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**IEEE Std 802.3x-1997 and
IEEE Std 802.3y-1997**

(Supplements to ISO/IEC 8802-3: 1996
[ANSI/IEEE Std 802.3, 1996 Edition])

IEEE Standards for Local and Metropolitan Area Networks:

Supplements to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications—

Specification for 802.3 Full Duplex Operation and Physical Layer Specification for 100 Mb/s Operation on Two Pairs of Category 3 or Better Balanced Twisted Pair Cable (100BASE-T2)

Sponsor

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

Approved 20 March 1997

IEEE Standards Board

Approved 5 September 1997

American National Standards Institute

Abstract for 802.3x-1997: Necessary changes and additions are made to provide for an additional, full duplex mode of operation on a speed-independent basis. Changes are made to the MAC and selected Physical Layer implementations (10BASE-T, 10BASE-FL, 100BASE-T) to support full duplex. A mechanism for pause-based flow control is also added.

Abstract for 802.3y-1997: Changes and additions to the 100BASE-T portion of IEEE Std 802.3 are provided to specify an additional 100 Mb/s transceiver type 100BASE-T, which can support full duplex operation over two pairs of Category 3 or better cabling.

Keywords: 100BASE-T2, Category 3, flow control, full duplex, MAC Control, management, Media Independent Interface (MII), pause, repeater

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ISBN 1-55937-905-7

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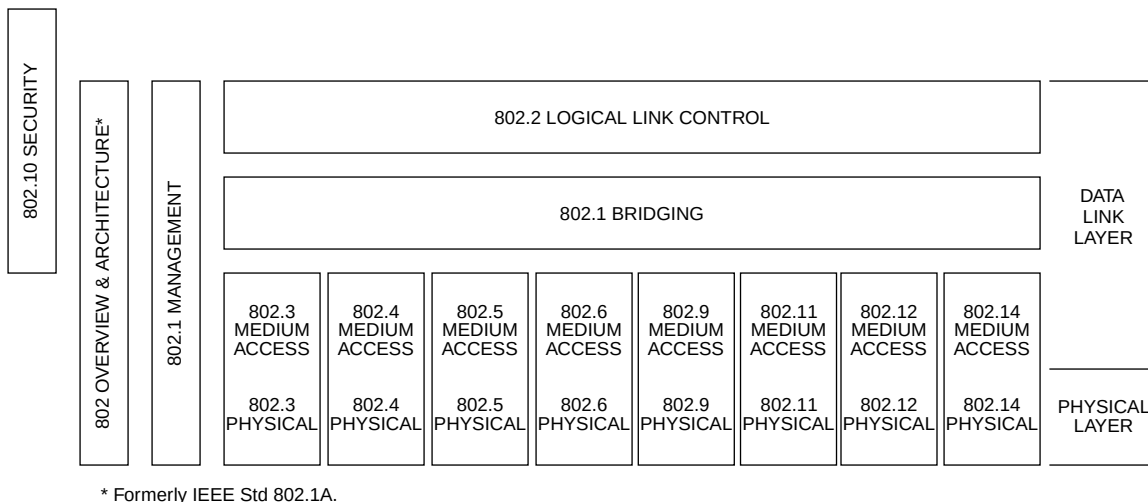
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Introduction

(This introduction is not part of IEEE Std 802.3x-1997 and IEEE Std 802.3y-1997.)

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.)



This family of standards deals with the Physical and Data Link layers as defined by the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) Open Systems Interconnection Basic Reference Model (ISO/IEC 7498-1: 1994). 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 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. This document forms part of the 802.1 scope of work.
- ANSI/IEEE Std 802.1B and 802.1k [ISO/IEC 15802-2] *LAN/MAN Management.* Defines an Open Systems Interconnection (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 [ISO/IEC 10038] *MAC Bridging.* 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 802.2 [ISO/IEC 8802-2] *Logical Link Control*
- ANSI/IEEE Std 802.3 [ISO/IEC 8802-3] *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 802.9 [ISO/IEC DIS 8802-9] *Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers*
- ANSI/IEEE Std 802.10 *Interoperable LAN/MAN Security*
- IEEE Std 802.11 *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*
- ANSI/IEEE Std 802.12 *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*

The following additional working group has authorized standards projects under development:

- IEEE 802.14 *Standard Protocol for Cable-TV Based Broadband Communication Network*

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

Conformance test methodology

An additional standards series, identified by the number 1802, has been established to identify the conformance test methodology documents for the 802 family of standards. Thus the conformance test documents for 802.3 are numbered 1802.3.

IEEE Std 802.3x-1997 and IEEE Std 802.3y-1997

This is a supplement to the IEEE 802.3 standard. At the time this supplement (IEEE Std 802.3x-1997 and IEEE Std 802.3y-1997) was published, the complete IEEE 802.3 standard consisted of the following published documents:

- ISO/IEC 8802-3: 1996 *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.*

Known as “the International Standard,” containing Clauses 1–20.
- IEEE Std 802.3u-1995 *Media Access Control (MAC) Parameters, Physical Layer, Medium Attachment Units, and Repeater for 100 Mb/s Operation, Type 100BASE-T.*

Supplement to the International Standard containing changes to Clauses 1, 2, 4, 5, 14, 19, 20 and adding new Clauses 21–30.
- IEEE Std 802.3r-1996 *Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications—Type 10BASE5 Medium Attachment Unit (MAU) Protocol Implementation Conformance Statement (PICS) Proforma (Subclause 8.8).*

A supplement to the International Standard containing the 10BASE5 MAU PICS Proforma, Subclause 8.8.
- IEEE Std 802.3x-1997 *Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications—Specification for 802.3 Full-Duplex Operation.*

and

IEEE Std 802.3y-1997 *Supplement to Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications—Physical Layer Specification for 100 Mb/s Operation On Two Pairs Of Category 3 Or Better Balanced Twisted Pair Cable (100BASE-T2): Parts 1 and 2.*

This supplement to the International Standard includes changes to Clauses 1–30, which are contained in the above documents, and adds new Clauses 31 and 32. Note that the changes to existing clauses contained in this supplement are in addition to the changes previously defined in IEEE Std 802.3u-1995.

Information on the current revision state of the standard may be obtained from
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IEEE Standards for Local and Metropolitan Area Networks:

**Supplement to Carrier Sense Multiple Access With Collision
Detection (CSMA/CD) Access Method and Physical Layer
Specifications**

**Supplement to IEEE Std 802.3, Including Changes, as
Published in ISO/IEC 8802-3: 1996 and
IEEE Std 802.3u-1995**

NOTE—The editing instructions contained in this supplement define how to merge the material contained herein into the existing base standard and its supplements to form the new comprehensive standard as created by the addition of IEEE Std 802.3x-1997 and IEEE Std 802.3y-1997.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~striketrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make large changes in existing text, subclauses, tables, or figures by removing existing material and replacing it with new material. When modifications are made to paragraphs of existing text, deletions are shown in ~~striketrough~~ type and additions are underscored. Editorial notes will not be carried over into future editions. Note that with the addition of the new footnote 5 in clause 2 that all subsequent footnotes will require renumbering in future editions.

1. Introduction

Insert the following new text in 1.1 between headings 1.1 and 1.1.1:

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 of from 1 Mb/s to 100 Mb/s. This edition of the International Standard provides the necessary specifications for the following three families of systems: 1 Mb/s baseband system, 10 Mb/s baseband and broadband systems, and a 100 Mb/s baseband system.

Replace the text of 1.1.1 with the following new text 1.1.1, 1.1.1.1, and 1.1.1.2:

1.1.1 Basic concepts

This International Standard provides for two distinct modes of operation: half duplex and full duplex. A given ISO/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 International Standard synonymously with “802.3 MAC,” and may represent an instance of either a half duplex or full duplex mode 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 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 transmits for an additional pre-defined 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 International Standard.

Half duplex operation can be used with all media and configurations allowed by this International Standard.

1.1.1.2 Full duplex operation

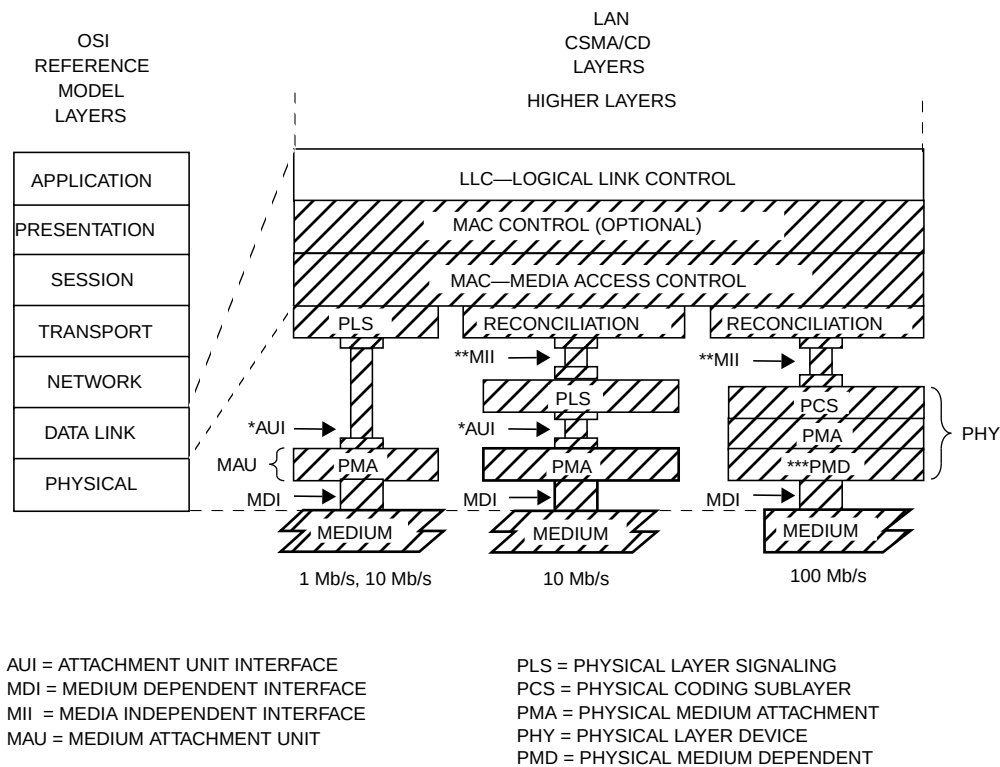
Full duplex operation allows simultaneous communication between a pair of stations using point-to-point media (dedicated channel). Full duplex operation does not require that transmitters defer, nor do they monitor or react to receive activity, as there is no contention for a shared medium in this mode. 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 International 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.

Replace Figure 1-1 with the following new Figure 1-1:



NOTE—The three types of layers below the MAC sublayer are mutually independent.

* AUI is optional for 10 Mb/s systems and is not specified for 1 Mb/s and 100 Mb/s systems.

** MII is optional for 10 Mb/s DTEs and for 100 Mb/s systems and is not specified for 1 Mb/s systems.

*** PMD is specified for 100BASE-X only; 100BASE-T4 does not use this layer.

For an exposed AUI residing below an MII, see 22.5.

Figure 1-1—ISO/IEC 8802-3 relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

Change the text of 1.1.3 to read as follows:

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:

- The interface between the MAC sublayer and the LLC sublayer its client includes facilities for transmitting and receiving frames, and provides per-operation status information for use by higher-layer error recovery procedures.
- 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 5 30.

1.3 References

The following standards contain provisions that, through references in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. 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, except where equivalent International Standards do not exist.

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.

Insert the following references into the current reference clause of ISO/IEC 8802-3:1996 [ANSI/IEEE Std 802.3, 1996 Edition]:

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

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

ISO/IEC 10038: 1993 [ANSI/IEEE Std 802.1D, 1993 Edition], Information technology—Telecommunications and information exchange between systems—Local area networks—Media access control (MAC) bridges.

ITU-T Recommendation I.430 (1995), Basic user-network interface—Layer 1 specification.⁵

1.4 Definitions

Change the following definitions of the current definitions clause of ANSI/IEEE Std 802.3, 1996 Edition (currently published in IEEE Std 802.3u-1995).

1.4.36 bridge: A layer 2 interconnection device that does not form part of a CSMA/CD collision domain but conforms to the ISO/IEC 10038: 1993 [ANSI/IEEE 802.1D, 1993 Edition] International Standard. A bridge does not form part of a CSMA/CD collision domain but, rather appears as a MAC to the collision domain. (See also IEEE Std 100-1996.)

1.4.40 Category 3 balanced eable cabling: Balanced 100 Ω and 120 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 16 MHz (i.e., performance meets the requirements of a Class C link as per ISO/IEC 11801: 1995). Commonly used by IEEE 802.3 10BASE-T installations. In addition to the requirements outlined in ISO/IEC 11801: 1995, IEEE 802.3 clauses 14, 23 and 32 specify additional requirements for this cabling when used with 10BASE-T, 100BASE-T4, and 100BASE-T2 respectively.

1.4.41 Category 4 balanced eable cabling: Balanced 100 Ω and 120 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 20 MHz as per ISO/IEC 11801. In addition to the requirements outlined in ISO/IEC 11801: 1995, IEEE 802.3 clauses 14, 23 and 32 specify additional requirements for this cabling when used with 10BASE-T, 100BASE-T4, and 100BASE-T2 respectively.

⁵ ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland.

1.4.42 Category 5 balanced cable cabling: Balanced 100 Ω and 120 Ω UTP cables and associated connecting hardware whose transmission characteristics are specified up to 100 MHz (i.e., performance meets the requirements of a Class D link as per ISO/IEC 11801: 1995). In addition to the requirements outlined in ISO/IEC 11801: 1995, IEEE 802.3 clauses 14, 23, 25 and 32 specify additional requirements for this cabling when used with 10BASE-T and 100BASE-T.

1.4.58 code-bit: Within IEEE 802.3, in 400BASE-X 100BASE-T, the unit of data passed across the PMA service interface, and the smallest signaling element used for transmission on the medium. A group of five code-bits constitutes a code-group in the 100BASE-X PCS. (See IEEE 802.3, clause 24.)

1.4.59 code-group: For IEEE 802.3, a set of encoded symbols representing encoded data or control information. For 100BASE-T4, a set of six ternary symbols, which, when representing data, conveys an octet. (See IEEE 802.3 clause 23.) For 100BASE-TX and 100BASE-FX, a set of five code-bits that, when representing data, conveys a nibble. For 100BASE-T2, a pair of PAM5 $\times$ 5 symbols that, when representing data, conveys a nibble. (See IEEE 802.3 clauses 23, 24, 32.)

1.4.60 collision domain: A single, half duplex mode CSMA/CD network. If two or more MAC sublayers are within the same collision domain and both transmit at the same time, a collision will occur. MAC sublayers separated by a repeater are in the same collision domain. MAC sublayers separated by a bridge are within different collision domains. (See IEEE 802.3.)

1.4.76 End-of-Stream Delimiter (ESD): Within IEEE 802.3, the End-of-Stream Delimiter is a code-group pattern used to terminate a normal data transmission. For 100BASE-T4, the ESD is indicated by the transmission of five predefined ternary code-groups named eop1-5. For 100BASE-X, the ESD is indicated by the transmission of the code-group /T/R. For 100BASE-T2, the ESD is indicated by two consecutive pairs of predefined PAM5 $\times$ 5 symbols (see table 32-15) which are generated using unique SSD/ESD coding rules.

1.4.93 full duplex: A type of networking that A mode of operation of a network, DTE, or MAU that supports duplex transmission as defined in IEEE Std 610.7-1995 100-1996. Although some types of full duplex networking are popularly referred to as Ethernet because they use the IEEE 802.3 defined frame, full duplex does not employ CSMA/CD and is not covered by this International Standard. Within the scope of this International Standard, this mode of operation allows for simultaneous communication between a pair of stations, provided that the Physical Layer is capable of supporting simultaneous transmission and reception without interference. (See IEEE 802.3.)

1.4.148 Physical Coding Sublayer (PCS): Within IEEE 802.3, a sublayer used in 100BASE-T to couple the MII and the PMA. The PCS contains the functions to encode data bits into code-groups that can be transmitted over the physical medium. Two Three PCS structures are defined for 100BASE-T: one for 100BASE-T4, one for 100BASE-X, and one for 100BASE-T2. (See IEEE 802.3, clauses 23, 24, and 32.)

1.4.149 Physical Layer entity Device (PHY): Within IEEE 802.3, the portion of the Physical Layer between the MDI and MII consisting of the PCS, PMA, and, if present, PMD sublayers. The PHY contains the functions that transmit, receive, and manage the encoded signals that are impressed on and recovered from the physical medium. (See IEEE 802.3, clauses 23–26 and 32.)

1.4.150 Physical Medium Attachment (PMA) sublayer: Within IEEE 802.3, that portion of the Physical Layer that contains the functions for transmission, collision detection, reception, and (in the case of 100BASE-T4), clock recovery and skew alignment. (See IEEE 802.3, clauses 7, 12, 14, 16, 17, 18, 23, 24, and 32.)

1.4.163 repeater: Within IEEE 802.3, a device as specified in clauses 9 and 27 that is used to extend the length, topology, or interconnectivity of the physical medium beyond that imposed by a single segment, up to the maximum allowable end-to-end transmission line length. Repeaters perform the basic actions of restoring signal amplitude, waveform, and timing applied to the normal data and collision signals. For wired

star topologies, repeaters provide a data distribution function. In 100BASE-T, a device that allows the interconnection of 100BASE-T Physical Layer network segments using similar or dissimilar PHY implementations (e.g., 100BASE-X to 100BASE-X, 100BASE-X to 100BASE-T4, etc.). Repeaters are only for use in half duplex mode networks. (See IEEE 802.3, clauses 9 and 27.)

1.4.180 Start-of-Stream Delimiter (SSD): Within IEEE 802.3, a pattern of defined code words used to delineate the boundary of a data transmission sequence on the Physical Layer stream. The SSD is unique in that it may be recognized independent of previously defined code-group boundaries and it defines subsequent code-group boundaries for the stream it delimits. For 100BASE-T4, SSD is a pattern of three predefined sosb code-groups (one per wire pair) indicating the positions of the first data code-group on each wire pair. For 100BASE-X, SSD consists of the code-group sequence /J/K/. For 100BASE-T2, the SSD is indicated by two consecutive pairs of predefined PAM5×5 symbols (± 2 , ± 2) (± 2 , 0) which are generated using unique SSD/ESD coding rules.

1.4.182 symbol: Within IEEE 802.3, the smallest unit of data transmission on the medium. Symbols are unique to the coding system employed. 100BASE-T4 uses ternary symbols; 10BASE-T and 100BASE-X use binary symbols or code bits; 100BASE-T2 uses quinary symbols.

1.4.183 symbol rate (SR): Within IEEE 802.3, the total number of symbols per second transferred to or from the Media Dependent Interface (MDI) on a single wire pair. For 100BASE-T4, the symbol rate is 25 megabaud MBd; for 100BASE-X, the symbol rate is 125 megabaud MBd; for 100BASE-T2, the symbol rate is 25 MBd.

1.4.185 Technology Ability Field: Within IEEE 802.3, an eight-bit field in the Auto-Negotiation base page that is used to indicate the abilities of a local station, such as support for 10BASE-T, 100BASE-T4, 100BASE-TX, and 100BASE-T2, as well as full duplex capabilities.

Insert the following new definitions in the current definitions clause of ANSI/IEEE Std 802.3, 1996 Edition (currently published in IEEE Std 802.3u-1995). These additions must be applied to future editions of ISO/IEC 8802-3, which will incorporate all the supplements, and necessitate further renumbering.

1.4.198 100BASE-T2: IEEE 802.3 specification for a 100Mb/s CSMA/CD LAN over two pairs of category 3 or better balanced cabling. (See IEEE 802.3, clause 32.)

1.4.199 dual duplex: Within IEEE 802.3, a signaling system which supports simultaneous duplex communication over two cabling pairs.

1.4.200 duplex channel: Within IEEE 802.3, a communications channel capable of simultaneous duplex communication.

1.4.201 half duplex: A mode of operation of a CSMA/CD LAN in which DTEs contend for access to a shared medium. Multiple, simultaneous transmissions in a half duplex mode CSMA/CD LAN result in interference, requiring resolution by the CSMA/CD access control protocol. (See IEEE 802.3.)

1.4.202 master PHY: Within IEEE 802.3, in a 100BASE-T2 link containing a pair of PHYs, the PHY which uses an external clock for generating its clock signals to determine the timing of transmitter and receiver operations. It also uses the master transmit scrambler generator polynomial for side-stream scrambling. Master and slave PHY status is determined during the Auto-Negotiation process which takes place prior to establishing the transmission link. *See also: slave PHY.*

1.4.203 PAM5 × 5: Within IEEE 802.3, a block coding technique utilizing a 5×5 matrix (representing two 5-level signals) to generate pairs of quinary codes representing data nibbles and control characters. In 100BASE-T2, PAM5 × 5 code pairs are sent in parallel across two wire pairs. (See IEEE 802.3, clause 32.)

1.4.204 prepend: To append to the beginning. For example, a MAC frame is prepended with a preamble, and appended with an FCS.

1.4.205 quinary: Five-level.

1.4.206 receiver training: Within IEEE 802.3, a startup routine in 100BASE-T2 used to acquire receiver parameters and synchronize the scramblers of two connected PHYs.

1.4.207 retraining: Within IEEE 802.3, the process of re-acquiring receiver parameters and synchronizing the scramblers of two connected 100BASE-T2 PHYs. *See:* **receiver training, blind mode.**

1.4.208 side stream scrambling: A data scrambling technique, used by 100BASE-T2 to randomize the sequence of transmitted symbols and avoid the presence of spectral lines in the signal spectrum. Synchronization of the scrambler and descrambler of connected PHYs is required prior to operation.

1.4.209 slave PHY: Within IEEE 802.3, in a 100BASE-T2 link containing a pair of PHYs, the PHY which recovers its clock from the received signal and uses it to determine the timing of transmitter operations. It also uses the slave transmit scrambler generator polynomial for side-stream scrambling. Master and slave PHY status is determined during the Auto-Negotiation process which takes place prior to establishing the transmission link. *See also:* **master PHY.**

1.4.210 switch: A layer 2 interconnection device which conforms to the ISO/IEC 10038 [ANSI/IEEE 802.1D-1990] International Standard. *Syn:* **bridge.**

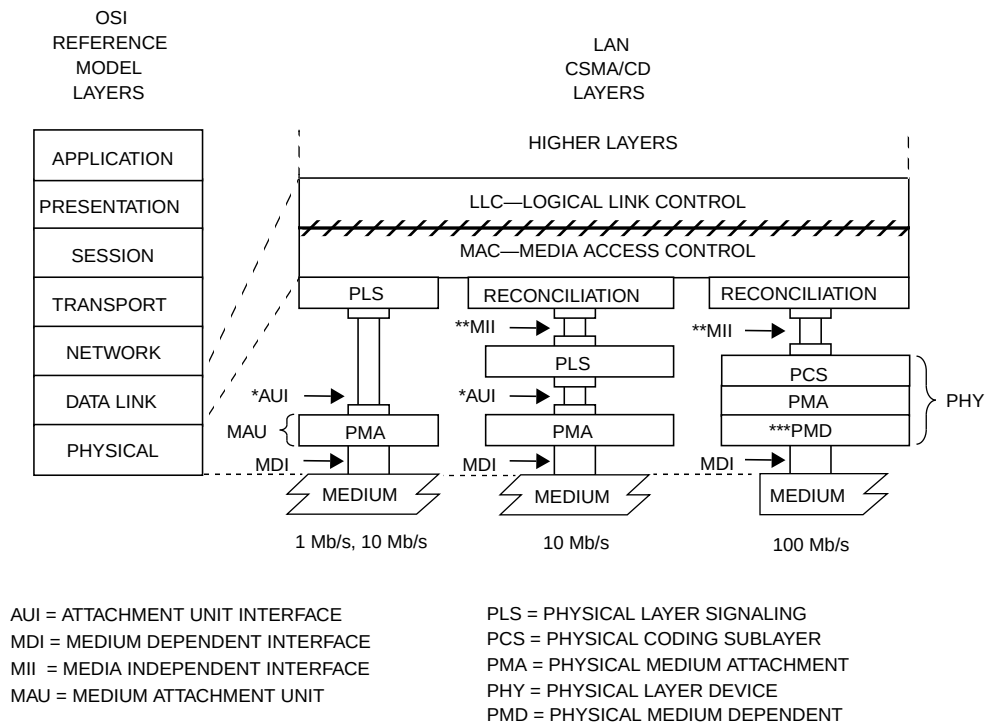
Changes to 2. MAC service specification

2.1 Scope and field of application

Change the text of 2.1 to read as follows:

This subclause specifies the services provided by the Media Access Control (MAC) sublayer and the optional MAC Control sublayer to the client of the MAC (MAC Client). MAC Clients may include the Logical Link Control (LLC) sublayer, Bridge Relay Entity, or other users of ISO/IEC LAN International Standard MAC services (see Figure 2-1b). 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~~ clauses 4 and 31.

Change the numbering of Figure 2-1 to 2-1a as follows:



NOTE—The three types of layers below the MAC sublayer are mutually independent.

* AUI is optional for 10 Mb/s systems and is not specified for 1 Mb/s and 100 Mb/s systems.

** MII is optional for 10 Mb/s DTEs and for 100 Mb/s systems and is not specified for 1 Mb/s systems.

*** PMD is specified for 100BASE-X only; 100BASE-T4 does not use this layer.

For an exposed AUI residing below an MII, see 22.5.

Figure 2-1a—Service specification relation to the LAN model

Insert new Figure 2-1b as follows:

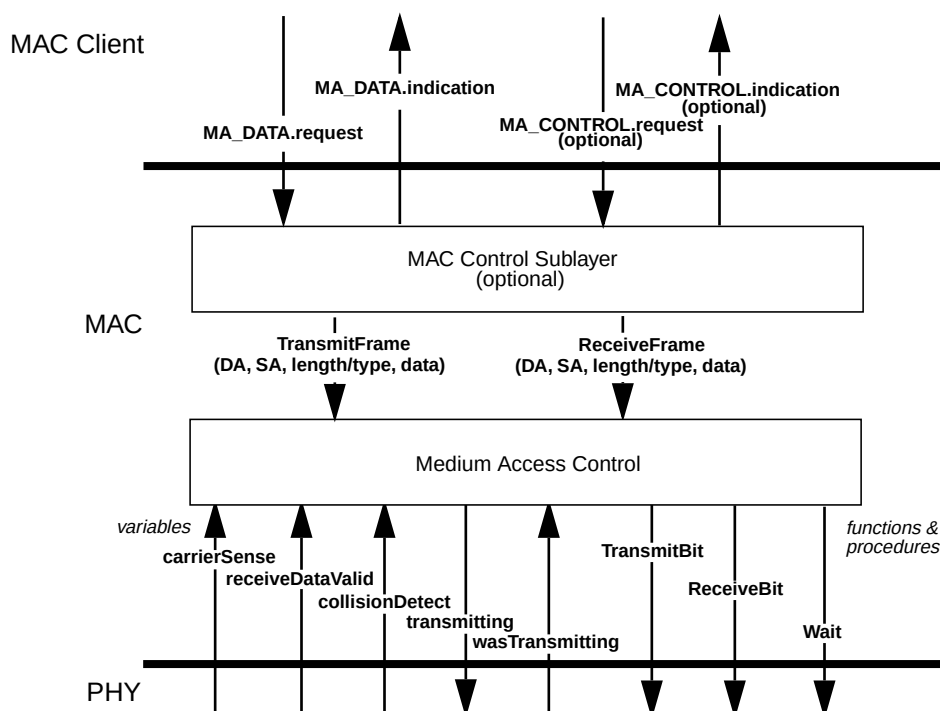


**Figure 2-1b—Service specification primitive relationships
(optional MAC control sublayer implemented)**

2.2 Overview of the service

2.2.1 General description of services provided by the layer

Change the text of 2.2.1 to read as follows:

The services provided by the MAC sublayer allow the local LLC sublayer MAC client 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.

The optional MAC control sublayer provides an additional service for controlling MAC operation. This may be used to provide flow control between peer MAC client entities across the underlying channel.

2.2.2 Model used for the service specification

The model used in this service specification is identical to that used in 1.2.

Change the text of 2.2.3 to read as follows:

2.2.3 Overview of interactions

MA_DATA.request

MA_DATA.indication

MA_CONTROL.request (used by optional MAC Control sublayer)

MA_CONTROL.indication (used by optional MAC Control sublayer)

The MA_DATA.request and MA_DATA.indication service primitives described in this subclause are ~~considered~~ mandatory. The MA_CONTROL.request and MA_CONTROL.indication service primitives are mandatory if the optional MAC Control sublayer is implemented.

2.3 Detailed service specification

2.3.1 MA_DATA.request

Change the text of 2.3.1.1. to read as follows:

2.3.1.1 Function

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

Change the text of 2.3.1.2 to read as follows:

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~~ prepended 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 the ~~LLC or higher layer~~ MAC client (see 2.3.1.5).

Change the text of 2.3.1.3 to read as follows:

2.3.1.3 When generated

This primitive is generated by the ~~LLC sublayer~~ MAC client 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~~ MAC client, such as required by Type 2 LLC service.

Change the text of 2.3.1.4 to read as follows:

2.3.1.4 Effect of receipt

The receipt of this primitive will cause the MAC entity to ~~append~~ insert 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.

2.3.2 MA_DATA.indication

Change the text of 2.3.2.1 to read as follows:

2.3.2.1 Function

This primitive defines the transfer of data from the MAC sublayer entity (through the optional MAC Control sublayer, if implemented) to the ~~LLC sublayer~~ MAC client entity or entities in the case of group addresses.

Change the text of 2.3.2.2. to read as follows:

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~~ MAC client entity.

Change the text of 2.3.2.3. to read as follows:

2.3.2.3 When generated

The MA_DATA.indication is passed from the MAC sublayer entity (through the optional MAC Control sublayer, if implemented) to the ~~LLC sublayer~~ MAC client entity or entities to indicate the arrival of a frame to the local MAC sublayer entity that is destined for the MAC Client. Such frames are reported only if they are validly formed, received without error, and their destination address designates the local MAC entity. Frames destined for the optional MAC Control sublayer are not passed to the MAC Client if the MAC Control sublayer is implemented.

Change the text of 2.3.2.4 to read as follows:

2.3.2.4 Effect of receipt

The effect of receipt of this primitive by the ~~LLC sublayer~~ MAC client is unspecified.

Change the text of 2.3.2.5 to read as follows:

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 MAC client~~ 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).

Insert the following new text 2.3.3, 2.3.3.1–2.3.3.4, 2.3.4, and 2.3.4.1–2.3.4.4 as new material.

2.3.3 MA_CONTROL.request

This primitive defines the transfer of control requests from the MAC client to the MAC Control sublayer. Implementation of the MA_CONTROL.request primitive is mandatory if the optional MAC Control sublayer is implemented in a device.

2.3.3.1 Function

This primitive defines the transfer of control commands from a MAC client entity to the local MAC Control sublayer entity.

2.3.3.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
MA_CONTROL.request      (  
    destination_address,  
    opcode,  
    request_operand_list  
)
```

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 prepended to the frame by the local MAC sublayer entity. The `opcode` specifies the control operation requested by the MAC client entity. The `request_operand_list` is an opcode-specific set of parameters.

The valid opcodes and their respective meanings are defined in clause 31.

2.3.3.3 When generated

This primitive is generated by a MAC client whenever it wishes to use the services of the optional MAC Control sublayer entity.

2.3.3.4 Effect of receipt

The effect of receipt of this primitive by the MAC Control sublayer is opcode-specific. (See clause 31.)

2.3.4 MA_CONTROL.indication

2.3.4.1 Function

This primitive defines the transfer of control status indications from the MAC Control sublayer to the MAC client. Implementation of the `MA_CONTROL.indication` primitive is mandatory if the optional MAC Control sublayer is implemented in a device.

2.3.4.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
MA_CONTROL.indication    (  
    opcode,  
    indication_operand_list  
)
```

The elements of the `indication_operand_list` are opcode-specific, and specified in the annexes to clause 31.

2.3.4.3 When generated

The `MA_CONTROL.indication` is generated by the MAC Control sublayer under conditions specific to each MAC Control operation.

2.3.4.4 Effect of receipt

The effect of receipt of this primitive by the MAC client is unspecified.

Changes to

Change the heading of clause 3 to read as follows:

3. MAC Media access control frame structure

Change the text of 3.1 to read as follows:

3.1 Overview

This clause defines in detail the frame structure for data communication systems using the ~~LAN MAC procedures~~ CSMA/CD MAC. It defines the syntax and semantics of the various components of the MAC frame.

Change the text of 3.1.1 to read as follows:

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/type field to indicate the length or protocol type of the following field containing the ~~LLC MAC Client~~ 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~~ MAC. See 4.4 for particular implementations.

Replace Figure 3-1 with new Figure 3-1 as shown below.

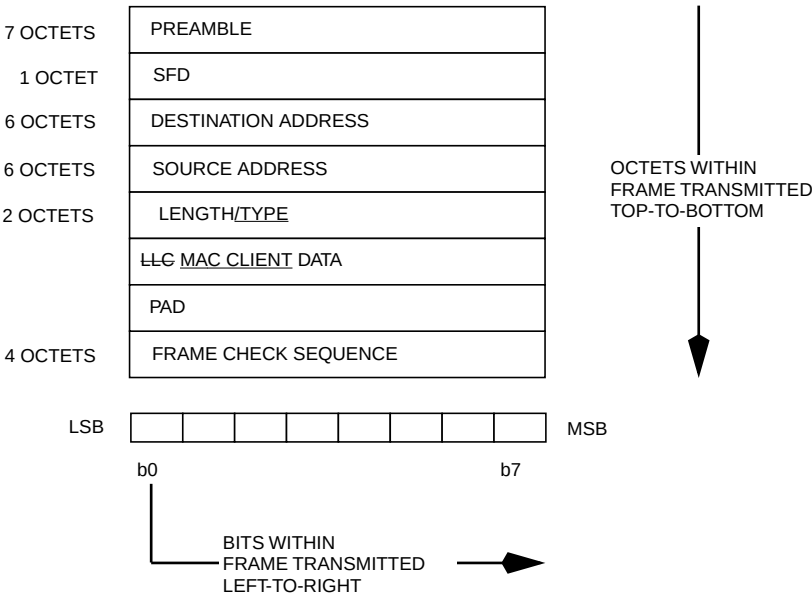


Figure 3-1—MAC frame format

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 Figure 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.

Change the text of the lettered list in 3.2.3 to read as follows:
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 Figure 3-2):

- a) Each address field shall ~~contain either 16 bits or be 48 bits in length. However, at any given time, the Source and Destination Address size shall be the same for all stations on a particular LAN. While IEEE 802 specifies the use of either 16 or 48 bit addresses, no conformant implementation of IEEE 802.3 uses 16 bit addresses. The use of 16 bit addresses is specifically excluded by this International Standard.~~
- b) ~~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.~~
- e) ~~b)~~ 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. 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 LAN. In the Source Address field, the first bit is reserved and set to 0.
- d) ~~c)~~ ~~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.
- e) ~~d)~~ Each octet of each address field shall be transmitted least significant bit first.

Replace Figure 3-2 with new Figure 3-2 as shown:

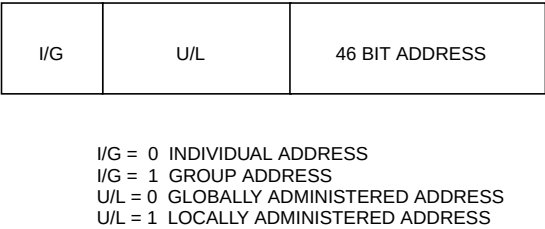


Figure 3-2—Address field format

Change the text of 3.2.3.1 to read as follows:

3.2.3.1 Address designation

A MAC sublayer address is of one of two types:

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

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 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 International Standard.⁶

Change the text of 3.2.6 to read as follows, and delete old Footnote 6 from ISO/IEC 8802-3:

3.2.6 Length/Type field

The Length field is a 2-octet field whose value⁶ indicates the number of LLC data octets in the data field. This two-octet field takes one of two meanings, depending on its numeric value. For numerical evaluation, the first octet is the most significant octet of this field.

- a) If the value of this field is less than or equal to the value of maxValidFrame (as specified in 4.2.7.1), then the Length/Type field indicates the number of MAC client data octets contained in the subsequent data field of the frame (Length interpretation).
- b) If the value of this field is greater than or equal to 1536 decimal (equal to 0600 hexadecimal), then the Length/Type field indicates the nature of the MAC client protocol (Type interpretation). The Length and Type interpretations of this field are mutually exclusive.

When used as a Type field, it is the responsibility of the MAC client to ensure that the MAC client operates properly when the MAC sublayer pads the supplied data, as discussed in 3.2.7.

⁶ For information on how to use MAC addresses, see IEEE Std 802-1990, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture (ANSI). 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; +1 732 562 3813; fax +1 732 562 1571. URL: <http://standards.ieee.org/>

⁶ ~~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 International Standard.~~

⁷ Type field assignments are administered by the Registration Authority, IEEE Standards Department, P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA; +1 732 562 3813; fax +1 732 562 1571. URL: <http://standards.ieee.org/>

~~If the value~~ Regardless of the interpretation of the Length/Type field, if the length of the data field 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/Type field is transmitted and received with the high order octet first.

Change the text of 3.2.7 to read as follows:

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 the International 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 International 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 the ~~LLC~~ MAC client 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~~ MAC client data that is n octets long is $\max(0, \text{minFrameSize} - (8 \times n + 2 \times \text{addressSize} + 48))$ bits. The maximum possible size of the ~~LLC~~ data field is $\text{maxFrameSize} - (2 \times \text{addressSize} + 48)/8$ octets. See 4.4 for a discussion of implementation parameters; see 4.2.3.3 for a discussion of the minFrameSize.

Change the text of 3.2.8 to read as follows:

3.2.8 Frame check sequence (FCS) field

A cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the FCS field. The 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/type, ~~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:

- The first 32 bits of the frame are complemented.
- 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.)
- $M(x)$ is multiplied by x^{32} and divided by $G(x)$, producing a remainder $R(x)$ of degree ≤ 31 . (EDITORIAL NOTE—This is a change from less than ($<$) to less than or equal to ($\leq$).)
- The coefficients of $R(x)$ are considered to be a 32-bit sequence.
- The bit sequence is complemented and the result is the CRC.

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 rightmost bit of the last octet. (The bits of the CRC are thus transmitted in the order $x^{31}, x^{30}, \dots, x^1, x^0$.) See reference [A23].

Change the text of 3.4 to read as follows and insert new Footnote 8:

3.4 Invalid MAC frame

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

- a) The frame length is inconsistent with ~~the~~ a length field value specified in the length/type field. If the length/type field contains a type value as defined by 3.2.6, then the frame length is assumed to be consistent with this field and should not be considered an invalid frame on this basis.
- b) It is not an integral number of octets in length.
- c) 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 the LLC or MAC Control sublayers.⁸ The occurrence of invalid MAC frames may be communicated to network management.

⁸ Invalid MAC frames may be ignored, discarded, or used in a private manner by MAC clients other than LLC or MAC control. The use of such frames is beyond the scope of this International Standard.

Changes to

4. Media access control

4.1 Functional model of the media access control method

Change the second paragraph of 4.1.1 to read as follows:

4.1.1 Overview

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 LAN LLC sublayer (or other MAC client). 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).

Insert the following as new text in 4.1.1 below the lettered list:

An optional MAC control sublayer, architecturally positioned between LLC (or other MAC client) and the MAC, is specified in clause 31. This MAC Control sublayer is transparent to both the underlying MAC and its client (typically LLC). The MAC sublayer operates independently of its client; i.e., it is unaware whether the client is LLC or the MAC Control sublayer. This allows the MAC to be specified and implemented in one manner, whether or not the MAC Control sublayer is implemented. References to LLC as the MAC client in text and figures apply equally to the MAC Control sublayer, if implemented.

This supplement provides for two modes of operation of the MAC sublayer:

- a) In *half duplex* mode, stations contend for the use of the physical medium, using the CSMA/CD algorithms specified. Bi-directional communication is accomplished by rapid exchange of frames, rather than full duplex operation. Half duplex operation is possible on all supported media; it is required on those media that are incapable of supporting simultaneous transmission and reception without interference, for example, 10BASE2 and 100BASE-T4.
- b) The *full duplex* mode of operation can be used when all of the following are true:
 - 1) The physical medium is capable of supporting simultaneous transmission and reception without interference (e.g., 10BASE-T, 10BASE-FL, and 100BASE-TX/FX).
 - 2) There are exactly two stations on the LAN. This allows the physical medium to be treated as a full duplex point-to-point link between the stations. Since there is no contention for use of a shared medium, the multiple access (i.e., CSMA/CD) algorithms are unnecessary.
 - 3) Both stations on the LAN are capable of and have been configured to use full duplex operation.

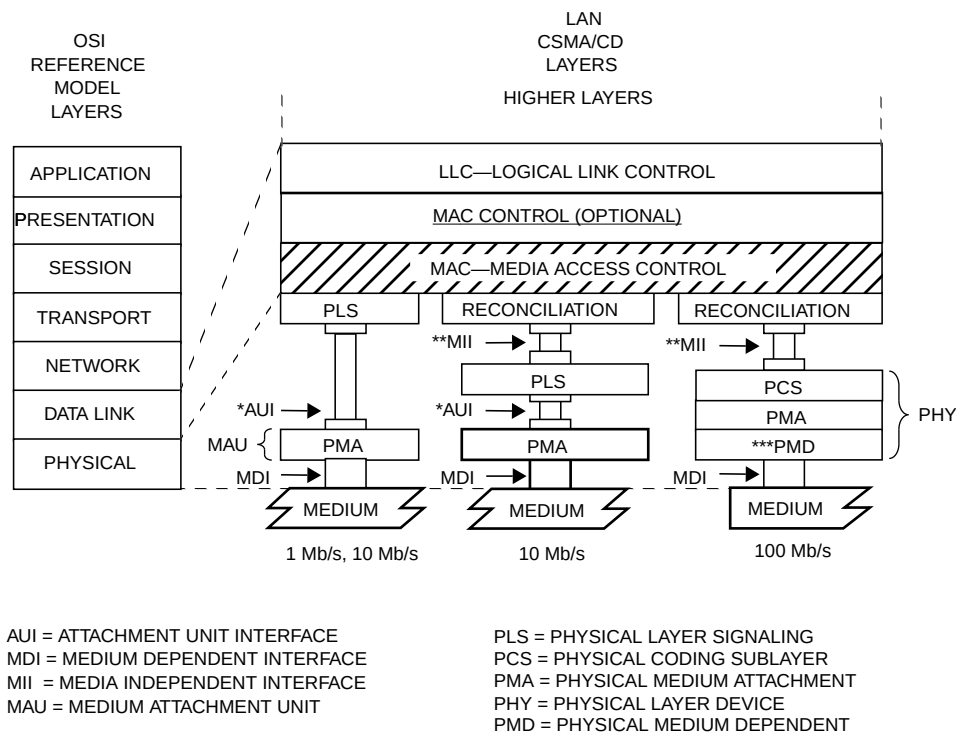
The most common configuration envisioned for full duplex operation consists of a central bridge (also known as a switch) with a dedicated LAN connecting each bridge port to a single device.

Change the last paragraph of 4.1.1 to read as follows:

The formal specification of the MAC in 4.2 comprises both the half duplex and full duplex modes of operation. The remainder of this clause provides a functional model of the CSMA/CD MAC method.

4.1.2 CSMA/CD operation

Replace Figure 4-1 with new Figure 4-1 below.



NOTE—The three types of layers below the MAC sublayer are mutually independent.

* AUI is optional for 10 Mb/s systems and is not specified for 1 Mb/s and 100 Mb/s systems.

** MII is optional for 10 Mb/s DTEs and for 100 Mb/s systems and is not specified for 1 Mb/s systems.

*** PMD is specified for 100BASE-X only.

For an exposed AUI residing below an MII, see 22.5.

Figure 4-1—MAC sublayer partitioning, relationship to the ISO Open Systems Interconnection (OSI) reference model

Change the last paragraph of 4.1.2 to read as follows:

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 MAC client 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

Change the text of 4.1.2.1.1 to read as follows:

4.1.2.1.1 Transmission without contention

When a LLC sublayer MAC client requests the transmission of a frame, the Transmit Data Encapsulation component of the CSMA/CD MAC sublayer constructs the frame from the LLC client-supplied data. It appends prepends a preamble and a start of frame delimiter to the beginning of the frame. Using information passed by the LLC sublayer provided by the client, 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 prepends destination and source addresses, the length count/type field, and appends 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.

In half duplex mode, 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 interframe 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~~ Physical Layer for transmission.

In full duplex mode, there is no need for Transmit Media Access Management to avoid contention with other traffic on the medium. Frame transmission may be initiated after the interframe delay, regardless of the presence of receive activity.

The ~~PLS~~ Physical Layer 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 clauses 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~~ MAC client and awaits the next request for frame transmission.

Change the text of 4.1.2.1.2 to read as follows:

4.1.2.1.2 Reception without contention

At each receiving station, the arrival of a frame is first detected by the ~~PLS~~ physical layer, which responds by synchronizing with the incoming preamble, and by turning on the ~~carrier sense~~ receiveDataValid 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~~ receiveDataValid, 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~~ receiveDataValid signal remains on. When the ~~carrier sense~~ receiveDataValid 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)~~, the Type/Length field, and the data to the ~~LLC sublayer~~ MAC client 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.

Change the text of 4.1.2.2 to read as follows:

4.1.2.2 Access interference and recovery

In half duplex mode, 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 this by deferring. When transmissions from two stations overlap, the resulting contention is called a collision. Collisions occur only in half duplex mode, where a collision indicates that there is more than one station attempting to use the shared physical medium. In full duplex mode, two stations may transmit to each other simultaneously without causing interference. The Physical Layer may generate a collision indication, but this is ignored by the full duplex MAC.

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 signal)~~ 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. In half duplex mode, 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~~ implementations that use this enforcement procedure ~~is~~ are 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.

In full duplex mode, a station ignores any collision detect signal generated by the Physical Layer. Transmit Media Access Management in a full duplex station will always be able to transmit its frames without contention, so there is never any need to jam or reschedule transmissions.

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.

Change the text of 4.1.3 to read as follows:

4.1.3 Relationships to the ~~LLC sublayer~~ MAC client and Physical Layer Layers

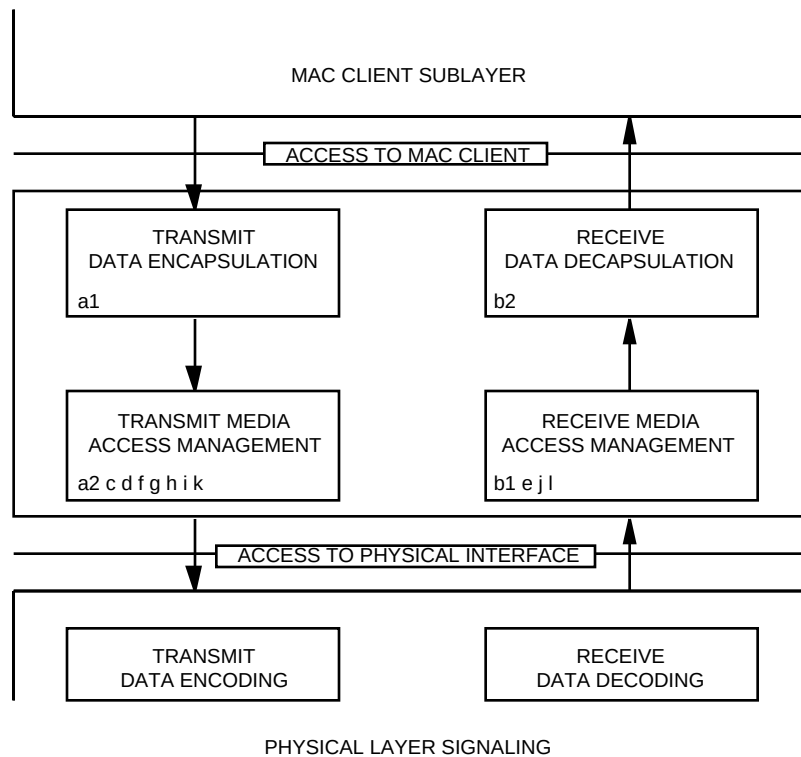
The CSMA/CD MAC sublayer provides services to the ~~LLC sublayer~~ MAC client required for the transmission and reception of frames. Access to these services is specified in 4.3. The CSMA/CD MAC sublayer makes a best effort to acquire the medium and transfer a serial stream of bits to the ~~PLS~~ Physical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

Change the text of 4.1.4 to read as follows:

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 International Standard, as shown in Figure 4-2:

Insert a new figure, Figure 4-2, in 4.1.4 as follows:



NOTE—Designations refer to functions listed in 4.1.4.

Figure 4-2—CSMA/CD Media Access Control functions

- a) For Frame Transmission
 - 1) Accepts data from the LLC sublayer MAC client and constructs a frame
 - 2) Presents a bit-serial data stream to the Physical Layer for transmission on the medium
- NOTE—Assumes data passed from the LLC client sublayer are octet multiples.
- b) For Frame Reception
 - 1) Receives a bit-serial data stream from the Physical Layer
 - 2) Presents to the LLC MAC client sublayer frames that are either broadcast frames or directly addressed to the local station
 - 3) Discards or passes to Network Management all frames not addressed to the receiving station
- c) In half duplex mode, defers transmission of a bit-serial stream whenever the physical medium is busy
- d) Appends proper FCS value to outgoing frames and verifies full octet boundary alignment
- e) Checks incoming frames for transmission errors by way of FCS and verifies octet boundary alignment
- f) Delays transmission of frame bit stream for specified interframe gap period
- g) In half duplex mode, halts transmission when collision is detected
- h) In half duplex mode, schedules retransmission after a collision until a specified retry limit is reached
- i) In half duplex mode, enforces collision to ensure propagation throughout network by sending jam message
- j) Discards received transmissions that are less than a minimum length
- k) Appends preamble, Start Frame Delimiter, DA, SA, length count/type field, and FCS to all frames, and inserts PAD field for frames whose LLC data length is less than a minimum value
- l) Removes preamble, Start Frame Delimiter, DA, SA, length count/type field, FCS and pad field (if necessary) from received frames

Change the heading of 4.2 to read as follows:

4.2 CSMA/CD Media Access Control (MAC) method: Precise specification

Change the text of the last paragraph of 4.2.2.1 to read as follows:

4.2.2.1 Ground rules for the procedural model

It is intended that the concurrency in the model reflect the parallelism intrinsic to the task of implementing the LLC MAC client and MAC procedures, although the actual parallel structure of the implementations is likely to vary.

Change the text of 4.2.2.3 to read as follows:

4.2.2.3 Organization of the procedural model

The procedural model used here is based on five cooperating concurrent processes. Three are actually defined in the MAC sublayer. The remaining two processes are provided by the clients of the MAC sublayer (that may include the LLC sublayer) and utilize the interface operations provided by the MAC sublayer. The five processes are thus:

- a) Frame Transmitter process
- b) Frame Receiver process
- c) Bit Transmitter process
- d) Bit Receiver process
- e) Deference process

This organization of the model is illustrated in Figure 4-3 and reflects the fact that the communication of entire frames is initiated by the client of the MAC sublayer, while the timing of collision backoff and of individual bit transfers is based on interactions between the MAC sublayer and the Physical-Layer-dependent bit time.

Replace Figure 4-3 with new Figure 4-3 as follows:

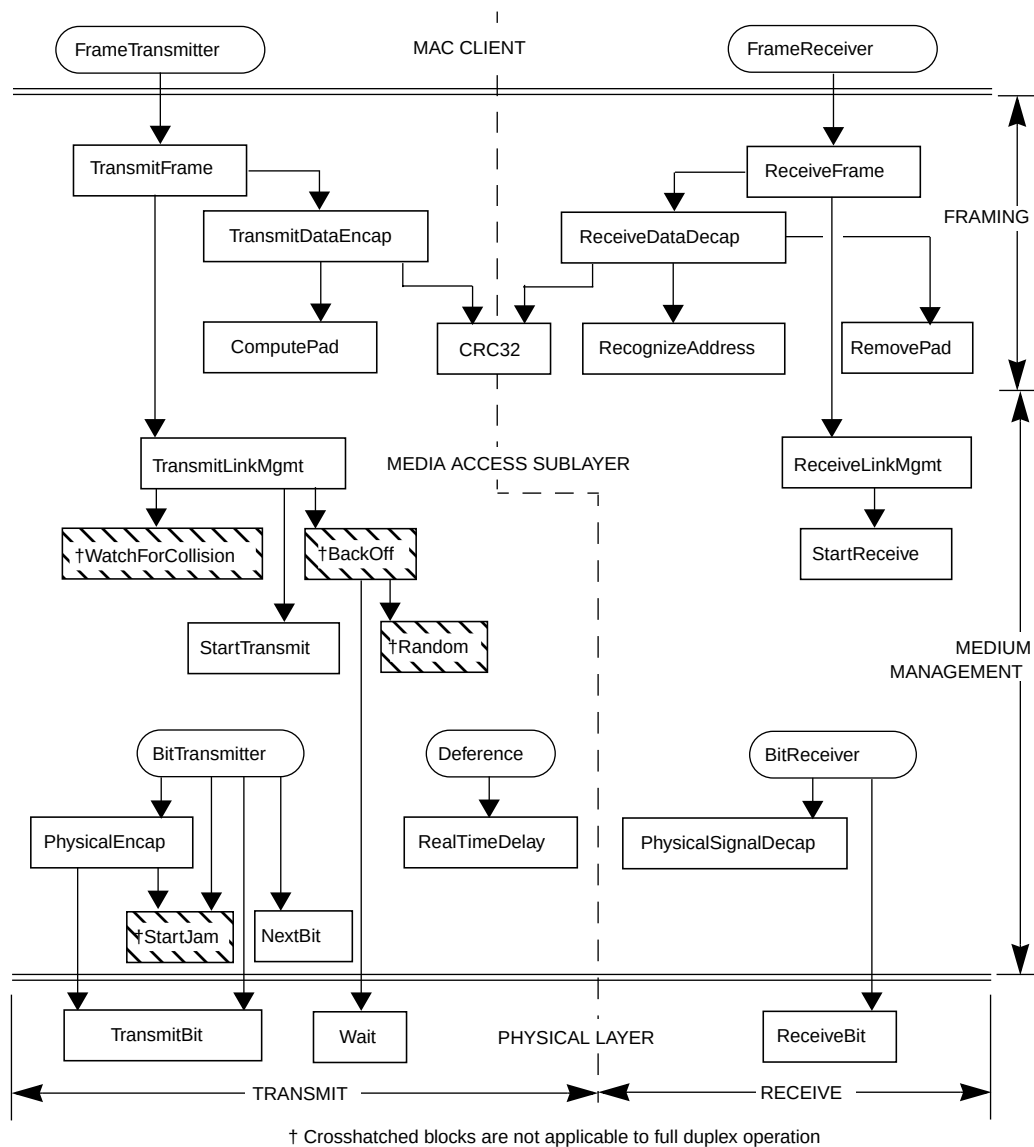


Figure 4-3—Relationship among CSMA/CD procedures

Figure 4-3 depicts the static structure of the procedural model, showing how the various processes and procedures interact by invoking each other. Figures 4-4 4-4a, 4-4b and 4-5 summarize the dynamic behavior of the model during transmission and reception, focusing on the steps that shall be performed, rather than the procedural structure that performs them. The usage of the shared state variables is not depicted in the figures, but is described in the comments and prose in the following subclauses.

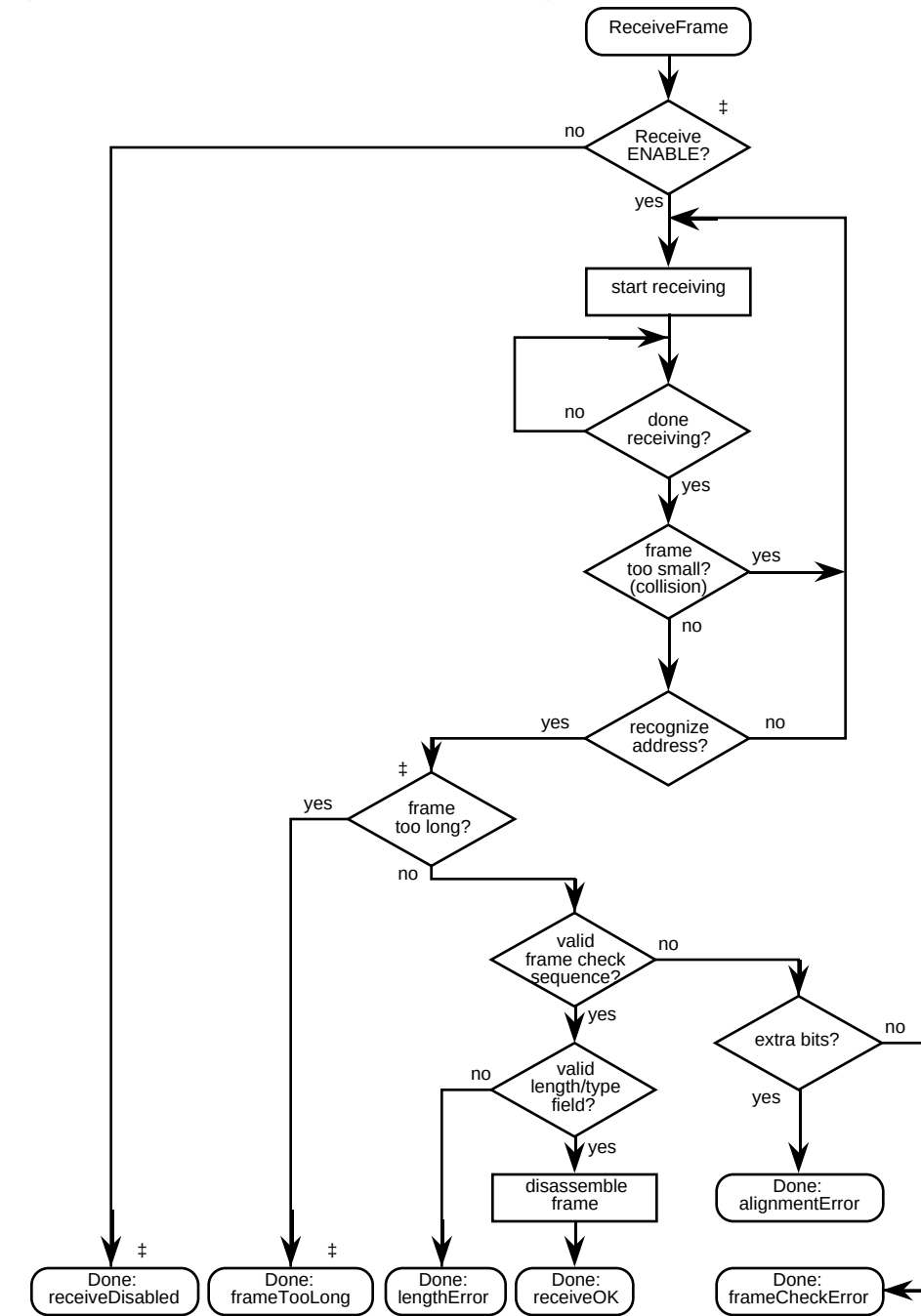
```

graph TD
    Start([TransmitFrame]) --> Enable{Transmit ENABLE?}
    Enable -- no --> Disabled([Done: transmitDisabled])
    Enable -- yes --> Assemble[assemble frame]
    Assemble --> Deferring{deferring on?}
    Deferring -- yes --> Deferring
    Deferring -- no --> StartTx[start transmission]
    StartTx --> Collision{half-duplex AND collisionDetect?}
    Collision -- yes --> Jam[send jam]
    Jam --> Attempts[increment attempts]
    Attempts --> TooMany{too many attempts?}
    TooMany -- yes --> Excessive([Done: excessiveCollisionError])
    TooMany -- no --> Backoff[compute backoff]
    Backoff --> Wait[wait backoff time]
    Wait --> Deferring
    Collision -- no --> DoneTx{transmission done?}
    DoneTx -- yes --> OK([Done: transmitOK])
    DoneTx -- no --> Collision
  
```

‡ For Layer Management

Figure 4-4a—Control flow summary

Replace Figure 4-4 part (b), Receive Frame, with new Figure 4-4b as follows:



‡ For Layer Management

(b) ReceiveFrame

Figure 4-4b—Control flow summary

Replace Figure 4-5 with new Figure 4-5 as follows:

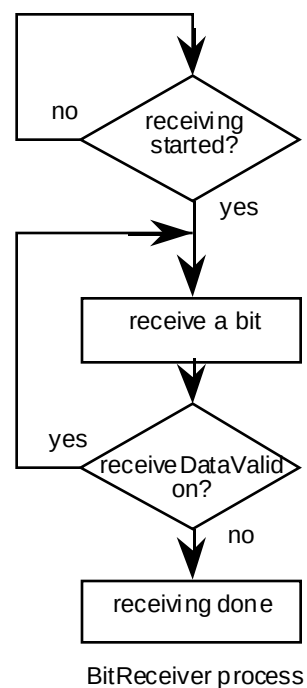
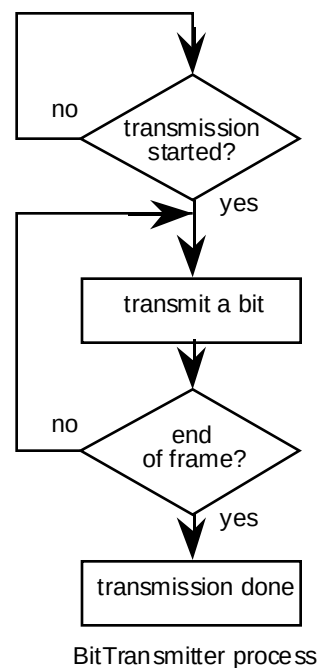
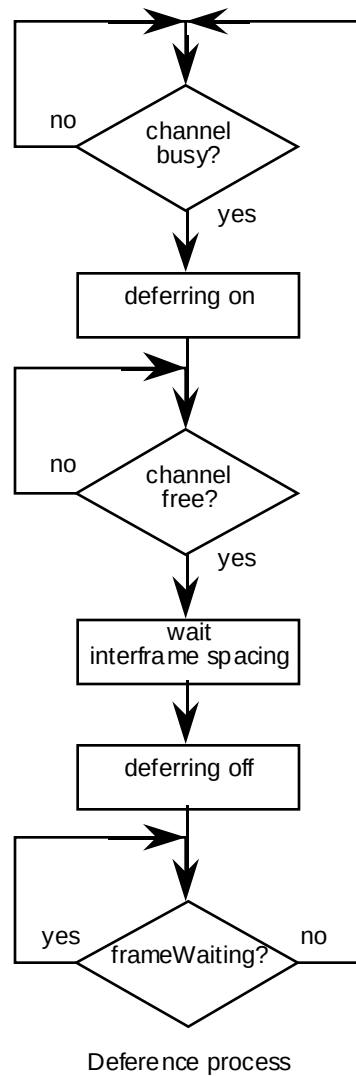


Figure 4-5—Control flow: MAC sublayer

Change the text of 4.2.3 to read as follows:

4.2.3 Frame transmission model

Frame transmission includes data encapsulation and Media Access management aspects:

- a) Transmit Data Encapsulation includes the assembly of the outgoing frame (from the values provided by the ~~LLC sublayer~~ MAC client) and frame check sequence generation.
- b) Transmit Media Access Management includes carrier deference, interframe spacing, collision detection and enforcement, and collision backoff and retransmission.

4.2.3.1 Transmit data encapsulation

Change the text of 4.2.3.1.1 to read as follows:

4.2.3.1.1 Frame assembly

The fields of the CSMA/CD MAC frame are set to the values provided by the ~~LLC sublayer~~ MAC client as arguments to the TransmitFrame operation (see 4.3) with the exception of the padding necessary to enforce the minimum frame size and the frame check sequence that is set to the CRC value generated by the MAC sublayer.

Change the text of 4.2.3.1.2 to read as follows:

4.2.3.1.2 Frame check sequence generation

The CRC value defined in 3.8 is generated and inserted in the frame check sequence field, following the fields supplied by the ~~LLC sublayer~~ MAC client.

4.2.3.2 Transmit media access management

Change the text of 4.2.3.2.1 to read as follows:

4.2.3.2.1 Carrier Deference

~~Even when it has nothing to transmit, the CSMA/CD MAC sublayer monitors the physical medium for traffic by watching the carrierSense signal provided by the PLS. Whenever the medium is busy, the CSMA/CD MAC sublayer defers to the passing frame by delaying any pending transmission of its own. After the last bit of the passing frame (that is, when carrierSense changes from true to false), the CSMA/CD MAC sublayer continues to defer for a proper interFrameSpacing (see 4.2.3.2.2).~~

~~If, at the end of interFrameSpacing, a frame is waiting to be transmitted, transmission is initiated independent of the value of carrierSense. When transmission has completed (or immediately, if there was nothing to transmit) the CSMA/CD MAC sublayer resumes its original monitoring of carrierSense.~~

When a frame is submitted by the ~~LLC sublayer~~ MAC client for transmission, the transmission is initiated as soon as possible, but in conformance with the rules of deference stated ~~above~~ below. The rules of deference differ between half duplex and full duplex modes.

a) Half duplex mode

Even when it has nothing to transmit, the CSMA/CD MAC sublayer monitors the physical medium for traffic by watching the carrierSense signal provided by the PLS. Whenever the medium is busy, the CSMA/CD MAC defers to the passing frame by delaying any pending transmission of its own. After the last bit of the passing frame (that is, when carrierSense changes from true to false), the CSMA/CD MAC continues to defer for a proper interFrameSpacing (see 4.2.3.2.2).

If, at the end of the interFrameSpacing, a frame is waiting to be transmitted, transmission is initiated independent of the value of carrierSense. When transmission has completed (or immediately, if there was nothing to transmit) the CSMA/CD MAC sublayer resumes its original monitoring of carrierSense.

NOTE—It is possible for the PLS carrier sense indication to fail to be asserted briefly during a collision on the media. If the Deference process simply times the interframe gap based on this indication it is possible for a short interframe gap to be generated, leading to a potential reception failure of a subsequent frame. To enhance system robustness the following optional measures, as specified in 4.2.8, are recommended when `interFrameSpacingPart1` is other than zero:

1) Upon completing a transmission, start timing the interpacket gap as soon as `transmitting` and `carrierSense` are both false.

2) When timing an interframe gap following reception, reset the interframe gap timing if `carrierSense` becomes true during the first 2/3 of the interframe gap timing interval. During the final 1/3 of the interval the timer shall not be reset to ensure fair access to the medium. An initial period shorter than 2/3 of the interval is permissible including zero.

b) Full duplex Mode

In full duplex mode, the CSMA/CD MAC does not defer pending transmissions based on the `carrierSense` signal from the PLS. Instead, it uses the internal variable `transmitting` to maintain proper MAC state while the transmission is in progress. After the last bit of a transmitted frame, (that is, when `transmitting` changes from true to false), the MAC continues to defer for a proper `interFrameSpacing` (see 4.2.3.2.2).

Change the heading of 4.2.3.2.3 to read as follows:

4.2.3.2.3 Collision handling (half duplex mode only)

Change the heading of 4.2.3.2.4 to read as follows:

4.2.3.2.4 Collision detection and enforcement (half duplex mode only)

Change the heading of 4.2.3.2.5 to read as follows:

4.2.3.2.5 Collision backoff and retransmission (half duplex mode only)

Insert 4.2.3.2.6 as new text after 4.2.3.2.5 as follows:

4.2.3.2.6 Full duplex transmission

In full duplex mode, there is never contention for a shared physical medium. The Physical Layer may indicate to the MAC that there are simultaneous transmissions by both stations, but since these transmissions do not interfere with each other, a MAC operating in full duplex mode must not react to such Physical Layer indications. Full duplex stations do not defer to received traffic, nor abort transmission, jam, backoff and reschedule transmissions as part of Transmit Media Access Management. Transmissions may be initiated whenever the station has a frame queued, subject only to the interframe spacing required to allow recovery for other sublayers and for the physical medium.

Change the text of 4.2.3.3 to read as follows:

4.2.3.3 Minimum frame size

The CSMA/CD Media Access mechanism requires that a minimum frame length of `minFrameSize` bits be transmitted. If `frameSize` is less than `minFrameSize`, then the CSMA/CD MAC sublayer shall append extra bits in units of octets, after the end of the `LLC MAC client` data field but prior to calculating, and appending, the FCS. The number of extra bits shall be sufficient to ensure that the frame, from the DA field through the FCS field inclusive, is at least `minFrameSize` bits. The content of the pad is unspecified.

Change the text of 4.2.4 to read as follows:

4.2.4 Frame reception model

CSMA/CD MAC sublayer frame reception includes both data decapsulation and Media Access management aspects:

- a) Receive Data Decapsulation comprises address recognition, frame check sequence validation, and frame disassembly to pass the fields of the received frame to the `LLC sublayer MAC client`
- b) Receive Media Access Management comprises recognition of collision fragments from incoming frames and truncation of frames to octet boundaries

4.2.4.1 Receive data decapsulation

Change the text of 4.2.4.1.3 to read as follows:

4.2.4.1.3 Frame disassembly

Upon recognition of the Start Frame Delimiter at the end of the preamble sequence, the CSMA/CD MAC sublayer accepts the frame. If there are no errors, the frame is disassembled and the fields are passed to the LLC sublayer MAC client by way of the output parameters of the ReceiveFrame operation.

4.2.4.2 Receive media access management

Change the text of the first paragraph of 4.2.4.2.1 to read as follows:

4.2.4.2.1 Framing

The CSMA/CD sublayer recognizes the boundaries of an incoming frame by monitoring the carrierSense receiveDataValid signal provided by the PLS Physical Layer. There are two possible length errors that can occur that indicate ill-framed data: the frame may be too long, or its length may not be an integer number of octets.

Change the text of 4.2.4.2.2 to read as follows:

4.2.4.2.2 Collision filtering

The smallest valid frame shall be at least one slotTime in length. This determines the minFrameSize. Any frame containing less than minFrameSize bits is presumed to be a fragment resulting from a collision. In half duplex mode, since occasional collisions are a normal part of the Media Access management procedure the discarding of such a fragment is not reported as an error to the LLC sublayer. While collisions do not occur in full duplex mode MACs, nevertheless a full duplex mode MAC also discards received frames containing less than minFrameSize bits. The discarding of such a fragment by a MAC is not reported as an error.

Change the text of 4.2.6 to read as follows:

4.2.6 Start frame sequence

The PLS recognizes the presence of activity on the medium through the carrier sense signal. This is the first indication. The receiveDataValid signal is the indication to the MAC that the frame reception process should begin. Upon reception of the sequence 10101011 immediately following a latter part of the preamble pattern the assertion of receiveDataValid, PhysicalSignalDecap shall begin passing successive bits to ReceiveLinkMgmt for passing to the LLC sublayer MAC Client.

Change the text of 4.2.7.1 to read as follows:

4.2.7.1 Common constants and types

The following declarations of constants and types are used by the frame transmission and reception sections of each CSMA/CD sublayer:

const

```
addressSize = ... ; {16 or 48 bits in compliance with 3.2.3}
lengthOrTypeSize = 16; {in bits}
LLC dataSize clientDataSize = ...; {LLC MAC client data; see 4.2.2.2, a)3)}
padSize = ...; {in bits, = max (0, minFrameSize - (2 x addressSize + lengthOrTypeSize + LLC
    clientDataSize + crcSize))}.
dataSize = ...; {= LLC clientDataSize + padSize}
crcSize = 32; {32 bit CRC = 4 octets}
frameSize = ...; {= 2 x addressSize + lengthOrTypeSize + dataSize + crcSize; see 4.2.2.2, a)}
minFrameSize = ...; {in bits, implementation-dependent; see 4.4}
maxFrameSize = ...; {in octets, implementation-dependent; see 4.4}
minTypeValue = 1536; {minimum value of the Length/Type field for Type interpretation}
```

$\text{maxValidFrame} = \text{maxFrameSize} - (2 \times \text{addressSize} + \text{lengthOrTypeSize} + \text{crcSize}) / 8$; {in octets,
the maximum length of the MAC Client data field. This constant is defined for
editorial convenience, as a function of other constants}

$\text{slotTime} = \dots$; {unit of time for collision handling, implementation-dependent; see 4.4}
 $\text{preambleSize} = \dots$; {in bits, physical-medium-dependent}
 $\text{sfdSize} = 8$; {8 bit start frame delimiter}
 $\text{headerSize} = \dots$; {sum of preambleSize and sfdSize }

type

$\text{Bit} = 0..1$;
 $\text{AddressValue} = \text{array } [1..\text{addressSize}] \text{ of Bit}$;
 $\text{LengthOrTypeValue} = \text{array } [1..\text{lengthOrTypeSize}] \text{ of Bit}$;
 $\text{DataValue} = \text{array } [1..\text{dataSize}] \text{ of Bit}$;
 $\text{CRCValue} = \text{array } [1..\text{crcSize}] \text{ of Bit}$;
 $\text{PreambleValue} = \text{array } [1..\text{preambleSize}] \text{ of Bit}$;
 $\text{SfdValue} = \text{array } [1..\text{sfdSize}] \text{ of Bit}$;
 $\text{ViewPoint} = (\text{fields}, \text{bits})$; {Two ways to view the contents of a frame}
 $\text{HeaderViewPoint} = (\text{headerFields}, \text{headerBits})$;
 $\text{Frame} = \text{record}$ {Format of Media Access frame}
 case view: ViewPoint of
 fields: (
 destinationField: AddressValue;
 sourceField: AddressValue;
 lengthOrTypeField: LengthOrTypeValue;
 dataField: DataValue;
 fcsField: CRCValue);
 bits: (contents: array [1..frameSize] of Bit)
 end; {Frame}
 $\text{Header} = \text{record}$ {Format of preamble and start frame delimiter}
 case headerView: HeaderViewPoint of
 headerFields: (
 preamble: PreambleValue;
 sfd: SfdValue);
 headerBits: (
 headerContents: array [1..headerSize] of Bit)
 end; {defines header for MAC frame}

Change the text of 4.2.7.2 to read as follows:

4.2.7.2 Transmit state variables

The following items are specific to frame transmission. (See also 4.4.)

const

$\text{interFrameSpacing} = \dots$; {minimum time between frames}
 $\text{interFrameSpacingPart1} = \dots$; {duration of first portion of interFrame timing. In range 0 up to $2/3$
 interFrameSpacing}
 $\text{interFrameSpacingPart2} = \dots$; {duration of remainder of interFrame timing. Equal to
 interFrameSpacing – interFrameSpacingPart1}
 $\text{attemptLimit} = \dots$; {Max number of times to attempt transmission}
 $\text{backOffLimit} = \dots$; {Limit on number of times to back off}
 $\text{jamSize} = \dots$; {in bits: the value depends upon medium and collision detect implementation}

var

outgoingFrame: Frame; {The frame to be transmitted}
outgoingHeader: Header;

```

currentTransmitBit, lastTransmitBit: 1..frameSize;
{Positions of current and last outgoing bits in outgoingFrame}
lastHeaderBit: 1..headerSize;
deferring: Boolean; {Implies any pending transmission must wait for the medium to clear}
frameWaiting: Boolean; {Indicates that outgoingFrame is deferring}
attempts: 0..attemptLimit; {Number of transmission attempts on outgoingFrame}
newCollision: Boolean; {Indicates that a collision has occurred but has not yet been jammed}
transmitSucceeding: Boolean; {Running indicator of whether transmission is succeeding}
halfDuplex: Boolean; {Indicates the desired mode. halfDuplex is a static variable; its value does not
change between invocations of the Initialize procedure}

```

4.2.7.3 Receive state variables

The following items are specific to frame reception (see also 4.4).

```

var
incomingFrame: Frame; {The frame being received}
currentReceiveBit: 1..frameSize; {Position of current bit in incomingFrame}
receiving: Boolean; {Indicates that a frame reception is in progress}
excessBits: 0..7; {Count of excess trailing bits beyond octet boundary}
receiveSucceeding: Boolean; {Running indicator of whether reception is succeeding}
validLength: Boolean; {Indicator of whether received frame has a length error}
exceedsMaxLength: Boolean; {Indicator of whether received frame has a length longer than the
maximum permitted length}

```

Change the text of 4.2.7.4 to read as follows:

4.2.7.4 Summary of interlayer interfaces

- a) The interface to the ~~LLC sublayer~~ MAC client, defined in 4.3.2, is summarized below:

```

type
‡ TransmitStatus = (transmitDisabled, transmitOK, excessiveCollisionError);
{Result of TransmitFrame operation}
‡ ReceiveStatus = (receiveDisabled, receiveOK, frameTooLong, frameCheckError, lengthError,
alignmentError); {Result of ReceiveFrame operation}

function TransmitFrame (
destinationParam: AddressValue;
sourceParam: AddressValue;
lengthOrTypeParam: LengthOrTypeValue;
dataParam: DataValue): TransmitStatus; {Transmits one frame}

function ReceiveFrame (
var destinationParam: AddressValue;
var sourceParam: AddressValue;
var lengthOrTypeParam: LengthOrTypeValue;
var dataParam: DataValue): ReceiveStatus; {Receives one frame}

```

- b) The interface to the Physical Layer, defined in 4.3.3, is summarized in the following:

```

var
receiveDataValid: Boolean; {Indicates incoming bits}
carrierSense: Boolean; {In half duplex mode, indicates that transmissions should defer}
transmitting: Boolean; {Indicates outgoing bits}
wasTransmitting: Boolean; {Indicates transmission in progress or just completed}
collisionDetect: Boolean; {Indicates medium contention}

```

```
procedure TransmitBit (bitParam: Bit); {Transmits one bit}  
function ReceiveBit: Bit; {Receives one bit}  
procedure Wait (bitTimes: integer); {Waits for indicated number of bit-times}
```

Change the text of 4.2.7.5 to read as follows:

4.2.7.5 State variable initialization

The procedure Initialize must be run when the MAC sublayer begins operation, before any of the processes begin execution. Initialize sets certain crucial shared state variables to their initial values. (All other global variables are appropriately reinitialized before each use.) Initialize then waits for the medium to be idle, and starts operation of the various processes.

If Layer Management is implemented, the Initialize procedure shall only be called as the result of the initializeMAC action (5.2.2.2.1).

```
procedure Initialize;  
begin  
    frameWaiting := false;  
    deferring := false;  
    newCollision := false;  
    transmitting := false; {In interface to Physical Layer; see below}  
    receiving := false;  
    halfDuplex := ...; {true for half duplex operation, false for full duplex operation. halfDuplex is a  
                        static variable; its value does not change between invocations of the Initialize  
                        procedure}  
    while carrierSense or receiveDataValid do nothing;  
    {Start execution of all processes}  
end; {Initialize}
```

Change the text of 4.2.8 to read as follows:

4.2.8 Frame transmission

The algorithms in this subclause define MAC sublayer frame transmission. The function TransmitFrame implements the frame transmission operation provided to the ~~LLC sublayer~~ MAC client:

```
function TransmitFrame (  
    destinationParam: AddressValue;  
    sourceParam: AddressValue;  
    lengthOrTypeParam: LengthOrTypeValue;  
    dataParam: DataValue): TransmitStatus;  
procedure TransmitDataEncap; ... {nested procedure; see body below}  
begin  
    if transmitEnabled then  
        begin  
            TransmitDataEncap;  
            TransmitFrame := TransmitLinkMgmt  
        end  
    else TransmitFrame := transmitDisabled  
end; {TransmitFrame}
```

If transmission is enabled, TransmitFrame calls the internal procedure TransmitDataEncap to construct the frame. Next, TransmitLinkMgmt is called to perform the actual transmission. The TransmitStatus returned indicates the success or failure of the transmission attempt.

TransmitDataEncap builds the frame and places the 32-bit CRC in the frame check sequence field:

```

procedure TransmitDataEncap;
begin
  with outgoingFrame do
    begin {assemble frame}
      view := fields;
      destinationField := destinationParam;
      sourceField := sourceParam;
      lengthOrTypeField := lengthOrTypeParam;
      dataField := ComputePad (lengthParam dataParam);
      fcsField := CRC32(outgoingFrame);
      view := bits
    end {assemble frame}
  with outgoingHeader do
    begin
      headerView := headerFields;
      preamble := ...; { * '1010...10,' LSB to MSB* }
      sfd := ...; { * '10101011,' LSB to MSB* }
      headerView := headerBits
    end
  end; {TransmitDataEncap}

```

ComputePad appends an array of arbitrary bits to the LLC dataField MAC client data to pad the frame to the minimum frame size.

```

function ComputePad(
  var dataParam: DataValue): DataValue;
begin
  ComputePad := {Append an array of size padSize of arbitrary bits to the LLC MAC client dataField}
end; {ComputePadParam}

```

TransmitLinkMgmt attempts to transmit the frame deferring first to any passing traffic. In half duplex mode, it first defers to any passing traffic. In half duplex mode, if a collision occurs, transmission is terminated properly and retransmission is scheduled following a suitable backoff interval:

```

function TransmitLinkMgmt: TransmitStatus;
begin
  attempts := 0; transmitSucceeding := false;
  lateCollisionCount := 0;
  deferred := false; {initialize}
  excessDefer := false;
  while (attempts < attemptLimit) and (not transmitSucceeding) do
    begin {loop}
      if attempts > 0 then BackOff;
      if halfDuplex then frameWaiting := true;
      lateCollisionError := false;
      ‡ while deferring do {defer to passing frame, if any2}
        begin
          ‡ nothing;
          if halfDuplex then deferred := true;
    end
  end

```

²The Deference process ensures that the reception of traffic does not cause deferring to be true when in full duplex mode. Deferring is used in full duplex mode to enforce the minimum interpacket gap spacing.