INTERNATIONAL STANDARD

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AMENDMENT 11
2019-02

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

Part 3: Standard for Ethernet

AMENDMENT 11: Physical layer and management parameters for serial 25 Gb/s ethernet operation over single-mode fiber

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

Partie 3: Norme pour Ethernet

AMENDEMENT 11: Paramètres de couche physique et de gestion pour le fonctionnement Ethernet en 25 Gb/s série sur fibre unimodale

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IEEE Std 802.3cc™-2017
(Amendment to
IEEE Std 802.3™-2015
as amended by
IEEE Std 802.3bw™-2015, IEEE Std 802.3by™-2016,
IEEE Std 802.3bq™-2016, IEEE Std 802.3bp™-2016,
IEEE Std 802.3br™-2016, IEEE Std 802.3bn™-2016,
IEEE Std 802.3bz™-2016, IEEE Std 802.3bu™-2016,
IEEE Std 802.3bv™-2017, IEEE Std 802.3-2015/Cor 1-2017,
and IEEE Std 802.3bs™-2017)

IEEE Standard for Ethernet

Amendment 11: Physical Layer and Management Parameters for Serial 25 Gb/s Ethernet Operation Over Single-Mode Fiber

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 6 December 2017

IEEE-SA Standards Board

Abstract: This amendment to IEEE Std 802.3-2015 adds Physical Layer (PHY) specifications and management parameters for 25 Gb/s operation over single-mode fiber at reaches of at least 10 km (25GBASE-LR) and 40 km (25GBASE-ER).

Keywords: 25 Gb/s Ethernet, 25GBASE-ER, 25GBASE-LR, 25GBASE-SR, Energy Efficient Ethernet (EEE), Ethernet, Forward Error Correction (FEC), IEEE 802.3™, IEEE 802.3by™, IEEE 802.3cc™, Physical Coding sublayer (PCS), Physical Medium Attachment (PMA) sublayer, Physical Medium Dependent (PMD) sublayer, Reconciliation sublayer (RS), single-mode fiber (SMF)

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Introduction

This introduction is not part of IEEE Std 802.3cc-2017, IEEE Standard for Ethernet—Amendment 11: Physical Layer and Management Parameters for Serial 25 Gb/s Ethernet Operation Over Single-Mode 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 802.3-2015 and are not maintained as separate documents.

At the publication date of IEEE Std 802.3cc-2017, IEEE Std 802.3 is composed of the following documents:

IEEE Std 802.3-2015

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

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

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

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

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

stations in a subscriber access network. Clause 68 specifies a 10 Gb/s Physical Layer specification. Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

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

IEEE Std 802.3bw™-2015

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

IEEE Std 802.3by™-2016

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

IEEE Std 802.3bq™-2016

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

IEEE Std 802.3bp™-2016

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

IEEE Std 802.3br™-2016

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

IEEE Std 802.3bn™-2016

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

IEEE Std 802.3bz™-2016

Amendment 7—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 125 and Clause 126. This amendment adds new rates of 2.5 Gb/s and 5 Gb/s and new Physical Layers for operation at 2.5 Gb/s and 5 Gb/s over balanced twisted-pair structured cabling systems.

IEEE Std 802.3bu™-2016

Amendment 8—This amendment includes changes to IEEE Std 802.3-2015 to define a methodology for the provision of power via a single twisted pair to connected Data Terminal Equipment (DTE) with IEEE 802.3 single twisted-pair interfaces.

IEEE Std 802.3bv™-2017

Amendment 9—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 115 and Annex 115A. This amendment adds point-to-point 1000 Mb/s Physical Layer (PHY) specifications and management parameters for operation on duplex plastic optical fiber (POF) targeting use in automotive, industrial, home-network, and other applications.

IEEE Std 802.3™-2015/Cor 1-2017

This corrigendum clarifies which lane of the media dependent interface (MDI) of a multi-lane Physical Layer entity (PHY) is used as the timestamping reference point.

IEEE Std 802.3bs™-2017

Amendment 10—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 116 through Clause 124 and Annex 119A through Annex 120E. This amendment adds MAC parameters, Physical Layers, and management parameters for the transfer of IEEE 802.3 format frames at 200 Gb/s and 400 Gb/s.

IEEE Std 802.3cc™-2017

Amendment 11—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 114. This amendment adds 25 Gb/s Physical Layer specifications and management parameters for operation over single-mode fiber.

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

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

Contents

IEEE Standard for Ethernet

Amendment 11: Physical Layer and Management Parameters for Serial 25 Gb/s Ethernet Operation Over Single-Mode Fiber

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. Introduction

1.4 Definitions

Insert the following new definition after 1.4.64c 25GBASE-CR-S (as inserted by IEEE Std 802.3by-2016):

1.4.64c1 25GBASE-ER: IEEE 802.3 Physical Layer specification for 25 Gb/s using 25GBASE-R encoding over single-mode fiber, with reach up to at least 40 km. (See IEEE Std 802.3, Clause 114.)

Insert the following new definition after 1.4.64e 25GBASE-KR-S (as inserted by IEEE Std 802.3by-2016):

1.4.64e1 25GBASE-LR: IEEE 802.3 Physical Layer specification for 25 Gb/s using 25GBASE-R encoding over single-mode fiber, with reach up to at least 10 km. (See IEEE Std 802.3, Clause 114.)

Insert the following new definition after 1.4.178 defect:

1.4.178a differential group delay (DGD): The time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal.

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 the following new entries in "APPROPRIATE SYNTAX" after the entry for 25GBASE-SR (as inserted by IEEE Std 802.3by-2016) and before the entry for 25GBASE-T (as inserted by IEEE Std 802.3bq-2016):

APPROPRIATE SYNTAX:

...

25GBASE-LR	25GBASE-R PCS/PMA over single-mode fiber PMD, with long reach, as specified in Clause 114
25GBASE-ER	25GBASE-R PCS/PMA over single-mode fiber PMD, with extended reach, as specified in Clause 114

...

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 two reserved rows in Table 45–7 (as modified by IEEE Std 802.3bq-2016, IEEE Std 802.3by-2017, and IEEE Std 802.3bs) 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 0 1 1 0 1 1 0 = 25GBASE-ER PMA/PMD 0 1 1 0 1 0 1 = 25GBASE-LR PMA/PMD ~~0 1 1 0 1 1 0 = reserved~~ ~~0 1 1 0 1 0 1 = 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)

Insert the following row after "25GBASE-SR" in Table 45–9 (as modified by IEEE Std 802.3by-2016) and before 25GBASE-T (as inserted by IEEE Std 802.3bq-2016) as follows (unchanged rows not shown):

Table 45–9—Transmit fault description location

PMA/PMD	Description location
25GBASE-LR, 25GBASE-ER	114.5.8

45.2.1.7.5 Receive fault (1.8.10)

Insert the following row after "25GBASE-SR" in Table 45–10 (as modified by IEEE Std 802.3by-2016) and before 25GBASE-T (as inserted by IEEE Std 802.3bq-2016) as follows (unchanged rows not shown):

Table 45–10—Receive fault description location

PMA/PMD	Description location
25GBASE-LR, 25GBASE-ER	114.5.9

45.2.1.8 PMD transmit disable register (Register 1.9)

Insert the following row after "25GBASE-SR" in Table 45–12 (as modified by IEEE Std 802.3by-2016) and before 25GBASE-T (as inserted by IEEE Std 802.3bq-2016) as follows (unchanged rows not shown):

Table 45–12—Transmit disable description location

PMA/PMD	Description location
25GBASE-LR and 25GBASE-ER	114.5.6

45.2.1.14b 25G PMA/PMD extended ability register (Register 1.19)

Change the reserved row of Table 45-17b (as modified by IEEE Std 802.3bq-2016) and insert two new rows immediately below it as follows (unchanged rows not shown):

Table 45–17b—25G PMA/PMD extended ability register bit definitions

Bit(s)	Name	Description	R/W[a]
~~1.19.15:6~~ 1.19.15:8	Reserved	Value always 0	RO
1.19.7	25GBASE-ER ability	1 = PMA/PMD is able to perform 25GBASE-ER 0 = PMA/PMD is not able to perform 25GBASE-ER	RO
1.19.6	25GBASE-LR ability	1 = PMA/PMD is able to perform 25GBASE-LR 0 = PMA/PMD is not able to perform 25GBASE-LR	RO

[a]RO = Read only

Insert 45.2.1.14b.aa and 45.2.1.14b.ab before 45.2.1.14b.a (as inserted by IEEE Std 802.3bq-2016) as follows:

45.2.1.14b.aa 25GBASE-ER ability (1.19.7)

When read as a one, bit 1.19.7 indicates that the PMA/PMD is able to operate as a 25GBASE-ER PMA/PMD type. When read as a zero, bit 1.19.7 indicates that the PMA/PMD is not able to operate as a 25GBASE-ER PMA/PMD type.

45.2.1.14b.ab 25GBASE-LR ability (1.19.6)

When read as a one, bit 1.19.6 indicates that the PMA/PMD is able to operate as a 25GBASE-LR PMA/PMD type. When read as a zero, bit 1.19.6 indicates that the PMA/PMD is not able to operate as a 25GBASE-LR PMA/PMD type.

78. Energy-Efficient Ethernet (EEE)

78.1 Overview

78.1.4 PHY types optionally supporting EEE

Insert new rows into Table 78–1 after 25GBASE-SR (as inserted by IEEE Std 802.3by-2016) and before 25GBASE-T (as inserted by IEEE Std 802.3bq-2016) as follows (unmodified rows not shown):

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

PHY or interface type	Clause
25GBASE-LR[b]	107, 108, 109, 114
25GBASE-ER[b]	107, 108, 109, 114

[a]25GAUI/XLAUI/CAUI-n shutdown is supported only when deep sleep is enabled for the associated PHY.
[b]The deep sleep mode of EEE is not supported for this PHY.

105. Introduction to 25 Gb/s networks

105.1 Overview

105.1.1 Scope

Change the first paragraph of 105.1.1 (as inserted by IEEE Std 802.3by-2016 and modified by IEEE Std 802.3bq-2016) as follows:

25 Gigabit Ethernet uses the IEEE 802.3 MAC sublayer, connected through a 25 Gigabit Media Independent Interface (25GMII) to Physical Layer entities such as 25GBASE-CR, 25GBASE-CR-S, 25GBASE-KR, 25GBASE-KR-S, 25GBASE-SR, ~~and~~ 25GBASE-T, 25GBASE-LR, and 25GBASE-ER.

105.1.2 Relationship of 25 Gigabit Ethernet to the ISO OSI reference model

Change item c) of 105.1.2 (as inserted by IEEE Std 802.3by-2016) as follows:

a) The Media Dependent Interface (MDI) as specified in Clause 110 for 25GBASE-CR and 25GBASE-CR-S, in Clause 111 for 25GBASE-KR and 25GBASE-KR-S, ~~or~~ in Clause 112 for 25GBASE-SR, or in Clause 114 for 25GBASE-LR and 25GBASE-ER uses a single-lane data path.

105.1.3 Nomenclature

Change the second paragraph of 105.1.3 (as inserted by IEEE Std 802.3by-2016) as follows:

The term 25GBASE-R refers to a specific family of Physical Layer implementations based upon the 64B/66B data coding method specified in Clause 107. The 25GBASE-R family is composed of 25GBASE-CR, 25GBASE-CR-S, 25GBASE-KR, 25GBASE-KR-S, ~~and~~ 25GBASE-SR, 25GBASE-LR, and 25GBASE-ER.

Insert rows to Table 105-1 in 105.1.3 (as inserted by IEEE Std 802.3by-2016) after 25GBASE-SR and before 25GBASE-T (as inserted by IEEE Std 802.3bq-2016) as follows (unchanged rows not shown):

Table 105–1—25 Gb/s PHYs

Name	Description
25GBASE-LR	25 Gb/s PHY using 25GBASE-R encoding over a duplex single-mode fiber, with reach up to at least 10 km (see Clause 114).
25GBASE-ER	25 Gb/s PHY using 25GBASE-R encoding over a duplex single-mode fiber, with reach up to at least 40 km (see Clause 114).

105.2 Physical Layer signaling systems

Change Table 105-2 (as inserted by IEEE Std 802.3by-2016 and modified by IEEE Std 802.3bq-2016) as follows:

Table 105–2—Nomenclature and clause correlation, 25 Gb/s Ethernet PHYs

Nomenclature	Clause/Annex																			
	28	73	74	78	106		107	108	109	109A	109B	110		111		112	113	114	
	Auto-Negotiation	Auto-Negotiation	BASE-R FEC	EEE	RS	25GMII	25GBASE-R PCS	25GBASE-R RS-FEC	PMA	25GAUI C2C	25GAUI C2M	25GBASE-CR PMD	25GBASE-CR-S PMD	25GBASE-KR PMD	25GBASE-KR-S PMD	25GBASE-SR PMD	25GBASE-T PCS/PMA	25GBASE-LR PMD	25GBASE-ER PMD
25GBASE-CR		M[a]	M	O[a]	M	O	M	M	M	O		M							
25GBASE-CR-S		M	M	O	M	O	M		M	O			M						
25GBASE-KR		M	M	O	M	O	M	M	M	O				M					
25GBASE-KR-S		M	M	O	M	O	M		M	O					M				
25GBASE-SR				O	M	O	M	M	M	O	O					M			
25GBASE-T	M			O	M	O											M		
25GBASE-LR				O	M	O	M	M	M	O	O							M	
25GBASE-ER				O	M	O	M	M	M	O	O								M

[a]O = Optional, M = Mandatory

105.3 Summary of 25 Gigabit Ethernet sublayers

105.3.5 Physical Medium Dependent (PMD) sublayer

Change the third paragraph of 105.3.5 (as inserted by IEEE Std 802.3by-2016) as follows:

The 25GBASE-R PMDs and their corresponding media are specified in Clause 110, Clause 111, ~~and~~ Clause 112, and Clause 114.

105.5 Delay constraints

Insert two new rows below 25GBASE-SR PMD in Table 105-3 (as inserted by IEEE Std 802.3by-2016) and above 25GBASE-T (as inserted by IEEE Std 802.3bq-2016) as follows:

Table 105–3—Sublayer delay constraints

Sublayer	Maximum (bit time)[a]	Maximum (pause_quanta)[b]	Maximum (ns)	Notes[c]
25GBASE-LR PMD	512	1	20.48	See 114.3.
25GBASE-ER PMD	512	1	20.48	See 114.3.

[a]1 bit time (BT) is equal to 40 ps. (See 1.4.117 for the definition of bit time.)
[b]1 pause_quantum is equal to 20.48 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.

105.7 Protocol implementation conformance statement (PICS) proforma

Change the first paragraph of 105.7 (as added by IEEE Std 802.3by-2016) as follows:

The supplier of a protocol implementation that is claimed to conform to any part of IEEE Std 802.3, Clause 45, Clause 73, Clause 74, Clause 106 through Clause 112, Clause 114, and related annexes demonstrates compliance by completing a protocol implementation conformance statement (PICS) proforma.

108. Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 25GBASE-R PHYs

108.5 Functions within the 25GBASE-R RS-FEC sublayer

108.5.3 Receive function

108.5.3.2 Reed-Solomon decoder

Change the third paragraph of 108.5.3.2 (as added by IEEE Std 802.3by-2016) as follows:

The Reed-Solomon decoder may provide the option to perform error detection without error correction to reduce the delay contributed by the 25GBASE-R RS-FEC sublayer. The presence of this option is indicated by the assertion of the FEC_bypass_correction_ability variable (see 108.6.4). When the option is provided, it is enabled by the assertion of the FEC_bypass_correction_enable variable (see 108.6.1). This option shall not be used when the 25GBASE-R RS-FEC sublayer is used to form part of a 25GBASE-SR, 25GBASE-LR, or 25GBASE-ER PHY.

108.7 Protocol implementation conformance statement (PICS) proforma for Clause 108, Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 25GBASE-R PHYs[1]

108.7.3 Major capabilities/options

Insert the following rows for *LR and *ER after *SR in the table in 108.7.3 (as added by IEEE Std 802.3by-2016):

Item	Feature	Subclause	Value/Comment	Status	Support
*LR	25GBASE-LR		Used to form a complete 25GBASE-LR PHY	O	Yes [ ] No [ ]
*ER	25GBASE-ER		Used to form a complete 25GBASE-ER PHY	O	Yes [ ] No [ ]

108.7.4 PICS proforma tables for Reed-Solomon Forward Error Correction (RS-FEC) sub-layer for 25GBASE-R PHYs

108.7.4.2 Receive function

Change the row with Item RF3 in the table in 108.7.4.2 (as added by IEEE Std 802.3by-2016) as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
RF3	Error correction not bypassed for 25GBASE-SR, 25GBASE-LR, or 25GBASE-ER	108.5.3.2	Error correction is not bypassed	BEC*(SR or LR or ER):M	Yes [ ] N/A [ ]

[1] *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.

Insert Clause 114 as follows:

114. Physical Medium Dependent (PMD) sublayer and medium, types 25GBASE-LR and 25GBASE-ER

114.1 Overview

This clause specifies the 25GBASE-LR PMD and 25GBASE-ER PMD together with the single-mode fiber medium. The PMD sublayer provides a point-to-point 25 Gb/s Ethernet link over a pair of single-mode fibers. When forming a complete Physical Layer, a PMD shall be connected to the appropriate PMA as shown in Table 114–1, 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 114–1—Physical Layer clauses associated with the 25GBASE-LR and 25GBASE-ER PMDs

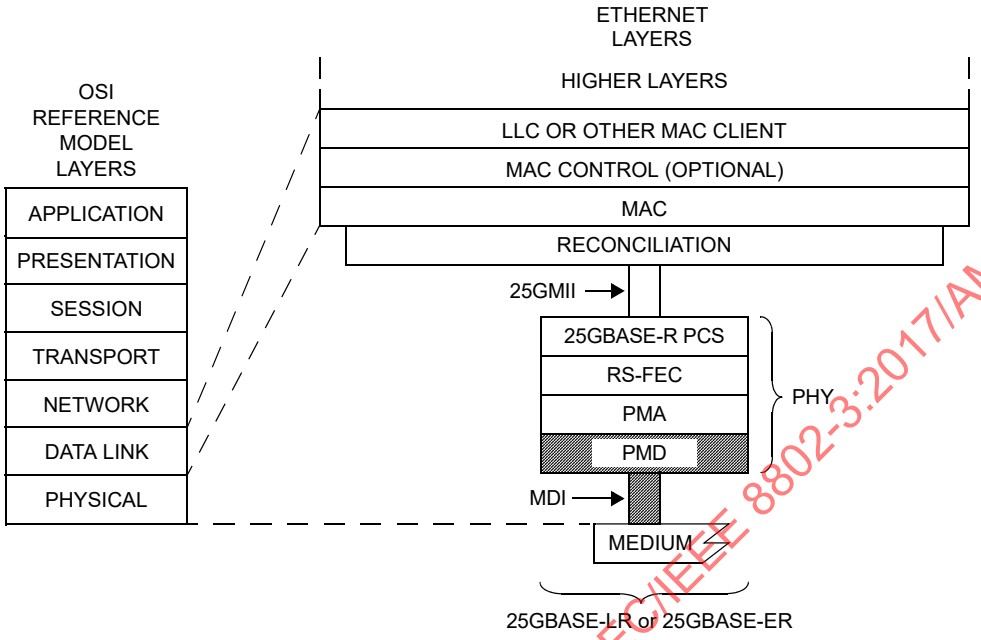
Associated clause	25GBASE-LR	25GBASE-ER
106—RS	Required	Required
106—25GMII[a]	Optional	Optional
107—PCS for 25GBASE-R	Required	Required
108—RS-FEC[b]	Required	Required
109—PMA for 25GBASE-R	Required	Required
109A—25GAUI C2C	Optional	Optional
109B—25GAUI C2M	Optional	Optional
78—Energy Efficient Ethernet	Optional	Optional

[a]The 25GMII is an optional interface. However, if the 25GMII is not implemented, a conforming implementation must behave functionally as though the RS and 25GMII were present.
[b]The option to bypass the Clause 108 RS-FEC correction function is not supported.

Figure 114–1 shows the relationship of the PMD and MDI (shown shaded) with other sublayers to the ISO/IEC Open System Interconnection (OSI) reference model. 25 Gigabit Ethernet is introduced in Clause 105 and the purpose of each PHY sublayer is summarized in 105.3.

25GBASE-LR and 25GBASE-ER 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.).



25GMII = 25 GIGABIT 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
LR = PMD FOR SINGLE-MODE FIBER - 10 km
ER = PMD FOR SINGLE-MODE FIBER - 40 km

Figure 114–1—25GBASE-LR and 25GBASE-ER PMDs' relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

114.1.1 Bit error ratio

The bit error ratio (BER) shall be less than 5×10^{-5} provided that the error statistics are sufficiently random that this results in a frame loss ratio (see 1.4.223) of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap when processed according to Clause 108.

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 6.2×10^{-10} for 64-octet frames with minimum interpacket gap when processed according to Clause 108.

114.2 Physical Medium Dependent (PMD) service interface

The PMD service interfaces for 25GBASE-LR and 25GBASE-ER are the same as PMD service interface for 25GBASE-SR as described in 112.2 with the BER as specified in 114.1.1.

114.3 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 25GBASE-LR or 25GBASE-ER PMD including 2 m of fiber in one direction shall be no more than 512 bit times (1 pause_quantum or 20.48 ns). A description of overall system delay constraints and the definitions for bit times and pause_quantum can be found in 105.5 and its references.

114.4 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 114–2 and the mapping of MDIO status variables to PMD status variables shall be as shown in Table 114–3.

Table 114–2—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

Table 114–3—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

114.5 PMD functional specifications

The 25GBASE-LR and 25GBASE-ER PMDs perform the Transmit and Receive functions, which convey data between the PMD service interface and the MDI.

114.5.1 PMD block diagram

The PMD block diagram is shown in Figure 114–2. 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 single-mode fiber patch cord (TP2), between 2 m and 5 m in length. Unless specified otherwise, all transmitter measurements and tests defined in 114.7 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) at the MDI (see 88.11.3). Unless specified otherwise, all receiver measurements and tests defined in 114.7 are made at TP3.

TP1 and TP4 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).

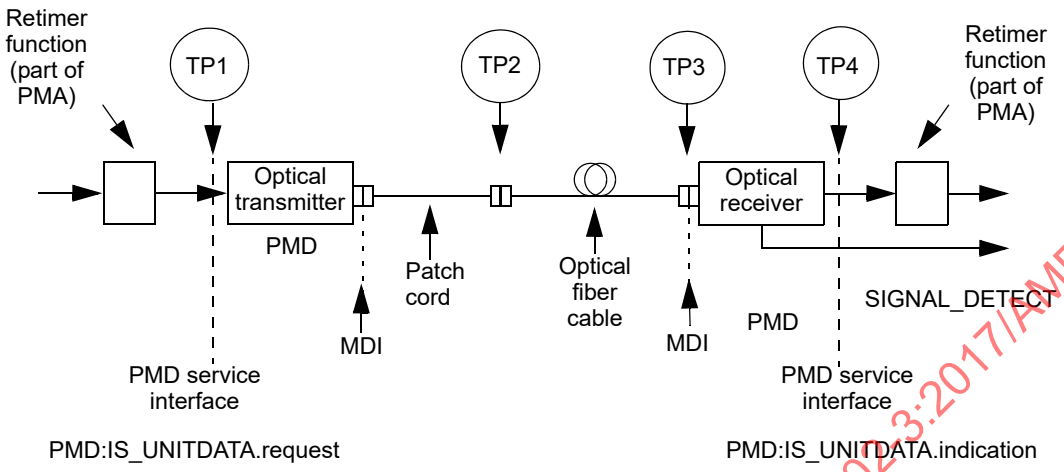


Figure 114–2—Block diagram for 25GBASE-LR and 25GBASE-ER transmit/receive paths

114.5.2 PMD transmit function

The PMD transmit function shall convert the bit stream requested by the PMD service interface messages PMD:IS_UNITDATA.request into an optical signal stream. The optical signal stream shall then be delivered to the MDI, all according to the transmit optical specifications in this clause. The higher optical power level in the signal stream shall correspond to tx_bit = one.

114.5.3 PMD receive function

The PMD receive function shall convert the optical signal stream received from the MDI into a bit stream for delivery to the PMD service interface using the messages PMD:IS_UNITDATA.indication, all according to the receive optical specifications in this clause. The higher optical power level in the signal stream shall correspond to rx_bit = one.

114.5.4 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 105.4.

SIGNAL_DETECT shall be the indicator of the presence of the optical signal. The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 114–4. The PMD receiver is not required to verify whether a compliant 25GBASE-R signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

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

Table 114–4—SIGNAL_DETECT value definition

Receive conditions	SIGNAL_DETECT value
Average optical power at TP3 ≤ –20 dBm for 25GBASE-LR and ≤ –26 dBm for 25GBASE-ER	FAIL
[(Optical power at TP3 ≥ receiver sensitivity (max) in OMA in Table 114–7) AND (compliant 25GBASE–R signal input)]	OK
All other conditions	Unspecified

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 PMD global 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. When the MDIO is implemented, the SIGNAL_DETECT value shall be continuously set in response to the magnitude of the optical signal, according to the requirements of Table 114–4.

114.5.5 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.

114.5.6 PMD global transmit disable function (optional)

The PMD_global_transmit_disable function is optional and allows the optical transmitter to be disabled.

a) When PMD_global_transmit_disable is set to one, this function shall turn off the optical transmitter so that it meets the requirement of the average launch power of the OFF transmitter in Table 114–6.

b) If PMD_fault is detected, then the PMD may set PMD_global_transmit_disable to one, turning off the optical transmitter.

114.5.7 PMD fault function (optional)

If the PMD has detected a local fault on 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.

114.5.8 PMD transmit fault function (optional)

If the PMD has detected a local fault on the transmitter, 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.

114.5.9 PMD receive fault function (optional)

If the PMD has detected a local fault on the receiver, the PMD shall set PMD_receive_fault 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.

114.6 PMD to MDI optical specifications for 25GBASE-LR and 25GBASE-ER

The operating ranges for the 25GBASE-LR and 25GBASE-ER PMDs are defined in Table 114–5. A 25GBASE-LR or 25GBASE-ER compliant PMD operates on IEC 60793-2-50 type B1.1 (dispersion unshifted), type B1.3 (low water peak), or type B6_a (bend insensitive) single-mode fibers according to the specifications defined in Table 114–11. A PMD that exceeds the operating range requirement while meeting all other optical specifications is considered compliant (e.g., a 25GBASE-LR PMD operating at 12.5 km meets the operating range requirement of 2 m to 10 km). The 25GBASE-ER PMD interoperates with the 25GBASE-LR PMD provided that the channel requirements defined in 114.11 are met.

Table 114–5—25GBASE-LR and 25GBASE-ER operating ranges

PMD type	Required operating range[a]
25GBASE-LR	2 m to 10 km
25GBASE-ER	2 m to 30 km
	2 m to 40 km[b]

[a]The RS-FEC correction function may not be bypassed for any operating distance.
[b]Links longer than 30 km for the same link power budget are considered engineered links. Attenuation for such links needs to be less than the worst case specified for IEC 60793-2-50 type B1.1, type B1.3, or type B6_a single-mode fiber.

114.6.1 25GBASE-LR and 25GBASE-ER transmitter optical specifications

The 25GBASE-LR and 25GBASE-ER transmitters shall meet the specifications in Table 114–6 per the definitions in 114.7.

Table 114–6—25GBASE-LR and 25GBASE-ER transmit characteristics

Description	25GBASE-LR	25GBASE-ER	Unit
Signaling rate (range)	25.78125 ± 100 ppm		GBd
Center wavelength (range)	1295 to 1325	1295 to 1310	nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Average launch power (max)	2	6	dBm
Average launch power[a] (min)	–7	–3	dBm
Optical Modulation Amplitude (OMA), (max)	2.2	6	dBm
Optical Modulation Amplitude (OMA),[b] (min)	–4	0	dBm
Launch power in OMA minus TDP (min)	–5	–1	dBm
Transmitter and dispersion penalty (TDP), (max)	2.7	2.7	dB

Table 114–6—25GBASE-LR and 25GBASE-ER transmit characteristics *(continued)*

Description	25GBASE-LR	25GBASE-ER	Unit
Average launch power of OFF transmitter (max)	–20		dBm
Extinction ratio (min)	3	4	dB
$RIN_{20}OMA$ (max)	–130		dB/Hz
Optical return loss tolerance (max)	20		dB
Transmitter reflectance[c] (max)	–26		dB
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} hits per sample.	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}		

[a]Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b]Even if the TDP < 1 dB, the OMA (min) must exceed this value.
[c]Transmitter reflectance is defined looking into the transmitter.

114.6.2 25GBASE-LR and 25GBASE-ER receive optical specifications

The 25GBASE-LR and 25GBASE-ER receivers shall meet the specifications in Table 114–7 per the definitions in 114.7.

Table 114–7—25GBASE-LR and 25GBASE-ER receive characteristics

Description	25GBASE-LR	25GBASE-ER	Unit
Signaling rate (range)	25.78125 ± 100 ppm		GBd
Center wavelength (range)	1295 to 1325		nm
Damage threshold[a] (min)	3	–3	dBm
Average receive power (max)	2	–4	dBm
Average receive power[b] (min)	–13.3	–21	dBm
Receive power (OMA), (max)	2.2	–4	dBm
Receiver reflectance (max)	–26		dB
Receiver sensitivity (OMA),[c] (max)	–12	–19	dBm
Stressed receiver sensitivity (OMA),[d] (max)	–9.5	–16.5	dBm
Conditions of stressed receiver sensitivity test			
Stressed eye closure[e]	2.5	2.5	dB
Stressed eye J2 Jitter[e]	0.27	0.27	UI
Stressed eye J4 Jitter[e]	0.39	0.39	UI
SRS eye mask definition {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} hits per sample.	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}		

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.
[b]Average receive power (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]Receiver sensitivity (OMA), (max) is informative.
[d]Measured with conformance test signal at TP3 (see 114.7.10) for the BER specified in 114.1.1.
[e]Stressed eye closure, stressed eye J2 Jitter, and stressed eye J4 Jitter are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

114.6.3 25GBASE-LR and 25GBASE-ER illustrative link power budgets

Illustrative power budgets and penalties for 25GBASE-LR and 25GBASE-ER channels are shown in Table 114–8.

Table 114–8—25GBASE-LR and 25GBASE-ER illustrative link power budgets

Parameter	25GBASE-LR	25GBASE-ER		Unit
Power budget (for maximum TDP)	9.7	20.7		dB
Operating distance	10	30	40[a]	km
Channel insertion loss	6.3[b]	15[b]	See 114.9[a]	dB
Maximum discrete reflectance	See 114.10	See 114.10		dB
Allocation for penalties[c] (for maximum TDP)	3.4	20.7 minus maximum channel insertion loss per Table 114–12		dB
Additional insertion loss allowed	0	Maximum channel insertion loss per Table 114–12 minus 15	0	dB

[a]Links longer than 30 km are considered engineered links. Attenuation for such links needs to be less than the worst case for cables containing IEC 60793-2-50 type B1.1, type B1.3, or type B6_a single-mode cabled optical fiber.
[b]The channel insertion loss is calculated using the maximum distance specified in Table 114–5 and fiber attenuation of 0.43 dB/km at 1295 nm plus an allocation for connection and splice loss given in 88.11.2.1.
[c]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

114.7 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.

114.7.1 Test patterns for optical parameters

The test patterns used in this clause shall be the same as those used for 100GBASE-SR4, as described in 95.8.1 and shown in Table 95-9, with the exception that pattern 5, the scrambled idle test pattern defined in 82.2.11, is encoded by Clause 108 RS-FEC for 25GBASE-LR and 25GBASE-ER. The multi-lane testing considerations described in 95.8.1.1 do not apply. Table 114–9 shows 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.

114.7.2 Wavelength

The wavelength shall be within the ranges given in Table 114–6 if measured per TIA-455-127-A or IEC 61280-1-3. The signal is modulated using the test pattern specified in Table 114–9.

Table 114–9—Test-pattern definitions and related subclauses

Parameter	Pattern	Related subclause
Wavelength	3, 5 or valid 25GBASE-R signal	114.7.2
Side mode suppression ratio	3, 5 or valid 25GBASE-R signal	—
Average optical power	3, 5 or valid 25GBASE-R signal	114.7.3
Optical modulation amplitude (OMA)	Square wave or 4	114.7.4
Transmitter and dispersion penalty (TDP)	3, 5 or valid 25GBASE-R signal	114.7.5
Extinction ratio	3, 5 or valid 25GBASE-R signal	114.7.6
$RIN_{20}OMA$	Square wave or 4	114.7.7
Transmitter optical waveform	3, 5 or valid 25GBASE-R signal	114.7.8
Stressed receiver sensitivity	3, 5 or valid 25GBASE-R signal	114.7.10
Calibration of OMA for receiver tests	Square wave or 4	87.8.11
Vertical eye closure penalty calibration	3, 5 or valid 25GBASE-R signal	87.8.11

114.7.3 Average optical power

The average optical power shall be within the limits given in Table 114–6 if measured using the methods given in IEC 61280-1-1. The average optical power is measured using the test pattern specified in Table 114–9.

114.7.4 Optical Modulation Amplitude (OMA)

OMA shall be as defined in 52.9.5 for measurement with a square wave (8 ones, 8 zeros) test pattern or 68.6.2 (from the variable MeasuredOMA in 68.6.6.2) for measurement with a PRBS9 test pattern. See 114.7.1 for test pattern information.

114.7.5 Transmitter and dispersion penalty (TDP)

Transmitter and dispersion penalty (TDP) shall be as defined in 52.9.10 with the BER as specified in 114.1.1. The measurement procedure for 25GBASE-LR and 25GBASE-ER is detailed in 114.7.5.1 to 114.7.5.4.

114.7.5.1 Reference transmitter requirements

The reference transmitter is a high-quality instrument-grade device, which can be implemented by a CW laser modulated by a high-performance modulator. The basic requirements are as follows:

a) Rise/fall times of less than 12 ps at 20% to 80%.
b) The output optical eye is symmetric and passes the transmitter optical waveform test of 114.7.8.
c) In the center 20% region of the eye, the worst-case vertical eye closure penalty as defined in 87.8.11.2 is less than 0.5 dB.
d) Total Jitter less than 0.2 UI peak-to-peak.
e) RIN of less than –138 dB/Hz.