE signal time (see SAS-3). ^g 29 998 080 OOB ⁱ (e.g., MRTT) is nominally 19.998 72 ms. Equal to: 11 718 × 64 × 40 OOB ⁱ . This is the time of the maximum number of complete receiver training patterns that fit into 20 ms. ^h 28 497 920 OOB ⁱ (e.g., TLT) is nominally 18.998 613 ms. Equal to: 11 132 × 64 × 40 OOB ⁱ . This is the time of the maximum number of complete receiver training patterns that fit into 19 ms. ⁱ 30 748 080 OOB ⁱ (e.g., MTWT) is nominally 20.498 72 ms. Equal to: RCDT + MRTT. ^j 750 000 000 OOB ⁱ (e.g., MTTT) is nominally 500 ms. ^k 750 750 000 OOB ⁱ (e.g., MTXT) is nominally 500.5 ms. Equal to: 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:

- a) if it supports the SNW, transmit and receive as defined for the SNW; or
- b) 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 a 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:

- a) SNW time (SNWT);
- b) rate change delay time (RCDT);
- c) speed negotiation transmit time (SNTT);

- d) speed negotiation lock time (SNLT); and
- e) actual lock time.

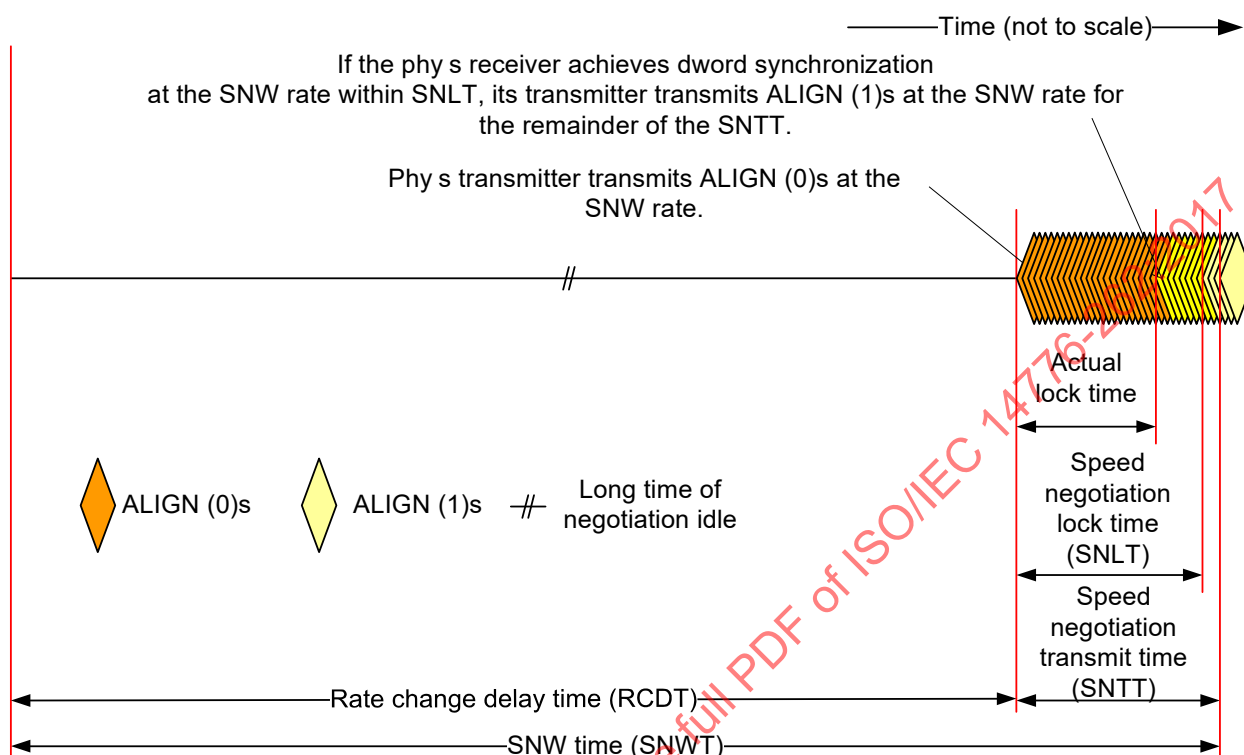


Figure 67 – SNW-1, SNW-2, and Final-SNW

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 70 defines the SNW rate used in SNW-1, SNW-2, and Final-SNW.

Table 70 – 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: a) 1.5 Gbit/s if SNW-1 is valid and SNW-2 is invalid; or 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).

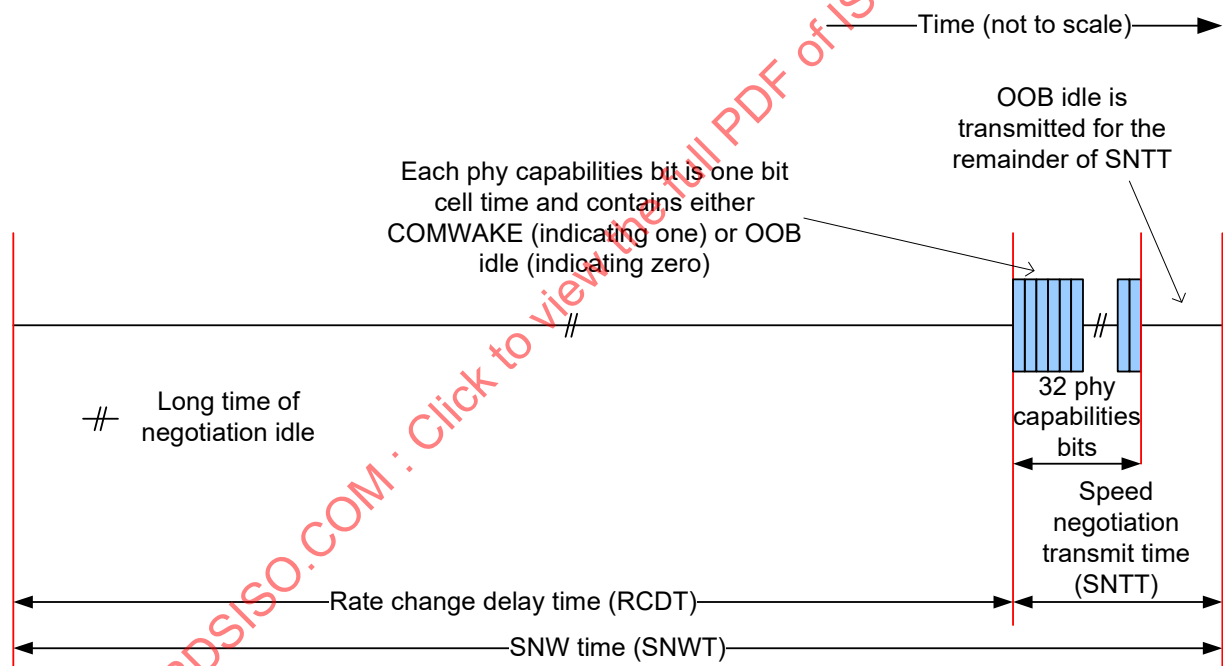


Figure 68 – SNW-3

Table 71 defines the content of each phy capabilities bit.

Table 71 – 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 52). 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:

- a) 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
- b) 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:

- a) maximum Train_Tx-SNW window time (MTXT);
- b) rate change delay time (RCDT);
- c) maximum transmitter train time (MTTT); and
- d) the point at which the transmitter is trained.

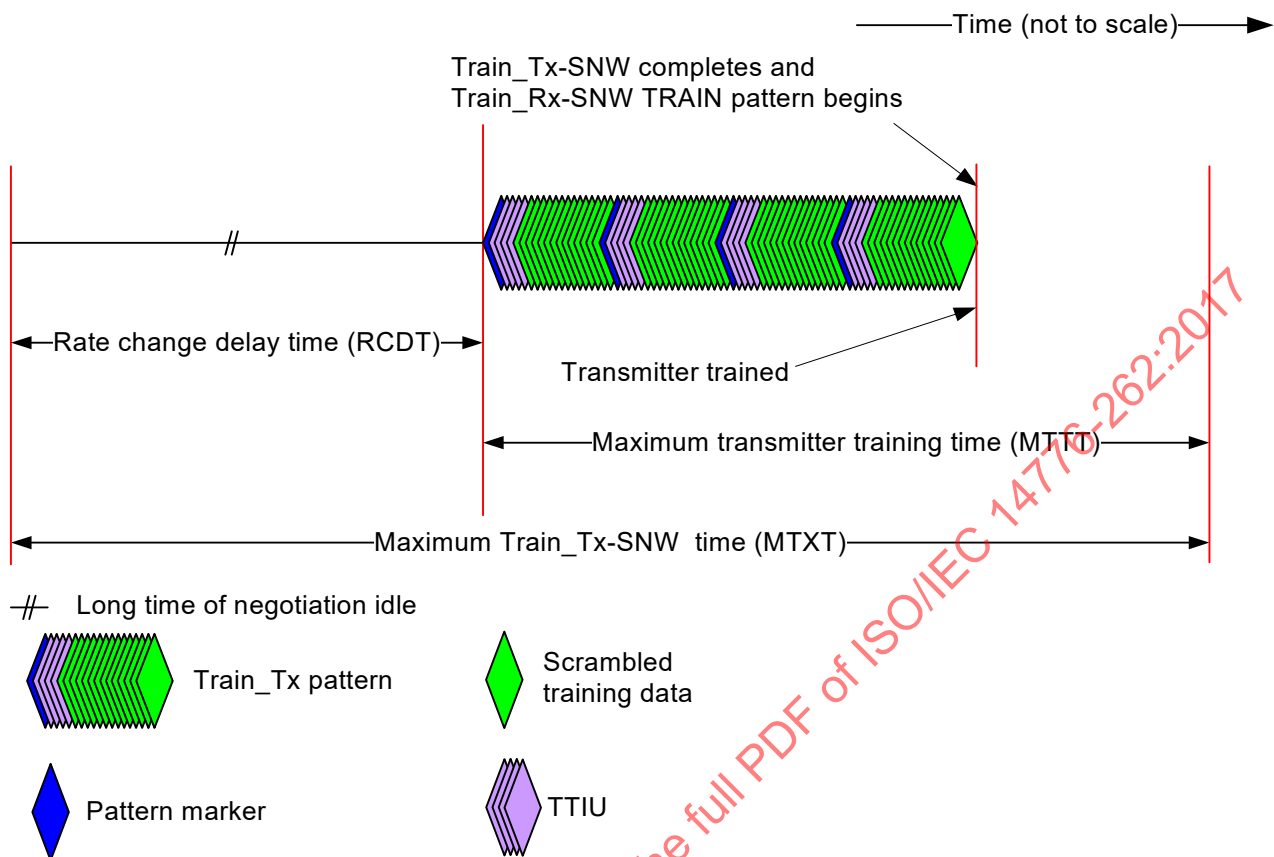


Figure 69 – Train_Tx-SNW

The Train_Tx-SNW contains transmitter training patterns formed by the Train_Tx pattern as defined in table 72.

Table 72 – Transmitter training pattern

Transmitter training pattern	Description
Train_Tx pattern	Sequence of: 1) pattern marker (see 5.10.4.2.3.4.3); 2) TTIU (see 5.10.4.2.3.5); and 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:

- 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
- 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 72.

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.

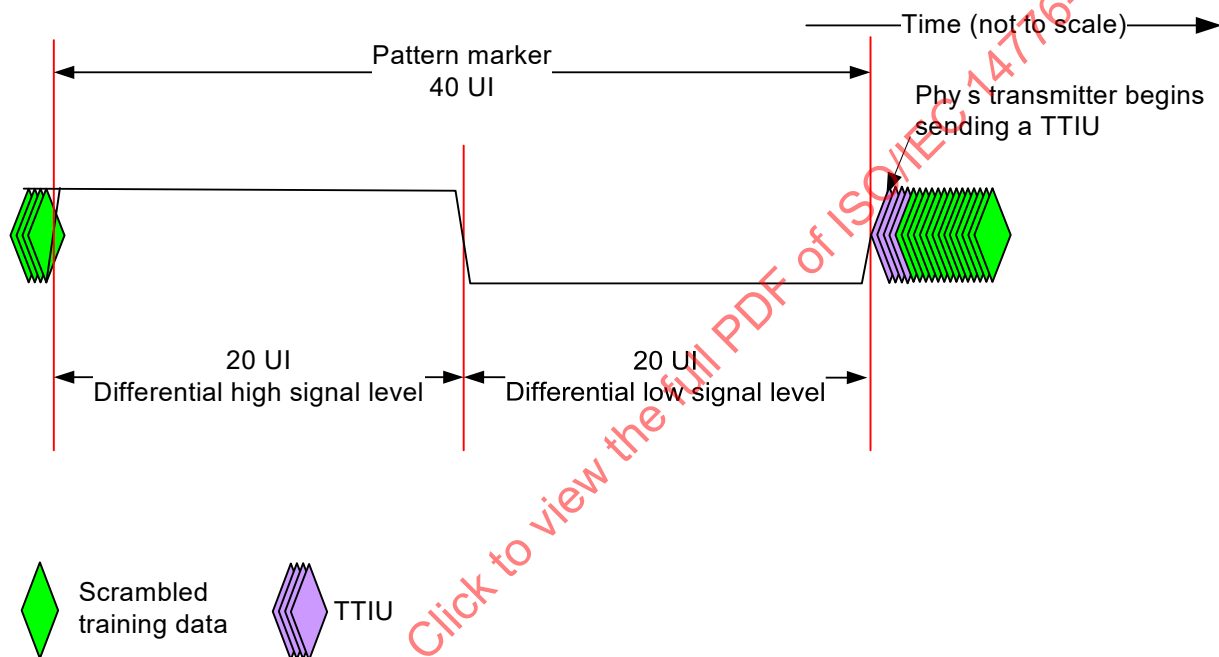


Figure 70 – Pattern marker transmission

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.

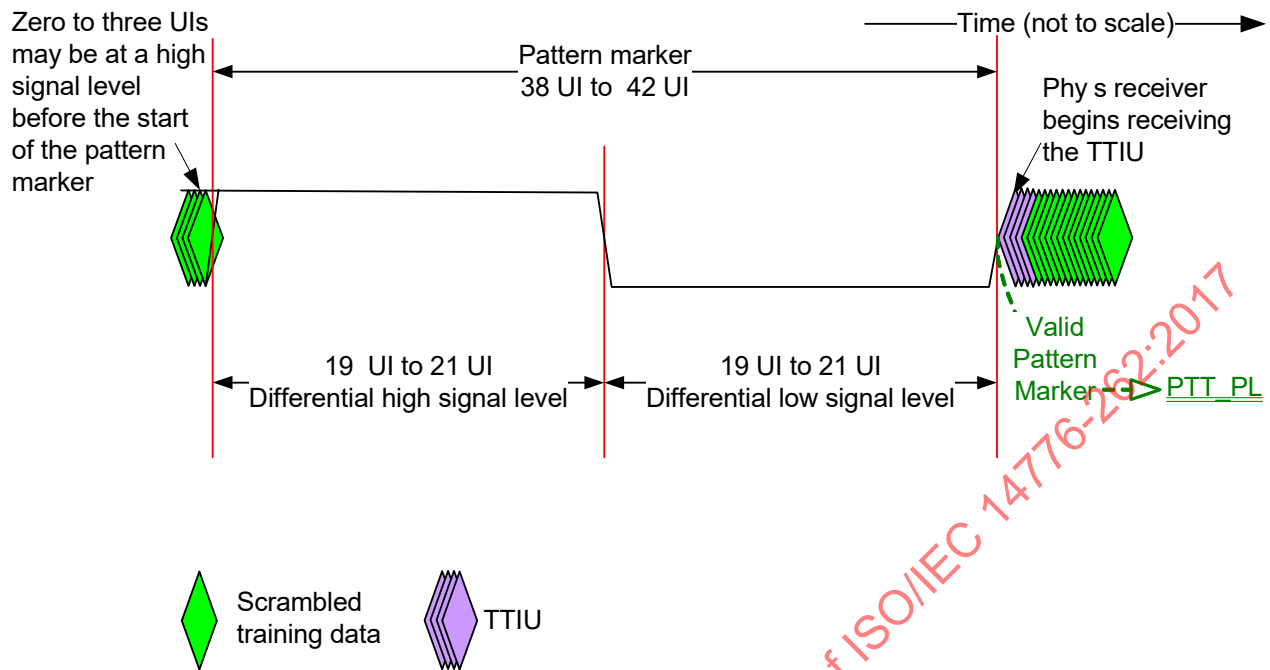


Figure 71 – Valid pattern marker detection

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.

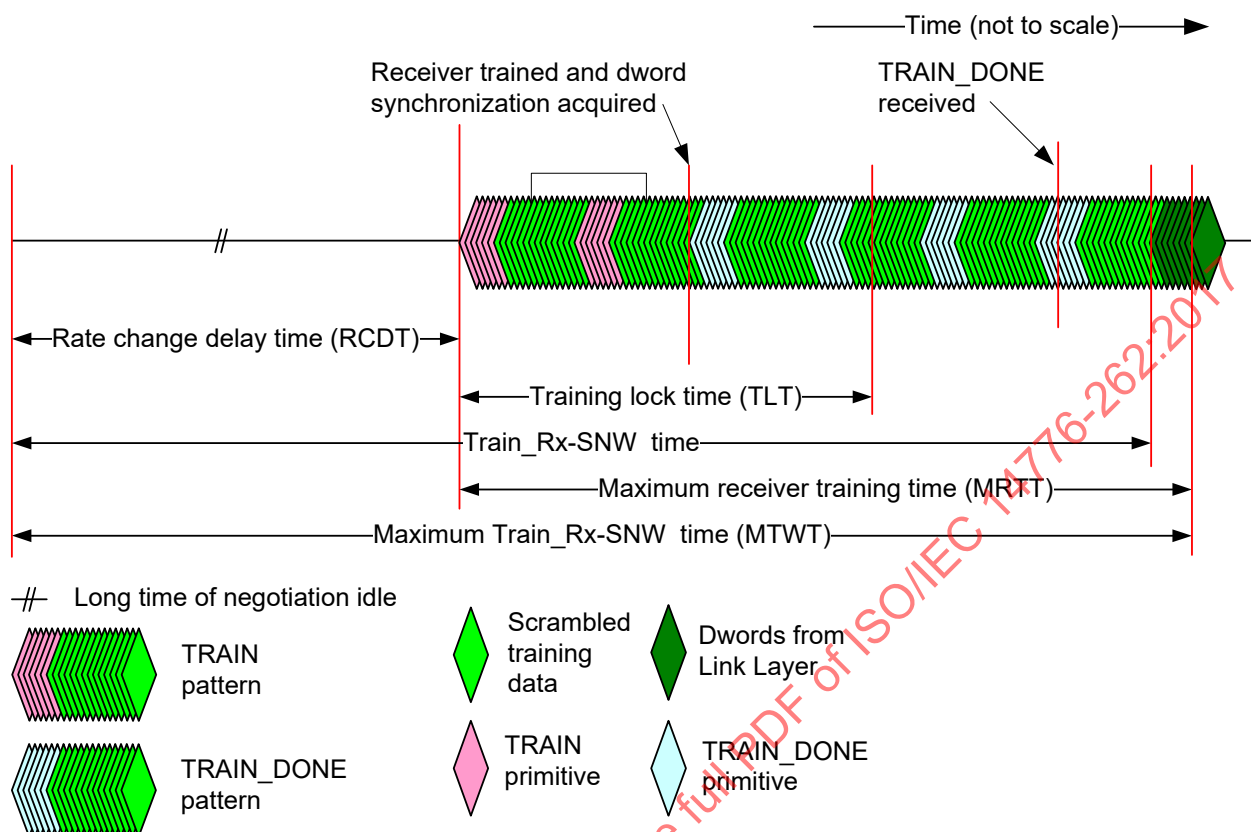


Figure 72 – Train_Rx-SNW

The Train_Rx-SNW contains receiver training patterns formed by TRAIN and TRAIN_DONE (see 6.2) as defined in table 73.

Table 73 – Receiver training patterns

Receiver training pattern	Description
TRAIN pattern	Sequence of: 1) TRAIN primitive sequence; and 2) 58 data dwords set to 00000000h that are transmitted scrambled and 8b10b encoded.
TRAIN_DONE pattern	Sequence of: 1) TRAIN_DONE primitive sequence; and 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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.

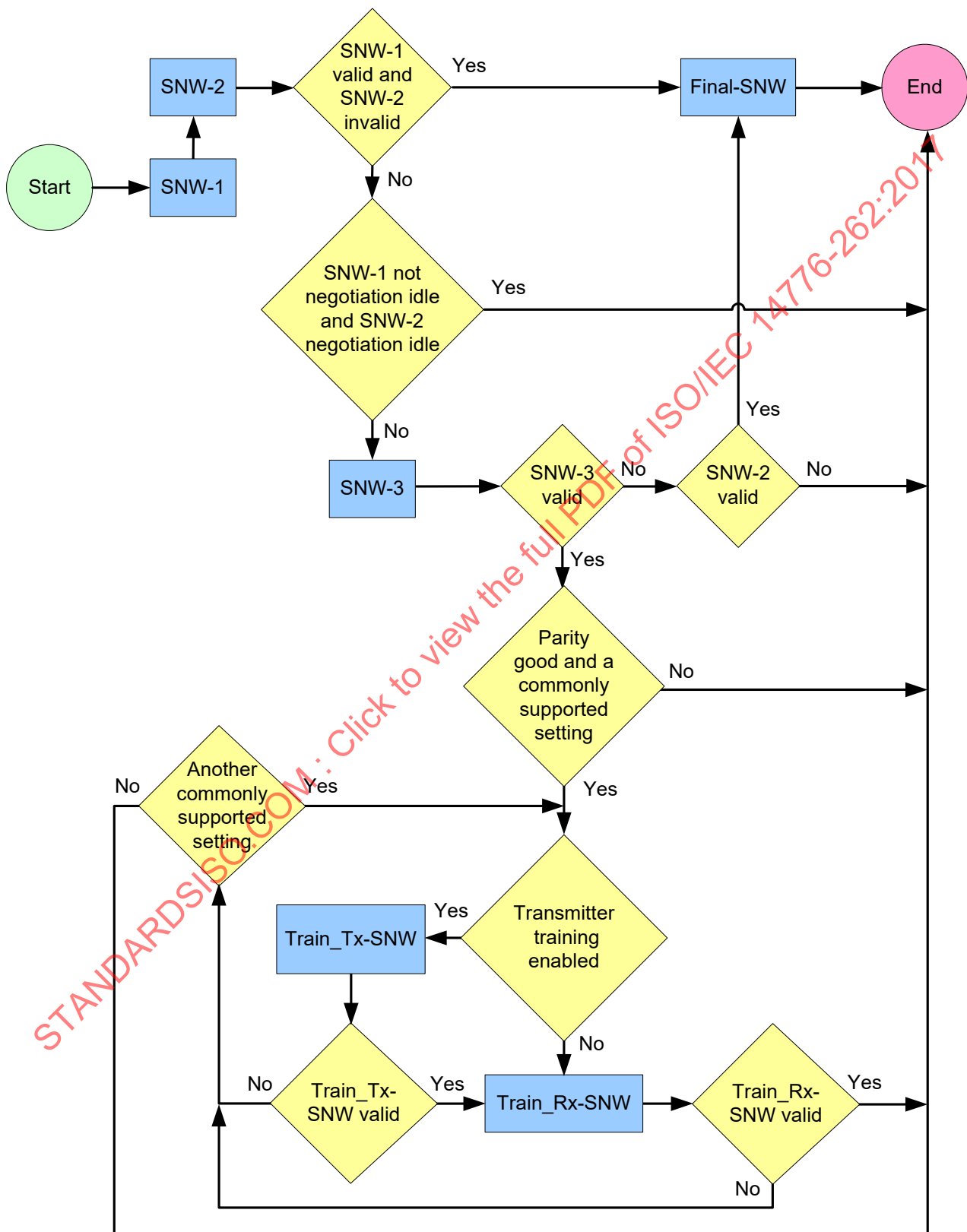


Figure 73 – SAS speed negotiation sequence SNW flowchart

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;
- 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.

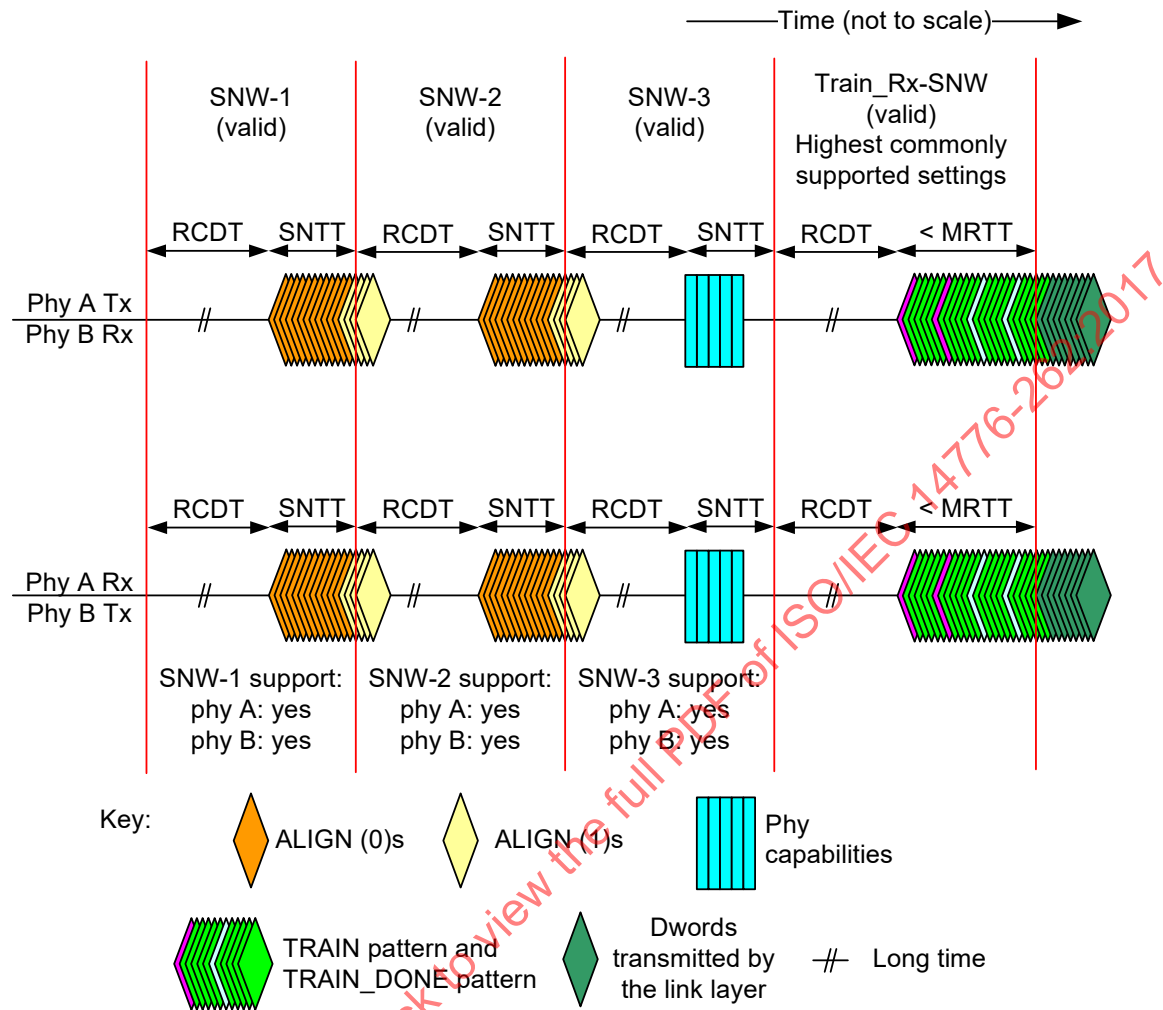


Figure 74 – SAS speed negotiation sequence (both phys SNW-1 through Train_Rx-SNW with no Train_Tx-SNW)

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.

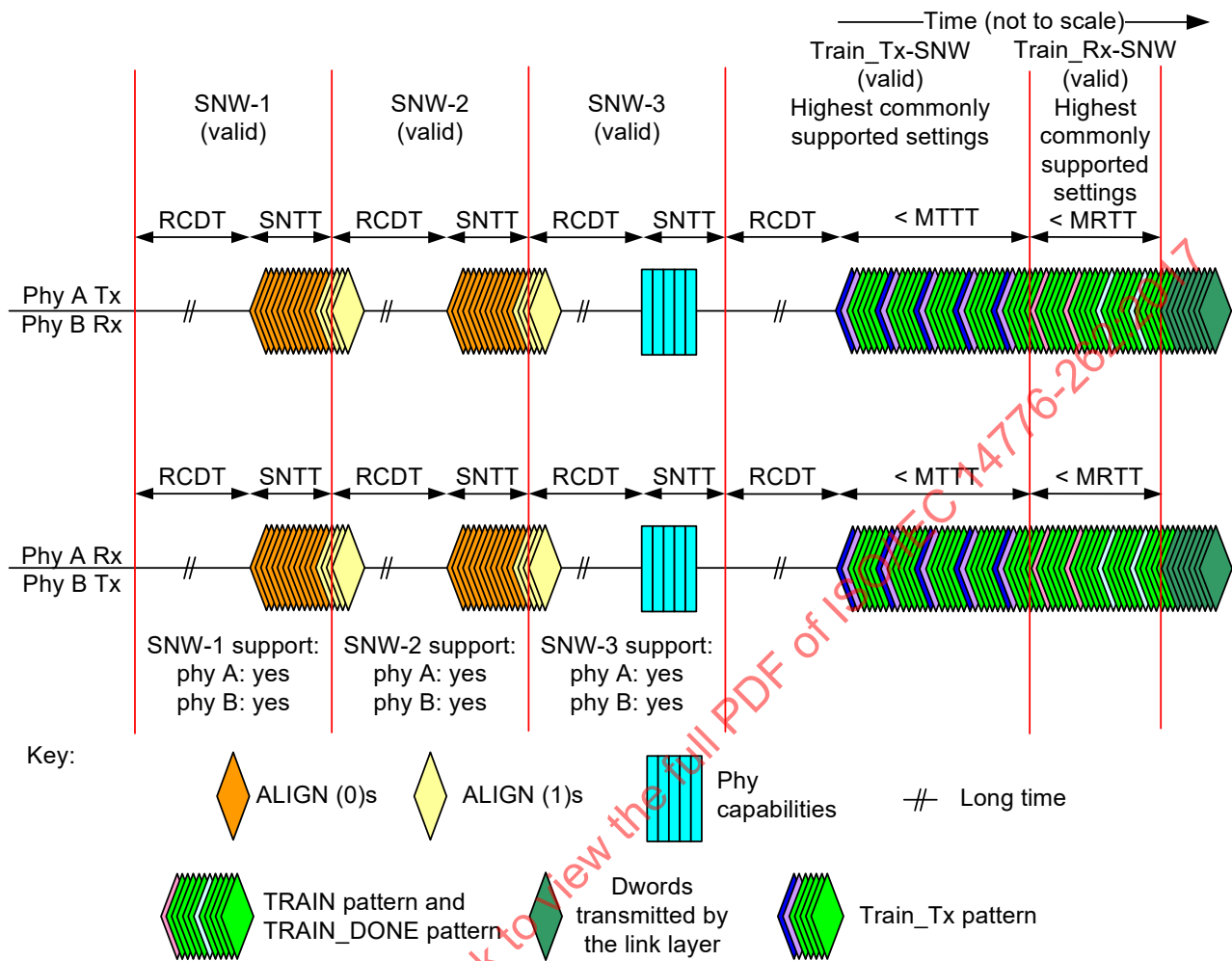


Figure 75 – SAS speed negotiation sequence (both phys SNW-1 through Train_Rx-SNW with Train_Tx-SNW)

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.

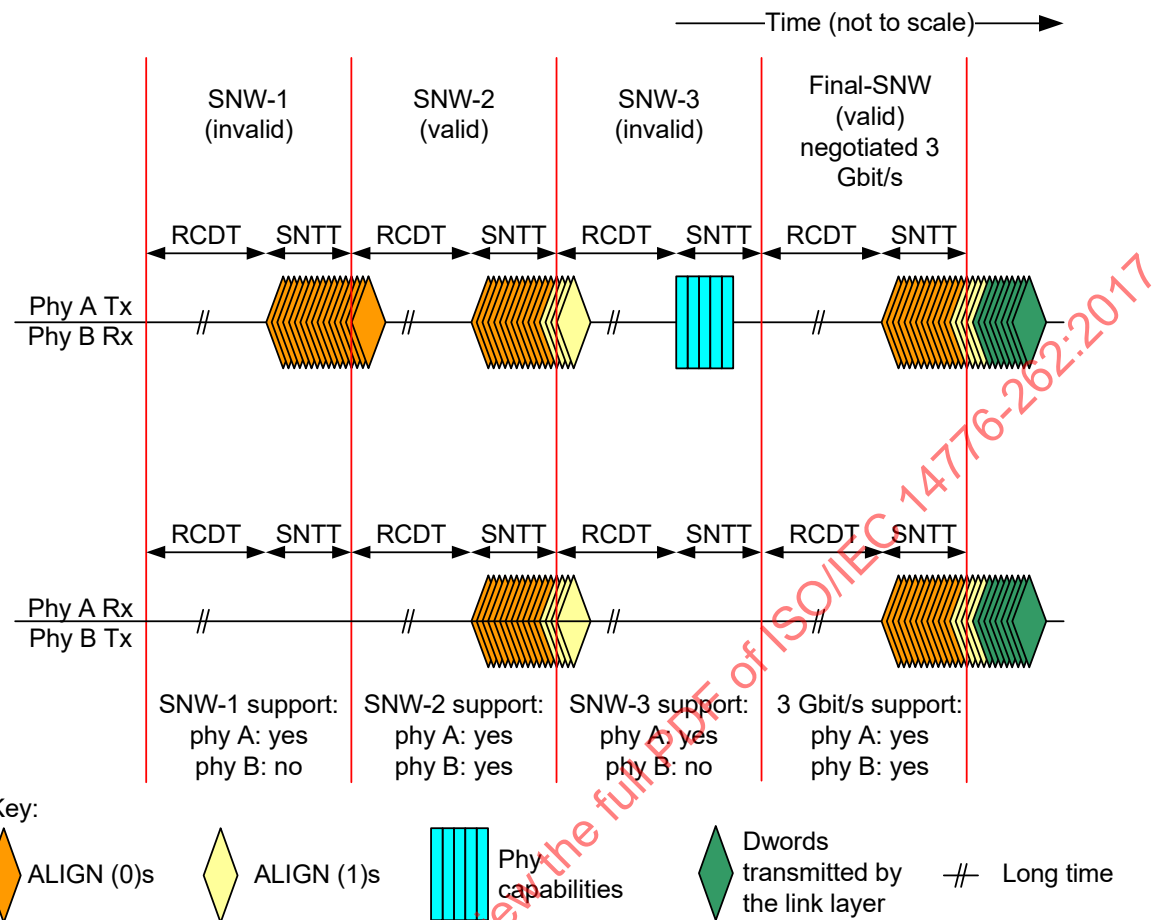


Figure 76 – SAS speed negotiation sequence (phy A: SNW-1 through SNW-3, phy B: SNW-2 only)

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.

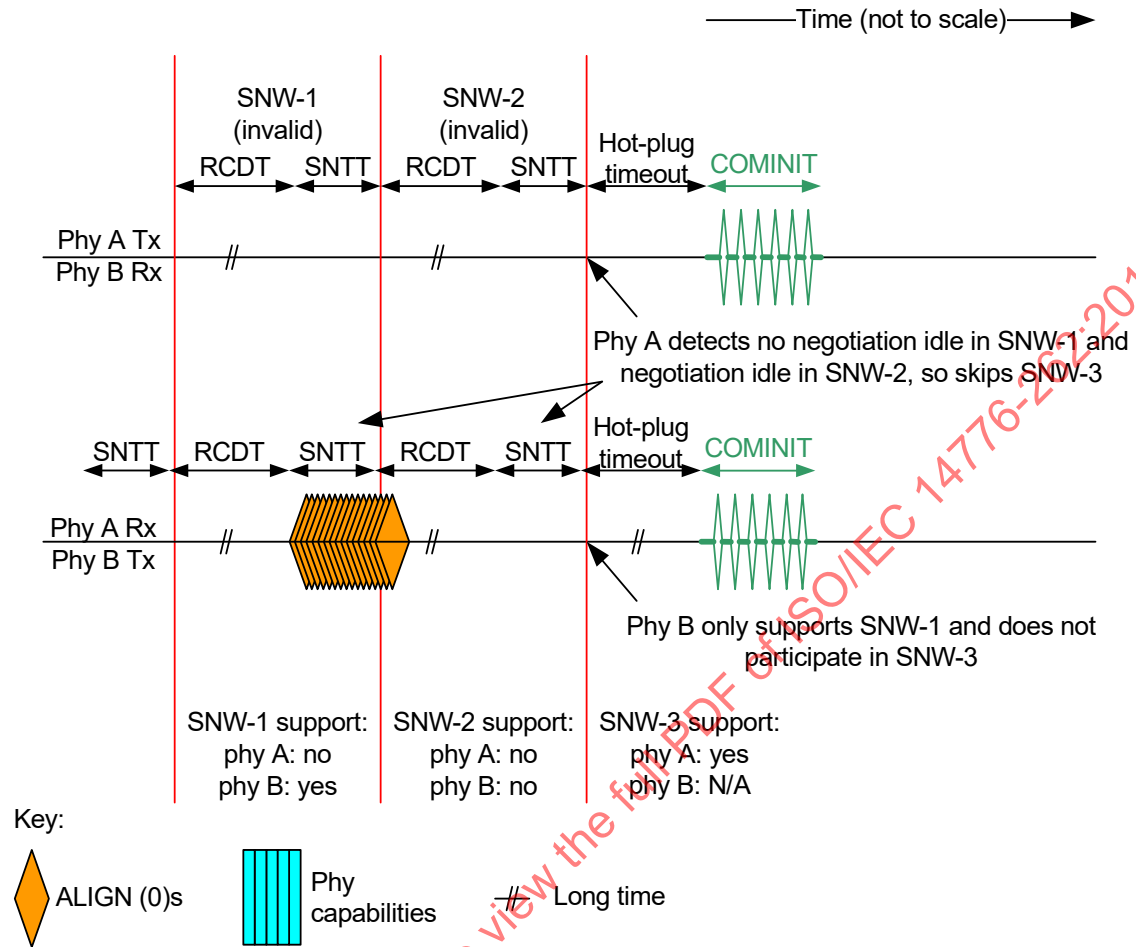


Figure 77 – SAS speed negotiation sequence (phy A: SNW-3 only, phy B: SNW-1 only)

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.

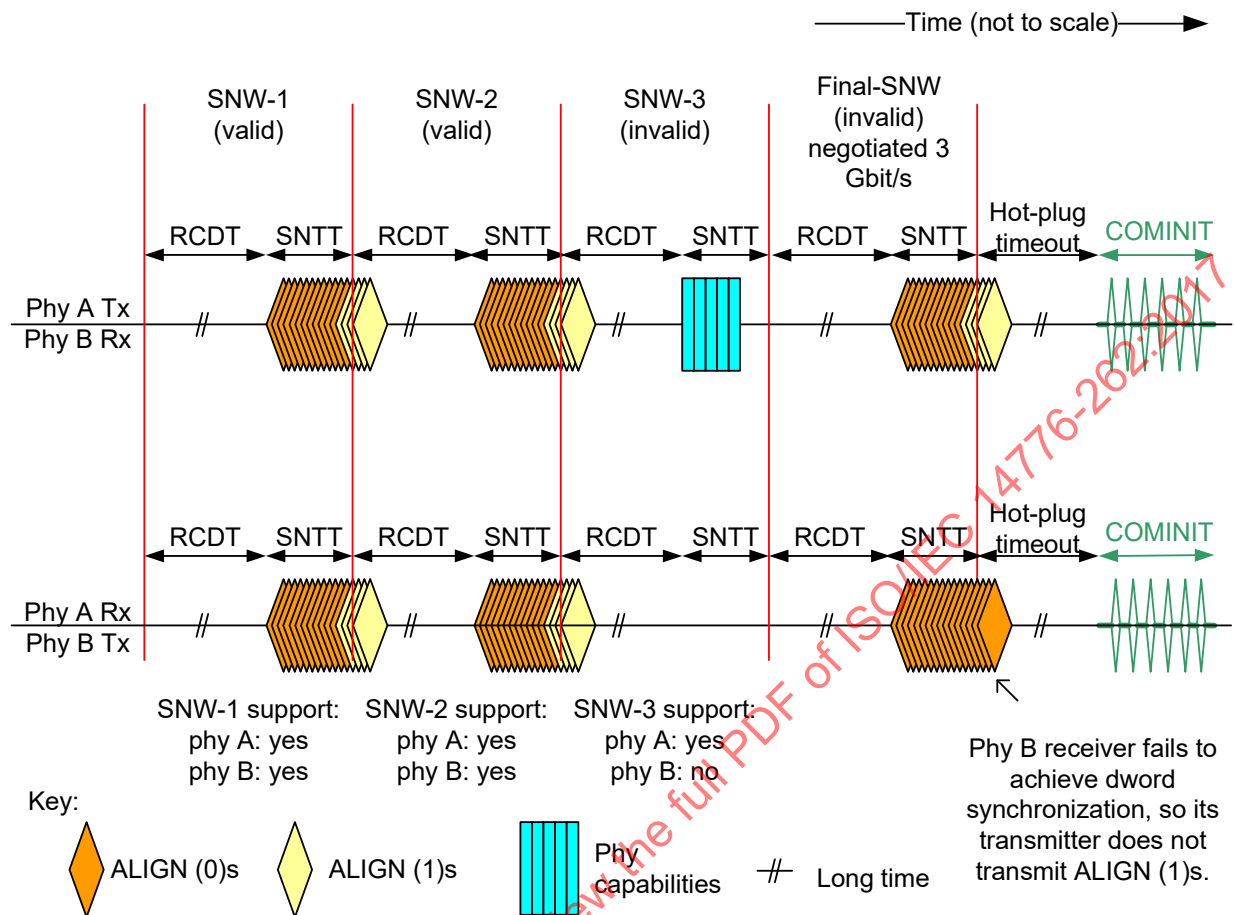


Figure 78 – SAS speed negotiation sequence - phy reset problem in Final-SNW

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).

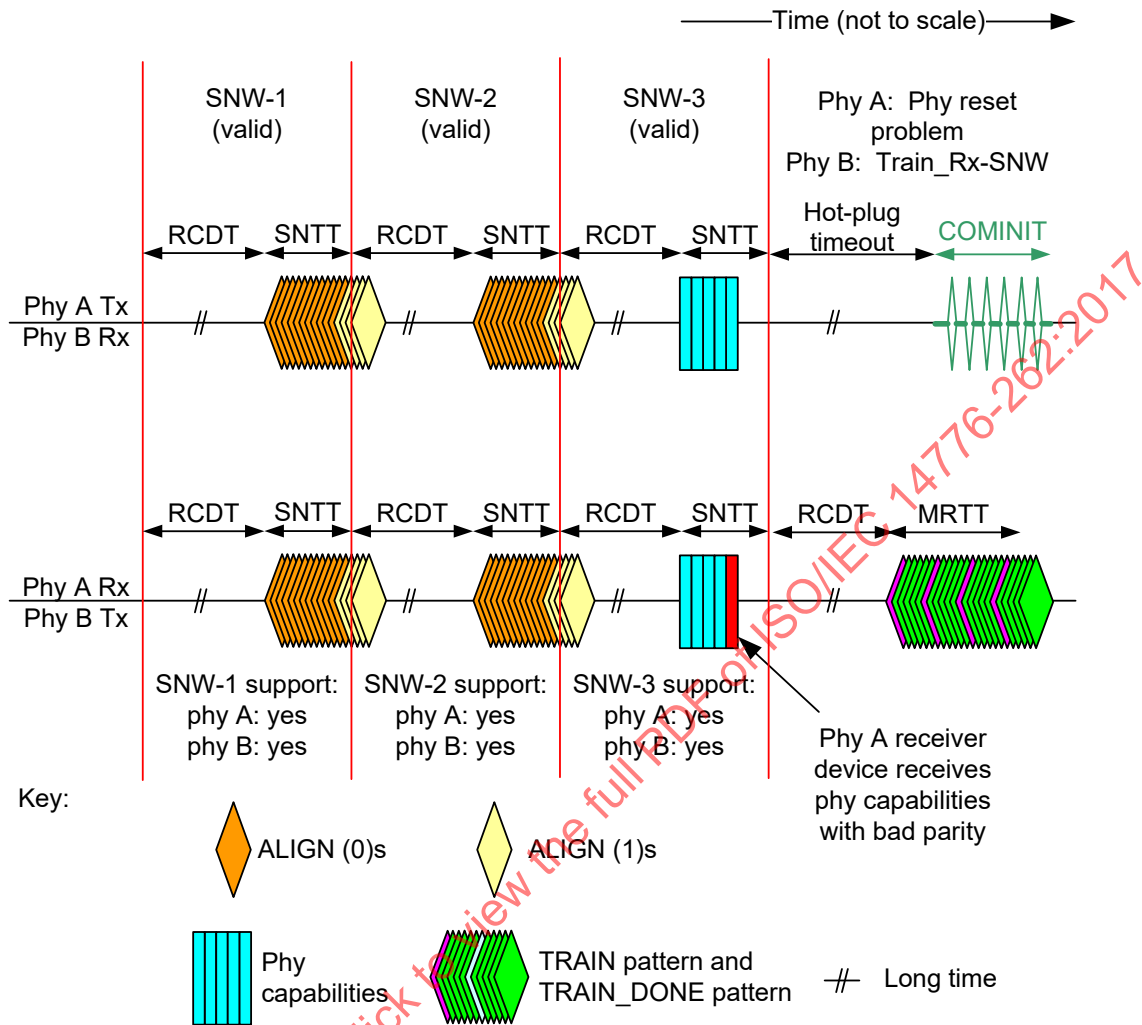


Figure 79 – SAS speed negotiation sequence - phy reset problem in SNW-3

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.

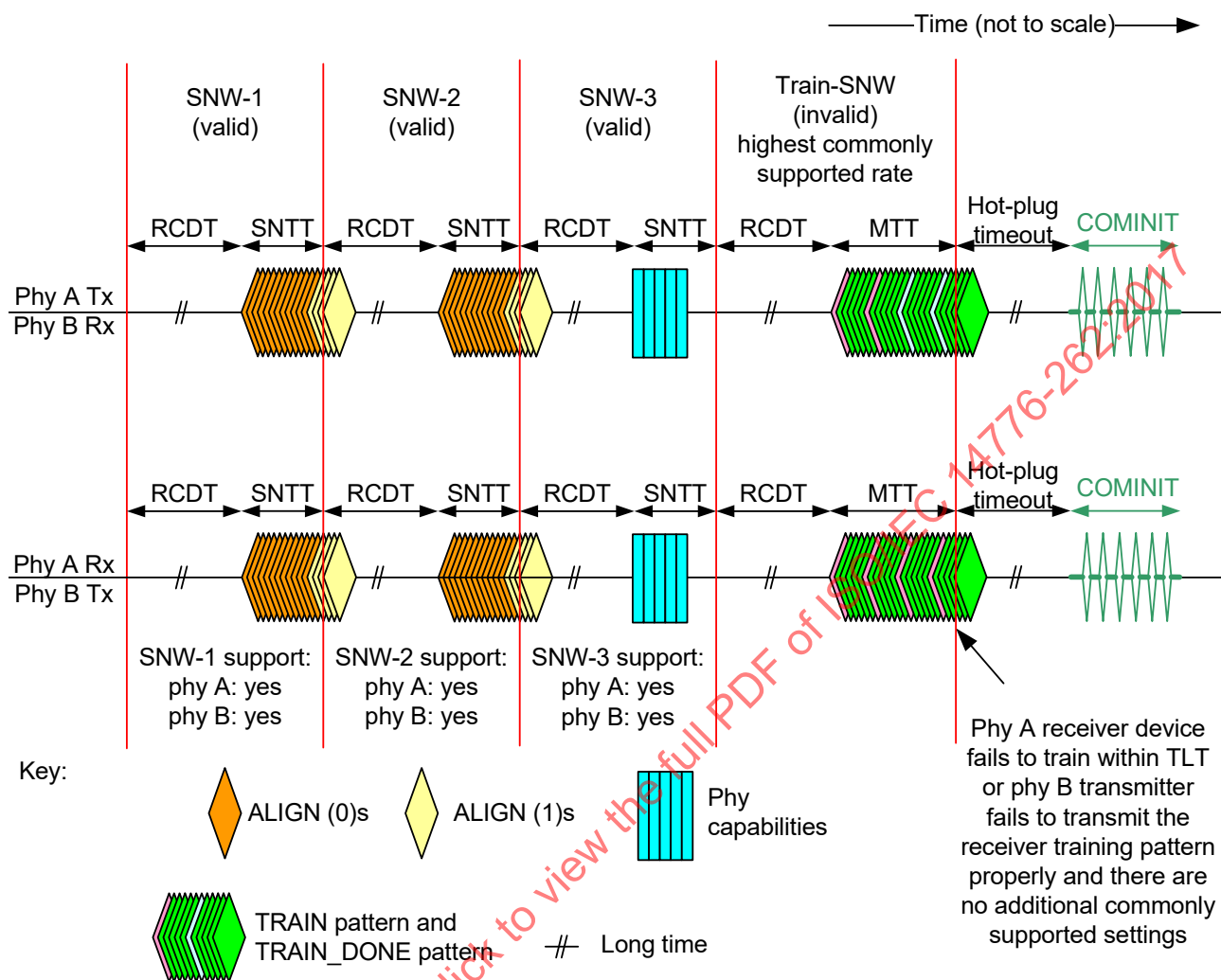


Figure 80 – SAS speed negotiation sequence - phy reset problem in Train_Rx-SNW

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.

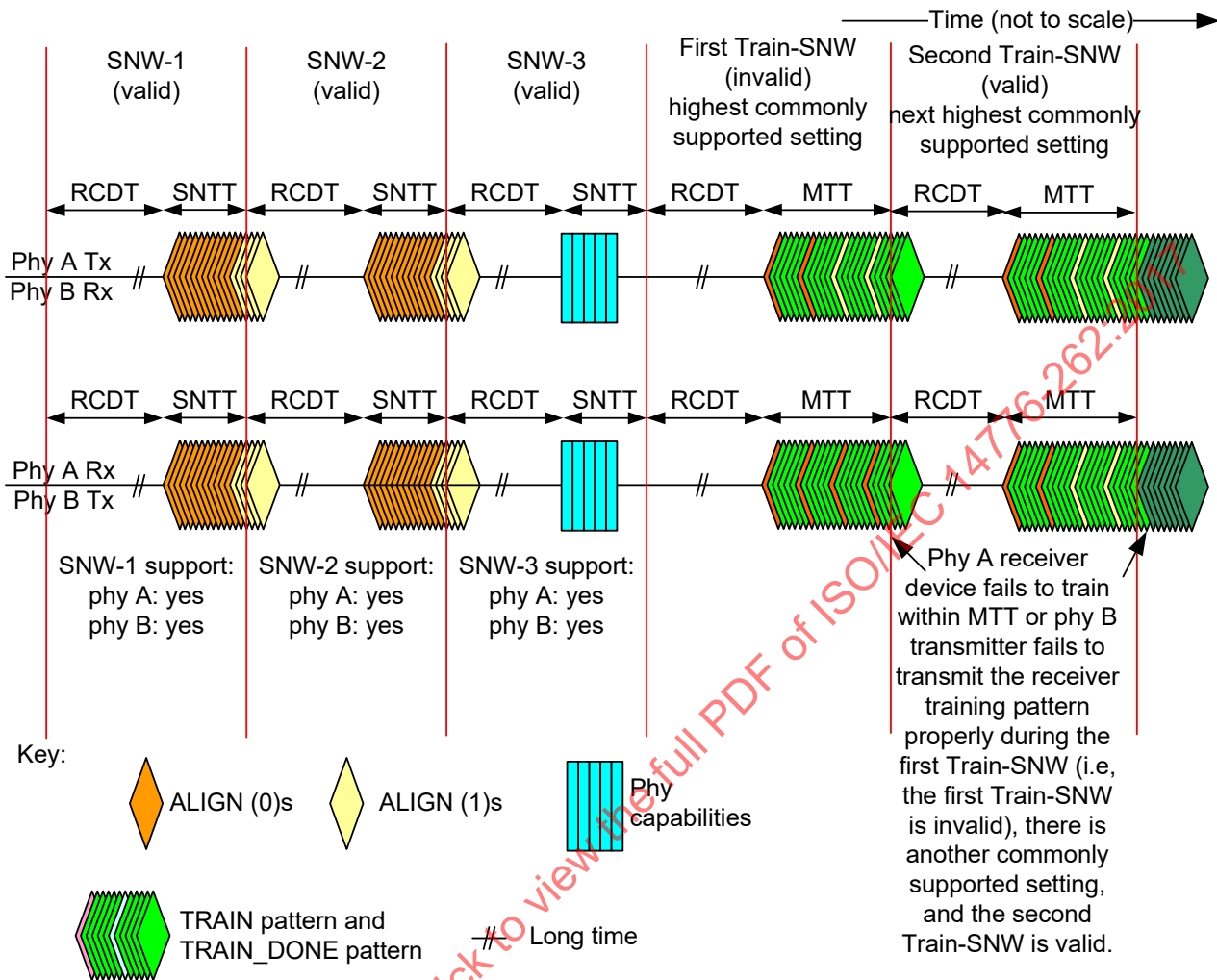


Figure 81 – SAS speed negotiation sequence - multiple Train_Rx-SNWs

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 which require transmitter training (see table 55), 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 TTUUs 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

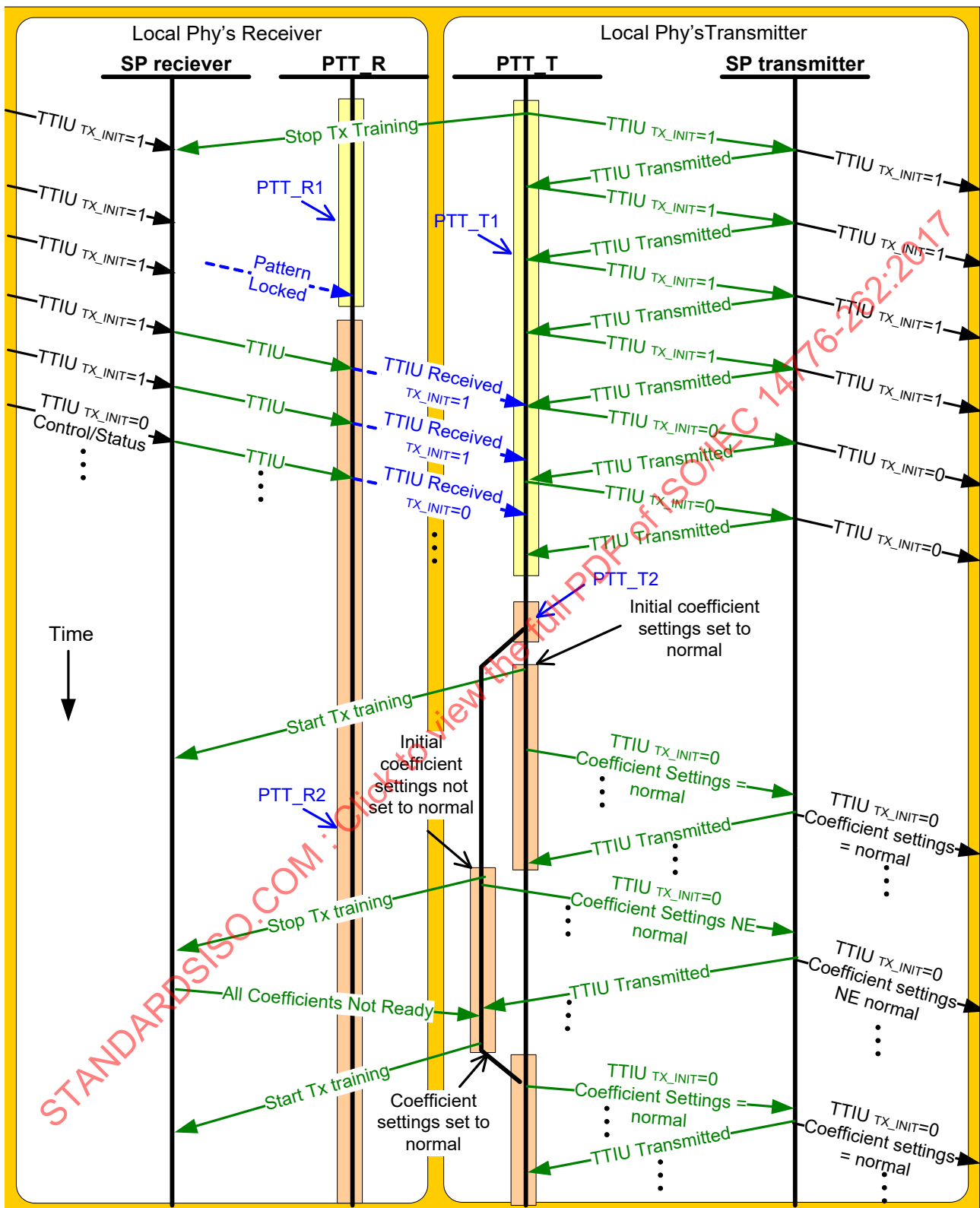
After RCDT during a Train_Tx-SNW, (see 5.10.4.2.3.4) the local phy and the attached phy both begin transmitting and receiving Train_Tx patterns. The point at which a transmitter training pattern lock occurs at the local phy's receiver may occur before or after a transmitter training pattern lock occurs 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 TTIs when the PTT_T1 state (see 5.14.4.3) receives a TTIU Received message from the PTT_R2 state (see 5.14.5.3); and
- b) that the attached phy's receiver is receiving TTIs when the PTT_T1 state receives a TTIU 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017



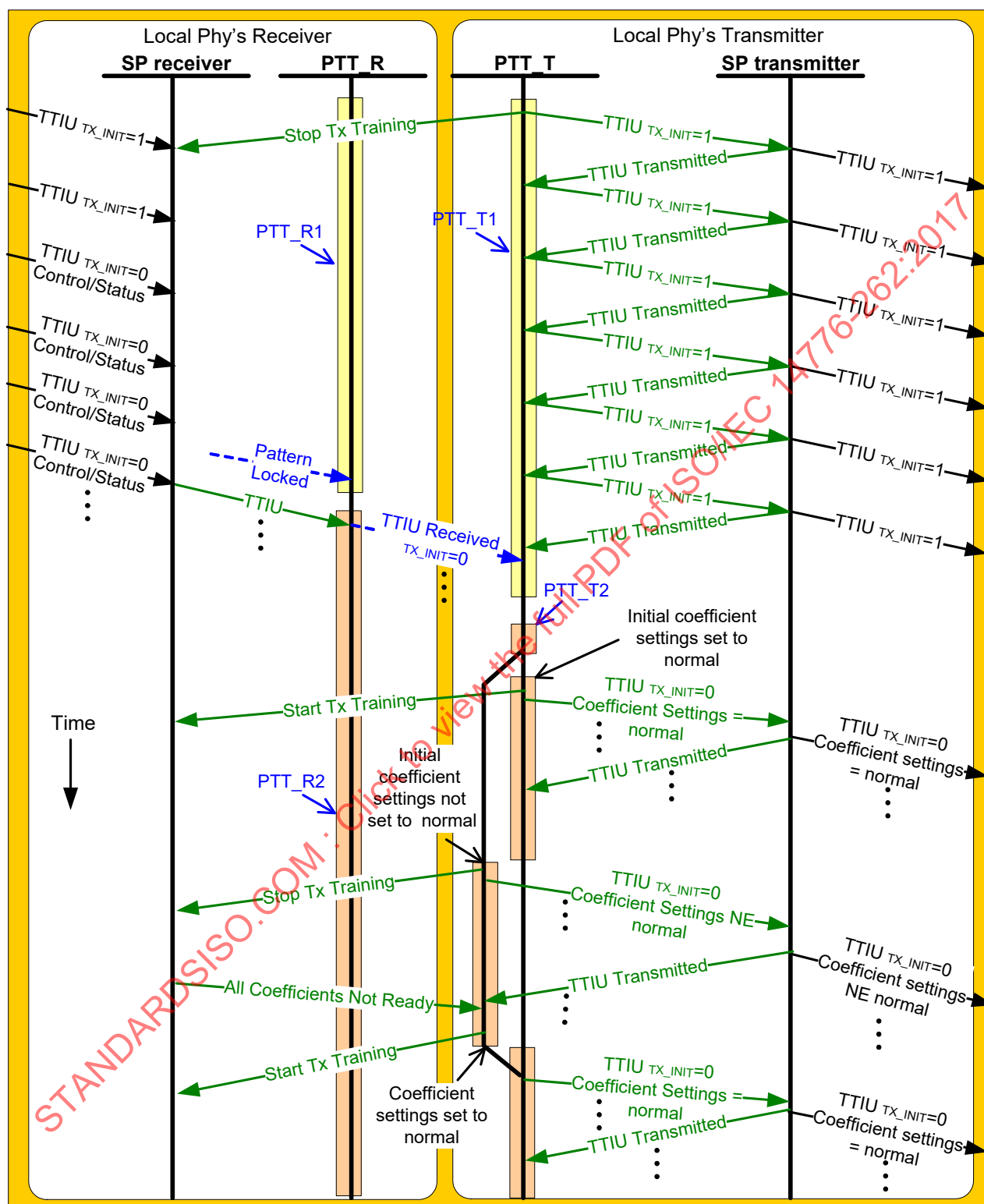
Key: Start Tx Training = Attached Phy's Transmitter Training (Start) message
 Stop Tx Training = Attached Phy's Transmitter Training (Stop) message

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 Phy's Transmitter Training (Start) message
 Stop Tx Training = Attached Phy's Transmitter Training (Stop) message

Processing PTT state name →

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 63); or
- f) decremented (see table 63).

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:

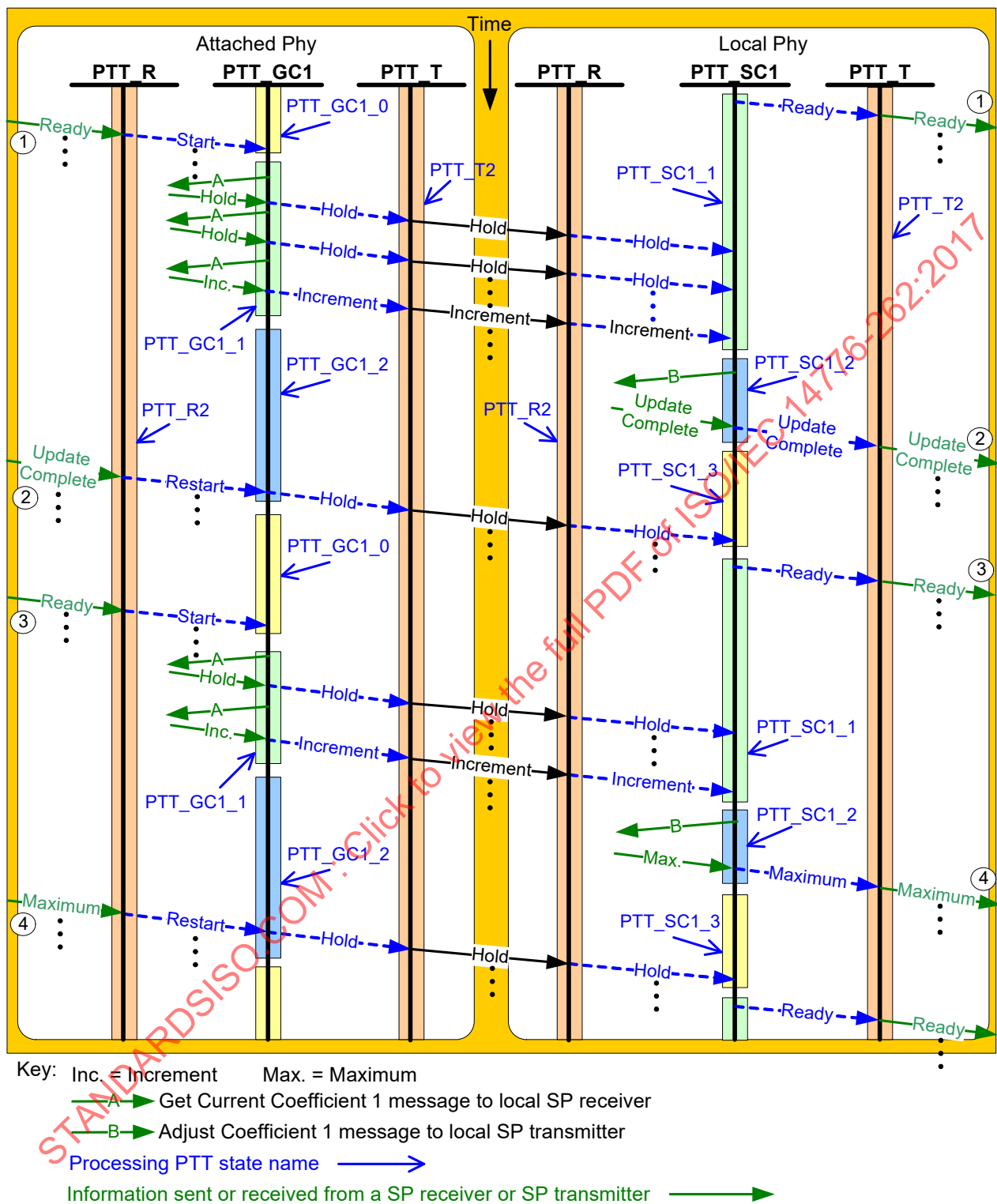
- a) PTT_GC1 state machine (see 5.14.9);
- b) PTT_GC2 state machine (see 5.14.10); and
- c) PTT_GC3 state machine (see 5.14.11).

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.

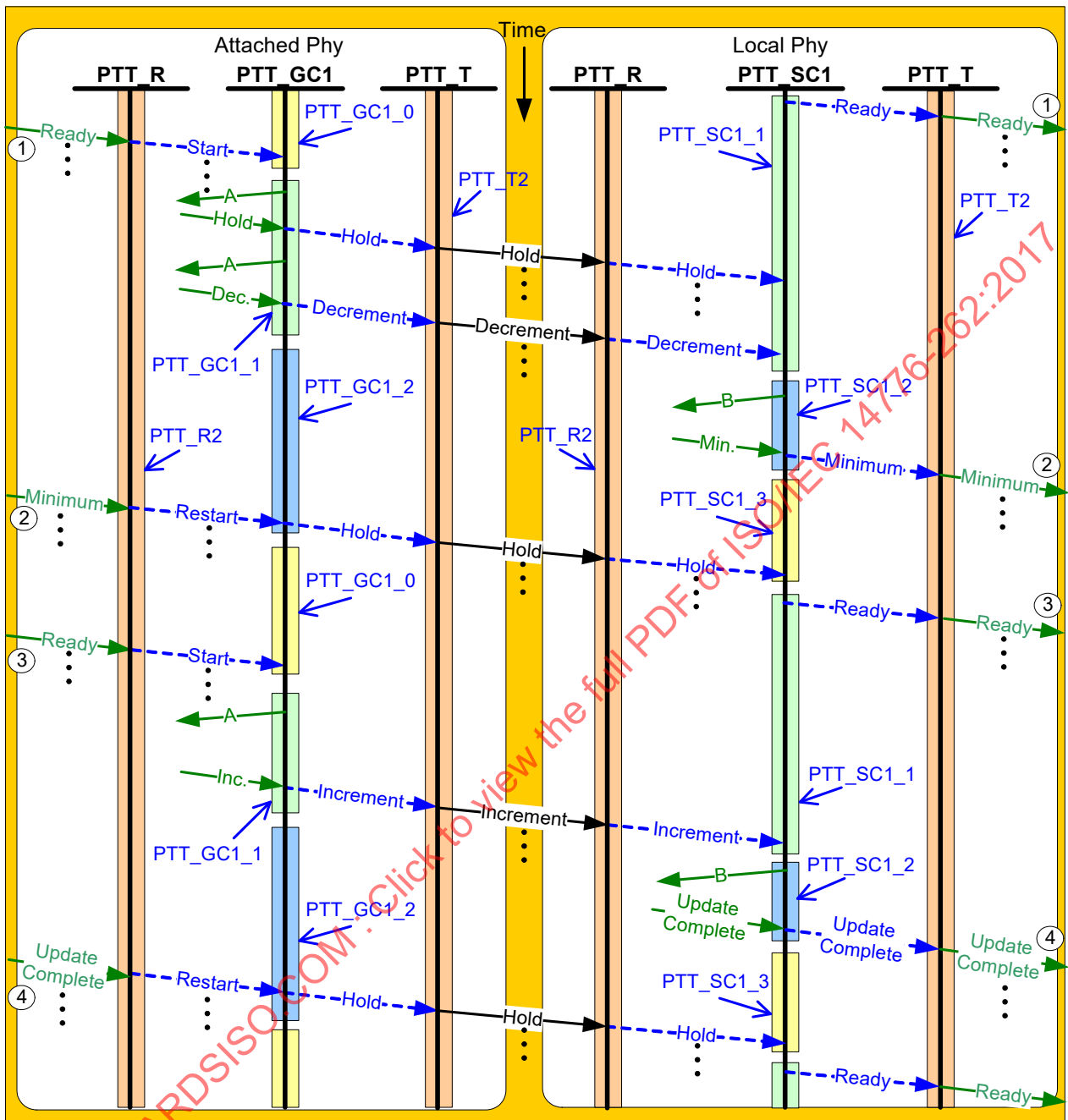


Note 1 - Not shown in this figure is the attached phy's receiver PTT_R state machine sending coefficient 1 status (i.e., ready, update complete, minimum, or maximum) to the attached SP receiver.

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 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.

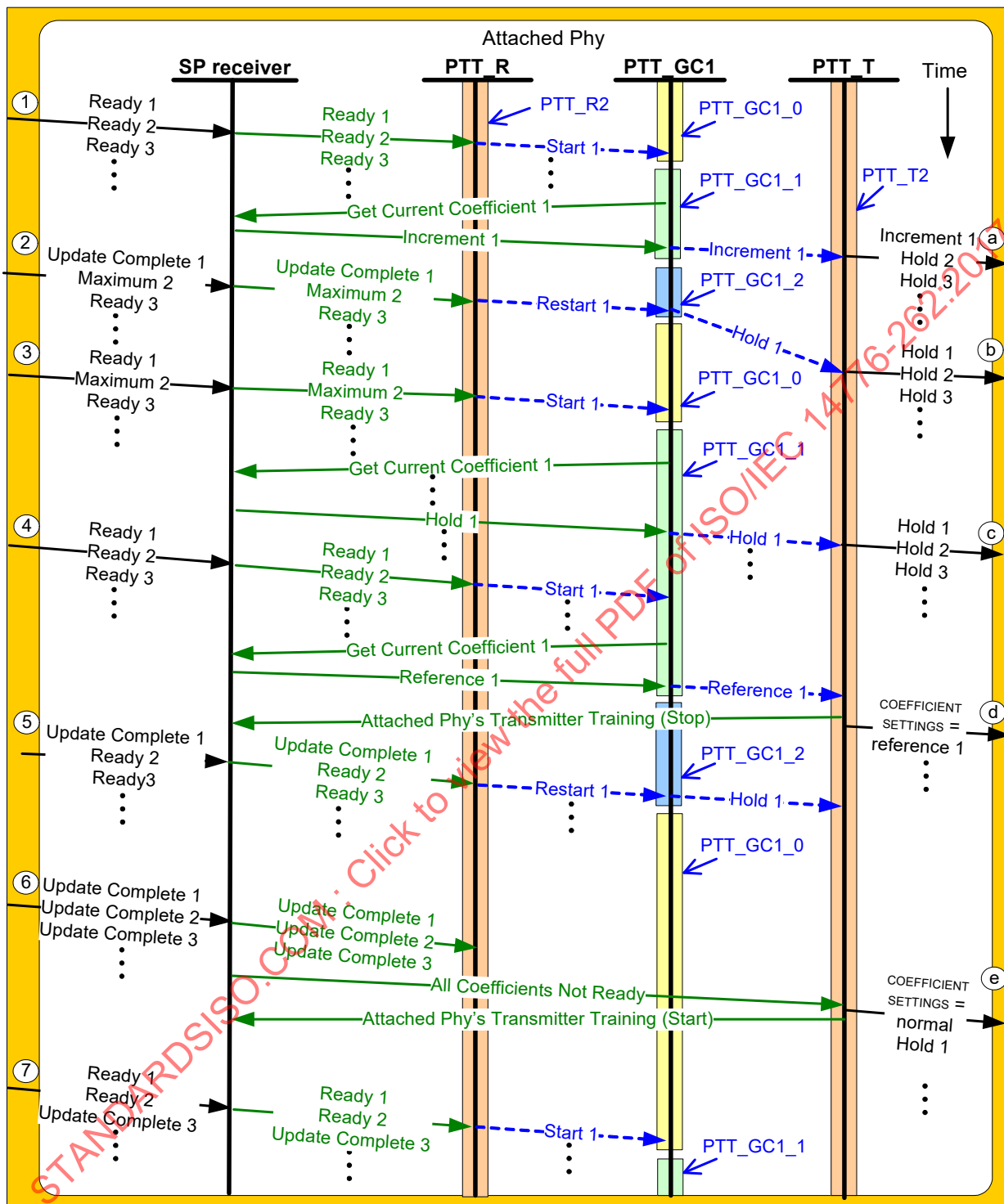
The processing of the attached phy's receiver coefficient setting requests is handled by the:

- 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.



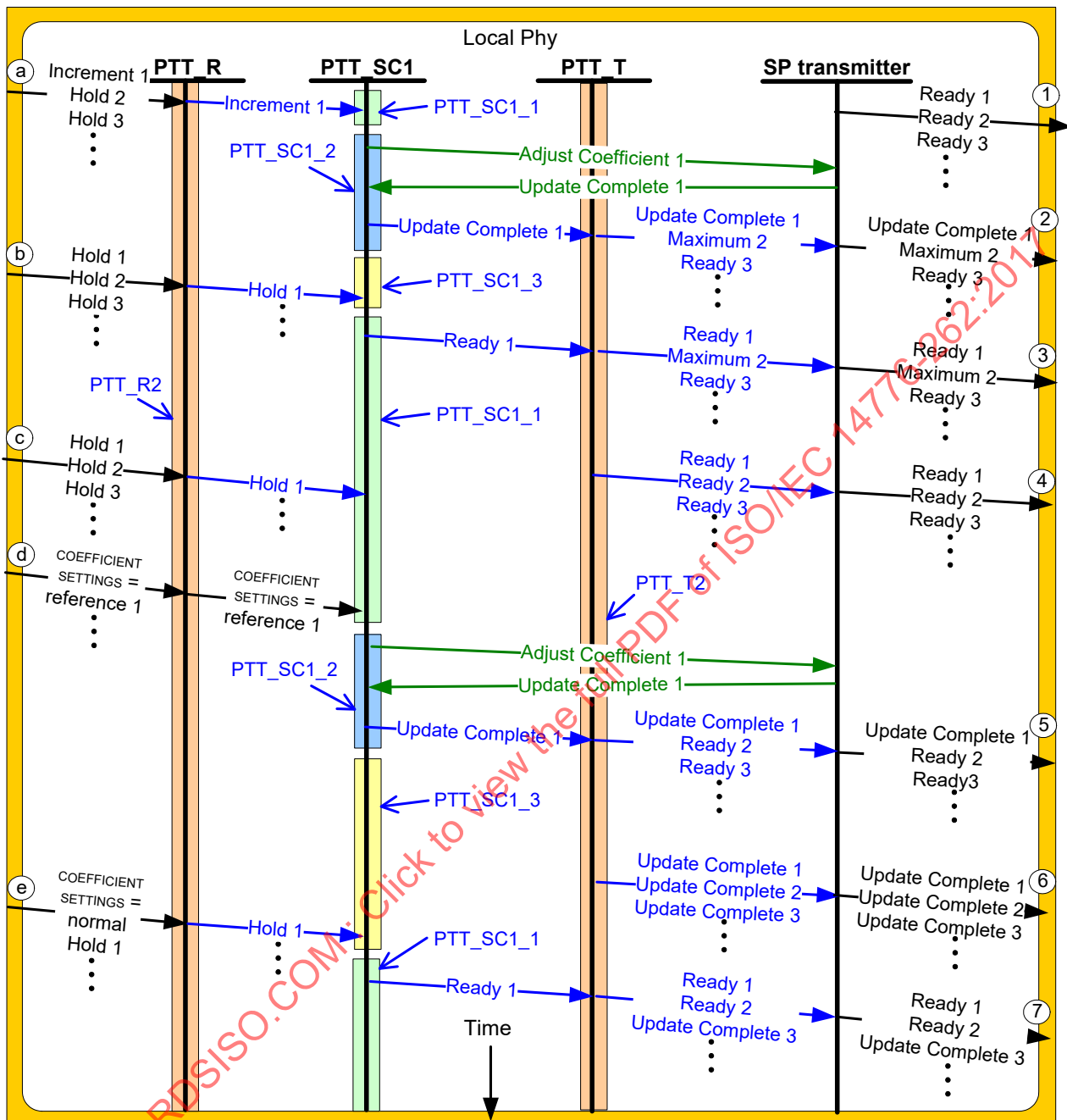
Key: Processing PTT state name →

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 5.14.5.3.1).

EXAMPLE 1 - Figure 88 shows the local phy's receiver completion of training before the attached phy's receiver indicates it has completed training.

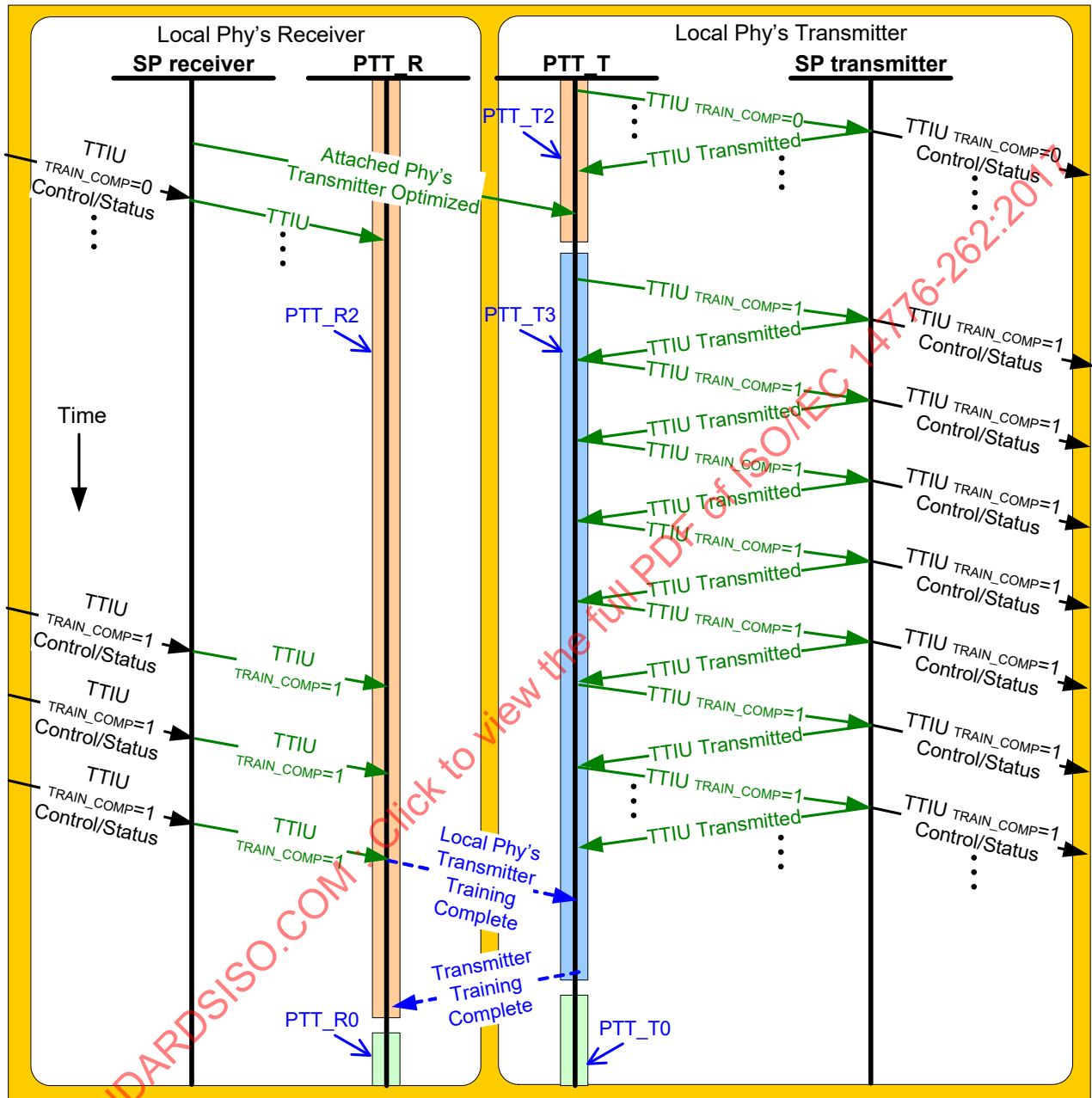


Figure 88 – Local phy's receiver indicates completion of training before the attached phy's receiver completes training

EXAMPLE 2 - Figure 89 shows the attached phy's receiver indication of completion of training before the local phy's receiver completes training.

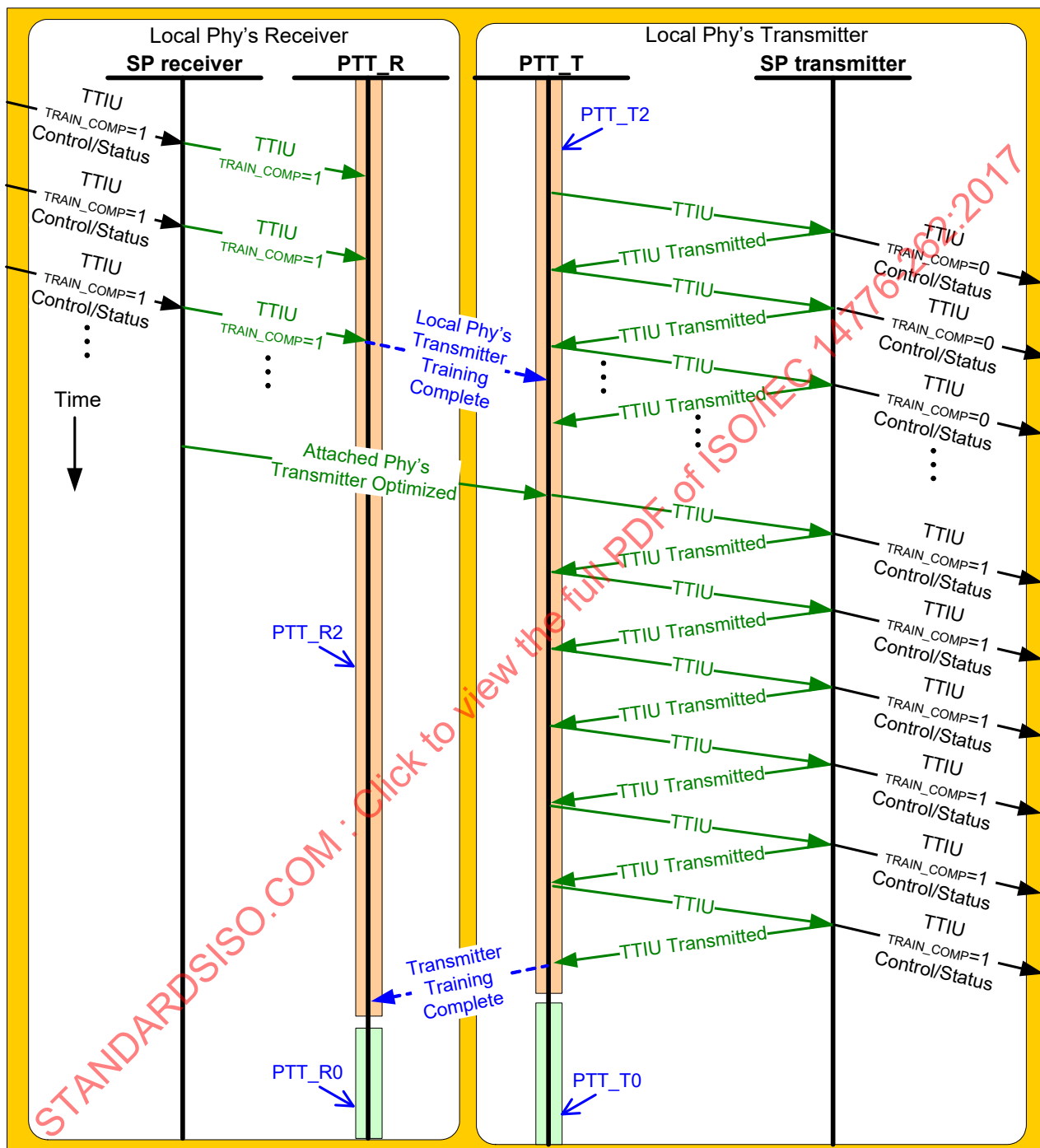


Figure 89 – Attached phy's receiver indicates completion of training before the local phy's receiver completes training

5.10.4.2.6.5 Invalid TTIU sequence

If the PTT_R state machine (see 5.14.5.3.1) 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.

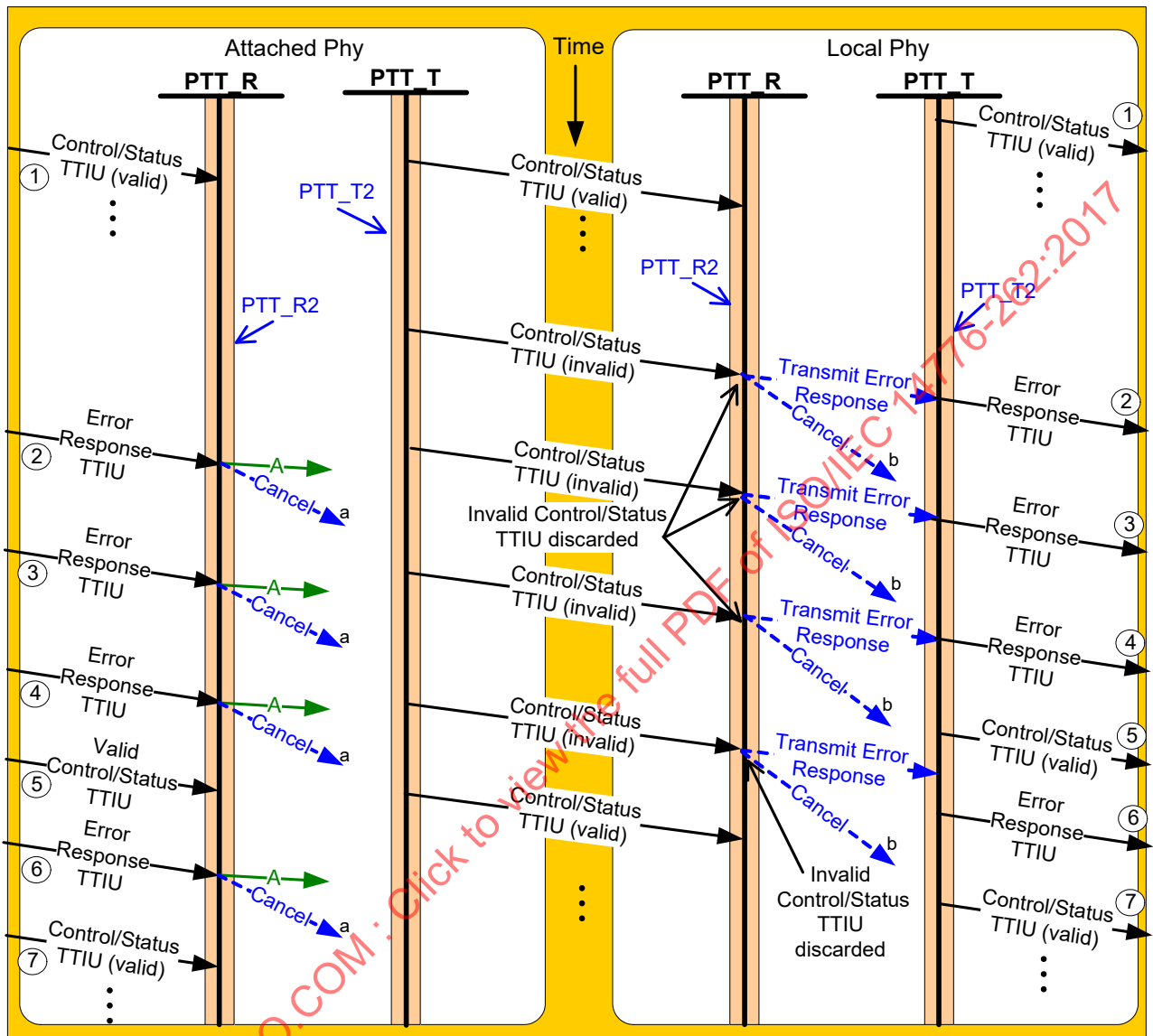
If the PTT_T2 state (see 5.14.4.4.4) or PTT_T3 state (see 5.14.4.5.5) receives a Transmit Error Response message, then that state builds and transmits an Error Response TTIU.

If the PTT_R2 state machine (see 5.14.5.3.1) 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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 →

^a Cancel message to PTT_GC1 state machine, PTT_GC2 state machine, and PTT_GC3 state machine.

^b 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 table 54, 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 67 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.

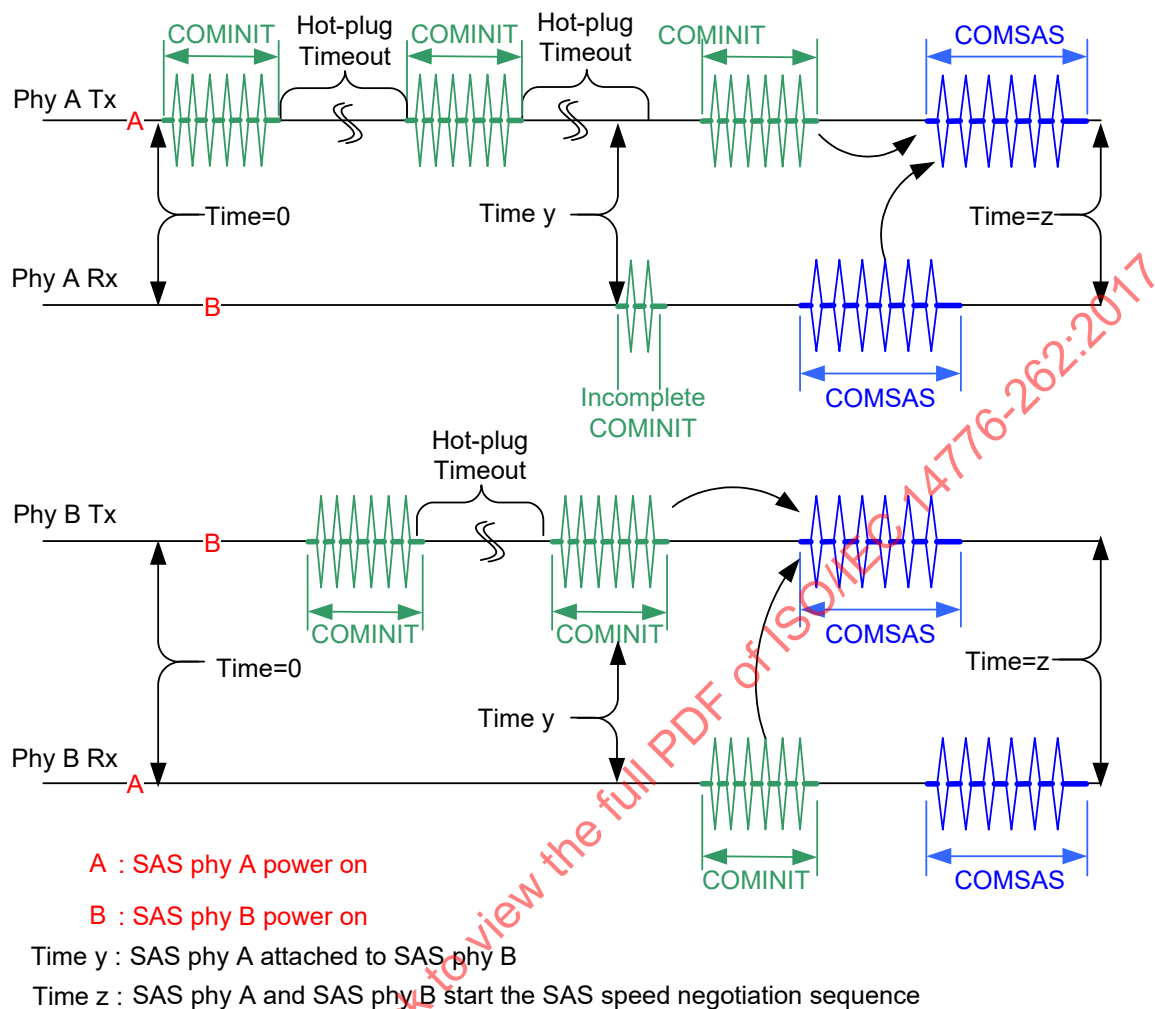


Figure 91 – Hot-plug and the phy reset sequence

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.

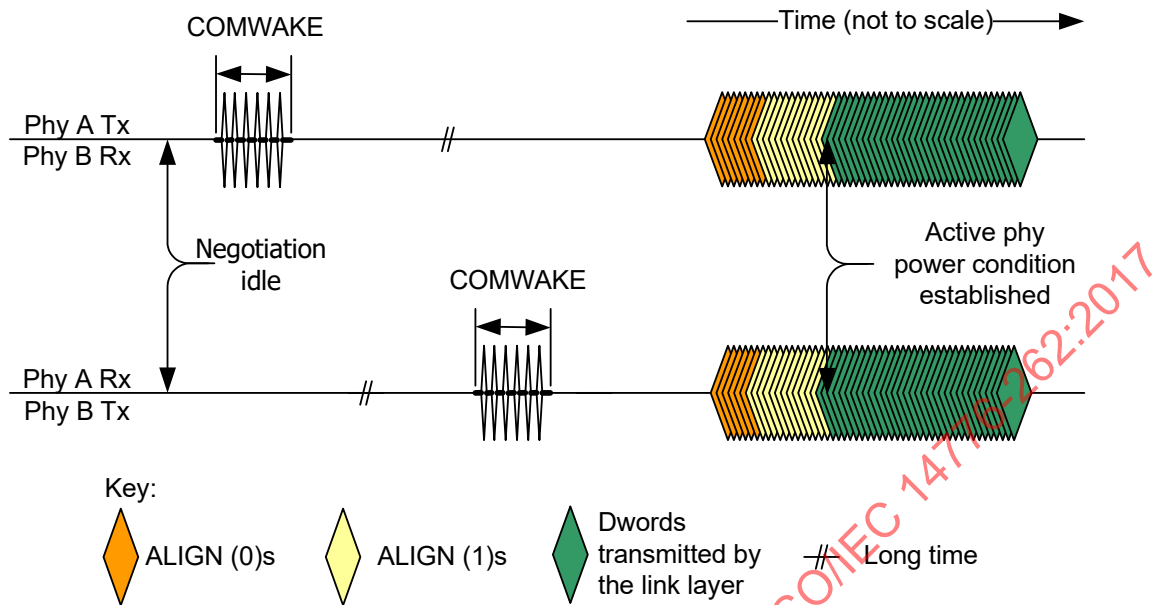


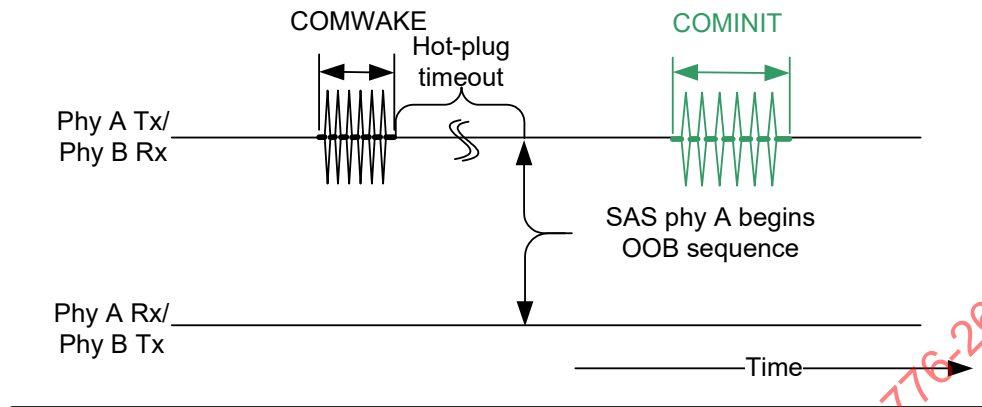
Figure 92 – Transition to active phy power condition

5.11.3 Events during low phy power condition

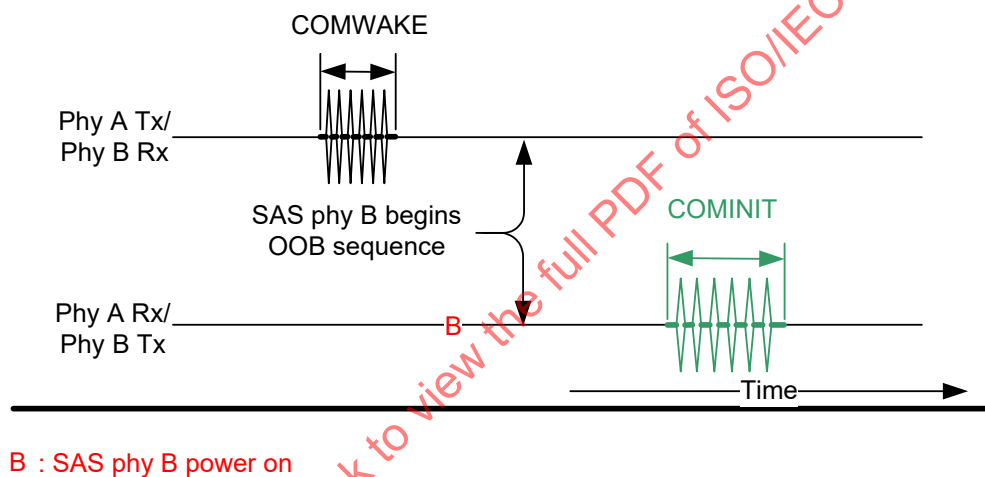
Figure 93 shows examples of responses to the following events that may occur during the transition from a low phy power condition to the active phy power condition:

- 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



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 272).

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 74.

Table 74 – 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 68)
Hot-Plug Timeout timer	Hot plug timeout (see table 67)
RCDT timer	RCDT (see table 69)
SNLT timer	SNLT (see table 69)
SNTT timer	SNTT (see table 69)
TLT timer	TLT (see table 69)
MRTT timer	MRTT (see table 69)
MTTT timer	MTTT (see table 69)
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 67), if the phy is in the partial phy power condition; or
- b) a phy wakeup slumber timeout (see table 67), 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 69 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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.

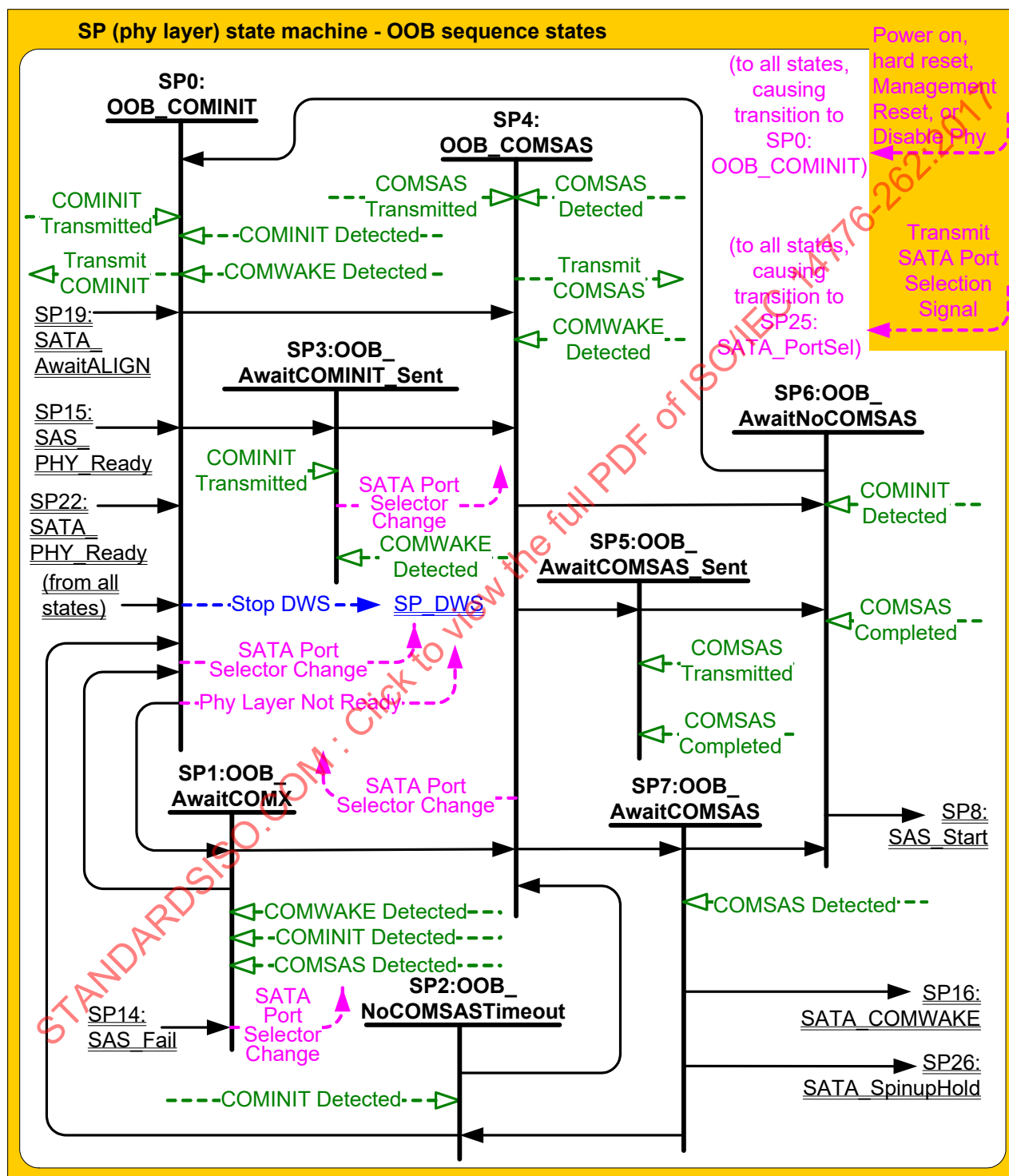


Figure 94 – SP (phy layer) state machine - OOB sequence states

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 COMWAKE 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 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 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 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 after receiving a COMINIT Detected message or a COMSAS Detected message. If COMSAS Detected was received, then this transition shall include 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 if the Hot-Plug Timeout timer expires.

5.12.3.4.3 Transition SP2:OOB_NoCOMSASTimeout to SP4:OOB_COMSAS

This transition shall occur 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 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 if this state receives a COMSAS Detected message or this state was entered with a COMSAS Detected argument, and 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 COMSAS Transmitted message and 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 receives a COMSAS Transmitted message and 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 after receiving a COMSAS Transmitted message.

If this state received a COMSAS Completed message, then it shall include 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 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 after receiving a COMSAS Completed message, or shall occur 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 if the phy does not support SATA and 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 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;
- 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 a negotiation idle consists of repetitions of the following steps:

- 1) transmission of six OOB_IDLEs with either starting disparity at a vendor specific bit rate of at least 1.5 Gbit/s; and
- 2) transmission of up to 512 data dwords set to 00000000h that are transmitted scrambled and 8b10b encoded at a vendor specific bit rate of at least 1.5 Gbit/s.

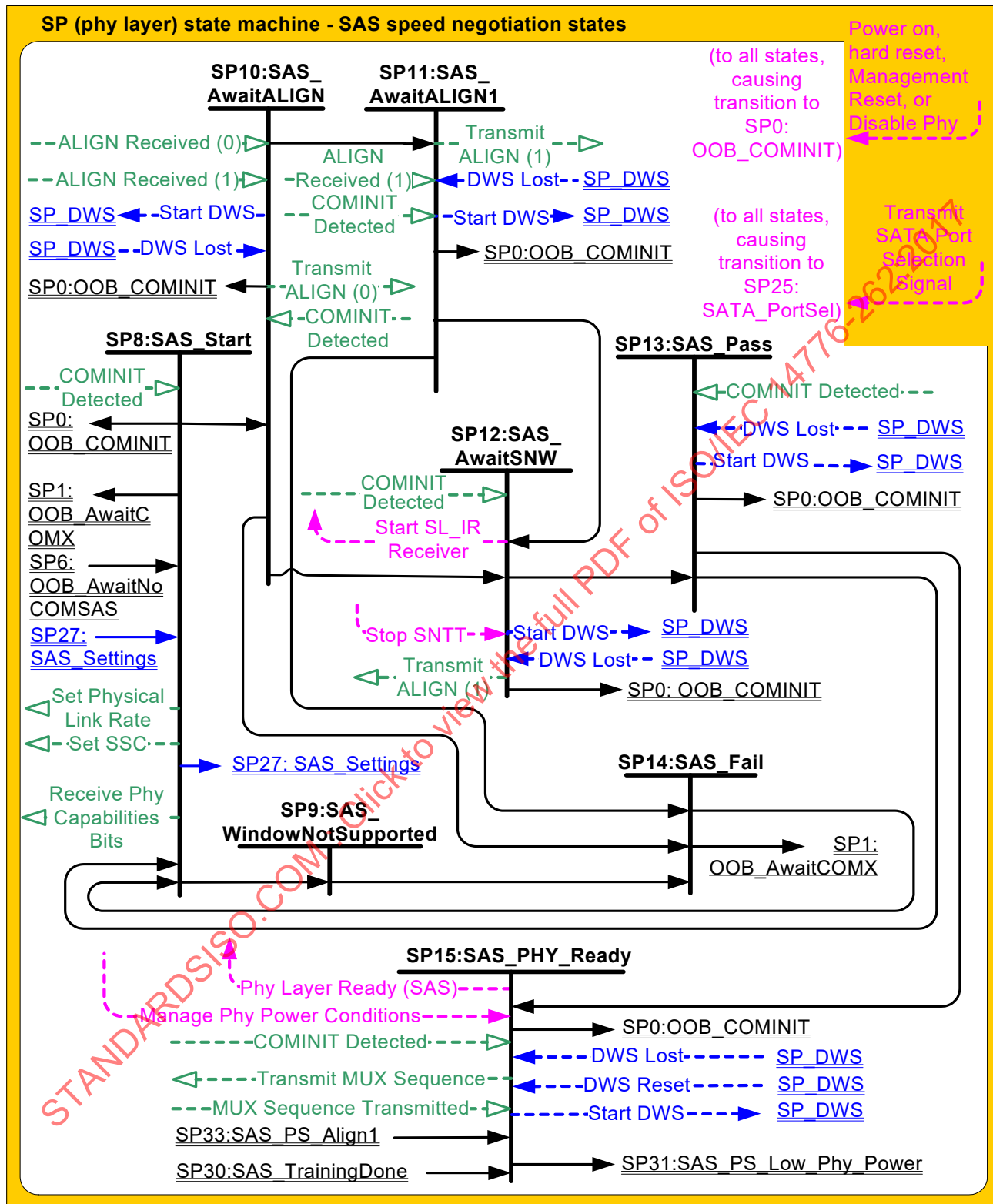


Figure 95 – SP (phy layer) state machine - SAS speed negotiation states

Figure 96 shows the SAS speed negotiation states related to SNW-3 and Train_Rx-SNW.

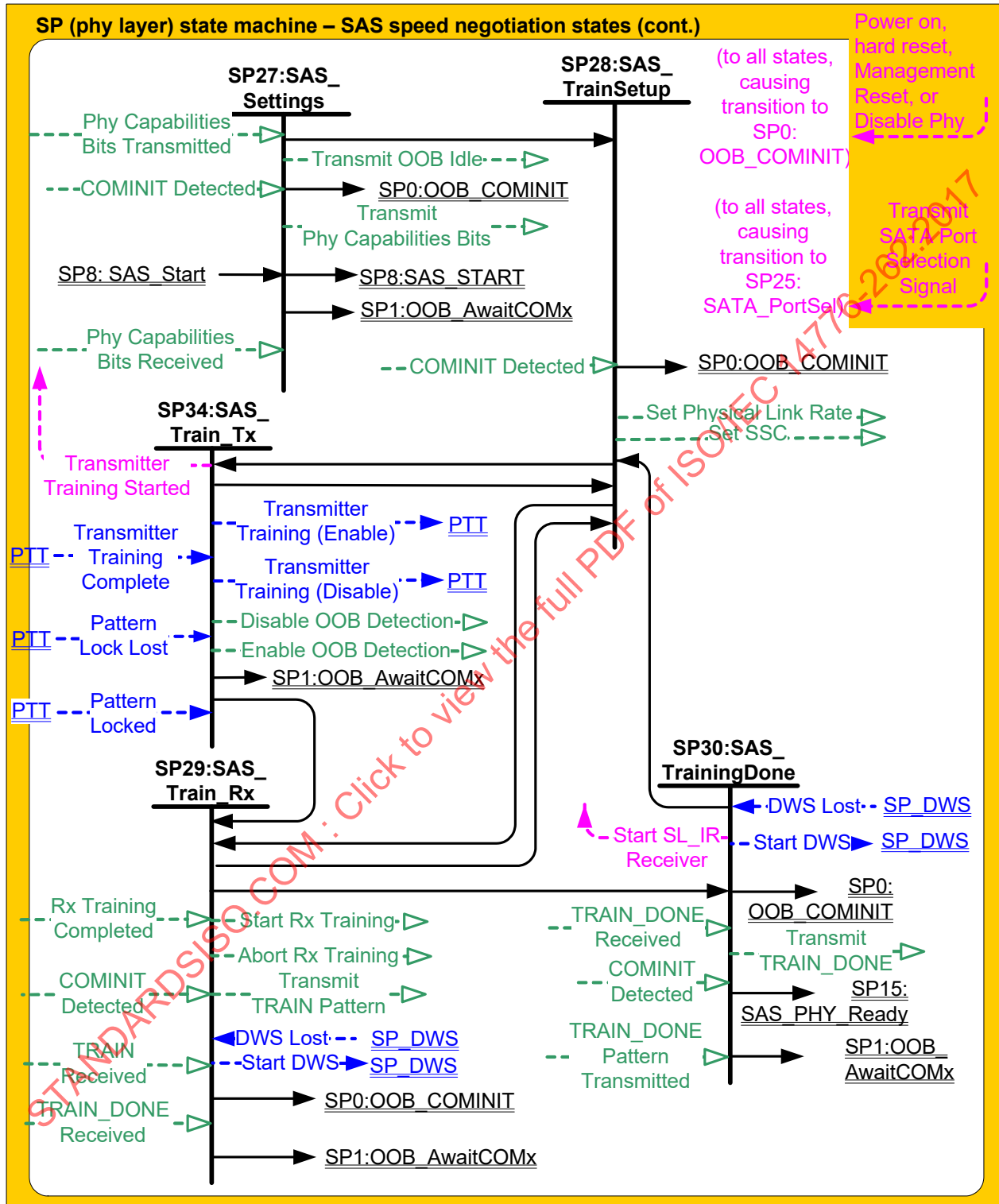


Figure 96 – SP (phy layer) state machine - SAS speed negotiation states for SNW-3 and Train_Rx-SNW and Train_Tx-SNW

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:

- a) SNW-2 if the Current SNW state machine variable is set to SNW-1;
- b) 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;
- c) Final-SNW if the Current SNW state machine variable is set to SNW-2, SNW-1 is valid, and SNW-2 is invalid;
- d) Final-SNW if the Current SNW state machine variable is set to SNW-3, SNW-3 is invalid, and SNW-2 is valid; or
- e) 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:

- a) the Current SNW state machine variable is not set to Unsupported Phy Attached; and
- b) the SNW specified by the Current SNW state machine variable is supported,

then this state shall send the messages specified in table 75 to the SP transmitter and SP receiver.

Table 75 – 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 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 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 after receiving:

- a) 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 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 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 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 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 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 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 the SNTT timer expires or after 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 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 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 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 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 54), 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.

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 occur after:

- a) receiving a COMINIT Detected message before receiving a DWS Lost message; or
- b) receiving a COMINIT Detected message 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 Manage Phy Power Conditions (Enter Partial) request or 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 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 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 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
 - a) 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 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 after the RCDT timer expires if:

- a) 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 after the RCDT timer expires if:

- a) 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 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
- a) 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 a 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:

- a) stop the TLT timer; and
- b) stop 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 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:
 - A) a TRAIN_DONE Received message before the MRTT timer expires; and
 - B) at least one TRAIN_DONE Pattern Transmitted message after receiving the TRAIN_DONE Received message in A) (i.e., after receiving TRAIN_DONE, transmit at least one more TRAIN_DONE);

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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

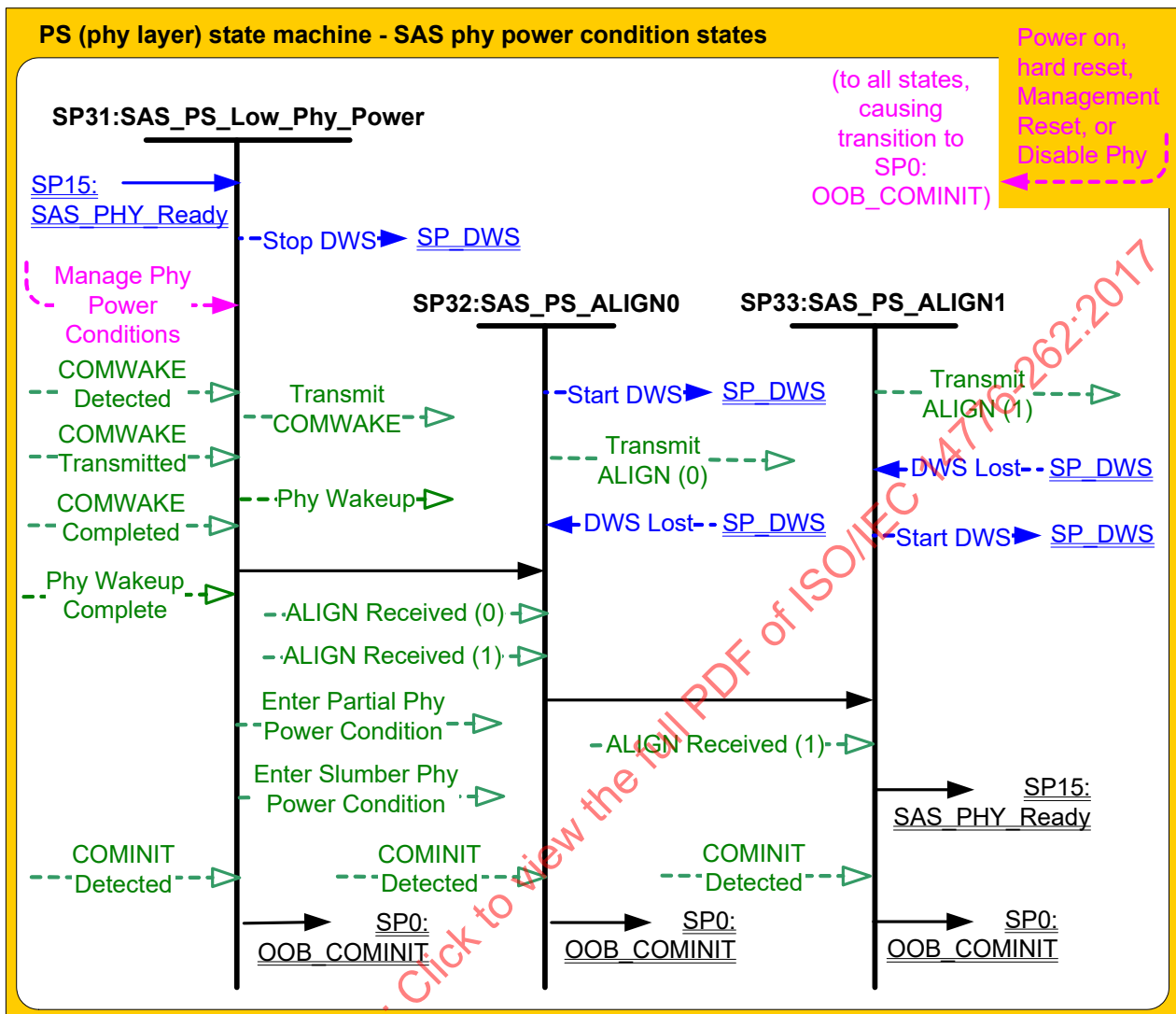


Figure 97 – SP (phy layer) state machine - SAS phy power condition states

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:

- send a Stop DWS message to the SP_DWS state machine; and
- 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:

- this state shall send an Enter Partial Phy Power Condition message to the SP transmitter and SP receiver;
- the phy shall enter the partial phy power condition (see 4.10.1.3); and
- this state shall set the SASPhyPwrCond state machine variable to Partial.

If this state is entered with a Slumber argument, then:

- 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 67);
 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:

- a) receives a COMWAKE Transmitted message; and
- b) receives 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).

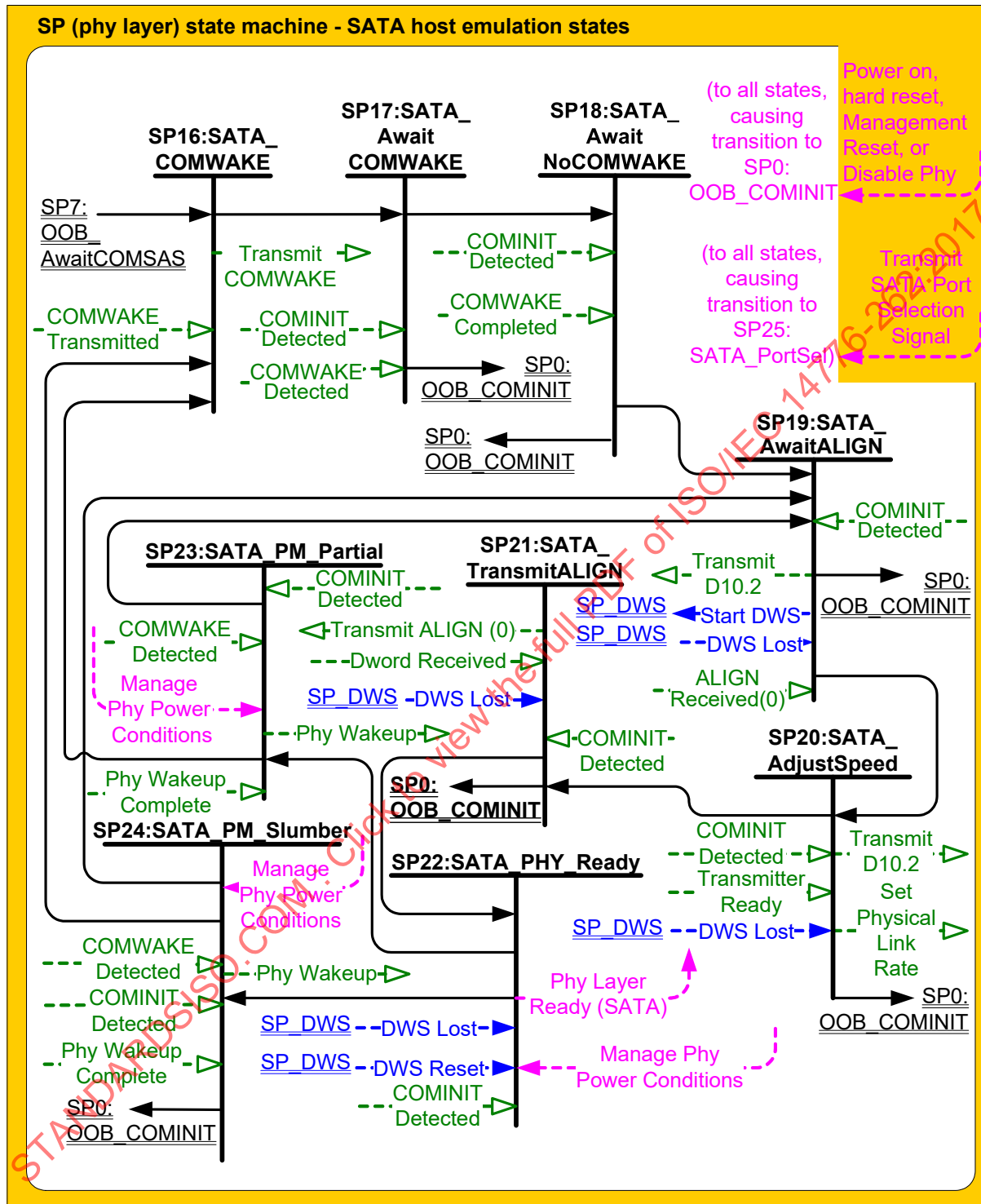


Figure 98 – SP (phy layer) state machine - SATA host emulation states

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 after receiving a COMINIT Detected message.

5.12.6.2.3 Transition SP16:SATA_COMWAKE to SP17:SATA_AwaitCOMWAKE

This transition shall occur 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 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 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 DWS Lost message or 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 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:

- a) after receiving a DWS Lost message or 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:

- a) if this state receives a Manage Phy Power Conditions (Exit) request; and
- b) after this state receives a Phy Wakeup Complete message.

5.12.6.10.4 Transition SP24:SATA_PM_Slumber to SP19:SATA_AwaitALIGN

This transition shall occur after this state receives a:

- a) Phy Wakeup Complete message; and
- b) COMWAKE Completed message.

5.12.7 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.

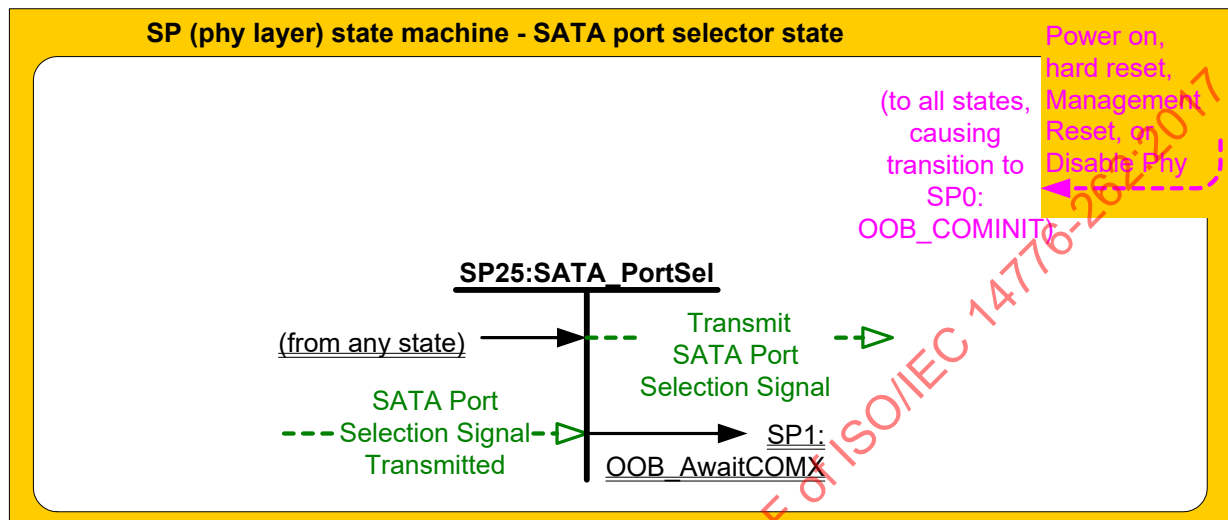


Figure 99 – SP (phy layer) state machine – SATA port selector state

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.

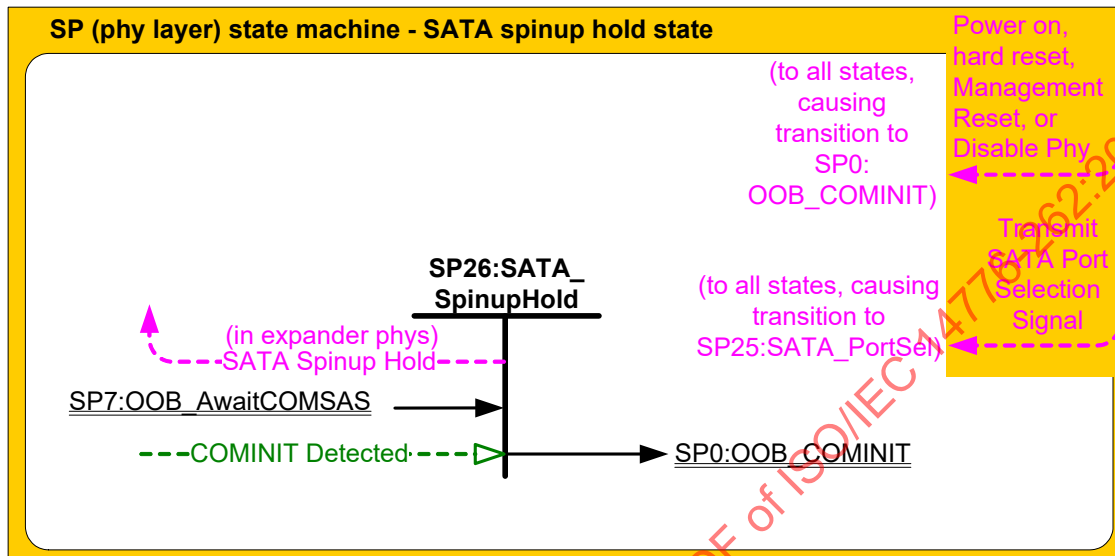


Figure 100 – SP (phy layer) state machine - SATA spinup hold state

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 76.

Table 76 – SP_DWS state machine timers

Timer	Initial value
DWS Reset Timeout timer	1 ms

Figure 101 shows the SP_DWS state machine.

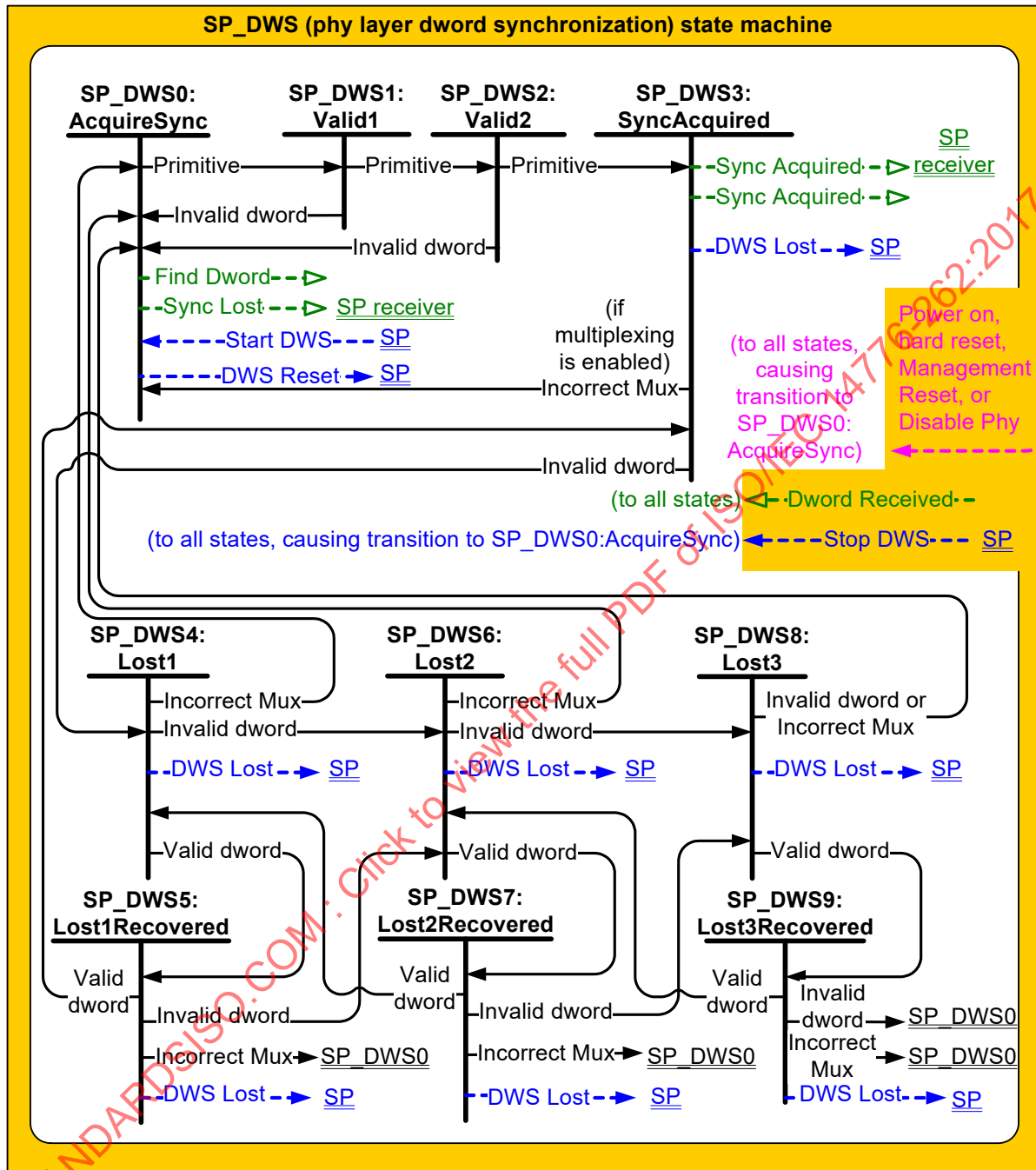


Figure 101 – SP_DWS (phy layer dword synchronization) state machine

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:

- 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 54), 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 3.1.99);
- 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 after sending a Find Dword message and 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 after receiving a Dword Received (Invalid) message or after the DWS Reset Timeout timer expires.

5.13.4.3 Transition SP_DWS1:Valid1 to SP_DWS2:Valid2

This transition shall occur 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 after receiving a Dword Received (Invalid) message or after the DWS Reset Timeout timer expires.

5.13.5.3 Transition SP_DWS2:Valid2 to SP_DWS3:SyncAcquired

This transition shall occur 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 after sending a DWS Lost message.

5.13.6.3 Transition SP_DWS3:SyncAcquired to SP_DWS4:Lost1

This transition shall occur 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 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 Dword Received (Data Dword) message or a Dword Received (Primitive) message.

5.13.7.4 Transition SP_DWS4:Lost1 to SP_DWS6:Lost2

This transition shall occur 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 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 Dword Received (Data Dword) message or a Dword Received (Primitive) message.

5.13.8.4 Transition SP_DWS5:Lost1Recovered to SP_DWS6:Lost2

This transition shall occur 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 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 Dword Received (Data Dword) message or a Dword Received (Primitive) message.

5.13.9.4 Transition SP_DWS6:Lost2 to SP_DWS8:Lost3

This transition shall occur 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 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 Dword Received (Data Dword) message or a Dword Received (Primitive) message.

5.13.10.4 Transition SP_DWS7:Lost2Recovered to SP_DWS8:Lost3

This transition shall occur 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 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 Dword Received (Data Dword) message or 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 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 Dword Received (Data Dword) message or 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 dwords 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 102 shows the PTT_T state machine.

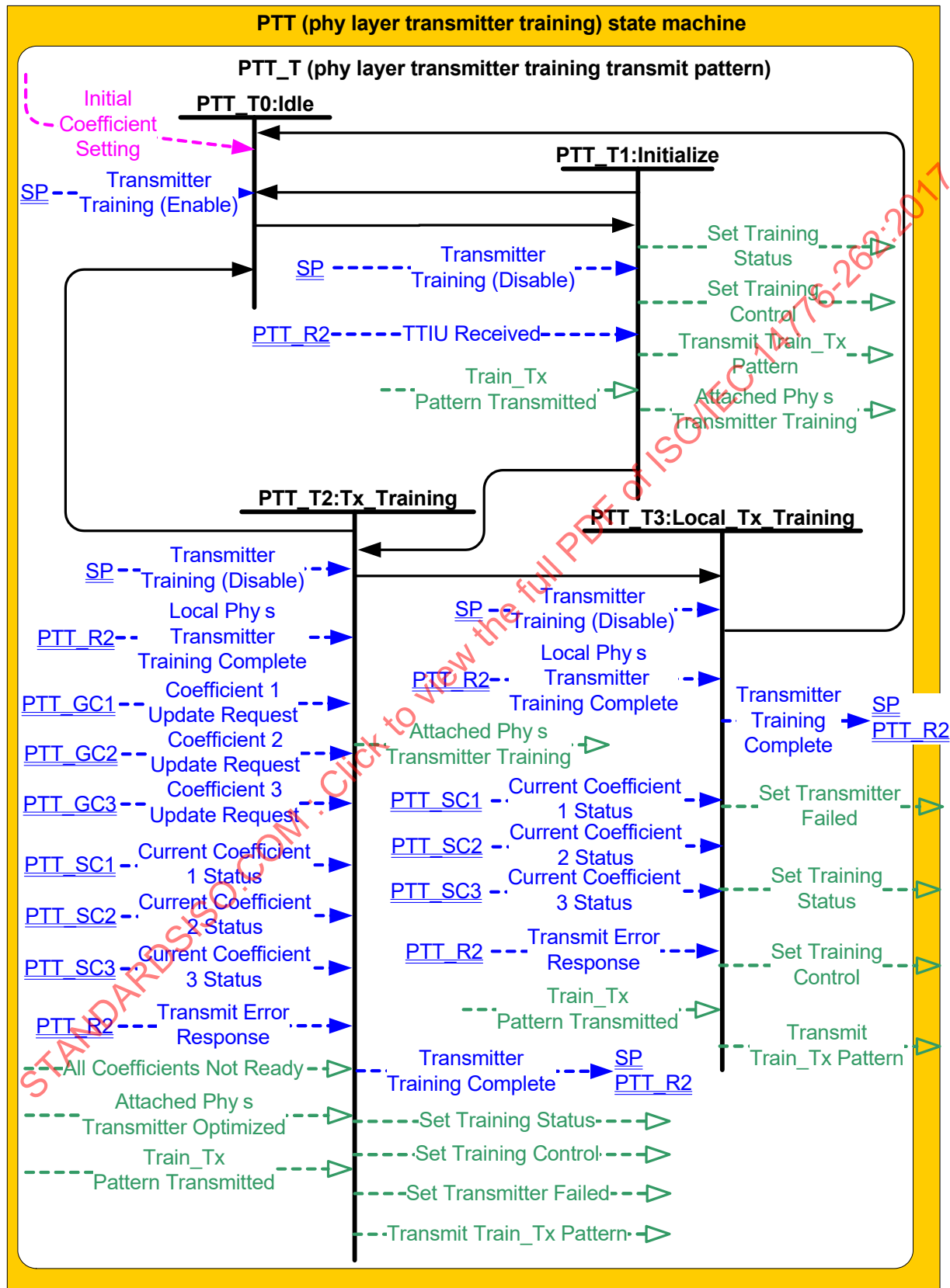


Figure 102 – PTT_T (phy layer transmitter training transmit pattern) state machine

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 after receiving a:

- a) Transmitter Training (Disable) message.

5.14.4.3.3 Transition PTT_T1:Initialize to PTT_T2:Tx_Training

This transition shall occur after receiving:

- a) 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 60) 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 77 defines the mapping of the messages received from the PTT_GC state machines to the Training Control word.

Table 77 – Mapping messages to the Training Control word

Message received	Training Control word field ^e
Coefficient 1 Update Request ^{a b}	COEFFICIENT 1 REQUEST
Coefficient 2 Update Request ^{a c}	COEFFICIENT 2 REQUEST
Coefficient 3 Update Request ^{a d}	COEFFICIENT 3 REQUEST
^a This message contains a Decrement, Increment, Hold, No_Equalization, Reference_1, or Reference_2 argument. ^b This message is from the PTT_GC1 state machine. ^c This message is from the PTT_GC2 state machine. ^d This message is from the PTT_GC3 state machine. ^e 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 78 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 78 – 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 ^e
Current Coefficient 1 Status ^{a b}	COEFFICIENT 1 STATUS
Current Coefficient 2 Status ^{a c}	COEFFICIENT 2 STATUS
Current Coefficient 3 Status ^{a d}	COEFFICIENT 3 STATUS
^a This message contains a Maximum, Minimum, Update_Complete, or Ready argument. ^b This message is from the PTT_SC1 state machine. ^c This message is from the PTT_SC2 state machine. ^d This message is from the PTT_SC3 state machine. ^e On receipt of the message this state shall: 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 2) send a Set Training Status message to the SP transmitter after receiving a Train_Tx Pattern Transmitted message.	

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 65) 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 79;
- 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 79 defines that mapping of the Transmit Error Response message arguments to the Error Response TTIU fields.

Table 79 – 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 60) 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 60) 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 after receiving an:

- a) 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 60) 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 78 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 65) 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 79;
- 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 60) 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

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 5.14.5.1) (initial state);
- b) PTT_R1:Initialize (see 5.14.5.2); and
- c) PTT_R2:Receive_Train_Tx_Pattern (see 5.14.5.3).

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.

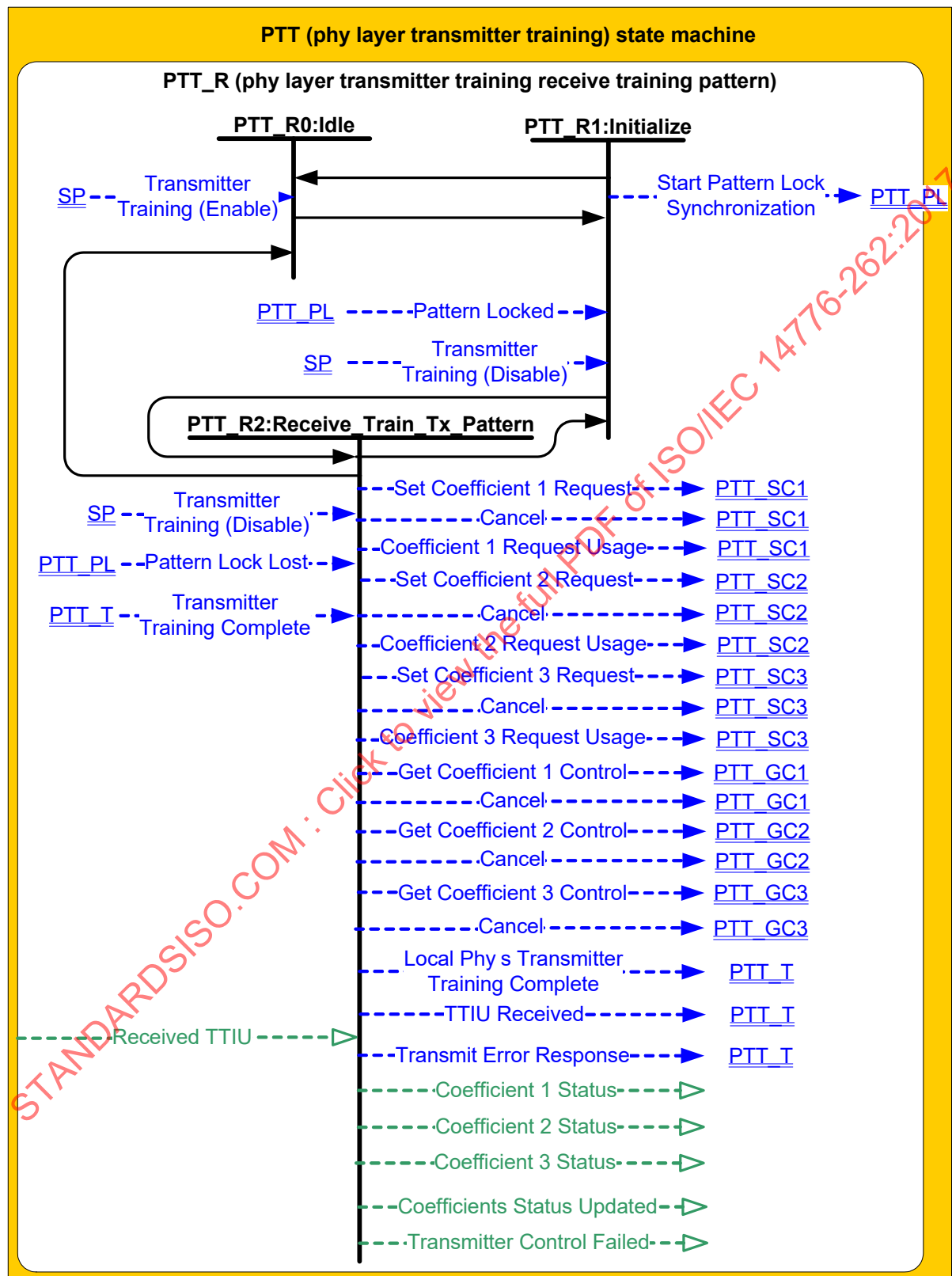


Figure 103 – PTT_R (phy layer transmitter training receive pattern) state machine

5.14.5.1 PTT_R0:Idle state

5.14.5.1.1 State description

This is the initial state of this state machine.

This state waits for a request to start transmitter training.

5.14.5.1.2 Transition PTT_R0:Idle to PTT_R1:Initialize

This transition shall occur after receiving a:

- a) Transmitter Training (Enable) message.

5.14.5.2 PTT_R1:Initialize state

5.14.5.2.1 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.

5.14.5.2.2 Transition PTT_R1:Initialize to PTT_R0:Idle

This transition shall occur after receiving a:

- a) Transmitter Training (Disable) message.

5.14.5.2.3 Transition PTT_R1:Initialize to PTT_R2:Receive_Train_Tx_Pattern

This transition shall occur after receiving a:

- a) Pattern Locked message.

5.14.5.3 PTT_R2:Receive_Train_Tx_Pattern state

5.14.5.3.1 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 an unsupported value, reserved value, reserved bit, or reserved combination in the Training Control word (see table 80), then this state shall:

- 1) send a Transmit Error Response message to the PTT_T state machine with the arguments defined in table 80;
- 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 80 – Transmit Error Response message arguments sent to PTT_T state machine

Training Control word field ^{a b}	Error		Transmit Error Response message Error arguments ^{c d}
	Condition	Reference	
PATTERN TYPE	Unsupported value	Table 59	Unsupported Pattern Type
	Reserved value		Reserved Pattern Type
COEFFICIENT 1 REQUEST	Reserved value	Table 62	Reserved Coefficient 1 Request
COEFFICIENT 2 REQUEST			Reserved Coefficient 2 Request
COEFFICIENT 3 REQUEST			Reserved Coefficient 3 Request
COEFFICIENT 1 REQUEST	More than one reserved value	Table 62	Multiple Reserved Coefficients Requested
COEFFICIENT 2 REQUEST			
COEFFICIENT 3 REQUEST			
COEFFICIENT 1 REQUEST	Reserved combination	Table 63	Reserved Coefficient Request Combination
COEFFICIENT 2 REQUEST			
COEFFICIENT 3 REQUEST			
 			

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 60), then this state shall:
 - 1) send:
 - 1) the messages and arguments shown in table 81 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 82;
 - 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 83 and table 84; 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 81 defines the mapping of transmitted status word fields to messages sent to the SP receiver.

Table 81 – Mapping the Training Status word to SP receiver messages

Training Status word field	Message to SP receiver
COEFFICIENT 1 STATUS	Coefficient 1 Status ^a
COEFFICIENT 2 STATUS	Coefficient 2 Status ^a
COEFFICIENT 3 STATUS	Coefficient 3 Status ^a
^a 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 82 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 82 – 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) ^a
	01b	update complete	Get Coefficient 1 Control (Restart) ^a
	10b	minimum	
	11b	maximum	
COEFFICIENT 2 STATUS	00b	ready	Get Coefficient 2 Control (Start) ^b
	01b	update complete	Get Coefficient 2 Control (Restart) ^b
	10b	minimum	
	11b	maximum	
COEFFICIENT 3 STATUS	00b	ready	Get Coefficient 3 Control (Start) ^c
	01b	update complete	Get Coefficient 3 Control (Restart) ^c
	10b	minimum	
	11b	maximum	
^a This message is sent to the PTT_GC1 state machine. ^b This message is sent to the PTT_GC2 state machine. ^c This message is sent to the PTT_GC3 state machine.			

Table 83 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 83 – 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 84	see table 84
01b	reference_1 ^g	COEFFICIENT 1 REQUEST	Set Coefficient 1 Request ^{a d}
		COEFFICIENT 2 REQUEST	Set Coefficient 2 Request ^{a e}
		COEFFICIENT 3 REQUEST	Set Coefficient 3 Request ^{a f}
10b	reference_2 ^g	COEFFICIENT 1 REQUEST	Set Coefficient 1 Request ^{b d}
		COEFFICIENT 2 REQUEST	Set Coefficient 2 Request ^{b e}
		COEFFICIENT 3 REQUEST	Set Coefficient 3 Request ^{b f}
11b	no_equalization ^g	COEFFICIENT 1 REQUEST	Set Coefficient 1 Request ^{c d}
		COEFFICIENT 2 REQUEST	Set Coefficient 2 Request ^{c e}
		COEFFICIENT 3 REQUEST	Set Coefficient 3 Request ^{c f}

^a 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.

^b 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.

^c 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.

^d This message is sent to the PTT_SC1 state machine.

^e This message is sent to the PTT_SC2 state machine.

^f This message is sent to the PTT_SC3 state machine.

^g The Coefficient 1 Request Usage message (see table 84), the Coefficient 2 Request Usage message (see table 84), or the Coefficient 3 Request Usage message (see table 84) shall not be sent to the PTT_SC1 state machine, PTT_SC 2 state machine, or PTT_SC 3 state machine.

Table 84 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 84 – 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 63)	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) ^a	Set Coefficient 2 Request (argument)	Coefficient 2 Request Usage (argument) ^a	Set Coefficient 1 Request (argument)	Coefficient 1 Request Usage (argument) ^a
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
^a 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.

5.14.5.3.2 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.

5.14.5.3.3 Transition PTT_R2:Receive_Train_Tx_Pattern to PTT_R1:Initialize

This transition shall occur after receiving a:

- 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 104 shows the PTT_SC1 state machine, PTT_SC2 state machine, and PTT_SC3 state machine.

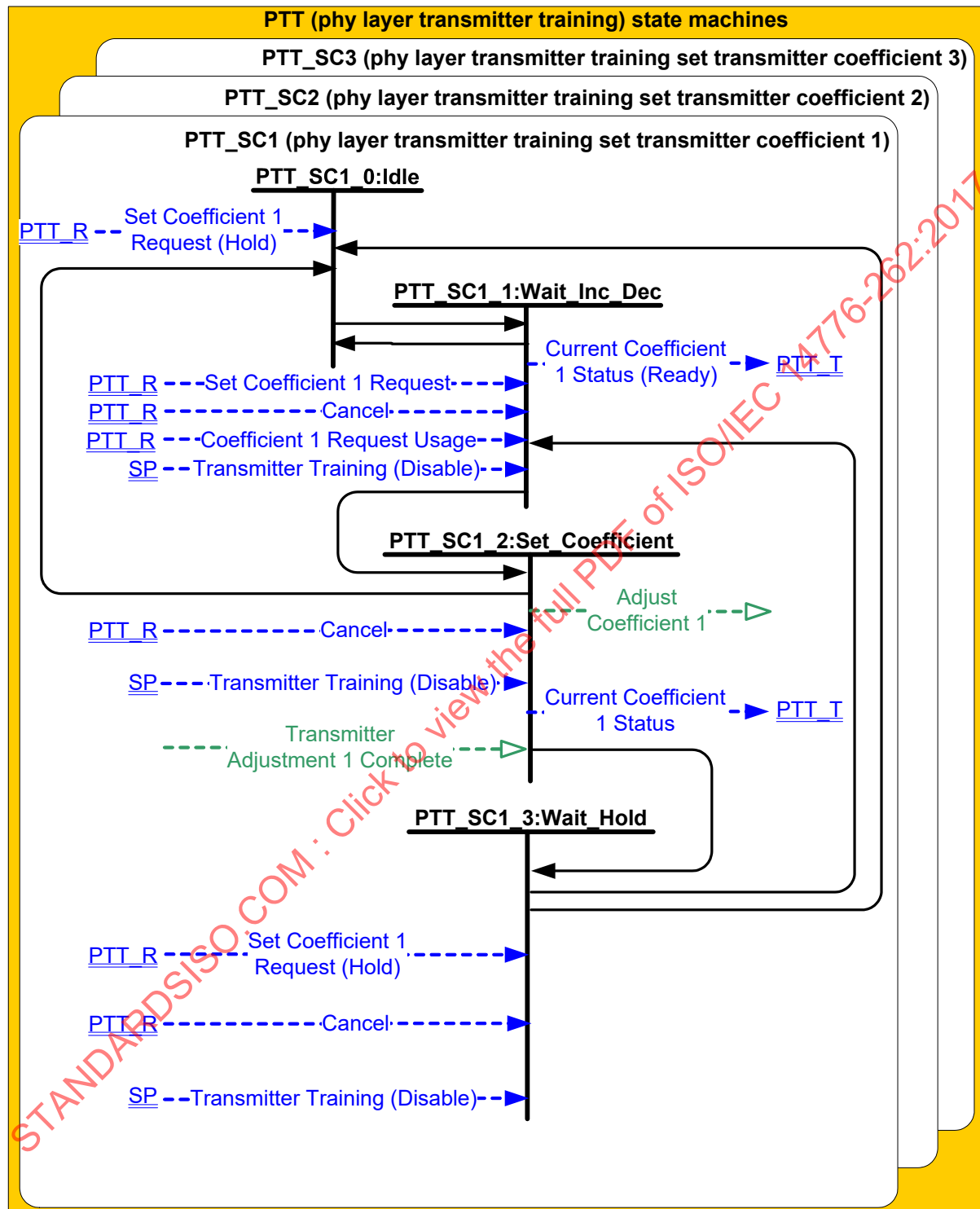


Figure 104 – PTT_SC1, PTT_SC2, and PTT_SC3 (phy layer transmitter training set transmitter coefficient) state machines

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 after receiving a:

- 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 after receiving a:

- 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 85.

Table 85 – 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:

- a) 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 after:

- a) 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 86.

Table 86 – PTT_SC1 messages to substitute for PTT_SC2 messages

PTT_SC1 message	PTT_SC2 message
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 87.

Table 87 – PTT_SC1 messages to substitute for PTT_SC3 messages

PTT_SC1 message	PTT_SC3 message
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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 105 shows the PTT_GC1 state machine, PTT_GC2 state machine, and PTT_GC3 state machine.

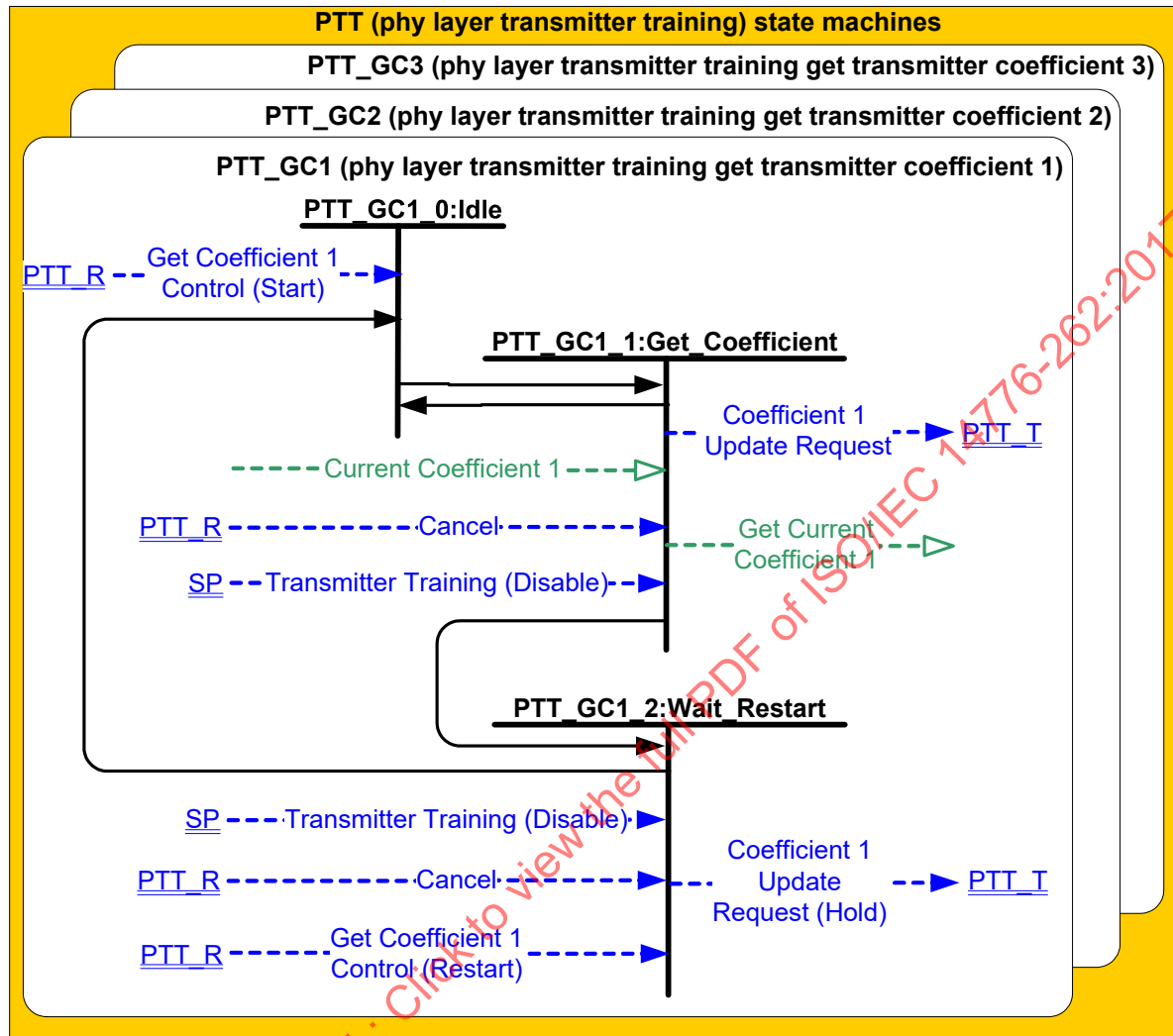


Figure 105 – PTT_GC1, PTT_GC2, and PTT_GC3 (phy layer transmitter training get transmitter coefficient) state machines

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 after receiving a:

- 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 88.

Table 88 – 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 89.

Table 89 – 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 90.

Table 90 – PTT_GC1 messages to substitute for PTT_GC2 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).

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 106 shows the PTT_PL state machine.

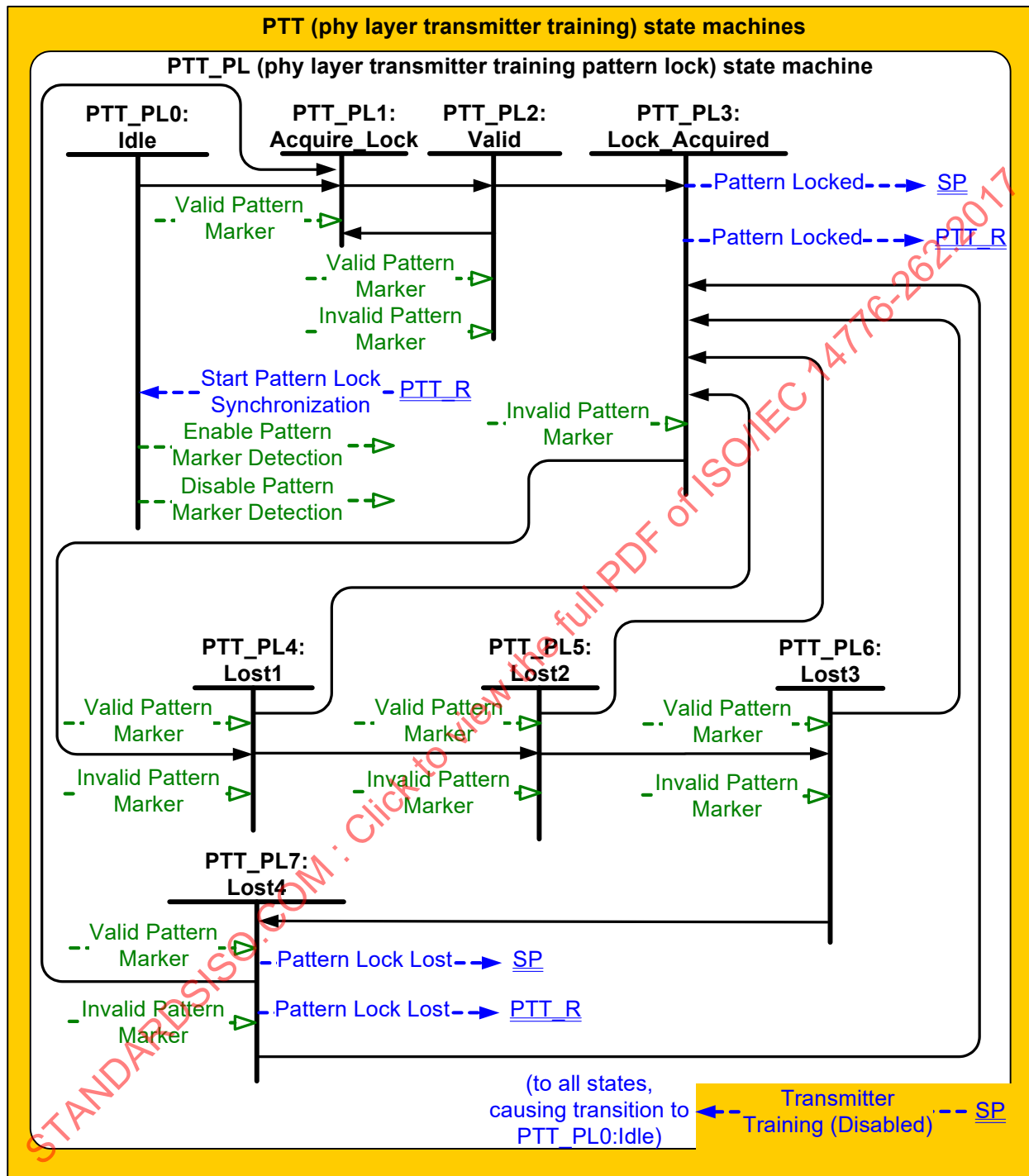


Figure 106 – PTT_PL (phy layer transmitter training pattern lock) state machine

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 after sending:

- a) 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 after receiving a:

- 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 after receiving an:

- a) Invalid Pattern Marker message.

5.14.12.4.3 Transition PTT_PL2:Valid to PTT_PL3:Lock_Acquired

This transition shall occur after receiving a:

- 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 after receiving an:

- a) 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 after receiving a:

- a) Valid Pattern Marker message.

5.14.12.6.3 Transition PTT_PL4:Lost1 to PTT_PL5:Lost2

This transition shall occur after receiving an:

- a) 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 after receiving a:

- a) Valid Pattern Marker message.

5.14.12.7.3 Transition PTT_PL5:Lost2 to PTT_PL6:Lost3

This transition shall occur after receiving an:

- a) 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 after receiving a:

- a) Valid Pattern Marker message.

5.14.12.8.3 Transition PTT_PL6:Lost3 to PTT_PL7:Lost4

This transition shall occur after receiving an:

- a) 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 after receiving a:

- a) Valid Pattern Marker message.

5.14.12.9.3 Transition PTT_PL7:Lost4 to PTT_PL1:Acquire_Lock

This transition shall occur after sending a:

- a) Pattern Lock Lost message.

5.15 Multiplexing

If SNW-3 indicates multiplexing is enabled (see table 54), 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).

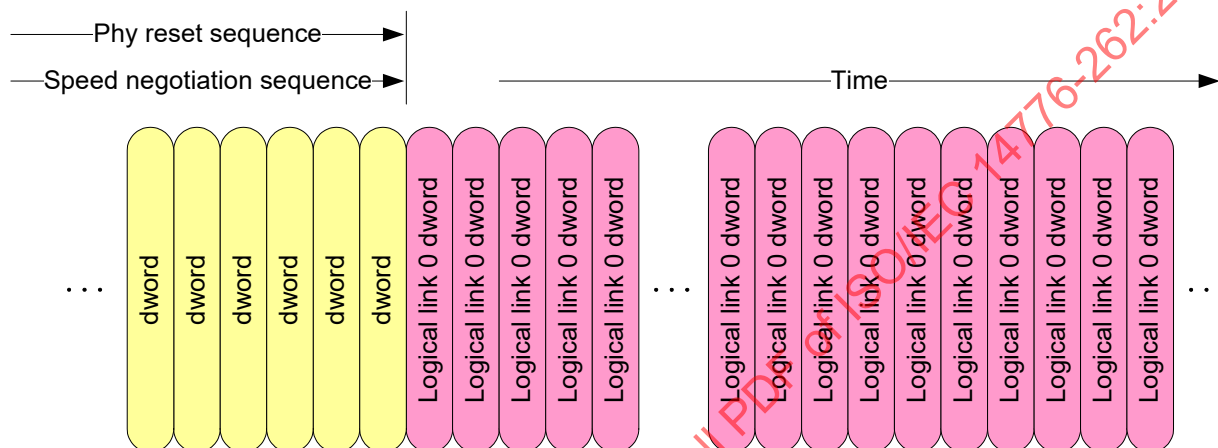


Figure 107 – Multiplexing disabled

Figure 108 shows multiplexing enabled (i.e., two logical links).

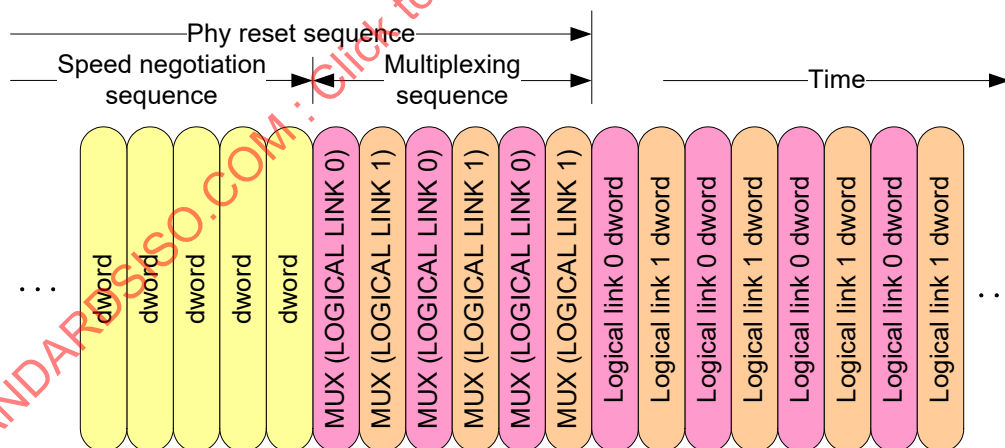


Figure 108 – Multiplexing enabled

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) 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
- b) 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).

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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 91 defines the primitive format.

Table 91 – 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 92 defines the deletable primitives.

Table 92 – Deletable primitives

Primitive	Use ^a	From ^b			To ^b			Primitive sequence type ^c
		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

^a The Use column indicates when the primitive is used:

- a) All: SAS logical links and SATA physical links;
- b) SAS: SAS logical links, both outside connections or inside any type of connection;
- c) NoConn: SAS logical links, outside connections;
- d) Conn: SAS logical links, inside connections;
- e) STP: SAS logical links, inside STP connections; or
- f) SpNeg: SAS physical links, during speed negotiation.

^b The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive:

- a) I for SAS initiator ports;
- b) E for expander ports; and
- c) T for SAS target ports.

Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port.

^c 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 93 defines the primitives not specific to the type of connection.

Table 93 – Primitives not specific to type of connection (part 1 of 2)

Primitive	Use ^a	From ^b			To ^b			Primitive sequence type ^c
		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			
CLOSE (CLEAR AFFILIATION)	STP	I					T	Triple
CLOSE (NORMAL)	Conn	I		T				
CLOSE (RESERVED 0)					I		T	
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

^a The Use column indicates when the primitive is used:

- a) All: SAS logical links and SATA physical links;
- b) SAS: SAS logical links, both outside connections or inside any type of connection;
- c) NoConn: SAS logical links, outside connections;
- d) Conn: SAS logical links, inside connections;
- e) STP: SAS logical links, inside STP connections; or
- f) SpNeg: SAS physical links, during speed negotiation.

^b The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive:

- a) I for SAS initiator ports;
- b) E for expander ports; and
- c) T for SAS target ports.

Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port.

^c 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 93 – Primitives not specific to type of connection (part 2 of 2)

Primitive	Use ^a	From ^b			To ^b			Primitive sequence type ^c
		I	E	T	I	E	T	
OPEN_REJECT (BAD DESTINATION)	NoConn		E					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)					I		T	
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	I			
OPEN_REJECT (WRONG DESTINATION)		I		T	I		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
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								

^a The Use column indicates when the primitive is used:

- a) All: SAS logical links and SATA physical links;
- b) SAS: SAS logical links, both outside connections or inside any type of connection;
- c) NoConn: SAS logical links, outside connections;
- d) Conn: SAS logical links, inside connections;
- e) STP: SAS logical links, inside STP connections; or
- f) SpNeg: SAS physical links, during speed negotiation.

^b The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive:

- a) I for SAS initiator ports;
- b) E for expander ports; and
- c) T for SAS target ports.

Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port.

^c 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 defines the primitives used only inside SSP and SMP connections.

Table 94 – Primitives used inside SSP and SMP connections

Primitive	Use ^a	From ^b			To ^b			Primitive sequence type ^c
		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 (RESERVED 1)								
DONE (RESERVED TIMEOUT 0)								
DONE (RESERVED TIMEOUT 1)								
EOF	SSP, SMP	I		T	I		T	Single
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 (RESERVED 1)								
SOF	SSP, SMP	I		T	I		T	Single

^a The Use column indicates when the primitive is used:

a) SSP: SAS logical links, inside SSP connections; or

b) SMP: SAS logical links, inside SMP connections.

^b The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive:

a) I for SSP initiator ports and SMP initiator ports;

b) E for expander ports; and

c) T for SSP target ports and SMP target ports.

Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port.

^c 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 lists the primitives used only inside STP connections and on SATA physical links.

Table 95 – Primitives used inside STP connections and on SATA physical links

Primitive	Use ^a	From ^b			To ^b			Primitive sequence type ^c
		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 ^d	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							
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

^a The Use column indicates when the primitive is used:

a) STP: SAS logical links, inside STP connections; or

b) SATA: SATA physical links.

^b The From and To columns indicate the type of ports that originate each primitive or are the intended destinations of each primitive:

a) I for STP initiator ports and SATA host ports;

b) E for expander ports; and

c) T for STP target ports and SATA device ports.

Expander ports are not considered originators of primitives that are being forwarded from expander port to expander port.

^c 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).

^d Although included in this table, SATA_ERROR is not a primitive (see 3.1.150) 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 96 defines the primitive encoding for deletable primitives.

Table 96 – Primitive encoding for deletable primitives

Primitive	Character				Hexadecimal
	1 st	2 nd	3 rd	4 th (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

Table 97 defines the primitive encoding for primitives not specific to type of connection.

Table 97 – Primitive encoding for primitives not specific to type of connection (part 1 of 2)

Primitive	Character				Hexadecimal
	1 st	2 nd	3 rd	4 th (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 97 – Primitive encoding for primitives not specific to type of connection (part 2 of 2)

Primitive	Character				Hexadecimal
	1 st	2 nd	3 rd	4 th (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 98 defines the primitive encodings for primitives used only inside SSP and SMP connections.

Table 98 – Primitive encoding for primitives used only inside SSP and SMP connections

Primitive	Character				Hexadecimal
	1 st	2 nd	3 rd	4 th (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 (RESERVED 1)	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
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 (RESERVED 1)	K28.5	D01.4	D30.0	D02.0	BC811E02h
SOF	K28.5	D24.0	D04.7	D07.3	BC18E467h

Table 99 lists the primitive encodings for primitives used only inside STP connections and on SATA physical links.

Table 99 – Primitive encoding for primitives that are used only inside STP connections and only on SATA physical links

Primitive	Character				Hexadecimal
	1 st	2 nd	3 rd	4 th (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 ^{a, b}	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
^a Except for SATA_ERROR, all values are defined by SATA. ^b Although included in this table, SATA_ERROR is not a primitive (see 3.1.150) 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 100 summarizes the types of primitive sequences.

Table 100 – Primitive sequences

Primitive sequence type	Transmit ^a	Receive ^b	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

^a Number of times the transmitter transmits the primitive to transmit the primitive sequence.
^b 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.

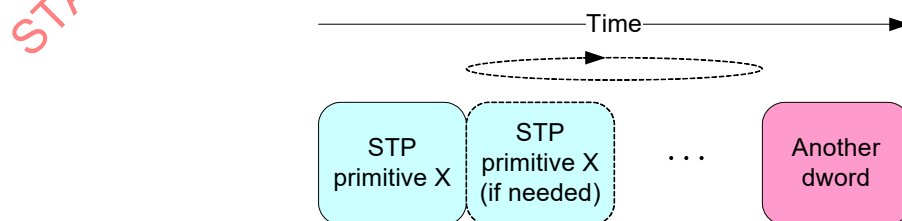
Receivers count each primitive received that is labeled as a single primitive sequence as a distinct single primitive sequence.

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.



Note: Another dword is a dword other than a deletable primitive or STP primitive X

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.

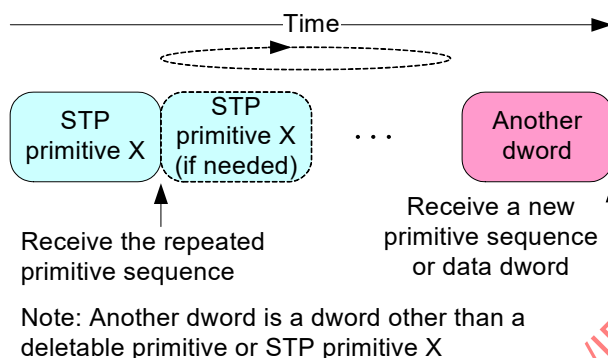


Figure 110 – Receiving a repeated primitive sequence

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.

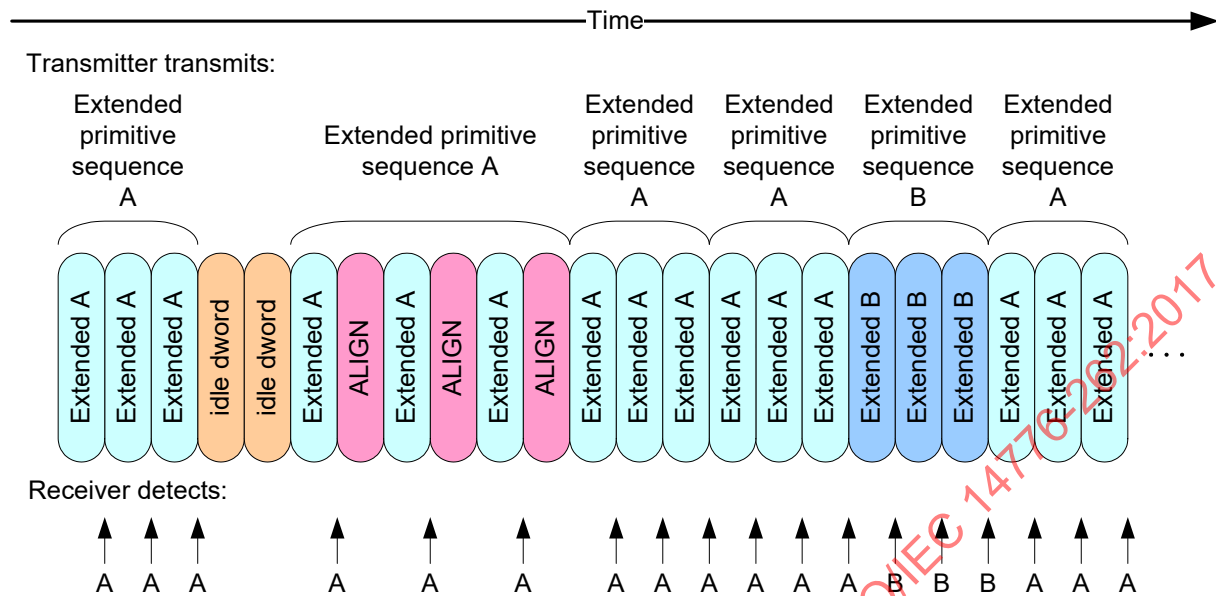


Figure 111 – Extended primitive sequences

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:

- a) the original primitive; or
- b) a deletable primitive.

Figure 112 shows examples of triple primitive sequences.

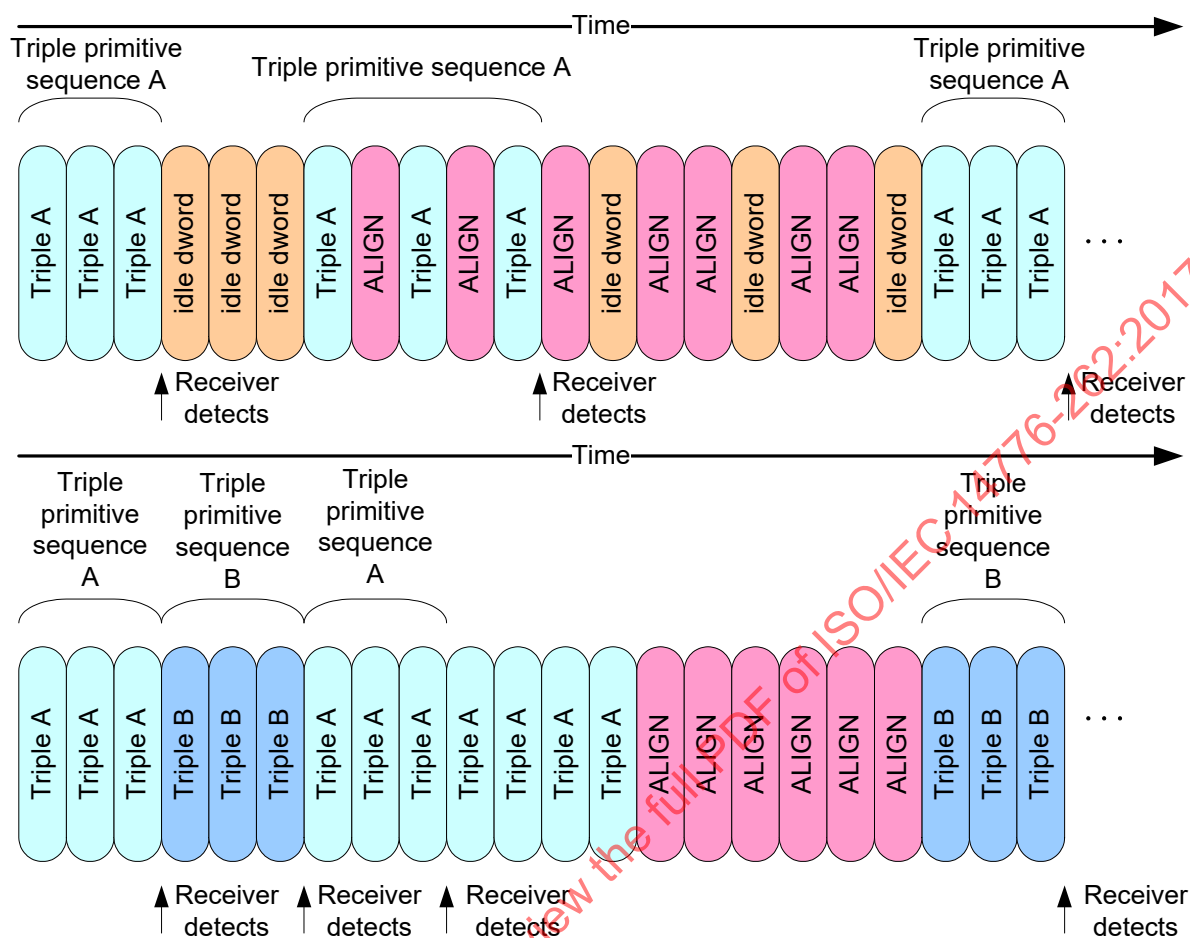


Figure 112 – Triple primitive sequences

6.2.4.7 Redundant primitive sequence

Primitives that form redundant primitive sequences (e.g., BROADCAST (CHANGE)) shall be transmitted six times consecutively. Any number of deletable primitives may be transmitted inside redundant primitive sequences as described in 6.2.4.1 unless prohibited by the primitives description (e.g., TRAIN, TRAIN_DONE).

A receiver shall detect a redundant primitive sequence after the identical primitive is received in any three of six consecutive dwords. After detecting a redundant primitive sequence, a receiver shall not detect a second instance of the same redundant primitive sequence until it has received six consecutive dwords that are not any of the following:

- a) the original primitive; or
- b) a deletable primitive.

Figure 113 shows examples of redundant primitive sequences.

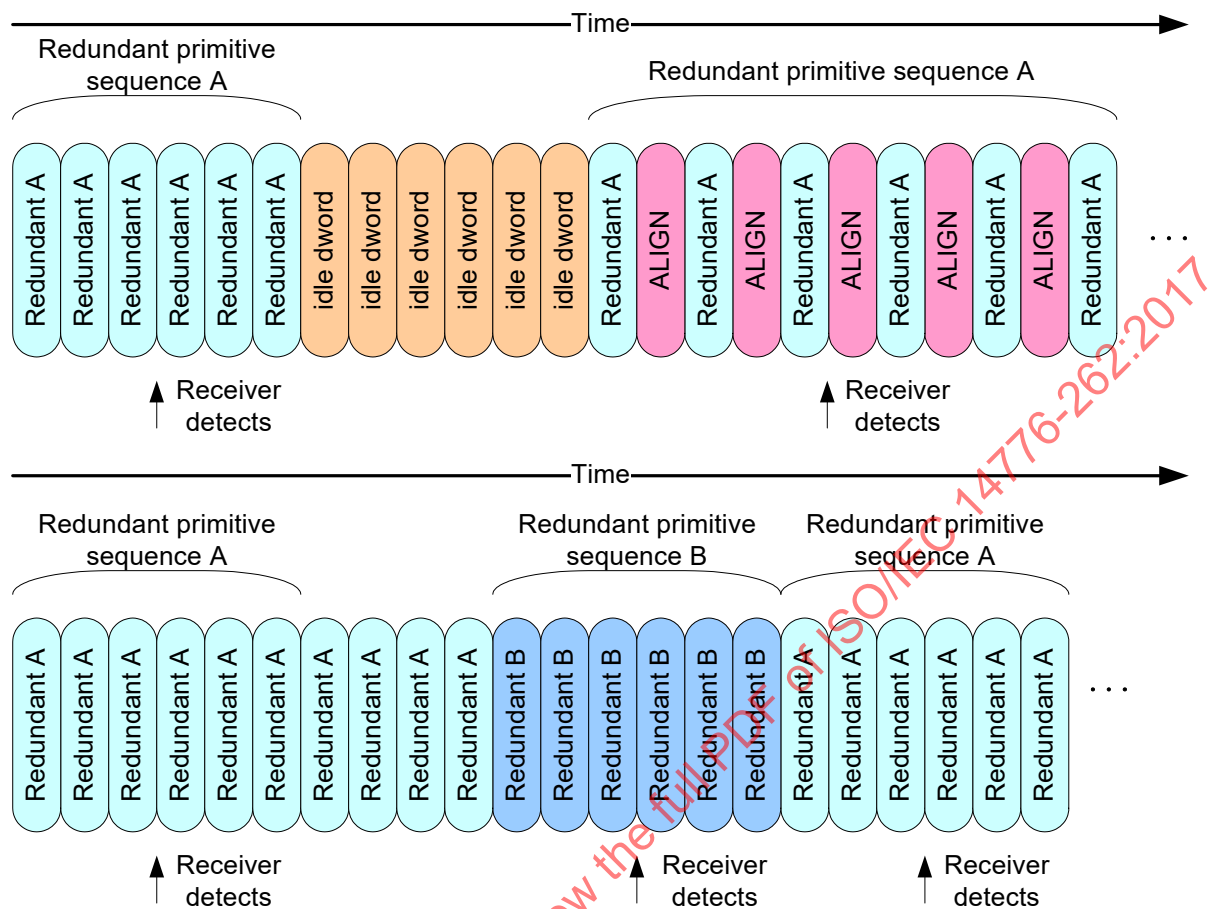


Figure 113 – Redundant primitive sequences

6.2.5 Deletable primitives

6.2.5.1 ALIGN

ALIGNs are used for:

- a) OOB signals (see 5.6);
- b) character and dword alignment during the speed negotiation sequence (see 5.10.4.2);
- c) physical link rate tolerance management after the phy reset sequence (see 6.3); and
- d) rate matching during connections (see 6.15).

ALIGNs are deletable primitives (see 6.3).

Table 101 defines the different versions of ALIGN primitives.

Table 101 – 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 54) 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 102.

Table 102 – 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 103.

Table 103 – 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 104.

Table 104 – 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 6.14.8 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 6.14.8 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 14 in 4.1.13) are defined in table 105.

Table 105 – 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. This primitive may be originated by a SAS initiator port or a SAS target port.

The versions of CLOSE representing different reasons are defined in table 106.

Table 106 – 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: a) the connection is not an STP connection; b) the connection is an STP connection, but affiliations are not implemented by the STP target port; or 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 6.14.7 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 51 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 107 shall result in the originating port abandoning the connection request.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Table 107 – 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	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. If the connection rate is 1.5 Gbit/s, then this shall be considered an abandon-class OPEN_REJECT. 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.
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 108 shall result in the originating port retrying the connection request.

Table 108 – Retry-class OPEN_REJECT primitives

Primitive	Originator	Description
OPEN_REJECT (NO DESTINATION) ^a	Expander phy	An expander device in the pathway is not configuring (see 4.6.4) and determines that: a) there is no such destination phy; 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 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).
OPEN_REJECT (PATHWAY BLOCKED) ^b	Expander phy	An expander device determined the pathway was blocked by higher priority connection requests.
OPEN_REJECT (RESERVED CONTINUE 0) ^c	Unknown	Reserved. Process the same as OPEN_REJECT (RETRY).
OPEN_REJECT (RESERVED CONTINUE 1) ^c		
OPEN_REJECT (RESERVED INITIALIZE 0) ^a	Unknown	Reserved. Process the same as OPEN_REJECT (NO DESTINATION).
OPEN_REJECT (RESERVED INITIALIZE 1) ^a		
OPEN_REJECT (RESERVED STOP 0) ^b	Unknown	Reserved. Process the same as OPEN_REJECT (PATHWAY BLOCKED).
OPEN_REJECT (RESERVED STOP 1) ^b		
OPEN_REJECT (RETRY) ^c	Destination phy or zoning expander phy	Either: 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); b) an expander device in the pathway is configuring (see 4.6.4) and would otherwise have returned OPEN_REJECT (NO DESTINATION) (see 4.6.4 and 6.14.4.2.5); c) an expander device in the pathway is locked and would otherwise have returned OPEN_REJECT (ZONE VIOLATION) (see 4.8.3.5 and 6.14.4.2.5); d) an expander device in the pathway has reduced functionality (see 4.5.8 and 6.14.4.2.5); or e) a phy with the destination SAS address exists but is in the slumber phy power condition (see 4.10.1.6).
^a 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. ^b 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. ^c If the I_T Nexus Loss timer is already running, it is stopped.		

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 109.

Table 109 – 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.

6.2.7.2 CREDIT_BLOCKED

CREDIT_BLOCKED specifies that no more RRDYs are going to be transmitted during this connection (i.e., credit is not going to be increased).

See 6.18.4 for details on SSP flow control.

6.2.7.3 DONE

DONE is used to start closing an SSP connection and specify a reason for doing so. This primitive may be originated by an SSP initiator port or an SSP target port. DONE is not used during an SMP or STP connection.

The versions of DONE representing different reasons are defined in table 110. The SSP state machines describe when these are used (see 6.18.8).

Table 110 – DONE primitives

Primitive	Description
DONE (ACK/NAK TIMEOUT)	The SSP state machines (see 6.18.8) 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 (RESERVED 0)	Reserved. Processed the same as DONE (NORMAL).
DONE (RESERVED 1)	
DONE (CREDIT TIMEOUT)	The SSP state machines (see 6.18.8) 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 6.18.7 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 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 111.

Table 111 – 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.

6.2.7.6 RRDY (Receiver ready)

RRDY is used to increase SSP frame credit.

The versions of RRDY representing different reasons are defined in table 112.

Table 112 – RRDY primitives

Primitive	Description
RRDY (NORMAL)	Increase transmit frame credit by one.
RRDY (RESERVED 0)	Reserved. Processed the same as RRDY (NORMAL).
RRDY (RESERVED 1)	

A phy shall not transmit RRDY after transmitting CREDIT_BLOCKED in a connection. See 6.18.4 for details on SSP flow control.

6.2.7.7 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 51 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 3.1.150) 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 113 (see 6.3.2).

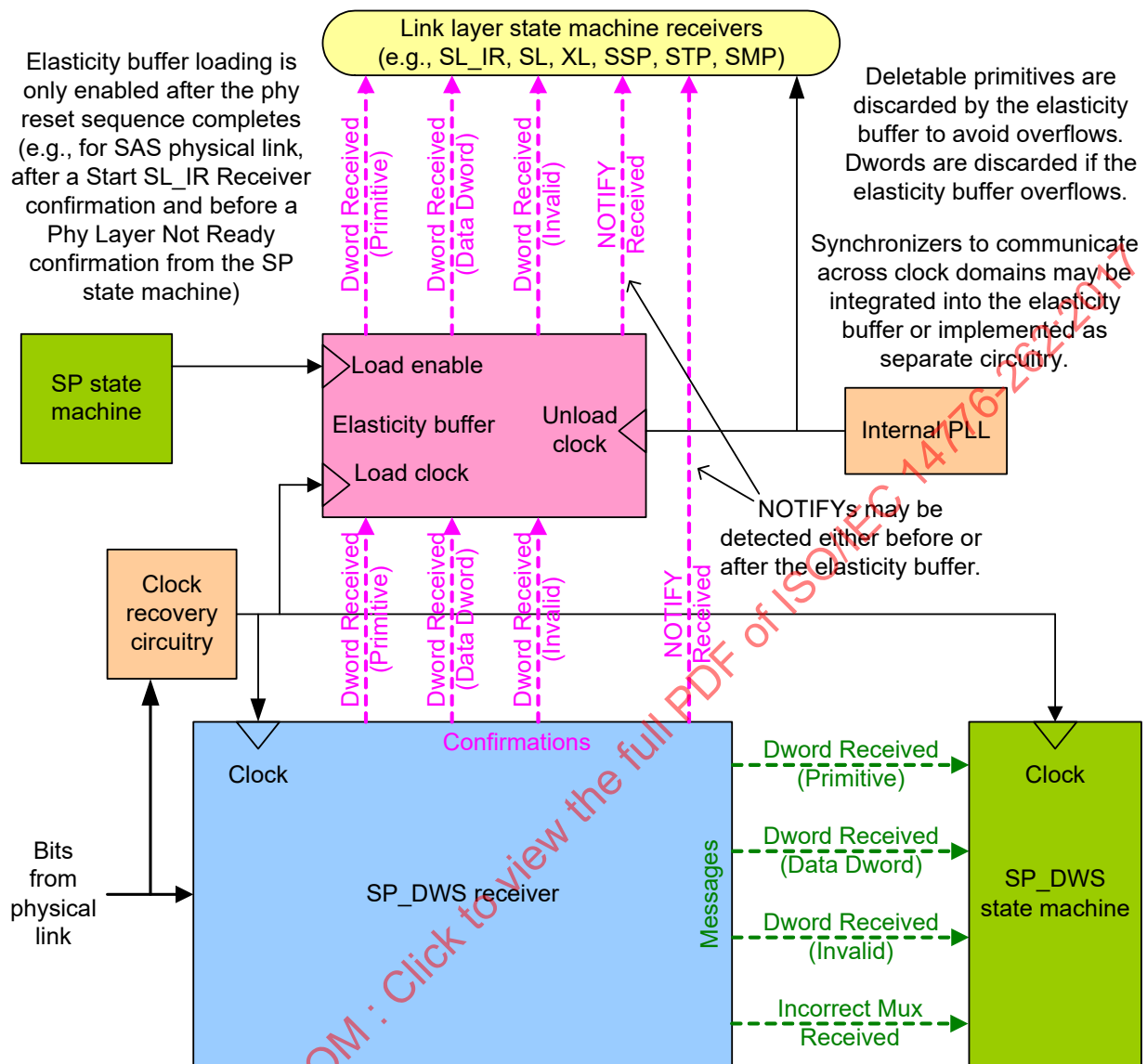


Figure 114 – Elasticity buffer

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 113.

Table 113 – Physical link rate tolerance management deletable primitive insertion requirement

Physical link rate	Requirement ^a
1.5 Gbit/s	One deletable primitive within every 128 dwords ^{b, c}
3 Gbit/s	Two deletable primitives within every 256 dwords ^{b, d}
6 Gbit/s	Four deletable primitives within every 512 dwords ^b
12 Gbit/s	Eight deletable primitives within every 1 024 dwords ^b
^a 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. ^b 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. ^c Phys compliant with SAS-1.1 were required to insert one deletable primitive within every 2 048 dwords at 1.5 Gbit/s. ^d Phys compliant with SAS-1.1 were required to insert two deletable primitives within every 4 096 dwords at 3 Gbit/s.	

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 113 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 which 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 or SMP connection is open.

SATA_SYNC is a continued primitive sequence which may contain vendor specific data dwords (see 6.2.4.4) which 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 114 defines notation used in the following text describing CRC calculation. Arithmetic is modulo 2.

Table 114 – CRC notation and definitions

Notation	Definition
$T(i)$	A transformation over the non-negative integers (i.e., Z^+): $T(i) = i + 7 - 2 \times (i \bmod 8)$, $i \geq 0$, $i \in Z^+$
$F(x)$	A polynomial representing the bits covered by the CRC: $F(x) = b_0x^{(k-1)} + b_1x^{(k-2)} + \dots + b_{(k-2)}x + b_{(k-1)}$ where: k is the number of bits; and b_i describes a bit, where the bit index i denotes that bit b_i is more significant than bit $b_{(i+1)}$. For example, if the frame, except for the CRC field, contains one data dword set to 516F3019h (i.e., $F(x) = 516F3019h$), then: $F(x) = x^{30} + x^{28} + x^{24} + x^{22} + x^{21} + x^{19} + x^{18} + x^{17} + x^{16} + x^{13} + x^{12} + x^4 + x^3 + x$ (i.e., $F(x) = 8AF60C98h$)
$F_t(x)$	$F(x)$ with the bit positions of each byte transposed (i.e., bit 7 is bit 0, bit 6 is bit 1, etc.): $F_t(x) = b_{T(0)}x^{(k-1)} + b_{T(1)}x^{(k-2)} + \dots + b_{T(k-2)}x + b_{T(k-1)}$ For example, if the frame, except for the CRC field, contains one data dword set to 516F3019h (i.e., $F(x) = 516F3019h$), then: $F_t(x) = x^{31} + x^{27} + x^{25} + x^{23} + x^{22} + x^{21} + x^{20} + x^{18} + x^{17} + x^{11} + x^{10} + x^7 + x^4 + x^3$ (i.e., $F_t(x) = 8AF60C98h$)
$L(x)$	The identity polynomial of degree 31 (i.e., a polynomial with all of the coefficients set to one): $L(x) = x^{31} + x^{30} + \dots + x + 1$ (i.e., $L(x) = FFFFFFFFh$)
$G(x)$	The CRC generator polynomial (i.e., the divisor polynomial): $G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$ (i.e., $G(x) = 1\_04C11DB7h$)
$R(x)$	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. If the received frame has no errors, then $M'(x) = M(x)$ and $M'(x)$ is of degree $k+31$.
$M_t'(x)$	$M'(x)$ 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: $R'(x) = x^{31} + x^{30} + x^{26} + x^{25} + x^{24} + x^{18} + x^{15} + x^{14} + x^{12} + x^{11} + x^{10} + x^8 + x^6 + x^5 + x^4 + x^3 + x + 1$ (i.e., $R'(x) = C704DD7Bh$)
$R_t'(x)$	$R'(x)$ with the bit positions of each byte transposed: $R_t'(x) = x^{28} + x^{27} + x^{26} + x^{23} + x^{22} + x^{20} + x^{19} + x^{18} + x^{17} + x^{16} + x^{14} + x^{10} + x^5 + 1$ (i.e., $R_t'(x) = 1CDF4421h$)

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.

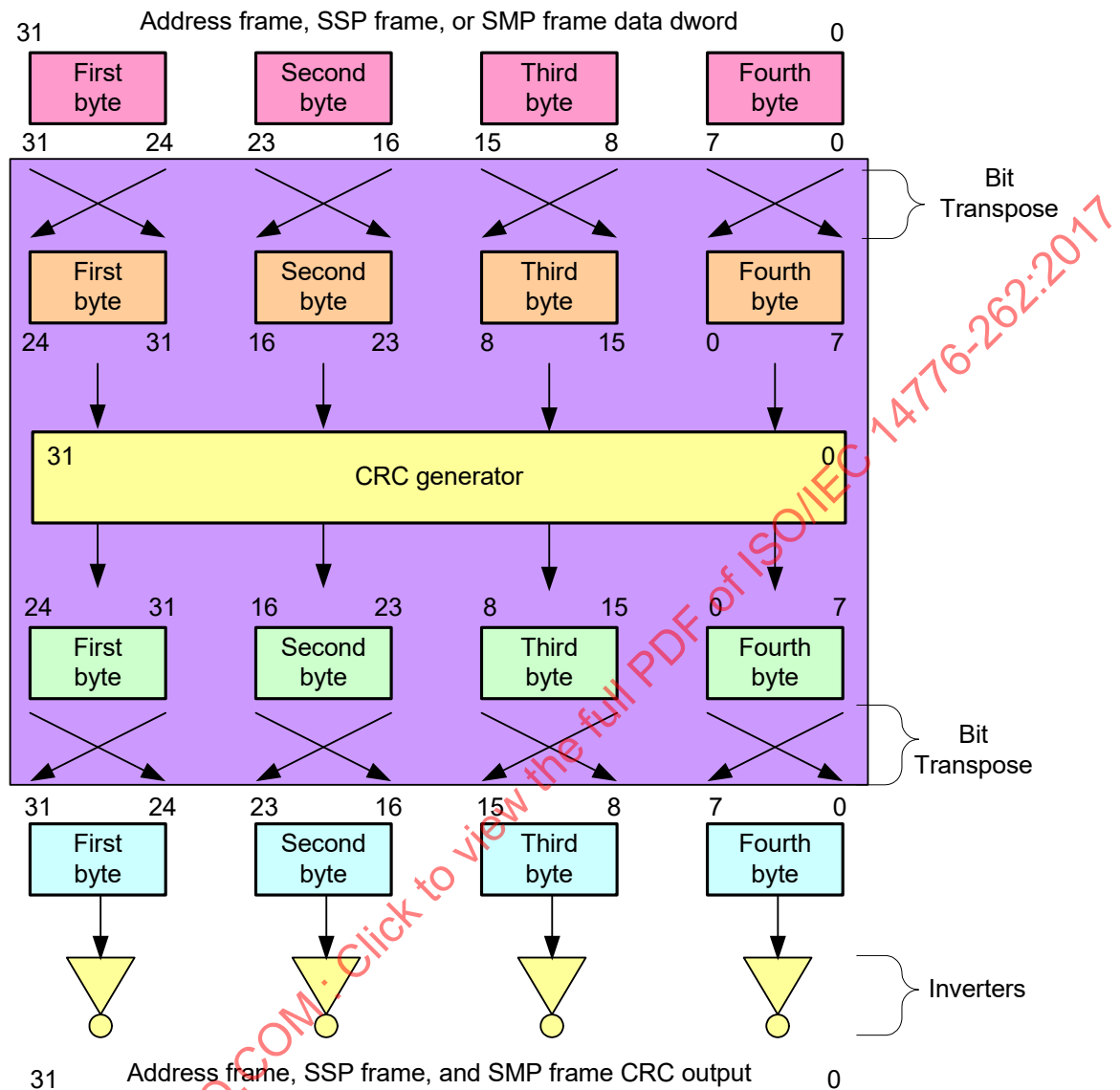


Figure 115 – Address frame, SSP frame, and SMP frame CRC bit ordering

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.

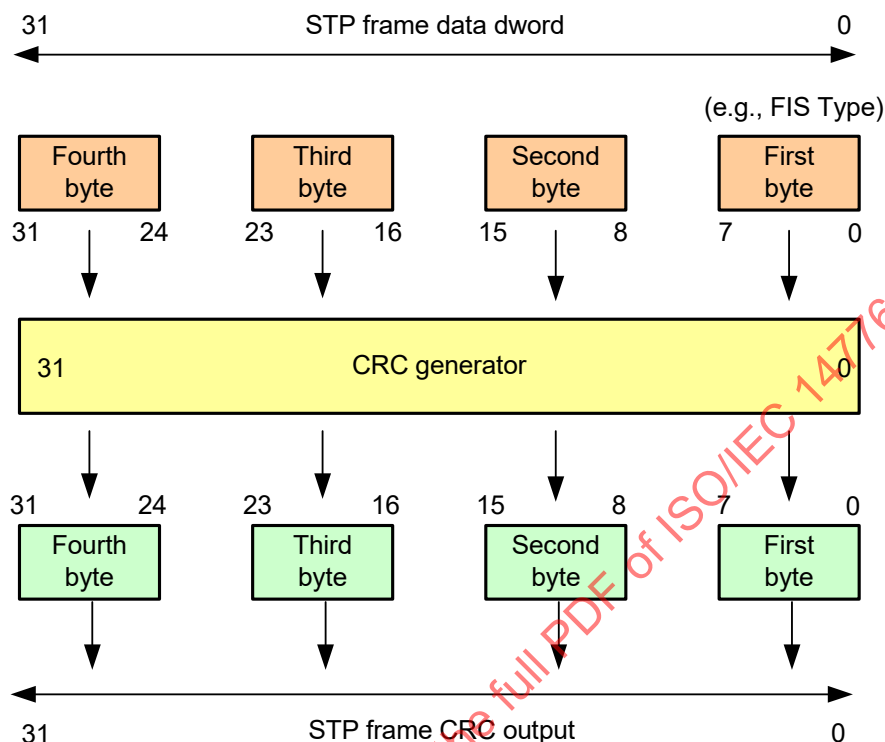


Figure 116 – STP frame CRC bit ordering

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:

$$R_t'(x) + L(x) = 1CDF4421h$$

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 115 lists the scrambling for different types of data dwords.

Table 115 – 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 through 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 through 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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.

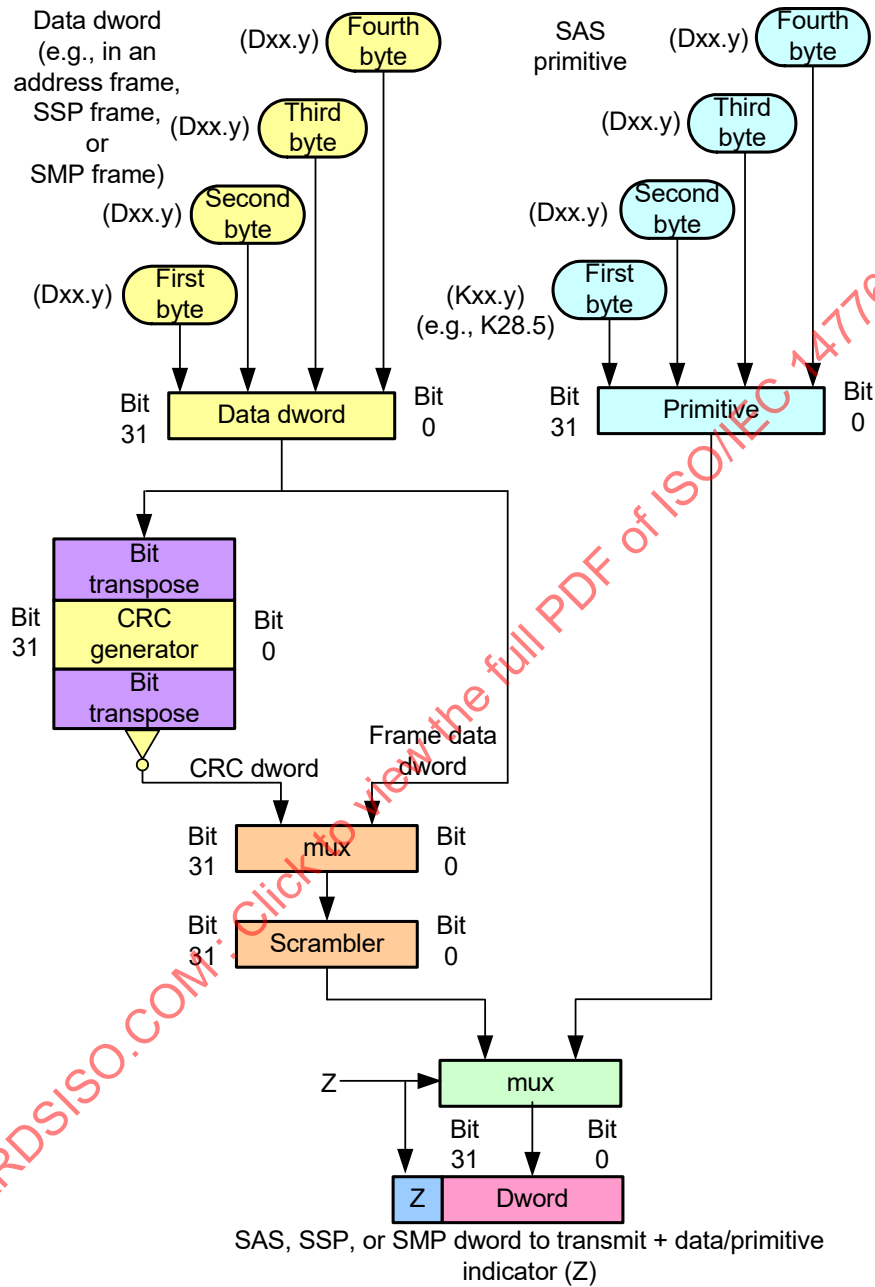


Figure 117 – Transmit path bit ordering

Figure 118 shows the routing of dwords received from the bit reception logic in figure 57 (see 5.5).

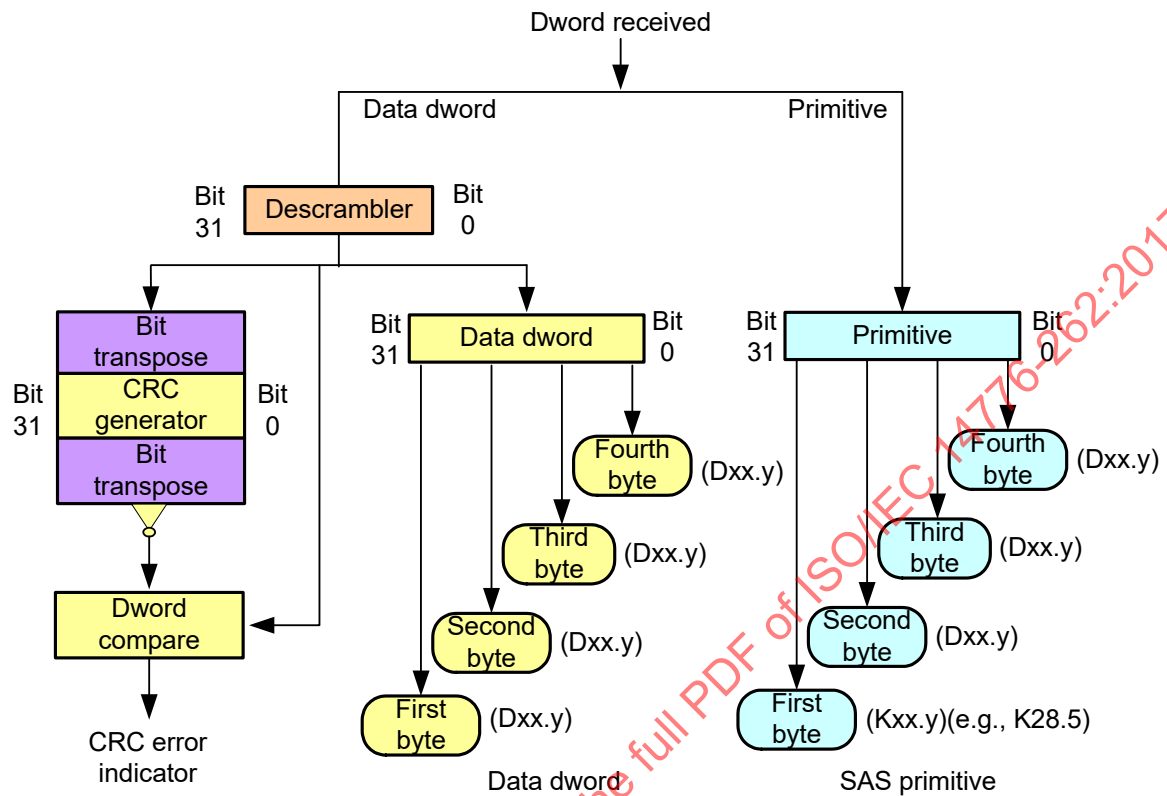


Figure 118 – Receive path bit ordering

Figure 119 shows the STP transmit path bit ordering.

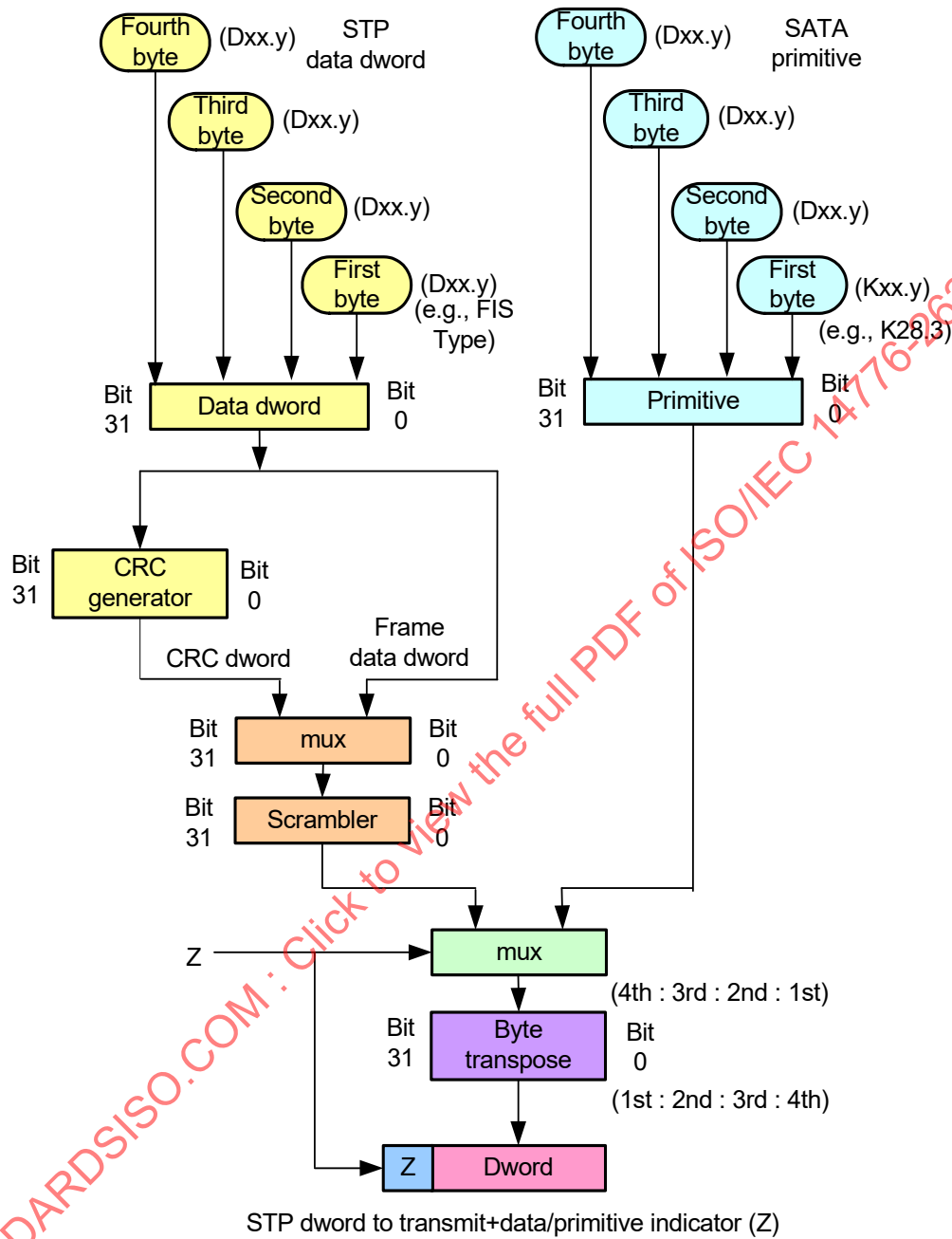


Figure 119 – STP transmit path bit ordering

Figure 120 shows the STP receive path bit ordering.

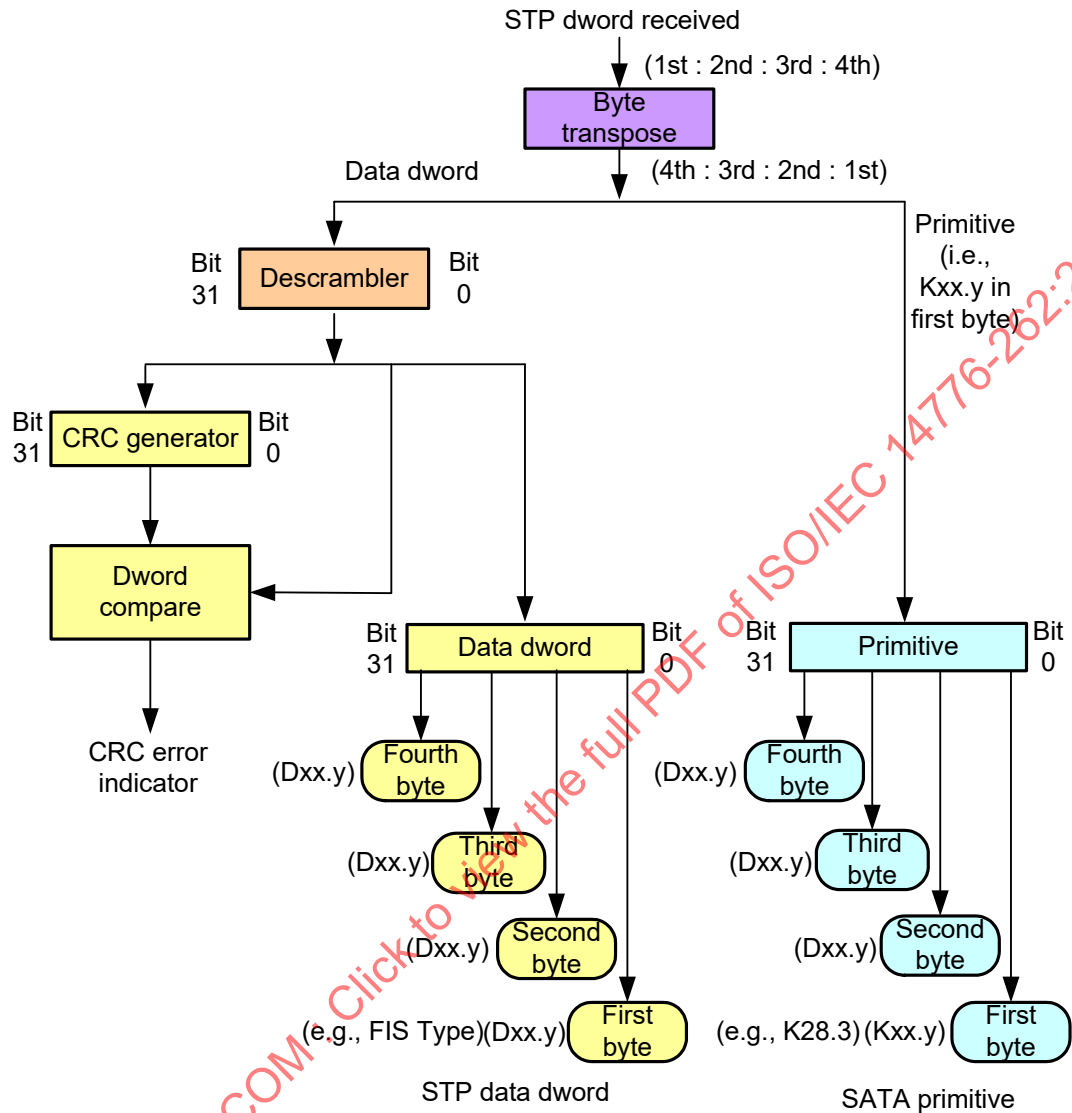


Figure 120 – STP receive path bit ordering

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.

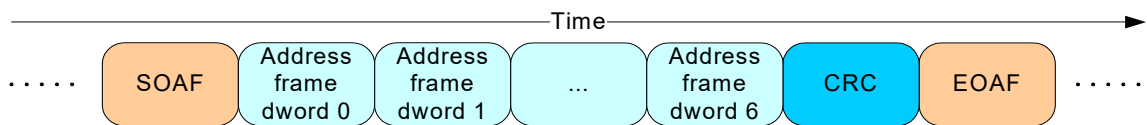


Figure 121 – Address frame transmission

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 116 defines the address frame format.

Table 116 – 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								(LSB)

The ADDRESS FRAME TYPE field indicates the type of address frame and is defined in table 117. This field determines the definition of the frame type dependent bytes.

Table 117 – 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.

The DEVICE TYPE field indicates the type of device containing the phy, and is defined in table 119.

Table 119 – DEVICE TYPE field

Code	Description
001b	End device
010b	Expander device
011b	Expander device compliant with SAS-1.1
All others	Reserved

The ADDRESS FRAME TYPE field shall be set to the value defined in table 118.

The REASON field indicates the reason for the link reset sequence and is defined in table 120.

Table 120 – 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 6.14.8)
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 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 121.

Table 121 – POWER CAPABLE field

Code	Description
00b	The device containing the phy: a) does not respond to PWR_GRANT with PWR_ACK, PWR_REQ with PWR_ACK, or PWR_DONE with PWR_ACK; and 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: a) issuing PWR_REQ and PWR_DONE; and 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: a) PWR_REQ with PWR_ACK; b) PWR_REQ with PWR_GRANT; and c) PWR_DONE with PWR_ACK.
11b	Reserved

The CRC field is defined in 6.8.1.

6.8.3 OPEN address frame

Table 122 defines the OPEN address frame format used for connection requests.

Table 122 – 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									
4		DESTINATION SAS ADDRESS							
...									
11									
12		SOURCE SAS ADDRESS							
...									
19									
20		SOURCE ZONE GROUP							
21		PATHWAY BLOCKED COUNT							
22	(MSB)	ARBITRATION WAIT TIME							
23									
24		MORE COMPATIBLE FEATURES (00000000h)							
...									
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 123.

Table 123 – SAS PROTOCOL field

Code	Description
000b	SMP
001b	SSP
010b	STP
All others	Reserved

The ADDRESS FRAME TYPE field shall be set to the value defined in table 122.

The FEATURES field specifies any additional features that are incompatible with SAS-1.1 and is defined in table 124.

Table 124 – 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 125.

Table 125 – 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:

- 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
- 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:

- 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 40 (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 40 (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 µs. Table 126 describes several values of the ARBITRATION WAIT TIME field. See 6.14.3 for details on arbitration fairness.

Table 126 – ARBITRATION WAIT TIME field

Code	Description
0000h	0 μ s
0001h	1 μ s
...	...
7FFFh	32 767 μ s
8000h	0 ms + 32 768 μ s
8001h	1 ms + 32 768 μ s
...	...
FFFFh	32 767 ms + 32 768 μ s

The MORE COMPATIBLE FEATURES field shall be set to the value defined in table 122. A phy receiving an OPEN address frame shall ignore 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.

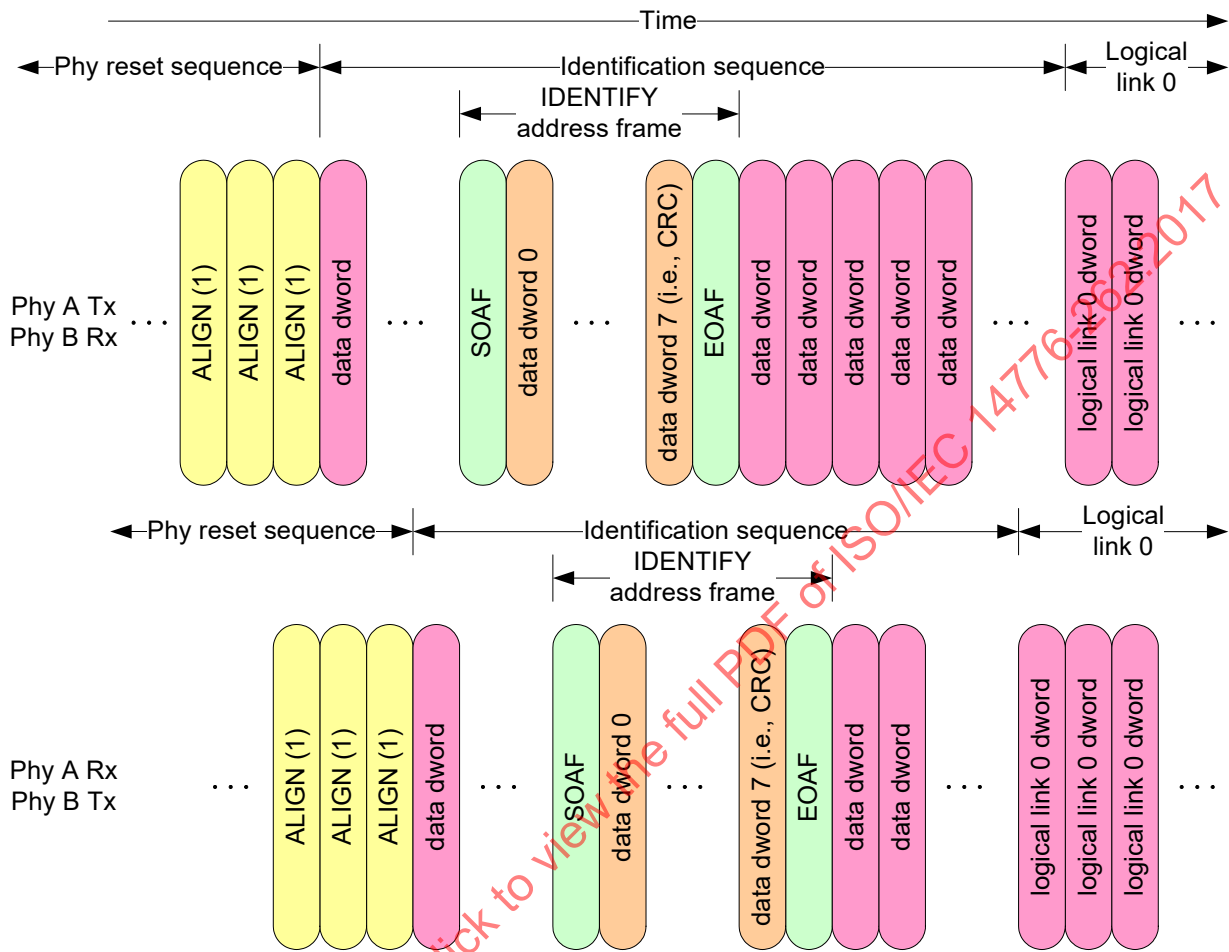
An identification sequence occurs when a logical phy:

- 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.

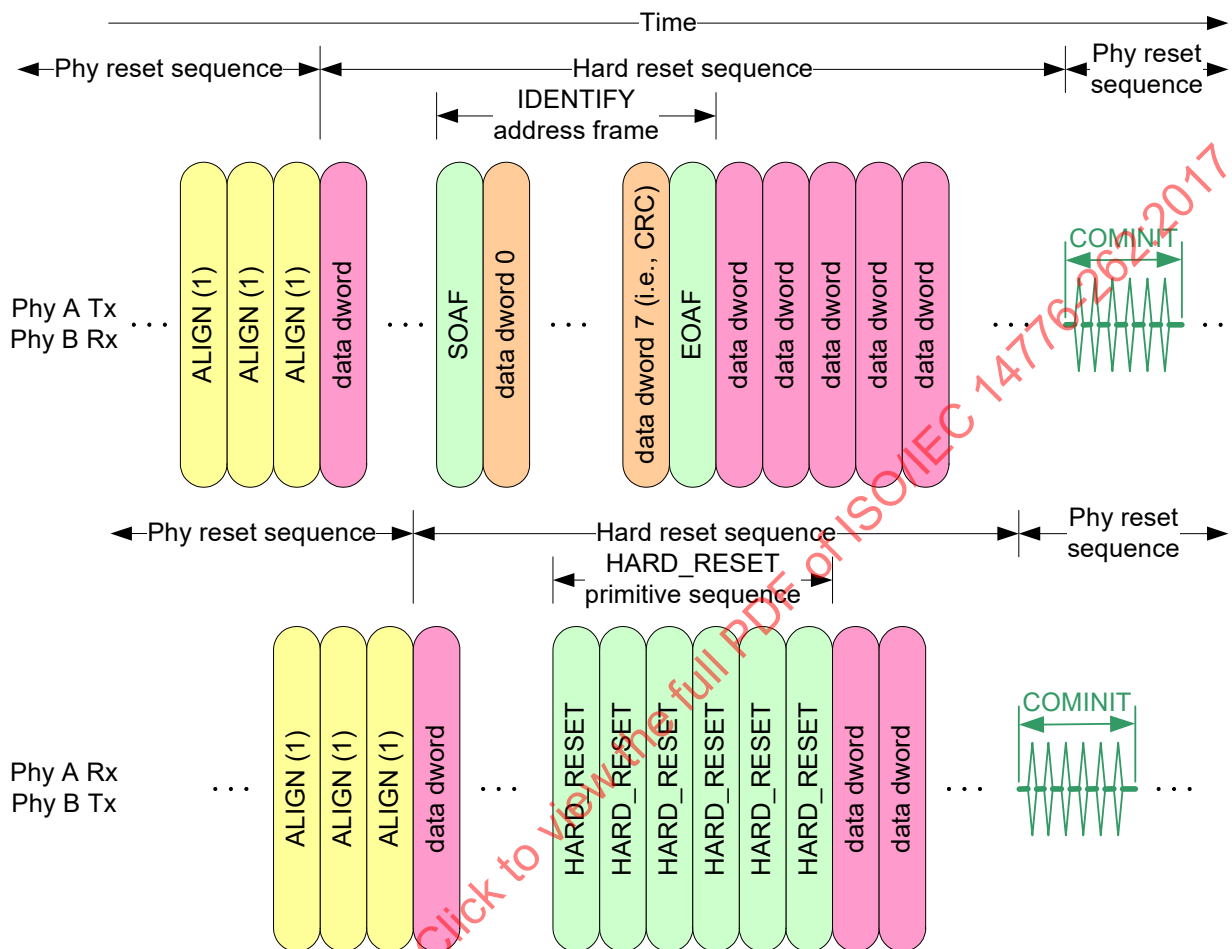
Figure 122 shows two phys with multiplexing disabled performing the identification sequence. Only one IDENTIFY address frame is shown in this example.



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:

- a) SL_IR_TIR (transmit IDENTIFY or HARD_RESET primitive sequence) state machine (see 6.10.3);
- b) SL_IR_RIF (receive IDENTIFY address frame) state machine (see 6.10.4); and
- c) 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:

- a) Enable Disable SAS Link (Enable); and
- b) Enable Disable SAS Link (Disable).

This state machine shall maintain the timers listed in table 127.

Table 127 – SL_IR_IRC state machine timers

Timer	Initial value
Receive Identify Timeout timer	1 ms

Figure 124 shows the SL_IR state machines.

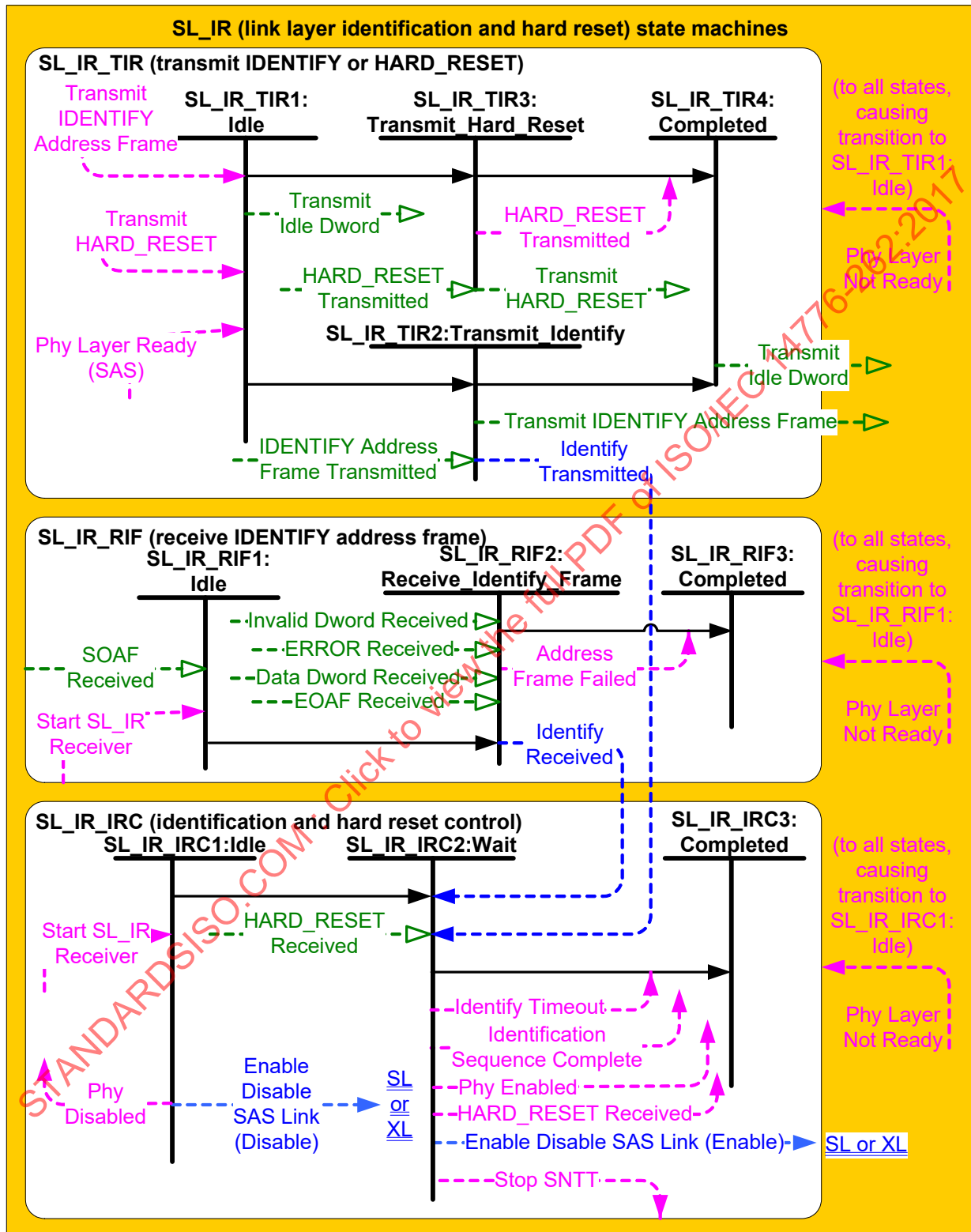


Figure 124 – SL_IR (link layer identification and hard reset) state machines

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 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 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 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 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 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 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.

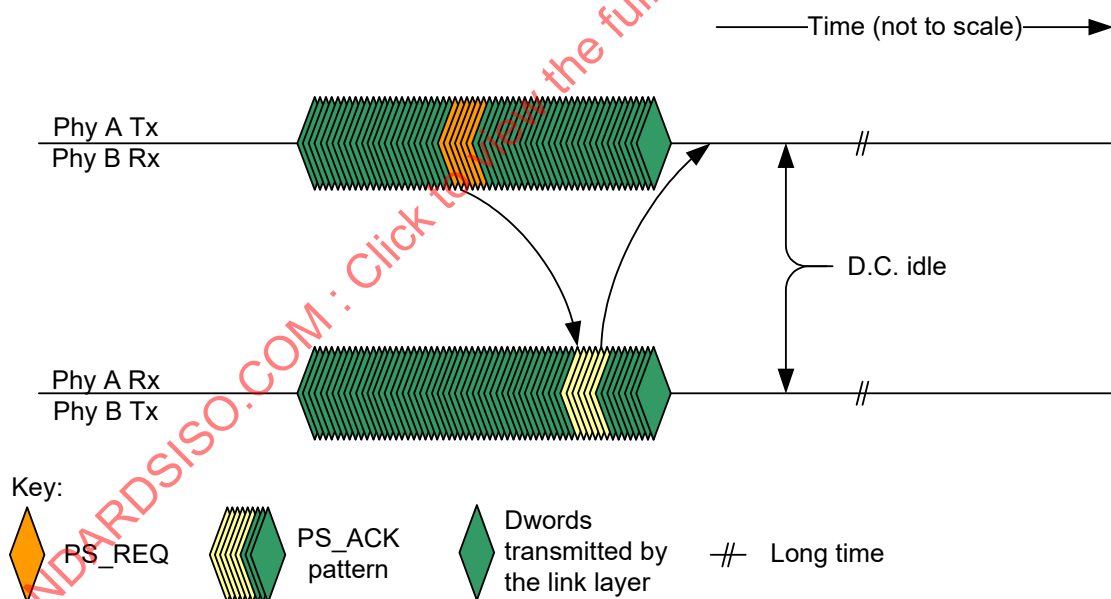


Figure 125 – Transitioning from the active phy power condition to a low phy power condition

The transition to a low phy power condition is acknowledged using a PS_ACK pattern as defined in table 128.

Table 128 – PS_ACK pattern

Pattern	Description
PS_ACK pattern	Sequence of: 1) PS_ACK primitive sequence (see 6.2.6.11); and 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 139 and table 142) 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):

- a) 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 client 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 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 client 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 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 129.

Table 129 – 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: a) for expander ports, the value in the POWER DONE TIMEOUT field in the SMP REPORT GENERAL function (see 9.4.3.4); and b) for SSP initiator ports, a vendor specific value.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 126 shows the SL_P_S state machine.

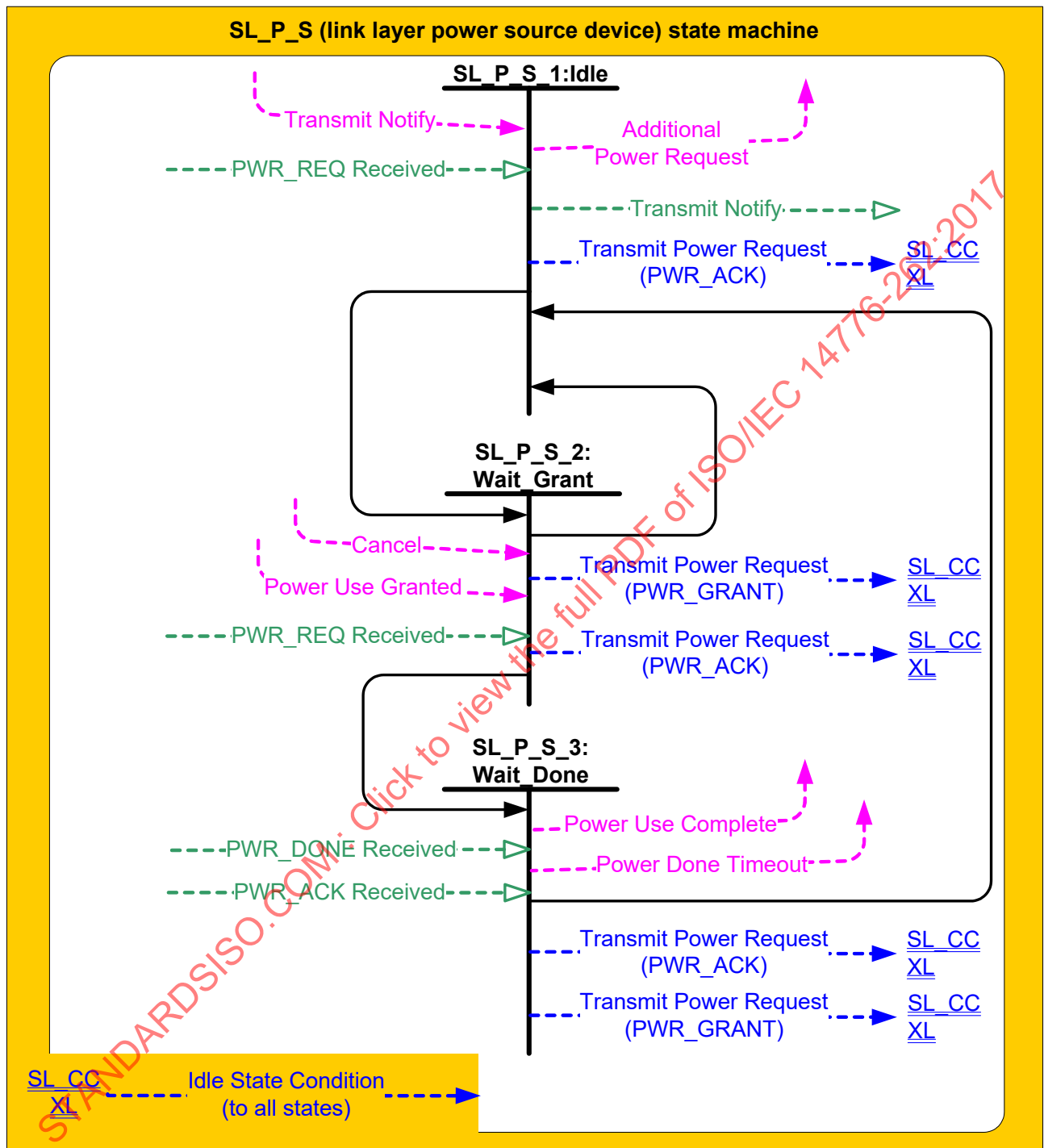


Figure 126 – SL_P_S (link layer power source device) state machine

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:

- a) 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 wait until receiving an Idle State Condition (Active) message before 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.

6.12.4.3.2 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 wait until receiving an Idle State Condition (Active) message before sending 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 wait until receiving an Idle State Condition (Active) message before sending 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 after:

- a) 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 after sending:

- a) 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 wait until receiving an Idle State Condition (Active) message before:

- a) sending a Transmit Power Request (PWR_GRANT) message to the SL_CC0:Idle state or XL0:Idle state; and
- b) initializing and starting the ACK Timeout timer.

If this state receives a PWR_DONE Received message, 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 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 130.

Table 130 – 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.

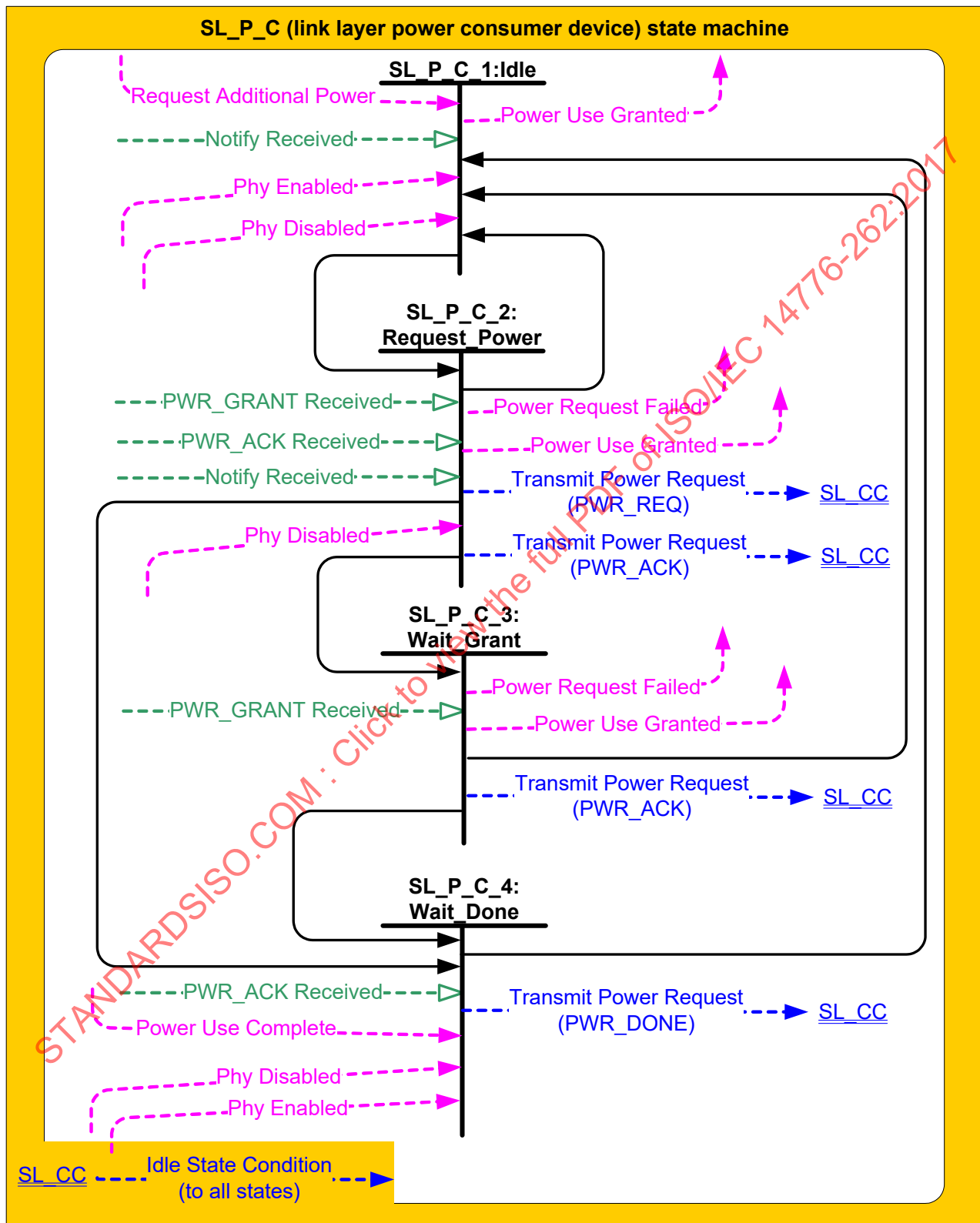


Figure 127 – SL_P_C (link layer power consumer device) state machine

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 after receiving:

- a) 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:

- 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 wait until receiving an Idle State Condition (Active) message before 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).

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) 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 after receiving:

- a) 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 wait until receiving an Idle State Condition (Active) message before 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).

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 after sending:

- a) 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.

If this state receives a Power Use Complete request and the last Idle State Condition message received contained an Inactive argument, then this state shall wait until receiving an Idle State Condition (Active) message before sending a Transmit Power Request (PWR_DONE) message to the SL_CC0:Idle state.

If this state receives a Power Use Complete request and the last Idle State Condition message received contained an Active argument, then this state shall initialize and start the ACK Timeout timer.

If this state receives a Power Use Complete request, the last Idle State Condition message received contained an Active argument, and this state has not received a Phy Disabled confirmation without a subsequent Phy Enabled confirmation, then this state shall send a Transmit Power Request (PWR_DONE) message to the SL_CC0:Idle state.

If the ACK Timeout timer expires, then this state shall, at least one time:

- a) send a Transmit Power Request (PWR_DONE) message to the SL_CC0:Idle state; and
- b) 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 6.14.8). A CLOSE primitive sequence is used for orderly closing of a connection (see 6.14.7).

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.

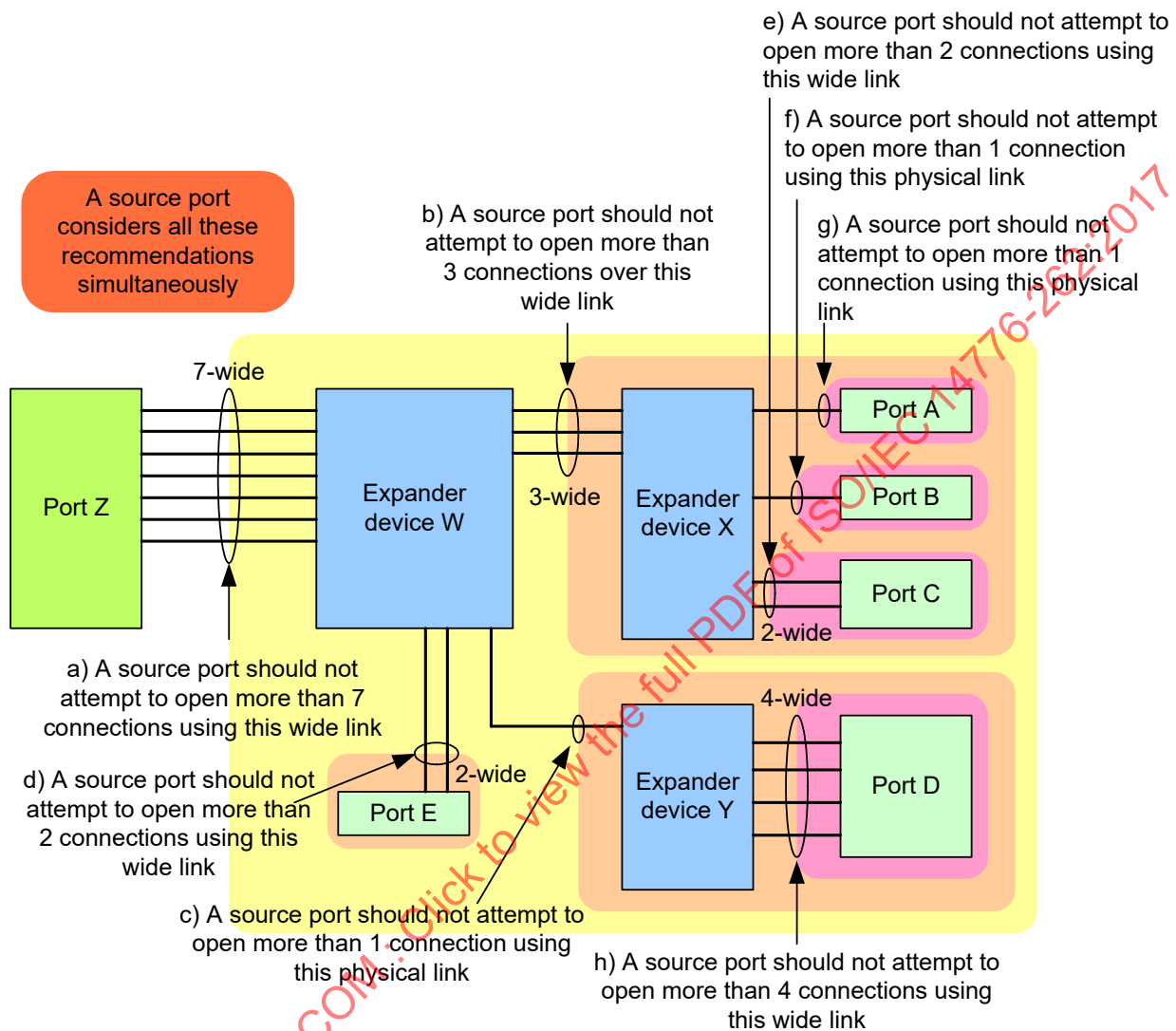


Figure 128 – Example simultaneous connection recommendations for wide ports

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 131.

Table 131 – 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. 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 4.5 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 which 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 μ s to 32 767 μ s and in milliseconds from 32 768 μ s to 32 767 ms + 32 768 μ s. The Arbitration Wait Time timer shall stop incrementing when its value reaches 32 767 ms + 32 768 μ 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 132, 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 132.

Table 132 – Arbitration priority for OPEN address frames passing on a logical link

Bits 79-64 (79 is MSB)	Bits 63-0 (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 133) 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 133) 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 133 – Arbitration priority for a Request Path request in the ECM

Bit 85 (85 is MSB)	Bit 84	Bits 83-68	Bits 67-4	Bits 3-0 (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 134.

Table 134 – Pathway recovery priority

Bits 71-64 (71 is MSB)	Bits 63-0 (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 6.14.8) 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.

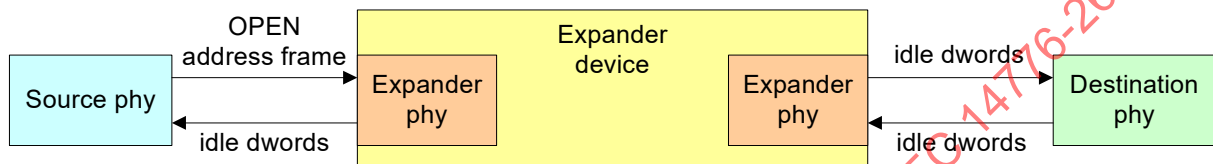
After a source phy transmits a BREAK primitive sequence to abort a connection request, the source phy shall expect one of the results listed in table 135.

Table 135 – Results of aborting a connection request

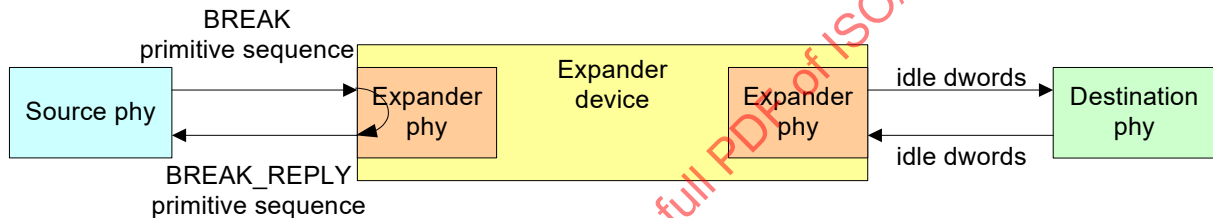
BREAK_REPLY method of responding to received BREAK primitive sequences	Result	Description
Disabled	Receive a BREAK primitive sequence	This confirms that the connection request has been aborted.
	Receive a BREAK_REPLY primitive sequence	Ignore the BREAK_REPLY primitive sequence.
Enabled	Receive a BREAK 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.

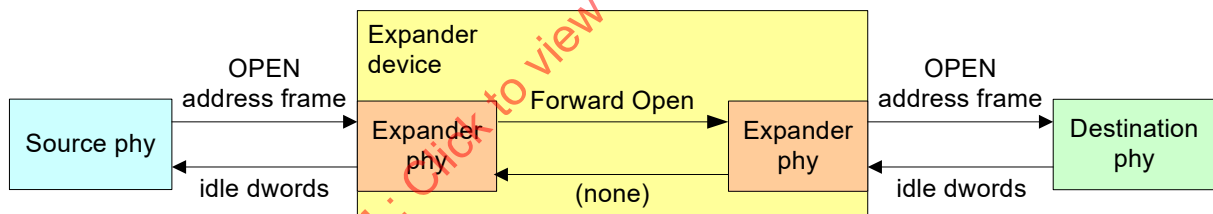
Case 1: OPEN address frame has not propagated through the expander device:



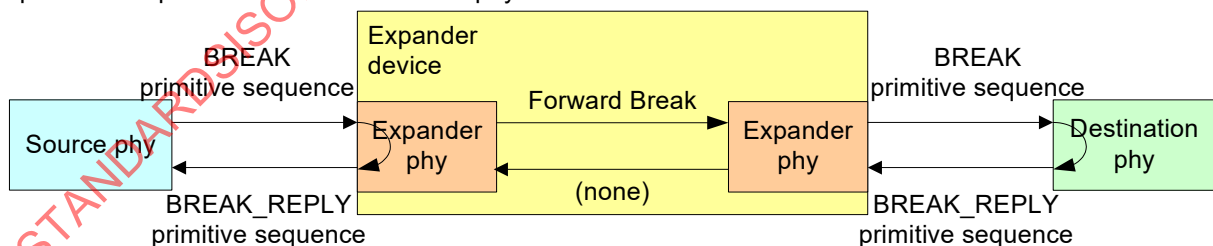
Case 1 result: Expander device transmits a BREAK_REPLY primitive sequence to the source phy.



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.

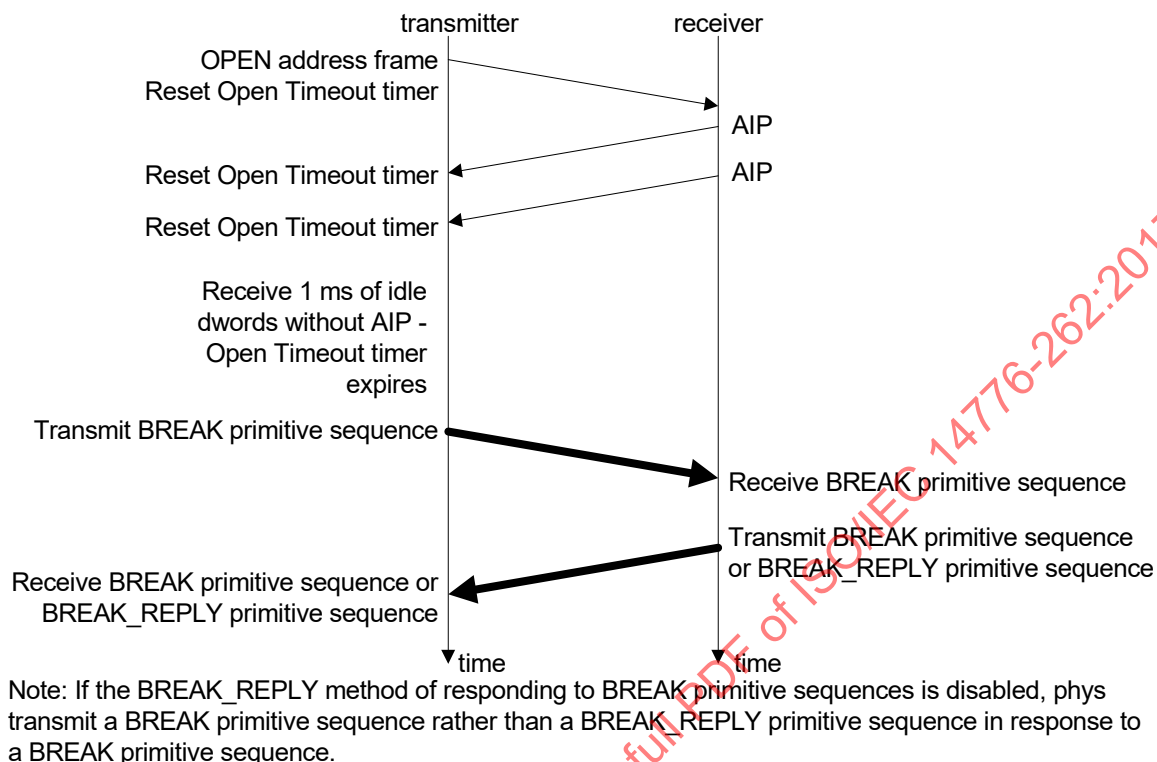


Figure 130 – Connection request timeout example

6.14.7 Closing a connection

CLOSE is used to close a connection of any protocol. See 6.18.7 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 136.

Table 136 – 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 6.14.8).

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.

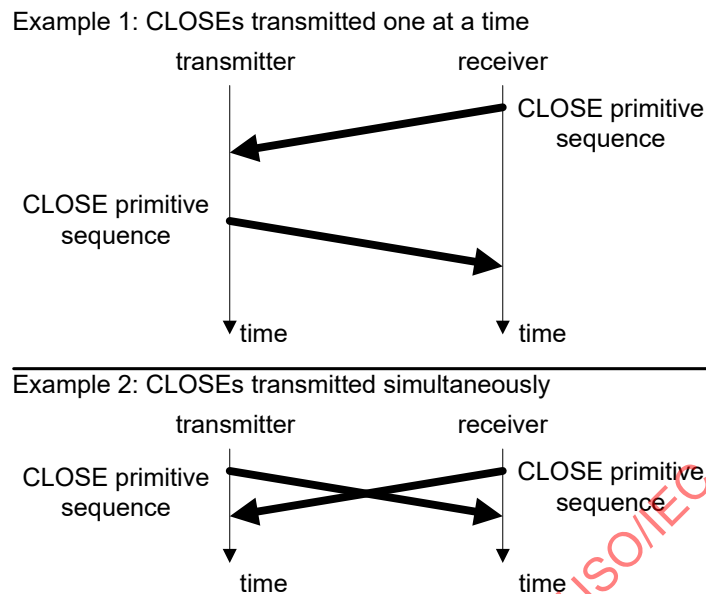


Figure 131 – Closing a connection example

6.14.8 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 137.

Table 137 – Results of breaking a connection

BREAK_REPLY method of responding to received BREAK primitive sequences	Result	Description
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 6.18.6 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 138.

Table 138 – 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 2 dwords that are not physical link rate tolerance management deletable primitives (i.e., every overlapping window of 2 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 4 dwords that are not physical link rate tolerance management deletable primitives (i.e., 3 in every overlapping window of 4 dwords)
	3 Gbit/s	One deletable primitive within every 2 dwords that are not physical link rate tolerance management deletable primitives (i.e., every overlapping window of 2 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 8 dwords that are not physical link rate tolerance management deletable primitives (i.e., 7 in every overlapping window of 8 dwords)
	3 Gbit/s	Three deletable primitives within every 4 dwords that are not physical link rate tolerance management deletable primitives (i.e., 3 in every overlapping window of 4 dwords)
	6 Gbit/s	One deletable primitive within every 2 dwords that are not physical link rate tolerance management deletable primitives (i.e., every overlapping window of 2 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.

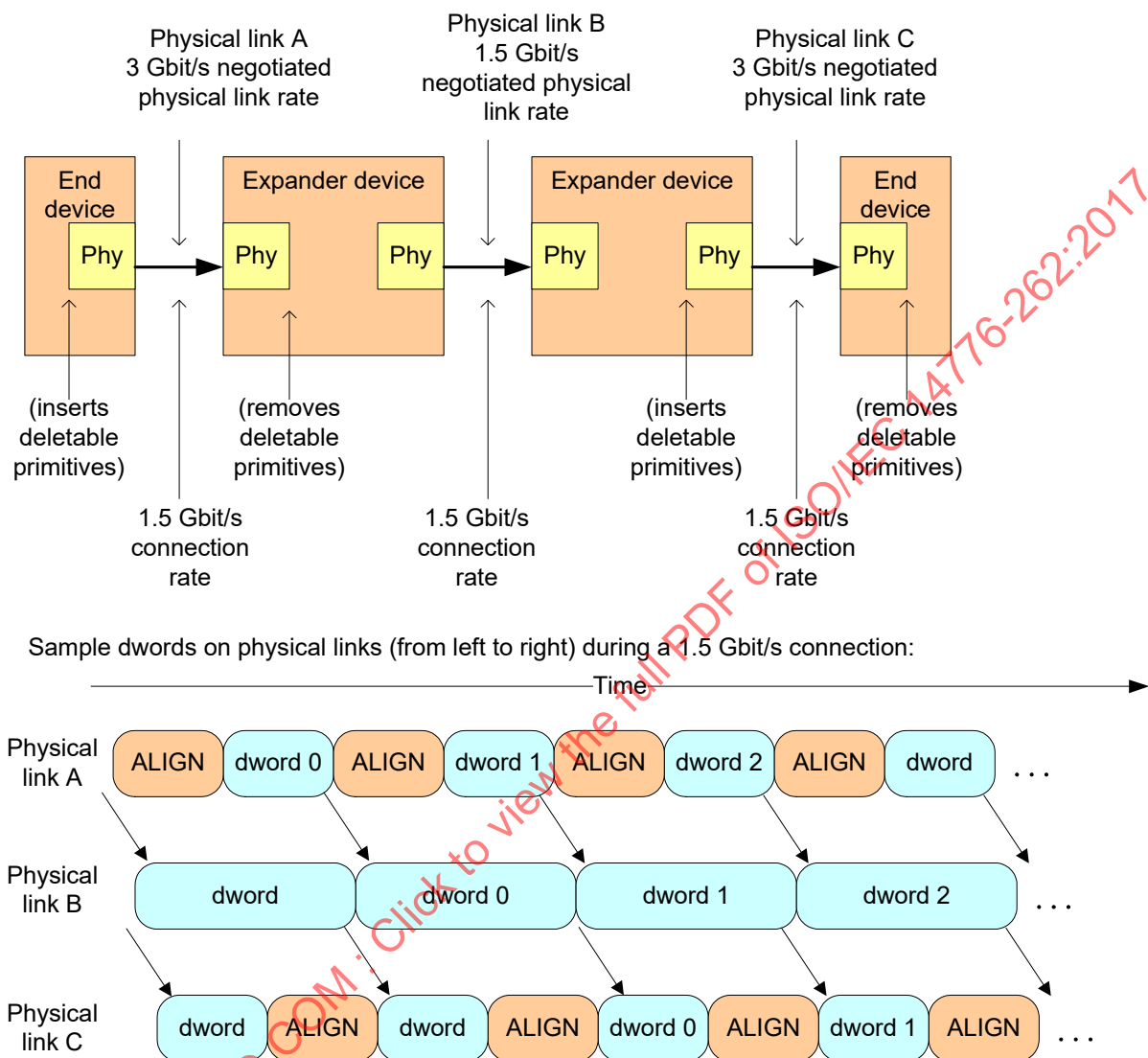


Figure 132 – Rate matching example

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;
- 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, handling both 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 133, figure 134, and figure 135 show the SL state machines.

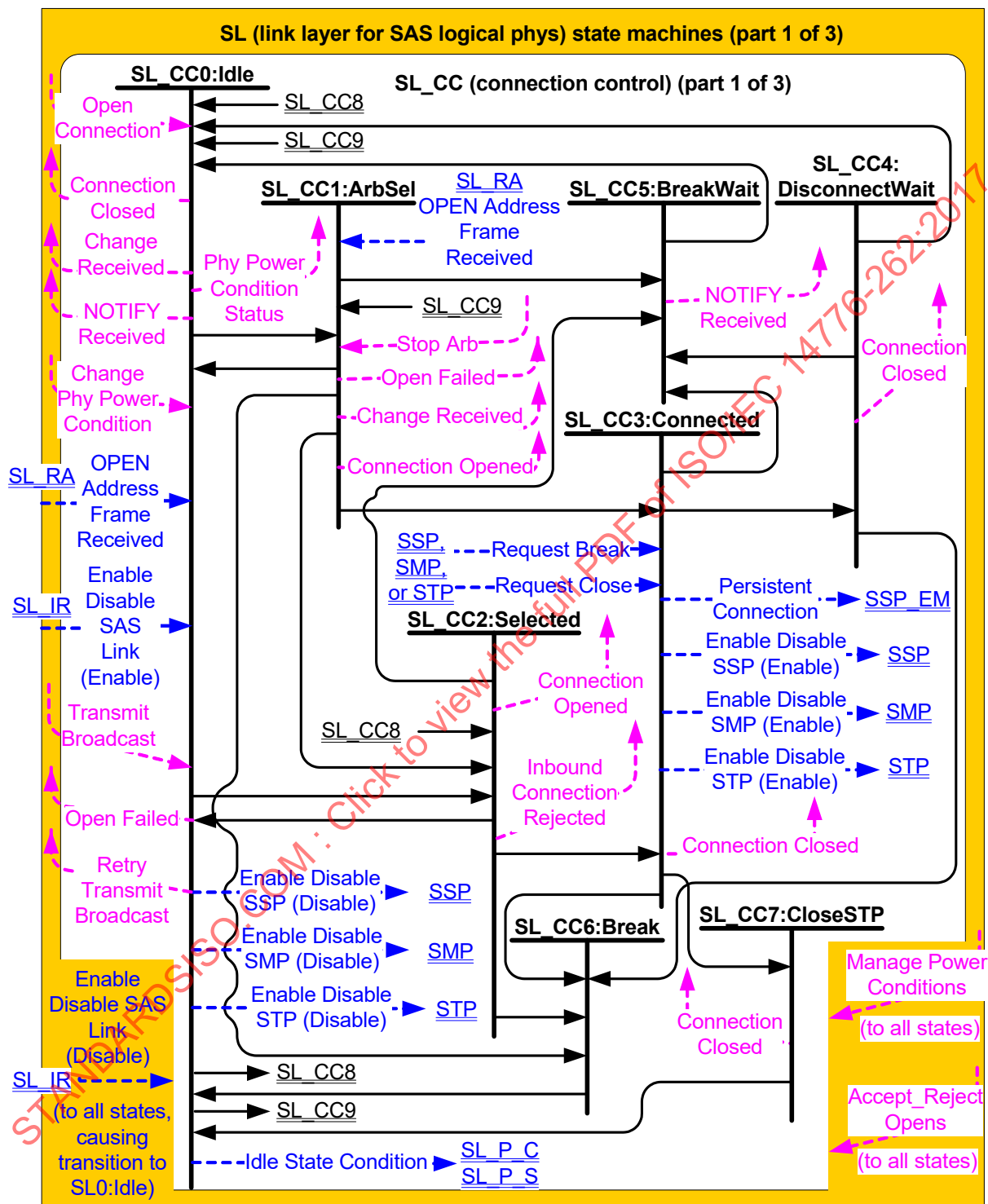


Figure 133 – SL (link layer for SAS logical phys) state machines (part 1)

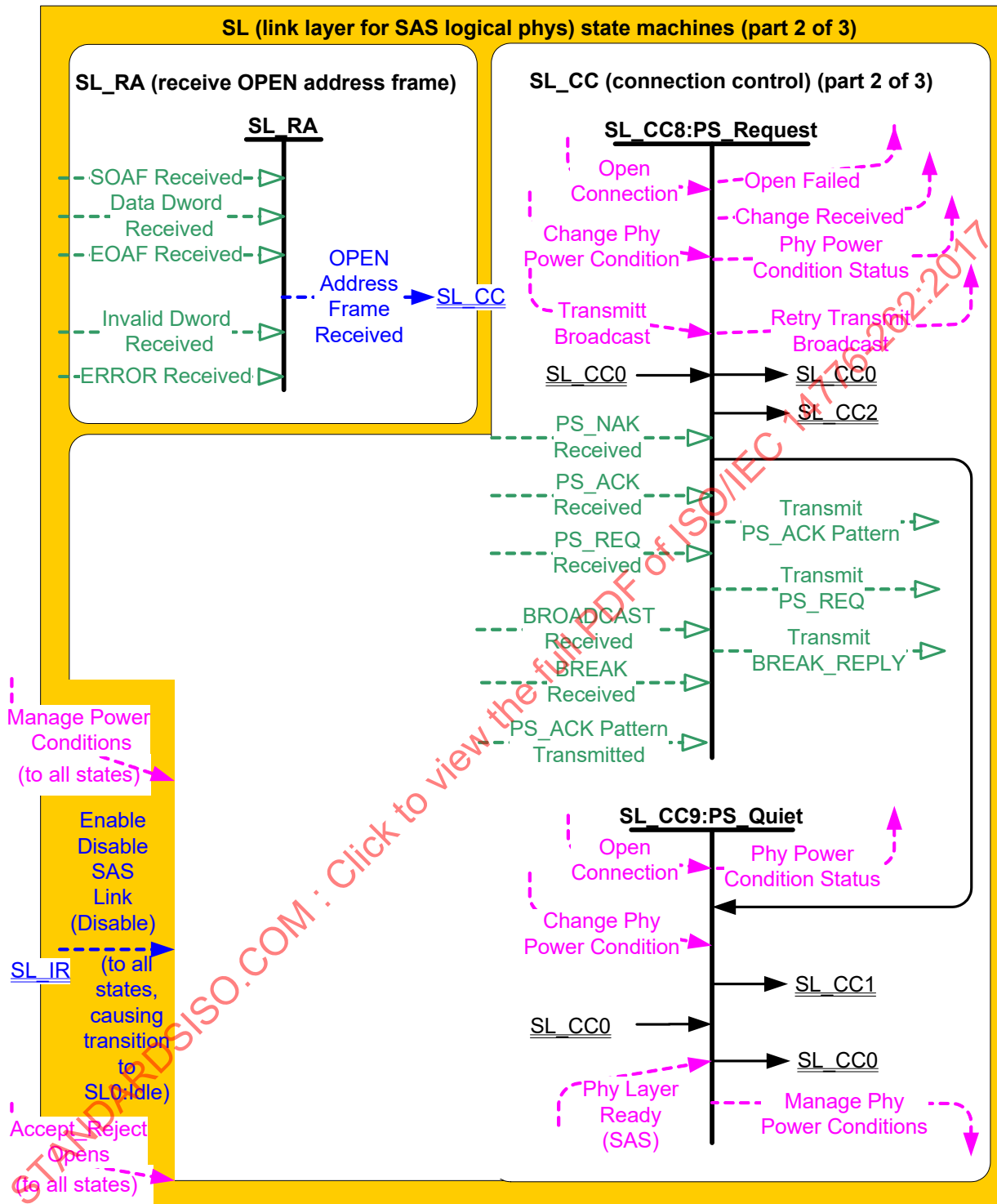


Figure 134 – SL (link layer for SAS logical phys) state machines (part 2)

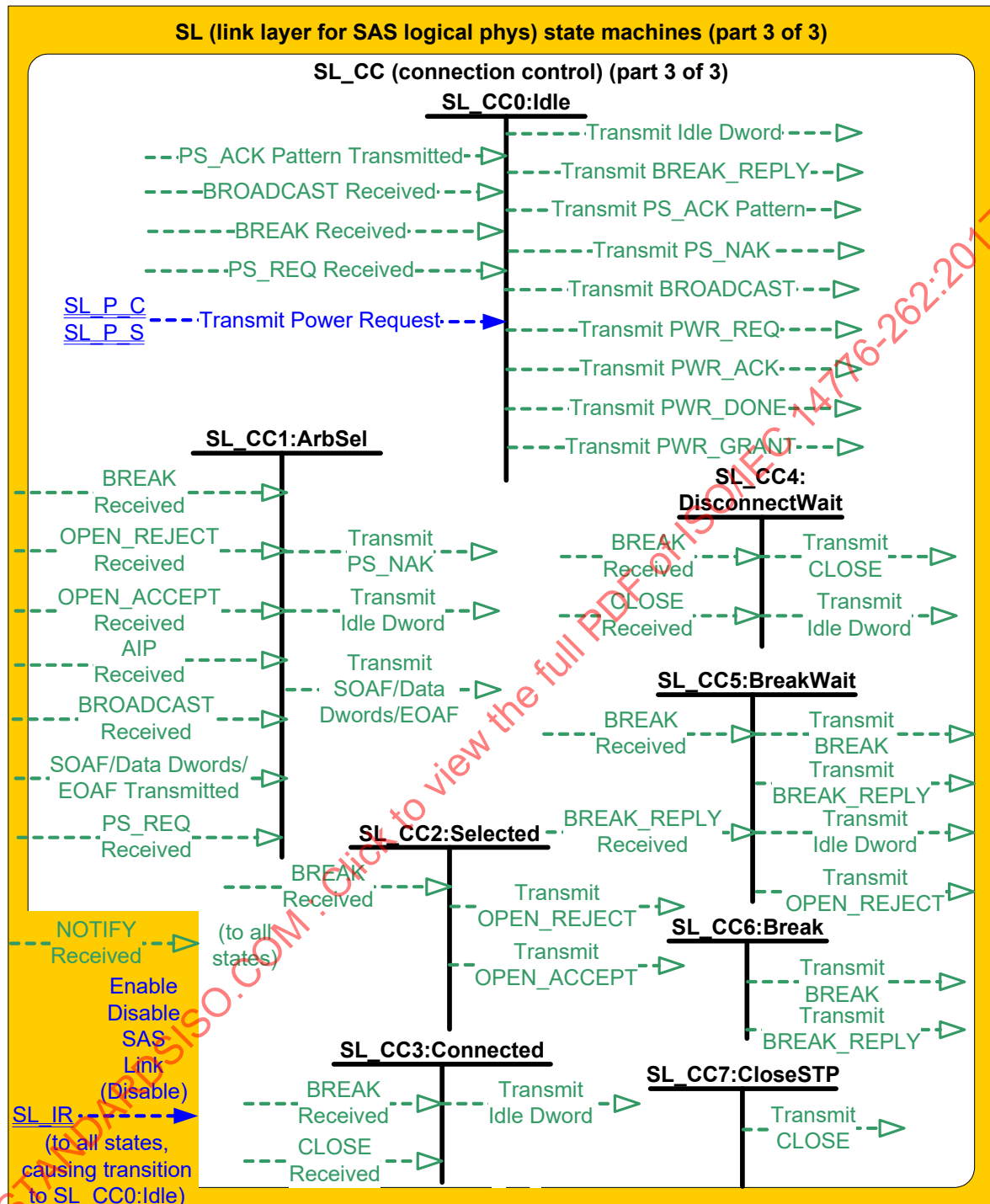


Figure 135 – SL (link layer for SAS logical phys) state machines (part 3)

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;
- 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 8; 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 a 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 6.18.8), 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 140) 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 140) 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 140) 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 140) 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 140) 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 139.

Table 139 – 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 140.

Table 140 – 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_CC0: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 Transmit PS_ACK Pattern message to the SL transmitter.

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 Transmit PS_ACK Pattern message to the SL transmitter.

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.

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 after:

- a) 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).

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 after:

- a) 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 141 after transmitting the OPEN address frame, then this state shall send the corresponding Open Failed confirmation listed in table 141 to the port layer.

Table 141 – OPEN_REJECT Received message to Open Failed confirmation mapping

OPEN_REJECT Received message	Open Failed confirmation
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)
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 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.

6.16.4.3.4 Transition SL_CC1:ArbSel to SL_CC3:Connected

This transition shall occur after sending:

- a) 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.

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; and
- b) the received OPEN address frame.

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 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 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 this state shall send an Enable Disable SMP (Enable) message to the SMP link layer state machines (see 6.20.5).

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 6.18.8).

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).

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 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 Power Loss Expected argument.

6.16.4.5.4 Transition SL_CC3:Connected to SL_CC6:Break

This transition shall occur 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 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 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 Power Loss Expected argument.

6.16.4.6.4 Transition SL_CC4:DisconnectWait to SL_CC6:Break

This transition shall occur 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 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 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),
- d) then this state shall send a Transmit PS_ACK Pattern message to the SL transmitter.

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 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 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.

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 143) 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 143) 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 142.

Table 142 – 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

The XL state machine shall maintain the state machine variables listed in table 143.

Table 143 – 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.

Figure 136 shows several states in the XL state machine.

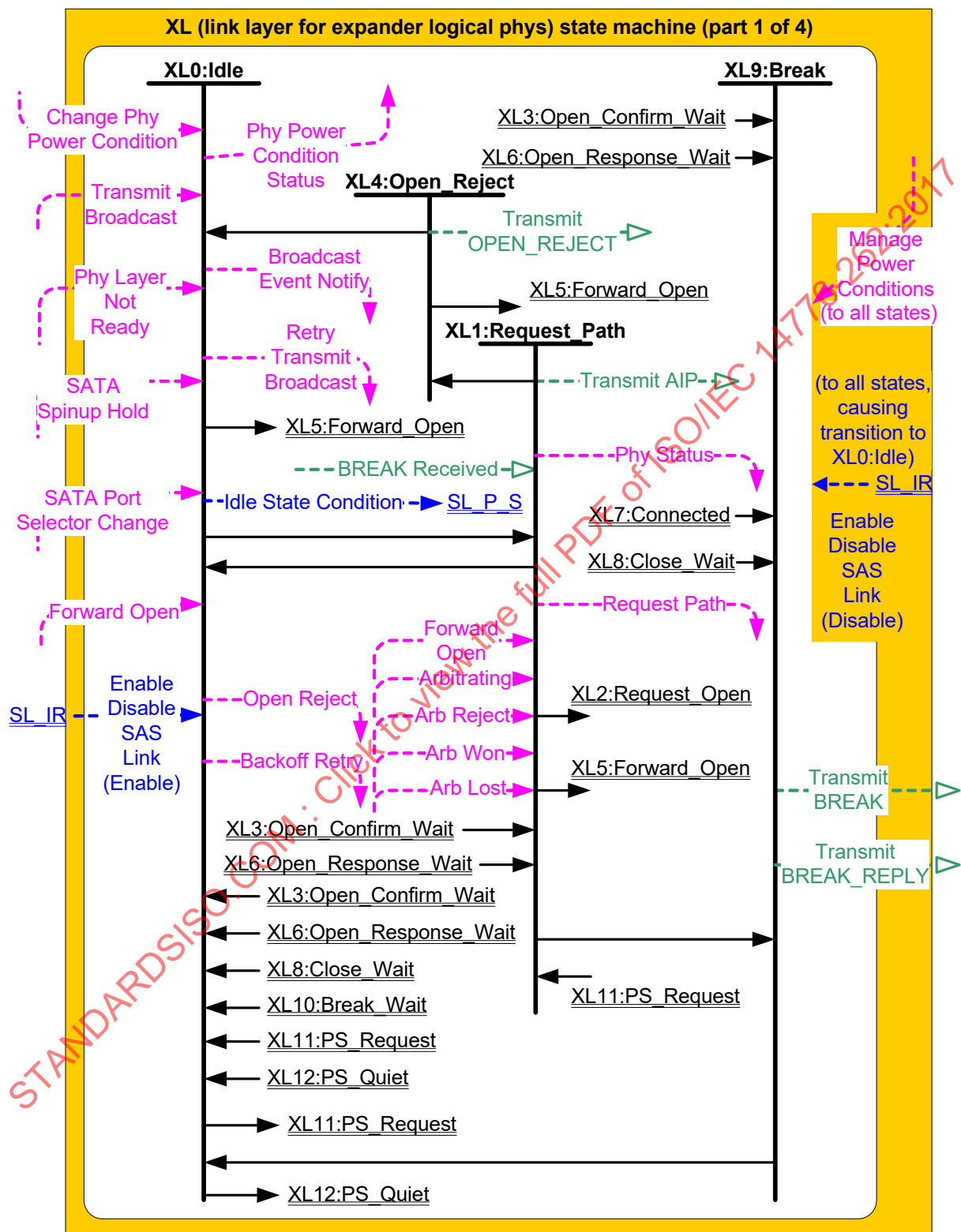


Figure 136 – XL (link layer for expander logical phys) state machine (part 1)

Figure 137 shows additional states in the XL state machine.

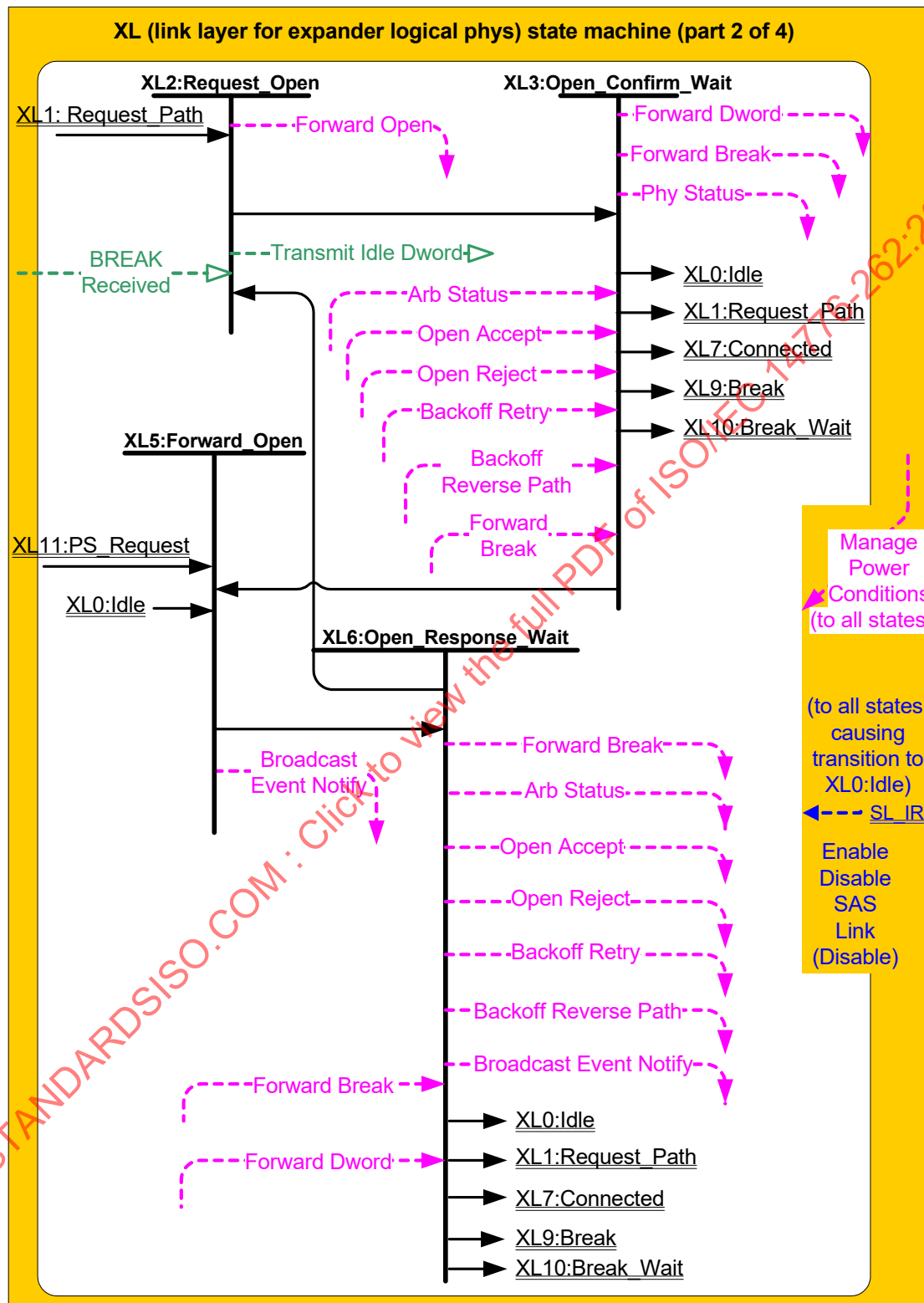


Figure 137 – XL (link layer for expander logical phys) state machine (part 2)

Figure 138 shows additional states in the XL state machine.

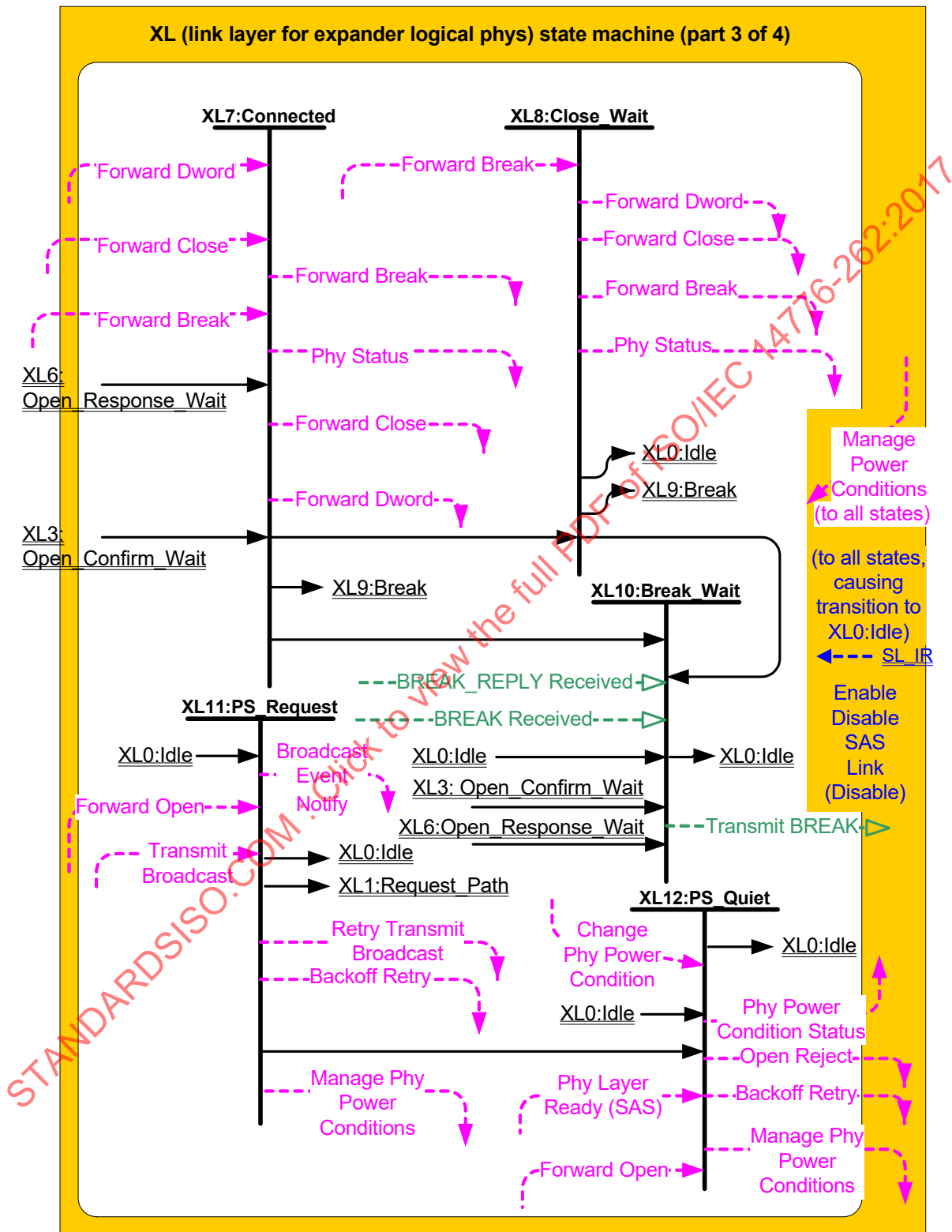


Figure 138 – XL (link layer for expander logical phys) state machine (part 3)

Figure 139 shows additional states in the XL state machine.

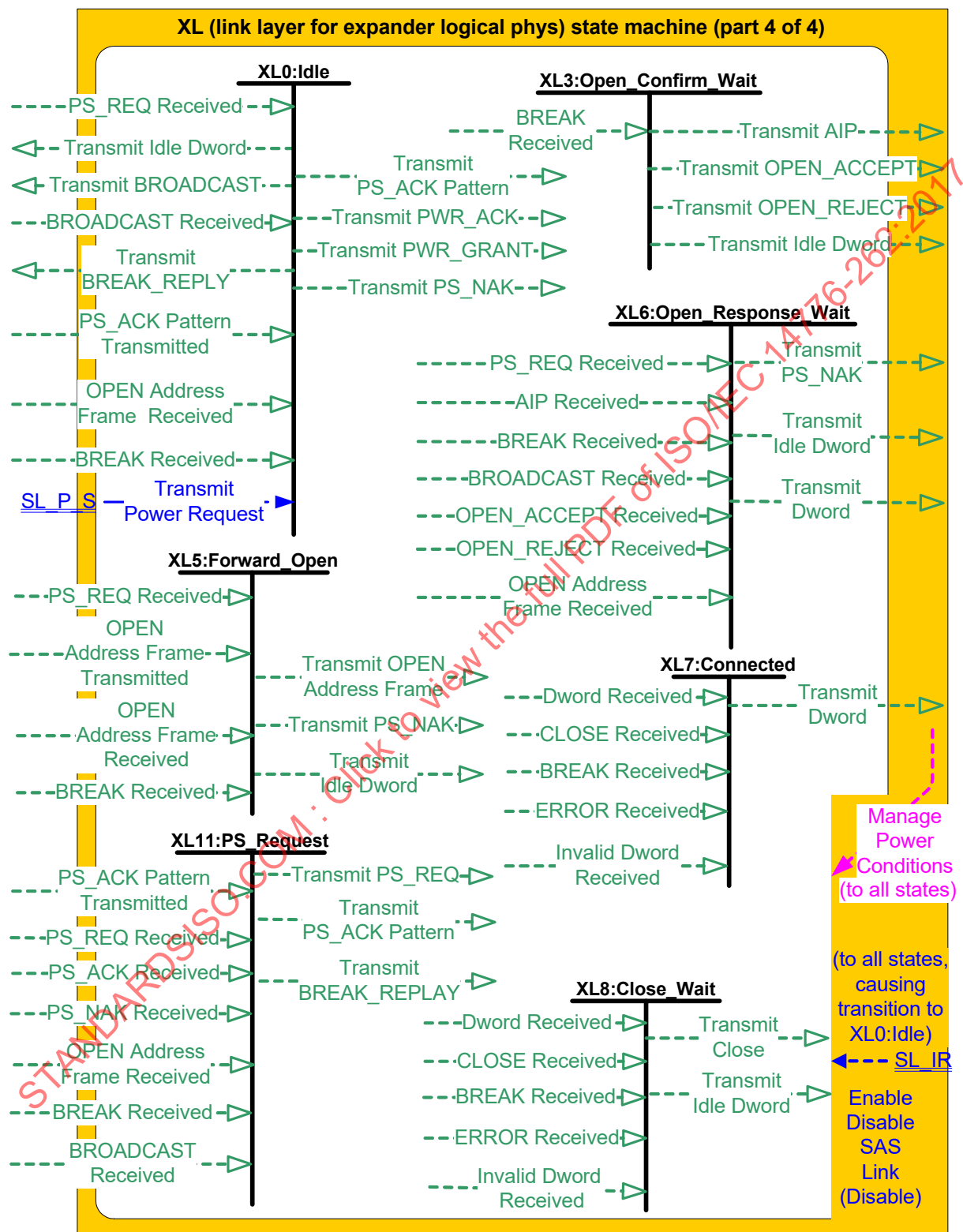


Figure 139 – XL (link layer for expander logical phys) state machine (part 4)

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) Transmit OPEN Address Frame; and
- o) 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).

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) Dword Received with an argument indicating the data dword or primitive received. Deletable primitives are not included; and
- m) 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 Transmit PS_ACK Pattern message to the XL transmitter.

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 Transmit PS_ACK Pattern message to the XL transmitter.

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 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 ECM.

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 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 from the ECM.

This transition shall include the Phy Power Condition argument (Enter Partial) 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).

6.17.3.3.2 Transition XL0:Idle to XL12:PS_Quiet

This transition shall occur after:

- a) receiving a PS_ACK Pattern Transmitted message from the XL 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).

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 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; and
- k) 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 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 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 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 after receiving an OPEN Address Frame Transmitted message.

If an OPEN Address Frame Received message or argument is received, then this state shall include an OPEN Address Frame Received argument with the transition.

If a BREAK Received message or argument is received, then this state shall include 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 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 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 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 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 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.

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,

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,

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 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 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 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 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.

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,

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,

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 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 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 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),
- d) then this state shall send a Transmit PS_ACK Pattern message to the XL transmitter.

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:

- a) receiving a PS_ACK Pattern Transmitted message from the XL transmitter; or
- b) receiving a PS_ACK Received message.

This transition shall include 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 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 ECM.

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 an Forward Open indication from the ECM, then this state shall send a Manage Phy Power Conditions (Exit) request to the phy layer and:

- a) if the phy is in a slumber phy power condition, send an Open Reject (Retry) response to the ECR; or
- b) if the phy is in 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 transmit at least one RRDY in that connection within 1 ms of transmitting an OPEN_ACCEPT. If the SSP phy is not able to grant 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).

When a connection is open and an SSP phy has no more SSP frames to transmit on that connection, the SSP phy transmits a DONE to start closing the connection (see 7.2.2.3.8). 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.

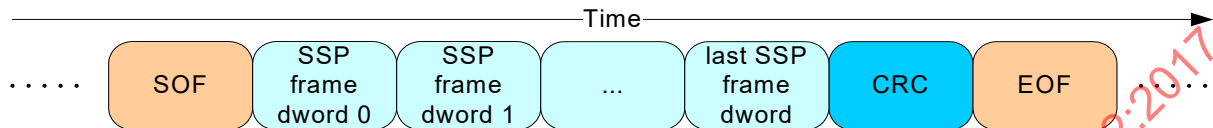


Figure 140 – SSP frame transmission

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 6.18.8.7). 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 6.18.8.7, 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 6.18.8.2).

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 RRDY to grant credit for permission for the other SSP phy in the connection to transmit frames. Each RRDY increments credit by one frame. Frame transmission decrements credit by one frame. Credit of zero frames is established at the beginning of each connection.

SSP phys shall not increment credit past 255 frames.

To prevent deadlocks where an SSP initiator port and SSP target port are both waiting on each other to provide credit, an SSP initiator port shall not refuse to provide credit by withholding RRDY because the SSP initiator port is waiting to transmit a frame. An SSP initiator port may refuse to provide credit for other reasons (e.g., temporary buffer full conditions).

An SSP target port may refuse to provide credit for any reason, including because the SSP target port is waiting to transmit a frame.

If credit is zero, SSP phys that are going to be unable to provide 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 6.18.8).

If credit is nonzero, SSP phys that are going to be unable to provide additional credit for 1 ms, even if they receive frames per the existing credit, may transmit CREDIT_BLOCKED.

After sending CREDIT_BLOCKED, an SSP phy shall not transmit any additional RRDYs in the connection.

6.18.5 Interlocked frames

Table 144 shows which SSP frames shall be interlocked and which are non-interlocked.

Table 144 – SSP frame interlock requirements

SSP frame type	Interlock requirement
COMMAND	Interlocked
TASK	Interlocked
XFER_RDY	Interlocked
DATA	Non-interlocked
RESPONSE	Interlocked
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 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 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 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 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 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 receive 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.

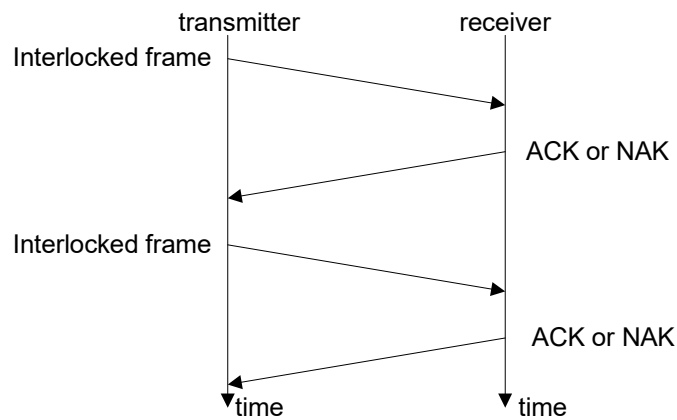
**Figure 141 – Interlocked frames**

Figure 142 shows an example of non-interlocked frame transmission with the same initiator port transfer tags.

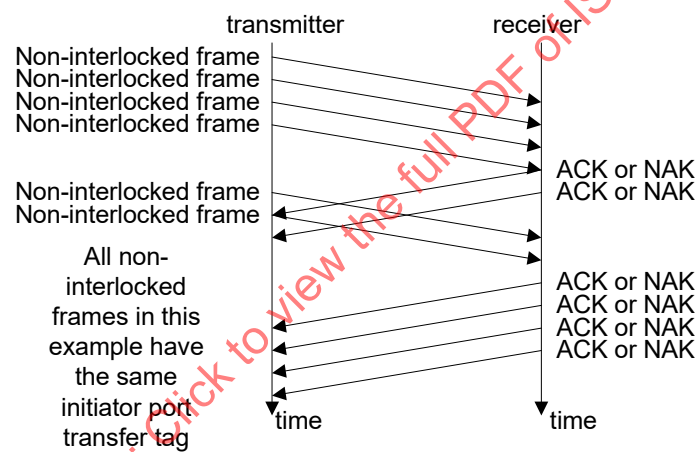
**Figure 142 – Non-interlocked frames with the same initiator port transfer tags**

Figure 143 shows an example of non-interlocked frame transmission with different initiator port transfer tags.

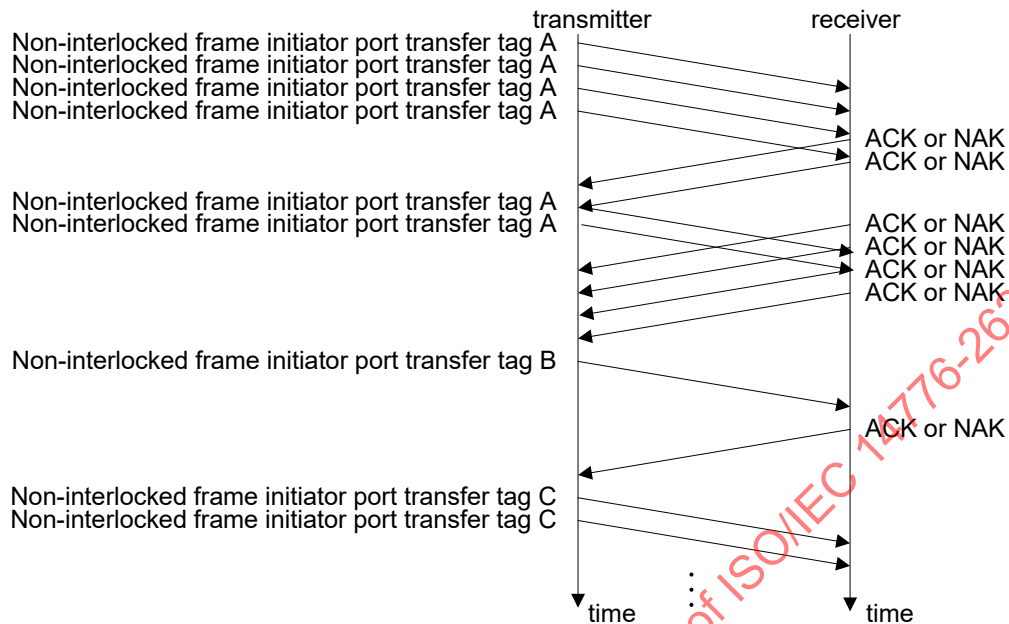


Figure 143 – Non-interlocked frames with different initiator port transfer tags

6.18.6 Breaking an SSP connection

In addition to the actions described in 6.14.8, 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
- 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.

6.18.7 Closing an SSP connection

DONE shall be exchanged prior to closing an SSP connection (see 7.2.2.3.8). The type of DONE indicates additional information about why the SSP connection is being closed as follows:

- DONE (NORMAL) specifies that the transmitter has no more SSP frames to transmit (i.e., normal completion);
- DONE (CREDIT TIMEOUT) specifies that the transmitter still has SSP frames to transmit but did not receive an RRDY granting frame credit within 1 ms, or the transmitter has received a CREDIT_BLOCKED and has consumed all RRDYs received; and
- 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.

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 6.18.8.5).

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 6.14.7).

Figure 144 shows the sequence for a closing an SSP connection.

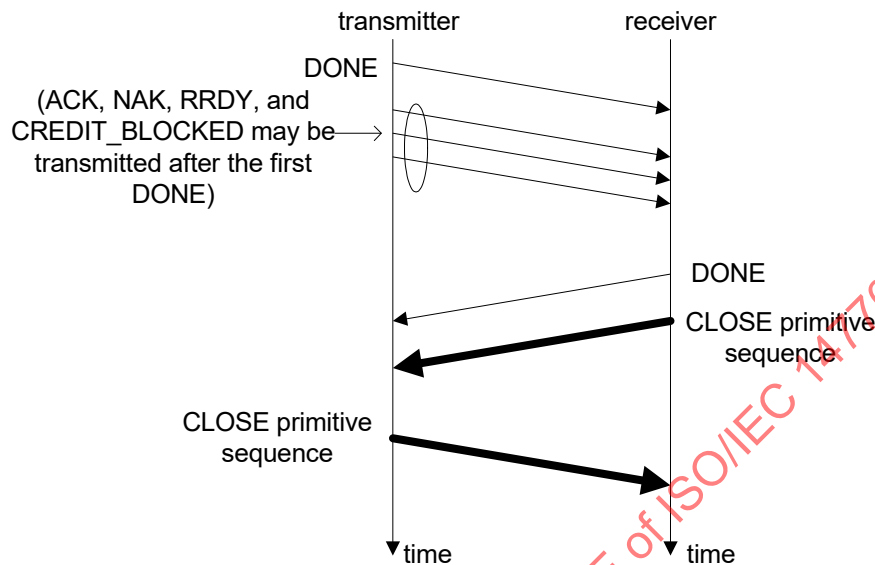


Figure 144 – Closing an SSP connection example

6.18.8 SSP (link layer for SSP phys) state machines

6.18.8.1 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:

- SSP_TIM (transmit interlocked frame monitor) state machine (see 6.18.8.3);
- SSP_TCM (transmit frame credit monitor) state machine (see 6.18.8.4);
- SSP_D (DONE control) state machine (see 6.18.8.5);
- SSP_TF (transmit frame control) state machine (see 6.18.8.6);
- SSP_RF (receive frame control) state machine (see 6.18.8.7);
- SSP_RCM (receive frame credit monitor) state machine (see 6.18.8.8);
- SSP_RIM (receive interlocked frame monitor) state machine (see 6.18.8.9);
- SSP_TC (transmit credit control) state machine (see 6.18.8.10); and
- SSP_TAN (transmit ACK/NAK control) state machine (see 6.18.8.11).

All the SSP state machines shall start after receiving an Enable Disable SSP (Enable) message from the SL state machines (see 6.16).

All the SSP state machines shall terminate after:

- receiving an Enable Disable SSP (Disable) message from the SL state machines;
- receiving a Request Close message from the SSP_D state machine indicating that the connection has been closed;
- receiving a Request Break message from the SSP_D state machine indicating that a BREAK primitive sequence has been transmitted; or
- 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 145.

Table 145 – SSP state machines timers

Timer	Initial value	State machine	Reference
ACK/NAK Timeout timer	1 ms	SSP_TIM	6.18.8.3
DONE Timeout timer	1 ms	SSP_D	6.18.8.5
Credit Timeout timer	1 ms	SSP_TF	6.18.8.6

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 145 shows the SSP state machines and states related to frame transmission.

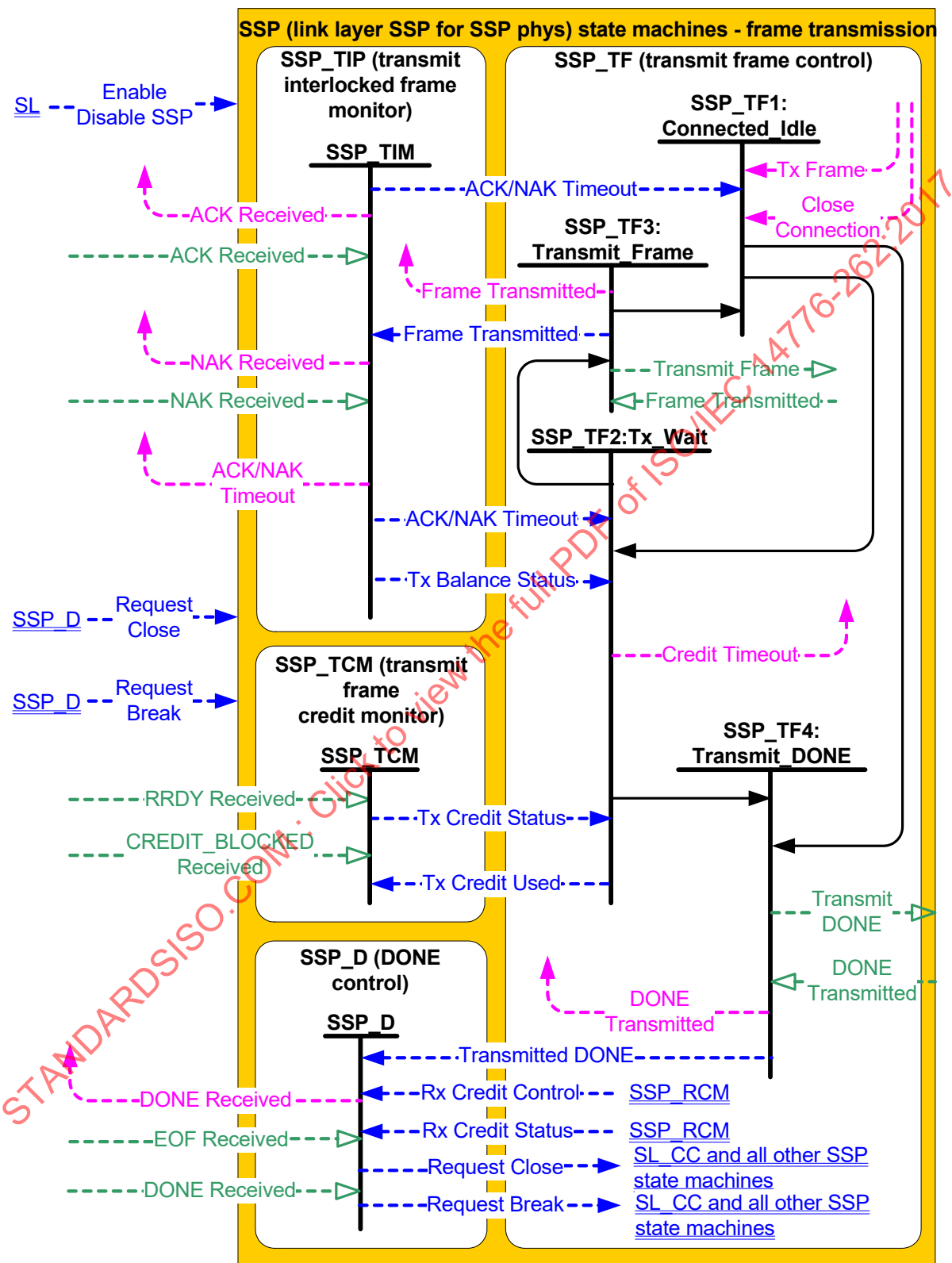


Figure 145 – SSP (link layer for SSP phys) state machines (part 1 - frame transmission)

Figure 146 shows the SSP state machines and states related to frame reception.

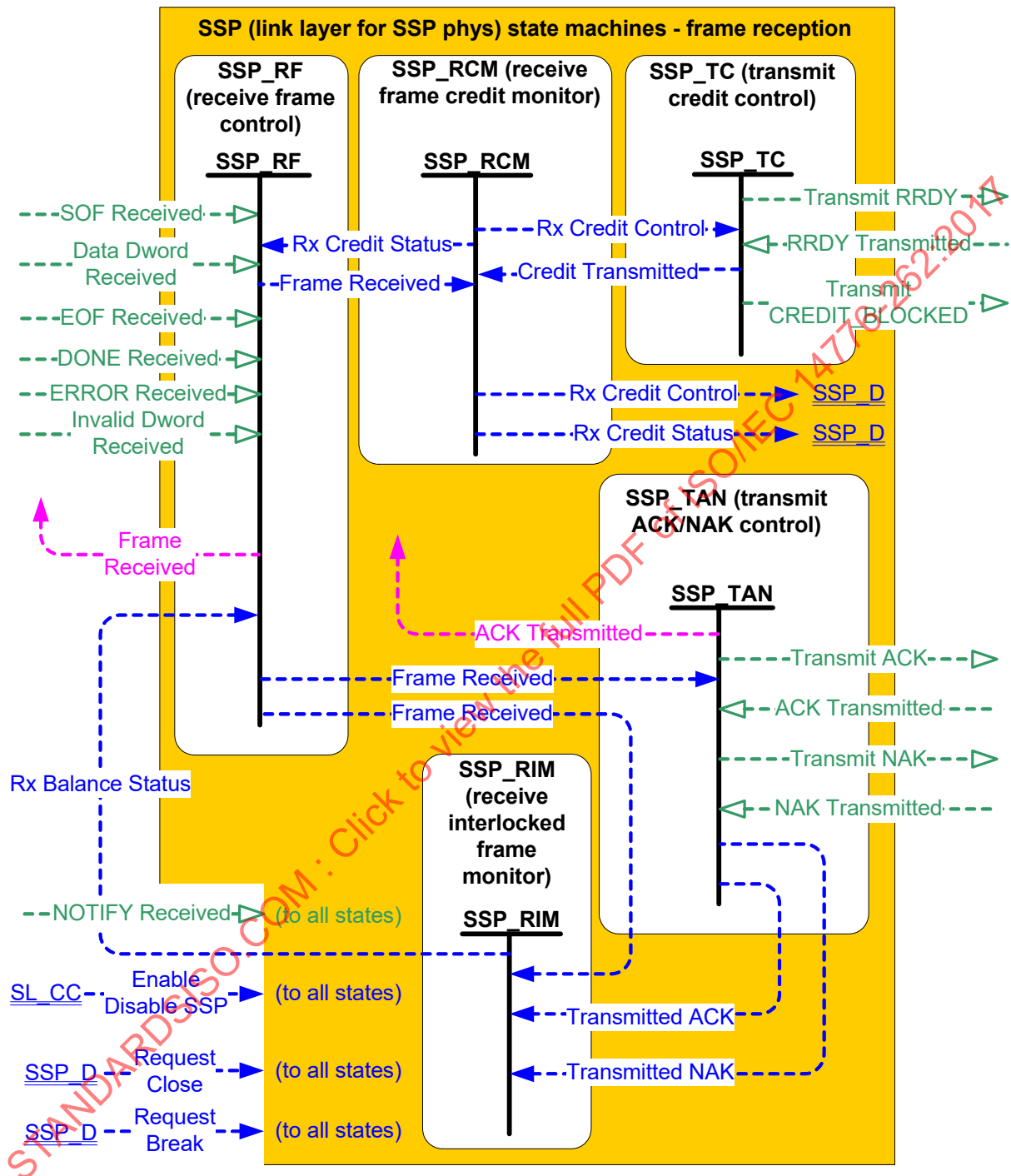


Figure 146 – SSP (link layer for SSP phys) state machines (part 2 - frame reception)

6.18.8.2 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;

- d) Transmit NAK with an argument indicating the specific type (e.g., Transmit NAK (CRC Error));
- e) Transmit Frame with an argument containing the frame contents; and
- f) Transmit DONE with an argument indicating the specific type (e.g., Transmit DONE (Normal)).

In response to the Transmit Frame message, the SSP transmitter transmits:

- 1) SOF;
- 2) the frame contents;
- 3) CRC; and
- 4) EOF.

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) ACK Transmitted;
- e) NAK Transmitted; and
- f) 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;
- 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; and
- k) 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.

6.18.8.3 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 send the Tx Balance Status (Balanced) message to the SSP_TF2:Tx_Wait state. 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.

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 an 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.

6.18.8.4 SSP_TCM (transmit frame credit monitor) state machine

The SSP_TCM state machine's function is to ensure that transmit 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 frame credits available. This state machine shall add one transmit frame credit for each RRDY Received message received and subtract one transmit frame credit for each Tx Credit Used message received.

The CREDIT_BLOCKED Received message indicates that transmit 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.

While transmit 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 frame credit is not available and transmit 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 frame credit is not available and transmit 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 frame credit to not available and transmit frame credit shall be set to not blocked.

6.18.8.5 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 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) a Rx Credit Status (Extended) message is received; or
- b) a 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 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) 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).

6.18.8.6 SSP_TF (transmit frame control) state machine

6.18.8.6.1 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 6.18.8.6.2) (initial state);

- b) SSP_TF2:Tx_Wait (see 6.18.8.6.3);
- c) SSP_TF3:Transmit_Frame (see 6.18.8.6.4); and
- d) SSP_TF4:Transmit_DONE (see 6.18.8.6.5).

This state machine shall start in the SSP_TF1:Connected_Idle state.

6.18.8.6.2 SSP_TF1:Connected_Idle state

6.18.8.6.2.1 State description

This state waits for a request to transmit a frame or to close the connection.

6.18.8.6.2.2 Transition SSP_TF1:Connected_Idle to SSP_TF2:Tx_Wait

This transition shall occur after a Tx Frame request is received or a Close Connection request is received.

If a Tx Frame (Balance Required) request was received, then this transition shall include a Transmit Frame Balance Required argument.

If a Tx Frame (Balance Not Required) request was 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.

6.18.8.6.2.3 Transition SSP_TF1:Connected_Idle to SSP_TF4:Transmit_DONE

This transition shall occur if an ACK/NAK Timeout message is received. This transition shall include an ACK/NAK Timeout argument.

6.18.8.6.3 SSP_TF2:Tx_Wait state

6.18.8.6.3.1 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:

- a) if the last Tx Credit Status message received had an argument of Not Available, then this state shall initialize and start the Credit Timeout timer; or
- b) if the last Tx Credit Status message had an argument other than Not Available, then this state shall stop the Credit Timeout timer.

6.18.8.6.3.2 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:

- a) the last Tx Balance Status message received had an argument of Balanced; and
- b) the last 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 after sending a Tx Credit Used message to the SSP_TCM state machine.

6.18.8.6.3.3 Transition SSP_TF2:Tx_Wait to SSP_TF4:Transmit_DONE

This transition shall occur and include 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 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.

6.18.8.6.4 SSP_TF3:Transmit_Frame state

6.18.8.6.4.1 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.

6.18.8.6.4.2 Transition SSP_TF3:Transmit_Frame to SSP_TF1:Connected_Idle

This transition shall occur after:

- a) receiving a Frame Transmitted message;
- b) sending an Frame Transmitted message to the SSP_TIM state machine; and
- c) sending a Frame Transmitted confirmation to the port layer.

6.18.8.6.5 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 (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 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.

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;
- 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.

6.18.8.7 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:

- a) this state receives more than 263 Data Dword Received messages (i.e., 1 052 bytes) after an SOF Received message and before an EOF Received message;
- b) this state receives fewer than 7 Data Dword Received messages (i.e., 28 bytes) after an SOF Received message and before an EOF Received message,
- c) this state receives an Rx Credit Status (Credit Exhausted) message; or
- d) this state receives 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:

- a) send a Frame Received message to the SSP_RCM state machine;
- b) send a Frame Received message to the SSP_RIM state machine; and
- c) send 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 Frame Received (Successful) message to the SSP_TAN state machine, and:

- a) send a Frame Received message to the SSP_RCM state machine;
- b) send a Frame Received message to the SSP_RIM state machine; and
- c) send a Frame Received (Successful) message to the SSP_TAN state machine, and:
 - A) if the last Rx Balance Status message received had an argument of Balanced, then send a Frame Received (ACK/NAK Balanced) confirmation to the port layer; or
 - B) if the last Rx Balance Status message received had an argument of Not Balanced, then send a Frame Received (ACK/NAK Not Balanced) confirmation to the port layer.

6.18.8.8 SSP_RCM (receive frame credit monitor) state machine

The SSP_RCM state machine's function is to ensure that there was 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.

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.

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 a 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 a 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 credit value for the current connection.

6.18.8.9 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.

6.18.8.10 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 a Rx Credit Control (Available) message, then this state machine shall send a number of Transmit RRDY (Normal) messages to the SSP transmitter as indicated by the 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).

If this state machine receives a RRDY Transmitted message, then this state machine shall send a Credit Transmitted message to the SSP_RCM state machine.

If this state machine receives a Rx Credit Control (Blocked) message, then this state machine shall send a Transmit CREDIT_BLOCKED message to the SSP transmitter.

6.18.8.11 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:

- a) send a Transmitted ACK message to the SSP_RIM state machine; and
- b) send 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.

6.19 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 147.

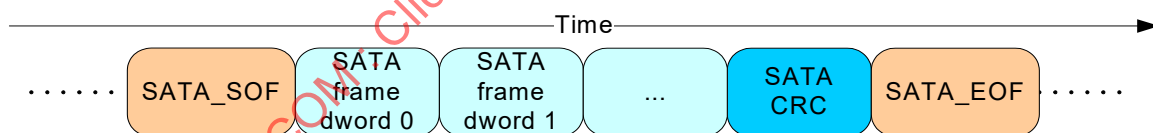


Figure 147 – STP frame transmission

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 146 summarizes STP link layer differences from the SATA link layer (see SATA) that affect behavior during an STP connection.

Table 146 – 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_HOLD_A.

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. 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.

NOTE 41 - SATA requires that frame transmission cease and SATA_HOLD_A be transmitted within 20 data dwords of receiving SATA_HOLD. Since the SATA physical link has non-zero propagation time, 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 (e.g., including data dwords, deletable primitives, SATA_EOF, and SATA_HOLDs followed by data dwords) after receiving SATA_HOLD before responding with SATA_HOLD_A.

NOTE 42 - SATA assumes that once a SATA_HOLD is transmitted, frame transmission ceases and SATA_HOLD_A arrives within 20 dwords. Since the SATA physical link has non-zero propagation time, one dword of margin is included.

While transmitting SATA_HOLD or SATA_HOLD_A, 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 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 (4×2^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);
- 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 (9.375×2^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);
- 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.

- 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:

$$\text{Minimum STP flow control buffer size} = (20 + ((2 \times Pd \times R) / 40))$$

where:

Pd 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 = $[20 + ((2 \times Pd \times R) / 40)]$. The 20 portion of this equation is based on the frame transmitter requirements (see SATA). The $[(2 \times Pd \times R) / 40]$ portion of this equation is the number of dwords on the wire during a round trip: $2 \times Pd$ 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 148 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

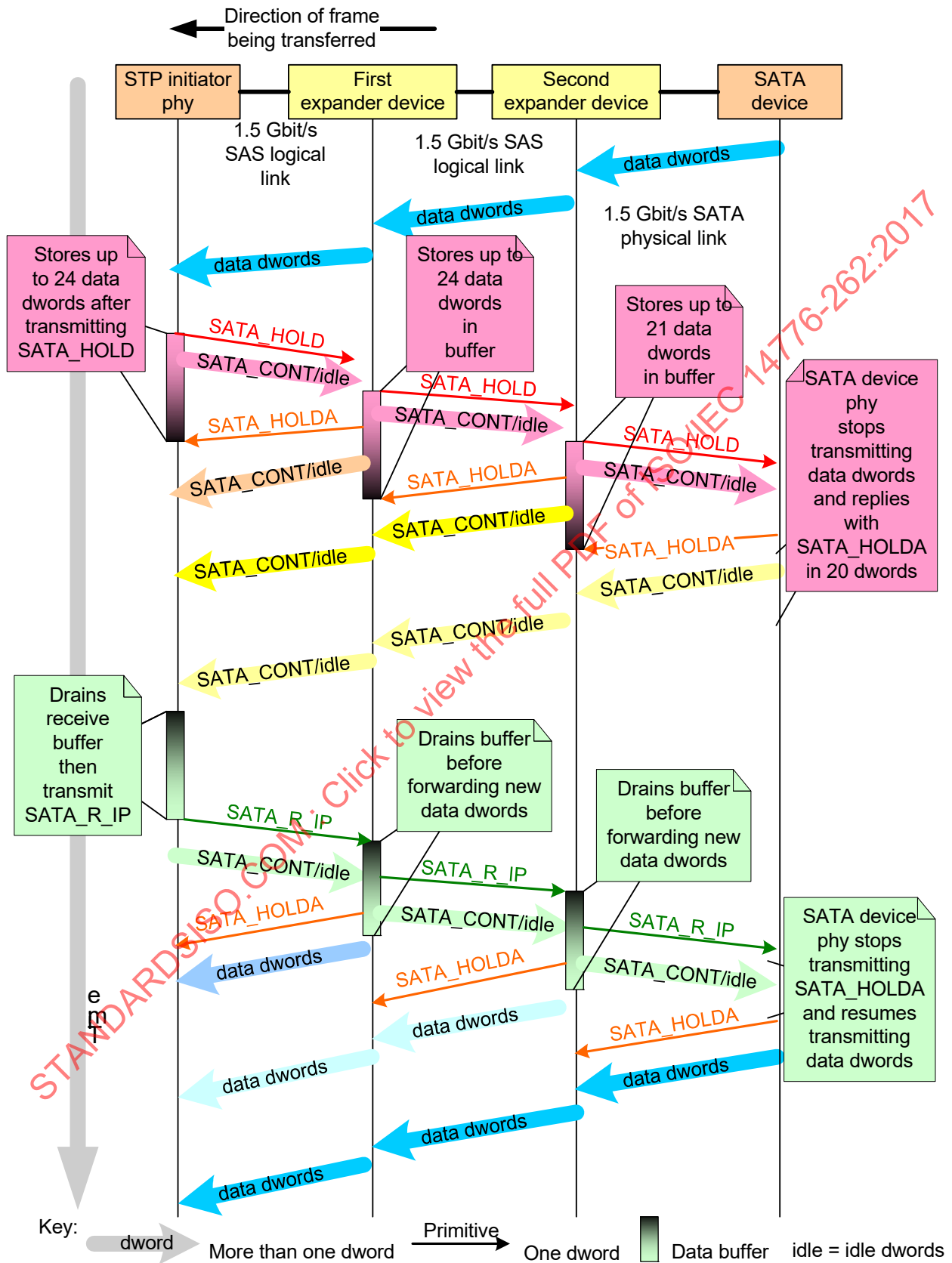


Figure 148 – STP flow control

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:

- a) the STP_BUFFER_TOO_SMALL bit set to one in the SMP_DISCOVER response (see 9.4.3.10); and
- b) the STP_BUFFER_TOO_SMALL bit set to one in 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 149 shows an example of transmitting a continued primitive sequence.

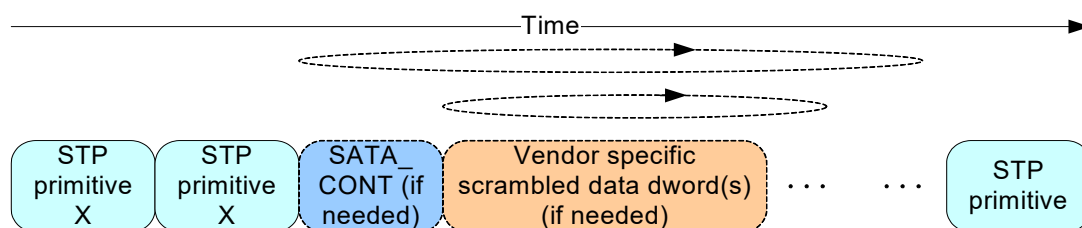


Figure 149 – Transmitting a continued primitive sequence

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 150 shows an example of receiving a continued primitive sequence.

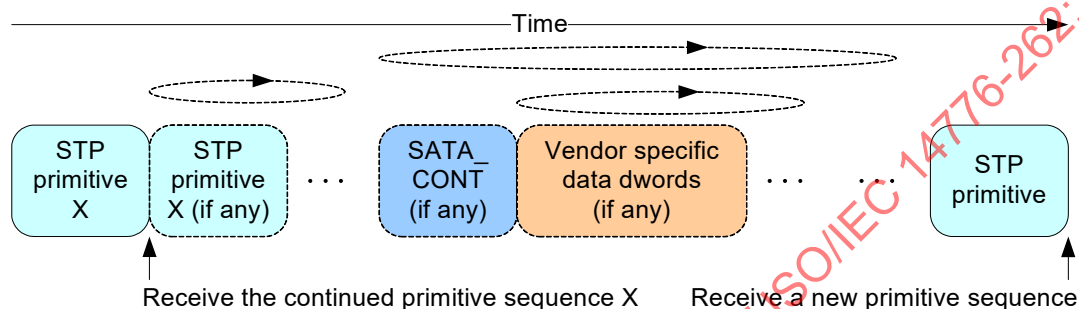


Figure 150 – Receiving a continued primitive sequence

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 147.

Table 147 – 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:

- a) ensure that the SATA NCQ tags in commands issued to the SATA device are unique across all affiliations;
- b) 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);
- c) 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
- d) 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:

- a) power on;
- b) 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;
- c) 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;
- d) 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;
- e) an STP connection to a phy in the STP target port is closed with a CLOSE (CLEAR AFFILIATION) primitive sequence; or
- f) 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 148.

Table 148 – 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 DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data (see ACS-2) receives a connection request for a SATA device before it has retrieved the IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI device data, then it shall return an OPEN_REJECT (NO DESTINATION). If the STP SATA bridge has a problem retrieving the IDENTIFY DEVICE data from an ATA device or IDENTIFY PACKET DEVICE data from an ATAPI 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:

- 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 151 shows an example of the simultaneous connection recommendations for an expander device containing STP ports. Multiplexing is disabled in this example.

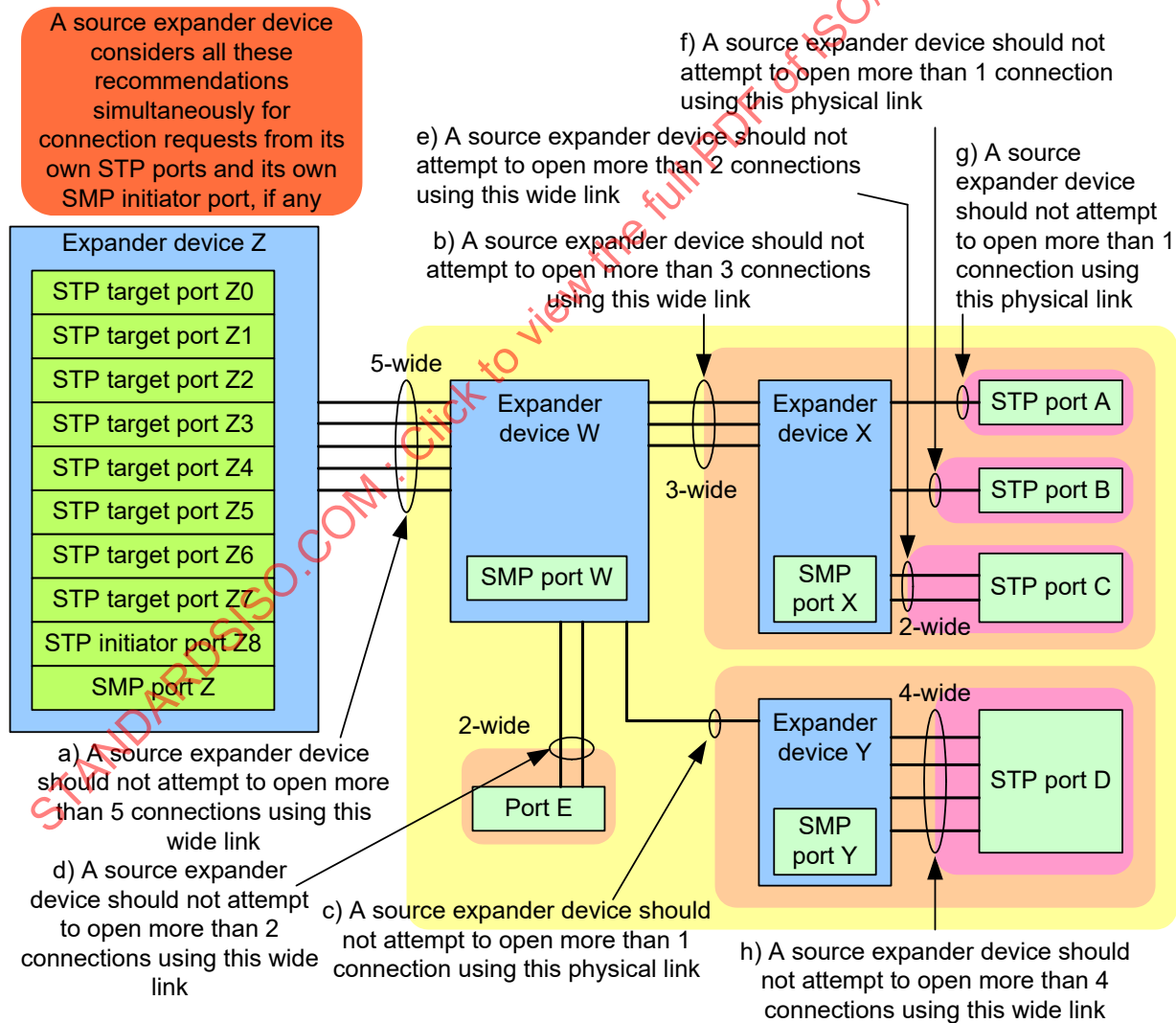


Figure 151 – Example simultaneous connection recommendations for an expander device

In figure 151, 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 6.14.7 for additional details on closing connections.

An STP SATA bridge shall break an STP connection if its SATA host phy loses dword synchronization (see 6.14.8).

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 152 shows an STP initiator port opening a connection, transmitting a single SATA frame, and closing the connection.

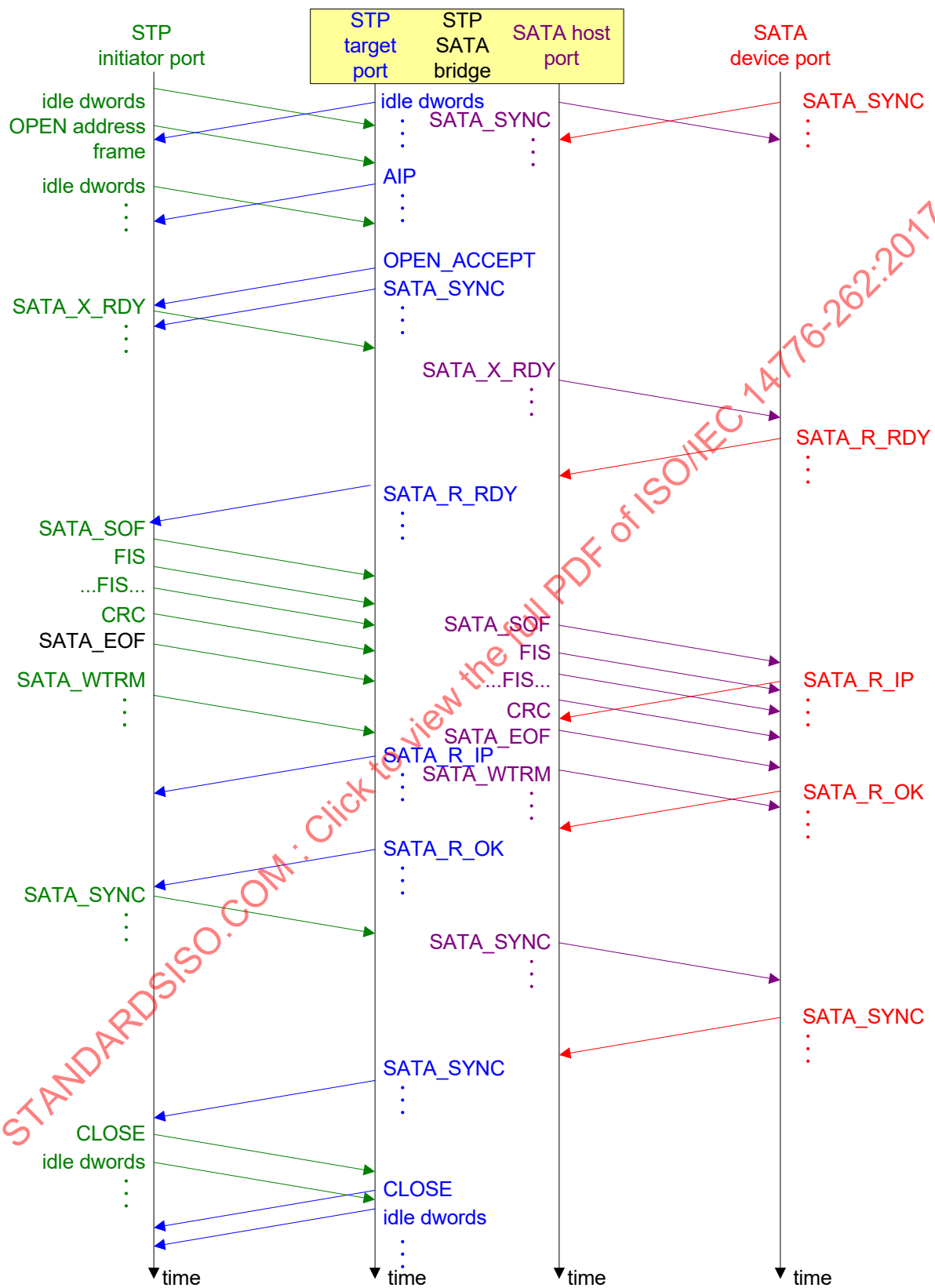


Figure 152 – STP initiator port opening an STP connection

Figure 153 shows a SATA device transmitting a SATA frame. In this example, the STP target port in the STP SATA bridge opens a connection to an STP initiator port to send just one frame, then closes the connection.

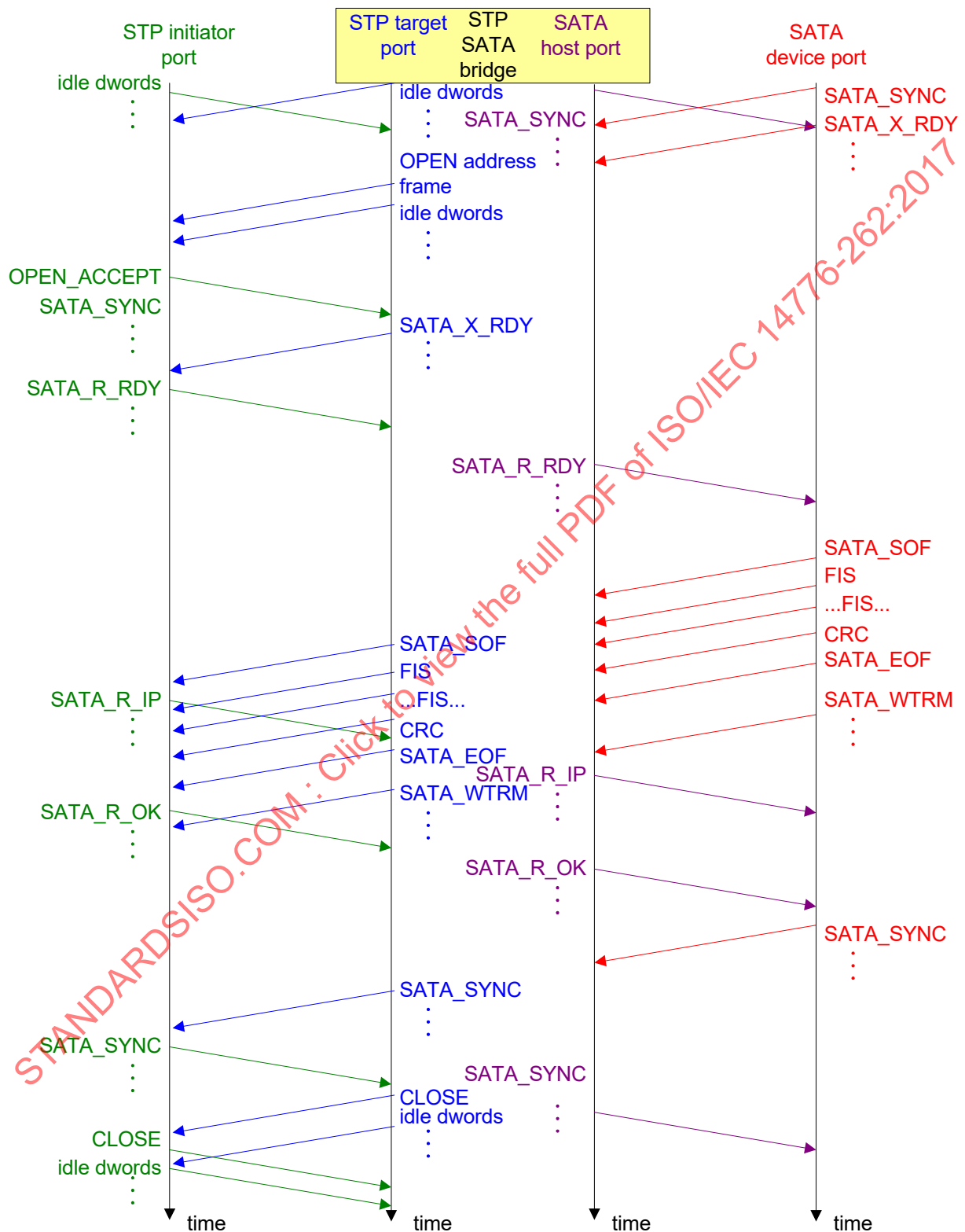


Figure 153 – STP target port opening an STP connection

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 154. 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 credit exchange with RRDY.

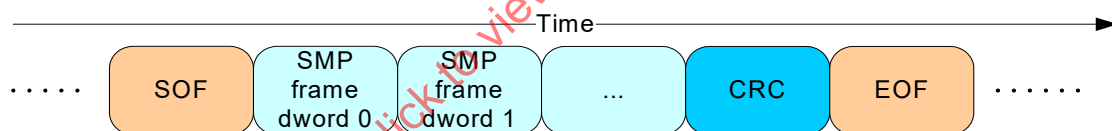


Figure 154 – SMP frame transmission

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 6.14.7 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:

- a) SMP_IP1:Idle (see 6.20.5.3.2) (initial state);
- b) SMP_IP2:Transmit_Frame (see 6.20.5.3.3); and
- c) 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 155 shows the SMP_IP state machine.

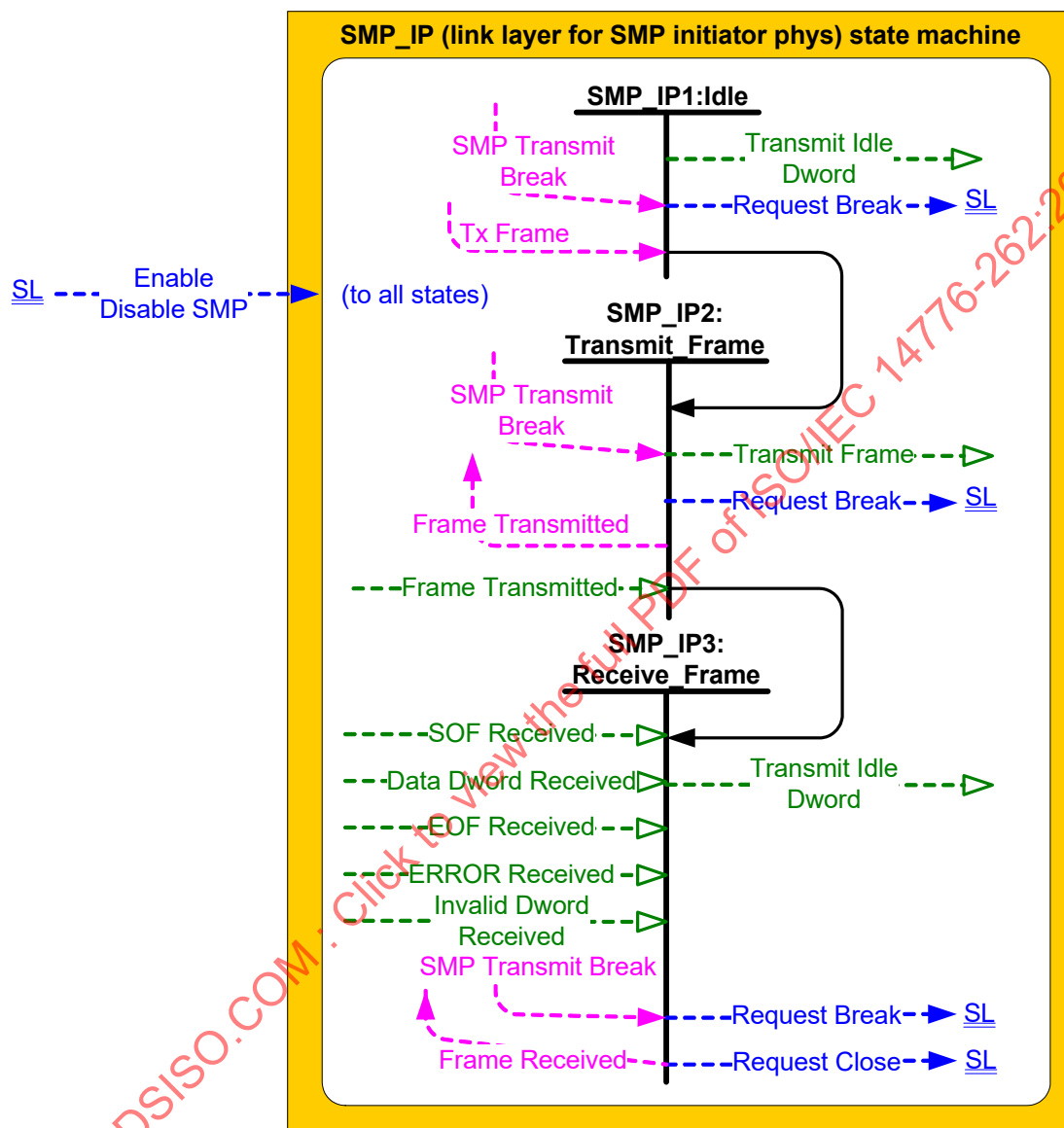


Figure 155 – SMP_IP (link layer for SMP initiator phys) state machine

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 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 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 previous versions of the standard may send vendor specific SMP frames containing 258 data dwords (i.e., 1 032 bytes).

- b) this state receives fewer than 2 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:

- a) send a Frame Received (SMP Successful) confirmation to the port layer; and
- b) send 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:

- SMP_TP1:Receive_Frame (see 6.20.5.4.2) (initial state); and
- 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 156 shows the SMP_TP state machine.

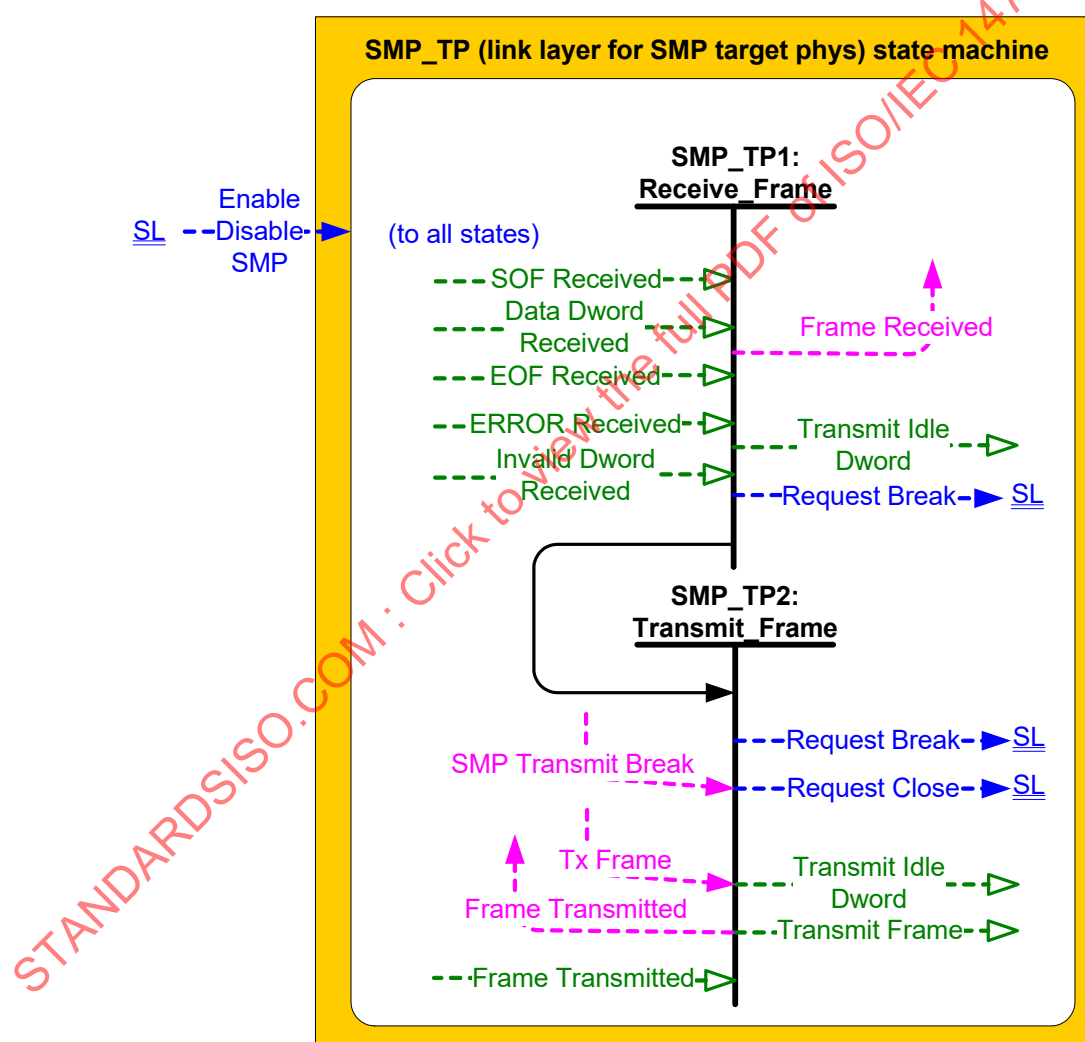


Figure 156 – SMP_TP (link layer for SMP target phys) state machine

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:

- 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 48 - SMP initiator phys compliant with previous versions of the standard may send vendor specific SMP frames containing 258 data dwords (i.e., 1 032 bytes).

- b) this state receives fewer than 2 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 and transport layers.

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) send requests to the SAS link layer state machines for connection management and frame transmission;
- c) receive confirmation from the SAS link layer state machines; and
- d) send confirmations to the SSP, SMP, and STP transport layer state machines.

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 157 shows examples of the port layer state machines and their interaction with the transport and link layers.

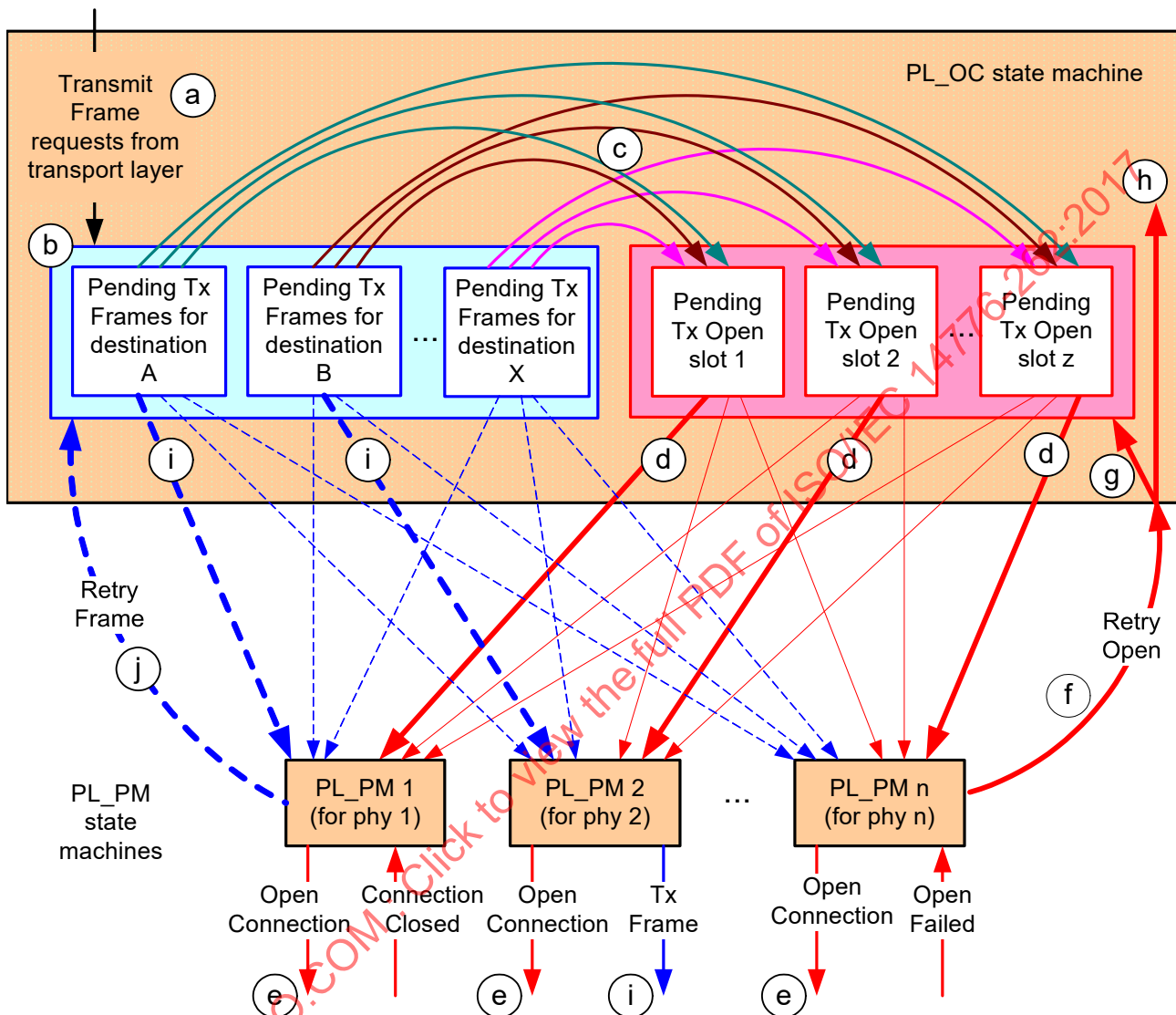


Figure 157 – Port layer examples

The following is a description of the example processes in figure 157. 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;
- 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 frame, 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 a 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) selects frames to transmit;
- e) selects phys on which to transmit frames;
- f) receives confirmations from the link layer;
- g) sends confirmations to the transport layer;
- h) has Arbitration Wait Time timers;
- i) has I_T Nexus Loss timers; and
- j) 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) a pool of pending Tx Frame messages for each destination SAS address; and
- b) a pool of pending 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 149.

Table 149 – 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: 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); 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); 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); 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; 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 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: 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); b) for SSP initiator ports, a vendor specific value; 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 d) for STP initiator ports, a vendor specific value.

PL_OC (port layer overall control)

The diagram illustrates the interaction between PL_OC1:Idle and PL_OC2:Overall_Control. The diagram shows various states and transitions, including Transmit Frame, Phy Enabled, HARD_RESET Received, Accept_Reject OPENS, and PL_PM messages. A large watermark 'Click to view the full PDF of ISO/IEC 14776-2:2017' is overlaid on the diagram.

Figure 158 – 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.

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:

- a) the protocol is 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) the protocol is 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) the protocol is 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.

This state may create an I_T Nexus Loss timer for that SAS address if:

- a) the protocol is SSP and the port is an SSP initiator port; or
- b) the protocol is STP and the port is an STP initiator port.

When this state creates an I_T Nexus Loss timer it shall:

- 1) initialize the I_T Nexus Loss timer as specified in table 149 (see 7.2.2.1); and
- 2) not start the 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.

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.

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.

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.

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 the destination SAS address, and the I_T Nexus Loss timer is not running, then this state shall:

- 1) initialize the I_T Nexus Loss timer; and
- 2) start the I_T Nexus Loss timer.

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 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 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 7.2.2.3.5).

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:

- a) if the I_T Nexus Loss timer is running, then this state shall not stop the timer; and
- b) 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 7.2.2.3.5).

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 149).

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 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 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 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:

- a) set the pathway blocked count argument in the Tx Open message to zero; and
- b) set 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:

- a) the protocol for the connection is 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) the protocol for the connection is 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 149 (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, then:

- a) if the Retry Open pathway blocked count argument is FFh, then this state shall set the Tx Open pathway blocked count argument to FFh; and
- b) if the Retry Open pathway blocked count argument is 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.

7.2.2.3.3 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 149).

7.2.2.3.4 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 150, then this state shall establish an I_T nexus loss event (see 7.2.2.3.7).

Table 150 defines the confirmation to be sent to the transport layer for each Unable To Connect message received.

Table 150 – 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)

7.2.2.3.5 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 7.2.2.3.7).

7.2.2.3.6 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 7.2.2.3.7).

7.2.2.3.7 PL_OC2:Overall_Control state - I_T nexus loss

If an I_T nexus loss event occurs, then this state shall perform the following:

- delete the I_T Nexus Loss timer for the SAS address;
- discard the Retry Open message;
- send a Transmission Status (I_T Nexus Loss) confirmation for the pending Tx Frame message from which the Retry Open message resulted;
- discard the pending Tx Frame message from which the Retry Open message resulted;
- 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

- 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 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.

7.2.2.3.8 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 this port is an SSP port, there are no pending Tx Frame messages for a destination SAS address with which a PL_PM state machine has established a connection, and 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 this port is an SSP port, has no pending Tx Frame messages for a destination SAS address with which a PL_PM state machine has established a connection, and 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 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).

7.2.2.3.9 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.

7.2.2.3.10 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.

7.2.2.3.11 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 151.

Table 151 – 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: a) for SSP target ports, the value in the BUS INACTIVITY TIME LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2); b) for STP target ports, the value in the STP BUS INACTIVITY TIME LIMIT field in the SMP REPORT GENERAL response (see 9.4.3.4); c) for SSP initiator ports, the value in the BUS INACTIVITY TIME LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2) of the destination SSP target port; or d) for STP initiator ports, the value in the STP BUS INACTIVITY TIME LIMIT field in the SMP REPORT GENERAL response (see 9.4.3.4) of the destination STP target port.
Maximum Connect Time Limit timer	Depending on the protocol used by the port: a) for an SSP target port, the value in the MAXIMUM CONNECT TIME LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2); b) for an STP target port, the value in the STP MAXIMUM CONNECT TIME LIMIT field in the SMP REPORT GENERAL response; c) for an SMP target port, 2 ms; d) for an SSP initiator port, the value in the MAXIMUM CONNECT TIME LIMIT field in the Disconnect-Reconnect mode page (see 9.2.7.2) of the destination SSP target port; or e) for an STP initiator port, the value in the STP MAXIMUM CONNECT TIME LIMIT field in the SMP REPORT GENERAL response of the destination STP target port.

Figure 159 shows part 1 of the PL_PM state machine.

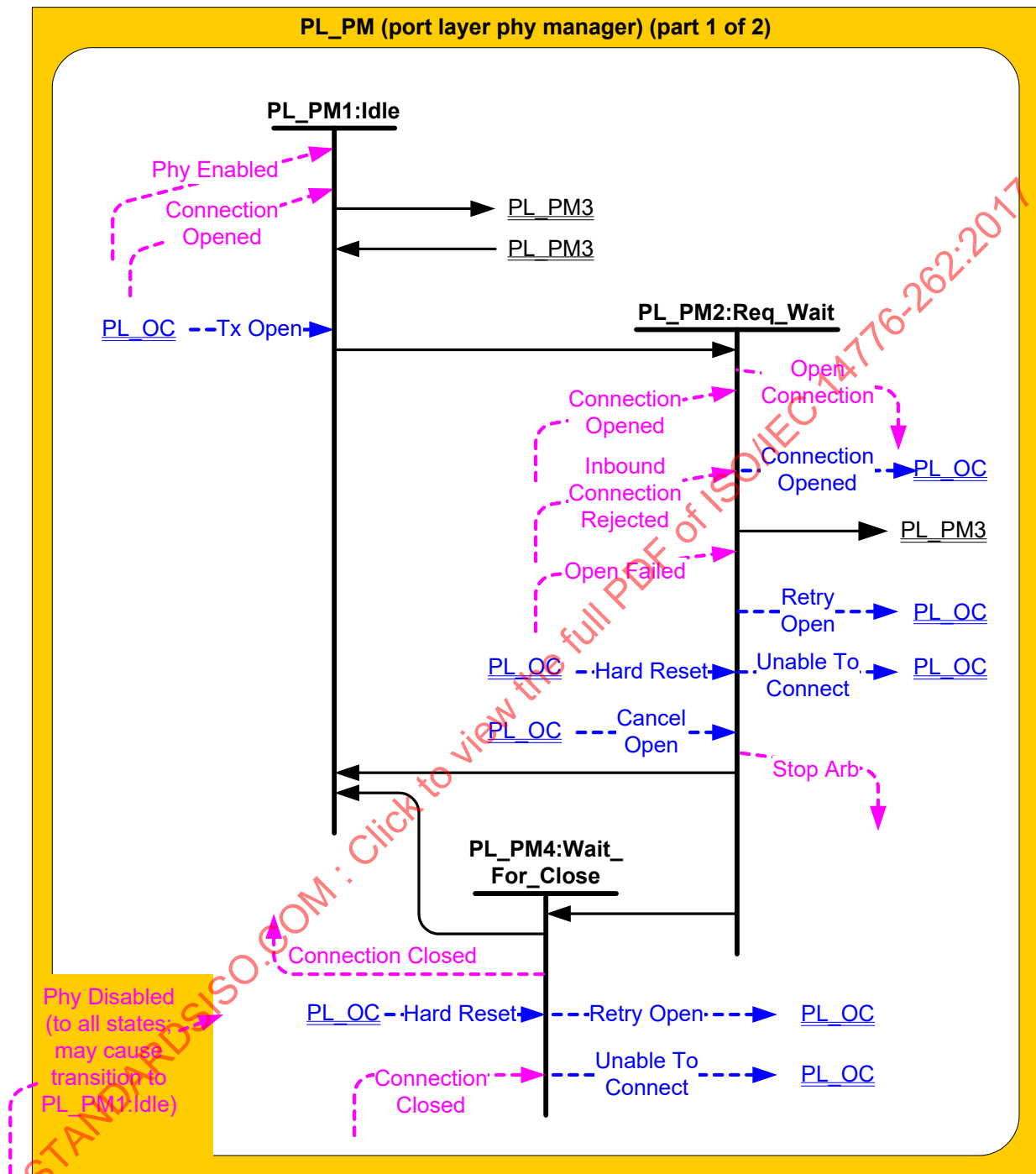


Figure 159 – PL_PM (port layer phy manager) state machine (part 1)

Figure 160 shows part 2 of the PL_PM state machine.

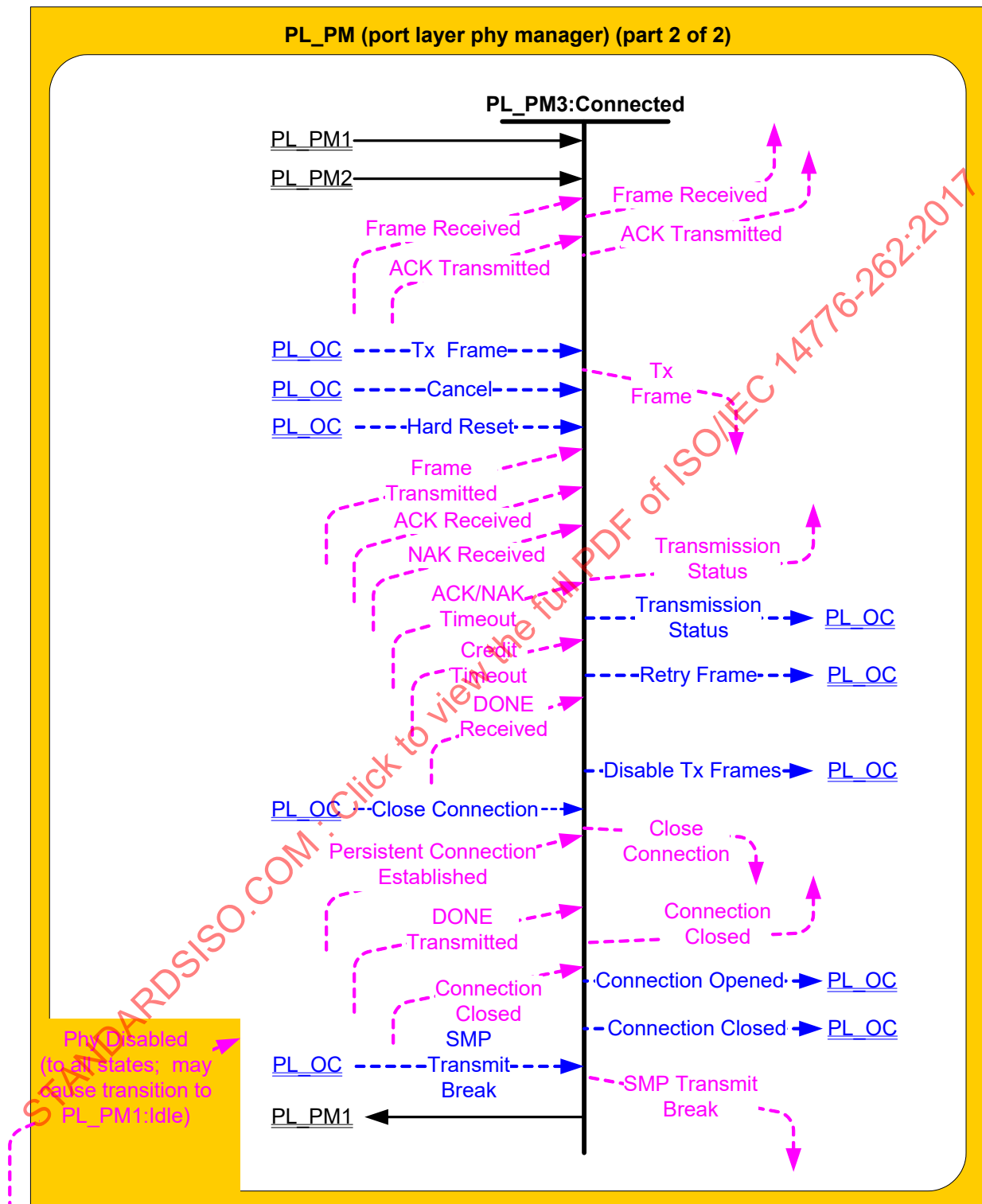


Figure 160 – PL_PM (port layer phy manager) state machine (part 2)

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.

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.

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 152, then this state shall send either a Retry Open message or an Unable To Connect message to the PL_OC state machine.

Table 152 defines the message to be sent to the PL_OC state machine for each Open Failed confirmation.

Table 152 – 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)
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:

- 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 argument 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.

An Unable To Connect message shall include the following arguments:

- a) Initiator Connection Tag set to the value received with the Tx Open message;
- b) Destination SAS Address set to the value received with the Tx Open message; and
- c) 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 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 MAXIMUM 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 MAXIMUM 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 151 (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 MAXIMUM 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 MAXIMUM 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 151 (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 TIME 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 TIME 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 151 (see 7.2.3.1); and
- 3) start the Bus Inactivity Time Limit timer.

If a Bus Inactivity Time Limit timer has been created and:

- a) the connection is SSP and this state receives a Tx Frame message; or
- b) the connection is 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 151 (see 7.2.3.1); 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:

- a) if 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 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 Maximum Connect Time Limit timer expires:

- a) if 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 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 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) 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) 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:

- a) if this state was entered as the result of the PL_PM2:Req_Wait state receiving 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) if this state was entered as the result of the PL_PM2:Req_Wait state receiving 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 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

8.2 SSP transport layer

8.2.1 SSP frame format

Table 153 defines the SSP frame format.

Table 153 – 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 156, table 158, table 160, table 161, or table 162)								
...									
m									
	Fill bytes, if needed								
n - 3	(MSB)	CRC							
...									
n									(LSB)

Table 154 defines the FRAME TYPE field, which defines the format of the INFORMATION UNIT field.

Table 154 – 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 155 defines the TLR CONTROL field for COMMAND frames. The TLR CONTROL field is reserved for all other frame types.

Table 155 – TLR CONTROL field for COMMAND frames

Code ^a	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: a) if the TRANSPORT LAYER RETRIES bit is set to 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 b) if the TRANSPORT LAYER RETRIES bit is set to 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. 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. 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: a) disable transport layer retries for this command; and b) set the RETRY DATA FRAMES bit to zero in any XFER_RDY frames that it transmits for this command.
^a 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 155) 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 154). 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 156 defines the Command information unit used in a COMMAND frame.

Table 156 – COMMAND frame - Command information unit

Byte\Bit	7	6	5	4	3	2	1	0
0	LOGICAL UNIT NUMBER							
...								
7								
8	Reserved							
9	ENABLE FIRST 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 157.

Table 157 – 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 158 defines the Task Management Function information unit used in a TASK frame.

Table 158 – 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 159 defines the TASK MANAGEMENT FUNCTION field.

Table 159 – TASK MANAGEMENT FUNCTION field (part 1 of 2)

Code	Task management function	Support ^a	Uses LOGICAL UNIT NUMBER field	Uses INITIATOR PORT TRANSFER TAG TO MANAGE field	Description ^b
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).
^a M = implementation is mandatory, X = implementation requirements are specified by SAM-5. ^b 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 159 – TASK MANAGEMENT FUNCTION field (part 2 of 2)

Code	Task management function	Support ^a	Uses LOGICAL UNIT NUMBER field	Uses INITIATOR PORT TRANSFER TAG TO MANAGE field	Description ^b
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				
^a M = implementation is mandatory, X = implementation requirements are specified by SAM-5. ^b 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

A 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 160 defines the Transfer Ready information unit used in a XFER_RDY frame.

Table 160 – XFER_RDY frame - Transfer Ready information unit

Byte\Bit	7	6	5	4	3	2	1	0
0	(MSB)							
...	REQUESTED OFFSET							
3	(LSB)							
4	(MSB)							
...	WRITE DATA LENGTH							
7	(LSB)							
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 in the Disconnect-Reconnect mode page is not set to 0000h, 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 9.2.7.2.4).

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 161 defines the Data information unit used in a DATA frame.

Table 161 – 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)):

- the number of bytes in frame header (i.e., 24);
- the number of bytes in the CRC field (i.e., 4); and
- 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:

- in response to an XFER_RDY frame; or
- 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 in the MAXIMUM BURST SIZE field is not set to zero in the Disconnect-Reconnect mode page, 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 9.2.7.2.4).

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.

The DATA OFFSET field shall be set to 00000000h in the initial write DATA frame for a command. If any additional write 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 write DATA frame.

The value in the DATA OFFSET field plus the size of the DATA field shall not be greater than 1_00000000h (i.e., a SCSI command shall not transfer more than 2^{32} bytes of write data and/or more than 2^{32} bytes of read data).

8.2.2.5 RESPONSE frame - Response information unit

8.2.2.5.1 RESPONSE frame - Response information unit overview

A RESPONSE frame is sent by an SSP target port to deliver:

- a) a service response, SCSI status (e.g., GOOD or CHECK CONDITION), and sense data, if any, for a command (see 8.2.3.3, 8.2.3.4, 8.2.3.5, and 8.2.3.6);
- b) a service response for a task management function (see 8.2.3.2); or
- c) an SSP-specific response (e.g., illegal frame format).

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Table 162 defines the Response information unit used in a RESPONSE frame.

Table 162 – RESPONSE frame - Response information unit

Byte\Bit	7	6	5	4	3	2	1	0
0	Reserved							
...								
7								
8	STATUS QUALIFIER							
9								
10	Reserved						DATAPRES	
11	STATUS							
12	Reserved							
...								
15								
16	(MSB)	SENSE DATA LENGTH (n bytes)						
...								
19		(LSB)						
20	(MSB)	RESPONSE DATA LENGTH (m bytes)						
...								
23		(LSB)						
24	RESPONSE DATA (see table 164 in 8.2.2.5.3) (if any)							
...								
23+m								
24+m	SENSE DATA (if any)							
...								
23+m+n								

Table 163 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 163 – 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:

- a) every TASK frame; and
- b) 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:

- a) 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);
- b) the SSP target port shall set the STATUS QUALIFIER field to the status qualifier for the command (see SAM-5);
- c) the SSP target port shall set the SENSE DATA LENGTH field to 00000000h and the RESPONSE DATA LENGTH field to 00000000h;
- d) the SSP initiator port shall ignore the SENSE DATA LENGTH field and the RESPONSE DATA LENGTH field; and
- e) 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:

- a) 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;
- b) the SSP initiator port shall ignore the STATUS field, the STATUS QUALIFIER field, and the SENSE DATA LENGTH field;
- c) the SSP target port shall not include the SENSE DATA field;
- d) the SSP target port shall set the RESPONSE DATA LENGTH field to 00000004h; and
- e) the SSP target port shall include the RESPONSE DATA field.

Table 164 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 164 – 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 165 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 165 – RESPONSE CODE field

Code	Description
00h	TASK MANAGEMENT FUNCTION COMPLETE ^a
02h	INVALID FRAME
04h	TASK MANAGEMENT FUNCTION NOT SUPPORTED ^a
05h	TASK MANAGEMENT FUNCTION FAILED ^a
08h	TASK MANAGEMENT FUNCTION SUCCEEDED ^a
09h	INCORRECT LOGICAL UNIT NUMBER ^a
0Ah	OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED ^b
All others	Reserved
^a Only valid when responding to a TASK frame. ^b 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;
- 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 154 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 166 lists the sequences of SSP frames supporting the SCSI transport protocol services described in 9.2.1.

Table 166 – 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 161 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.

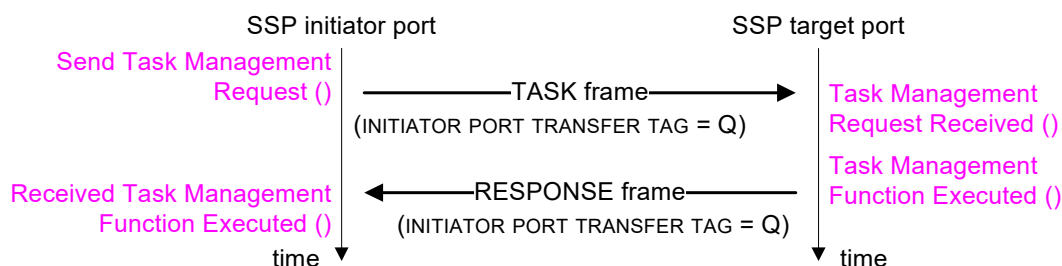


Figure 161 – Task management function sequence of SSP frames

8.2.3.3 Non-data command sequence of SSP frames

Figure 162 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.

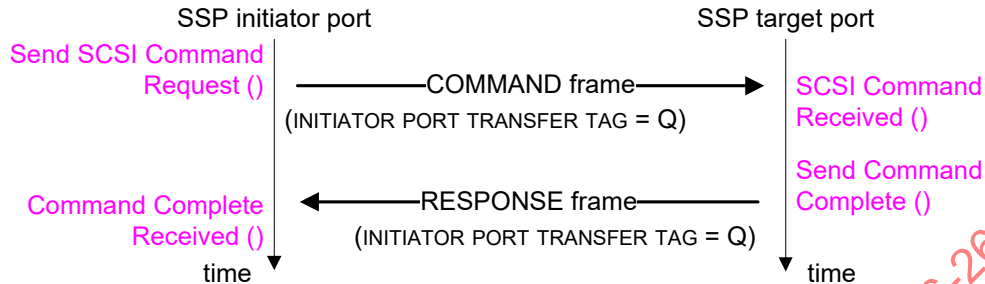


Figure 162 – Non-data command sequence of SSP frames

8.2.3.4 Write command sequence of SSP frames

Figure 163 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.

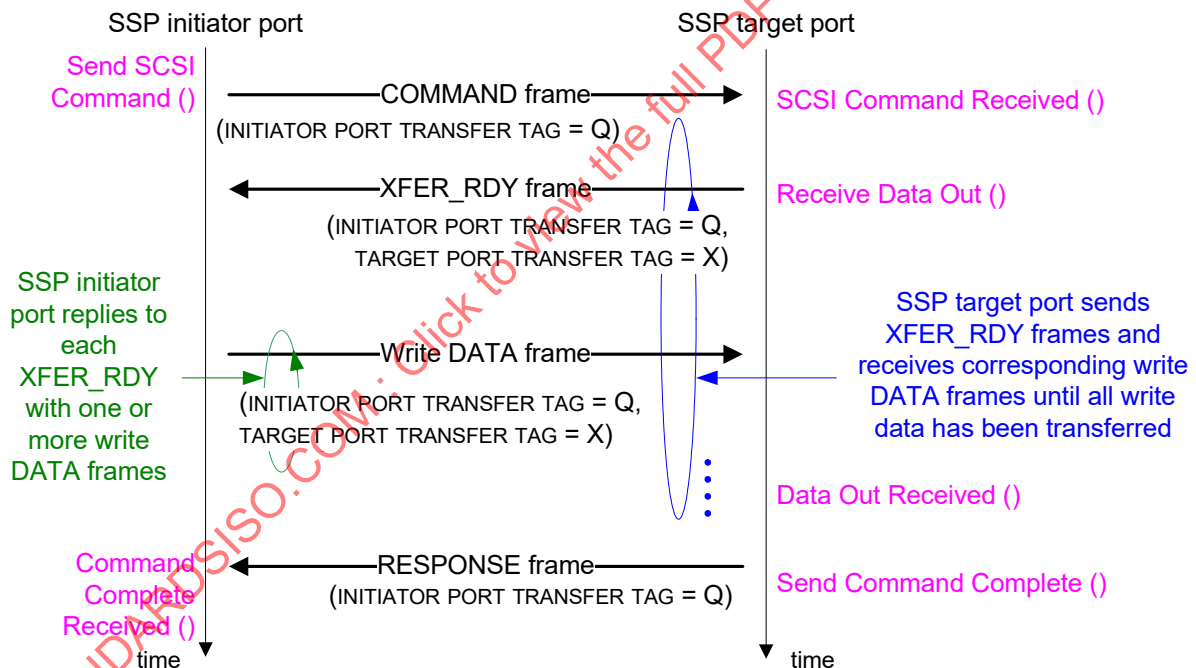


Figure 163 – Write command sequence of SSP frames

8.2.3.5 Read command sequence of SSP frames

Figure 164 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.

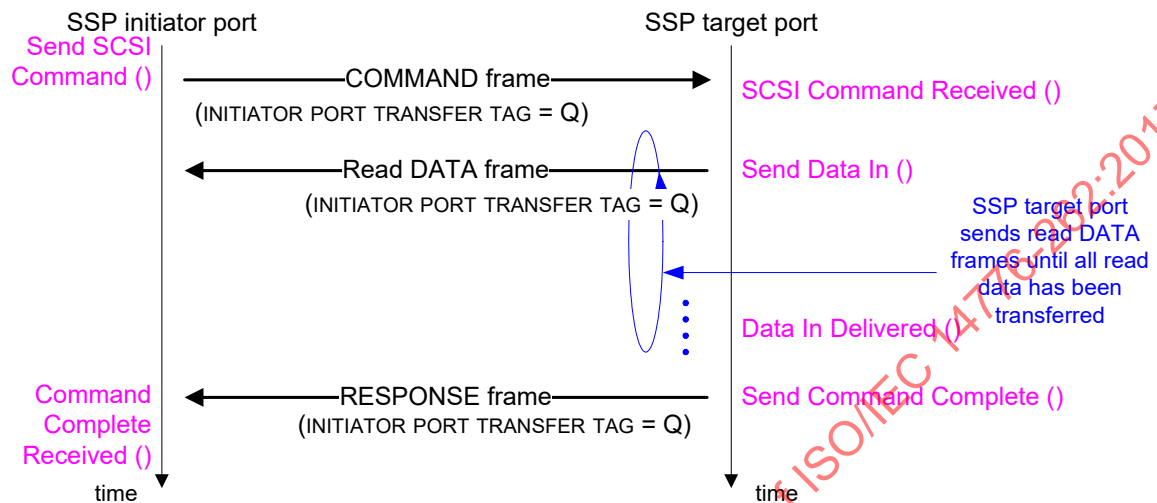


Figure 164 – Read command sequence of SSP frames

8.2.3.6 Bidirectional command sequence of SSP frames

Figure 165 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.

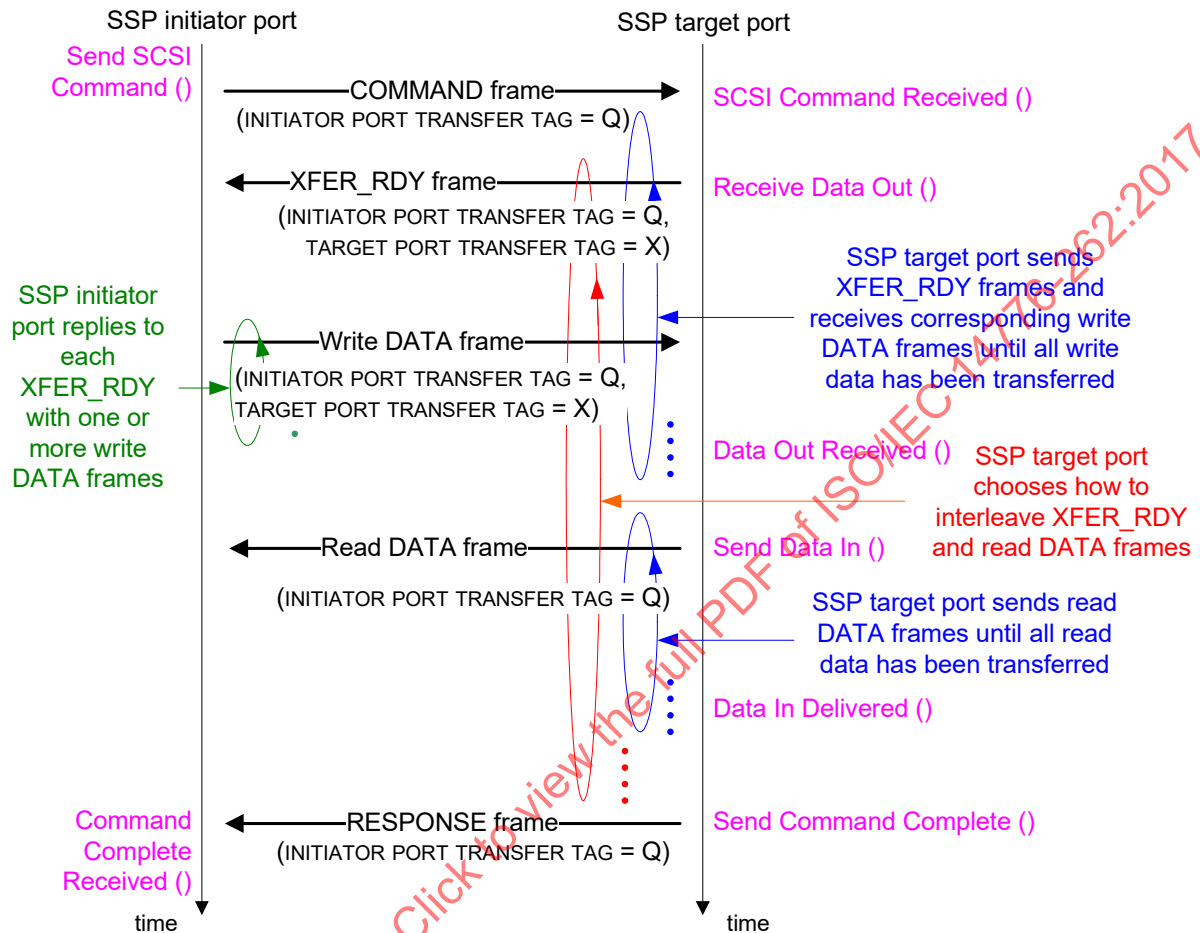


Figure 165 – Bidirectional command sequence of SSP frames

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;
- 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 6.18.8.6.5);
- 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 6.18.8.6.5);
- 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 6.18.8.6.5); 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 6.18.8.6.5);
- 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 6.18.8.6.5); 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 6.18.8.6.5);
- 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 6.18.8.6.5); 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 6.18.8.6.5); 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 6.18.8.6.5); 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_IFR 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_IFR 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_IFR 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_LFR 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:

- receive and process transport protocol service requests and transport protocol service responses from the SCSI application layer;
- receive and process other SAS connection management requests from the SCSI application layer;
- send transport protocol service indications and transport protocol service confirmations to the SCSI application layer;
- send requests to the port layer to transmit frames and manage SAS connections; and
- receive confirmations from the port layer.

The following confirmations between the ST state machines and the port layer:

- Transmission Status; and
- Frame Received;

include the following as arguments:

- initiator port transfer tag;
- Destination SAS Address; and
- 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:

- ST_IFR (initiator frame router) state machine (see 8.2.6.2.2); and
- ST_ITS (initiator transport server) state machine (see 8.2.6.2.3).

Each SAS initiator port includes:

- 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).

Figure 166 shows the ST_I state machines.

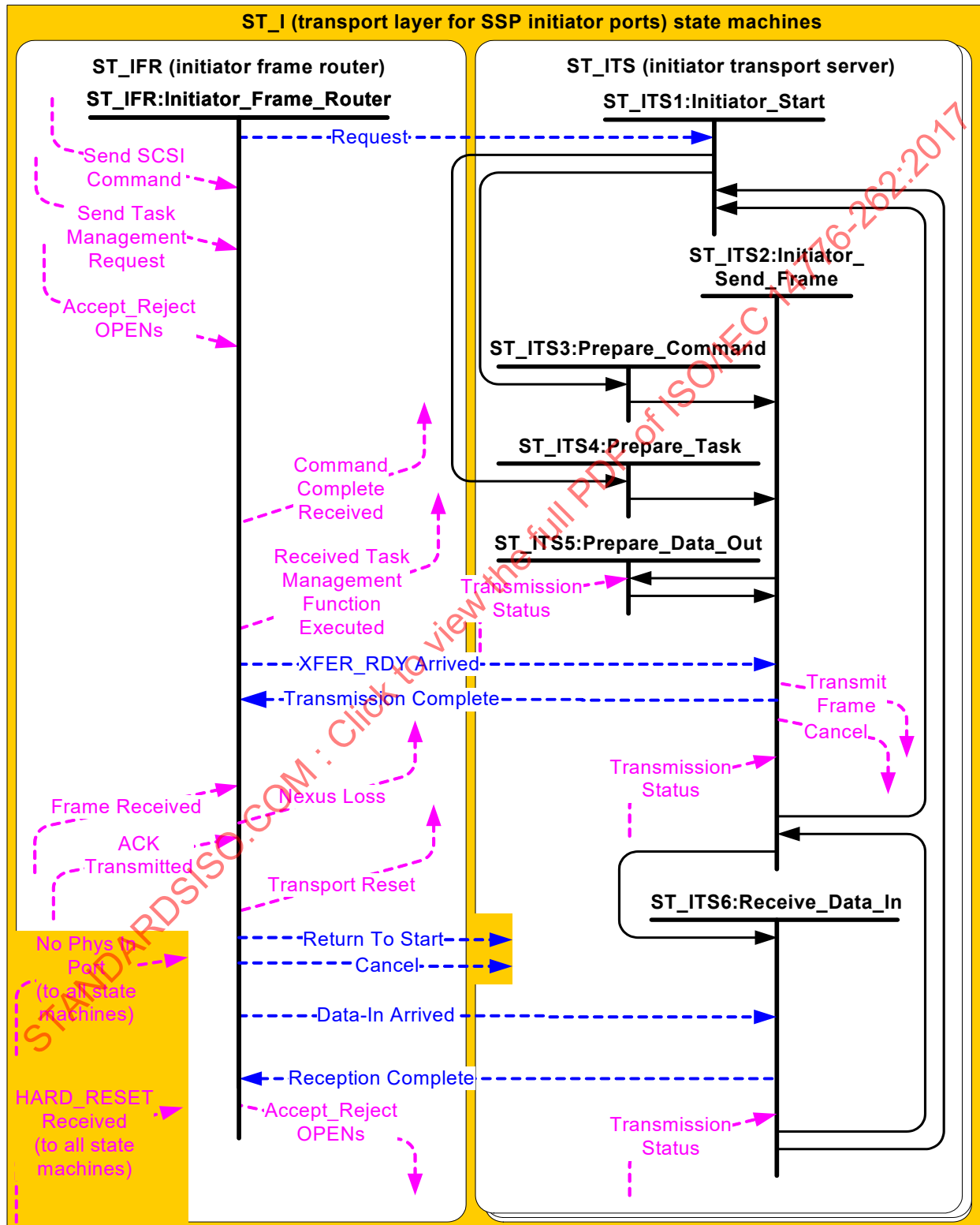


Figure 166 – ST_I (transport layer for SSP initiator ports) state machines

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 154 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 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 192; 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 202.

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 167 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 167 – 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 (Command Failed, ACK/NAK Timeout)	Command Complete Received (Service Delivery or Target Failure - ACK/NAK Timeout)
Transmission Complete (Command Failed, Connection Failed)	Command Complete Received (Service Delivery or Target Failure - Connection Failed)
Transmission Complete (Command Failed, NAK Received)	Command Complete Received (Service Delivery or Target Failure - NAK Received)
Transmission Complete (Task Failed, ACK/NAK Timeout)	Received Task Management Function Executed (Service Delivery or Target Failure - ACK/NAK Timeout)
Transmission Complete (Task Failed, Connection Failed)	Received Task Management Function Executed (Service Delivery or Target Failure - Connection Failed)
Transmission Complete (Task Failed, NAK Received)	Received Task Management Function Executed (Service Delivery or Target Failure - NAK Received)
Transmission Complete (XFER_RDY Incorrect Write Data Length)	Command Complete Received (Service Delivery or Target Failure - XFER_RDY Incorrect Write Data Length)
Transmission Complete (XFER_RDY Requested Offset Error)	Command Complete Received (Service Delivery or Target Failure - XFER_RDY Requested Offset Error)
Transmission Complete (Cancel Acknowledged)	Command Complete Received (Service Delivery or Target Failure - Cancel Acknowledged)
Reception Complete (Command Failed, ACK/NAK Timeout)	Command Complete Received (Service Delivery or Target Failure - ACK/NAK Timeout)
Reception Complete (Data Offset Error)	Command Complete Received (Service Delivery or Target Failure - DATA Data Offset Error)
Reception Complete (Too Much Read Data)	Command Complete Received (Service Delivery or Target Failure - DATA Too Much Read Data)
Reception Complete (Incorrect Data Length)	Command Complete Received (Service Delivery or Target Failure - DATA Incorrect Data Length)
Reception Complete (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:

- receives and processes messages from the ST_IFR state machine;
- sends messages to the ST_IFR state machine;
- sends request to the port layer regarding frame transmission;
- receives confirmations from the port layer regarding frame transmission; and
- receives HARD_RESET Received confirmations and No Phys In Port confirmations from the port layer.

This state machine consists of the following states:

- ST_ITS1:Initiator_Start state (see 8.2.6.2.3.2) (initial state);
- ST_ITS2:Initiator_Send_Frame state (see 8.2.6.2.3.3);
- ST_ITS3:Prepare_Command state (see 8.2.6.2.3.4);
- ST_ITS4:Prepare_Task state (see 8.2.6.2.3.5);
- ST_ITS5:Prepare_Data_Out state (see 8.2.6.2.3.6); and
- 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 168.

Table 168 – 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 169.

Table 169 – 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.

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 150), 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 150), 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 a 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 170 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 170 – 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: a) the RETRY DATA FRAMES bit was set to zero in the XFER_RDY frame requesting the data; or 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:

- Destination SAS Address; and
- 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 171. If the verification fails, then this state shall send the Transmission Complete message specified in table 171 to the ST_IFR state machine.

Table 171 – Transmission Complete messages for XFER_RDY frame verification failures

Message sent to the ST_IFR state machine ^a	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.
^a 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:

- set the Data-Out Buffer Offset state machine variable to the Requested Offset Xfer_Rdy state machine argument;
- set the Previous Requested Offset state machine variable to the Requested Offset Xfer_Rdy state machine argument; and
- 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) a Transmission Status (Frame Transmitted) confirmation followed by a Transmission Status (ACK Received) confirmation for a COMMAND frame requesting a write operation; 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 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:Process_Data_In

This transition shall occur 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 172.

If the verification fails, then this state sends the Reception Complete message specified in table 172 to the ST_IFR state machine.

Table 172 – Reception Complete messages for read DATA frame verification failures

Message sent to the ST_IFR state machine ^a	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: a) the number of bytes in the DATA field in the read Data information unit is zero; or b) this is not the last read DATA frame for the command and the NUMBER OF FILL BYTES field is not set to 00b.
^a 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: 1) Reception Complete (Data Offset Error); 2) Reception Complete (Too Much Read Data); or 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:Receve_Data_In to ST_ITS2:Initiator_Send_Frame

This transition shall occur 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 173.

Table 173 – 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).

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 167 shows the ST_T state machines.

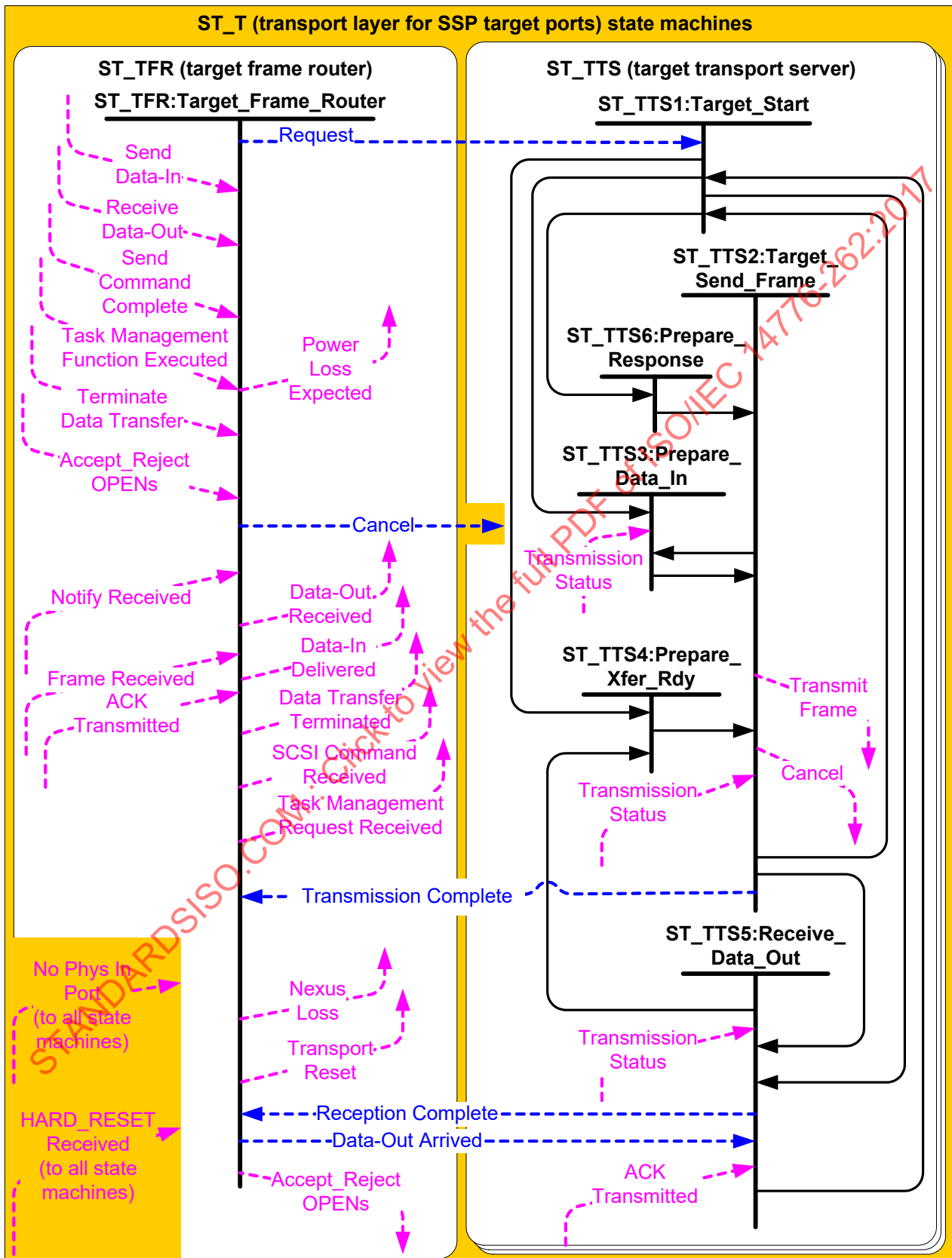


Figure 167 – ST_T (transport layer for SSP target ports) state machines

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 154 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 174; and
- c) the Response Fence argument set to the Task Management Function Executed transport protocol service response Response Fence argument.

Table 174 specifies which argument to send with the Request (Send Transport Response) message based on the Service Response argument that was received.

Table 174 – Task Management Function Executed Service Response argument mapping to Request (Send Transport Response) Service Response argument

Task Management Function Executed transport protocol service response Service Response argument received	Request (Send Transport Response) message Service Response argument
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.

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 175 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Table 175 – 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) ^a	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
^a 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 176.

Table 176 – 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 177.

Table 177 – 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;
- 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 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 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 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 after receiving a Request (Send Transport Response) message.

The transition shall include 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.

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 178 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 a 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 178 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Table 178 – 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: a) the Read Data Offset state machine variable is equal to the Read Data Buffer End state machine variable; and b) the Read Data Offset state machine variable is equal to 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: a) if transport layer retries are disabled; or b) if transport layer retries are 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: a) if transport layer retries are disabled; or b) if transport layer retries are 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 179 defines messages that this state shall send to the ST_TFR state machine upon receipt of the listed confirmations and arguments.

Table 179 – 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 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 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 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:

- a) if a Cancel message was not received, then the read DATA frame as an argument; or
- b) if a Cancel message was 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:

- a) if a Cancel message was not received, then the XFER_RDY frame as an argument; or
- b) if a Cancel message was 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 180. If the verification test fails, then this state sends the message specified in table 180 to the ST_TFR state machine.

Table 180 – Reception Complete message for write DATA frame verification failures

Message sent to the ST_TFR state machine ^a	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: a) less than the Requested Write Data Offset state machine variable; or 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: a) the number of bytes in the DATA field in the write Data information unit is zero; or 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.
^a 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: 1) Reception Complete (Data Offset Error); 2) Reception Complete (Too Much Write Data); or 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:

- set the FRAME TYPE field to 07h (i.e., RESPONSE frame);
- set the HASHED DESTINATION SAS ADDRESS field to the hashed value of the Application Response or Transport Response Destination SAS Address argument;
- set the HASHED SOURCE SAS ADDRESS field to the hashed value of the SSP target port's SAS address;
- set the RETRY DATA FRAMES set to zero;
- set the RETRANSMIT bit to zero;
- set the CHANGING DATA POINTER bit to zero;
- 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;
- set the TARGET PORT TRANSFER TAG field to a vendor specific value;
- set the DATA OFFSET field to 00000000h;
- set the information unit as specified in this subclause; and
- 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:

- set the NUMBER OF FILL BYTES field to the number of fill bytes, based on the length of the response data, if any;
- in the information unit, set the DATAPRES field to RESPONSE DATA;
- in the information unit, set the STATUS field to 00h;
- in the information unit, set the STATUS QUALIFIER field to 0000h;
- in the information unit, set the SENSE DATA LENGTH field to 00000000h;
- in the information unit, set the RESPONSE DATA LENGTH field to 00000004h;
- in the information unit, set the RESPONSE DATA field as specified in table 181; and
- in the information unit, do not include the SENSE DATA field.

Table 181 defines how the RESPONSE DATA field shall be set based on the arguments received with the Request (Send Transport Response) message.

Table 181 – 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:

- a) 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;
- b) in the information unit, set the STATUS field to the status;
- c) in the information unit, set the STATUS QUALIFIER field to the status qualifier, if any;
- d) in the information unit, set the SENSE DATA LENGTH field to the length of the sense data, if any;
- e) in the information unit, set the RESPONSE DATA LENGTH field to 00000000h;
- f) in the information unit, do not include the RESPONSE DATA field;
- g) in the information unit, set the SENSE DATA field to the sense data, if any; and
- h) 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:

- a) if a Cancel message was not received, then the RESPONSE frame as an argument; or
- b) if a Cancel message was 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 182 defines the SMP frame format.

Table 182 – 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 183 defines the SMP FRAME TYPE field, which defines the format of the frame-type dependent bytes.

Table 183 – 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:

- 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 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 184 defines the SMP_REQUEST frame format.

Table 184 – 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								(LSB)

The SMP FRAME TYPE field shall be set to the value defined in table 184.

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. 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 185 defines the SMP_RESPONSE frame format.

Table 185 – 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								

The SMP FRAME TYPE field shall be set to the value defined in table 185.

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 request bytes (see 6.20.5.3.4). SMP response frames defined in 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 168 shows the sequence of SMP frames.

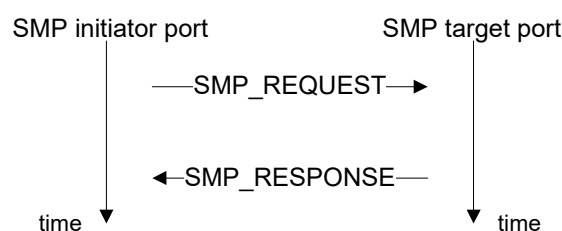


Figure 168 – Sequence of SMP frames

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 169 shows the MT_IP state machine.

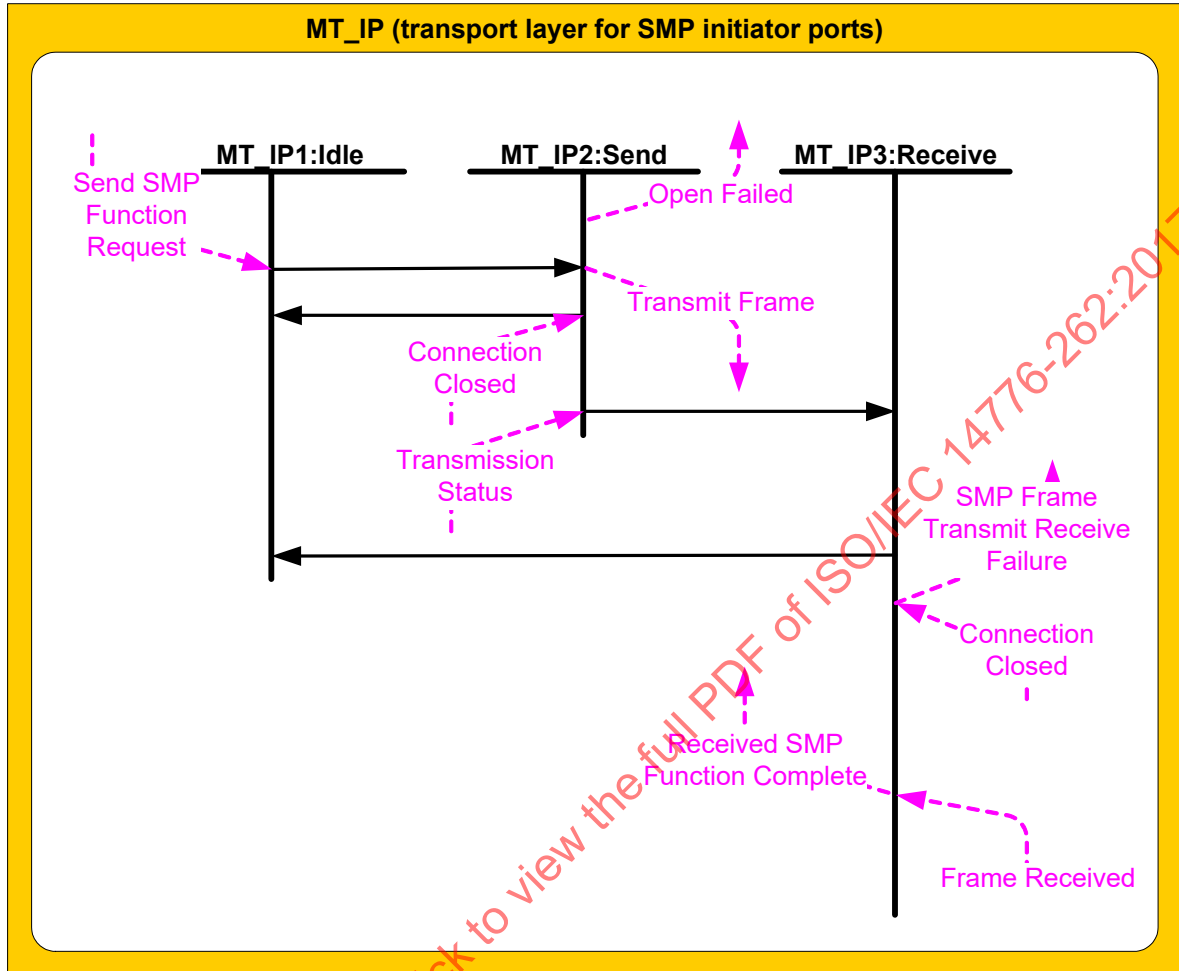


Figure 169 – MT_IP (transport layer for SMP initiator ports) state machine

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:

- Connection Rate;
- Destination SAS Address; and
- Request Bytes.

8.4.5.2.2.2 Transition MT_IP1:Idle to MT_IP2:Send

This transition shall occur after a Send SMP Function Request request is received. This transition shall include the following arguments:

- Connection Rate;
- Destination SAS Address; and
- 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 receiving either a Connection Closed confirmation or a Transmission Status confirmation other than a Transmission Status (Frame Transmitted) confirmation, and after 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 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:

- a) MT_TP1:Idle (see 8.4.5.3.2) (initial state); and
- b) MT_TP2:Respond (see 8.4.5.3.3).

This state machine shall start in the MT_TP1:Idle state.

Figure 170 shows the MT_TP state machine.

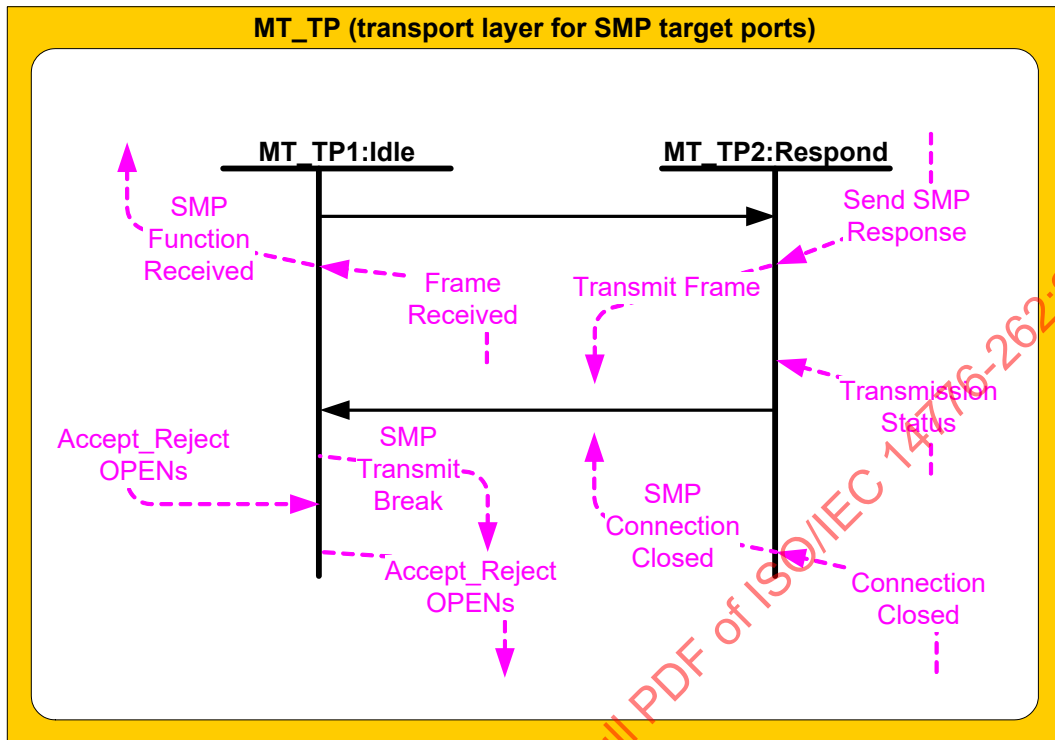


Figure 170 – MT_TP (transport layer for SMP target ports) state machine

The MT_TP state machine shall comply with the time limits listed in table 186.

Table 186 – 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 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 186 (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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

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]))

This standard defines the transport protocol services required by SAM-5 in support of this procedure call. Table 187 describes the mapping of the Execute Command procedure call to transport protocol services and the SSP implementation of each transport protocol service.

Table 187 – Execute Command procedure call transport protocol services

Transport protocol service	I/T ^a	SSP implementation	Reference
Command and status			
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
Data-In delivery ^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
Data-Out delivery ^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
Terminate Data Transfer ^b			
Terminate Data Transfer request	T		9.2.1.10
Data Transfer Terminated confirmation	T		9.2.1.11
^a I/T indicates whether the SSP initiator port (I) or the SSP target port (T) implements the transport protocol service. ^b 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 188 describes the mapping of these procedure calls to transport protocol services and the SSP implementation of each transport protocol service.

Table 188 – Task management function procedure call transport protocol services

Transport protocol service	I/T ^a	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
^a 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 189 shows how the arguments to the Send SCSI Command transport protocol service are used.

Table 189 – Send SCSI Command transport protocol service arguments

Argument	SAS SSP implementation
I_T_L_Q nexus	I_T_L_Q nexus, where: a) I specifies the SSP initiator port to send the COMMAND frame; b) T specifies the SSP target port to which the COMMAND frame is to be sent; c) L specifies the LOGICAL UNIT NUMBER field in the COMMAND frame header; and 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. ^a
[Data-Out Buffer]	Internal to the SSP initiator port.
[Data-Out Buffer Size]	Maximum of 2^{32} bytes. ^a
[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.
^a 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 190 shows how the arguments to the SCSI Command Received transport protocol service are determined.

Table 190 – SCSI Command Received transport protocol service arguments

Argument	SAS SSP implementation
I_T_L_Q nexus	I_T_L_Q nexus, where: a) I indicates the SSP initiator port that sent the COMMAND frame; b) T indicates the SSP target port that received the COMMAND frame; c) L indicates the value of the LOGICAL UNIT NUMBER field in the COMMAND frame header; and 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 191 shows how the arguments to the Send Command Complete transport protocol service are used.

Table 191 – Send Command Complete transport protocol service arguments

Argument	SAS SSP implementation
I_T_L_Q nexus	I_T_L_Q nexus, where: a) I specifies the SSP initiator port to which the RESPONSE frame is to be sent; b) T specifies the SSP target port to send the RESPONSE frame; c) L specifies the LOGICAL UNIT NUMBER field in the RESPONSE frame header; and 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: a) COMMAND COMPLETE: The DATAPRES field is set to NO_DATA or SENSE_DATA; or 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 an 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 192 shows how the arguments to the Command Complete Received transport protocol service are determined.

Table 192 – Command Complete Received transport protocol service arguments

Argument	SAS SSP implementation
I_T_L_Q nexus	I_T_L_Q nexus, where: a) I indicates the SSP initiator port that received the RESPONSE frame; b) T indicates the SSP target port that sent the RESPONSE frame; c) L indicates the value of the LOGICAL UNIT NUMBER field in the RESPONSE frame header or COMMAND frame header; and 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: a) COMMAND COMPLETE: The RESPONSE frame contains a DATAPRES field set to NO_DATA or SENSE_DATA; or b) SERVICE DELIVERY OR TARGET FAILURE: Either: 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 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 193 shows how the arguments to the Send Data-In transport protocol service are used.

Table 193 – Send Data-In transport protocol service arguments

Argument	SAS SSP implementation
I_T_L_Q nexus	I_T_L_Q nexus, where: a) I specifies the SSP initiator port to which the read DATA frame is to be sent; b) T specifies the SSP target port to send the read DATA frame; c) L specifies the LOGICAL UNIT NUMBER field in the read DATA frame header; and 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 194 shows how the arguments to the Data-In Delivered transport protocol service are determined.

Table 194 – Data-In Delivered transport protocol service arguments

Argument	SAS SSP implementation
I_T_L_Q nexus	I_T_L_Q nexus, where: a) I indicates the SSP initiator port that sent the read DATA frame; b) T indicates the SSP target port that received the read DATA frame; c) L indicates the value of the LOGICAL UNIT NUMBER field in the read DATA frame header; and 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: a) DELIVERY SUCCESSFUL: The read DATA frame received an ACK; or 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 195 shows how the arguments to the Receive Data-Out transport protocol service are used.

Table 195 – Receive Data-Out transport protocol service arguments

Argument	SAS SSP implementation
I_T_L_Q nexus	I_T_L_Q nexus, where: a) I specifies the SSP initiator port to which the XFER_RDY frame is to be sent; b) T specifies the SSP target port to send the XFER_RDY frame; c) L specifies the LOGICAL UNIT NUMBER field in the XFER_RDY frame header; and 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 196 shows how the arguments to the Data-Out Received transport protocol service are determined.

Table 196 – Data-Out Received transport protocol service arguments

Argument	SAS SSP implementation
I_T_L_Q nexus	I_T_L_Q nexus, where: a) I indicates the SSP initiator port to which the XFER_RDY frame was sent; b) T indicates the SSP target port that sent the XFER_RDY frame; c) L indicates the value of the LOGICAL UNIT NUMBER field in the XFER_RDY frame header; and 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: 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 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 197 shows how the arguments to the Terminate Data Transfer transport protocol service are used.

Table 197 – 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 198 shows how the arguments to the Data Transfer Terminated transport protocol service are determined.

Table 198 – 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 199 shows how the arguments to the Send Task Management Request transport protocol service are used.

Table 199 – Send Task Management Request transport protocol service arguments

Argument	SAS SSP implementation
Nexus	I_T nexus, I_T_L nexus, or I_T_L_Q nexus (depending on the Function Identifier), where: a) I specifies the SSP initiator port to send the TASK frame; b) T specifies the SSP target port to which the TASK frame is sent; 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 d) Q (for an I_T_L_Q nexus) specifies the INITIATOR PORT TRANSFER TAG TO MANAGE field in the TASK frame header.
Function Identifier	Specifies the TASK MANAGEMENT FUNCTION field in the TASK frame. Only these task management functions are supported: a) ABORT TASK (Nexus argument specifies an I_T_L_Q Nexus); b) ABORT TASK SET (Nexus argument specifies an I_T_L Nexus); c) CLEAR ACA (Nexus argument specifies an I_T_L Nexus); d) CLEAR TASK SET (Nexus argument specifies an I_T_L Nexus); e) I_T NEXUS RESET (Nexus argument specifies an I_T Nexus); f) LOGICAL UNIT RESET (Nexus argument specifies an I_T_L Nexus); g) QUERY TASK (Nexus argument specifies an I_T_L_Q Nexus); h) QUERY TASK SET (Nexus argument specifies an I_T_L Nexus); and i) QUERY ASYNCHRONOUS EVENT (Nexus argument specifies an I_T_L Nexus).
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 200 shows how the arguments to the Task Management Request Received transport protocol service are determined.

Table 200 – Task Management Request Received transport protocol service arguments

Argument	SAS SSP implementation
Nexus	I_T nexus, I_T_L nexus, or I_T_L_Q nexus (depending on the Function Identifier), where: a) I indicates the SSP initiator port that sent the TASK frame; b) T indicates the SSP target port that received the TASK frame; 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 d) Q (for an I_T_L_Q nexus) indicates the INITIATOR PORT TRANSFER TAG TO MANAGE field in the TASK frame header.
Function Identifier	Indicates the TASK MANAGEMENT FUNCTION field in the TASK frame. Only these task management functions are supported: a) ABORT TASK (Nexus argument indicates an I_T_L_Q Nexus); b) ABORT TASK SET (Nexus argument indicates an I_T_L Nexus); c) CLEAR ACA (Nexus argument indicates an I_T_L Nexus); d) CLEAR TASK SET (Nexus argument indicates an I_T_L Nexus); e) I_T NEXUS RESET (Nexus argument indicates an I_T Nexus); f) LOGICAL UNIT RESET (Nexus argument indicates an I_T_L Nexus); g) QUERY TASK (Nexus argument indicates an I_T_L_Q Nexus); h) QUERY TASK SET (Nexus argument indicates an I_T_L Nexus); and i) QUERY ASYNCHRONOUS EVENT (Nexus argument indicates an I_T_L Nexus).
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 201 shows how the arguments to the Task Management Function Executed transport protocol service are used.

Table 201 – 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: a) I specifies the SSP initiator port to which the RESPONSE frame is sent; b) T specifies the SSP target port to send the RESPONSE frame; 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 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: a) FUNCTION COMPLETE: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to TASK MANAGEMENT FUNCTION COMPLETE; b) FUNCTION SUCCEEDED: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to TASK MANAGEMENT FUNCTION SUCCEEDED; c) FUNCTION REJECTED: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to TASK MANAGEMENT FUNCTION NOT SUPPORTED; 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; e) SERVICE DELIVERY OR TARGET FAILED: The DATAPRES field is set to RESPONSE_DATA and the RESPONSE CODE field is set to TASK MANAGEMENT FUNCTION FAILED; or 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 202 shows how the arguments to the Received Task Management Function Executed transport protocol service are determined.

Table 202 – Received Task Management Function Executed transport protocol service arguments

Argument	SAS SSP implementation
Nexus	I_T nexus, I_T_L nexus, or I_T_L_Q nexus (depending on the function), where: a) I indicates the SSP initiator port that received the RESPONSE frame; b) T indicates the SSP target port that sent the RESPONSE frame; 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 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.
Service Response	Indicates the response to the TASK frame: 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; 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; 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; 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 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: A) INVALID FRAME; B) TASK MANAGEMENT FUNCTION FAILED; or C) OVERLAPPED INITIATOR PORT TRANSFER TAG ATTEMPTED.
[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;
- 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 203, 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 203.

Table 203 – 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 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:

- abort all task management functions received on that I_T nexus; and
- respond to the overlapped command as defined in SAM-5.

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 a task management function in any logical unit; or
- 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:

- abort all commands received on that I_T nexus;
- abort all task management functions received on that I_T nexus; and
- 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:

- an SSP initiator port to deliver an indication of an event to a SCSI application client; and
- an SSP target port to deliver an indication of an event to a task manager and a SCSI device server.

Table 204 lists the SCSI transport protocol services for event notifications supported by this standard.

Table 204 – SCSI transport protocol events

Delivered transport protocol service indication	I/T ^a	SSP implementation	Reference
Transport Reset (IN (SCSI Port)) ^b	I/T	Transport Reset	4.4.2
Nexus Loss (IN (I_T Nexus)) ^c	I/T	Nexus Loss	4.4.3
Power Loss Expected (IN (SCSI Port)) ^d	T	Power Loss Expected	6.2.5.3.3
^a I/T indicates whether the SSP initiator port (I) or the SSP target port (T) implements the transport protocol service. ^b The specific SCSI port in the SCSI device for which a transport reset was detected. ^c The specific I_T nexus that has been detected as lost. ^d The specific SCSI port in the SCSI device for which an unexpected power loss 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-2 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 205 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 205 – 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 206 defines the parameters which 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 206. 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 206 – 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 TIME LIMIT						
5								(LSB)
6		Reserved						
7								
8	(MSB)	MAXIMUM 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 to the value defined in table 206.

The PAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 206.

The PAGE LENGTH field is defined in SPC-4 and shall be set to the value defined in table 206.

The BUS INACTIVITY TIME LIMIT field is defined in SPC-4 and 9.2.7.2.2.

The MAXIMUM 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 TIME LIMIT field

The BUS INACTIVITY TIME LIMIT field contains the maximum time, in 100 μ 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. When this time is exceeded, 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 MAXIMUM CONNECT TIME LIMIT field

The MAXIMUM CONNECT TIME LIMIT field contains the maximum duration of a connection (see 4.1.12) in 100 μ s increments (e.g., a value of 0001h in this field means that the time is less than or equal to 100 μ s and a value of 0002h in this field means that the time is less than or equal to 200 μ s). When this time is exceeded, 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

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.

For write data, the value shall specify the maximum amount of data that an SSP target port requests via a single XFER_RDY frame (see 8.2.2.3).

This value 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.

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 207 defines the format of the page for SAS SSP.

Table 207 – 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 LAYER 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 to the value defined in table 207.

The PAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 207.

The PAGE LENGTH field is defined in SPC-4 and shall be set to the value defined in table 207.

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 to the value defined in table 207 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:

- 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 208 defines the format of the page for SAS SSP.

Table 208 – 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	(MSB)	I_T NEXUS LOSS TIME						(LSB)
5								
6	(MSB)	INITIATOR RESPONSE TIMEOUT						(LSB)
7								
8	(MSB)	REJECT TO OPEN LIMIT						(LSB)
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 to the value defined in table 208.

The PAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 208.

The PAGE LENGTH field is defined in SPC-4 and shall be set to the value defined in table 208.

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 4.1.13). 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 to the value defined in table 208 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). Table 209 defines the values of the I_T NEXUS LOSS TIME field. This value is enforced by the port layer (see 7.2.2).

Table 209 – I_T NEXUS LOSS TIME field

Code ^a	Description
0000h	Vendor specific amount of time.
0001h to FFFh	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).
^a 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 µs 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 210 defines the format of this mode page.

Table 210 – 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)	PAGE LENGTH (n - 3)						(LSB)	
3									
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 211)								
...									
55									
...	...								
n - 47	SAS phy mode descriptor (last) (see table 211)								
...									
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 to the value defined in table 210.

The PAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 210.

The SUBPAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 210.

The PAGE LENGTH field is defined in SPC-4 and shall be set to the value defined in table 210 (i.e., 4 + ((the value of the NUMBER OF PHYS field) × (the length in bytes of the SAS phy mode descriptor))).

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set to the value defined in table 210 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Table 211 defines the SAS phy mode descriptor.

Table 211 – 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							
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 212 defines the format of this mode page.

Table 212 – 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)							
3									
4	Reserved								
5	Reserved				PROTOCOL IDENTIFIER (6h)				
6	(MSB)	POWER LOSS TIMEOUT							
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 to the value defined in table 212.

The PAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 212.

The SUBPAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 212.

The PAGE LENGTH field is defined in SPC-4 and shall be set to the value defined in table 212.

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set to the value defined in table 212 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.

Table 213 defines the format of this mode page.

Table 213 – 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)	PAGE LENGTH (n - 3)						
3								(LSB)
4	Reserved							
5	Reserved				PROTOCOL IDENTIFIER (6h)			
6	GENERATION CODE							
7	NUMBER OF PHYS							
Enhanced phy control mode descriptor list								
8	Enhanced phy control mode descriptor (first) (see table 214)							
...								
27								
...	...							
n - 19	Enhanced phy control mode descriptor (last) (see table 214)							
...								
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 to the value defined in table 213.

The PAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 213.

The SUBPAGE CODE field is defined in SPC-4 and shall be set to the value defined in table 213.

The PAGE LENGTH field is defined in SPC-4 and shall be set to the value defined in table 213 (i.e., 4 + ((the value of the NUMBER OF PHYS field) × (the length in bytes of the SAS phy mode descriptor))).

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set to the value defined in table 213 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 214 defines the enhanced phy control mode descriptor.

Table 214 – 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)						(LSB)
3								
4	PROGRAMMED PHY CAPABILITIES							
...								
7								
8	CURRENT PHY CAPABILITIES							
...								
11								
12	ATTACHED PHY CAPABILITIES							
...								
15								
16	Reserved							
17								
18	Reserved	OPTICAL MODE ENABLED	NEGOTIATED SSC	NEGOTIATED PHYSICAL LINK RATE				
19	Reserved					ENABLE SLUMBER	ENABLE PARTIAL	HARDWARE MUXING SUPPORTED

The DESCRIPTOR LENGTH field contains the length in bytes that follow in the descriptor and shall be set to the value defined in table 214.

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 216 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 215.

Table 215 – Protocol Specific Port log parameters

Parameter code	Description	Resettable or Changeable ^a	Reference	Support Required
0000h	Reserved			
0001h to FFFFh	Protocol-Specific Port log parameter for SAS target ports	Never	9.2.8.2	Optional

^a 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 216.

Table 216 – 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 217)							
...								
...	...							
	Protocol Specific Port log parameter (last) (see table 217)							
...								
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 216 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 217 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 217 – 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)							(LSB)
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 218)							
...								
8 + m								
...	...							
y - m	SAS phy log descriptor (last) (see table 218)							
...								
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 217 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).

Table 218 – SAS phy log descriptor (part 2 of 2)

Byte\Bit	7	6	5	4	3	2	1	0
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 285 in 9.4.3.14.4)							
...								
63								
...								
m - 11	Phy event descriptor (last) (see table 285 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 and shall be set to the value defined in table 218. 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 285 (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 219 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 219 – 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-2) 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 220 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 220 – Diagnostic pages affected by zoning

Diagnostic page code	Description	Reference
02h	Enclosure Control diagnostic page	SES-2 and 9.2.9.3
	Enclosure Status diagnostic page	SES-2 and 9.2.9.4
0Ah	Additional Element Status diagnostic page	SES-2 and 9.2.9.5

9.2.9.2 Protocol Specific diagnostic page

The Protocol Specific diagnostic page for SAS SSP 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.

Table 221 defines the Protocol Specific diagnostic page for SAS SSP.

Table 221 – 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)							
3	PAGE LENGTH (001Ch)							
3	(LSB)							
4	PHY IDENTIFIER							
5	PHY TEST FUNCTION							
6	PHY TEST PATTERN							
7	Reserved	PHY TEST FUNCTION SATA	PHY TEST FUNCTION 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 to the value defined in table 221.

The PROTOCOL IDENTIFIER field is defined in SPC-4 and shall be set to the value defined in table 221 indicating this is a SAS SSP specific diagnostic page.

The PAGE LENGTH field is defined in SPC-4 and shall be set to the value defined in table 221.

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 222. 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 222 – PHY TEST FUNCTION field

Code	Name	Description
00h	STOP	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. If the selected phy is not performing a phy test function, then this function has no effect on the selected phy. ^a
01h	TRANSMIT PATTERN	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. 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. ^a
02h to EFh	Reserved	
F0h to FFh	Vendor specific	
^a 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 223. 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 223 – 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	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. 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.
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 224. 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 224 – PHY TEST FUNCTION SSC field

Code	Description
00b	No-spreading
01b	Center-spreading SSC ^a
10b	Down-spreading SSC
11b	Reserved
^a 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 225. 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 225 – 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 223).

The PHY TEST PATTERN DWORDS CONTROL field defined in table 226 controls whether the bytes in the PHY TEST PATTERN DWORDS field are sent as control characters or data characters.

Table 226 – 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 which is used in this standard (see table 50 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 227 lists some examples of TWO_DWORDS phy test patterns.

Table 227 – TWO_DWORDS phy test pattern examples

PHY TEST PATTERN DWORDS CONTROL field	PHY TEST PATTERN DWORDS field	Description
00h	4A4A4A4A 4A4A4A4Ah	D10.2 characters (see table 48 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 B5B5B5B5h	D21.5 characters (see table 48 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 78787878h	D24.3 characters (see table 48 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 D926D926h	Pairs of D25.6 and D6.1 characters (see table 48 in 5.3.6). This pattern contains 1001b repeating and has half the highest possible frequency.
00h	7E7E7E7E 7E7E7E7Eh	D30.3 characters (see table 48 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., 1111000111b), followed by the inverse (e.g., 0000111000b). This pattern may be used for measuring transmitter equalization and SSC-induced jitter (see SAS-3).
88h	BC4A4A7B BC4A4A7Bh	ALIGN (0) primitives (see table 97 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 BC070707h	ALIGN (1) primitives (see table 97 in 6.2.3). This pattern appears during the SAS speed negotiation sequences (see 5.10.4.2).
80h	BC4A4A7B 4A787E7Eh	Pairs of an ALIGN (0) (see table 97 in 6.2.3) and a dword containing D10.2, D24.3, D30.3, and D30.3 characters (see table 48 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-2) 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 228.

Table 228 – Summary of states in the SA_PC state machine

State	Reference	Modified ^a	States that contribute to definition	
			SPC-4	SBC-3
SA_PC_0:Powered_On ^b	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
^a 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. ^b 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.

STANDARDSISO.COM : Click to view the full PDF of ISO/IEC 14776-262:2017

Figure 171 shows the SA_PC state machine.

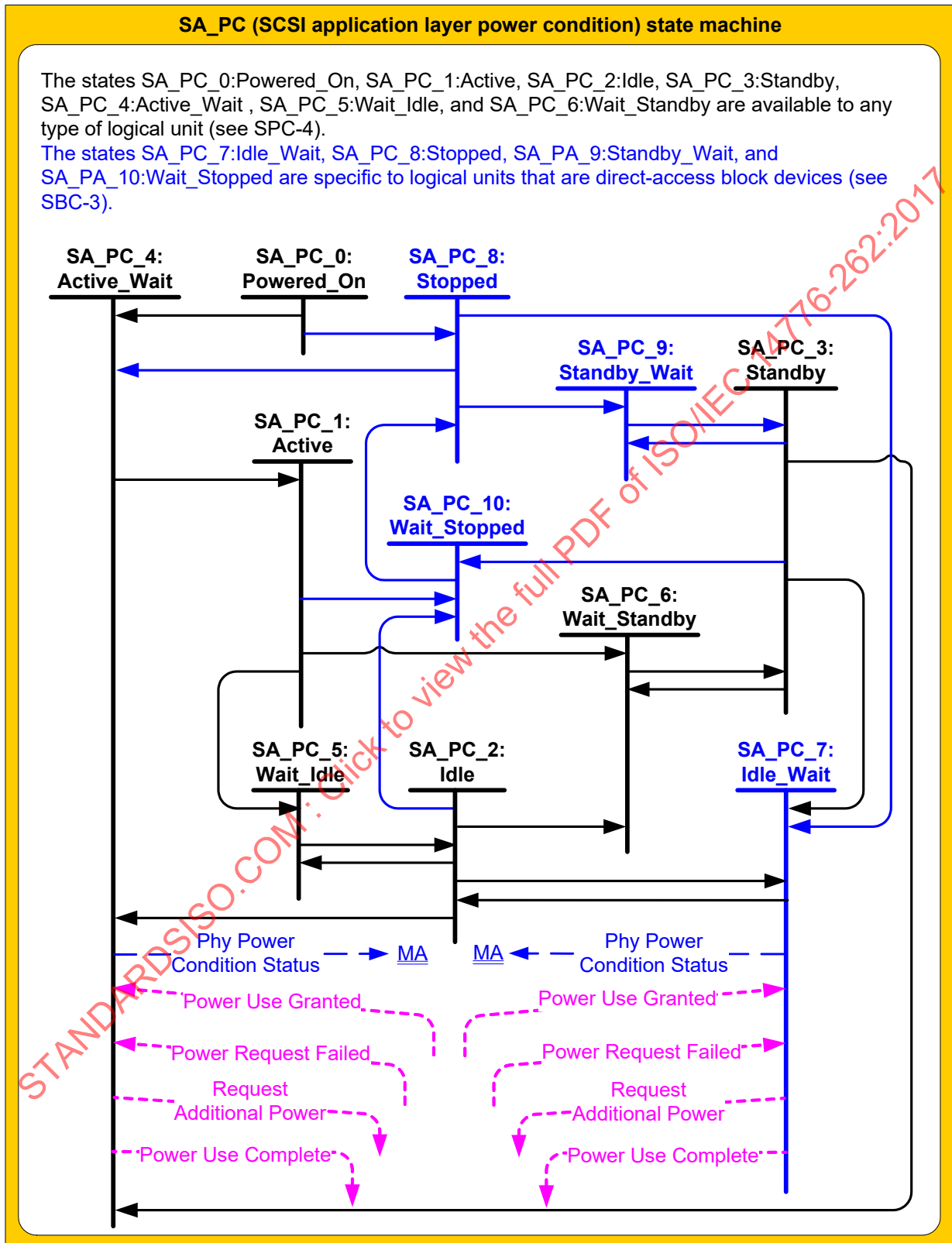


Figure 171 – SA_PC (SCSI application layer power condition) state machine for SAS

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 CFF 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 CFF 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 CFF 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 after:

- a) 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 CFF 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 CFF 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 after:

- a) 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 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 229 lists VPD pages for which this standard defines special requirements.

Table 229 – 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	See ^a
^a Mandatory if the SSP target port and logical unit support the TLR CONTROL field set to a non-zero value in the SSP frame header, otherwise optional.			

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 230.

Table 230 – 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 ^a (see 4.2.4)	Relative port identifier ^b as described in SAM-5 and SPC-4
^a The DESIGNATOR field contains the SAS address of the SSP target port through which the INQUIRY command was received. ^b 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 231.

Table 231 – 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 ^a
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)
^a 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.

Table 232 defines the Protocol Specific Logical Unit Information VPD page for logical units with SAS target ports.

Table 232 – 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 233)							
...								
...	...							
	Logical unit information descriptor (last) (see table 233)							
...								
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 to the value defined in table 232.

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 233 defines the logical unit information descriptor for logical units with SAS target ports.

Table 233 – 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 CONTROL 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 to the value defined in table 233 indicating that this is a SAS SSP specific descriptor.

The DESCRIPTOR LENGTH field is defined in SPC-4 and shall be set to the value defined in table 233.

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.

9.3 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 234.

Table 234 – READY LED signal behavior

Power condition ^a (see 9.2.10) or activity	READY LED MEANING bit set to zero ^b	READY LED MEANING bit set to one
active power condition or an idle power condition	The SAS target device shall: a) while not processing a command, assert the READY LED signal continuously; or b) while processing a command, toggle the READY LED signal between the asserted and negated states in a vendor-specified manner. (i.e., the LED is usually on, but flashes on and off while commands are processed)	The SAS target device shall: a) while not processing a command, negate the READY LED signal continuously; or b) while processing a command, toggle the READY LED signal between the asserted and negated states in a vendor-specified manner. (i.e., The LED is usually off, but flashes on and off while commands are processed)
a standby power condition or stopped power condition	The SAS target device shall: a) while not processing a command, negate the READY LED signal continuously; or b) while processing a command, toggle the READY LED signal between the asserted and negated states in a vendor-specified manner. (i.e., the LED is usually off, but flashes on and off while commands are processed) 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.	
spinup/spindown	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).	
formatting media	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).	
^a 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. ^b 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.		

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 235 defines the SMP functions.

Table 235 – SMP functions (FUNCTION field) (part 1 of 2)

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
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		

Table 235 – SMP functions (FUNCTION field) (part 2 of 2)

Function code	SMP function	Description	Reference
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
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 236 defines the SMP request frame format.

Table 236 – SMP request frame format

Byte ^a \ 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	(LSB)							

^a Shaded byte numbers (e.g., bytes 0 through 3 and (n - 3) through 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 is set to the value defined in table 236 (see 9.4.3.2.1).

9.4.3.2.3 FUNCTION field

The FUNCTION field specifies which SMP function is being requested and is defined in table 235 (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 238 (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 236 (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 client 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 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 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 237 defines the SMP response frame format.

Table 237 – SMP response frame format

Byte ^a \ 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	(LSB)							

^a Shaded byte numbers (e.g., bytes 0 through 3 and (n - 3) through 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 is set to the value defined in table 237 (see 9.4.3.3.1).

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 235 (see 9.4.3.1).

9.4.3.3.4 FUNCTION RESULT field

The FUNCTION RESULT field is defined in table 238.

Table 238 – 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.
05h	BUSY	ZONE UNLOCK, ENABLE DISABLE ZONING, CONFIGURE ZONE MANAGER PASSWORD, CONFIGURE ZONE PHY INFORMATION, CONFIGURE ZONE PERMISSION TABLE	For ZONE UNLOCK, the locked zoning expander device is processing the activate step. For the other functions, the management device server is currently saving zoning values.
06h	INCOMPLETE DESCRIPTOR LIST	ZONED BROADCAST, CONFIGURE ZONE PHY INFORMATION, CONFIGURE ZONE PERMISSION TABLE, CONFIGURE PHY 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 304), 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).

Table 238 – FUNCTION RESULT field (part 2 of 4)

Code	Name	SMP function(s)	Description
10h	PHY DOES NOT EXIST	DISCOVER, REPORT PHY ERROR LOG, REPORT PHY SATA, REPORT ROUTE INFORMATION, REPORT PHY EVENT, DISCOVER LIST, CONFIGURE ZONE PHY INFORMATION, CONFIGURE ROUTE INFORMATION, PHY CONTROL, PHY TEST FUNCTION, CONFIGURE PHY 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 EXIST	REPORT ROUTE INFORMATION, CONFIGURE ROUTE 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 SUPPORT SATA	REPORT PHY SATA, PHY CONTROL	See 9.4.3.12 and 9.4.3.28
13h	UNKNOWN PHY OPERATION	PHY CONTROL	See 9.4.3.28
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.

Table 238 – FUNCTION RESULT field (part 3 of 4)

Code	Name	SMP function(s)	Description
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
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: a) an unlocked zoning expander device receives an SMP zone configuration function request, a ZONE ACTIVATE request, or a ZONE UNLOCK request; or 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: a) the ACTIVATE REQUIRED bit is set to one in the request; and 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.

Table 238 – FUNCTION RESULT field (part 4 of 4)

Code	Name	SMP function(s)	Description
26h	NO PHYSICAL PRESENCE	CONFIGURE ZONE MANAGER PASSWORD	The following conditions are true: a) the NEW ZONE MANAGER PASSWORD field is set to DISABLED (see table 34 in 4.8.1); and 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 For REPORT ZONE MANAGER PASSWORD, see 9.4.3.8 For ENABLE DISABLE ZONING, CONFIGURE ZONE MANAGER PASSWORD, CONFIGURE ZONE PHY INFORMATION, and CONFIGURE ZONE PERMISSION TABLE, the following conditions are true the: a) SAVE field is set to 01b or 11b; and 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
All others	Reserved		

Table 239 defines the priority of the SMP function results defined in table 238.

Table 239 – Function result priority (part 1 of 4)

SMP function	SMP function result priority
REPORT GENERAL (see 9.4.3.4)	1) INVALID REQUEST FRAME LENGTH; 2) SMP FUNCTION FAILED; and 3) SMP FUNCTION ACCEPTED
REPORT MANUFACTURER INFORMATION (see 9.4.3.5)	1) INVALID REQUEST FRAME LENGTH; 2) SMP FUNCTION FAILED; and 3) SMP FUNCTION ACCEPTED
REPORT SELF-CONFIGURATION STATUS (see 9.4.3.6)	1) INVALID REQUEST FRAME LENGTH; 2) SMP FUNCTION FAILED; and 3) SMP FUNCTION ACCEPTED
REPORT ZONE PERMISSION TABLE (see 9.4.3.7)	1) INVALID REQUEST FRAME LENGTH; 2) SOURCE ZONE GROUP DOES NOT EXIST; 3) SAVING NOT SUPPORTED; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED
REPORT ZONE MANAGER PASSWORD (see 9.4.3.8)	1) INVALID REQUEST FRAME LENGTH; 2) NO MANAGEMENT ACCESS RIGHTS; 3) SAVING NOT SUPPORTED; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED
REPORT BROADCAST (see 9.4.3.9)	1) INVALID REQUEST FRAME LENGTH; 2) SMP FUNCTION FAILED; and 3) SMP FUNCTION ACCEPTED
DISCOVER (see 9.4.3.10)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) PHY VACANT; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED
REPORT PHY ERROR LOG (see 9.4.3.11)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) PHY VACANT; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED
REPORT PHY SATA (see 9.4.3.12)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) PHY VACANT; 4) PHY DOES NOT SUPPORT SATA; 5) SMP FUNCTION FAILED; and 6) SMP FUNCTION ACCEPTED
REPORT ROUTE INFORMATION (see 9.4.3.13)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) PHY VACANT; 4) INDEX DOES NOT EXIST; 5) SMP FUNCTION FAILED; and 6) SMP FUNCTION ACCEPTED

Table 239 – Function result priority (part 2 of 4)

SMP function	SMP function result priority
REPORT PHY EVENT (see 9.4.3.14)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) PHY VACANT; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED
DISCOVER LIST (see 9.4.3.15)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) UNKNOWN DESCRIPTOR TYPE; 4) UNKNOWN PHY FILTER; 5) SMP FUNCTION FAILED; and 6) SMP FUNCTION ACCEPTED
REPORT PHY EVENT LIST (see 9.4.3.16)	1) INVALID REQUEST FRAME LENGTH; 2) SMP FUNCTION FAILED; and 3) SMP FUNCTION ACCEPTED
REPORT EXPANDER ROUTE TABLE LIST (see 9.4.3.17)	1) INVALID REQUEST FRAME LENGTH; 2) SMP FUNCTION FAILED; and 3) SMP FUNCTION ACCEPTED
CONFIGURE GENERAL (see 9.4.3.18)	1) INVALID REQUEST FRAME LENGTH; 2) SMP ZONE VIOLATION; 3) INVALID EXPANDER CHANGE COUNT; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED
ENABLE DISABLE ZONING (see 9.4.3.19)	1) INVALID REQUEST FRAME LENGTH; 2) ZONE LOCK VIOLATION; 3) UNKNOWN ENABLE DISABLE ZONING VALUE; 4) INVALID EXPANDER CHANGE COUNT; 5) SAVING NOT SUPPORTED; 6) SMP FUNCTION FAILED; and 7) SMP FUNCTION ACCEPTED
ZONED BROADCAST (see 9.4.3.20)	1) INVALID REQUEST FRAME LENGTH; 2) INCOMPLETE DESCRIPTOR LIST; 3) SMP ZONE VIOLATION; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED
ZONE LOCK (see 9.4.3.21)	1) INVALID REQUEST FRAME LENGTH; 2) NO MANAGEMENT ACCESS RIGHTS; 3) INVALID EXPANDER CHANGE COUNT; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED
ZONE ACTIVATE (see 9.4.3.22)	1) INVALID REQUEST FRAME LENGTH; 2) ZONE LOCK VIOLATION; 3) INVALID EXPANDER CHANGE COUNT; 4) SMP FUNCTION FAILED; and 5) SMP FUNCTION ACCEPTED

Table 239 – Function result priority (part 3 of 4)

SMP function	SMP function result priority
ZONE UNLOCK (see 9.4.3.23)	1) INVALID REQUEST FRAME LENGTH; 2) ZONE LOCK VIOLATION; 3) NOT ACTIVATED; 4) BUSY; 5) SMP FUNCTION FAILED; and 6) SMP FUNCTION ACCEPTED
CONFIGURE ZONE MANAGER PASSWORD (see 9.4.3.24)	1) INVALID REQUEST FRAME LENGTH; 2) INVALID EXPANDER CHANGE COUNT; 3) NO MANAGEMENT ACCESS RIGHTS; 4) NO PHYSICAL PRESENCE; 5) SAVING NOT SUPPORTED; 6) DISABLED PASSWORD NOT SUPPORTED; 7) SMP FUNCTION FAILED; and 8) SMP FUNCTION ACCEPTED
CONFIGURE ZONE PHY INFORMATION (see 9.4.3.25)	1) INVALID REQUEST FRAME LENGTH; 2) INCOMPLETE DESCRIPTOR LIST; 3) PHY DOES NOT EXIST; 4) PHY VACANT; 5) ZONE LOCK VIOLATION; 6) INVALID EXPANDER CHANGE COUNT; 7) SAVING NOT SUPPORTED; 8) ZONE GROUP OUT OF RANGE; 9) SMP FUNCTION FAILED; and 10) SMP FUNCTION ACCEPTED

Table 239 – Function result priority (part 4 of 4)

SMP function	SMP function result priority
CONFIGURE ZONE PERMISSION TABLE (see 9.4.3.26)	1) INVALID REQUEST FRAME LENGTH; 2) INCOMPLETE DESCRIPTOR LIST; 3) ZONE LOCK VIOLATION; 4) INVALID EXPANDER CHANGE COUNT; 5) SAVING NOT SUPPORTED; 6) ZONE GROUP OUT OF RANGE; 7) SMP FUNCTION FAILED; and 8) SMP FUNCTION ACCEPTED
CONFIGURE ROUTE INFORMATION (see 9.4.3.27)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) PHY VACANT; 4) INVALID EXPANDER CHANGE COUNT; 5) INDEX DOES NOT EXIST; 6) SMP FUNCTION FAILED; and 7) SMP FUNCTION ACCEPTED
PHY CONTROL (see 9.4.3.28)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) PHY VACANT; 4) SMP ZONE VIOLATION; 5) INVALID EXPANDER CHANGE COUNT; 6) UNKNOWN PHY OPERATION; 7) PHY DOES NOT SUPPORT SATA; 8) AFFILIATION VIOLATION; 9) SMP FUNCTION FAILED; and 10) SMP FUNCTION ACCEPTED
PHY TEST FUNCTION (see 9.4.3.29)	1) INVALID REQUEST FRAME LENGTH; 2) PHY DOES NOT EXIST; 3) PHY VACANT; 4) SMP ZONE VIOLATION; 5) INVALID EXPANDER CHANGE COUNT; 6) UNKNOWN PHY TEST FUNCTION; 7) PHY TEST FUNCTION IN PROGRESS; 8) SMP FUNCTION FAILED; and 9) SMP FUNCTION ACCEPTED
CONFIGURE PHY EVENT (see 9.4.3.30)	1) INVALID REQUEST FRAME LENGTH; 2) INCOMPLETE DESCRIPTOR LIST; 3) PHY DOES NOT EXIST; 4) PHY VACANT; 5) SMP ZONE VIOLATION; 6) INVALID EXPANDER CHANGE COUNT; 7) UNKNOWN PHY EVENT SOURCE; 8) SMP FUNCTION FAILED; and 9) SMP FUNCTION ACCEPTED

9.4.3.3.5 RESPONSE LENGTH field

A RESPONSE LENGTH field set to 00h indicates that either:

- a) no dwords follow the RESPONSE LENGTH field before the CRC field; or
- b) 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 237 (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 the 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-1.2 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 240 defines the request format.

Table 240 – 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)							
...	CRC							
7	(LSB)							

The SMP FRAME TYPE field is defined in 9.4.3.2.2 and shall be set to the value defined in table 240.

The FUNCTION field is defined in 9.4.3.2.3 and shall be set to the value defined in table 240.

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 28 bytes defined in table 241 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 24.1; 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 to the value defined in table 240

The CRC field is defined in 9.4.3.2.7.

Table 241 defines the response format.

Table 241 – 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) EXPANDER CHANGE COUNT (LSB)							
5	(MSB) EXPANDER ROUTE INDEXES (LSB)							
6	(MSB) EXPANDER ROUTE INDEXES (LSB)							
7	(MSB) 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							
...	ENCLOSURE LOGICAL IDENTIFIER							
19	ENCLOSURE LOGICAL IDENTIFIER							
20	ENCLOSURE LOGICAL IDENTIFIER							
...	Reserved							
27	Reserved							
28	Reserved							
29	Reserved							

Table 241 – REPORT GENERAL response (part 3 of 3)

Byte\Bit	7	6	5	4	3	2	1	0
64	(MSB)	LAST PHY EVENT LIST DESCRIPTOR INDEX						(LSB)
65								
66	(MSB)	MAXIMUM NUMBER OF STORED PHY EVENT LIST DESCRIPTORS						(LSB)
67								
68	(MSB)	STP REJECT TO OPEN LIMIT						(LSB)
69								
70		Reserved						
71								
72	(MSB)	CRC						(LSB)
...								
75								

The SMP FRAME TYPE field is defined in 9.4.3.3.2 and shall be set to the value defined in table 241.

The FUNCTION field is defined in 9.4.3.3.3 and shall be set to the value defined in table 241.

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 241 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 would otherwise have resulted 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 ENCLOSURE LOGICAL IDENTIFIER field identifies the enclosure, if any, in which the device is located, and is defined in SES-2. 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 STP BUS INACTIVITY TIME LIMIT field indicates the bus inactivity time limit for STP connections, which is set by the CONFIGURE GENERAL function (see 9.4.3.18).

The STP MAXIMUM CONNECT TIME LIMIT field indicates the maximum connect time limit for STP connections, which is set 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 which is set 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 242.

Table 242 – 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.