

ANSI/IEEE Std 802.4-1990

(Revision of ANSI/IEEE 802.4-1985)

(Adopted by ISO/IEC and redesignated as
ISO/IEC 8802-4: 1990)

**Information processing systems—
Local area networks—**

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

**Adopted by the ISO/IEC and redesignated as
ISO/IEC 8802-4: 1990**

Sponsor

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

Abstract: This Local Area Network (LAN) standard, ISO/IEC 8802-4 : 1990 (ANSI/IEEE Std 802.4-1990), deals with all elements of the token-passing bus access method and its associated physical signaling and media technologies. To facilitate interconnection of stations by way of a LAN using the token-passing bus access method, this standard specifies the characteristics of the transmission medium; the signaling method used; the frame formats transmitted; the actions of a station upon receipt of a frame; the services provided at the conceptual interface between the Medium Access Control (MAC) sublayer and the Logical Link Control (LLC) sublayer; and the actions, entities, and values used by management. There are four medium characteristics and signaling methods: 5 and 10 Mb/s phase-coherent FSK; 1, 5, and 10 Mb/s broadband; 10 and 20 Mb/s fiber optic; and 1 Mb/s phase-continuous FSK.

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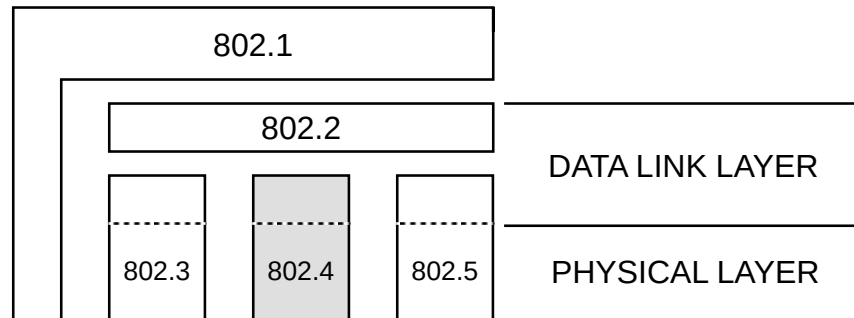
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Foreword to IEEE Std 802.4-1990 (Revision of IEEE Std 802.4-1985)

(This Foreword is not a part of ISO/IEC 8802-4 : 1990 or of IEEE Std 802.4-1990.)

This standard is part of a family of standards for Local Area Networks (LANs). The relationship between this 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 ISO Open Systems Interconnection Basic Reference Model (ISO 7498 : 1984). The access standards define three types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. The standards defining these technologies are

- (1) IEEE Std 802.3-1988 [ISO 8802-3], a bus utilizing CSMA/CD as the access method,
- (2) IEEE Std 802.4-1990 [ISO/IEC 8802-4], a bus utilizing token passing as the access method,
- (3) IEEE Std 802.5-1989, a ring utilizing token passing as the access method.

Other access methods (for example, metropolitan area networks and integrated voice-data networks) are under investigation.

IEEE Std 802.2-1989 [ISO 8802-2], the Logical Link Control standard, is used in conjunction with the medium access standards

IEEE 802.1¹ (a series of related standards) describes the relationship among the family of 802 standards and their relationship to the ISO Open Systems Interconnection Basic Reference Model in more detail. IEEE 802.1 will also contain networking management standards and information on internetworking.

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

¹IEEE Std 802.1A-1990, Overview and Architecture of Network Standards; IEEE Std 802.1D-1990, MAC (Media Access Control) Bridges; and IEEE Std 802.1E-1990, System Load Protocol have been approved as IEEE Standards, but are not yet published. Other projects in the 802.1 series are currently under development.

Summary of Changes

This standard is a major revision of IEEE Std 802.4-1985 (ISO/DIS 8802/4). This revision incorporates the results of over four years of work by the IEEE 802.4 Working Group and by other organizations.

This section of the Foreword summarizes the changes for the reader's convenience.

The management sections, Sections 3 and 9, have been completely rewritten. These revised sections are now in conformance with the work of the IEEE 802 Committee and in alignment, to the extent possible, with other groups working on management standards.

The access control machine (ACM), the heart of the Medium Access Control (MAC) protocol, has been revised. Errors and ambiguities that existed in the previous version were corrected, and enhancements were made to improve error recovery. The intention in revising the ACM was to retain complete interoperability with the ACM described by the previous standard. We believe that intention has been realized.

The name of the request_with_response option has been changed from "immediate response" option to avoid conflicts with other uses of the phrase immediate response (see 6.1.1 and 6.6.2).

Additional MAC Capabilities (6.7) has been added to give implementors suggestions for providing extra MAC features and to give guidance to conformance testers.

The specification of an interface within the Physical Layer for a separate modem has been included as Section 10.

Section 11 has been reserved to retain compatible section numbers and for future additions.

The phase-coherent FSK Physical Layer and medium, described in Sections 12 and 13, underwent revision. Based on implementation experience, the working group found it necessary to make substantive technical changes to the standard. The transmit and receive levels were changed, the preamble pattern and length were changed, and a receiver blanking specification was added. The result of these changes is that the implementations of this revised standard will not interoperate with implementations of the previous standard.

The broadband Physical Layer and medium, described in Sections 14 and 15, underwent minor revisions to clarify the specification and to provide guidance for conformance testing.

A fiber optic Physical Layer and medium specification has been added as Sections 16 and 17.

The 1 Mb/s phase-continuous FSK Physical Layer and medium specification was moved from Sections 10 and 11 to Sections 18 and 19, to avoid renumbering the more commonly referenced Physical Layer and media sections. The coding of the end delimiter coding pattern was changed to increase the reliability (Hamming distance) of the protocol.

This standard was submitted to ISO/IEC JTC1 for consideration as a revision and addendum to the previous edition of the token bus LAN standard, IEEE Std 802.4-1985 (ISO/DIS 8802/4). To facilitate processing of that document, portions that were not appropriate for an international standard were prefaced with a note enclosed in braces{...}.

These same portions contained within the current edition are not a part of the International Standard and are stated as such. These portions are peculiar to the IEEE version of this standard and consist of areas relating to

- (1) References to national standards
- (2) Recommended frequency allocations for North American CATV systems (see 14.8.4)
- (3) Recommendations and guidelines related to safety concerns

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions to this standard may occur either to clarify existing material, to correct possible errors, or to incorporate new, related material.

Readers wishing to know the state of revisions should contact the
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Special thanks to our past chairman, 1983–87, under whose guidance we developed the current draft and reached committee consensus:

Robert H. Douglas, *past Chair*

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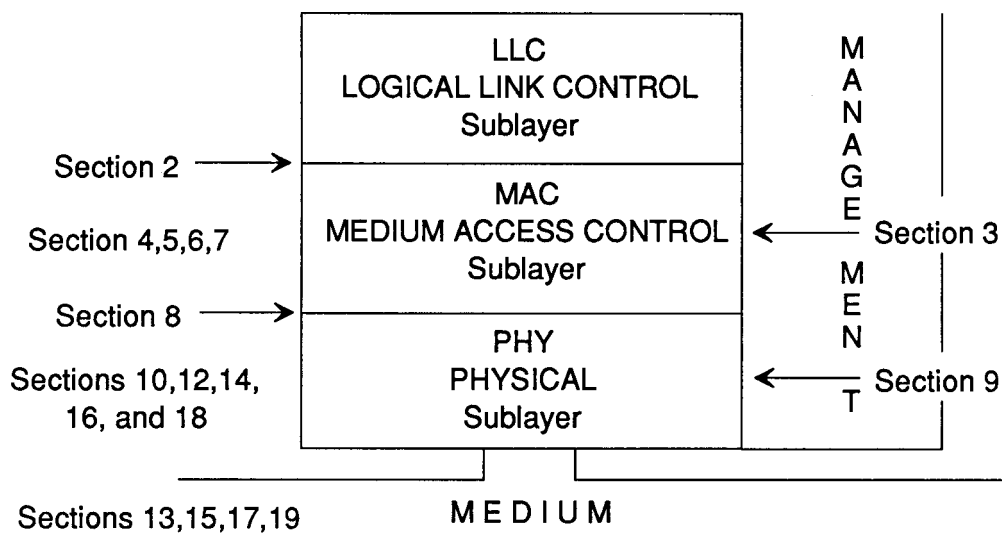
Information processing systems— Local area networks—

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

1. Introduction and Overview

This portion of the Local Area Network (LAN) standards deals with all elements of the token-passing bus access method and its associated physical signaling and media technologies. The access function coordinates the use of the shared medium among the attached stations and has the relationship to the other protocol functions given by Fig 1-1.

Fig 1-1
Relationship of Adjacent Protocol Layers



1.1 Scope. For the purpose of compatible interconnection of stations by way of a LAN using the token-passing bus access method this standard

- (1) Specifies the electrical and/or optical and physical characteristics of the transmission medium,
- (2) Specifies the electrical or optical signaling method used,
- (3) Specifies the frame formats transmitted,
- (4) Specifies the actions of a station upon receipt of a frame,
- (5) Specifies the services provided at the conceptual interface between the Medium Access Control (MAC) sublayer and the Logical Link Control (LLC) sublayer above it,
- (6) Specifies the actions, entities, and values used to manage the MAC sublayer and Physical Layer Entity (PLE).

Within this standard the operation of a station is specified in terms of the layered model shown in Fig 1-1 and described in ISO 7498 : 1984 [13].¹ Additional information on the 802 family of LAN standards can be found in IEEE Std 802-1990 [9].²

Figure 1-1 also shows which sections of the standard specify interfaces between layers and which sections specify the operation of the layers themselves.

Recommendations for frequency allocations for community antenna television (CATV) systems are subjects for national standardization and are outside the scope of this International Standard.

1.2 Definitions. The definitions used in this standard are consistent with ISO 2382-9 : 1984 [12]. A more specific information processing vocabulary pertaining to LAN systems is in development as WP 2382/25.

1.3 References.³ When the following standards referred to in this standard are superseded by an approved revision, the latest revision shall apply. References to IEEE and ISA standards are not a part of this International Standard.

[1] ANSI/ISA-S72.01-1986, PROWAY-LAN Industrial Data Highway.⁴

[2] CCITT Recommendation X.150, Principles of Maintenance Testing for Public Data Networks Using Data Terminal Equipment (DTE) Data Circuit-Terminating (DCE) Test Loops. In Vol. VIII.3 of the *CCITT Blue Books*—Data communication network transmission, signaling and switching, network aspects,

¹The numbers in brackets correspond to those of the references listed in 1.3.

²IEEE Std 802-1990, Overview and Architecture of Network Standards; IEEE Std 802.1D-1990, MAC (Media Access Control) Bridges; and IEEE Std 802.1E-1990, System Load Protocol have been approved as IEEE Standards, but are not yet published. Other projects in the 802.1 series are currently under development.

³See Index to locate citations in the text of the following publications.

⁴ISA documents are available from the Instrument Society of America, Standards Dept., 67 Alexandria Drive, P.O. Box 12277, Research Triangle Park, NC 27709.

maintenance and administrative arrangements. Geneva: International Telecommunications Union, 1989.⁵

[3] CISPR Publication 22 (1985), Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment.⁶

[4] IEC Publication 169-8 (1978), Radio Frequency Connectors, Part 8: RF Coaxial Connectors with Inner Diameter of Outer Conductor 6.5 mm (0.256 in) with Bayonet Lock and Characteristic Impedance of 50 Ω (type BNC).

[5] IEC Publication 807-2 (1985), Detailed Specification for a Range of Connectors and Round Contacts (Fixed Solder Contact Types).

[6] IEC Publication 825 (1984), Radiation Safety of Laser Products, Equipment Classification, Requirements and User's Guide.

[7] IEC Publication 950 (1986), Safety of Information Technology Equipment, Including Electrical Business Equipment (Amendment 1, 1988).

[8] IEEE C37.90.1-1989, IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems (ANSI).⁷

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

[10] Reserved for future use.⁸

[11] IEEE Std 802.7-1989, IEEE Recommended Practices for Broadband Local Area Networks (ANSI).

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

[13] ISO 7498 : 1984, Information processing systems—Open systems interconnection—Basic reference model.

[14] ISO/IEC 7498-4 : 1989, Information processing systems—Open systems interconnection—Basic reference model—Part 4: Management framework.

[15] ISO 8802-2 : 1989 (IEEE Std 802.2-1989), Information processing systems—Local area networks—Part 2: Logical link control.

⁵CCITT documents are available in the US from the US Dept. of Commerce, National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161. CCITT documents are also available from CCITT General Secretariat, International Telecommunications Union (ITU), Sales Section, Place des Nations, CH-1211, Genève 20, Switzerland/Suisse.

⁶CISPR and IEC documents are available in the US from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018. These documents are also available from International Electrotechnical Commission, 3 rue de Varembe, Case postale 131, CH1211, Genève 20 Switzerland/Suisse.

⁷IEEE documents are available from the Service Center, Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

⁸When the following IEEE project is approved and published, it will become a part of this reference section: P802.1B, Local Area Networks and Metropolitan Networks Management.

⁹ISO documents are available in the US from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018. ISO documents are also available from the ISO Office, 1 rue de Varembe, Case postale 56, CH-1211, Genève 20, Switzerland/Suisse.

[16] ISO 8824 : 1987, Information processing systems—Open systems interconnection—Specification of abstract syntax notation one (ASN.1).

[17] Reserved for future use.¹⁰

[18] Reserved for future use.¹¹

[19] Reserved for future use.¹²

[20] Reserved for future use.¹³

1.4 Conformance. Implementations that claim conformance with this standard shall

- (1) Offer the mandatory LLC-MAC interface services specified in Section 2,
- (2) Support the mandatory layer management actions, entities, and values specified in Sections 3 and 9,
- (3) Generate, transmit, receive, and recognize the frames and sequences specified in Section 4,
- (4) Support the mandatory capabilities, constraints, and behavior of the medium access protocol specified in Sections 6 and 7,
- (5) Offer the mandatory MAC sublayer-Physical Layer interface services specified in Section 8,
- (6) Support the mandatory capabilities, features, and constraints of at least one of the specified PLEs and medium specifications defined in Sections 12 and 13, 14 and 15, 16 and 17, and 18 and 19,
- (7) Support at least one of the data rates specified for the chosen PLE, and
- (8) Support the capabilities, behavior, or values defined for all options claimed to be supported by the implementation.

Unless otherwise stated herein, all specifications shall apply over the entire operating environmental range for which the manufacturer claims conformance.

A number of options are specified in this standard. An implementation shall indicate which, if any, of these options are supported.

¹⁰When the following ISO/IEC project is completed, approved, and published, it will become a part of this reference section: JTC1 DIS 9314-3, Information processing systems—Fibre distributed data interface (FDDI)—Part 3: Physical layer medium dependent (PMD) requirements.

¹¹When the following ISO/IEC project is completed, approved, and published, it will become a part of this reference section: JTC1 DIS 9595, Information processing systems—Open systems interconnection—Management information services definition.

¹²When the following ISO/IEC project is completed, approved, and published it will become a part of this reference section: JTC1 DIS 9596, Information processing systems—Open Systems Interconnection—Management information protocol specification.

¹³When the following ISO/IEC project is completed, approved, and published, it will become a part of this reference section: JTC1 DIS 10039, Information technology—Telecommunications and information exchange between systems—Medium access control service definition.

1.5 Overview of the Token Method

1.5.1 The Essence of the Token Access Method

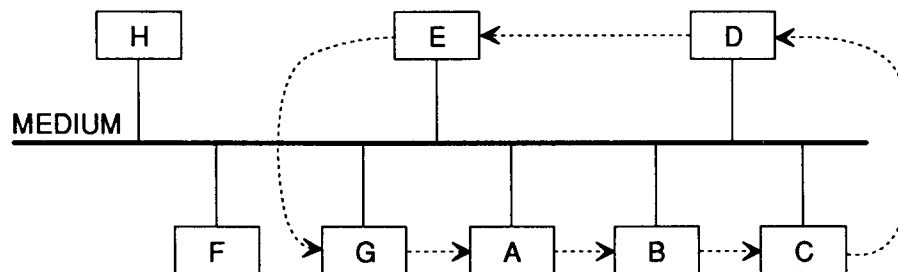
- (1) A *token* controls the right of access to the physical medium; the station which holds (possesses) the token has momentary control over the medium.
- (2) The token is passed by stations residing on the medium. As the token is passed from station to station a logical ring is formed.
- (3) Steady state operation consists of a data transfer phase and a token transfer phase.
- (4) Ring maintenance functions within the stations provide for ring initialization, lost token recovery, new station addition to the logical ring, and general housekeeping of the logical ring. The ring maintenance functions are replicated among all the token-using stations on the network.

Shared media generally can be categorized into two major types. These types are *broadcast* and *sequential*. This standard deals exclusively with the broadcast type. On a broadcast medium, every station may receive all signals transmitted. Media of the broadcast type are usually configured as a physical bus.

In Fig 1-2, note that the token medium access method is always sequential in a logical sense. That is, during normal, steady state operation, the right to access the medium passes from station to station. Furthermore, note that the physical connectivity has little impact on the order of the logical ring and that stations can respond to a query from the token holder even without being part of the logical ring. (For example, stations H and F can receive frames and could respond but cannot initiate a transmission since they will never be sent the token.)

The MAC sublayer provides sequential access to the shared bus medium by passing control of the medium from station to station in a logically circular fashion. The MAC sublayer determines when the station has the right to access the shared medium by recognizing and accepting the token from the predecessor station, and it determines when the token shall be passed to the successor station.

Fig 1-2
Logical Ring on Physical Bus



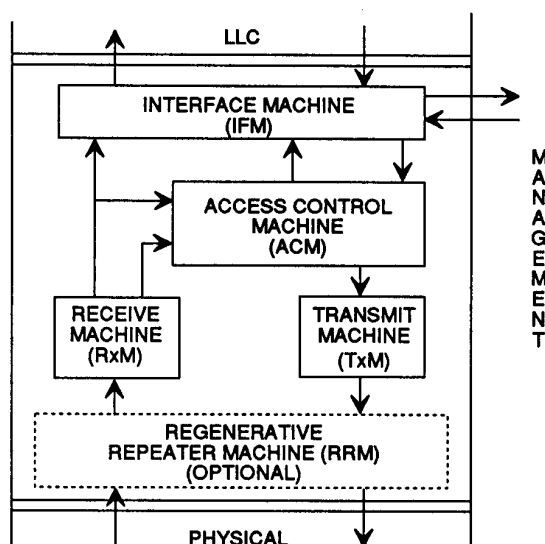
1.5.2 General Sublayer Functions

- (1) Lost token timer
- (2) Distributed initialization
- (3) Token holding timer
- (4) Limited data buffering
- (5) Node address recognition
- (6) Frame encapsulation (including token preparation)
- (7) Frame check sequence (FCS) generation and checking
- (8) Valid token recognition
- (9) Ring member addition/deletion
- (10) Node failure error recovery

1.6 MAC Sublayer Internal Structure. The MAC sublayer performs several functions that are loosely coupled. The descriptions and specifications of the MAC sublayer in this standard are organized in terms of one of several possible partitionings of these functions. The partitioning used here is illustrated in Fig 1-3, which shows five asynchronous logical “machines,” each of which handles some of the MAC functions, as discussed in 1.6.1 through 1.6.5.

Of these five machines, the access control machine (ACM) is the most critical and the most complex; it is the key control mechanism for the token-passing bus access method, and it cooperates closely with ACMs in other stations given only limited information regarding the state of the network. Because of its impor-

Fig 1-3
MAC Sublayer Functional Partitioning



tance, and because much of its operation is not easily inferred from its functional requirements, the explanation and specification of the ACM are the major concerns of Sections 5, 6, and 7.

The interface machine (IFM) and receive machine (RxM) participate heavily in the operation of the MAC sublayer protocol. They are, however, discussed only in sufficient detail so that the reader will understand their role in the MAC sublayer in support of the ACM. The level of discussion was chosen to avoid any ambiguities which might compromise the coexistence of conformant stations on a single bus.

1.6.1 Interface Machine (IFM). This machine acts as an interface and buffer between the LLC and MAC sublayers and between network management and the MAC sublayer. It interprets all incoming MA-UNITDATA and other service primitives and generates appropriate outgoing service primitives. This machine handles the mapping of “quality of service” parameters from the LLC view to the MAC view, where this is necessary. It handles queuing of service requests, for example, requests to send an LLC protocol data unit (PDU). Finally, it performs the “address recognition” function on received data frames, accepting only those addressed to this station.

1.6.2 Access Control Machine (ACM). This machine cooperates with the ACMs of all other stations on the bus in handling the token to control transmission access to the shared bus. The ACM may (optionally) manage multiple MAC access classes so as to provide different levels of “quality of service” to the LLC sublayer. The ACM is also responsible for initialization and maintenance of the logical ring, including the admission of new stations. Finally, it has responsibility for the detection of and, where possible, recovery from faults and failures in the token-passing bus network.

1.6.3 Receive Machine (RxM). This machine accepts atomic symbol inputs from the Physical Layer and assembles them into frames which it validates and passes to the IFM and ACM. The RxM accomplishes this by recognizing the frame start and the frame end delimiters (SD and ED), checking the FCS and validating the frame’s structure. The RxM also identifies and indicates the reception of *noise_bursts* and the *bus_quiet* condition.

1.6.4 Transmit Machine (TxM). This machine generally accepts a frame from the ACM and transmits it, as a sequence of atomic_symbols in the proper format, to the PLE. The TxM builds a MAC protocol-data-unit by prefacing each frame with the required preamble and SD, and appending the FCS and ED. When operating with a Regenerative Repeater Machine (RRM), the TxM’s operation may be some what different.

1.6.5 Regenerative Repeater Machine (RRM). This machine is an optional MAC component that is present only in special “repeater” stations, for example, a broadband remodulator. In such repeater stations, the RRM, when appropriate, repeats the incoming atomic_symbol stream, from the PLE, back to the PLE for retransmission; in such cases the PLE is understood to be connected to at least two different segments of a single bus. The RxM and TxM may cooperate with the RRM in such repeating operations.

1.7 PLE and Medium. The broad outlines for the PLE sections of this standard and also an introduction to the various physical signaling techniques and media defined for LANs using the token-passing MAC protocol are given here.

Four bus media and corresponding PLEs are specified for use with the token-passing MAC protocol.

Each PLE and corresponding bus medium is described in a pair of consecutive sections (that is, Sections 12 and 13, Sections 14 and 15, Sections 16 and 17, and Sections 18 and 19), consisting of the following:

- (1) A section specifying a specific PLE, including how the generic management objects (Section 9) in that PLE are particularized, and
- (2) A section specifying the medium appropriate to that PLE.

Four different PLEs with corresponding media suitable for use with the token-passing bus MAC protocol are specified in this standard. They are distinguished primarily by the different forms of media and signaling specified for each type of PLE. The remainder of this subsection outlines the salient points of each type of PLE and corresponding medium.

1.7.1 Summary of Phase-Coherent Frequency Shift Keying (FSK)

Topology. Omnidirectional bus

Cable. 75 Ω coaxial cable, such as RG-11 type or semirigid

Connector at Station. 75 Ω female F-series, to be specified by IEC (see NOTES in 13.5.1)

Recommended Cable Configuration. CATV trunk of either RG-11 type or semi rigid and flexible drop cables of up to 50 m in length

Trunk Connection Unit. 75 Ω nondirectional 20 dB passive impedance-matching tap

Repeaters. Active regenerative repeaters used for high-fanout branching and extension of the system beyond the limits of a single segment of the cable

Transmit Level. + 63 to + 66 dB (1 mV, 75 Ω) [dBmV]

Receiver Sensitivity. + 10 dBmV to + 66 dBmV

Data Rates. 5 Mb/s and 10 Mb/s

Signaling. Direct encoding of *data* and *non_data* symbols, each as an integral number of cycles of constant frequency, with frequency changes only at the zero crossings of the waveforms. Two frequencies are used:

- (1) The lower is 1 Hz/(b/s) (that is, 5 MHz at 5 Mb/s, 10 MHz at 10 Mb/s)
- (2) The higher is 2 Hz/(b/s) (that is, 10 MHz at 5 Mb/s, 20 MHz at 10 Mb/s)

The symbol representations are

zero—two full cycles of the higher frequency

one—one full cycle of the lower frequency

pairs of *non_data*—one full cycle of the higher frequency, one full cycle of the lower frequency, and another one full cycle of the higher frequency

Pad_idle. Alternating *one* and *zero* symbols, starting with *one*

Clock Recovery. From zero crossings in the received signal

Transmit Data Timing. Phase-locked to transmit frequencies. All ports of a regenerative repeater use the same transmit data timing and, hence, identical transmit frequencies.

1.7.2 Summary of Multilevel Duobinary Amplitude Modulation/Phase Shift Keying (AM/PSK)

Topology. Directional bus with active repeater

Cable. 75 Ω coaxial cable, such as RG-6 type or semirigid

Connector at Station. 75 Ω female F-series, to be specified by IEC (see NOTE in 15.5.1)

Recommended Cable Configuration. CATV-like semirigid trunk and flexible drop cable

Trunk Connection Unit. 75 Ω directional passive impedance-matching tap

Repeaters. Regenerative repeater used as system data-rate clock source, as central assessor of contention and noise, and to retransmit all signaling received on the directional medium

Amplifiers. Standard CATV bidirectional (or unidirectional for dual-cable configuration) broadband amplifiers used for extension of the system beyond the basic signal loss budget

Channel Bandwidths. 1.5 MHz, 6 MHz, and 12 MHz

Transmit Level

In 1.5 MHz bandwidth, + 41 dB (1 mV, 75 Ω) [dBmV]

In 6 MHz bandwidth, + 47 dB (1 mV, 75 Ω) [dBmV]

In 12 MHz bandwidth, + 50 dB (1 mV, 75 Ω) [dBmV]

Receiver Sensitivity

In 1.5 MHz, -13 to + 4 dB (1 mV, 75 Ω) [dBmV]

In 6 MHz, -7 to +10 dB (1 mV, 75 Ω) [dBmV]

In 12 MHz, -4 to +13 dB (1 mV, 75 Ω) [dBmV]

Data Rates. 1 Mb/s in 1.5 MHz, 5 Mb/s in 6 MHz, 10 Mb/s in 12 MHz

Channel Frequency Assignments. Channel frequency assignments are a subject for national standardization. The following North American recommended channel assignments are included for information only. They are not a part of this International Standard.

For 10 Mb/s, channels 3' and 4' (59.75–71.75 MHz) and P and Q (252–264 MHz)

For 5 Mb/s, channels 3' (59.75–65.75 MHz) and P (252–258 MHz), or 4' (65.75–71.75 MHz) and Q (258–264 MHz)

For 1 Mb/s, any of the eight equally spaced 1.5 MHz subchannels of reverse channels 3' and 4', paired with the corresponding forward channels P and Q

Scrambler. A self-sync scrambler with a generator polynomial of $1 + X^{-6} + X^{-7}$ is applied to all framed data prior to encoding for transmission, both to increase the average number of transitions within a transmission and to randomize spectral components of the transmitted modulation.

Signaling. *Data* and *non_data* symbols are encoded so as to specify the amplitude of the eventual modulation. A single form is defined in this standard: One MAC-symbol per PHY-symbol, together with compatibility considerations for an additional form described in 14.11.

In both forms of signaling, the middle level is used only to signal the *non_data* symbols found in frame delimiters and reported *silence*, and to break up long sequences of a single other signaling level (see 14.8.2.1 (4) (c)). Such long sequences are unlikely since a scrambler is applied to framed data before it is encoded for transmission.

For one MAC-symbol per PHY-symbol signaling, the symbol representations at the receiver are

{0} = *zero*—zero amplitude

{4} = *one*—“maximum” amplitude

{2} = *non_data*—“middle” amplitude of one half “maximum”

Modulation. Multilevel duobinary AM/PSK

Pad_idle. Alternating {4} and {0} symbols, starting with {4}

Reported Silence. The repeated sequence of symbols transmitted by the remodulator to report that it is not receiving any signaling. The sequence has a period of four symbols and the repetition may break off after any symbol of the sequence. Listening modems can set their automatic gain control (AGC), and can determine the signaling mode of the system by the sequence used.

For one MAC-symbol per PHY-symbol signaling, the sequence is:

{2} {2} {0} {4}

For a possible future two MAC-symbols per PHY-symbol signaling mode, the following sequence is reserved:

{2} {2} {4} {0}

Implementations that detect this reserved repeating sequence should either switch to the enhanced mode of operation or inhibit transmission.

Clock Recovery. From level transitions within the received signaling

Transmit Data Timing. Sourced by remodulator; frequency-locked to received data timing at all other stations

1.7.3 Summary of Fiber Optic Media

Topology. Directional bus using active or passive stars

Cable. The standard assumes a silica fiber optic waveguide with the following nominal characteristics: a core diameter of 62.5 μm , outside diameter of 125 μm , and an effective numerical aperture of 0.275.

NOTE: Operation using a 50 μm alternate test fiber is described in Appendixes 16.10 and 17.9.

Connector at Station. The cable plant interface connector (CPIC) is a duplex connector as defined in ISO/IEC 9314-3 [16].

Repeaters. Active regenerative repeaters used for high-fanout star topologies

Transmit Characteristics. -7 to -11 dBm effective optical launch power with center wavelength between 800 and 910 nm

Receiver Sensitivity

Moderate sensitivity: -11 to -31 dBm effective power with silence level of -40 dBm

High sensitivity: -21 to -41 dBm effective power with silence level of -50 dBm

Data Rates. 5 Mb/s, 10 Mb/s, and 20 Mb/s

Signaling. Manchester encoding of *data* and *non_data* symbols

The symbol representations are

$\{H L\} = \text{zero}$

$\{L H\} = \text{one}$

$\{L L H H\}$ and $\{H H L L\} = \text{pairs of non_data symbols}$

Pad_idle. Alternating one and zero symbols, starting with *one*

Clock Recovery. From transitions generated by the Manchester encoding

Transmit Data Timing. Phase-locked to transmit frequencies. All ports of a regenerative repeater use the same transmit data timing and, hence, identical transmit frequencies.

1.7.4 Summary of Phase-Continuous FSK

Topology. Omnidirectional bus

Trunk Cable. 75 Ω coaxial cable, such as types RG-6, RG-11, and semirigid

Drop Cable. 35–50 Ω coaxial cable stub, less than 350 mm long

Connector at Station. 50 Ω male BNC-series, see IEC 169-8 (1978) [4]

Recommended Cable Configuration. Long unbranched trunk cable with very short “stub” drop cables

Trunk Connection Unit. 75 Ω tee connector

Repeaters. Active regenerative repeaters used for branching and extension of the system beyond the basic signal loss budget

Transmit Level. $+54$ to $+60$ dB (1 mV, 37.5 Ω)

Receiver Sensitivity. $+24$ dB (1 mV, 37.5 Ω)

Data Rate. 1 Mb/s

Signaling. Manchester encoding of *data* and *non_data* symbols

The symbol representations are

$\{H L\}$ = *zero*—initial high, final low level

$\{L H\}$ = *one*—initial low, final high level

$\{L L H H\}$ and $\{H H L L\}$ = pairs of *non_data* symbols, initial pair of low level followed by a final pair of high level or vice versa

Modulation. Phase-continuous FSK (a form of frequency modulation), with Manchester representation:

- (1) Frequency of high level = 6.25 ± 0.08 MHz
- (2) Frequency of low level = 3.75 ± 0.08 MHz

Pad_idle. Alternating *one* and *zero* symbols, starting with *one*

Clock Recovery. From transitions generated by the Manchester encoding

1.7.5 Alternate Physical Layer and Medium for Industrial Control.

Alternate Physical Layers and media for industrial control are specified in ANSI/ISA-S72.01-1986 [1]. These alternate Physical Layers and media are compatible at the MAC sublayer-Physical Layer interface.

1.8 Access Method Characteristics. An understanding of the basic characteristics of the token-passing access method is useful, so as to better understand where and when a token-passing bus is an appropriate LAN technology.

Some of the important features of this medium access method are as follows:

- (1) The method is efficient in the sense that, under high offered load, the coordination of the stations requires only a small percentage of the medium's capacity.
- (2) The method is fair in the sense that it offers each station an equal share of the medium's capacity. It does not, however, require any station to use its full share.
- (3) The method permits multiple classes of service.
- (4) The method coordinates the stations' transmissions so that they minimize and control their interference with each other.
- (5) The method imposes no additional requirements on the medium or the PLE's capabilities over those necessary for transmission and reception of multibit, multiframe sequences at the specified bit error rate.
- (6) In the absence of system noise, the method provides computable, deterministic, worst-case bounds on access delay for the highest priority class of service for any given network and loading configuration.
- (7) Periods of controlled interference are distinguishable; system noise measurements are possible during the remaining periods.
- (8) The method places minimal constraints on how a station that momentarily controls the medium may use its share of the medium's capacity.

- (9) The method efficiently supports the proposed LLC Type 3 Service by allowing the token holding station to wait for the receiving station to respond to the token holder's transmission.
- (10) Though not specified by this standard, the method permits the presence of large numbers of low-cost, reduced-function stations in the network, together with one or more full-function stations. (At least one full-function station is needed to make the system operational.) An example of a reduced function station is one that does not contain access control logic.

1.9 Standard Organization. This standard is organized in 19 sections, which are summarized below.

Section 1 (this section) begins with a general discussion of the token-passing bus access method. The MAC sublayer functional partitioning used in subsequent discussions is introduced here. The PLE and media options are also surveyed. Finally, features of the token-passing bus access method are reviewed.

Section 2 details the logical interfaces between the LLC sublayer and the MAC sublayer, and the services and command interfaces (such as sending a frame) provided to the LLC sublayer.

Section 3 details the management parameters, actions, and events within the MAC sublayer.

Section 4 details the general MAC frame structure, including delimiters, addressing, and the FCS. All of the frame formats that the MAC handles, including MAC control frames, are enumerated.

Section 5 discusses the basic concepts of the access protocol and provides an informal description of the actions in each state of the ACM. The other state machines of the MAC sublayer are also described in Section 5.

Section 6 contains definitions of essential MAC terms and components.

Section 7 specifies the MAC ACM by means of a state machine model. This is the definitive specification of the token-passing bus MAC operation. Section 7 also describes the MAC sublayer variables, functions, and procedures used in the state machine.

Section 8 details the logical interface between the MAC sublayer and the Physical Layer. Included here are descriptions of the interface symbols, requests, and responses.

Section 9 details the management parameters, actions, and events within the PLE.

Section 10 defines the logical, electrical, and mechanical interface within the PLE between the station and a separated modem.

Section 11 is reserved.

Sections 12 and 13 detail the PLE and medium, respectively, for a single-channel (that is, omnidirectional) phase-coherent-FSK coaxial cable bus at 5 Mb/s or 10 Mb/s.

Sections 14 and 15 detail the PLE and medium, respectively, for a dual-channel (that is, head-ended) broadband duobinary AM/PSK coaxial cable bus at 1 Mb/s, 5 Mb/s, or 10 Mb/s.

Sections 16 and 17 detail the PLE and medium, respectively, for a fiber optic bus at 5 Mb/s, 10Mb/s, or 20 Mb/s.

Sections 18 and 19 detail the PLE and medium, respectively, for a single-channel (that is, omnidirectional) phase-continuous-FSK coaxial cable bus at 1 Mb/s.

2. LLC-MAC Interface Service Specification

This section specifies the services provided to the Logical Link Control (LLC) sublayer, and to the alternative sublayer specified in ANSI/ISA-S72.01-1986 [1], at the boundary between the LLC functions and the Medium Access Control (MAC) sublayer of the Data Link Layer of the reference model. This standard specifies these services in an abstract way. It does not specify or constrain the implementation entities and interfaces within a computer system. The relationship of this section to other sections of this standard and to LAN specifications is illustrated in Fig 2-1.

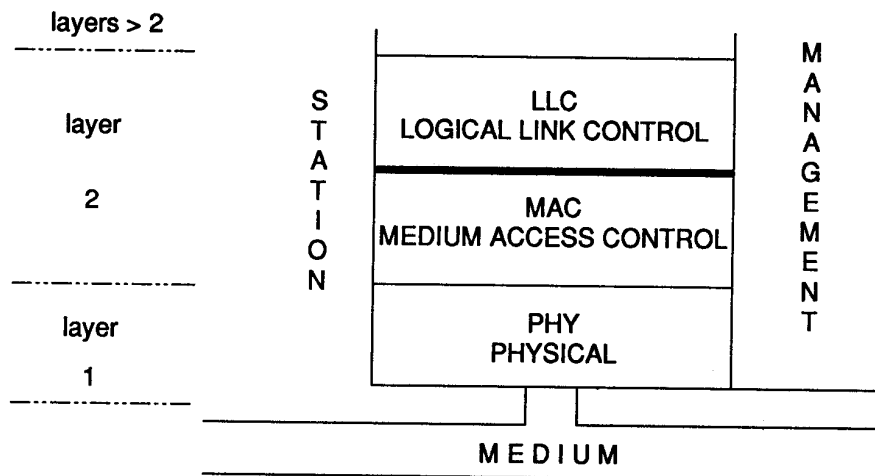
NOTES: (1) The exact relationship of the layers described in this standard to the layers defined by the Open Systems Interconnection (OSI) Basic Reference Model (ISO 7498 : 1984 [13]) is for future study.

(2) Work is in process to produce a single service specification that is common to all the MAC sublayers; see ISO/IEC 10039 [20]. When that standard is completed, approved, and published, Section 2 will be deleted.

2.1 Overview of the LLC-MAC Service

2.1.1 General Description of Services Provided. This section informally describes the services provided to the LLC sublayer by the token-passing MAC sublayer, both of the Data Link Layer. These services provide only connectionless

Fig 2-1
Relation to LAN Model



data transfer services between peer LLC entities. They provide the means by which LLC entities can exchange MAC service data units (M_SDU) without the establishment of an underlying point-to-point connection. The data transfer can be point-to-point or multipoint, unacknowledged or acknowledged.

2.1.2 Model Used for the Service Specification. The model and descriptive method are detailed in Appendix A.

2.1.3 Overview of Interactions. The primitives associated with this connectionless data transfer service are

- (1) MA-UNITDATA request
- (2) MA-UNITDATA indication
- (3) MA-UNITDATA confirm

An MA-UNITDATA request primitive is passed to the MAC sublayer to request that an M_SDU be sent. (All M_SDUs are sent using connectionless procedures.) An MA-UNITDATA indication primitive is passed from the MAC sublayer to indicate the arrival of an M_SDU. An MA-UNITDATA confirm primitive is passed from the MAC sublayer to indicate the status of the previous associated MA-UNITDATA request primitive.

2.1.4 Basic Services and Options. All services are mandatory and are required in all implementations.

2.2 Detailed Interactions with the LLC Entity. This subsection describes in detail the primitives and parameters associated with the connectionless data transfer services provided to LLC by MAC. Note that the parameters are specified in an abstract sense. The parameters specify the information that shall be available to the receiving entity. A specific implementation is not constrained in the method of making this information available. For example, the M_SDU parameter associated with some of the data transfer service primitives may be provided by actually passing the MAC service data unit, by passing a descriptor, or by other means. The values of some selection parameters may be implied by an implementation.

2.2.1 MA-UNITDATA request

2.2.1.1 Function. This primitive is the service request primitive for the connectionless data transfer service.

2.2.1.2 Semantics. The primitive shall provide parameters as follows:

```
MA-UNITDATA request  (
                        destination address,
                        source address,
                        M_SDU,
                        desired_quality
                      )
```

The `destination_address` parameter specifies either an individual or a group MAC-entity address. The `source_address` parameter specifies the originating MAC-entity address, typically the local station. The `M_SDU` parameter specifies the MAC service data unit to be transmitted by the MAC sublayer entity for the requesting LLC sublayer entity.

The `desired_quality` parameter specifies the desired quality of service. The semantics of this parameter include both MAC-level priority, with a range of 0 (lowest) to 7 (highest) (see 6.6.1.2), and MAC-level delivery confirmation service, with values of `request_with_no_response`, `request_with_response`, and `response`.

2.2.1.3 When Generated. This primitive is passed from the LLC sublayer entity to the MAC sublayer entity to request that the MAC sublayer entity compose and transmit the specified frame at the desired quality of service on the LAN.

2.2.1.4 Effect on Receipt. Receipt of this primitive causes the MAC sublayer entity to attempt to compose and transmit the specified frame.

2.2.1.5 Additional Comments. A value of `request_with_response` for the delivery-confirmation component of the quality parameter indicates that the next MA-UNITDATA indication should itself have a quality parameter specifying `response`, in which case that next MA-UNITDATA indication shall be associated with this MA-UNITDATA request.

A value of `response` for the delivery-confirmation component of the quality parameter indicates that the immediately prior MA-UNITDATA indication shall itself have had a quality parameter specifying `request_with_response`.

A group `destination_address` should not be used when specifying `request_with_response`.

2.2.2 MA-UNITDATA indication

2.2.2.1 Function. This primitive is the service indication primitive for the connectionless data transfer service.

2.2.2.2 Semantics. The primitive shall provide parameters as follows:

```
MA-UNITDATA indication  (
                        destination_address,
                        source_address,
                        M_SDU,
                        quality
                        )
```

The `destination_address` and `source_address` parameters specify the DA and SA fields of a frame (see Section 4) as received by the local MAC entity, and thus the MAC entities purportedly involved in the communication. The `M_SDU` parameter specifies the MAC service data unit as received by the local MAC sublayer entity.

The quality parameter specifies the delivered quality of service. The semantics of this parameter include both MAC-level priority, with a range of 0 (lowest) to 7 (highest) (see 6.6.1.2), and MAC-level delivery-confirmation service, with values of `request_with_no_response`, `request_with_response`, and `response`.

2.2.2.3 When Generated. This primitive is passed from the MAC sublayer entity to the LLC sublayer entity to indicate the arrival of a data frame from the Physical Layer entity (PLE). Such frames are reported only when they are free of detected errors and their (individual or group) destination address designates the local MAC entity.

2.2.2.4 Effect on Receipt. The effect of receipt of this primitive by the LLC entity is specified in ISO 8802-2 : 1989 (IEEE Std 802.2-1989) [15].

2.2.2.5 Additional Comments. In the absence of undetected errors, the contents of the M_SDU parameter are logically complete and unchanged relative to the M_SDU parameter in the associated MA-UNITDATA request at the sending station.

NOTE: This is a guarantee of transparency.

A value of request_with_response for the delivery-confirmation component of the quality parameter indicates that the receiving LLC sublayer entity should immediately respond with an MA-UNITDATA request which itself has a quality parameter specifying response.

A value of response for the delivery-confirmation component of the quality parameter indicates that this MA-UNITDATA indication may be associated with a prior MA-UNITDATA request which itself had a quality parameter specifying request_with_response, and which was issued by the same LLC sublayer entity.

2.2.3 MA-UNITDATA confirm

2.2.3.1 Function. This primitive provides the LLC sublayer with status information for the previous associated MA-UNITDATA request primitive.

2.2.3.2 Semantics. The primitive shall provide parameters as follows:

```
MA-UNITDATA confirm  (
                        destination_address,
                        source_address,
                        status,
                        provided_quality
                      )
```

The destination_address and source_address parameters specify the destination address and source address fields of the associated MA-UNITDATA request primitive. The status parameter indicates the status of the service provided for a previous associated MA-UNITDATA request primitive.

The provided_quality parameter specifies the quality of service actually provided for the previous request. The semantics of this parameter include both MAC-level priority, with a range of 0 (lowest) to 7 (highest) (see 6.6.1.2), and MAC-level delivery confirmation service.

2.2.3.3 When Generated. This primitive is passed from the MAC sublayer entity to the LLC sublayer entity to indicate the status of the service provided for the previous associated LLC data transfer request.

A success indication is passed when the request has been completed successfully, either because no response was requested or because the requested response was received. A failure indication is passed upon local failure or when a requested response is not received, even after the specified number of retries. When the quality parameter of that request specifies request_with_response, a failure indication is also passed if the allowed number of retries has occurred with no response.

2.2.3.4 Effect on Receipt. The effect of receipt of this primitive by the LLC sublayer entity is specified in ISO 8802-2 : 1989 (IEEE Std 802.2-1989) [15].

2.2.3.5 Additional Comments. It is assumed that sufficient information is available to the LLC sublayer to associate the status with the appropriate request.

3. MAC Sublayer Management

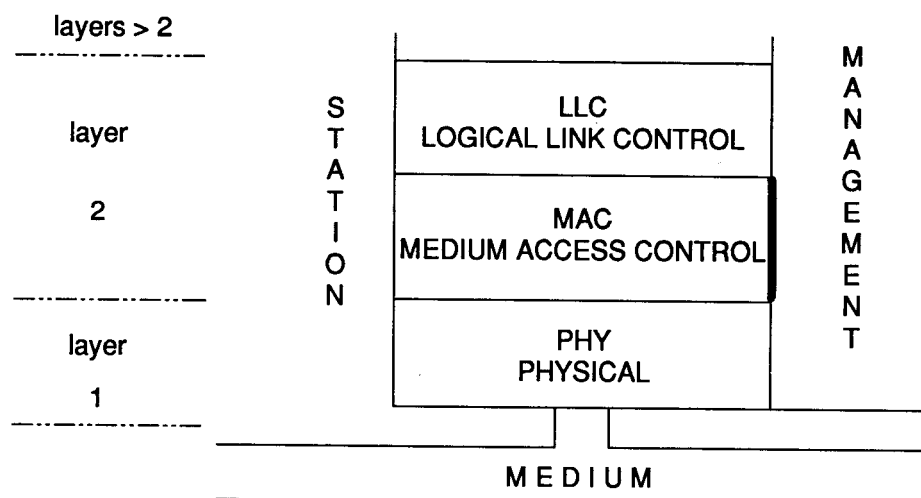
This section specifies the abstract entities (parameters, events, and actions) used in managing the Medium Access Control (MAC) sublayer. The relationship of this section to other sections of this standard and to Local Area Network (LAN) specifications is illustrated in Fig 3-1.

There are two ways to manage a MAC sublayer: locally or remotely.

Local management is required to initially configure a MAC and to operate it when remote management is not available. Since the operation of local MAC management, other than the need to manage the entities described in this section, does not affect station interoperability, the specification of local management is outside the scope of this standard.

This standard uses the concept of remote management as defined in the Open Systems Interconnection (OSI) Management Framework described in ISO/IEC 7498-4 : 1989 [14]. Remote management uses a communications protocol to manipulate and observe the managed entities. This section is designed to be used with the companion remote management standard described by IEEE P802.1B [9]. Other protocols, such as described by ISO/IEC 9595 [18] and ISO/IEC 9596 [19], may also be used.

Fig 3-1
Relation to LAN Model



To implement a remote management protocol, the identification and value representation of the managed entities must be defined. Such a definition is given by a layer management interface (LMI) protocol.

NOTE: The definition of a MAC sublayer LIM protocol is under study. An addendum to this standard is planned that will contain this protocol.

Within this document the general term “management” is used to refer to either local or remote management, unless otherwise indicated.

3.1 Overview. This section describes the entities communicable via the LMI, shown as a thick line in Fig 3-1. The MAC sublayer entities described in this section consist of

- (1) Parameters within the MAC sublayer written and read by the management entity,
- (2) Actions initiated by the management entity that cause changes within the MAC sublayer,
- (3) Events within the MAC sublayer entity that are passed to the management entity.

The notation used to specify the entities defined in this section is the Abstract Transfer Syntax and Notation (ASN.1), defined in ISO 8824 : 1987 [16]. This syntax differs from that used in Sections 4 through 7 to describe the token bus MAC. The difference is in the spelling of the entity names. The ASN.1 notation does not allow the underscore character, “_”, and uses a combination of uppercase and lowercase characters to improve readability.

For example, this section defines a parameter *inRing*. Section 7 defines a parameter *in_ring*. While the syntax of the names is different, the parameters are equivalent.

3.2 MAC Management Facilities. This subsection contains a description of use of the management parameters, actions, and events within the token-passing bus MAC sublayer.

3.2.1 Organization. There are three types of management entities:

- (1) Parameters
- (2) Actions
- (3) Events

The MAC sublayer parameters accessible by the management entity are described first. These parameters are organized into groups. The groups not only collect the variables, they also define collections of parameters that can be accessed in a common manner.

NOTE: In implementing control of access to parameters, the intent of this standard is to implement the granularity of access control only to the group level. Thus, all parameters within a group share a common access level.

Any or all of the parameters in a group may be passed in a single remote management request. The semantics and grouping of the parameters so communicated are specified in the following subsections.

3.2.2 ResourceTypeID. This subsection discusses the parameters of the MAC sublayer LMI that are common to any layer. These parameters create a “name plate” that identifies the basic attributes of the MAC sublayer.

The ResourceTypeID is common to all MAC sublayers. Implementation of this group shall be required. The ResourceTypeID group is defined in IEEE P802.1B [9].

3.2.2.1 resourceType. This parameter identifies the resource as a MAC sublayer.

3.2.2.2 standardRevision. This parameter identifies the revision of this standard implemented by the MAC sublayer.

3.2.2.3 ImeOptions. This parameter identifies the options supported by the implementation. The options defined by this standard are priority and request_with_response.

3.2.3 MAC Characteristics Group. The MAC characteristics group defines attributes of the MAC sublayer that are specific to a token-passing bus MAC sublayer. The implementation of the parameters in the MAC characteristics group shall be optional except for maxSDUSize, which is required. All parameters shall be read-only.

3.2.3.1 maxSDUSize. The maximum size service data unit that the sublayer implementation is capable of accepting.

The value of maxSDUSize is between 516 (to allow 512 octet frames) and 8191 octets.

3.2.3.2 transmitTimeDelay. The estimated maximum delay incurred by the MAC in sending a data frame, including the time in the MAC transmit queue. The value of this parameter is for use by higher layers in computing a time-out delay to use in detecting lost frames. The type is an array of time values indexed by MAC service class (see 6.6.1.2).

The units of this parameter and methods of computing the values are for future study.

3.2.4 MAC Management Group. The MAC management parameters describe the current state of the MAC sublayer. The implementation of access by the management entity to these parameters shall be optional. Access by the management entity to these parameters shall be read-only to prevent unpredictable changes to MAC operation. In order to change the value of one of these parameters, the management entity must change the corresponding value in the initialization group (see 3.2.7) and then perform the reset action to force the station to reinitialize.

3.2.4.1 state. MAC sublayer state. The current state of the MAC entity. The MAC state is changed by management actions (see 3.2.11) and events within the MAC access control machine (ACM) (see Section 7).

The range of values of the state parameter is offline, tokenBus, tokenBus-Bridge, and tokenBusRepeater.

NOTE: The operation of a station in the token-passing bus bridge mode is for future study. Bridge operation is envisioned to include acceptance of frames addressed to stations on networks other than the one to which the station is connected.

3.2.4.2 testStatus. The status of a previously initiated test. Negative, implementation-dependent values shall be treated as “failure” by entities that lack further information on the implementation-dependent meaning.

See 7.1.1 for a detailed description of the following parameters of the MAC management group.

3.2.4.3 ts. This station’s address.

3.2.4.4 slotTime. The network slot_time.

3.2.4.5 minPostSilencePreambleLength. The minimum number of octets of preamble to prefix to a frame after silence. The value is obtained from the PLE and used by the transmit machine (TxM).

3.2.5 Station Performance Group. These parameters affect the operation of the station and the station’s performance in the network. Management may read and write the station performance parameters in order to alter network operation without having to re-initialize the station. The implementation of access by the management entity to these parameters shall be optional.

See 7.1.1 for a detailed description of the parameters of the station performance group.

3.2.5.1 maxInterSolicitCount

3.2.5.2 maxRetryLimit

3.2.5.3 hiPriTokenHoldTime

3.2.5.4 targetRotationTime

3.2.5.5 ringMaintenanceTimerInitialValue

3.2.5.6 inRingDesired

3.2.6 Station Monitoring Group. These parameters reflect the current status of the network and the station’s status with respect to the network.

The implementation of access by the management entity to these parameters shall be optional. The station monitoring parameters shall be read-only with the exception of maxTokenRotationTime, which shall be read-write.

See 7.1.6 for a description of the parameters of the station monitoring group not discussed in the following paragraphs.

3.2.6.1 ns. The address of the next station in the logical ring.

3.2.6.2 ps. The address of the previous station in the logical ring.

3.2.6.3 nsKnown

3.2.6.4 inRing

3.2.6.5 soleActiveStation

3.2.6.6 lastTokenRotationTime. The observed token rotation time for the last token rotation, timed from token arrival to token arrival. Units are octet times.

A value of zero indicates that the value is not currently available; for example, possibly when the station is not a member of the logical ring. A negative value indicates a range overflow.

3.2.6.7 maxTokenRotationTime. The maximum token rotation time. The value is created by comparing the old value of maxTokenRotationTime with the value of lastTokenRotationTime whenever the token is received. If the old maxTokenRotationTime value is less than the lastTokenRotationTime, the value of maxTokenRotationTime is set equal to the value of lastTokenRotationTime. Units are octet times.

The value of this parameter may be set to zero by the management entity to begin a time interval over which the maximum token rotation time is to be measured.

A value of zero indicates that the value is not currently available. A negative value indicates a range overflow.

The creation of other statistics from the maximum and instantaneous token rotation time variables is for future study.

3.2.6.8 approximateRingSize. The approximate number of stations in the logical ring.

A possible method of obtaining the value of `approximateRingSize` is for the station to count the number of valid token frames that it hears between sending and receiving the token. Such a simplistic approach is prone to error when tokens are repeated or heard in error. Implementors can improve the approximation with more sophisticated techniques if desired.

A value of zero means the value is currently unavailable, for example, possibly when the station is not a member of the logical ring. A negative value indicates a range overflow.

3.2.7 Initialization Group. The initialization parameters are copied to the MAC sublayer operational parameters when the station is initialized. The initialization parameters shall be required in implementations where the corresponding operational parameters exist. The initialization parameters shall be readable and writeable by the management entity.

See 7.1.7 for a detailed description of the parameters of the initialization group.

3.2.7.1 initTS

3.2.7.2 initSlotTime

3.2.7.3 initMaxInterSolicitCount

3.2.7.4 initMaxRetryLimit

3.2.7.5 initHiPriTokenHoldTime

3.2.7.6 initTargetRotationTime

3.2.7.7 initRingMaintenanceTimerInitialValue

3.2.7.8 initInRingDesired

3.2.8 Interface Machine (IFM) Counters Group. These parameters monitor the operation of the IFM. In counting frame length, octets in a frame are counted between the start delimiter and the end delimiter, exclusively. Service class to access class correspondence is specified in 6.6.1.2.

The implementation of the IFM counters and access by the management entity shall be optional. Access by the management entity to these parameters shall be read-only.

3.2.8.1 messagesSent. The number of data frames sent at the corresponding access class.

3.2.8.2 octetsSent. The number of octets in data frames sent at the corresponding access class, including control fields and excluding delimiters.

3.2.8.3 messagesReceived. The number of valid data frames received and accepted at the corresponding access class.

3.2.8.4 octetsReceived. The number of octets of valid data frames received and accepted at the corresponding access class, including control fields and excluding delimiters.

NOTES: (1) This standard does not include a count of frames discarded at the MAC-LLC interface due to lack of buffer space. The presumption is that the LLC sublayer is responsible for buffer management and discarding frames for lack of space.

(2) It is possible to have underruns while transmitting frames and/or overruns while receiving frames. Implementations may have counters that record the occurrence of these events. It is recommended that these counters be included in private management parameters of the IFM counters group.

3.2.9 Access Control Machine (ACM) Counters Group. These parameters monitor the operation of the ACM. The implementation of the ACM counters and access by the management entity shall be optional.

Implementation of a threshold facility associated with each counter shall be treated as a separate option. Thus, one of three conditions exists: No implementation, 32-bit counters without threshold, or 32-bit counters with threshold. If implemented, access by the management entity to these parameters shall be read only, except for the portions associated with the threshold mechanism. (The threshold facility can be used to generate an event to the management entity when the value of a counter exceeds a specified value.)

NOTE: The condition described in 6.7.4 can cause the `token_pass_failure`, `who_follows_query`, and `solicit_any` counters to increment during correct operation of the network.

3.2.9.1 whoFollowsQuery. The number of occurrences of the ACM `who_follows_query` state transition. (See 7.2.3.8.)

3.2.9.2 tokenPassFailed. The number of occurrences of the ACM `token_pass_failed` state transition when `pass_state` equals `pass_token`.

3.2.9.3 solicitAny. The number of occurrences of the ACM `solicit_any` state transition not due to the ACM `do_solicit_any` state transition.

3.2.9.4 noSuccessor. The number of occurrences of the ACM `no_successor_8` state transition.

3.2.9.5 unexpectedFrame. The number of occurrences of the ACM `unexpected_frame_6` and `unexpected_frame_10` state transitions.

3.2.9.6 claimToken. The number of occurrences of the ACM `no_token` state transition.

3.2.10 Receiver Machine (RxM) Counters Group. These parameters monitor the operation of the RxM. The implementation of the RxM counters and access by the management entity shall be optional. Thus the implementation of the MAC variable `noise_expected` discussed in the next paragraph, shall also be optional. Access to the RxM counters shall be read-only, except for the portions associated with the optional threshold mechanism.

The MAC variable `noise_expected` is used only in the definition of the RxM counters and is not described elsewhere in this standard. The `noise_expected` variable attempts to track the state of the network so that errors reported by the modem can be classified.

Errors reported by the modem may actually be induced by “collisions” when multiple stations transmit during times when contention can occur. By tracking

the state of the network, the ACM attempts to predict the times of possible contention. The variable `noise_expected` conveys this information.

To simplify the explanation, the ACM state tables in 7.2 do not include the variable `noise_expected`. If required to implement the counters defined in this subsection, `noise_expected` shall be reset whenever the ACM

- (1) Receives or sends a valid token frame
 - (2) Receives or sends a valid data frame
- The `noise_expected` variable shall be set whenever the ACM
- (a) Traverses the initialize arc
 - (b) Receives or sends a `solicit_successor_1` frame
 - (c) Receives or sends a `solicit_successor_2` frame
 - (d) Receives or sends a `resolve_contention` frame
 - (e) Receives or sends a `who_follows` frame
 - (f) Receives or sends a `claim_token` frame

Implementation of a threshold facility associated with each counter except `validFrames` shall be treated as a separate option. Thus, one of three conditions exists: No implementation, simple 32-bit counters, or thresholded 32-bit counters. If implemented, access by the management entity to these parameters shall be read only, except for the portions associated with the threshold mechanism.

3.2.10.1 validFrames. The number of valid frames received of all types, including MAC control frames. (See 4.1.)

3.2.10.2 modemErrors. The number of noise bursts that occur when `noise_expected` is reset. `modemErrors` is a count of noise bursts that are probably caused by errors in the PLE or as the result of noise introduced on the medium.

The following counters are defined in order to aid in diagnosing the cause of errors reported in `modemErrors`. The value of `modemErrors` is the sum of the values of the following counters:

- (1) **fcsErrors.** The number of frames received with incorrect frame check sequence (FCS) and E-bit reset when `noise_expected` is reset. (This value represents a count of FCS errors not previously detected by a remodulator or other repeater.)
- (2) **eBitErrors.** The number of frames received with the E-bit set and the FCS invalid when `noise_expected` is reset. (This value represents a count of FCS errors previously detected by a remodulator or other repeater.)
- (3) **nonSilence.** The number of occurrences of non-silence followed by silence in which a start delimiter was not detected when `noise_expected` is reset. (This error is possibly caused by a noise "hit" on the start delimiter.)
- (4) **frameFragments.** The number of occurrences of a start delimiter followed by a start delimiter, invalid symbol sequence, or silence without an intervening end delimiter. `frameFragments` is only incremented when `noise_expected` is reset. (This error is probably caused by premature termination of a frame by an abort sequence.)

The treatment of frames that are received with the correct FCS and the E-bit set is not specified by this standard. However, if such frames are discarded by the MAC as invalid, the count of such discarded frames shall be included in `eBitErrors`.

3.2.11 Action Definitions. Actions are requests by the management entity to perform some activity. The reset and initialize with a value of initializeTokenBus actions shall be required locally. All other actions shall be optional.

3.2.11.1 reset Action. This action causes the MAC sublayer to go to the OFFLINE state. The MAC sublayer shall remain in this state until a local initialize action occurs. A remote initialize action shall be ignored following a remote reset action.

The action may be used to disable the MAC sublayer if it is suspected of malfunctioning.

3.2.11.2 initialize Action. This action resets the MAC sublayer and then causes the station's ACM to traverse the initialize arc and enter the IDLE state in accordance with the action request parameter. A remote initialize action shall be ignored if the MAC sublayer is already in the OFFLINE state. The action request parameter may assume the values tokenBus, tokenBusBridge, or tokenBusRepeater.

Following an initialize action, the values of the counters specified in 3.2.8 through 3.2.10 are unspecified.

3.2.11.3 initiateTest Action. The initiateTest action commences an internal test of the MAC sublayer if the station is in the OFFLINE state. The result of the most recently initiated test is reported in the parameter testStatus. (See 3.2.4.2.)

The effect of the initiateTest action when the station is not in the OFFLINE state is for future study.

3.2.12 Event Definitions. Events are spontaneously reported by the sublayer to the management entity. Remote reporting of events shall be optional.

Local support of the thresholdReached event is required when thresholded counters are implemented. Support of the newSuccessor event shall be optional. Passing of the new successor's address shall be optional. Support of the noSuccessor event shall be optional. Local support of the duplicateAddressFault and faultyTransmitterFault events shall be required.

NOTE: In implementing routing of events, the intent of this standard is to provide a unique routing path for each event.

3.2.12.1 thresholdReached. A thresholded counter has passed the threshold value. The event value shall be the counter's parameter identifier.

3.2.12.2 newSuccessor. The station's successor has changed. The event value shall be the new successor address.

3.2.12.3 noSuccessor. The station now considers itself the sole member or not a member of the ring.

3.2.12.4 duplicateAddressFault. The station has detected another station with the same MAC address. The state transition causing this event is duplicate_address_1. (See 6.7.1 for possible additional detection methods.)

3.2.12.5 faultyTransmitterFault. The station has decided that it may have a faulty transmitter. The state transitions associated with such a decision are

- (1) end_all_contention
- (2) no_future

4. Frame Formats

This section defines the required Medium Access Control (MAC) frame formats. This includes all allowed frame formats and the arrangement of all frame subfields. The term frame as used here refers to the protocol data units (PDUs) exchanged by MAC sublayer entities. The MAC service data units received from the Logical Link Control (LLC) sublayer are contained within some of these MAC frames. The frame components and formats used by medium access control are also described in this section.

The MAC frames and abort sequences are described in the following subsections. First, the components of the frames are discussed, followed by the definition of the valid frame formats. All frames sent or received by the MAC sublayer shall conform to the following general format:

PREAMBLE	SD	FC	DA	SA	DATA_UNIT . . .	FCS	ED
----------	----	----	----	----	-----------------	-----	----

where

PREAMBLE = pattern sent to set receiver's modem clock and level
(1 or more octets)
SD = start delimiter (1 octet)
FC = frame control (1 octet)
DA = destination address (2 or 6 octets)
SA = source address (2 or 6 octets)
DATA_UNIT = information (0 or more octets)
FCS = frame check sequence (4 octets)
ED = end delimiter (1 octet)

The number of octets between SD and ED, exclusive, of a data frame (see 4.1.3.2) shall be 8191 octets or fewer.

The abort sequence shall conform to the following format:

SD	ED
----	----

where

SD = start delimiter (1 octet)
ED = end delimiter (1 octet)

Within this section the following acronyms are used for the addresses of the station under discussion, its successor and its predecessor in the logical ring:

TS—this station's address
 NS—next station's address
 PS—previous station's address

4.1 Frame Components. This subsection describes the frame components that are shown in the previous illustrations in greater detail.

A valid frame consists of preamble, a start delimiter, a frame control octet, destination and source addresses, possibly a data unit, a valid FCS, and an end delimiter, and does not meet any of the criteria of an invalid frame as described in 4.2.3. This definition excludes abort sequences from the set of valid frames.

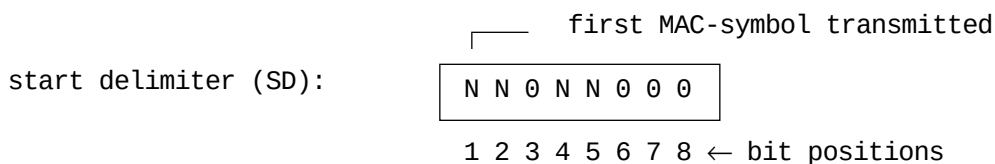
4.1.1 Preamble. The preamble pattern precedes every transmitted frame. Preamble is sent by the MAC sublayer entity as an appropriate number of *pad_idle* symbols. Preamble may be decoded by the receiver as arbitrary data symbols that occur outside frame delimiters. Preamble is primarily used by the receiving modem to acquire signal level and phase lock by using a known pattern. The preamble pattern is chosen for each modulation scheme and data rate for this purpose. The parameter *min_post_silence_preamble_length* specifies the minimum amount of preamble on the first frame transmitted after a period of “transmitted” *silence*. See 7.1.1 for use of the parameter within the MAC sublayer. See 12.6, 14.7, 16.6, and 18.6 for the specification of the different physical layers.

A secondary purpose for the preamble is to guarantee a minimum ED to SD time period to allow stations to process the frame previously received. The minimum amount of preamble transmitted is a function of both the data rate and the modulation scheme. The standard requires that the duration of the preamble shall be at least 2 μ s, regardless of data rate, and that an integral number of octets shall be sent. Thus, at a data rate of 1 Mb/s, one octet of preamble is required to meet the integral number of octet requirements, and at a data rate of 10 Mb/s, three octets are required to meet the minimum time requirement.

The maximum amount of preamble is constrained by the “jabber” control in the PLE. Additionally, for *claim_token* frames, all stations shall use the minimum number of preamble octets to ensure that all frames are of uniform specified length.

4.1.2 Start Delimiter (SD). The frame structure requires an SD, which begins the frame. The SD consists of signaling patterns that are always distinguishable from data.

The SD is coded as follows (see 12.7, 14.8, 14.11, 16.7, and 18.7 for representations of the symbol coding as present on the medium):



where

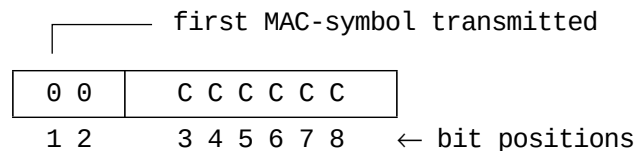
N = *non_data* MAC-symbol
 0 = *zero* MAC-symbol
 1 = *one* MAC-symbol

4.1.3 Frame Control (FC) Field. The FC octet determines what class of frame is being sent from among the following general categories:

- (1) MAC control
- (2) LLC data

The FC format for each of these categories is illustrated by the following:

4.1.3.1 MAC Control Frame



where

CCCCCC = type of MAC_control frame as follows:

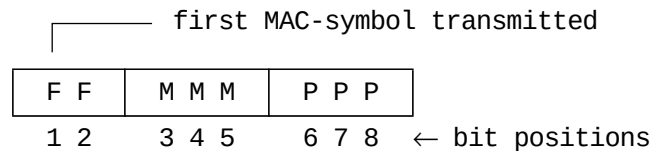
C C C C C C

3 4 5 6 7 8 ← bit positions

0 0 0 0 0 0	claim_token
0 0 0 0 0 1	solicit_successor_1 (has 1 response window)
0 0 0 0 1 0	solicit_successor_2 (has 2 response windows)
0 0 0 0 1 1	who_follows (has 3 response windows)
0 0 0 1 0 0	resolve_contention (has 4 response windows)
0 0 1 0 0 0	token
0 0 1 1 0 0	set_successor

4.1.3.2 Data frames

first MAC-symbol transmitted



where

F F = frame type:
 (1 2 ← bit positions)

0 1 = LLC_data_frame
 1 0 = reserved (former management)
 1 1 = reserved (further study)

M M M = MAC-action:
 (3 4 5 ← bit positions)

0	0	0	= request_with_no_response
0	0	1	= request_with_response (see 6.6.2)
0	1	0	= response (see 6.6.2)

P P P = priority:
 (6 7 8 ← bit positions)

1	1	1	= highest priority
1	1	0	
1	0	1	
1	0	0	
0	1	1	
0	1	0	
0	0	1	
0	0	0	= lowest priority

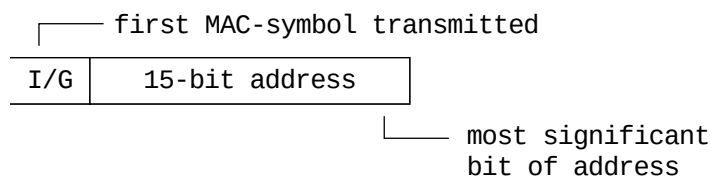
NOTE: The use of the “10” in the frame type field to indicate frames destined for the management entity is not recommended and is included only to retain backwards compatibility with previous versions of this standard.

Other bit patterns in the FC octet are reserved for future study. The action of a station upon receiving an FC value not defined in this standard is not specified.

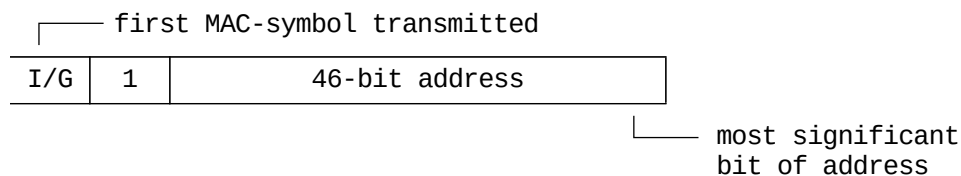
4.1.4 Address Fields. Each frame shall contain two address fields: The destination address field and the source address field, in that order. Addresses shall be either 16 bits or 48 bits in length. All addresses on a given Local Area Network (LAN) shall be of the same length.

4.1.4.1 Destination Address Field. The following illustration shows the possible representations of destination addresses:

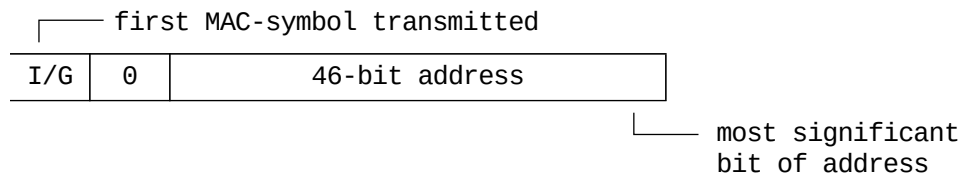
(1) 16-bit address form



(2) 48-bit locally administered form



(3) 48-bit universally administered form



where

I/G = individual/group address bit

The first MAC-symbol transmitted of the destination address (the I/G bit) distinguishes individual addresses from group addresses:

0 = individual address

1 = group address

For 48-bit addresses, the second MAC-symbol transmitted of source or destination addresses (the local/universal or L/U bit) distinguishes locally administered addresses from universally administered, unique addresses.

Individual Addresses. An individual address identifies a particular station on the LAN and shall be distinct from all other individual station addresses on the same LAN.

Group Addresses. A group address is used to address a frame to multiple destination stations. Group addresses may be associated with zero, one, or more stations on a given LAN. In particular, a group address is an address associated by convention with a group of logically related stations.

Broadcast Addresses. The group address consisting of all *ones* (that is, 16 or 48 *ones* for two- or six-octet addressing, respectively) shall constitute a broadcast address, denoting the set of all stations on the given LAN.

NOTE: For some of the frame types used by the token-passing bus MAC procedures, the contents of the destination address field are irrelevant. In such cases, the originating station's own address or any other individual addresses may be sent in this field.

Address Administration (48-bit addresses only). There are two methods of administering the set of 48-bit station addresses: locally or through a universal authority. The second bit transmitted of the destination address indicates whether the address has been assigned by a universal or local administrator.

0 = universally administered

1 = locally administered

Universal Administration. With this method, all individual addresses are distinct from the individual addresses of all other LAN stations on a universal basis. The procedure for administration of these addresses is not specified in this standard.

NOTE: Information concerning the Registration Authority and its procedures may be obtained on request to the Secretary General, ISO Central Secretariat, 1 rue de Varembe, Case postale 56, CH1211, Genève, Switzerland/Suisse, quoting the number of this International Standard.

For information on universal address administration contact the Secretary, IEEE Standards Board, Institute of Electrical and Electronics Engineers, Inc., P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA.

Local Administration. Individual station addresses are administered by a local (to the LAN) authority. (This is the only method allowed for 16-bit addresses.)

NOTE: Appendix 4.3 contains a suggested method for hierarchical structuring of locally administered addresses.

4.1.4.2 Source Address Field. The source address identifies the station originating the frame and has the same format and length as the destination address in a given frame, except that the I/G bit shall be set to 0; the significance of it being set to 1 is a subject for future study.

4.1.4.3 Numerical Interpretation of Addresses. Strictly speaking, addresses are bit strings which serve as unique station identifiers or group identifiers. For the purpose of the MAC address comparison within the token bus MAC sublayer, as used in ordering the logical ring and as expressed in the formal access control machine of 7.2.3, each MAC-address bit string is interpreted as if it were an unsigned integer value sent least significant bit first, and thus as if the last bit transmitted had the highest numeric significance.

NOTE: This interpretation does not extend beyond the logical ring ordering operations of the token-passing bus MAC sublayer.

Additionally, the address bits are used in determining delays in the contention process and transmission lengths in the token claiming process. These processes start with the most significant address bits, under the above interpretation, using two bits at a time. Thus the internal processing order is reversed from the serial transmission order on the medium.

4.1.5 MAC Data_Unit Field. Depending on the bit pattern specified in the frame's FC octet, the MAC data_unit field can contain either an LLC protocol data_unit as specified in ISO 8802-2 : 1989 (IEEE Std 802.2-1989) [15], or a value specific to one of the MAC control frames.

In the case where the MAC data_unit field contains a LLC PDU, the MAC data_unit field shall be transmitted to the Physical Layer in the same bit order as received from the LLC sublayer. Likewise, the MAC data_unit field shall be delivered to the LLC sublayer in the same bit order as received from the Physical Layer.

4.1.6 Frame Check Sequence (FCS) Field. The FCS is a 32-bit frame checking sequence, based upon the following standard generator polynomial of degree 32:

$$X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} \\ + X^8 + X^7 + X^5 + X^4 + X^2 + X + 1$$

The FCS is the one's complement of the sum (modulo 2) of

(1) The remainder of

$$X^K * (X^{31} + X^{30} + X^{29} + \dots + X^2 + X + 1)$$

divided (modulo 2) by the standard 32-bit generating polynomial, where K is the number of bits in the FC, address (SA and DA), and MAC data_unit fields, and

- (2) The remainder of the division (modulo 2) by the standard generator polynomial of the product of X^{32} by the content of the FC, address (SA and DA), and MAC data_unit fields.

The FCS is transmitted commencing with the coefficient of the highest degree term.

As a typical implementation, at the transmitter, the initial content of the register of the device computing the remainder of the division is preset to all ones and is then modified by the generator polynomial (as described above) on the FC, address, and data_unit fields. The one's complement of the resulting remainder is transmitted as the 32-bit FCS.

At the receiver, the initial content of the register of the device computing the remainder is preset to all ones. The incoming serial data bits and the FCS, when divided by the generator polynomial, result, in the absence of transmission errors, in a unique non-zero remainder value. The unique remainder value for the 32-bit FCS is the polynomial:

$$X^{31} + X^{30} + X^{26} + X^{25} + X^{24} + X^{18} + X^{15} + X^{14} + X^{12} \\ + X^{11} + X^{10} + X^8 + X^6 + X^5 + X^4 + X^3 + X + 1$$

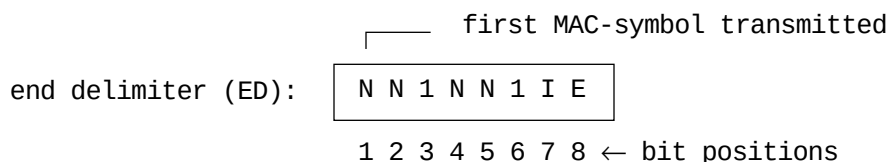
NOTES: (1) To test the FCS generation and checking logic in a station, an implementation should provide a means of bypassing the FCS generation circuitry and providing an FCS from an external source. The ability to pass frames that have FCS errors along with the received FCS value and an error indication, to higher levels of the protocol, is another desirable testability feature.

(2) The FCS polynomial provides a Hamming distance of four in the frame transmission and frame detection process, provided that the total frame length, between SD and ED exclusive, is less than 11454 octets. The maximum data frame length, 8191, is 11454 rounded down to the nearest power of two (minus one).

4.1.7 End Delimiter (ED). The frame structure requires an ED, which ends the frame and determines the position of the FCS. The data between the SD and the ED shall be an integral number of octets. All bits between the SDs and EDs are covered by the FCS.

The ED consists of signaling patterns that are always distinguishable from data. The ED also contains bits of information that are not error checked.

The ED is coded as follows:



where

N = *non_data* MAC-symbol

1 = *one* MAC-symbol

I = intermediate bit (1 = more to transmit,
0 = end of transmission)

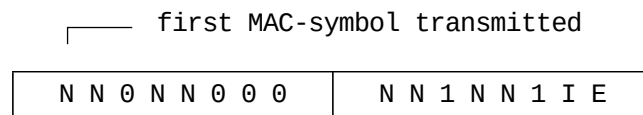
E = error bit (0 = no error, 1 = error)

The seventh ED MAC-symbol is called the intermediate bit (or “I” bit). If *one*, it indicates that more transmissions from the station follow. If *zero*, it indicates that this is the last frame transmitted by the station and silence follows the ED. The I bit assists a repeater and possibly the Physical Layer in determining what follows the ED.

The eighth ED MAC-symbol is called the error bit (or “E” bit). When set to *one* by a repeater, the error bit indicates that this frame had an FCS error within the frame and the error did not occur on the communication path between the immediately preceding sending station/repeater and this receiving station. When the error bit is set to *one*, the receiving station may treat the frame as an invalid frame. The originating station shall always transmit the error bit as *zero*.

4.1.8 Abort Sequence. The abort sequence is used to prematurely terminate the transmission of a frame. The abort sequence shall be transmitted on an octet boundary relative to that part of the aborted frame already transmitted.

An abort sequence consists of the following pattern:



An abort sequence shall also be transmitted by a repeater upon receiving an invalid coding sequence.

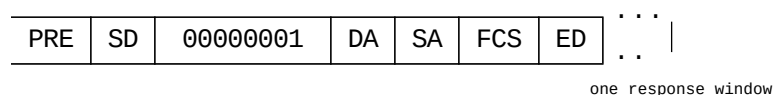
4.2 Enumeration of Frame Types. This subsection shows how the components of the frames are arranged in the various frame types transmitted by the MAC sublayer. Section 5 discusses the frames and terminology used here.

4.2.1 MAC Control Frame Formats. The following frames are sent and received by the MAC sublayer and are not passed to higher layers.

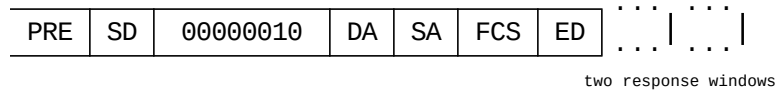
4.2.1.1 Claim_token. The frame has a data_unit whose value is arbitrary and whose length in octets is 0, 2, 4, or 6 times the system’s slot_time also measured in octets.

PRE	SD	00000000	DA	SA	arbitrary value, length = (0,2,4,6) * slot_time octets	FCS	ED
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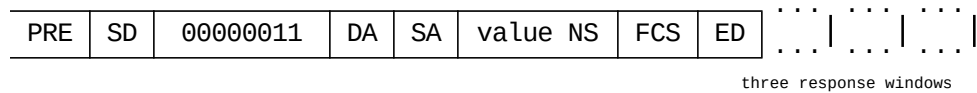
4.2.1.2 Solicit_successor_1. The frame has a DA equal to the value of the station’s NS and a null data_unit. One response window always follows this frame.



4.2.1.3 Solicit_successor_2. The frame has DA equal to the value of the station's NS or TS and a null data_unit. Two response windows always follow this frame.



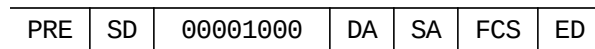
4.2.1.4 Who_follows. The frame has a data_unit equal to the value of the station's NS. The format and length of the data_unit is the same as a source address. Three response windows always follow this frame. (This gives receivers two extra slot_times to make a comparison with an address other than TS.).



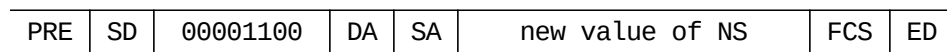
4.2.1.5 Resolve_contention. The frame has a null data_unit. Four response windows always follow this frame.



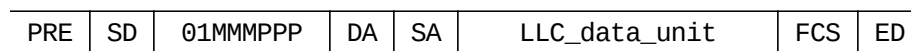
4.2.1.6 Token. The frame has DA equal to the value of the station's NS, and has a null data_unit.



4.2.1.7 Set_successor. The frame has data_unit equal to the value of the station's NS or TS. The format and length of the data_unit are the same as that of a source address.



4.2.2 LLC Data Frame Format. LLC data frames have a DA and data_unit specified by a station's LLC sublayer. A frame of this type with a non-null data_unit shall be passed to the receiving station's LLC sublayer (see 4.1.3.2).



4.2.3 Invalid Frames. An invalid frame is defined as one which meets at least one of the following conditions:

- (1) It is identified as such by the PLE. (For example, it contains *bad_signal* symbols.)
- (2) It is not an integral number of octets in length.
- (3) It does not consist of an SD, one FC field, two properly formed address fields, one data_unit field of appropriate length (dependent on the bit pattern specified in the FC field), one FCS field, and an ED, in that order.
- (4) The FCS computation, when applied to all octets between the SD and the ED, fails to yield the unique remainder specified in 4.1.6.

An implementation may also include any of the following additional conditions for an invalid frame:

- (5) The FC field contains an undefined bit pattern.
- (6) The error bit within the ED is set to *one*.

Invalid frames shall be treated as noise. Their existence, as noise bursts, is relevant at some points in the token bus elements of procedure.

Appendix

(This Appendix is not a part of this International Standard or of IEEE Std 802.4-1990, but is included for information only.)

4.3 Appendix—Recommendation for a Hierarchical Structure for Locally Administered Addresses. The concepts introduced in this Appendix are under study for inclusion in a future revision of this standard.

This Appendix describes an addressing structure for a bus network divided into multiple logical segments, with one or more MAC bridge stations interconnecting the segments. Structuring MAC addresses in a hierarchical fashion can facilitate the operation of these bridge stations.

A logical segment is defined as the collection of all stations of a LAN that have the same segment address and that can exchange frames without any intermediary MAC bridge entity. Stations of a segment can communicate with stations with different segment addresses only through a MAC bridge or some other intermediary. For example, for a token bus implementation, the stations of a logical segment share a single token forming a single logical ring distinct from other logical segments.

A hierarchical address permits a MAC bridge station to recognize frames that require forwarding to other logical segments.

The source and destination address partitioning recommended for this purpose is