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ANSI/IEEE Std 802.3

Fourth edition
1993-07-08

Information technology — Local and metropolitan area networks —

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

Technologie de l'information — Réseaux locaux et métropolitains —

Partie 3: Accès multiple par sruveillance du signal et détection de collision et spécifications pour la couche physique

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International Standard ISO/IEC 8802-3 : 1993
ANSI/IEEE Std 802.3, 1993 Edition

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Information technology— Local and metropolitan area networks—

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

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Abstract: This Local and Metropolitan Area Network standard, ISO/IEC 8802-3 : 1993 [ANSI/IEEE Std 802.3, 1993 Edition], specifies the media access control characteristics for the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method. It also specifies the media, Medium Attachment Unit (MAU) and physical layer repeater unit for 10 Mb/s baseband and broadband systems, and it provides a 1 Mb/s baseband implementation. Specifications for MAU types 10BASE5, 10BASE2, FOIRL (fiber optic inter-repeater link), 10BROAD36, 1BASE5, and 10BASE-T are included. System considerations for multisegment 10 Mb/s baseband networks are provided. Layer and sublayer interface specifications are aligned to the ISO Open Systems Interconnection Basic Reference Model and 8802 models. The 8802-3 internal model is defined and used.

Keywords: data processing, information interchange, local area networks, mode of data transmission, network interconnection, models





Adopted as an International Standard by the
International Organization for Standardization
and by the
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International Standard ISO/IEC 8802-3 : 1993

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

In 1985, IEEE Standard 802.3-1985 was adopted by ISO Technical Committee 97, *Information processing systems*, as draft International Standard ISO/DIS 8802-3. Following the procedures described above, the Standard was subsequently approved by ISO and published as ISO 8802-3 : 1989, incorporating ISO 8802-3/DAD 1 which had resulted from the adoption by ISO in 1987 of ANSI/IEEE Std 802.3a.

A further revision was subsequently approved by ISO/IEC JTC 1 in 1990, incorporating ISO/IEC 8802-3/Amendments 2 and 5.

A third edition, published in 1992, incorporated ISO/IEC 8802-3/Amendments 3 and 4.

This fourth edition cancels and replaces ISO/IEC 8802-3 : 1992 and incorporates ISO/IEC 8802-3/Amendment 6, *Maintenance Ballot*; Amendment 7, *Layer management*; and Amendment 9, *System considerations for multisegment 10 Mb/s baseband networks and Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T*. These amendments were approved in 1992.

For the purpose of assigning organizationally unique identifiers, the Institute of Electrical and Electronics Engineers, Inc., USA, has been designated by the ISO Council as the Registration Authority. Communications on this subject should be addressed to

Registration Authority for ISO/IEC 8802-3
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During the preparation of this International Standard, information was gathered on patents upon which application of this standard might depend. Relevant patents were identified as belonging to Xerox Corporation. However, ISO and IEC cannot give authoritative or comprehensive information about evidence, validity or scope of patent and like rights. The patent-holder has stated that licenses will be granted under reasonable terms and conditions and communications on this subject should be addressed to

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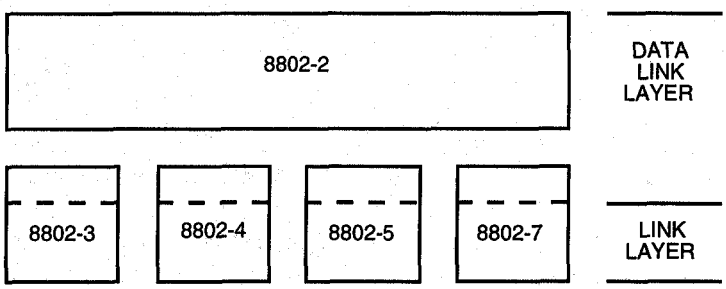
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Foreword to International Standard ISO/IEC 8802-3 : 1993

This standard is part of a family of standards for Local and Metropolitan Area Networks. The relationship between this standard and the other members of the family is shown below. (The numbers in the figure refer to ISO standard numbers.)



This family of standards deals with the Physical and Data Link layers as defined by the ISO Open Systems Interconnection Basic Reference Model (ISO 7498 : 1984). The access standards define four 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 these technologies are as follows:

(1) ISO/IEC 8802-3 [ANSI/IEEE Std 802.3, 1993 Edition], a bus utilizing CSMA/CD as the access method,
(2) ISO/IEC 8802-4 [ANSI/IEEE Std 802.4-1990], a bus utilizing token passing as the access method,
(3) ISO/IEC 8802-5 [ANSI/IEEE Std 802.5-1992], a ring utilizing token passing as the access method,
(4) ISO 8802-7, a ring utilizing slotted ring as the access method.

ISO 8802-2 [ANSI/IEEE Std 802.2-1989], *Logical Link Control protocol*, is used in conjunction with the medium access standards.

ISO/IEC 10038 [ANSI/IEEE Std 802.1D, 1993 Edition], *Media access control (MAC) bridges*, specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.

The reader of this document is urged to become familiar with the complete family of standards.

The main body of this standard serves for both the ISO/IEC 8802-3 and ANSI/IEEE Std 802.3 standards. ISO/IEC and IEEE each have unique foreword sections. The Annex applies to the IEEE standard only. The Appendixes serve as useful reference material to both standards.

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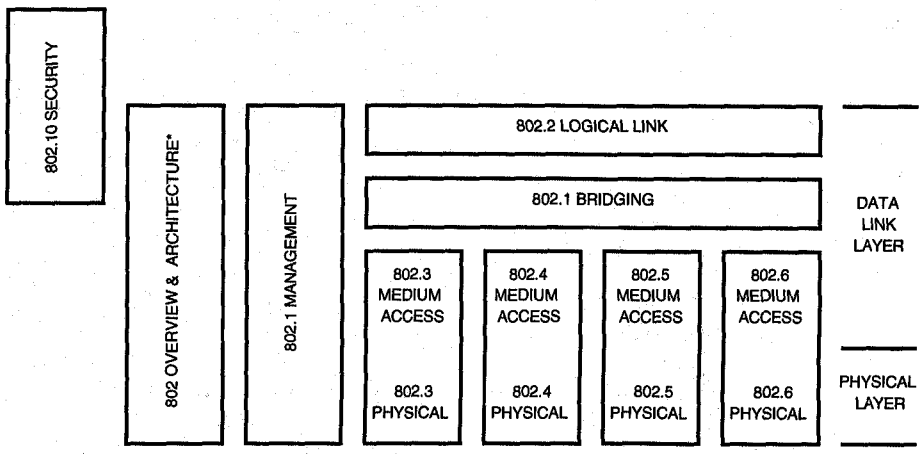
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Foreword to ANSI/IEEE Std 802.3, 1993 Edition

(This Foreword is not a part of this International Standard or of ANSI/IEEE 802.3, 1993 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 Basic Reference Model (ISO 7498 : 1984). The access standards define several 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 these technologies are as follows:

- IEEE Std 802†: Overview and Architecture. This standard provides an overview to the family of IEEE 802 standards. This document forms part of the 802.1 scope of work.
- IEEE Std 802.1B: LAN/MAN Management. Defines an Open System Interconnection (OSI) management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.
- ISO/IEC 10038 : 1993 [ANSI/IEEE Std 802.1D] MAC Bridging. Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.
- IEEE Std 802.1E: 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.
- ISO 8802-2 [ANSI/IEEE Std 802.2]: Logical Link Control
- ISO/IEC 8802-3 [ANSI/IEEE Std 802.3]: CSMA/CD Access Method and Physical Layer Specifications

†The 802 Architecture and Overview Specification, originally known as IEEE Std 802.1A, has been renumbered as IEEE Std 802. This has been done to accommodate recognition of the base standard in a family of standards. References to IEEE Std 802.1A should be considered as references to IEEE Std 802.

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- ISO/IEC 8802-4 [ANSI/IEEE Std 802.4]: Token Bus Access Method and Physical Layer Specifications
- ISO/IEC 8802-5 [ANSI/IEEE Std 802.5]: Token Ring Access Method and Physical Layer Specifications
- IEEE Std 802.6: Metropolitan Area Network Access Method and Physical Layer Specifications
- IEEE Std 802.10: Interoperable Local Area Network Security, *Currently Contains* Secure Data Exchange (SDE)

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

- IEEE Std 802.7: IEEE Recommended Practice for Broadband Local Area Networks

The reader of this document is urged to become familiar with the complete family of standards.

Conformance Test Methodology

Another standards series, identified by the number 1802, has been established to identify the conformance test methodology documents for the 802 family of standards. This makes the correspondence between the various 802 standards and their applicable conformance test requirements readily apparent. Thus the conformance test documents for 802.3 are numbered 1802.3, the conformance test documents for 802.5 will be 1802.5, and so on. Similarly, ISO will use 18802 to number conformance test standards for 8802 standards.

ISO/IEC 8802-3 : 1993 (ANSI/IEEE Std 802.3, 1993 Edition)

This edition of the standard defines 10 Mb/s baseband and broadband implementations and a 1 Mb/s baseband implementation of the Physical Layer using the CSMA/CD access method. It is anticipated that future editions of the standard may provide additional implementations of the physical layer to support different needs (for example, media, and data rates).

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.

Readers wishing to know the state of revisions should contact

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The IEEE 802.3 Working Group acknowledges and appreciates that many concepts embodied in this standard are based largely upon the CSMA/CD access method earlier described in *The Ethernet* specification as written jointly by individuals from Xerox Corporation, Digital Equipment Corporation, and Intel Corporation. Appreciation is also expressed to Robert M. Metcalfe and David R. Boggs for their pioneering work in establishing the original concepts.

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ANSI/IEEE Std 802.3c-1985 was approved by the American National Standards Institute on June 4, 1986.

When the IEEE 802.3 Working Group approved ANSI/IEEE Std 802.3d-1987 (9.9), it had the following membership:

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The IEC TC83 Committee on Information Technology Equipment also provided very helpful input to the development of the FOIRL Standard (9.9).

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When the IEEE Standards Board approved ANSI/IEEE Std 802.3d-1987 (9.9) on December 12, 1985, it had the following membership:

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ANSI/IEEE Std 802.3d-1987 was approved by the American National Standards Institute on February 9, 1989.

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When the IEEE 802.3 Working Group approved ANSI/IEEE Std 802.3b-1985 (Section 11), it had the following membership:

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When the IEEE Standards Board approved ANSI/IEEE Std 802.3b-1985 (Section 11) on September 19, 1985, it had the following membership:

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ANSI/IEEE Std 802.3b-1985 was approved by the American National Standards Institute on February 28, 1986.

When the IEEE 802.3 Working Group approved ANSI/IEEE Std 802.3e-1987 (Section 12) in November 1986, it had the following membership:

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When the IEEE Standards Board approved ANSI/IEEE Std 802.3e-1987 (Section 12) on June 11, 1987, it had the following membership:

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ANSI/IEEE Std 802.3e-1987 was approved by the American National Standards Institute on December 15, 1987.

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When the IEEE 802.3 Working Group approved ANSI/IEEE Std 802.3h-1990 (Section 5), it had the following membership:

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When the IEEE 802.3 Working Group approved ANSI/IEEE Std 802.3i-1990 (Sections 13 and 14), it had the following membership:

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Information technology—Local and metropolitan area networks—

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

1. Introduction

1.1 Overview

1.1.1 Basic Concepts. The Carrier Sense Multiple Access with Collision Detection (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 sends a few additional bytes 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 sections of this standard.

This is a comprehensive standard for Local Area Networks employing CSMA/CD as the access method. This standard is intended to encompass several media types and techniques for signal rates of from 1 Mb/s to 20 Mb/s. This edition of the standard provides the necessary specifications for 10 Mb/s baseband and broadband systems, a 1 Mb/s baseband system, and a Repeater Unit.

1.1.2 Architectural Perspectives. There are two important ways to view local area network design corresponding to

(1) *Architecture.* Emphasizing the logical divisions of the system and how they fit together.
(2) *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 Model for Open Systems Interconnection (see Fig 1-1). See ISO 7498:1984 [10].[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 An architectural organization of the standard has two main advantages:

(1) *Clarity.* A clean overall division of the design along architectural lines makes the standard clearer.
(2) *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 Local Area Network standards.

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[1] The numbers in brackets correspond to those of the references listed in 1.3; when preceded by A, they correspond to those listed in the Annex.

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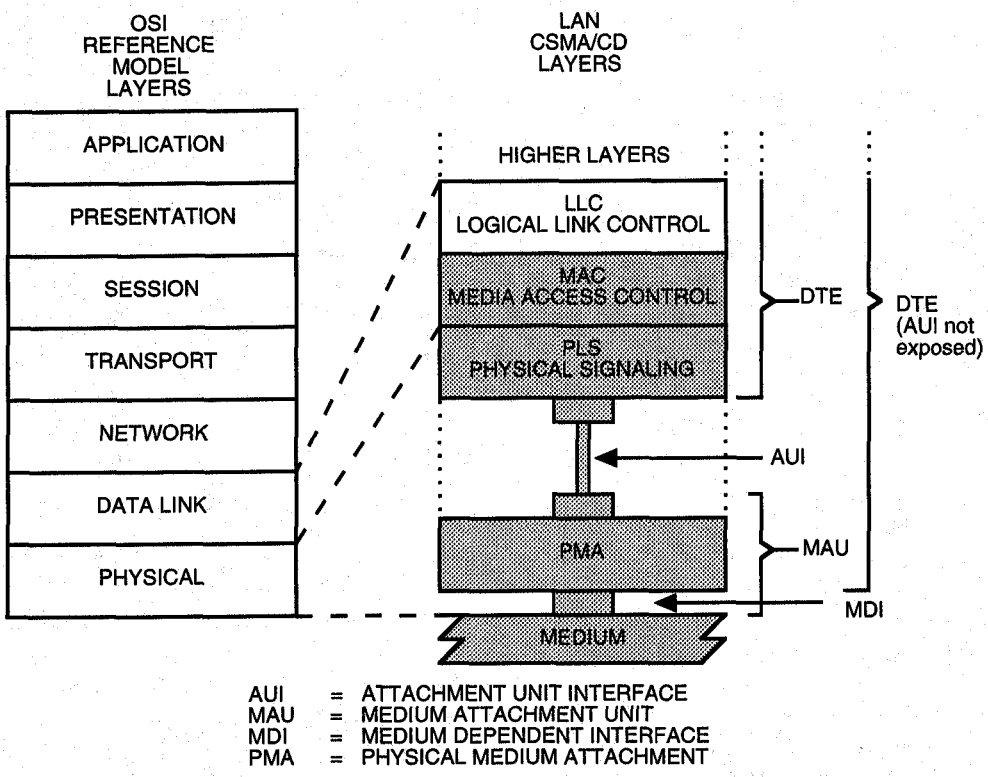


Fig 1-1
LAN Standard Relationship to the ISO Open Systems Interconnection (OSI) Reference Model

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

(1) *Medium-Dependent Interface (MDI).* To communicate in a compatible manner, all stations shall adhere rigidly to the exact specification of physical media signals defined in Section 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 8802-3 [IEEE 802.3] Local Area Network requires complete compatibility at the Physical Medium interface (that is, the coaxial cable interface).

(2) *Attachment Unit Interface (AUI).* It is anticipated that most DTEs will be located some distance from their connection to the coaxial cable. A small amount of circuitry will exist in the Medium Attachment Unit (MAU) directly adjacent to the coaxial 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 specification is required.

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 Sections 2 and 6. In general, the interface requirements are as follows:

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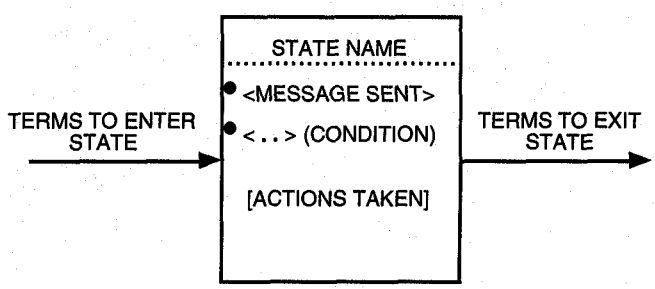
(1) The interface between the MAC sublayer and the LLC sublayer includes facilities for transmitting and receiving frames, and provides per-operation status information for use by higher-layer error recovery procedures.
(2) The interface between the MAC sublayer and the Physical Layer includes signals for framing (carrier sense, 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 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 Section 5.

1.1.4 Application Areas. The applications environment for the Local Area Network 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 Fig 1-2).



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

Fig 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.

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Some devices described in this standard (e.g., repeaters) are allowed to have two or more ports. State diagrams 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:

(1) The character ":" (colon) is a delimiter used to denote that a term assignment statement follows.
(2) 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 Fig 1-3).

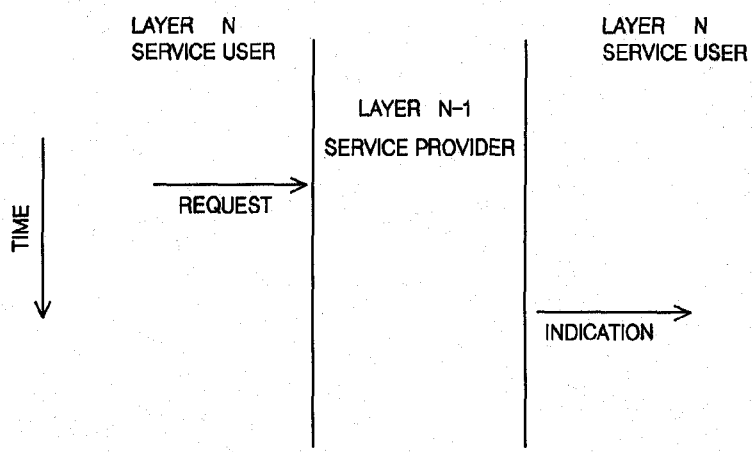


Fig 1-3
Service Primitive Notation

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:

(1) REQUEST. The request primitive is passed from layer N to layer N-1 to request that a service be initiated.

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(2) 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 section. 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 References

[1] CISPR Publication 22 (1985), Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment.[2]

[2] IEC Publication 96-1, Radio-frequency cables, Part 1: General requirements and measuring methods.[3]

[3] IEC Publication 96-1A, 1st Supplement to Radio-frequency cables, Part 1: Appendix Section 5.4, Terminated triaxial test method for transfer impedance up to 100 MHz.

[4] IEC Publication 169-8 and -16, Radio-frequency connectors, Part 8: Radio-frequency coaxial connectors with inner diameter of outer conductor 6.5 mm (0.256 in) with bayonet lock—Characteristic impedance 50 ohms (Type BNC); Part 16: Radio-frequency coaxial connectors with inner diameter of outer conductor 7 mm (0.276 in) with screw coupling—Characteristic impedance 50 ohms (75 ohms) (Type N).

[5] IEC Publication 380, Safety of electrically energized office machines.

[6] IEC Publication 435, Safety of data processing equipment.

[2]CISPR documents are available from the International Electrotechnical Commission, 3 rue de Varembé, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse. CISPR documents 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.

[3]IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. IEC 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.

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[7] IEC Publication 807-2, Rectangular connectors for frequencies below 3 MHz, Part 2: Detail specification for a range of connectors with round contacts—Fixed solder contact types.

[8] IEC Publication 950, Safety of Information Technology Equipment, Including Electrical Business Equipment.

[9] ISO 2382-9 : 1984, Data processing—Vocabulary—Part 09: Data communication.[4]

[10] ISO 7498 : 1984, Information processing systems–open systems interconnection–Basic reference model.

[11] IEC Publication 60, High-voltage test techniques.

[12] IEC Publication 68, Environmental testing.

[13] IEC Publication 793-1, Optical fibres, Part 1: Generic specification.

[14] IEC Publication 793-2, Optical fibres, Part 2: Product specifications.[5]

[15] IEC Publication 794-1, Optical fibre cables, Part 1: Generic specification.

[16] IEC Publication 794-2, Optical fibres cables, Part 2: Product specifications.

[17] IEC Publication 825, Radiation safety of laser products, equipment classification, requirements, and user's guide.

[18] IEC Publication 874-1, Connectors for optical fibres and cables, Part 1: Generic specification.

[19] IEC Publication 874-2, Connectors for optical fibres and cables, Part 2: Sectional specification for fibre optic connector type F-SMA.

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

[21] ISO 8877 : 1987, Information processing systems—Interface connector and contact assignments for ISDN basic access interface located at reference points S and T.

Local and national standards such as those supported by ANSI, EIA, IEEE, MIL, NFPA, and UL are not a formal part of the ISO/IEC 8802-3 standard. Reference to such local or national standards may be useful resource material and are identified by a bracketed number beginning with the letter A and located in Annex A.

1.4 Definitions. The definitions used in this standard are consistent with ISO 2382-9:1984 [9]. A more specific Part 25, pertaining to LAN systems, is in development.

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[4]ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. 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.

[5] Subsection 9.9 is to be read with the understanding that the following changes to IEC Publication 793-2 [14] have been requested:
(1) Correction of the numerical aperture tolerance in Table III to ± 0.015.
(2) Addition of another bandwidth category, of ≥ 150 MHz referred to 1 km, for the type A1b fiber in Table III.

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2. MAC Service Specification

2.1 Scope and Field of Application. This section specifies the services provided by the Media Access Control (MAC) sublayer to the Logical Link Control (LLC) sublayer for the ISO [IEEE] Local Area Network standard (see Fig 2-1). The services are described in an abstract way and do not imply any particular implementation, or any exposed interface. There is not necessarily a one-to-one correspondence between the primitives and the formal procedures and interfaces described in 4.2 and 4.3.

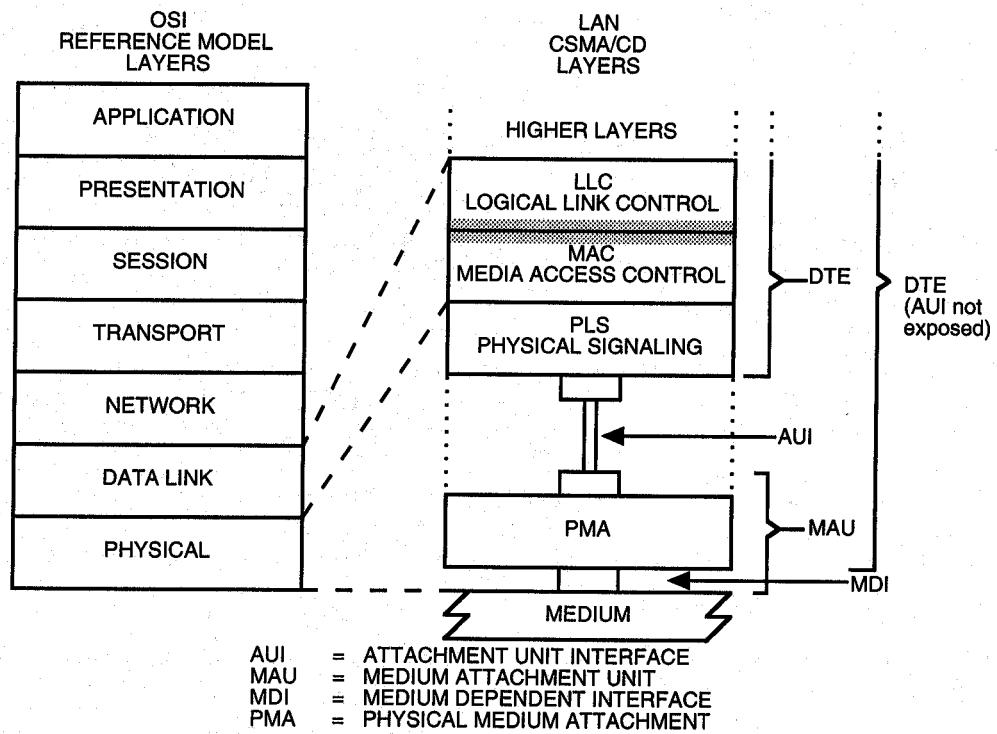


Fig 2-1
Service Specification Relation to the LAN Model

2.2 Overview of the Service

2.2.1 General Description of Services Provided by the Layer. The services provided by the MAC sublayer allow the local LLC sublayer entity to exchange LLC data units with peer LLC sublayer entities. Optional support may be provided for resetting the MAC sublayer entity to a known state.

2.2.2 Model Used for the Service Specification. The model used in this service specification is identical to that used in 1.2.

2.2.3 Overview of Interactions

MA_DATA.request
MA_DATA.indication

2.2.4 Basic Services and Options. The MA_DATA.request and MA_DATA.indication service primitives described in this section are considered mandatory.

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2.3 Detailed Service Specification

2.3.1 MA_DATA.request

2.3.1.1 Function. This primitive defines the transfer of data from a local LLC sublayer entity to a single peer LLC entity or multiple peer LLC entities in the case of group addresses.

2.3.1.2 Semantics of the Service Primitive. The semantics of the primitive are as follows:

```
MA_DATA.request     (
                    destination_address,
                    m_sdu,
                    service_class
                    )
```

The destination_address parameter may specify either an individual or a group MAC entity address. It must contain sufficient information to create the DA field that is appended to the frame by the local MAC sublayer entity and any physical information. The m_sdu parameter specifies the MAC service data unit to be transmitted by the MAC sublayer entity. There is sufficient information associated with m_sdu for the MAC sublayer entity to determine the length of the data unit. The service_class parameter indicates a quality of service requested by LLC or higher layer (see 2.3.1.5).

2.3.1.3 When Generated. This primitive is generated by the LLC sublayer entity whenever data shall be transferred to a peer LLC entity or entities. This can be in response to a request from higher protocol layers or from data generated internally to the LLC sublayer, such as required by Type 2 service.

2.3.1.4 Effect of Receipt. The receipt of this primitive will cause the MAC entity to append all MAC specific fields, including DA, SA, and any fields that are unique to the particular media access method, and pass the properly formed frame to the lower protocol layers for transfer to the peer MAC sublayer entity or entities.

2.3.1.5 Additional Comments. The CSMA/CD MAC protocol provides a single quality of service regardless of the service_class requested.

2.3.2 MA_DATA.indication

2.3.2.1 Function. This primitive defines the transfer of data from the MAC sublayer entity to the LLC sublayer entity or entities in the case of group addresses.

2.3.2.2 Semantics of the Service Primitive. The semantics of the primitive are as follows:

```
MA_DATA.indication  (
                    destination_address,
                    source_address,
                    m_sdu,
                    reception_status
                    )
```

The destination_address parameter may be either an individual or a group address as specified by the DA field of the incoming frame. The source_address parameter is an individual address as specified by the SA field of the incoming frame. The m_sdu parameter specifies the MAC service data unit as received by the local MAC entity. The reception_status parameter is used to pass status information to the peer LLC sublayer entity.

2.3.2.3 When Generated. The MA_DATA.indication is passed from the MAC sublayer entity to the LLC sublayer entity or entities to indicate the arrival of a frame to the local MAC sublayer entity. Such

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frames are reported only if they are validly formed, received without error, and their destination address designates the local MAC entity.

2.3.2.4 Effect of Receipt. The effect of receipt of this primitive by the LLC sublayer is unspecified.

2.3.2.5 Additional Comments. If the local MAC sublayer entity is designated by the destination_address parameter of an MA_DATA.request, the indication primitive will also be invoked by the MAC entity to the local LLC entity. This full duplex characteristic of the MAC sublayer may be due to unique functionality within the MAC sublayer or full duplex characteristics of the lower layers (for example, all frames transmitted to the broadcast address will invoke MA_DATA.indication at all stations in the network including the station that generated the request).

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3. Media Access Control Frame Structure

3.1 Overview. This section defines in detail the frame structure for data communication systems using local area network MAC procedures. It defines the relative positions of the various components of the MAC frame. It defines the method for representing station addresses. It defines a partition of the address space into individual (single station) and group (multicast or multistation) addresses, and into user administered and globally administered addresses.

3.1.1 MAC Frame Format. Figure 3-1 shows the eight fields of a frame: the preamble, Start Frame Delimiter (SFD), the addresses of the frame's source and destination, a length field to indicate the length of the following field containing the LLC data to be transmitted, a field that contains padding if required, and the frame check sequence field containing a cyclic redundancy check value to detect errors in received frames. Of these eight fields, all are of fixed size except the LLC data and PAD fields, which may contain any integer number of octets between the minimum and maximum values determined by the specific implementation of the CSMA/CD Media Access mechanism. See 4.4 for particular implementations.

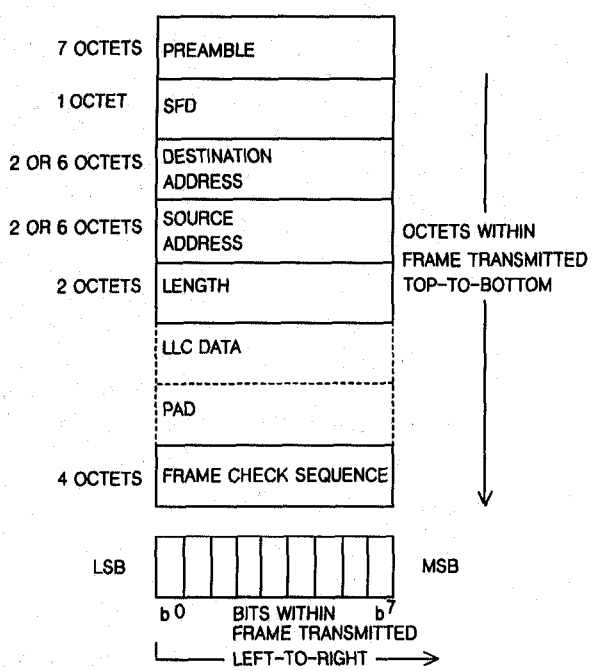


Fig 3-1
MAC Frame Format

The minimum and maximum frame size limits in 4.4 refer to that portion of the frame from the destination address field through the frame check sequence field, inclusive.

Relative to Fig 3-1, the octets of a frame are transmitted from top to bottom, and the bits of each octet are transmitted from left to right.

3.2 Elements of the MAC Frame

3.2.1 Preamble Field. The preamble field is a 7-octet field that is used to allow the PLS circuitry to reach its steady-state synchronization with the received frame timing (see 4.2.5).

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3.2.2 Start Frame Delimiter (SFD) Field. The SFD field is the sequence 10101011. It immediately follows the preamble pattern and indicates the start of a frame.

3.2.3 Address Fields. Each MAC frame shall contain two address fields: the Destination Address field and the Source Address field, in that order. The Destination Address field shall specify the destination addressee(s) for which the frame is intended. The Source Address field shall identify the station from which the frame was initiated. The representation of each address field shall be as follows (see Fig 3-2):

(1) Each address field shall contain either 16 bits or 48 bits. However, at any given time, the Source and Destination Address size shall be the same for all stations on a particular local area network.
(2) The support of 16 or 48 bit address length for Source and Destination Address shall be left to the manufacturer as an implementation decision. There is no requirement that manufacturers support both sizes.
(3) The first bit (LSB) shall be used in the Destination Address field as an address type designation bit to identify the Destination Address either as an individual or as a group address. In the Source Address field, the first bit is reserved and set to 0. If this bit is 0, it shall indicate that the address field contains an individual address. If this bit is 1, it shall indicate that the address field contains a group address that identifies none, one or more, or all of the stations connected to the local area network.
(4) For 48 bit addresses, the second bit shall be used to distinguish between locally or globally administered addresses. For globally administered (or U, universal) addresses, the bit is set to 0. If an address is to be assigned locally, this bit shall be set to 1. Note that for the broadcast address, this bit is also a 1.
(5) Each octet of each address field shall be transmitted least significant bit first.

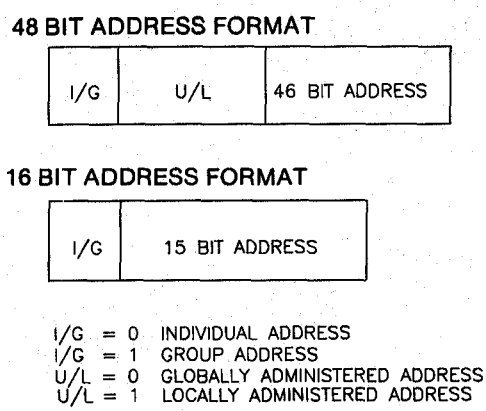


Fig 3-2
Address Field Format

3.2.3.1 Address Designation. A MAC sublayer address is of one of two types:

(1) *Individual Address*. The address associated with a particular station on the network.
(2) *Group Address*. A multidestination address, associated with one or more stations on a given network. There are two kinds of multicast address:
  (a) *Multicast-Group Address*. An address associated by higher-level convention with a group of logically related stations.
  (b) *Broadcast Address*. A distinguished, predefined multicast address that always denotes the set of all stations on a given local area network.

All 1's in the Destination Address field (for 16 or 48 bit address size LANs) shall be predefined to be the Broadcast address. This group shall be predefined for each communication medium to consist of all stations

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actively connected to that medium; it shall be used to broadcast to all the active stations on that medium. All stations shall be able to recognize the Broadcast address. It is not necessary that a station be capable of generating the Broadcast address.

The address space shall also be partitioned into locally administered and globally administered addresses. The nature of a body and the procedures by which it administers these global (U) addresses is beyond the scope of this standard.[6]

3.2.4 Destination Address Field. The Destination Address field specifies the station(s) for which the frame is intended. It may be an individual or multicast (including broadcast) address.

3.2.5 Source Address Field. The Source Address field specifies the station sending the frame. The Source Address field is not interpreted by the CSMA/CD MAC sublayer.

3.2.6 Length Field. The length field is a 2-octet field whose value[7] indicates the number of LLC data octets in the data field. If the value is less than the minimum required for proper operation of the protocol, a PAD field (a sequence of octets) will be added at the end of the data field but prior to the FCS field, specified below. The procedure that determines the size of the pad field is specified in 4.2.8. The length field is transmitted and received with the high order octet first.

3.2.7 Data and PAD Fields. The data field contains a sequence of n octets. Full data transparency is provided in the sense that any arbitrary sequence of octet values may appear in the data field up to a maximum number specified by the implementation of this standard that is used. A minimum frame size is required for correct CSMA/CD protocol operation and is specified by the particular implementation of the standard. If necessary, the data field is extended by appending extra bits (that is, a pad) in units of octets after the LLC data field but prior to calculating and appending the FCS. The size of the pad, if any, is determined by the size of the data field supplied by LLC and the minimum frame size and address size parameters of the particular implementation. The maximum size of the data field is determined by the maximum frame size and address size parameters of the particular implementation.

The length of PAD field required for LLC data that is n octets long is max (0, minFrameSize – (8 × n + 2 × addressSize + 48)) bits. The maximum possible size of the LLC data field is maxFrameSize – (2 × addressSize + 48)/8 octets. See 4.4 for a discussion of implementation parameters; see 4.2.3.3 for a discussion of the minFrameSize.

3.2.8 Frame Check Sequence Field. A cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the FCS field. The frame check sequence (FCS) field contains a 4-octet (32-bit) cyclic redundancy check (CRC) value. This value is computed as a function of the contents of the source address, destination address, length, LLC data and pad (that is, all fields except the preamble, SFD, and FCS). The encoding is defined by the following generating polynomial.

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

Mathematically, the CRC value corresponding to a given frame is defined by the following procedure:

(1) The first 32 bits of the frame are complemented.
(2) The n bits of the frame are then considered to be the coefficients of a polynomial M(x) of degree n-1. (The first bit of the Destination Address field corresponds to the $x^{(n-1)}$ term and the last bit of the data field corresponds to the x^0 term.)
(3) M(x) is multiplied by x^{32} and divided by G(x), producing a remainder R(x) of degree <31.
(4) The coefficients of R(x) are considered to be a 32-bit sequence.
(5) The bit sequence is complemented and the result is the CRC.

[6]For information on how to use MAC addresses, see IEEE Std 802-1990, Overview and Architecture. To apply for an Organizationally Unique Identifier for building a MAC address, contact the Registration Authority, IEEE Standards Department, P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA; (908) 562-3813; fax (908) 562-1571.

[7] Packets with a length field value greater than those specified in 4.4.2 may be ignored, discarded, or used in a private manner. The use of such packets is beyond the scope of this standard.

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The 32 bits of the CRC value are placed in the frame check sequence field so that the x^{31} term is the left-most bit of the first octet, and the x^0 term is the right most bit of the last octet. (The bits of the CRC are thus transmitted in the order x^{31}, x^{30}, . . . , x^1, x^0.) See reference [A18].

3.3 Order of Bit Transmission. Each octet of the MAC frame, with the exception of the FCS, is transmitted low-order bit first.

3.4 Invalid MAC Frame. An invalid MAC frame shall be defined as one that meets at least one of the following conditions:

(1) The frame length is inconsistent with the length field.
(2) It is not an integral number of octets in length.
(3) The bits of the incoming frame (exclusive of the FCS field itself) do not generate a CRC value identical to the one received.

The contents of invalid MAC frames shall not be passed to LLC. The occurrence of invalid MAC frames may be communicated to network management.

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4. Media Access Control

4.1 Functional Model of the Media Access Control Method

4.1.1 Overview. The architectural model described in Section 1 is used in this section to provide a functional description of the Local Area Network CSMA/CD MAC sublayer.

The MAC sublayer defines a medium-independent facility, built on the medium-dependent physical facility provided by the Physical Layer, and under the access-layer-independent local area network LLC sublayer. It is applicable to a general class of local area broadcast media suitable for use with the media access discipline known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

The LLC sublayer and the MAC sublayer together are intended to have the same function as that described in the OSI model for the Data Link Layer alone. In a broadcast network, the notion of a data link between two network entities does not correspond directly to a distinct physical connection. Nevertheless, the partitioning of functions presented in this standard requires two main functions generally associated with a data link control procedure to be performed in the MAC sublayer. They are as follows:

(1) Data encapsulation (transmit and receive)
  (a) Framing (frame boundary delimitation, frame synchronization)
  (b) Addressing (handling of source and destination addresses)
  (c) Error detection (detection of physical medium transmission errors)
(2) Media Access Management
  (a) Medium allocation (collision avoidance)
  (b) Contention resolution (collision handling)

The remainder of this section provides a functional model of the CSMA/CD MAC method.

4.1.2 CSMA/CD Operation. This section provides an overview of frame transmission and reception in terms of the functional model of the architecture. This overview is descriptive, rather than definitional; the formal specifications of the operations described here are given in 4.2 and 4.3. Specific implementations for CSMA/CD mechanisms that meet this standard are given in 4.4. Figure 4-1 provides the architectural model described functionally in the sections that follow.

The Physical Layer Signaling (PLS) component of the Physical Layer provides an interface to the MAC sublayer for the serial transmission of bits onto the physical media. For completeness, in the operational description that follows some of these functions are included as descriptive material. The concise specification of these functions is given in 4.2 for the MAC functions and in Section 7 for PLS.

Transmit frame operations are independent from the receive frame operations. A transmitted frame addressed to the originating station will be received and passed to the LLC sublayer at that station. This characteristic of the MAC sublayer may be implemented by functionality within the MAC sublayer or full duplex characteristics of portions of the lower layers.

4.1.2.1 Normal Operation

4.1.2.1.1 Transmission Without Contention. When a LLC sublayer requests the transmission of a frame, the Transmit Data Encapsulation component of the CSMA/CD MAC sublayer constructs the frame from the LLC-supplied data. It appends a preamble and a start of frame delimiter to the beginning of the frame. Using information passed by the LLC sublayer, the CSMA/CD MAC sublayer also appends a PAD at the end of the MAC information field of sufficient length to ensure that the transmitted frame length satisfies a minimum frame size requirement (see 4.2.3.3). It also appends destination and source addresses, a length count field, and a frame check sequence to provide for error detection. The frame is then handed to the Transmit Media Access Management component in the MAC sublayer for transmission.

Transmit Media Access Management then attempts to avoid contention with other traffic on the medium by monitoring the carrier sense signal provided by the Physical Layer Signaling (PLS) component and deferring to passing traffic. When the medium is clear, frame transmission is initiated (after a brief inter-

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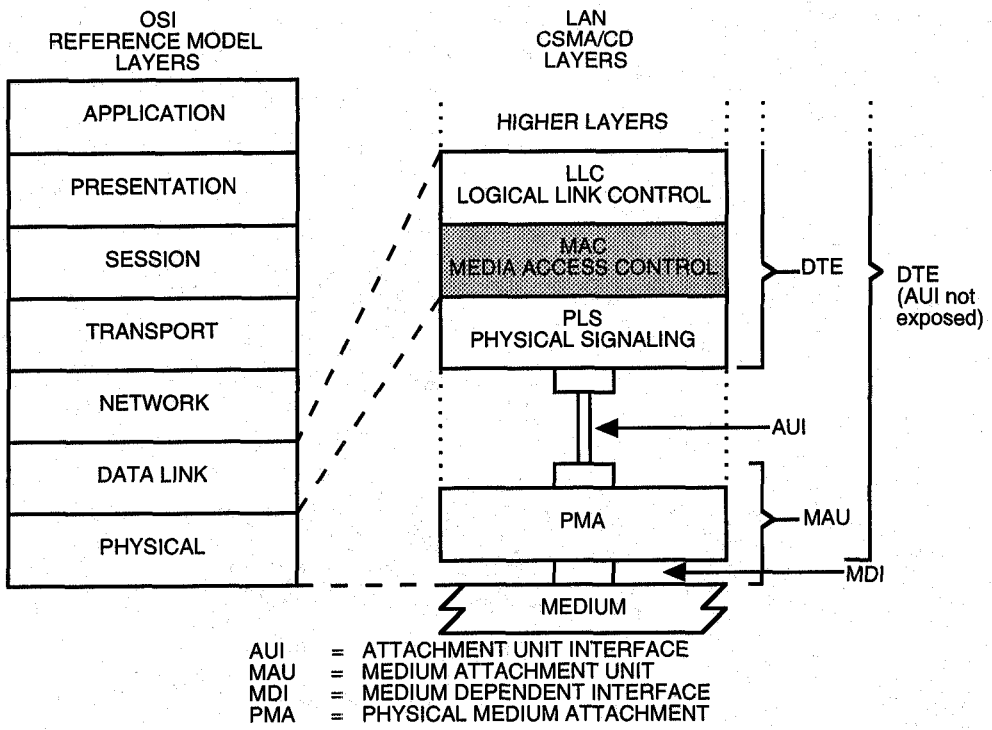


Fig 4-1
MAC Sublayer Partitioning, Relationship to the ISO Open Systems Interconnection (OSI) Reference Model

frame delay to provide recovery time for other CSMA/CD MAC sublayers and for the physical medium). The MAC sublayer then provides a serial stream of bits to the PLS interface for transmission.

The PLS performs the task of actually generating the electrical signals on the medium that represent the bits of the frame. Simultaneously, it monitors the medium and generates the collision detect signal, which, in the contention-free case under discussion, remains off for the duration of the frame. A functional description of the Physical Layer is given in Sections 7 and beyond.

When transmission has completed without contention, the CSMA/CD MAC sublayer so informs the LLC sublayer using the LLC to MAC interface and awaits the next request for frame transmission.

4.1.2.1.2 Reception Without Contention. At each receiving station, the arrival of a frame is first detected by the PLS, which responds by synchronizing with the incoming preamble, and by turning on the carrier sense signal. As the encoded bits arrive from the medium, they are decoded and translated back into binary data. The PLS passes subsequent bits up to the MAC sublayer, where the leading bits are discarded, up to and including the end of the preamble and Start Frame Delimiter.

Meanwhile, the Receive Media Access Management component of the MAC sublayer, having observed carrier sense, has been waiting for the incoming bits to be delivered. Receive Media Access Management collects bits from the PLS as long as the carrier sense signal remains on. When the carrier sense signal is removed, the frame is truncated to an octet boundary, if necessary, and passed to Receive Data Decapsulation for processing.

Receive Data Decapsulation checks the frame's Destination Address field to decide whether the frame should be received by this station. If so, it passes the Destination Address (DA), the Source Address (SA), and the LLC data unit (LLCDU) to the LLC sublayer along with an appropriate status code indicating *reception_complete* or *reception_too_long*. It also checks for invalid MAC frames by inspecting the frame check sequence to detect any damage to the frame enroute, and by checking for proper octet-boundary alignment of the end of the frame. Frames with a valid FCS may also be checked for proper octet boundary alignment.

4.1.2.2 Access Interference and Recovery. If multiple stations attempt to transmit at the same time, it is possible for them to interfere with each other's transmissions, in spite of their attempts to avoid

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this by deferring. When transmissions from two stations overlap, the resulting contention is called a collision. A given station can experience a collision during the initial part of its transmission (the collision window) before its transmitted signal has had time to propagate to all stations on the CSMA/CD medium. Once the collision window has passed, a transmitting station is said to have acquired the medium; subsequent collisions are avoided since all other (properly functioning) stations can be assumed to have noticed the signal (by way of carrier sense) and to be deferring to it. The time to acquire the medium is thus based on the round-trip propagation time of the physical layer whose elements include the PLS, PMA, and physical medium.

In the event of a collision, the transmitting station's Physical Layer initially notices the interference on the medium and then turns on the collision detect signal. This is noticed in turn by the Transmit Media Access Management component of the MAC sublayer, and collision handling begins. First, Transmit Media Access Management enforces the collision by transmitting a bit sequence called jam. In 4.4 an implementation that uses this enforcement procedure is provided. This ensures that the duration of the collision is sufficient to be noticed by the other transmitting station(s) involved in the collision. After the jam is sent, Transmit Media Access Management terminates the transmission and schedules another transmission attempt after a randomly selected time interval. Retransmission is attempted again in the face of repeated collisions. Since repeated collisions indicate a busy medium, however, Transmit Media Access Management attempts to adjust to the medium load by backing off (voluntarily delaying its own retransmissions to reduce its load on the medium). This is accomplished by expanding the interval from which the random retransmission time is selected on each successive transmit attempt. Eventually, either the transmission succeeds, or the attempt is abandoned on the assumption that the medium has failed or has become overloaded.

At the receiving end, the bits resulting from a collision are received and decoded by the PLS just as are the bits of a valid frame. Fragmentary frames received during collisions are distinguished from valid transmissions by the MAC sublayer's Receive Media Access Management component.

4.1.3 Relationships to LLC Sublayer and Physical Layer. The CSMA/CD MAC sublayer provides services to the LLC sublayer required for the transmission and reception of frames. Access to these services is specified in 4.3. The CSMA/CD MAC sublayer makes a best effort to acquire the medium and transfer a serial stream of bits to the PLS. Although certain errors are reported to the LLC, error recovery is not provided by MAC. Error recovery may be provided by the LLC or higher (sub)layers.

4.1.4 CSMA/CD Access Method Functional Capabilities. The following summary of the functional capabilities of the CSMA/CD MAC sublayer is intended as a quick reference guide to the capabilities of the standard, as depicted in Fig 4-2:

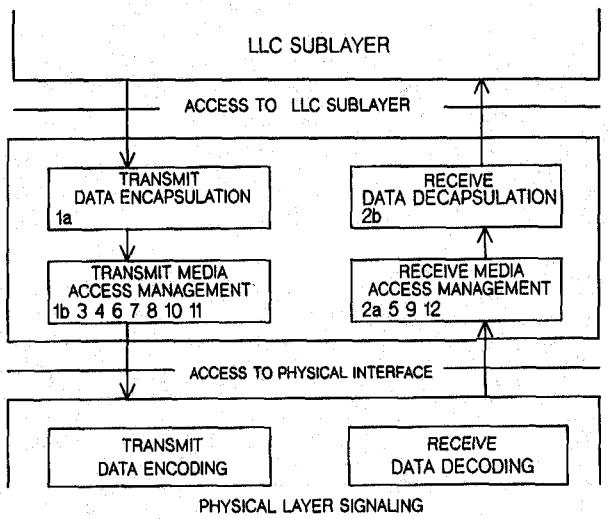
(1) For Frame Transmission
  (a) Accepts data from the LLC sublayer and constructs a frame
  (b) Presents a bit-serial data stream to the physical layer for transmission on the medium

  NOTE: Assumes data passed from the LLC sublayer are octet multiples.

(2) For Frame Reception
  (a) Receives a bit-serial data stream from the physical layer
  (b) Presents to the LLC sublayer frames that are either broadcast frames or directly addressed to the local station
  (c) Discards or passes to Network Management all frames not addressed to the receiving station
(3) Defers transmission of a bit-serial stream whenever the physical medium is busy
(4) Appends proper FCS value to outgoing frames and verifies full octet boundary alignment
(5) Checks incoming frames for transmission errors by way of FCS and verifies octet boundary alignment
(6) Delays transmission of frame bit stream for specified interframe gap period
(7) Halts transmission when collision is detected
(8) Schedules retransmission after a collision until a specified retry limit is reached
(9) Enforces collision to ensure propagation throughout network by sending jam message
(10) Discards received transmissions that are less than a minimum length
(11) Appends preamble, Start Frame Delimiter, DA, SA, length count, and FCS to all frames, and inserts pad field for frames whose LLC data length is less than a minimum value

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(12) Removes preamble, Start Frame Delimiter, DA, SA, length count, FCS and pad field (if necessary) from received frames



NOTE: Numbers refer to functions listed in 4.1.4.

Fig 4-2
CSMA/CD Media Access Control Functions

4.2 CSMA/CD Media Access Control Method (MAC): Precise Specification

4.2.1 Introduction. A precise algorithmic definition is given in this section, providing procedural model for the CSMA/CD MAC process with a program in the computer language Pascal. See references [A2] and [A17] for resource material. Note whenever there is any apparent ambiguity concerning the definition of some aspect of the CSMA/CD MAC method, it is the Pascal procedural specification in 4.2.7 through 4.2.10 which should be consulted for the definitive statement. Sections 4.2.2 through 4.2.6 provide, in prose, a description of the access mechanism with the formal terminology to be used in the remaining subsections.

4.2.2 Overview of the Procedural Model. The functions of the CSMA/CD MAC method are presented below, modeled as a program written in the computer language Pascal. This procedural model is intended as the primary specification of the functions to be provided in any CSMA/CD MAC sublayer implementation. It is important to distinguish, however, between the model and a real implementation. The model is optimized for simplicity and clarity of presentation, while any realistic implementation shall place heavier emphasis on such constraints as efficiency and suitability to a particular implementation technology or computer architecture. In this context, several important properties of the procedural model shall be considered.

4.2.2.1 Ground Rules for the Procedural Model

(1) First, it shall be emphasized that *the description of the MAC sublayer in a computer language is in no way intended to imply that procedures shall be implemented as a program executed by a computer.* The implementation may consist of any appropriate technology including hardware, firmware, software, or any combination.
(2) Similarly, it shall be emphasized that it is the behavior of any MAC sublayer implementations that shall match the standard, not their internal structure. The internal details of the procedural model are useful only to the extent that they help specify that behavior clearly and precisely.
(3) The handling of incoming and outgoing frames is rather stylized in the procedural model, in the sense that frames are handled as single entities by most of the MAC sublayer and are only serial-

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