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

**Part 3:
Standard for Ethernet**

**AMENDMENT 3: Physical layers and
management parameters for 25 Gb/s and
40 Gb/s operation, types 25GBASE-T and
40GBASE-T**

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

Partie 3: Norme pour Ethernet

*AMENDEMENT 3: Couches physiques et paramètres de gestion pour
l'exploitation des interfaces à 25 Go/s et 40 Go/s, types 25GBASE-T et
40GBASE-T*



Reference number
ISO/IEC/IEEE 8802-3:2017/Amd.3:2017(E)

Documents
Document Sharing Hub
© IEEE 2016



COPYRIGHT PROTECTED DOCUMENT

© IEEE 2016

All rights reserved. Unless otherwise specified, 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 either ISO or IEEE at the address below or ISO's member body in the country of the requester.

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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

stds.ipr@ieee.org
www.ieee.org

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. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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.

The main task of ISO/IEC JTC 1 is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is called to the possibility that implementation of this standard may require the use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. ISO/IEEE is not responsible for identifying essential patents or patent claims for which a license may be required, for conducting inquiries into the legal validity or scope of patents or patent claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance or a Patent Statement and Licensing Declaration Form, 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 ISO or the IEEE Standards Association.

ISO/IEC/IEEE 8802-3:2017/Amd.3 was prepared by the LAN/MAN of the IEEE Computer Society (as IEEE STD 802.3bq-2016). It was adopted by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*, in parallel with its approval by the ISO/IEC national bodies, under the “fast-track procedure” defined in the Partner Standards Development Organization cooperation agreement between ISO and IEEE. IEEE is responsible for the maintenance of this document with participation and input from ISO/IEC national bodies.

IEEE Std 802.3bq™-2016

(Amendment to
IEEE Std 802.3™-2015
as amended by
IEEE Std 802.3bw™-2015, and
IEEE Std 802.3by™-2016)

IEEE Standard for Ethernet

Amendment 3: Physical Layer and Management Parameters for 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

Sponsor

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 30 June 2016

IEEE-SA Standards Board

Abstract: This amendment to IEEE Std 802.3-2015 specifies new Physical Coding Sublayer (PCS) interfaces and new Physical Medium Attachment (PMA) sublayer interfaces for 25 Gb/s Ethernet and 40 Gb/s Ethernet. 25GBASE-T and 40GBASE-T specify LAN interconnects for up to 30 m of balanced twisted-pair structured cabling, for 25 Gb/s and 40 Gb/s, respectively.

Keywords: 25GBASE-T, 25 Gigabit Ethernet, 25GMII, 40GBASE-T, 40 Gigabit Ethernet, Auto-Negotiation, Ethernet, IEEE 802[®], IEEE 802.3[™], IEEE 802.3bq[™], Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, structured cabling, XLGMII

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

Copyright © 2016 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 8 September 2016. 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.

Print: ISBN 978-1-5044-2282-6 STD21086
PDF: ISBN 978-1-5044-2283-3 STDPD21086

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.

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 Notice” or “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

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. Volunteers 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 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.

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.

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. An official 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 <http://ieeexplore.ieee.org/Xplore/home.jsp> 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 <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://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 <http://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.

Participants

The following individuals were officers and members of the IEEE 802.3 Working Group at the beginning of the IEEE P802.3by Working Group ballot. Individuals may have not voted, voted for approval, disapproval or abstained on this standard.

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

David Chalupsky, *IEEE P802.3bq 25G/40GBASE-T Task Force Chair*
George Zimmerman, *IEEE P802.3bq 25G/40GBASE-T Task Force Editor-in-Chief*

John Abbott	Eugene Dai	Brian Holden
David Abramson	Shaoan Dai	Rita Horner
Shadi Abughazaleh	John D'Ambrosia	Bernd Hormmeyer
Faisal Ahmad	Mike Darling	Victor Hou
Dale Amason	Yair Darshan	Rui Hua
J. Michael Andrewartha	Piers Dawe	Liang-wei Huang
Oleksandr Babenko	Fred Dawson	Scott Irwin
Kwang-Hyun Baek	Ian Dedic	Kazuhiko Ishibe
Amrik Bains	Chris Diminico	Hideki Isono
Koussalya Balasubramanian	Thuyen Dinh	Tom Issenhuth
Thananya Baldwin	Curtis Donahue	Kenneth Jackson
Denis Beaudoin	Dan Dove	Jack Jewell
Christian Beia	Mike Dudek	Wenbin Jiang
Yakov Belopolsky	David Dwelley	Andrew Jimenez
Michael Bennett	Hesham Elbakoury	Chad Jones
Vipul Bhatt	David Estes	Antony Joseph
William Bliss	John Ewen	Yasuaki Kawatsu
Brad Booth	Josef Faller	Michael Kelsen
Martin Bouda	Shahar Feldman	Yongbum Kim
David Brandt	German Feyh	Jonathan King
Ralf-Peter Braun	Alan Flatman	Scott Kipp
Theodore Brillhart	Howard Frazier	Michael Klempa
Paul Brooks	Richard Frosch	Avi Kliger
David Brown	Michael Furlong	Curtis Knittle
Matthew Brown	Andrew Gardner	Shigeru Kobayashi
Thomas Brown	Mike Gardner	Keisuke Kojima
Phillip Brownlee	Ali Ghiasi	Paul Kolesar
Mark Bugg	Joel Goergen	Tom Kolze
Juan-Carlos Calderon	Zhigang Gong	Glen Kramer
J. Martin Carroll	Steven Gorshe	Albert Kuo
Clark Carty	James Graba	Hans Lackner
Mandeep Chadha	Robert Grow	Efstathios Larios
Jacky Chang	Mark Gustlin	Wayne Larsen
Xin Chang	Marek Hajduczenia	Mark Laubach
David Chen	Bernie Hammond	Greg Le Cheminant
Wheling Cheng	Jeffrey Heath	Arthur Lee
Ahmad Chini	Carl Herman	David Lewis
Golam Choudhury	David Hess	Lei Li
Peter Cibula	Yasuo Hidaka	Mike Peng Li
Christopher R. Cole	Riu Hirai	Shaohua Li
Keith Conroy	Thomas Hogenmueller	Thomas Lichtenegger

Ru Jian Lin	John Petrilla	Tomoo Takahara
Robert Lingle	Rick Pimpinella	Satoshi Takahashi
James Liu	Neven Pischl	Kiyoto Takahata
Zhenyu Liu	Rainer Poehmerer	Alexander Tan
William Lo	William Powell	Toshiki Tanaka
Miklos Lukacs	Richard Prodan	Mehmet Tazebay
Kent Lusted	Rick Rabinovich	Brian Teipen
Jeffery Maki	Saifur Rahman	Geoffrey Thompson
James Malkemus	Adee Ran	Alan Tipper
Yonatan Malkiman	Ram Rao	Pirooz Tooyserkani
Edwin Mallette	Alon Regev	Nathan Tracy
Arthur Marris	Duane Remein	David Tremblay
Chris Mash	Victor Renteria	Albert Tretter
Kirsten Matheus	Michael Ressler	Stephen Trowbridge
Erdem Matoglu	Poldi (Pavlick) Rimboim	Wen-Cheng Tseng
Laurence Matola	Christopher Roth	Yoshihiro Tsukamoto
Brett McClellan	Salvatore Rotolo	Mike Tu
Thomas McDermott	Hisaya Sakamoto	Alan Ugolini
John McDonough	Vineet Salunke	John Ulm
Richard Mei	Sam Sambasivan	Ed Ulrichs
Richard Mellitz	Yasuo Sasaki	Sterling A. Vaden
Bryan Moffitt	Fred Schindler	Stefano Valle
Leo Montreuil	Stefan Schnee	Paul Vanderlaan
Paul Mooney	Peter Scruton	Robert Wagner
Charles Moore	Alexander Seiger	Robert Wang
Andy Moorwood	Naoshi Serizawa	Tongtong Wang
Thomas Mueller	Megha Shanbhag	Xiaofeng Wang
Ron Muir	Masood Shariff	Xinyuan Wang
Dale Murray	Stephen Shellhammer	Zhong Feng Wang
Henry Muyshondt	Bazhong Shen	Markus Weber
Edward Nakamoto	Mizuki Shirao	Brian Welch
Gary Nicholl	Kapil Shrikhande	Yang Wen
Paul Nikolich	Jeff Slavick	Matthias Wendt
Kevin Noll	Scott Sommers	Oded Wertheim
Ronald Nordin	Yoshiaki Sone	Natalie Wienckowski
Mark Nowell	Xiaolu Song	Ludwig Winkel
David Ofelt	Tom Souvignier	Peter Wu
Ichiro Ogura	Bryan Sparrowhawk	Yu Xu
Tom Palkert	Edward Sprague	Lennart Yseboodt
Sujan Pandey	Peter Stassar	Liquan Yuan
Sesha Panguluri	Leonard Stencel	Hayato Yuki
Carlos Pardo	Robert Stone	Garold Yurko
Moon Park	Steve Swanson	Andrew Zambell
Pravin Patel	Andre Szczepanek	Jin Zhang
Petar Pepeljugoski	William Szeto	Yan Zhuang
Gerald Pepper	Bharat Tailor	Helge Zinner
Ruben Perez De Aranda Alonso	Akio Tajima	Pavel Zivny
Michael Peters	Takayuki Tajima	Gaoling Zou

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

Shadi Abughazaleh	David Hess	Arumugam Paventhan
Thomas Alexander	Yasuo Hidaka	Michael Peters
Richard Alfvin	Guido Hiertz	Adee Ran
Carol Ansley	Werner Hoelzl	R. K. Rannow
Peter Anslow	Rita Horner	Alon Regev
Butch Anton	Tetsushi Ikegami	Maximilian Riegel
Stefan Aust	Noriyuki Ikeuchi	Robert Robinson
Amrik Bains	Sergiu Iordanescu	Benjamin Rolfe
Saman Behtash	Scott Irwin	Martin Rossbach
Michael Bennett	Osamu Ishida	Frank Schewe
Gennaro Boggia	Atsushi Ito	Dieter Schicketanz
Ralf-Peter Braun	Peter Jones	Takeshi Shimizu
Nancy Bravin	Adri Jovin	Kapil Shrikhande
Theodore Brillhart	Shinkyō Kaku	David Solomon
Matthew Brown	Piotr Karocki	Ju-Hyung Son
Jairo Bustos Heredia	John Kay	Thomas Starai
William Byrd	Stuart Kerry	Peter Stassar
Steven B. Carlson	Yongbum Kim	Eugene Stoudenmire
Juan Carreon	Scott Kipp	Walter Struppler
Clark Carty	Bruce Kraemer	Mitsutoshi Sugawara
Mandeep Chadha	Mark Laubach	Patricia Thaler
David Chalupsky	David L. Law	James Theodoras
Minho Cheong	David Lewis	David Thompson
Keng Hua Chuang	Jon Lewis	Geoffrey Thompson
Peter Cibula	Arthur H. Light	Michael Thompson
Charles Cook	William Lo	Sterling Vaden
John D'Ambrosia	Elvis Maculuba	Dmitri Varsanofiev
Christopher Diminico	Valerie Maguire	Prabodh Varshney
Yezid Donoso	Jeffery Maki	Balasubramanian Vittal
Sourav Dutta	Arthur Marris	George Vlantis
German Feyh	Brett McClellan	Roy Wang
Matthias Fritsche	Thomas Mcdermott	Hung-Yu Wei
Yukihiro Fujimoto	Richard Mellitz	Peter Wu
James Graba	Bryan Moffitt	Oren Yuen
Randall Groves	Charles Moorwood	Andrew Zambell
Marek Hajduczenia	Michael Newman	Zhen Zhou
Adam Healey	Nick S. A. Nikjoo	George Zimmerman
Marco Hernandez	Satoshi Obara	

When the IEEE-SA Standards Board approved this standard on 30 June 2016, it had the following membership:

Jean-Philippe Faure, *Chair*
Ted Burse, *Vice Chair*
John D. Kulick, *Past Chair*
Konstantinos Karachalios, *Secretary*

Chuck Adams
Masayuki Ariyoshi
Stephen Dukes
Jianbin Fan
Ronald W. Hotchkiss
J. Travis Griffith

Gary Hoffman
Michael Janezic
Joseph L. Koepfinger*
Hung Ling
Kevin Lu
Gary Robinson
Annette D. Reilly

Mehmet Ulema
Yingli Wen
Howard Wolfman
Don Wright
Yu Yuan
Daidi Zhong

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 802.3bq™-2016, IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T.

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

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

Some of the major additions to IEEE Std 802.3 are identified in the marketplace with their project number. This is most common for projects adding higher speeds of operation or new protocols. For example, IEEE Std 802.3u™ added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3z™ added 1000 Mb/s operation (also called Gigabit Ethernet), IEEE Std 802.3ae™ added 10 Gb/s operation (also called 10 Gigabit Ethernet), IEEE Std 802.3ah™ specified access network Ethernet (also called Ethernet in the First Mile), and IEEE Std 802.3ba added 40 Gb/s operation (also called 40 Gigabit Ethernet) and 100 Gb/s operation (also called 100 Gigabit Ethernet). These major additions are all now included in and are superseded by IEEE Std 802.3-2015 and are not maintained as separate documents.

At the date of IEEE Std 802.3bq-2016 publication, IEEE Std 802.3 is composed of the following documents:

IEEE Std 802.3-2015

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

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

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

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

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

IEEE Std 802.3bw-2015

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

IEEE Std 802.3by-2016

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

IEEE Std 802.3bq-2016

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

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

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

Contents

1.	Introduction.....	24
1.3	Normative references	24
1.4	Definitions	24
1.5	Abbreviations.....	25
28.	Physical Layer link signaling for Auto-Negotiation on twisted pair	26
28.3	State diagrams and variable definitions	26
28.3.1	State diagram variables.....	26
28.3.2	State diagram timers	26
28.5	Protocol implementation conformance statement (PICS) proforma for Clause 28, Physical Layer link signaling for Auto-Negotiation on twisted pair	26
28.5.3	Major capabilities/options	26
28.5.4	PICS proforma tables for Physical Layer link signaling for Auto-Negotiation on twisted pair	27
28.5.4.8	State diagrams.....	27
30.	Management.....	28
30.2	Managed objects	28
30.2.5	Capabilities	28
30.3	Layer management for DTEs.....	28
30.3.2	PHY device managed object class.....	28
30.3.2.1	PHY device attributes	28
30.3.2.1.2	aPhyType	28
30.3.2.1.3	aPhyTypeList.....	29
30.5	Layer management for medium attachment units (MAUs).....	29
30.5.1	MAU managed object class.....	29
30.5.1.1	MAU attributes	29
30.5.1.1.2	aMAUType	29
30.5.1.1.4	aMediaAvailable.....	29
30.5.1.1.19	aSNROpMarginChnIA	29
30.5.1.1.20	aSNROpMarginChnIB.....	30
30.5.1.1.21	aSNROpMarginChnIC.....	30
30.5.1.1.22	aSNROpMarginChnID	30
30.5.1.1.24	aLDFastRetrainCount.....	31
30.5.1.1.25	aLPFastRetrainCount.....	31
30.6	Management for link Auto-Negotiation	31
30.6.1	Auto-Negotiation managed object class.....	31
30.6.1.1	Auto-Negotiation attributes	31
30.6.1.1.5	aAutoNegLocalTechnologyAbility	31
45.	Management Data Input/Output (MDIO) Interface.....	32
45.2	MDIO Interface Registers.....	32
45.2.1	PMA/PMD registers	32
45.2.1.6	PMA/PMD control 2 register (Register 1.7).....	33
45.2.1.7	PMA/PMD status 2 register (Register 1.8).....	33
45.2.1.7.4	Transmit fault (1.8.11).....	33
45.2.1.7.5	Receive fault (1.8.10)	33

45.2.1.8	PMD transmit disable register (Register 1.9)	34
45.2.1.12	40G/100G PMA/PMD extended ability register (Register 1.13)	34
45.2.1.9a	40GBASE-T ability (1.13.6)	34
45.2.1.14b	25G PMA/PMD extended ability register (Register 1.19)	35
45.2.1.14b.a	25GBASE-T ability (1.19.5)	35
45.2.1.62	10MultiGBASE-T status (Register 1.129)	35
45.2.1.62.1	LP information valid (1.129.0)	35
45.2.1.63	10MultiGBASE-T pair swap and polarity register (Register 1.130)	35
45.2.1.64	10MultiGBASE-T TX power backoff and PHY short reach setting (Register 1.131)	36
45.2.1.64.1	10MultiGBASE-T TX power backoff settings (1.131.15:10)	36
45.2.1.64.2	PHY short reach mode (1.131.0)	36
45.2.1.65	10MultiGBASE-T test mode register (Register 1.132)	36
45.2.1.65.1	Test mode control (1.132.15:13)	37
45.2.1.65.2	Transmitter test frequencies (1.132.12:10)	37
45.2.1.66	SNR operating margin channel A register (Register 1.133)	37
45.2.1.67	SNR operating margin channel B register (Register 1.134)	37
45.2.1.68	SNR operating margin channel C register (Register 1.135)	37
45.2.1.69	SNR operating margin channel D register (Register 1.136)	37
45.2.1.74	RX signal power channel A register (Register 1.141)	38
45.2.1.75	RX signal power channel B register (Register 1.142)	38
45.2.1.76	RX signal power channel C register (Register 1.143)	38
45.2.1.77	RX signal power channel D register (Register 1.144)	38
45.2.1.78	10MultiGBASE-T skew delay register (Registers 1.145 and 1.146)	38
45.2.1.79	10MultiGBASE-T fast retrain status and control register (Register 1.147)	39
45.2.1.79.1	LP fast retrain count (1.147.15:11)	39
45.2.1.79.2	LD fast retrain count (1.147.10:6)	39
45.2.1.79.5	Fast retrain signal type (1.147.2:1)	39
45.2.1.79.6	Fast retrain enable (1.147.0)	39
45.2.3	PCS registers	40
45.2.3.1	PCS control 1 register (Register 3.0)	40
45.2.3.1.2	Loopback (3.0.14)	40
45.2.3.2	PCS status 1 register (Register 3.1)	40
45.2.3.2.7	PCS receive link status (3.1.2)	40
45.2.3.6	PCS control 2 register (Register 3.7)	41
45.2.3.6.1	PCS type selection (3.7.23:0)	41
45.2.3.7	PCS status 2 register (Register 3.8)	42
45.2.3.7.3aa	25GBASE-T capable (3.8.9)	42
45.2.3.7.3b	40GBASE-T capable (3.8.6)	42
45.2.3.9	EEE control and capability 1 (Register 3.20)	42
45.2.3.9.4a	40GBASE-T EEE supported (3.20.7)	43
45.2.3.9a	EEE control and capability 2 (Register 3.21)	43
45.2.3.9a.1	25GBASE-T EEE supported (3.21.2)	43
45.2.3.13	BASE-R and 10MultiGBASE-T PCS status 1 register (Register 3.32)	43
45.2.3.13.1	BASE-R and 10MultiGBASE-T receive link status (3.32.12)	44
45.2.3.13.4	BASE-R and 10MultiGBASE-T PCS high BER (3.32.1)	44
45.2.3.13.5	BASE-R and 10MultiGBASE-T block lock (3.32.0)	45
45.2.3.14	BASE-R and 10MultiGBASE-T PCS status 2 register (Register 3.33)	45

45.2.3.14.1	Latched block lock (3.33.15).....	45
45.2.3.14.2	Latched high BER (3.33.14).....	46
45.2.3.14.3	BER (3.33.13:8).....	46
45.2.3.14.4	Errored blocks (3.33.7:0).....	46
45.2.7	Auto-Negotiation registers	46
45.2.7.10	10MultiGBASE-T AN control 1 register (Register 7.32).....	47
45.2.7.10.4a	40GBASE-T capability (7.32.11).....	48
45.2.7.10.4b	25GBASE-T capability (7.32.10).....	48
45.2.7.10.4c	25GBASE-T Fast retrain ability (7.32.9)	48
45.2.7.10.4d	40GBASE-T Fast retrain ability (7.32.3)	48
45.2.7.10.5	10GBASE-T LD PMA training reset request (7.32.2).....	48
45.2.7.10.6	10GBASE-T Fast retrain ability (7.32.1)	49
45.2.7.10.7	10GBASE-T LD loop timing ability (7.32.0).....	49
45.2.7.11	10MultiGBASE-T AN status 1 register (Register 7.33).....	49
45.2.7.11.1	MASTER-SLAVE configuration fault (7.33.15)	49
45.2.7.11.2	MASTER-SLAVE configuration resolution (7.33.14).....	50
45.2.7.11.7	10GBASE-T Link partner PMA training reset request (7.33.9)	50
45.2.7.11.7a	Link partner 40GBASE-T capability (7.33.8).....	50
45.2.7.11.7b	Link partner 25GBASE-T capability (7.33.7).....	50
45.2.7.11.7c	25GBASE-T Fast retrain ability (7.33.2)	50
45.2.7.11.8	10GBASE-T Fast retrain ability (7.33.1)	51
45.2.7.11.9	40GBASE-T Fast retrain ability (7.33.0)	51
45.2.7.13	EEE advertisement (Register 7.60).....	51
45.2.7.13.4a	40GBASE-T EEE supported (7.60.9).....	52
45.2.7.13.12a	25GBASE-T EEE supported (7.60.0).....	52
45.2.7.14	EEE link partner ability (Register 7.61)	52
45.2.7.14a	MultiGBASE-T AN control 2 (Register 7.64).....	52
45.2.7.14a.1	25GBASE-T THP Bypass Request	53
45.2.7.14a.2	40GBASE-T THP Bypass Request	53
45.2.7.14b	MultiGBASE-T AN status 2 (Register 7.65).....	53
45.2.7.14b.1	25GBASE-T Link Partner THP Bypass Request	54
45.2.7.14b.2	40GBASE-T Link Partner THP Bypass Request	54
45.5	Protocol implementation conformance statement (PICS) proforma for Clause 45, Management Data Input/Output (MDIO) interface	55
45.5.3	PICS proforma tables for the Management Data Input Output (MDIO) interface	55
45.5.3.2	PMA/PMD MMD options	55
45.5.3.3	PMA/PMD Management functions	55
45.5.3.6	PCS options.....	55
45.5.3.7	PCS management functions	56
45.5.3.8	Auto-Negotiation options	56
45.5.3.9	Auto-Negotiation management functions.....	57
55.	Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 10GBASE-T.....	58
55.3.4	PMA training side-stream scrambler polynomials	58
55.6	Management interfaces	58
55.6.1.2	10GBASE-T Auto-Negotiation page use	58
55.6.2	MASTER-SLAVE configuration resolution	58
55.12.3	Physical Coding Sublayer (PCS)	59

78.	Energy-Efficient Ethernet (EEE)	60
78.1	Overview	60
78.1.3	Reconciliation sublayer operation	60
78.1.3.3.1	PHY LPI transmit operation	60
78.1.4	PHY types optionally supporting EEE	60
78.2	LPI mode timing parameters description	60
78.3	Capabilities Negotiation	61
78.5	Communication link access latency	61
80.	Introduction to 40 Gb/s and 100 Gb/s networks	62
80.1	Overview	62
80.1.3	Relationship of 40 Gigabit and 100 Gigabit Ethernet to the ISO OSI reference model	62
80.1.4	Nomenclature	62
80.1.5	Physical Layer signaling systems	63
80.4	Delay Constraints	64
81.	Reconciliation Sublayer (RS) and Media Independent Interface for 40 Gb/s and 100 Gb/s operation (XLGMII and CGMII)	65
81.1	Overview	65
81.1.7.3	Mapping of PLS_CARRIER.indication	65
81.3.4	Link fault signaling	66
81.3.4.1	Variables and counters	66
81.3.4.2	State diagram	67
81.5	Protocol implementation conformance statement (PICS) proforma for Clause 81, Reconciliation Sublayer (RS) and Media Independent Interface for 40 Gb/s and 100 Gb/s operation	68
81.5.3.7	Link Interruption	68
105.	Introduction to 25 Gb/s networks	69
105.1	Overview	69
105.1.1	Scope	69
105.1.2	Relationship of 25 Gigabit Ethernet to the ISO OSI reference model	69
105.1.3	Nomenclature	70
105.2	Physical Layer signaling systems	70
105.3	Summary of 25 Gigabit Ethernet sublayers	71
105.3.1	Reconciliation Sublayer (RS) and 25 Gigabit Media Independent Interface (25GMII)	71
105.3.6	Auto-Negotiation (AN)	71
105.5	Delay constraints	71
113.	Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, types 25GBASE-T and 40GBASE-T	72
113.1	Overview	72
113.1.1	Nomenclature	72
113.1.2	Relationship of 25GBASE-T and 40GBASE-T to other standards	73
113.1.3	Operation of 25GBASE-T and 40GBASE-T	73
113.1.3.1	Summary of Physical Coding Sublayer (PCS)	77
113.1.3.2	Summary of Physical Medium Attachment (PMA) sublayer	78

113.1.3.3	Summary of EEE capability	78
113.1.4	Signaling.....	79
113.1.5	Interfaces	80
113.1.6	Conventions in this clause	80
113.2	25GBASE-T and 40GBASE-T service primitives and interfaces	80
113.2.1	Technology Dependent Interface	81
113.2.1.1	PMA_LINK.request.....	81
113.2.1.1.1	Semantics of the primitive.....	81
113.2.1.1.2	When generated	81
113.2.1.1.3	Effect of receipt	81
113.2.1.2	PMA_LINK.indication	81
113.2.1.2.1	Semantics of the primitive.....	81
113.2.1.2.2	When generated	82
113.2.1.2.3	Effect of receipt	82
113.2.2	PMA service interface	82
113.2.2.1	PMA_TXMODE.indication.....	83
113.2.2.1.1	Semantics of the primitive.....	83
113.2.2.1.2	When generated	84
113.2.2.1.3	Effect of receipt	84
113.2.2.2	PMA_CONFIG.indication.....	84
113.2.2.2.1	Semantics of the primitive.....	84
113.2.2.2.2	When generated	84
113.2.2.2.3	Effect of receipt	84
113.2.2.3	PMA_UNITDATA.request.....	84
113.2.2.3.1	Semantics of the primitive.....	85
113.2.2.3.2	When generated	85
113.2.2.3.3	Effect of receipt	85
113.2.2.4	PMA_UNITDATA.indication	85
113.2.2.4.1	Semantics of the primitive.....	85
113.2.2.4.2	When generated	86
113.2.2.4.3	Effect of receipt	86
113.2.2.5	PMA_SCRSTATUS.request.....	86
113.2.2.5.1	Semantics of the primitive.....	86
113.2.2.5.2	When generated	86
113.2.2.5.3	Effect of receipt	86
113.2.2.6	PMA_PCSSTATUS.request.....	86
113.2.2.6.1	Semantics of the primitive.....	86
113.2.2.6.2	When generated	86
113.2.2.6.3	Effect of receipt	87
113.2.2.7	PMA_RXSTATUS.indication	87
113.2.2.7.1	Semantics of the primitive.....	87
113.2.2.7.2	When generated	87
113.2.2.7.3	Effect of receipt	87
113.2.2.8	PMA_REMRXSTATUS.request.....	87
113.2.2.8.1	Semantics of the primitive.....	87
113.2.2.8.2	When generated	87
113.2.2.8.3	Effect of receipt	88
113.2.2.9	PMA_ALERTDETECT.indication.....	88
113.2.2.9.1	Semantics of the primitive.....	88
113.2.2.9.2	When generated	88
113.2.2.9.3	Effect of receipt	88
113.2.2.10	PCS_RX_LPI_STATUS.request	88
113.2.2.10.1	Semantics of the primitive.....	88
113.2.2.10.2	When generated	88

113.2.2.10.3	Effect of receipt	88
113.2.2.11	PMA_PCSDATAMODE.indication	89
113.2.2.11.1	Semantics of the primitive	89
113.2.2.11.2	When generated	89
113.2.2.11.3	Effect of receipt	89
113.2.2.12	PMA_FR_ACTIVE.indication	89
113.2.2.12.1	Semantics of the primitive	89
113.2.2.12.2	When generated	89
113.2.2.12.3	Effect of receipt	89
113.3	Physical Coding Sublayer (PCS)	89
113.3.1	PCS service interface (25GMII/XLGMII)	89
113.3.2	PCS functions	90
113.3.2.1	PCS Reset function	91
113.3.2.2	PCS Transmit function	91
113.3.2.2.1	Use of blocks	92
113.3.2.2.2	65B-LDPC transmission code	92
113.3.2.2.3	Notation conventions	92
113.3.2.2.4	Transmission order	95
113.3.2.2.5	Block structure	95
113.3.2.2.6	Control codes	95
113.3.2.2.7	Ordered sets	100
113.3.2.2.8	Idle (/I/)	100
113.3.2.2.9	LPI (/LI/)	100
113.3.2.2.10	Start (/S/)	100
113.3.2.2.11	Terminate (/T/)	101
113.3.2.2.12	ordered set (/O/)	101
113.3.2.2.13	Error (/E/)	101
113.3.2.2.14	Transmit process	101
113.3.2.2.15	64B/65B to 512B/513B Transcoder	101
113.3.2.2.16	Aggregation	104
113.3.2.2.17	PCS Scrambler	104
113.3.2.2.18	LDPC framing and LDPC encoder	106
113.3.2.2.19	Reed Solomon encoder	106
113.3.2.2.20	DSQ128 bit mapping	107
113.3.2.2.21	DSQ128 to 4D-PAM16	109
113.3.2.2.22	Block-LDPC framer	109
113.3.2.2.23	EEE capability	109
113.3.2.3	PCS Receive function	110
113.3.2.3.1	Frame and block synchronization	111
113.3.2.3.2	PCS descrambler	112
113.3.2.3.3	Invalid blocks	112
113.3.3	Test-pattern generators	112
113.3.4	PMA training side-stream scrambler polynomials	113
113.3.4.1	Generation of bits S_{an} , S_{bn} , S_{cn} , S_{dn}	113
113.3.4.2	Generation of 4D symbols TA_n , TB_n , TC_n , TD_n	113
113.3.4.3	PMA training mode descrambler polynomials	113
113.3.5	LPI signaling	114
113.3.5.1	LPI Synchronization	115
113.3.5.2	Quiet period signaling	116
113.3.5.3	Refresh period signaling	116
113.3.6	Detailed functions and state diagrams	117
113.3.6.1	State diagram conventions	117
113.3.6.2	State diagram parameters	117
113.3.6.2.1	Constants	117

113.3.6.2.2	Variables	118
113.3.6.2.3	Timers	120
113.3.6.2.4	Functions	120
113.3.6.2.5	Counters	122
113.3.6.3	State diagrams	123
113.3.7	PCS management	123
113.3.7.1	Status	123
113.3.7.2	Counters	124
113.3.7.3	Loopback	130
113.4	Physical Medium Attachment (PMA) sublayer	130
113.4.1	PMA functional specifications	130
113.4.2	PMA functions	131
113.4.2.1	PMA Reset function	131
113.4.2.2	PMA Transmit function	131
113.4.2.2.1	Alert signal	131
113.4.2.2.2	Link failure signal	133
113.4.2.3	PMA transmit disable function	133
113.4.2.3.1	Global PMA transmit disable function	133
113.4.2.3.2	PMA pair by pair transmit disable function	133
113.4.2.3.3	PMA MDIO function mapping	133
113.4.2.4	PMA Receive function	134
113.4.2.5	PHY Control function	135
113.4.2.5.1	Infocfield notation	136
113.4.2.5.2	Start of Frame Delimiter	136
113.4.2.5.3	Current transmitter settings	136
113.4.2.5.4	Next transmitter settings	137
113.4.2.5.5	Requested transmitter settings	137
113.4.2.5.6	Message Field	137
113.4.2.5.7	SNR_margin	138
113.4.2.5.8	Transition counter	139
113.4.2.5.9	Coefficient exchange handshake	139
113.4.2.5.10	Ability Fields	139
113.4.2.5.11	Reserved fields	139
113.4.2.5.12	Vendor-specific field	139
113.4.2.5.13	Coefficient Field	140
113.4.2.5.14	CRC16	140
113.4.2.5.15	Startup sequence	140
113.4.2.5.16	Fast retrain function	143
113.4.2.6	Link Monitor function	144
113.4.2.7	Refresh Monitor function	144
113.4.2.8	Clock Recovery function	144
113.4.3	MDI	144
113.4.3.1	MDI signals transmitted by the PHY	144
113.4.3.2	Signals received at the MDI	145
113.4.4	Automatic MDI/MDI-X configuration	146
113.4.5	State variables	146
113.4.5.1	State diagram variables	146
113.4.5.2	Timers	149
113.4.5.3	Functions	150
113.4.5.4	Counters	150
113.4.6	State diagrams	151
113.4.6.1	PHY Control state diagram	151
113.4.6.2	Transition counter state diagrams	152
113.4.6.3	Link Monitor state diagram	154

113.4.6.4	EEE Refresh monitor state diagram	155
113.4.6.5	Fast retrain state diagram	156
113.5	PMA electrical specifications	156
113.5.1	Isolation requirement	156
113.5.2	Test modes	156
113.5.2.1	Test fixtures	159
113.5.3	Transmitter electrical specifications	160
113.5.3.1	Maximum output droop	160
113.5.3.2	Transmitter nonlinear distortion	160
113.5.3.3	Transmitter timing jitter	161
113.5.3.4	Transmitter power spectral density (PSD) and power level	161
113.5.3.5	Transmit clock frequency	162
113.5.4	Receiver electrical specifications	162
113.5.4.1	Receiver differential input signals	162
113.5.4.2	Receiver frequency tolerance	163
113.5.4.3	Rejection of External EM Fields	163
113.5.4.4	Alien crosstalk noise rejection	163
113.5.4.5	Short reach mode	164
113.6	Management interfaces	164
113.6.1	Support for Auto-Negotiation	164
113.6.1.1	25G/40GBASE-T use of registers during Auto-Negotiation	165
113.6.1.2	25G/40GBASE-T Auto-Negotiation page use	165
113.6.1.3	Sending Next Pages	165
113.6.2	MASTER-SLAVE configuration resolution	167
113.7	Link segment characteristics	169
113.7.1	Cabling system characteristics	170
113.7.2	Link segment transmission parameters	170
113.7.2.1	Insertion loss	170
113.7.2.2	Differential characteristic impedance	171
113.7.2.3	Return loss	171
113.7.2.4	Coupling parameters between duplex channels comprising one link segment	171
113.7.2.4.1	Differential near-end crosstalk	171
113.7.2.4.2	Multiple disturber near-end crosstalk (MDNEXT) loss	172
113.7.2.4.3	Multiple disturber power sum near-end crosstalk (PSNEXT) loss	173
113.7.2.4.4	Attenuation to crosstalk ratio, far end (ACRF)	174
113.7.2.4.5	Multiple disturber attenuation to crosstalk ratio, far-end (MDACRF)	174
113.7.2.4.6	Multiple disturber power sum attenuation to crosstalk ratio, far-end (PS-ACRF)	175
113.7.2.5	Maximum link delay	175
113.7.2.6	Link delay skew	175
113.7.3	Coupling parameters between link segments	175
113.7.3.1	Multiple disturber alien near-end crosstalk (MDANEXT) loss	176
113.7.3.1.1	Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss	176
113.7.3.2	Multiple disturber alien far-end crosstalk (MDAFEXT) loss	176
113.7.3.2.1	Multiple disturber power sum alien attenuation to crosstalk, far end crosstalk (PSAACRF)	177
113.7.4	Direct attach cable assembly—Short Reach Mode	177
113.7.4.1	Insertion loss	177
113.7.4.2	Return loss	178

113.7.4.3	Coupling parameters between direct attach cable assembly duplex channels comprising one link segment	178
113.7.4.3.1	Differential near-end crosstalk	178
113.7.4.3.2	Multiple disturber near-end crosstalk (MDNEXT) loss	179
113.7.4.3.3	Multiple disturber power sum near-end crosstalk (PSNEXT) loss	179
113.7.4.3.4	Attenuation to crosstalk ratio, far end (ACRF)	179
113.7.4.3.5	Multiple disturber attenuation to crosstalk ratio, far-end (MDACRF)	180
113.7.4.3.6	Maximum link delay	180
113.7.4.3.7	Link delay skew	180
113.7.4.3.8	Multiple disturber alien near-end crosstalk (MDANEXT) loss	180
113.7.4.3.9	Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss	180
113.7.4.3.10	Multiple disturber power sum alien attenuation to crosstalk, far end crosstalk (PSAACRF)	181
113.7.5	Noise environment	182
113.8	MDI specification	182
113.8.1	MDI connectors	182
113.8.2	MDI electrical specifications	182
113.8.2.1	MDI return loss	184
113.8.2.2	MDI impedance balance	184
113.8.2.3	MDI fault tolerance	185
113.9	Environmental specifications	185
113.9.1	General safety	185
113.9.2	Network safety	185
113.9.3	Installation and maintenance guidelines	186
113.9.4	Telephone voltages	186
113.9.5	Electromagnetic compatibility	186
113.9.6	Temperature and humidity	186
113.10	PHY labeling	186
113.11	Delay constraints	186
113.12	Protocol implementation conformance statement (PICS) proforma for Clause 113, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, types 25GBASE-T and 40GBASE-T	188
113.12.1	Identification	188
113.12.1.1	Implementation identification	188
113.12.1.2	Protocol summary	188
113.12.2	Major capabilities/options	189
113.12.3	Physical Coding Sublayer (PCS)	189
113.12.3.1	PCS Receive functions	191
113.12.3.2	Other PCS functions	191
113.12.4	Physical Medium Attachment (PMA)	191
113.12.5	Management interface	194
113.12.6	PMA Electrical Specifications	195
113.12.7	Characteristics of the link segment	197
113.12.8	Characteristics of the direct attach cable assembly	197
113.12.9	MDI requirements	198
113.12.10	General safety and environmental requirements	198
113.12.11	Timing requirements	199

Annex 28B (normative) IEEE 802.3 Selector Base Page definition	200
28B.3 Priority resolution	200
Annex 28C (normative) Next Page Message Code field definitions	201
28C.11 Message code 9—10MultiGBASE-T and 1000BASE-T technology message code ..	201
Annex 28D (normative) Description of extensions to Clause 28 and associated annexes	202
28D.8 Extensions required for Clause 113 (25GBASE-T and 40GBASE-T).....	202
Annex 113A (informative) Description of cable clamp and test setup.....	203
113A.1 Overview	203
113A.2 Description of cable clamp	203
113A.3 Cable clamp measurement, calibration, and validation	205
113A.4 Test setup	208
Annex A (informative) Bibliography	209

IEEE Standard for Ethernet

Amendment 3: Physical Layer and Management Parameters for 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

IMPORTANT NOTICE: *IEEE Standards documents are not intended to ensure safety, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers 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.*

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

(This amendment is based on IEEE Std 802.3™-2015 as amended by IEEE Std 802.3bw™-2015 and IEEE Std 802.3by™-2016.)

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 ~~strike through~~ (to remove old material) and underline (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.¹

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

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

1. Introduction

1.3 Normative references

Insert the following references in alphanumeric order:

ANSI/TIA-568-C.2-1-2016, Balanced Twisted-Pair Telecommunications Cabling and Components Standard, Addendum 1: Specifications for 100 Ω Category 8 Cabling.²

ISO/IEC DIS 11801-1:2016, Information technology—Generic cabling for customer premises—Part 1: General Requirements.³

1.4 Definitions

Insert the 25GBASE-T definition after 1.4.64g 25GBASE-SR (added by IEEE Std 802.3by-2016) as follows:

1.4.64h 25GBASE-T: IEEE 802.3 Physical Layer specification for a 25 Gb/s LAN using four pairs of ANSI/TIA Category 8, ISO/IEC Class I, or ISO/IEC Class II balanced copper cabling. (See IEEE Std 802.3, Clause 113.)

Insert the 40GBASE-T definition after 1.4.72 40GBASE-SR4 as follows:

1.4.72a 40GBASE-T: IEEE 802.3 Physical Layer specification for a 40 Gb/s LAN using four pairs of ANSI/TIA Category 8, ISO/IEC Class I, or ISO/IEC Class II balanced copper cabling. (See IEEE Std 802.3, Clause 113.)

Insert the Category 8 balanced cabling definition after 1.4.131 Category 7A balanced cabling as follows:

1.4.131a Category 8 balanced cabling: Balanced 100 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 2000 MHz (i.e., cabling components that meet the Category 8.1 or Category 8.2 requirements specified in ISO/IEC DIS 11801-1:2016 or Category 8 specified in ANSI/TIA-568-C.2-1-2016). In addition to the requirements outlined in ISO/IEC DIS 11801-1 and ANSI/TIA-568-C.2-1, IEEE Std 802.3 [Clause 14](#), [Clause 23](#), [Clause 25](#), [Clause 40](#), Clause 55, and Clause 113 specify additional requirements for this cabling when used with 10BASE-T, 100BASE-T, 10GBASE-T, 25GBASE-T, and 40GBASE-T.

Insert the Infocfield definition into the list after 1.4.237 in-band signaling and insert the MultiGBASE-T definition into the list after 1.4.277 mixing segment as follows:

1.4.237a Infocfield: A 16 octet frame transmitted at regular intervals containing messages for startup operation by certain PHYs. (See IEEE Std 802.3, Clause 55 and Clause 113).

1.4.277a MultiGBASE-T: PHYs that belong to the set of specific BASE-T PHYs at speeds in excess of 1000 Mb/s, including 10GBASE-T, 25GBASE-T, and 40GBASE-T. (See IEEE Std 802.3, Clause 55 and Clause 113).

²ANSI publications are available from the American National Standards Institute (<http://www.ansi.org>).

³ISO/IEC publications are available from the ISO Central Secretariat (<http://www.iso.org/>). ISO publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

1.5 Abbreviations

Insert the following new abbreviation in alphanumeric order:

ACRF attenuation to crosstalk ratio, far-end

28. Physical Layer link signaling for Auto-Negotiation on twisted pair

28.3 State diagrams and variable definitions

28.3.1 State diagram variables

Insert rows for 25GigT and 40GigT in the first list in 28.3.1 below the row for 10GigT as follows:

25GigT; represents that the 25GBASE-T PMA is the signal source.

40GigT; represents that the 40GBASE-T PMA is the signal source.

28.3.2 State diagram timers

Change last sentence in the first paragraph of definition of link_fail_inhibit_timer as follows:

link_fail_inhibit_timer

Timer for qualifying a link_status=FAIL indication or a link_status=READY indication when a specific technology link is first being established. A link will only be considered “failed” if the link_fail_inhibit_timer has expired and the link has still not gone into the link_status=OK state. The link_fail_inhibit_timer shall expire 750 ms to 1000 ms after entering the FLP LINK GOOD CHECK state for devices operating at 10/100/1000 Mb/s. The link_fail_inhibit_timer shall expire 2000 ms to 2250 ms after entering the FLP LINK GOOD CHECK state for devices ~~operating at 10 Gb/s in the MultiGBASE-T PHY set.~~

Change description for the link_fail_inhibit_timer (10 Gb/s devices) Parameter in Table 28–9 as follows (unchanged rows not shown):

Table 28–9—Timer min./max. value summary

Parameter	Min.	Typ.	Max.	Units
link_fail_inhibit_timer (10 Gb/s devices in the MultiGBASE-T set)	2000		2250	ms

28.5 Protocol implementation conformance statement (PICS) proforma for Clause 28, Physical Layer link signaling for Auto-Negotiation on twisted pair⁴

28.5.3 Major capabilities/options

*Change row for *10G in 28.5.3 as follows (unchanged rows not shown):*

Item	Feature	Subclause	Status	Support	Value/Comment
*10MG	Implementation supports a member of the MultiGBASE-T PHY set (see 1.4.277a) 10GBASE-T PHY	55 and	O		N/A

⁴Copyright 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.

IEEE Std 802.3bq-2016
 IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

28.5.4 PICS proforma tables for Physical Layer link signaling for Auto-Negotiation on twisted pair

28.5.4.8 State diagrams

Change rows for Items SD10 and SD11 in 28.5.4.8 as follows (unchanged rows not shown):

Item	Feature	Subclause	Status	Support	Value/Comment
SD10	link_fail_inhibit_timer (10/100/1000 Mb/s)	28.3.2	40MG: M		Expires 750 ms to 1000 ms after entering the FLP LINK GOOD CHECK state
SD11	link_fail_inhibit_timer (MultiGBASE-T devices 10 Gb/s)	28.3.2	40MG: M		Expires 2000 ms to 2250 ms after entering the FLP LINK GOOD CHECK state upon successful master/slave resolution

30. Management

30.2 Managed objects

30.2.5 Capabilities

Change column header from 10GBASE-T Operating Margin package (conditional) to MultiGBASE-T Operating Margin package (conditional) in Table 30-1e as follows (unchanged lines not shown):

Table 30-1e—Capabilities

			DTE	Repeater	MAU	
			Basic Package (mandatory)			
			Mandatory Package (mandatory)			
			Recommended Package (optional)			
			Optional Package (optional)			
			Array Package (optional)			
			Excessive Deferral Package (optional)			
			Multiple PHY Package (optional)			
			PHY Error Monitor Capability (optional)			
			Basic Control Capability (mandatory)			
			Performance Monitor Capability (optional)			
			Address Tracking Capability (optional)			
			100/1000 Mb/s Monitor Capability (optional)			
			1000 Mb/s Burst Monitor Capability (optional)			
			Basic Package (mandatory)			
			MAU Control Package (optional)			
			Media Loss Tracking Package (conditional)			
			Broadband DTE MAU Package (conditional)			
			MLL Capability (conditional)			
			PHY Error Monitor Capability (optional)			
			40MultiGBASE-T Operating Margin package (conditional)			
			Forward Error Correction Package (conditional)			
			Energy-Efficient Ethernet (optional)			
			Auto-Negotiation Package (mandatory)			

30.3 Layer management for DTEs

30.3.2 PHY device managed object class

30.3.2.1 PHY device attributes

30.3.2.1.2 aPhyType

Insert new entries in APPROPRIATE SYNTAX (as modified by IEEE Std 802.3bw-2015 and IEEE Std 802.3by-2016) after the entries for 25GBASE-R (25GBASE-T) and for 40GBASE-R (40GBASE-T) as follows:

25GBASE-T	Clause 113 25 Gb/s DSQ128
40GBASE-T	Clause 113 40 Gb/s DSQ128

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

30.3.2.1.3 aPhyTypeList

Insert new entries in APPROPRIATE SYNTAX (as modified by IEEE Std 802.3bw-2015 and IEEE Std 802.3by-2016) after the entries for 25GBASE-R (25GBASE-T) and for 40GBASE-R (40GBASE-T) as follows:

25GBASE-T	Clause 113 25 Gb/s DSQ128
40GBASE-T	Clause 113 40 Gb/s DSQ128

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 new entries in APPROPRIATE SYNTAX (as modified by IEEE Std 802.3bw-2015 and IEEE Std 802.3by-2016) after the entries for 25GBASE-SR (25GBASE-T) and for 40GBASE-FR (40GBASE-T) as follows:

25GBASE-T	Four-pair twisted-pair balanced copper cabling PHY as specified in Clause 113
40GBASE-T	Four-pair twisted-pair balanced copper cabling PHY as specified in Clause 113

30.5.1.1.4 aMediaAvailable

Change the sixth paragraph of BEHAVIOUR DEFINED AS (as modified by IEEE Std 802.3bw-2015 and IEEE Std 802.3by-2016) as follows:

For 40 Gb/s and 100 Gb/s the enumerations map to value of the link_fault variable (see 81.3.4) within the Link Fault Signaling state diagram (see 81.3.4.1 and Figure 46-11) as follows: the values OK and Link Interruption maps to the enumeration “available”, the value Local Fault maps to the enumeration “not available” and the value Remote Fault maps to the enumeration “remote fault.”

Change the eighth paragraph of BEHAVIOUR DEFINED AS (as modified by IEEE Std 802.3by-2016) as follows:

For 10 Gb/s and 25 Gb/s the enumerations map to value of the link_fault variable within the Link Fault Signaling state diagram (Figure 46-11) as follows: the values OK and Link Interruption maps to the enumeration “available”, the value Local Fault maps to the enumeration “not available” and the value Remote Fault maps to the enumeration “remote fault”.

30.5.1.1.19 aSNROpMarginChnIA

Change text to include both 25GBASE-T and 40GBASE-T (as part of the MultiGBASE-T operating package) as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

BEHAVIOUR DEFINED AS:

The current SNR operating margin measured at the slicer input for channel A for the ~~10GBASE-T~~ ~~MultiGBASE-T~~ PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of −12.7 dB to 12.7 dB. If a [Clause 45](#) MDIO Interface to the PMA/PMD is present, then this attribute maps to the SNR operating margin channel A register (see 45.2.1.66).;

30.5.1.1.20 aSNROpMarginChnIB

Change text to include 25GBASE-T and 40GBASE-T (as part of the MultiGBASE-T operating package) as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:

The current SNR operating margin measured at the slicer input for channel B for the ~~10GBASE-T~~ ~~MultiGBASE-T~~ PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of −12.7 dB to 12.7 dB. If a [Clause 45](#) MDIO Interface to the PMA/PMD is present, then this attribute maps to the SNR operating margin channel B register (see 45.2.1.67).;

30.5.1.1.21 aSNROpMarginChnIC

Change text to include 25GBASE-T and 40GBASE-T (as part of the MultiGBASE-T operating package) as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:

The current SNR operating margin measured at the slicer input for channel C for the ~~10GBASE-T~~ ~~MultiGBASE-T~~ PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of −12.7 dB to 12.7 dB. If a [Clause 45](#) MDIO Interface to the PMA/PMD is present, then this attribute maps to the SNR operating margin channel C register (see 45.2.1.68).;

30.5.1.1.22 aSNROpMarginChnID

Change text to include 25GBASE-T and 40GBASE-T (as part of the MultiGBASE-T operating package) as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:

The current SNR operating margin measured at the slicer input for channel D for the ~~10GBASE-T~~ ~~MultiGBASE-T~~ PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of −12.7 dB to 12.7 dB. If a [Clause 45](#) MDIO Interface to the PMA/PMD is present, then this attribute maps to the SNR operating margin channel D register (see 45.2.1.69).;

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

30.5.1.1.24 aLDFastRetrainCount

Change text of aLDFastRetrainCount to include 25GBASE-T and 40GBASE-T (as part of the Energy Efficient Ethernet package (optional)) as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1000 counts per second

BEHAVIOUR DEFINED AS:

A count of the number of ~~10GBASE-T~~ fast retrains initiated by the local device. ~~The indication reflects the state of the PHY event.~~ This counter can be derived from fr_tx_counter (see 45.2.1.79.2 and 55.4.5.4+ and 113.4.5.4-). If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute can be derived from the LD fast retrain count register (see 45.2.1.79.2).;

30.5.1.1.25 aLPFastRetrainCount

Change text of aLPFastRetrainCount to include 25GBASE-T and 40GBASE-T (as part of the Energy Efficient Ethernet package (optional)) as follows:

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1000 counts per second

BEHAVIOUR DEFINED AS:

A count of the number of ~~10GBASE-T~~ fast retrains initiated by the link partner. ~~The indication reflects the state of the PHY event.~~ This counter can be derived from fr_rx_counter (see 45.2.1.79.1 and 55.4.5.4+ and 113.4.5.4-). If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute can be derived from to the LP fast retrain count register (see 45.2.1.79.1).;

30.6 Management for link Auto-Negotiation

30.6.1 Auto-Negotiation managed object class

30.6.1.1 Auto-Negotiation attributes

30.6.1.1.5 aAutoNegLocalTechnologyAbility

Insert new entries in APPROPRIATE SYNTAX (as modified by IEEE Std 802.3by-2016) after the entries for 10GBASE-KRFD (25GBASE-T) and for 40GBASE-CR4 (40GBASE-T) as follows:

25GBASE-T	25GBASE-T as specified in Clause 113
40GBASE-T	40GBASE-T as specified in Clause 113

45. Management Data Input/Output (MDIO) Interface

45.2 MDIO Interface Registers

45.2.1 PMA/PMD registers

Change the names for register addresses 1.129 to 1.144, 1.145 through 1.146, and 1.147 in Table 45–3 as follows (unchanged rows not shown):

Table 45–3—PMA/PMD registers

Register address	Register name	Subclause
1.129	10Multi GBASE-T status	45.2.1.62
1.130	10Multi GBASE-T pair swap and polarity	45.2.1.63
1.131	10Multi GBASE-T TX power backoff and PHY short reach setting	45.2.1.64
1.132	10Multi GBASE-T test mode	45.2.1.65
1.133	10GBASE-T SNR operating margin channel A	45.2.1.66
1.134	10GBASE-T SNR operating margin channel B	45.2.1.67
1.135	10GBASE-T SNR operating margin channel C	45.2.1.68
1.136	10GBASE-T SNR operating margin channel D	45.2.1.69
1.137	10GBASE-T m Minimum margin channel A	45.2.1.70
1.138	10GBASE-T m Minimum margin channel B	45.2.1.71
1.139	10GBASE-T m Minimum margin channel C	45.2.1.72
1.140	10GBASE-T m Minimum margin channel D	45.2.1.73
1.141	10GBASE-T RX signal power channel A	45.2.1.74
1.142	10GBASE-T RX signal power channel B	45.2.1.75
1.143	10GBASE-T RX signal power channel C	45.2.1.76
1.144	10GBASE-T RX signal power channel D	45.2.1.77
1.145 through 1.146	10Multi GBASE-T skew delay	45.2.1.78
1.147	10Multi GBASE-T fast retrain status and control register	45.2.1.79

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

45.2.1.6 PMA/PMD control 2 register (Register 1.7)

Change the indicated two reserved rows and insert four new rows (two of which are reserved) in alphanumeric order in the 1.7.5:0 row of Table 45-7 (as modified by IEEE Std 802.3bw-2015 and IEEE Std 802.3by-2016), as follows (unchanged rows not shown):

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

Bit(s)	Name	Description	R/W ^a
1.7.5:0	PMA/PMD type selection	<u>1 1 0 1 1 1</u> = 25GBASE-T PMA <u>1 1 0 1 1 0</u> = reserved <u>1 1 0 1 0 x</u> = reserved <u>1 1 0 x 0 x x</u> = reserved for future use <u>1 0 0 1 1 1</u> = reserved <u>1 0 0 1 1 0</u> = 40GBASE-T PMA	R/W

^aR/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 description locations for 25GBASE-T after 25GBASE-SR (see IEEE Std 802.3by-2016) and before 40GBASE-KR4 and description for 40GBASE-T after the row for 40GBASE-FR in Table 45-9 as follows (unchanged rows not shown):

Table 45-9—Transmit fault description location

PMA/PMD	Description location
<u>25GBASE-T</u>	<u>113.4.2.2</u>
<u>40GBASE-T</u>	<u>113.4.2.2</u>

45.2.1.7.5 Receive fault (1.8.10)

Insert description locations for 25GBASE-T after 25GBASE-SR (see IEEE Std 802.3by-2016) and before 40GBASE-KR4 and description for 40GBASE-T after the row for 40GBASE-FR in Table 45-10 as follows (unchanged rows not shown):

Table 45-10—Receive fault description location

PMA/PMD	Description location
<u>25GBASE-T</u>	<u>113.4.2.4</u>
<u>40GBASE-T</u>	<u>113.4.2.4</u>

45.2.1.8 PMD transmit disable register (Register 1.9)

Insert description location for 25GBASE-T after row for 25GBASE-SR (see IEEE Std 802.3by-2016) and before 40GBASE-KR and 40GBASE-T after the row for 40GBASE-FR in Table 45–12 as follows (unchanged rows not shown):

Table 45–12—Transmit disable description location

PMA/PMD	Description location
25GBASE-T	113.4.2.3
40GBASE-T	113.4.2.3

45.2.1.12 40G/100G PMA/PMD extended ability register (Register 1.13)

Change the name and description for bit 1.13.6 in Table 45–16 as follows (unchanged rows not shown):

Table 45–16—40G/100G PMA/PMD Extended Ability register bit definitions

Bit(s)	Name	Description	R/W ^a
1.13.6	Reserved 40GBASE-T ability	Value always 0 1 = PMA/PMD is able to perform 40GBASE-T 0 = PMA/PMD is not able to perform 40GBASE-T	RO

^aRO = Read only

45.2.1.9a 40GBASE-T ability (1.13.6)

Insert 45.2.1.12.9a after 45.2.1.12.9 as follows:

When read as a one, bit 1.13.6 indicates that the PMA/PMD is able to operate as a 40GBASE-T PMA type. When read as a zero, bit 1.13.6 indicates that the PMA/PMD is not able to operate as a 40GBASE-T PMA type.

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

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

Change the reserved row, and insert a row below it with the description for bit 1.19.5 in Table 45–17bb (inserted by IEEE Std 802.3by-2016) as follows (unchanged rows not shown):

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

Bit(s)	Name	Description	R/W ^a
1.19.15:6 5	Reserved	Value always 0	RO
<u>1.19.5</u>	<u>25GBASE-T ability</u>	<u>1 = PMA/PMD is able to perform 25GBASE-T</u> <u>0 = PMA/PMD is not able to perform 25GBASE-T</u>	<u>RO</u>

^aRO = Read only

45.2.1.14b.a 25GBASE-T ability (1.19.5)

Insert 45.2.1.14b.a before 45.2.1.14b.1 (inserted by IEEE Std 802.3by-2016) as follows:

When read as a one, bit 1.19.5 indicates that the PMA/PMD is able to operate as a 25GBASE-T PMA type. When read as a zero, bit 1.19.5 indicates that the PMA/PMD is not able to operate as a 25GBASE-T PMA type.

Change the title and text of 45.2.1.62 to include 25GBASE-T and 40GBASE-T as follows:

45.2.1.62 ~~40~~MultiGBASE-T status (Register 1.129)

The assignments of bits in the ~~40~~MultiGBASE-T status register is shown in Table 45–54.

45.2.1.62.1 LP information valid (1.129.0)

Change the text of 45.2.1.62.1 to include 25GBASE-T and 40GBASE-T as follows:

When read as a one, bit 1.129.0 indicates that the startup protocol defined in 55.4.2.5 (for 10GBASE-T) or 113.4.2.5 (for 25G/40GBASE-T) has been completed, and that the contents of bits 1.130.11:0, 1.131.15:10, 1.145.14:8, 1.146.14:8, and 1.146.6:0, which are established during the startup protocol, are valid. When read as a zero, bit 1.129.0 indicates that the startup process has not been completed, and that the contents of these bits that are established during the startup protocol are invalid. A ~~40~~MultiGBASE-T PMA in the MultiG-BASE-T set shall return a value of zero in bit 1.129.1 if PMA link_status=FAIL.

Change title of Table 45–54 to include 25GBASE-T and 40GBASE-T as follows:

Table 45–54—~~40~~MultiGBASE-T status register bit definitions

Change the title of 45.2.1.63 to include 25GBASE-T and 40GBASE-T as follows:

45.2.1.63 ~~40~~MultiGBASE-T pair swap and polarity register (Register 1.130)

Change the title in Table 45–55 to include 25GBASE-T and 40GBASE-T as follows:

Table 45–55—~~40~~MultiGBASE-T pair swap and polarity register bit definitions

Change the title and text of 45.2.1.64 to include 25GBASE-T and 40GBASE-T as follows:

45.2.1.64 ~~40~~MultiGBASE-T TX power backoff and PHY short reach setting (Register 1.131)

The complete assignment of bits in the ~~40~~MultiGBASE-T TX power backoff and short reach mode settings register is shown in Table 45–56.

Change the title in Table 45–56 to include 25GBASE-T and 40GBASE-T as follows:

Table 45–56—~~40~~MultiGBASE-T TX power backoff and PHY short reach setting register bit definitions

Change the title and text of 45.2.1.64.1 to include 25GBASE-T and 40GBASE-T as follows:

45.2.1.64.1 ~~40~~MultiGBASE-T TX power backoff settings (1.131.15:10)

The ~~40~~MultiGBASE-T TX power backoff settings reflects the TX power backoff selected during the startup negotiation process. The 10GBASE-T startup negotiation process and all TX power backoff settings are defined in 55.4.2.5 and 55.4.5.1. The 25GBASE-T and 40GBASE-T startup negotiation process and all TX power backoff settings are defined in 113.4.2.5 and 113.4.5.1. If LP information valid bit, 1.129.0, is set to one then bits 1.131.15:13 indicates the TX power backoff setting of the link partner and bits 1.131.12:10 indicates the TX power backoff setting of the local device.

45.2.1.64.2 PHY short reach mode (1.131.0)

Change the text of 45.2.1.64.2 to include 25GBASE-T and 40GBASE-T as follows:

The short reach mode of the 10GBASE-T PHY provides a means for operation on a cable plant that has parametric performance equivalent to 30 m of Class F and Class EA cabling as defined in 55.5.4.5. The short reach mode of the 25GBASE-T and 40GBASE-T PHYs provides for operation on a direct attach link segment that has parametric performance defined in 113.7.4. If bit 1.131.0 is a one, the PHY is in short reach mode. If bit 1.131.0 is a zero, the PHY is not in short reach mode; the PHY is operating in normal mode. The default value for this bit is zero. For 25GBASE-T and 40GBASE-T, setting this bit to a one puts the PHY in short reach mode, and setting this bit to a zero puts the PHY into normal (non-short reach) mode.

Change the title and text of 45.2.1.65 to include 25GBASE-T and 40GBASE-T as follows:

45.2.1.65 ~~40~~MultiGBASE-T test mode register (Register 1.132)

The assignment of bits in the ~~40~~MultiGBASE-T test mode register is shown in Table 45–57. The default values for each bit should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Change the title in Table 45–57 to include 25GBASE-T and 40GBASE-T as follows:

Table 45–57—~~40~~MultiGBASE-T test mode register bit definitions

Change text of 45.2.1.65.1 and 45.2.1.65.2 to include references to 25G/40GBASE-T and Clause 113 as follows:

45.2.1.65.1 Test mode control (1.132.15:13)

Transmitter test mode operations defined by bits 1.132.15:13, are described for 10GBASE-T in 55.5.2 and Table 55–12, and for 25G/40GBASE-T in 113.5.2 and Table 113–17. The default value for bits 1.132.15:13 is zero.

45.2.1.65.2 Transmitter test frequencies (1.132.12:10)

When test mode 4 is selected by setting bits 1.132.15:13 to one, zero, zero respectively, bits 1.132.12:10 select the transmit test frequency as shown in Table 45–57. Detailed use and operation of these transmitter test frequencies is described in 55.5.2 and 113.5.2.

45.2.1.66 SNR operating margin channel A register (Register 1.133)

Change the text of 45.2.1.66 to include 25GBASE-T and 40GBASE-T as follows:

Register 1.133 contains the current SNR operating margin measured at the slicer input for channel A for the ~~10GBASE-T PMA~~s in the MultiGBASE-T set. It is reported with 0.1 dB of resolution to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.67 SNR operating margin channel B register (Register 1.134)

Change the text of 45.2.1.67 to include 25GBASE-T and 40GBASE-T as follows:

Register 1.134 contains the current SNR operating margin measured at the slicer input for channel B for the ~~10GBASE-T PMA~~s in the MultiGBASE-T set. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.68 SNR operating margin channel C register (Register 1.135)

Change the text of 45.2.1.68 to include 25GBASE-T and 40GBASE-T as follows:

Register 1.135 contains the current SNR operating margin measured at the slicer input for channel C for the ~~10GBASE-T PMA~~s in the MultiGBASE-T set. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.69 SNR operating margin channel D register (Register 1.136)

Change the text of 45.2.1.69 to include 25GBASE-T and 40GBASE-T as follows:

Register 1.136 contains the current SNR operating margin measured at the slicer input for channel D for the ~~10GBASE-T PMA~~s in the MultiGBASE-T set. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.74 RX signal power channel A register (Register 1.141)

Change the text of 45.2.1.74 to include 25GBASE-T and 40GBASE-T as follows:

The RX signal power channel A register is read only and contains the receive signal power measured at the MDI during training as described in 55.4.3.1 and 113.4.3.1. The RX signal power should reflect the power measured when the device transitions out of the state PMA_Training_Init_M or MA_Training_Init_S (as appropriate, see 55.4.6.1 and 113.4.6.1), when the link partner is transmitting with PBO_tx = 4 (8 dB power backoff). It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –20 dBm to 5.5 dBm. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.75 RX signal power channel B register (Register 1.142)

Change the text of 45.2.1.75 to include 25GBASE-T and 40GBASE-T as follows:

The RX signal power channel B register is read only and contains the receive signal power measured at the MDI during training as described in 55.4.3.1 and 113.4.3.1. The RX signal power should reflect the power measured when the device transitions out of the state PMA_Training_Init_M or MA_Training_Init_S (as appropriate, see 55.4.6.1 and 113.4.6.1), when the link partner is transmitting with PBO_tx = 4 (8 dB power backoff). It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –20 dBm to 5.5 dBm. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.76 RX signal power channel C register (Register 1.143)

Change the text of 45.2.1.76 to include 25GBASE-T and 40GBASE-T as follows:

The RX signal power channel C register is read only and contains the receive signal power measured at the MDI during training as described in 55.4.3.1 and 113.4.3.1. The RX signal power should reflect the power measured when the device transitions out of the state PMA_Training_Init_M or MA_Training_Init_S (as appropriate, see 55.4.6.1 and 113.4.6.1), when the link partner is transmitting with PBO_tx = 4 (8 dB power backoff). It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –20 dBm to 5.5 dBm. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.77 RX signal power channel D register (Register 1.144)

Change the text of 45.2.1.77 to include 25GBASE-T and 40GBASE-T as follows:

The RX signal power channel D register is read only and contains the receive signal power measured at the MDI during training as described in 55.4.3.1 and 113.4.3.1. The RX signal power should reflect the power measured when the device transitions out of the state PMA_Training_Init_M or MA_Training_Init_S (as appropriate, see 55.4.6.1 and 113.4.6.1), when the link partner is transmitting with PBO_tx = 4 (8 dB power backoff). It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –20 dBm to 5.5 dBm. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

Change the title and text of 45.2.1.78 to include 25GBASE-T and 40GBASE-T as follows:

45.2.1.78 40G MultiGBASE-T skew delay register (Registers 1.145 and 1.146)

The skew delay register reports the current skew delay on each of the pair with respect to physical pair A (see Table 45–58). It is reported with 1.25 ns resolution to an accuracy of 2.5 ns equal to one symbol period

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

(see [55.1.3](#) and [113.1.2](#)) of the PHY (e.g., 1.25 ns for 10GBASE-T) to an accuracy of two symbol periods (e.g., 2.5 ns for 10GBASE-T). The number reported is in two's complement notation with positive values representing delay and negative values representing advance with respect to physical pair A. If the delay exceeds the maximum amount that can be represented by the range (~~-64 symbols to +63 symbols~~ ~~-80 ns to +78.75 ns~~), the field displays the maximum respective value. The value shall be updated at least once per second.

Change title of Table 45–58 to include 25GBASE-T and 40GBASE-T.

Table 45–58—~~40~~MultiGBASE-T skew delay register bit definitions

Change the title of 45.2.1.79 to include 25GBASE-T and 40GBASE-T as follows:

45.2.1.79 ~~40~~MultiGBASE-T fast retrain status and control register (Register 1.147)

Change the title of Table 45–59 to include 25GBASE-T and 40GBASE-T as follows

Table 45–59—~~40~~MultiGBASE-T fast retrain status and control register bit definitions

45.2.1.79.1 LP fast retrain count (1.147.15:11)

Change the text of 45.2.1.79.1 to include 25GBASE-T and 40GBASE-T as follows:

These bits map to fr_rx_counter as defined in [55.4.5.4](#) for 10GBASE-T and [113.4.5.4](#) for 25GBASE-T and 40GBASE-T. The counter is a 5-bit count of the number of ~~10GBASE-T~~ fast retrains requested by the link partner. These bits shall be reset to all zeros when read or upon execution of the PMA reset. These bits shall be held at all ones in the case of overflow.

45.2.1.79.2 LD fast retrain count (1.147.10:6)

Change the text of 45.2.1.79.2 to include 25GBASE-T and 40GBASE-T as follows:

These bits map to fr_tx_counter as defined in [55.4.5.4](#) for 10GBASE-T and [113.4.5.4](#) for 25GBASE-T and 40GBASE-T. The counter is a 5-bit count of the number of ~~10GBASE-T~~ fast retrains requested by the local device. These bits shall be reset to all zeros when read or upon execution of the PMA reset. These bits shall be held at all ones in the case of overflow.

45.2.1.79.5 Fast retrain signal type (1.147.2:1)

Change the text of 45.2.1.79.5 to add reference to 113.3.6.2.2 as follows:

For PHYs that support fast retrain, these bits map to fr_sigtype as defined in [55.3.6.2.2](#) and [113.3.6.2.2](#). When Fast retrain signal type is set to 00, the PMA sends IDLE characters on the receive path during fast retrain. When Fast retrain signal type is set to 01, the PMA sends Local Fault on the receive path during fast retrain. When Fast retrain signal type is set to 10, the PMA sends Link Interruption on the receive path during fast retrain.

45.2.1.79.6 Fast retrain enable (1.147.0)

Change the text of 45.2.1.79.6 to add reference to 113.4.5.1 as follows:

For PHYs that support fast retrain, this bit controls fr_enable as defined in [55.4.5.1](#) and [113.4.5.1](#). When PMA reset is executed, this bit is set to one.

NOTE—Setting this bit to zero while a link is up will cause the PHY to stop supporting fast retrain, and the link will drop if the link partner initiates a fast retrain.

45.2.3 PCS registers

Change the names of register addresses 3.20, 3.21, 3.32 and 3.33 in Table 45–119 as follows (unchanged rows not shown):

Table 45–119—PCS registers

Register address	Register name	Subclause
3.20	EEE control and capability <u>1</u>	45.2.3.9
3.21	Reserved EEE control and capability <u>2</u>	<u>45.2.3.9a</u>
3.32	BASE-R and 40 MultiGBASE-T PCS status 1	45.2.3.13
3.33	BASE-R and 40 MultiGBASE-T PCS status 2	45.2.3.14

45.2.3.1 PCS control 1 register (Register 3.0)

45.2.3.1.2 Loopback (3.0.14)

Change the text of 45.2.3.1.2 to include 25GBASE-T and 40GBASE-T as follows:

When the ~~10GBASE-T~~ any MultiGBASE-T or the 10GBASE-R mode of operation is selected for the PCS using the PCS type selection field (3.7.23:0), the PCS shall be placed in a loopback mode of operation when bit 3.0.14 is set to a one. When bit 3.0.14 is set to a one, the 10GBASE-R or ~~10GBASE-T~~ any PCS in the MultiGBASE-T set shall accept data on the transmit path and return it on the receive path. The speed of the loopback is selected by the PCS control 1 (Register 3.0) defined in 45.2.3.1. The specific behavior of the 10GBASE-R PCS during loopback is specified in 49.2. The specific behavior for the 10GBASE-T PCS during loopback is specified in 55.3.7.3. The specific behavior for the 25GBASE-T and 40GBASE-T PCS during loopback is specified in 113.3.7.3. For all other port types, the PCS loopback functionality is not applicable and writes to this bit shall be ignored and reads from this bit shall return a value of zero.

45.2.3.2 PCS status 1 register (Register 3.1)

45.2.3.2.7 PCS receive link status (3.1.2)

Change the text of 45.2.3.2.7 to include 25GBASE-T and 40GBASE-T as follows:

When read as a one, bit 3.1.2 indicates that the PCS receive link is up. When read as a zero, bit 3.1.2 indicates that the PCS receive link is down. When a 10/40/100GBASE-R, 10GBASE-W, or ~~10GBASE-T~~ any MultiGBASE-T mode of operation is selected for the PCS using the PCS type selection field (3.7.23:0), this bit is a latching low version of bit 3.32.12. When a 10GBASE-X mode of operation is selected for the PCS using the PCS type selection field (3.7.23:0), this bit is a latching low version of bit 3.24.12. The receive link status bit shall be implemented with latching low behavior.

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

45.2.3.6 PCS control 2 register (Register 3.7)

Change Table 45–123 (as modified by IEEE Std 802.3by-2016) as follows:

Table 45–123—PCS control 2 register bit definitions

Bit(s)	Name	Description	R/W ^a
3.7:15:34	Reserved	Value always 0	RO
3.7:23:0	PCS type selection	3 2 1 0 1 1 x x= reserved 1 0 1 x= reserved 1 0 0 1= Select 25GBASE-T PCS type 1 0 0 0= reserved 0 1 1 1= Select 25GBASE-R PCS type 0 1 1 0= reserved Select 40GBASE-T PCS type 0 1 0 1= Select 100GBASE-R PCS type 0 1 0 0= Select 40GBASE-R PCS type 0 0 1 1= Select 10GBASE-T PCS type 0 0 1 0= Select 10GBASE-W PCS type 0 0 0 1= Select 10GBASE-X PCS type 0 0 0 0= Select 10GBASE-R PCS type	R/W

^aR/W = Read/Write, RO = Read only

45.2.3.6.1 PCS type selection (3.7:23:0)

Change the title and text of 45.2.3.6.1 (as modified by IEEE Std 802.3by-2016) to include revised PCS selection bits as follows:

The PCS type shall be selected using bits 23 through 0. The PCS type abilities of the PCS are advertised in bits 3.8.9 and 3.8.7:0. A PCS shall ignore writes to the PCS type selection bits that select PCS types it has not advertised in the PCS status 2 register. It is the responsibility of the STA entity to ensure that mutually acceptable MMD types are applied consistently across all the MMDs on a particular PHY. The PCS type selection defaults to a supported ability.

45.2.3.7 PCS status 2 register (Register 3.8)

Change the reserved row in Table 45–124 (as modified by IEEE Std 802.3by-2016) as shown below, insert a new row for name and description for bit 3.8.9 above the reserved row, and change the reserved row 3.8.6 (as inserted by IEEE Std 802.3by-2016) as follows (unchanged rows not shown):

Table 45–124—PCS status 2 register bit definitions

Bit(s)	Name	Description	R/W ^a
3.8.9	25GBASE-T capable	1 = PCS is able to support 25GBASE-T PCS type 0 = PCS is not able to support 25GBASE-T PCS type	RO
3.8.9:8	Reserved	Value always 0	RO
3.8.6	Reserved 40GBASE-T capable	Value always 0 1 = PCS is able to support 40GBASE-T PCS type 0 = PCS is not able to support 40GBASE-T PCS type	RO

^aRO = Read only, LH = Latching high

Insert 45.2.3.7.3aa after 45.2.3.7.3 and before 45.2.3.7.3a (as inserted by IEEE Std 802.3by-2016) as follows:

45.2.3.7.3aa 25GBASE-T capable (3.8.9)

When read as a one, bit 3.8.9 indicates that the PCS is able to support the 25GBASE-T PCS type. When read as a zero, bit 3.8.9 indicates that the PCS is not able to support the 25GBASE-T PCS type.

Insert 45.2.3.7.3b after 45.2.3.7.3a (as inserted by IEEE Std 802.3by-2016) as follows:

45.2.3.7.3b 40GBASE-T capable (3.8.6)

When read as a one, bit 3.8.6 indicates that the PCS is able to support the 40GBASE-T PCS type. When read as a zero, bit 3.8.6 indicates that the PCS is not able to support the 40GBASE-T PCS type.

Change the name of Register 3.20 in title and text as shown:

45.2.3.9 EEE control and capability 1 (Register 3.20)

This register is used to indicate the capability of the PCS to support EEE functions for each PHY type. The assignment of bits in the EEE control and capability 1 register is shown in Table 45–125.

IEEE Std 802.3bq-2016
IEEE Standard for Ethernet—Amendment 3: Physical Layer and Management Parameters for
25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T

Change the title of Table 45-125, and the name and definition of bit 3.20.7 as follows (unchanged rows not shown):

Table 45-125—EEE control and capability 1 register bit definitions

Bit(s)	Name	Description	R/W ^a
3.20.7	Reserved 40GBASE-T EEE	Value always 0 1 = EEE is supported for 40GBASE-T 0 = EEE is not supported for 40GBASE-T	RO

^a Read/Write, RO = Read only

Insert 45.2.3.9.4a after 45.2.3.9.4 as follows:

45.2.3.9.4a 40GBASE-T EEE supported (3.20.7)

If the device supports EEE operation for 40GBASE-T as defined in 113.1.3.3, this bit shall be set to one.

Insert 45.2.3.9a, Table 45-125a, and 45.2.3.9a.1 after 45.2.3.9 as follows:

45.2.3.9a EEE control and capability 2 (Register 3.21)

Register 3.21 extends register 3.20 and is used to indicate the capability of the PCS to support EEE functions for each PHY type. The assignment of bits in the EEE control and capability 2 register is shown in Table 45-125a.

Table 45-125a—EEE control and capability 2 register bit definitions

Bit(s)	Name	Description	R/W ^a
3.21.15:3	Reserved	Value always 0	RO
3.21.2	25GBASE-T EEE	1 = EEE is supported for 25GBASE-T 0 = EEE is not supported for 25GBASE-T	RO
3.21.1:0	Reserved	Value always 0	RO

^a Read/Write, RO = Read only

45.2.3.9a.1 25GBASE-T EEE supported (3.21.2)

If the device supports EEE operation for 25GBASE-T as defined in 113.1.3.3, this bit shall be set to one.

45.2.3.13 BASE-R and ~~40~~MultiGBASE-T PCS status 1 register (Register 3.32)

Change the title and text of 45.2.3.13 to include 25GBASE-T and 40GBASE-T as follows:

The assignment of bits in the BASE-R and ~~40~~MultiGBASE-T PCS status 1 register is shown in Table 45-128. All the bits in the BASE-R and ~~40~~MultiGBASE-T PCS status 1 register are read only; a write to the BASE-R and ~~40~~MultiGBASE-T PCS status 1 register shall have no effect. A PCS device that ~~does not~~ implements neither BASE-R and 40GBASE-T nor any member of the MultiGBASE-T set shall return a zero for all bits in the BASE-R and ~~40~~MultiGBASE-T PCS status 1 register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits. The

contents of register 3.32 are undefined when the BASE-R PCS or MultiGBASE-T the 10GBASE-T PCS is operating in seed test-pattern mode, PRBS31 test-pattern mode, or PRBS9 test-pattern mode.

Change the title and names and descriptions of bits 3.32.12, 3.3.2.1, and 3.32.0 rows in Table 45–128 as follows (unchanged bits not shown):

Table 45–128—BASE-R and ~~40~~MultiGBASE-T PCS status 1 register bit definitions

Bit(s)	Name	Description	R/W ^a
3.32.12	BASE-R and 40 <u>Multi</u> G-BASE-T receive link status	1 = BASE-R or 40 <u>Multi</u> GBASE-T any <u>Multi</u> GBASE-T PCS receive link up 0 = BASE-R or 40 <u>Multi</u> GBASE-T any <u>Multi</u> GBASE-T PCS receive link down	RO
3.32.1	BASE-R and 40 <u>Multi</u> G-BASE-T PCS high BER	1 = BASE-R or 40 <u>Multi</u> GBASE-T any <u>Multi</u> GBASE-T PCS reporting a high BER 0 = BASE-R or 40 <u>Multi</u> GBASE-T any <u>Multi</u> GBASE-T PCS not reporting a high BER	RO
3.32.0	BASE-R and 40 <u>Multi</u> G-BASE-T PCS block lock	1 = BASE-R or 40 <u>Multi</u> GBASE-T any <u>Multi</u> GBASE-T PCS locked to received blocks 0 = BASE-R or 40 <u>Multi</u> GBASE-T any <u>Multi</u> GBASE-T PCS not locked to received blocks	RO

^aRO = Read only

45.2.3.13.1 BASE-R and ~~40~~MultiGBASE-T receive link status (3.32.12)

Change the title and text of 45.2.3.13.1 to include 25GBASE-T and 40GBASE-T as follows:

When read as a one, bit 3.32.12 indicates that the PCS is in a fully operational state. When read as a zero, bit 3.32.12 indicates that the PCS is not fully operational. This bit is a reflection of the PCS_status variable defined in 49.2.14.1 for 10GBASE-R, in 55.3.6.1 for 10GBASE-T, in 113.3.7.1 for 25GBASE-T and 40GBASE-T, and in 82.3.1 for 40/100GBASE-R.

45.2.3.13.4 BASE-R and ~~40~~MultiGBASE-T PCS high BER (3.32.1)

Change the title and text of 45.2.3.13.4 to include 25GBASE-T and 40GBASE-T as follows:

For BASE-R, when read as a one, bit 3.32.1 indicates that the 64B/66B receiver is detecting a BER of $\geq 10^{-4}$. When read as a zero, bit 3.32.1 indicates that the 64B/66B receiver is detecting a BER of $< 10^{-4}$. This bit is a direct reflection of the state of the hi_ber variable in the 64B/66B state diagram and is defined in 49.2.13.2.2 for 10GBASE-R and in 82.2.19.2.2 for 40/100GBASE-R.

For ~~10GBASE-T~~ any member of the MultiGBASE-T set, when read as a one, bit 3.32.1 indicates that the 64B/65B receiver is detecting a BER of $\geq 10^{-4}$. When read as a zero, bit 3.32.1 indicates that the 64B/65B receiver is detecting a BER of $< 10^{-4}$. This bit is a direct reflection of the state of the hi_lfer variable in the MultiGBASE-T 64B/65B state diagrams, and is defined in 55.3.6.1 for 10GBASE-T and 113.3.6.2.2 for 25GBASE-T and 40GBASE-T.

Change the title and text of 45.2.3.13.5 to include 25GBASE-T and 40GBASE-T as follows:

45.2.3.13.5 BASE-R and ~~40~~MultiGBASE-T block lock (3.32.0)

When read as a one, bit 3.32.0 indicates that the 64B/66B receiver for BASE-R or the 64B/65B receiver for ~~the 10GBASE-T~~ a member of the MultiGBASE-T set has block lock. When read as a zero, bit 3.32.0 indicates that the 64B/66B receiver for BASE-R or the 64B/65B receiver for ~~the 10GBASE-T~~ member of the MultiGBASE-T set has not achieved block lock. This bit is a direct reflection of the state of the block_lock variable in the 64B/66B state diagram and is defined in 49.2.13.2.2 for 10GBASE-R and in 82.2.19.2.2 for 40/100GBASE-R. For the 10GBASE-T PCS the block_lock variable in the 64B/65B state diagram is defined in 55.3.2.3. For both the 25GBASE-T and 40GBASE-T PCS, the block_lock variable in the 64B/65B state diagram is defined in 113.3.6.2.2. For a multi-lane PCS, this bit indicates that the receiver has both block lock and alignment for all lanes and is identical to 3.50.12 (see 45.2.3.21.1).

Change the title and text of 45.2.3.14 to include 25GBASE-T and 40GBASE-T as follows:

45.2.3.14 BASE-R and ~~40~~MultiGBASE-T PCS status 2 register (Register 3.33)

The assignment of bits in the BASE-R and ~~40~~MultiGBASE-T PCS status 2 register is shown in Table 45–129. All the bits in the BASE-R and ~~40~~MultiGBASE-T PCS status 2 register are read only; a write to the BASE-R and ~~40~~MultiGBASE-T PCS status 2 register shall have no effect. A PCS device that ~~does not implement~~ neither BASE-R and 10GBASE-T nor any member of the MultiGBASE-T set shall return a zero for all bits in the BASE-R and ~~40~~MultiGBASE-T PCS status 2 register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits. The contents of register 3.33 are undefined when the BASE-R or the ~~10GBASE-T~~ MultiGBASE-T set PCS is operating seed test-pattern mode, PRBS31 test-pattern mode, or PRBS9 test-pattern mode.

Change the title and descriptions of bits 3.33.15 and 3.33.14 in Table 45–129 as follows (unchanged bits not shown):

Table 45–129—BASE-R and ~~40~~MultiGBASE-T PCS status 2 register bit definitions

Bit(s)	Name	Description	R/W ^a
3.33.15	Latched block lock	1 = BASE-R or 10GBASE-T <u>any MultiGBASE-T</u> PCS has block lock 0 = BASE-R or 10GBASE-T <u>any MultiGBASE-T</u> PCS does not have block lock	RO/LL
3.33.14	Latched high BER	1 = BASE-R or 10GBASE-T <u>any MultiGBASE-T</u> PCS has reported a high BER 0 = BASE-R or 10GBASE-T <u>any MultiGBASE-T</u> PCS has not reported a high BER	RO/LH

^aRO = Read only, LL = Latching low, LH = Latching high, NR = Non Roll-over

45.2.3.14.1 Latched block lock (3.33.15)

Change the text of 45.2.3.14.1 to include 25GBASE-T and 40GBASE-T as follows:

When read as a one, bit 3.33.15 indicates that the 10/40/100GBASE-R or ~~the 10GBASE-T~~ a member of the MultiGBASE-T set PCS has achieved block lock. When read as a zero, bit 3.33.15 indicates that the 10/40/100GBASE-R or ~~the 10GBASE-T~~ a member of the MultiGBASE-T set PCS has lost block lock.

The latched block lock bit shall be implemented with latching low behavior.

This bit is a latching low version of the 10/40/100GBASE-R and ~~40~~MultiGBASE-T PCS block lock status bit (3.32.0).

45.2.3.14.2 Latched high BER (3.33.14)

Change the text of 45.2.3.14.2 to include 25GBASE-T and 40GBASE-T as follows:

When read as a one, bit 3.33.14 indicates that the 10/40/100GBASE-R or ~~the 10GBASE-T~~ a member of the MultiGBASE-T set PCS has detected a high BER. When read as a zero, bit 3.33.14 indicates that the 10/40/100GBASE-R or ~~the 10GBASE-T~~ a member of the MultiGBASE-T set PCS has not detected a high BER.

The latched high BER bit shall be implemented with latching high behavior.

This bit is a latching high version of the 10/40/100GBASE-R and ~~40~~MultiGBASE-T PCS high BER status bit (3.32.1).

45.2.3.14.3 BER (3.33.13:8)

Change the text of 45.2.3.14.3 to include 25GBASE-T and 40GBASE-T as follows:

The BER counter is a six bit count as defined by the `ber_count` variable in 49.2.14.2 and 82.2.19.2.4 for 10/40/100GBASE-R and defined by ~~the counter~~ `lfer_count` variable in 55.3.6.2 for 10GBASE-T and in 113.3.6.2.2 for 25GBASE-T and 40GBASE-T. These bits shall be reset to all zeros when the BASE-R and ~~40~~MultiGBASE-T PCS status 2 register is read by the management function or upon execution of the PCS reset. If the BER high order counter, 3.44 (see 45.2.3.23) is not implemented then these bits shall be held at all ones in the case of overflow.

45.2.3.14.4 Errored blocks (3.33.7:0)

Change the text of 45.2.3.14.4 to include 25GBASE-T and 40GBASE-T as follows:

The errored blocks counter is an eight bit count defined by the `errored_block_count` counter specified in 49.2.14.2 for 10GBASE-R, in 82.3.1 for 40/100GBASE-R and defined by ~~the counter~~ `errored_block_count` variable in 55.3.6.2 for 10GBASE-T and in 113.3.6.2 for 25GBASE-T and 40GBASE-T. These bits shall be reset to all zeros when the errored blocks count is read by the management function or upon execution of the PCS reset. If the Errored blocks high order counter, 3.45 (see 45.2.3.20) is not implemented then these bits shall be held at all ones in the case of overflow.

45.2.7 Auto-Negotiation registers

Change the title and names for register addresses 7.32 and 7.33 to reference MultiGBASE-T (unchanged rows not shown), insert rows for registers 7.64 and 7.65 (to end of table, after 7.63) for MultiGBASE-T AN control 2 and MultiGBASE-T status 2 registers, adjust the reserved row, and add a new reserved row in Table 45–200 as follows: