INTERNATIONAL STANDARD

ISO/ IEC/IEEE 8802-3

Third edition
2021-02

AMENDMENT 9
2021-12

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

Part 3: Standard for Ethernet

AMENDMENT 9: Physical layer specifications and management parameters for 25 Gb/s and 50 Gb/s passive optical networks

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

Partie 3: Norme pour Ethernet

AMENDEMENT 9: Spécifications de couche physique et paramètres de gestion pour réseaux optiques passifs à 25 Gb/s et 50 Gb/s

Reference number
ISO/IEC/IEEE 8802-3:2021/Amd.9:2021(E)

© IEEE 2020



COPYRIGHT PROTECTED DOCUMENT

© IEEE 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from IEEE at the address below.

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

Published in Switzerland

© IEEE 2020 – All rights reserved

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO/IEC documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents) or the IEC list of patent declarations received (see patents.iec.ch).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html. In the IEC, see www.iec.ch/understanding-standards.

ISO/IEC/IEEE 8802-3:2021/Amd 9 was prepared by the LAN/MAN of the IEEE Computer Society (as [IEEE Std 802.3 ca™-2020) 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*.

A list of all parts in the ISO/IEC/IEEE 8802 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

© IEEE 2020 – All rights reserved

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

IEEE Standard for Ethernet

Amendment 9: Physical Layer Specifications and Management Parameters for 25 Gb/s and 50 Gb/s Passive Optical Networks

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 4 June 2020

IEEE SA Standards Board

Copyright © 2020 IEEE. All rights reserved.

Abstract: 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 standard 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. Backward compatibility with deployed 1G-EPON and ITU-T G.984 GPON is maintained with 25GBASE-PQ for the specific case of 1G-EPON and GPON ONUs using reduced-band (40 nm) lasers. The EPON operation is defined for distances of at least 20 km, and for a split ratio of at least 1:32.

Keywords: 25 Gb/s Ethernet passive optical networks (25G-EPON), 50 Gb/s Ethernet passive optical networks (50G-EPON), amendment, forward error correction (FEC), IEEE 802.3™, IEEE 802.3ca™, Multi-Channel Reconciliation Sublayer (MCRS), Multipoint MAC Control (MPMC), Physical Coding Sublayer (PCS), Physical Media Attachment (PMA), Physical Medium Dependent (PMD), PON, Point-to-Multipoint (P2MP)

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

Copyright © 2020 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 3 July 2020. Printed in the United States of America.

IEEE and 802 are registered trademarks in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-1-5044-6768-1 STD24221
Print: ISBN 978-1-5044-6769-8 STDPD24221

IEEE prohibits discrimination, harassment and bullying.

For more information, visit http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Copyright © 2020 IEEE. All rights reserved.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading "Important Notices and Disclaimers Concerning IEEE Standards Documents." They can also be obtained on request from IEEE or viewed at https://standards.ieee.org/ipr/disclaimers.html.

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association ("IEEE SA") Standards Board. IEEE ("the Institute") develops its standards through a consensus development process, approved by the American National Standards Institute ("ANSI"), which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied "AS IS" and "WITH ALL FAULTS."

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Copyright © 2020 IEEE. All rights reserved.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Copyright © 2020 IEEE. All rights reserved.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. A current IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE SA Website at https://ieeexplore.ieee.org or contact IEEE at the address listed previously. For more information about the IEEE SA or IEEE's standards development process, visit the IEEE SA Website at https://standards.ieee.org.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE SA Website at the following URL: https://standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE SA Website at https://standards.ieee.org/about/sasb/patcom/patents.html. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Copyright © 2020 IEEE. All rights reserved.

Participants

The following individuals were officers and members of the IEEE 802.3 Working Group at the beginning of the IEEE P802.3ca Working Group ballot.

David J. Law, *IEEE 802.3 Working Group Chair*
Adam Healey, *IEEE 802.3 Working Group Vice-Chair*
Pete Anslow, *IEEE 802.3 Working Group Secretary, Phase 1*
Jon Lewis, *IEEE 802.3 Working Group Secretary, Phase 2*
Steven B. Carlson, *IEEE 802.3 Working Group Executive Secretary*
Valerie Maguire, *IEEE 802.3 Working Group Treasurer*

Curtis Knittle, *IEEE P802.3ca Nx25G-EPON Task Force Chair*
Glen Kramer, *IEEE P802.3ca Nx25G-EPON Task Force Vice-Chair*
Marek Hajduczenia, *IEEE P802.3ca Nx25G-EPON Task Force Editor-in-Chief*

John Abbott
David Abramson
Andrea Agnes
Dale Amason
Hongming An
Jes Asmussen
Richard Baca
Tim Baggett
Amrik Bains
Thananya Baldwin
Steven Baumgartner
Denis Beaudoin
Liav Ben-Artsi
Piergiorgio Beruto
Vipul Bhatt
Gao Bo
Martin Bouda
David Brandt
Ralf-Peter Braun
Paul Brooks
Alan Brown
Matthew Brown
Michal Brychta
Gary Burrell
Jairo Bustos Heredia
Adrian Butter
John Calvin
Clark Carty
Craig Chabot
David Chalupsky
Frank Chang
Xin Chang
Golam Choudhury
Keng Hua Chuang
Kamal Dalmia
John D'Ambrosia
Piers Dawe
Fred Dawson
John Deandrea
Gerrit den Besten
Claudio DeSanti
Chris Diminico
Hormoz Djahanshahi
Curtis Donahue
Liang Du
Kathryn Dube
Mike Dudek
Marc Dupuis
Frank Effenberger
David Estes
John Ewen
Borhan Fathi Moghadam
Vincent Ferretti
Brian Franchuk
Matthias Fritsche
Richard Frosch
Shiyong Fu
Mike Gardner
Claude Gauthier
Ali Ghiasi
Joel Goergen
Zhigang Gong
Steven Gorshe
Jens Gottron
Steffen Graber
Olaf Grau
Robert Grow
Mark Gustlin
Hayden Haynes
Xiang He
Howard Heck
Brian Holden
Rita Horner
Bernd Horrmeyer
Gergely Huszak
Yasuhiro Hyakutake
Jonathan Ingham
Kazuhiko Ishibe
Hideki Isono
Tom Issenhuth
Kenneth Jackson
Andrew Jimenez
John Johnson
Chad Jones
Peter Jones
Lokesh Kabra
Manabu Kagami
Upen Kareti
Yasuaki Kawatsu
Yong Kim
Mark Kimber
Jonathan King
Michael Klempa
Elizabeth Kochuparambil
Wojciech Koczwara
Paul Kolesar
Taiji Kondo
Olaf Krieger
Hans Lackner
Jeffrey Lapak
Mark Laubach
Han Hyub Lee
June Hee Lee
Alex Levin
Jon Lewis
David Li
Mike-Peng Li
Jane Lim
Alex Lin
Dekun Liu
Hai-Feng Liu
Karen Liu
Zhenyu Liu
William Lo
Yuchun Lu
Miklos Lukacs
Kent Lusted
Ilya Lyubomirsky
Jeffery Maki
David Malicoat
Flavio Marques
Arthur Marris
Chris Mash
Takeo Masuda
Kirsten Matheus
Erdem Matoglu
Marco Mazzini
Mick McCarthy
Brett McClellan
Larry McMillan
Greg McSorley
Richard Mellitz

Copyright © 2020 IEEE. All rights reserved.

Martin Miller
Toshiyuki Moritake
Thomas Mueller
Edward Nakamoto
Paul Neveux
Gary Nicholl
Shawn Nicholl
John Nolan
Kevin Noll
Mark Nowell
David Ofelt
Josef Ohni
Tom Palkert
Sujan Pandey
Carlos Pardo
Earl Parsons
Gerald Pepper
Phong Pham
David Piehler
Rick Pimpinella
Christopher Pohl
William Powell
Dino Pozzebon
Rick Rabinovich
Zvi Rechtman
Alon Regev
Duane Remein
Victor Renteria
Salvatore Rotolo
Alexander Rysin
Toshiaki Sakai
Hamid Salehi
Sam Sambasivan
Edward Sayre
James Schuessler
Steve Sekel
Masood Shariff
Mizuki Shirao
Jialong Shuai
Jeff Slavick
Daniel Smith
Scott Sommers
Tom Souvignier
Bryan Sparrowhawk
Edward Sprague
Peter Stassar
Heath Stewart
David Stover
Junqing Sun
Liyang Sun
Steve Swanson
Bharat Tailor
Tomoo Takahara
Kohichi Tamura
Mehmet Tazebay
Ronald Tellas
Geoffrey Thompson
Pirooz Tooyserkani
Nathan Tracy
David Tremblay
Stephen Trowbridge
Ta Chin Tseng
Ed Ulrichs
Alexander Umnov
Ricky Vernickel
Marco Vitali
Robert Voss
Dylan Walker
Haifei Wang
Roy Wang
Tongtong Wang
Xinyuan Wang
Xuehuan Wang
Christoph Wechsler
Brian Welch
Matthias Wendt
Natalie Wienckowski
James Withey
Mau-Lin Wu
Peter Wu
Markus Wucher
Dayin Xu
Yu Xu
Shuto Yamamoto
Adrian Young
James Young
Lennart Yseboodt
Andrew Zambell
Conrad Zerna
Richard (Yujia) Zhou
Yan Zhuang
Martin Zielinski
George Zimmerman
Pavel Zivny
Harald Zweck

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

Thomas Alexander
Nancy Bravin
Matthew Brown
Demetrio Bucaneg, Jr.
Jairo Bustos Heredia
William Byrd
Steven B. Carlson
Juan Carreon
Clark Carty
Pin Chang
Xin Chang
Chan Chen
Joseph Coffey
Charles Cook
John Deandrea
Claudio DeSanti
Vincent Ferretti
Avraham Freedman
Matthias Fritsche
Joel Goergen
Zhigang Gong
Randall Groves
Martin Gubow
Marek Hajduczenia
Adam Healey
Marco Hernandez
David Hess
Werner Hoelzl
Yasuhiro Hyakutake
Raj Jain
SangKwon Jeong
Lokesh Kabra
Stuart Kerry
Yongbum Kim
Curtis Knittle
Glen Kramer
Mark Laubach
David J. Law
Pi-Cheng Law
Han Hyub Lee
Hyeong Ho Lee
David Lewis
Jon Lewis
Karen Liu
Javier Luiso
Valerie Maguire
Jeffery Maki
David Malicoat
Brett McClellan
Richard Mellitz
Tremont Miao
Raymond Nering
Paul Neveux
Paul Nikolich
Satoshi Obara
Thomas Palkert
Carlos Pardo
Bansi Patel
Dev Paul
Arumugam Paventhan
David Piehler
William Powell
R. K. Rannow
Maximilian Riegel
Robert Robinson
Benjamin Rolfe
Dieter Schicketanz
Thomas Starai
Mitsutoshi Sugawara
Ronald Tellas
Geoffrey Thompson
David Tremblay
Mark-Rene Uchida
Dmitri Varsanofiev
George Vlantis
Lisa Ward
Karl Weber
Andreas Wolf
Yu Yuan
Oren Yuen
Zhen Zhou
Pavel Zivny

Copyright © 2020 IEEE. All rights reserved.

When the IEEE SA Standards Board approved this standard on 4 June 2020, it had the following membership:

Gary Hoffman, *Chair*
Jon Walter Rosdahl, *Vice Chair*
Jean-Philippe Faure, *Past Chair*
Konstantinos Karachalios, *Secretary*

Ted Burse
J. Travis Griffith
Grace Gu
Guido R. Hiertz
Joseph L. Koepfinger*
John D. Kulick
David J. Law
Howard Li
Dong Liu
Kevin Lu
Paul Nikolich
Damir Novosel
Dorothy Stanley
Mehmet Ulema
Lei Wang
Sha Wei
Philip B. Winston
Daidi Zhong
Jingyi Zhou

*Member Emeritus

Copyright © 2020 IEEE. All rights reserved.

Introduction

This introduction is not part of IEEE Std 802.3ca-2020, IEEE Standard for Ethernet. Amendment 9: Physical Layer Specifications and Management Parameters for 25 Gb/s and 50 Gb/s Passive Optical Networks.

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 802.3ca-2020 publication, IEEE Std 802.3 was composed of the following documents:

IEEE Std 802.3-2018

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

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

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

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

Section Five—Includes Clause 56 through Clause 77 and Annex 57A through Annex 76A. Clause 56 through Clause 67 and Clause 75 through Clause 77, as well as associated annexes, specify subscriber access and other Physical Layers and sublayers for operation from 512 kb/s to 10 Gb/s, and defines

Copyright © 2020 IEEE. All rights reserved.

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.

Copyright © 2020 IEEE. All rights reserved.

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.

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.

Copyright © 2020 IEEE. All rights reserved.

Contents

1. Introduction ... 23

1.3 Normative references ... 23
1.4 Definitions ... 23
1.5 Abbreviations ... 25

30. Management ... 26

30.3 Layer management for DTEs ... 26
30.3.2 PHY device managed object class ... 26
30.3.2.1 PHY device attributes ... 26
30.3.2.1.2 aPhyType ... 26
30.3.2.1.3 aPhyTypeList ... 26
30.3.5 MPCP managed object class ... 27
30.3.5.1 MPCP Attributes ... 27
30.3.5.1.2 aMPCPAdminState ... 27
30.3.5.1.3 aMPCPMode ... 27
30.3.5.1.4 aMPCPLinkID ... 27
30.5 Layer management for medium attachment units (MAUs) ... 27
30.5.1 MAU managed object class ... 27
30.5.1.1 MAU attributes ... 27
30.5.1.1.2 aMAUType ... 27

45. Management Data Input/Output (MDIO) Interface ... 31

45.2 MDIO Interface Registers ... 31
45.2.1 PMA/PMD registers ... 31
45.2.1.23a PMA/PMD control 3 register (Register 1.29) ... 31
45.2.1.23a.1 Downstream differential encoding (1.29.15) ... 31
45.2.1.23a.2 PMA/PMD type selection (1.29.5:0) ... 31
45.2.1.134a Nx25G-EPON PMA/PMD extended ability register (Registers 1.1000 through 1.1002) ... 33
45.2.1.134a.1 25GBASE-PQX-U3 (1.1000.15) ... 35
45.2.1.134a.2 25GBASE-PQX-U2 (1.1000.14) ... 35
45.2.1.134a.3 25GBASE-PQX-D3 (1.1000.13) ... 35
45.2.1.134a.4 25GBASE-PQX-D2 (1.1000.12) ... 35
45.2.1.134a.5 25GBASE-PQG-U3 (1.1000.11) ... 35
45.2.1.134a.6 25GBASE-PQG-U2 (1.1000.10) ... 35
45.2.1.134a.7 25GBASE-PQG-D3 (1.1000.9) ... 36
45.2.1.134a.8 25GBASE-PQG-D2 (1.1000.8) ... 36
45.2.1.134a.9 25/10GBASE-PQX-U3 (1.1000.7) ... 36
45.2.1.134a.10 25/10GBASE-PQX-U2 (1.1000.6) ... 36
45.2.1.134a.11 25/10GBASE-PQX-D3 (1.1000.5) ... 36
45.2.1.134a.12 25/10GBASE-PQX-D2 (1.1000.4) ... 36
45.2.1.134a.13 25/10GBASE-PQG-U3 (1.1000.3) ... 36
45.2.1.134a.14 25/10GBASE-PQG-U2 (1.1000.2) ... 36
45.2.1.134a.15 25/10GBASE-PQG-D3 (1.1000.1) ... 36
45.2.1.134a.16 25/10GBASE-PQG-D2 (1.1000.0) ... 37
45.2.1.134a.17 50/25GBASE-PQX-U3 (1.1001.15) ... 37
45.2.1.134a.18 50/25GBASE-PQX-U2 (1.1001.14) ... 37
45.2.1.134a.19 50/25GBASE-PQX-D3 (1.1001.13) ... 37

Copyright © 2020 IEEE. All rights reserved.

45.2.1.134a.20 50/25GBASE-PQX-D2 (1.1001.12) ... 37
45.2.1.134a.21 50/25GBASE-PQG-U3 (1.1001.11) ... 37
45.2.1.134a.22 50/25GBASE-PQG-U2 (1.1001.10) ... 37
45.2.1.134a.23 50/25GBASE-PQG-D3 (1.1001.9) ... 37
45.2.1.134a.24 50/25GBASE-PQG-D2 (1.1001.8) ... 37
45.2.1.134a.25 50/10GBASE-PQX-U3 (1.1001.7) ... 38
45.2.1.134a.26 50/10GBASE-PQX-U2 (1.1001.6) ... 38
45.2.1.134a.27 50/10GBASE-PQX-D3 (1.1001.5) ... 38
45.2.1.134a.28 50/10GBASE-PQX-D2 (1.1001.4) ... 38
45.2.1.134a.29 50/10GBASE-PQG-U3 (1.1001.3) ... 38
45.2.1.134a.30 50/10GBASE-PQG-U2 (1.1001.2) ... 38
45.2.1.134a.31 50/10GBASE-PQG-D3 (1.1001.1) ... 38
45.2.1.134a.32 50/10GBASE-PQG-D2 (1.1001.0) ... 38
45.2.1.134a.33 50GBASE-PQX-U3 (1.1002.7) ... 38
45.2.1.134a.34 50GBASE-PQX-U2 (1.1002.6) ... 39
45.2.1.134a.35 50GBASE-PQX-D3 (1.1002.5) ... 39
45.2.1.134a.36 50GBASE-PQX-D2 (1.1002.4) ... 39
45.2.1.134a.37 50GBASE-PQG-U3 (1.1002.3) ... 39
45.2.1.134a.38 50GBASE-PQG-U2 (1.1002.2) ... 39
45.2.1.134a.39 50GBASE-PQG-D3 (1.1002.1) ... 39
45.2.1.134a.40 50GBASE-PQG-D2 (1.1002.0) ... 39
45.2.3 PCS registers ... 40
45.2.3.1 PCS control 1 register (Register 3.0) ... 40
45.2.3.6 PCS control 2 register (Register 3.7) ... 41
45.2.3.6.1 PCS type selection (3.7.34:0) ... 41
45.2.3.8 PCS status 3 register (Register 3.9) ... 41
45.2.3.8.aa 25GBASE-PQ capable (3.9.7) ... 42
45.2.3.8.ab 25/10GBASE-PQ capable (3.9.6) ... 42
45.2.3.8.ac 25GBASE-PQ Rx only capable (3.9.5) ... 42
45.2.3.8.ad 25GBASE-PQ Tx only capable (3.9.4) ... 42
45.2.3.41 10/1GBASE-PRX and 10GBASE-PR10G-EPON and Nx25G-EPON corrected FEC codewords counter (Register 3.76, 3.77) ... 42
45.2.3.42 10/1GBASE-PRX and 10GBASE-PR10G-EPON and Nx25G-EPON uncorrected FEC codewords counter (Register 3.78, 3.79) ... 43
45.2.3.43 10GBASE-PR and, 10/1GBASE-PRX, and Nx25G-EPON BER monitor interval timer control register (Register 3.80) ... 43
45.2.3.44 10GBASE-PR and, 10/1GBASE-PRX, and Nx25G-EPON BER monitor status (Register 3.81) ... 44
45.2.3.44.1 10GBASE-PR and, 10/1GBASE-PRX, and Nx25G-EPON PCS high BER (3.81.0) ... 44
45.2.3.44.2 10GBASE-PR and, 10/1GBASE-PRX, and Nx25G-EPON PCS latched high BER (3.81.1) ... 45
45.2.3.45 10GBASE-PR and, 10/1GBASE-PRX, and Nx25G-EPON BER monitor threshold control (Register 3.82) ... 45
45.2.3.45a Nx25G-EPON synchronization pattern registers (Registers 3.83 through 3.134) ... 45
45.2.3.45a.1 SP3 bit 257 (3.83.5) ... 46
45.2.3.45a.2 SP3 balanced (3.83.4) ... 46
45.2.3.45a.3 SP2 bit 257 (3.83.3) ... 46
45.2.3.45a.4 SP2 balanced (3.83.2) ... 46
45.2.3.45a.5 SP1 bit 257 (3.83.1) ... 47
45.2.3.45a.6 SP1 balanced (3.83.0) ... 47
45.2.3.45a.7 SP1 pattern (3.84.0 through 3.99.15) ... 47
45.2.3.45a.8 SP1 length (3.100.15:0) ... 47

Copyright © 2020 IEEE. All rights reserved.

45.2.3.45a.9 SP2 pattern (3.101.0 through 3.116.15) ... 47
45.2.3.45a.10 SP2 length (3.117.15:0) ... 47
45.2.3.45a.11 SP3 pattern (3.118.0 through 3.133.15) ... 47
45.2.3.45a.12 SP3 length (3.134.15:0) ... 47
45.5 Protocol implementation conformance statement (PICS) proforma for Clause 45, Management Data Input/Output (MDIO) interface ... 48
45.5.1 Introduction ... 48
45.5.2 Identification ... 48
45.5.2.1 Implementation identification ... 48
45.5.2.2 Protocol summary ... 48
45.5.3 PICS proforma tables for the Management Data Input Output (MDIO) interface ... 49
45.5.3.3 PMA/PMD management functions ... 49
45.5.3.7 PCS management functions ... 49

56. Introduction to Ethernet for subscriber access networks ... 50

56.1 Overview ... 50
56.1.2 Summary of P2MP sublayers ... 50
56.1.2.1 Multipoint MAC Control Protocol (MPCP) ... 52
56.1.2.2 Reconciliation Sublayer (RS) and media independent interfaces ... 52
56.1.3 Physical Layer signaling systems ... 52

67. System considerations for Ethernet subscriber access networks ... 59

67.1 Overview ... 59

141. Physical Medium Dependent (PMD) sublayer and medium for Nx25G-EPON passive optical networks ... 61

141.1 Overview ... 61
141.1.1 Terminology ... 61
141.1.2 Positioning of the PMD sublayer within the IEEE 802.3 architecture ... 61
141.1.3 PHY link types ... 61
141.2 PMD nomenclature ... 64
141.2.1 Introduction ... 64
141.2.2 PMD rate classes ... 64
141.2.3 PMD coexistence classes ... 64
141.2.4 PMD transmission direction classes ... 64
141.2.5 PMD power classes ... 64
141.2.6 PMD naming ... 65
141.2.7 Supported combinations of OLT and ONU PMDs ... 65
141.2.7.1 PHY Links supporting medium power budget ... 66
141.2.7.2 PHY Links supporting high power budget ... 67
141.3 PMD functional specifications ... 67
141.3.1 PMD service interface ... 67
141.3.1.1 Channel-to-wavelength mapping ... 67
141.3.1.2 Delay constraints ... 68
141.3.1.3 PMD_UNITDATA[i].request ... 68
141.3.1.4 PMD_UNITDATA[i].indication ... 68
141.3.1.5 PMD_SIGNAL[i].request ... 69
141.3.1.6 PMD_SIGNAL[i].indication ... 69
141.3.2 PMD block diagram ... 69
141.3.3 PMD transmit function ... 70
141.3.4 PMD receive function ... 70

Copyright © 2020 IEEE. All rights reserved.

141.3.5 PMD signal detect function ... 70
141.3.5.1 ONU PMD signal detect ... 70
141.3.5.2 OLT PMD signal detect ... 71
141.3.5.3 Nx25G-EPON signal detect functions ... 71
141.4 Wavelength allocation ... 71
141.5 PMD to MDI optical specifications for OLT PMDs ... 72
141.5.1 Transmitter optical specifications ... 72
141.5.2 Receiver optical specifications ... 72
141.6 PMD to MDI optical specifications for ONU PMDs ... 77
141.6.1 Transmitter optical specifications ... 77
141.6.2 Receiver optical specifications ... 80
141.7 Definitions of optical parameters and measurement methods ... 82
141.7.1 Insertion loss ... 82
141.7.2 Test patterns ... 82
141.7.3 Wavelength and spectral width measurement ... 82
141.7.4 Optical power measurements ... 82
141.7.5 Extinction ratio measurements ... 82
141.7.6 Optical Modulation Amplitude (OMA) test procedure ... 82
141.7.7 Relative intensity noise optical modulation amplitude (RINxOMA) measuring procedure ... 82
141.7.8 Transmit optical waveform (transmit eye) ... 83
141.7.9 Transmitter and dispersion penalty (TDP) for 25G ... 83
141.7.9.1 Reference transmitter requirements ... 83
141.7.9.2 Channel requirements ... 83
141.7.9.3 Reference receiver requirements ... 83
141.7.9.4 Test procedure ... 83
141.7.10 Receive sensitivity ... 84
141.7.11 Stressed receiver conformance test ... 84
141.7.12 Jitter measurements ... 84
141.7.13 Laser on/off timing measurement ... 84
141.7.13.1 Definitions ... 84
141.7.13.2 Test specification ... 84
141.7.14 Receiver settling timing measurement ... 86
141.7.14.1 Definitions ... 86
141.7.14.2 Test specification ... 86
141.8 Environmental, safety, and labeling ... 87
141.8.1 General safety ... 87
141.8.2 Laser safety ... 87
141.8.3 Installation ... 87
141.8.4 Environment ... 87
141.8.5 PMD labeling ... 87
141.9 Characteristics of the fiber optic cabling ... 88
141.9.1 Fiber optic cabling model ... 88
141.9.2 Optical fiber and cable ... 88
141.9.3 Optical fiber connection ... 88
141.9.4 Medium Dependent Interface (MDI) ... 89
141.10 Protocol implementation conformance statement (PICS) proforma for Clause 141, Physical Medium Dependent (PMD) sublayer and medium for Nx25G-EPON passive optical networks ... 90
141.10.1 Introduction ... 90
141.10.2 Identification ... 90
141.10.2.1 Implementation identification ... 90
141.10.2.2 Protocol summary ... 90
141.10.3 Major capabilities/options ... 91

Copyright © 2020 IEEE. All rights reserved.

141.10.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 25/10GBASE-PQ, 25GBASE-PQ, 50/10GBASE-PQ, 50/25GBASE-PQ, and 50GBASE-PQ 94
141.10.4.1 PMD functional specifications 94
141.10.4.2 PMD to MDI optical specifications for 25/10GBASE-PQG-D2 95
141.10.4.3 PMD to MDI optical specifications for 25/10GBASE-PQG-D3 95
141.10.4.4 PMD to MDI optical specifications for 25/10GBASE-PQX-D2 95
141.10.4.5 PMD to MDI optical specifications for 25/10GBASE-PQX-D3 96
141.10.4.6 PMD to MDI optical specifications for 25GBASE-PQG-D2 96
141.10.4.7 PMD to MDI optical specifications for 25GBASE-PQG-D3 96
141.10.4.8 PMD to MDI optical specifications for 25GBASE-PQX-D2 96
141.10.4.9 PMD to MDI optical specifications for 25GBASE-PQX-D3 97
141.10.4.10 PMD to MDI optical specifications for 50/10GBASE-PQG-D2 97
141.10.4.11 PMD to MDI optical specifications for 50/10GBASE-PQG-D3 97
141.10.4.12 PMD to MDI optical specifications for 50/10GBASE-PQX-D2 97
141.10.4.13 PMD to MDI optical specifications for 50/10GBASE-PQX-D3 98
141.10.4.14 PMD to MDI optical specifications for 50/25GBASE-PQG-D2 98
141.10.4.15 PMD to MDI optical specifications for 50/25GBASE-PQG-D3 98
141.10.4.16 PMD to MDI optical specifications for 50/25GBASE-PQX-D2 98
141.10.4.17 PMD to MDI optical specifications for 50/25GBASE-PQX-D3 99
141.10.4.18 PMD to MDI optical specifications for 50GBASE-PQG-D2 99
141.10.4.19 PMD to MDI optical specifications for 50GBASE-PQG-D3 99
141.10.4.20 PMD to MDI optical specifications for 50GBASE-PQX-D2 99
141.10.4.21 PMD to MDI optical specifications for 50GBASE-PQX-D3 100
141.10.4.22 PMD to MDI optical specifications for 25/10GBASE-PQG-U2 100
141.10.4.23 PMD to MDI optical specifications for 25/10GBASE-PQG-U3 100
141.10.4.24 PMD to MDI optical specifications for 25/10GBASE-PQX-U2 100
141.10.4.25 PMD to MDI optical specifications for 25/10GBASE-PQX-U3 101
141.10.4.26 PMD to MDI optical specifications for 25GBASE-PQG-U2 101
141.10.4.27 PMD to MDI optical specifications for 25GBASE-PQG-U3 101
141.10.4.28 PMD to MDI optical specifications for 25GBASE-PQX-U2 101
141.10.4.29 PMD to MDI optical specifications for 25GBASE-PQX-U3 102
141.10.4.30 PMD to MDI optical specifications for 50/10GBASE-PQG-U2 102
141.10.4.31 PMD to MDI optical specifications for 50/10GBASE-PQG-U3 102
141.10.4.32 PMD to MDI optical specifications for 50/10GBASE-PQX-U2 102
141.10.4.33 PMD to MDI optical specifications for 50/10GBASE-PQX-U3 103
141.10.4.34 PMD to MDI optical specifications for 50/25GBASE-PQG-U2 103
141.10.4.35 PMD to MDI optical specifications for 50/25GBASE-PQG-U3 103
141.10.4.36 PMD to MDI optical specifications for 50/25GBASE-PQX-U2 103
141.10.4.37 PMD to MDI optical specifications for 50/25GBASE-PQX-U3 104
141.10.4.38 PMD to MDI optical specifications for 50GBASE-PQG-U2 104
141.10.4.39 PMD to MDI optical specifications for 50GBASE-PQG-U3 104
141.10.4.40 PMD to MDI optical specifications for 50GBASE-PQX-U2 104
141.10.4.41 PMD to MDI optical specifications for 50GBASE-PQX-U3 105
141.10.4.42 Definitions of optical parameters and measurement methods 105
141.10.4.43 Characteristics of the fiber optic cabling and MDI 106
141.10.4.44 Environmental specifications 106

142. Physical Coding Sublayer and Physical Media Attachment for Nx25G-EPON 107

142.1 Overview 107
142.1.1 Conventions 107
142.1.1.1 State diagrams 107
142.1.1.2 Hexadecimal notation 107

Copyright © 2020 IEEE. All rights reserved.

142.1.1.3 Timers ... 110
142.1.1.4 Operations on variables ... 110
142.1.1.5 Operations on wrap-around variables ... 111
142.1.1.6 FIFO access operations ... 111
142.1.2 Delay constraints ... 112
142.1.3 Burst transmission ... 112
142.1.3.1 Default synchronization pattern parameters ... 113
142.2 PCS transmit data path ... 114
142.2.1 64B/66B line encoder ... 114
142.2.2 Scrambler ... 116
142.2.3 64B/66B to 256B/257B transcoder ... 116
142.2.4 FEC encoder ... 116
142.2.4.1 Low-density parity-check coding ... 116
142.2.4.2 FEC encoder processing ... 119
142.2.4.3 Interleaver ... 121
142.2.5 Transmit data path state diagrams ... 126
142.2.5.1 Constants ... 126
142.2.5.2 Variables ... 127
142.2.5.3 Functions ... 129
142.2.5.4 State diagrams ... 130
142.2.5.4.1 PCS Input process ... 130
142.2.5.4.2 PCS Framer process ... 131
142.2.5.4.3 PCS Transmit process ... 132
142.3 PCS receive data path ... 133
142.3.1 FEC decoder ... 133
142.3.1.1 Receive interleaving ... 133
142.3.2 256B/257B to 64B/66B transcoder ... 134
142.3.3 Descrambler ... 134
142.3.4 64B/66B decoder ... 135
142.3.5 Receive data path state diagrams ... 136
142.3.5.1 Constants ... 136
142.3.5.2 Variables ... 137
142.3.5.3 Functions ... 139
142.3.5.4 OLT Synchronizer process state diagram ... 140
142.3.5.5 ONU Synchronizer process state diagram ... 140
142.3.5.6 PCS ONU BER Monitor process ... 141
142.3.5.7 PCS Output process ... 142
142.4 Nx25G-EPON PMA ... 142
142.4.1 Service Interface ... 142
142.4.1.1 PMA_UNITDATA[i].request ... 143
142.4.1.1.1 Semantics of the service primitive ... 143
142.4.1.1.2 When generated ... 143
142.4.1.1.3 Effect of receipt ... 143
142.4.1.2 PMA_UNITDATA[i].indication ... 143
142.4.1.2.1 Semantics of the service primitive ... 143
142.4.1.2.2 When generated ... 143
142.4.1.2.3 Effect of receipt ... 143
142.4.1.3 PMA_SIGNAL[i].request ... 144
142.4.1.4 PMA_SIGNAL[i].indication ... 144
142.4.1.4.1 Semantics of the service primitive ... 144
142.4.1.4.2 When generated ... 144
142.4.1.4.3 Effect of receipt ... 144
142.4.2 Differential encoder ... 144
142.4.3 Differential decoder ... 145

Copyright © 2020 IEEE. All rights reserved.

142.4.4 PMA transmit clock ... 145
142.4.4.1 Loop-timing specifications for ONUs ... 145
142.4.5 TCDR measurement ... 145
142.4.5.1 Definitions ... 145
142.4.5.2 Test specification ... 145
142.5 Protocol implementation conformance statement (PICS) proforma for Clause 142, Physical Coding Sublayer and Physical Media Attachment for Nx25G-EPON ... 147
142.5.1 Introduction ... 147
142.5.2 Identification ... 147
142.5.2.1 Implementation identification ... 147
142.5.2.2 Protocol summary ... 147
142.5.3 PCS capabilities/options ... 148
142.5.4 PCS processes ... 148
142.5.5 PMA processes ... 149

143. Multi-Channel Reconciliation Sublayer ... 150

143.1 Overview ... 150
143.2 Summary of major concepts ... 150
143.2.1 Concept of a logical link and LLID ... 151
143.2.2 Concept of an MCRS channel ... 151
143.2.3 Binding of multiple MACs to multiple xMII instances ... 151
143.2.4 Transmission and reception over multiple MCRS channels ... 152
143.2.4.1 Transmission unit ... 152
143.2.4.2 Transmission envelopes ... 152
143.2.4.3 Envelope headers ... 152
143.2.4.4 Interpacket gap adjustment ... 153
143.2.5 Dynamic channel bonding ... 154
143.2.5.1 LLID transmission over multiple MCRS channels ... 155
143.2.5.2 MCRS channel skew remediation mechanism ... 156
143.2.5.3 *EnvTx* and *EnvRx* buffers ... 156
143.2.5.4 Envelope position alignment marker ... 158
143.2.6 MDIO addressing model for multi-channel architecture ... 158
143.3 MCRS functional specifications ... 160
143.3.1 MCRS interfaces ... 160
143.3.1.1 PLS service primitives ... 160
143.3.1.1.1 Mapping of PLS_DATA[ch].request primitive ... 161
143.3.1.1.2 Mapping of PLS_SIGNAL[ch].indication primitive ... 161
143.3.1.1.3 Mapping of PLS_DATA[ch].indication primitive ... 161
143.3.1.1.4 Mapping of PLS_DATA_VALID[ch].indication primitive ... 162
143.3.1.1.5 Mapping of PLS_CARRIER[ch].indication primitive ... 162
143.3.1.2 MCRS control primitives ... 162
143.3.1.2.1 MCRS_CTRL[ch].request(link_id, epam, env_length) primitive ... 162
143.3.1.2.2 MCRS_CTRL[ch].indication() primitive ... 162
143.3.1.2.3 MCRS_ECH[ch].indication(Llid) primitive ... 162
143.3.1.3 XGMII interfaces ... 162
143.3.1.4 25GMII interfaces ... 162
143.3.2 Envelope header format ... 163
143.3.2.1 CRC8 calculation test sequences ... 164
143.3.3 Transmit functional specifications ... 165
143.3.3.1 Conventions ... 166
143.3.3.2 Application-specific parameter definitions ... 166
143.3.3.3 Constants ... 166
143.3.3.4 Variables ... 167

Copyright © 2020 IEEE. All rights reserved.

143.3.3.5 Functions ... 169
143.3.3.6 State diagrams ... 171
143.3.3.6.1 Input process ... 171
143.3.3.6.2 Transmit process ... 171
143.3.4 Receive functional specifications ... 173
143.3.4.1 Conventions ... 174
143.3.4.2 Constants ... 174
143.3.4.3 Variables ... 175
143.3.4.4 Functions ... 176
143.3.4.5 State diagrams ... 177
143.3.4.5.1 Receive process ... 177
143.3.4.5.2 Output process ... 178
143.4 Nx25G-EPON MCRS requirements ... 178
143.4.1 Nx25G-EPON architecture ... 178
143.4.1.1 MCRS channels ... 180
143.4.1.2 Symmetric and asymmetric data rates ... 180
143.4.1.3 Nx25G-EPON application-specific parameters ... 181
143.4.1.3.1 Constants ... 181
143.4.1.3.2 Transmit variables ... 181
143.4.2 MCRS time synchronization ... 181
143.4.3 Delay variability constraints ... 182
143.4.4 Asymmetric rate operation ... 182
143.5 Protocol implementation conformance statement (PICS) proforma for Clause 143, Multi-Channel Reconciliation Sublayer ... 185
143.5.1 Introduction ... 185
143.5.2 Identification ... 185
143.5.2.1 Implementation identification ... 185
143.5.2.2 Protocol summary ... 185
143.5.3 Generic MCRS ... 186
143.5.4 MCRS in Nx25G-EPON ... 186
143.5.4.1 Major capabilities/option ... 186
143.5.4.2 MCRS implementation in Nx25G-EPON ... 187

144. Multipoint MAC Control for Nx25G-EPON ... 188

144.1 Overview ... 188
144.1.1 Principles of point-to-multipoint operation ... 188
144.1.1.1 Transmission arbitration ... 188
144.1.1.2 Concept of logical links ... 189
144.1.1.3 ONU discovery and registration ... 191
144.1.2 Position of Multipoint MAC Control (MPMC) within the IEEE 802.3 hierarchy ... 191
144.1.3 Functional block diagram ... 191
144.1.4 Service interfaces ... 191
144.1.4.1 MAC Control service (MCS) interface ... 191
144.1.4.2 MAC Control interconnect (MCI) ... 194
144.1.4.3 MAC service Interface ... 194
144.1.4.4 MCRS Control interface ... 194
144.1.5 Conventions ... 194
144.2 Protocol-independent operation ... 194
144.2.1 Control Parser and Control Multiplexer ... 195
144.2.1.1 Constants ... 195
144.2.1.2 Counters ... 195
144.2.1.3 Variables ... 195
144.2.1.4 Functions ... 196

Copyright © 2020 IEEE. All rights reserved.

144.2.1.5 Control Parser state diagram ... 197
144.2.1.6 Control Multiplexer state diagram ... 198
144.3 Multipoint Control Protocol (MPCP) ... 198
144.3.1 Principles of Multipoint Control Protocol (MPCP) ... 198
144.3.1.1 Ranging measurement and time synchronization ... 198
144.3.1.2 Granting access to the PON media by the OLT ... 201
144.3.2 MPCP block diagram ... 202
144.3.3 Delay variability requirements ... 204
144.3.4 Logical link identifier (LLID) types ... 204
144.3.4.1 Physical Layer ID (PLID) ... 204
144.3.4.2 Management link ID (MLID) ... 205
144.3.4.3 User link ID (ULID) ... 205
144.3.4.4 Group link ID (GLID) ... 205
144.3.5 Allocation of LLID values ... 205
144.3.6 MPCPDU structure and encoding ... 206
144.3.6.1 GATE description ... 207
144.3.6.2 REPORT description ... 209
144.3.6.3 REGISTER_REQ description ... 211
144.3.6.4 REGISTER description ... 212
144.3.6.5 REGISTER_ACK description ... 214
144.3.6.6 DISCOVERY description ... 216
144.3.6.7 SYNC_PATTERN description ... 218
144.3.7 Discovery process ... 220
144.3.7.1 Constants ... 222
144.3.7.2 Counters ... 223
144.3.7.3 Variables ... 223
144.3.7.4 Functions ... 225
144.3.7.5 Messages ... 226
144.3.7.6 Discovery Initiation state diagram ... 226
144.3.7.7 Registration Completion state diagram ... 227
144.3.7.8 ONU Registration state diagram ... 228
144.3.8 Granting process ... 230
144.3.8.1 Constants ... 230
144.3.8.2 Counters ... 231
144.3.8.3 Variables ... 231
144.3.8.4 Functions ... 232
144.3.8.5 Timers ... 232
144.3.8.6 Messages ... 232
144.3.8.7 GATE Generation state diagram ... 232
144.3.8.8 GATE Reception state diagram ... 233
144.3.8.9 OLT Envelope Commitment state diagram ... 233
144.3.8.10 ONU Envelope Commitment state diagram ... 234
144.3.8.11 Envelope Activation state diagram ... 235
144.3.9 Discovery process in dual-rate systems ... 235
144.3.9.1 OLT rate-specific discovery ... 235
144.3.9.2 ONU rate-specific registration ... 236
144.4 Channel Control Protocol (CCP) ... 237
144.4.1 CCP block diagram ... 237
144.4.2 Principles of Channel Control Protocol ... 238
144.4.2.1 Disabling a downstream channel at an ONU ... 239
144.4.2.2 Enabling a downstream channel at an ONU ... 239
144.4.2.3 Disabling an upstream channel at an ONU ... 239
144.4.2.4 Enabling an upstream channel at an ONU ... 240
144.4.2.5 Local channel state changes at an ONU ... 240

Copyright © 2020 IEEE. All rights reserved.

144.4.3 CCPDU structure and encoding 240
144.4.3.1 CC_REQUEST description 241
144.4.3.2 CC_RESPONSE description 243
144.4.4 Channel Control operation 244
144.4.4.1 Constants 244
144.4.4.2 Variables 245
144.4.4.3 Functions 246
144.4.4.4 Messages 247
144.4.4.5 OLT CCPDU processing state diagram 247
144.4.4.6 ONU CCPDU processing state diagram 248
144.5 Protocol implementation conformance statement (PICS) proforma for Clause 144, Multipoint MAC Control for Nx25G-EPON 249
144.5.1 Introduction 249
144.5.2 Identification 249
144.5.2.1 Implementation identification 249
144.5.2.2 Protocol summary 249
144.5.3 Major capabilities/options 250
144.5.4 PICS proforma tables for Multipoint MAC Control 250
144.5.4.1 Clock tracking 250
144.5.4.2 LLID 250
144.5.4.3 Protocol-independent state diagrams 251
144.5.4.4 MPCP 251
144.5.4.5 CCP 254

Annex A (informative) Bibliography 255

Annex 31A (normative) MAC Control opcode assignments 256

Annex 142A (informative) Encoding example for QC-LDPC(16952,14392) FEC and interleaving 258

142A.1 Example of initial control seed sequence 258
142A.2 QC-LDPC FEC encoder test vectors 258

Copyright © 2020 IEEE. All rights reserved.

IEEE Standard for Ethernet

Amendment 9: Physical Layer Specifications and Management Parameters for 25 Gb/s and 50 Gb/s Passive Optical Networks

(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, and IEEE Std 802.3ch™-2020.)

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

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

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

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

Copyright © 2020 IEEE. All rights reserved.

1. Introduction

1.3 Normative references

Change the references for ITU-T Recommendations G.652 and G.657 as follows:

ITU-T Recommendation G.652, ~~2009~~2016—Characteristics of a single-mode optical fibre and cable.[2]

ITU-T Recommendation G.657, ~~2009~~2016—Characteristics of a bending-loss insensitive single-mode optical fibre and cable~~ for the access network~~.

1.4 Definitions

Insert the following two new definitions after 1.4.90 "200GXS":

1.4.90a 25/10G-EPON: An EPON architecture supporting a maximum sustained throughput of 25 Gb/s in the downstream direction and 10 Gb/s in the upstream direction (asymmetric rate).

1.4.90b 25/25G-EPON: An EPON architecture supporting a maximum sustained throughput of 25 Gb/s in both downstream and upstream directions (symmetric rate).

Insert the following new definition after 1.4.100 "25GBASE-T":

1.4.100a 25G-EPON: An EPON architecture supporting a maximum sustained throughput of 25 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 25/10G-EPON and 25/25G-EPON architectures.

Insert the following three new definitions before 1.4.128aa "50GBASE-CR" as inserted by IEEE Std 802.3cd-2018:

1.4.128aaa 50/10G-EPON: An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in the downstream direction and 10 Gb/s in the upstream direction (asymmetric rate).

1.4.128aab 50/25G-EPON: An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in the downstream direction and 25 Gb/s in the upstream direction (asymmetric rate).

1.4.128aac 50/50G-EPON: An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in both downstream and upstream directions (symmetric rate).

Insert the following new definition after 1.4.128ah "50 Gb/s Media Independent Interface (50GMII)" as inserted by IEEE Std 802.3cd-2018:

1.4.128ai 50G-EPON: An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 50/10G-EPON, 50/25G-EPON, and 50/50G-EPON architectures.

Insert the following three new definitions after 1.4.244 "Energy-Efficient Ethernet (EEE)":

1.4.244a envelope: In the Multi-Channel Reconciliation Sublayer (MCRS, see IEEE Std 802.3, Clause 143), an envelope encapsulates data belonging to a specific LLID being transmitted on a specific

[2]ITU-T publications are available from the International Telecommunications Union (https://www.itu.int/).

Copyright © 2020 IEEE. All rights reserved.

MCRS channel, i.e., the data or idles sourced from a specific MAC instance and sent over a specific MCRS channel.

1.4.244b envelope allocation: In Nx25G-EPON, an envelope allocation represents a transmission window allocated to a single LLID (including GLID). A single GATE MPCPDU can carry up to seven envelope allocations.

1.4.244c envelope descriptor: A set of parameters consisting of LLID, StartTime, and EnvLength. An envelope descriptor defines a specific envelope pending transmission. Envelope descriptors are generated by the local MPCP sublayer and are passed to MCRS at the appropriate time to start the envelope transmission.

Insert the following three new definitions after 1.4.245 "envelope frame":

1.4.245a envelope header: An MCRS-specific marker that is inserted at the beginning of every envelope (envelope start header) and in place of every frame preamble (envelope continuation header). The envelope header includes fields that identify the LLID that sourced the encapsulated data and the length of the data (in units of EQ). Envelope headers also include a CRC8 field used to detect bit errors.

1.4.245b envelope quantum: A unit of information volume. Each envelope quantum represents 64 bits of data plus the layer-specific encoding. Thus, at the MAC Control sublayer and above, an envelope quantum is equal to 64 bits. Within the MCRS, an envelope quantum contains 72 bits (i.e., 64 bits of data and 8 bits of control). Within the PCS, after the 64B/66B encoding, an envelope quantum contains 66 bits, and after 256B/257B encoding, four envelope quanta are packed into a single 257-bit block.

1.4.245c EQT: The unit of measurement of time for time-related parameters specified in IEEE Std 802.3, Clause 144 Multipoint MAC Control for Nx25G-EPON. Each EQT is equal to the time required to transmit one EQ between the MCRS and the PCS across 25GMII, and equal to 2.56 ns.

Insert the following new definition after 1.4.277 "Gigabit Media Independent Interface (GMII)":

1.4.277a GPON: A Gigabit-capable Passive Optical Network, as specified in ITU-T G.984.2.

NOTE—ITU-T G.984.2 [B48a].

Change definition 1.4.278 as shown below:

1.4.278 grant: Within P2MP protocols, a permission to transmit at a specific time, for a specific duration. Grants are issued by the OLT (master) to ONUs (slaves) by means of GATE messages. In IEEE Std 802.3, Clause 64 and Clause 77, a GATE MPCPDU contains one or multiple grants issued to a single LLID, with each grant resulting in one or multiple upstream bursts transmitted by the ONU. In Clause 144, a grant includes envelope allocations for multiple LLIDs and there is a one-to-one correspondence between the grants issued to an ONU and upstream bursts transmitted by that ONU.

Change 1.4.312 (renumbered from 1.4.313 due to the deletion of 1.4.294 by IEEE Std 802.3bt-2018) as follows:

1.4.312 Logical Link Identifier (LLID): A numeric identifier assigned to a P2MP association between an OLT and ONU established through the Point-to-Point Emulation sublayer. Each P2MP association is assigned a unique LLID. The P2MP association is bound to an ONU DTE, where ~~a~~ the ONU MAC ~~would~~ is to observe a private association. In Nx25G-EPON, an LLID is also a collective term that refers to a Physical Layer ID (PLID), management link ID (MLID), user link ID (ULID), and a group link ID (GLID).

Copyright © 2020 IEEE. All rights reserved.

Insert the following new definition after 1.4.319 "maximum differential input" (renumbered from 1.4.320 due to the deletion of 1.4.294 by IEEE Std 802.3bt-2018):

1.4.319a MCRS channel: In IEEE Std 802.3, Clause 143, an MCRS channel represents one of a number of defined paths along which data passes in an MCRS.

Insert the following new definition after 1.4.332 "modulation error ratio (MER)" (renumbered from 1.4.333 due to the deletion of 1.4.294 by IEEE Std 802.3bt-2018):

1.4.332a Multi-Channel Reconciliation Sublayer (MCRS): The MCRS provides a mapping function that reconciles the signals at a specific Media Independent Interface (xMII) to a specific Media Access Control (MAC) Physical Signaling Sublayer (PLS) service definitions.

Insert the following new definition after 1.4.350 "NRZI" (renumbered from 1.4.351 due to the deletion of 1.4.294 by IEEE Std 802.3bt-2018):

1.4.350a Nx25G-EPON: An EPON architecture operating at a number of different downstream and upstream speeds. This term collectively refers to 25/10G-EPON, 25/25G-EPON, 50/10G-EPON, 50/25G-EPON, and 50/50G-EPON architectures.

1.5 Abbreviations

Insert the following new abbreviations into the list, in alphabetical order:

ECH	envelope continuation header
EQ	envelope quantum
EQT	envelope quantum time
ESH	envelope start header
GLID	group link ID
GPON	Gigabit-capable Passive Optical Network (see ITU-T G.984.2 [B48a])
MACI	MA_CONTROL.indication
MACR	MA_CONTROL.request
MADI	MA_DATA.indication
MADR	MA_DATA.request
MCRS	Multi-Channel Reconciliation Sublayer
MLID	management link ID
PLID	Physical Layer ID
QC-LDPC	quasi-cyclic low-density parity check
ULID	user link ID

Copyright © 2020 IEEE. All rights reserved.