INTERNATIONAL STANDARD

ISO/IEC 8802-3

IEEE Std 802.3

Sixth edition
2000-12-15

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

Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications

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

Partie 3: Accès multiples par surveillance du signal et détection de collision (CSMA/CD) et spécifications pour la couche physique

Reference number
ISO/IEC 8802-3:2000(E)
IEEE
Std 802.3, 2000 edition

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International Standard ISO/IEC 8802-3: 2000(E)
IEEE Std 802.3, 2000 Edition

(Incorporating IEEE Std 802.3, 1998 Edition,
IEEE Std 802.3ac-1998, IEEE Std 802.3ab-1999,
and 802.3ad-2000)

Information technology—

Telecommunications and information exchange between systems—

Local and metropolitan area networks—

Specific requirements—

Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications

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IEEE Computer Society

Adopted as an International Standard by the
International Organization for Standardization
and by the
International Electrotechnical Commission

IEEE

American National Standard

Abstract: The media access control characteristics for the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method for shared medium local area networks are described. The control characteristics for full duplex dedicated channel use are also described. Specifications are provided for MAU types 1BASE5 at 1 Mb/s; Attachment Unit Interface (AUI) and MAU types 10BASE5, 10BASE2, FOIRL (fiber optic inter-repeater link), 10BROAD36, 10BASE-T, 10BASE-FL, 10BASE-FB, and 10BASE-FP at 10 Mb/s; Media Independent Interface (MII) and PHY types 100BASE-T4, 100BASE-TX, 100BASE-FX, and 100BASE-T2 at 100 Mb/s; and the Gigabit MII (GMII) and 1000BASE-X PHY types, 1000BASE-SX, 1000BASE-LX, and 1000BASE-CX, which operate at 1000 Mb/s (Gigabit Ethernet) as well as PHY type 1000BASE-T. Repeater specifications are provided at each speed. Full duplex specifications are provided at the Physical Layer for 10BASE-T, 10BASE-FL, 100BASE-TX, 100BASE-FX, 100BASE-T2, and Gigabit Ethernet. System considerations for multisegment networks at each speed and management information base (MIB) specifications and additions to support Virtual Bridged Local Area Networks (VLANs) as specified in IEEE P802.1Q are also provided. Also specified is an optional Link Aggregation sublayer which multiple physical links to be aggregated together to form a single logical link.

Keywords: Aggregated Link; Aggregator; Auto Negotiation; Category 5; copper; data processing; Ethernet; gigabit; information interchange, Link Aggregation; local area networks, management; MASTER-SLAVE; medium dependent interface; mode of data transmission; models; network interconnection; physical coding sublayer; Physical Layer; physical medium attachment; repeater; type field; VLAN TAG

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Print: ISBN 0-7381-2673-X SH94892
PDF: ISBN 0-7381-2674-8 SS94892

International Standard ISO/IEC 8802-3:2000 (E)

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International Standard ISO/IEC 8802-3 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*.

This sixth edition cancels and replaces the fifth edition (ISO/IEC 8802-3:1996), which has been technically revised.

ISO/IEC 8802 consists of the following parts, under the general title *Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements*:

— *Part 1: Overview of Local Area Network Standards*

— *Part 2: Logical link control*

— *Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

— *Part 4: Token-passing bus access method and physical layer specifications*

— *Part 5: Token ring access method and physical layer specifications*

— *Part 6: Distributed Queue Dual Bus (DQDB) access method and physical layer specifications*

— *Part 9: Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers*

— *Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications*

— *Part 12: Demand-Priority access method, physical layer and repeater specifications*

Annexes F to H, 23A, 27A to 28D, 30A to 31B and 43B form a normative part of this part of ISO/IEC 8802. Annexes A to E, 22A to 22C, 23B, 23C, 29A, 29B, 32A, 36A, 36B, 38A, 40A to 40C, 43A and 43C are for information only.

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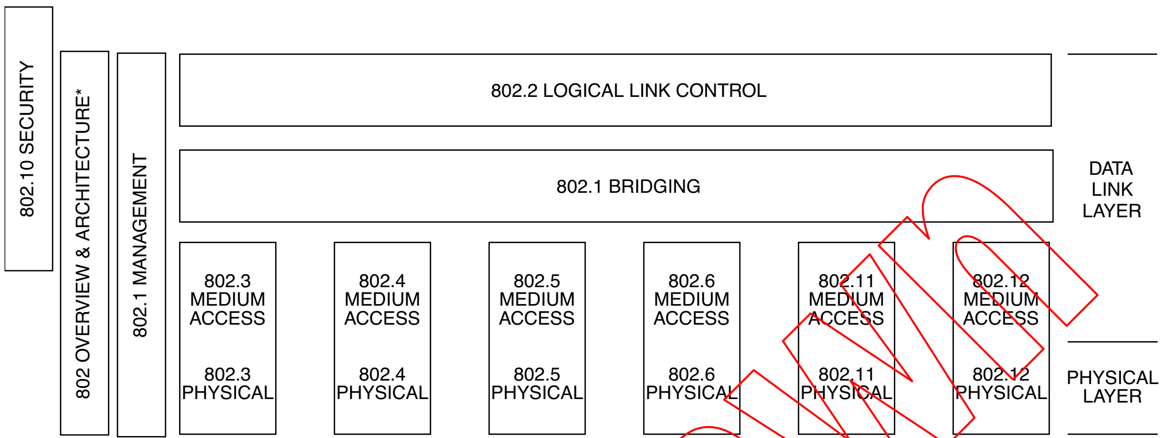
Introduction to IEEE Std 802.3, 2000 Edition

This standard is part of a family of standards for local and metropolitan area networks. The relationship between the standard and other members of the family is shown below. (The numbers in the figure refer to IEEE standard numbers.)



* Formerly IEEE Std 802.1A.

This family of standards deals with the Physical and Data Link layers as defined by the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) Basic Reference Model (ISO/IEC 7498-1: 1994). The access standards define seven types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The standards defining the technologies noted above are as follows:

- IEEE Std 802 — *Overview and Architecture*. This standard provides an overview to the family of IEEE 802 Standards.
- ANSI/IEEE Std 802.1B and 802.1k [ISO/IEC 15802-2] — *LAN/MAN Management*. Defines an OSI management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.
- ANSI/IEEE Std 802.1D — *Media Access Control (MAC) Bridges*. Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.
- ANSI/IEEE Std 802.1E [ISO/IEC 15802-4] — *System Load Protocol*. Specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.
- ANSI/IEEE Std 802.1F — *Common Definitions and Procedures for IEEE 802 Management Information*.
- ANSI/IEEE Std 802.1G [ISO/IEC 15802-5] — *Remote Media Access Control (MAC) Bridging*. Specifies extensions for the interconnection, using non-LAN communication technologies, of geographically separated IEEE 802 LANs below the level of the logical link control protocol.
- IEEE Std 802.1H [ISO/IEC TR 11802-5] — *Media Access Control (MAC) Bridging of Ethernet V2.0 in Local Area Networks*.
- ANSI/IEEE Std 802.2 [ISO/IEC 8802-2] — *Logical Link Control*.
- ANSI/IEEE Std 802.3 — *CSMA/CD Access Method and Physical Layer Specifications*.

- ANSI/IEEE Std 802.4 [ISO/IEC 8802-4] *Token Passing Bus Access Method and Physical Layer Specifications.*
- ANSI/IEEE Std 802.5 [ISO/IEC 8802-5] *Token Ring Access Method and Physical Layer Specifications.*
- ANSI/IEEE Std 802.6 [ISO/IEC 8802-6] *Distributed Queue Dual Bus Access Method and Physical Layer Specifications.*
- ANSI/IEEE Std 802.10 *Interoperable LAN/MAN Security.*
- ANSI/IEEE Std 802.11 [ISO/IEC DIS 8802-11] *Wireless LAN Medium Access Control (MAC) and Physical Layer Specifications.*
- ANSI/IEEE Std 802.12 [ISO/IEC 8802-12] *Demand Priority Access Method, Physical Layer and Repeater Specifications.*

In addition to the family of standards, the following is a recommended practice for a common Physical Layer technology:

- IEEE Std 802.7 *IEEE Recommended Practice for Broadband Local Area Networks.*

Conformance test methodology

An additional standard, 1802.3 provides conformance test information for 10BASE-T.

IEEE Std 802.3, 2000 Edition

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated to this standard within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Details on the contents of this standard are provided on the following pages.

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The following individuals participated in the 802.3 working group during various stages of the standard's development. This list includes individuals who worked on the Amendments 802.3ac, 802.3ab, and 802.3ad.

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ANSI/IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
802.3-1985, Original 10 Mb/s standard, MAC, PLS, AUI, 10BASE5	23 June 1983 (IEEE) 31 December 1984 (ANSI)	**Donald C. Loughry,** *Working Group Chair*
802.3a-1988 (Clause 10), 10 Mb/s MAU 10BASE2	15 November 1985 (IEEE) 28 December 1987 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Alan Flatman,** *Task Force Chair*
802.3b-1985 (Clause 11), 10 Mb/s Broadband MAU, 10BROAD36	19 September 1985 (IEEE) 28 February 1986 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Menachem Abraham,** *Task Force Chair*
802.3c-1985 (9.1–9.8), 10 Mb/s Baseband Repeater	12 December 1985 (IEEE) 4 June 1986 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Geoffrey O. Thompson,** *Task Force Chair*
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802.3e-1987 (Clause 12), 1 Mb/s MAU and Hub 1BASE5	11 June 1987 (IEEE) 15 December 1987 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Robert Galin,** *Task Force Chair*
802.3h-1990 (Clause 5), 10 Mb/s Layer Management, DTEs	28 September 1990 (IEEE) 11 March 1991 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Andy J. Luque,** *Task Force Chair*
802.3i-1990 (Clauses 13 and 14), 10 Mb/s UTP MAU, 10 BASE-T	28 September 1990 (IEEE) 11 March 1991 (ANSI)	**Donald C. Loughry**, *Working Group Chair* **Patricia Thaler,** *Task Force Chair (initial)* **Richard Anderson,** *Task Force Chair (final)*
802.3j-1993 (Clauses 15–18), 10 Mb/s Fiber MAUs 10BASE-FP, FB, and FL	15 September 1993 (IEEE) 15 March 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Keith Amundsen,** *Task Force Chair (initial)* **Frederick Scholl,** *Task Force Chair (final)* **Michael E. Lee,** *Technical Editor*
802.3k-1993 (Clause 19), 10 Mb/s Layer Management, Repeaters	17 September 1992 (IEEE) 8 March 1993 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*
802.3*l*-1992 (14.10), 10 Mb/s PICS Proforma 10BASE-T MAU	17 September 1992 (IEEE) 23 February 1993 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Mike Armstrong,** *Task Force Chair and Editor* **Paul Nikolich,** *Vice Chair* **William Randle,** *Editorial Coordinator*
802.3m-1995, Maintenance 2	21 September 1995 (IEEE) 16 July 1996 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
802.3n-1995, Maintenance 3	21 September 1995 (IEEE) 4 April 1996 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
802.3p-1993 (Clause 20), Management, 10 Mb/s Integrated MAUs	17 June 1993 (IEEE) 4 January 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*
802.3q-1993 (Clause 5), 10 Mb/s Layer Management, GDMO Format	17 June 1993 (IEEE) 4 January 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*

ANSI/IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
802.3r-1996 (8.8), Type 10BASE5 Medium Attachment Unit PICS proforma	29 July 1996 (IEEE) 6 January 1997 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Imre Juhász**, *Task Force Chair* **William Randle,** *Task Force Editor*
802.3s-1995, Maintenance 4	21 September 1995 (IEEE) 8 April 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
802.3t-1995, 120 Ω informative annex to 10BASE-T	14 June 1995 (IEEE) 12 January 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Jacques Christ,** *Task Force Chair*
802.3u-1995 (Clauses 21–30), Type 100BASE-T MAC parameters, Physical Layer, MAUs, and Repeater for 100 Mb/s Operation	14 June 1995 (IEEE) 4 April 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Peter Tarrant,** *Task Force Chair (Phase 1)* **Howard Frazier,** *Task Force Chair (Phase 2)* **Paul Sherer,** *Editor-in-Chief (Phase 1)* **Howard Johnson,** *Editor-in-Chief (Phase 2)* **Colin Mick,** *Comment Editor*
802.3v-1995, 150 Ω informative annex to 10BASE-T	12 December 1995 (IEEE) 16 July 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Larry Nicholson,** *Task Force Chair*
802.3x-1997 and 802.3y-1997 (Revisions to 802.3, Clauses 31 and 32), Full Duplex Operation and Type 100BASE-T2	20 March 1997 (IEEE) 5 September 1997 (ANSI)	**Geoffrey O. Thompson,** *Chair* **David J. Law,** *Vice Chair* **Rich Seifert,** *Task Force Chair and Editor (802.3x)* **J. Scott Carter,** *Task Force Chair (802.3y)* **Colin Mick,** *Task Force Editor (802.3y)*
802.3z-1998 (Clauses 34–39, 41–42), Type 1000BASE-X MAC Parameters, Physical Layer, Repeater, and Management Parameters for 1000 Mb/s Operation	25 June 1998 (IEEE)	**Geoffrey O. Thompson,** *Chair* **David J. Law,** *Vice Chair* **Howard M. Frazier, Jr.,** *Task Force Chair and Editor* **Howard W. Johnson,** *Task Force Editor*
802.3aa-1998, Maintenance 5	25 June 1998 (IEEE)	**Geoffrey O. Thompson,** *Chair* **Colin Mick**, *Task Force Editor (100BASE-T Maintenance)*
802.3ac-1998, Frame Extensions for Virtual Bridged Local Area Network (VLAN) Tagging on 802.3 Networks	16 September 1998 (IEEE)	**Geoffrey O. Thompson,** *Chair* **David J. Law,** *Vice Chair* **Andy J. Luque,** *Secretary* **Ian Crayford,** *Task Force Chair* **Rich Seifert,** *Task Force Editor*
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 July 1999 (IEEE)	**Geoffrey O. Thompson,** *Chair* **David J. Law,** *Vice Chair* **Robert M. Grow,** *Secretary* **George Eisler**, *Task Force Chair* **Colin Mick**, *Task Force Editor*
802.3ad-2000 (Clause 43), Aggregation of Multiple Link Segments	30 March 2000 (IEEE)	**Geoffrey O. Thompson,** *Chair* **David J. Law,** *Vice Chair* **Robert M. Grow,** *Secretary* **Steven Haddock,** *Task Force Chair* **Tony Jeffree,** *Co-Editor* **Rich Seifert,** *CoEditor*

Catherine Berger was the IEEE Standards Project Editor who prepared this edition.

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Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and physical layer specifications

1. Introduction

1.1 Overview

This is a comprehensive International Standard for Local Area Networks (LANs) employing CSMA/CD as the access method. This International Standard is intended to encompass several media types and techniques for signal rates from 1 Mb/s to 1000 Mb/s. This edition of the standard provides the necessary specifications for the following families of systems: a 1 Mb/s baseband system, 10 Mb/s baseband and broadband systems, a 100 Mb/s baseband system, and a 1000 Mb/s baseband system. In addition, it specifies a method for linearly incrementing a system's data rate by aggregating multiple physical links of the same speed into one logical link.

1.1.1 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.

1.1.1.1 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 all media and configurations allowed by this standard.

1.1.1.2 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.

1.1.2 Architectural perspectives

There are two important ways to view local area network (LAN) design corresponding to

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.[1]) The Logical Link Control (LLC) sublayer and MAC sublayer together encompass the functions intended for the Data Link Layer as defined in the OSI model.

1.1.2.1 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.

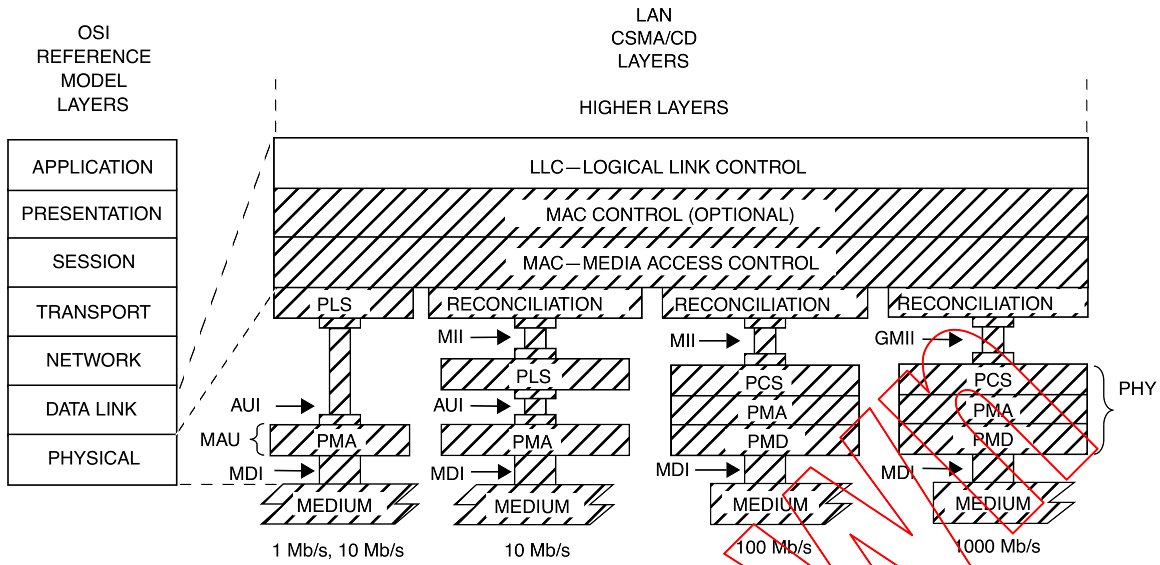
Partitioning the Data Link Layer allows various media access methods within the family of LAN standards.

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.

1.1.2.2 Compatibility interfaces

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

[1] For information about references, see 1.3.



AUI = ATTACHMENT UNIT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MAU = MEDIUM ATTACHMENT UNIT

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

Figure 1–1—LAN standard relationship to the ISO/IEC Opens Systems Interconnection (OSI) reference model

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 Clause 8 (and beyond) 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 by way of the ISO/IEC 8802-3 [ANSI/IEEE Std 802.3] Local Area Network requires complete compatibility at the Physical Medium interface (that is, the physical cable interface).

b) *Attachment Unit Interface (AUI)*. It is anticipated that most DTEs will be 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 highly 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 highly 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 gigabit-capable MAC or repeater unit to a gigabit PHY. While conformance with implementation of this interface is not strictly necessary to ensure communication, it is highly recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at gigabit 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 highly 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.

1.1.3 Layer interfaces

In the architectural model used here, the layers interact by way of well-defined interfaces, providing services as specified in Clauses 2 and 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 will be discussed in Clause 30.

1.1.4 Application areas

The applications environment for the LAN is intended to be commercial and light industrial. Use of CSMA/CD LANs in home or heavy industrial environments, while not precluded, is not considered within the scope of this standard.

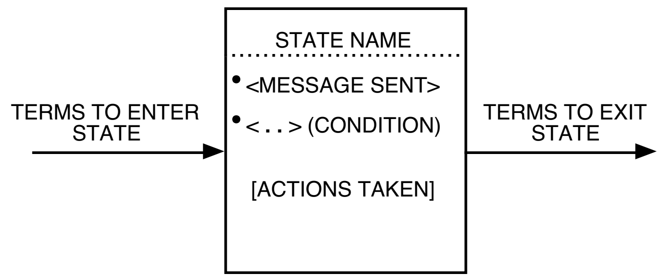
1.2 Notation

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.)

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



Key:
( ) = condition, for example, (if no_collision)
[ ] = action, for example, [reset PLS functions]
* = logical AND
+ = logical OR
Tw = Wait Time, implementation dependent
Td = Delay Timeout
Tb = Backoff Timeout
UCT = unconditional transition

Figure 1–2—State diagram notation example

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, required 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 convention is 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).

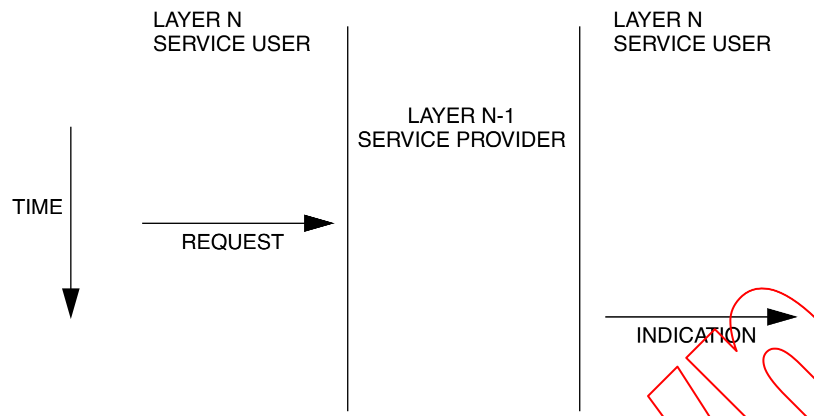


Figure 1–3—Service primitive notation

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.

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 in Mb/s> <medium type> <maximum segment length (× 100 m)>

For example, the standard contains a 10 Mb/s baseband specification identified as "TYPE 10BASE5," meaning a 10 Mb/s baseband medium whose maximum segment length is 500 m. Each successive Physical Layer specification will state its own unique TYPE identifier along similar lines.

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*).

1.3 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties 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.

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).[2]

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

ANSI X3.237-1995, Rev 2.1 (1 January 1995), FDDI Low-Cost Fibre Physical Layer—Medium Dependent (LCF-PMD) (ISO/IEC CD 9314-9).

ANSI X3.263: 1995, Revision 2.2 (1 March 1995), FDDI Twisted Pair—Physical Medium Dependent (TP-PMD) (ISO/IEC CD 9314-10).

ANSI/TIA/EIA-568-A, Commercial Building Telecommunications Cabling Standard.CISPR 22: 1993, Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment.[3]

IEC 60060 (all parts), High-voltage test techniques.[4]

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 60169-8: 1978 and -16: 1982, Radio-frequency connectors, Part 8: R.F. coaxial connectors with inner diameter of outer conductor 6.5 mm (0.256 in) with bayonet lock—Characteristic impedance 50 ohms (Type

[2]ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (www.ansi.org/).

[3]CISPR documents are available from the International Electrotechnical Commission, 3 rue de Varembé, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse (www.iec.ch/). CISPR documents are also available in the United States from the American National Standards Institute.

[4]In the 2000 edition of this standard, IEC publications have been renumbered in accordance with IEC's revised numbering system. In 1997, all existing publications were issued a designation in the 60000 series. Thus IEC 60 became IEC 60060, IEC 169-8 became IEC 60169-8, etc. IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (www.iec.ch/). IEC publications are also available in the United States from the American National Standards Institute.

BNC); 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: 1995, Optical fibres—Part 1: Generic specification.

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

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

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

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: 1993, Safety of laser products—Part 1: Equipment classification, requirements and user's guide.

IEC 60825-2: 1993, Safety of laser products—Part 2: Safety of optical fibre communication systems.

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 61000-4-3, Electromagnetic Compatibility (EMC)—Part 4: Testing and measurement techniques—Section 3: Radiated, radio-frequency, electromagnetic field immunity test.

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 61076-3-103 (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 61754-4: 1997, Fibre optic connector interfaces—Part 4: Type SC connector family.

IEEE Std 802-1990, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.[5]

IEEE Std 802.1F-1993 (Reaff 1998), IEEE Standards for Local and Metropolitan Area Networks: Common Definitions and Procedures for IEEE 802 Management Information.

IEEE P802.1Q/D11 (July 30, 1998), Draft Standard for Local and Metropolitan Area Networks: Virtual Bridged Local Area Networks.[6]

IETF RFC 1155, *Structure and Identification of Management Information for TCP/IP-based Internets,* Rose, M., and K. McCloghrie, May 1990.[7]

IETF RFC 1157, *A Simple Network Management Protocol (SNMP),* Case, J., Fedor, M., Schoffstall, M., and J. Davin, May 1990.

IETF RFC 1212, *Concise MIB Definitions,* Rose, M., and K. McCloghrie, March 1991.

IETF STD 17, RFC 1213, *Management Information Base for Network Management of TCP/IP-based internets: MIB-II,* McCloghrie K., and M. Rose, Editors, March 1991.

IETF RFC 1215, *A Convention for Defining Traps for use with the SNMP,* M. Rose, March 1991.

IETF RFC 1901, *Introduction to Community-based SNMPv2,* Case, J., McCloghrie, K., Rose, M., and S. Waldbusser, January 1996.

IETF RFC 1902, *Structure of Management Information for Version 2 of the Simple Network Management Protocol (SNMPv2),* Case, J., McCloghrie, K., Rose, M., and S. Waldbusser, January 1996.

IETF RFC 1903, *Textual Conventions for Version 2 of the Simple Network Management Protocol (SNMPv2),* Case, J., McCloghrie, K., Rose, M., and S. Waldbusser, January 1996.

IETF RFC 1904, *Conformance Statements for Version 2 of the Simple Network Management Protocol (SNMPv2),* Case, J., McCloghrie, K., Rose, M., and S. Waldbusser, January 1996.

IETF RFC 1905, *Protocol Operations for Version 2 of the Simple Network Management Protocol (SNMPv2),* Case, J., McCloghrie, K., Rose, M., and S. Waldbusser, January 1996.

IETF RFC 1906, *Transport Mappings for Version 2 of the Simple Network Management Protocol (SNMPv2),* Case, J., McCloghrie, K., Rose, M., and S. Waldbusser, January 1996.

IETF RFC 2233, *The Interfaces Group MIB using SMIv2,* McCloghrie, K., and F. Kastenholz, November 1997.

IETF RFC 2271, *An Architecture for Describing SNMP Management Frameworks,* Harrington, D., Presuhn, R., and B. Wijnen, January 1998.

IETF RFC 2272, *Message Processing and Dispatching for the Simple Network Management Protocol (SNMP),* Case, J., Harrington D., Presuhn R., and B. Wijnen, January 1998.

IETF RFC 2273, *SNMPv3 Applications,* Levi, D., Meyer, P., and B. Stewart, January 1998.

[5]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (standards.ieee.org/).

[6]Numbers preceded by P are IEEE authorized standards projects that were not approved by the IEEE-SA Standards Board at the time this publication went to press. For information about obtaining drafts, contact the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[7]IEFT RFCs are available from the Internet Engineering Task Force website at http://www.ietf.org/rfc.html.

IETF RFC 2274, *User-based Security Model (USM) for version 3 of the Simple Network Management Protocol (SNMPv3),* Blumenthal, U., and B. Wijnen, January 1998.

IETF RFC 2275, *View-based Access Control Model (VACM) for the Simple Network Management Protocol (SNMP),* Wijnen, B., Presuhn, R., and K. McCloghrie, January 1998.

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.[8]

ISO/IEC 2382-9: 1995, Information technology—Vocabulary—Part 9: Data communication.

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 8825: 1990, Information technology—Open Systems Interconnection—Specification of basic encoding rules for Abstract Syntax Notation One (ASN.1).

ISO/IEC 8877: 1992, Information technology—Telecommunications and information exchange between systems—Interface connector and contact assignments for ISDN Basic Access Interface located at reference points S and T.

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

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 10164-1: 1993, Information technology—Open Systems Interconnection—Systems management—Part 1: Object Management Function.

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[8]ISO/IEC publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iso.ch/). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (http://www.ansi.org/).

ISO/IEC 10165-1: 1993, Information technology—Open Systems Interconnection—Management information services—Structure of management information—Part 1: Management Information Model.

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 10742: 1994, Information technology—Telecommunications and information exchange between systems—Elements of management information related to OSI Data Link Layer standards.

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

ISO/IEC 15802-2: 1995 [ANSI/IEEE Std 802.1B-1992 and IEEE Std 802.1k-1993], Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 2: LAN/MAN Management.

ISO/IEC 15802-3: 1998 [IEEE Std 802.1D, 1998 Edition), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 3: Media Access Control (MAC) bridges.[9]

ITU-T Recommendation G.957 (1995) Digital line systems—Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.[10]

ITU-T Recommendation I.430 (1995), Basic user-network interface—Layer 1 specification.

MATLAB Matrix Laboratory Software.[11]

NOTE—Local and national standards such as those supported by ANSI, EIA, IEEE, MIL, NPFA, 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.

[9]As this standard goes to press, IEEE Std 802.1D-1998 is approved but not yet published. The draft standard is, however, available from the IEEE. It is being prepared as ISO/IEC 15802-3: 1998 [ANSI/IEEE Std 802.1D, 1998 Edition]. The anticipated publication date is no later than December 1998. Contact the IEEE Standards Department at 1 (732) 562-3800 for status information.

[10]ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland (www.itu.int/).

[11]For information on MatLab contact: The MathWorks, 24 Park Way, Natick, MA, (www.mathworks.com).