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AMENDMENT 7
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Telecommunications and exchange between information technology systems — Requirements for local and metropolitan area networks —

Part 3: **Standard for Ethernet**

AMENDMENT 7: Physical layer and management parameters for 400 Gb/s over multimode fiber

Télécommunications et échange entre systèmes informatiques — Exigences pour les réseaux locaux et métropolitains —

Partie 3: Norme pour Ethernet

AMENDEMENT 7: Couche physique et paramètres de gestion pour 400 Gb/s sur fibres multimodales

Reference number
ISO/IEC/IEEE 8802-3:2021/Amd.7:2021(E)

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IEEE Std 802.3cm™-2020
(Amendment to IEEE Std 802.3™-2018
as amended by IEEE Std 802.3cb™-2018,
IEEE Std 802.3bt™-2018,
IEEE Std 802.3cd™-2018,
IEEE Std 802.3cn™-2019,
IEEE Std 802.3cg™-2019,
and IEEE Std 802.3cq™-2020)

IEEE Standard for Ethernet

Amendment 7: Physical Layer and Management Parameters for 400 Gb/s over Multimode Fiber

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 30 January 2020

IEEE SA Standards Board

Abstract: This amendment to IEEE Std 802.3-2018 adds Clause 150. This amendment adds Physical Layer (PHY) specifications and management parameters for 400 Gb/s operation on four pairs (400GBASE-SR4.2) and eight pairs (400GBASE-SR8) of multimode fiber, over reaches of at least 100 m.

Keywords: 400 Gb/s Ethernet, 400 Gigabit Ethernet, 400GBASE-SR8, 400GBASE-SR4.2, amendment, Energy Efficient Ethernet (EEE), Ethernet, Forward Error Correction (FEC), IEEE 802.3™, IEEE 802.3cd, IEEE 802.3cm, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, Physical Medium Dependent (PMD) sublayer, Reconciliation Sublayer (RS), multimode fiber (MMF)

This standard is dedicated to the memory of our friend and colleague Jonathan P. King.

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Introduction

This introduction is not part of IEEE Std 802.3cm-2020, IEEE Standard for Ethernet. Amendment 7: Physical Layer and Management Parameters for 400 Gb/s over Multimode Fiber.

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

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

Some of the major additions to IEEE Std 802.3 are identified in the marketplace with their project number. This is most common for projects adding higher speeds of operation or new protocols. For example, IEEE Std 802.3u™ added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3z added 1000 Mb/s operation (also called Gigabit Ethernet), IEEE Std 802.3ae added 10 Gb/s operation (also called 10 Gigabit Ethernet), IEEE Std 802.3ah™ specified access network Ethernet (also called Ethernet in the First Mile) and IEEE Std 802.3ba added 40 Gb/s operation (also called 40 Gigabit Ethernet) and 100 Gb/s operation (also called 100 Gigabit Ethernet). These major additions are all now included in and are superseded by IEEE Std 802.3-2018 and are not maintained as separate documents.

At the date of IEEE Std 802.3cm-2020 publication, IEEE Std 802.3 was composed of the following documents:

IEEE Std 802.3-2018

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

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

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

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

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

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

Section Seven—Includes Clause 96 through Clause 115 and Annex 97A through Annex 115A. Clause 96 through Clause 98, Clause 104, and associated annexes, specify Physical Layers and optional features for 100 Mb/s and 1000 Mb/s operation over a single twisted pair. Clause 100 through Clause 103, as well as associated annexes, specify Physical Layers for the operation of the EPON protocol over coaxial distribution networks. Clause 105 through Clause 114 and associated annexes include general information on 25 Gb/s operation as well as 25 Gb/s Physical Layer specifications. Clause 99 specifies a MAC merge sublayer for the interspersing of express traffic. Clause 115 and its associated annex specify a Physical Layer for 1000 Mb/s operation over plastic optical fiber.

Section Eight—Includes Clause 116 through Clause 126 and Annex 119A through Annex 120E. Clause 116 through Clause 124 and associated annexes include general information on 200 Gb/s and 400 Gb/s operation as well the 200 Gb/s and 400 Gb/s Physical Layer specifications. Clause 125 and Clause 126 include general information on 2.5 Gb/s and 5 Gb/s operation as well as 2.5 Gb/s and 5 Gb/s Physical Layer specifications.

IEEE Std 802.3cb™-2018

Amendment 1—This amendment includes changes to IEEE Std 802.3-2018 and its amendments, and adds Clause 127 through Clause 130, Annex 127A, Annex 128A, Annex 128B, and Annex 130A. This amendment adds new Physical Layers for operation at 2.5 Gb/s and 5 Gb/s over electrical backplanes.

IEEE Std 802.3bt™-2018

Amendment 2—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 145, Annex 145A, Annex 145B, and Annex 145C. This amendment adds power delivery using all four pairs in the structured wiring plant, resulting in greater power being available to end devices. This amendment also allows for lower standby power consumption in end devices and adds a mechanism to better manage the available power budget.

IEEE Std 802.3cd™-2018

Amendment 3—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 131 through Clause 140 and Annex 135A through Annex 136D. This amendment adds MAC parameters, Physical Layers, and management parameters for the transfer of IEEE 802.3 format frames at 50 Gb/s, 100 Gb/s, and 200 Gb/s.

IEEE Std 802.3cn™-2019

Amendment 4—This amendment includes changes to IEEE Std 802.3-2018 and adds 50 Gb/s, 200 Gb/s, and 400 Gb/s Physical Layer specifications and management parameters for operation over single-mode fiber with reaches of at least 40 km.

IEEE Std 802.3cg™-2019

Amendment 5—This amendment includes changes to IEEE Std 802.3-2018 and its amendments, and adds Clause 146 through Clause 148 and Annex 146A and Annex 146B. This amendment adds 10 Mb/s Physical Layer specifications and management parameters for operation on a single balanced pair of conductors.

IEEE Std 802.3cq™-2020

Amendment 6—This amendment includes editorial and technical corrections, refinements, and clarifications to Clause 33 and related portions of the standard.

IEEE Std 802.3cm™-2020

Amendment 7—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 150. This amendment adds Physical Layer (PHY) specifications and management parameters for 400 Gb/s operation on four pairs (400GBASE-SR4.2) and eight pairs (400GBASE-SR8) of multimode fiber, over reaches of at least 100 m.

Two companion documents exist, IEEE Std 802.3.1 and IEEE Std 802.3.2. IEEE Std 802.3.1 describes Ethernet management information base (MIB) modules for use with the Simple Network Management Protocol (SNMP). IEEE Std 802.3.2 describes YANG data models for Ethernet. IEEE Std 802.3.1 and IEEE Std 802.3.2 are updated to add management capability for enhancements to IEEE Std 802.3 after approval of those enhancements.

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

Contents

IEEE Standard for Ethernet

Amendment 7: Physical Layer and Management Parameters for 400 Gb/s over Multimode Fiber

(This amendment is based on IEEE Std 802.3™-2018 as amended by IEEE Std 802.3cb™-2018, IEEE Std 802.3bt™-2018, IEEE Std 802.3cd™-2018, IEEE Std 802.3cn™-2019, IEEE Std 802.3cg™-2019 and IEEE_Std_802.3cq-2020.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

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

Cross references that refer to clauses, tables, equations, or figures not covered by this amendment are highlighted in green.[1]

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

1. Introduction

1.3 Normative references

Insert the following two references in alphanumeric order:

ANSI/TIA-604-18-A:2018, FOCIS 18—Fiber Optic Connector Intermateability Standard—Type MPO-16.[2]

IEC 61754-7-2:2017, Fibre optic interconnecting devices and passive components—Fibre optic connector interfaces—Part 7-2: Type MPO connector family—Two fibre rows.[3]

1.4 Definitions

Insert two new definitions after 1.4.110 "400GBASE-SR16" as follows:

1.4.110a 400GBASE-SR4.2: IEEE 802.3 Physical Layer specification for 400 Gb/s using 400GBASE-R encoding over eight lanes on multimode fiber in a bidirectional WDM format, with reach up to at least 150 m. (See IEEE Std 802.3, Clause 150.)

1.4.110b 400GBASE-SR8: IEEE 802.3 Physical Layer specification for 400 Gb/s using 400GBASE-R encoding over eight lanes of multimode fiber, with reach up to at least 100 m. (See IEEE Std 802.3, Clause 138.)

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

[3]IEC publications are available from the International Electrotechnical Commission (https://www.iec.ch/) and the American National Standards Institute (https://www.ansi.org).

30. Management

30.5 Layer management for medium attachment units (MAUs)

30.5.1 MAU managed object class

30.5.1.1 MAU attributes

30.5.1.1.2 aMAUType

Insert 400GBASE-SR8 and 400GBASE-SR4.2 PHY types into the "APPROPRIATE SYNTAX" section of 30.5.1.1.2 after 400GBASE-SR16, as follows:

…

400GBASE-SR8	400GBASE-R PCS/PMA over 8-lane multimode fiber PMD as specified in Clause 138
400GBASE-SR4.2	400GBASE-R PCS/PMA over 8-lane multimode fiber PMD as specified in Clause 150

…

45. Management Data Input/Output (MDIO) Interface

45.2 MDIO Interface Registers

45.2.1 PMA/PMD registers

45.2.1.6 PMA/PMD control 2 register (Register 1.7)

Change the indicated reserved rows of Table 45–7 (as modified by IEEE Std 802.3cn-2019) as follows (unchanged rows not shown):

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

Bit(s)	Name	Description	R/W[a]
…			
1.7.6:0	PMA/PMD type selection	6 5 4 3 2 1 0 … ~~1 1 0 0 0 0 x = reserved~~ 1 1 0 0 0 0 1 = reserved 1 1 0 0 0 0 0 = 400GBASE-SR4.2 PMA/PMD ~~1 0 1 1 1 1 x = reserved~~ 1 0 1 1 1 1 1 = 400GBASE-SR8 PMA/PMD 1 0 1 1 1 1 0 = reserved …	R/W

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

45.2.1.7 PMA/PMD status 2 register (Register 1.8)

45.2.1.7.4 Transmit fault (1.8.11)

Change the row for 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4 in Table 45–9 (as inserted by IEEE Std 802.3cd-2018) and insert a new row for 400GBASE-SR4.2 after the row for 400GBASE-SR16 as follows (unchanged rows not shown):

Table 45–9—Transmit fault description location

PMA/PMD	Description location
…	
50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4, 400GBASE-SR8	138.5.10
…	
400GBASE-SR4.2	150.5.10
…	

45.2.1.7.5 Receive fault (1.8.10)

Change the row for 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4 in Table 45–10 (as inserted by IEEE Std 802.3cd-2018) and insert a new row for 400GBASE-SR4.2 after the row for 400GBASE-SR16 as follows (unchanged rows not shown):

Table 45–10—Receive fault description location

PMA/PMD	Description location
…	
50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4, 400GBASE-SR8	138.5.11
…	
400GBASE-SR4.2	150.5.11
…	

45.2.1.8 PMD transmit disable register (Register 1.9)

Change the row for 50GBASE-SR, 100GBASE-SR2, and 200GBASE-SR4 in Table 45–12 (as inserted by IEEE Std 802.3cd-2018) and insert a new row for 400GBASE-SR4.2 after the row for 400GBASE-SR16 as follows (unchanged rows not shown):

Table 45–12—Transmit disable description location

PMA/PMD	Description location
…	
50GBASE-SR, 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8	138.5.7
…	
400GBASE-SR4.2	150.5.7
…	

45.2.1.21 400G PMA/PMD extended ability register (Register 1.24)

Change the row for bits 1.24.9:6 in Table 45–24 (as inserted by IEEE Std 802.3cn-2019) as follows (unchanged rows not shown):

Table 45–24—400G PMA/PMD extended ability register bit definitions

Bit(s)	Name	Description	R/W[a]
…			
1.24.9:86	Reserved	Value always 0	RO
1.24.7	400GBASE-SR4.2 ability	1 = PMA/PMD is able to perform 400GBASE-SR4.2 0 = PMA/PMD is not able to perform 400GBASE-SR4.2	RO
1.24.6	400GBASE-SR8 ability	1 = PMA/PMD is able to perform 400GBASE-SR8 0 = PMA/PMD is not able to perform 400GBASE-SR8	RO
…			

[a]RO = Read only

Insert 45.2.1.21.1b and 45.2.1.21.1c after 45.2.1.21.1a (as inserted by IEEE Std 802.3cn-2019) as follows:

45.2.1.21.1b 400GBASE-SR4.2 ability (1.24.7)

When read as a one, bit 1.24.7 indicates that the PMA/PMD is able to operate as a 400GBASE-SR4.2 PMA/PMD type. When read as a zero, bit 1.24.7 indicates that the PMA/PMD is not able to operate as a 400GBASE-SR4.2 PMA/PMD type.

45.2.1.21.1c 400GBASE-SR8 ability (1.24.6)

When read as a one, bit 1.24.6 indicates that the PMA/PMD is able to operate as a 400GBASE-SR8 PMA/PMD type. When read as a zero, bit 1.24.6 indicates that the PMA/PMD is not able to operate as a 400GBASE-SR8 PMA/PMD type.

78. Energy-Efficient Ethernet (EEE)

78.1 Overview

78.1.4 PHY types optionally supporting EEE

Insert two new rows in Table 78–1 immediately below 400GBASE-SR16, as follows (unchanged rows not shown):

Table 78–1—Clauses associated with each PHY or interface type

PHY or interface type	Clause
…	
400GBASE-SR8[b]	119, 120, 138
400GBASE-SR4.2[b]	119, 120, 150
…	

[b] The deep sleep mode of EEE is not supported for this PHY.

116. Introduction to 200 Gb/s and 400 Gb/s networks

116.1 Overview

116.1.2 Relationship of 200 Gigabit and 400 Gigabit Ethernet to the ISO OSI reference model

Change exception g) in 116.1.2 (as modified by IEEE Std 802.3cn-2019) as follows:

g) The MDIs as specified in Clause 122 for 400GBASE-FR8, 400GBASE-LR8, and 400GBASE-ER8, in Clause 138 for 400GBASE-SR8, and in Clause 150 for 400GBASE-SR4.2, all use ~~uses~~ an 8-lane data path.

116.1.3 Nomenclature

Insert two new rows below 400GBASE-SR16 in Table 116–2 as follows (unchanged rows not shown):

Table 116–2—400 Gb/s PHYs

Name	Description
…	
400GBASE-SR8	400 Gb/s PHY using 400GBASE-R encoding over eight lanes of multimode fiber, with reach up to at least 100 m (see Clause 138)
400GBASE-SR4.2	400 Gb/s PHY using 400GBASE-R encoding over eight lanes on multimode fiber in a bidirectional WDM format, with reach up to at least 150 m (see Clause 150)
…	

116.1.4 Physical Layer signaling systems

Change Table 116–4 (as modified by IEEE Std 802.3cn-2019) as follows:

Table 116–4—PHY type and clause correlation (400GBASE optical)

PHY type	Clause[a]																
	78	117		118	119	120	120B	120C	120D	120E	123	<u>138</u>	<u>150</u>	124	122		
	EEE	RS	400GMII	400GMII Extender	400GBASE-R PCS	400GBASE-R PMA	400GAUI-16 C2C	400GAUI-16 C2M	400GAUI-8 C2C	400GAUI-8 C2M	400GBASE-SR16 PMD	<u>400GBASE-SR8 PMD</u>	<u>400GBASE-SR4.2 PMD</u>	400GBASE-DR4 PMD	400GBASE-FR8 PMD	400GBASE-LR8 PMD	400GBASE-ER8 PMD
400GBASE-SR16	O	M	O	O	M	M	O	O	O	O	M						
<u>400GBASE-SR8</u>	<u>O</u>	<u>M</u>	<u>O</u>	<u>O</u>	<u>M</u>	<u>M</u>	<u>O</u>	<u>O</u>	<u>O</u>	<u>O</u>		<u>M</u>					
<u>400GBASE-SR4.2</u>	<u>O</u>	<u>M</u>	<u>O</u>	<u>O</u>	<u>M</u>	<u>M</u>	<u>O</u>	<u>O</u>	<u>O</u>	<u>O</u>			<u>M</u>				
400GBASE-DR4	O	M	O	O	M	M	O	O	O	O				M			
400GBASE-FR8	O	M	O	O	M	M	O	O	O	O					M		
400GBASE-LR8	O	M	O	O	M	M	O	O	O	O						M	
400GBASE-ER8	O	M	O	O	M	M	O	O	O	O							M

[a] O = Optional, M = Mandatory.

116.2 Summary of 200 Gigabit and 400 Gigabit Ethernet sublayers

116.2.5 Physical Medium Dependent (PMD) sublayer

Change the second paragraph of 116.2.5 (as amended by IEEE Std 802.3cd-2018) as follows:

The 200GBASE-R PMDs and their corresponding media are specified in Clause 121, Clause 122, and Clause 136 through Clause 138. The 400GBASE-R PMDs and their corresponding media are specified in Clause 122 through Clause 124<u>, Clause 138, and Clause 150</u>.

116.4 Delay constraints

Change Table 116–6 (as amended by IEEE Std 802.3cn-2019) as follows:

Table 116–6—Sublayer delay constraints (400GBASE)

Sublayer	Maximum (bit time)[a]	Maximum (pause_quanta)[b]	Maximum (ns)	Notes[c]
400G MAC, RS, and MAC Control	98 304	192	245.76	See 117.1.4.
400GBASE-R PCS or 400GXS[d]	320 000	625	800	See 119.5.
400GBASE-R PMA	36 864	72	92.16	See 120.5.4.
400GBASE-SR16 PMD	8 192	16	20.48	Includes 2 m of fiber. See 123.3.1.
400GBASE-SR8 PMD	8 192	16	20.48	Includes 2 m of fiber. See 138.3.1.
400GBASE-SR4.2 PMD	8 192	16	20.48	Includes 2 m of fiber. See 150.3.1.
400GBASE-DR4 PMD	8 192	16	20.48	Includes 2 m of fiber. See 124.3.1.
400GBASE-FR8 PMD	8 192	16	20.48	Includes 2 m of fiber. See 122.3.1.
400GBASE-LR8 PMD	8 192	16	20.48	Includes 2 m of fiber. See 122.3.1.
400GBASE-ER8 PMD	8 192	16	20.48	Includes 2 m of fiber. See 122.3.1.

[a] For 400GBASE-R, 1 bit time (BT) is equal to 2.5 ps. (See 1.4.160 for the definition of bit time.)
[b] For 400GBASE-R, 1 pause_quantum is equal to 1.28 ns. (See 31B.2 for the definition of pause_quanta.)
[c] Should there be a discrepancy between this table and the delay requirements of the relevant sublayer clause, the sublayer clause prevails.
[d] If an implementation includes the 400GMII extender, the delay associated with the 400GMII extender includes two 400GXS sublayers.

116.5 Skew constraints

Change Table 116–7 and Table 116–8 as follows:

Table 116–7—Summary of Skew constraints

Skew points	Maximum Skew (ns)[a]	Maximum Skew for 200GBASE-R or 400GBASE-R PCS lane (UI)[b]	Notes[c]
SP1	29	≈ 770	See 120.5.3.1
SP2	43	≈ 1142	See 120.5.3.3, 121.3.2, 122.3.2, 123.3.2, ~~or~~ 124.3.2, 138.3.2, or 150.3.2
SP3	54	≈ 1434	See 121.3.2, 122.3.2, 123.3.2, ~~or~~ 124.3.2, 138.3.2, or 150.3.2
SP4	134	≈ 3559	See 121.3.2, 122.3.2, 123.3.2, ~~or~~ 124.3.2, 138.3.2, or 150.3.2
SP5	145	≈ 3852	See 121.3.2, 122.3.2, 123.3.2, ~~or~~ 124.3.2, 138.3.2, or 150.3.2
SP6	160	≈ 4250	See 120.5.3.5
At PCS receive	180	≈ 4781	See 119.2.5.1

[a] The Skew limit includes 1 ns allowance for PCB traces that are associated with the Skew points.
[b] The symbol ≈ indicates approximate equivalent of maximum Skew in UI based on 1 UI equals 37.64706 ps at PCS lane signaling rate of 26.5625 GBd.
[c] Should there be a discrepancy between this table and the Skew requirements of the relevant sublayer clause, the sublayer clause prevails.

Table 116–8—Summary of Skew Variation constraints

Skew points	Maximum Skew Variation (ns)	Maximum Skew Variation for 26.5625 GBd PMD lane (UI)[a]	Maximum Skew Variation for 53.125 GBd PMD lane (UI)[b]	Notes[c]
SP1	0.2	≈ 5	N/A	See 120.5.3.1
SP2	0.4	≈ 11	≈ 21	See 120.5.3.3, 121.3.2, 122.3.2, 123.3.2, ~~or~~ 124.3.2, 138.3.2, or 150.3.2
SP3	0.6	≈ 16	≈ 32	See 121.3.2, 122.3.2, 123.3.2, ~~or~~ 124.3.2, 138.3.2, or 150.3.2
SP4	3.4	≈ 90	≈ 181	See 121.3.2, 122.3.2, 123.3.2, ~~or~~ 124.3.2, 138.3.2, or 150.3.2
SP5	3.6	≈ 96	≈ 191	See 121.3.2, 122.3.2, 123.3.2, ~~or~~ 124.3.2, 138.3.2, or 150.3.2
SP6	3.8	≈ 101	N/A	See 120.5.3.5
At PCS receive	4	≈ 106	N/A	See 119.2.5.1

[a] The symbol ≈ indicates approximate equivalent of maximum Skew Variation in UI based on 1 UI equals 37.64706 ps at PMD lane signaling rate of 26.5625 GBd.
[b] The symbol ≈ indicates approximate equivalent of maximum Skew Variation in UI based on 1 UI equals 18.82353 ps at PMD lane signaling rate of 53.125 GBd.
[c] Should there be a discrepancy between this table and the Skew requirements of the relevant sublayer clause, the sublayer clause prevails.

Change the title of Clause 138 as follows:

138. Physical Medium Dependent (PMD) sublayer and medium, type 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4, 400GBASE-SR8

Clause 138 was added to IEEE Std 802.3-2018 by IEEE Std 802.3cd-2018 and modified by IEEE Std 802.3cn-2019.

138.1 Overview

Change the first paragraph of 138.1 and Table 138–3 as follows:

This clause specifies the 50GBASE-SR, 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8 PMDs together with the multimode fiber medium. The optical signals generated by these ~~three~~ PMD types are modulated using a 4-level pulse amplitude modulation (PAM4) format. The PMD sublayers provide point-to-point 50, 100, ~~and~~ 200, and 400 Gigabit Ethernet links over one, two, ~~or~~ four, or eight pairs of multimode fiber, with a reach of up to at least 100 m.

Table 138–3—Physical Layer clauses associated with the 200GBASE-SR4 and 400GBASE-SR8 PMDs

Associated clause	200GBASE-SR4	400GBASE-SR8
117—RS	Required	Required
117—200GMII[a]	Optional	Not applicable
117—400GMII[a]	Not applicable	Optional
118—200GMII Extender	Optional	Not applicable
118—400GMII Extender	Not applicable	Optional
119—PCS for 200GBASE-R	Required	Not applicable
119—PCS for 400GBASE-R	Not applicable	Required
120—PMA for 200GBASE-R	Required	Not applicable
120—PMA for 400GBASE-R	Not applicable	Required
120B—200GAUI-8 C2C	Optional	Not applicable
120B—400GAUI-16 C2C	Not applicable	Optional
120C—200GAUI-8 C2M	Optional	Not applicable
120C—400GAUI-16 C2M	Not applicable	Optional
120D—200GAUI-4 C2C	Optional	Not applicable
120D—400GAUI-8 C2C	Not applicable	Optional

Table 138–3—Physical Layer clauses associated with the 200GBASE-SR4 and 400GBASE-SR8 PMDs *(continued)*

Associated clause	200GBASE-SR4	400GBASE-SR8
120E—200GAUI-4 C2M	Optional	Not applicable
120E—400GAUI-8 C2M	Not applicable	Optional
78—Energy-Efficient Ethernet	Optional	Optional

[a]The 200GMII and 400GMII are is an optional interfaces. However, if the appropriate interface200GMII is not implemented, a conforming implementation must behave functionally as though the RS and 200GMII or 400GMII were present.

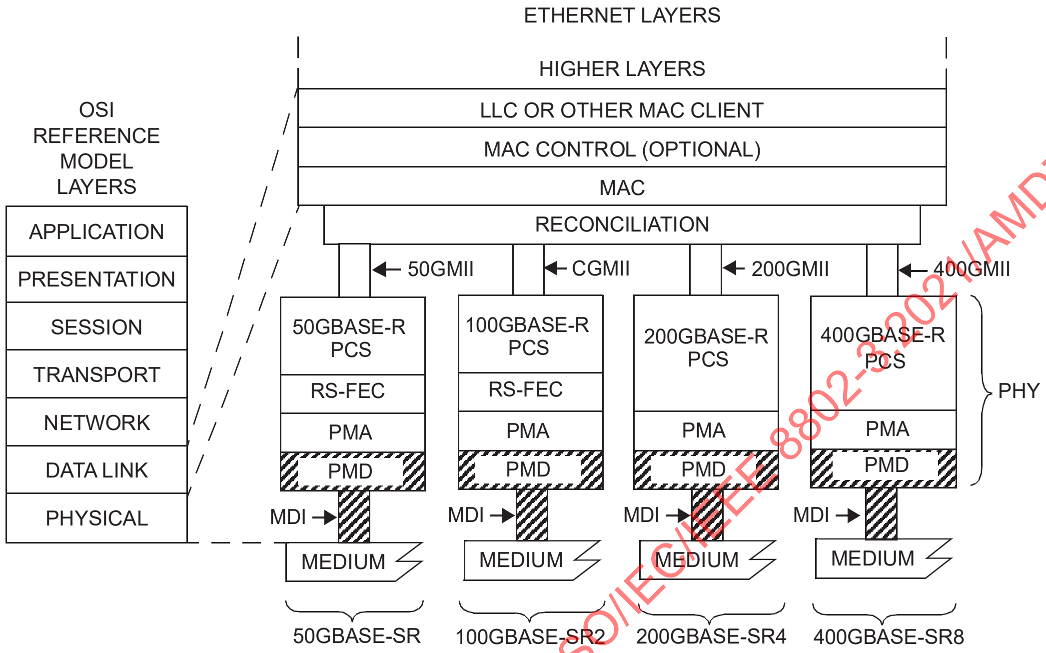
Change the third, fourth, and fifth paragraphs of 138.1 as follows:

Figure 138–1 shows the relationship of the PMDs and MDIs (shown shaded) with other sublayers to the ISO/IEC Open System Interconnection (OSI) reference model. 50 Gigabit Ethernet is introduced in Clause 131 and the purpose of each PHY sublayer is summarized in 131.2. 100 Gigabit Ethernet is introduced in Clause 80 and the purpose of each PHY sublayer is summarized in 80.2. 200 Gigabit Ethernet and 400 Gigabit Ethernet areis introduced in Clause 116 and the purpose of each PHY sublayer is summarized in 116.2.

50GBASE-SR, 100GBASE-SR2, and 200GBASE-SR4, and 400GBASE-SR8 PHYs with the optional Energy-Efficient Ethernet (EEE) fast wake capability may enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization (see Clause 78). The deep sleep mode of EEE is not supported.

Further relevant information may be found in Clause 1 (terminology and conventions, references, definitions and abbreviations) and Annex A (bibliography, referenced as [B1], [B2], etc.). The 50GBASE-SR, 100GBASE-SR2, and 200GBASE-SR4, and 400GBASE-SR8 sublayers provide point-to-point 50, 100, and 200, and 400 Gigabit Ethernet links over one, two, or four, or eight pairs of multimode fiber, up to at least 100 m.

Replace Figure 138–1 as follows:



400GMII = 400 Gb/s MEDIA INDEPENDENT INTERFACE
200GMII = 200 Gb/s MEDIA INDEPENDENT INTERFACE
50GMII = 50 Gb/s MEDIA INDEPENDENT INTERFACE
CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
RS-FEC = REED-SOLOMON FORWARD ERROR CORRECTION
SR = PMD FOR MULTIMODE FIBER

Figure 138–1—50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4, 400GBASE-SR8 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

138.1.1 Bit error ratio

Change the second paragraph of 138.1.1 as follows:

For the 200GBASE-SR4 and 400GBASE-SR8 PMDs, the bit error ratio (BER) when processed by the PMA (Clause 120) shall be less than 2.4×10^{-4} provided that the error statistics are sufficiently random that this results in a frame loss ratio (see 1.4.275) of less than 1.7×10^{-12} for 64-octet frames with minimum interpacket gap when additionally processed by the PCS (Clause 119). For a complete Physical Layer, the frame loss ratio may be degraded to 6.2×10^{-11} for 64-octet frames with minimum interpacket gap due to additional errors from the electrical interfaces. If the error statistics are not sufficiently random to meet this requirement, then the BER shall be less than that required to give a frame loss ratio of less than 1.7×10^{-12} for 64-octet frames with minimum interpacket gap.

138.2 Physical Medium Dependent (PMD) service interface

Change 138.2 as follows:

This subclause specifies the services provided by the 50GBASE-SR, 100GBASE-SR2~~, and~~ 200GBASE-SR4, and 400GBASE-SR8 PMDs. The service interfaces for these PMDs are described in an abstract manner and do not imply any particular implementation. The PMD service interface supports the exchange of encoded data between the PMA entity that resides just above the PMD, and the PMD entity. The PMD translates the encoded data to and from signals suitable for the specified medium.

The 50GBASE-SR PMD service interface is an instance of the inter-sublayer service interface defined in 131.3, with a single symbol stream (n = 1).

The 100GBASE-SR2 PMD service interface is an instance of the inter-sublayer service interface defined in 116.3, with two parallel symbol streams (n = 2).

The 200GBASE-SR4 PMD service interface is an instance of the inter-sublayer service interface defined in 116.3, with four parallel symbol streams (n = 4).

The 400GBASE-SR8 PMD service interface is an instance of the inter-sublayer service interface defined in 116.3, with eight parallel symbol streams (n = 8).

The service interface primitives are summarized as follows:

PMD:IS_UNITDATA_*i*.request
PMD:IS_UNITDATA_*i*.indication
PMD:IS_SIGNAL.indication

The 50GBASE-SR PMD has a single symbol stream, hence $i = 0$.

The 100GBASE-SR2 PMD has two parallel symbol streams, hence $i = 0$ to 1.

The 200GBASE-SR4 PMD has four parallel symbol streams, hence $i = 0$ to 3.

The 400GBASE-SR8 PMD has eight parallel symbol streams, hence $i = 0$ to 7.

In the transmit direction, the PMA continuously sends *n* streams of PAM4 symbols to the PMD, one per lane, using the PMD:IS_UNITDATA_*i*.request primitive, at a nominal signaling rate of 26.5625 GBd. The PMD converts these streams of symbols into appropriate signals on the MDI.

In the receive direction, the PMD continuously sends *n* streams of PAM4 symbols to the PMA, corresponding to the signals received from the MDI, one per lane, using the PMD:IS_UNITDATA_*i*.indication primitive, at a nominal signaling rate of 26.5625 GBd.

The SIGNAL_OK parameter of the PMD:IS_SIGNAL.indication primitive corresponds to the variable SIGNAL_DETECT parameter as defined in 138.5.4. The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL. When SIGNAL_DETECT = FAIL, the rx_symbol parameters are undefined.

NOTE—SIGNAL_DETECT = OK does not guarantee that the rx_symbol parameters are known to be good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the BER defined in 138.1.1.

138.3 Delay and Skew

138.3.1 Delay constraints

Change 138.3.1 as follows:

An upper bound to the delay through the PMA and PMD is required for predictable operation of the MAC Control PAUSE operation.

The sum of the transmit and receive delays at one end of the link contributed by the 50GBASE-SR PMD including 2 m of fiber in one direction shall be no more than 1024 bit times (2 pause_quanta or 20.48 ns).

The sum of the transmit and receive delays at one end of the link contributed by the 100GBASE-SR2 PMD including 2 m of fiber in one direction shall be no more than 2048 bit times (4 pause_quanta or 20.48 ns).

The sum of the transmit and receive delays at one end of the link contributed by the 200GBASE-SR4 PMD including 2 m of fiber in one direction shall be no more than 4096 bit times (8 pause_quanta or 20.48 ns).

The sum of the transmit and receive delays at one end of the link contributed by the 400GBASE-SR8 PMD including 2 m of fiber in one direction shall be no more than 8192 bit times (16 pause_quanta or 20.48 ns).

Descriptions of overall system delay constraints and the definitions for bit times and pause_quanta, can be found in 131.4 for 50GBASE-SR, in 80.4 for 100GBASE-SR2, and in 116.4 and its references for 200GBASE-SR4 and 400GBASE-SR8.

138.3.2 Skew Constraints

Change the title of 138.3.2.2 as follows:

138.3.2.2 Skew Constraints for 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8

138.4 PMD MDIO function mapping

Change Table 138–4 and Table 138–5 as follows:

Table 138–4—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/bit number	PMD control variable
Reset	PMA/PMD control 1 register	1.0.15	PMD_reset
Global PMD transmit disable	PMD transmit disable register	1.9.0	PMD_global_transmit_disable
~~PMD transmit disable 3~~	~~PMD transmit disable register~~	~~1.9.4~~	~~PMD_transmit_disable_3~~
~~PMD transmit disable 2~~	~~PMD transmit disable register~~	~~1.9.3~~	~~PMD_transmit_disable_2~~
~~PMD transmit disable 1~~	~~PMD transmit disable register~~	~~1.9.2~~	~~PMD_transmit_disable_1~~
~~PMD transmit disable 0~~	~~PMD transmit disable register~~	~~1.9.1~~	~~PMD_transmit_disable_0~~
PMD transmit disable *n*–1 to PMD transmit disable 0	PMD transmit disable register	1.9.*n* to 1.9.1	PMD_transmit_disable_*n*–1 to PMD_transmit_disable_0

Table 138–5—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	PMA/PMD status 1 register	1.1.7	PMD_fault
Transmit fault	PMA/PMD status 2 register	1.8.11	PMD_transmit_fault
Receive fault	PMA/PMD status 2 register	1.8.10	PMD_receive_fault
Global PMD receive signal detect	PMD receive signal detect register	1.10.0	PMD_global_signal_detect
~~PMD receive signal detect 3~~	~~PMD receive signal detect register~~	~~1.10.4~~	~~PMD_signal_detect_3~~
~~PMD receive signal detect 2~~	~~PMD receive signal detect register~~	~~1.10.3~~	~~PMD_signal_detect_2~~
~~PMD receive signal detect 1~~	~~PMD receive signal detect register~~	~~1.10.2~~	~~PMD_signal_detect_1~~
~~PMD receive signal detect 0~~	~~PMD receive signal detect register~~	~~1.10.1~~	~~PMD_signal_detect_0~~
PMD receive signal detect *n*–1 to PMD receive signal detect 0	PMD receive signal detect register	1.10.*n* to 1.10.1	PMD_signal_detect_*n*–1 to PMD_signal_detect_0

138.5 PMD functional specifications

Change 138.5 as follows:

The 50GBASE-SR, 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8 PMDs perform the Transmit and Receive functions, which convey data between the PMD service interface and the MDI.

138.5.1 PMD block diagram

Change the first paragraph of 138.5.1 as follows:

The PMD block diagram for ~~200GBASE-SR4~~ 400GBASE-SR8 is shown in Figure 138–2. The block diagrams for 200GBASE-SR4, 100GBASE-SR2, and 50GBASE-SR are equivalent to Figure 138–2, but for four lanes, two lanes, and one lane per direction, respectively.

Replace Figure 138–2 as follows:

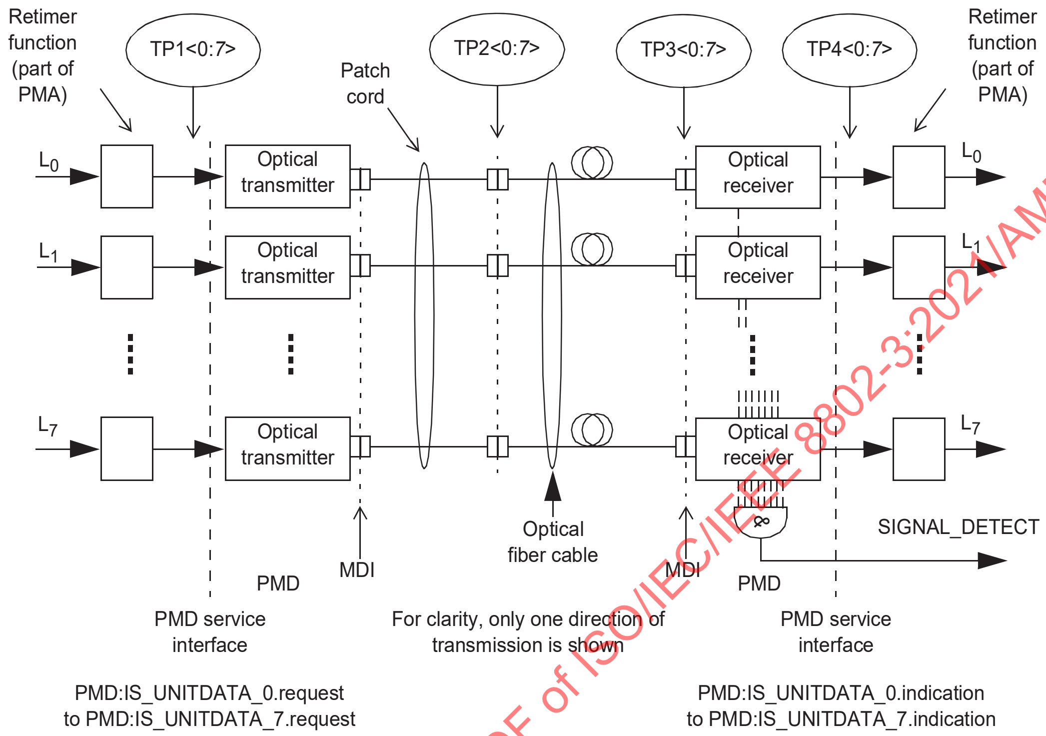


Figure 138–2—Block diagram for 400GBASE-SR8 transmit/receive paths

Change the last paragraph of 138.5.1 as follows:

TP1<0:~~3~~7> and TP4<0:~~3~~7> are informative reference points that may be useful to implementers for testing components (these test points will not typically be accessible in an implemented system).

138.5.2 PMD transmit function

Change 138.5.2 as follows:

The PMD Transmit function shall convert the one, two, ~~or~~ four, or eight signal streams requested by the PMD service interface messages PMD:IS_UNITDATA_*i*.request into one, two, ~~or~~ four, or eight separate optical signal streams. The 50GBASE-SR PMD has a single symbol stream, hence $i = 0$. The 100GBASE-SR2 PMD has two parallel symbol streams, hence $i = 0$ to 1. The 200GBASE-SR4 PMD has four parallel symbol streams, hence $i = 0$ to 3. The 400GBASE-SR8 PMD has eight parallel symbol streams, hence $i = 0$ to 7. Each optical signal stream shall then be delivered to the MDI, which contains one, two, ~~or~~ four, or eight parallel light paths for transmit, according to the transmit optical specifications in this clause. The four optical power levels in the signal stream in order from lowest to highest shall correspond to tx_symbols zero, one, two, and three, respectively.

138.5.3 PMD receive function

Change 138.5.3 as follows:

The PMD Receive function shall convert the one, two, ~~or~~ four, or eight parallel optical signal streams received from the MDI into separate symbol streams for delivery to the PMD service interface using the messages PMD:IS_UNITDATA_0.indication to PMD:IS_UNITDATA_~~3~~7.indication, all according to the receive optical specifications in this clause. The four optical power levels in each signal in order from lowest to highest shall correspond to rx_symbols zero, one, two, and three, respectively.

138.5.4 PMD global signal detect function

Change the second paragraph of 138.5.4 as follows:

SIGNAL_DETECT shall be a global indicator of the presence of optical signals on all lanes. The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 138–6. The PMD receiver is not required to verify whether a compliant 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8 signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Change Table 138–6 as follows:

Table 138–6—SIGNAL_DETECT value definition

Receive conditions	SIGNAL_DETECT value
For any lane; Average optical power at TP3 ≤ –30 dBm	FAIL
For all lanes; [(Optical power at TP3 ≥ average receive power, each lane (min) in Table 138–8) AND (compliant 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8 signal input)]	OK
All other conditions	Unspecified

138.5.5 PMD lane-by-lane signal detect function

Change 138.5.5 as follows:

Various implementations of the Signal Detect function are permitted by this standard. When the MDIO is implemented, each PMD_signal_detect_*i*, where *i* represents the lane number in the range 0:~~3~~7, shall be continuously set in response to the magnitude of the optical signal on its associated lane, according to the requirements of Table 138–6.

138.5.8 PMD lane-by-lane transmit disable function (optional)

Change 138.5.8 as follows:

The PMD lane-by-lane transmit disable function is optional and allows the optical transmitter in each lane to be selectively disabled.

a) When a PMD_transmit_disable_*i* variable (where *i* represents the lane number in the range 0:~~3~~<u>7</u>) is set to one, this function shall turn off the optical transmitter associated with that variable so that the transmitter meets the requirements of the average launch power of the OFF transmitter in Table 138–8.

b) If a PMD_fault is detected, then the PMD may set each PMD_transmit_disable_*i* to one, turning off the optical transmitter in each lane.

If the optional PMD lane-by-lane transmit disable function is not implemented in MDIO, an alternative method may be provided to independently disable each transmit lane.

138.6 Lane assignments

Change the first sentence of 138.6 as follows:

There are no lane assignments (within a group of transmit or receive lanes) for 100GBASE-SR2<u>,</u>~~ or~~ 200GBASE-SR4<u>, or 400GBASE-SR8</u>.

Change the title of 138.7 as follows:

138.7 PMD to MDI optical specifications for 50GBASE-SR, 100GBASE-SR2,~~ and~~ 200GBASE-SR4<u>, and 400GBASE-SR8</u>

Change the first sentence of 138.7 and Table 138–7 as follows:

The operating range for the 50GBASE-SR, 100GBASE-SR2,~~ and~~ 200GBASE-SR4<u>, and 400GBASE-SR8</u> PMDs is defined in Table 138–7.

Table 138–7—Operating range

PMD type	Required operating range[a]
50GBASE-SR 100GBASE-SR2 200GBASE-SR4 <u>400GBASE-SR8</u>	0.5 m to 70 m for OM3
	0.5 m to 100 m for OM4
	0.5 m to 100 m for OM5

[a]The PCS FEC correction function may not be bypassed for any operating distance.

138.7.1 Transmitter optical specifications

Change the text of 138.7.1 as follows:

Each lane of a 50GBASE-SR, 100GBASE-SR2<u>,</u> ~~and~~ 200GBASE-SR4<u>, and 400GBASE-SR8</u> transmitter shall meet the specifications in Table 138–8 per the definitions in 138.8.

138.7.2 Receiver optical specifications

Change the text of 138.7.2, and footnote g of Table 138–9, as follows:

Each lane of a 50GBASE-SR, 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8 receiver shall meet the specifications in Table 138–9 per the definitions in 138.8.

Table 138–9—Receive characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Modulation format	PAM4	
Center wavelength (range)	840 to 860	nm
Damage threshold[a] (min)	5	dBm
Average receive power, each lane (max)	4	dBm
Average receive power, each lane[b] (min)	–8.4	dBm
Receive power, each lane (OMA_{outer}) (max)	3	dBm
Receiver reflectance (max)	–12	dB
Stressed receiver sensitivity (OMA_{outer}), each lane[c] (max)	–3.4	dBm
Receiver sensitivity (OMA_{outer}), each lane[d] (max)	Equation (138–1)	dBm
Conditions of stressed receiver sensitivity test:[e]		
Stressed eye closure (SECQ), lane under test	4.5	dB
SECQ – $10\log_{10}(C_{eq})$[f], each lane (max)	4.5	dB
OMA_{outer} of each aggressor lane[g]	3	dBm

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level on one lane. The receiver does not have to operate correctly at this input power.
[b]Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Measured with conformance test signal at TP3 (see 138.8.10) for the BER specified in 138.1.1.
[d]Receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 4.5 dB.
[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.
[f]C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.
[g]Only applies to 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8.

138.7.3 Illustrative link power budget

Change the text of 138.7.3 as follows:

An illustrative power budget and penalties for 50GBASE-SR, 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8 channels are shown in Table 138–10.

138.8 Definition of optical parameters and measurement methods

138.8.1 Test patterns for optical parameters

Change Table 138–12 as follows (unchanged rows not shown):

Table 138–12—Test-pattern definitions and related subclauses

Parameter	Pattern	Related subclause
Wavelength, spectral width	3, 4, 5, 6, or valid 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8 signal	138.8.2
Average optical power	3, 4, 5, 6, or valid 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8 signal	138.8.3
…		
Stressed receiver sensitivity	3, 5, or valid 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8 signal	138.8.10
…		

138.8.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

Change the second exception in 138.8.5 as follows:

— The optical channel requirements in 121.8.5.2 do not apply. For 400GBASE-SR8, the optical splitter and variable reflector are adjusted so that each transmitter is tested with an optical return loss equal to the "Optical return loss tolerance (max)" given in Table 138–8.

Change the fourth exception in 138.8.5 as follows:

— The reference equalizer to be used for TDECQ for 50GBASE-SR, 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8 is specified in 138.8.5.1.

138.8.5.1 TDECQ reference equalizer

Change the first sentence in 138.8.5.1 as follows:

The reference equalizer for 50GBASE-SR, 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8 is a 5 tap, T spaced, feed-forward equalizer (FFE), where T is the symbol period.

138.8.10 Stressed receiver sensitivity

Change the last exception in 138.8.10 as follows:

— For 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8, the OMA_{outer} of the aggressor lanes is specified in Table 138–9.

138.9 Safety, installation, environment, and labeling

138.9.2 Laser safety

Change the first paragraph of 138.9.2 as follows:

50GBASE-SR, 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8 optical transceivers shall conform to Hazard Level 1M laser requirements as defined in IEC 60825-1 and IEC 60825-2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore.

138.9.4 Environment

Change the first paragraph of 138.9.4 as follows:

Normative specifications in this clause shall be met by a system integrating a 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8 PMD over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

138.9.5 Electromagnetic emission

Change 138.9.5 as follows:

A system integrating a 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8 PMD shall comply with applicable local and national codes for the limitation of electromagnetic interference.

138.9.7 PMD labeling requirements

Change the first paragraph of 138.9.7 as follows:

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8).

138.10 Fiber optic cabling model

Change the first sentence of 138.10 as follows:

The fiber optic cabling (channel) contains 1, 2, ~~or~~ 4, or 8 optical fibers for each direction to support 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8, respectively.

138.10.1 Fiber optic cabling model

Change footnote 'a' of Table 138–14 as follows:

~~Only applies~~ Applies only to 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8.

138.10.3 Medium Dependent Interface (MDI)

Change the first sentence of 138.10.3 as follows:

The 50GBASE-SR, 100GBASE-SR2, ~~or~~ 200GBASE-SR4, or 400GBASE-SR8 PMD is coupled to the fiber optic cabling at the MDI.

Change the title of 138.10.3.1 as follows:

138.10.3.1 Optical lane assignments for 100GBASE-SR2, ~~and~~ 200GBASE-SR4, and 400GBASE-SR8

Insert new text and new Figure 138–7a at the end of 138.10.3.1 as follows:

400GBASE-SR8 has two optical lane assignment options: Option A for a dual-row twelve-fiber interface, and option B for a single-row sixteen-fiber interface.

For a dual-row twelve-fiber interface, the eight transmit and eight receive optical lanes of 400GBASE-SR8 shall occupy the positions depicted in Figure 138–7a (option A) when looking into the MDI receptacle with the connector keyway feature on top. The interface contains sixteen active lanes within 24 total positions. The four center positions in each row are unused. The transmit optical lanes occupy the leftmost four positions in each row. The receive optical lanes occupy the rightmost four positions in each row.

For a single-row sixteen-fiber interface, the eight transmit and eight receive optical lanes of 400GBASE-SR8 shall occupy the positions depicted in Figure 138–7a (option B) when looking into the MDI receptacle with the connector keyway feature on top. The interface contains sixteen active lanes within sixteen total positions. The transmit optical lanes occupy the leftmost eight positions. The receive optical lanes occupy the rightmost eight positions.

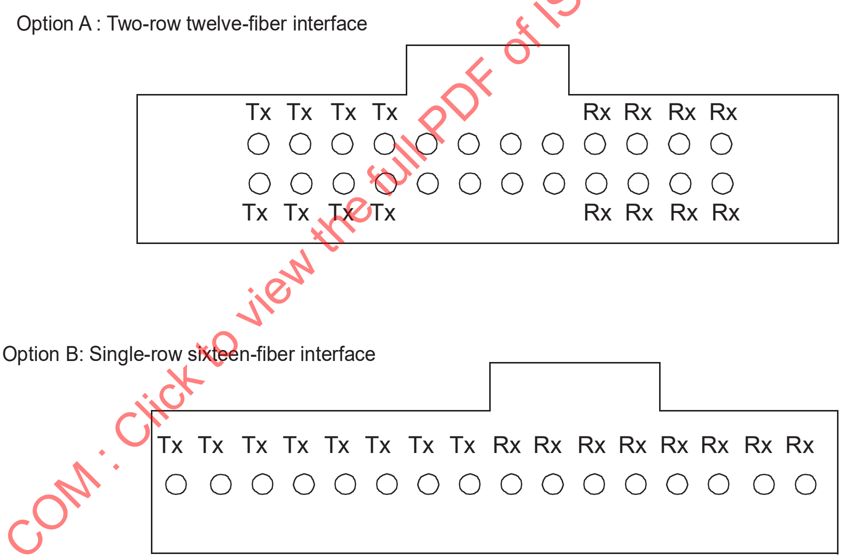


Figure 138–7a—Optical lane assignments for 400GBASE-SR8

Insert new subclause 138.10.3.4 after 138.10.3.3 as follows:

138.10.3.4 MDI requirements for 400GBASE-SR8

The MDI shall optically mate with the compatible plug on the optical fiber cabling. The MDI connection shall meet the interface performance specifications of IEC 61753-1 and IEC 61753-022-2 for performance grade Bm/2m. 400GBASE-SR8 has two optical lane assignment options: Option A for a dual-row twelve-fiber interface, and option B for a single-row sixteen-fiber interface.

For Option A, the MDI adapter or receptacle shall meet the dimensional specifications for interface 7-2-3: *MPO adapter interface - opposed keyway* configuration, or interface 7-2-10: *MPO active device receptacle, flat interface*, as defined in IEC 61754-7-2. The plug terminating the optical fiber cabling shall meet the dimensional specifications of interface 7-2-4: *MPO female plug connector, flat interface for 16 to 24 fibers*, as defined in IEC 61754-7-2. The MPO female plug connector and MDI are structurally similar to those depicted in Figure 138–8, but with two rows of fibers.

For Option B, the MDI adapter or receptacle shall meet the dimensional specifications for designation FOCIS 18 A-1-0, or designation FOCIS 18 R-1x16-1-0-1-2-0, as defined in ANSI/TIA-604-18-A. The plug terminating the optical fiber cabling shall meet the dimensional specifications of designation FOCIS 18 P-1x16-1-0-2-2-0, as defined in ANSI/TIA-604-18-A. The MPO female plug connector and MDI are structurally similar to those depicted in Figure 138–8, but with sixteen fibers and an offset keyway as well as a different pin diameter and location.

Change the title of 138.11 as follows:

138.11 Protocol implementation conformance statement (PICS) proforma for Clause 138, Physical Medium Dependent (PMD) sublayer and medium, type 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4, 400GBASE-SR8[4]

138.11.1 Introduction

Change the first paragraph of 138.11.1 as follows:

The supplier of a protocol implementation that is claimed to conform to Clause 138, Physical Medium Dependent (PMD) sublayer and medium, type 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4, 400GBASE-SR8, shall complete the following protocol implementation conformance statement (PICS) proforma.

138.11.2 Identification

138.11.2.2 Protocol summary

Change the table in 138.11.2.2 as follows:

Identification of protocol standard	IEEE Std 802.3cm-2020, Clause 138, Physical Medium Dependent (PMD) sublayer and medium, type 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4, 400GBASE-SR8
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3cm-2020.)	

Date of Statement	

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

138.11.3 Major capabilities/options

Change the table in 138.11.3 as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
*SR	50GBASE-SR PMD	138.7	Device supports requirements for 50GBASE-SR PHY	O	Yes [ ] No [ ]
*SR2	100GBASE-SR2 PMD	138.7	Device supports requirements for 100GBASE-SR2 PHY	O	Yes [ ] No [ ]
*SR4	200GBASE-SR4 PMD	138.7	Device supports requirements for 200GBASE-SR4 PHY	O	Yes [ ] No [ ]
*SR8	400GBASE-SR8 PMD	138.7	Device supports requirements for 400GBASE-SR8 PHY	O	Yes [ ] No [ ]
*SR8A	400GBASE-SR8 MDI option A	138.10.3.4	Device has MDI with dual-row twelve-fiber interface	SR8:O.1	Yes [ ] No [ ]
*SR8B	400GBASE-SR8 MDI option B	138.10.3.4	Device has MDI with single-row sixteen-fiber interface	SR8:O.1	Yes [ ] No [ ]
*INS	Installation / cable	138.10.1	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]
TP1	Reference point TP1 exposed and available for testing	138.5.1	This point may be made available for use by implementers to certify component conformance	O	Yes [ ] No [ ]
TP4	Reference point TP4 exposed and available for testing	138.5.1	This point may be made available for use by implementers to certify component conformance	O	Yes [ ] No [ ]
DC	Delay constraints	138.3.1	Device conforms to delay constraints	M	Yes [ ]
SC	Skew constraints	138.3.2	Device conforms to Skew and Skew Variation constraints	M	Yes [ ]
*MD	MDIO capability	138.4	Registers and interface supported	O	Yes [ ] No [ ]

Change the title of 138.11.4 as follows:

138.11.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4, 400GBASE-SR8

138.11.4.1 PMD functional specifications

Change the row for item F1 in the table in 138.11.4.1 as follows (unchanged rows not shown):

Item	Feature	Subclause	Value/Comment	Status	Support
F1	Compatible with 50GBASE-R, ~~or~~ 100GBASE-R, ~~or~~ 200GBASE-R, or 400GBASE-R PCS and PMA	138.1		M	Yes [ ]
…					

138.11.4.6 Characteristics of the fiber optic cabling and MDI

Insert new rows for items OC5a and OC5b after item OC5 in the table in 138.11.4.6 as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
…					
OC5a	MDI layout for 400GBASE-SR8 option A	138.10.3.1	Optical lane assignments per Figure 138–7a	SR8A:M	Yes [ ] N/A [ ]
OC5b	MDI layout for 400GBASE-SR8 option B	138.10.3.1	Optical lane assignments per Figure 138–7a	SR8B:M	Yes [ ] N/A [ ]
…					

Insert a new row for item OC8a after item OC8 in the table in 138.11.4.6 as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
…					
OC8a	MDI mating 400GBASE-SR8	138.10.3.4	MDI optically mates with plug on the cabling	SR8:M	Yes [ ] N/A [ ]
…					

Change the rows for items OC9 and OC10 in the table in 138.11.4.6 as follows (unchanged rows not shown):

Item	Feature	Subclause	Value/Comment	Status	Support
…					
OC9	MDI dimensions for 100GBASE-SR2 and 200GBASE-SR4	138.10.3.3	Per IEC 61754-7-1 interface 7-1-3 or interface 7-1-10	(SR2 or SR4):M	Yes [ ] N/A [ ]
OC10	Cabling connector dimensions for 100GBASE-SR2 and 200GBASE-SR4	138.10.3.3	Per IEC 61754-7-1 interface 7-1-4	INS*(SR2 or SR4):M	Yes [ ] N/A [ ]
…					

Insert new rows for items OC10a and OC10b after item OC10 in the table in 138.11.4.6 as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
…					
OC10a	MDI dimensions for 400GBASE-SR8	138.10.3.4	Per IEC 61754-7-2 interfaces 7-2-3 or 7-2-10, or per ANSI/TIA-604-18-A designation FOCIS 18 A-1-0 or FOCIS 18 R-1x16-1-0-1-2-0	SR8:M	Yes [ ] N/A [ ]
OC10b	Cabling connector dimensions for 400GBASE-SR8	138.10.3.4	Per IEC 61754-7-2 interface 7-2-4 or ANSI/TIA-604-18-A designation FOCIS 18 P-1x16-1-0-2-2-0	INS*SR8:M	Yes [ ] N/A [ ]
…					

Insert a new row for item OC12 at the end of the table in 138.11.4.6 as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
…					
OC12	MDI requirements for 400GBASE-SR8	138.10.3.4	Per IEC 61753-1 and IEC 61753-022-2, performance grade Bm/2m	INS*SR8:M	Yes [ ] N/A [ ]

Insert new Clause 150 as follows:

150. Physical Medium Dependent (PMD) sublayer and medium, type 400GBASE-SR4.2

150.1 Overview

This clause specifies the 400GBASE-SR4.2 PMD together with the multimode fiber medium. 400GBASE-SR4.2 uses the same media as 200GBASE-SR4. The 4.2 nomenclature is used to indicate that transmission is over four fiber pairs (eight individual fibers) with the use of two wavelengths. For 400GBASE-SR4.2 these wavelengths propagate in opposite directions on each individual fiber. The optical signal generated by this PMD type is modulated using a 4-level pulse amplitude modulation (PAM4) format. The PMD sublayer provides point-to-point 400 Gigabit Ethernet links over four pairs of multimode fiber, with a reach of up to at least 70 m on OM3, 100 m on OM4, and 150 m on OM5. When forming a complete Physical Layer, a PMD shall be connected to the appropriate PMA, as shown in Table 150–1, to the medium through the MDI and optionally with the management functions that may be accessible through the management interface defined in Clause 45, or equivalent.

Table 150–1—Physical Layer clauses associated with the 400GBASE-SR4.2 PMD

Associated clause	400GBASE-SR4.2
117—RS	Required
117—400GMII[a]	Optional
118—400GMII Extender	Optional
119—PCS for 400GBASE-R	Required
120—PMA for 400GBASE-R	Required
120B—400GAUI-16 C2C	Optional
120C—400GAUI-16 C2M	Optional
120D—400GAUI-8 C2C	Optional
120E—400GAUI-8 C2M	Optional
78—Energy-Efficient Ethernet	Optional

[a]The 400GMII is an optional interface. However, if the 400GMII is not implemented, a conforming implementation must behave functionally as though the RS and 400GMII were present.

Figure 150–1 shows the relationship of the PMD and MDI (shown shaded) with other sublayers to the ISO/IEC Open System Interconnection (OSI) reference model. 400 Gigabit Ethernet is introduced in Clause 116 and the purpose of each PHY sublayer is summarized in 116.2.

400GBASE-SR4.2 PHYs with the optional Energy-Efficient Ethernet (EEE) fast wake capability may enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization (see Clause 78). The deep sleep mode of EEE is not supported.

Further relevant information may be found in Clause 1 (terminology and conventions, references, definitions and abbreviations) and Annex A (bibliography, referenced as [B1], [B2], etc.).

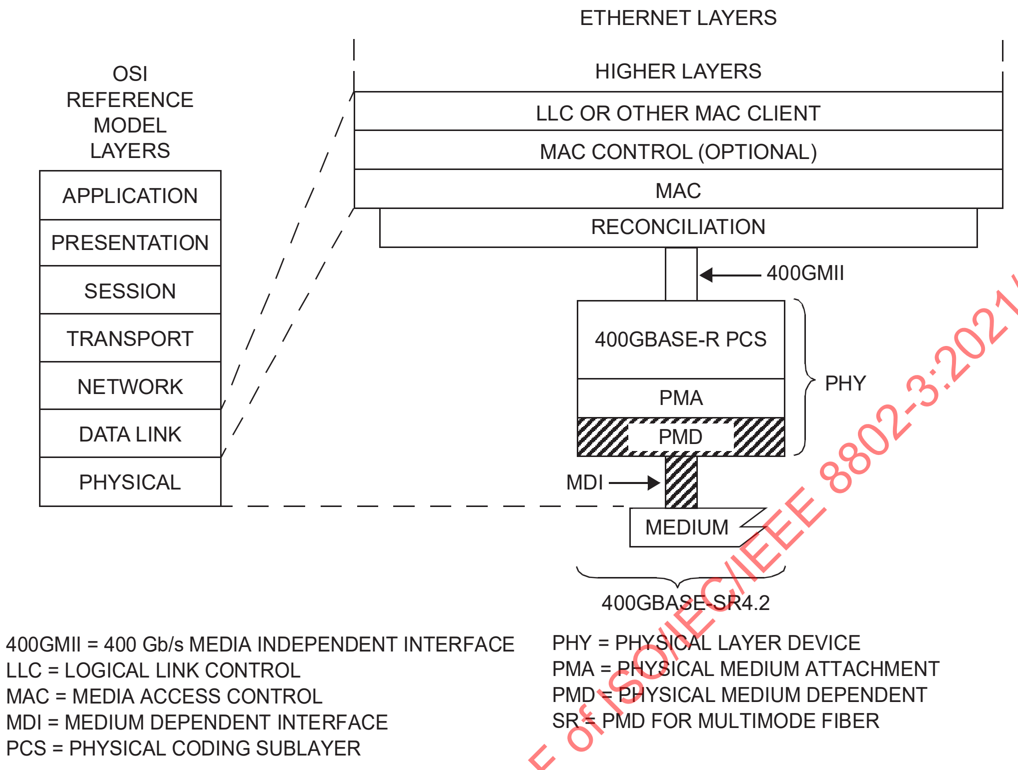


Figure 150–1—400GBASE-SR4.2 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

150.1.1 Bit error ratio

The bit error ratio (BER) when processed by the PMA (Clause 120) shall be less than 2.4×10^{-4} provided that the error statistics are sufficiently random that this results in a frame loss ratio (see 1.4.275) of less than 1.7×10^{-12} for 64-octet frames with minimum interpacket gap when additionally processed by the PCS (Clause 119). For a complete Physical Layer, the frame loss ratio may be degraded to 6.2×10^{-11} for 64-octet frames with minimum interpacket gap due to additional errors from the electrical interfaces. If the error statistics are not sufficiently random to meet this requirement, then the BER shall be less than that required to give a frame loss ratio of less than 1.7×10^{-12} for 64-octet frames with minimum interpacket gap.

150.2 Physical Medium Dependent (PMD) service interface

This subclause specifies the services provided by the 400GBASE-SR4.2 PMD. The service interface for this PMD is described in an abstract manner and does not imply any particular implementation. The PMD service interface supports the exchange of encoded data between the PMA entity that resides just above the PMD, and the PMD entity. The PMD translates the encoded data to and from signals suitable for the specified medium.

The 400GBASE-SR4.2 PMD service interface is an instance of the inter-sublayer service interface defined in 116.3, with eight parallel symbol streams (*n* = 8).

The service interface primitives are summarized as follows:

PMD:IS_UNITDATA_*i*.request
PMD:IS_UNITDATA_*i*.indication
PMD:IS_SIGNAL.indication

The 400GBASE-SR4.2 PMD has eight parallel symbol streams, hence *i* = 0 to 7.

In the transmit direction, the PMA continuously sends *n* streams of PAM4 symbols to the PMD, one per lane, using the PMD:IS_UNITDATA_*i*.request primitive, at a nominal signaling rate of 26.5625 GBd. The PMD converts these streams of symbols into appropriate signals on the MDI.

In the receive direction, the PMD continuously sends *n* streams of PAM4 symbols to the PMA, corresponding to the signals received from the MDI, one per lane, using the PMD:IS_UNITDATA_*i*.indication primitive, at a nominal signaling rate of 26.5625 GBd.

The SIGNAL_OK parameter of the PMD:IS_SIGNAL.indication primitive corresponds to the variable SIGNAL_DETECT parameter as defined in 150.5.4. The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL. When SIGNAL_DETECT = FAIL, the rx_symbol parameters are undefined.

NOTE—SIGNAL_DETECT = OK does not guarantee that the rx_symbol parameters are known to be good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the BER defined in 150.1.1.

150.3 Delay and Skew

150.3.1 Delay constraints

An upper bound to the delay through the PMA and PMD is required for predictable operation of the MAC Control PAUSE operation.

The sum of the transmit and receive delays at one end of the link contributed by the 400GBASE-SR4.2 PMD including 2 m of fiber in one direction shall be no more than 8192 bit times (16 pause_quanta or 20.48 ns).

Descriptions of overall system delay constraints and the definitions for bit times and pause_quanta, can be found in 116.4 and its references.

150.3.2 Skew constraints

The Skew (relative delay) between the PCS lanes must be kept within limits so that the information on the PCS lanes can be reassembled by the PCS. The Skew Variation must also be limited to ensure that a given PCS lane always traverses the same physical lane.

Skew and Skew Variation are defined in 116.5 and specified at the points SP1 to SP6 shown in Figure 116–4 and Figure 116–5.

If the PMD service interface is physically instantiated so that the Skew at SP2 can be measured, then the Skew at SP2 is limited to 43 ns and the Skew Variation at SP2 is limited to 400 ps.

The Skew at SP3 (the transmitter MDI) shall be less than 54 ns and the Skew Variation at SP3 shall be less than 600 ps.

The Skew at SP4 (the receiver MDI) shall be less than 134 ns and the Skew Variation at SP4 shall be less than 3.4 ns.

If the PMD service interface is physically instantiated so that the Skew at SP5 can be measured, then the Skew at SP5 shall be less than 145 ns and the Skew Variation at SP5 shall be less than 3.6 ns.

For more information on Skew and Skew Variation see 116.5.

150.4 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that may provide control and status information for and about the PMD. If the MDIO interface is implemented, the mapping of MDIO control variables to PMD control variables shall be as shown in Table 150–2, and the mapping of MDIO status variables to PMD status variables shall be as shown in Table 150–3.

Table 150–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/bit number	PMD control variable
Reset	PMA/PMD control 1 register	1.0.15	PMD_reset
Global PMD transmit disable	PMD transmit disable register	1.9.0	PMD_global_transmit_disable
PMD transmit disable 7 to PMD transmit disable 0	PMD transmit disable register	1.9.8 to 1.9.1	PMD_transmit_disable_7 to PMD_transmit_disable_0

Table 150–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	PMA/PMD status 1 register	1.1.7	PMD_fault
Transmit fault	PMA/PMD status 2 register	1.8.11	PMD_transmit_fault
Receive fault	PMA/PMD status 2 register	1.8.10	PMD_receive_fault
Global PMD receive signal detect	PMD receive signal detect register	1.10.0	PMD_global_signal_detect
PMD receive signal detect 7 to PMD receive signal detect 0	PMD receive signal detect register	1.10.8 to 1.10.1	PMD_signal_detect_7 to PMD_signal_detect_0

150.5 PMD functional specifications

The 400GBASE-SR4.2 PMD performs the Transmit and Receive functions, which convey data between the PMD service interface and the MDI.

150.5.1 PMD block diagram

The PMD block diagram is shown in Figure 150–2. For purposes of system conformance, the PMD sublayer is standardized at the points described in this subclause. The optical transmit signal is defined at the output end of a multimode fiber patch cord (TP2), between 2 m and 5 m in length. Unless specified otherwise, all transmitter measurements and tests defined in 150.8 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) at the MDI (see 150.10.3). Unless specified otherwise, all receiver measurements and tests defined in 150.8 are made at TP3.

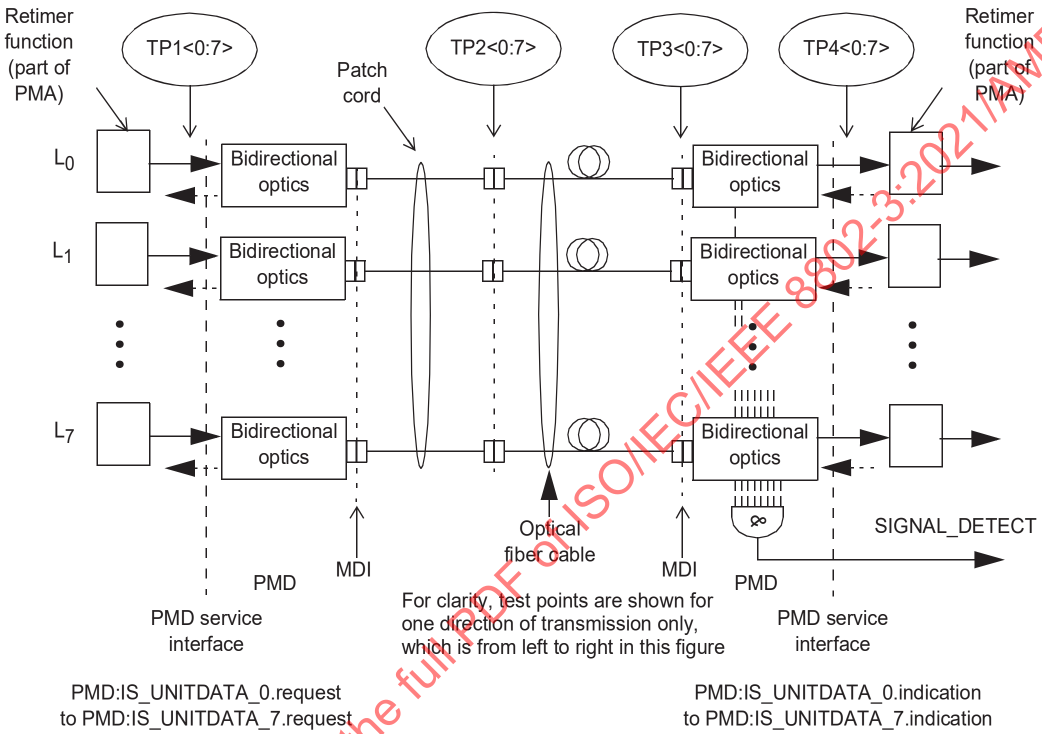


Figure 150–2—Block diagram for 400GBASE-SR4.2 transmit/receive paths

TP1<0:7> and TP4<0:7> are informative reference points that may be useful to implementers for testing components (these test points will not typically be accessible in an implemented system).

150.5.2 PMD transmit function

The PMD Transmit function shall convert the eight signal streams requested by the PMD service interface messages PMD:IS_UNITDATA_*i*.request into eight separate optical signal streams. The 400GBASE-SR4.2 PMD has eight parallel symbol streams, hence $i = 0$ to 7. Each optical signal stream shall then be delivered to the MDI, which contains eight parallel light paths for transmit, according to the transmit optical specifications in this clause. The four optical power levels in the signal stream in order from lowest to highest shall correspond to tx_symbols zero, one, two, and three, respectively.

150.5.3 PMD receive function

The PMD Receive function shall convert the eight parallel optical signal streams received from the MDI into separate symbol streams for delivery to the PMD service interface using the messages PMD:IS_UNITDATA_0.indication to PMD:IS_UNITDATA_7.indication, all according to the receive optical specifications in this clause. The four optical power levels in each signal in order from lowest to highest shall correspond to rx_symbols zero, one, two, and three, respectively.

150.5.4 PMD global signal detect function

The PMD global signal detect function shall report the state of SIGNAL_DETECT via the PMD service interface. The SIGNAL_DETECT parameter is signaled continuously, while the PMD:IS_SIGNAL.indication message is generated when a change in the value of SIGNAL_DETECT occurs. The SIGNAL_DETECT parameter defined in this clause maps to the SIGNAL_OK parameter in the inter-sublayer service interface primitives defined in 116.3.

SIGNAL_DETECT shall be a global indicator of the presence of optical signals on all lanes. The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 150–4. The PMD receiver is not required to verify whether a compliant 400GBASE-SR4.2 signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Table 150–4—SIGNAL_DETECT value definition

Receive conditions	SIGNAL_DETECT value
For TxRx pair type TR[a]; Average optical power at TP3 ≤ –30 dBm for wavelength range 900 nm to 918 nm	FAIL
For TxRx pair type RT[a]; Average optical power at TP3 ≤ –30 dBm for wavelength range 844 nm to 863 nm	FAIL
For TxRx pair type TR[a]; [(Optical power at TP3 ≥ average receive power, each lane (min) in Table 150–7 for wavelength range 900 nm to 918 nm) AND (compliant 400GBASE-SR4.2 signal input)]	OK
For TxRx pair type RT[a]; [(Optical power at TP3 ≥ average receive power, each lane (min) in Table 150–7 for wavelength range 844 nm to 863 nm) AND (compliant 400GBASE-SR4.2 signal input)]	OK
All other conditions	Unspecified

[a]TxRx pair types are defined in 150.6.

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD including the effects of crosstalk, power supply noise, etc.

Various implementations of the Signal Detect function are permitted by this standard, including implementations that generate the SIGNAL_DETECT parameter values in response to the amplitude of the modulation of the optical signal and implementations that respond to the average optical power of the modulated optical signal.

150.5.5 PMD lane-by-lane signal detect function

Various implementations of the Signal Detect function are permitted by this standard. When the MDIO is implemented, each PMD_signal_detect_*i*, where *i* represents the lane number in the range 0:7, shall be continuously set in response to the magnitude of the optical signal on its associated lane, according to the requirements of Table 150–4.

150.5.6 PMD reset function

If the MDIO interface is implemented, and if PMD_reset is asserted, the PMD shall be reset as defined in 45.2.1.1.1.

150.5.7 PMD global transmit disable function (optional)

The PMD global transmit disable function is optional and allows all of the optical transmitters to be disabled.

a) When the PMD_global_transmit_disable variable is set to one, this function shall turn off all of the optical transmitters so that each transmitter meets the requirements of the average launch power of the OFF transmitter in Table 150–7.
b) If a PMD_fault is detected, then the PMD may set the PMD_global_transmit_disable variable to one, turning off the optical transmitter in each lane.

150.5.8 PMD lane-by-lane transmit disable function (optional)

The PMD lane-by-lane transmit disable function is optional and allows the optical transmitter in each lane to be selectively disabled.

a) When a PMD_transmit_disable_*i* variable (where *i* represents the lane number in the range 0:7) is set to one, this function shall turn off the optical transmitter associated with that variable so that the transmitter meets the requirements of the average launch power of the OFF transmitter in Table 150–7.
b) If a PMD_fault is detected, then the PMD may set each PMD_transmit_disable_*i* to one, turning off the optical transmitter in each lane.

If the optional PMD lane-by-lane transmit disable function is not implemented in MDIO, an alternative method may be provided to independently disable each transmit lane.

150.5.9 PMD fault function (optional)

If the PMD has detected a local fault on any of the transmit or receive paths, the PMD shall set PMD_fault to one.

If the MDIO interface is implemented, PMD_fault shall be mapped to the fault bit as specified in 45.2.1.2.3.

150.5.10 PMD transmit fault function (optional)

If the PMD has detected a local fault on any transmit lane, the PMD shall set PMD_transmit_fault to one.

If the MDIO interface is implemented, PMD_transmit_fault shall be mapped to the transmit fault bit as specified in 45.2.1.7.4.

150.5.11 PMD receive fault function (optional)

If the PMD has detected a local fault on any receive lane, the PMD shall set the PMD_receive_fault variable to one.

If the MDIO interface is implemented, PMD_receive_fault shall be mapped to the receive fault bit as specified in 45.2.1.7.5.

150.6 Wavelength ranges

The transmit and receive wavelength ranges for the 400GBASE-SR4.2 PMD are defined in Table 150–5. Two TxRx pair types (combinations of Tx and Rx types that connect to a single fiber) are defined:

— TxRx pair type TR comprises a transmitter that uses the wavelength range 844 nm to 863 nm and a receiver that uses the wavelength range 900 nm to 918 nm.

— TxRx pair type RT comprises a transmitter that uses the wavelength range 900 nm to 918 nm and a receiver that uses the wavelength range 844 nm to 863 nm.

When connecting a 400GBASE-SR4.2 PMD to another 400GBASE-SR4.2 PMD, it is a requirement that every TxRx pair type RT at each end of the link be connected to a TxRx pair type TR at the other end of the link. The positioning of transmit and receive lanes at the MDI is specified in 150.10.3.1.

NOTE—There is no requirement to associate a particular electrical lane with a particular optical lane, as the PCS is capable of receiving lanes in any arrangement.

Table 150–5—Wavelength ranges

TxRx pair type	Transmit wavelength range	Receive wavelength range
TR	844 nm to 863 nm	900 nm to 918 nm
RT	900 nm to 918 nm	844 nm to 863 nm

150.7 PMD to MDI optical specifications for 400GBASE-SR4.2

The operating range for the 400GBASE-SR4.2 PMD is defined in Table 150–6. A compliant PMD operates on 50/125 µm multimode fibers, type A1a.2 (OM3), type A1a.3 (OM4), or type A1a.4 (OM5), according to the specifications defined in Table 150–13. A PMD that exceeds the operating range requirement while meeting all other optical specifications is considered compliant (e.g., a 400GBASE-SR4.2 PMD operating at 120 m on OM4 meets the operating range requirement of 0.5 m to 100 m on OM4).

Table 150–6—Operating range

PMD type	Required operating range[a]
400GBASE-SR4.2	0.5 m to 70 m for OM3
	0.5 m to 100 m for OM4
	0.5 m to 150 m for OM5

[a]The PCS FEC correction function may not be bypassed for any operating distance.

150.7.1 Transmitter optical specifications

Each lane of a 400GBASE-SR4.2 transmitter shall meet the specifications in Table 150–7 per the definitions in 150.8.

Table 150–7—Transmit characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Modulation format	PAM4	—
Center wavelength (range), λ_1 for TxRx pair type TR Center wavelength (range), λ_2 for TxRx pair type RT	844 to 863 900 to 918	nm nm
RMS spectral width[a] (max) for TxRx pair type TR RMS spectral width[a] (max) for TxRx pair type RT	0.6 0.65	nm nm
Average launch power, each lane (max)	4	dBm
Average launch power, each lane (min)	–6.2	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	3	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[b]	–4.2	dBm
Launch power in OMA_{outer} minus TDECQ (min)	–5.6	dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	4.5	dB
TDECQ – $10\log_{10}(C_{eq})$[c], each lane (max)	4.5	dB
Average launch power of OFF transmitter, each lane (max)	–30	dBm
Extinction ratio, each lane (min)	3	dB
Transmitter transition time, each lane (max)	31	ps
$RIN_{12}OMA$ (max)	–128	dB/Hz
Optical return loss tolerance (max)	12	dB
Encircled flux[d]	≥ 86% at 19 µm ≤ 30% at 4.5 µm	—

[a]RMS spectral width is the standard deviation of the spectrum.
[b]Even if the TDECQ < 1.4 dB, the OMA (min) must exceed this value.
[c]C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.
[d]If measured into type A1a.2, type A1a.3, or type A1a.4, 50 µm fiber, in accordance with IEC 61280-1-4.

150.7.2 Receiver optical specifications

Each lane of a 400GBASE-SR4.2 receiver shall meet the specifications in Table 150–8 per the definitions in 150.8.

Table 150–8—Receive characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Modulation format	PAM4	—
Center wavelength (range), λ_1 for TxRx pair type RT Center wavelength (range), λ_2 for TxRx pair type TR	844 to 863 900 to 918	nm nm
Damage threshold[a] (min)	5	dBm
Average receive power, each lane (max)	4	dBm
Average receive power, each lane[b] (min)	–8.2	dBm
Receive power, each lane (OMA_{outer}) (max)	3	dBm
Receiver reflectance (max)	–12	dB
Stressed receiver sensitivity (OMA_{outer}), each lane[c] (max)	–3.5	dBm
Receiver sensitivity (OMA_{outer}), each lane[d] (max)	Equation (150–1)	dBm
Conditions of stressed receiver sensitivity test:[e]		
Stressed eye closure for PAM4 (SECQ), lane under test	4.5	dB
SECQ – $10\log_{10}(C_{eq})$[f] (max), lane under test	4.5	dB
OMA_{outer} of each aggressor lane	3	dBm

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level on one lane. The receiver does not have to operate correctly at this input power.
[b]Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Measured with conformance test signal at TP3 (see 150.8.10) for the BER specified in 150.1.1.
[d]Receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 4.5 dB.
[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.
[f]C_{eq} is a coefficient defined in 121.8.5.3, which accounts for the reference equalizer noise enhancement.

150.7.3 Illustrative link power budget

An illustrative power budget and penalties for 400GBASE-SR4.2 channels, which apply to both wavelength ranges, are shown in Table 150–9.

Table 150–9—Illustrative link power budget

Parameter	OM3	OM4	OM5	Unit
Effective modal bandwidth at 850 nm (min)[a]	2000	4700		MHz·km
Effective modal bandwidth at 910 nm (min)[a]	1260	1980	3100	MHz·km
Power budget (for max TDECQ)	6.9			dB
Operating distance	0.5 to 70	0.5 to 100	0.5 to 150	m
Channel insertion loss[b]	1.7	1.8	2	dB
Allocation for penalties[c] (for max TDECQ)	4.9			dB
Additional insertion loss allowed	0.3	0.2	0	dB

[a]Per IEC 60793-2-10.
[b]The channel insertion loss is calculated using the maximum distance specified in Table 150–6 and cabled optical fiber attenuation of 3 dB/km at 850 nm plus an allocation for connection and splice loss given in 150.10.2.2.1.
[c]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

150.8 Definition of optical parameters and measurement methods

All transmitter optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

150.8.1 Test patterns for optical parameters

While compliance is to be achieved in normal operation, specific test patterns are defined for measurement consistency and to enable measurement of some parameters. Table 150–11 gives the test patterns to be used in each measurement, unless otherwise specified, and also lists references to the subclauses in which each parameter is defined. Any of the test patterns given for a particular test in Table 150–11 may be used to perform that test. The test patterns used in this clause are shown in Table 150–10.

Table 150–10—Test patterns

Pattern	Pattern description	Defined in
Square wave	Square wave (8 threes, 8 zeros)	120.5.11.2.4
3	PRBS31Q	120.5.11.2.2
4	PRBS13Q	120.5.11.2.1
5	Scrambled idle	119.2.4.9
6	SSPRQ	120.5.11.2.3