

This is a preview - click here to buy the full publication

INTERNATIONAL  
STANDARD

**ISO/IEC/  
IEEE  
8802-3**

First edition  
2014-04-01

---

---

**Standard for Ethernet**

*Norme pour Ethernet*

Withdrawn



Reference number  
ISO/IEC/IEEE 8802-3:2014(E)

© IEEE 2012

Withdrawn



## COPYRIGHT PROTECTED DOCUMENT

© IEEE 2012

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from ISO, IEC or IEEE at the respective address below.

ISO copyright office  
Case postale 56  
CH-1211 Geneva 20  
Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.org](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

IEC Central Office  
3, rue de Varembé  
CH-1211 Geneva 20  
Switzerland  
E-mail [inmail@iec.ch](mailto:inmail@iec.ch)  
Web [www.iec.ch](http://www.iec.ch)

Institute of Electrical and Electronics Engineers, Inc.  
3 Park Avenue, New York  
NY 10016-5997, USA  
E-mail [stds.ipr@ieee.org](mailto:stds.ipr@ieee.org)  
Web [www.ieee.org](http://www.ieee.org)

Published in Switzerland

## 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 was prepared by the LAN/MAN Standards Committee of the IEEE Computer Society (as IEEE 802.3-2012). 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.

(blank page)

Withdrawn

# IEEE Standard for Ethernet

IEEE Computer Society

Sponsored by the  
LAN/MAN Standards Committee

Withdrawn

---

IEEE  
3 Park Avenue  
New York, NY 10016-5997  
USA

**IEEE Std 802.3™-2012**  
(Revision of  
IEEE Std 802.3-2008)

28 December 2012

Withdrawn

**IEEE Std 802.3™-2012**

(Revision of  
IEEE Std 802.3-2008)

# IEEE Standard for Ethernet

Sponsor

**LAN/MAN Standards Committee  
of the  
IEEE Computer Society**

Approved 30 August 2012

**IEEE-SA Standard Board**

Withdrawing

**Abstract:** Ethernet local area network operation is specified for selected speeds of operation from 1 Mb/s to 100 Gb/s using a common media access control (MAC) specification and management information base (MIB). The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) MAC protocol specifies shared medium (half duplex) operation, as well as full duplex operation. Speed specific Media Independent Interfaces (MIIs) allow use of selected Physical Layer devices (PHY) for operation over coaxial, twisted-pair or fiber optic cables. System considerations for multisegment shared access networks describe the use of Repeaters that are defined for operational speeds up to 1000 Mb/s. Local Area Network (LAN) operation is supported at all speeds. Other specified capabilities include various PHY types for access networks, PHYs suitable for metropolitan area network applications, and the provision of power over selected twisted-pair PHY types.

**Keywords:** 10BASE; 100BASE; 1000BASE; 10GBASE; 40GBASE; 100GBASE; 10 Gigabit Ethernet; 40 Gigabit Ethernet; 100 Gigabit Ethernet; attachment unit interface; AUI; Auto Negotiation; Backplane Ethernet; data processing; DTE Power via the MDI; EPON; Ethernet; Ethernet in the First Mile; Ethernet passive optical network; Fast Ethernet; Gigabit Ethernet; GMII; information exchange; IEEE 802.3; local area network; management; medium dependent interface; media independent interface; MDI; MIB; MII; PHY; physical coding sublayer; Physical Layer; physical medium attachment; PMA; Power over Ethernet; repeater; type field; VLAN TAG; XGMII

---

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

Copyright © 2012 by The Institute of Electrical and Electronics Engineers, Inc.  
All rights reserved. Published 28 December 2012. Printed in the United States of America.

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

**PDF:** ISBN 973-07381-7312-2    **STD97287**  
**Print:** ISBN 973-07381-7327-6    **STDPD97287**

*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.*



**Notice and Disclaimer of Liability Concerning the Use of IEEE Documents:** IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. 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 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.

Use of an IEEE Standard is wholly voluntary. IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon any IEEE Standard document.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained in its standards is free from patent infringement. IEEE Standards documents are supplied "AS IS."

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. 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 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.

**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 the official position of IEEE or any of its committees and shall not be considered to be, nor 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 to ensure 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. Any person who would like to participate in evaluating comments or revisions to an IEEE standard is welcome to join the relevant IEEE working group at <http://standards.ieee.org/develop/wg/>.

Comments on standards should be submitted to the following address:

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

**Photocopies:** Authorization to photocopy portions of any individual standard for internal or personal use is granted by The Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, 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.

## Notice to users

### 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

This document is copyrighted by the IEEE. It is made available 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 this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

### Updating of IEEE documents

Users of IEEE standards 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. 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](http://standards.ieee.org) or contact the IEEE at the address listed previously. For more information about the IEEE Standards Association or the IEEE standards development process, visit the [IEEE-SA website](http://standards.ieee.org).

### Errata

Errata, if any, for this and all other standards can be accessed 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 <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 nondiscriminatory. 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 of the IEEE 802.3 working group at the beginning of the working group ballot of this revision:

**David J. Law**, *Working Group Chair*  
**Wael William Diab**, *Working Group Vice-Chair*  
**Adam Healey**, *Working Group Secretary*  
**Steven B. Carlson**, *Working Group Executive Secretary*  
**Valerie Maguire**, *Working Group Treasurer*

**Wael William Diab**, *IEEE P802.3 (802.3bh) Task Force Chair and Chief Editor*  
**Valerie Maguire**, *IEEE P802.3 (802.3bh) Task Force Recording Secretary and Clause Editor*  
**Peter Anslow**, *IEEE P802.3 (802.3bh) Task Force Section Editor*  
**Marek Hajduczenia**, *IEEE P802.3 (802.3bh) Task Force Section Editor*

## Historical participants

The following individuals participated in the IEEE 802.3 working group during various stages of the standard's development. Since the initial publication, many IEEE standards have added functionality or provided updates to material included in this standard. Included is a historical list of participants who have dedicated their valuable time, energy, and knowledge to the creation of this material:

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
IEEE Std 802.3-1985, Original 10 Mb/s standard, MAC, PLS, AUI, 10BASE5	23 June 1983 (IEEE) 31 December 1984 (ANSI)	<b>Donald C. Loughry</b> , <i>Working Group Chair</i>
IEEE Std 802.3a-1988 (Clause 10), 10 Mb/s MAU 10BASE2	15 November 1985 (IEEE) 28 December 1987 (ANSI)	<b>Donald C. Loughry</b> , <i>Working Group Chair</i> <b>Alan Flatman</b> , <i>Task Force Chair</i>
IEEE Std 802.3b-1985 (Clause 11), 10 Mb/s Broad-band MAU, 10BROAD36	19 September 1985 (IEEE) 28 February 1986 (ANSI)	<b>Donald C. Loughry</b> , <i>Working Group Chair</i> <b>Menachem Abraham</b> , <i>Task Force Chair</i>
IEEE Std 802.3c-1985 (9.1–9.8), 10 Mb/s Baseband Repeater	12 December 1985 (IEEE) 4 June 1986 (ANSI)	<b>Donald C. Loughry</b> , <i>Working Group Chair</i> <b>Geoffrey O. Thompson</b> , <i>Task Force Chair</i>
IEEE Std 802.3d-1987 (9.9), 10 Mb/s Fiber MAU, FOIRL	10 December 1987 (IEEE) 9 February 1989 (ANSI)	<b>Donald C. Loughry</b> , <i>Working Group Chair</i> <b>Steven Moustakas</b> , <i>Task Force Chair</i>
IEEE Std 802.3e-1987 (Clause 12), 1 Mb/s MAU and Hub 1BASE5	11 June 1987 (IEEE) 15 December 1987 (ANSI)	<b>Donald C. Loughry</b> , <i>Working Group Chair</i> <b>Robert Galin</b> , <i>Task Force Chair</i>
IEEE Std 802.3h-1990 (Clause 5), 10 Mb/s Layer Management, DTEs	28 September 1990 (IEEE) 11 March 1991 (ANSI)	<b>Donald C. Loughry</b> , <i>Working Group Chair</i> <b>Andy J. Luque</b> , <i>Task Force Chair</i>
IEEE Std 802.3i-1990 (Clauses 13 and 14), 10 Mb/s UTP MAU, 10 BASE-T	28 September 1990 (IEEE) 11 March 1991 (ANSI)	<b>Donald C. Loughry</b> , <i>Working Group Chair</i> <b>Patricia Thaler</b> , <i>Task Force Chair (initial)</i> <b>Richard Anderson</b> , <i>Task Force Chair (final)</i>

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
IEEE Std 802.3j-1993 (Clauses 15–18), 10 Mb/s Fiber MAUs 10BASE-FP, 10BASE-FB, and 10BASE-FL	15 September 1993 (IEEE) 15 March 1994 (ANSI)	<b>Patricia Thaler</b> , <i>Working Group Chair</i> <b>Keith Amundsen</b> , <i>Task Force Chair (initial)</i> <b>Frederick Scholl</b> , <i>Task Force Chair (final)</i> <b>Michael E. Lee</b> , <i>Technical Editor</i>
IEEE Std 802.3k-1993 (Clause 19), 10 Mb/s Layer Management, Repeaters	17 September 1992 (IEEE) 8 March 1993 (ANSI)	<b>Patricia Thaler</b> , <i>Working Group Chair</i> <b>Joseph S. Skorupa</b> , <i>Task Force Chair</i> <b>Geoffrey O. Thompson</b> , <i>Vice Chair and Editor</i>
IEEE Std 802.3l-1992 (14.10), 10 Mb/s PICS Proforma 10BASE-T MAU	17 September 1992 (IEEE) 23 February 1993 (ANSI)	<b>Patricia Thaler</b> , <i>Working Group Chair</i> <b>Mike Armstrong</b> , <i>Task Force Chair and Editor</i> <b>Paul Nikolich</b> , <i>Vice Chair</i> <b>William Randle</b> , <i>Editorial Coordinator</i>
IEEE Std 802.3m-1995, Maintenance 2	21 September 1995 (IEEE) 16 July 1996 (ANSI)	<b>Patricia Thaler</b> , <i>Working Group Chair</i> <b>Gary Robinson</b> , <i>Maintenance Chair</i>
IEEE Std 802.3n-1995, Maintenance 3	21 September 1995 (IEEE) 4 April 1996 (ANSI)	<b>Patricia Thaler</b> , <i>Working Group Chair</i> <b>Gary Robinson</b> , <i>Maintenance Chair</i>
IEEE Std 802.3p-1993 (Clause 20), Management, 10 Mb/s Integrated MAUs	17 June 1993 (IEEE) 4 January 1994 (ANSI)	<b>Patricia Thaler</b> , <i>Working Group Chair</i> <b>Joseph S. Skorupa</b> , <i>Task Force Chair</i> <b>Geoffrey O. Thompson</b> , <i>Vice Chair and Editor</i>
IEEE Std 802.3q-1993 (Clause 5), 10 Mb/s Layer Management, GDMO Format	17 June 1993 (IEEE) 4 January 1994 (ANSI)	<b>Patricia Thaler</b> , <i>Working Group Chair</i> <b>Joseph S. Skorupa</b> , <i>Task Force Chair</i> <b>Geoffrey O. Thompson</b> , <i>Vice Chair and Editor</i>
IEEE Std 802.3r-1996 (8.8), Type 10BASE5 Medium Attachment Unit PICS proforma	29 July 1996 (IEEE) 6 January 1997 (ANSI)	<b>Patricia Thaler</b> , <i>Working Group Chair</i> <b>Imre Juhász</b> , <i>Task Force Chair</i> <b>William Randle</b> , <i>Task Force Editor</i>
IEEE Std 802.3s-1995, Maintenance 4	21 September 1995 (IEEE) 8 April 1996 (ANSI)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>Gary Robinson</b> , <i>Maintenance Chair</i>
IEEE Std 802.3t-1995, 120 $\Omega$ informative annex to 10BASE-T	14 June 1995 (IEEE) 12 January 1996 (ANSI)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>Jacques Christ</b> , <i>Task Force Chair</i>
IEEE Std 802.3u-1995 (Clauses 21–30), Type 100BASE-T MAC param- eters, Physical Layer, MAUs, and Repeater for 100 Mb/s Operation	14 June 1995 (IEEE) 4 April 1996 (ANSI)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>Peter Tarrant</b> , <i>Task Force Chair (Phase 1)</i> <b>Howard Frazier</b> , <i>Task Force Chair (Phase 2)</i> <b>Paul Sherer</b> , <i>Task Force Editor-in-Chief (Phase 1)</i> <b>Howard Johnson</b> , <i>Task Force Editor-in-Chief (Phase 2)</i> <b>Colin Mick</b> , <i>Task Force Comment Editor</i>
IEEE Std 802.3v-1995, 150 $\Omega$ informative annex to 10BASE-T	12 December 1995 (IEEE) 16 July 1996 (ANSI)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>Larry Nicholson</b> , <i>Task Force Chair</i>
IEEE Std 802.3x-1997 and IEEE Std 802.3y-1997 (Revi- sions to IEEE Std 802.3, Clauses 31 and 32), Full- Duplex Operation and Type 100BASE-T2	20 March 1997 (IEEE) 5 September 1997 (ANSI)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Rich Seifert</b> , <i>Task Force Chair and Editor (802.3x)</i> <b>J. Scott Carter</b> , <i>Task Force Chair (802.3y)</i> <b>Colin Mick</b> , <i>Task Force Editor (802.3y)</i>
IEEE Std 802.3z-1998 (Clauses 34–39, 41–42), Type 1000BASE-X MAC Param- eters, Physical Layer, Repeater, and Management Parameters for 1000 Mb/s Operation	25 June 1998 (IEEE)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Howard M. Frazier, Jr.</b> , <i>Task Force Chair</i> <b>Howard W. Johnson</b> , <i>Task Force Editor</i>
IEEE Std 802.3aa-1998, Maintenance 5	25 June 1998 (IEEE)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>Colin Mick</b> , <i>Task Force Editor</i>

<b>IEEE Std 802.3 document</b>	<b>Date approved by IEEE and ANSI</b>	<b>Officers at the time of working group ballot</b>
IEEE Std 802.3ab-1999 (Clause 40), Physical Layer Parameters and Specifications for 1000 Mb/s Operation Over 4 Pair of Category 5 Balanced Copper Cabling, Type 1000BASE-T	26 June 1999 (IEEE)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Robert M. Grow</b> , <i>Working Group Secretary</i> <b>George Eisler</b> , <i>Task Force Chair</i> <b>Colin Mick</b> , <i>Task Force Editor</i>
IEEE Std 802.3ac-1998, Frame Extensions for Virtual Bridged Local Area Network (VLAN) Tagging on IEEE 802.3 Networks	16 September 1998 (IEEE)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Andy J. Luque</b> , <i>Working Group Secretary</i> <b>Ian Crayford</b> , <i>Task Force Chair</i> <b>Rich Seifert</b> , <i>Task Force Editor</i>
IEEE Std 802.3ad-2000 (Clause 43), Aggregation of Multiple Link Segments	30 March 2000 (IEEE)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Robert M. Grow</b> , <i>Working Group Secretary</i> <b>Steven Haddock</b> , <i>Task Force Chair</i> <b>Tony Jeffree</b> , <i>Task Force Co-Editor</i> <b>Rich Seifert</b> , <i>Task Force Co-Editor</i>
IEEE Std 802.3-2002 (IEEE 802.3ag, Maintenance 6, Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	14 January 2002 (IEEE)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Robert M. Grow</b> , <i>Working Group Secretary</i>
IEEE Std 802.3ae-2002, (Clauses 44–53) Media Access Control (MAC) Parameters, Physical Layers, and Management Parameters for 10 Gb/s Operation	13 June 2002 (IEEE)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Robert M. Grow</b> , <i>Working Group Secretary</i> <b>R. Jonathan Thatcher</b> , <i>Task Force Chair</i> <b>Stephen Haddock</b> , <i>Task Force Vice Chair</i> <b>Bradley J. Booth</b> , <i>Task Force Editor</i> <b>Lacreshia Laningham</b> , <i>Task Force Assistant Editor</i> <b>Benjamin Brown</b> , <i>Logic Track Chair</i> <b>Walter Thirion</b> , <i>Optical Track Chair</i>
IEEE Std 802.3af-2003, (Clause 33) Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)	12 June 2003 (IEEE)	<b>Geoffrey O. Thompson</b> , <i>Working Group Chair (Phase 1)</i> <b>Robert M. Grow</b> , <i>Working Group Chair (Phase 2)</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Robert M. Grow</b> , <i>Working Group Secretary (Phase 1)</i> <b>Steven B. Carlson</b> , <i>Working Group Secretary (Phase 2)</i> <b>Steven B. Carlson</b> , <i>Task Force Chair</i> <b>Michael S. McCormack</b> , <i>Task Force Editor (Phase 1)</i> <b>John J. Jetzt</b> , <i>Task Force Editor (Phase 2)</i> <b>Chad M. Jones</b> , <i>Task Force Comment Editor</i>
IEEE Std 802.3ah-2004, Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks	6 April 2005 (IEEE)	<b>Robert M. Grow</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Steven B. Carlson</b> , <i>Working Group Secretary</i> <b>Howard Frazier</b> , <i>Task Force Chair</i> <b>Wael W. Diab</b> , <i>Task Force Editor-in-Chief</i> <b>Hugh Barrass</b> , <i>Task Force Vice-Chair</i> <b>Scott Simon</b> , <i>Task Force Recording Secretary</i> <b>Behrooz Rezvani</b> , <i>Task Force Executive Secretary</i>
IEEE Std 802.3aj-2003, Maintenance 7	11 September 2003 (IEEE)	<b>Robert M. Grow</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair, Task Force Chair</i> <b>Steven B. Carlson</b> , <i>Working Group Secretary</i> <b>Catherine K. N. Berger</b> , <i>Task Force Editor</i>
IEEE Std 802.3ak-2004, Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4	9 February 2004 (IEEE)	<b>Robert M. Grow</b> , <i>Working Group Chair</i> <b>David J. Law</b> , <i>Working Group Vice Chair</i> <b>Steven B. Carlson</b> , <i>Working Group Secretary</i> <b>Daniel J. Dove</b> , <i>Task Force Chair</i> <b>Howard A. Baumer</b> , <i>Task Force Editor</i>

<b>IEEE Std 802.3 document</b>	<b>Date approved by IEEE and ANSI</b>	<b>Officers at the time of working group ballot</b>
IEEE Std 802.3-2005 (IEEE 802.3REVam, Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	9 June 2005 (IEEE)	<b>Robert M. Grow</b> , Working Group Chair <b>David J. Law</b> , Working Group Vice Chair <b>Wael W. Diab</b> , Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Piers Dawe</b> , Review Editor
IEEE Std 802.3an-2006, Physical Layer and Management Parameter for 10 Gb/s Operation, Type 10GBASE-T	8 June 2006 (IEEE)	<b>Robert M. Grow</b> , Working Group Chair <b>David J. Law</b> , Working Group Vice Chair <b>Wael William Diab</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Bradley Booth</b> , Task Force Chair <b>Sanjay Kasturia</b> , Task Force Editor-in-Chief <b>George Eisler</b> , Task Force Recording Secretary
IEEE Std 802.3ap-2007, Ethernet Operation over Electrical Backplanes	22 March 2007 (IEEE)	<b>Robert M. Grow</b> , Working Group Chair <b>David J. Law</b> , Working Group Vice-Chair <b>Wael W. Diab</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Bradley Booth</b> , Working Group Treasurer <b>Adam Healey</b> , Task Force Chair <b>John D'Ambrosia</b> , Task Force Secretary <b>Schelte vanDoorn</b> , Task Force Editor-in-Chief (Phase 1) <b>Ilango S. Ganga</b> , Task Force Editor-in-Chief (Phase 2)
IEEE Std 802.3aq-2006, Physical Layer and Management Parameters for 10 Gb/s Operation, Type 10GBASE-LRM	15 September 2006 (IEEE)	<b>Robert M. Grow</b> , Working Group Chair <b>David J. Law</b> , Working Group Vice Chair <b>Wael William Diab</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>David G. Cunningham</b> , Task Force Chair <b>Nick Weiner</b> , Task Force Editor <b>Piers Dawe</b> , Task Force Contributing Editor
IEEE Std 802.3as-2006, Frame format extensions	15 September 2006 (IEEE)	<b>Robert M. Grow</b> , Working Group Chair <b>David J. Law</b> , Working Group Vice Chair <b>Wael William Diab</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Kevin Q Daines</b> , Task Force Chair <b>Glenn W. Parsons</b> , Task Force Editor
IEEE Std 802.3-2005/Cor 1-2006 (IEEE 802.3au), DTE Power via MDI Isolation corrigendum	8 June 2006 (IEEE)	<b>Robert M. Grow</b> , Working Group Chair <b>David J. Law</b> , Working Group Vice Chair, Task Force Editor <b>Wael W. Diab</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary
IEEE Std 802.3-2005/Cor 2-2007 (IEEE 802.3aw), 10GBASE-T corrigendum	7 June 2007 (IEEE)	<b>Robert M. Grow</b> , Working Group Chair <b>David J. Law</b> , Working Group Vice Chair, Task Force Editor <b>Wael W. Diab</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Bradley Booth</b> , Working Group Treasurer
IEEE Std 802.3-2008 (IEEE 802.3ay), Maintenance #9 (Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	26 September 2008 (IEEE)	<b>Robert M. Grow</b> , Working Group Chair <b>David J. Law</b> , Working Group Vice Chair, Task Force Editor <b>Wael William Diab</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Bradley Booth</b> , Working Group Treasurer
IEEE Std 802.3at-2009 Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements	11 September 2009 (IEEE)	<b>David J. Law</b> , Working Group Chair <b>Wael William Diab</b> , Working Group Vice Chair <b>Adam Healey</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Bradley Booth</b> , Working Group Treasurer <b>Mike McCormack</b> , Task Force Chair <b>D. Matthew Landry</b> , Task Force Chief Editor <b>Chad Jones</b> , Task Force Comment Editor

<b>IEEE Std 802.3 document</b>	<b>Date approved by IEEE and ANSI</b>	<b>Officers at the time of working group ballot</b>
IEEE Std 802.3av-2009 Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks	11 September 2009 (IEEE)	<b>David J. Law</b> , Working Group Chair <b>Wael William Diab</b> , Working Group Vice Chair <b>Adam Healey</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Bradley Booth</b> , Working Group Treasurer <b>Glen Kramer</b> , Task Force Chair <b>Duane Remoin</b> , Task Force Chief Editor <b>Marek Hajduczenia</b> , Task Force Assistant Editor
IEEE Std 802.3az-2010 Media Access Control Parameters, Physical Layers, and Management Parameters for Energy-Efficient Ethernet	30 September 2010 (IEEE)	<b>David J. Law</b> , Working Group Chair <b>Wael William Diab</b> , Working Group Vice Chair <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Adam Healey</b> , Working Group Secretary <b>Bradley Booth</b> , Working Group Treasurer <b>Michael Bennett</b> , Task Force Chair <b>Sanjay Kasturia</b> , Task Force Editor-in-Chief
IEEE Std 802.3ba Media Access Control Parameters, Physical Layers, and Management Parameters for 40 Gb/s and 100 Gb/s Operation	17 June 2010 (IEEE)	<b>David J. Law</b> , Working Group Chair <b>Wael William Diab</b> , Working Group Vice-Chair <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Adam Healey</b> , Working Group Secretary <b>Bradley Booth</b> , Working Group Treasurer <b>John D'Ambrosia</b> , Task Force Chair <b>Ilango S. Ganga</b> , Task Force Editor-in-Chief
IEEE Std 802.3-2008/Cor 1-2009 (IEEE 802.3bb) Pause Reaction Delay Corrigendum.	9 December 2009 (IEEE)	<b>David J. Law</b> , Working Group Chair <b>Wael William Diab</b> , Working Group Vice-Chair <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Adam Healey</b> , Working Group Secretary <b>Bradley Booth</b> , Working Group Treasurer
IEEE Std 802.3bc-2009 Ethernet Organizationally Specific Type, Length, Value (TLVs)	11 September 2009 (IEEE)	<b>David J. Law</b> , Working Group Chair and Task Force Editor <b>Wael W. Diab</b> , Working Group Vice Chair, Task Force Chair <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Adam Healey</b> , Working Group Secretary <b>Bradley Booth</b> , Working Group Treasurer
IEEE Std 802.3bd-2011 MAC Control Frame for Priority-based Flow Control	16 June 2011 (IEEE)	<b>Tony Jeffree</b> , IEEE 802.1 Working Group Chair <b>Paul Congdon</b> , IEEE 802.1 Working Group Vice Chair <b>David J. Law</b> , IEEE 802.3 Working Group Chair <b>Wael W. Diab</b> , IEEE 802.3 Working Group Vice Chair <b>Pat Thaler</b> , Data Center Bridging Task Group Chair
IEEE Std 802.3bf-2011 Media Access Control (MAC) Service Interface and Management Parameters to Support Time Synchronization Protocols	16 May 2011 (IEEE)	<b>David J. Law</b> , Working Group Chair <b>Wael William Diab</b> , Working Group Vice-Chair <b>Adam Healey</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Valerie Maguire</b> , Working Group Treasurer <b>Steven B. Carlson</b> , Task Force Chair <b>Marek Hajduczenia</b> , Task Force Editor-in-Chief
IEEE Std 802.3bg-2011 Physical Layer and Management Parameters for Serial 40 Gb/s Ethernet Operation Over Single-Mode Fiber	31 March 2011 (IEEE)	<b>David J. Law</b> , Working Group Chair <b>Wael William Diab</b> , Working Group Vice-Chair <b>Adam Healey</b> , Working Group Secretary <b>Steven B. Carlson</b> , Working Group Executive Secretary <b>Valerie Maguire</b> , Working Group Treasurer <b>Mark Nowell</b> , Task Force Chair <b>Pete Anslow</b> , Task Force Editor-in-Chief

Ali Abaye	Phil L. Arst	James Binder	Maurice Caldwell
Fazal Abbas	Doug Artman	Larry Birenbaum	Richard Cam
Ghani Abbas	Jean-Pierre Astorg	Jeff E. Bisberg	Bob Campbell
John S. Abbott	Mehran Ataee	Michel Bohbot	Peter Campbell
Justin Abbott	Ilan Atias	Mark Bohrer	Robert R. Campbell
Hamlet Abedmamoore	Steve Augusta	Jean-Michel Bonnamy	Luigi Canavese
Joe Abler	Phil Auld	Bradley J. Booth	James T. Carlo
Menachem Abraham	Siamack Ayandeh	Paul Booth	Craig Carlson
Shadi AbuGhazaleh	Kameran Azadet	Paul Bottorff	Steven B. Carlson
Martin Adams	Joseph N. Babanezhad	Thomas J. Boucino	Dan Carnine
Luc Adriaennsens	Chet Babla	Samuel Bourche	J. Martin Carroll
Don Aelmore	Gerard E. Bachand	David Bourque	J. Scott Carter
Puneet Agarwal	Guna Bala	Gary Bourque	Andrew Castellano
Akira Agata	R. V. Balakrishnam	Sidney Bouzaglo	Ron Cates
Oscar Agazzi	Koussalya Balasubramanian	Kirk Bovill	Jeffrey D. Catlin
John R. Agee	Vittal Balasubramanian	John Bowerman	Mandeep Chadha
Nand Aggarwal	Andy Baldman	Richard Bowers	David Chalupsky
Paul Ahrens	Thananya Baldwin	Peter Bradshaw	Edward Chang
Youichi Akasaka	Keith Balmer	Al Braga	Edward G. Chang
Vish Akella	Mogens Cash Balsby	Richard Brand	Edward S. Chang
Reza Alavi	Bruce Bandali	Rudolf Brandner	Frank Chang
Alan Albrecht	Jaya Bandyopadhyay	Ralf-Peter Braun	Justin Chang
Keith Albright	Majid Barazande-Pour	Richard S. Brehove	Kiwon Chang
Don Alderrou	Ozdal Barkan	Dirk Breuer	Luke Chang
Jan Alexander	Ian Barker	Steve Brewer	Samuel Chang
Thomas Alexander	Eyal Barnea	Robert F. Bridge	Sun-Hyok Chang
Abe Ali	Barry Barnett	Vince Bridgers	Thomas Chantrell
Brad Allen	Jim Barnette	Dave Brier	Howard Charney
David Allen	Hugh Barrass	Andrew Brierley-Green	Jian Chen
John Allen	Bob Barrett	Rhett Brikovskis	Xiaopeng Chen
Zehavit Alon	Scott Barrick	Charles Brill	Zinan (Nan) Chen
Arne Alping	Meir Bartur	Robert D. Brink	Linda Cheng
Michael Altman	Yoram Barzilai	Rick Brooks	Weiyong Cheng
Yehuda Alush	Howard Baumer	Alan M. Brown	Kok-Wui Cheong
Karen Amavisca	Denis Beaudoin	Benjamin Brown	Giovanni Cherubini
Andrew Ambrose	Michael Beck	Daniel J. Brown	Rao Cherukuri
Khaled Amer	Jonathan Beckwith	Dave Brown	Albert Chiang
Nitish Amin	Christian Beia	Jack Brown	David Chin
Keith Amundsen	Edward Beili	Kevin Brown	Hon Wah Chin
Ole Christian Andersen	Alexei Beliaev	Matthew Brown	Jae hun Cho
Arlan J. Anderson	William Belknap	Suzy Brown	Francis Choi
Eric Anderson	Eran Bello	Phillip Brownlee	Jin-Seek Choi
Jon Anderson	Yakov Belopolsky	Brian Brunn	Rahul Chopra
Paul Anderson	Randy J. Below	Robert Brunner	Joseph Chou
Richard Anderson	Vincent Bemmell	Steve F. Buck	Golam Choudhury
Stephen D. Anderson	Michael Bennett	Lisa Buckman	Jacky Chow
Stephen J. Anderson	Richard Bennett	Mark Bugg	Kuen Chow
Tony Anderson	Miles Benson	Juan Bulnes	Henry Choy
Ralph Andersson	Sidney Berglund	Bill Bunch	Chris Christ
Jack S. Andresen	Ernest E. Bergmann	James Burgess	Jacques Christ
Peter Anslow	April Bergstrom	Scott Burton	George Chu
Ekkehard Antz	David J. Berman	Robert A. Busse	Hwan-Seok Chung
Ken-ichi Arai	Roberto Bertoldi	Thomas T. Butler	Yue-Der Chzh
Bert Armijo	John L. Bestel	Roy Bynum	Albert Claessen
Mike Armstrong	Dave Bethune	Ed Cady	Guss Claessen
Susie Armstrong	Vipul Bhatt	Luca Cafiero	G. J. Clancy
Brian Arnold	Sudeep Bhoja	John Cagle	Brice Clark
Lewis B. Aronson	Harmeet Bhugra	Jeffrey C. Cain	Susan Roden Clarke
Simcha Aronson	Jan Bialkowski	Donald Caldwell	George Claseman



Terry Cobb	Bernard O. Debbasch	Herman Eiliya	Richard Froke
Michael Coden	Michael deBie	George Eisler	Ingrid Fromm
Kelly B. Coffey	Tom Debiec	Martin Elhøj	Richard Frosch
Larry Cohen	John DeCramer	David Elie-Dit-Cosaque	Hongyan Fu
Christopher R. Cole	Joel Dedrick	Kevin M. Elliff	Judy Fuess
Doug Coleman	Steve Deffley	Michael Elswick	Yukihiro Fujimoto
Régis Colla	Dave Delaney	Paul "Skip" Ely	Atsuhisa Fukuoka
Kevin Cone	Moshe De-Leon	Richard Ely	John Fuller
Herbert V. Congdon	Bill Delveaux	Kent English	Darrell Furlong
Paul Congdon	Ralph DeMent	Gregory Ennis	Mel Gable
Patrick Conlon	Joe DeNicholas	Gianfranco Enrico	Robert D. Gaglianella
Don Connor	Tazio M. DeNicolo	Brian S. Ensign	Justin Gaither
Robert Conte	Sanjay Desai	Norman Erbacher	Robert Galin
Charles I. Cook	Claudio Desanti	Tooraj Esmailian	Sharad Gandhi
Ronald J. Cooper	Peter Desaulniers	Nick Esser	Tom Gandy
Stephen Cooper	Mark Devon	Daniel Essig	Ilango S. Ganga
Neil Coote	Sanjay Dhawan	David Estes	Robin Gangopadhy
Edward Cornejo	Chris Di Minico	Judith Estrin	Xiao Ming Gao
Ronald Crane	Wael William Diab	Jim Everitt	Clete Gardenhour
George Cravens	Patrick Diamond	Steve Evitts	Geoffrey M. Garner
Ian Crayford	Erik Dickens	John F. Ewen	Denton Gentry
John Creigh	Bryan Dietz	Richard Fabbri	John George
J. Francois Crepin	Chris DiMinico	Siavash Fallahi	Floyd H. Gerhardt
Bill Cronin	Thomas J. Dineen	Sabina Fanfoni	Keith Gerhardt
Peter Cross	Zheming Ding	Janos Farkas	Mark Gerhold
Richard Cross	Sean Dingman	Rebecca Farley	Anoop Ghanwani
Brian Cruikshank	Thuyen Dinh	Donald Fedyk	Ali Ghiasi
Diego Crupnicoff	Hans Peter Dittler	Eldon Feist	Sajol Ghoshal
Kai Cui	Hamish Dobson	Daniel Feldman	Dimitrios Giannakopoulos
David Cullerot	David W. Dolfi	Dongming Feng	Giorgio Giaretta
Chris Cullin	Mark Donhowe	Feifei (Felix) Feng	Pat Gilliland
David G. Cunningham	Hank (H. N.) Dorris	Severn Ferdun	George Gintis
Joe Curcio	Daniel Dove	Jean-Loup Ferrant	Joel Goergen
Robert A. Curtis	James Doyle	Mark Feuerstraeter	Franz Goetz
Simon Cushin	Daniel S. Draper	Jens Fiedler	Adi Golbert
Dariusz Dabiri	Scott Dredge	Julien Fiere	Glenn Golden
Robert Dahlgren	Brian Drever	Dave Fifield	Moty Goldis
Saleem Dahmouh	Steve Dreyer	Norival Figueira	Matthew Goldman
Fumio Daido	John Dring	Juan Figueroa	Timothy D. Goodman
Bernard Daines	Michael Dudek	Robert G. Finch	Steve Goody
Kevin Q Daines	Marcus Duell	Norman Finn	Rich Graham
John Dallesasse	Richard Dugan	Farzin Firoozmand	Russ Granger
John D'Ambrosia	Raymond S. Duley	David Fischer	Eric B. Grann
Nabil Damouny	Linda Dunbar	Thomas Fischer	Tom Grasmehr
Rupert S. Dance	Joseph E. Dupuis	John Fitzgerald	C. Thomas Gray
Mark Darby	Marc R. Dupuis	Alan Flatman	Eric Gray
Yair Darshan	David Dwelley	Steve Flickinger	Larry Green
Peter Dartnell	J. Craig Easley	Norbert Folkens	Martin Green
Subrata Datta	Paul Eastman	Christian G. Folting	Jonathan E. Greenlaw
John Davidson	Jeff Ebeling	Harry Forbes	Bryan Gregory
David Davies	Peter Ecclesine	Brian Ford	Richard Grenier
Edward Davis	Edward J. Eckert	Richard Fransen	Karanvir Grewal
Peter Dawe	Clay Eddings	Roger Fraser	Michael R. Grimwood
Piers Dawe	Phil Edholm	Howard M. Frazier	Edward Grivna
John De Andrea	Tom Edsall	Robert Frazier	Robert M. Grow
Kathryn de Graaf	Dean Edwards	Ladd Freitag	Robert Gudz
Gerald de Grace	Gareth Edwards	Ken Friedenbach	Andreas Gulle
Michael de la Garrigue	Frank J. Effenberger	Scott Fritz	Karunakar Gulukota
Moshe De Leon	John Egan	Krister Frojdh	Ajay Gummalla

Richard Gumpertz	Susan Hennenfent	Woo-Hyuk Jang	Harold W. Katz
Craig Gunther	Ken Herrity	Stephen Janshego	Boris Katzenberg
Bin Guo	Pierre Herve	Jonathan Jedwab	Dave Kaufman
Sandeep Gupta	James H. Hesson	Tony Jeffree	Sumesh Kaul
Sudhir Gupta	John Hickey	George D. Jelatis	Yasuaki Kawatsu
Tanmay Gupta	Chip Hicks	Ernie Jensen	Kevin Kayser
Mitch Gusat	Tetsuya Higuchi	John J. Jetzt	Hal Keen
Jonas Gustafsson	Olli-Pekka Hiironen	Jack L. Jewell	Paul Kellam
Mark Gustlin	John Hill	Pankaj Jha	N. Patrick Kelly
Paul J. Gyugyi	Tricia Hill	Jessica Xin Jiang	Joe Kennedy
Russ Gyurek	Sammy Hindi	Qiaofeng Jiang	John J. Kenny
Steven Haas	William Hingston	Wenbin Jiang	Scott Kesler
Michael Hackert	Henry Hinrichs	Ni Jie	Dawson Kesling
Tariq Haddad	David Hinzl	Andrew C. Jimenez	Lior Khermosh
Stephen Haddock	Kengo Hirano	Robert Jin	Tuan Khuu
Atikem Haile-Mariam	Ryan Hirth	Thomas K. Joergensen	Gary Kidwell
Marek Hajduczenia	Charlie Hochstedler	Clarence Joh	Keti Kilcrease
Sharam Hakimi	Charles Hoffner	Michael D. Johas Teener	Bob Kilgore
Clive Hallatt	Jay Hoge	Richard John	Chan Kim
Hiroshi Hamano	Brian Holden	Donald C. Johnson	Dae Young Kim
Farid Hamidy	Bryan Hoover	Howard Johnson	Jin H. Kim
Kevin Hamilton	Gregory Hopkins	Mize Johnson	Seung-Hwan Kim
Bernie Hammond	Keith Hopwood	Scott Johnson	Su-Hyung Kim
Benny Hanigal	Rita Horner	Cristopher Jolly	Yongbum Kim
Greg Hankins	Steven E. Horowitz	Chad M. Jones	Marc Kimpe
G. Y. Hanna	Michael Horvat	Nick Jones	Mitsunobu Kimura
Chris Hansen	Yoshifumi Hotta	William W. Jones	John Kincaid
Johannes Hansen	Stanley Hronik	Ulf Jonsson	Bill Kind
Mogens Hansen	Henry Hsiaw	Bheom-Soon Joo	Jonathan P. King
Del Hanson	Jacob Hsu	Seong-Soon Joo	Neal King
Onn Haran	Fred Huang	Anthony Jordan	Scott G. Kipp
Hacene Hariti	Xi Huang	Thomas K. Jørgensen	Paul Kish
Guy Harkins	Charles Hudson	Juan Jover	Tadayoshi Kitayama
Milton C. Harper	Chuck Hudson	Imre Juhász	Philippe Klein
Doug Harshbarger	Todd Hudson	Jason Julyan	Richard Knight
G. R. Hartley	Michael Hughes	Kwi-Yung Jung	Mike Ko
Lloyd Hasley	Walter K. Hurwitz	Dieter W. Junkers	Hiroshi Kobayashi
Marwan Hassoun	Dean Huumala	Paul Jury	Shoukei Kobayashi
Mehdi Hatamian	Thong Huynh	David Kabal	Satoshi Kodama
W. B. Hatfield	David W. Hyer	Jayant Kadambi	Henriecus Koeman
Tom Hatley	Haruhiko Ichino	Vic Kairis	David J. Koenen
Stephen Haughey	Hiroki Ikeda	Shinkyō Kaku	Christine Koenig
Haw Ming Haung	Nicholas Ilyadis	Omer Kal	David E. Kohl
Kirk Hayden	James Innis	Mohan Kalkunte	Srinivas Kola
Claude Hayek	Romain Insler	Amrit Kalla	Paul F. Kolesar
Robert Hays	Kazuhiko Ishibe	Joel S. Kalman	Steven Koller
Carl G. Hayssen	Osamu Ishida	Matt Kaltenbach	Kishan Rao Konda
Asif Hazarika	Hideki Isono	Puru Kamat	Masashi Kono
Adam Healey	Hirotake Iwadate	Ron Kao	David Kooistra
Jeffrey Heath	Steve Jackson	Hadriel Kaplan	Derek Koonce
Gaby Hecht	Krista S Jacobsen	Rainer Kaps	Paul Kopera
Jim Heckroth	Michael R. Jacobson	Roger Karam	Leonid Koshevoy
Chris Heegard	Mike Jacobson	Abhay Karandikar	Josef Kosilek
Gopal Hegde	Ajit Jadeja	Jaime Kardontchik	Donald E. Kotas
Wolfgang Heidasch	John M. Jaeger	Yuji Kasai	William F. Kous
Ronen Heldman	Brent Jaffa	Allen Kasey	Tetsu Koyama
David Helster	Raj Jain	Prakash Kashyap	Seiji Kozaki
Ariel Hendel	David V. James	Sanjay Kasturia	Josef Kozilek
Itzik Hendel	Eric Jang	Toyoyuki Kato	Glen Koziuk

Glen Kramer	Hyeong Ho Lee	Meilissa R. Lum	Jim McGrath
Daniel Krent	Jack Lee	Andy J. Luque	Chris McGugan
Subi Krishnamurthy	Kyusang Lee	Kent Lusted	Alan McGuire
Lars Paul Krolner	Michael E. Lee	Sharon Lutz	James McIntosh
Joerg-R Kropp	Wesley Lee	Jeffrey Lynch	Keith McKechnie
Simon Kropveld	Ying Lee	Mark Lynn	Donna McMaster
George Kubovcik	Vincent Lefebvre	Eric R. Lynskey	Tim McShane
Pankaj Kumar	Richard Lefkowitz	Ian Lyon	Greg McSorley
Vinod Kumar	Amir Lehr	Henning Lysdal	James D. McVey
Ted Kummert	Brian E. Lemoff	Gael Mace	Grahame Measor
Aniruddha Kundu	John Lemon	Ben Mack-Crane	Mounir Meghelli
David Kung	Richard Lena	Brian MacLeod	Mukesh Mehta
Jeffrey Kuo	Andreas Lenkisch	Kenneth MacLeod	Richard Y. Mei
David Kurcharczyk	Lisa Leo	Sam Madani	Vince Melendy
Christopher Kurker	Robert H. Leonowich	Anthony Magee	Richard Mellitz
Yasuyuki Kuroda	Michael Lerer	Joseph Maggiolino	Avraham Menachem
Hidetsune Kurokawa	Warayot Lertniphonphun	Randall Magliozzi	Menucher Menuchery
Toshihiko Kusano	Amir Leshem	Valerie Maguire	Mark Merrill
Gerard Kuyt	Raymond W. K. Leung	Ariel Maislos	John Messenger
Bengt Kvist	Tommy Leung	Rabih Makarem	Jo Beth Metzger
Bruce Kwan	Avinoam Levy	Jeffery J. Maki	Steve Metzger
Alan Kwentus	Van Lewing	Trey Malpass	Jeffrey Meyer
Lee LaBarre	David Lewis	Daniel Maltbie	Yossi Meyouhas
Adel Henry Labib	Richard Lewis	Jeff Mandin	Amir Mezer
Richard LaCerte	Mike Peng Li	Jim Mangin	Tremont Miao
Hans Lackner	Sam Liang	Bob Marchetti	Joseph Micallef
Gadi Lahat	William P. Lidinsky	Luciano Marchitto	Thomas Michaelis
Kari Laihonen	Seyoun Lim	Carlo Mariotti	Richard Michalowski
Ashvin Lakshmikantha	John O. Limb	Arthur Marris	Colin Mick
Lowell D. Lamb	Chan-De Lin	Charles Marsh	Martin R. Milbury
Lawrence J. Lamers	George Lin	Robert Marshall	Jim Millar
Erik Lander	Ray Lin	Robert A. Marsland	Bruce D. Miller
D. Matthew Landry	Ru Jian Lin	Arlen Martin	C. Kenneth Miller
William Lane	Yoseph L. Linde	Arlon Martin	Larry D. Miller
Gordon Langlands	Wayne Lindquist	David W. Martin	Brian Mixek
Daun Langston	Thomas A. Lindsay	Jeff Martin	Jacob (Kobi) Mizrahi
Jeff Lapak	Laurie Lindsey	Koichiro Mashiko	Fanny Mlinarsky
Ed Lare	Robert Lingle	Scott Mason	Reza Moattar
Ferdinando Lari	Marina Lipshteyn	Thomas Mathey	Merrick Moeller
Loren Larsen	Cathy Liu	Ziad Albert Matni	Fred Mohamadi
Donald C. Larson	Chang-Chi Liu	Hideyuki Matsuo	Dirk S. Mohl
Ryan Latchman	Fengkun Liu	Bob Matthys	Mart L. Molle
Tony Lau	William D. Livingston	Bret A. Matz	Ray Mompont
Tony Lauck	Martin Lobel	Bob Mayer	John Monson
Bruce LaVigne	Terry Lockyer	Joseph Mazor	Gabriel Montenegro
David J. Law	Hugh Logan	David S. McCallum	Cindy Montstream
Eric Lawrence	Larry Lomelino	Kent McCammon	Charles Moore
Michael Lawton	Leland Long	Philip L. McCarron	Paul B. Moore
John Laynor	Sherry J. Lorei	Frank McCarthy	Robert Moore
Yannick Le Goff	Jahan Lotfi	C. Phillip McClay	Andy Moorwood
My Le	James A. Lott	Brett McClellan	Matthew Mora
Quang Le	Dennis Lou	Kelly McClellan	Octavio Morales
Michael Lebar	Donald C. Loughry	Mike McConnell	Kazuyuki Mori
Greg LeCheminant	Bob Love	John McCool	Shohei Moriwaki
Changoo Lee	Rick Loveless	Michael S. McCormack	Robert L. Morrell
Chun-Tsung Lee	Raul Lozano	Gary McCoy	John Morris
Dong-Soo Lee	Ken Lu	Andy McDonald	Robert Mortonson
Eugene Lee	Fred A. Lucas	John McDonough	Simon Moseley
Fu-Ho Lee	James A. Lucas	Jerry McDowell	Jack Moses

Steven Moustakas	Raj Ojha	Y. Lisa Peng	Dan Rausch
Wayne A. Mueller	Mitsuji Okada	Petar Pepeljugoski	Peter Rautenberg
Robert Muir	Vladimir Oksman	Gerald Pepper	Eric Rawson
Shankar Mukherjee	Guy P. Oliveira	Drew D. Perkins	Robert Reed
Shimon Muller	Chris Oliver	Gerry Pesavento	Ivan Reede
Eric Multanen	Lloyd Oliver	William R. Peters	Dennis Rehm
Carrie Munson	David Olsen	Brian Peterson	Eugene Reilly
Ken Murakami	Bengt-Erik Olsson	David Peterson	Jim Reinstedler
Denis Murphy	Mike Oltmanns	John Petrilla	Maurice Reintjes
Thomas Murphy	Barry O'Mahony	Abhijit Phanse	Duane Remein
Brian Murray	Padraig OMathuna	Thomas L. Phinney	Andreas Rendel
Narayan Murthy	Keith Onodera	David Piede	Lawrence Rennie
Samba Murthy	Toshio Ooka	Roy Pierce	Victor Renteria
Angela Muscat	Philip Orlik	Robert Pieters	Tamir Reshef
Robert Musk	Aidan O'Rourke	Antti Pietilainen	Michael Ressler
Jim Muth	Akihiro Otaka	Velu C. Pillai	Pedro Reviriego
Yaron Nachman	Michael O'Toole	Rick Pimpinella	Bill Reysen
Gerard Nadeau	Tony O'Toole	Armin Pitzer	Behrooz Rezvani
Takeshi Nagahori	Michel Ouellette	Ed Pivonka	June-Koo (Kevin) Rhee
Ken Naganuma	George Oughton	Timothy R. Plunkett	Dave Richkas
Hari Naidu	George Oulundsén	David Poisner	Joseph Rickert
Wendell Nakamine	Pat Overs	Peter Pondillo	Sean Riley
Edward Nakamoto	Kazuyuki Ozawa	Petre Popescu	Poldi (Pavlick) Rimboim
Karl Nakamura	Paul Pace	Hayim Porat	John Ritger
Nersi Nazari	Robert R. Pace	Jeff Porter	Paul Rivett
W. P. Neblett	Charles Palanzo	Carl R. Posthuma	Ramez Rizk
Erwan Nedellec	Thomas Palkert	Bill Poston	Ramz Rizk
Jay Neer	Sesha Panguluri	David Potter	Anthony Rizzolo
Darcy Nelson	Donald Pannell	Kimberly Pottratz	Iain Robertson
James Nelson	Bill Panos	Scott R. Powell	Gary Robinson
Kristian Nelson	Gabriel D Papandrea	Gideon Prat	Steven Robinson
Trung Nguyen	Keshab K. Parhi	Bernd Prediger	Stuart Robinson
Thinh Nguyenphu	Jim Parker	Robert S. Printis	Timothy Rock
Henry T. Nicholas	Gavin Parnaby	Max Pritikin	Michael Rodensky
Gary Nicholl	Bidyut Parruck	John Proffitt	A. Rodriguez
Larry Nicholson	Elwood T. Parsons	Steve Pryor	Carlos Rodriguez
Paul Nikolich	Glenn W. Parsons	Haoli Qian	Josef Roese
David Nim	Vasu Parthasarathy	William Quackenbush	Shawn Rogers
Glenn Nishida	Joel Paslaski	Holger Quast	Derek Rohde
Shinji Nishimura	Jerry Pate	Tomas J. Quigley	Dan Romascanu
George Noh	Bhavesb Patel	Jim Quilici	Tume Römer
Kazuhiro Nojima	Dipak M. Patel	Patrick W. Quinn	Albrecht Rommel
Kevin Nolish	Piyush Patel	John Quirk	David Roos
Takumi Nomura	Pravin Patel	Rick Rabinovich	Robert Rosenthal
Michael Nootbaar	Sandeep Patel	Jerry K. Radcliffe	Floyd Ross
Ronald Nordin	Shashi Patel	Ted Rado	Tam Ross
Bob Norton	Vijay Pathak	Sreen Raghavan	Michael Rothenberg
Bob Noseworthy	Martin Patoka	Jurgen Rahn	Jessy Rouyer
Ahmad Nouri	Aidan Paul	Mohammad Rajabzadeh	Tony Rowell
Mark Nowell	Prasun K. Paul	Shlomo Rakib	Archana Roy
Ivan Oakley	Alex Pavlovsky	Naresh Raman	Larry Rubin
Satoshi Obara	John Payne	Brian Ramelson	Paul F. Russo
John Oberstar	Tony Peatfield	Brian J. Ramsey	Bill Ryan
J. Michael O'Connor	Anthony Peck	Adee Ran	Valerie Rybinski
David Ofelt	Neil Peers	Karen Randall	Hyunsurk (Eric) Ryu
Gourgen Oganessyan	Jan P. Peeters-Weem	William Randle	Khosrow Sadeghi
Stephen Oh	Arkadiy Peker	Randy K. Rannow	Jonathan Sadler
Steven O'Hara	Joseph Pelissier	Sailesh K. Rao	Naoto Saeki
Peter Ohlén	Jim Pelster	Jennifer G. Rasimas	Dalit Sagi

Ali Sajassi	Farhad Shafai	Bryan Sparrowhawk	Victor J. Tarassov
Ed Sakaguchi	Haim Shafir	Ben Speiser	Peter Tarrant
Dolors Sala	Amit Shah	Gary Spencer	Mike Tate
Peter Sallaway	Sunil Shah	Michael Spratt	Tsutomu Tatsuta
Joseph Salowe	Vadim Shain	Nurit Sprecher	Jim Tatum
Panagiotis Saltsidis	Abhijit Shanbhag	Matthew B. Squire	James M. Tavacoli
Michael M. Salzman	Megha Shanbhag	David Srodzinski	Sadry Tavana
Moni Samaan	Ron Shani	Joseph St. Amand	Ken Taylor
Sam Sambasivan	Sam Shen	David N. Stacy	Mark Taylor
Fred Sammartino	Ben Sheppard	Clayton Stanford	Tim Teckman
Henry Samueli	Paul Sherer	Patrick H. Stanley	Michael D. Johas Teener
Anthony Sanders	Robbie Shergill	Kevin Stanton	Antonio Teixeira
Gianluca Sanitá	Siddharth Sheth	Nick Stapleton	Vivek Telang
Mark Sankey	Masayuki Shigematsu	Graham Starkins	José Tellado
Concita Saracino	Cheng-Chung Shih	Peter Staub	Patricia Thaler
Arindam Sarkar	Hyungsoo Shin	Margit Stearns	R. Jonathan Thateher
Bill Sarles	Jong-Yoon Shin	Henk Steenman	Sashisekaran Thiagarajan
F. Sarles	Ramin Shirani	David E. Stein	Walter Thirion
Akira Sasaki	Zion Shohet	Gary Stephens	Geoffrey O. Thompson
Stan Sassower	Larry Shorthill	Claus Stetter	Douglas Thomson
Ramesh Sastry	Avadhani Shridhar	Ronald Steudler	Lars E. Thon
Satish Sathe	Kapil Shrikhande	Donald S. Stewart	David Thorne
John Sauer	Martin Siegmund	Dean M. Stoddart	Ao Ting
Raj Savara	Som Sikdar	Daniel P. Stokesberry	Nathan Tobol
Olindo Savi	Nathan Silberman	Mario Stoltz	John Todd
T. Shannon Sawyer	Tim Simmons	Christopher Stook	Bruce Tolley
Sabit Say-Otun	Scott Simon	Olaf Storaasli	Carlos A. Tomaszewski
Edward Sayre	Jesse Simsarian	Steve Storozum	Peter Tomaszewski
J. David Schell	Bharat Singh	Rick Strohmayer	Paul Torgerson
Dieter W. Schickeltanz	Charan J. Singh	Stephen Strong	Luis Torres
Frederick Schindler	Paramjeet (P. J.) Singh	Richard Stuart	Rick Townsend
Ronald Schmidt	Semir Sirazi	Alan Sugg	Hidehiro Toyoda
Tom Schmitt	Ramesh Sivakolundu	Robert Sultan	Mario Träber
Peter Schoenmaker	Joseph Skorupa	Ron Sulyma	Nathan Tracy
Frederick Scholl	James P. Skoutas	Robert Summers	Mario Traeber
Thomas Schramm	Jeff Slavick	Ken F. Sumner	Hiep Tran
Thomas Schrans	Dinah Sloan	Tetsuyuki Suzuki	Matthew Traverso
Walter Schreuer	Tom Slykhouse	Hiroshi Suzuki	Francois Tremblay
Ted Schroeder	Andrew Smith	Ken-ichi Suzuki	Stephen J. Trowbridge
Scott Schube	David A. Smith	Muneyoshi Suzuki	Thomas E. Truman
Benjamin Schultz	Eric Smith	Naoki Suzuki	Shinji Tsuji
Klaus Schulz	Grant Smith	Daniel Svensson	Shiji Tsuju
David Schwartz	Michael Smith	Steve Swanson	Eddie Tsumura
Peter Schwartz	Robert Smith	Norman L. Swenson	Zbigniew Turlej
Harvey R. Scull	Robert W. Smith	Andre Szczepanek	Brad Turner
Anthony Seaman	Steve Smith	Daniel Sze	Edward Turner
Michael Seaman	Robert Snyder	Tad Szostak	Wendell Turner
Shawn Searles	Dror Sofer	Richard Taborek	Bulent Tusiray
Stephn Sedio	Ran Soffer	Dimitry Taich	Jacob Twersky
Ted Seely	Gregory Somer	Bharat Tailor	Bor-long Twu
Brian Seemann	Jaeyeon Song	Akio Tajima	Marcos Tzannes
Khorvash (Kory) Sefidvash	Jian Song	Eiichi Takahashi	Kiyoshi Uematsu
Rich Seifert	Massimo Sorbara	Hidenori Takahashi	Herbert Uhl
Katsutoshi Seki	David Sorensen	Noriyuki Takeda	Jayshree Ullal
Steve Selee	Michel Sorenson	Martin Takessian	Steven Ulrich
Lee Sendelbach	Walter Sotelo	Motoyuki Takizawa	Alexander Umnov
Shoichiro Seno	Stephen Soto	Keiji Tanaka	Gottfried Ungerboeck
Murat Serbay	Walt Soto	Wen-Tsung Tang	Sterling A. Vaden
Koichiro Seto	Fulvio Spagna	Sandray Tarana	Todd Vafiades

Magesh Valliappan	Chiung Hung Wang	Bruce Williams	Steven Yang
Nicholas Van Bavel	Greg Wang	Richard Williams	Yinglin (Frank) Yang
Schelto J. van Doorn	Peter Wang	Erica Williamson	Ronald Yara
David J. Van Goor	Yun-Che Wang	Robert S. Williamson	Masaki Yasukawa
Peter Van Laanen	Ken Ward	Roger Wilmarth	Lee Chung Yiu
Erik van Oosten	Tim Warland	Joris Wils	Doug Yoder
Paul Z. Vanderlaan	David Warren	Izumi Wilson	Tetsuya Yokomoto
Schelto vanDoorn	Jeff Warren	Mike Wincn	Nobushige Yokota
Dono Van-Mierop	Marc Warshaw	Mark Wingrove	Tae-Whan Yoo
Andre VanSchyndel	Ted Washburn	Darin Winterton	Bin Yeong Yoon
Albert Vareljian	Yuji Watanabe	Mike Witkowski	Chong Ho Yoon
Kumaran Veerayah	Bruce Watson	Kevin Witt	Jason Yorks
V. Kumar Venkatavaraton	Robert Watson	Andrew Witzner	Osamu Yoshihara
Ramakrishna Vepa	Dong Wei	John Wolcott	Takashi Yoshikawa
Gérard Vergnaud	Yuehua Wei	Jonghwa Won	George Young
Bill Verheggen	Jason Weil	King Won	Ken Young
Iain Verigin	Lyle Weiman	Shin-Hee Won	Leonard Young
Robert Verne	Nick Weiner	David Wong	Nariman Yousefi
Anoop Vetteth	Brian Weis	Don Wong	Ben Yu
Nader Vijeh	Alan Weissberger	Edward Wong	Hong Yu
Ron Vilozny	Andrew Weitzner	Leo Wong	Mark Yu
John Visser	Moti Weizman	Percy Wong	Nick Zades
Ionel Marius Vladan	Jim Welch	Bill Woodruff	Nelson Zagalsky
David Vogel	Fred Weniger	Paul Woodruff	Hank Zannini
Moshe Voloshin	Jason Wertz	Ted K. Woodward	Jamie Zartman
Brian Von Herzen	Willem Wery	Chien-Hsien Wu	Li Zeng
John von Voros	Alan Wetzal	Choa-Ping Wu	Jing-fan Zhang
Manoj Wadekar	David White	Robert Wu	Lizhi Zhong
William Wager	Hugh E. White	Stefan M. Wurster	Igor Zhovnirovsky
Martin Wagner	Lawrence White	Ariel Yagil	George Zimmerman
P. E. Wainwright	Martin White	Michael Yam	Pavel Zivny
Ikuo Wakayama	Tony Whitlow	Masaki Yamada	Bob Zona
Rick Walker	Bill Wiedemann	Hajime Yamashita	Mo R. Zonoun
Chang Jung Wang	Joseph A. Wiencko	Shuntaro Yamazaki	Glen Zorn
Chenxi Wang	Bert Wijnen	Howard Yang	

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

Thomas Alexander	Junghoon Jee	Stephen Palm
Jon Anderson	Michael D. Johas Teener	Glenn Parsons
Mark Anderson	Vincent Jones	Petar Pepeljugin
Peter Anslow	Shinkyu Kaku	Randy Perrie
Arthur Astrin	Piotr Karocki	John Petrilla
Kwok Shum Au	Stuart Kerry	Rick Pimpinella
Hugh Barrass	Lior Khermosh	Subburajan Ponnuswamy
Christian Beia	Yongbum Kim	Venkatesha Prasad
Jacob Ben Ary	Jonathan King	Jayaram Ramasastry
Michael Bennett	Paul Kolesar	R. K. Rannow
Brad Booth	Bruce Kraemer	Maximilian Riegel
Ralf-Peter Braun	Glen Kramer	Benjamin Rolfe
Nancy Bravin	Thomas Kurihara	Randall Safier
Matthew Brown	Lowell Lamb	Bartien Sayogo
William Bush	Mark Laubach	Stephen Schwarm
William Byrd	David J. Law	Rich Seifert
Steven B. Carlson	Matthew Lawson	Gil Shultz
Mandeep Chadha	David Lewis	Jeff Slavick
Keith Chow	Vincent Lipsio	Jeremy Smith
Charles Cook	Shen Loh	Kapil Sood
Glenn Davis	William Lumpkins	Matthew Squire
Piers J. G. Dawe	Greg Luri	Manikantan Srinivasan
Wael William Diab	Kent Lusted	Dorothy Stanley
Thomas Dineen	Michael Lynch	Thomas Starai
Daniel Dove	Elvis Maculuba	Walter Struppler
Michael Dudek	Valerie Maguire	Patrik Sundstrom
Sourav Dutta	Jeffery Maki	Joseph Tardo
David Dwelley	Wayne Manges	William Taylor
Richard Edgar	Roger Marks	Patricia Thaler
Howard Frazier	Arthur Marris	David Thompson
Yukihiro Fujimoto	William McBride	Geoffrey Thompson
Ilango Ganga	Edward McCall	Michael Thompson
Devon Gayle	C. Phillip McClay	Jerry Thrasher
Michael Grimwood	Brett McClellan	Stephen Trowbridge
Randall Groves	Michael McCormack	Edward Turner
Robert Grow	Michael McInnis	Dmitri Varsanofiev
Michael Gundlach	Jonathon McLendon	Prabodh Varshney
Chris Guy	Richard Mellitz	Srinivasa Vemuru
Marek Hajduczenia	Steven Methley	John Vergis
Hiroshi Hamano	Tremont Miao	Balasubramanian Vittal
Adam Healey	Charles Moorwood	Ionel Marius Vladan
David Hunter	Jose Morales	George Vlantis
C. Huntley	Joseph Moran	Ludwig Winkel
Noriyuki Ikeuchi	Shimon Muller	Forrest Wright
James Innis	Michael S. Newman	Oren Yuen
Paul Isaacs	Nick S. A. Nikjoo	Janusz Zalewski
Osamu Ishida	Satoshi Obara	Daidi Zhong
Akio Iso	Thomas Palkert	Zhen Zhou
Atsushi Ito		George Zimmerman

When the IEEE-SA Standards Board approved this standard on 30 August 2012, it had the following membership:

**Richard H. Hulett, Chair**  
**John Kulick, Vice Chair**  
**Robert M. Grow, Vice Chair**  
**Konstantinos Karachalios, Secretary**

Satish Aggarwal  
Masayuki Ariyoshi  
Peter Balma  
William Bartley  
Ted Burse  
Clint Chaplin  
Wael Diab  
Jean-Philippe Faure

Alexander Gelman  
Paul Houzé  
Jim Hughes  
Young Kuyn Kim  
Joseph L. Koepfinger\*  
David J. Law  
Thomas Lee  
Hung Ling

Oleg Logvinov  
Ted Olsen  
Gary Robinson  
Jon Walter Rosdahl  
Mike Seavey  
Yatin Trivedi  
Phil Winston  
Yu Yuan

\*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Richard DeBlasio, *DOE Representative*  
Michael Janezic, *NIST Representative*

Lisa Perry  
*IEEE Standards Program Manager, Document Development*

Kathryn M. Bennett  
*IEEE Standards Program Manager, Technical Program Development*





## Introduction

This introduction is not part of IEEE Std 802.3-2012, IEEE Standard for Ethernet.

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 this standard. Each IEEE 802.3 project/amendment is identified with a suffix (e.g., IEEE Std 802.3ba<sup>TM</sup>-2010). A historical listing of all projects that have added to or modified IEEE Std 802.3 follows as a part of this introductory material. The listing is in chronological order of project initiation and for each project describes: subject, clauses added (if any), approval dates, and committee officers.

The Media Access Control (MAC) protocol specified in IEEE Std 802.3 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was included in the experimental Ethernet developed at Xerox Palo Alto Research Center. While the experimental Ethernet had a 2.94 Mb/s data rate, IEEE Std 802.3-1985 specified operation at 10 Mb/s. Since 1985, new media options, new speeds of operation, and new capabilities have been added to IEEE Std 802.3.

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<sup>TM</sup> added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3x specified full duplex operation and a flow control protocol, 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<sup>TM</sup> 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 802.3-2012 and are not maintained as separate documents.

### IEEE Std 802.3-2012

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

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

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

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

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

Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

Section Six—Includes Clause 78 through Clause 90 and Annex 83A through Annex 86A. 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 89 and associated annexes includes general information on 40 Gb/s and 100 Gb/s operation as well the 40 Gb/s and 100 Gb/s Physical Layer specifications. Clause 90 specifies Ethernet support for time synchronization protocols.

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

Withdrawn

## List of special symbols

For the benefit of users who have received this document by electronic means, what follows is a list of special symbols and operators. If any of these symbols or operators fail to print out correctly, the editors apologize and hope that this table will at least help to sort out the meaning of the resulting funny-shaped blobs and strokes.

### Special symbols and operators

Printed character	Meaning	Font
*	Boolean AND	Symbol
+	Boolean OR, arithmetic addition	Symbol
^	Boolean XOR	Times New Roman
!	Boolean NOT	Symbol
×	Multiplication	Symbol
<	Less than	Symbol
≤	Less than or equal to	Symbol
>	Greater than	Symbol
≥	Greater than or equal to	Symbol
=	Equal to	Symbol
≈	Approximately equal to	Symbol
≠	Not equal to	Symbol
←	Assignment operator	Symbol
∈	Indicates membership	Symbol
∉	Indicates nonmembership	Symbol
±	Plus or minus (a tolerance)	Symbol
°	Degrees	Symbol
∑	Summation	Symbol
√	Square root	Symbol
—	Big dash (em dash)	Times New Roman
-	Little dash (en dash), subtraction	Times New Roman
	Vertical bar	Times New Roman
†	Dagger	Times New Roman
‡	Double dagger	Times New Roman
α	Lower case alpha	Symbol
β	Lower case beta	Symbol
γ	Lower case gamma	Symbol
δ	Lower case delta	Symbol
ε	Lower case epsilon	Symbol
λ	Lower case lambda	Symbol
μ	Lower case mu	Times New Roman
Π	Upper case pi	Symbol
Ω	Upper case omega	Symbol

Withdrawn

# IEEE Standard for Ethernet

## SECTION ONE

This section includes Clause 1 through Clause 20, Annex A through Annex H, and Annex 4A.

### Contents

1. Introduction.....	1
1.1 Overview.....	1
1.1.1 Scope.....	1
1.1.2 Basic concepts.....	2
1.1.2.1 Half duplex operation .....	2
1.1.2.2 Full duplex operation .....	2
1.1.3 Architectural perspectives.....	2
1.1.3.1 Architectural rationale .....	3
1.1.3.2 Compatibility interfaces.....	3
1.1.4 Layer interfaces.....	6
1.1.5 Application areas .....	6
1.2 Notation .....	6
1.2.1 State diagram conventions .....	6
1.2.2 Service specification method and notation .....	7
1.2.2.1 Classification of service primitives.....	8
1.2.3 Physical Layer and media notation .....	8

1.2.4	Physical Layer message notation .....	9
1.2.5	Hexadecimal notation .....	9
1.2.6	Accuracy and resolution of numerical quantities .....	9
1.3	Normative references .....	9
1.4	Definitions .....	16
1.5	Abbreviations .....	44
2.	Media Access Control (MAC) service specification .....	49
2.1	Scope and field of application .....	49
2.2	Overview of the service .....	49
2.2.1	General description of services provided by the layer .....	49
2.2.2	Model used for the service specification .....	49
2.2.3	Overview of interactions .....	49
2.2.4	Basic services .....	50
2.3	Detailed service specification .....	50
2.3.1	MA_DATA.request .....	50
2.3.1.1	Function .....	50
2.3.1.2	Semantics of the service primitive .....	50
2.3.1.3	When generated .....	50
2.3.1.4	Effect of receipt .....	50
2.3.1.5	Additional comments .....	50
2.3.2	MA_DATA.indication .....	51
2.3.2.1	Function .....	51
2.3.2.2	Semantics of the service primitive .....	51
2.3.2.3	When generated .....	51
2.3.2.4	Effect of receipt .....	52
2.3.2.5	Additional comments .....	52
3.	Media Access Control (MAC) frame and packet specifications .....	53
3.1	Overview .....	53
3.1.1	Packet format .....	53
3.1.2	Service interface mappings .....	54
3.2	Elements of the MAC frame and packet .....	54
3.2.1	Preamble field .....	54
3.2.2	Start Frame Delimiter (SFD) field .....	54
3.2.3	Address fields .....	54
3.2.3.1	Address designation .....	55
3.2.4	Destination Address field .....	55
3.2.5	Source Address field .....	56
3.2.6	Length/Type field .....	56
3.2.7	MAC Client Data field .....	56
3.2.8	Pad field .....	57
3.2.9	Frame Check Sequence (FCS) field .....	57
3.2.10	Extension field .....	57
3.3	Order of bit transmission .....	58
3.4	Invalid MAC frame .....	58
4.	Media Access Control .....	59
4.1	Functional model of the MAC method .....	59
4.1.1	Overview .....	59
4.1.2	CSMA/CD operation .....	60

4.1.2.1	Normal operation .....	60
4.1.2.1.1	Transmission without contention .....	60
4.1.2.1.2	Reception without contention .....	61
4.1.2.2	Access interference and recovery .....	61
4.1.3	Relationships to the MAC client and Physical Layers .....	62
4.2	CSMA/CD Media Access Control (MAC) method: Precise specification .....	62
4.2.1	Introduction .....	62
4.2.2	Overview of the procedural model .....	62
4.2.2.1	Ground rules for the procedural model .....	63
4.2.2.2	Use of Pascal in the procedural model .....	63
4.2.2.3	Organization of the procedural model .....	64
4.2.2.4	Layer management extensions to procedural model .....	64
4.2.3	Packet transmission model .....	64
4.2.3.1	Transmit data encapsulation .....	65
4.2.3.2	Transmit media access management .....	70
4.2.3.2.1	Deference .....	70
4.2.3.2.2	Interpacket gap .....	70
4.2.3.2.3	Collision handling (half duplex mode only) .....	71
4.2.3.2.4	Collision detection and enforcement (half duplex mode only) .....	71
4.2.3.2.5	Collision backoff and retransmission (half duplex mode only) .....	71
4.2.3.2.6	Full duplex transmission .....	72
4.2.3.2.7	Packet bursting (half duplex mode only) .....	72
4.2.3.3	Minimum frame size .....	72
4.2.3.4	Carrier extension (half duplex mode only) .....	73
4.2.4	Frame reception model .....	73
4.2.4.1	Receive data decapsulation .....	73
4.2.4.1.1	Address recognition .....	73
4.2.4.1.2	Frame check sequence validation .....	74
4.2.4.1.3	Frame disassembly .....	74
4.2.4.2	Receive media access management .....	74
4.2.4.2.1	Framing .....	74
4.2.4.2.2	Collision filtering .....	74
4.2.5	Preamble generation .....	75
4.2.6	Start frame sequence .....	75
4.2.7	Global declarations .....	75
4.2.7.1	Common constants, types, and variables .....	75
4.2.7.2	Transmit state variables .....	77
4.2.7.3	Receive state variables .....	78
4.2.7.4	State variable initialization .....	78
4.2.8	Frame transmission .....	79
4.2.9	Frame reception .....	86
4.2.10	Common procedures .....	89
4.3	Interfaces to/from adjacent layers .....	90
4.3.1	Overview .....	90
4.3.2	MAC service .....	90
4.3.2.1	MAC client transmit interface state diagram .....	90
4.3.2.1.1	Variables .....	90
4.3.2.1.2	Functions .....	91
4.3.2.1.3	Messages .....	91
4.3.2.1.4	MAC client transmit interface state diagram .....	91
4.3.2.2	MAC client receive interface state diagram .....	92
4.3.2.2.1	Variables .....	92
4.3.2.2.2	Functions .....	92
4.3.2.2.3	Messages .....	92

4.3.2.2.4	MAC client receive interface state diagram .....	93
4.3.3	Services required from the Physical Layer .....	93
4.4	Specific implementations.....	95
4.4.1	Compatibility overview .....	95
4.4.2	MAC parameters.....	96
4.4.3	Configuration guidelines.....	97
5.	Layer Management .....	99
5.1	Introduction.....	99
5.1.1	Systems Management overview .....	99
5.1.2	Layer Management model .....	99
5.1.3	Packages.....	100
5.1.4	Conformance requirements.....	100
5.2	Management facilities.....	100
5.2.1	Introduction.....	100
5.2.2	DTE MAC Sublayer Management facilities.....	100
5.2.2.1	DTE MAC sublayer attributes .....	102
5.2.2.1.1	aMACID .....	102
5.2.2.1.2	aFramesTransmittedOK.....	102
5.2.2.1.3	aSingleCollisionFrames .....	102
5.2.2.1.4	aMultipleCollisionFrames .....	102
5.2.2.1.5	aFramesReceivedOK .....	103
5.2.2.1.6	aFrameCheckSequenceErrors .....	103
5.2.2.1.7	aAlignmentErrors.....	103
5.2.2.1.8	aOctetsTransmittedOK .....	103
5.2.2.1.9	aFramesWithDeferredXmissions .....	104
5.2.2.1.10	aLateCollisions .....	104
5.2.2.1.11	aFramesAbortedDueToXSColls .....	104
5.2.2.1.12	aFramesLostDueToIntMACXmitError .....	104
5.2.2.1.13	aCarrierSenseErrors .....	105
5.2.2.1.14	aOctetsReceivedOK.....	105
5.2.2.1.15	aFramesLostDueToIntMACRcvError .....	105
5.2.2.1.16	aPromiscuousStatus .....	105
5.2.2.1.17	aReadMulticastAddressList .....	106
5.2.2.1.18	aMulticastFramesXmittedOK .....	106
5.2.2.1.19	aBroadcastFramesXmittedOK .....	106
5.2.2.1.20	aFramesWithExcessiveDeferral.....	106
5.2.2.1.21	aMulticastFramesReceivedOK .....	107
5.2.2.1.22	aBroadcastFramesReceivedOK .....	107
5.2.2.1.23	aInRangeLengthErrors.....	107
5.2.2.1.24	aOutOfRangeLengthField.....	107
5.2.2.1.25	aFrameTooLongErrors.....	108
5.2.2.1.26	aMACEnableStatus.....	108
5.2.2.1.27	aTransmitEnableStatus .....	108
5.2.2.1.28	aMulticastReceiveStatus .....	108
5.2.2.1.29	aReadWriteMACAddress .....	109
5.2.2.1.30	aCollisionFrames .....	109
5.2.2.2	DTE MAC Sublayer actions .....	109
5.2.2.2.1	acInitializeMAC.....	109
5.2.2.2.2	acAddGroupAddress.....	109
5.2.2.2.3	acDeleteGroupAddress .....	110
5.2.2.2.4	acExecuteSelfTest.....	110
5.2.2.3	ResourceTypeID Managed Object Class .....	110



5.2.2.3.1	ResourceTypeID .....	110
5.2.3	DTE Physical Sublayer Management facilities .....	110
5.2.3.1	DTE Physical Sublayer attributes .....	110
5.2.3.1.1	aPHYID .....	110
5.2.3.1.2	aSQETestErrors .....	110
5.2.4	DTE Management procedural model.....	111
5.2.4.1	Common constants and types .....	111
5.2.4.2	Transmit variables and procedures .....	111
5.2.4.3	Receive variables and procedures.....	113
5.2.4.4	Common procedures .....	115
6.	Physical Signaling (PLS) service specifications.....	117
6.1	Scope and field of application .....	117
6.2	Overview of the service .....	117
6.2.1	General description of services provided by the layer.....	117
6.2.2	Model used for the service specification .....	117
6.2.3	Overview of interactions.....	117
6.2.4	Basic services and options .....	118
6.3	Detailed service specification .....	118
6.3.1	Peer-to-peer service primitives .....	118
6.3.1.1	PLS_DATA.request.....	118
6.3.1.1.1	Function .....	118
6.3.1.1.2	Semantics of the service primitive.....	118
6.3.1.1.3	When generated .....	118
6.3.1.1.4	Effect of receipt .....	118
6.3.1.2	PLS_DATA.indication .....	119
6.3.1.2.1	Function .....	119
6.3.1.2.2	Semantics of the service primitive.....	119
6.3.1.2.3	When generated .....	119
6.3.1.2.4	Effect of receipt .....	119
6.3.2	Sublayer-to-sublayer service primitives .....	119
6.3.2.1	PLS_CARRIER.indication .....	119
6.3.2.1.1	Function .....	119
6.3.2.1.2	Semantics of the service primitive.....	119
6.3.2.1.3	When generated .....	119
6.3.2.1.4	Effect of receipt .....	119
6.3.2.2	PLS_SIGNAL.indication.....	120
6.3.2.2.1	Function .....	120
6.3.2.2.2	Semantics of the service primitive.....	120
6.3.2.2.3	When generated .....	120
6.3.2.2.4	Effect of receipt .....	120
6.3.2.3	PLS_DATA_VALID.indication .....	120
6.3.2.3.1	Function .....	120
6.3.2.3.2	Semantics of the service primitive.....	120
6.3.2.3.3	When generated .....	120
6.3.2.3.4	Effect of receipt .....	120
7.	Physical Signaling (PLS) and Attachment Unit Interface (AUI) specifications .....	121
7.1	Scope.....	121
7.1.1	Definitions .....	121
7.1.2	Summary of major concepts .....	121
7.1.3	Application.....	122

7.1.4	Modes of operation .....	122
7.1.5	Allocation of function .....	122
7.2	Functional specification .....	122
7.2.1	PLS–PMA (DTE–MAU) Interface protocol .....	122
7.2.1.1	PLS to PMA messages .....	123
7.2.1.1.1	output message .....	123
7.2.1.1.2	output_idle message .....	124
7.2.1.1.3	normal message .....	124
7.2.1.1.4	isolate message (optional) .....	124
7.2.1.1.5	mau_request message (optional) .....	124
7.2.1.2	PMA to PLS interface .....	126
7.2.1.2.1	input message .....	126
7.2.1.2.2	input_idle message .....	128
7.2.1.2.3	signal_quality_error message .....	128
7.2.1.2.4	mau_available message .....	128
7.2.1.2.5	mau_not_available message (optional) .....	128
7.2.2	PLS interface to MAC and management entities .....	129
7.2.2.1	PLS–MAC interface .....	129
7.2.2.1.1	OUTPUT_UNIT .....	129
7.2.2.1.2	OUTPUT_STATUS .....	129
7.2.2.1.3	INPUT_UNIT .....	129
7.2.2.1.4	CARRIER_STATUS .....	129
7.2.2.1.5	SIGNAL_STATUS .....	130
7.2.2.1.6	DATA_VALID_STATUS .....	130
7.2.2.2	PLS–management entity interface .....	130
7.2.2.2.1	RESET_REQUEST .....	130
7.2.2.2.2	RESET_RESPONSE .....	131
7.2.2.2.3	MODE_CONTROL .....	131
7.2.2.2.4	SQE_TEST .....	131
7.2.3	Frame structure .....	131
7.2.3.1	Silence .....	132
7.2.3.2	Preamble .....	132
7.2.3.3	Start of Frame Delimiter (SFD) .....	132
7.2.3.4	Data .....	132
7.2.3.5	End of transmission delimiter .....	132
7.2.4	PLS functions .....	132
7.2.4.1	Reset and Identify function .....	133
7.2.4.2	Mode function .....	133
7.2.4.3	Output function .....	134
7.2.4.4	Input function .....	134
7.2.4.5	Error Sense function .....	134
7.2.4.6	Carrier Sense function .....	135
7.3	Signal characteristics .....	135
7.3.1	Signal encoding .....	135
7.3.1.1	Data encoding .....	135
7.3.1.2	Control encoding .....	139
7.3.2	Signaling rate .....	140
7.3.3	Signaling levels .....	140
7.4	Electrical characteristics .....	140
7.4.1	Driver characteristics .....	140
7.4.1.1	Differential output voltage, loaded .....	140
7.4.1.2	Requirements after idle .....	142
7.4.1.3	AC common-mode output voltage .....	142
7.4.1.4	Differential output voltage, open circuit .....	142

7.4.1.5	DC common-mode output voltage.....	142
7.4.1.6	Fault tolerance.....	143
7.4.2	Receiver characteristics .....	143
7.4.2.1	Receiver threshold levels .....	143
7.4.2.2	AC differential input impedance.....	144
7.4.2.3	AC common-mode range.....	144
7.4.2.4	Total common-mode range.....	144
7.4.2.5	Idle input behavior .....	145
7.4.2.6	Fault tolerance.....	145
7.4.3	AUI cable characteristics .....	145
7.4.3.1	Conductor size .....	146
7.4.3.2	Pair-to-pair balanced crosstalk.....	146
7.4.3.3	Differential characteristic impedance .....	146
7.4.3.4	Transfer impedance.....	146
7.4.3.5	Attenuation.....	146
7.4.3.6	Timing jitter .....	146
7.4.3.7	Delay .....	146
7.5	Functional description of interchange circuits.....	147
7.5.1	General.....	147
7.5.2	Definition of interchange circuits .....	147
7.5.2.1	Circuit DO–Data Out.....	148
7.5.2.2	Circuit DI–Data In .....	148
7.5.2.3	Circuit CO–Control Out (optional).....	148
7.5.2.4	Circuit CI–Control In.....	148
7.5.2.5	Circuit VP–Voltage Plus.....	149
7.5.2.6	Circuit VC–Voltage Common .....	149
7.5.2.7	Circuit PG–Protective Ground.....	149
7.5.2.8	Circuit shield terminations.....	149
7.6	Mechanical characteristics.....	149
7.6.1	Definition of mechanical interface.....	149
7.6.2	Line interface connector.....	149
7.6.3	Contact assignments .....	150
8.	Medium Attachment Unit and baseband medium specifications, type 10BASE5 .....	153
8.1	Scope.....	153
8.1.1	Overview.....	153
8.1.1.1	Medium Attachment Unit .....	153
8.1.1.2	Repeater unit .....	154
8.1.2	Definitions.....	154
8.1.3	Application perspective: MAU and MEDIUM objectives .....	154
8.1.3.1	Object.....	154
8.1.3.2	Compatibility considerations .....	154
8.1.3.3	Relationship to PLS and AU interface.....	155
8.1.3.4	Modes of operation .....	155
8.2	MAU functional specifications .....	155
8.2.1	MAU Physical Layer functions .....	155
8.2.1.1	Transmit function requirements.....	155
8.2.1.2	Receive function requirements .....	156
8.2.1.3	Collision Presence function requirements .....	157
8.2.1.4	Monitor function requirements (optional) .....	157
8.2.1.5	Jabber function requirements.....	158
8.2.2	MAU interface messages .....	158
8.2.2.1	DTE Physical Layer to MAU Physical Layer messages .....	158

8.2.2.2	MAU Physical Layer to DTE Physical Layer .....	159
8.2.2.2.1	input message.....	159
8.2.2.2.2	input_idle message.....	159
8.2.2.2.3	mau_available message.....	159
8.2.2.2.4	signal_quality_error message .....	159
8.2.3	MAU state diagrams .....	160
8.3	MAU–medium electrical characteristics .....	160
8.3.1	MAU-to-coaxial cable interface .....	160
8.3.1.1	Input impedance.....	160
8.3.1.2	Bias current.....	161
8.3.1.3	Coaxial cable signaling levels.....	161
8.3.1.4	Transmit output levels symmetry .....	167
8.3.1.5	Collision detect thresholds.....	167
8.3.2	MAU electrical characteristics.....	167
8.3.2.1	Electrical isolation .....	167
8.3.2.2	Power consumption.....	168
8.3.2.3	Reliability.....	168
8.3.3	MAU–DTE electrical characteristics.....	168
8.3.4	MAU–DTE mechanical connection.....	168
8.4	Characteristics of the coaxial cable .....	168
8.4.1	Coaxial cable electrical parameters .....	168
8.4.1.1	Characteristic impedance .....	168
8.4.1.2	Attenuation.....	168
8.4.1.3	Velocity of propagation .....	169
8.4.1.4	Edge jitter, untapped cable.....	169
8.4.1.5	Transfer impedance.....	169
8.4.1.6	Cable dc loop resistance .....	169
8.4.2	Coaxial cable properties.....	170
8.4.2.1	Mechanical requirements.....	170
8.4.2.1.1	General construction.....	170
8.4.2.1.2	Center conductor.....	170
8.4.2.1.3	Dielectric material.....	170
8.4.2.1.4	Shielding system.....	170
8.4.2.1.5	Overall jacket.....	170
8.4.2.2	Jacket marking .....	171
8.4.3	Total segment dc loop resistance .....	171
8.5	Coaxial trunk cable connectors.....	171
8.5.1	Inline coaxial extension connector .....	171
8.5.2	Coaxial cable terminator.....	172
8.5.2.1	Termination.....	172
8.5.2.2	Earthing.....	172
8.5.3	MAU-to-coaxial cable connection.....	172
8.5.3.1	Electrical requirements .....	172
8.5.3.2	Mechanical requirements .....	173
8.5.3.2.1	Connector housing .....	173
8.5.3.2.2	Contact reliability .....	173
8.5.3.2.3	Shield probe characteristics .....	174
8.6	System considerations.....	174
8.6.1	Transmission system model.....	174
8.6.2	Transmission system requirements .....	175
8.6.2.1	Cable sectioning.....	175
8.6.2.2	MAU placement.....	175
8.6.2.3	Trunk cable system grounding.....	175
8.6.3	Labeling .....	176

8.7	Environmental specifications.....	176
8.7.1	General safety requirements .....	176
8.7.2	Network safety requirements .....	176
8.7.2.1	Installations .....	176
8.7.2.2	Grounding .....	177
8.7.2.3	Safety .....	177
8.7.2.4	Breakdown path .....	177
8.7.2.5	Isolation boundary .....	177
8.7.2.6	Installation and maintenance guidelines .....	177
8.7.3	Electromagnetic environment .....	178
8.7.3.1	Susceptibility levels .....	178
8.7.3.2	Emission levels .....	178
8.7.4	Temperature and humidity .....	178
8.7.5	Regulatory requirements.....	178
8.8	Protocol implementation conformance statement (PICS) proforma for Clause 8, Medium Attachment Unit and baseband medium specifications, type 10BASE5.....	179
8.8.1	Overview.....	179
8.8.2	Abbreviations and special symbols.....	179
8.8.2.1	Status symbols .....	179
8.8.2.2	Abbreviations.....	179
8.8.3	Instructions for completing the PICS proforma.....	179
8.8.3.1	General structure of the PICS proforma .....	179
8.8.3.2	Additional information .....	180
8.8.3.3	Exception information .....	180
8.8.3.4	Conditional items .....	180
8.8.4	Identification .....	181
8.8.4.1	Implementation identification.....	181
8.8.4.2	Protocol summary .....	181
8.8.5	Global statement of conformance .....	181
8.8.6	PICS proforma tables for MAU.....	182
8.8.6.1	MAU compatibility.....	182
8.8.6.2	Transmit function .....	182
8.8.6.3	Receive function .....	183
8.8.6.4	Collision function .....	184
8.8.6.5	Monitor function .....	184
8.8.6.6	Jabber function .....	185
8.8.6.7	MAU to coaxial cable interface .....	186
8.8.6.8	MAU electrical characteristics .....	187
8.8.6.9	MAU-DTE requirements .....	187
8.8.6.10	MAU to coaxial cable connection .....	188
8.8.6.11	Safety requirements .....	188
8.8.7	PICS proforma tables for MAU AUI characteristics.....	189
8.8.7.1	Signal characteristics .....	189
8.8.7.2	DI and CI driver characteristics .....	189
8.8.7.3	DO receiver characteristics .....	190
8.8.7.4	CO receiver characteristics .....	191
8.8.7.5	Circuit termination.....	191
8.8.7.6	Mechanical characteristics .....	192
8.8.8	PICS proforma tables for 10BASE5 coaxial cable.....	193
8.8.8.1	10BASE5 coaxial cable characteristics .....	193
9.	Repeater unit for 10 Mb/s baseband networks.....	195
9.1	Overview.....	195

9.2	References.....	196
9.3	Definitions .....	196
9.4	Compatibility interface .....	196
9.4.1	AUI compatibility .....	196
9.4.2	Mixing segment compatibility .....	196
9.4.2.1	Direct coaxial cable attachment compatibility.....	196
9.4.2.2	“N” connector compatibility .....	196
9.4.2.3	BNC compatibility .....	196
9.4.2.4	BFOC/2.5 (10BASE-FP) compatibility .....	196
9.4.3	Link segment compatibility .....	197
9.4.3.1	Vendor-dependent IRL .....	197
9.4.3.2	Fiber optic FOIRL compatibility .....	197
9.4.3.3	Twisted-pair jack compatibility .....	197
9.4.3.4	Fiber optic 10BASE-FB and 10BASE-FL compatibility .....	197
9.5	Basic functions.....	197
9.5.1	Repeater set network properties.....	197
9.5.2	Signal amplification.....	197
9.5.3	Signal symmetry .....	197
9.5.4	Signal retiming.....	198
9.5.5	Data handling.....	198
9.5.5.1	Start-of-packet propagation delays .....	198
9.5.5.2	Start-of-packet variability .....	198
9.5.6	Collision handling.....	199
9.5.6.1	Collision presence.....	199
9.5.6.2	Jam generation .....	199
9.5.6.3	Collision-jam propagation delays .....	199
9.5.6.4	Transmit recovery time.....	200
9.5.6.5	Carrier recovery time.....	200
9.5.7	Electrical isolation .....	200
9.6	Detailed repeater functions and state diagrams .....	201
9.6.1	State diagram notation .....	201
9.6.2	Data and collision handling .....	204
9.6.3	Preamble regeneration .....	204
9.6.4	Fragment extension.....	204
9.6.5	MAU Jabber Lockup Protection .....	205
9.6.6	Auto-Partitioning/Reconnection (optional) .....	205
9.6.6.1	Overview.....	205
9.6.6.2	Detailed auto-partition/reconnection algorithm state diagram .....	205
9.7	Electrical isolation .....	208
9.7.1	Environment A requirements.....	208
9.7.2	Environment B requirements .....	208
9.8	Reliability.....	208
9.9	Medium attachment unit and baseband medium specification for a vendor-independent FOIRL .....	209
9.9.1	Scope.....	209
9.9.1.1	Overview.....	209
9.9.1.2	Application perspective: FOMAU and medium objectives.....	211
9.9.1.3	Compatibility considerations .....	211
9.9.1.4	Relationship to AUI.....	211
9.9.1.5	Mode of operation.....	211
9.9.2	FOMAU functional specifications.....	211
9.9.2.1	Transmit function requirements.....	212
9.9.2.2	Receive function requirements .....	213
9.9.2.3	Collision Presence function requirements .....	213

9.9.2.4	Jabber function requirements.....	214
9.9.2.5	Low Light Level Detection function requirements.....	214
9.9.2.6	Repeater Unit to FOMAU Physical Layer messages.....	215
9.9.2.7	FOMAU Physical Layer to repeater unit messages.....	215
9.9.2.7.1	input message.....	215
9.9.2.7.2	input_idle message.....	215
9.9.2.7.3	fomau_available message .....	215
9.9.2.7.4	signal_quality_error message .....	215
9.9.2.8	FOMAU state diagrams .....	216
9.9.3	FOMAU electrical characteristics .....	217
9.9.3.1	Electrical isolation .....	217
9.9.3.2	Power consumption.....	217
9.9.3.3	Reliability.....	218
9.9.3.4	FOMAU/Repeater unit electrical characteristics .....	218
9.9.3.5	FOMAU/Repeater unit mechanical connection.....	218
9.9.4	FOMAU/Optical medium interface .....	218
9.9.4.1	Transmit optical parameters.....	218
9.9.4.1.1	Wavelength .....	218
9.9.4.1.2	Spectral width .....	218
9.9.4.1.3	Optical modulation .....	218
9.9.4.1.4	Optical idle signal .....	218
9.9.4.1.5	Transmit optical logic polarity.....	218
9.9.4.1.6	Optical rise and fall times .....	220
9.9.4.1.7	Transmit optical pulse edge jitter.....	220
9.9.4.1.8	Peak coupled optical power .....	221
9.9.4.2	Receive optical parameters .....	221
9.9.4.2.1	Receive peak optical power range .....	221
9.9.4.2.2	Receive optical pulse edge jitter .....	221
9.9.4.2.3	Receive optical logic polarity .....	221
9.9.5	Characteristics of the optical fiber cable link segment .....	221
9.9.5.1	Optical fiber medium .....	222
9.9.5.2	Optical medium connector plug and socket.....	222
9.9.6	System requirements.....	222
9.9.6.1	Optical transmission system considerations .....	222
9.9.6.2	Timing considerations.....	223
9.9.7	Environmental specifications.....	224
9.9.7.1	Safety requirements .....	224
9.9.7.1.1	Electrical safety.....	224
9.9.7.1.2	Optical source safety.....	224
9.9.7.2	Electromagnetic environment .....	224
9.9.7.2.1	Susceptibility levels .....	224
9.9.7.2.2	Emission levels .....	224
9.9.7.3	Temperature and humidity .....	225
10.	Medium attachment unit and baseband medium specifications, type 10BASE2 .....	227
10.1	Scope.....	227
10.1.1	Overview.....	227
10.1.1.1	Medium attachment unit (normally contained within the data terminal equipment [DTE]).....	228
10.1.1.2	Repeater unit .....	228
10.1.2	Definitions .....	228
10.1.3	Application perspective: MAU and medium objectives.....	228
10.1.3.1	Object.....	228

10.1.3.2	Compatibility considerations .....	229
10.1.3.3	Relationship to PLS and AUI .....	229
10.1.3.4	Mode of operation.....	229
10.2	References.....	229
10.3	MAU functional specifications .....	229
10.3.1	MAU Physical Layer functional requirements .....	230
10.3.1.1	Transmit function requirements.....	230
10.3.1.2	Receive function requirements .....	231
10.3.1.3	Collision Presence function requirements .....	231
10.3.1.4	Jabber functional requirements .....	232
10.3.2	MAU interface messages .....	232
10.3.2.1	DTE to MAU messages .....	232
10.3.2.2	MAU to DTE messages .....	232
10.3.2.2.1	input message.....	234
10.3.2.2.2	input_idle message.....	234
10.3.2.2.3	mau_available message.....	234
10.3.2.2.4	signal_quality_error (SQE) message .....	234
10.3.3	MAU state diagrams .....	234
10.4	MAU–medium electrical characteristics .....	235
10.4.1	MAU-to-coaxial cable interface .....	235
10.4.1.1	Input impedance.....	235
10.4.1.2	Bias current.....	235
10.4.1.3	Coaxial cable signaling levels.....	235
10.4.1.4	Transmit output levels symmetry .....	237
10.4.1.5	Collision detect thresholds.....	237
10.4.2	MAU electrical characteristics.....	237
10.4.2.1	Electrical isolation .....	237
10.4.2.2	Power consumption.....	237
10.4.2.3	Reliability.....	238
10.4.3	MAU–DTE electrical characteristics.....	238
10.5	Characteristics of coaxial cable system .....	238
10.5.1	Coaxial cable electrical parameters .....	238
10.5.1.1	Characteristic impedance .....	238
10.5.1.2	Attenuation.....	238
10.5.1.3	Velocity of propagation .....	238
10.5.1.4	Edge jitter, entire segment without DTEs attached .....	238
10.5.1.5	Transfer impedance.....	239
10.5.1.6	Cable dc loop resistance .....	239
10.5.2	Coaxial cable physical parameters.....	239
10.5.2.1	Mechanical requirements .....	239
10.5.2.1.1	General construction .....	240
10.5.2.1.2	Center conductor .....	240
10.5.2.1.3	Dielectric material.....	240
10.5.2.1.4	Shielding system .....	240
10.5.2.1.5	Overall jacket.....	240
10.5.2.2	Jacket marking .....	240
10.5.3	Total segment dc loop resistance .....	240
10.6	Coaxial trunk cable connectors .....	241
10.6.1	In-line coaxial extension connector .....	241
10.6.2	Coaxial cable terminator.....	242
10.6.3	MAU-to-coaxial cable connection.....	242
10.7	System considerations.....	242
10.7.1	Transmission system model.....	242
10.7.2	Transmission system requirements .....	244



10.7.2.1	Cable sectioning.....	244
10.7.2.2	MAU placement.....	244
10.7.2.3	Trunk cable system earthing .....	244
10.7.2.4	Static discharge path .....	244
10.7.2.4.1	Installation environment .....	244
10.8	Environmental specifications.....	245
10.8.1	Safety requirements .....	245
10.8.1.1	Installations .....	245
10.8.1.2	Earthing.....	245
10.8.2	Electromagnetic environment .....	245
10.8.2.1	Susceptibility levels .....	245
10.8.2.2	Emission levels .....	245
10.8.3	Regulatory requirements.....	245
11.	Broadband medium attachment unit and broadband medium specifications, type 10BROAD36 .....	247
11.1	Scope.....	247
11.1.1	Overview.....	247
11.1.2	Definitions .....	249
11.1.3	MAU and medium objectives .....	249
11.1.4	Compatibility considerations .....	250
11.1.5	Relationship to PLS and AUI .....	250
11.1.6	Mode of operation.....	250
11.2	MAU functional specifications.....	250
11.2.1	MAU functional requirements.....	250
11.2.1.1	Transmit function requirements.....	250
11.2.1.2	Receive function requirements .....	251
11.2.1.3	Collision Detection function requirements.....	251
11.2.1.3.1	Collision enforcement transmitter requirements.....	252
11.2.1.3.2	Collision enforcement detection requirements .....	252
11.2.1.4	Jabber function requirements.....	252
11.2.2	DTE PLS to MAU and MAU to DTE PLS messages .....	253
11.2.2.1	DTE Physical Layer to MAU Physical Layer messages .....	253
11.2.2.2	MAU Physical Layer to DTE Physical Layer messages .....	253
11.2.2.2.1	input message.....	253
11.2.2.2.2	input_idle message.....	253
11.2.2.2.3	mau_available message.....	253
11.2.2.3	signal_quality_error message .....	253
11.2.3	MAU state diagrams .....	254
11.2.3.1	MAU state diagram messages.....	254
11.2.3.2	MAU state diagram signal names .....	254
11.3	MAU characteristics .....	257
11.3.1	MAU-to-coaxial cable interface .....	257
11.3.1.1	Receive interface.....	257
11.3.1.1.1	Receive input impedance .....	257
11.3.1.1.2	Receiver squelch requirements .....	257
11.3.1.1.3	Receive level requirements.....	258
11.3.1.1.4	Receiver selectivity and linearity requirements.....	258
11.3.1.1.5	Receive input mechanical requirements .....	258
11.3.1.2	Transmit interface .....	258
11.3.1.2.1	Transmit output impedance .....	258
11.3.1.2.2	Transmitted RF packet format .....	258
11.3.1.2.3	Transmit spectrum and group delay characteristics.....	259
11.3.1.2.4	Transmit out-of-band spectrum .....	261

11.3.1.2.5	Transmit level requirements .....	261
11.3.1.2.6	Nontransmitting signal leakage requirement .....	261
11.3.1.2.7	Transmit spurious output requirement .....	261
11.3.1.2.8	Collision enforcement signal leakage requirement.....	262
11.3.1.2.9	Transmit output mechanical requirements.....	262
11.3.2	MAU frequency allocations.....	262
11.3.2.1	Single-cable systems frequency allocations .....	262
11.3.2.2	Dual-cable systems frequency allocations .....	263
11.3.3	AUI electrical characteristics.....	263
11.3.3.1	Electrical isolation requirements .....	263
11.3.3.2	Current consumption.....	263
11.3.3.3	Driver and receiver requirements .....	264
11.3.3.4	AUI mechanical connection.....	264
11.3.4	MAU transfer characteristics .....	264
11.3.4.1	AUI to coaxial cable framing characteristics.....	264
11.3.4.1.1	Scrambler and differential encoding requirements.....	265
11.3.4.2	Coaxial cable to AUI framing characteristics.....	266
11.3.4.3	Circuit DO to circuit DI framing characteristics.....	267
11.3.4.4	AUI to coaxial cable delay characteristics.....	267
11.3.4.4.1	Circuit DO to RF data signal delay.....	267
11.3.4.4.2	Circuit DO to CE RF output delay.....	267
11.3.4.4.3	Transmit postamble to SQE test signal delay.....	267
11.3.4.4.4	SQE test signal length.....	267
11.3.4.5	Coaxial cable to AUI delay characteristics.....	267
11.3.4.5.1	Received RF to circuit DI delay .....	268
11.3.4.5.2	Received RF to CE RF output and circuit CI delay.....	268
11.3.4.5.3	Collision enforcement to circuit CI delay.....	268
11.3.4.5.4	Receive data to SQE test delay.....	268
11.3.4.6	Delay from circuit DO to circuit DI.....	269
11.3.4.7	Interpacket gap requirement .....	270
11.3.4.8	Bit error ratio .....	270
11.3.5	Reliability.....	270
11.4	System considerations.....	271
11.4.1	Delay budget and network diameter .....	271
11.4.2	MAU operation with packets shorter than 512 bits .....	271
11.5	Characteristics of the coaxial cable system .....	272
11.5.1	Electrical requirements .....	272
11.5.2	Mechanical requirements .....	272
11.5.3	Delay requirements .....	272
11.6	Frequency translator requirements for the single-cable version .....	273
11.6.1	Electrical requirements .....	273
11.6.2	Mechanical requirements .....	273
11.7	Environmental specifications.....	273
11.7.1	Safety requirements .....	273
11.7.2	Electromagnetic environment .....	274
11.7.2.1	Susceptibility levels .....	274
11.7.2.2	Emission levels .....	274
11.7.3	Temperature and humidity.....	274
12.	Physical signaling, medium attachment, and baseband medium specifications, type 1BASE5 .....	275
12.1	Introduction.....	275
12.1.1	Overview.....	275

12.1.2	Scope.....	275
12.1.3	Definitions .....	275
12.1.4	General characteristics .....	275
12.1.5	Compatibility .....	276
12.1.6	Objectives of type 1BASE5 specification .....	276
12.2	Architecture .....	276
12.2.1	Major concepts.....	276
12.2.2	Application perspective .....	277
12.2.3	Packet structure.....	277
12.2.3.1	Silence.....	278
12.2.3.2	Preamble .....	278
12.2.3.3	Start-of-frame delimiter .....	279
12.2.3.4	Data.....	279
12.2.3.5	End-of-transmission delimiter .....	279
12.3	DTE physical signaling (PLS) specification.....	280
12.3.1	Overview.....	280
12.3.1.1	Summary of major concepts .....	280
12.3.1.2	Application perspective .....	280
12.3.2	Functional specification .....	281
12.3.2.1	PLS-PMA interface.....	281
12.3.2.1.1	output message.....	281
12.3.2.1.2	output_idle message.....	281
12.3.2.1.3	input message.....	281
12.3.2.1.4	input_idle message.....	281
12.3.2.2	PLS-MAC interface .....	282
12.3.2.2.1	OUTPUT_UNIT .....	282
12.3.2.2.2	OUTPUT_STATUS .....	282
12.3.2.2.3	INPUT_UNIT .....	282
12.3.2.2.4	CARRIER_STATUS .....	282
12.3.2.2.5	SIGNAL_STATUS.....	282
12.3.2.3	PLS functions.....	283
12.3.2.3.1	State diagram variables.....	283
12.3.2.3.2	Output function .....	283
12.3.2.3.3	Input function.....	284
12.3.2.3.4	Error Sense function .....	284
12.3.2.3.5	Carrier Sense function .....	285
12.3.2.4	Signal encoding.....	285
12.3.2.4.1	Data transmission rate.....	285
12.3.2.4.2	Data symbol encoding .....	285
12.3.2.4.3	Collision presence encoding .....	285
12.3.2.4.4	Idle line encoding.....	286
12.4	Hub specification .....	287
12.4.1	Overview.....	287
12.4.1.1	Summary of major concepts .....	288
12.4.1.2	Application perspective .....	288
12.4.2	Hub structure.....	288
12.4.2.1	Upward side .....	288
12.4.2.2	Downward side .....	288
12.4.3	Hub PLS functional specification .....	289
12.4.3.1	Hub PLS to PMA interface .....	289
12.4.3.2	Hub PLS functions.....	289
12.4.3.2.1	State diagram variables.....	289
12.4.3.2.2	Upward Signal Transfer function .....	290
12.4.3.2.3	Jabber function.....	290

12.4.3.2.4	Downward Signal Transfer function.....	291
12.4.3.2.5	Retiming (jitter removal) .....	293
12.4.3.2.6	Header hub wrap-around .....	293
12.4.3.2.7	Collision presence startup.....	293
12.4.3.3	Reliability.....	294
12.5	Physical medium attachment (PMA) specification .....	294
12.5.1	Overview.....	294
12.5.2	PLS–PMA interface.....	294
12.5.3	Signal characteristics .....	295
12.5.3.1	Transmitter characteristics .....	295
12.5.3.1.1	Differential output voltage.....	295
12.5.3.1.2	Output timing jitter .....	298
12.5.3.1.3	Transmitter impedance balance .....	298
12.5.3.1.4	Common-mode output voltage .....	299
12.5.3.1.5	Common-mode tolerance.....	299
12.5.3.1.6	Transmitter fault tolerance.....	300
12.5.3.2	Receiver characteristics .....	300
12.5.3.2.1	Differential input voltage.....	300
12.5.3.2.2	Input timing jitter .....	300
12.5.3.2.3	Idle input behavior .....	300
12.5.3.2.4	Differential input impedance .....	301
12.5.3.2.5	Common-mode rejection .....	301
12.5.3.2.6	Noise immunity.....	302
12.5.3.2.7	Receiver fault tolerance.....	302
12.6	Medium Dependent Interface (MDI) specification.....	302
12.6.1	Line interface connector .....	302
12.6.2	Connector contact assignments.....	303
12.6.3	Labeling .....	303
12.7	Cable medium characteristics .....	304
12.7.1	Overview.....	304
12.7.2	Transmission parameters .....	304
12.7.2.1	Attenuation.....	304
12.7.2.2	Differential characteristic impedance .....	304
12.7.2.3	Medium timing jitter .....	304
12.7.2.4	Dispersion.....	305
12.7.3	Coupling parameters .....	305
12.7.3.1	Pair-to-pair crosstalk.....	305
12.7.3.2	Multiple-disturber crosstalk.....	305
12.7.3.3	Balance.....	306
12.7.4	Noise environment.....	306
12.7.4.1	Impulse noise .....	306
12.7.4.2	Crosstalk .....	307
12.8	Special link specification .....	307
12.8.1	Overview.....	307
12.8.2	Transmission characteristics .....	307
12.8.3	Permitted configurations.....	307
12.9	Timing.....	307
12.9.1	Overview.....	307
12.9.2	DTE timing .....	308
12.9.3	Medium timing .....	308
12.9.4	Special link timing .....	308
12.9.5	Hub timing .....	308
12.10	Safety .....	309
12.10.1	Isolation .....	309

12.10.2	Telephony voltages .....	310
13.	System considerations for multisegment 10 Mb/s baseband networks .....	311
13.1	Overview .....	311
13.1.1	Repeater usage .....	312
13.2	Definitions .....	312
13.3	Transmission System Model 1 .....	312
13.4	Transmission System Model 2 .....	319
13.4.1	Round-trip collision delay .....	319
13.4.1.1	Worst-case path delay value (PDV) selection .....	319
13.4.1.2	Worst-case PDV calculation .....	319
13.4.2	Interpacket gap (IPG) shrinkage .....	320
13.4.2.1	Worst-case path variability value (PVV) selection .....	321
13.4.2.2	Worst-case path variability value (PVV) calculation .....	321
13.5	Full duplex topology limitations .....	321
14.	Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T including type 10BASE-Te .....	323
14.1	Scope .....	323
14.1.1	Overview .....	323
14.1.1.1	Medium Attachment Unit (MAU) .....	323
14.1.1.2	Repeater unit .....	324
14.1.1.3	Twisted-pair media .....	324
14.1.2	Definitions .....	324
14.1.3	Application perspective .....	325
14.1.3.1	Objectives .....	325
14.1.3.2	Compatibility considerations .....	326
14.1.3.3	Modes of operation .....	326
14.1.4	Relationship to PLS and AU .....	326
14.2	MAU functional specifications .....	326
14.2.1	MAU functions .....	327
14.2.1.1	Transmit function requirements .....	328
14.2.1.2	Receive function requirements .....	328
14.2.1.3	Loopback function requirements (half duplex mode only) .....	329
14.2.1.4	Collision Presence function requirements (half duplex mode only) .....	329
14.2.1.5	signal_quality_error Message (SQE) Test function requirements .....	329
14.2.1.6	Jabber function requirements .....	329
14.2.1.7	Link Integrity Test function requirements .....	330
14.2.1.8	Auto-Negotiation .....	331
14.2.2	PMA interface messages .....	331
14.2.2.1	PLS to PMA messages .....	331
14.2.2.1.1	PMA to PLS messages .....	331
14.2.2.2	PMA to twisted-pair link segment messages .....	332
14.2.2.3	Twisted-pair link segment to PMA messages .....	332
14.2.2.4	Interface message time references .....	332
14.2.3	MAU state diagrams .....	332
14.2.3.1	State diagram variables .....	332
14.2.3.2	State diagram timers .....	338
14.3	MAU electrical specifications .....	338
14.3.1	MAU-to-MDI interface characteristics .....	338
14.3.1.1	Isolation requirement .....	338
14.3.1.2	Transmitter specifications .....	339

14.3.1.2.1	Differential output voltage .....	340
14.3.1.2.2	Transmitter differential output impedance .....	343
14.3.1.2.3	Output timing jitter .....	344
14.3.1.2.4	Transmitter impedance balance .....	344
14.3.1.2.5	Common-mode output voltage .....	344
14.3.1.2.6	Transmitter common-mode rejection.....	345
14.3.1.2.7	Transmitter fault tolerance.....	345
14.3.1.3	Receiver specifications .....	346
14.3.1.3.1	Receiver differential input signals .....	346
14.3.1.3.2	Receiver differential noise immunity .....	346
14.3.1.3.3	Idle input behavior .....	347
14.3.1.3.4	Receiver differential input impedance.....	347
14.3.1.3.5	Common-mode rejection .....	347
14.3.1.3.6	Receiver fault tolerance .....	347
14.3.2	MAU-to-AUI specification.....	347
14.3.2.1	MAU-AUI electrical characteristics .....	347
14.3.2.2	MAU-AUI mechanical connection .....	348
14.3.2.3	Power consumption.....	348
14.4	Characteristics of the simplex link segment .....	349
14.4.1	Overview.....	349
14.4.2	Transmission parameters .....	349
14.4.2.1	Insertion loss .....	349
14.4.2.2	Differential characteristic impedance.....	349
14.4.2.3	Medium timing jitter.....	349
14.4.2.4	Delay .....	350
14.4.3	Coupling parameters .....	350
14.4.3.1	Differential near-end crosstalk (NEXT) loss .....	350
14.4.3.1.1	Twenty-five-pair cable and twenty-five-pair binder groups.....	350
14.4.3.1.2	Four-pair cable.....	350
14.4.3.1.3	Other cables .....	350
14.4.3.2	Multiple-disturber NEXT (MDNEXT) loss .....	350
14.4.4	Noise environment.....	351
14.4.4.1	Impulse noise.....	351
14.4.4.2	Crosstalk noise .....	351
14.5	MDI specification .....	351
14.5.1	MDI connectors .....	351
14.5.2	Crossover function.....	352
14.6	System considerations.....	353
14.7	Environmental specifications.....	354
14.7.1	General safety .....	354
14.7.2	Network safety .....	354
14.7.2.1	Installation .....	354
14.7.2.2	Grounding .....	354
14.7.2.3	Installation and maintenance guidelines .....	354
14.7.2.4	Telephony voltages .....	354
14.7.3	Environment.....	355
14.7.3.1	Electromagnetic emission .....	355
14.7.3.2	Temperature and humidity .....	355
14.8	MAU labeling .....	355
14.9	Timing summary.....	356
14.10	Protocol implementation conformance statement (PICS) proforma for Clause 14, Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T and type 10BASE-Te .....	357
14.10.1	Introduction.....	357

14.10.1.1	Scope.....	357
14.10.1.2	Reference .....	357
14.10.1.3	Definitions .....	357
14.10.1.4	Conformance.....	357
14.10.2	Identification of implementation .....	358
14.10.2.1	Supplier information .....	358
14.10.2.2	Implementation information .....	358
14.10.3	Identification of the protocol .....	358
14.10.4	PICS proforma for 10BASE-T .....	359
14.10.4.1	Abbreviations.....	359
14.10.4.2	PICS Completion instructions and implementation statement .....	359
14.10.4.3	Additional information .....	359
14.10.4.4	References.....	359
14.10.4.5	PICS proforma tables for MAU.....	360
14.10.4.5.1	MAU functions .....	360
14.10.4.5.2	Transmit function.....	361
14.10.4.5.3	Receive function .....	361
14.10.4.5.4	Loopback function .....	362
14.10.4.5.5	Collision Detect function .....	362
14.10.4.5.6	signal_quality_error Message Test function.....	363
14.10.4.5.7	Jabber function.....	363
14.10.4.5.8	Link Integrity Test function.....	364
14.10.4.5.9	MAU state diagram requirements.....	365
14.10.4.5.10	AUI requirements .....	365
14.10.4.5.11	Isolation requirements.....	365
14.10.4.5.12	Transmitter specification.....	366
14.10.4.5.13	Receiver specification.....	367
14.10.4.5.14	MDI requirements.....	368
14.10.4.5.15	Safety requirements .....	368
14.10.4.6	PICS proforma tables for MAU AUI characteristics.....	369
14.10.4.6.1	Signal characteristics .....	369
14.10.4.6.2	DI and CI driver characteristics .....	369
14.10.4.6.3	DO receiver characteristics.....	370
14.10.4.6.4	Power consumption.....	370
14.10.4.6.5	Circuit termination.....	371
14.10.4.6.6	Mechanical characteristics .....	371
14.10.4.7	PICS proforma tables for 10BASE-T link segment.....	372
14.10.4.7.1	10BASE-T link segment characteristics .....	372
14.10.4.8	PICS proforma tables for Auto-Negotiation able MAUs .....	373
15.	Fiber optic medium and common elements of medium attachment units and star, type 10BASE-F.....	375
15.1	Scope.....	375
15.1.1	Overview.....	375
15.1.1.1	Fiber optic medium attachment units (MAUs) .....	375
15.1.1.2	Fiber optic passive star .....	375
15.1.1.3	Repeater unit .....	376
15.1.2	Definitions .....	377
15.1.3	Applications perspective: MAUs, stars, and fiber optic medium .....	377
15.1.3.1	Objectives .....	377
15.1.3.2	Compatibility considerations .....	377
15.1.3.3	Relationship to PLS and AUI .....	378
15.1.3.4	Guidelines for implementation of systems .....	379

15.1.3.5	Modes of operation .....	379
15.2	MDI optical characteristics .....	380
15.2.1	Transmit optical parameters.....	380
15.2.1.1	Center wavelength .....	380
15.2.1.2	Spectral width .....	380
15.2.1.3	Optical modulation extinction ratio .....	380
15.2.1.4	Optical Idle Signal amplitude .....	380
15.2.1.5	Optical transmit pulse logic polarity.....	380
15.2.1.6	Optical transmit pulse rise and fall times.....	380
15.2.1.7	Optical transmit pulse overshoot and undershoot.....	380
15.2.1.8	Optical transmit pulse edge jitter .....	380
15.2.1.9	Optical transmit pulse duty cycle distortion .....	382
15.2.1.10	Optical transmit average power range .....	382
15.2.1.11	Optical transmit signal templates.....	382
15.2.1.11.1	10BASE-FP optical transmit signal template .....	383
15.2.1.11.2	10BASE-FB optical transmit signal template.....	384
15.2.1.11.3	10BASE-FL Optical transmit signal template.....	386
15.2.2	Receive optical parameters .....	387
15.2.2.1	Optical receive average power range.....	387
15.2.2.2	Optical receive pulse edge jitter.....	387
15.2.2.3	Optical receive pulse logic polarity .....	388
15.2.2.4	Optical receive pulse rise and fall times .....	388
15.3	Characteristics of the fiber optic medium.....	388
15.3.1	Optical fiber and cable.....	388
15.3.1.1	Attenuation.....	388
15.3.1.2	Modal bandwidth .....	388
15.3.1.3	Propagation delay .....	388
15.3.2	Optical medium connector plug and socket.....	389
15.3.2.1	Optical connector insertion loss.....	389
15.3.2.2	Optical connector return loss .....	389
15.3.3	Fiber optic medium insertion loss.....	390
15.3.3.1	10BASE-FP segment insertion loss .....	390
15.3.3.2	10BASE-FB and 10BASE-FL segment insertion loss .....	390
15.3.4	Electrical isolation .....	390
15.4	MAU reliability.....	390
15.5	MAU–AUI specification.....	390
15.5.1	MAU–AUI electrical characteristics .....	390
15.5.2	MAU–AUI mechanical connections.....	391
15.5.3	Power consumption.....	391
15.5.4	MAU–AUI messages.....	391
15.5.4.1	PLS to PMA messages.....	391
15.5.4.2	PMA to PLS messages.....	391
15.5.4.2.1	signal_quality_error message .....	391
15.6	Environmental specifications.....	392
15.6.1	Safety requirements .....	392
15.6.2	Electromagnetic environment .....	392
15.6.3	Other environmental requirements .....	393
15.7	MAU labeling .....	393
15.7.1	10BASE-FP star labeling.....	393
15.8	Protocol implementation conformance statement (PICS) proforma for Clause 15, Fiber optical medium and common elements of medium attachment units and star, type 10BASE-F.....	394
15.8.1	Introduction.....	394
15.8.2	Abbreviations and special symbols.....	394



15.8.2.1	Status symbols .....	394
15.8.2.2	Abbreviations.....	394
15.8.3	Instructions for completing the pics proforma.....	394
15.8.3.1	General structure of the PICS proforma .....	394
15.8.3.2	Additional information .....	395
15.8.3.3	Exception information .....	395
15.8.3.4	Conditional items .....	396
15.8.4	Identification .....	396
15.8.4.1	Implementation identification.....	396
15.8.4.2	Protocol summary .....	396
15.8.5	Major capabilities/options.....	397
15.8.6	PICS Proforma for the fiber optic medium.....	397
15.8.6.1	Characteristics of the fiber optic medium.....	397
15.8.6.2	Optical medium connector plug and socket.....	398
15.8.6.3	Fiber optic medium insertion loss.....	398
15.8.6.4	Electrical isolation requirements .....	398
16.	Fiber optic passive star and medium attachment unit, type 10BASE-FP.....	399
16.1	Scope.....	399
16.1.1	Overview.....	399
16.1.1.1	10BASE-FP medium attachment unit.....	399
16.1.1.2	10BASE-FP Star.....	399
16.1.1.3	Repeater unit .....	399
16.2	PMA interface messages.....	400
16.2.1	PMA-to-MDI interface signal encodings .....	400
16.2.2	PMA-to-MDI OTD messages .....	400
16.2.2.1	OTD_output.....	400
16.2.2.2	OTD_idle .....	400
16.2.2.3	OTD_manch_violation.....	401
16.2.3	MDI ORD-to-PMA messages.....	401
16.2.3.1	ORD_input.....	401
16.2.3.2	ORD_idle .....	402
16.2.3.3	ORD_crv .....	402
16.3	10BASE-FP MAU functional specifications .....	402
16.3.1	Transmit function requirements .....	402
16.3.1.1	Preamble encoding.....	403
16.3.1.1.1	Synchronization pattern .....	403
16.3.1.1.2	Packet header code rule violation .....	403
16.3.1.1.3	Unique word .....	403
16.3.1.2	Data transmit.....	403
16.3.1.3	Collision encoding (unique word jam) .....	404
16.3.2	Receive function requirements .....	404
16.3.2.1	Preamble reconstruction and alignment.....	404
16.3.2.2	Data receive .....	404
16.3.2.3	Signal presence during collision .....	404
16.3.3	Loopback function requirements .....	404
16.3.4	Collision presence function requirements.....	405
16.3.4.1	CI Circuit signaling.....	405
16.3.4.2	Collision detection .....	405
16.3.4.3	End of collision.....	406
16.3.5	signal_quality_error Message (SQE) Test function requirements.....	406
16.3.6	Jabber function requirements.....	406
16.3.7	Link fault detection and low light function requirements.....	407

16.3.8	Interface message time references .....	408
16.3.9	MAU state diagram.....	408
16.3.9.1	MAU state diagram variables .....	408
16.3.9.2	MAU state diagram timers.....	410
16.3.9.3	MAU state diagram counters .....	411
16.4	Timing summary.....	416
16.5	10BASE-FP Star functional specifications.....	416
16.5.1	Star functions .....	416
16.5.1.1	Number of ports .....	416
16.5.1.2	Optical power division.....	416
16.5.1.3	Configuration .....	417
16.5.1.4	Reliability.....	417
16.5.2	Star optical characteristics .....	417
16.5.2.1	Star insertion loss.....	417
16.5.2.2	Star single output port uniformity.....	417
16.5.2.3	Star directivity.....	417
16.6	Protocol implementation conformance statement (PICS) proforma for Clause 16, Fiber optic passive star and medium attachment unit, type 10BASE-FP .....	418
16.6.1	Introduction.....	418
16.6.2	Abbreviations and special symbols.....	418
16.6.2.1	Status symbols .....	418
16.6.2.2	Abbreviations.....	418
16.6.3	Instructions for completing the PICS proforma.....	418
16.6.3.1	General structure of the PICS proforma .....	418
16.6.3.2	Additional information .....	419
16.6.3.3	Exception information .....	419
16.6.3.4	Conditional items .....	420
16.6.4	Identification.....	420
16.6.4.1	Implementation identification.....	420
16.6.4.2	Protocol summary .....	420
16.6.5	Major capabilities/options.....	421
16.6.6	PICS proforma for the type 10BASE-FP MAU .....	421
16.6.6.1	Compatibility considerations .....	421
16.6.6.2	Optical transmit parameters .....	422
16.6.6.3	Optical receive parameters.....	423
16.6.6.4	Optical medium connector plug and socket.....	423
16.6.6.5	MAU functions .....	423
16.6.6.6	PMA interface messages.....	423
16.6.6.7	PMA to MDI OTD messages.....	424
16.6.6.8	MDI to PMA messages .....	424
16.6.6.9	Transmit functions .....	424
16.6.6.10	Collision Encoding (Unique Word Jam) function .....	425
16.6.6.11	Receive functions.....	425
16.6.6.12	Preamble reconstruction and alignment function .....	426
16.6.6.13	Data receive function .....	426
16.6.6.14	Signal presence during collision .....	426
16.6.6.15	Loopback function .....	427
16.6.6.16	Collision presence function .....	427
16.6.6.17	signal_quality_error Message (SQE) test function.....	428
16.6.6.18	Jabber function.....	428
16.6.6.19	Link Fault Detect function.....	428
16.6.6.20	MAU state diagram requirements .....	429
16.6.6.21	MAU-to-AUI signal characteristics.....	429
16.6.6.22	MAU-to-AUI DI and CI driver characteristics .....	429

16.6.6.23	AUI-to-MAU DO receiver characteristics.....	430
16.6.6.24	MAU-to-AUI circuit termination.....	430
16.6.6.25	MAU-to-AUI mechanical connections.....	431
16.6.6.26	MAU reliability.....	431
16.6.6.27	Power consumption.....	432
16.6.6.28	PLS-PMA requirements.....	432
16.6.6.29	signal_quality_error message (SQE).....	432
16.6.6.30	Environmental requirements.....	433
16.6.6.31	MAU labeling.....	433
16.6.7	PICS proforma tables for 10BASE-FP stars.....	433
16.6.7.1	Star basic functions.....	433
16.6.7.2	Star optical characteristics.....	434
16.6.7.3	Star environmental requirements.....	434
16.6.7.4	10BASE-FP star labeling.....	434
17.	Fiber optic medium attachment unit, type 10BASE-FB.....	435
17.1	Scope.....	435
17.1.1	Overview.....	435
17.1.1.1	Medium attachment unit.....	435
17.1.1.2	Relationship to repeater.....	435
17.1.1.3	Remote diagnostic messages.....	435
17.1.2	Relationship to AUI.....	435
17.2	PMA interface messages.....	436
17.2.1	PMA-to-MDI interface signal encodings.....	436
17.2.2	PMA-to-MDI OTD messages.....	436
17.2.2.1	OTD_output.....	437
17.2.2.2	OTD_sync_idle.....	437
17.2.2.3	OTD_remote_fault.....	437
17.2.3	MDI ORD-to-PMA messages.....	437
17.2.3.1	Status decoding.....	437
17.2.3.2	ORD_input.....	437
17.2.3.3	ORD_sync_idle.....	437
17.2.3.4	ORD_remote_fault.....	438
17.2.3.5	ORD_invalid_data.....	438
17.2.4	Transitions between signals.....	438
17.2.5	Signaling rate.....	438
17.3	MAU functional specifications.....	438
17.3.1	Transmit function requirements.....	438
17.3.1.1	Data transmit.....	439
17.3.1.2	Synchronous idle.....	439
17.3.1.3	Fault signaling.....	439
17.3.2	Receive function requirements.....	439
17.3.2.1	Data receive.....	439
17.3.2.2	Remote status message handling.....	439
17.3.3	Collision function requirements.....	439
17.3.3.1	Collision detection.....	439
17.3.3.2	End of collision.....	440
17.3.4	Loopback function requirements.....	440
17.3.5	Fault-handling function requirements.....	440
17.3.6	Jabber function requirements.....	440
17.3.7	Low light level detection function requirements.....	441
17.3.8	Synchronous qualification function requirements.....	441
17.3.9	Interface message time references.....	442

17.3.10	MAU state diagrams .....	442
17.3.10.1	MAU state diagram variables .....	442
17.3.10.2	MAU state diagram timers .....	443
17.4	Timing summary .....	446
17.5	Protocol implementation conformance statement (PICS) proforma for Clause 17, Fiber optical medium attachment unit, type 10BASE-FB .....	447
17.5.1	Introduction .....	447
17.5.2	Abbreviations and special symbols .....	447
17.5.2.1	Status symbols .....	447
17.5.2.1.1	Abbreviations .....	447
17.5.3	Instructions for completing the PICS proforma .....	447
17.5.3.1	General structure of the PICS proforma .....	447
17.5.3.2	Additional information .....	448
17.5.3.3	Exception information .....	448
17.5.3.4	Conditional items .....	449
17.5.4	Identification .....	449
17.5.4.1	Implementation identification .....	449
17.5.4.2	Protocol summary .....	449
17.5.5	PICS proforma for the type 10BASE-FB MAU .....	449
17.5.6	PICS proforma for the type 10BASE-FB MAU .....	450
17.5.6.1	Compatibility considerations .....	450
17.5.6.2	Optical transmit parameters .....	450
17.5.6.3	Optical receive parameters .....	451
17.5.6.4	Optical medium connector plug and socket .....	451
17.5.6.5	MAU functions .....	452
17.5.6.6	PMA-to-MDI OTD messages and signaling .....	452
17.5.6.7	MDI ORD-to-PMA messages and signaling .....	453
17.5.6.8	Transitions between signals .....	453
17.5.6.9	Signaling rate .....	453
17.5.6.10	Transmit functions .....	454
17.5.6.11	Receive functions .....	454
17.5.6.12	Data receive function .....	455
17.5.6.13	Remote status message handling .....	455
17.5.6.14	Collision function requirements .....	455
17.5.6.15	End of collision .....	456
17.5.6.16	Loopback function .....	456
17.5.6.17	Fault-handling function .....	456
17.5.6.18	Jabber-handling function .....	457
17.5.6.19	Low light detection .....	457
17.5.6.20	Synchronous qualification .....	458
17.5.6.21	MAU state diagram requirements .....	458
17.5.6.22	MAU reliability .....	458
17.5.6.23	PLS-PMA requirements .....	459
17.5.6.24	signal_quality_error message (SQE) .....	459
17.5.6.25	Environmental requirements .....	459
17.5.6.26	MAU labeling .....	459
18.	Fiber optic medium attachment unit, type 10BASE-FL .....	461
18.1	Scope .....	461
18.1.1	Overview .....	461
18.1.1.1	10BASE-FL medium attachment unit (MAU) .....	461
18.1.1.2	Repeater unit .....	461
18.2	PMA interface messages .....	461

18.2.1	PMA to fiber optic link segment messages .....	462
18.2.1.1	OTD_output .....	462
18.2.1.2	OTD_idle .....	462
18.2.2	Fiber optic link segment to PMA messages.....	462
18.2.2.1	ORD_input.....	462
18.2.2.2	ORD_idle.....	462
18.2.3	Interface message time references .....	463
18.3	MAU functional specifications .....	463
18.3.1	MAU functions .....	463
18.3.1.1	Transmit function requirements.....	464
18.3.1.2	Receive function requirements .....	465
18.3.1.3	Loopback function requirements (half duplex mode only) .....	465
18.3.1.4	Collision Presence function requirements (half duplex mode only).....	465
18.3.1.5	signal_quality_error Message (SQE) Test function requirements.....	466
18.3.1.6	Jabber function requirements.....	466
18.3.1.7	Link Integrity Test function requirements .....	466
18.3.1.8	Auto-Negotiation .....	467
18.3.2	MAU state diagrams .....	467
18.3.2.1	MAU state diagram variables .....	467
18.3.2.2	MAU state diagram timers.....	469
18.4	Timing summary.....	474
18.5	Protocol implementation conformance statement (PICS) proforma for Clause 18, Fiber optic medium attachment unit, type 10BASE-FL.....	475
18.5.1	Introduction.....	475
18.5.2	Abbreviations and special symbols.....	475
18.5.2.1	Status symbols .....	475
18.5.2.2	Abbreviations.....	475
18.5.3	Instructions for completing the PICS proforma.....	476
18.5.3.1	General structure of the PICS proforma .....	476
18.5.3.2	Additional information .....	476
18.5.3.3	Exception information .....	476
18.5.3.4	Conditional items .....	477
18.5.4	Identification.....	477
18.5.4.1	Implementation identification.....	477
18.5.4.2	Protocol summary .....	477
18.5.5	Major capabilities/options.....	478
18.5.6	PICS proforma tables for the type 10BASE-FL MAU.....	478
18.5.6.1	Compatibility considerations .....	478
18.5.6.2	Optical transmit parameter .....	479
18.5.6.3	Optical receive parameters .....	480
18.5.6.4	Optical medium connector plug and socket.....	480
18.5.6.5	MAU functions .....	481
18.5.6.6	PMA interface messages.....	481
18.5.6.7	PMA-to-MDI OTD messages.....	481
18.5.6.8	MDI ORD-to-PMA messages.....	481
18.5.6.9	Transmit function .....	482
18.5.6.10	Receive function .....	482
18.5.6.11	Loopback function .....	483
18.5.6.12	Collision Presence function .....	483
18.5.6.13	signal_quality_error Message (SQE) Test function.....	483
18.5.6.14	Jabber function.....	484
18.5.6.15	Link Integrity Test function.....	484
18.5.6.16	MAU state diagram requirements.....	486
18.5.6.17	MAU-to-AUI signal characteristics.....	486

18.5.6.18	MAU-to-AUI DI and CI driver characteristics .....	487
18.5.6.19	AUI-to-MAU DO receiver characteristics .....	487
18.5.6.20	AUI circuit termination .....	488
18.5.6.21	MAU-to-AUI mechanical connections .....	488
18.5.6.22	MAU reliability .....	489
18.5.6.23	Power consumption .....	489
18.5.6.24	PLS–PMA requirements .....	489
18.5.6.25	signal_quality_error message (SQE) .....	489
18.5.6.26	Environmental requirements .....	490
18.5.6.27	MAU labeling .....	490
19.	Layer Management for 10 Mb/s baseband repeaters .....	491
19.1	Introduction .....	491
19.1.1	Scope .....	491
19.1.2	Relationship to objects in IEEE Std 802.1F-1993 .....	491
19.1.3	Definitions .....	491
19.1.4	Symbols and abbreviations .....	491
19.1.5	Management model .....	492
19.2	Managed objects .....	493
19.2.1	Introduction .....	493
19.2.2	Overview of managed objects .....	493
19.2.2.1	Text description of managed objects .....	493
19.2.2.2	Port functions to support management .....	493
19.2.2.3	Containment .....	495
19.2.2.4	Naming .....	496
19.2.2.5	Packages and capabilities .....	496
19.2.3	Repeater managed object class .....	498
19.2.3.1	Repeater attributes .....	498
19.2.3.1.1	aRepeaterID .....	498
19.2.3.1.2	aRepeaterGroupCapacity .....	498
19.2.3.1.3	aGroupMap .....	498
19.2.3.1.4	aRepeaterHealthState .....	498
19.2.3.1.5	aRepeaterHealthText .....	499
19.2.3.1.6	aRepeaterHealthData .....	499
19.2.3.1.7	aTransmitCollisions .....	499
19.2.3.2	Repeater actions .....	499
19.2.3.2.1	acResetRepeater .....	499
19.2.3.2.2	acExecuteNonDisruptiveSelfTest .....	500
19.2.3.3	Repeater notifications .....	500
19.2.3.3.1	nRepeaterHealth .....	500
19.2.3.3.2	nRepeaterReset .....	501
19.2.3.3.3	nGroupMapChange .....	501
19.2.4	ResourceTypeID Managed Object Class .....	501
19.2.5	Group managed object class .....	501
19.2.5.1	Group attributes .....	501
19.2.5.1.1	aGroupID .....	501
19.2.5.1.2	aGroupPortCapacity .....	502
19.2.5.1.3	aPortMap .....	502
19.2.5.2	Group Notifications .....	502
19.2.5.2.1	nPortMapChange .....	502
19.2.6	Port managed object class .....	502
19.2.6.1	Port Attributes .....	502
19.2.6.1.1	aPortID .....	502

19.2.6.1.2	aPortAdminState .....	503
19.2.6.1.3	aAutoPartitionState .....	503
19.2.6.1.4	aReadableFrames .....	503
19.2.6.1.5	aReadableOctets .....	503
19.2.6.1.6	aFrameCheckSequenceErrors .....	504
19.2.6.1.7	aAlignmentErrors .....	504
19.2.6.1.8	aFramesTooLong .....	504
19.2.6.1.9	aShortEvents .....	504
19.2.6.1.10	aRunts .....	505
19.2.6.1.11	aCollisions .....	505
19.2.6.1.12	aLateEvents .....	505
19.2.6.1.13	aVeryLongEvents .....	506
19.2.6.1.14	aDataRateMismatches .....	506
19.2.6.1.15	aAutoPartitions .....	506
19.2.6.1.16	aLastSourceAddress .....	506
19.2.6.1.17	aSourceAddressChanges .....	507
19.2.6.2	Port Actions .....	507
19.2.6.2.1	acPortAdminControl .....	507
20.	Layer Management for 10 Mb/s baseband medium attachment units .....	509
20.1	Introduction .....	509
20.1.1	Scope .....	509
20.1.2	Management model .....	509
20.2	Managed objects .....	509
20.2.1	Text description of managed objects .....	509
20.2.1.1	Naming .....	509
20.2.1.2	Containment .....	510
20.2.1.3	Packages .....	510
20.2.2	MAU Managed object class .....	511
20.2.2.1	MAU attributes .....	511
20.2.2.1.1	aMAUID .....	511
20.2.2.1.2	aMAUType .....	511
20.2.2.1.3	aMediaAvailable .....	512
20.2.2.1.4	aLoseMediaCounter .....	512
20.2.2.1.5	aJabber .....	512
20.2.2.1.6	aMAUAdminState .....	513
20.2.2.1.7	aBbMAUXmitRcvSplitType .....	513
20.2.2.1.8	aBroadbandFrequencies .....	513
20.2.2.2	MAU actions .....	514
20.2.2.2.1	acResetMAU .....	514
20.2.2.2.2	acMAUAdminControl .....	514
20.2.2.3	MAU notifications .....	514
20.2.2.3.1	nJabber .....	514
Annex A (informative)	Bibliography .....	515
Annex B (informative)	System guidelines .....	519
B.1	Baseband system guidelines and concepts, 10 Mb/s .....	519
B.1.1	Overall system objectives .....	519
B.1.2	Analog system components and parameter values .....	519
B.1.3	Minimum frame length determination .....	521
B.1.4	System jitter budgets .....	522

B.1.4.1	Nominal jitter values.....	522
B.1.4.2	Decoder evaluation .....	523
B.1.5	Systems consideration calculations .....	524
B.1.5.1	Overview.....	524
B.1.5.2	Maximum collision fragment size .....	524
B.1.5.2.1	Left-end base SDV.....	525
B.1.5.2.2	Mid-base SDV .....	526
B.1.5.2.3	Right-end base SDV .....	526
B.1.5.3	Interpacket Gap (IPG) shrinkage .....	527
B.1.5.3.1	Transmitting end segment variability value.....	527
B.1.5.3.2	Mid-segment variability value.....	528
B.1.5.4	Timing parameters for round-trip delay and variability calculations .....	528
B.1.5.4.1	MAU parameters.....	528
B.1.5.4.2	Repeater parameters.....	529
B.1.5.4.3	Media parameters.....	529
B.1.5.4.4	DTE parameters .....	529
B.2	System parameters and budgets for 1BASE5 .....	531
B.2.1	Delay budget .....	531
B.2.2	Minimum frame length determination .....	532
B.2.3	Jitter budget.....	533
B.3	Example crosstalk computation for multiple disturbers, balanced-pair cable .....	534
B.4	10BASE-T guidelines .....	536
B.4.1	System jitter budget .....	536
B.4.2	Filter characteristics .....	536
B.4.3	Notes for conformance testing .....	536
B.4.3.1	Notes for 14.3.1.2.1 on differential output voltage.....	536
B.4.3.2	Note for 14.3.1.2.2 on transmitter differential output impedance .....	537
B.4.3.3	Note for 14.3.1.2.3 on output timing jitter.....	537
B.4.3.4	General note on common-mode tests.....	538
B.4.3.5	Note for 14.3.1.3.4 on receiver differential input impedance.....	538
B.4.3.6	Note for 14.3.1.3.3 on receiver idle input behavior.....	538
B.4.3.7	Note for 14.3.1.3.5 on receiver common-mode rejection .....	538
B.5	10BASE-F.....	539
B.5.1	System jitter budget .....	539
B.5.2	10BASE-FP fiber optic segment loss budget .....	539
Annex C (informative)	State diagram, MAC sublayer .....	542
Annex D (informative)	Application context, selected medium specifications .....	543
D.1	Introduction.....	543
D.2	Type 10BASE5 applications .....	543
D.3	Type 10BASE2 applications .....	543
D.4	Type FOIRL and 10BASE-F applications; alternative fiber optic medium applications .....	544
D.4.1	Alternative fiber types .....	544
D.4.1.1	Theoretical coupling losses.....	544
D.4.1.2	Maximum launch power .....	545
D.4.2	Type 10BASE-FP applications using 50/125 $\mu\text{m}$ fiber .....	546
D.4.2.1	Coupled transmit power.....	546
D.4.2.2	Star coupler loss.....	546
D.4.2.3	Collision detection .....	547
D.5	10BASE-T use of cabling systems with a nominal differential characteristic impedance of 120 $\Omega$ .....	547



D.6	10BASE-T use of cabling systems with a nominal differential characteristic impedance of 150 $\Omega$ .....	548
	Annex E (informative) Receiver wavelength design considerations (FOIRL).....	550
	Annex F (normative) Additional attributes required for systems .....	551
F.1	Introduction .....	551
F.1.1	Scope.....	551
F.2	Objects/Attributes/Actions/Notifications .....	551
F.2.1	TimeSinceSystemReset attribute .....	551
F.2.2	RepeaterResetTimeStamp attribute .....	552
F.2.3	ResetSystemAction action .....	552
	Annex G (normative) Additional material required for conformance testing .....	553
G.1	Introduction .....	553
G.1.1	Material in support of the aDataRateMismatches attribute.....	553
	Annex H (normative) GDMO specifications for CSMA/CD managed objects .....	554
	Annex 4A (informative) Simplified full duplex media access control.....	555
4A.1	Functional model of the MAC method .....	555
4A.1.1	Overview.....	555
4A.1.2	Full duplex operation .....	556
4A.1.2.1	Transmission.....	556
4A.1.2.2	Reception .....	556
4A.1.3	Relationships to the MAC client and Physical Layers .....	557
4A.2	Media access control (MAC) method: precise specification .....	557
4A.2.1	Introduction.....	557
4A.2.2	Overview of the procedural model .....	557
4A.2.2.1	Ground rules for the procedural model.....	557
4A.2.2.2	Use of Pascal in the procedural model.....	558
4A.2.2.3	Organization of the procedural model .....	558
4A.2.2.4	Layer management extensions to procedural model.....	563
4A.2.3	Packet transmission model.....	563
4A.2.3.1	Transmit data encapsulation .....	563
4A.2.3.2	Transmit media access management.....	563
4A.2.3.2.1	Deference .....	563
4A.2.3.2.2	Interpacket gap.....	564
4A.2.3.2.3	Transmission.....	564
4A.2.3.2.4	Minimum frame size .....	564
4A.2.4	Frame reception model .....	564
4A.2.4.1	Receive data decapsulation .....	564
4A.2.4.1.1	Address recognition .....	564
4A.2.4.1.2	Frame check sequence validation .....	565
4A.2.4.1.3	Frame disassembly.....	565
4A.2.4.2	Receive media access management .....	565
4A.2.5	Preamble generation .....	565
4A.2.6	Start frame sequence .....	565
4A.2.7	Global declarations .....	566
4A.2.7.1	Common constants, types, and variables .....	566
4A.2.7.2	Transmit state variables .....	567

4A.2.7.3	Receive state variables .....	567
4A.2.7.4	State variable initialization .....	567
4A.2.8	Frame transmission .....	568
4A.2.9	Frame reception .....	571
4A.2.10	Common procedures .....	574
4A.3	Interfaces to/from adjacent layers .....	574
4A.3.1	Overview .....	574
4A.3.2	MAC service .....	574
4A.3.2.1	MAC client transmit interface state diagram .....	574
4A.3.2.1.1	Variables .....	574
4A.3.2.1.2	Functions .....	575
4A.3.2.1.3	Messages .....	575
4A.3.2.1.4	MAC client transmit interface state diagram .....	575
4A.3.2.2	MAC client receive interface state diagram .....	575
4A.3.2.2.1	Variables .....	576
4A.3.2.2.2	Functions .....	576
4A.3.2.2.3	Messages .....	576
4A.3.2.2.4	MAC client receive interface state diagram .....	576
4A.3.3	Services required from the Physical Layer .....	578
4A.4	Specific implementations .....	579
4A.4.1	Compatibility overview .....	579
4A.4.2	MAC parameters .....	579

Withhold

# IEEE Standard for Ethernet

**Section One:** This section includes Clause 1 through Clause 20, Annex A through Annex H, and Annex 4A.

**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>.

## 1. Introduction

### 1.1 Overview

This is an international standard for Local and Metropolitan Area Networks (LANs and MANs), employing CSMA/CD as the shared media access method and the IEEE 802.3 (Ethernet) protocol and frame format for data communication. This international standard is intended to encompass several media types and techniques for a variety of MAC data rates as shown in Figure 1–1 and in 4.4.2.

#### 1.1.1 Scope

This standard defines Ethernet local area, access and metropolitan area networks. Ethernet is specified at selected speeds of operation; and uses a common media access control (MAC) specification and management information base (MIB). The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) MAC protocol specifies shared medium (half duplex) operation, as well as full duplex operation. Speed specific Media Independent Interfaces (MIIs) provide an architectural and optional implementation interface to selected Physical Layer entities (PHY). The Physical Layer encodes frames for transmission and decodes received frames with the modulation specified for the speed of operation, transmission medium and supported link length. Other specified capabilities include: control and management protocols, and the provision of power over selected twisted pair PHY types.

### 1.1.2 Basic concepts

This standard provides for two distinct modes of operation: half duplex and full duplex. A given IEEE 802.3 instantiation operates in either half or full duplex mode at any one time. The term “CSMA/CD MAC” is used throughout this standard synonymously with “802.3 MAC,” and may represent an instance of either a half duplex or full duplex mode data terminal equipment (DTE), even though full duplex mode DTEs do not implement the CSMA/CD algorithms traditionally used to arbitrate access to shared-media LANs.

#### 1.1.2.1 Half duplex operation

In half duplex mode, the CSMA/CD media access method is the means by which two or more stations share a common transmission medium. To transmit, a station waits (defers) for a quiet period on the medium (that is, no other station is transmitting) and then sends the intended message in bit-serial form. If, after initiating a transmission, the message collides with that of another station, then each transmitting station intentionally transmits for an additional predefined period to ensure propagation of the collision throughout the system. The station remains silent for a random amount of time (backoff) before attempting to transmit again. Each aspect of this access method process is specified in detail in subsequent clauses of this standard.

Half duplex operation can be used with certain media types and configurations as defined by this standard. For allowable configurations, see 4.4.2.

#### 1.1.2.2 Full duplex operation

Full duplex operation allows simultaneous communication between a pair of stations using point-to-point media (dedicated channel). Full duplex operation does not require that transmitters defer, nor do they monitor or react to receive activity, as there is no contention for a shared medium in this mode. Full duplex mode can only be used when all of the following are true:

- a) The physical medium is capable of supporting simultaneous transmission and reception without interference.
- b) There are exactly two stations connected with a full duplex point-to-point link. Since there is no contention for use of a shared medium, the multiple access (i.e., CSMA/CD) algorithms are unnecessary.
- c) Both stations on the LAN are capable of, and have been configured to use, full duplex operation.

The most common configuration envisioned for full duplex operation consists of a central bridge (also known as a switch) with a dedicated LAN connecting each bridge port to a single device. Repeaters as defined in this standard are outside the scope of full duplex operation.

Full duplex operation constitutes a proper subset of the MAC functionality required for half duplex operation.

### 1.1.3 Architectural perspectives

There are two important ways to view network design corresponding to the following:

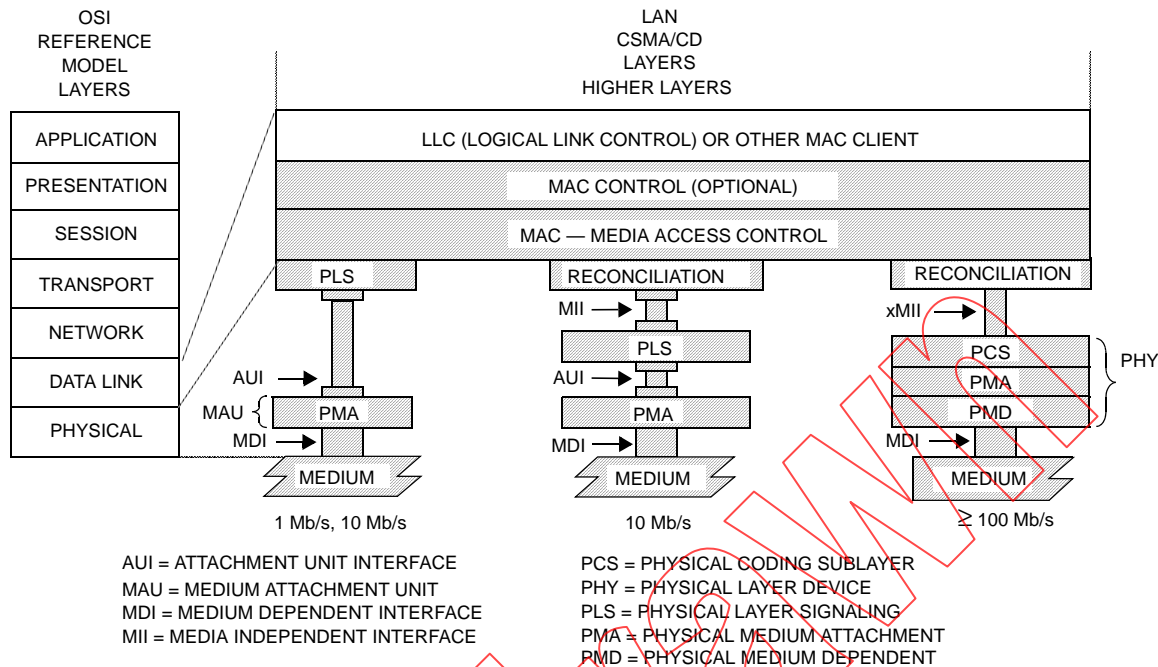
- a) *Architecture*. Emphasizing the logical divisions of the system and how they fit together.
- b) *Implementation*. Emphasizing actual components, their packaging, and interconnection.

This standard is organized along architectural lines, emphasizing the large-scale separation of the system into two parts: the Media Access Control (MAC) sublayer of the Data Link Layer and the Physical Layer. These layers are intended to correspond closely to the lowest layers of the ISO/IEC Model for Open Systems Interconnection (see Figure 1–1). (See ISO/IEC 7498-1:1994.<sup>1</sup>) The Logical Link Control (LLC) sublayer

---

<sup>1</sup>For information about references, see 1.3.

and MAC sublayer together encompass the functions intended for the Data Link Layer as defined in the OSI model.



NOTE—In this figure, the xMII is used as a generic term for the Media Independent Interfaces for implementations of 100 Mb/s and above. For example: for 100 Mb/s implementations this interface is called MII; for 1 Gb/s implementations it is called GMII; for 10 Gb/s implementations it is called XGMII; etc.

**Figure 1-1—IEEE 802.3 standard relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model**

### 1.1.3.1 Architectural rationale

An architectural organization of the standard has two main advantages:

- a) *Clarity.* A clean overall division of the design along architectural lines makes the standard clearer.
- b) *Flexibility.* Segregation of medium-dependent aspects in the Physical Layer allows the LLC and MAC sublayers to apply to a family of transmission media.

Partitioning the Data Link Layer allows various media access methods within the family of LAN standards.

The architectural model is based on a set of interfaces that may be different from those emphasized in implementations. One critical aspect of the design, however, shall be addressed largely in terms of the implementation interfaces: compatibility.

### 1.1.3.2 Compatibility interfaces

The following important compatibility interfaces are defined within what is architecturally the Physical Layer.

- a) *Medium Dependent Interfaces (MDI).* To communicate in a compatible manner, all stations shall adhere rigidly to the exact specification of physical media signals defined in the appropriate clauses in this standard, and to the procedures that define correct behavior of a station. The medium-independent aspects of the LLC sublayer and the MAC sublayer should not be taken as detracting from

this point; communication in an Ethernet Local Area Network requires complete compatibility at the Physical Medium interface (that is, the physical cable interface).

- b) *Attachment Unit Interface (AUI)*. Some DTEs are located some distance from their connection to the physical cable. A small amount of circuitry will exist in the Medium Attachment Unit (MAU) directly adjacent to the physical cable, while the majority of the hardware and all of the software will be placed within the DTE. The AUI is defined as a second compatibility interface. While conformance with this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing MAUs and DTEs. The AUI may be optional or not specified for some implementations of this standard that are expected to be connected directly to the medium and so do not use a separate MAU or its interconnecting AUI cable. The PLS and PMA are then part of a single unit, and no explicit AUI implementation is required.
- c) *Media Independent Interface (MII)*. It is anticipated that some DTEs will be connected to a remote PHY, and/or to different medium dependent PHYs. The MII is defined as a third compatibility interface. While conformance with implementation of this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs. The MII is optional.
- d) *Gigabit Media Independent Interface (GMII)*. The GMII is designed to connect a 1 Gb/s capable MAC or repeater unit to a 1 Gb/s PHY. While conformance with implementation of this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 1 Gb/s speeds. The GMII is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the GMII. The GMII is optional.
- e) *Ten-bit Interface (TBI)*. The TBI is provided by the 1000BASE-X PMA sublayer as a physical instantiation of the PMA service interface. The TBI is recommended for 1000BASE-X systems, since it provides a convenient partition between the high-frequency circuitry associated with the PMA sublayer and the logic functions associated with the PCS and MAC sublayers. The TBI is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the TBI. The TBI is optional.
- f) *10 Gigabit Media Independent Interface (XGMII)*. The XGMII is designed to connect a 10 Gb/s capable MAC to a 10 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows maximum flexibility in intermixing PHYs and DTEs at 10 Gb/s speeds. The XGMII is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the XGMII. The XGMII is optional.
- g) *10 Gigabit Attachment Unit Interface (XAUI)*. The XAUI is designed to extend the connection between a 10 Gb/s capable MAC and a 10 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 10 Gb/s speeds. The XAUI is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the XAUI. The XAUI is optional.
- h) *10 Gigabit Sixteen-Bit Interface (XSBI)*. The XSBI is provided as a physical instantiation of the PMA service interface for 10GBASE-R and 10GBASE-W PHYs. While conformance with implementation of this interface is not necessary to ensure communication, it provides a convenient partition between the high-frequency circuitry associated with the PMA sublayer and the logic functions associated with the PCS and MAC sublayers. No mechanical connector is specified for use with the XSBI. The XSBI is optional.
- i) *40 Gigabit Media Independent Interface (XLGMII)*. The XLGMII is designed to connect a 40 Gb/s capable MAC to a 40 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 40 Gb/s speeds. The XLGMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the XLGMII. The XLGMII is optional.
- j) *40 Gigabit Attachment Unit Interface (XLAUI)*. The XLAUI is a physical instantiation of the PMA service interface to extend the connection between 40 Gb/s capable PMAs. While conformance with

implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 40 Gb/s speeds. The XLAUI is intended for use as a chip-to-chip or a chip-to-module interface. No mechanical connector is specified for use with the XLAUI. The XLAUI is optional.

- k) *40 Gigabit Parallel Physical Interface (XLPPi)*. The XLPPi is provided as a physical instantiation of the PMD service interface for 40GBASE-SR4 and 40GBASE-LR4 PMDs. The XLPPi has four lanes. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in connecting the 40GBASE-SR4 or 40GBASE-LR4 PMDs. The XLPPi is intended for use as a chip-to-module interface. No mechanical connector is specified for use with the XLPPi. The XLPPi is optional.
- l) *100 Gigabit Media Independent Interface (CGMII)*. The CGMII is designed to connect a 100 Gb/s capable MAC to a 100 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 100 Gb/s speeds. The CGMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the CGMII. The CGMII is optional.
- m) *100 Gigabit Attachment Unit Interface (CAUI)*. The CAUI is a physical instantiation of the PMA service interface to extend the connection between 100 Gb/s capable PMAs. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 100 Gb/s speeds. The CAUI is intended for use as a chip-to-chip or a chip-to-module interface. No mechanical connector is specified for use with the CAUI. The CAUI is optional.
- n) *100 Gigabit Parallel Physical Interface (CPPI)*. The CPPI is provided as a physical instantiation of the PMD service interface for 100GBASE-SR10 PMDs. The CPPI has ten lanes. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in connecting the 100GBASE-SR10 PMDs. The CPPI is intended for use as a chip-to-module interface. No mechanical connector is specified for use with the CPPI. The CPPI is optional.

### 1.1.4 Layer interfaces

In the architectural model used here, the layers interact by way of well-defined interfaces, providing services as specified in Clause 2 and Clause 6. In general, the interface requirements are as follows:

- a) The interface between the MAC sublayer and its client includes facilities for transmitting and receiving frames, and provides per-operation status information for use by higher-layer error recovery procedures.
- b) The interface between the MAC sublayer and the Physical Layer includes signals for framing (carrier sense, receive data valid, transmit initiation) and contention resolution (collision detect), facilities for passing a pair of serial bit streams (transmit, receive) between the two layers, and a wait function for timing.

These interfaces are described more precisely in 4.3. Additional interfaces are necessary to provide for MAC Control services, and to allow higher level network management facilities to interact with these layers to perform operation, maintenance, and planning functions. Network management functions are described in Clause 30.

### 1.1.5 Application areas

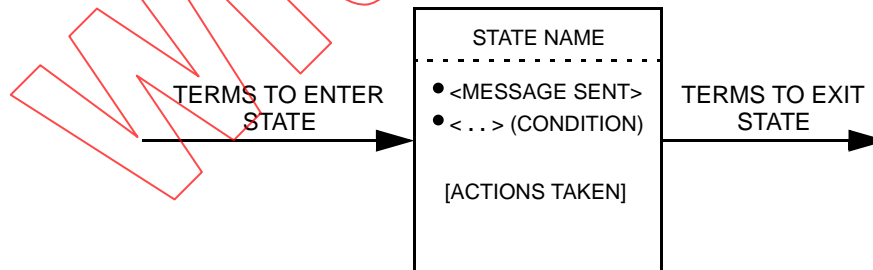
Use of this standard is not restricted to any specific environments or applications.

In the context of this standard, the term “LAN” is used to indicate all networks that utilize the IEEE 802.3 (Ethernet) protocol for communication. These may include (but are not limited to) LANs and MANs.

## 1.2 Notation

### 1.2.1 State diagram conventions

The operation of a protocol can be described by subdividing the protocol into a number of interrelated functions. The operation of the functions can be described by state diagrams. Each diagram represents the domain of a function and consists of a group of connected, mutually exclusive states. Only one state of a function is active at any given time (see Figure 1–2).



Key: ( ) = condition, for example, (if no\_collision)  
 [ ] = action, for example, [reset PLS functions]  
 \* = logical AND  
 + = logical OR, arithmetic addition  
 Tw = Wait Time, implementation dependent  
 Td = Delay Timeout  
 Tb = Backoff Timeout  
 UCT = unconditional transition

Figure 1–2—State diagram notation example



Each state that the function can assume is represented by a rectangle. These are divided into two parts by a horizontal line. In the upper part the state is identified by a name in capital letters. The lower part contains the name of any ON signal that is generated by the function. Actions are described by short phrases and enclosed in brackets.

All permissible transitions between the states of a function are represented graphically by arrows between them. A transition that is global in nature (for example, an exit condition from all states to the IDLE or RESET state) is indicated by an open arrow. Labels on transitions are qualifiers that must be fulfilled before the transition will be taken. The label UCT designates an unconditional transition. Qualifiers described by short phrases are enclosed in parentheses.

State transitions and sending and receiving of messages occur instantaneously. When a state is entered and the condition to leave that state is not immediately fulfilled, the state executes continuously, sending the messages and executing the actions contained in the state in a continuous manner.

Some devices described in this standard (e.g., repeaters) are allowed to have two or more ports. State diagrams that are capable of describing the operation of devices with an unspecified number of ports require a qualifier notation that allows testing for conditions at multiple ports. The notation used is a term that includes a description in parentheses of which ports must meet the term for the qualifier to be satisfied (e.g., ANY and ALL). It is also necessary to provide for term-assignment statements that assign a name to a port that satisfies a qualifier. The following conventions are used to describe a term-assignment statement that is associated with a transition:

- a) The character “:” (colon) is a delimiter used to denote that a term assignment statement follows.
- b) The character “←” (left arrow) denotes assignment of the value following the arrow to the term preceding the arrow.

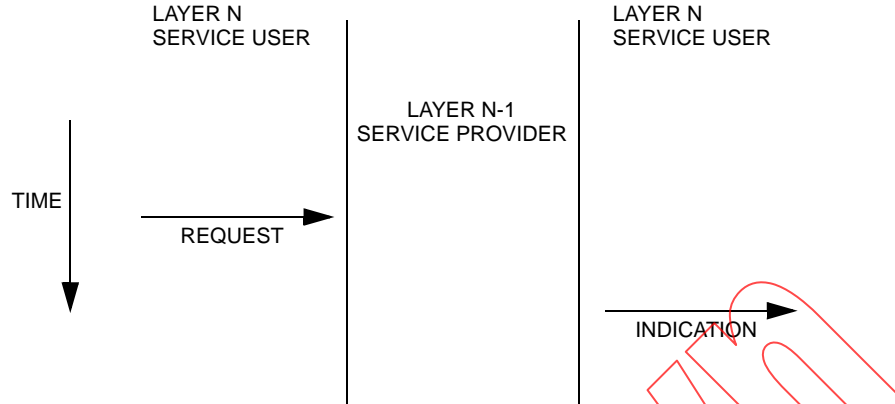
The state diagrams contain the authoritative statement of the functions they depict; when apparent conflicts between descriptive text and state diagrams arise, the state diagrams are to take precedence. This does not override, however, any explicit description in the text that has no parallel in the state diagrams.

The models presented by state diagrams are intended as the primary specifications of the functions to be provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology. It is the functional behavior of any unit that must match the standard, not its internal structure. The internal details of the model are useful only to the extent that they specify the external behavior clearly and precisely.

### 1.2.2 Service specification method and notation

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher (sub)layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition of service is independent of any particular implementation (see Figure 1–3).

Specific implementations may also include provisions for interface interactions that have no direct end-to-end effects. Examples of such local interactions include interface flow control, status requests and indications, error notifications, and layer management. Specific implementation details are omitted from this service specification both because they will differ from implementation to implementation and because they do not impact the peer-to-peer protocols.



**Figure 1–3—Service primitive notation**

### 1.2.2.1 Classification of service primitives

Primitives are of two generic types:

- a) **REQUEST.** The request primitive is passed from layer N to layer N-1 to request that a service be initiated.
- b) **INDICATION.** The indication primitive is passed from layer N-1 to layer N to indicate an internal layer N-1 event that is significant to layer N. This event may be logically related to a remote service request, or may be caused by an event internal to layer N-1.

The service primitives are an abstraction of the functional specification and the user-layer interaction. The abstract definition does not contain local detail of the user/provider interaction. For instance, it does not indicate the local mechanism that allows a user to indicate that it is awaiting an incoming call. Each primitive has a set of zero or more parameters, representing data elements that shall be passed to qualify the functions invoked by the primitive. Parameters indicate information available in a user/provider interaction; in any particular interface, some parameters may be explicitly stated (even though not explicitly defined in the primitive) or implicitly associated with the service access point. Similarly, in any particular protocol specification, functions corresponding to a service primitive may be explicitly defined or implicitly available.

### 1.2.3 Physical Layer and media notation

Users of this standard need to reference which particular implementation is being used or identified. Therefore, a means of identifying each implementation is given by a simple, three-field, type notation that is explicitly stated at the beginning of each relevant clause. In general, the Physical Layer type is specified by these fields:

<data rate> <modulation type> <additional distinction>

The data rate, if only a number, is in Mb/s, and if suffixed by a “G”, is in Gb/s. The modulation type (e.g., BASE) indicates how encoded data is transmitted on the medium. The additional distinction may identify characteristics of transmission or medium and, in some cases, the type of PCS encoding used (examples of additional distinctions are “T” for twisted pair, “B” for bidirectional optics, and “X” for a block PCS coding used for that speed of operation). Expansions for defined Physical Layer types are included in 1.4.

### 1.2.4 Physical Layer message notation

Messages generated within the Physical Layer, either within or between PLS and the MAU (that is, PMA circuitry), are designated by an italic type to designate either form of physical or logical message used to execute the Physical Layer signaling process (for example, *input\_idle* or *mau\_available*).

### 1.2.5 Hexadecimal notation

Numerical values designated by the 0x prefix indicate a hexadecimal interpretation of the corresponding number. For example: 0x0F represents an 8-bit hexadecimal value of the decimal number 15; 0x00000000 represents a 32-bit hexadecimal value of the decimal number 0; etc.

Numerical values designated with a 16 subscript indicate a hexadecimal interpretation of the corresponding number. For example: 0F<sub>16</sub> represents an 8-bit hexadecimal value of the decimal number 15.

### 1.2.6 Accuracy and resolution of numerical quantities

Unless otherwise stated, numerical limits in this standard are to be taken as exact, with the number of significant digits and trailing zeros having no significance.

## 1.3 Normative references

The following standards contain provisions that, through reference in this text, constitute provisions of this standard. Standards may be subject to revision, and parties subject to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid international standards. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI T1.269-2000, Information Interchange—Structure and Representation of Trace Message Formats For The North American Telecommunications System.<sup>2</sup>

ANSI T1.417-2001, Spectrum Management for Loop Transmission Systems.

ANSI T1.424-2004, Interface between networks and customer installations—Very-high Speed Digital Subscriber Lines (VDSL) Metallic Interface (Trial-Use Standard).

ANSI T1.601-1992, Telecommunications—Integrated Services Digital Network (ISDN)—Basic Access Interface for Use on Metallic Loops for Application on the Network Side of the NT (Layer 1 Specification).

ANSI T1.605-1991, Telecommunications—Integrated Services Digital Network (ISDN)—Basic Access Interface for S and T Reference Point (Layer 1 Specification).

ANSI X3.230-1994 (FC-PH), Information Technology—Fibre Channel—Physical and Signaling Interface.

ANSI X3.263-1995, Revision 2.2 (1 March 1995), FDDI Twisted Pair—Physical Medium Dependent (TP-PMD).

ANSI/TIA-568-C.0-2010, Generic Telecommunications Cabling.

ANSI/TIA-568-C.2-2010, Copper Cabling Components.

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

ANSI/TIA-568-C.3-2008, Optical Fiber Cabling Components Standard.

ANSI/TIA/EIA-455-175A-92, Chromatic Dispersion Measurement of Single-Mode Optical Fibers by the Differential Phase-Shift Method.

ANSI/TIA/EIA-455-203-2001, Launched Power Distribution Measurement Procedure for Graded-Index Multimode Transmitters.

ANSI/TIA/EIA-455-204-2000, Measurement of Bandwidth on Multimode Fiber.

ANSI/TIA/EIA-568-A-1995, Commercial Building Telecommunications Cabling Standard.

ATIS-0600416.1999(R2010), Network to Customer Installation Interfaces—Synchronous Optical NETWORK (SONET)—Physical Layer Specification: Common Criteria.<sup>3</sup>

ATIS-0900105.2008, Synchronous Optical Network (SONET)—Basic Description including Multiplex Structure, Rates, and Formats.

CISPR 22: 1993, Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment.<sup>4</sup>

EIA/JEDEC Standard EIA/JESD8-6, High Speed Transceiver Logic (HSTL), August 1995.<sup>5</sup>

ETSI TS 101 270-1 (1999), Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (VDSL); Part 1: Functional requirements.<sup>6</sup>

IEC 60060 (all parts), High-voltage test techniques.<sup>7</sup>

IEC 60068, Basic environmental testing procedures.

IEC 60096-1:1986, Radio-frequency cables, Part 1: General requirements and measuring methods and Amd. 2:1993.

IEC 60169-16:1982, Radio-frequency connectors, Part 16: R.F. coaxial connectors with inner diameter of outer conductor 7 mm (0.276 in) with screw coupling—Characteristic impedance 50 ohms (75 ohms) (Type N).

IEC 60603-7:1990, Connectors for frequencies below 3 MHz for use with printed boards, Part 7: Detail specification for connectors, 8-way, including fixed and free connectors with common mating features, with assessed quality.

IEC 60793-1:1992, Optical fibres—Part 1: Generic specification.

IEC 60793-1:1995, Optical fibres—Part 1: Generic specification.

IEC 60793-1-41:2001, Optical fibres—Part 1-41: Measurement methods and test procedures—Bandwidth.

<sup>3</sup>ATIS publications are available from the Alliance for Telecommunications Industry Solutions (<http://atis.org>).

<sup>4</sup>CISPR documents are available from the International Electrotechnical Commission (<http://www.iec.ch/>). CISPR documents are also available in the United States from the American National Standards Institute (<http://www.ansi.org>).

<sup>5</sup>EIA publications are available from the IHS Standards Store (<http://global.ihs.com/>). JEDEC publications are available from the JEDEC Solid State Technology Association (<http://www.jedec.org>).

<sup>6</sup>ETSI publications are available from the European Telecommunications Standards Institute (<http://www.etsi.org>).

<sup>7</sup>IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch/>). IEC publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org>).

IEC 60793-1-42:2007, Optical fibres—Part 1-42: Measurement methods and test procedures—Chromatic dispersion.

IEC 60793-1-48:2007, Optical fibres—Part 1-48: Measurement methods and test procedures—Polarization mode dispersion.

IEC 60793-2:1992, Optical fibres—Part 2: Product specifications.

IEC 60793-2-10:2011, Optical fibres—Part 2-10: Product specifications—Sectional specification for category A1 multimode fibres.

IEC 60793-2-50:2008, Optical fibres—Part 2-50: Product specifications—Sectional specification for class B single-mode fibres.

IEC 60794-1:1993, Optical fibre cables—Part 1: Generic specification.

IEC 60794-1:1996, Optical fibre cables—Part 1: Generic specification.

IEC 60794-2:1989, Optical fibre cables—Part 2: Product specifications.

IEC 60794-2-11:2005, Optical fibre cables—Part 2-11: Indoor cables—Detailed specification for simplex and duplex cables for use in premises cabling.

IEC 60794-3-12:2005, Optical fibre cables—Part 3-12: Outdoor fibre cables—Detailed specification for duct and directly buried optical telecommunication cables for use in premises cabling.

IEC 60807-2:1992, Rectangular connectors for frequencies below 3 MHz, Part 2: Detail specification for a range of connectors with assessed quality, with trapezoidal shaped metal shells and round contacts—Fixed solder contact types.

IEC 60807-3:1990, Rectangular connectors for frequencies below 3 MHz, Part 3: Detail specification for a range of connectors with trapezoidal shaped metal shells and round contacts—Removable crimp contact types with closed crimp barrels, rear insertion/rear extraction.

IEC 60825-1, Safety of laser products—Part 1: Equipment classification and requirements.

IEC 60825-2, Safety of laser products—Part 2: Safety of optical fibre communication systems (OFCS).

IEC 60874-1:1993, Connectors for optical fibres and cables—Part 1: Generic specification.

IEC 60874-2:1993, Connectors for optical fibres and cables—Part 2: Sectional specification for fibre optic connector, Type F-SMA.

IEC 60874-10:1992, Connectors for optical fibres and cables—Part 10: Sectional specification, Fibre optic connector type BFOC/2,5.

IEC 60950:1991, Safety of information technology equipment.

IEC 60950-1, Information technology equipment—Safety—Part 1: General requirements.

IEC 61076-3-101:1997, Connectors with assessed quality, for use in d.c., low-frequency analogue and in digital high-speed data applications—Part 3: Rectangular connectors—Section 101: Detail specification for a range of shielded connectors with trapezoidal shaped shells and non-removable rectangular contacts on a 1.27 mm × 2.54 mm centre-line.

IEC 61076-3-113, Ed. 1.0 (draft, 48B/1437/CD, 2 April 2004.) [48B Secretariat 1327] Connectors for electronic equipment—Part 3-113: Screened, serial multi-conductor cable to board connectors suitable for 10 Gbit/sec data rates.<sup>8</sup>

IEC 61076-3-103 (48B/574/NP), Detail specification for rectangular connectors, with assessed quality, 6 and 8 way, fixed and free shielded connectors with ribbon contacts for high speed data applications.

IEC 61196-1:1995, Radio-frequency cables—Part 1: Generic specification—General, definitions, requirements and test methods.

IEC 61280-1-1:1998, Fibre optic communication subsystem basic test procedures—Part 1-1: Test procedures for general communication subsystems—Transmitter output optical power measurement for single-mode optical fibre cable.

IEC 61280-1-3:2010, Fibre optic communication subsystem test procedures—Part 1-3: General communication subsystems—Central wavelength and spectral width measurement.

IEC 61280-1-4:2003, Fibre optic communication subsystem test procedures—Part 1-4: General communication subsystems—Collection and reduction of two-dimensional nearfield data for multimode fibre laser transmitters.

IEC 61280-1-4:2009, Fibre optic communication subsystem test procedures—Part 1-4: General communication subsystems—Light source encircled flux measurement method.

IEC 61280-2-2:2008, Fiber optic communication sub-system basic test procedures—Part 2-2: Test procedures for digital systems—Optical eye pattern, waveform, and extinction ratio.

IEC 61280-4-1:2003, Fiber-optic communication subsystem test procedures—Part 4-1: Cable plant and links—Multimode fibre-optic cable plant attenuation measurement.

IEC 61280-4-1:2009, Fibre-optic communication subsystem test procedures—Part 4-1: Installed cable plant—Multimode attenuation measurement.

IEC 61280-4-2:2000, Fibre optic communication subsystem basic test procedures—Fibre optic cable plant—Single-mode fibre optic cable plant attenuation.

IEC 61753-1-1:2000, Fibre optic interconnecting devices and passive components performance standard—Part 1-1: General and guidance—Interconnecting devices (connectors).

IEC 61753-021-2:2002, Fibre optic passive component performance standard—Part 021-2: Fibre optic connectors terminated on single-mode fibre to category C Controlled environment.

IEC 61753-022-2, Performance standard—Part 022-2: Fibre optic connectors terminated on multimode fibre for Category C—Controlled environment, performance Class M.

IEC 61754-1:1996, Fibre optic interfaces —Part 1: General and guidance.

IEC 61754-4:1997, Fibre optic connector interfaces—Part 4: Type SC connector family.

IEC 61754-7, Fibre optic connector interfaces—Part 7: Type MPO connector family.

<sup>8</sup>At the time IEEE Std 802.3-2012 was published, IEC 61076-3-113 is a committee draft. This document is available at (<http://www.bsigroup.com/>).

IEEE Std 1394™-1995 IEEE Standard for a High Performance Serial Bus.<sup>9,10</sup>

IEEE Std 802®, IEEE Standards for Local and Metropolitan Area Networks—Overview and Architecture.

IEEE Std 802.1AB™-2009, IEEE Standard for Local and metropolitan area networks—Station and Media Access Control Connectivity Discovery.

IEEE Std 802.1D™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Bridges.

IEEE Std 802.1F™-1993 (Reaff 1998), IEEE Standard for Local and metropolitan area networks—Common Definitions and Procedures for IEEE 802 Management Information.

IEEE Std 802.1Q™, IEEE Standard for Local and metropolitan area networks—Virtual Bridged Local Area Networks.

IEEE Std 802.3.1™-2011, IEEE Standard for Management Information Base (MIB) Module Definitions for Ethernet.

IEEE Std 802.5v™-2001, IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements. Part 5: Token Ring Access Method and Physical Layer Specifications. Amendment 5: Gigabit Token Ring Operation.

IEEE Std 802.9a™-1995, IEEE Standards for Local and Metropolitan Area Networks: Supplement to Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers: Specification of IsLAN16-T.

IETF RFC 3621 (December 2003), *Power Ethernet MIB*, Berger, A., and Romascanu, D.<sup>11</sup>

IETF RFC 4836 (April 2007), *Definitions of Managed Objects for IEEE 802.3 Medium Attachment Units (MAUs)*, Beili, E.

ISO/IEC 8802-2:1998, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 2: Logical link control.<sup>12</sup>

ISO/IEC 7498-1:1994, Information technology—Open Systems Interconnection—Basic Reference Model: The Basic Model.

ISO/IEC 7498-4:1989, Information processing systems—Open Systems Interconnection—Basic Reference Model—Part 4: Management Framework.

ISO/IEC 8824:1990, Information technology—Open Systems Interconnection—Specification of Abstract Syntax Notation One (ASN.1).

ISO/IEC 9314-1:1989, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 1: Token Ring Physical Layer Protocol (PHY).

<sup>9</sup>IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

<sup>10</sup>The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.

<sup>11</sup>IETF RFCs are available from the Internet Engineering Task Force (<http://www.ietf.org/rfc.html>).

<sup>12</sup>ISO/IEC publications are available from the International Organization for Standardization (<http://www.iso.ch/>) and the International Electrotechnical Commission (<http://www.iec.ch/>). ISO/IEC publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

ISO/IEC 9314-2:1989, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 2: Token Ring Media Access Control (MAC).

ISO/IEC 9314-3:1990, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 3: Physical Layer Medium Dependent (PMD).

ISO/IEC 9646-1:1994, Information technology—Open Systems Interconnection—Conformance testing methodology and framework—Part 1: General concepts.

ISO/IEC 9646-2:1994, Information technology—Open Systems Interconnection—Conformance testing methodology and framework—Part 2: Abstract test suite specification.

ISO/IEC 10040:1992, Information technology—Open Systems Interconnection—Systems management overview.

ISO/IEC 10165-2:1992, Information technology—Open Systems Interconnection—Structure of management information: Definition of management information.

ISO/IEC 10165-4:1992, Information technology—Open Systems Interconnection—Management information services—Structure of management information—Part 4: Guidelines for the definition of managed objects.

ISO/IEC 11801:1995, Information technology—Generic cabling for customer premises.<sup>13</sup>

ISO/IEC 11801:2002, Information technology—Generic cabling for customer premises.

ISO/IEC 11801:2002 Amendment 1:2008, Information technology—Generic cabling for customer premises.

ISO/IEC 11801:2002 Amendment 2:2010, Information technology—Generic cabling for customer premises.

ISO/IEC 15802-1:1995, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 1: Medium Access Control (MAC) service definition.

ISO/IEC TR 24750:2007, Information technology—Assessment and mitigation of installed balanced cabling channels in order to support of 10GBASE-T.

ITU-T Recommendation G.650.1, 2010—Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable.<sup>14</sup>

ITU-T Recommendation G.652, 2009—Characteristics of a single-mode optical fibre and cable.

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

ITU-T Recommendation G.671, 2009—Transmission characteristics of optical components and subsystems.

ITU-T Recommendation G.691, 2006—Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers.

ITU-T Recommendation G.694.1—Spectral grids for WDM applications: DWDM frequency grid.

<sup>13</sup>Previous editions of ISO/IEC standards are available from Deutsches Institut für Normung (<http://www.din.de>).

<sup>14</sup>ITU-T publications are available from the International Telecommunications Union (<http://www.itu.int/>).



- ITU-T Recommendation G.694.2—Spectral grids for WDM applications: CWDM wavelength grid.
- ITU-T Recommendation G.695, 2010—Optical interfaces for coarse wavelength division multiplexing applications.
- ITU-T Recommendation G.957, 2006—Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.
- ITU-T Recommendation G.959.1, 2009—Optical transport network physical layer interfaces.
- ITU-T Recommendation G.975—Forward error correction for submarine systems.
- ITU-T Recommendation G.991.2, 2001—Amendment 1.
- ITU-T Recommendation G.991.2, 2001—Single-pair high-speed digital subscriber line (SHDSL) transceivers.
- ITU-T Recommendation G.993.1, 2003—Amendment 1.
- ITU-T Recommendation G.993.1, 2001—Very high speed digital subscriber line foundation.
- ITU-T Recommendation G.994.1, 2004—Handshake procedures for digital subscriber line (DSL) transceivers.
- ITU-T Recommendation I.430, 1995—Basic user-network interface—Layer 1 specification.
- ITU-T Recommendation O.150, 1996—General requirements for instrumentation for performance measurements on digital transmission equipment.
- ITU-T Recommendation O.153, 1992—Basic parameters for the measurement of error performance at bit rates below the primary rate.
- ITU-T Recommendation O.172, 2005—Jitter and wander measuring equipment for digital systems which are based on the synchronous digital hierarchy (SDH).
- MATLAB Matrix Laboratory Software.<sup>15</sup>
- SFF-8436, Rev 4.1, August 24, 2011, Specification for QSFP+ 10 Gbs 4X Pluggable Transceiver.<sup>16</sup>
- SFF-8642, Rev 2.7, February 26, 2010, Specification for Mini Multilane 12 Gbs 12X Shielded Connector.
- TIA-455-127-A-2006, FOTP-127-A, Basic Spectral Characterization of Laser Diodes.<sup>17</sup>
- TIA TSB-155-A-2010, Guidelines for the Assessment and Mitigation of Installed Category 6 Cabling to Support 10GBASE-T.

NOTE—Local and national standards such as those supported by ANSI, EIA, MIL, NFPA, and UL are not a formal part of this standard except where no international standard equivalent exists. A number of local and national standards are referenced as resource material; these bibliographical references are located in the bibliography in Annex A.<sup>18</sup>

<sup>15</sup>For information on MatLab, contact The MathWorks (<http://www.mathworks.com>).

<sup>16</sup>SFF specifications are available at <ftp://ftp.seagate.com/sff>.

<sup>17</sup>TIA publications are available from the IHS Standards Store (<http://global.ihs.com/>) or from the Telecommunications Industry Association (<http://www.tiaonline.org>).

<sup>18</sup>Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement this standard.