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Draft for Development

Token bus local area networks

Part 1. Technical specification
(ISO DP 8802/4; IEEE 802.4 Draft F)



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British Standards Institution

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This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature because the application of standardization to LAN technology is rapidly advancing and not yet sufficiently stable, pending the outcome of deliberations in the International Standards Committee (ISO/TC 97, SC 6 Telecommunications and Information Exchange between Systems).

It should be applied on this provisional basis, so that information experience of its practical application may be obtained.

A review of this Draft for Development will be carried out not later than two years after its publication. Notification of the start of the review period, with a request for the submission of comments from users of this Draft for Development will be made in an announcement in the appropriate issue of *BSI News*. Observations which it is felt should receive attention before the official call for comments will be welcomed.

According to the replies received, the responsible BSI Committee will judge whether the Draft for Development can be converted into a British Standard or what other action should be taken.

National foreword

This Draft for Development has been prepared under the direction of the Office and Information Standards Committee, at the request of the Department of Trade and Industry.

The primary objective of this Draft for Development is to give advance guidance to product and systems designers concerned with local area networks.

The text of the Draft for Development is identical with Draft F of the standard finalized and approved by the Institute of Electrical and Electronics Engineers, Inc., IEEE 802.4 'Token-passing bus access method and physical layer specifications'. Earlier drafts of the IEEE standard were submitted to the International Organization for Standardization (ISO) TC 97/SC 6, Telecommunications and Information Exchange between Systems, for study, and Draft E (July 1983) was circulated as Draft Proposal ISO/DP 8802/4 with a closing date for voting of 29 February 1984. As a result of comments submitted by the International Electrotechnical Commission (IEC) SC 65C and other groups, notably the USA committee for PROWAY, it was decided to amend the IEEE and ISO drafts to further accommodate the needs of the process control industry. The responsible BSI Technical Committee decided, therefore, to await the publication of Draft F before publishing an equivalent Draft for Development. The text of this Draft for Development has also been submitted for circulation as ISO/DIS 8802/4.

For ease of reproduction the IEEE text has been reproduced unchanged. It should be noted, however, that the recommended frequency allocations for North American CATV systems and the recommendations and guidelines related to safety although reproduced, do not form part of the Draft for Development, nor does it form part of Draft International Standard ISO/DIS 8802/4. It has not been deleted, however, as it gives useful guidance on USA practice, and margin marks adjacent to the text will refer the reader to the introduction. Users of the Draft for Development are advised to make reference to appropriate UK regulations and standards on electrical safety. Additionally, deleted text in IEEE 802.4 has been erased for clarity.

The UK has actively participated through BSI Technical Committee OIS/6, in the development of this Draft for Development. The Technical Committee will review any agreed amendments or addenda to the ISO text and will, where appropriate, update the text of this Draft for Development via an amendment or revision. When the ISO Draft reaches an appropriate level of agreement and stability, this Draft for Development may then be converted to a British Standard.

Other British Standard publications on local area networks include:

- DD 98 CSMA/CD local area networks
Part 1 Technical specification
Part 2 Guidance for implementors
- DD 99 Logical link control for local area networks
Part 1 Technical specification

- BS 6531 10 Mbps slotted ring local area network
Part 1 Specification for the coding of bits and structure of slots and mini-packets
Part 2 Specification for configuration
Part 3 Specification for free-standing repeaters
Part 4 Specification for basic and enhanced class nodes with Type 1 node/DTE interface
Part 5 Specification for monitor
Part 6 Specification for logging station
Part 7 Specification for slave power supplies

- BS 6532 Data terminal equipment for attachment to 10 Mbps slotted ring local area network
Part 1 Specification for media access control procedures for data terminal equipment
Part 2 Specification for implementation requirements for media access control in general purpose data terminal equipment

BS 6531 and BS 6532 have been submitted to ISO and will be issued in due course as a single draft, ISO/DP 8802/6. IEEE 802.6 'Metropolitan area networks' has not been submitted to ISO.

This Draft for Development has been designated Part 1 in anticipation that an eventual Part 2 will be published as a Technical Guide to Part 1.

In accord with Article 4 (iii) of the Memorandum of Understanding between HM Government and BSI (1982), the Department of Trade and Industry recommend the use of this Part of DD 100 in the UK as part of the FOCUS Intercept Strategy.

For information, a list of published British Standards and Drafts for Development (together with those scheduled for publication at the time of publication of this Draft for Development) for OSI data communications is attached as national appendix A. Press Releases for new OSI and data communications British Standard publications will be issued to the computing press, and details of all new publications will be recorded in full in *BSI News*. A Standing Order Scheme (SOS) is available to subscribing members of BSI, by which interested parties will receive all OSI and data communications British Standard publications, i.e. including British Standards, Drafts for Development and amendments, as soon as they are published thus ensuring prompt receipt of all publications in this area. Full details of the SOS may be obtained from Marketing Department, BSI, Linford Wood, Milton Keynes, MK14 6LE (Telephone 0908 320033) quoting reference SOS Subsection 444.

IMPORTANT. The parts of the text that are presented thus '~~parts-of-the-text~~' are to be regarded as being for trial use.

Terminology and conventions. The text of IEEE 802.4 has been approved as suitable for publication as a Draft for Development. Some terminology and certain conventions are not identical with those used in Drafts for Development; attention is drawn especially to the following.

Wherever the words 'IEEE standard 802.4' appear, they should be read as 'DD 100 : Part 1'.

DD 100: Part 1: 1985

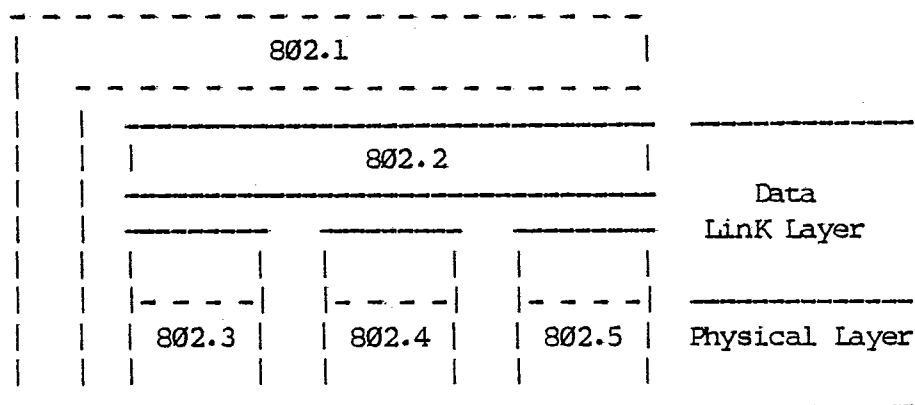
Cross-references**International standard**ISO/DP 8802/2
(IEEE 802.2—1984)**Corresponding British Standard**DD 99 Logical link control for
local area networks
Part 1 Technical specification
(ISO/DP 8802/2; IEEE 802.2
Draft E March 1984)
(Identical)

ISO 7498—1984

BS 6568 : 1984 Description of
basic reference model for open
systems interconnection
(Identical)

Foreword

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 System Interconnection Reference Model. 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 802.3-198X (ISO DP 8802/3), a bus utilizing CSMA/CD as the access method
- (2) IEEE Std 802.4-198X (ISO DP 8802/4), a bus utilizing token passing as the access method
- (3) IEEE Project 802.5¹, a ring utilizing token passing as the access method

Other access methods (e.g., metropolitan area networks) are under investigation.

IEEE Std 802.2 (ISO DP 8802/2), the Logical Link Control protocol standard, is used in conjunction with the medium access standards.

¹ Approval and publication of this standard is pending IEEE Standard Board action.

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Documents

1. Introduction and Overview

This portion of the LAN standards deals with all elements of the token passing bus access method and its associated physical signalling 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.

1.1 Scope. For the purpose of compatible interconnection of stations by way of a Local Area Network using the Token-Passing Bus access method this standard

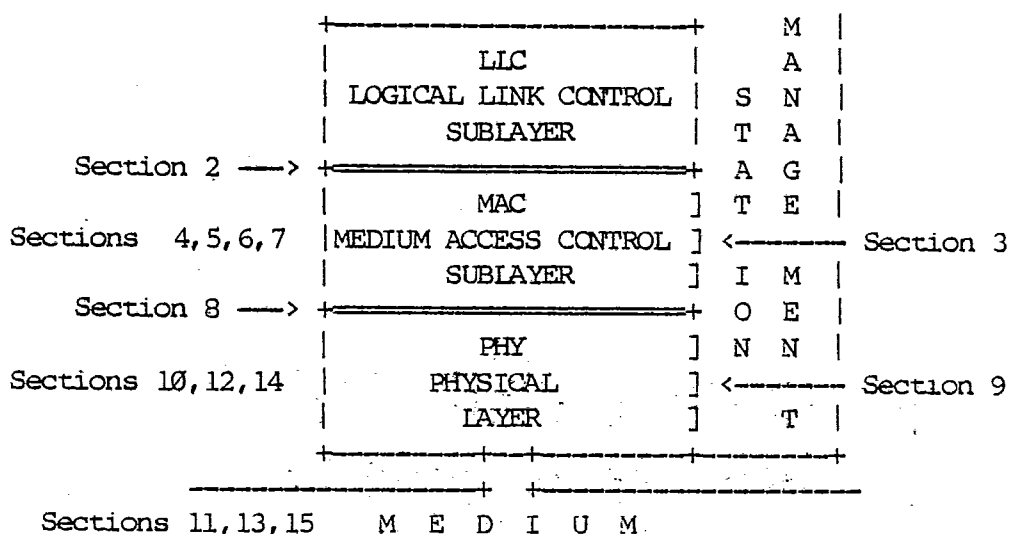


Fig 1
Relationship of Adjacent Protocol Layers

- (1) Specifies the electrical and physical characteristics of the transmission medium
- (2) Specifies the electrical signalling method used
- (3) Specifies the frame formats transmitted
- (4) Specifies the actions of a station upon receipt of a data frame
- (5) Specifies the services provided at the conceptual interface between the Medium Access Control sublayer and the Logical Link Control sublayer above it.

Within this standard the operation of a station is specified in terms of the layered model shown in Fig 1, see Ref [3].³

The figure also shows which sections of the standard specify interfaces between layers and which sections specify the operation of the layers themselves.

1.2 Definitions. Terms that are used in a specific or specialized manner in one section of this standard are defined at the beginning of that section.⁴

³The numbers in brackets correspond with those of the references in 1.3

⁴Specialized terms used in this standard are defined in the glossary of IEEE Std 802.1 (ISO 8802/1). See footnote 5.

1.3 References

{NOTE: References to ANSI, IEEE, and ISA Standards are not part of the ISO Standard.}

[1] Reserved for future use⁵

[2] IEEE Std 802.2-1984 (ISO DP 8802/2), Local Area Network Standard - Logical Link Control.⁶

[3] ISO/DIS 7498 Data Processing - Open System Intercommunication Basic Reference Model, Feb 4, 1982.⁷

[4] ANSI MIL Std 1851A-1983, Ada^R Programming Language.^{8,9}

[5] ISA-8572.01, PROWAY-LAN (Local Network) An Industrial Data Highway.¹⁰

[6] The Yellow Book, "Data Communication over the Telephone Network", CCITT Recommendations of the V Series, Vol 8, Fascicle 8.1, ITU, Geneva, Nov. 1980 (esp. V.35 - V.37).

[7] The Yellow Book, "Data Communication Network Transmission, Signalling and Switching, Network Aspects, Maintenance, Administrative Arrangements", CCITT Recommendation X.150, Vol 8, Fascicle 8.3, ITU, Geneva, Nov. 1980.

⁵When the following document is completed, approved, and published, it will become a part of this reference section.

[1] IEEE Std 802.1 (ISO 8802/1), Local Area Network Standard - Overview, Interworking, and Management.

⁸Ada is a registered trademark of the US government, Ada Joint Program Office.

⁹For reference purposes, a copy of this standard has been retained at the BSI Library, Linford Wood, Milton Keynes MK14 6LE.

¹⁰ISA documents are available from Instrument Society of America, 67 Alexander Drive, PO Box 12277, Research Triangle Park, NC 27709, USA.

[8] The Yellow Book, "Line Transmission of Non-telephone Signals", CCITT Recommendations of the H Series, Vol. III, Fascicle III.4, ITU, Geneva, 1980 (esp. H.14).

[9] The Yellow Book, "Impedance Matching Between Repeaters and Coaxial Pair in Television Transmission", Annex A of Recommendation J.73, Vol. III, Fascicle III.4, ITU, Geneva, 1980.

1.4 Compliance. Implementations that claim compliance with this standard shall

(1) Offer the mandatory LLC - MAC interface and services specified in this standard

(2) Offer the mandatory station management interface and services specified in this standard

(3) Support the medium access protocol specified in this standard

(4) Support at least one of the specified physical layers and their associated media

(5) Support at least one of the data rates specified for the selected physical layer.

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

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 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 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 but cannot initiate a transmission since they will never be sent the token.)

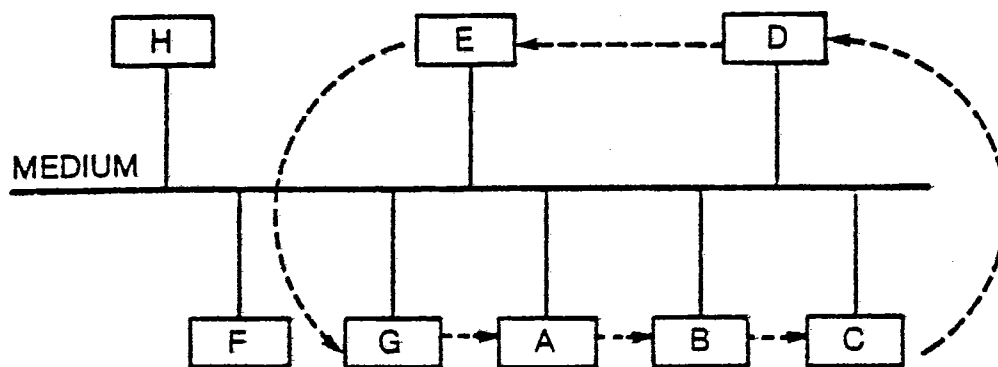


Fig 2
Logical Ring on Physical Bus

The Medium Access Control (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.

1.5.2 General Sublayer Functions

- (1) Lost token timer
- (2) Distributed initialization
- (3) Token holding timer (for multiple classes of service)
- (4) Limited data buffering
- (5) Node address recognition
- (6) Frame encapsulation (including token preparation)

- (7) FCS generation and checking
- (8) Valid token recognition
- (9) New ring member addition
- (10) Node failure error recovery

1.6 MAC Layer Internal Structure. The MAC layer performs several functions which are loosely coupled. The descriptions and specifications of the MAC layer in this standard are organized in terms of one of several possible partitionings of these functions. The partitioning used here is illustrated in Fig 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.

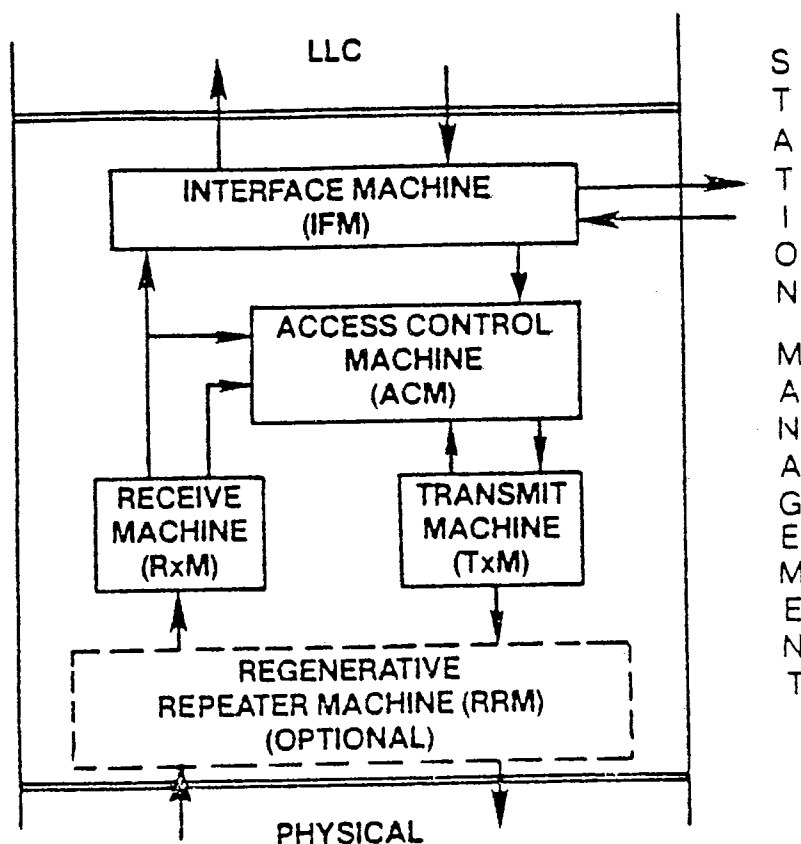


Fig 3
MAC Layer Functional Partitioning

1.6.1 Interface Machine (IFM). This machine acts as an interface and buffer between the LLC and MAC layers and between Station Management and MAC layers. It interprets all incoming MA_DATA 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 LLC 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 layer. 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 bus network.

1.6.3 Receive Machine (RxM). This machine accepts atomic-symbol inputs from the physical layer, 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 frame check sequence (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 data frame from the ACM and transmits it, as a sequence of atomic-symbols in the proper format, to the physical layer. 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, its operation may be somewhat different.

1.6.5 Regenerative Repeater Machine (RRM). This machine is an optional MAC component which is present only in special "repeater" stations, for example, a broadband, head-end remodulator. In such repeater stations, the RRM, when appropriate, repeats the incoming atomic-symbol stream, from the physical layer, back to the physical layer for retransmission; in such cases the physical layer 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.

Of these five machines, the ACM is the most critical and most complex; it is the key control mechanism for the token-bus access method, and it must cooperate closely with ACMs in other stations given only limited information about the state of the network. Because of its importance, 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 of this standard.

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

1.7 Physical Layer and Media. The broad outlines for the physical layer sections of this standard and also an introduction to the various physical signalling techniques and media defined for local area networks using the token-passing medium access protocol are given here.

Three bus media and corresponding physical layer entities are specified for use with token-passing medium access protocol.

Each physical layer entity and corresponding bus medium is described in a pair of consecutive sections (that is, Sections 10 and 11, Sections 12 and 13, and Sections 14 and 15), consisting of:

- (1) A section specifying a specific physical layer entity, including how the generic interface service specification (Section 9) between that physical layer entity and the station's Station Management functions is particularized, and
- (2) A section specifying the medium appropriate to that physical layer entity.

Three different physical layer entities with corresponding media suitable for use with the token bus medium access protocol are specified in this standard. They are distinguished primarily by the different forms of signalling specified for each type of physical layer entity. The remainder of this subsection outlines the salient points of each type of physical layer entity and corresponding medium.

1.7.1 Summary of Phase Continuous FSK (Frequency Shift Keying)

Topology: Omnidirectional bus

Trunk Cable: 75 ohmcoaxial cable, such as types RG-6, RG-11, and semi-rigid

Drop Cable: 35 ohmto 50 ohmcoaxial cable stub, less than 350 mm long

Connector at Station: 50 ohmmale BNC-series

Recommended Cable Configuration: Long unbranched trunk cable with very short "stub" drop cables

Trunk Connection Unit: 75 ohm tee connector

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

Transmit Level: +54 dB to +60 dB (1 mV, 37.5 ohm)

Receiver Sensitivity: +24 dB (1 mV, 37.5 ohm)

Data Rate: 1 Mb/s

Signalling: Manchester encoding of data and non-data symbols

The symbol representations are:

{HL} = zero — initial high, final low level

{LH} = one — initial low, final high level

{LL HH} = pairs of non-data symbols

— initial pair of low level followed by
a final pair of high level

Modulation: Phase continuous FSK (a form of Frequency Modulation), with Manchester representation:

(1) Frequency of high level = $6.25\text{MHz} \pm 0.08\text{ MHz}$

(2) Frequency of low level = $3.75\text{MHz} \pm 0.08\text{ MHz}$

Pad-idle: Alternating one and zero symbols

Clock Recovery: From transitions generated by the Manchester encoding

1.7.2 Summary of Phase Coherent FSK

Topology: Omnidirectional bus

Cable: 75 ohm coaxial cable, such as types RG-6 and semi-rigid

Connector at Station: 75 ohm female F-series

Recommended Cable Configuration: CATV-like semi-rigid trunk and flexible drop cable

Trunk Connection Unit: 75 ohm nondirectional passive impedance-matching tap

Repeaters: Active regenerative repeaters used for high-fanout branching and extension of the system beyond the basic signal loss budget

Transmit Level: +60 dB to +63 dB (1 mV, 75 ohm) [dBmV]

Receiver Sensitivity: -15 dB (1 mV, 75 ohm) [dBmV]

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

Signalling: 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: Consecutive one symbols

Clock Recovery: From zero crossings in the received signalling

Transmit Data Timing: Phase locked to transmit frequencies. All ports of a regenerative repeater shall use the same transmit data timing and hence exactly the same transmit frequencies.

1.7.3 Summary of Multilevel Duobinary AM/PSK

Topology: Directional bus with active head-end repeater

Cable: 75 ohmcoaxial cable, such as types RG-6 and semi-rigid

Connector at Station: 75 ohmfemale F-series

Recommended Cable Configuration: CATV-like semi-rigid trunk and flexible drop cable

Trunk Connection Unit: 75 ohmdirectional passive impedance-matching tap

Repeaters: Head-end regenerative repeater used as system data-rate clock source, as central assessor of contention and noise, and to retransmit all signalling received on the directional medium

Amplifiers: Standard CATV bidirectional mid-split or sub-split or high-split (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, +24 dB to +44 dB (1 mV, 75 ohm) [dBmV], adjustable

In 6 MHz bandwidth, +30 dB to +50 dB (1 mV, 75 ohm) [dBmV], adjustable

In 12 MHz bandwidth, +33 dB to +53 dB (1 mV, 75 ohm) [dBmV], adjustable

Receiver Sensitivity:

In 1.5 MHz, -16 dB to +4 dB (1 mV, 75 ohm) [dBmV]

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

In 12 MHz, -7 dB to +13 dB (1 mV, 75 ohm) [dBmV]

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

{NOTE: The following channel assignments are not part of the ISO Standard.}

Recommended North American Channel Assignments:

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

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

Signalling: 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 baud "three-symbol" ({0}, {4}, {2}) signalling together with compatibility considerations for three additional forms; the additional forms are described in 14.12.

In all of these forms of signalling, the middle level is used only to signal the non-data symbols found in frame delimiters and reported "silence", and as a "kicker" to break up long sequences of a single other signalling level. Such long sequences are unlikely since a scrambler is applied to framed data before it is encoded for transmission.

For one MAC-symbol per baud signalling, the symbol representations at the receiver are:

{0} = zero — zero amplitude

{4} = one — "maximum" amplitude

{2} = non-data symbols or "kickers", always occurring in pairs with a "median" amplitude of one half the "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 head-end to report that it is not receiving any signalling. 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 AGC, and can determine the signalling mode of the system by the sequence used:

For one MAC-symbol per baud signalling, the sequence is:

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

For possible future two and four MAC-symbols per baud signalling modes, the following sequences are reserved:

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

{2} {0} {4}

{2} {4} {0}

Implementations which detect any of these reserved repeating sequences should either switch to the corresponding mode of operation or inhibit transmission.

Clock Recovery: From level transitions within the received signalling

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

1.7.4 Alternate Physical Layer and Medium for Industrial Control. Alternate physical layers and media for industrial control are specified in Ref [5]. These alternate physical layers and media are compatible at the MAC-Physical interface.

1.8 Access Method Characteristics. An understanding of the basic characteristics of the token-passing access method is useful, in order 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 media and the modem capabilities over those necessary for transmission and reception of multibit, multiframe sequences at the specified mean 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 which momentarily controls the medium may use its share of the medium's capacity. In particular, the access method does not prohibit any station from using other specialized access methods (such as poll/response for example) during that station's access periods, provided only that those specialized methods do not confuse the other stations on the network as to the (distributed) state of the overall access mechanism.

(9) 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. (It is assumed that at least one full-function station is needed to make the system operational, for example, initialize.) An example of a reduced function station is one that can "receive only" and therefore does not contain access control logic.

1.9 Standard Organization. This standard is organized in 15 sections, which are summarized below:

Section 1 begins with a general discussion of the token-passing bus access method. The MAC layer functional partitioning used in subsequent discussions is introduced here. The Physical layer and Media options are also surveyed. Finally, features of the token-passing bus access method are reviewed.

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

Section 3 details the interface between the station management entity and the MAC layer. It describes the initialization services (such as setting timer values) provided by the station management.

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

enumerated.

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

Section 6 contains definitions of essential MAC terms and components and specifies those mandatory compliance requirements for the MAC sublayer protocols which are not covered elsewhere.

Section 7 specifies the MAC access control machine 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 layer variables, functions and procedures used in the state machine.

Section 8 details the interface between the medium access control sublayer and the physical layer. Included here are descriptions of the interface symbols, requests, and responses.

Section 9 describes the generic interfaces between the station management entity and the various token-passing bus physical layers.

Sections 10 and 11 detail the physical layer and medium, respectively, for a single-channel (that is, omni-directional) Phase Continuous FSK coaxial cable bus at 1 Mb/s.

Sections 12 and 13 detail the physical layer and medium, respectively, for a single-channel (that is, omni-directional) Phase Coherent FSK coaxial cable bus at 5 Mb/s or 10 Mb/s.

Sections 14 and 15 detail the physical layer 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.

This section specifies the services provided to the logical link control (LLC) sublayer, and to the alternative sublayer specified in Ref [5], at the boundary between the logical link control functions and the medium access 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 4.

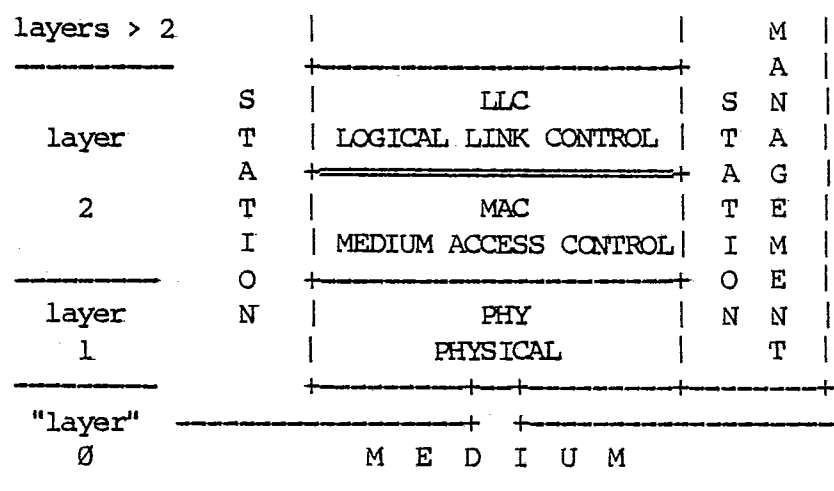


Fig 4
Relation to LAN Model

NOTE: The exact relationship of the layers described in this standard to the layers defined by the OSI Reference Model, is for future study.

2.1 Overview of the LLC - MAC Service

2.1.1 General Description of Services Provided. This section describes informally the services provided to the logical link control sublayer by the token-passing medium access control sublayer, both of the data link layer. These services only provide connectionless data transfer services between peer LLC entities. They provide the means by which logical link control 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_DATA.request
- (2) MA_DATA.indication
- (3) MA_DATA.confirmation

An MA_DATA.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_DATA.indication primitive is passed from the MAC sublayer to indicate the arrival of an m_sdu. An MA_DATA.confirmation primitive is passed from the MAC sublayer to convey the local results of the previous associated MA_DATA.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 LLC connectionless data transfer services. 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. The MAC sublayer may also provide local confirmation mechanisms for all request type primitives.

2.2.1 MA_DATA.request

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

2.2.1.2 Semantics. The primitive shall provide parameters as follows:

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

destination_address specifies either an individual or a group MAC-entity address.

`m_sdu` specifies the MAC service data unit to be transmitted by the MAC sublayer entity for the requesting LLC sublayer entity.

`desired_quality` 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 a 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 local area network.

2.2.1.4 Effect on Receipt. Receipt of this primitive causes the MAC 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_DATA.indication` should itself have a quality parameter specifying `response`, in which case that next `MA_DATA.indication` shall be associated with this `MA_DATA.request`.

A value of `response` for the delivery confirmation component of the quality parameter indicates that the immediately prior `MA_DATA.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_DATA.indication`

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

2.2.2.2 Semantics. The primitive shall provide parameters as follows:

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

`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 involved in the transmission.

`m_sdu` specifies the MAC service data unit as received by the local MAC sublayer entity.

`quality` 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_responder`~~, 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 frame from the physical layer entity. 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 the Logical Link Control standard, Ref [2].

2.2.2.5 Additional Comments. In the absence of errors, the contents of the `m_sdu` parameter are logically complete and unchanged relative to the `m_sdu` parameter in the associated `MA_DATA.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 MAC-user entity should immediately respond with an `MA_DATA.request` which itself has a `quality` parameter specifying `responder`.

A value of `response` for the delivery-confirmation component of the `quality` parameter indicates that this `MA_DATA.indication` may be associated with a prior `MA_DATA.request` which itself had a `quality` parameter specifying ~~`request_with_responder`~~, and which was issued by the same MAC-user entity.

2.2.3 `MA_DATA.confirmation`

2.2.3.1 Function. This primitive is the service confirmation primitive for the LLC connectionless data transfer service.

2.2.3.2 Semantics. The primitive shall provide parameters as follows:

```
MA_DATA.confirmation
( quality,
  status )
```

`quality` specifies the quality of service actually provided. The semantics of this parameter (for example, priority, MAC-level delivery confirmation) are left for further study.

`status` indicates the local success or failure of the

corresponding previous MA_DATA.request.

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

When the quality parameter of that request specifies ~~request_with_no_response~~ or response, the MA_DATA.confirmation is passed immediately after the transmission of the corresponding frame.

When the quality parameter of that request specifies ~~request_with_response~~, the MA_DATA.confirmation is passed when the requested response frame is received, or when the allowed number of retries has occurred, or upon local failure.

2.2.3.4 Effect on Receipt. The effect of receipt of this primitive by the LLC sublayer entity is specified in [2].

2.2.3.5 Additional Comments. Success of this request indicates that the previously specified m_sdu has been transmitted correctly to the best of the local MAC entity's knowledge. In the case that the corresponding MA_DATA.request had a quality parameter specifying ~~request_with_response~~, the MA_DATA.confirmation is associated with the MA_DATA.indication conveying the response, if any such occurred. Also, it is assumed that sufficient information is available to the LLC sublayer entity to associate the confirmation with the corresponding request.

3. Station Management - MAC Interface Service Specification

This section specifies the services provided to and by the station management functions by and to the token-passing MAC sublayer of this standard. This standard specifies these services in an abstract way. The standard 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 other LAN specifications is illustrated in Fig 5.

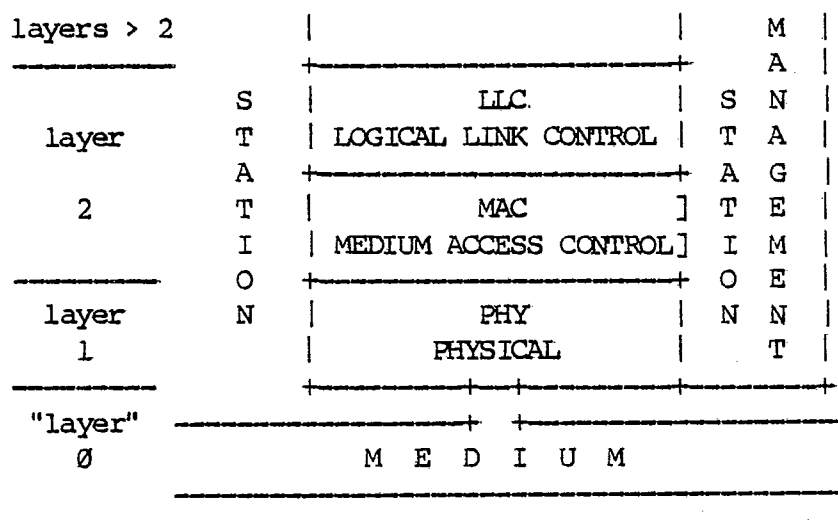


Fig 5
Relation to LAN Model

3.1 Overview of the Station Management - MAC Service

3.1.1 General Description of Services Provided. This subsection describes informally the services provided to and by the station management functions by and to the token-passing medium access control sublayer of the data link layer. These services are local administrative services between the MAC sublayer and its manager. They provide the means and method of

(1) Resetting the MAC entity, selecting the MAC entity's MAC address (and implicitly the length of all MAC addresses on the network) and the token-passing protocol appropriate for the network (for example, token bus, token bus repeater), and confirming that the MAC entity can implement that protocol.

(2) Specifying the values of timer and counter preset constants appropriate for the network (for example, a bus slot_time).

(3) Determining whether the MAC entity should be a member of the token-passing ring, and whether its address appears to be unique to the local network.

(4) Reading the current values of some of the MAC-entity's parameters.

(5) Notifying the station management entity of relevant changes in the MAC-entity's parameters.

(6) Specifying the set of group addresses which the MAC entity recognizes.

(7) Providing the means for which station management peer entities can exchange MAC service data units (m_sdus) without the establishment of an underlying point_to_point connection.

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

3.1.3 Overview of Interactions. The primitives associated with local administrative services are

MA_INITIALIZE_PROTOCOL.request
 MA_INITIALIZE_PROTOCOL.confirmation
 MA_SET_VALUE.request
 MA_SET_VALUE.confirmation
 MA_READ_VALUE.request
 MA_READ_VALUE.confirmation
 MA_EVENT.indication
 MA_FAULT_REPORT.indication
 MA_GROUP_ADDRESS.request
 MA_GROUP_ADDRESS.confirmation
 MA_CDATA.request
 MA_CDATA.indication
 MA_CDATA.confirmation

3.1.3.1 MA_INITIALIZE_PROTOCOL. The MA_INITIALIZE_PROTOCOL.request primitive is passed to the MAC sublayer to reset the entire MAC sublayer and to select the MAC entity's MAC address (and implicitly the length of all MAC addresses on the network), the token-passing protocol appropriate for the network (that is, token_bus) and the station's role in that network (for example, originate_only or originate_and_repeat). It elicits an immediate MA_INITIALIZE_PROTOCOL.confirmation specifying whether the desired protocol is available.

3.1.3.2 MA_SET_VALUE. The MA_SET_VALUE.request primitive is passed to the MAC sublayer from the station management entity to set the value of a MAC variable. The MA_SET_VALUE.confirmation returns a success or failure indication for the associated primitive.

3.1.3.3 MA_READ_VALUE. The MA_READ_VALUE.request primitive is passed to the MAC sublayer from the station management entity to request the value of a MAC variable. The MA_READ_VALUE.confirmation returns the value of the requested MAC variable.

3.1.3.4 MA_EVENT. The MA_EVENT.indication primitive is passed to the station management entity to indicate that the value of a significant MAC variable has changed or some other significant event has occurred.

3.1.3.5 MA_FAULT_REPORT. The MA_FAULT_REPORT.indication primitive is passed to the station management entity to indicate that an error has been inferred by the MAC entity.

3.1.3.6 MA_GROUP_ADDRESS. The MA_GROUP_ADDRESS.request primitive is passed to the MAC sublayer to specify the set of MAC-level group addresses which the MAC entity should recognize, so that valid MAC-level frames with these destination addresses will be passed to a MAC-user entity by way of the appropriate indicate primitive. The MA_GROUP_ADDRESS.confirmation primitive returns a success or failure indication for the associated request primitive.

3.1.3.7 MA_CDATA. The MA_CDATA.request primitive is passed to the MAC sublayer to request that a station management m_sdu be sent. (All m_sdus in station management frames are sent using connectionless procedures, see 4.2.3 for frame format.) An MA_CDATA.indication primitive is passed from the MAC sublayer to indicate the arrival of a station management m_sdu. An MA_CDATA.confirmation primitive is passed from the MAC sublayer to convey the local results of the previous associated MA_CDATA.request primitive.

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

3.2 Detailed Interactions with the Station Management Entity. The primitives and parameters associated with the MAC administrative services are described in detail here. 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 station address (TS) or set-of-group-addresses parameters associated with some of the administrative service primitives may be provided by actually

passing MAC addresses, by passing descriptors, or by other means. The values of some selection parameters may be implied by an implementation. The MAC sublayer may also provide local confirmation mechanisms for all request type primitives.

3.2.1 MA_INITIALIZE_PROTOCOL.request

3.2.1.1 Function. This primitive is the service request primitive for the protocol initialization service. It also functions as a RESET service request primitive for the entire MAC sublayer.

3.2.1.2 Semantics. This primitive shall provide parameters as follows:

MA_INITIALIZE_PROTOCOL.request
(desired_protocol)

desired_protocol specifies the token-passing protocol which the MAC entity should implement: simple token_Bus or token_bus_repeater (for example, a head-end station on a broadband medium).

3.2.1.3 When Generated. This primitive is passed from the station management entity to the MAC sublayer entity to request that the MAC sublayer entity reset itself and reconfigure itself as specified by the parameters.

3.2.1.4 Effect of Receipt. Receipt of this primitive causes the MAC entity to reset itself exactly as at power-on, select the desired protocol, and generate a MA_INITIALIZE_PROTOCOL.confirmation to indicate the availability of the desired protocol.

3.2.1.5 Additional Comments. This primitive causes the MAC entity to be a nonmember of the token-passing ring.

3.2.2 MA_INITIALIZE_PROTOCOL.confirmation

3.2.2.1 Function. This primitive is the service confirmation primitive for the protocol initialization service.

3.2.2.2 Semantics. This primitive shall provide parameters as follows:

MA_INITIALIZE_PROTOCOL.confirmation
(status)

status indicates the success or failure of the initialization request.

3.2.2.3 When Generated. This primitive is passed from the MAC sublayer entity to the station management entity to indicate the success or failure of the previous associated protocol initialization request.

3.2.2.4 Effect of Receipt. The effect of receipt of this primitive is unspecified.

3.2.3 MA_SET_VALUE.request

3.2.3.1 Function. This primitive is the service request primitive for the setting of values of MAC sublayer variables.

3.2.3.2 Semantics. This primitive shall provide parameters as follows:

```
MA_SET_VALUE.request
( variable_name,
  desired_value )
```

variable_name indicates which MAC sublayer variable is to be assigned the specified desired_value.

The following variables shall be settable by way of this primitive

- (1) TS (station address, see 7.1.1)
- (2) slot_time
- (3) hi_pri_token_hold_time
- (4) max_ac_4_rotation_time (if priority option is implemented)
- (5) max_ac_2_rotation_time (if priority option is implemented)
- (6) max_ac_0_rotation_time (if priority option is implemented)
- (7) max_ring_maintenance_rotation_time
- (8) ring_maintenance_timer_initial_value
- (9) max_inter_solicit_count
- (10) min_post_silence_preamble_length (see 4.1.1)
- (11) in_ring_desired
- (12) event_enable_mask (see 3.2.7)
- ~~(13) max_retry_time~~

Other MAC variables are for future study.

The range of desired_value is the range defined in Section 7 for the specified MAC variable.

3.2.3.3 When Generated. This primitive is passed from the station management entity to the MAC sublayer entity to request that the MAC sublayer entity change the value of the specified variable.

3.2.3.4 Effect of Receipt. The receipt of this primitive causes the variable value to be changed and to generate the associated MA_SET_VALUE.confirmation primitive.

3.2.4 MA_SET_VALUE.confirmation

3.2.4.1 Function. This primitive is the service confirmation primitive for the MAC sublayer set value service.

3.2.4.2 Semantics. This primitive shall provide parameters as follows:

```
MA_SET_VALUE.confirmation
( status )
```

status indicates the success or failure of the set value request. If the MAC variable of the MA_SET_VALUE.request is not implemented, status shall be returned as failure.

3.2.4.3 When Generated. This primitive is passed from the MAC sublayer entity to the station management entity to indicate the success or failure of the previous associated MA_SET_VALUE.request.

3.2.4.4 Effect of Receipt. The effect of receipt of this primitive is unspecified.

3.2.5 MA_READ_VALUE.request

3.2.5.1 Function. This primitive is the service request primitive for the reading of values of MAC sublayer variables.

3.2.5.2 Semantics. This primitive shall provide parameters as follows:

MA_READ_VALUE.request
(variable_name)

variable_name indicates which of the MAC sublayer variables is to be read.

Readable MAC sublayer variables are:

- (1) Address of successor, NS (see Section 4)
- (2) Address of predecessor, PS (see Section 4)
- (3) ~~Number of retries on request with response frames~~

A partial list of variables under study are:

- (1) Number of stations in ring
- (2) Measured token rotation time
- (3) Number of valid received frames
- (4) Number of received frames with FCS errors

3.2.5.3 When Generated. This primitive is passed from the station management entity to the MAC sublayer entity to request that the MAC sublayer entity return the value of the specified variable.

3.2.5.4 Effect of Receipt. The receipt of this primitive causes the value of the specified variable to be returned by way of the associated MA_READ_VALUE.confirmation primitive.

3.2.6 MA_READ_VALUE.confirmation

3.2.6.1 Function. This primitive is the service confirmation primitive for the read value service.

3.2.6.2 Semantics. This primitive shall provide parameters as follows:

MA_READ_VALUE.confirmation
(current_value,
status)

If status equals success, current_value has taken on the current value of the MAC variable specified in the associated read value primitive. If status equals failure, the MAC

variable is not readable or not implemented and the value of `current_value` is not specified.

3.2.6.3 When Generated. This primitive is passed from the MAC sublayer entity to the station management entity to indicate the success or failure of the previous associated `MA_READ_VALUE.request`.

3.2.6.4 Effect of Receipt. The effect of receipt of this primitive is unspecified.

3.2.7 `MA_EVENT.indication`

3.2.7.1 Function. This primitive is the service indication primitive by which station management is informed of significant events within the MAC sublayer.

3.2.7.2 Semantics. This primitive shall provide parameters as follows:

`MA_EVENT.indication`
(`event`)

`event` identifies the event that has occurred within the MAC sublayer. The events that cause an `MA_EVENT.indication` are

- (1) Change of successor address
- (2) Change of successor address to null

Additional events are for future study.

3.2.7.3 When Generated. This primitive is passed from the MAC sublayer entity to the station management entity to indicate the occurrence of an enabled significant event within the MAC sublayer. It is enabled when an `MA_SET_VALUE.request` has set the `event_enable_mask` to a non-zero value.

3.2.7.4 Effect of Receipt. The effect of receipt of this primitive is unspecified.

3.2.8 `MA_FAULT_REPORT.indication`

3.2.8.1 Function. This primitive is the service indication primitive for MAC failure indications.

3.2.8.2 Semantics. This primitive shall provide parameters, as follows:

`MA_FAULT_REPORT.indication`
(`fault_type`)

`fault_type` identifies the particular fault condition the MAC layer has detected

- (1) `Duplicate_address`
- (2) `Faulty_transmitter`

The `duplicate_address` fault is indicated when the MAC sublayer entity has inferred that there is another MAC entity on the network which has the same MAC address as the current value of the variable `TS`.

The `faulty_transmitter` fault is indicated when the MAC sublayer entity has inferred evidence that the station's

transmitter is not being received correctly by other stations in the network.

3.2.8.3 When Generated. This primitive is passed from the MAC sublayer entity to the station management entity to indicate that the MAC entity has detected a failure condition within the protocol. The indication is passed when the access control machine transitions to the OFFLINE state.

The situations in which an MA_FAULT_REPORT.indication is passed are defined in Section 7 in the ACM state tables.

3.2.8.4 Effect of Receipt. The effect of receipt of this primitive is unspecified.

3.2.8.5 Additional Comments. This primitive is generated in response to detection of a network administration or hardware fault which may be due to failure of circuitry in either the detecting station or another station.

3.2.9 MA_GROUP_ADDRESS.request

3.2.9.1 Function. This primitive is the service request primitive for the protocol's group address activation service.

3.2.9.2 Semantics. This primitive shall provide parameters as follows:

MA_GROUP_ADDRESS.request
(set of group-addresses)

set of group-addresses specifies zero or more group MAC-entity addresses.

3.2.9.3 When Generated. This primitive is passed from the station management entity to the MAC sublayer entity to request that the MAC sublayer entity recognize the specified set of group addresses, so that valid MAC-level frames with these destination addresses will be passed to a MAC-user entity by way of the appropriate indicate primitive.

3.2.9.4 Effect of Receipt. Receipt of this primitive causes the MAC sublayer entity to load the desired set of group addresses for comparison with the destination address of MAC-user frames and to return a MA_GROUP_ADDRESS.confirmation primitive. The last set of group addresses loaded are the only ones recognized. Loading zero (no) group addresses deactivates the group address recognition service.

3.2.9.5 Additional Comments. The predefined broadcast group address (of all one bits) is always recognized and cannot be disabled.

3.2.10 MA_GROUP_ADDRESS.confirmation

3.2.10.1 Function. This primitive is the confirmation primitive for the protocol's group address activation service.

3.2.10.2 Semantics. This primitive shall provide parameters as follows:

MA_GROUP_ADDRESS.confirmation
(status)

status indicates the success or failure of the request.

3.2.10.3. When Generated. This primitive is passed from the MAC sublayer entity to the station management entity to indicate the success or failure of the previous associated MA_GROUP_ADDRESS.request.

3.2.10.4 Effect of Receipt. The effect of receipt of this primitive is unspecified.

NOTE: To provide a basis for network monitoring and analysis, an implementation also may support

(1) Reception of all MAC-user frames, independent of destination address

(2) Reception of all frames, including MAC_control frames, as specified in 4.13

3.2.11 MA_CDATA.request

3.2.11.1 Function. This primitive is the service request primitive for the station management connectionless data transfer service.

3.2.11.2 Semantics. This primitive shall provide parameters as follows:

MA_CDATA.request
(destination_address,
m_sdu,
desired_quality)

destination_address specifies either an individual or a group MAC-entity address.

m_sdu specifies the MAC service data unit to be transmitted by the MAC sublayer entity for the requesting station management entity.

desired_quality 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.

3.2.11.3 When Generated. This primitive is passed from the station management 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 local area network.

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

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

A value of response for the delivery-confirmation component of the quality parameter indicates that the immediately-prior ~~MA_CDATA.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~~.

3.2.12 MA_CDATA.indication

3.2.12.1 Function. This primitive is the service indication primitive for the station management connectionless data transfer service.

3.2.12.2 Semantics. This primitive shall provide parameters as follows:

```
MA_CDATA.indication
( destination_address,
  source_address,
  m_sdu,
  quality )
```

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 involved in the transmission.

m_sdu specifies the MAC service data unit as received by the local MAC sublayer entity.

quality 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~~.

3.2.12.3 When Generated. This primitive is passed from the MAC sublayer entity to the station management entity to indicate the arrival of a frame from the local area network communications medium. Such frames are reported only when they are free of detected errors and their (individual or group) destination address designates the local MAC entity.

3.2.12.4 Effect of Receipt. The effect of receipt of this primitive is unspecified.

3.2.12.5 Additional Comments. In the absence of errors, the contents of the `m_sdu` parameter are logically complete and unchanged relative to the `m_sdu` parameter in the associated `MA_CDATA.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 MAC-user entity should immediately respond with an `MA_CDATA.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_CDATA.indication` may be associated with a prior `MA_CDATA.request` which itself had a quality parameter specifying `request_with_response`, and which was issued by the same MAC-user entity.

3.2.13 MA_CDATA.confirmation

3.2.13.1 Function. This primitive is the service confirmation primitive for the station management connectionless data transfer service.

3.2.13.2 Semantics. This primitive shall provide parameters as follows:

```
MA_CDATA.confirmation
( quality,
  status )
```

`quality` specifies the quality of service actually provided. The semantics of this parameter are identical to those of 3.2.11.2.

`status` indicates the local success or failure of the corresponding previous `MA_CDATA.request`.

3.2.13.3 When Generated. This primitive is passed from the MAC sublayer entity to the station management entity to confirm the success or failure of the service provided for the previous associated station management data transfer request.

When the quality parameter of that request specifies `request_with_no_response` or `response`, the `MA_CDATA.confirmation` is passed immediately after the transmission of the corresponding frame.

When the quality parameter of that request specifies `request_with_response`, the `MA_CDATA.confirmation` is passed when the requested response frame is received, or when the allowed number of retries has occurred, or upon local failure.

3.2.13.4 Effect of Receipt. The effect of receipt of this primitive is unspecified.

3.2.13.5 Additional Comments. Success of this request

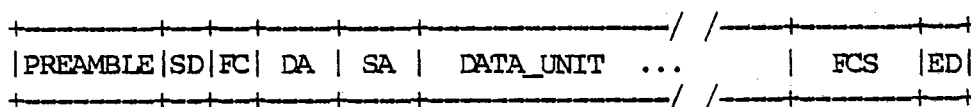
indicates that the previously requested m_sdu has been transmitted correctly to the best of the local MAC entity's knowledge. In the case that the corresponding MA_GDATA_request had a quality parameter specifying request_with_response, the MA_GDATA_confirmation is associated with the MA_GDATA_indication conveying the response, if any such occurred. Also, it is assumed that sufficient information is available to the station management entity to associate the confirmation with the corresponding request.

4. Frame Formats

This section defines the required 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 exchanged by MAC sublayer entities. The MAC_service_data_units received from the LLC sublayer are contained within these MAC frames.

The frame components and formats used by medium access control are also described in this section.

The MAC level transmit 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:



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)

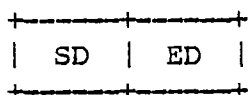
DATA_UNIT = information (0 or more octets)

FCS = frame check sequence (4 octets)

ED = end delimiter (1 octet)

The number of octets between SD and ED, exclusive, shall be 8191 or fewer.

The abort sequence shall conform to the following format:



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 which are shown in the previous illustrations in greater detail.

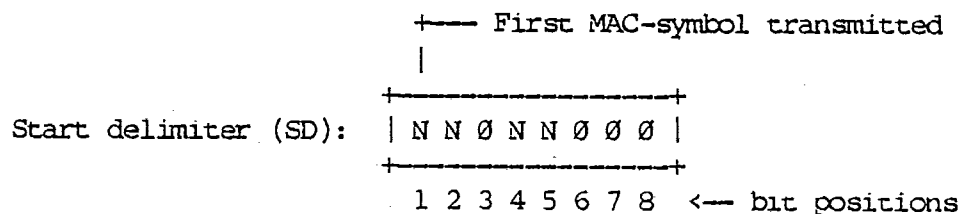
4.1.1 Preamble. The preamble pattern preceeds every transmitted frame. Preamble is sent by MAC as an appropriate number of pad_idle symbols. Preamble may be decoded by the receiver as arbitrary data symbols that occur outside frame delimiters. Preamble is primarily used by the receiving modem to acquire 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 10.6, 12.6 and 14.8 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 us, regardless of data rate, and that an integer number of octets shall be sent. Thus at a data rate of 1 Mb/s one octet of preamble is required to meet the integer number of octets requirement, 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 physical layer. 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. The frame structure requires a start delimiter, which begins the frame. The start delimiter consists of signalling patterns that are always distinguishable from data.

The start delimiter is coded as follows: (See 10.7, 12.7, 14.9 and 14.12 for representations of the symbol coding as present on the medium.)



where

N = non data MAC-symbol

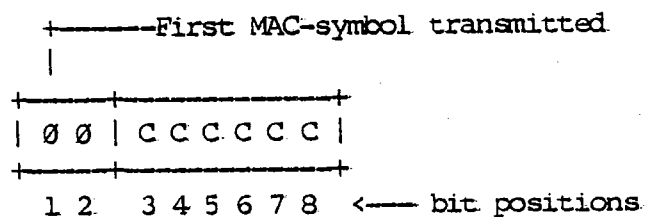
Ø = zero MAC-symbol

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

- (1) MAC control
- (2) LLC data
- (3) Station management data
- (4) Special purpose — reserved for future use

The frame formats for each of these categories is illustrated below.

4.1.3.1 MAC control frame



where

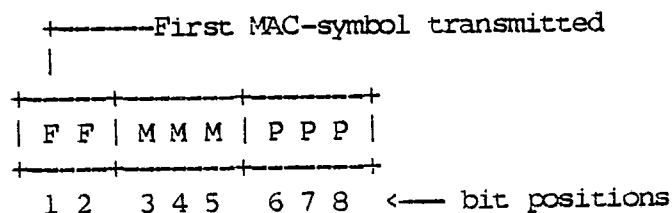
CCCCCC = type of MAC_control frame as follows:

C C C C C C

3 4 5 6 7 8 ← bit positions

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

4.1.3.2 Data frames



where

F F = Frame type:

(1 2 ← bit positions)

0 1 = LLC_data_frame

1 0 = station_management_data_frame

1 1 = special_purpose_data_frame - reserved

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

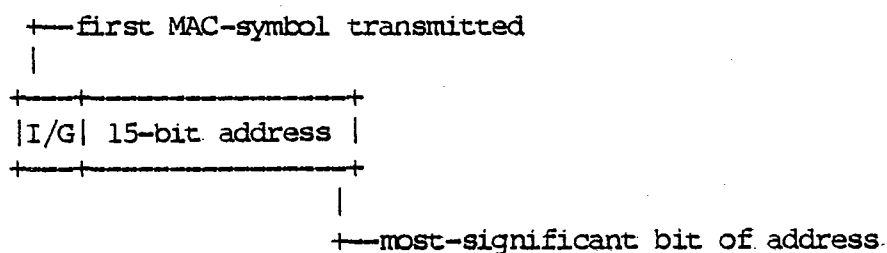
0 0 0 = lowest priority

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

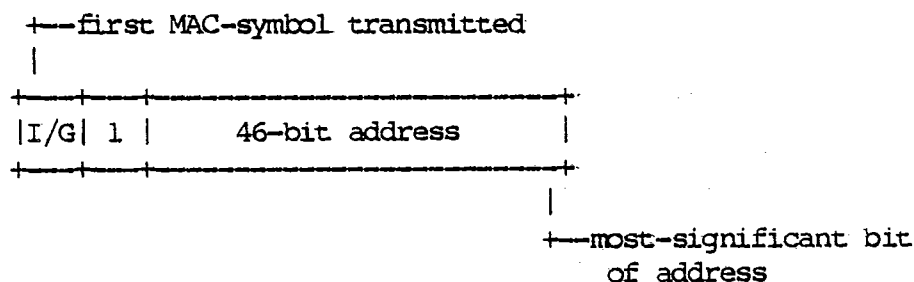
4.1.4 Address Fields. Each frame shall contain two address fields: the destination address field and the source address field, in that order. Addresses shall be either 16 bits or 48 bits in length. All addresses on a given LAN shall be of the same length.

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

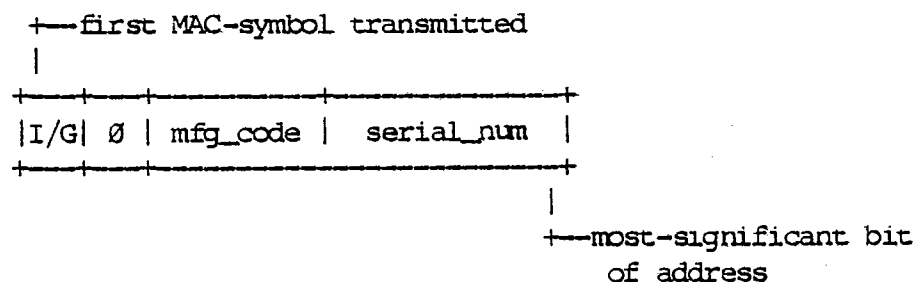
(1) 16-bit address form



(2) 48-bit locally administered form



(3) 48-bit globally administered or universal form



where

I/G = individual/group address indication 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 globally administered, universally unique addresses.

NOTE: `mfg_code` and `serial_num` merely demonstrate a way of partitioning and assigning 48-bit globally administered addresses, which was employed at the time this standard was drafted. This already-existing practice dictated the numeric interpretation of addresses used in the protocol's address comparison operations.

Individual Addressess: 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 Addressess: 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 bus MAC procedures, the contents of the destination address field is irrelevant. In such cases, the originating station's own address or any other properly formed address can 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 global authority. The second bit transmitted of the destination address indicates whether the address has been assigned by a global or local administrator.

0 = globally administered

1 = locally administered

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

Local Administration: Individual station addresses are administered by a local (to the LAN) authority. (This is the only method allowed for 16-bit 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 individual/group bit shall be set to 0; the significance of it being set to 1 is a subject for future

study.

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

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 7.2.4, 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 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 frame control octet, the MAC data unit field can contain either

(1) An LLC protocol data unit as specified in the Logical Link Control standard, Ref [2], which is used to exchange LLC information between LLC entities.

(2) A MAC management data frame which is used to exchange MAC management information between MAC management entities.

(3) A value specific to one of the MAC control frames.

Each octet of the MAC data unit field shall be transmitted low_order bit first.

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 Frame Control, 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 Frame Control, 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 frame control, address and information fields. The one's complement of the resulting remainder is transmitted as the 32-bit FCS sequence.

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

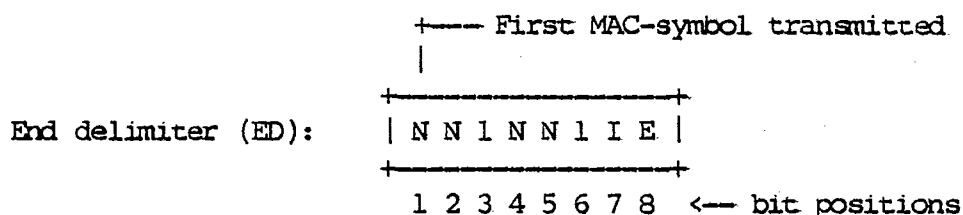
$$X^{31} + X^{30} + X^{26} + X^{25} + X^{24} + X^{18} + X^{15} + X^{14} + X^{12} \\ + X^{11} + X^{10} + X^8 + X^6 + X^5 + X^4 + X^3 + X + 1$$

NOTE: 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.

4.1.7 End Delimiter. The frame structure requires an end delimiter (ED), which ends the frame and determines the position of the frame check sequence. The data between the SD and the ED shall be an integral number of octets. All bits between the start and end delimiters are covered by the frame check sequence.

The end delimiter consists of signalling patterns that are always distinguishable from data. The end delimiter also contains bits of information that are not error checked.

The end delimiter is coded as follows:



where

N = non_data MAC-symbol

1 = one MAC-symbol

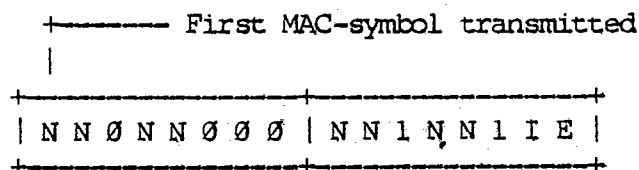
I = Intermediate bit (1 = more to transmit,
 0 = end of transmission)

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

The seventh ED MAC-symbol is called the intermediate bit. 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 in determining what follows the ED.

The eighth ED MAC-symbol is called the error bit. When set to one by a repeater, the error bit indicates that the immediately preceeding frame had an FCS error within the frame, and thus that the error did not occur on the communication path between that prior repeating station and this receiving station. When the error bit is set, the receiving station may treat the frame as an invalid frame.

4.1.8 Abort Sequence. This pattern prematurely terminates the transmission of a frame. The abort sequence is sent by a station that does not wish to continue to send a frame it has already begun. An abort sequence is inserted by a repeater upon receiving an invalid coding sequence. When a repeater originates an abort sequence upon receiving an invalid coding sequence, it shall be originated on an octet boundary. An abort sequence consists of the following pattern:



where

N = non_data MAC-symbol

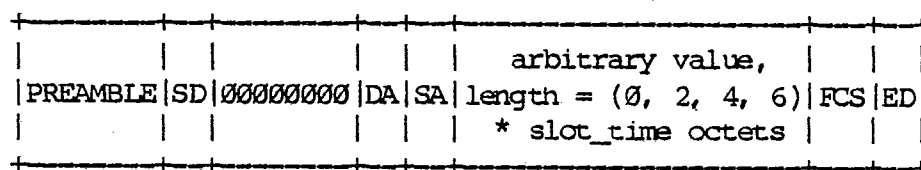
0 = zero MAC-symbol

1 = one MAC-symbol

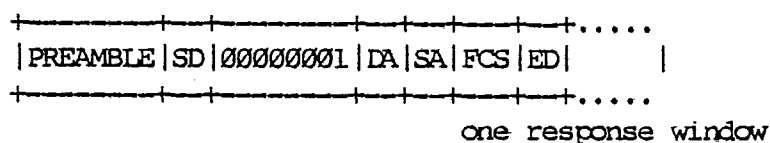
4.2 Enumeration Of Frame Types. This subsection shows how the components of the frames are arranged in the various frame types transmitted by the MAC sublayer. Section 5 discusses the frames and terminology used here.

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.

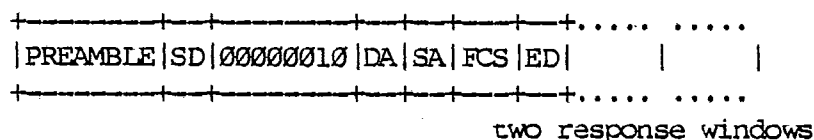
4.2.1.1 Claim_token. The frame has a data_unit whose value is arbitrary and whose length in octets (between addresses and FCS exclusive) is 0, 2, 4, or 6 times the system's slot_time also measured in octets.



4.2.1.2 Solicit_successor_1. The frame has a DA = the contents of the station's NS register and a null data unit. One response window always follows this frame.



4.2.1.3 Solicit_successor_2. The frame has DA = the contents of the station's NS or TS register and a null data unit. Two response windows always follow this frame.



4.2.1.4 Who_follows. The frame has a data_unit = the value of the station's NS register. 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.)

```

+-----+-----+-----+-----+-----+-----+-----+-----+
|PREAMBLE|SD|00000011|DA|SA|value NS|FCS|ED|         |         |         |
+-----+-----+-----+-----+-----+-----+-----+-----+
                                     three response windows

```

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

```

+-----+-----+-----+-----+-----+-----+-----+-----+
|PREAMBLE|SD|00000100|DA|SA|FCS|ED|         |         |         |
+-----+-----+-----+-----+-----+-----+-----+-----+
                                     four response windows

```

4.2.1.6 Token. The frame has DA = the contents of the station's NS register, and has a null data_unit.

```

+-----+-----+-----+-----+-----+-----+-----+-----+
|PREAMBLE|SD|00001000|DA|SA|FCS|ED|
+-----+-----+-----+-----+-----+-----+-----+-----+

```

4.2.1.7 Set_Successor. The frame has DA = the SA of the last frame received, and data_unit = the value of the station's NS or TS register. The format and length of the data_unit is the same as that of a source address.

```

+-----+-----+-----+-----+-----+-----+-----+-----+
|PREAMBLE|SD|00001100|DA|SA| new value of NS |FCS|ED|
+-----+-----+-----+-----+-----+-----+-----+-----+

```

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)

```

+-----+-----+-----+-----+-----+-----+-----+-----+
|PREAMBLE|SD|01MMPPPP|DA|SA| LLC_data_unit |FCS|ED|
+-----+-----+-----+-----+-----+-----+-----+-----+

```

4.2.3 Station Management Data Frame Format. Station management data frames have a DA and data-unit specified by a station's station management entity. A frame of this type with a non-null data-unit shall be passed to the receiving station's station management sublayer. (see 4.1.3.2)

```

+-----+-----+-----+-----+-----+-----+-----+-----+
|PREAMBLE|SD|10MMPPPP|DA|SA| station_mgmt_data_unit |FCS|ED|
+-----+-----+-----+-----+-----+-----+-----+-----+

```