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AMENDMENT 14
2022-10

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

Part 3:
Standard for Ethernet

AMENDMENT 14: Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s optical access PHYs

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

Partie 3: Norme pour Ethernet

AMENDEMENT 14: Liaisons physiques (PHY) d'accès optique 10 Gb/s, 25 Gb/s et 50 Gb/s bidirectionnelles

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Institute of Electrical and Electronics Engineers, Inc
3 Park Avenue, New York
NY 10016-5997, USA

Email: stds.ipr@ieee.org
Website: www.ieee.org

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ISO/IEC/IEEE 8802-3:2021/Amd.14 was prepared by the LAN/MAN of the IEEE Computer Society (as IEEE 802.3cp-2021) and drafted in accordance with its editorial rules. It was adopted, under the "fast-track procedure" defined in the Partner Standards Development Organization cooperation agreement between ISO and IEEE, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*.

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IEEE Std 802.3cp™-2021
(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,
IEEE Std 802.3cq™-2020,
IEEE Std 802.3cm™-2020,
IEEE Std 802.3ch™-2020,
IEEE Std 802.3ca™-2020,
IEEE Std 802.3cr™-2021,
IEEE Std 802.3cu™-2021,
IEEE Std 802.3cv™-2021,
and IEEE Std 802.3ct™-2021)

IEEE Standard for Ethernet

Amendment 14: Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 16 June 2021

IEEE SA Standards Board

Abstract: This amendment to IEEE Std 802.3-2018 adds Physical Layer specifications and management parameters for 10 Gb/s, 25 Gb/s, and 50 Gb/s Ethernet optical interfaces for bidirectional operation over a single strand of single-mode fiber with reaches of at least 10 km, 20 km, and 40 km.

Keywords: 10GBASE-BR10, 10GBASE-BR20, 10GBASE-BR40, 25GBASE-BR10, 25GBASE-BR20, 25GBASE-BR40, 50GBASE-BR10, 50GBASE-BR20, 50GBASE-BR40, bidirectional (BiDi), Ethernet, forward error correction (FEC), IEEE 802.3™, IEEE 802.3cp™, multi-gigabit Ethernet bidirectional Physical Layers, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, Physical Medium Dependent (PMD) sublayer

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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David J. Law, *IEEE 802.3 Working Group Chair*
Adam Healey, *IEEE 802.3 Working Group Vice-Chair*
Jon Lewis, *IEEE 802.3 Working Group Secretary*
Steven B. Carlson, *IEEE 802.3 Working Group Executive Secretary*
Valerie Maguire, *IEEE 802.3 Working Group Treasurer*

Frank Effenberger, *IEEE P802.3cp Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs Task Force Chair*
Duane Remein, *IEEE P802.3cp Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs Task Force Editor-in-Chief, Phase 1*
Yuanqiu Luo, *IEEE P802.3cp Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs Task Force Editor-in-Chief, Phase 2*

David Abramson
Pete Anslow
Michikazu Aono
Nobuyasu Araki
Tim Baggett
Thananya Baldwin
Steven Baumgartner
Denis Beaudoin
Gitesh Bhagwat
Rich Boyer
David Brandt
Ralf-Peter Braun
Theodore Brillhart
Paul Brooks
Matthew Brown
Leon Bruckman
Jairo Bustos Heredia
Adrian Butter
John Calvin
Clark Carty
David Chalupsky
Jacky Chang
Xin Chang
Chan Chen
Golam Choudhury
Keng Hua Chuang
John D'Ambrosia
Piers J. G. Dawe
Fred Dawson
Gerrit den Besten
Claudio DeSanti
Curtis Donahue
Liang Du
Kathryn Dube
Mike Dudek
David Estes
John Ewen
Vincent Ferretti
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Takashi Fukuoka
Ali Ghiasi
Joel Goergen
Steven Gorshe
Hideki Goto
Steffen Graber
Olaf Grau
Robert Grow
Martin Gubow
Mark Gustlin
Marek Hajduczenia
Howard Heck
David Hess
Brian Holden
Bernd Horrmeyer
Yasuhiro Hyakutake
Jonathan Ingham
Kazuhiko Ishibe
Hideki Isono
Tom Issenhuth
Hiroaki Ito
Kenneth Jackson
Andrew Jimenez
John Johnson
Chad Jones
Peter Jones
Lokesh Kabra
Haysam Kadry
Manabu Kagami
Upen Kareti
Athanasios Kasapi
Yong Kim
Mark Kimber
Michael Klempa
Curtis Knittle
Elizabeth Kochuparambil
Sam Kocsis
Wojciech Koczwara
Paul Kolesar
Taiji Kondo
Daniel Koppermueller
Glen Kramer
Taketo Kumada
Hans Lackner
Frank Lambrecht
Mark Laubach
Greg Le Cheminant
David Lewis
Mike-Peng Li
Alex Lin
Robert Lingle
Hai-Feng Liu
Williiam Lo
Kent Lusted
Jeffery Maki
David Malicoat
Eric Maniloff
Flavio Marques
Arthur Marris
Takeo Masuda
Mick McCarthy
Brett McClellan
Larry McMillan
Greg McSorley
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Shimon Muller
Sean Murphy
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Paul Neveux
Gary Nicholl
Shawn Nicholl
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Rubén Perez DeAranda Alonso
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Rick Rabinovich
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Lennart Yseboodt
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Xingxin Zhang
Chunhui Zhu
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Martin Zielinski
George Zimmerman
Pavel Zivny

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Rob Aekins
Robert Aiello
Thomas Alexander
Philip E. Beecher
Rich Boyer
Ralf-Peter Braun
Jairo Bustos Heredia
William Byrd
Steven B. Carlson
Juan Carreon
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Xiang He
Adam Healey
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Scott Mansfield
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R. K. Rannow
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David Tremblay
Mark-Rene Uchida
Alexander Umnov
Dmitri Varsanofiev
Ruoxu Wang
James Weaver
Stephen Webb
Karl Weber
Matthias Wendt
Andreas Wolf
Peter Wu
James Young
Yu Yuan
Oren Yuen

Introduction

This introduction is not part of IEEE Std 802.3cp-2021, IEEE Standard for Ethernet—Amendment 14: Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs.

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 802.3cp-2021 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.

IEEE Std 802.3ch™-2020

Amendment 8—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 149, Annex 149A, Annex 149B, and Annex 149C. This amendment adds physical layer specifications and management parameters for operation at 2.5 Gb/s, 5 Gb/s, and 10 Gb/s over a single balanced pair of conductors.

IEEE Std 802.3ca™-2020

Amendment 9—This amendment to IEEE Std 802.3-2018 extends the operation of Ethernet passive optical networks (EPONs) to multiple channels of 25 Gb/s providing both symmetric and asymmetric operation for the following data rates (downstream/upstream): 25/10 Gb/s, 25/25 Gb/s, 50/10 Gb/s, 50/25 Gb/s, and 50/50 Gb/s. This amendment specifies the 25 Gb/s EPON Multi-Channel Reconciliation Sublayer (MCRS), Nx25G-EPON Physical Coding Sublayers (PCSs), Physical Media Attachment (PMA) sublayers, and Physical Medium Dependent (PMD) sublayers that support both symmetric and asymmetric data rates while maintaining backward compatibility with already deployed 10 Gb/s EPON equipment. The EPON operation is defined for distances of at least 20 km, and for a split ratio of at least 1:32.

IEEE Std 802.3cr™-2021

Amendment 10—This amendment includes changes to IEEE Std 802.3-2018 and adds Annex J. This amendment replaces references to the IEC 60950 series of standards (including IEC 60950-1 “Information technology equipment—Safety—Part 1: General requirements”) with appropriate references to the IEC 62368 “Audio/video, information and communication technology equipment” series and makes appropriate changes to the standard corresponding to the new references.

IEEE Std 802.3cu™-2021

Amendment 11—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 151. This amendment adds Physical Layer (PHY) specifications and management parameters for 100 Gb/s and 400 Gb/s operation over single-mode fiber, based on 100 Gb/s per wavelength optical signaling.

IEEE Std 802.3cv™-2021

Amendment 12—This amendment includes editorial and technical corrections, refinements, and clarifications to Clause 145, Power over Ethernet, and related portions of the standard.

IEEE Std 802.3ct™-2021

Amendment 13—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 152 through Clause 154 and Annex 154A. This amendment adds 100 Gb/s Physical Layer specifications and management parameters for operation over DWDM systems with reaches of at least 80 km.

IEEE Std 802.3cp™-2021

Amendment 14—This amendment includes changes to IEEE Std 802.3-2018 and adds Clause 157, Clause 158, Clause 159, and Clause 160. This amendment adds Physical Layer specifications and management parameters for 10 Gb/s, 25 Gb/s, and 50 Gb/s Ethernet optical interfaces for bidirectional operation over a single strand of single-mode fiber.

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.

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IEEE Standard for Ethernet

Amendment 14: Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs

(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, IEEE Std 802.3cq™-2020, IEEE Std 802.3cm™-2020, IEEE Std 802.3ch™-2020, IEEE Std 802.3ca™-2020, IEEE Std 802.3cr™-2021, IEEE Std 802.3cu™-2021, IEEE Std 802.3cv™-2021, and IEEE Std 802.3ct™-2021.)

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 <u>underscore</u> (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.

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

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

1. Introduction

1.4 Definitions

Insert the following three new definitions after 1.4.52 "10BROAD36":

1.4.52a 10GBASE-BR10: IEEE 802.3 Physical Layer specification for a 10 Gb/s bidirectional link over one single-mode fiber with reach up to at least 10 km. There are different specifications for 10GBASE-BR10-D and 10GBASE-BR10-U; a transmission path connects one to the other. (See IEEE Std 802.3, Clause 158.)

1.4.52b 10GBASE-BR20: IEEE 802.3 Physical Layer specification for a 10 Gb/s bidirectional link over one single-mode fiber with reach up to at least 20 km. There are different specifications for 10GBASE-BR20-D and 10GBASE-BR20-U; a transmission path connects one to the other. (See IEEE Std 802.3, Clause 158.)

1.4.52c 10GBASE-BR40: IEEE 802.3 Physical Layer specification for a 10 Gb/s bidirectional link over one single-mode fiber with reach up to at least 40 km. There are different specifications for 10GBASE-BR40-D and 10GBASE-BR40-U; a transmission path connects one to the other. (See IEEE Std 802.3, Clause 158.)

Insert the following three new definitions after 1.4.91 "25GBASE":

1.4.91a 25GBASE-BR10: IEEE 802.3 Physical Layer specification for a 25 Gb/s bidirectional link over one single-mode fiber with reach up to at least 10 km. There are different specifications for 25GBASE-BR10-D and 25GBASE-BR10-U; a transmission path connects one to the other. (See IEEE Std 802.3, Clause 159.)

1.4.91b 25GBASE-BR20: IEEE 802.3 Physical Layer specification for a 25 Gb/s bidirectional link over one single-mode fiber with reach up to at least 20 km. There are different specifications for 25GBASE-BR20-D and 25GBASE-BR20-U; a transmission path connects one to the other. (See IEEE Std 802.3, Clause 159.)

1.4.91c 25GBASE-BR40: IEEE 802.3 Physical Layer specification for a 25 Gb/s bidirectional link over one single-mode fiber with reach up to at least 40 km. There are different specifications for 25GBASE-BR40-D and 25GBASE-BR40-U; a transmission path connects one to the other. (See IEEE Std 802.3, Clause 159.)

Insert the following three new definitions after 1.4.128aac "50/50G-EPON" as inserted by IEEE Std 802.3ca-2020:

1.4.128aad 50GBASE-BR10: IEEE 802.3 Physical Layer specification for a 50 Gb/s bidirectional link over one single-mode fiber with reach up to at least 10 km. There are different specifications for 50GBASE-BR10-D and 50GBASE-BR10-U; a transmission path connects one to the other. (See IEEE Std 802.3 Clause 160.)

1.4.128aae 50GBASE-BR20: IEEE 802.3 Physical Layer specification for a 50 Gb/s bidirectional link over one single-mode fiber with reach up to at least 20 km. There are different specifications for 50GBASE-BR20-D and 50GBASE-BR20-U; a transmission path connects one to the other. (See IEEE Std 802.3, Clause 160.)

1.4.128aaf 50GBASE-BR40: IEEE 802.3 Physical Layer specification for a 50 Gb/s bidirectional link over one single-mode fiber with reach up to at least 40 km. There are different specifications for 50GBASE-BR40-D and 50GBASE-BR40-U; a transmission path connects one to the other. (See IEEE Std 802.3, Clause 160.)

1.5 Abbreviations

Insert the following new abbreviation into the list in 1.5, in alphanumeric order:

BiDi bidirectional

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 types into the "APPROPRIATE SYNTAX" section of 30.5.1.1.2 after 10GBASE-T1 (as inserted by IEEE Std 802.3ch-2020) as follows:

APPROPRIATE SYNTAX:

…

10GBASE-BR10-D	One single-mode fiber OLT PHY supporting a distance of at least 10 km as specified in Clause 158
10GBASE-BR10-U	One single-mode fiber ONU PHY supporting a distance of at least 10 km as specified in Clause 158
10GBASE-BR20-D	One single-mode fiber OLT PHY supporting a distance of at least 20 km as specified in Clause 158
10GBASE-BR20-U	One single-mode fiber ONU PHY supporting a distance of at least 20 km as specified in Clause 158
10GBASE-BR40-D	One single-mode fiber OLT PHY supporting a distance of at least 40 km as specified in Clause 158
10GBASE-BR40-U	One single-mode fiber ONU PHY supporting a distance of at least 40 km as specified in Clause 158

…

Insert the following new types into the "APPROPRIATE SYNTAX" section of 30.5.1.1.2 after 25GBASE-T as follows:

APPROPRIATE SYNTAX:

…

25GBASE-BR10-D	One single-mode fiber OLT PHY supporting a distance of at least 10 km as specified in Clause 159
25GBASE-BR10-U	One single-mode fiber ONU PHY supporting a distance of at least 10 km as specified in Clause 159
25GBASE-BR20-D	One single-mode fiber OLT PHY supporting a distance of at least 20 km as specified in Clause 159
25GBASE-BR20-U	One single-mode fiber ONU PHY supporting a distance of at least 20 km as specified in Clause 159
25GBASE-BR40-D	One single-mode fiber OLT PHY supporting a distance of at least 40 km as specified in Clause 159
25GBASE-BR40-U	One single-mode fiber ONU PHY supporting a distance of at least 40 km as specified in Clause 159

…

Insert the following new types into the "APPROPRIATE SYNTAX" section of 30.5.1.1.2 after 50GBASE-ER (as inserted by IEEE Std 802.3cn-2019) as follows:

APPROPRIATE SYNTAX:

…

50GBASE-BR10-D	One single-mode fiber OLT PHY supporting a distance of at least 10 km as specified in Clause 160
50GBASE-BR10-U	One single-mode fiber ONU PHY supporting a distance of at least 10 km as specified in Clause 160
50GBASE-BR20-D	One single-mode fiber OLT PHY supporting a distance of at least 20 km as specified in Clause 160
50GBASE-BR20-U	One single-mode fiber ONU PHY supporting a distance of at least 20 km as specified in Clause 160
50GBASE-BR40-D	One single-mode fiber OLT PHY supporting a distance of at least 40 km as specified in Clause 160
50GBASE-BR40-U	One single-mode fiber ONU PHY supporting a distance of at least 40 km as specified in Clause 160

…

Change the first paragraph of the "BEHAVIOUR DEFINED AS" section of 30.5.1.1.2 as follows:

BEHAVIOUR DEFINED AS:

Returns a value that identifies the internal MAU type. If an AUI is to be identified to access an external MAU, the type "AUI" is returned. A SET operation to one of the possible enumerations indicated by aMAUTypeList will force the MAU into the new operating mode. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the mode force bits specified in 22.2.4.1. If a Clause 45 MDIO Interface is present, then this will map to the PCS type selection bit(s) in the 10G WIS Control 2 register specified in 45.2.2.6.6, the PCS Control 2 register specified in 45.2.3.6.1, the PMA/PMD type selection bits in the PMA/PMD Control 2 register specified in 45.2.1.6, the PMA/PMD control 1 register specified in 45.2.1.1, the ~~25G~~ RS-FEC Enable bit in the RS-FEC control register specified in 45.2.1.110.1, and the PCS control 1 register 45.2.3.1. If Clause 28, Clause 37, or Clause 73 Auto-Negotiation is operational, then this will change the advertised ability to the single enumeration specified in the SET operation, and cause an immediate link renegotiation. A change in the MAU type will also be reflected in aPHYType.

30.5.1.1.16 aFECmode

Change the last paragraph of the "BEHAVIOUR DEFINED AS" section of 30.5.1.1.16 as follows:

BEHAVIOUR DEFINED AS:

…

If a Clause 45 MDIO Interface is present, then this attribute maps to the FEC control register (see 45.2.10.3) for 1000BASE-PX, to the BASE-R FEC control register (see 45.2.1.102) and the ~~25G~~ RS-FEC Enable bit in the RS-FEC control register (see 45.2.1.110) for 10GBASE-R and 25GBASE-R, or FEC enable bit in the BASE-R FEC control register (see 45.2.1.102).;

44. Introduction to 10 Gb/s baseband network

44.3 Delay constraints

Insert a new row at the end of Table 44–2, as modified by IEEE Std 802.3ch-2020, as follows (unchanged rows not shown):

Table 44–2—Round-trip delay constraints (informative)

Sublayer	Maximum (bit time)	Maximum (pause_quanta)	Notes
…			
10GBASE-BRx RS-FEC	24 576	48	See 108.4.

45. Management Data Input/Output (MDIO) Interface

45.2 MDIO Interface Registers

45.2.1 PMA/PMD registers

Change the row for registers 1.34 and 1.35 in Table 45–3 as follows (unchanged rows not shown):

Table 45–3—PMA/PMD registers

Register address	Register name	Subclause
…		
1.34~~, 1.35~~	BiDi PMA/PMD extended ability 1~~Reserved~~	45.2.1.27a
1.35	BiDi PMA/PMD extended ability 2	45.2.1.27b
…		

45.2.1.6 PMA/PMD control 2 register (Register 1.7)

Change the indicated reserved rows of Table 45–7 (as inserted by IEEE Std 802.3cn-2019) as follows (unchanged table rows and bit description lines 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 1 x x x x = reserved~~ 1 1 1 1 1 x x = reserved 1 1 1 1 0 1 x = reserved 1 1 1 1 0 0 1 = reserved 1 1 1 1 0 0 0 = 50GBASE-BR40-U PMA/PMD 1 1 1 0 1 1 1 = 50GBASE-BR20-U PMA/PMD 1 1 1 0 1 1 0 = 50GBASE-BR10-U PMA/PMD 1 1 1 0 1 0 1 = 50GBASE-BR40-D PMA/PMD 1 1 1 0 1 0 0 = 50GBASE-BR20-D PMA/PMD 1 1 1 0 0 1 1 = 50GBASE-BR10-D PMA/PMD 1 1 1 0 0 1 0 = 25GBASE-BR40-U PMA/PMD 1 1 1 0 0 0 1 = 25GBASE-BR20-U PMA/PMD 1 1 1 0 0 0 0 = 25GBASE-BR10-U PMA/PMD ~~1 1 0 1 x x x = reserved~~ 1 1 0 1 1 1 1 = 25GBASE-BR40-D PMA/PMD 1 1 0 1 1 1 0 = 25GBASE-BR20-D PMA/PMD 1 1 0 1 1 0 1 = 25GBASE-BR10-D PMA/PMD 1 1 0 1 1 0 0 = 10GBASE-BR40-U PMA/PMD 1 1 0 1 0 1 1 = 10GBASE-BR20-U PMA/PMD 1 1 0 1 0 1 0 = 10GBASE-BR10-U PMA/PMD 1 1 0 1 0 0 1 = 10GBASE-BR40-D PMA/PMD 1 1 0 1 0 0 0 = 10GBASE-BR20-D PMA/PMD ~~1 1 0 0 1 x x = reserved~~ 1 1 0 0 1 1 1 = 10GBASE-BR10-D PMA/PMD 1 1 0 0 1 1 0 = reserved 1 1 0 0 1 0 x = 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 a new row in Table 45–9 after the row for "5GBASE-KR" (as inserted by IEEE Std 802.3cb-2018) as follows (unchanged rows not shown):

Table 45–9—Transmit fault description location

PMA/PMD	Description location
…	
10GBASE-BR10, 10GBASE-BR20, 10GBASE-BR40	158.5.8
…	

Insert a new row in Table 45–9 after the row for "25GBASE-LR, 25GBASE-ER" as follows (unchanged rows not shown):

Table 45–9—Transmit fault description location

PMA/PMD	Description location
…	
25GBASE-BR10, 25GBASE-BR20, 25GBASE-BR40	159.5.8
…	

Insert a new row in Table 45–9 after the row for "50GBASE-FR, 50GBASE-LR, 50GBASE-ER" (as changed by IEEE Std 802.3cn-2019) as follows (unchanged rows not shown):

Table 45–9—Transmit fault description location

PMA/PMD	Description location
…	
50GBASE-BR10, 50GBASE-BR20, 50GBASE-BR40	160.5.8
…	

45.2.1.7.5 Receive fault (1.8.10)

Insert a new row in Table 45–10 after the row for "5GBASE-KR" (as inserted by IEEE Std 802.3cb-2018) as follows (unchanged rows not shown):

Table 45–10—Receive fault description location

PMA/PMD	Description location
…	
10GBASE-BR10, 10GBASE-BR20, 10GBASE-BR40	158.5.9
…	

Insert a new row in Table 45–10 after the row for "25GBASE-LR, 25GBASE-ER" as follows (unchanged rows not shown):

Table 45–10—Receive fault description location

PMA/PMD	Description location
…	
25GBASE-BR10, 25GBASE-BR20, 25GBASE-BR40	159.5.9
…	

Insert a new row in Table 45–9 after the row for "50GBASE-FR, 50GBASE-LR, 50GBASE-ER" (as changed by IEEE Std 802.3cn-2019) as follows (unchanged rows not shown):

Table 45–10—Receive fault description location

PMA/PMD	Description location
…	
50GBASE-BR10, 50GBASE-BR20, 50GBASE-BR40	160.5.9
…	

45.2.1.8 PMD transmit disable register (Register 1.9)

Insert a new row in Table 45–12 after the row for "5GBASE-KR" (as inserted by IEEE Std 802.3cb-2018) as follows (unchanged rows not shown):

Table 45–12—Transmit disable description location

PMA/PMD	Description location
…	
10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40	158.5.6
…	

Insert a new row in Table 45–12 after the row for "25GBASE-LR and 25GBASE-ER" as follows (unchanged rows not shown):

Table 45–12—Transmit disable description location

PMA/PMD	Description location
…	
25GBASE-BR10, 25GBASE-BR20, and 25GBASE-BR40	159.5.6
…	

Insert a new row in Table 45–12 after the row for "50GBASE-FR, 50GBASE-LR, and 50GBASE-ER" (as changed by IEEE Std 802.3cn-2019) as follows (unchanged rows not shown):

Table 45–12—Transmit disable description location

PMA/PMD	Description location
…	
50GBASE-BR10, 50GBASE-BR20, and 50GBASE-BR40	160.5.6
…	

Insert new subclauses 45.2.1.27a and 45.2.1.27b after 45.2.1.27 as follows:

45.2.1.27a BiDi PMA/PMD extended ability 1 (Register 1.34)

The assignment of bits in the BiDi PMA/PMD extended ability 1 register is shown in Table 45–31a.

Table 45–31a—BiDi PMA/PMD extended ability 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.34.15:12	Reserved	Value always 0	RO
1.34.11	25GBASE-BR40-U ability	1 = PMA/PMD is able to perform 25GBASE-BR40-U 0 = PMA/PMD is not able to perform 25GBASE-BR40-U	RO
1.34.10	25GBASE-BR40-D ability	1 = PMA/PMD is able to perform 25GBASE-BR40-D 0 = PMA/PMD is not able to perform 25GBASE-BR40-D	RO
1.34.9	25GBASE-BR20-U ability	1 = PMA/PMD is able to perform 25GBASE-BR20-U 0 = PMA/PMD is not able to perform 25GBASE-BR20-U	RO
1.34.8	25GBASE-BR20-D ability	1 = PMA/PMD is able to perform 25GBASE-BR20-D 0 = PMA/PMD is not able to perform 25GBASE-BR20-D	RO
1.34.7	25GBASE-BR10-U ability	1 = PMA/PMD is able to perform 25GBASE-BR10-U 0 = PMA/PMD is not able to perform 25GBASE-BR10-U	RO
1.34.6	25GBASE-BR10-D ability	1 = PMA/PMD is able to perform 25GBASE-BR10-D 0 = PMA/PMD is not able to perform 25GBASE-BR10-D	RO
1.34.5	10GBASE-BR40-U ability	1 = PMA/PMD is able to perform 10GBASE-BR40-U 0 = PMA/PMD is not able to perform 10GBASE-BR40-U	RO
1.34.4	10GBASE-BR40-D ability	1 = PMA/PMD is able to perform 10GBASE-BR40-D 0 = PMA/PMD is not able to perform 10GBASE-BR40-D	RO
1.34.3	10GBASE-BR20-U ability	1 = PMA/PMD is able to perform 10GBASE-BR20-U 0 = PMA/PMD is not able to perform 10GBASE-BR20-U	RO
1.34.2	10GBASE-BR20-D ability	1 = PMA/PMD is able to perform 10GBASE-BR20-D 0 = PMA/PMD is not able to perform 10GBASE-BR20-D	RO
1.34.1	10GBASE-BR10-U ability	1 = PMA/PMD is able to perform 10GBASE-BR10-U 0 = PMA/PMD is not able to perform 10GBASE-BR10-U	RO
1.34.0	10GBASE-BR10-D ability	1 = PMA/PMD is able to perform 10GBASE-BR10-D 0 = PMA/PMD is not able to perform 10GBASE-BR10-D	RO

[a]RO = Read only

45.2.1.27a.1 25GBASE-BR40-U ability (1.34.11)

When read as a one, bit 1.34.11 indicates that the PMA/PMD is able to operate as a 25GBASE-BR40-U PMA/PMD type. When read as a zero, bit 1.34.11 indicates that the PMA/PMD is not able to operate as a 25GBASE-BR40-U PMA/PMD type.

45.2.1.27a.2 25GBASE-BR40-D ability (1.34.10)

When read as a one, bit 1.34.10 indicates that the PMA/PMD is able to operate as a 25GBASE-BR40-D PMA/PMD type. When read as a zero, bit 1.34.10 indicates that the PMA/PMD is not able to operate as a 25GBASE-BR40-D PMA/PMD type.

45.2.1.27a.3 25GBASE-BR20-U ability (1.34.9)

When read as a one, bit 1.34.9 indicates that the PMA/PMD is able to operate as a 25GBASE-BR20-U PMA/PMD type. When read as a zero, bit 1.34.9 indicates that the PMA/PMD is not able to operate as a 25GBASE-BR20-U PMA/PMD type.

45.2.1.27a.4 25GBASE-BR20-D ability (1.34.8)

When read as a one, bit 1.34.8 indicates that the PMA/PMD is able to operate as a 25GBASE-BR20-D PMA/PMD type. When read as a zero, bit 1.34.8 indicates that the PMA/PMD is not able to operate as a 25GBASE-BR20-D PMA/PMD type.

45.2.1.27a.5 25GBASE-BR10-U ability (1.34.7)

When read as a one, bit 1.34.7 indicates that the PMA/PMD is able to operate as a 25GBASE-BR10-U PMA/PMD type. When read as a zero, bit 1.34.7 indicates that the PMA/PMD is not able to operate as a 25GBASE-BR10-U PMA/PMD type.

45.2.1.27a.6 25GBASE-BR10-D ability (1.34.6)

When read as a one, bit 1.34.6 indicates that the PMA/PMD is able to operate as a 25GBASE-BR10-D PMA/PMD type. When read as a zero, bit 1.34.6 indicates that the PMA/PMD is not able to operate as a 25GBASE-BR10-D PMA/PMD type.

45.2.1.27a.7 10GBASE-BR40-U ability (1.34.5)

When read as a one, bit 1.34.5 indicates that the PMA/PMD is able to operate as a 10GBASE-BR40-U PMA/PMD type. When read as a zero, bit 1.34.5 indicates that the PMA/PMD is not able to operate as a 10GBASE-BR40-U PMA/PMD type.

45.2.1.27a.8 10GBASE-BR40-D ability (1.34.4)

When read as a one, bit 1.34.4 indicates that the PMA/PMD is able to operate as a 10GBASE-BR40-D PMA/PMD type. When read as a zero, bit 1.34.4 indicates that the PMA/PMD is not able to operate as a 10GBASE-BR40-D PMA/PMD type.

45.2.1.27a.9 10GBASE-BR20-U ability (1.34.3)

When read as a one, bit 1.34.3 indicates that the PMA/PMD is able to operate as a 10GBASE-BR20-U PMA/PMD type. When read as a zero, bit 1.34.3 indicates that the PMA/PMD is not able to operate as a 10GBASE-BR20-U PMA/PMD type.

45.2.1.27a.10 10GBASE-BR20-D ability (1.34.2)

When read as a one, bit 1.34.2 indicates that the PMA/PMD is able to operate as a 10GBASE-BR20-D PMA/PMD type. When read as a zero, bit 1.34.2 indicates that the PMA/PMD is not able to operate as a 10GBASE-BR20-D PMA/PMD type.

45.2.1.27a.11 10GBASE-BR10-U ability (1.34.1)

When read as a one, bit 1.34.1 indicates that the PMA/PMD is able to operate as a 10GBASE-BR10-U PMA/PMD type. When read as a zero, bit 1.34.1 indicates that the PMA/PMD is not able to operate as a 10GBASE-BR10-U PMA/PMD type.

45.2.1.27a.12 10GBASE-BR10-D ability (1.34.0)

When read as a one, bit 1.34.0 indicates that the PMA/PMD is able to operate as a 10GBASE-BR10-D PMA/PMD type. When read as a zero, bit 1.34.0 indicates that the PMA/PMD is not able to operate as a 10GBASE-BR10-D PMA/PMD type.

45.2.1.27b BiDi PMA/PMD extended ability 2 (Register 1.35)

The assignment of bits in the BiDi PMA/PMD extended ability 2 register is shown in Table 45–31b.

Table 45–31b—BiDi PMA/PMD extended ability 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.35.15:6	Reserved	Value always 0	RO
1.35.5	50GBASE-BR40-U ability	1 = PMA/PMD is able to perform 50GBASE-BR40-U 0 = PMA/PMD is not able to perform 50GBASE-BR40-U	RO
1.35.4	50GBASE-BR40-D ability	1 = PMA/PMD is able to perform 50GBASE-BR40-D 0 = PMA/PMD is not able to perform 50GBASE-BR40-D	RO
1.35.3	50GBASE-BR20-U ability	1 = PMA/PMD is able to perform 50GBASE-BR20-U 0 = PMA/PMD is not able to perform 50GBASE-BR20-U	RO
1.35.2	50GBASE-BR20-D ability	1 = PMA/PMD is able to perform 50GBASE-BR20-D 0 = PMA/PMD is not able to perform 50GBASE-BR20-D	RO
1.35.1	50GBASE-BR10-U ability	1 = PMA/PMD is able to perform 50GBASE-BR10-U 0 = PMA/PMD is not able to perform 50GBASE-BR10-U	RO
1.35.0	50GBASE-BR10-D ability	1 = PMA/PMD is able to perform 50GBASE-BR10-D 0 = PMA/PMD is not able to perform 50GBASE-BR10-D	RO

[a]RO = Read only

45.2.1.27b.1 50GBASE-BR40-U ability (1.35.5)

When read as a one, bit 1.35.5 indicates that the PMA/PMD is able to operate as a 50GBASE-BR40-U PMA/PMD type. When read as a zero, bit 1.35.5 indicates that the PMA/PMD is not able to operate as a 50GBASE-BR40-U PMA/PMD type.

45.2.1.27b.2 50GBASE-BR40-D ability (1.35.4)

When read as a one, bit 1.35.4 indicates that the PMA/PMD is able to operate as a 50GBASE-BR40-D PMA/PMD type. When read as a zero, bit 1.35.4 indicates that the PMA/PMD is not able to operate as a 50GBASE-BR40-D PMA/PMD type.

45.2.1.27b.3 50GBASE-BR20-U ability (1.35.3)

When read as a one, bit 1.35.3 indicates that the PMA/PMD is able to operate as a 50GBASE-BR20-U PMA/PMD type. When read as a zero, bit 1.35.3 indicates that the PMA/PMD is not able to operate as a 50GBASE-BR20-U PMA/PMD type.

45.2.1.27b.4 50GBASE-BR20-D ability (1.35.2)

When read as a one, bit 1.35.2 indicates that the PMA/PMD is able to operate as a 50GBASE-BR20-D PMA/PMD type. When read as a zero, bit 1.35.2 indicates that the PMA/PMD is not able to operate as a 50GBASE-BR20-D PMA/PMD type.

45.2.1.27b.5 50GBASE-BR10-U ability (1.35.1)

When read as a one, bit 1.35.1 indicates that the PMA/PMD is able to operate as a 50GBASE-BR10-U PMA/PMD type. When read as a zero, bit 1.35.1 indicates that the PMA/PMD is not able to operate as a 50GBASE-BR10-U PMA/PMD type.

45.2.1.27b.6 50GBASE-BR10-D ability (1.35.0)

When read as a one, bit 1.35.0 indicates that the PMA/PMD is able to operate as a 50GBASE-BR10-D PMA/PMD type. When read as a zero, bit 1.35.0 indicates that the PMA/PMD is not able to operate as a 50GBASE-BR10-D PMA/PMD type.

45.2.1.110 RS-FEC control register (Register 1.200)

Change the row for bit 1.200.2 in Table 45–88 as follows (unchanged rows not shown):

Table 45–88—RS-FEC control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.200.2	~~25G~~ RS-FEC Enable	1 = ~~The 25GBASE-R~~<u>Clause 108</u> Reed-Solomon FEC is enabled 0 = ~~The 25GBASE-R~~<u>Clause 108</u> Reed-Solomon FEC is disabled	R/W

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

Change the title and content of 45.2.1.110.1 as follows:

45.2.1.110.1 ~~25G~~ RS-FEC enable (1.200.2)

Bit 1.200.2 enables the ~~25GBASE-R~~ Reed-Solomon FEC described in Clause 108. When set to a one, this bit enables the ~~25GBASE-R~~ Reed-Solomon FEC. When set to a zero, bit 1.200.2 disables the ~~25GBASE-R~~ Reed-Solomon FEC (see 108.6.3). <u>Writes to bit 1.200.2 are ignored and reads return a one if the RS-FEC does not have the ability to disable the RS-FEC function.</u>

49. Physical Coding Sublayer (PCS) for 64B/66B, type 10GBASE-R

49.2 Physical Coding Sublayer (PCS)

49.2.2 Functions within the PCS

Change the second to fifth paragraphs of 49.2.2 as follows:

When communicating with the XGMII, the PCS uses a four octet-wide, synchronous data path, with packet delimiting being provided by transmit control signals (TXCn = 1) and receive control signals (RXCn = 1). When communicating with the PMA, ~~or~~ WIS, or FEC, the PCS uses a 16-bit wide, synchronous data path that conveys 16 encoded bits. Alignment to 64B/66B block is performed in the PCS. The WIS, ~~and~~ PMA, and FEC sublayers operate independent of block and packet boundaries. The PCS provides the functions necessary to map packets between the XGMII format and the PMA service interface format.

When the transmit channel is in normal mode, the PCS Transmit process continuously generates blocks based upon the TXD <31:0> and TXC <3:0> signals on the XGMII. The Gearbox function of the PCS Transmit process then packs the resulting bits into 16-bit transmit data-units. Transmit data-units are sent to the PMA, ~~or~~ WIS, or FEC service interface via the PMA_UNITDATA.request, ~~or~~ WIS_UNITDATA.request, or FEC_UNITDATA.request primitive, respectively. When the WIS is present, the PCS Transmit process also adapts between the XGMII and WIS data rates by deleting idle characters.

When the transmit channel is in test-pattern mode, a test pattern is packed into the transmit data-units that are sent to the PMA service interface via the PMA_UNITDATA.request primitive.

When the receive channel is in normal mode, the PCS Synchronization process continuously monitors PMA_SIGNAL.indication(SIGNAL_OK), ~~or~~ WIS_SIGNAL.indication(SIGNAL_OK), or FEC_SIGNAL.indication(SIGNAL_OK). When SIGNAL_OK indicates OK, then the PCS Synchronization process accepts data-units via the PMA_UNITDATA.indication primitive, ~~or~~ the WIS_UNITDATA.indication primitive~~,~~ or the FEC_UNITDATA.indication primitive. It attains block synchronization based on the 2-bit synchronization headers and conveys received blocks to the PCS Receive process. The PCS Synchronization process sets the sync_status flag to indicate whether the PCS has obtained synchronization.

49.2.13.2.2 Variables

Change the definition of the "signal_ok" variable in 49.2.13.2.2 as follows:

signal_ok

Boolean variable that is set based on the most recently received value of PMA_SIGNAL.indication(SIGNAL_OK), ~~or~~ WIS_SIGNAL.indication(SIGNAL_OK), or FEC_SIGNAL.indication(SIGNAL_OK). It is true if the value was OK and false if the value was FAIL.

56. Introduction to Ethernet for subscriber access networks

56.1 Overview

Change the second paragraph of 56.1 (as modified by IEEE Std 802.3ca-2020) splitting it into two paragraphs as follows:

In addition, a mechanism for network Operations, Administration, and Maintenance (OAM) is included to facilitate network operation and troubleshooting. ~~100BASE-LX10 extends the reach of 100BASE-X to achieve 10 km over conventional single-mode two-fiber cabling.~~

The relationships between these EFM elements and the ISO/IEC Open System Interconnection (OSI) reference model are shown in Figure 56–1 and Figure 56–1a for point-to-point topologies, Figure 56–2 for 1G-EPON topologies, Figure 56–3 for 10/10G-EPON topologies, Figure 56–4 for 10/1G-EPON topologies, Figure 56–5 for EPoC topologies, and Figure 56–6 for Nx25G-EPON topologies.

Insert new Figure 56–1a after Figure 56–1 as follows:

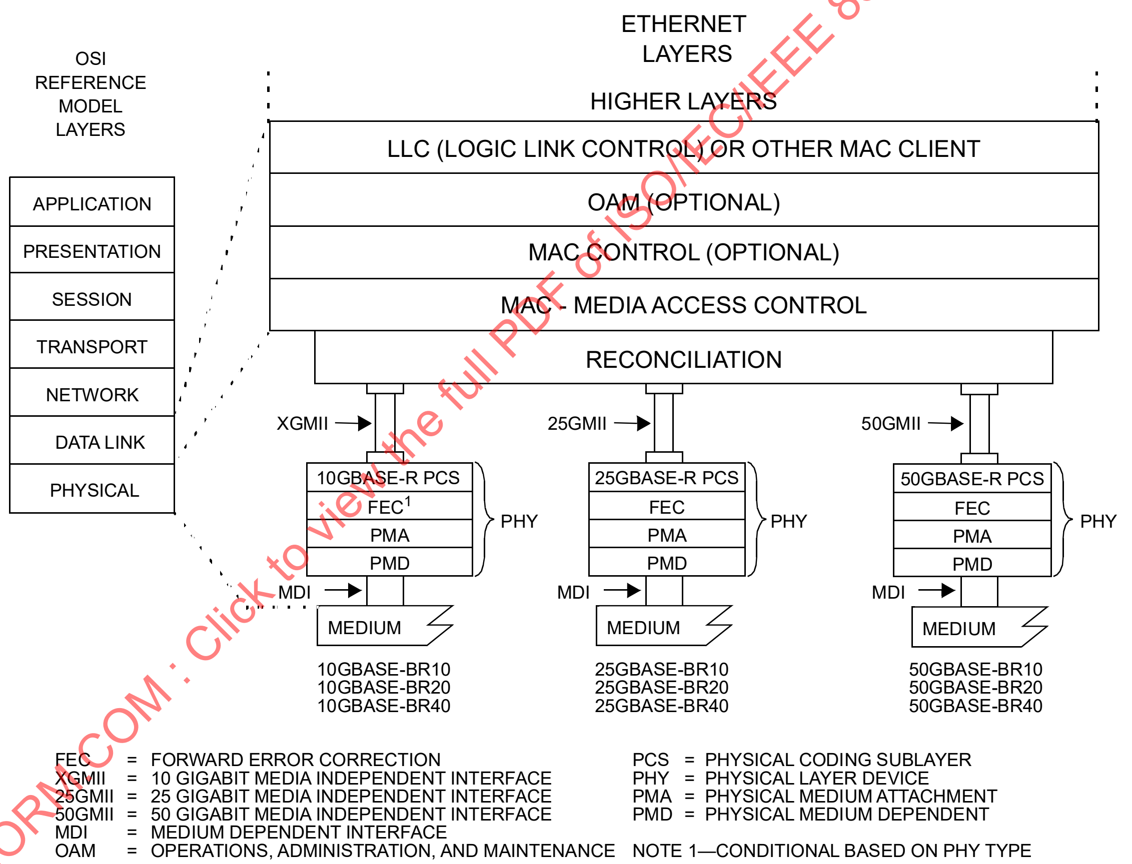


Figure 56–1a—Architectural positioning of EFM: higher rate P2P topologies

Change 56.1.1 as follows. Note that footnotes 2 and 3 are deleted.

56.1.1 Summary of P2P sublayers

EFM P2P supports operation at several different bit rates, depending on the characteristics of the underlying medium. ~~In the case of point-to-point optical fiber media, bit rates of 100 Mb/s and 1000 Mb/s are supported, using the 100BASE-X and 1000BASE-X Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayers defined in 66.1 and 66.2, respectively. In the case of point-to-point copper, EFM supports a variety of bit rates, depending on the span and the signal-to-noise ratio (SNR) characteristics of the medium as described in Clause 61 through Clause 63. 2BASE-TL supports a nominal bit rate of 2 Mb/s at a nominal reach of 2700 meters.[2] 10PASS-TS supports a nominal bit rate of 10 Mb/s at a nominal reach of 750 meters.[3]~~

Insert new subclauses 56.1.1.1 and 56.1.1.2 at the end of 56.1.1 as follows:

56.1.1.1 P2P fiber media

The 100BASE-X Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayers are used to support a bit rate of 100 Mb/s as defined in 66.1. 100BASE-LX10 extends the reach of 100BASE-X to achieve 10 km over conventional single-mode two-fiber cabling.

The 1000BASE-X PCS and PMA sublayers are used to support a bit rate of 1000 Mb/s as defined in 66.2.

The 10GBASE-R PCS, RS-FEC, and PMA sublayers are used to support a bit rate of 10 Gb/s as defined in Clause 158.

The 25GBASE-R PCS, RS-FEC, and PMA sublayers are used to support a bit rate of 25 Gb/s as defined in Clause 159.

The 50GBASE-R PCS, RS-FEC, and PMA sublayers are used to support a bit rate of 50 Gb/s as defined in Clause 160.

56.1.1.2 P2P copper media

The P2P copper links support a variety of bit rates, depending on the span and the signal-to-noise ratio (SNR) characteristics of the medium as described in Clause 61 and Clause 63.

The 2BASE-TL P2P link supports a nominal bit rate of 2 Mb/s at a nominal reach of 2700 meters (see Annex 63B for a more detailed discussion of bit rates and reach).

The 10PASS-TS P2P link supports a nominal bit rate of 10 Mb/s at a nominal reach of 750 meters (see Annex 62B for a more detailed discussion of bit rates and reach).

56.1.2 Summary of P2MP sublayers

56.1.2.2 Reconciliation Sublayer (RS) and media independent interfaces

Change the first sentence of 56.1.2.2 as follows:

The Clause 22 RS and MII, Clause 35 RS and GMII, ~~and~~ Clause 46 RS and XGMII, Clause 106 RS and 25GMII, and Clause 132 RS and 50GMII are all employed for the same purpose in EFM, that being the interconnection between the MAC sublayer and the PHY sublayers.

[2] ~~Refer to Annex 63B for a more detailed discussion of bit rates and reach.~~

[3] ~~Refer to Annex 62B for a more detailed discussion of bit rates and reach.~~

56.1.3 Physical Layer signaling systems

Insert the following text below the second paragraph of 56.1.3:

EFM extends the family of 10GBASE-R Physical Layer signaling systems to include the following combinations of bidirectional PMDs defined in Clause 158:

— 10GBASE-BR10-D and 10GBASE-BR10-U
— 10GBASE-BR20-D and 10GBASE-BR20-U
— 10GBASE-BR40-D and 10GBASE-BR40-U

EFM extends the family of 25GBASE-R Physical Layer signaling systems to include the following combinations of bidirectional PMDs defined in Clause 159:

— 25GBASE-BR10-D and 25GBASE-BR10-U
— 25GBASE-BR20-D and 25GBASE-BR20-U
— 25GBASE-BR40-D and 25GBASE-BR40-U

EFM extends the family of 50GBASE-R Physical Layer signaling systems to include the following combinations of bidirectional PMDs defined in Clause 160:

— 50GBASE-BR10-D and 50GBASE-BR10-U
— 50GBASE-BR20-D and 50GBASE-BR20-U
— 50GBASE-BR40-D and 50GBASE-BR40-U

Insert new rows into Table 56–1 and change table footnote a (as modified by IEEE Std 802.3ca-2020) after the row for "1000BASE-BX10-U" as follows (unchanged rows not shown):

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

Name	Location	Rate[a]	Nominal reach (km)	Medium	Clause
…					
10GBASE-BR10-D	OLT	10 Gb/s	10	One single-mode fiber	158
10GBASE-BR10-U	ONU				
10GBASE-BR20-D	OLT		20		
10GBASE-BR20-U	ONU				
10GBASE-BR40-D	OLT		40		
10GBASE-BR40-U	ONU				
25GBASE-BR10-D	OLT	25 Gb/s	10	One single-mode fiber	159
25GBASE-BR10-U	ONU				
25GBASE-BR20-D	OLT		20		
25GBASE-BR20-U	ONU				
25GBASE-BR40-D	OLT		40		
25GBASE-BR40-U	ONU				
50GBASE-BR10-D	OLT	50 Gb/s	10	One single-mode fiber	160
50GBASE-BR10-U	ONU				
50GBASE-BR20-D	OLT		20		
50GBASE-BR20-U	ONU				
50GBASE-BR40-D	OLT		40		
50GBASE-BR40-U	ONU				
…					

[a] For Physical Layer signaling systems the transmit rate is denoted with the abbreviation "(tx)" to the location; whereas, the receive rate is denoted with the abbreviation "(rx)".

Change Table 56–2 as follows reformatting header rows to accommodate added columns:

Table 56–2—Nomenclature and clause correlation for P2P systems

Nomenclature	Clause																					
	57	78	58		59		61	62	63	66		49	51	158	107	108	109	159	133	134	135	160
	OAM	EEE	100BASE-LX10 PMD	100BASE-BX10 PMD	1000BASE-LX10 PMD	1000BASE-BX10 PMD	Cu PCS	10PASS-TS PMA & PMD	2BASE-TL PMA & PMD	100BASE-X PCS, PMA	1000BASE-X PCS, PMA	10GBASE-R PCS	10GBASE-R PMA	10GBASE-BRx PMD	25GBASE-R PCS	Reed-Solomon FEC	25GBASE-R PMA	25GBASE-BRx PMD	50GBASE-R PCS	50GBASE-R RS-FEC	50GBASE-R PMA	50GBASE-BRx PMD
2BASE-TL	O[a]						M		M													
10PASS-TS	O						M	M														
100BASE-LX10	O		M							M												
100BASE-BX10	O			M						M												
1000BASE-LX10	O				M						M											
1000BASE-BX10	O					M					M											
10GBASE-BR10	O											M	M	M								
10GBASE-BR20	O											M	M	M		M						
10GBASE-BR40	O											M	M	M								
25GBASE-BR10	O	O													M	M	M	M				
25GBASE-BR20	O	O													M	M	M	M				
25GBASE-BR40	O	O													M	M	M	M				
50GBASE-BR10	O	O																	M	M	M	M
50GBASE-BR20	O	O																	M	M	M	M
50GBASE-BR40	O	O																	M	M	M	M

[a]O = Optional, M = Mandatory

78. Energy-Efficient Ethernet (EEE)

78.1.4 PHY types optionally supporting EEE

Insert new rows in Table 78–1 (as modified by IEEE Std 802.3cd-2018) as follows, with 25GBASE-BR10 after 25GBASE-SR, 25GBASE-BR20 and 25GBASE-BR40 after 25GBASE-LR, 50GBASE-BR10 after 50GBASE-FR, and 50GBASE-BR20 and 50GBASE-BR40 after 50GBASE-LR (unchanged rows not shown):

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

PHY or interface type	Clause
…	
25GBASE-BR10[b]	159
…	
25GBASE-BR20[b]	159
25GBASE-BR40[b]	159
…	
50GBASE-BR10[b]	160
…	
50GBASE-BR20[b]	160
50GBASE-BR40[b]	160
…	

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

105. Introduction to 25 Gb/s networks

105.5 Delay constraints

Insert three new rows at the end of Table 105–3 as follows (unchanged rows not shown):

Table 105–3—Sublayer delay constraints

Sublayer	Maximum (bit time)[a]	Maximum (pause_quanta)[b]	Maximum (ns)	Notes[c]
…				
25GBASE-BR10 PMD	512	1	20.48	See 158.3.
25GBASE-BR20 PMD	512	1	20.48	See 158.3.
25GBASE-BR40 PMD	512	1	20.48	See 158.3.

[a]1 bit time (BT) is equal to 40 ps. (See 1.4.160 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.

Change the title of Clause 108 as follows:

108. Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 10GBASE-R and 25GBASE-R PHYs

108.1 Overview

108.1.1 Scope

Change 108.1 as follows:

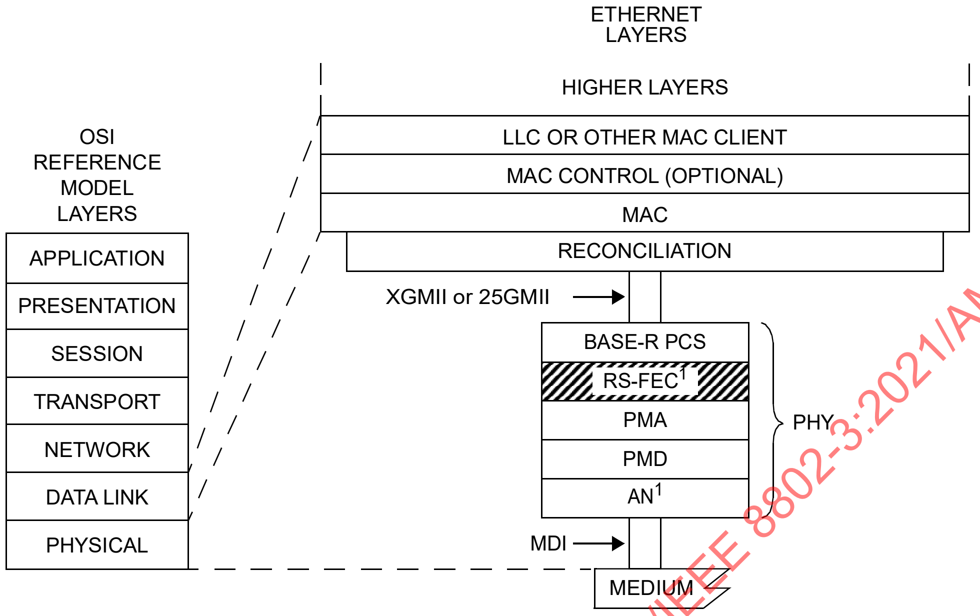
This clause specifies a Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 10GBASE-R and 25GBASE-R PHYs. The specification is closely related to that of the RS-FEC sublayer for 100GBASE-R PHYs, specified in Clause 91. Annex 91A provides examples of RS-FEC codewords constructed with the method specified in this clause.

Change the title and text of 108.1.2 as follows:

108.1.2 Position of RS-FEC in the 10GBASE-R and 25GBASE-R PHY sublayers

Figure 108–1 shows the relationship of the 10GBASE-R and 25GBASE-R RS-FEC sublayer to the ISO/IEC Open System Interconnection (OSI) reference model.

Replace Figure 108–1 with the following figure:



25GMII = 25 GIGABIT MEDIA INDEPENDENT INTERFACE
AN = AUTO-NEGOTATION
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
XGMII = 10 GIGABIT MEDIA INDEPENDENT INTERFACE

NOTE 1—CONDITIONAL BASED ON PHY TYPE

Figure 108–1—10GBASE-R and 25GBASE-R RS-FEC relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

Insert new subclause 108.1.3 and its subclauses after 108.1.2 as follows:

108.1.3 Inter-sublayer interfaces

An FEC service interface is provided to allow the RS-FEC sublayer to transfer information to and from the PCS. An abstract service model is used to define the operation of this interface. For 10GBASE-R, the FEC service interface directly maps to the PMA service interface of the PCS defined in Clause 49 and the lower FEC sublayer interface maps to the service interface provided by the serial PMA sublayer defined in Clause 51. For 25GBASE-R, the FEC service interface is an instance of the inter-sublayer service interface defined in 105.4, as is the PMA service interface defined in 109.2.

This standard defines these interfaces in terms of bits, octets, data-group, data units, and signals; however, implementers may choose other data-path widths and other control mechanisms for implementation convenience, provided that the implementation adheres to the logical model of the service interface.

108.1.3.1 Functional block diagram for 10GBASE-R PHYs

Figure 108–1a shows the functional block diagram of RS-FEC for 10GBASE-R PHYs and the relationship between the PCS and PMA sublayers.

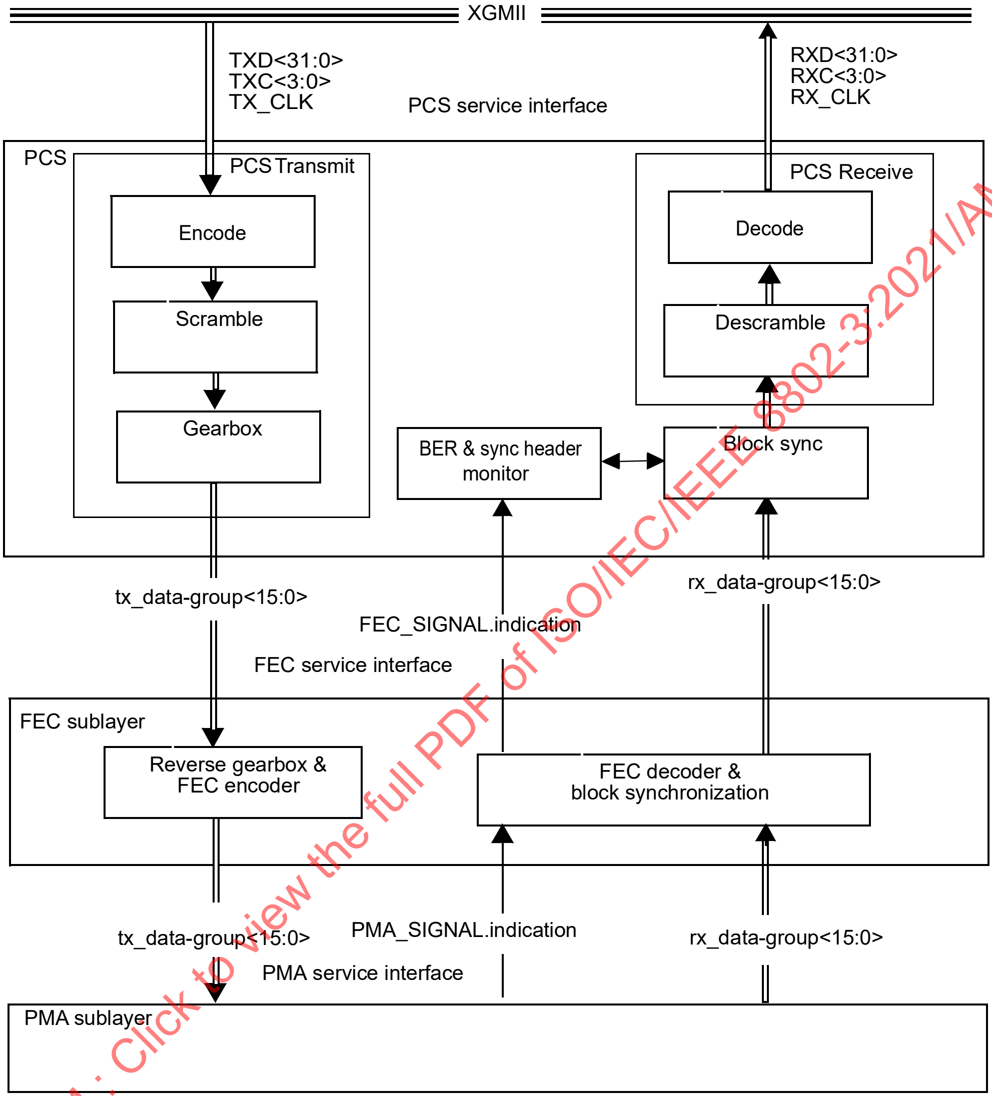


Figure 108–1a—Functional block diagram for 10GBASE-R PHYs

108.1.3.2 Functional block diagram for 25GBASE-R PHYs

Figure 108–1b shows the functional block diagram of FEC for 25GBASE-R PHYs and the relationship between the PCS and PMA sublayers.

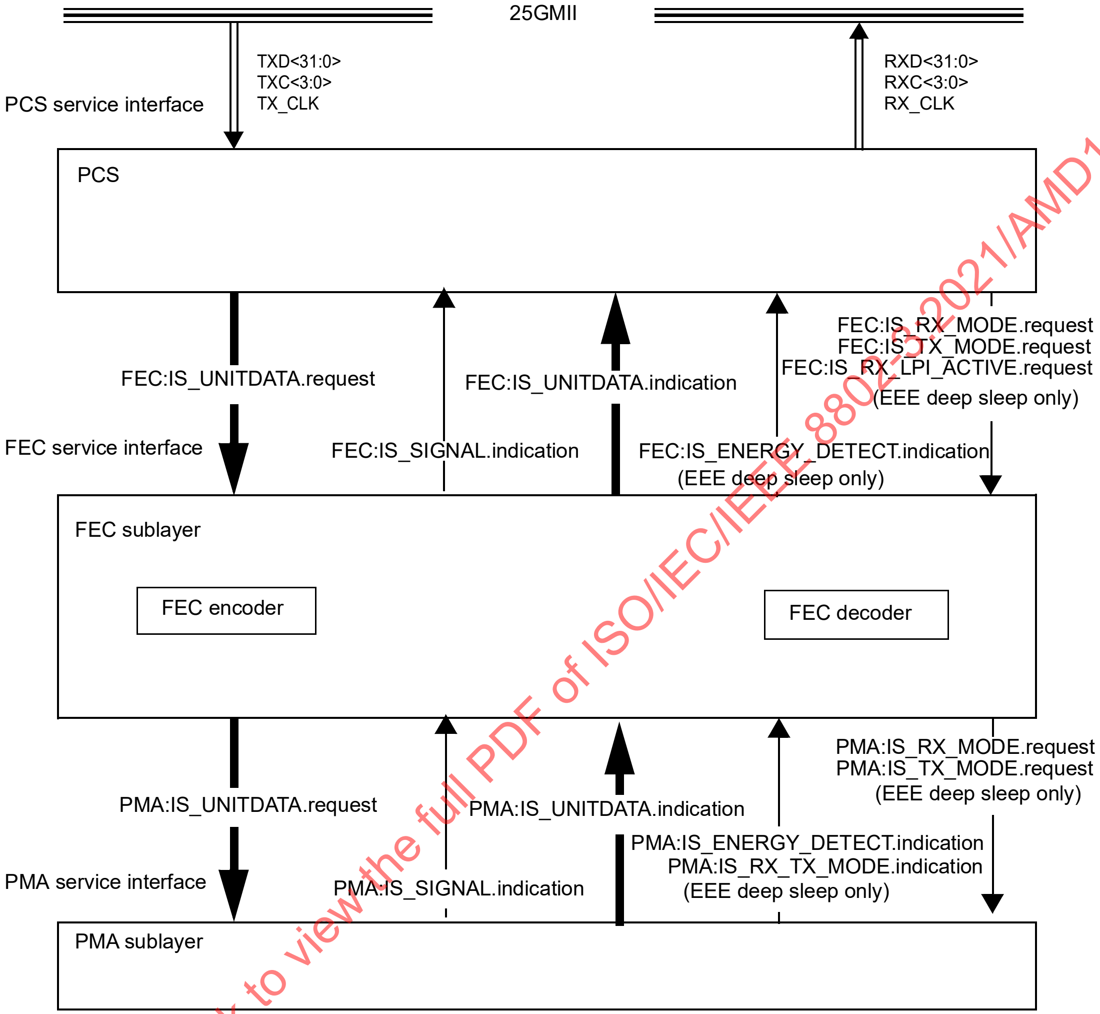


Figure 108–1b—Functional block diagram for 25GBASE-R PHYs

108.2 FEC service interface

Change 108.2 as follows:

This subclause specifies the services provided by the 10GBASE-R and 25GBASE-R RS-FEC sublayer. The service interface is described in an abstract manner and does not imply any particular implementation.

The FEC service interface is provided to allow the PCS to transfer information to and from the RS-FEC. The FEC service interface is equivalent to the PMA service interface for 10GBASE-R PHYs and is an instance of the inter-sublayer service interface defined in 105.4 for 25GBASE-R PHYs.

The service primitives are defined differently for 10GBASE-R PHYs and for 25GBASE-R PHYs.

The PCS may be connected to the 10GBASE-R and 25GBASE-R RS-FEC using an optional physical instantiation of the PMA service interface (see Clause 51 and Annex 109A), in which case a PMA is the client of the FEC service interface.~~The FEC service interface is provided to allow the PCS to transfer information to and from the 25GBASE-R RS-FEC. The PCS may be connected to the 25GBASE-R RS-FEC using an optional 25GAUI chip-to-chip (C2C) instantiation of the PMA service interface (see Annex 109A), in which case a PMA is the client of the FEC service interface.~~

~~The FEC service interface is an instance of the inter-sublayer service interface defined in 105.4. The FEC service interface primitives are summarized as follows:~~

~~FEC:IS_UNITDATA.request(tx_bit)~~
~~FEC:IS_UNITDATA.indication(rx_bit)~~
~~FEC:IS_SIGNAL.indication~~

~~The PCS (or PMA) continuously sends a bit stream to the 25GBASE-R RS-FEC using the FEC:IS_UNITDATA.request(tx_bit) primitive, at a nominal signaling rate of 25.78125 GBd.~~

~~The 25GBASE-R RS-FEC continuously sends a bit stream to the PCS (or PMA) using the FEC:IS_UNITDATA.indication(rx_bit) primitive, at a nominal signaling rate of 25.78125 GBd. The actual signaling rate is equal to the underlying PMD signaling rate.~~

~~The SIGNAL_OK parameter of the FEC:IS_SIGNAL.indication primitive can take one of two values: OK or FAIL. The value is set to OK when the RS-FEC receive function has identified codeword boundaries as indicated by FEC_align_status equal to true. That value is set to FAIL when the RS-FEC receive function is unable to reliably establish codeword boundaries as indicated by FEC_align_status equal to false.~~

~~If the optional EEE deep sleep capability is supported, then the FEC service interface includes four additional primitives as follows:~~

~~FEC:IS_TX_MODE.request~~
~~FEC:IS_RX_MODE.request~~
~~FEC:IS_RX_TX_MODE.indication~~
~~FEC:IS_ENERGY_DETECT.indication~~

~~When the tx_mode parameter of the FEC:IS_TX_MODE.request primitive is QUIET or ALERT, the RS-FEC sublayer may disable transmit functional blocks to conserve energy. Otherwise the RS-FEC transmit function operates normally. The value of tx_mode is passed to the client sublayer via the PMA:IS_TX_MODE.request primitive.~~

~~When the rx_mode parameter of the FEC:IS_RX_MODE.request primitive is QUIET, the RS-FEC sublayer may disable receive functional blocks to conserve energy. Otherwise the RS-FEC receive function operates normally. The value of rx_mode is passed to the client sublayer via the PMA:IS_RX_MODE.request primitive.~~

~~The rx_tx_mode parameter of the FEC:IS_RX_TX_MODE.indication primitive is used to communicate the link partner's value of tx_mode as inferred by the PMA. It is assigned the value that is received via the PMA:IS_RX_TX_MODE.indication primitive.~~

~~The energy_detect parameter of the FEC:IS_ENERGY_DETECT.indication primitive is used to communicate that the PMD has detected the return of energy on the interface following a period of quiescence. It is assigned the value that is received via the PMA:IS_ENERGY_DETECT.indication primitive.~~

Insert new subclause 108.2.1 and its subclauses at the end of 108.2 as follows:

108.2.1 10GBASE-R service primitives

The following primitives are defined within the FEC service interface for 10GBASE-R PHYs:

FEC_UNITDATA.request(tx_data-group<15:0>)
FEC_UNITDATA.indication(rx_data-group<15:0>)
FEC_SIGNAL.indication(SIGNAL_OK)

The FEC service interface directly maps to the PMA service interface of the 10GBASE-R PCS defined in Clause 49. The FEC_UNITDATA.request maps to the PMA_UNITDATA.request primitive, the FEC_UNITDATA.indication maps to the PMA_UNITDATA.indication primitive, and the FEC_SIGNAL.indication maps to the PMA_SIGNAL.indication primitive of the 10GBASE-R PCS.

108.2.1.1 FEC_UNITDATA.request

This primitive defines the transfer of data in the form of constant-width data units from the PCS to the RS-FEC. The data supplied via FEC_UNITDATA.request is mapped by the RS-FEC transmit process into the payload capacity of the outgoing FEC block stream.

108.2.1.1.1 Semantics of the service primitive

FEC_UNITDATA.request(tx_data-group<15:0>)

The data conveyed by FEC_UNITDATA.request is a 16-bit vector representing a single data unit that has been prepared for transmission by the 10GBASE-R PCS Transmit process.

108.2.1.1.2 When generated

The 10GBASE-R PCS sends tx_data-group<15:0> to the RS-FEC at a nominal rate of 644.53125 MHz, corresponding to the 10GBASE-R signaling rate of 10.3125 GBd.

108.2.1.1.3 Effect of receipt

Upon receipt of this primitive, the RS-FEC transmit process maps the data conveyed by the tx_data unit<15:0> parameter into the payload of the transmitted FEC block stream, adds FEC overhead as required, scrambles the data, and transfers the result to the PMA via the PMA_UNITDATA.request primitives.

108.2.1.2 FEC_UNITDATA.indication

This primitive defines the transfer of received data in the form of constant-width data units from the RS-FEC to the PCS. FEC_UNITDATA.indication is generated by the RS-FEC receive process in response to FEC block data received from the PMA.

108.2.1.2.1 Semantics of the service primitive

FEC_UNITDATA.indication(rx_data-group<15:0>)

The rx_data-group<15:0> parameter is a 16-bit vector that represents the data unit transferred by the RS-FEC to the 10GBASE-R PCS.

108.2.1.2.2 When generated

The RS-FEC sends one rx_data-group<15:0> to the 10GBASE-R PCS for each 16 bits received from the PMA sublayer. The nominal rate of generation of the FEC_UNITDATA.indication primitive is 644.53125 Mtransfers/s.

108.2.1.2.3 Effect of receipt

The effect of receipt of this primitive by the RS-FEC client is unspecified by the RS-FEC sublayer. See 49.2.

108.2.1.3 FEC_SIGNAL.indication

This primitive is sent by the RS-FEC to the PCS to indicate the status of the receive process. FEC_SIGNAL.indication is generated by the RS-FEC receive process in order to propagate the detection of severe error conditions (e.g., no valid signal being received from the PMA sublayer) to the PCS.

108.2.1.3.1 Semantics of the service primitive

FEC_SIGNAL.indication(SIGNAL_OK)

The SIGNAL_OK parameter can take one of two values: OK or FAIL. A value of OK denotes that the RS-FEC receive process is successfully delineating valid payload information from the incoming data stream received from the PMA sublayer indicated by the fec_signal_ok variable equal to true, and this payload information is being presented to the PCS via the FEC_UNITDATA.indication primitive. A value of FAIL denotes that errors have been detected by the Receive process indicated by the fec_signal_ok variable equal to false, that prevent valid data from being presented to the PCS, in this case the FEC_UNITDATA.indication primitive and its associated rx_data-group<15:0> parameter are meaningless.

108.2.1.3.2 When generated

The RS-FEC generates the FEC_SIGNAL.indication primitive to the 10GBASE-R PCS whenever there is a change in the value of the SIGNAL_OK parameter and FEC block synchronization is achieved.

108.2.1.3.3 Effect of receipt

The effect of receipt of this primitive by the RS-FEC client is unspecified by the RS-FEC sublayer. See 49.2.

108.2.2 25GBASE-R service primitives

For 25GBASE-R PHYs the FEC service interface is an instance of the inter-sublayer service interface defined in 105.4. The FEC service interface primitives are summarized as follows:

FEC:IS_UNITDATA.request(tx_bit)
FEC:IS_UNITDATA.indication(rx_bit)
FEC:IS_SIGNAL.indication

The PCS (or PMA) continuously sends a bit stream to the RS-FEC using the FEC:IS_UNITDATA.request(tx_bit) primitive, at a nominal signaling rate of 25.78125 GBd.

The RS-FEC continuously sends a bit stream to the PCS (or PMA) using the FEC:IS_UNITDATA.indication(rx_bit) primitive, at a nominal signaling rate of 25.78125 GBd. The actual signaling rate is equal to the underlying PMD signaling rate.

The SIGNAL_OK parameter of the FEC:IS_SIGNAL.indication primitive can take one of two values: OK or FAIL. The value is set to OK when the RS-FEC receive function has identified codeword boundaries as indicated by FEC_align_status equal to true. That value is set to FAIL when the RS-FEC receive function is unable to reliably establish codeword boundaries as indicated by FEC_align_status equal to false.

If the optional EEE deep sleep capability is supported, then the FEC service interface includes four additional primitives as follows:

FEC:IS_TX_MODE.request
FEC:IS_RX_MODE.request
FEC:IS_RX_TX_MODE.indication
FEC:IS_ENERGY_DETECT.indication

When the tx_mode parameter of the FEC:IS_TX_MODE.request primitive is QUIET or ALERT, the RS-FEC sublayer may disable transmit functional blocks to conserve energy. Otherwise the RS-FEC transmit function operates normally. The value of tx_mode is passed to the client sublayer via the PMA:IS_TX_MODE.request primitive.

When the rx_mode parameter of the FEC:IS_RX_MODE.request primitive is QUIET, the RS-FEC sublayer may disable receive functional blocks to conserve energy. Otherwise the RS-FEC receive function operates normally. The value of rx_mode is passed to the client sublayer via the PMA:IS_RX_MODE.request primitive.

The rx_tx_mode parameter of the FEC:IS_RX_TX_MODE.indication primitive is used to communicate the link partner's value of tx_mode as inferred by the PMA. It is assigned the value that is received via the PMA:IS_RX_TX_MODE.indication primitive.

The energy_detect parameter of the FEC:IS_ENERGY_DETECT.indication primitive is used to communicate that the PMD has detected the return of energy on the interface following a period of quiescence. It is assigned the value that is received via the PMA:IS_ENERGY_DETECT.indication primitive.

108.3 PMA compatibility

Change 108.3 as follows:

For 10GBASE-R PHYs, the 10GBASE-R and 25GBASE-R RS-FEC sublayer is a client of the 10GBASE-R PMA subylayer defined in Clause 51. For 25GBASE-R PHYs, the 10GBASE-R and ~~The~~ 25GBASE-R RS-FEC sublayer is a client of the 25GBASE-R PMA sublayer defined in Clause 109.

When 25GAUI C2C is used between a device that includes a PCS and a device that includes the RS-FEC, the 25GBASE-R PMA sublayer is the client of the 10GBASE-R and 25GBASE-R RS-FEC sublayer.

108.4 Delay constraints

Change 108.4 as follows:

The maximum delay contributed by the 10GBASE-R and 25GBASE-R RS-FEC sublayer (sum of transmit and receive delays at one end of the link) shall be no more than 24 576 bit times (48 pause_quanta ~~or 983.04 ns~~). A description of overall system delay constraints and the definitions for bit times and pause_quanta can be found in 44.3 and 105.5.

Change the title of 108.5 as follows:

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

108.5.1 Functional block diagram

Change the text of 108.5.1 as follows (Figure 108–2 remains unchanged):

A functional block diagram of the ~~25GBASE-R~~ RS-FEC sublayer is shown in Figure 108–2.

Insert subclause 108.5.1.1 at the end of 108.5.1 as follows:

108.5.1.1 Reverse gearbox and gearbox functions for 10GBASE-R

The reverse gearbox function adapts between the 66-bit width of the 64B/66B blocks and the 16-bit width of the PCS interface. It receives the 16-bit stream from the PCS interface and converts it back to 66-bit encoded blocks for the RS-FEC encoder to process. The reverse gearbox function operates in the same manner as the block synchronization function defined in 49.2.9.

The reverse gearbox function receives data via 16-bit FEC_UNITDATA.request primitives. It forms a bit stream from the primitives by concatenating requests with the bits of each primitive in order to form tx_data-group<0> to tx_data-group<15> (see Figure 49–6). It obtains lock to the 66-bit blocks in the bit stream using the sync headers and outputs 66-bit blocks. Lock is obtained as specified in the lock state diagram shown in Figure 49–14.

The reverse gearbox functionality is necessary only when the optional PMA compatibility interface named XSBI is implemented between the PCS and RS-FEC functions, since that interface passes data via a 16-bit wide path. When the XSBI is not implemented, the internal data-path width between the PCS and RS-FEC is an implementation choice. Depending on the path width, the reverse gearbox function may not be necessary.

The gearbox adapts between the 66-bit width of the blocks and the 16-bit width of the PMA interface. It receives the 66-bit blocks. When the transmit channel is operating in normal mode, the gearbox sends 16 bits of transmit data at a time via the PMA_UNITDATA.request primitive. The UNITDATA.request primitive is fully packed with bits. For example, if one block happened to start with the sync header on bits 0 and 1 of a PMA_UNITDATA.request, then the last two bits of that block would be on bits 0 and 1 of a PMA_UNITDATA.request and the next block would begin with a sync header on bits 2 and 3 of that PMA_UNITDATA.request. When a PMA_UNITDATA.request contains bits from two blocks, then the bits from the first block shall be placed in the lowest numbered bits of tx_data-group<15:0>. The bits shall be packed into the tx_data-group in sequence with the lowest numbered bit of the block going into the lowest numbered bit of the part of tx_data-group<15:0> bits containing bits from that block (see Figure 49–5).

The gearbox functionality is necessary when the optional PMA compatibility interface, XSBI, is implemented since that interface passes data over a 16-bit wide path. When the XSBI is not implemented, the internal data-path width between the PCS and PMA is an implementation choice. Depending on the path width, the gearbox functionality may not be necessary.

108.5.2 Transmit function

108.5.2.2 Rate compensation for codeword markers in the transmit direction

Change the first paragraph of 108.5.2.2 as follows:

The RS-FEC transmit process periodically inserts codeword markers into the transcoded block stream (see 108.5.2.4). In order to maintain the same bit rate after codeword marker insertion, the RS-FEC transmit process shall perform the rate compensation function described below, or its functional equivalent:

a) Decode the PCS blocks received by descrambling (see 49.2.10) and applying the PCS receive process (see 49.2.11) to obtain the XGMII or 25GMII character stream.
b) Delete Idle control characters (/I/), Low Power Idle control characters (/LI/), and ordered sets, according to the rules in 49.2.4.7 and 49.2.4.10, to create room as necessary for the periodically occurring codeword markers.
c) Re-encode the data stream obtained, by applying the PCS transmit process (see 49.2.5) and scrambler (see 49.2.6) to obtain 64B/66B blocks.

108.5.2.4 Codeword marker insertion

Change the first and second paragraphs of 108.5.2.4 as follows:

In order to support codeword alignment in the receive direction, the ~~25GBASE-R~~ RS-FEC shall periodically insert codeword markers into the stream of transcoded blocks as the first 257 bits of every 1024th RS-FEC codeword (see 108.5.2.5). The distance between the beginning of successive codeword markers is therefore 20480 257-bit transcoded blocks, equivalent to 81920 64B/66B blocks.

Room for codeword markers is created by the rate compensation for codeword markers in the transmit direction process (see 108.5.2.2) such that the bit rates at the input and the output of the ~~25GBASE-R~~ RS-FEC sublayer are equal.

108.5.2.5 Reed-Solomon encoder

Change 108.5.2.5 as follows:

The ~~25GBASE-R~~ RS-FEC sublayer employs the Reed-Solomon code RS(528,514) operating over the Galois Field GF(2^{10}) where the symbol size is 10 bits. The encoder described in 91.5.2.7 shall be used.

Replace Figure 108–3 with the following figure:

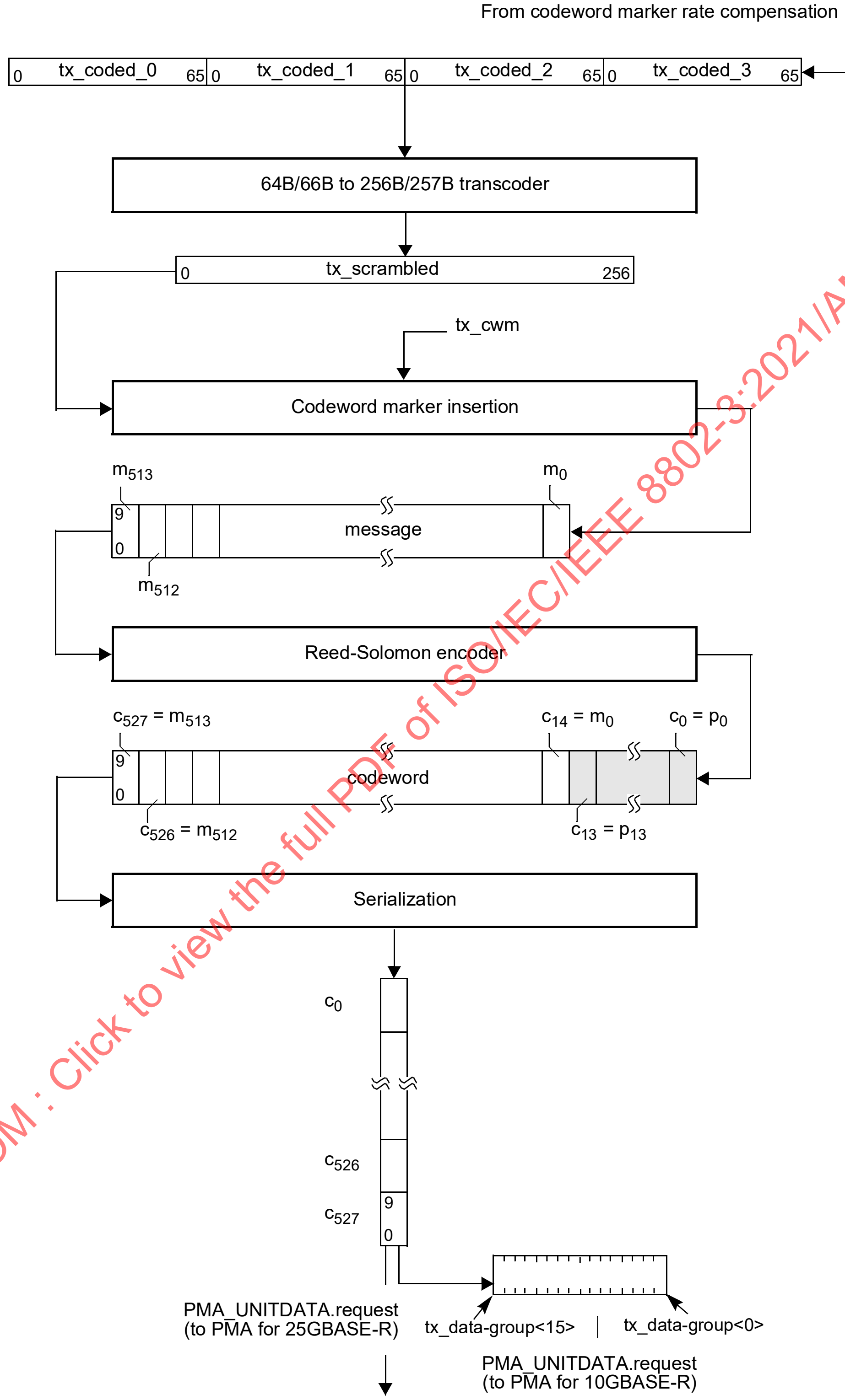


Figure 108–3—Transmit bit ordering

108.5.3 Receive function

108.5.3.1 Codeword marker lock

Change the first paragraph of 108.5.3.1 as follows:

The ~~25GBASE-R~~ RS-FEC shall implement the codeword marker lock process as described in this subclause.

108.5.3.2 Reed-Solomon decoder

Change the second and third paragraphs of 108.5.3.2 as follows:

The ~~25GBASE-R~~ RS-FEC sublayer shall be capable of correcting any combination of up to 7 symbol errors in a codeword. The ~~25GBASE-R~~ RS-FEC sublayer shall also be capable of indicating when a codeword contains errors that were not corrected. The probability that the decoder fails to indicate a codeword with 8 or more symbol errors as uncorrected is expected to be lower than 10^{-6}.

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 10GBASE-BR20, 25GBASE-SR, 25GBASE-LR, or 25GBASE-ER PHY.

NOTE 1—The PHY may rely on the error correction capability of the ~~25GBASE-R~~ RS-FEC sublayer to achieve its performance objectives. It is recommended that acceptable performance of the underlying link is verified before error correction is bypassed.

Change the fifth paragraphs of 108.5.3.2 as follows:

The Reed-Solomon decoder may optionally provide the ability to bypass the error indication feature 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_indication_ability variable (see 108.6.5). When the option is provided it is enabled by the assertion of the FEC_bypass_indication_enable variable (see 108.6.2).

Change the seventh paragraphs of 108.5.3.2 as follows:

When FEC_bypass_indication_enable is asserted, additional error monitoring is performed by the ~~25GBASE-R~~ RS-FEC sublayer to reduce the likelihood that errors in a packet are not detected. The Reed-Solomon decoder counts the number of symbol errors detected in consecutive non-overlapping blocks of 8192 codewords. When the number of symbol errors in a block of 8192 codewords exceeds 417, the Reed-Solomon decoder shall cause synchronization header rx_coded<1:0> of each subsequent 66-bit block that is delivered to the PCS to be assigned a value of 00 or 11 for a period of 60 ms to 75 ms.

108.5.3.5 256B/257B to 64B/66B transcoder

Change the second paragraph of 108.5.3.5 as follows:

The transcoder described in 91.5.3.5 shall be used, with the exception that in step f2), h<3:0> is derived by cross-referencing to g<3:0> using Figure 49–7 instead of Figure 82–5, to account for the block types used by the ~~25GBASE-R~~ PCS.

108.5.3.6 Rate compensation for codeword markers in the receive direction

Change the first paragraph of 108.5.3.6 as follows:

After the codeword markers have been discarded from transcoding and the stream of rx_coded<65:0> vectors has been obtained, to compensate for the deleted codeword markers, the RS-FEC receive process shall perform the rate compensation function described below, or its functional equivalent:

a) Decode the stream of rx_coded vectors by descrambling (see 49.2.10) and applying the PCS receive process (see 49.2.11) to obtain the <u>XGMII or </u>25GMII character stream.

b) Insert /I/ or /LI/, according to the rules in 49.2.4.7, to fill in as necessary for any deleted codeword markers or rapid codeword markers.

c) Re-encode the data stream obtained, by applying the PCS transmit process (see 49.2.5) and scrambling (see 49.2.6) to obtain 64B/66B blocks rx_coded_out<65:0>.

Replace Figure 108–5 with the following figure:

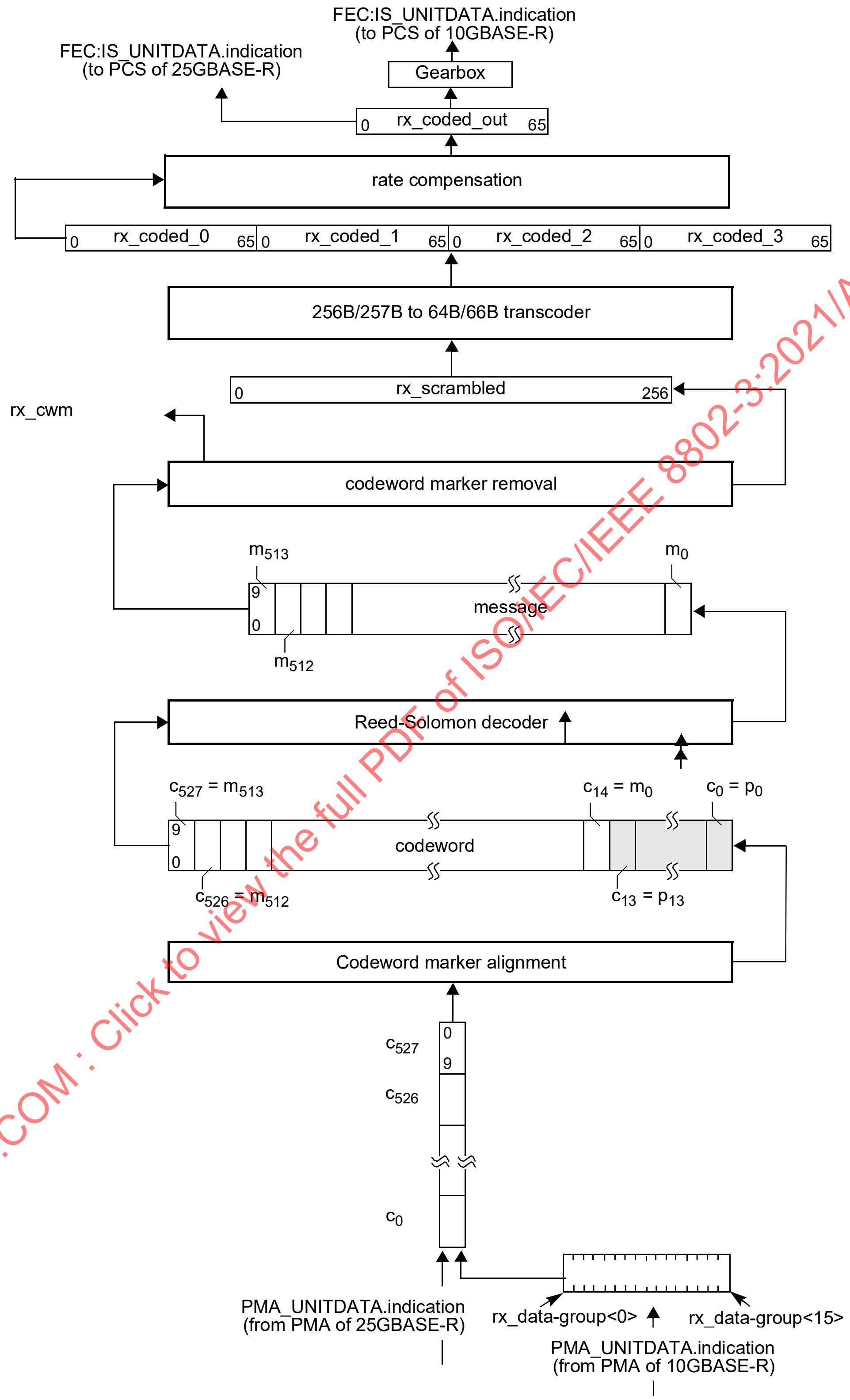


Figure 108–5—Receive bit ordering

108.5.4 Detailed functions and state diagrams

108.5.4.2 State variables

Change the definition of the reset variable in 108.5.4.2 as follows:

reset

Boolean variable that controls the resetting of the ~~25GBASE-R~~ RS-FEC sublayer. It is true whenever a reset is necessary including when reset is initiated from the MDIO, during power on, and when the MDIO has put the ~~25GBASE-R~~ RS-FEC sublayer into low-power mode.

Change the title of 108.6 as follows:

108.6 ~~25GBASE-R~~ RS-FEC MDIO function mapping

Change the row for "25G RS-FEC enable" in Table 108–1 as follows (unchanged rows not shown):

Table 108–1—MDIO/RS-FEC control variable mapping

MDIO control variable	PMA/PMD register name	Register/bit number	FEC variable
…			
~~25G~~ RS-FEC enable	RS-FEC control register	1.200.2	FEC_Enable

Change the title and content of 108.6.3 as follows:

108.6.3 ~~25G~~ RS-FEC Enable

The RS-FEC sublayer ~~shall~~ may have capability to enable or disable the FEC function for some PHY types. For those PHY types, a~~A~~n MDIO interface or an equivalent management interface shall be provided to access the variable FEC_Enable for the RS-FEC sublayer. When FEC_Enable variable is set to a one, the RS-FEC performs the transmit function as specified in 108.5.2 and the receive function as specified in 108.5.3. When the variable is set to zero, the RS-FEC transmit and receive functions are disabled, and the RS-FEC sublayer is bypassed, effectively connecting its service interface to the service interface of its underlying sublayer. Implementation of this bypass function should cause a minimal delay in the transmit and receive paths. This variable is mapped to the bit defined in 45.2.1.110.1 (1.200.2).

108.6.4 FEC_bypass_correction_ability

Change 108.6.4 as follows:

The Reed-Solomon decoder may have the option to perform error detection without error correction (see 108.5.3.2) to reduce the delay contributed by the ~~25GBASE-R~~ RS-FEC sublayer. This variable is set to one ~~to indicate that~~ if the decoder has the ability to bypass error correction. The variable is set to zero if this ability is not supported. This variable is mapped to the bit defined in 45.2.1.111 (1.201.0).

108.6.5 FEC_bypass_indication_ability

Change 108.6.5 as follows:

The Reed-Solomon decoder may have the option to bypass the error indication function (see 108.5.3.2) to reduce the delay contributed by the ~~25GBASE-R~~ RS-FEC sublayer. This variable is set to one to indicate that the decoder has the ability to bypass error indication. The variable is set to zero if this ability is not supported. This variable is mapped to the bit defined in 45.2.1.111 (1.201.1).

Change the title of 108.7 as follows:

108.7 Protocol implementation conformance statement (PICS) proforma for Clause 108, Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 10GBASE-R and 25GBASE-R PHYs[4]

108.7.1 Introduction

Change the first paragraph of 108.7.1 as follows:

The supplier of a protocol implementation that is claimed to conform to Clause 108, Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 10GBASE-R and 25GBASE-R PHYs, shall complete the following protocol implementation conformance statement (PICS) proforma.

108.7.2 Identification

108.7.2.2 Protocol summary

Change the table in 108.7.2.2 as follows:

Identification of protocol standard	IEEE Std 802.3cp-2021, Clause 108, Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 10GBASE-R and 25GBASE-R PHYs
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 802.3cp-2021.)	

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.

108.7.3 Major capabilities/options

Insert a new row for item "*BR20" before the row for item "*KR" and change the row for item "EF" in the table in 108.7.3 as follows (unchanged rows not shown):

Item	Feature	Subclause	Value/Comment	Status	Support
*BR20	10GBASE-BR20		Used to form a complete 10GBASE-BR20 PHY	O	Yes [ ] No [ ]
…					
EF	~~25G~~ RS-FEC enable	108.6.3	Has the capability to ~~enable and~~ disable the ~~25G~~ RS-FEC function	(KR or CR): M	Yes [ ] N/A [ ]
…					

Change the title of 108.7.4 as follows:

108.7.4 PICS proforma tables for Reed-Solomon Forward Error Correction (RS-FEC) sublayer for 10GBASE-R and 25GBASE-R PHYs

108.7.4.2 Receive function

Change the row for item "RF3" in the table in 108.7.4.2 as follows (unchanged rows not shown):

Item	Feature	Subclause	Value/Comment	Status	Support
…					
RF3	Error correction not bypassed for 10GBASE-BR20, 25GBASE-SR, 25GBASE-LR, or 25GBASE-ER	108.5.3.2	Error correction is not bypassed	BEC*(SR or LR or ER or BR20):M	Yes [ ] N/A [ ]
…					

Clause 131 was added to IEEE Std 802.3-2018 by IEEE Std 803.3cd-2018.

131. Introduction to 50 Gb/s networks

131.4 Delay constraints

Insert three new rows at the end of Table 131–4 (as modified by IEEE Std 802.3cn-2019) as follows (unchanged rows not shown):

Table 131–4—Sublayer delay constraints (50GBASE)

Sublayer	Maximum (bit time)[a]	Maximum (pause_quanta)[b]	Maximum (ns)	Notes[c]
…				
50GBASE-BR10 PMD	1 024	2	20.48	Includes 2 m of fiber. See 160.3.1.
50GBASE-BR20 PMD	1 024	2	20.48	Includes 2 m of fiber. See 160.3.1.
50GBASE-BR40 PMD	1 024	2	20.48	Includes 2 m of fiber. See 160.3.1.

[a]For 50GBASE-R, 1 bit time is equal to 20 ps. (See 1.4.160 for the definition of bit time.)
[b]For 50GBASE-R, 1 pause_quantum is equal to 10.24 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.

Insert new Clause 157 to Clause 160 in numeric order as follows:

157. Introduction to 10 Gb/s, 25 Gb/s, and 50 Gb/s BiDi PHYs

157.1 Overview

157.1.1 Scope

This clause describes the general requirements for 10 Gb/s, 25 Gb/s, and 50 Gb/s Ethernet bidirectional Physical Layer entities (PHYs). Within this clause this family of PHYs is collectively referred to as Multi-Gigabit Ethernet BiDi PHYs. These PHYs are divided into two variants based on the direction of transmission; optical line terminal (OLT) PHYs transmit in the downstream direction and optical network unit (ONU) PHYs transmit in the upstream direction.

All Multi-Gigabit Ethernet BiDi PHYs specified herein use the IEEE 802.3 MAC sublayer operating at a data rate of 10 Gb/s, 25 Gb/s, or 50 Gb/s as appropriate and are defined for full duplex operation only.

The Multi-Gigabit Ethernet BiDi PHYs provide a frame loss ratio of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap.

157.1.2 Relationship of Multi-Gigabit Ethernet BiDi PHYs to the ISO OSI reference model

The Multi-Gigabit Ethernet BiDi PHYs couple to the IEEE 802.3 MAC. The relationships among the IEEE 802.3 Multi-Gigabit Ethernet BiDi Physical Coding Sublayer (PCS), forward error correction (FEC), physical medium attachment (PMA), and physical medium dependent (PMD) sublayers and the IEEE 802.3 MAC, with respect to the ISO Open System Interconnection (OSI) reference model are shown in Figure 157–1. While this specification defines interfaces in terms of bits, octets, and frames, implementations may choose other data path widths for implementation convenience. Exceptions to this are specified in 44.1.3 (for 10 Gb/s), 105.1.2 (for 25 Gb/s), and 131.1.2 (for 50 Gb/s). In addition to these exceptions the MDI specifications for Multi-Gigabit Ethernet BiDi PHYs are as follows:

- For 10 Gb/s PHYs, see Clause 158
- For 25 Gb/s PHYs, see Clause 159
- For 50 Gb/s PHYs, see Clause 160

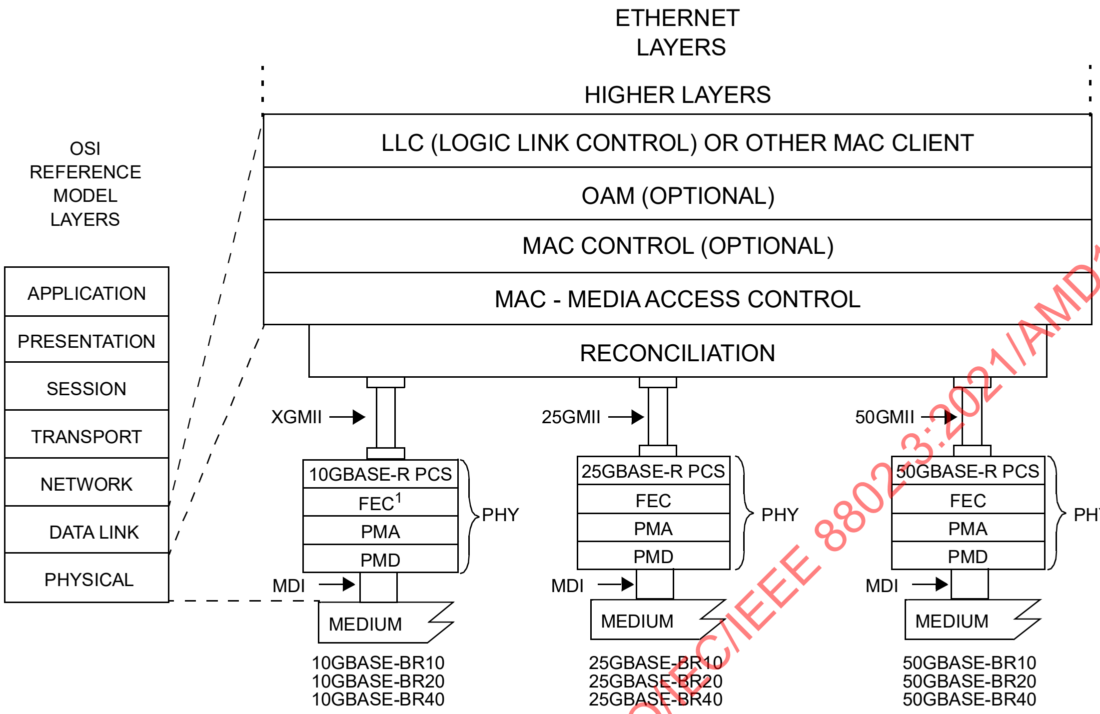
157.1.3 Nomenclature

For Multi-Gigabit Ethernet BiDi PHYs, the following nomenclature is used, with individual elements shown in Table 157–1:

rGBASE-BRx-d

Table 157–1—PMD parameter elements

Parameter	Description	Allowed values
r	PMD rate	10, 25, 50
x	PMD reach in km	10, 20, 40
d	PMD transmit direction	D = OLT PMDs, U = ONU PMDs



FEC = FORWARD ERROR CORRECTION
XGMII = 10 GIGABIT MEDIA INDEPENDENT INTERFACE
25GMII = 25 GIGABIT MEDIA INDEPENDENT INTERFACE
50GMII = 50 GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION, AND MAINTENANCE

PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

NOTE 1—CONDITIONAL BASED ON PHY TYPE

Figure 157–1—Architectural positioning of Multi-Gigabit Ethernet BiDi PHYs

B refers to bidirectional, and R refers to the 64B/66B encoding. The term xMII is used to generically refer to the family of Media Independent Interfaces (MII) including the XGMII, 25GMII, or 50GMII. All Multi-Gigabit Ethernet BiDi PHYs are listed in Table 157–2.

Table 157–2—Multi-Gigabit Ethernet BiDi PHYs

Name	Description
10GBASE-BR10-D	10 Gb/s OLT PHY using 10GBASE-R encoding over one single-mode fiber, with reach up to at least 10 km (see Clause 158).
10GBASE-BR20-D	10 Gb/s OLT PHY using 10GBASE-R encoding over one single-mode fiber, with reach up to at least 20 km (see Clause 158).
10GBASE-BR40-D	10 Gb/s OLT PHY using 10GBASE-R encoding over one single-mode fiber, with reach up to at least 40 km (see Clause 158).
10GBASE-BR10-U	10 Gb/s ONU PHY using 10GBASE-R encoding over one single-mode fiber, with reach up to at least 10 km (see Clause 158).

Table 157–2—Multi-Gigabit Ethernet BiDi PHYs *(continued)*

Name	Description
10GBASE-BR20-U	10 Gb/s ONU PHY using 10GBASE-R encoding over one single-mode fiber, with reach up to at least 20 km (see Clause 158).
10GBASE-BR40-U	10 Gb/s ONU PHY using 10GBASE-R encoding over one single-mode fiber, with reach up to at least 40 km (see Clause 158).
25GBASE-BR10-D	25 Gb/s OLT PHY using 25GBASE-R encoding over one single-mode fiber, with reach up to at least 10 km (see Clause 159).
25GBASE-BR20-D	25 Gb/s OLT PHY using 25GBASE-R encoding over one single-mode fiber, with reach up to at least 20 km (see Clause 159).
25GBASE-BR40-D	25 Gb/s OLT PHY using 25GBASE-R encoding over one single-mode fiber, with reach up to at least 40 km (see Clause 159).
25GBASE-BR10-U	25 Gb/s ONU PHY using 25GBASE-R encoding over one single-mode fiber, with reach up to at least 10 km (see Clause 159).
25GBASE-BR20-U	25 Gb/s ONU PHY using 25GBASE-R encoding over one single-mode fiber, with reach up to at least 20 km (see Clause 159).
25GBASE-BR40-U	25 Gb/s ONU PHY using 25GBASE-R encoding over one single-mode fiber, with reach up to at least 40 km (see Clause 159).
50GBASE-BR10-D	50 Gb/s OLT PHY using 50GBASE-R encoding over one single-mode fiber, with reach up to at least 10 km (see Clause 160).
50GBASE-BR20-D	50 Gb/s OLT PHY using 50GBASE-R encoding over one single-mode fiber, with reach up to at least 20 km (see Clause 160).
50GBASE-BR40-D	50 Gb/s OLT PHY using 50GBASE-R encoding over one single-mode fiber, with reach up to at least 40 km (see Clause 160).
50GBASE-BR10-U	50 Gb/s ONU PHY using 50GBASE-R encoding over one single-mode fiber, with reach up to at least 10 km (see Clause 160).
50GBASE-BR20-U	50 Gb/s ONU PHY using 50GBASE-R encoding over one single-mode fiber, with reach up to at least 20 km (see Clause 160).
50GBASE-BR40-U	50 Gb/s ONU PHY using 50GBASE-R encoding over one single-mode fiber, with reach up to at least 40 km (see Clause 160).

157.1.4 Physical Layer signaling systems

This standard specifies a family of Physical Layer implementations. Table 157–3, Table 157–4, and Table 157–5 specify the correlation between PHY types and specific clauses for the PCS, FEC, PMA and PMD. Implementations conforming to one or more PHY types meet the requirements of the corresponding clauses.

Table 157–3—Nomenclature and clause correlation, 10GBASE-BRx

Nomenclature	Clause								
	78	46		49	108	51	158		
	EEE	RS	XGMII	10GBASE-R PCS	FEC	Serial PMA	10GBASE-BR10 PMD	10GBASE-BR20 PMD	10GBASE-BR40 PMD
10GBASE-BR10-D	O	M[a]	O	M		M	M		
10GBASE-BR20-D	O	M	O	M	M	M		M	
10GBASE-BR40-D	O	M	O	M		M			M
10GBASE-BR10-U	O	M	O	M		M	M		
10GBASE-BR20-U	O	M	O	M	M	M		M	
10GBASE-BR40-U	O	M	O	M		M			M

[a]M = Mandatory, O = Optional

Table 157–4—Nomenclature and clause correlation, 25GBASE-BRx

Nomenclature	Clause										
	78	106		107	108	109	109A	109B	159		
	EEE	RS	25GMII	25GBASE-R PCS	25GBASE-R FEC	PMA	25GAUI C2C	25GAUI C2M	25GBASE-BR10 PMD	25GBASE-BR20 PMD	25GBASE-BR40 PMD
25GBASE-BR10-D	O[a]	M	O	M	M	M	O	O	M		
25GBASE-BR20-D	O	M	O	M	M	M	O	O		M	
25GBASE-BR40-D	O	M	O	M	M	M	O	O			M
25GBASE-BR10-U	O	M	O	M	M	M	O	O	M		
25GBASE-BR20-U	O	M	O	M	M	M	O	O		M	
25GBASE-BR40-U	O	M	O	M	M	M	O	O			M

[a]M = Mandatory, O = Optional

Table 157–5—Nomenclature and clause correlation, 50GBASE-BRx

Nomenclature	Clause														
	78	132		133	134	135	135B	135C	135D	135E	135F	135G	160		
	EEE	RS	50GMII	50GBASE-R PCS	50GBASE-R FEC	PMA	50GAUI C2C	50GAUI C2M	50GAUI-2 C2C	50GAUI-2 C2M	50GAUI-1 C2C	50GAUI-1 C2M	50GBASE-BR10 PMD	50GBASE-BR20 PMD	50GBASE-BR40 PMD
50GBASE-BR10-D	O[a]	M	O	M	M	M	O	O	O	O	O	O	M		
50GBASE-BR20-D	O	M	O	M	M	M	O	O	O	O	O	O		M	
50GBASE-BR40-D	O	M	O	M	M	M	O	O	O	O	O	O			M
50GBASE-BR10-U	O	M	O	M	M	M	O	O	O	O	O	O	M		
50GBASE-BR20-U	O	M	O	M	M	M	O	O	O	O	O	O		M	
50GBASE-BR40-U	O	M	O	M	M	M	O	O	O	O	O	O			M

[a]M = Mandatory, O = Optional

157.2 Summary of Multi-Gigabit Ethernet BiDi sublayers

157.2.1 Reconciliation Sublayer (RS) and Media Independent Interface (XGMII, 25GMII, and 50GMII)

The RS provides a mapping between the signals provided at the xMII and the MAC/PLS service definition. The xMII provides a logical interconnection between the MAC sublayer and Physical Layer entities (PHY). The xMII may be physically instantiated or can logically connect layers within a device. While the xMII is an optional interface, it is used extensively in this standard as a basis for functional specification and provides a common service interface for the Physical Coding Sublayer (PCS). The specific RS and xMII for each Multi-Gigabit Ethernet BiDi PHY are given in Table 157–3, Table 157–4, and Table 157–5.

157.2.2 Physical Coding Sublayer (PCS)

The PCS performs encoding of data from the xMII to 64B/66B code blocks and transfers the encoded data to the PMA or FEC sublayer and performs decoding of 64B/66B blocks from the PMA or FEC sublayer and transfers the decoded data to the xMII. The specific PCS for each Multi-Gigabit Ethernet BiDi PHY is given in Table 157–3, Table 157–4, and Table 157–5.

157.2.3 Forward error correction (FEC) sublayer

An FEC sublayer is required for all Multi-Gigabit BiDi PHYs except 10GBASE-BR10 and 10GBASE-BR40, where the FEC sublayer is not applicable. The FEC sublayer can be placed in between the PCS and PMA sublayers or between two PMA sublayers. The specific FEC for each Multi-Gigabit Ethernet BiDi PHY is given in Table 157–3, Table 157–4, and Table 157–5.

157.2.4 Physical Medium Attachment (PMA) sublayer

The PMA sublayer provides a medium independent means for the PCS or FEC sublayers to support the use of a range of physical media. The PMA performs the mapping of transmit and receive data streams between the PCS or FEC and PMA via the PMA service interface and mapping of transmit and receive data streams between the PMA and PMD via the PMD service interface.

The PMA performs retiming of the received data stream when appropriate, optionally provides data loopback at the PMA or PMD service interface, and optionally provides test pattern generation and checking. The PMA also may provide an observable electrical interface for the 25GAUI or 50GAUI chip-to-chip (C2C) or chip-to-module (C2M).

The specific PMA for each Multi-Gigabit Ethernet BiDi PHY is given in Table 157–3, Table 157–4, and Table 157–5.

157.2.5 Physical Medium Dependent (PMD) sublayer

The PMD sublayer is responsible for interfacing to the transmission medium. The MDI connects the PMD to the medium and is defined in the associated PMD clause. The specific PMD for each Multi-Gigabit Ethernet BiDi PHY is given in Table 157–3, Table 157–4, and Table 157–5.

157.2.6 Management interface (MDIO/MDC)

The optional MDIO/MDC management interface (Clause 45) provides an interconnection between MDIO Manageable Devices (MMDs) and Station Management (STA) entities.

157.2.7 Management

Managed objects, attributes, and actions are defined for all Multi-Gigabit Ethernet BiDi PHY components. These items are defined in Clause 30.

157.3 Service interface specification method and notation

The service interface specification for Multi-Gigabit Ethernet BiDi Physical Layers is as per the definition in 1.2.2.

The 10GBASE-BRx PHYs use the inter-sublayer service interfaces specified in 49.2.2.

The 25GBASE-BRx PHYs use the inter-sublayer service interfaces specified in 105.4.

The 50GBASE-BRx PHYs use the inter-sublayer service interfaces specified in 131.3.

157.4 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

The maximum delay constraints for 10GBASE-BRx PHY sublayers are specified in 44.3.

The maximum delay constraints for 25GBASE-BRx PHY sublayers are specified in 105.5.

The maximum delay constraints for 50GBASE-BRx PHY sublayers are specified in 131.4.

157.5 ONU silent start

Silent start is provided by Multi-Gigabit Ethernet BiDi ONU PHYs to reduce the likelihood of disruption to established services if a Multi-Gigabit Ethernet BiDi ONU PHY is inadvertently attached to a point-to-multipoint network.

All members of the Multi-Gigabit Ethernet BiDi PHY family include PCS registers or variable equivalents that:

a) Indicate the receive status of the PCS (see 49.2.14.1 and 45.2.3.15.1).

b) Disable the PHYs transmitter (see 45.2.1.8).

By monitoring the PCS receive status indicator and appropriately setting the PHY transmitter control, upper layer management can prevent transmission by a Multi-Gigabit Ethernet BiDi ONU PHY when connected to an incompatible network (e.g., an EPON).

Transmission by a Multi-Gigabit Ethernet BiDi ONU PHY is disallowed whenever a receive fault is declared by the status indicator; once the status indicator declares the PCS is receiving a proper Multi-Gigabit Ethernet BiDi PHY signal for a pre-determined time period (e.g., 1 second) transmission may be enabled. Note that silent start does not apply to the OLT PHY types.

157.6 Protocol implementation conformance statement (PICS) proforma

The supplier of a protocol implementation that is claimed to conform to any part of IEEE Std 802.3, Clause 45, Clause 49, Clause 73, Clause 74, Clause 106 through Clause 112, Clause 114, Clause 158 through Clause 160, and related annexes demonstrates compliance by completing a protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. A PICS is included at the end of each clause as appropriate. Each of the Multi-Gigabit Ethernet BiDi PICS conforms to the same notation and conventions used in 21.6.

158. Physical Medium Dependent (PMD) sublayer and medium, types 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40

158.1 Overview

This clause specifies the 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40 PMDs together with the single-mode fiber medium, shown in Table 158–1. Within this clause these PMDs are jointly referred to by the term 10GBASE-BRx. The 10GBASE-BRx PHYs are divided into two variants based on the direction of transmission. Optical line terminal (OLT) PMDs transmit in the downstream direction and receive in the upstream direction. Optical network unit (ONU) PMDs transmit in the upstream direction and receive in the downstream direction. The PMD variant is indicated with a suffix of D for OLT PMDs and U for ONU PMDs.

In order to form a complete Physical Layer, each PMD is combined with the appropriate physical sublayers indicated in Table 158–1 and optionally with the management functions that may be accessible through the management interface defined in Clause 45, or equivalent.

Table 158–1—PMD type and associated clauses

Associated clause	10GBASE-BR10 10GBASE-BR40	10GBASE-BR20
46—RS	Required	Required
46—XGMII	Optional	Optional
47—XGXS and XAUI	Optional	Optional
49—Type R PCS	Required	Required
108—RS-FEC	Not applicable	Required[a]
51—Serial PMA	Required	Required

[a] The option to bypass the Clause 108 RS-FEC correction function is not supported (see 108.6.3).

Figure 158–1 depicts the relationships of the serial PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

158.1.1 Bit error ratio

For the 10GBASE-BR10 and 10GBASE-BR40 PMDs, the bit error ratio (BER) shall be less than 10^{-12}.

For the 10GBASE-BR20 PMD, the 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 1.4.275) 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.

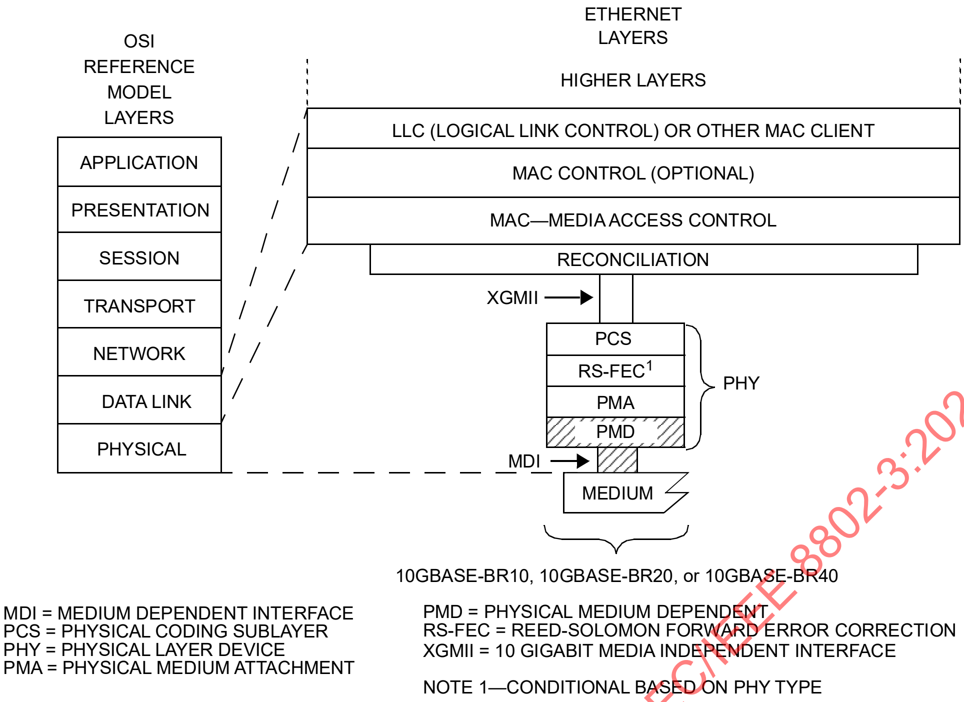


Figure 158–1—10GBASE-BRx PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

158.2 PMD sublayer service interface

The PMD service interfaces for 10GBASE-BRx are the same as PMD service interface for 10GBASE-R as described in 49.2 with the BER as specified in 158.1.1.

158.3 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 PMA and PMD shall incur a round-trip delay (transmit and receive) of not more than 512 bit times, or 1 pause_quantum, including 2 m of fiber. A description of overall system delay constraints and the definitions for bit times and pause_quanta can be found in 44.3.

158.4 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 158–2, and MDIO status variables to PMD status variables as shown in Table 158–3.

Table 158–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global Transmit Disable	Transmit disable register	1.9.0	PMD_global_transmit_disable

Table 158–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD Receive signal detect	Receive signal detect register	1.10.0	PMD_global_signal_detect

158.5 PMD functional specifications

The 10GBASE-BRx PMDs perform the Transmit and Receive functions that convey data between the PMD service interface and the MDI.

158.5.1 PMD block diagram

For purposes of system conformance, the PMD sublayer is standardized at test points TP2 and TP3 as shown in Figure 158–2. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 m and 5 m in length, of a type consistent with the link type connected to the transmitter. Unless specified otherwise, all transmitter measurements and tests defined in 158.8 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 158.8 are made at TP3. TP1 and TP4 are informative reference points that may be useful to implementers for testing components (these test points are not typically accessible in an implemented system).

158.5.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) defined in 52.1.1.1 to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit = ONE.

158.5.3 PMD receive function

The PMD Receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit) defined in 52.1.1.2. The higher optical power level shall correspond to rx_bit = ONE.

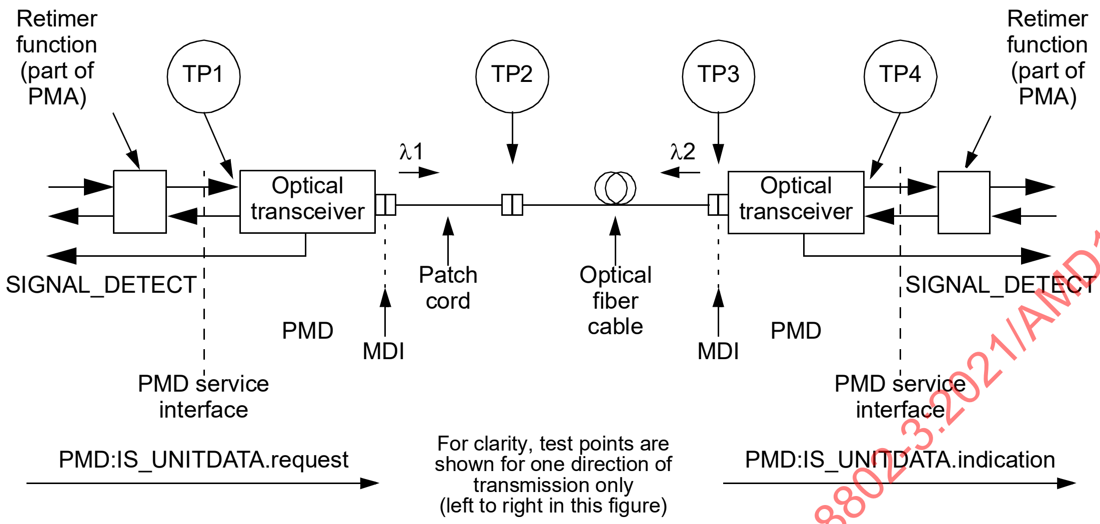


Figure 158–2—Block diagram for 10GBASE-BRx transmit/receive paths

158.5.4 PMD signal detect function

The PMD Signal Detect function shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT) which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence. If the MDIO interface is implemented, then PMD_global_signal_detect (MDIO register bit 1.10.0) shall be continuously set to the value of SIGNAL_DETECT as described in 45.2.1.9.7.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 158–4. The PMD receiver is not required to verify whether a compliant 10GBASE-BRx signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Implementations should 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.

Table 158–4—SIGNAL_DETECT value definition

Receive conditions	Signal Detect value
Input optical power ≤ –30 dBm average power for 10GBASE-BR10 and 10GBASE-BR40, input optical power ≤ –33 dBm average power for 10GBASE-BR20	FAIL
Input optical power ≥ Receiver sensitivity (max) in OMA in Table 158–7 AND compliant 10GBASE-BRx signal input	OK
All other conditions	Unspecified

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.

158.5.5 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.

158.5.6 PMD global transmit disable function

PMDs compliant with this clause shall include the PMD_global_transmit_disable function that allows the optical transmitter to be disabled.

When asserted, this function shall turn off the optical transmitter so that it meets the requirements of the average launch power of OFF transmitter in Table 158–6.

If a PMD_transmit_fault is detected, then the PMD may set the PMD_global_transmit_disable variable to one, turning off the optical transmitter.

158.5.7 PMD fault function

If the MDIO is implemented, PMD_fault is the logical OR of PMD_receive_fault, PMD_transmit_fault and any other implementation specific fault.

158.5.8 PMD transmit fault function

The PMD_transmit_fault function is optional. The faults detected by this function are implementation specific, but should not include the assertion of the PMD_global_transmit_disable function.

If a PMD_transmit_fault (optional) is detected, then the PMD_global_transmit_disable function should also be asserted.

158.5.9 PMD receive fault function

The 10GBASE-BRx-U PMD shall include the PMD_receive_fault function, in the 10GBASE-BRx-D PMD this function is optional. PMD_receive_fault is the logical OR of NOT SIGNAL_DETECT and any implementation specific fault.

158.5.10 ONU silent start

Silent start shall be provided by 10GBASE-BR10-U, 10GBASE-BR20-U, and 10GBASE-BR40-U PHYs. See 157.5.

158.6 PMD to MDI optical specifications for 10GBASE-BRx

The operating range for 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40 PMDs is defined in Table 158–5. A 10GBASE-BRx compliant PMD supports Types B1.1 and B1.3 single-mode fibers according to the specifications defined in 158.11. A PMD that exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., operating at 12.5 km meets the minimum range requirement of 2 m to 10 km).

Table 158–5—10GBASE-BRx operating ranges

PMD Type	Required operating range
10GBASE-BR10	2 m to 10 km
10GBASE-BR20[a]	2 m to 20 km
10GBASE-BR40	2 m to 40 km

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

158.6.1 10GBASE-BRx transmitter optical specifications

The 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40 transmitters shall meet the specifications defined in Table 158–6 per the measurement techniques defined in 158.8.

Table 158–6—10GBASE-BRx transmit characteristics

Description	10GBASE-BR10	10GBASE-BR20	10GBASE-BR40	Unit
Signaling speed (nominal)		10.3125		GBd
Signaling speed variation from nominal (max)		±100		ppm
10GBASE-BRx-D center wavelength (range)		1320 to 1340		nm
10GBASE-BRx-U center wavelength (range)		1260 to 1280		nm
Side-mode suppression ratio (min)		30		dB
Average launch power (max)	0.5	–5.6	3	dBm
Average launch power[a] (min)	–8.2	–12	–3	dBm
Optical Modulation Amplitude[b] (OMA) (min)	–5.2	–9	0	dBm
Transmitter and dispersion penalty (TDP) (max)	3.2	2	2.6	dB
Launch power (min) in OMA minus TDP	–6.2	–10	–1	dBm
Average launch power of OFF transmitter[c] (max)		–30		dBm
Extinction ratio (min)	3.5	5	5.5	dB
RIN_xOMA (max)[d]		–128		dB/Hz
Optical return loss tolerance (max)	12	21		dB
Transmitter reflectance[e] (max)		–12		dB
Transmitter eye mask definition B {X1, X2, X3, Y1, Y2, Y3}, hit ratio 5×10^{-5} per sample		{0.235, 0.395, 0.45, 0.235, 0.265, 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] The OMA (min) requirement holds even if the TDP < 1 dB.
[c] Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable, or other optional transmitter shutdown conditions.
[d] In RIN_xOMA, "x" is the optical return loss tolerance (max) for the PHY under test.
[e] Transmitter reflectance is defined looking into the transmitter.

158.6.2 10GBASE-BRx receive optical specifications

The 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40 receivers shall meet the specifications defined in Table 158–7 per the measurement techniques defined in 158.8.

Table 158–7—10GBASE-BRx receive characteristics

Description	10GBASE-BR10	10GBASE-BR20	10GBASE-BR40	Unit
Signaling speed (nominal)	10.3125			GBd
Signaling speed variation from nominal (max)	±100			ppm
10GBASE-BRx-D center wavelength (range)	1260 to 1280			nm
10GBASE-BRx-U center wavelength (range)	1320 to 1340			nm
Damage threshold[a] (min)	4	–4.6	4	dBm
Average receive power (max)	0.5	–5.6	–7	dBm
Average receive power[b] (min)	–14.4	–27.2	–21.2	dBm
Receiver sensitivity (max) in OMA[c]	–12.6	–25	–19	dBm
Receiver reflectance (max)	–12	–26		dB
Stressed receiver sensitivity (max) in OMA[d, e]	–10.3	–22.7	–16.8	dBm
Conditions of stressed receiver sensitivity test:				
Vertical eye closure penalty[f] (min)	2.2	—	2.7	dB
Stressed eye jitter[g] (min)	0.3	—	0.3	UI pk-pk
Stressed eye closure[h]	—	2.5	—	dB
Stressed eye J2 Jitter[h]	—	0.27	—	UI
Stressed eye J4 Jitter[h]	—	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. The receiver does not have to operate correctly at this input power.
[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 is informative.
[d] Measured with conformance test signal at TP3 (see 158.8.9.1.3) for BER = 10^{-12} for BR10 and BR40, and for BER = 5×10^{-5} for BR20.
[e] The stressed sensitivity values in the table are for system level BER measurements, which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effect of CDR circuits.
[f] Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[g] Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[h] 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.

158.6.3 10GBASE-BRx illustrative link power budgets

Illustrative power budgets and penalties for a 10GBASE-BRx channel are shown in Table 158–8.

Table 158–8—10GBASE-BRx illustrative link power budget[a, b]

Parameter	10GBASE-BR10	10GBASE-BR20	10GBASE-BR40	Unit
Power budget	9.4	18	21	dB
Operating distance	10	20	40[c]	km
Channel insertion loss	6.2[d]	15[e]	18[e]	dB
Maximum discrete reflectance (max)		–26		dB
Allocation for penalties	3.2	3		dB

[a] Budget numbers are rounded to nearest 0.1 dB.
[b] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[c] Links longer than 30 km are considered engineered links.
[d] The channel insertion loss is calculated using the maximum distance specified in Table 158–5 and cabled optical fiber attenuation of 0.4 dB/km plus an allocation for connection and splice loss given in 158.11.2.1.
[e] The channel insertion loss is calculated using the maximum distance specified in Table 158–5 and cabled optical fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 158.11.2.1.

158.7 Jitter specifications for 10GBASE-BRx

The jitter specifications for 10GBASE-BRx are defined by the transmitter eye mask requirements in Table 158–7, using the definitions in 158.8.7 and the reference receiver defined in 158.8.10.3.

158.8 Definition of optical parameters and measurement methods

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

158.8.1 Test patterns

Compliance is to be achieved in normal operation. Two types of test pattern are used, square wave (158.8.1.2) and others (158.8.1.1). Table 158–11 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.

Test pattern generation and checking functions, such as the ones defined in 49.2.8 and in 49.2.12, are required for testing a PMD. Tests may utilize test pattern generators and checkers in other sublayers (e.g., the PCS of Clause 49) or in the test equipment, as appropriate.

NOTE—Test patterns for specific optical tests are designed to emulate system operation, which would entail passing valid 10GBASE-BRx data.

158.8.1.1 Test pattern definition

Patterns 1, 2, and 3 are defined in Table 158–10.

For 10GBASE-BRx, two test pattern segments are specified, in two variants, “normal” (n) and “inverted” (i). Both are 8448 bits long. They may be generated dynamically by the 58-bit scrambler and "control block" sync header generation defined in 49.2.6, and using the scrambler starting seeds specified in Table 158–9 and the method of generation in 49.2.8. The segments are assembled into patterns, each containing four segments, as described in Table 158–10. Each may be held as a static pattern in test equipment, or generated or detected dynamically using the methods of 49.2.8 and 49.2.12 respectively, or otherwise.

Each segment contains a sync header transition every 66 bits.

Table 158–9—Pattern segments

Segments	Seed[57:0][a]
A_n	0x3C8B44DCAB6804F
B_n	0x34906BB85A38884

[a] The "invert" segments A_i and B_i are generated using the inverted seeds for A_n and B_n, respectively.

Table 158–10—Test patterns

Pattern	Pattern for 10GBASE-R
1	B_n B_i B_n B_i
2	A_n A_i A_n A_i
3	PRBS31[a]

[a] The PRBS31 test pattern is identical to the one defined in 49.2.8.

Test pattern 1 is generated with the data input mode programmed to select LF data input. Test pattern 2 is generated with the data input mode programmed to select all zero data input.

Pattern 1 represents typical scrambled data while pattern 2 represents a less typical pattern that could happen by chance and is thought to be more demanding of the transmission process including the clock recovery subsystem. Both patterns are balanced over their length of 33 792 bits.

NOTE—While other test methods and patterns could be used, it is the implementer's responsibility to ensure that measurements carried out with the specified patterns achieve the requirements specified.

158.8.1.2 Square wave pattern definition

A pattern consisting of four to eleven consecutive ones followed by an equal run of zeros may be used as a square wave. These patterns have fundamental frequencies at approximately 1289 MHz.

158.8.2 Wavelength and side-mode suppression ratio (SMSR)

The wavelength and SMSR shall be within the range given in Table 158–6 if measured per IEC 61280-1-3. The transmitter is modulated using the test pattern defined in Table 158–11.

Table 158–11—Test pattern definitions and related subclauses

Test	Pattern	Related subclause
Average optical power	1, 3, or valid 10GBASE-R signal	158.8.3
OMA (modulated optical power)	Square	158.8.5
Extinction ratio	1 or 3	158.8.4
Transmit eye	1 or 3	158.8.7
RIN$_x$OMA	Square	158.8.6
Wavelength	1, 3, or valid 10GBASE-R signal	158.8.2
Side-mode suppression ratio	1, 3, or valid 10GBASE-R signal	158.8.2
Vertical eye closure penalty calibration	2 or 3	158.8.9
Receiver sensitivity	1 or 3	158.8.9
Receiver overload	1 or 3	—
Stressed receive conformance	2 or 3	158.8.9
Transmitter and dispersion penalty	2 or 3	158.8.10

158.8.3 Average optical power

The average optical power shall be within the limits given in Table 158–6 if measured using the methods given in IEC 61280-1-1. The average optical power is measured using the test pattern specified in Table 158–11.

158.8.4 Extinction ratio

The extinction ratio shall be within the limits given in Table 158–6 if measured using the methods specified in IEC 61280-2-2. The extinction ratio is measured using the test pattern defined in Table 158–11.

158.8.5 Optical Modulation Amplitude (OMA)

OMA shall meet the requirements in Table 158–7 when measured using the method defined in 52.9.5. See 158.8.1 for test pattern information.

158.8.6 Relative Intensity Noise (RIN$_x$OMA)

RIN$_x$OMA shall meet the requirement in Table 158–7 when measured using the method of 52.9.6, with x being the “Optical return loss tolerance (max)” specified in Table 158–7 for the PMD under test.

158.8.7 Transmitter optical waveform (transmitter eye)

The required optical transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 86–4. The transmitter optical waveform of a port transmitting the test pattern specified in Table 158–11 shall meet specifications according to the methods specified in 86.8.4.6.1 with the filter nominal reference frequency f_r of 7.5 GHz and the filter tolerances as specified for STM-64 in ITU-T G.691. Compensation may be made for variation of the reference receiver filter response from an ideal fourth-order Bessel-Thomson response.

158.8.8 Receiver sensitivity

Receiver sensitivity, which is defined for an ideal input signal, is informative and testing is not required. If measured, the test signal should have negligible impairments such as intersymbol interference (ISI), rise/fall times, jitter and RIN. Instead, the normative requirement for receivers is stressed receiver sensitivity.

158.8.9 Stressed receiver sensitivity

158.8.9.1 Stressed receiver sensitivity for 10GBASE-BR10 and 10GBASE-BR40

Stressed receiver sensitivity shall be within the limits given in Table 158–7 if measured using the method defined in 158.8.9.1.1, 158.8.9.1.2, and 158.8.9.1.4, with the conformance test signal at TP3 as described in 158.8.9.1.3 and 158.8.9.1.5, using the test pattern specified for SRS in Table 158–11.

Receivers shall operate with BER less than 10^{-12} when tested with a conditioned input signal that combines vertical eye closure and jitter according to this clause.

The measurements in this subclause are performed with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is to be the same pattern defined for this measurement in 158.8.1. The reflectance of the optical link should be at its maximum level.

158.8.9.1.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 158–3. A suitable pattern generator is used to continuously generate a signal or test pattern according to 158.8.1. The optical test signal is conditioned (stressed) using the methodology as defined in 158.8.9.1.3, while applying sinusoidal jitter as defined in 158.8.9.1.5. The receiver of the system under test is tested for conformance by enabling the error counter on the receiving side. The optical power penalty for the stressed eye is intended to be similar to its vertical eye closure penalty. This is not necessarily the same as the highest TDP anticipated in service, but represents a standardized test condition for the receiver.

A suitable test set is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics. The test fiber called out for 10GBASE-BRx is not needed to characterize the receiver input signal; nor is it used during testing.

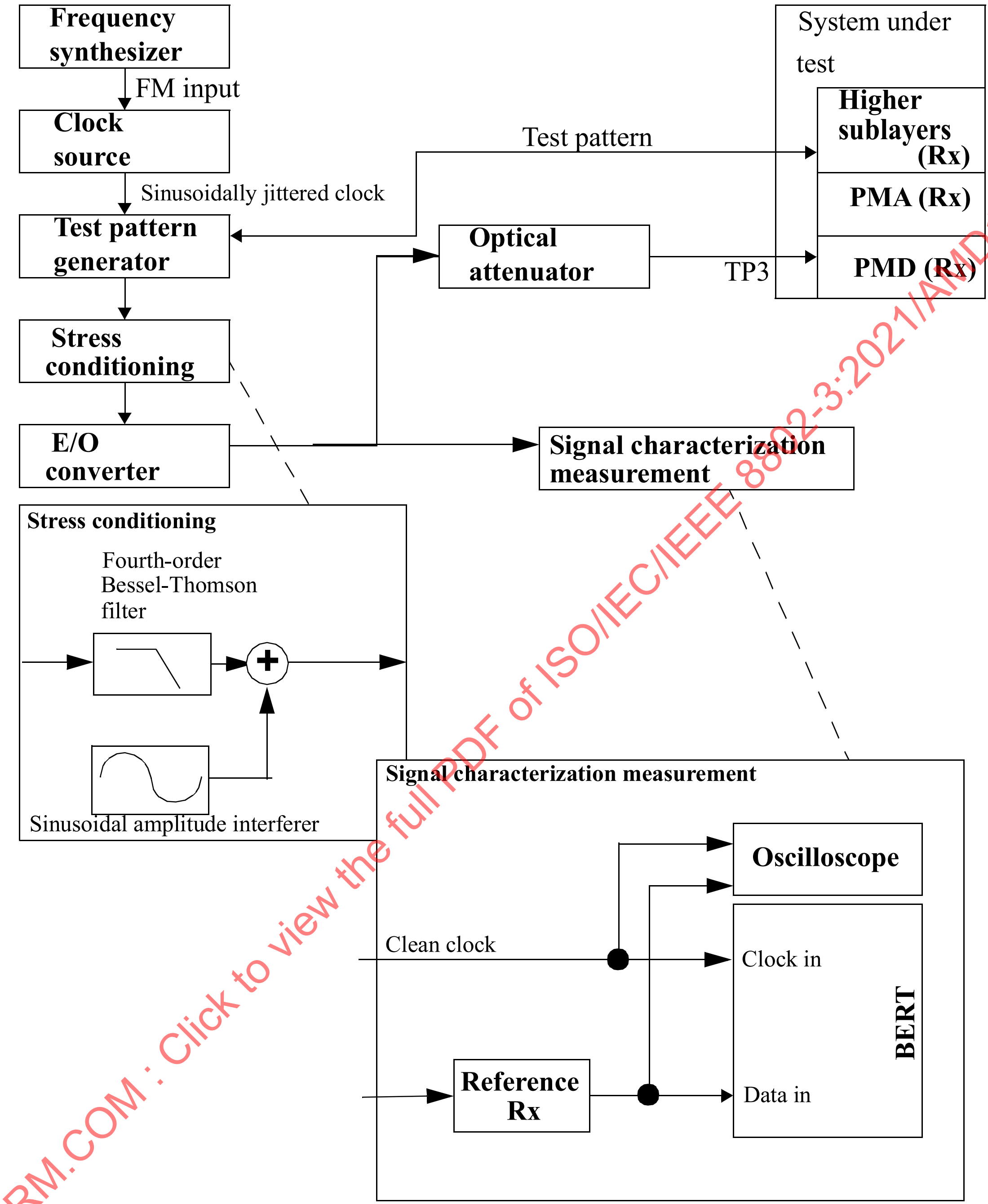


Figure 158–3—Stressed receiver conformance test block diagram

The fourth-order Bessel-Thomson filter is used to create ISI-induced vertical eye closure penalty (VECP). The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the slowed edge rates from the filter, also causes jitter. The nature of the jitter is intended to emulate instantaneous bit shrinkage that can occur with DDJ. This type of jitter cannot be created by simple phase modulation. The sinusoidal phase modulation represents other forms of jitter and also verifies that the receiver under test can track low-frequency jitter. The frequency of the sinusoidal interference may be set at any frequency between 100 MHz and 2 GHz, although care should be taken to avoid a harmonic relationship between the sinusoidal interference, the sinusoidal jitter, the data rate, and the pattern repetition rate.

For improved visibility for calibration, it is imperative that the Bessel-Thomson filter and all other elements in the signal path (cables, DC blocks, E/O converter, etc.) have wide and smooth frequency response and linear phase response throughout the spectrum of interest. Baseline wander and overshoot and undershoot should be minimized. If this is achieved, then data dependent effects should be minimal, and short data patterns can be used for calibration with the benefit of providing much improved trace visibility on sampling oscilloscopes. Actual patterns for testing the receiver shall be as specified in Table 158–11.

To further improve visibility for calibration, random noise effects, such as RIN and random clock jitter, should also be minimized. A small amount of residual noise and jitter from all sources is unavoidable, but should be less than 0.25 UI peak-peak of jitter at the 10^{-12} points.

The Bessel-Thomson filter and the E/O converter should have the appropriate frequency response to result in the appropriate level of initial ISI eye closure before the sinusoidal terms are added. The E/O converter should be fast and linear such that the waveshape and edge rates are predominantly controlled or limited by the electrical circuitry. Electrical summing requires high linearity of all elements including the E/O converter. Summing with an optical coupler after the E/O converter is an option that eases linearity requirements, but requires a second source for the interfering signal, complicates settings of extinction ratio, and adds more RIN.

The vertical and horizontal eye closures to be used for receiver conformance testing are verified using an optical reference receiver with a 7.5 GHz fourth-order ideal Bessel-Thomson response. Use of ITU-T G.691 tolerance filters may significantly degrade this calibration. Care should be taken to ensure that all the light from the fiber is collected by the fast photodetector and that there is negligible mode selective loss, especially in the optical attenuator and the optical coupler, if used.

The clock output from the clock source in Figure 158–3 is modulated with the sinusoidal jitter. To use an oscilloscope to calibrate the final stressed eye jitter that includes the sinusoidal jitter component, a separate clock source (clean clock of Figure 158–3) is required that is synchronized to the source clock, but not modulated with the jitter source.

158.8.9.1.2 Parameter definitions

The primary parameters of the conformance test signal are vertical eye closure penalty (VECP) and stressed eye jitter, J. Vertical eye closure penalty is measured at the time center of the eye (halfway between 0 and 1 on the unit interval scale as defined in 158.8.7) and is calculated relative to the measured OMA value. J is defined from the 0.5th to the 99.5th percentile of the jitter histogram. J is measured at the average optical power, which can be obtained with AC-coupling. The values of these components are defined by their histogram results.

The vertical eye closure penalty is given by Equation (158–1).

$$\text{Vertical eye closure penalty [dB, optical]} = 10 \times \log\frac{OMA}{A_O} \qquad (158\text{–}1)$$

where

A_O is the amplitude of the eye opening from the 99.95th percentile of the lower histogram to the 0.05th percentile of the upper histogram.
OMA is the normal amplitude without ISI, as shown in Figure 158–4.

158.8.9.1.3 Stressed receiver conformance test signal characteristics and calibration

The conformance test signal is used to validate that the PMD receiver meets BER requirements with near worst case waveforms including pulse width shrinkage, power, simulated channel penalties, and a swept frequency sinusoidal jitter contribution applied at TP3.

Signal characteristics are described below along with a suggested approach for calibration.

The test signal includes vertical eye closure and high-probability jitter components. For this test, these two components are defined by peak values that include all but 0.1% for VECP and all but 1% for jitter of their histograms. Histograms should include at least 10 000 hits, and should be about 1% width in the direction not being measured. Residual low-probability noise and jitter should be minimized—that is, the outer slopes of the final histograms should be as steep as possible down to very low probabilities.

The following steps describe a suggested method for calibrating a stressed eye generator:

1) Set the signaling speed of the test pattern generator to satisfy the requirements of 158.6.2.
2) Turn on the calibration pattern. A short pattern may be used for calibration if the conditions described in 158.8.9.1.1 are met, but this increases the risk that the longer test pattern used during testing over-stresses the device under test. In any case, a pattern shorter than PRBS10 is not recommended.
3) Set the extinction ratio to approximately the "Extinction ratio (min)" value given in 158.6.1. Sinusoidal interference and jitter signals should be turned off at this point. If optical summing is used, the extinction ratio may need to be adjusted after the sinusoidal interference signal is added below.
4) Measure the OMA of the test signal (without attenuation). OMA is measured per the method in 158.8.5 using the square wave pattern.
5) The requirements for vertical eye closure and jitter of the stressed eye test signal are given by the Vertical eye closure penalty (VECP) and Stressed eye jitter (J) values given in Table 158–7.

   There are three components involved in calibration for vertical eye closure and J. These are a linear phase filter, sinusoidal interference, and sinusoidal jitter.

   Without sinusoidal jitter or sinusoidal interference, greater than two thirds of the vertical eye closure penalty value should be created by use of a linear phase, low jitter filter (such as Bessel-Thomson). The filter should be tested with the prescribed test patterns to verify that residual jitter and baseline wander are small, not to exceed 0.25 UI peak-peak. If not, the stress may be more than desired, leading to conservative results. However, compensation is not allowed. Once done, revert to the calibration pattern, if different than the final test pattern specified in Table 158–11.

   Any remaining vertical eye closure required should be created with sinusoidal interference or sinusoidal jitter.

   Sinusoidal jitter (phase modulation) should be added per the template of Table 158–12. For calibration purposes, sinusoidal jitter frequencies should be well within the flat portion of the template greater than 4 MHz.

   Iterate the settings for sinusoidal interference and/or jitter until all constraints are met, including jitter (J), vertical eye closure (VECP), and that sinusoidal jitter above 4 MHz is as specified in Table 158–12.

Verify that the optical power penalty for the stressed eye (relative to the reference transmitter per 158.8.10) is greater than or equal to VECP.

To emulate the effects of DCD or data-dependent jitter, at least 5 ps peak-to-peak of pulse shrinkage jitter should have been achieved.

6) Decrease the amplitude with the optical attenuator until the OMA complies with the OMA values given in Table 158–7 for 10GBASE-BRx. If high linearity exists, then the sinusoidal interference should not change the OMA value. OMA can be approximated with histograms as suggested in Figure 158–4. However, the normative definition for OMA is as given in 158.8.5.
7) For testing, turn on the actual required test pattern(s) per 158.8.1.

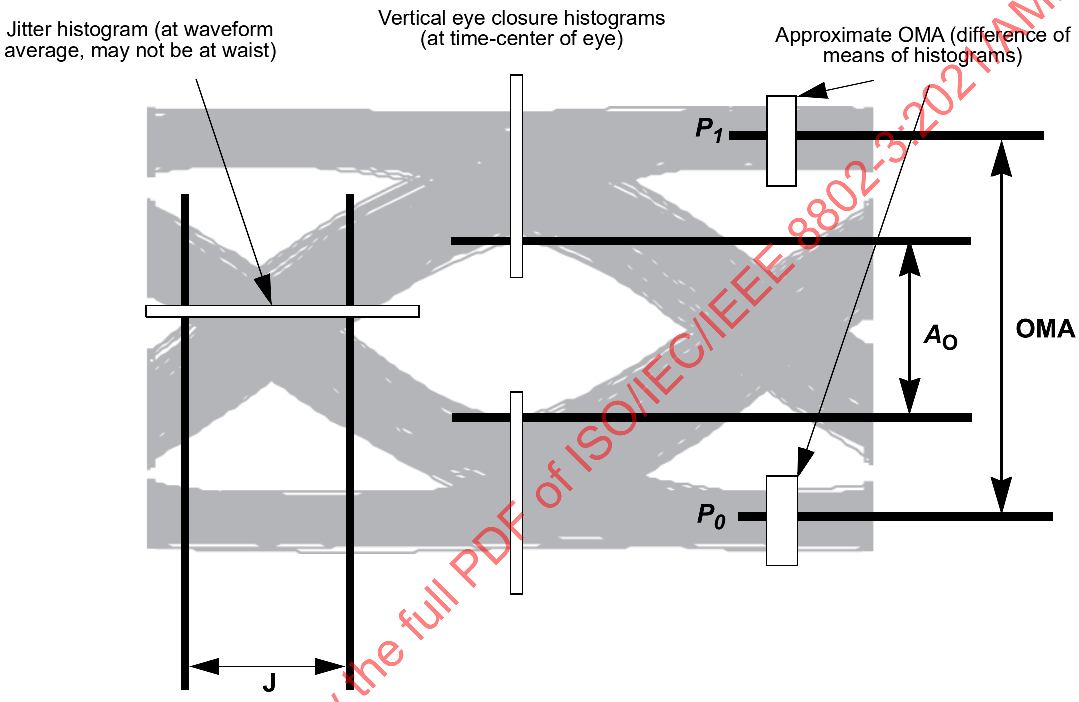


Figure 158–4—Required characteristics of the conformance test signal at TP3

Care should be taken when characterizing the signal used to make receiver tolerance measurements. In the case of a transmit jitter measurement, excessive and/or uncalibrated noise/jitter in the test system makes it more difficult to meet the specification and may have a negative impact on yield but does not effect interoperability. Running the receiver tolerance test with a signal that is under-stressed may result in the deployment of non-compliant receivers. Care should be taken to minimize and/or correct for the noise/jitter introduced by the reference receiver, filters, oscilloscope, and BERT. While the details of measurement and test equipment are beyond the scope of this standard, it is recommended that the implementer fully characterize the test equipment and apply appropriate guard bands to ensure that the receive input signal meets the specified requirements.

158.8.9.1.4 Stressed receiver conformance test procedure

The test apparatus is set up as described in 158.8.9.1.1, 158.8.9.1.2 and 158.8.9.1.3. The sinusoidal jitter is then stepped across the frequency and amplitude range specified in 158.8.9.1.5 while monitoring BER at the receiver. The BER is to be compliant for all jitter frequencies. This method does not result in values for jitter contributed by the receiver. A receiver meeting the requirements of this test is expected to operate with the worst-case optical input.

158.8.9.1.5 Sinusoidal jitter for receiver conformance test

The sinusoidal jitter is used to test receiver jitter tolerance. The amplitude of the applied sinusoidal jitter is dependent on frequency as specified in Table 158–12.

Table 158–12—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter, peak-to-peak (UI)
f < 40 kHz	Not specified
40 kHz < f ≤ 4 MHz	$2 \times 10^5 / f$
4 MHz < f < 10 *LB*[a]	0.05

[a] *LB* = loop bandwidth; upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

158.8.9.2 Stressed receiver sensitivity for 10GBASE-BR20

Stressed receiver sensitivity shall be within the limits given in Table 158–7 if measured using the method defined in 95.8.8 with the following exceptions:

a) The centers of the vertical histograms through the eye diagram are 0.45 UI and 0.55 UI, and the width of each histogram is 0.02 UI (see Figure 95–4).
b) Added sinusoidal jitter is as specified in Table 158–12.
c) The stressed eye J2 Jitter, stressed eye J4 Jitter, stressed eye closure, and SRS eye mask are as given in Table 158–7.
d) The test pattern is as given in Table 158–11.
e) The reference receiver used to verify the conformance test signal is required to have the bandwidth given in 158.8.7.
f) The SEC created by the selection of the appropriate bandwidth for the combination of the low-pass filter and the E/O converter with the sinusoidal jitter, sinusoidal interferer 1, sinusoidal interferer 2, and the Gaussian noise generator turned off is at least 1.5 dB.
g) The conditions for receiver aggressor lanes do not apply.
h) The reflectance of the optical link should be at its maximum level.

158.8.10 Transmitter and dispersion penalty (TDP)

Transmitter and dispersion penalty (TDP) shall be as defined in 52.9.10 with the BER as specified in 158.1.1. The measurement procedure for 10GBASE-BRx is detailed in 158.8.10.1 to 158.8.10.4.

158.8.10.1 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) The rise/fall times are less than 30 ps at 20% to 80%.
b) The output optical eye is symmetric and passes the eye mask test of 158.8.7.
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) Jitter less than 0.2 UI peak-peak.
e) RIN is minimized to less than –136 dB/Hz.

158.8.10.2 Channel requirements

The transmitter is tested using an optical channel that meets the requirements listed in Table 158–13.

Table 158–13—Transmitter compliance channel specifications

PMD Type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c] (max)
	Minimum	Maximum		
10GBASE-BR10	$0.23 \times \lambda \times [1 - (1324 / \lambda)^4]$	$0.23 \times \lambda \times [1 - (1300 / \lambda)^4]$	Minimum	12 dB
10GBASE-BR20	$0.46 \times \lambda \times [1 - (1324 / \lambda)^4]$	$0.46 \times \lambda \times [1 - (1300 / \lambda)^4]$	Minimum	21 dB
10GBASE-BR40	$0.92 \times \lambda \times [1 - (1324 / \lambda)^4]$	$0.92 \times \lambda \times [1 - (1300 / \lambda)^4]$	Minimum	21 dB

[a] The dispersion is measured for the wavelength of the device under test. The coefficient assumes 10 km for 10GBASE-BR10, 20 km for 10GBASE-BR20, and 40 km for 10GBASE-BR40. The link may be as short as 2 m, and the minimum or maximum dispersion may be 0.
[b] There is no intent to stress the sensitivity of the BERT's optical receiver.
[c] The optical return loss is applied at TP2.

A 10GBASE-BRx transmitter is to be compliant with a total dispersion at least as negative as the "minimum dispersion" and at least as positive as the "maximum dispersion" columns specified in Table 158–13 for the wavelength of the device under test. This may be achieved with channels consisting of fibers with lengths chosen to meet the dispersion requirements.

To verify that the fiber has the correct amount of dispersion, the measurement method defined in IEC 60793-1-42 may be used. The measurement is made in the linear power regime of the fiber.

The channel provides a maximum optical return loss specified in Table 158–13. The state of polarization of the back reflection is adjusted to create the greatest RIN. The method of 158.8.6 may be used.

158.8.10.3 Reference receiver requirements

The reference receiver is required to have the bandwidth given in 158.8.7. The sensitivity of the reference receiver is limited by Gaussian noise. The receiver has minimal threshold offset, deadband, hysteresis, baseline wander, deterministic jitter, or other distortions. Decision sampling is instantaneous with minimal uncertainty and setup/hold properties.

The nominal sensitivity of the reference receiver, S, is measured in OMA using the set up of Figure 52–12 without the test fiber and with the transversal filter removed. The sensitivity S must be corrected for any significant reference transmitter impairments including any vertical eye closure. It is measured while sampling at the eye center or corrected for off-center sampling. It is calibrated at the wavelength of the transmitter under test.

For all transmitter and dispersion penalty measurements, determination of the center of the eye is required. Center of the eye is defined as the time halfway between the left and right sampling points within the eye where the measured BER is greater than or equal to 10^{-3}.

The clock recovery unit (CRU) used in the TDP measurement has a corner frequency of 4 MHz and a slope of 20 dB/decade. When using a clock recovery unit as a clock for BER measurements, passing of low-frequency jitter from the data to the clock removes this low-frequency jitter from the measurement.

158.8.10.4 Test procedure

The test procedure is as defined in 52.9.10.4 with the BER as specified in 158.1.1.

158.9 Safety, installation, environment, and labeling

158.9.1 General safety

All equipment subject to this clause shall conform to the general safety requirements as specified in J.2.

158.9.2 Laser safety

10GBASE-BRx optical transceivers shall conform to Hazard Level 1 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.

Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation explicitly defines requirements and usage restrictions on the host system necessary to meet these safety certifications.[5]

158.9.3 Installation

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

158.9.4 Environment

Normative specifications in this clause shall be met by a system integrating a 10GBASE-BRx PMD over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

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

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

158.9.5 Electromagnetic emission

A system integrating a 10GBASE-BRx PMD shall comply with applicable local and national codes for the limitation of electromagnetic interference.

[5]A host system that fails to meet the manufacturer's requirements and/or usage restrictions may emit laser radiation in excess of the safety limits of one or more safety standards. In such a case, the host manufacturer is required to obtain its own laser safety certification.

158.9.6 Temperature, humidity, and handling

The optical link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

158.9.7 PMD labeling requirements

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., 10GBASE-BR10-D). Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 158.9.2.

158.10 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 158–5.

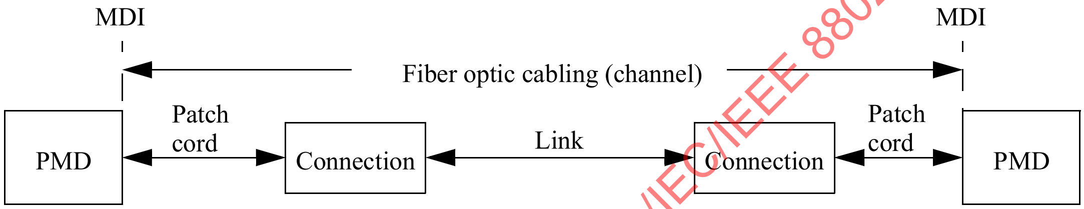


Figure 158–5—Fiber optic cabling model

The channel insertion loss is given in Table 158–8. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion, reflections, and polarization mode dispersion meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-7/method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

Table 158–14—Fiber optic cabling (channel) characteristics

Description	10GBASE-BR10	10GBASE-BR20	10GBASE-BR40	Unit
Operating distance (max)	10	20	40	km
Channel insertion loss[a, b](max)	6.2	15	18	dB
Channel insertion loss (min)	0	0	10	dB
Positive dispersion[b] (max)	35	70	141	ps/nm
Negative dispersion[b] (min)	–64	–127	–254	ps/nm
DGD_max[c]	10	10	10	ps
Optical return loss (min)	21	21	21	dB

[a] These channel insertion loss values include cable, connectors, and splices.
[b] Over the wavelength range 1260 nm to 1340 nm.
[c] Differential Group Delay (DGD) is 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. DGD_max is the maximum differential group delay that the system must tolerate.

158.11 Characteristics of the fiber optic cabling (channel)

The 10GBASE-BRx fiber optic cabling shall meet the specifications defined in Table 158–14. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together.

158.11.1 Optical fiber and cable

The optical fiber cable requirements are satisfied by cables containing ITU-T G.652.B (dispersion unshifted), type G.652.D (low water peak, dispersion unshifted), or type G.657.A1 or type G.657.A2 (bend insensitive) fibers or the requirements in Table 158–14 where they differ.

158.11.2 Optical fiber connection

An optical fiber connection, as shown in Figure 158–5, consists of a mated pair of optical connectors.

158.11.2.1 Connection insertion loss

The maximum link distances for single-mode fiber are calculated based on an allocation of 2 dB total connection and splice loss for 10GBASE-BR10 and 10GBASE-BR40. The maximum link distances for single-mode fiber are calculated based on an allocation of 5 dB total connection and splice loss for 10GBASE-BR20.

158.11.2.2 Maximum discrete reflectance

The maximum discrete reflectance for 10GBASE-BR10 shall be less than –20 dB.

The maximum discrete reflectance for 10GBASE-BR20 and 10GBASE-BR40 shall be less than –26 dB.

158.11.3 Medium Dependent Interface (MDI) requirements

The 10GBASE-BRx PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" (as shown in Figure 158–5). Examples of an MDI include the following:

a) Connectorized fiber pigtail.
b) PMD receptacle.

When the MDI is a connector plug and receptacle connection, it shall meet the interface performance specifications of IEC 61753-1-1, IEC 61753-021-2, and IEC 61753-022-2.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 158.5.1, not at the MDI.

158.12 Requirements for interoperation between 10GBASE-BRx PMDs

The 10GBASE-BR10 and 10GBASE-BR40 PMDs can interoperate with each other (over an engineered link) provided that the fiber optic cabling (channel) characteristics are met, with the exception of the maximum and minimum channel insertion loss values, which are given in Table 158–15 for the two link directions separately. Attenuators may be used to achieve the required losses.

Table 158–15—Channel insertion loss requirements for interoperation between 10GBASE-BR10 and 10GBASE-BR40

Direction	Min loss	Max loss	Unit
10GBASE-BR10 transmitter to 10GBASE-BR40 receiver	7.5	12.8	dB
10GBASE-BR40 transmitter to10GBASE-BR10 receiver	2.5	11.6	dB

158.13 Protocol implementation conformance statement (PICS) proforma for Clause 158, Physical Medium Dependent (PMD) sublayer and medium, types 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40[6]

158.13.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 158, Physical Medium Dependent (PMD) sublayer and medium, types 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40, shall complete the following protocol implementation conformance statement (PICS) proforma.

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

158.13.2 Identification

158.13.2.1 Implementation identification

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

158.13.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3cp-2021, Clause 158, Physical Medium Dependent (PMD) sublayer and medium, types 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40
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 802.3cp-2021.)	

Date of Statement	

[6] *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.

158.13.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*BR10	10GBASE-BR10 PMD	158.6	Device supports requirements for 10GBASE-BR10 PHY	O.1	Yes [ ] No [ ]
*BR20	10GBASE-BR20 PMD	158.6	Device supports requirements for 10GBASE-BR20 PHY	O.1	Yes [ ] No [ ]
*BR40	10GBASE-BR40 PMD	158.6	Device supports requirements for 10GBASE-BR40 PHY	O.1	Yes [ ] No [ ]
*INS	Installation / cable	158.10	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	158.5.1	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	158.5.1	This point may be made available for use by implementers to certify component conformance	O	Yes [ ] No [ ]
DC	Delay constraints	158.3	Device conforms to delay constraints	M	Yes [ ]
*MD	MDIO capability	158.4	Registers and interface supported	O	Yes [ ] No [ ]

158.13.4 PICS proforma tables for PMD sublayer and medium, types 10GBASE-BR10, 10GBASE-BR20, and 10GBASE-BR40

158.13.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
F1	Compatible with 10GBASE-R PCS and PMA	158.1		M	Yes [ ]
F2	Integration with management functions	158.1		O	Yes [ ] No [ ]
F3	Bit error ratio	158.1.1	Meets the BER specified in 158.1.1	M	Yes [ ]
F4	Transmit function	158.5.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
F5	Mapping between optical signal and logical signal for transmitter	158.5.2	Higher optical power is a one	M	Yes [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
F6	Receive function	158.5.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
F7	Conversion of optical signal to electrical signal	158.5.3	For delivery to the PMD service interface	M	Yes [ ]
F8	Mapping between optical signal and logical signal for receiver	158.5.3	Higher optical power is a one	M	Yes [ ]
F9	Global Signal Detect function	158.5.4	Report to the PMD service interface the message PMD:IS_SIGNAL.indication (SIGNAL_DETECT)	M	Yes [ ]
F10	Global Signal Detect behavior	158.5.4	SIGNAL_DETECT is a global indicator of the presence of an optical signal	M	Yes [ ]
F11	PMD reset function	158.5.5	Resets the PMD sublayer	MD:O	Yes [ ] No [ ] N/A [ ]
F12	Jitter	158.7	Meets the specifications defined in 158.7	M	Yes [ ]
F13	ONU silent start	158.5.10	Meets the specifications defined in 158.5.10	M	Yes [ ]

158.13.4.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
M1	Management register set	158.4		MD:M	Yes [ ] N/A [ ]
M2	Global transmit disable function	158.5.6	Disables the optical transmitter with the PMD_global_transmit_disable variable	M	Yes [ ]
M3	PMD_receive_fault function	158.5.9	PMD_receive_fault is the logical OR of NOT SIGNAL_DETECT and any implementation specific fault	MD:O	Yes [ ] No [ ] N/A [ ]

158.13.4.3 PMD to MDI optical specifications for 10GBASE-BR10

Item	Feature	Subclause	Value/Comment	Status	Support
BR101	Transmitter meets specifications in Table 158–6	158.6.1	Per measurement techniques defined in 158.8	BR10:M	Yes [ ] N/A [ ]
BR102	Receiver meets specifications in Table 158–7	158.6.2	Per measurement techniques defined in 158.8	BR10:M	Yes [ ] N/A [ ]

158.13.4.4 PMD to MDI optical specifications for 10GBASE-BR20

Item	Feature	Subclause	Value/Comment	Status	Support
BR201	Transmitter meets specifications in Table 158–6	158.6.1	Per measurement techniques defined in 158.8	BR20:M	Yes [ ] N/A [ ]
BR202	Receiver meets specifications in Table 158–7	158.6.2	Per measurement techniques defined in 158.8	BR20:M	Yes [ ] N/A [ ]

158.13.4.5 PMD to MDI optical specifications for 10GBASE-BR40

Item	Feature	Subclause	Value/Comment	Status	Support
BR401	Transmitter meets specifications in Table 158–6	158.6.1	Per measurement techniques defined in 158.8	BR40:M	Yes [ ] N/A [ ]
BR402	Receiver meets specifications in Table 158–7	158.6.2	Per measurement techniques defined in 158.8	BR40:M	Yes [ ] N/A [ ]

158.13.4.6 Optical measurement methods

Item	Feature	Subclause	Value/Comment	Status	Support
M1	General measurement	158.8	Meets the specifications defined in 158.8	M	Yes [ ]

158.13.4.7 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	158.9.1	Conforms to J.2	M	Yes [ ]
ES2	Laser safety —IEC Hazard Level 1	158.9.2	Conforms to Hazard Level 1 laser requirements defined in IEC 60825-1 and IEC 60825-2	M	Yes [ ]
ES3	Electromagnetic interference	158.9.5	Complies with applicable local and national codes for the limitation of electromagnetic interference	M	Yes [ ]

158.13.4.8 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
OC1	Fiber optic cabling	158.11	Meets the specifications defined in Table 158–14	INS: M	Yes [ ] N/A [ ]
OC2	Maximum discrete reflectance	158.11.2.2	Less than –20 dB for 10GBASE-BR10, less than –26 dB for 10GBASE-BR20 and 10GBASE-BR40	INS: M	Yes [ ] N/A [ ]
OC3	MDI requirements	158.11.3	Meets IEC 61753-1-1, IEC 61753-021-2, and IEC 61753-022-2	INS: M	Yes [ ] N/A [ ]

159. Physical Medium Dependent (PMD) sublayer and medium, types 25GBASE-BR10, 25GBASE-BR20, and 25GBASE-BR40

159.1 Overview

This clause specifies the 25GBASE-BR10, 25GBASE-BR20, and 25GBASE-BR40 PMDs together with the single-mode fiber medium. Within this clause these PMDs are jointly referred to by the term 25GBASE-BRx. The 25GBASE-BRx PHYs are divided into two variants based on the direction of transmission. Optical line terminal (OLT) PMDs transmit in the downstream direction and receive in the upstream direction. Optical network unit (ONU) PHYs transmit in the upstream direction and receive in the downstream direction. The PMD variant is indicated with a suffix of D for OLT PMDs and U for ONU PMDs. The PMD sublayer provides a point-to-point 25 Gb/s Ethernet link over one single-mode fiber. When forming a complete Physical Layer, a PMD shall be connected to the appropriate PMA as shown in Table 159–1, 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 159–1—Physical Layer clauses associated with the 25GBASE-BRx PMDs

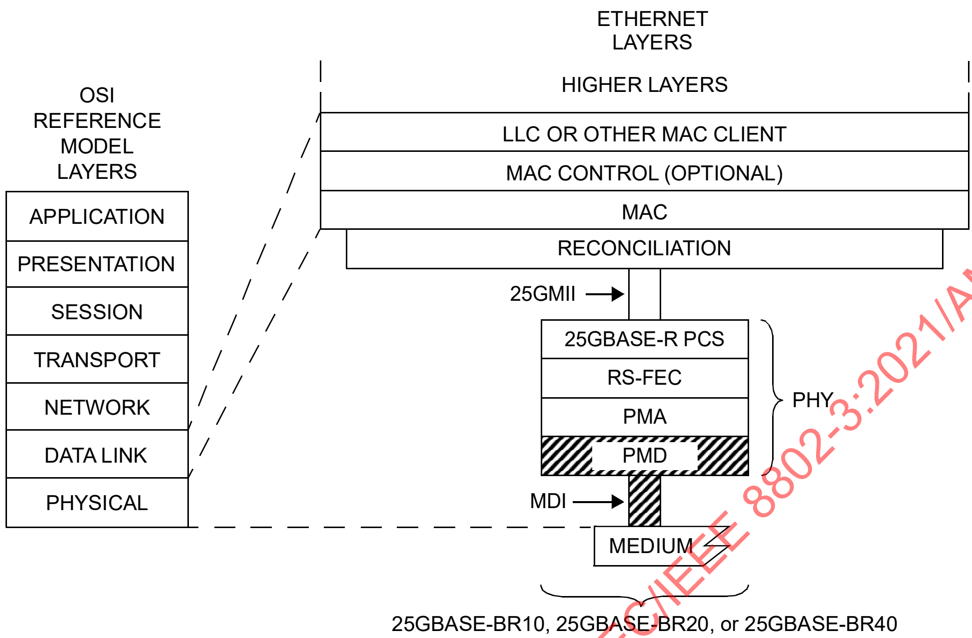
Associated clause	25GBASE-BR10, 25GBASE-BR20, 25GBASE-BR40
106—RS	Required
106—25GMII[a]	Optional
107—PCS for 25GBASE-R	Required
108—RS-FEC[b]	Required
109—PMA for 25GBASE-R	Required
109A—25GAUI C2C	Optional
109B—25GAUI C2M	Optional
78—Energy-Efficient Ethernet	Optional

[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 159–1 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.

The 25GBASE-BRx 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

Figure 159–1—25GBASE-BRx PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

159.1.1 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 1.4.275) 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.

159.2 Physical Medium Dependent (PMD) service interface

The PMD service interfaces for 25GBASE-BRx are the same as PMD service interface for 25GBASE-SR as described in 112.2 with the BER as specified in 159.1.1.

159.3 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 a 25GBASE-BRx 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.

159.4 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 159–2 and the mapping of MDIO status variables to PMD status variables shall be as shown in Table 159–3.

Table 159–2—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 159–3—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

159.5 PMD functional specifications

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

159.5.1 PMD block diagram

The PMD block diagram is shown in Figure 159–2. 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 159.7 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 159.7 are made at TP3. TP1 and TP4 are informative reference points that may be useful to implementers for testing components (these test points are not typically accessible in an implemented system).

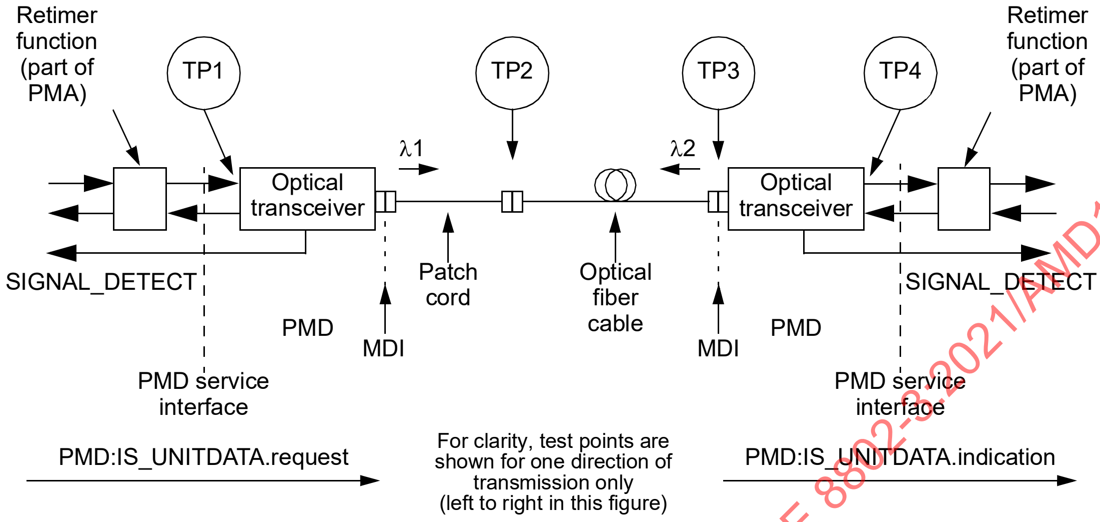


Figure 159–2—Block diagram for 25GBASE-BRx transmit/receive paths

159.5.2 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. The optical signal 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 shall correspond to tx_bit = one.

159.5.3 PMD receive function

The PMD Receive function shall convert the optical signal 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 shall correspond to rx_bit = one.

159.5.4 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 159–4. The PMD receiver is not required to verify whether a compliant 25GBASE-BRx signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Table 159–4—SIGNAL_DETECT value definition

Receive conditions	SIGNAL_DETECT value
Average optical power at TP3 ≤ –20 dBm for 25GBASE-BR10 and ≤ –26 dBm for 25GBASE-BR20 and 25GBASE-BR40	FAIL
[(Optical power at TP3 ≥ receiver sensitivity (max) in OMA in Table 159–7) AND (compliant 25GBASE–BRx signal input)]	OK
All other conditions	Unspecified

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 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 159–4.

159.5.5 PMD reset function

If PMD_reset is asserted, the PMD shall be reset as defined in 45.2.1.1.1.

159.5.6 PMD global transmit disable function

PMDs compliant with this clause shall include the PMD global transmit disable function that allows the optical transmitter to be disabled.

When the PMD_global_transmit_disable variable 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 159–6.

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

159.5.7 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.

159.5.8 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.

PMD_transmit_fault shall be mapped to the transmit fault bit as specified in 45.2.1.7.4.

159.5.9 PMD receive fault function

The 25GBASE-BRx-U PMD shall include the PMD_receive_fault function, in the 25GBASE-BRx-D PMD this function is optional. If the PMD has detected a local fault on the receiver, the PMD shall set PMD_receive_fault to one.

PMD_receive_fault shall be mapped to the receive fault bit as specified in 45.2.1.7.5.

159.5.10 ONU silent start

Silent start shall be provided by 25GBASE-BR10-U, 25GBASE-BR20-U, and 25GBASE-BR40-U PHYs. See 157.5.

159.6 PMD to MDI optical specifications for 25GBASE-BRx

The operating ranges for the 25GBASE-BRx PMDs are defined in Table 159–5. 25GBASE-BRx compliant PMDs operate on ITU-T G.652.B (dispersion unshifted), type G.652.D (low water peak, dispersion unshifted), or type G.657.A1 or type G.657.A2 (bend insensitive) single-mode fibers according to the specifications defined in 159.7. A PMD that exceeds the operating range requirement while meeting all other optical specifications is considered compliant (e.g., a 25GBASE-BR10 PMD operating at 12.5 km meets the operating range requirement of 2 m to 10 km).

Table 159–5—25GBASE-BRx operating ranges

PMD type	Required operating range[a]
25GBASE-BR10	2 m to 10 km
25GBASE-BR20	2 m to 20 km
25GBASE-BR40	2 m to 40 km

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

159.6.1 25GBASE-BRx transmitter optical specifications

The 25GBASE-BRx transmitters shall meet the specifications in Table 159–6 per the definitions in 159.7.

Table 159–6—25GBASE-BRx transmit characteristics

Description	25GBASE-BR10	25GBASE-BR20	25GBASE-BR40	Unit
Signaling rate (range)	25.78125 ± 100 ppm			GBd
25GBASE-BRx-D center wavelength (range)	1320 to 1340	1306 to 1322		nm
25GBASE-BRx-U center wavelength (range)	1260 to 1280	1281 to 1297		nm
Side-mode suppression ratio (SMSR), (min)	30			dB
Average launch power (max)	2	0	6	dBm
Average launch power[a] (min)	–7	–7.5	–3	dBm
Optical Modulation Amplitude (OMA), (max)	2.2	3	6	dBm
Optical Modulation Amplitude (OMA)[b], (min)	–4	–4.5	0	dBm
Launch power in OMA minus TDP (min)	–5	–5.5	–1	dBm
Transmitter and dispersion penalty (TDP), (max)	2.7			dB
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] The OMA (min) requirement holds even if the TDP < 1 dB.
[c] Transmitter reflectance is defined looking into the transmitter.

159.6.2 25GBASE-BRx receiver optical specifications

The 25GBASE-BRx receivers shall meet the specifications in Table 159–7 per the definitions in 159.7.

Table 159–7—25GBASE-BRx receive characteristics

Description	25GBASE-BR10	25GBASE-BR20	25GBASE-BR40	Unit
Signaling rate (range)	25.78125 ± 100 ppm			GBd
25GBASE-BRx-D center wavelength (range)	1260 to 1280	1281 to 1297		nm
25GBASE-BRx-U center wavelength (range)	1320 to 1340	1306 to 1322		nm
Damage threshold[a] (min)	3	1	–3	dBm
Average receive power (max)	2	0	–4	dBm
Average receive power[b] (min)	–13.3	–22.5	–21	dBm
Receive power (OMA), (max)	2.2	–4		dBm
Receiver reflectance (max)	–26			dB
Receiver sensitivity (OMA)[c], (max)	–12	–20.5	–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			dB
Stressed eye J2 Jitter[e]	0.27			UI
Stressed eye J4 Jitter[e]	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 159.7) for the BER specified in 159.1.1.
[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.

159.6.3 25GBASE-BRx illustrative link power budgets

Illustrative power budgets and penalties for 25GBASE-BRx channels are shown in Table 159–8.

Table 159–8—25GBASE-BRx illustrative link power budgets

Parameter	25GBASE-BR10	25GBASE-BR20	25GBASE-BR40	Unit
Power budget (for maximum TDP)	9	17.7	20.7	dB
Operating distance	10	20	40	km
Channel insertion loss	6.3[a]	15[b]	18[a]	dB
Maximum discrete reflectance	See 159.10	–26		dB
Allocation for penalties[c] (for maximum TDP)	2.7			dB

[a] The channel insertion loss is calculated using the maximum distance specified in Table 159–5 and fiber attenuation of 0.4 dB/km plus an allocation for connection and splice loss given in 159.10.2.1.
[b] The channel insertion loss is calculated using the maximum distance specified in Table 159–5 and fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 159.10.2.1.
[c] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

159.7 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.

159.7.1 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 159–9, 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-BRx. The multi-lane testing considerations described in 95.8.1.1 do not apply. Table 159–9 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.

159.7.2 Wavelength and side-mode suppression ratio (SMSR)

The wavelength and SMSR shall be within the ranges given in Table 159–6 if measured per IEC 61280-1-3. The signal is modulated using the test pattern specified in Table 159–9.

159.7.3 Average optical power

The average optical power shall be within the limits given in Table 159–6 if measured using the methods given in IEC 61280-1-1. The average optical power is measured using the test pattern specified in Table 159–9.

159.7.4 Optical Modulation Amplitude (OMA)

OMA shall meet the requirements in Table 159–6 when measured using the method defined in 52.9.5. See 159.7.1 for test pattern information.

Table 159–9—Test pattern definitions and related subclauses

Test	Pattern	Related subclause
Wavelength	3, 5 or valid 25GBASE-R signal	159.7.2
Side-mode suppression ratio	3, 5 or valid 25GBASE-R signal	159.7.2
Average optical power	3, 5 or valid 25GBASE-R signal	159.7.3
Optical modulation amplitude (OMA)	Square wave or 4	159.7.4
Transmitter and dispersion penalty (TDP)	3, 5 or valid 25GBASE-R signal	159.7.5
Extinction ratio	3, 5 or valid 25GBASE-R signal	159.7.6
$RIN_{20}OMA$	Square wave or 4	159.7.7
Transmitter optical waveform	3, 5 or valid 25GBASE-R signal	159.7.8
Stressed receiver sensitivity	3, 5 or valid 25GBASE-R signal	159.7.10
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

159.7.5 Transmitter and dispersion penalty (TDP)

Transmitter and dispersion penalty (TDP) shall be as defined in 52.9.10 with the BER as specified in 159.1.1. The measurement procedure for 25GBASE-BRx is detailed in 159.7.5.1 to 159.7.5.4.

159.7.5.1 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 159.7.8.
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.

159.7.5.2 Channel requirements

The channel requirements for testing the transmitter are described in 88.8.5.2, where the requirements for 100GBASE-LR4 apply to 25GBASE-BR10 and the requirements for 100GBASE-ER4 apply to 25GBASE-BR20 and 25GBASE-BR40.

159.7.5.3 Reference receiver requirements

The reference receiver is required to have the bandwidth given in 159.7.8. The sensitivity of the reference receiver is limited by Gaussian noise. The receiver has minimal threshold offset, deadband, hysteresis, baseline wander, deterministic jitter, or other distortions. Decision sampling has minimal uncertainty and setup/hold times.

The nominal sensitivity of the reference receiver, S, is measured in OMA using the setup of Figure 52–12 without the test fiber and with the transversal filter removed. The sensitivity S must be corrected for any significant reference transmitter impairments including any vertical eye closure. It is measured while sampling at the eye center or corrected for off-center sampling. It is calibrated at the wavelength of the transmitter under test.

For all transmitter and dispersion penalty measurements, determination of the center of the eye is required. Center of the eye is defined as the time halfway between the left and right sampling points within the eye where the measured BER is greater than or equal to 10^{-3}.

The clock recovery unit (CRU) used in the TDP measurement has a corner frequency of 10 MHz and a slope of 20 dB/decade. When using a clock recovery unit as a clock for BER measurements, passing of low-frequency jitter from the data to the clock removes this low-frequency jitter from the measurement.

159.7.5.4 Test procedure

The test procedure is as defined in 52.9.10.4 with the BER as specified in 159.1.1.

159.7.6 Extinction ratio

The extinction ratio shall be within the limits given in Table 159–6 if measured using the methods specified in IEC 61280-2-2. The extinction ratio is measured using the test pattern defined in Table 159–9.

NOTE—Extinction ratio and OMA are defined with different test patterns (see Table 159–9).

159.7.7 Relative Intensity Noise ($RIN_{20}OMA$)

RIN shall be as defined by the measurement methodology of 52.9.6 with the following exceptions:

a) The optical return loss is 20 dB.
b) The upper –3 dB limit of the measurement apparatus is to be approximately equal to the signaling rate (i.e., 25.8 GHz).

159.7.8 Transmitter optical waveform (transmit eye)

The required optical transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 86–4. The transmitter optical waveform of a port transmitting the test pattern specified in Table 159–9 shall meet specifications according to the methods specified in 86.8.4.6.1 with the exception that the clock recovery unit's high-frequency corner bandwidth is 10 MHz. The filter nominal reference frequency f_r is 19.34 GHz and the filter tolerances are as specified for STM-64 in ITU-T G.691. Compensation may be made for variation of the reference receiver filter response from an ideal fourth-order Bessel-Thomson response and for any excess reference receiver noise.

159.7.9 Receiver sensitivity

Receiver sensitivity, which is defined for an ideal input signal, is informative and compliance is not required. If measured, the test signal should have negligible impairments such as intersymbol interference (ISI), rise/fall times, jitter and RIN. Instead, the normative requirement for receivers is stressed receiver sensitivity.

159.7.10 Stressed receiver sensitivity

Stressed receiver sensitivity shall be within the limits given in Table 159–7 if measured using the method defined in 95.8.8 with the following exceptions:

a) The centers of the vertical histograms through the eye diagram are 0.45 UI and 0.55 UI, and the width of each histogram is 0.02 UI (see Figure 95–4).
b) Added sinusoidal jitter is as specified in Table 159–10.
c) The stressed eye J2 Jitter, stressed eye J4 Jitter, stressed eye closure, and SRS eye mask are as given in Table 159–7.
d) The test pattern is as given in Table 159–9.
e) The reference receiver used to verify the conformance test signal is required to have the bandwidth given in 159.7.8.
f) The SEC created by the selection of the appropriate bandwidth for the combination of the low-pass filter and the E/O converter with the sinusoidal jitter, sinusoidal interferer 1, sinusoidal interferer 2, and the Gaussian noise generator turned off is at least 1.5 dB.
g) The conditions for receiver aggressor lanes do not apply.
h) The reflectance of the optical link should be at its maximum level.

Table 159–10—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter, peak-to-peak (UI)
f < 100 kHz	Not specified
100 kHz < f ≤ 10 MHz	$5 \times 10^5 / f$
10 MHz < f < 10 LB[a]	0.05

[a] LB = loop bandwidth; upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

159.8 Safety, installation, environment, and labeling

159.8.1 General safety

All equipment subject to this clause shall conform to the general safety requirements as specified in J.2.

159.8.2 Laser safety

25GBASE-BRx optical transceivers shall conform to Hazard Level 1 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.

Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation explicitly defines requirements and usage restrictions on the host system necessary to meet these safety certifications.[7]

[7] A host system that fails to meet the manufacturer's requirements and/or usage restrictions may emit laser radiation in excess of the safety limits of one or more safety standards. In such a case, the host manufacturer is required to obtain its own laser safety certification.

159.8.3 Installation

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

159.8.4 Environment

Normative specifications in this clause shall be met by a system integrating a 25GBASE-BRx PMD over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

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

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

159.8.5 Electromagnetic emission

A system integrating a 25GBASE-BRx PMD shall comply with applicable local and national codes for the limitation of electromagnetic interference.

159.8.6 Temperature, humidity, and handling

The optical link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

159.8.7 PMD labeling requirements

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., 25GBASE-BR10-D). Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 159.8.2.

159.9 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 159–3.

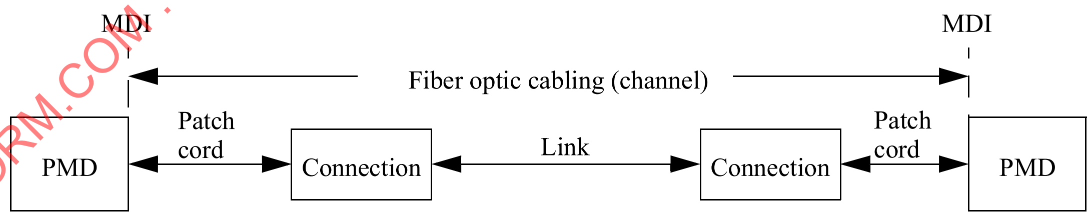


Figure 159–3—Fiber optic cabling model

The channel insertion loss is given in Table 159–8. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion, reflections, and polarization mode dispersion meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-7/method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards. The maximum channel insertion loss for 25GBASE-BR40 is specified by Table 159–11.

Table 159–11—Maximum channel insertion loss versus number of discrete reflectances for 25GBASE-BR40

Maximum channel insertion loss (dB)		Number of discrete reflectances > –55 dB and ≤ –35 dB										
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Number of discrete reflectances > –35 dB and ≤ –26 dB	**0**	18	18	18	17.9	17.9	17.9	17.8	17.8	17.8	17.7	17.7
	1	17.9	17.9	17.9	17.8	17.8	17.7	17.7	17.6	17.6	17.5	—[a]
	2	17.8	17.8	17.7	17.7	17.6	17.6	17.5	17.4	17.4	—[a]	—[a]
	3	17.7	17.6	17.6	17.4	17.4	17.3	—[a]	—[a]	—[a]	—[a]	—[a]
	4	17.5	17.4	17.3	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]
	> 4	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]

[a]The indicated combination of reflectances is not supported.

159.10 Characteristics of the fiber optic cabling (channel)

The 25GBASE-BRx fiber optic cabling shall meet the specifications defined in Table 159–12. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together.

Table 159–12—Fiber optic cabling (channel) characteristics

Description	25GBASE-BR10	25GBASE-BR20	25GBASE-BR40	Unit
Operating distance (max)	10	20	40	km
Channel insertion loss[a, b] (max)	6.2	15	18	dB
Channel insertion loss (min)	0	0	10	dB
Positive dispersion[b] (max)	35	38.5	79	ps/nm
Negative dispersion[b] (min)	–64	–83	–166	ps/nm
DGD_max[c]	8	10.3	10.3	ps
Optical return loss (min)	21	21	21	dB

[a] These channel insertion loss values include cable, connectors, and splices.
[b] Over the wavelength range 1260 nm to 1340 nm for 25GBASE-BR10 and 1281 nm to 1322 nm for 25GBASE-BR20 and 25GBASE-BR40.
[c] Differential Group Delay (DGD) is 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. DGD_max is the maximum differential group delay that the system must tolerate.

159.10.1 Optical fiber cable

The optical fiber cable requirements are satisfied by cables containing ITU-T G.652.B (dispersion unshifted), type G.652.D (low water peak, dispersion unshifted), or type G.657.A1 or type G.657.A2 (bend insensitive) fibers or the requirements in Table 159–12 where they differ.

159.10.2 Optical fiber connection

An optical fiber connection, as shown in Figure 159–3, consists of a mated pair of optical connectors.

159.10.2.1 Connection insertion loss

Connections with different loss characteristics may be used provided the requirements of Table 159–12 are met. The maximum link distance for 25GBASE-BR10 and 25GBASE-BR40 is based on an allocation of 2 dB total connection and splice loss. The maximum link distance for 25GBASE-BR20 is based on an allocation of 5 dB total connection and splice loss.

159.10.2.2 Maximum discrete reflectance

For 25GBASE-BR10, the maximum value for each discrete reflectance shall be less than or equal to the value shown in Table 159–13 corresponding to the number of discrete reflectances above –55 dB within the channel.

For 25GBASE-BR40, the maximum value of channel insertion loss is dependent on the number and maximum value of the discrete reflectances within the channel as given in Table 159–11. Discrete reflectances below –55 dB may be ignored when determining the supported channel insertion loss.

Table 159–13—Maximum value of each discrete reflectance for 25GBASE-BR10

Number of discrete reflectances above –55 dB[a]	Maximum value for each discrete reflectance for 25GBASE-BR10
1 to 4	–26 dB
6	–30 dB
8	–32 dB
10	–34 dB

[a] For numbers of discrete reflectances in between two numbers shown in the table, the lower of the two corresponding maximum discrete reflectance values applies.

159.10.3 Medium Dependent Interface (MDI) requirements

The 25GBASE-BRx PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the “fiber optic cabling” (as shown in Figure 159–3). Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

When the MDI is a connector plug and receptacle connection, it shall meet the interface performance specifications of IEC 61753-1-1 and IEC 61753-021-2.

NOTE—Transmitter compliance testing is performed at TP2 as defined in 159.5.1, not at the MDI.

159.11 Requirements for interoperation between 25GBASE-BRx PMDs

The 25GBASE-BR20 and 25GBASE-BR40 PMDs can interoperate with each other (over an engineered link) provided that the fiber optic cabling (channel) characteristics are met, with the exception of the maximum and minimum channel insertion loss values, which are given in Table 159–14 for the two link directions separately. Attenuators may be used to achieve the required losses.

Table 159–14—Channel insertion loss requirements for interoperation between 25GBASE-BR20 and 25GBASE-BR40

Direction	Min loss	Max loss	Unit
25GBASE-BR20 transmitter to 25GBASE-BR40 receiver	4	15	dB
25GBASE-BR40 transmitter to 25GBASE-BR20 receiver	6	18	dB

159.12 Protocol implementation conformance statement (PICS) proforma for Clause 159, Physical Medium Dependent (PMD) sublayer and medium, types 25GBASE-BR10, 25GBASE-BR20, and 25GBASE-BR40[8]

159.12.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 159, Physical Medium Dependent (PMD) sublayer and medium, types 25GBASE-BR10, 25GBASE-BR20, and 25GBASE-BR40, shall complete the following protocol implementation conformance statement (PICS) proforma.

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

159.12.2 Identification

159.12.2.1 Implementation identification

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

159.12.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3cp-2021, Clause 159, Physical Medium Dependent (PMD) sublayer and medium, types 25GBASE-BR10, 25GBASE-BR20, and 25GBASE-BR40
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 802.3cp-2021.)	

Date of Statement	

[8]*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.

159.12.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*BR10	25GBASE-BR10 PMD	159.6	Device supports requirements for 25GBASE-BR10 PHY	O.1	Yes [ ] No [ ]
*BR20	25GBASE-BR20 PMD	159.6	Device supports requirements for 25GBASE-BR20 PHY	O.1	Yes [ ] No [ ]
*BR40	25GBASE-BR40 PMD	159.6	Device supports requirements for 25GBASE-BR40 PHY	O.1	Yes [ ] No [ ]
*INS	Installation / cable	159.9	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	159.5.1	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	159.5.1	This point may be made available for use by implementers to certify component conformance	O	Yes [ ] No [ ]
DC	Delay constraints	159.3	Device conforms to delay constraints	M	Yes [ ]
*MD	MDIO capability	159.4	Registers and interface supported	O	Yes [ ] No [ ]

159.12.4 PICS proforma tables for PMD sublayer and medium, types 25GBASE-BR10, 25GBASE-BR20, and 25GBASE-BR40

159.12.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
F1	Compatible with 25GBASE-R PCS, RS-FEC, and PMA	159.1		M	Yes [ ]
F2	Integration with management functions	159.1		O	Yes [ ] No [ ]
F3	Bit error ratio	159.1.1	Meets the BER specified in 159.1.1	M	Yes [ ]
F4	Transmit function	159.5.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
F5	Mapping between optical signal and logical signal for transmitter	159.5.2	Higher optical power is a one	M	Yes [ ]
F6	Receive function	159.5.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
F7	Conversion of optical signal to electrical signal	159.5.3	For delivery to the PMD service interface	M	Yes [ ]
F8	Mapping between optical signal and logical signal for receiver	159.5.3	Higher optical power is a one	M	Yes [ ]
F9	Global Signal Detect function	159.5.4	Report to the PMD service interface the message PMD:IS_SIGNAL.indication (SIGNAL_DETECT)	M	Yes [ ]
F10	Global Signal Detect behavior	159.5.4	SIGNAL_DETECT is a global indicator of the presence of an optical signal	M	Yes [ ]
F11	PMD reset function	159.5.5	Resets the PMD sublayer	MD:O	Yes [ ] No [ ] N/A [ ]
F12	ONU silent start	159.5.10	Meets the specifications defined in 159.5.10	M	Yes [ ]

159.12.4.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
M1	Management register set	159.4		MD:M	Yes [ ] N/A [ ]
M2	Global transmit disable function	159.5.6	Disables the optical transmitter with the PMD_global_transmit_disable variable	M	Yes [ ]
M3	PMD_fault function	159.5.7	Sets PMD_fault to one if a local fault is detected	MD:O	Yes [ ] No [ ] N/A [ ]
M4	PMD_transmit_fault function	159.5.8	Sets PMD_transmit_fault to one if a local fault is detected	MD:O	Yes [ ] No [ ] N/A [ ]
M5	PMD_receive_fault function	159.5.9	Sets PMD_receive_fault to one if a local fault is detected	MD:O	Yes [ ] No [ ] N/A [ ]