IEEE Std 802.5-1989
(Revision of ANSI/IEEE Std 802.5-1985)

LOCAL AREA NETWORKS

802.5

IEEE Standard

Token Ring Access Method

Published by
The Institute of Electrical and
Electronics Engineers, Inc

IEEE Std 802.5-1989: Token Ring Access Method and Physical Layer Specifications

This standard specifies the formats and protocols used by the Token-Passing Ring medium access control (MAC) sublayer, the physical layer, and the means of attachment to the token-passing ring physical medium.

IEEE Std 802.5-1989 aids in the compatible interconnection of data processing equipment by way of a local area network using the token-passing ring access method.

It defines the frame format, including delimiters, addressing, and frame check sequence. It also defines MAC protocol, and introduces MAC frames, timers, and priority stacks. This standard describes the services provided by the MAC sublayer to the station management and the logical link control sublayer. It also describes the services provided by the physical layer to station management and the MAC sublayer. These services are defined in service primitives and associated parameters.

Also defined are:

- Physical layer functions of symbol encoding and decoding
- Symbol timing
- Latency buffing
- 1 Mb/s and 4 Mb/s, Shielded Twisted Pair attachment of the station to the medium

➨ **Important: ANSI/IEEE Std 802.2-1985 is the basic document in our LAN series. Make sure you have it, if you're ordering any of our other LAN standards.**

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IEEE Standards for
Local Area Networks:

Token Ring Access Method and Physical Layer Specifications

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IEEE Standards for Local Area Networks:

Token Ring Access Method and Physical Layer Specifications

Sponsor

Technical Committee on Computer Communications of the IEEE Computer Society

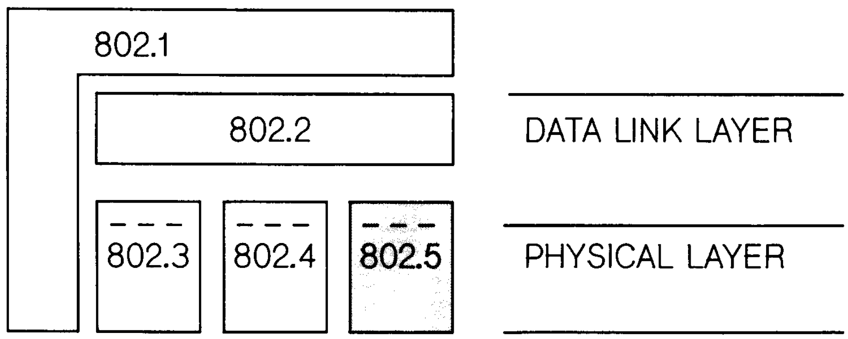
Approved June 2, 1989

IEEE Standards Board

Foreword

(This Foreword is not a part of IEEE Std 802.5-1989, Token Ring Access Method and Physical Layer Specifications.)

This standard is part of a family of standards for Local Area Networks (LANs). The relationship between this standard and the 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) ANSI/IEEE Std 802.3-1988 [ISO 8802-3], a bus utilizing CSMA/CD as the access method,

(2) ANSI/IEEE Std 802.4-1985 [ISO 8802-4], a bus utilizing token passing as the access method,

(3) IEEE Std 802.5-1989 [ISO 8802-5], a ring utilizing token passing as the access method.

Other access methods (for example, metropolitan area networks) are under investigation. ANSI/IEEE Std 802.2-1985, Logical Link Control protocol, is used in conjunction with the medium access standards.

A companion document, P802.1, describes the relationship among these standards and their relationship to the ISO Open Systems Interconnection Reference Model in more detail. This companion document will contain internetworking and network management issues.

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

NOTE: This IEEE Std 802.5-1989 specifies that each octet of the information field shall be transmitted most significant bit (MSB) first. This convention is reversed from that used in ANSI/IEEE Std 802.3-1988 and ANSI/IEEE Std 802.4-1985, standards that are least significant bit (LSB) first transmission. While the transmission of MSB first is used for the IEEE 802.5-1989 token ring, this does not imply that MSB transmission is preferable for any other type of local area network. Anyone considering the interconnection of the IEEE 802.5-1989 token ring with other IEEE standard networks should keep in mind the need to perform bit reordering in the gateway between networks.

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APPENDIXES

IEEE Standards for Local Area Networks:

Token Ring Access Method and Physical Layer Specifications

1. General

1.1 Scope. For the purpose of compatible interconnection of data processing equipment via a local area network using the token-passing ring access method, this standard

(1) Defines the frame format, including delimiters, addressing, and frame check sequence, and introduces medium access control (MAC) frames, timers, and priority stacks (see Section 3);

(2) Defines the MAC protocol. The finite-state machine and state tables are supplemented with a prose description of the algorithms (see Section 4);

(3) Defines the physical layer (PHY) functions of symbol encoding and decoding, symbol timing, and latency buffering (see Section 5);

(4) Describes the services provided by the MAC to the station management (SMT) and the logical link control sublayer (LLC) and the services provided by the PHY to SMT and the MAC. These services are defined in terms of service primitives and associated parameters (see Section 6);

(5) Defines the 4 and 16 Mbit/s, shielded twisted pair attachment of the station to the medium including the definition of the medium interface connector (MIC) (see Section 7). The previously specified 1 Mbit/s mode of operation is not covered by this standard. Users and implementers of 1 Mbit/s should refer to ANSI/IEEE Std 802.5-1985, under which it is allowed.

The definition of suitable media (twisted pair, coaxial cable, and optical fiber) for connecting stations that meet the attachment standard specified herein is a subject for future consideration. Until such time as specific media are specified, the specifications in Section 7 shall define the performance bounds to which an operating network, including media and trunk coupling unit(s) TCUs, shall conform.

A particular emphasis of this standard is to specify the homogeneous externally visible characteristics needed for interconnection compatibility, while avoiding unnecessary constraints upon and changes to internal design and implementation of the heterogeneous processing equipment to be interconnected.

The applications environment for the Local Area Network is intended to be commercial and light industrial. The use of token ring LANs in home and heavy industrial environments, while not precluded, has not been considered in the development of this standard.

1.2 Definitions

abort sequence. A sequence that terminates the transmission of a frame prematurely.

accumulated jitter. The jitter measured against the clock of the active monitor. Like alignment jitter, this is not a type of jitter but a way to measure total jitter growth throughout the ring. It is normally used to determine the required size of the elastic buffer.

alignment jitter. The jitter measured against the clock of the upstream adapter. This is not a type of jitter per se; rather, it is a way to measure jitter. When "zero transferred jitter" is specified, the jitter measured is alignment jitter.

broadcast transmission. A transmission addressed to all stations.

channel. The channel is the transmission path from the MIC at the transmitter to the first MIC at the receiver. It may include trunk coupling units (TCUs) and connectors in addition to transmission line.

configuration report server (CRS). A function that controls the configuration of the ring. It receives configuration information from the stations on the ring, and either forwards them to the network manager, or uses them to maintain a configuration of the ring. It can also, when requested by the network manager, check the status of stations on the ring, change operation parameters of stations on the ring, and remove stations from the ring.

correlated jitter. The portion of the total jitter that is related to the data pattern. Since every adapter receives the same *pattern*, this jitter is *correlated* among all adapters and therefore grows in a *systematic* way along the ring. Correlated jitter is also called *pattern jitter* or *systematic jitter*.

differential Manchester encoding. A signalling method used to encode clock and data bit information into bit symbols. Each bit symbol is split into two halves, where the second half is the inverse symbol of the first half. A 0 bit is represented by a polarity change at the start of the bit time. A 1 bit is represented by no polarity change at the start of the bit time. Differential Manchester encoding is polarity-independent.

fill. A bit sequence that may be either 0 bits, 1 bits, or any combination thereof.

frame. A transmission unit that carries a protocol data unit (PDU) on the ring.

jitter. The time-varying difference between the phase of the recovered clock and the phase of the source clock. Jitter is measured in fractions of a clock cycle, or unit interval (UI).

logical link control sublayer (LLC). That part of the data link layer that supports media-independent data link functions, and uses the services of the MAC to provide services to the network layer.

medium. The material on which the data may be represented. Twisted pairs, coaxial cables, and optical fibers are examples of media.

medium access control sublayer (MAC). The portion of the IEEE 802 data station that controls and mediates the access to the ring.

medium interface connector (MIC). The connector between the station and TCU at which all transmitted and received signals are specified.

monitor. The monitor is that function that recovers from various error situations. It is contained in each ring station; however, only the monitor in one of the stations on a ring is the *active monitor* at any point in time. The monitor function in all other stations on the ring is in standby mode.

multiple frame transmission. A transmission where more than one frame is transmitted when a token is captured.

physical layer (PHY). The layer responsible for interfacing with the medium, detecting and generating signals on the medium, and converting and processing signals received from the medium and the MAC.

protocol data unit (PDU). Information delivered as a unit between peer entities that contain control information and, optionally, data.

repeat. The action of a station in receiving a bit stream (for example, frame, token, or fill) from the previous station and placing it on the medium to the next station. The station repeating the bit stream may copy it into a buffer or modify control bits as appropriate.

repeater. A device used to extend the length, topology, or interconnectivity of the transmission medium beyond that imposed by a single transmission segment.

ring error monitor (REM). A function that collects ring error data from ring stations. The REM may log the received errors, or analyze this data and record statistics on the errors.

ring latency. In a token ring MAC system, the time (measured in bit times at the data transmission rate) required for a signal to propagate once around the ring. The ring latency time includes the signal propagation delay through the ring medium plus the sum of the propagation delays through each station connected to the token ring.

ring parameter server (RPS). That function that is responsible for initializing a set of operational parameters in ring stations on a particular ring.

service data unit (SDU). Information delivered as a unit between adjacent entities that may also contain a PDU of the upper layer.

station (or data station). A physical device that may be attached to a shared medium local area network for the purpose of transmitting and receiving information on that shared medium. A data station is identified by a destination address (DA).

static phase offset. The constant difference between the phase of the recovered clock and the optimal sampling position of the received data.

station management (SMT). The conceptual control element of a station that interfaces with all of the layers of the station and is responsible for the setting and resetting of control parameters, obtaining reports of error conditions, and determining if the station should be connected to or disconnected from the medium.

token. The symbol of authority that is passed between stations using a token access method to indicate which station is currently in control of the medium.

transferred jitter. The amount of jitter in the recovered clock of the upstream adapter. Transferred jitter is important because each adapter must both limit the amount of jitter it generates, and track the jitter delivered by the upstream adapter.

transmit. The action of a station generating a frame, token, abort sequence, or fill and placing it on the medium to the next station. In use, this term contrasts with *repeat*.

trunk cable. The transmission cable that interconnects two TCUs.

trunk coupling unit (TCU). A physical device that enables a station to connect to a trunk cable. The TCU contains the means for inserting the station into the ring or, conversely, bypassing the station.

uncorrelated jitter. The portion of the total jitter that is independent of the data pattern. This jitter is generally caused by *noise* that is *uncorrelated* among adapters and therefore grows in a *nonsystematic* way along the ring. Uncorrelated jitter is also called noise jitter or nonsystematic jitter.

unit interval (UI). One half of a bit time. 125 ns for 4 Mbit/s transmission and 31.25 ns for 16 Mbit/s transmission. UI is used in the specification of jitter.

upstream neighbor's address (UNA). The address of the station functioning upstream from a specific station.

1.3 Abbreviations

A	=	address-recognized bit
AC	=	access control (field)

AMP	=	active monitor present
BCN	=	beacon
C	=	frame-copied bit
CL	=	claim
CRS	=	configuration report server
DA	=	destination address
DAT	=	duplicate address test
DC	=	destination class
E	=	error-detected bit
ED	=	ending delimiter
EFS	=	end-of-frame sequence
ETR	=	early token release
FA	=	functional address
FAI	=	functional address indicator
FC	=	frame control (field)
FCS	=	frame-check sequence
FR	=	frame
FS	=	frame status (field)
I	=	intermediate frame bit
LAN	=	local area networks
LLC	=	logical link control (sublayer)
M	=	monitor bit
MA	=	my (station's) address
MAC	=	medium access control (sublayer)
MIC	=	medium interface connector
P	=	priority (of the AC)
PDU	=	protocol data unit
PHY	=	physical (layer)
Pm	=	priority of queued PDU
Pr	=	last priority value received
PRG	=	purge
Px	=	the greater value of Pm or Rr
R	=	reservation (of the AC)
REM	=	ring error monitor
RPS	=	ring parameter server
Rr	=	last reservation value received
RUA	=	received upstream neighbor's address
SA	=	source address
SD	=	starting delimiter
SDU	=	service data unit
SFS	=	start-of-frame sequence
SMP	=	standby monitor present
SMT	=	station management
Sr	=	highest stacked received priority
SUA	=	stored upstream neighbor's address
Sx	=	highest stacked transmitted priority

TAM = timer, active monitor
TCU = trunk coupling unit
THT = timer, holding token
TK = token
TNT = timer, no token
TQP = timer, queue PDU
TRR = timer, return to repeat
TSM = timer, standby monitor
TVX = timer, valid transmission
TX = transmit
UI = unit interval
UNA = upstream neighbor's address

1.4 References. This standard shall be used in conjunction with the following publications or their approved revisions:

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

[2] IEC Publication 380 (1985) (2nd Edition), Safety of Electronically Energized Office Machines.

[3] IEC Publication 435 (1983) (3rd Edition), Safety of Data Processing Equipment.

[4] IEC Publication 950 (1986), Safety of Information Technology Equipment.

[5] ISO Management Architecture, ISO/DIS 7499 Part 4, OSI Management Framework.[2]

[1] CISPR and IEC publications are available in the US from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, USA. These publications are also available from International Electrotechnical Commission, 3 rue de Varembé, Case Postale 131, CH-1211, Genève 20, Switzerland/Suisse.

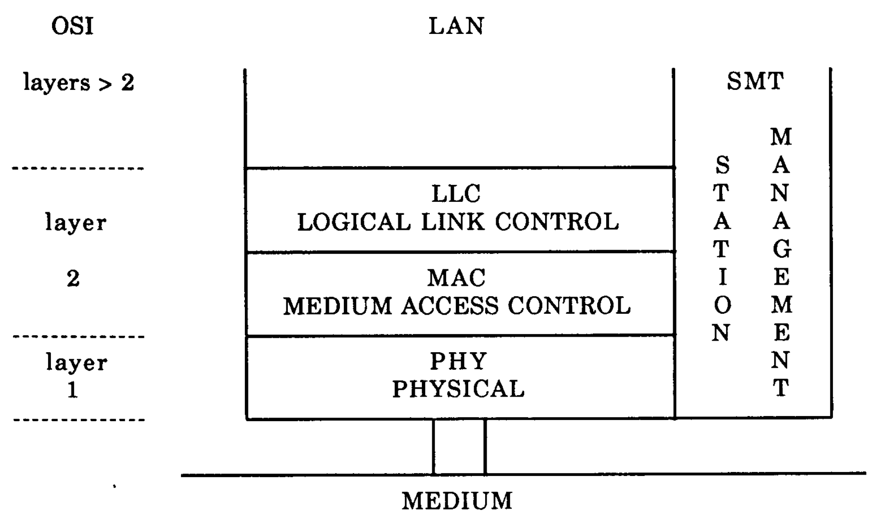
[2] This draft document is currently in production; when it is published it will become a part of the references of this standard.

2. General Description

There are two important ways to view local area network design: architectural, which emphasizes the logical divisions of the system and how they fit together, and implementational, which emphasizes the actual components, their packaging, and their interconnection.

This standard presents the architectural view, emphasizing the large-scale separation of the system into two parts: the MAC of the data link layer and the PHY. These layers are intended to correspond closely to the lowest layers of the ISO Basic Reference Model of Open Systems Interconnection (see Fig 2-1). The LLC and MAC together encompass the functions intended for the data link layer of the OSI model.

Fig 2-1
Relation of the OSI Reference Model to the LAN Model



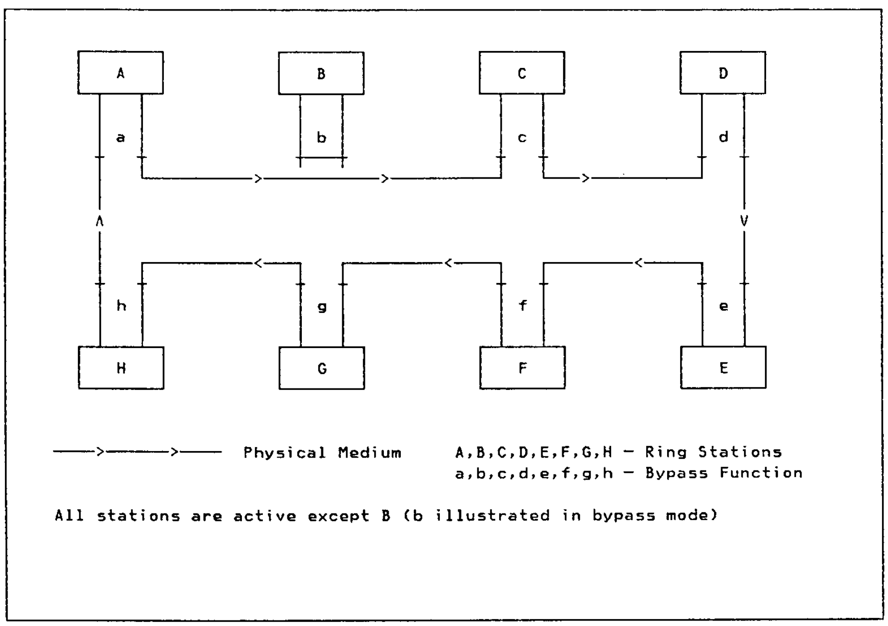
An architectural organization of the standard has the advantages of clarity (a clean overall division of the design along architectural lines makes the standard clearer) and flexibility (segregation of the access-method-dependent aspects of the MAC and PHY allows the LLC to apply to a variety of LAN access methods).

It should be noted that the exact relationship of the layers described in this standard to the layers defined by the OSI Reference Model is for further study.

A token ring consists of a set of stations serially connected by a transmission medium. (See Fig 2-2.) Information is transferred sequentially, bit by bit, from one active station to the next. Each station generally regenerates and repeats each bit and serves as the means for attaching one or more devices (terminals, work stations) to the ring for the purpose of communicating with other devices on the network. A given station (the one that has access to the medium) transfers information onto the ring, where the information circulates from one station to the next. The addressed destination station(s) *copies* the information as it passes. Finally, the station that transmitted the information effectively removes the information from the ring.

A station gains the right to transmit its information onto the medium when

Fig 2-2
Token Ring Configuration



it detects a token passing on the medium. The token is a control signal comprised of a unique signalling sequence that circulates on the medium following each information transfer. Any station, upon detection of an appropriate token, may capture the token by modifying it to a SFS and appending appropriate control and status fields, address fields, information field, FCS, and the EFS. At the completion of its information transfer and after appropriate checking for proper operation, the station initiates a new token, which provides other stations the opportunity to gain access to the ring.

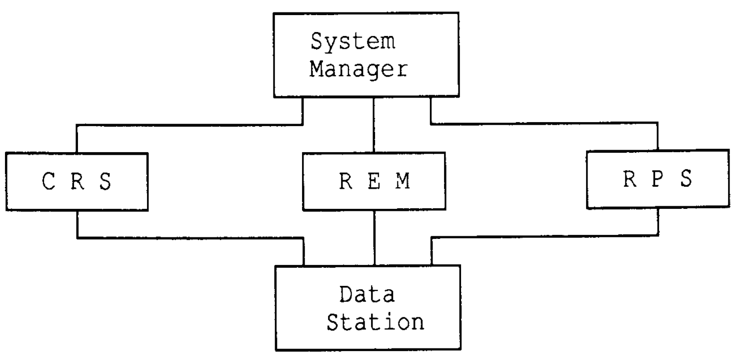
A token holding timer controls the maximum period of time a station shall use (occupy) the medium before passing the token.

Multiple levels of priority are available for independent and dynamic assignment depending upon the relative class of service required for any given message, for example, synchronous (real-time voice), asynchronous (interactive), immediate (network recovery). The allocation of priorities shall be by mutual agreement among users of the network.

Error detection and recovery mechanisms are provided to restore network operation in the event that transmission errors or medium transients (for example, those resulting from station insertion or removal) cause the access method to deviate from normal operation. Detection and recovery for these cases utilizes a network monitoring function that is performed in a specific station with back-up capability in all other stations that are attached to the ring.

Each ring in a token ring network has a set of server stations (*servers*) that are the means through which the systems manager manages the stations in a token ring system. Such arrangement is depicted in Fig 2-3.

Fig 2-3
Relationship of Data Stations, Servers, and System Manager



SERVERS: CRS — Configuration Report Server
REM — Ring Error Monitor
RPS — Ring Parameter Server

Servers are data collection and distribution points on each ring where reports from the data stations are gathered. Servers then communicate the necessary information to the systems manager for the purpose of managing a token ring system.

Data stations communicate with the servers by reporting errors that are detected such as lost token, FCS error, or lost frames, and requesting operating parameters when inserting into the ring, reporting changes in configuration due to insertion or removal of stations (UNA changes), responding to requests for various status information, and removal from the ring when requested.

The station to server message format and content is specified in Section 3; and the protocol for message exchange specified in Section 4.

The specification of the format and protocol for the information interchange between the servers and the systems manager is not covered by this standard. However, the abstract entities (parameters, events, and actions) specified in 6.3 and 6.4 are the elements of such communication.

3. Formats and Facilities

3.1 Formats. There are two basic formats used in token rings: tokens and frames. In the following discussion, the figures depict the formats of the fields *in the sequence they are transmitted on the medium*, with the left-most bit or symbol transmitted first.

Processes that require comparison of fields or bits perform that comparison upon those fields or bits *as depicted*, with the left-most bit or symbol compared first and, for the purpose of comparison, considered most significant.

3.1.1 Token Format

SD	AC	ED

SD = Starting Delimiter (1 octet)
AC = Access Control (1 octet)
ED = Ending Delimiter (1 octet)

The token shall be the means by which the right to transmit (as opposed to the normal process of repeating) is passed from one station to another.

3.1.2 Frame Format

| <— SFS —>| <———— FCS Coverage ————> | <— EFS —> |

SD	AC	FC	DA	SA	INFO	FCS	ED	FS

SFS = Start-of-Frame Sequence
SD = Starting Delimiter (1 octet)
AC = Access Control (1 octet)
FC = Frame Control (1 octet)
DA = Destination Address (2 or 6 octets)
SA = Source Address (2 or 6 octets)
INFO = Information (0 or more octets) *
FCS = Frame-Check Sequence (4 octets)
EFS = End-of-Frame Sequence
ED = Ending Delimiter (1 octet)
FS = Frame Status (1 octet)

* See 3.2.5 for limitation of information field length.

The frame format shall be used for transmitting both MAC and LLC messages to the destination station(s). It may or may not have an information field.

3.1.2.1 Abort Sequence

SD	ED

This sequence shall be used for the purpose of terminating the transmission of a frame prematurely. The abort sequence may occur anywhere in the bit stream; that is, receiving stations shall be able to detect an abort sequence even if it does not occur on octet boundaries.

3.1.3 Fill. When a station is transmitting (as opposed to repeating), it shall transmit fill preceding or following frames, tokens, or abort sequences to avoid what would otherwise be an inactive or indeterminate transmitter state.

Fill may be either 0 or 1 bits or any combination thereof and may be *any number* of bits in length, within the constraints of the THT.

3.2 Field Descriptions. The following is a detailed description of the individual fields in the tokens and frames.

3.2.1 Starting Delimiter (SD)

J K 0 J K 0 0 0

J = non-data-J
K = non-data-K
0 = zero bit

(For a discussion of non-data symbols, see 5.1)

A frame or token shall be started with these eight symbols. If otherwise, it shall not be considered valid.

3.2.2 Access Control (AC)

P P P	T	M	R R R

PPP = priority bits
T = token bit
M = monitor bit
RRR = reservation bits

3.2.2.1 Priority Bits. The priority bits shall indicate the priority of a token and, therefore, which stations are allowed to use the token. In a multiple-priority system, stations use different priorities depending on the priority of the PDU to be transmitted.

The eight levels of priority increase from the lowest (000) to the highest (111) priority. For purposes of comparing priority values, the priority shall be transmitted most significant bit first; for example, 110 has higher priority than 011 (left-most bit transmitted first).

3.2.2.2 Token Bit. The token bit is a 0 in a token and a 1 in a frame. When a station with a PDU to transmit detects a token that has a priority equal to or less than the PDU to be transmitted, it may change the token to a SFS and transmit the PDU.

3.2.2.3 Monitor (M) Bit. The M bit is used to prevent a token that has a priority greater than 0 or any frame from continuously circulating on the ring. If an active monitor detects a frame or a high priority token with the M bit equal to 1, the frame or token is aborted.

This bit shall be transmitted as 0 in all frames and tokens. The active monitor inspects and modifies this bit. All other stations shall repeat this bit as received.

3.2.2.4 Reservation Bits. The reservation bits allow stations with high priority PDUs to request (in frames or tokens as they are repeated) that the next token be issued at the requested priority. The precise protocol for setting these bits is described in 4.2.2.

The eight levels of reservation increase from 000 to 111. For purposes of comparing reservation values, the reservation shall be transmitted most significant bit first; for example, 110 has higher priority than 011 (left-most bit transmitted first).

3.2.3 Frame Control (FC)

F F	Z Z Z Z Z Z

FF = frame-type bits
ZZZZZZ = control bits

The FC field defines the type of the frame and certain MAC and information frame functions.

3.2.3.1 Frame-type Bits. The frame-type bits shall indicate the type of the frame as follows:

00 = MAC frame (contains a MAC PDU)
01 = LLC frame (contains an LLC PDU)
1x = undefined format (reserved for future use)

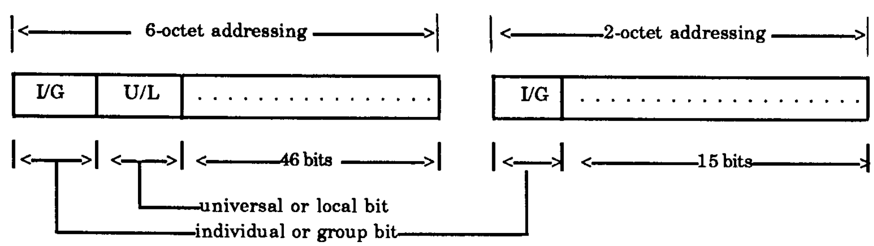
MAC Frames. If the frame-type bits indicate a MAC frame, all stations on the ring shall interpret and, based on the finite state of the station, act on the ZZZZZZ control bits.

LLC Frames. If the frame-type bits indicate an LLC frame, the ZZZZZZ bits are designated as rrrYYY. The rrr bits are reserved and shall be transmitted as 0's in all transmitted frames and ignored upon reception. The YYY bits may be used to carry the priority (Pm) of the PDU from the source LLC entity to the target LLC entity or entities. Note that P (the priority in the AC field of a frame) is less than or equal to Pm when the frame is transmitted onto the ring.

Undefined Format. The value "1x" is reserved for frame types that may be defined in the future. However, although currently undefined, any future frame formats shall adhere to the following conditions:

(1) The format shall be delimited by the 2-octet SFS field and the 2-octet EFS field, as defined in this standard. Additional fields may follow the EFS field.
(2) The position of the FC field shall be unchanged.
(3) The SFS and EFS of the format shall be separated by an integral number of octets. This number shall be at least 1 (that is, the FC field) and the maximum length is subject to the constraints of the THT.
(4) All symbols between the SFS and EFS shall be 0 and 1 bits.
(5) All stations on the ring check for data symbols and an integral number of octets between the SFS and EFS fields. The error-detected (E) bit of formats that are repeated shall be set to 1 when a non-data symbol or a non-integral number of octets is detected between the SFS and EFS fields.
(6) All bit errors that occur in the FC field that have a hamming distance of less than four must be detectable by stations using this format and shall not be accepted by any other station conforming to this standard.

3.2.4 Destination and Source Address (DA and SA) Fields. Each frame shall contain two address fields: the destination (station) address and the source (station) address, in that order. Addresses may be either 2 or 6 octets in length; however, all stations of a specific LAN shall have addresses of equal length.



3.2.4.1 Destination Address (DA). The DA identifies the station(s) for which the information field of the frame is intended. Included in the DA is a bit to indicate whether the DA is an individual or group address and, for 6-octet addresses only, the second bit indicates whether it is a universally or locally administered address.

Individual and Group Addresses. The first bit transmitted of the DA distinguishes individual from group addresses:

0 = individual address 1 = group address

Individual addresses identify a particular station on the LAN and shall be distinct from all other individual station addresses on the same LAN (in the case of local administration), or from the individual addresses of other LAN stations on a global basis (in the case of universal administration).

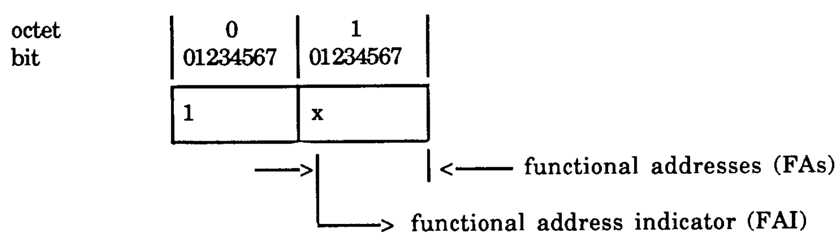
A group address shall be used to address a frame to multiple destination stations. Group addresses may be associated with zero or more stations on a given LAN. In general, a group address is an address associated by convention with a group of logically related stations.

Broadcast Address. The group address consisting of 16 or 48 1's (for 2- or 6-octet addressing, respectively) shall constitute a broadcast address, denoting the set of all stations on a given LAN. Stations using 48-bit addressing must also recognize X'C000FFFFFFFF' as a broadcast address in MAC frames.

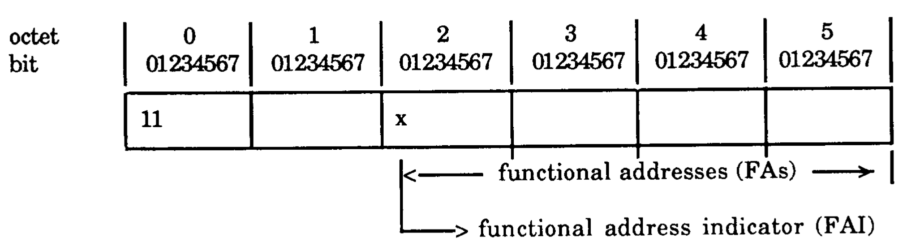
Null Address. An address of 16 or 48 0's (for 2- or 6-octet addressing, respectively) shall be considered a null address. It will mean the frame is not addressed to any particular station.

Functional Addresses (FAs). FAs are a subset of locally administered group addresses. They are bit-significant addresses used to identify well-known functional entities. The Functional Address Indicator (FAI) identifies a FA versus a conventional group MAC address. This indicator is set to a B'1' for conventional group addresses and B'0' for FAs.

2-Octet Addressing



6-Octet Addressing



The following functional addresses are defined:

Function Name	Functional Address (FA)	
	2-Octet	6-Octet
Active monitor	X'01'	X'00000001'
Ring parameter server (RPS)	X'02'	X'00000002'
Ring error monitor (REM)	X'08'	X'00000008'
Configuration report server (CRS)	X'10'	X'00000010'

Address Administration. There are two methods of administering the set of 6-octet station addresses: locally or through a universal authority. The second bit transmitted of the DA 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 global basis. The procedure for administration of these addresses is not specified in this standard.

Information concerning the registration authority and its procedures may be obtained on request to the Secretary General, ISO Central Secretariat, Case Postal 56, CH-1211 Genève, Switzerland.

For information on global address administration contact the Registration Authority for ISO 8802-5, c/o The Institute of Electrical and Electronics Engineers, Inc, 445 Hoes Lane, PO Box 1331, 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 2-octet addresses.)

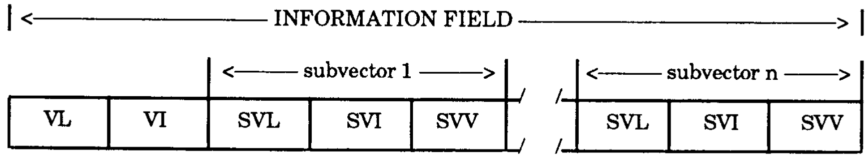
3.2.4.2 Source Address (SA) Field. The SA shall identify the station originating the frame and shall have the same format and length as the DA in a given frame. The individual/group bit shall be 0.

3.2.5 Information (INFO) Field. The information field contains zero, one, or more octets that are intended for MAC, SMT, or LLC. Although there is no maximum length specified for the information field, the time required to transmit a frame may be no greater than the token holding period that has been established for the station.

The format of the information field is indicated in the frame-type bits of the FC field. The frame types defined are MAC frame and LLC frame.

3.2.5.1 MAC Frame Format. Figure 3-1 defines the format of the information field, when present, for MAC frames.

Vector. The fundamental unit of MAC and SMT information. A vector contains its length, an identifier of its function, and zero or more subvectors. Only one vector is permitted per MAC frame.



VL (2 octets) = vector length
VI (2 octets) = vector identifier
SVL (1 octet) = subvector length
SVI (1 octet) = subvector identifier
SVV (n octets) = subvector value

Fig 3-1
MAC Frame Information Field Structure

VL (vector length). A 16-bit binary number that gives the length, in octets, of the vector. The length includes the VL field and can have values such that X'0004' ≤ VL ≤ X'FFFF' (subject to the constraints of the THT (token holding timer).

VI (vector identifier). A 2-octet code point that identifies the vector.

DESTINATION CLASS (DC) (4 bits)	SOURCE CLASS (4 bits)	VECTOR CODE (8 bits)

The first octet of the vector identifier of a MAC frame is divided into two 4-bit function class fields. The DC provides a means to route the frame to the appropriate management function within a ring station. The source class provides the ring station the ability to ensure that the source of the vector is valid. The function classes are as follows:

Function Class	Class Value
Ring Station (RS)	X'0'
Configuration report server (CRS)	X'4'
Ring parameter server (RPS)	X'5'
Ring error monitor (REM)	X'6'

The second octet of the vector identifier is the code that uniquely identifies the vector.

Code points from X'C0' through X'FE' are unreserved and are set aside to permit the implementer to define special system-dependent functions that do not have general applicability. Such special system-dependent functions are beyond the scope of this standard.

SV (subvector). Vectors require all data or modifiers to be contained within subvectors. One subvector is required to contain each piece of data or modifier that is being transported. A subvector is not position-dependent within a vector, but rather, each subvector must be identified by its subvector identifier.

SVL (subvector length). An 8-bit binary number that gives the length, in octets, of the subvector. The length includes the length of the SVL field. A subvector length of X'FF' means that the subvector is longer than 254 octets and the actual length is included in the next two octets.

SVI (subvector identifier). A 1-octet code point that identifies the subvector. The code point of X'FF' indicates that an expanded identifier is being used and is contained in the next two octets.

The subvectors are of two types. The subvectors with code points from X'00' through X'7F' are used so that certain specific strings that are common to many vectors can be formatted and labeled in a standard manner. This standardization is intended to facilitate sharing of data between MAC and SMT applications and make the data as application-independent as possible.

The subvectors with code points from X'80' through X'FE' are for specific definition within a particular vector by vector identifier. For example, the subvector X'90' can have an entirely different definition in every different vector. The subvector X'40' has only one definition across all vectors and applications.

Subvectors themselves may contain other subvectors and other types of vectors and optional fields that are unique only to the particular subvector to which they belong.

3.2.5.2 LLC Frame Format. The format of the information field for LLC frames is not specified in this standard. However, in order to promote interworking among stations, all stations shall be capable of receiving frames whose information field is up to and including 133 octets in length.

3.2.5.3 Order of Bit Transmission. Each octet of the information field shall be transmitted most significant bit first.

3.2.6 Frame Check Sequence (FCS). The FCS shall be a 32-bit sequence based on the following standard generator polynomial of degree 32.

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

The FCS shall be the 1's complement of the sum (modulo 2) of the following:

(1) The remainder of $X^k \times (X^{31} + X^{30} + X^{29} + \ldots + X^2 + X + 1)$ divided (modulo 2) by G(X), where k is the number of bits in the FC, DA, SA, and INFO fields, and

(2) The remainder after multiplication by X^{32} and then division (modulo 2) by G(X) of the content (treated as a polynomial) of the FC, DA, SA, and INFO fields.

The FCS shall be transmitted commencing with the coefficient of the highest term.

As a typical implementation, at the transmitter, the initial remainder of the division is preset to all 1's and is then modified by division of the FC, DA, SA, and INFO fields by the generator polynomial, G(X). The 1's complement of this remainder is transmitted, most significant bit first, as the FCS.

At the receiver, the initial remainder is preset to all 1's and the serial incoming bits of FC, DA, SA, INFO, and FCS, when divided by G(X), results, in the absence of transmission errors, in a unique non-zero remainder value. The unique remainder value is the polynomial:

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

3.2.7 Ending Delimiter (ED)

J K I J K I	I	E

J = non-data-J
K = non-data-K
1 = binary one
I = intermediate frame bit
E = error-detected bit

The transmitting station shall transmit the delimiter as shown. Receiving stations shall consider the ED valid if the first six symbols J K 1 J K 1 are received correctly.

3.2.7.1 Intermediate Frame Bit (I Bit). If the I flag is utilized to determine the end of a station's transmission, the I bit shall be transmitted as 1 in intermediate (or first) frames of a multiple frame transmission. The I bit in the last or only frame of the transmission shall be transmitted as 0.

3.2.7.2 Error-Detected Bit (E Bit). The E bit shall be transmitted as 0 by the station that originates the token, abort sequence, or frame. All stations on the ring check tokens and frames for errors (for example, FCS error, non-data symbols: see 4.2.1). The E bit of tokens and frames that are repeated shall be set to 1 when a frame with error is detected; otherwise the E bit is repeated as received.

3.2.8 Frame Status (FS)

A C r r	A C r r

A = address recognized bits
C = frame copied bits
r = reserved bits

These reserved bits are reserved for future standardization. They shall be transmitted as 0's; however, their value shall be ignored by the receivers.

3.2.8.1 Address Recognized (A) Bits and Frame Copied (C) Bits. The A and C bits shall be transmitted as 0 by the station originating the frame. If another station recognizes the DA as its own address or relevant group address it shall set the A bits to 1. If it copies the frame (into its receive buffer), it shall also set the C bits to 1. This allows the originating station to differentiate among three conditions:

(1) Station non-existent/non-active on this ring
(2) Station exists but frame not copied
(3) Frame copied

The A and C bits shall be set without regard to the value of the E bit and only if the frame is *good* as defined in 4.2.1. Only the values that are 00rr 00rr, 10rr 10rr, and 11rr 11rr shall be considered valid. All other values are invalid and ignored by the receiver.

If a destination station detects that the A bits have already been set, and the DA is not a group address, it may imply that a duplicate address problem exists. The second condition (station existent but frame not copied) allows the originating station to log the instances when, for example, congestion has prevented a destination station from copying the frame.

3.3 Medium Access Control (MAC) Frames. The following are descriptions of various MAC frames that are used in the management of the token ring. Values for PDU priority (Pm), FC, DA, INFO field content (Vector Identifier—VI, Subvector Identifier—SVI, and Subvector Value—SVV) associated with the particular MAC supervisory frame are indicated in 3.3.3.

Frames with the following FC values are to be handled as follows:

(1) If the value of the FC of the frame is X'00' and it is addressed to the station, it will be copied only if there is sufficient free buffer available for copying.
(2) If the value of the FC of the frame is X'01' and it is addressed to the station, every effort will be made to copy the frame including overwriting previously received information.
(3) If the value of the FC of the frame is greater than X'01', it will be addressed to all stations on the ring. It will be copied only if there is sufficient free buffer available for copying. If the frame is not copied, action will be based on the value of the FC field.

The digits enclosed by X' and ' (for example, X'07') are the hexadecimal value of the assigned code point. Values other than those defined below will be ignored by the receiving station(s). All unassigned values are reserved for future specification. The general format for the information field of MAC frames is described under 3.2.5.

3.3.1 Vector Description

3.3.1.1 Claim Token MAC Frame (CL_TK). When a station that is in standby state determines that there is no active monitor operating on the ring, it shall enter a *claiming token* state. While in this state the station shall send claim token frames and inspect the SA of the claim token MAC frames it receives. If the SA matches its own MA and the RUA subvector matches the SUA, it has claimed the token and shall enter active monitor mode and generate a new token. (For a more detailed description, see Fig 4-5.)

3.3.1.2 Duplicate Address Test MAC Frame (DAT). This frame is transmitted with DA equal to MA as part of the initialization process. If the frame returns with the A bits set to 1, it indicates that there is another station on the ring with the same address. If such an event occurs, the station's network manager is notified and the station returns to bypass state. A station that copies a DAT frame will ignore it.

3.3.1.3 Active Monitor Present MAC Frame (AMP). This frame is transmitted by the active monitor. It shall be queued for transmission following the successful purging of the ring or following the expiration of the TAM. Any station in standby state that receives this frame shall reset its TSM.

An AMP is transmitted at the ring service priority (Pr) that exists at the time a token is received after an AMP PDU is queued. The default value for Pm for this frame is seven; see 6.3.2.1 to change this value.

3.3.1.4 Standby Monitor Present MAC Frame (SMP). This frame is transmitted by the standby monitor(s). After receipt of an AMP or SMP frame whose A and C bits equal 0, the TQP is reset. When timer TQP expires, an SMP PDU shall be queued for transmission.

The queueing of a SMP PDU is delayed for a period of TQP to assure that the transmission of SMP frames do not use more than 1% of the bandwidth of the ring in any TQP period of time.

Stations that receive an AMP or SMP frame in which the value of the A and C bits are 0 will regard the frame as having originated from their upstream neighbor's station. Therefore, a station that copies such a frame shall record the SA contained in the frame as the SUA for later transmission as a subvector in certain MAC frames as well as performing a comparison with certain MAC frames.

3.3.1.5 Beacon MAC Frame (BCN). This frame shall be sent as a result of serious ring failure (for example, broken cable, jabbering station, etc). It is useful in localizing the fault. The transmission of BCN is covered in Fig 4-5.

The immediate upstream station is part of the failure domain about which the BCN is reporting. Therefore, as noted above, the address of the upstream station that was previously recorded is included in the MAC info field.

3.3.1.6 Purge MAC Frame (PRG). This frame is transmitted by the active monitor. It shall be transmitted following claiming the token or to perform reinitialization of the ring following the detection of an M bit set to 1 or the expiration of timer TVX.

3.3.1.7 Change Parameters MAC Frame (CHG_PARM). This frame is sent by the CRS to set appropriate ring operational values.

3.3.1.8 Initialize Ring Station (INIT). This frame is sent by the RPS in response to the Request Initialization MAC frame sent to the RPS. This frame sets appropriate ring operational values in a station.

3.3.1.9 Lobe Media Test MAC Frame (TEST). This frame can be sent by a station to test the continuity and bit error rate of the wire in a loop-back path, prior to the station's physical insertion in the ring. The DA field of this frame is the null address (16 or 48 zeros). The wrap data is a bit string that can be chosen arbitrarily by the transmitting station.

3.3.1.10 Remove Ring Station MAC Frame (REMOVE). This frame is sent by the CRS to a specific station causing an unconditional removal.

3.3.1.11 Report Error MAC Frame (ERROR). This frame is sent by a station to the REM. When a timer expires, the values of the counters are reported, if they have been incremented since the last expiration. If a counter overflows before the threshold timer expires, the counter values are reported at the time of the overflow. A timer value of 0 implies no report will be sent.

3.3.1.12 Report Active Monitor Error MAC Frame (ACTIVE_ERROR). This frame is sent by the active monitor to the REM when it receives a Purge or an AMP MAC frame that it did not transmit, or when it receives a Claim Token MAC frame. In this case this indicates that a duplicate active monitor or another station has detected an error in the active monitor. It is also sent by a station in Claim Token State if it receives a Claim Token MAC frame in which the SA is equal to the MA but RUA≠SUA. In this case, this report indicates a possible duplicate address on the ring.

3.3.1.13 Report Neighbor Notification Incomplete MAC Frame (NN_INCMP). This frame is sent by the active monitor to the REM when its TAM expires before the completion of the neighbor notification process, detected by not receiving an AMP or SMP with A equal to C equal to 0. It indicates a congested station, a failing station, or a high bit error rate on the ring.

3.3.1.14 Report New Active Monitor MAC Frame (NEW_MON). This frame is sent by a station to the CRS to report that it has become the active monitor.

3.3.1.15 Report Ring Station Addresses MAC Frame (RPT_ADDR). This frame is sent by a station to the sender of Request Ring Station Addresses MAC frame.

3.2.1.16 Report Ring Station Attachments MAC Frame (RPT_ATTCH). This frame is sent by a station to the sender of Request Ring Station Attachments MAC frame.

3.3.1.17 Report Ring Station State MAC Frame (RPT_STATE). This frame is sent by a station to the sender of Request Ring Station State MAC frame.

3.3.1.18 Report SUA Change MAC Frame (SUA_CHG). This frame is sent by a station to the CRS when a change is made in the station's SUA as the result of the neighbor notification process.

3.3.1.19 Request Initialization MAC Frame (RQ_INIT). This frame is sent by a station to its RPS after successfully inserting (transition made to Standby State) in the ring. This is to inform the RPS that a station has been inserted and will accept modified parameters from either the RPS or CRS.

3.3.1.20 Request Ring Station Addresses MAC Frame (RQ_ADDR). This frame is sent by one of the management servers (CRS, REM, or RPS) to a specific station to request the different addresses recognized by the ring station.

3.3.1.21 Request Ring Station Attachments MAC Frame (RQ_ATTCH). This frame is sent by one of the management servers (CRS, REM, or RPS) to a specific station to request information on the functions active in the ring station.

3.3.1.22 Request Ring Station State MAC Frame (RQ_STATE). This frame is sent by one of the management servers (CRS, REM, or RPS) to a specific station to request the state information of the ring station.

3.3.1.23 Response MAC Frame (RSP). This frame is sent by a station to acknowledge receipt of, or to report an error (for example a syntax error) in, a received MAC frame. It reports on whether or not the corresponding received frame was processed correctly by the receiving station.

The MAC frames requiring a response include Change Parameters MAC frame and Initialize Ring Station MAC frame.

3.3.2 Subvector Descriptions. Below is a list of subvectors, listed in alphabetical order, along with their respective subvector values.

3.3.2.1 Assign Physical Drop Number. This subvector has a value field 4 octets long. It specifies the physical location of the target station. It is installation-dependent.

3.3.2.2 Authorized Access Priority. This subvector has a value field 2 octets long. The system administrator assigns maximum priorities to each station.

3.3.2.3 Authorized Function Classes. This subvector has a value field 2 octets long. It indicates the functional classes that are allowed to be active in the station. Valid range is B'0000 0000 0000 0000' to B'1111 1111 1111 1111' where each bit 0 to 15 corresponds to function class B'0000' to B'1111'. Defined function classes are the following:

Function Class	Class Value
Ring Station (RS)	X'0'
Configuration report server (CRS)	X'4'
Ring parameter server (RPS)	X'5'
Ring error monitor (REM)	X'6'

3.3.2.4 BCN Type. This subvector has a value field 2 octets long and is used to indicate the type of error detected. It has one of the following possible values:

X'0001'—Issued by station during reconfiguration (for future study)
X'0002'—Continuous J symbols received
X'0003'—Timer TNT expired during claiming token; no FR_CL_TK received
X'0004'—Timer TNT expired during claiming token; FR_CL_TK (SA<MA) received

3.3.2.5 Correlator. This subvector has a value field 2 octets long and is used by the sending station to relate its transmitted requests with the responses it receives. Any pattern of bits may be used as the correlator.

3.3.2.6 Error Code. This subvector has a value field 2 octets long and is used in the Report Active Monitor Error MAC frame. It has the following code points:

X'0001'—Active monitor error, used when the active monitor receives a Claim Token MAC frame, indicating that another station detected an error in the active monitor.

X'0002'—Duplicate active monitor, used when the active monitor receives a Purge or an AMP MAC frame that it did not transmit, indicating the presence of another active monitor.

X'0003'—Duplicate address, used when a station in Claim Token Status receives a Claim Token MAC frame in which the SA equals the station's individual address (SA equal to MA) but the RUA is different from the station's SUA. This indicates that another station on the ring has the same individual address.

3.3.2.7 Error Report Timer Value. This subvector has a value field 2 octets long. It is used to determine the value of TER. (The value shall be stated in increments of 10 ms).

3.3.2.8 Functional Address (FA). This subvector has a value field 1 or 4 octets long (depending on whether 2- or 6-octet addressing is used) and specifies the FAs of the reporting station.

3.3.2.9 Group Address. This subvector has a value field 1 or 2 octets in length for 2-octet addressing and 4 or 6 octets in length for 6-octet addressing. It contains the group address of the reporting station.

3.3.2.10 Isolating Error Counts. This subvector has a value field 6 octets long and is used in the Report Error MAC frame. It indicates the number of each type of error detected since the last error report. The counters listed below are not required, but are recommended. Refer to 3.8 for a description of each of the counters.

Octet 0—line error	Octet 2—burst error	Octet 4—abort delimiter transmitted
Octet 1—internal error	Octet 3—A/C error	Octet 5—reserved

3.3.2.11 Local Ring Number. This subvector has a value field 2 octets long. It indicates the local ring number of the sending station.

3.3.2.12 Nonisolating Error Counts. This subvector has a value field 6 octets long and is used in the Report Error MAC frame. It indicates the number of each type of error detected since the last error report. The counters listed below are not required, but are recommended. Refer to 3.8 for a description of each of the counters.

Octet 0—lost frame error	Octet 2—frame-copied error	Octet 4—token error
Octet 1—receive congestion	Octet 3—frequency error	Octet 5—reserved

3.3.2.13 Physical Drop Number. This subvector has a value field 4 octets long. It reports the physical location of the sending station. It is installation-dependent.

3.3.2.14 Product Instance ID. This subvector's value is used by a station manufacturer to identify a station's characteristics, such as serial number, machine type, model number, plant of manufacture, etc. The format of this subvector value is not specified.

3.3.2.15 Upstream Neighbor's Address (UNA). This subvector value field is 2 or 6 octets long (depending on whether 2- or 6-octet addressing is used) and contains the address of the upstream neighbor of the sending station.

3.3.2.16 Response Code. This subvector has a value field 4 octets long and is used in the Response MAC frame. It consists of a 2-octet response code followed by another 2 octets containing the source class, DC, and the MVID in the received MAC frame that caused the station to send the Response MAC frame. The response code points are as follows:

X'0001'—Positive acknowledgement. The MAC frame was accepted by the station.
X'8001'—MAC frame data field incomplete. The MAC frame was too short to contain the vector length and the vector ID.
X'8002'—Vector length error. Vector length does not agree with the length of the frame or a subvector was found that did not fit within the vector.
X'8003'—Unrecognized Vector ID. The vector ID is not recognized by the station.
X'8004'—Inappropriate source class. The source class is not valid for the MVID.
X'8005'—Subvector length error. The length of a recognized subvector is less than 2 or exceeds the maximum allowed.
X'8006'—Reserved.
X'8007'—Missing subvector. A subvector required to process the MAC frame is not in the MAC frame.
X'8008'—Subvector unknown. A subvector received in the MAC frame is not known by the adapter.
X'8009'—MAC frame too long. The received frame was rejected because it exceeded maximum length.
X'800A'—Function requested was disabled. The received MAC frame was not executed because the function requested was disabled.

3.3.2.17 Ring Station Version Number. This subvector is used in the Request Initialization and Report Ring Station State MAC frames. The contents of this subvector are implementation-specific.

3.3.2.18 Ring Station Status Vector. This subvector is used in the Report Ring Station State MAC frame. The contents of the vector are implementation-specific.

3.3.2.19 SA of Received MAC Frame. This subvector has a value field 2 or 6 octets long (depending on whether 2- or 6-octet addressing is used) and is used in the Report Neighbor Notification Incomplete MAC frame. It indicates the SA of the last AMP or SMP when the neighbor notification process does not complete.

3.3.2.20 Wrap Data. The length and function of this subvector are product implementation choices. The subvector is used in the Lobe Media Test MAC frame.

3.3.2.21 Station Identifier. This subvector has a value field 6 octets long and is used in the Report Station State MAC frame. It uniquely identifies the station.

3.3.3 Table of MAC Frames. Shown on the next two pages is a table of MAC frames and the subvectors that they contain.

Vector (in vector code order)	FC Pm	DA	Subvector/Comment
X'0002' BCN	X'02' 0	all sta this ring	X'01' BCN Type X'0B' Physical Drop Number X'02' UNA
X'0003' Claim Token	X'03' 0	all sta this ring	X'0B' Physical Drop Number X'02' UNA
X'0004' Ring Purge	X'04' 0	all sta this ring	X'0B' Physical Drop Number X'02' UNA
X'0005' AMP	X'05' 7	all sta this ring	X'0B' Physical Drop Number X'02' UNA
X'0006' SMP	X'06' 3	all sta this ring	X'0B' Physical Drop Number X'02' UNA
X'0007' DAT	X'01' 3	DA=SA= MA	none
X'0008' Lobe Media Test	X'00' 3	48 0's	X'26' Wrap Data
X'0408' Remove Ring Station	X'01' 3	Target Address	
X'040C' Change Parameters RESPONSE REQUIRED	X'00' 3	Target Address	X'09' Correlator X'03' Local Ring Number X'04' Assign Physical Drop Number X'05' Error Timer Value X'06' Authorized Function Classes X'07' Authorized Access Priority
X'050D' Initialize Ring Station RESPONSE REQUIRED	X'00' 3	Target Address	X'09' Correlator X'03' Local Ring Number X'04' Assign Physical Drop Number X'05' Error Timer Value
X'0*0E' Request Station Addresses	X'00' 3	Target Address	X'09' Correlator * DC = SC of rcvd frame
X'0*0F' Request Station State	X'00' 3	Target Address	X'09' Correlator * DC = SC of rcvd frame
X'0*10' Request Station Attachments	X'00' 3	Target Address	X'09' Correlator * DC = SC of rcvd frame

Vector (in vector code order)	FC	DA Pm	Subvector/Comment
X'4025' Report New Active Monitor	X'00' 3	CRS FA	X'0B' Physical Drop Number X'02' UNA X' 22' Product Instance ID
X'4026' Report SUA Change	X'00' 3	CRS FA	X'02' UNA X' 0B' Physical Drop Number
X'5020' Request Initialization	X'00' 3	RPS FA	X'22' Product Instance ID X'02' UNA X' 23' Ring Station Version Number
X'6027' Report Neighbor Notification Incomplete	X'00' 3	REM FA	X'0A' SA of Last AMP or SMP Frame
X'6028' Report Active Monitor Error	X'00' 3	REM FA	X'30' Error Code X'0B' Physical Drop Number X'02' UNA
X'6029' Report Error	X'00' 3	REM FA	X'2D' Isolating Error Count X'2E' Nonisolating Error Count X'0B' Physical Drop Number X'02' UNA
X'*000' Response	X'00' 0	SA of rcvd frame	X'09' Correlator X'20' Response Code * DC=SC of rcvd frame
X'*022' Report Station Addresses	X'00' 0	SA of request	X'09' Correlator X'02' UNA X' 0B' Physical Drop Number X'2B' Group Address(es) X'2C' FA(s) * Function class of requestor
X'*023' Report Station State	X'00' 0	SA of request	X'09' Correlator X'23' Ring Station Version Number X'28' Station Identifier X' 29' Ring Station Status * Function class of requestor
X'*024' Report Station Attachments	X'00' 0	SA of request	X'09' Correlator X'22' Product Instance ID X' 06' Authorized Function Classes X'07' Authorized Access Priority X'2C' FA(s) * Function class of requestor

3.4 Timers. The value of these timers shall be established by mutual agreement among the users of the LAN.

The term *reset,* when applied to timers, is to be understood to mean the timer is reset to its initial value and (re)started.

3.4.1 Timer, Return to Repeat (TRR). Each station shall have a timer TRR to ensure that the station shall return to Repeat State. TRR shall have a value greater than the maximum ring latency. The maximum ring latency consists of the signal propagation delay around a maximum-length ring plus the sum of all station latencies. The operation of TRR is described in the operational finite-state machine. The default time-out value of TRR shall be 2.5 ms.

3.4.2 Timer, Holding Token (THT). Each station shall have a timer THT to control the maximum period of time the station may transmit frames after capturing a token. A station may initiate transmission of a frame if such transmission can be completed before timer THT expires. The operation of THT is described in the operational finite-state machine. The default time-out value of THT shall be 10 ms.

3.4.3 Timer, Queue PDU (TQP). Each station shall have a timer TQP for the purpose of timing the enqueuing of a SMP PDU after reception of a AMP or SMP frame in which the A and C bits were equal to 0. The default time-out value of TQP is 10 ms.

3.4.4 Timer, Valid Transmission (TVX). Each station shall have a timer TVX that is used by the active monitor to detect the absence of valid transmissions. The operation of TVX is described in the monitor finite-state machine. The time-out value of TVX shall be the sum of the time-out value of THT plus the time-out value of TRR.

3.4.5 Timer, No Token (TNT). Each station shall have a timer TNT to recover from various token-related error situations. TNT shall have a time-out value equal to TRR plus n times THT (where n is the maximum number of stations on the ring). The operation of TNT is described in the monitor finite-state machines. The default time-out value of TNT shall be 1 s.

3.4.6 Timer, Active Monitor (TAM). Each station shall have a timer TAM that is used by the active monitor to stimulate the enqueuing of a AMP PDU for transmission. The default time-out value of timer TAM shall be 3 s.

3.4.7 Timer, Standby Monitor (TSM). Each station shall have a timer TSM that is used by the stand-by monitor(s) to assure that there is an active monitor on the ring and to detect a continuous stream of tokens. The default time-out value of timer TSM shall be 7 s.

3.4.8 Timer, Error Report (TER). Each station shall have a timer TER that is used to report error counters as detected by the station. This timer is reset upon entering Standby state (State S4). When this timer expires, the station queues a Report Error PDU if any of counter is not zero, and resets this timer. The default time-out value of timer TER shall be 2 s.

3.4.9 Timer, BCN Transmit (TBT). Each station shall have a timer TBT that is used to specify the length of time a station shall remain in BCN transmit before entering Bypass state. The default time-out value of timer TBT shall be 26 s.

3.4.10 Timer, BCN Receive (TBR). Each station shall have a timer TBR that is used by that station to control the time a station receives BCN frames from its downstream neighbor before entering Bypass state. The default time-out value of timer TBR shall be 160 ms.

3.5 Flags. Flags are used to *remember* the occurrence of a particular event. They shall be set when the event occurs. The flags used are the following:

3.5.1 I Flag. A flag that is set upon receiving an ED with the I bit equal to 0. Implementation of this flag is mutually exclusive with the implementation of the Frame Count counter (see 3.8.11).

3.5.2 SFS Flag. A flag that is set upon receiving an SFS sequence.

3.5.3 MA Flag. A flag that is set upon receiving an SA that is equal to the station's address.

3.5.4 SMP Flag. A flag used by the standby monitors that is set upon receiving an SMP or AMP with the address recognized and C bits set to 0.

3.5.5 NN Flag. A flag used by the active monitor that is set when the active monitor receives an AMP or SMP with the address recognized and C bits set to 0, indicating the neighbor notification process has completed.

3.5.6 BR Flag. A flag used by all stations that is set when the station receives a BCN frame other than type 1 from its active downstream neighbor (RUA=MA). It is reset upon the receipt of any frame other than the frame described above.

3.5.7 ETR Flag. A flag used by all stations to indicate whether or not the ETR option is selected. If this flag is set, the ETR option is active. This flag is settable through the management entity. Implementation of the ETR capability is optional.

3.5.7.1 NOT_MA Flag. A flag used to indicate if the SA of the last transmitted frame is not equal to MA. This flag is set only if the SA is composed of only 0 and 1 bits and the frame count (FR_CNT) equals 1. Implementation of this flag is mandatory if the Frame Count counter is implemented (see 3.8.11).

3.6 Priority Registers and Stacks

3.6.1 Pr and Rr Registers. The value of the priority (P) and reservation (R) of the most recently received AC field are stored in registers as Pr and Rr.

3.6.2 Sr and Sx Stacks. If, at the time of transmission of a token, the value of Rr or Pm (the priority of a queued PDU) is greater than Pr, a token with a priority of the higher of Rr or Pm shall be transmitted. At the same time the station shall store the value of Pr in a stack as Sr and shall store the value of the priority of the token that was transmitted in a stack as Sx.

The use of the Pr and Rr registers and the Sr and Sx stacks in performing the priority function is described in detail in Section 4.

3.7 Latency Buffer. The latency buffer serves two purposes. The first is to ensure that there are at least 24 bits of latency in the ring. The second is to provide phase jitter compensation. The latency buffer is described in more detail in Section 5.

The token management is structured so that only one latency buffer shall be active in a normally functioning ring and is provided by the active monitor in the ring.

3.8 Counters

3.8.1 Line Error. This counter is incremented when a frame or token is copied or repeated by a station, the E bit is zero in the frame or token and one of the following conditions exists:

(1) There is a non-data bit (J or K bit) between the SD and the ED of the frame or token.

(2) There is a FCS error in a frame.

The first station detecting a line error increments its appropriate error counter and sets E=1 in the ED of the frame; this prevents other stations from also logging the error and isolates the source of the disturbance to the proper error domain.

3.8.2 Internal Error. This counter is incremented when a station recognizes a recoverable internal error. This can be used for detecting a station in marginal operating condition.

3.8.3 Burst Error. This counter is incremented when a station detects the absence of transitions for five half-bit times (burst-five error). Note that only one station detects a burst-five error because the first station to detect it converts it to a burst-four.

3.8.4 AC Error. This counter is incremented when a station receives an AMP or SMP frame in which A is equal to C is equal to 0, and then receives another SMP frame with A is equal to C is equal to 0 without first receiving an AMP frame.

3.8.5 Abort Delimiter Transmitted (AD_TRANS). This counter is incremented when a station transmits an abort delimiter while transmitting.

3.8.6 Lost Frame Error (LOST_FR). This counter is incremented when a station is transmitting and its TRR timer expires. This counts how often frames transmitted by a particular station fails to return to it (thus causing the active monitor to issue a new token).

3.8.7 Receive Congestion Error (RCV_CON). This counter is incremented when a station recognizes a frame addressed to its specific address, but has no available buffer space indicating the station is congested.

3.8.8 Frame Copied Error (FR_COPIED). This counter is incremented when a station recognizes a frame addressed to its specific address and detects that the FS field A bits are set to 1 indicating a possible line hit or duplicate address.

3.8.9 Frequency Error (FREQ). This counter is incremented when the frequency of the incoming signal differs by more than that specified in Section 7 from the expected frequency.

3.8.10 Token Error. This counter is incremented when a station acting as the active monitor recognizes an error condition that needs a token transmitted. This occurs when the TVX timer expires (see transition (03) of the Active Monitor FSM).

3.8.11 Frame Count (FR_CNT). This counter indicates the number of frames originated by the station which, by station calculation, are still on the ring. It is incremented when a SFS is transmitted and decremented when an ED is stripped. Implementation of this counter is mandatory if the ETR option is implemented (see 3.5.7).

4. Token Ring Protocols

This section specifies the procedures that shall be used in the MAC.

4.1 Overview. The subsections of 4.1 provide a descriptive overview of frame transmission and reception. The formal specification of the operation is given in 4.2.

4.1.1 Frame Transmission. Access to the physical medium (the ring) is controlled by passing a token around the ring. The token gives the downstream (receiving) station (relative to the station passing the token) the opportunity to transmit a frame or a sequence of frames. Upon request for transmission of an LLC PDU or SMT PDU, MAC prefixes the PDU with the appropriate FC, DA, and SA fields and enqueues it to await the reception of a token that may be used for transmission.

Such a token has a priority less than or equal to the priority of the PDU(s) that is to be sent. Upon queuing the PDU for transmission and prior to receiving a usable token, if a frame or an unusable token is repeated on the ring, the station requests a token of appropriate priority in the RRR bits of the repeated AC field. Upon receipt of a usable token, it is changed to a SFS by setting the token bit.

At this time, the station stops repeating the incoming signal and begins transmitting a frame. During transmission, the FCS for the frame is accumulated and appended to the end of the information field.

4.1.2 Token Transmission. After transmission of the frame(s) has been completed, the station checks to see if the station's address has returned in the SA field, as indicated by the MA_FLAG. If it has not been seen, the station transmits fill until the MA_FLAG is set, at which time the station transmits a token.

4.1.3 Stripping. After transmission of the token the station will remain in transmit state until all of the frames that the station originated are removed from the ring. This is done to avoid unnecessary recovery action that would be caused if a frame were allowed to continuously circulate on the ring.

4.1.4 Frame Reception. Stations, while repeating the incoming signal stream, check it for frames they should copy or act upon. If the frame-type bits indicate a MAC frame, the control bits are interpreted by all stations on the ring. In addition, if the frame's DA field matches the station's individual address, relevant group address, or broadcast address, the FC, DA, SA, INFO, and FS fields are copied into a receive buffer and subsequently forwarded to the appropriate sublayer.

4.1.5 Priority Operation. The priority bits (PPP) and the reservation bits (RRR) contained in the AC field work together in an attempt to match the service priority of the ring to the highest priority PDU that is ready for transmission on the ring. As previously noted in 3.6, values are stored in registers as Pr and Rr. The current ring service priority is indicated by the priority bits in the AC field, that is circulated on the ring.

The priority mechanism operates in such a way that *fairness* (equal access to the ring) is maintained for all stations within a priority level. This is accomplished by having the same station that raised the service priority level of the ring (the *stacking station*) return the ring to the original service priority. As previously noted in 3.6, the Sx and Sr stacks are used to perform this function.

The priority operation is explained as follows:

When a station has a priority (a value greater than zero) PDU (or PDUs) ready to transmit, it requests a priority token. This is done by changing the reservation bits (RRR) as the station repeats the AC field. If the priority level (Pm) of the PDU that is ready for transmission is greater than the RRR bits, the station increases the value of RRR field to the value Pm. If the value of the RRR bits is equal to or greater than Pm, the reservation bits (RRR) are repeated unchanged.

After a station has claimed the token, it transmits PDUs that are at or above the present ring service priority level until it has completed transmission of those PDUs or until the transmission of another frame could not be completed before timer THT expires (see 3.2.4). The priority of all of the PDUs that are transmitted should be at the present ring service priority value. The station will then generate a new token for transmission on the ring.

If the station does not have additional PDUs to transmit that have a priority (Pm) or does not have a reservation request (as contained in register Rr) neither of which is greater than the present ring service priority (as contained in register Pr), the token is transmitted with its priority at the present ring service priority and the reservation bits (RRR) at the greater of Rr or Pm and no further action is taken.

However, if the station has a PDU ready for transmission or a reservation request (Rr), either of which is greater than the present ring service priority, the token is generated with its priority at the greater of Pm or Rr and its reservation bits (RRR) as 0. Since the station has raised the service priority level of the ring, the station becomes the stacking station and, as such, stores the value of the old ring service priority as Sr and the new ring service priority as Sx. (These values will be used later to lower the service priority of the ring when there are no PDUs ready to transmit on the ring whose Pm is equal to or greater than the stacked Sx.)

Note that since a station may have raised the service priority of the ring more than once before the service priority is returned to a lower priority, (for example, from 1 to 3 and then 5 to 6) it may have multiple Sx and Sr values stored and, hence, be referred to as *stacked*. Also note that this usage of the terms *stack* and *stacked* are not to be confused with other usages of these same terms.

Having become a stacking station, the station claims every token that it receives that has a priority (PPP) equal to its Sx in order to examine the RRR bits of the AC field for the purpose of raising, maintaining, or lowering the service priority of the ring. The new token is transmitted with its PPP bits equal to the value of the reservation bits (RRR) but no lower than the value of the Sr that was the original ring priority service level.

If the value of the new ring service priority (PPP equal to Rr) is greater than Sr, the RRR bits are transmitted as 0 and the old ring service priority contained in Sx is replaced with a new value Sx equal to Rr, and the station continues its role as a stacking station.

However, if the Rr value is equal to or less than the value of the Sr, the new token is transmitted at a priority value of the Sr, both Sx and Sr are removed *(popped)* from the stack, and if no other values of Sx and Sr are stacked, the station discontinues its role as a stacking station.

Note that a stacking station that has claimed the token may transmit PDUs as well as examining RRR bits, as described above. Of course only those PDUs that have a priority equal to or greater than the ring service priority may be transmitted.

The frames that are transmitted to initialize the ring have a PPP field that is equal to 0. The receipt of a PPP field whose value is less than a stacked Sx will cause any Sx or Sr values that may be stacked to be cleared in all stations on the ring (see Fig 4-3).

The complete description of Priority Operating is contained in the Operational Finite-State Machine.

4.1.6 Beaconing and Neighbor Notification. When a hard failure is detected in a token ring local area network, its cause must be isolated to the proper failure domain so that recovery actions can take place. The failure domain consists of

(1) the station reporting the failure (the beaconing station),

(2) the station upstream of the beaconing station, and

(3) the ring medium between them.

For example, if a failure occurred within the domain shown in Fig 4-1, station G would report upon it by transmitting BCN MAC frames.

A failure that causes bit disruption within the transmitter side of station F, in the medium between stations F and G, or within the receiver side of station G, will be detected and reported upon by station G using a BCN MAC frame. This alerts all other stations on the ring that the token protocol has been suspended until such a time that the disruption terminates or is removed.

To do accurate problem determination, all elements of the failure domain must be known at the time that the failure is detected. This implies that at any given time, each station should know the identity of its upstream neighbor station. A process for obtaining this identity, known as neighbor notification, is described below.

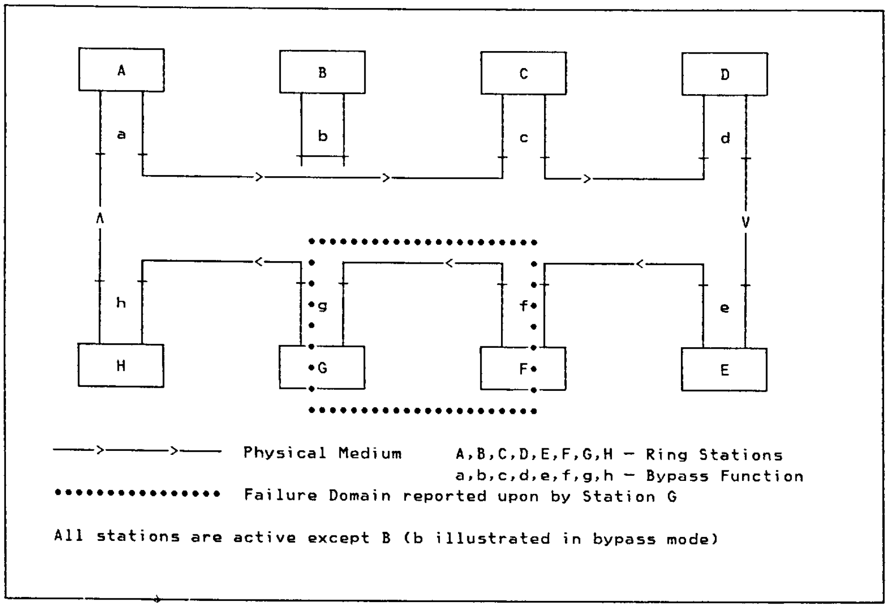


Fig 4-1
An Example of a Failure Domain

Neighbor notification has its basis in the address recognized and frame-copied bits (the A and C bits) of the FS field. These bits are transmitted as 0's. If a station recognizes the DA of the frame as one of its own, the station sets the A bits to 1 in the passing frame. If a station also copies the frame, then the C bits are also set to a 1.

When a frame is broadcast to all stations on a ring, the first station downstream of the broadcaster will see that the A and C bits are all 0's. Since a broadcast frame will have its DA recognized by all of the stations on the ring, the first station downstream will, in particular, set the A bits to 1. All stations further downstream will, therefore, not see the A and C bits as all 0's. This process continues in a circular, daisy-chained fashion to let every station know the identity of its upstream neighbor (see the note under 3.3.4).

The monitor begins neighbor notification by broadcasting the AMP MAC frame. The station immediately downstream from it takes the following actions:

(1) Resets its timer TSM, based on seeing the AMP value in the FC field;
(2) If possible, copies the broadcast AMP MAC frame and stores the upstream station's identity in an UNA memory location;

(3) Sets the A bits (and C bits if the frame was copied) of the passing frame to 1's;

(4) At a suitable transmit opportunity, broadcasts a similar SMP MAC frame.

One by one, each station receives an SMP frame with the A and C bits set to 0's, stores its UNA, and continues the process by broadcasting such a frame itself.

Since the AMP frame must pass each station on a regular basis (the AMP MAC frame sent by the monitor), the continuous transmission of tokens onto a ring can be detected. In addition to the timer TAM in the active monitor, each standby station has a timer TSM that is reset each time an AMP MAC frame passes. If timer TSM expires, that standby monitor station begins transmitting Claim Token frames.

4.1.7 Error Reporting. When a station detects an error condition on the ring (such as FCS error, lost token, or lost frame) it increments the appropriate error counter. These errors are reported on a periodic basis to the REM. Persistent errors of this type can be detected, isolated, and necessary action taken.

4.1.8 Administration of Ring Parameters. Upon insertion into the ring, a station requests the value of the various ring settable operating parameters from the RPS to assure compatible operation among stations on the ring.

4.1.9 Configuration Control. As part of the function of maintaining the configuration of the ring, stations notify the CRS when they detect a change in the address of their upstream neighbor (detected during the neighbor notification process). This indicates either a station has inserted into or removed from the ring. The CRS can alter the configuration of the ring by requesting stations to remove themselves from the ring. The CRS can also query ring stations for various status information.

4.1.10 Early Token Release (ETR). The ETR option increases available bandwidth and improves the data transmission efficiency of the token-ring protocol. It allows a transmitting station to release a token as soon as it completes frame transmission, whether or not the frame header has returned to the station. The priority used for tokens released prior to receiving the frame's header will be the priority of the most recently received frame.

It should be noted that the access delay for priority traffic may increase when an ETR system is heavily loaded with short frames. Short frames may disable the use of priority reservations, since a short frame may be transmitted in its entirety and the next token released before the frame's header returns to the originating station.

Stations implementing ETR option are compatible and interoperable with stations that do not.

4.2 Specification. The operation of the ring is described in this section.

In the case of a discrepancy between the FSM diagrams/tables and the supporting text, the FSM diagrams/tables shall take precedence.

The MAC receives from the PHY a serial stream of symbols. Each symbol shall be one of the following:

0 = binary zero
1 = binary one
J = non-data-J
K = non-data-K

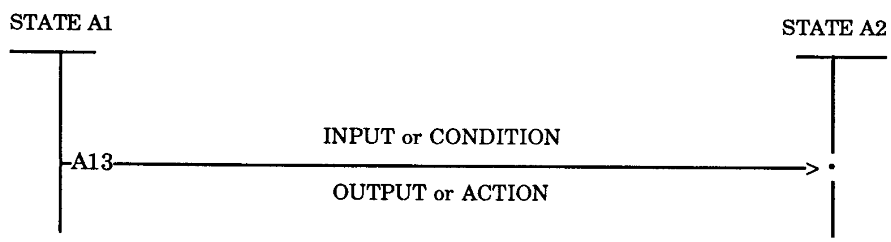
(See 5.1 for a detailed description of these symbols.)

From the received symbols MAC detects various types of input data, such as tokens, MAC frames, and LLC information frames.

In turn, MAC stores values, sets flags, and performs certain internal actions (as noted in Fig 4-2) as well as generating tokens, frames, or fill, or flipping bits and delivering them to the PHY in the form of a serial stream of the 0, 1, J, and K symbols.

For the purpose of accumulating the FCS and storing the contents of a frame, J and K symbols that are not part of the SD or ED shall be interpreted as 1 and 0 bits, respectively.

Finite-State Machine (FSM) Notation. The notation used in the FSM diagrams is as follows:



States are shown as vertical lines. Transitions are shown as horizontal lines with a number indicating the transition (for example, A13) and the arrow indicating the direction of transition.

The inputs or conditions shown above the line are the requirements to make the transition. The output or action shown below the line occur simultaneously with making the transition. The transition begins when the input occurs or the condition specified is met and is complete when the output or action has occurred. If the state transition is in progress, then no other FSM transition may be initiated.

If the exit conditions of a state are satisfied at the time the state is entered, no action is taken in that state and the state is immediately exited.

4.2.1 Receive Actions. Three varieties of frame identification are used in the state transitions and at the service interfaces described in this standard: *good frame, validly formed frame,* and *frame with error*. These frame varieties are indicated by combinations of the following properties:

Properties of a Frame

(A) Is bounded by a valid SD and ED
(B) Has the E (error) bit equal to 0

(C) Is an integral number of octets in length
(D) Is composed of only 0 and 1 bits between the SD and ED
(E) Has the FF bits of the FC field equal to 00 or 01
(F) Has a valid FCS
(G) Has a minimum of 10 octets for 2-octet addressing or 18 octets for 6-octet addressing between SD and ED
(H) Does not contain a valid SD or ED between the bounding SD or ED

The three frame varieties are defined below. This is not an inclusive list of all possible bit sequence formats; for example, other format sequences known in this standard are the token and the abort sequence. Note that the value of the I, E, A, and C bits are not part of these definitions.

Good Frame (FR_GOOD). A bit sequence that satisfies the following condition, based on the properties of a frame listed above:

A &C &D & E & F & G

Validly Formed Frame. A bit sequence that satisfies the following condition:

A & C & E & G & H

Frame with Error (FR_WITH_ERROR). A bit sequence that satisfies the following condition:

A & (¬C | ¬D | (E & ¬F) | (E & ¬G))

The various internal actions that are taken as a result of an input received from the ring are summarized in Fig 4-2. They are explained as follows:

(R01) Line Error. If the frame is a FR_WITH_ERROR with the E bit equal to 0, then the Line Error counter is incremented.

Fig 4-2
Receive Action Table

REF	RECEIVE	ACTION
R01	FR_WITH_ERROR & E = 0	INCR (LINE ERROR)
R02	TK (P < Sx)	CLEAR STACKS
R03	SA=MA	SET MA_FLAG
R04	TOKEN | FRAME	STORE (Pr & Rr)
R05	I=0	SET I_FLAG
R06	SFS	SET SFS_FLAG
R07	FR_(DA=MA & A=1)	INCR (FR_COPIED)
R08	RCV_ED	DECR (FR_CNT)
R09	SA≠MA & FR_CNT=1	SET NOT_MA_FLAG

(R02) Priority Level Error. If there is a Sx stored and a token is received with a priority (P) less than the value of Sx, then an error has occurred. Therefore, the stacks shall be cleared.

(R03) MA Received. If the SA that is received is equal to the station's individual address, the MA flag shall be set. Note that the MA flag shall be set without regard to whether it is a good frame, a validly formed frame, or a frame with error.

(R04) AC Field Received. Upon the receipt of an AC field in a token or a frame, the value of the priority bits shall be stored as Pr, and the reservation bits shall be stored as Rr and the previously stored Pr and Rr shall be discarded.

(R05) I Bit Equal Zero Received. If an EFS with the I bit equal to 0 is received, the I_FLAG (if implemented) shall be set.

(R06) SFS Received. If a SFS is received, the SFS_FLAG shall be set.

(R07) DA = MA and A = 1. If a frame is received in which the DA equals the station's individual address and the address-recognized (A) bits are set to 1, the frame-copied error counter is incremented.

(R08) ED Received. If an ED is received, the FR_CNT conter (if implemented) shall be decremented.

(R09) SA ≠ MA Received and FR_CNT = 1. If the received SA does not equal this station's address and the frame count equals 1, the NOT_MA flag (if implemented) shall be set.

4.2.2 Operational Finite-State Machine. The operational finite-state machine (see Figs 4-3 and 4-4) is explained as follows:

4.2.2.1 STATE T0: REPEAT (Repeat State). In Repeat state, the bits that are received are, in general, repeated on the line to the next station. Certain bits and fields in the repeated bit stream may be modified and certain actions taken without changing state. Transition shall be made to STATE T1: TX DATA_FR (Transmit Data Frame(s)) when there are one or more PDUs queued for transmission and the conditions for transmission are satisfied. Transition shall be made to STATE T4: TX ZEROS, MOD STACKS (Transmit Zeros and Modify Stacks) for the purpose of modifying the priority stacks.

(T01) Usable Token Received. If a PDU is queued for transmission and a token is received whose priority (P) is equal to or less than the PDU priority (Pm), the station shall change the token to a SFS (by changing the token bit from 0 to 1) and transmit M and R as 0, initiate the transmission of the enqueued PDU, reset the Token Holding Timer and the MA flag, set the FR_CNT counter (if implemented) to 1, and make a transition to STATE T1.

(T02) RESUME (Operational FSM Activity). When the station is in monitor states of Bypass, Inserted, Transmit Claim Token, Transmit BCN, Transmit

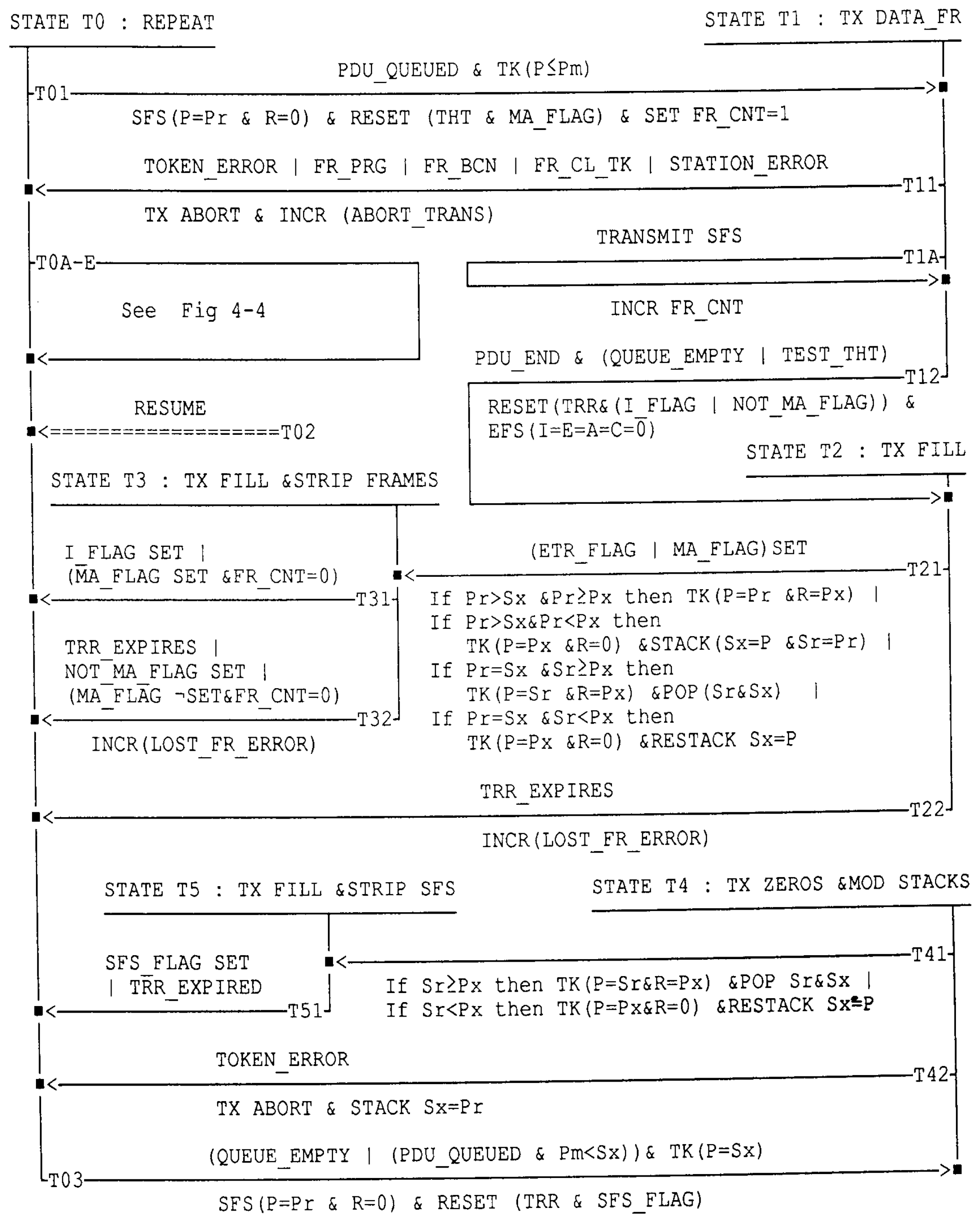


Fig 4-3
Operational Finite-State Machine

REF	INPUT	OUTPUT
T0A	PDU_QUEUED & (FR(R<Pm) | TK(P>Pm>R&P≠Sx))	SET R=Pm
T0B	FR_WITH_ERROR	SET E=1
T0C	DA=MA (ADDRESS RECOGNIZED)	SET A=1
T0D	FR_COPIED	SET C=1
T0E	FR_NOT_COPIED	INCR (RCV_CON)

Fig 4-4
Repeat State Loop Table

Fill, or Transmit Purge (for example, not in Initialize, Standby, or Active states) activity of the Operational FSM is suspended. Upon reentry into Initialize, Standby, or Active Monitor states, activity of the operational FSM shall be resumed in Repeat state.

(T03) Re-Stack Operation. If there are no frames enqueued with priority (Pm) equal to or greater than the Sx and a token is received with priority (P) equal to the Sx, the following actions are taken. The token shall be changed to a SFS by changing the T bit from 0 to 1, the Sx popped from the stack, resetting timer TRR and the SFS flag and making a transition to STATE T4. If there is no Sx value stacked, the test P=Sx shall be considered being false.

As an option, the action taken on this transmition may be the action specified on transition T41, bypassing states T4 and T5, and returning directly to State 0.

A number of actions may be taken without changing state. These actions are shown in Fig 4-4 and are explained as follows:

(T0A) Request Usable Token. If there is a PDU queued for transmission with priority Pm, the reservation (R) shall be set to Pm on frames in which the reservation is less than Pm, and on tokens in which the priority is greater than Pm and the reservation is less than Pm and the priority is not equal to the Sx.

(T0B) Frame With Error. The E (error) bit shall be transmitted as 1 if a frame with error is detected. (See Reference R01 in 4.2.1).

(T0C) Own Address Detected. If the station detected its own address or relevant group address in the DA field, the A bits in the FS field shall be transmitted as 1.

(T0D) Frame Copied. If the station copies the frame from the ring, the C bits in the FS field shall be transmitted as 1.

(T0E) Frame Not Copied. If the station recognizes a frame addressed to it, but cannot copy the frame, then the station increments its receive congestion error counter.

4.2.2.2 STATE T1: TX DATA_FR (Transmit Data Frame(s)). While in this state, the station transmits one or more frames. The first and all subsequent PDUs that are transmitted shall have a Pm equal to or greater than the priority of the token that was used. All frames transmitted shall have P equal to Pr and M and R equal to 0. On the receive side, as noted in Fig 4-2, the station shall monitor the receive data for the value of the priority and reservation bits, its station address that has been transmitted in the SA field, and the ED.

The foregoing does not imply that the ability to transmit multiple frames while in this state is mandatory.

(T1A) Increment Frame Counter. When the SFS is transmitted, the FR_CNT counter shall be incremented.

(T11) Abort STATE T1—Error Recovery Action. If after changing the token bit from a 0 to a 1, the station detects that the token did not end with an ED, or if a BCN, Purge, or Claim Token frame is subsequently received, or if an error has occurred within the station, the transmission shall be terminated immediately with an Abort Sequence, the PDU dequeued, LLC notified of the event, the abort transmitted error counter incremented, and transition made to STATE T0.

As an option, it is permitted not to execute this transition when a Purge, BCN, or Claim Token MAC frame is received.

(T12) End-of-Frame Transmission. If the transmission of the PDU is completed (PDU_END) and there are no more PDUs to transmit at this priority or a higher priority (QUEUE_EMPTY), or if the transmission of an additional frame could not be completed before THT expires (TEST_THT), an EFS shall be transmitted with the I, E, A, and C bits equal to 0; timer TRR, the I_FLAG, or NOT_MA FLAG (whichever is implemented) shall be reset; and transition made to STATE T2.

4.2.2.3 STATE T2: TX FILL (Transmit Fill). If a SA equal to the station's address has not been received (that is, MA_FLAG reset) or the early token release flag (ETR_FLAG) is not set, the station shall transmit fill until one of the flags is set or TRR expires. If upon entering STATE T2 the ETR_FLAG or MA_FLAG is already set, transition shall be made directly to STATE T3 via transitions T21.

(T21) Token Transmission. If the header of the frame has been received (MA_FLAG SET) or early token release option is selected (ETR_FLAG SET) then:

if Pr is greater than Sx, and Pr is greater than or equal to the greater of the PDU priority or the Px, then a token is transmitted with the P equal to Pr, and R equal to Px; or

if Pr is greater than Sx, and Pr is less than Px, then a token is transmitted with the P equal to Px and the R equal to 0, and Pr shall be stacked as Sr and P shall be stacked as Sx; or

if Pr is equal to Sx, and Sr is greater than or equal to Px, then a token is transmitted with the P equal to Sr, and the R equal Px and Sr, and Sx popped from the stack; or

if Pr is equal to Sx, and Sr is less than Px, then a token is transmitted with the P equal to Px, and the R equal 0, and Sx is restacked equal to P;
and transition made to STATE T3. If there is no Sx value stacked, the text Pr > Sx shall be considered true and the text P = Sx shall be considered false.

The option of transmitted P = Pr when Pr = Sx and Sx ≥ Px is permitted.

(T22) TRR Expires. If, while waiting for the MA_FLAG to be set, timer TRR expires, transition shall be made directly to Repeat state (STATE T0) and the lost frame counter incremented.

4.2.2.4 STATE T3: TX FILL, STRIP FRAMES (Transmit Fill and Strip Frames). The station shall transmit fill until one of the conditions in transition T31 or T32 is met. If upon entering STATE T3 the condition is already satisfied, transition shall be made directly to STATE T0.

(T31) Strip Complete. If the I FLAG is set, or if the MA_FLAG is set and the ED of the last frame (FR_CNT = 0) is received, transition shall be made to STATE T0.

(T32) Lost Frame. If the TRR time expires, or if the SA of the last frame transmitted is received that does not equal MA (NOT_MA_FLAG SET), or if while waiting for the MA flag to be set, the ED of the last frame transmitted is received (FR_CNT = 0 and MA_FLAG NOT SET), the lost frame error counter shall be incremented and transition made to Repeat state (STATE T0).

4.2.2.5 STATE T4: TX ZEROS, MOD STACK (Transmit Zeros and Modify Stack). A continuous string of 0's shall be transmitted immediately following the SFS until the internal logic of the station can perform the necessary functions to transmit a token.

Transmission of 0's may or may not terminate on an octet boundary. Note that this state shall cause consecutive SDs to exist on the ring without an intervening ED and that the SD of the transmitted token may not occur on an octet boundary relative to the transmitted 0's.

(T41) Token Transmission. If Sr is greater than or equal to Px, then a token is transmitted with the P equal to Sr, the R equal to Px, and Sr and Sx popped from the stack; or if Sr is less than Px, then a token is transmitted with the P equal to Px, the R equal to 0, and Sx restacked equal to P; and transition made to STATE T5.

(T42) Token Recognition Error. If after changing a token to a SFS, the station detects that the token did not end properly (with MRRR, JK1JK1), the transmission shall be terminated immediately with an abort sequence, Pr stacked as Sx and transition shall be made to STATE T0.

4.2.2.6 STATE T5: TX FILL, STRIP SFS (Transmit Fill and Strip SFS). In this state, fill shall be transmitted until the transmitted SFS is received or TRR expires.

(T51) Strip Complete. Upon receipt of the SFS or TRR expiring, transition shall be made to STATE T0.

4.2.3 Standby Monitor Finite-State Machine. (See Fig 4-5.) Upon coming on-line or after the station has been reset, (re)initialization is performed to assure that no other station on the ring has the same address as this station and that its (re)entry into the ring is known to its immediate downstream neighbor.

Upon completion of initialization, transition is made to Standby state where the ring is monitored to assure that there is a properly operating active monitor on the ring. It does so by observing the tokens and AMP frames as they are repeated on the ring. If tokens and AMP frames are not periodically detected, the standby monitor shall time-out and initiate claiming token. When in Transmit Claim Token and Transmit BCN states (STATES S3 and S5), the station shall utilize its own oscillator for transmission timing.

The standby monitor function is explained as follows:

4.2.3.1 STATE S0 : BYPASS. In this state the station is not inserted in the ring.

(S01) ENTER BYPASS. Transition from any other state of the monitor to Standby Monitor Bypass state (STATE S0).

(S02). Upon activation of the insertion logic (see 5.3.2.3), timer TSM is reset and transition made to STATE S1.

4.2.3.2 STATE S1 : INSERTED. In this state the station synchronizes its receive clock with the receive signal and then, having achieved synchronization, repeats the received symbols on the line and awaits the receipt of an AMP or PRG MAC frame.

(S11). If an AMP or PRG is not received before timer TSM expires, it is assumed that there is no active monitor in the ring, timer TNT is reset, and transition is made to the Claiming Token state (STATE S3).

(S12). If a FR_BCN is received, the station shall return to Bypass state (STATE S0).

(S13). However, if AMP or PRG has been received, a DAT PDU is enqueued for transmission awaiting the receipt of a usable token, timer TSM is reset, and transition made to Initialize state (STATE S2).

4.2.3.3 STATE S2 : INITIALIZE. This state exists to detect the existence of a duplicate station address on the ring. This enhances the validity of later checks within the FSMs for SA = MA, etc. This is particularly useful in environments in which the station address assignments are not rigidly controlled. While in this state the station transmits the queued DAT_PDU when a useable token is received and repeats the received symbols on the line until one of the following events occur.

The option of a station transmitting multiple DAT_PDUs to ensure there is not a duplicate address on the ring is permitted.

(S21). If the DAT MAC frame that was transmitted by the station is not received before timer TSM has expired or if a BCN MAC frame is received or if a DAT MAC frame that the station originated (DA=MA) is received with the

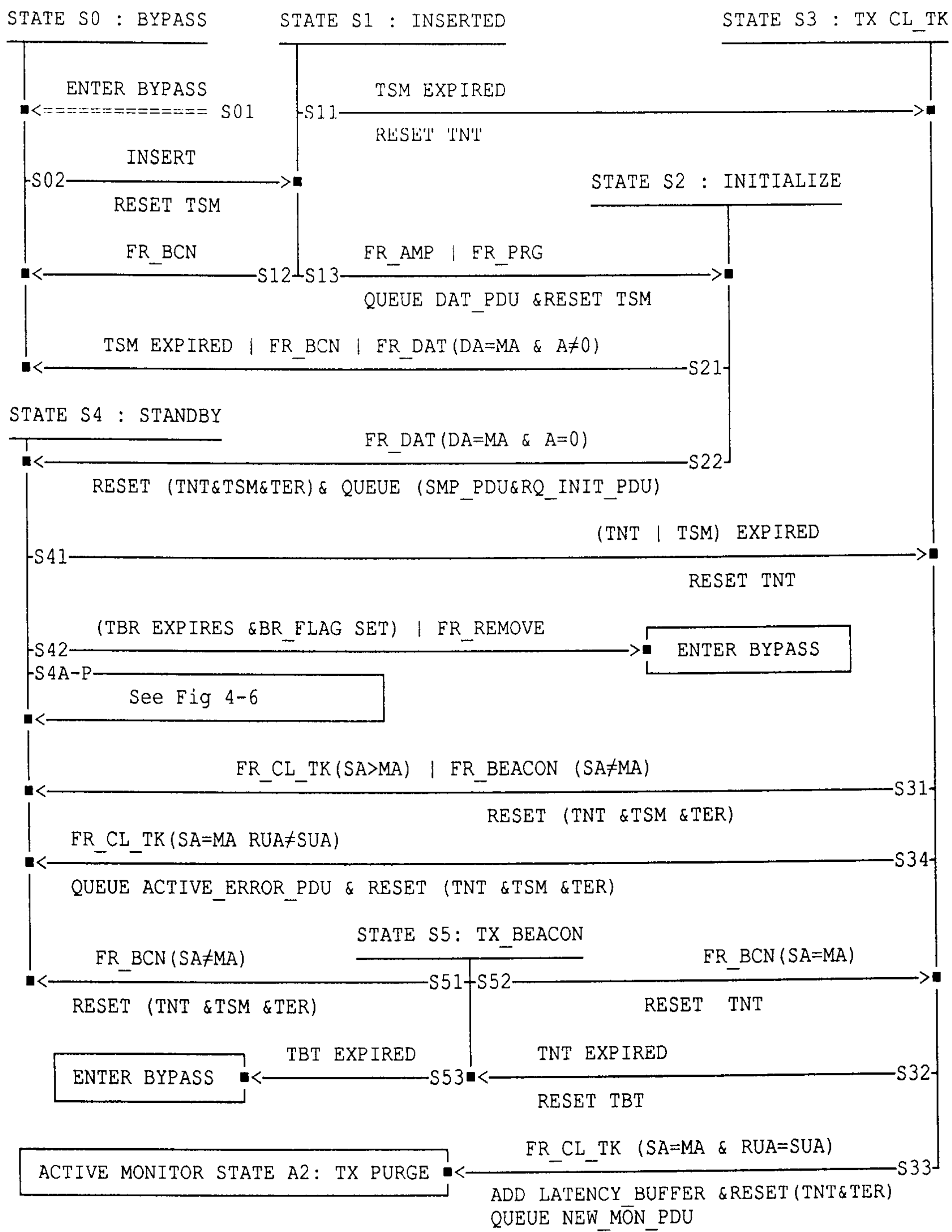


Fig 4-5
Standby Monitor Finite-State Machine

Address Recognized bits not set to zero (A≠0), the station returns to Bypass state (STATE S0).

(S22). However, if the DAT MAC frame is returned indicating that there is not another station on the ring with the same address (A=0), an SMP and a Request Initialization PDU is enqueued for transmission awaiting the receipt of a usable token, timers TNT, TSM, and TER are reset, and transition is made to Standby state (STATE S4).

4.2.3.4 STATE S3 : TX CLAIM_TOKEN (Transmit Claim Token). In this state, Claim Token MAC frames are continuously transmitted. If the SUA value is unknown, a null (all zeros) address will be used as the SUA.

The option of delaying transition to active monitor state until multiple CL_TK frames have been received is permitted.

(S31). If a Claim Token MAC frame is received in which the SA is greater than the station's address, or a BCN frame in which the SA does not equal the station's address, timers TNT, TSM, and TER are reset, and transition is made to Standby state (STATE S4).

The option of this transition occurring on receipt of a PURGE is permitted.

(S32). However, if timer TNT expires, timer TBT is reset, and transition is made to beaconing state (STATE S5).

(S33). Or, if the station receives a FR_CL_TK with a SA equal to the station's address and an RUA equal to the SUA, the bid for active monitor has been won. The latency buffer shall be inserted in the ring, timer TNT and TER reset, New Active Monitor PDU queued, and transition made to ACTIVE MONITOR Purge state (STATE A2).

The option of queueing the New Active Monitor PDU on transition All rather than on S33 is permitted.

(S34). If a Claim Token MAC frame is received in which the SA is equal to the station's address, but the received UNA does not equal the station's stored UNA, timers TNT, TSM and TER are reset, a Report Active Monitor Error PDU is queued, and transition is made to Standby state (STATE S4).

4.2.3.5 STATE S4: STANDBY. In this state the monitor is in standby mode, monitoring the ring to ascertain that there is a properly operating active monitor on the ring. It does so by observing the tokens and AMP frames as they are repeated on the ring. If tokens and AMP frames are not periodically detected, the standby monitor will time-out and initiate claiming token.

(S41). If timers TNT or TSM expire, timer TNT is reset and transition made to Claiming Token state (STATE S3).

(S42). If timer TBR expires and BR flag is set or a Remove Ring Station MAC frame is received, transition is made to Bypass state (STATE S0). Optionally, the station may ignore the Remove Ring Station MAC frame, in such case it shall queue a RSP_PDU indicating rejection of the requested action.

A number of actions may be taken without changing state. These actions are shown in Fig 4-6 and are explained as follows:

(S4A). If a BCN frame is received, timers TNT and TSM are reset without changing state.

(S4B). If a BCN frame is received and the RUA equals the station's address, the FR_BCN is not Type 1, and the BR flag is not set, then timer TBR is reset and the BR flag is set without changing state.

(S4C). If a frame is received that is not a frame as specified in S4B, then the BR flag is reset without changing state.

(S4D). If a Claim Token frame, a Purge frame, or a token is received, timer TNT is reset without changing state.

Fig 4-6
Standby State Transition Loop Table

REF	EVENT	ACTION
	BCN AUTO — REMOVAL	
S4A	FR_BCN	RESET (TNT & TSM)
S4B	FR_BCN & RUA=MA & TYPE (¬1) & BR_FLAG ¬SET	RESET TBR & SET BR_FLAG
S4C	¬(FR_BCN & RUA=MA & TYPE (¬1))	RESET BR_FLAG
	ASSURE PRESENCE OF ACTIVE MONITOR	
S4D	FR_CL_TK $\mid$ FR_PRG $\mid$ TOKEN	RESET TNT
	NEIGHBOR NOTIFICATION	
S4E	FR_SMP (A & C=0) & SMP_FLAG ¬SET	RESET TQP & SET (SUA=SA & SMP_FLAG)
S4F	FR_SMP (A & C=0) & SMP_FLAG SET	RESET TQP & INCR (AC) & SET (SUA=SA)
S4G	FR_AMP (A & C=0)	RESET (TQP & TSM) & SET (SUA=SA & SMP_FLAG)
S4H	SUA≠SA & (FR_SMP (A & C=0) $\mid$ FR_AMP (A &C=0))	QUEUE SUA_CHG_PDU
S4I	FR_AMP (A & C≠0)	RESET (TSM & SMP_FLAG)
S4J	TQP EXPIRES	QUEUE SMP_PDU
	CONFIGURATION CONTROL	
S4K	TER EXPIRES	QUEUE ERROR_PDU &RESET (ERROR COUNTERS & TER)
S4L	FR_CHG_PARM $\mid$ FR_INIT	SET APPROPRIATE PARMS & QUEUE RSP_PDU
S4M	FR_RQ_ADDR	QUEUE RPT_ADDR_PDU
S4N	FR_RQ_STATE	QUEUE RPT_STATE_PDU
S4P	FR_RQ_ATTCH	QUEUE RPT_ATTCH_PDU

(S4E). If an FR_SMP whose A and C bits equal 0 is received and the SMP Flag is not set, the SA of the SMP frame shall be stored as the SUA, the SMP Flag shall be set, and timer TQP be reset.

(S4F). If an FR_SMP whose A and C bits equal 0 is received and the SMP Flag is set, the SA of the SMP frame shall be stored as the SUA, the A/C error counter incremented and timer TQP be reset.

(S4G). If an FR_AMP whose A and C bits equal 0 is received, the SA of the AMP frame shall be stored as the SUA and timers TQP and TSM reset and the SMP Flag shall be set.

(S4H). If the SA does not equal the previously stored upstream neighbor's address (SUA) in a received FR_SMP or FR_AMP with A and C equal to zero the station shall queue a Report SUA Change PDU.

(S4I). If an FR_AMP whose A and C bits do not equal 0 is received, timer TSM and SMP flag shall be reset.

(S4J). If timer TQP expires a SMP PDU shall be enqueued for transmission.

(S4K). If timer TER expires and any error counter is not zero, an Error Report PDU shall be enqueued for transmission and error counters (line error, internal error, burst error, ac error, abort delimiter transmitted error, lost frame error, received congestion error, frame-copied error, frequency error, and token error) reset.

(S4L). If a Change Parameters or Initialize Ring Station MAC frame is received, the station sets the appropriate operational parameters and queues a Response PDU.

(S4M). If the station receives a Request Station Addresses frame, the station queues a Report Station Addresses PDU.

(S4N). If the station receives a Request Station State frame, the station queues a Report Station State PDU.

(S4P). If the station receives a Request Station Attachments frame, the station queues a Report Station Attachments PDU.

4.2.3.6 STATE S5: TX BCN (Transmit Beacon). This state is entered when a serious ring failure has occurred. MAC supervisory BCN frames will continue to be transmitted until BCN MAC frames are received, at which time:

(S51). If SA does not equal MA in a received FR_BCN, timers TNT, TSM and TER shall be reset, transition made to Standby state (STATE S4).

(S52). However, if SA does equal MA in a received FR_BCN, transition shall be made to Claiming Token state (STATE S3) after resetting timer TNT.

(S53). If timer TBT expires, the station enters Bypass state (STATE S0).

4.2.4 Active Monitor Finite-State Machine. The function of the active monitor is to recover from various error situations such as absence of validly formed frames or tokens on the ring, a persistently circulating priority token, or a persistently circulating frame. In normal operation there is only one active monitor in a ring at any point in time.

The active monitor shall utilize its own oscillator to provide timing for all symbols repeated or transmitted on the ring. The active monitor also supplies the latency buffer for the ring.

The operation of the active monitor is explained as follows:

4.2.4.1 STATE A0: ACTIVE. The active monitor is in this state when the ring is operating normally.

A number of actions may be taken without changing state. These actions are shown in Fig 4-7 and are explained as follows:

(A0A). The M bit is set to 1 on a token whose M bit is 0 and whose priority is greater than 0 or a frame whose M bit is 0, and timer TVX reset.

(A0B). Receipt of a token whose M bit and priority are 0 will cause timer TVX to be reset.

(A0C). If timer TAM expires and NN_FLAG is set, an AMP PDU is enqueued for transmission awaiting the receipt of a usable token, and timer TAM and NN flag are reset without changing state.

(A0D). If timer TAM expires and NN_FLAG is not set, an AMP PDU is enqueued for transmission awaiting the receipt of a usable token, a Report Neighbor Notification Incomplete PDU is queued, and timer TAM reset without changing state.

(A0E). If an FR_SMP whose A and C bits equal 0 or FR_AMP whose A and C bits equal 0 and SA equals MA is received, the SA of the SMP frame shall be stored as the SUA and the neighbor notification flag set.

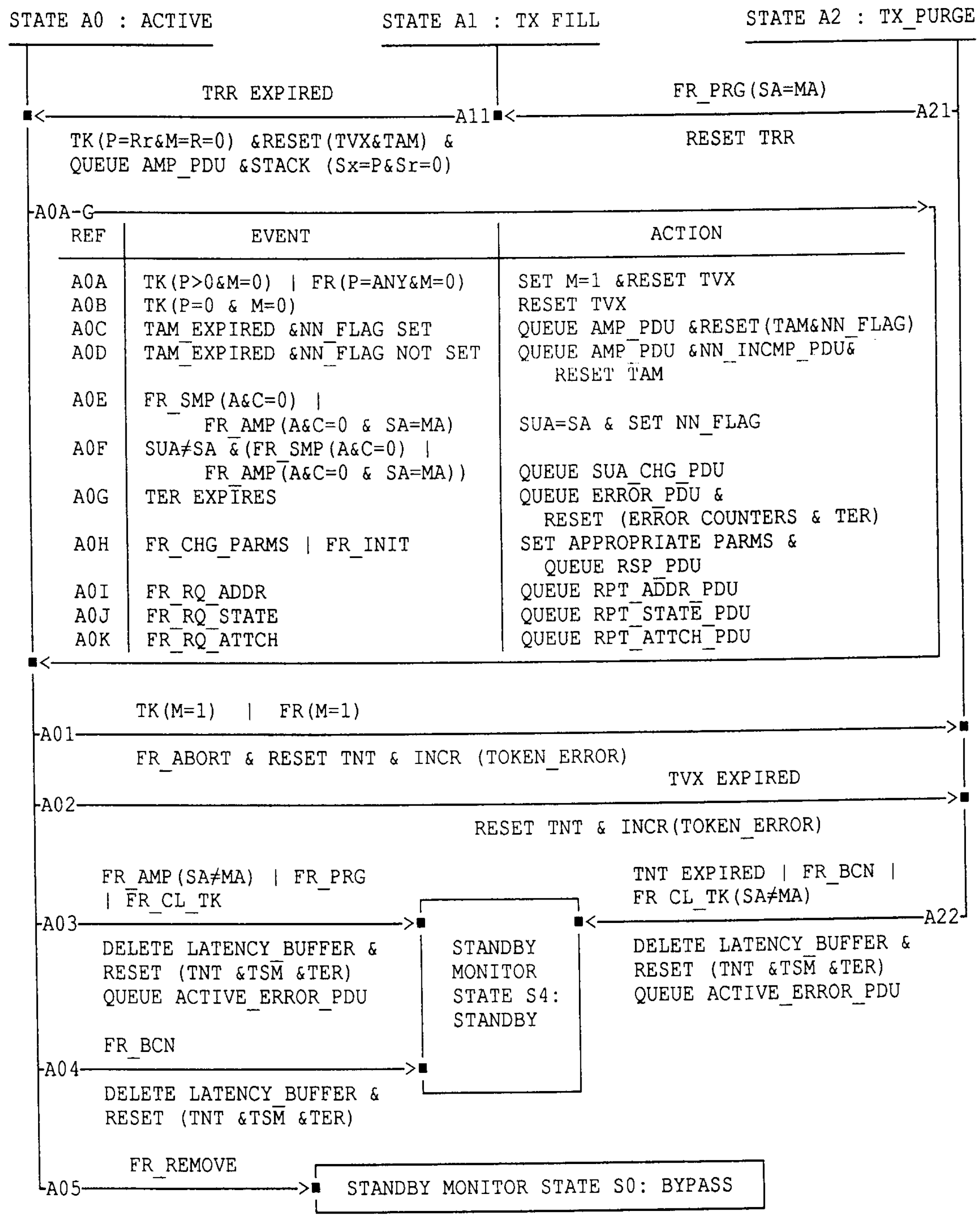
(A0F). If the SA does not equal the previously stored upstream neighbor's address (SUA) in the received FR_SMP whose A and C bits equal 0 or FR_AMP whose A and C bits equal 0 and SA equals MA, the station queues a Report SUA Change PDU.

(A0G). If timer TER expires and any error counter is not zero, an Error Report PDU frame shall be enqueued for transmission and error counters (line error, internal error, burst error, ac error, abort delimiter transmitted error, lost frame error, received congestion error, frame copied error, frequency error, and token error) and TER shall be reset.

(A0H). If a Change Parameters or Initialize Ring Station MAC frame is received, the station sets the appropriate operational parameters and queues a Response PDU.

(A0I). If the station receives Request Station Addresses frame, the station queues a Report Station Addresses PDU with the appropriate information.

(A0J). If the station receives Request Station State frame, the station queues a Report Station State PDU with the appropriate information.



REF	EVENT	ACTION
A0A	TK(P>0&M=0) | FR(P=ANY&M=0)	SET M=1 &RESET TVX
A0B	TK(P=0 & M=0)	RESET TVX
A0C	TAM_EXPIRED &NN_FLAG SET	QUEUE AMP_PDU &RESET(TAM&NN_FLAG)
A0D	TAM_EXPIRED &NN_FLAG NOT SET	QUEUE AMP_PDU &NN_INCMP_PDU& RESET TAM
A0E	FR_SMP(A&C=0) | FR_AMP(A&C=0 & SA=MA)	SUA=SA & SET NN_FLAG
A0F	SUA≠SA &(FR_SMP(A&C=0) | FR_AMP(A&C=0 & SA=MA))	QUEUE SUA_CHG_PDU
A0G	TER EXPIRES	QUEUE ERROR_PDU & RESET (ERROR COUNTERS & TER)
A0H	FR_CHG_PARMS | FR_INIT	SET APPROPRIATE PARMS & QUEUE RSP_PDU
A0I	FR_RQ_ADDR	QUEUE RPT_ADDR_PDU
A0J	FR_RQ_STATE	QUEUE RPT_STATE_PDU
A0K	FR_RQ_ATTCH	QUEUE RPT_ATTCH_PDU

Fig 4-7
Active Monitor Finite-State Machine

(A0K). If the station receives a Request Station Attachments frame, the station queues a Report Station Attachments PDU with the appropriate information.

(A01). If a frame or a token that is being repeated has its M bit equal to 1, the frame or token is aborted, timer TNT is reset, the token error counter incremented, and transition made to Transmit Purge state (STATE A2).

(A02). If timer TVX expires, timer TNT is reset, token error counter is incremented, and transition made to Transmit Purge state (STATE 2).

(A03). If the active monitor station receives an AMP frame with a SA that does not equal the station's address, a Purge frame, or a Claim Token frame, the latency buffer shall be deleted, timers TNT, TSM, and TER reset, a Report Active Monitor Error PDU is queued, and transition made to STANDBY MONITOR Standby state (STATE S4).

(A04). If the monitor station receives a BCN frame, the latency buffer shall be deleted, timers TNT, TSM, and TER reset, and transition made to STANDBY MONITOR Standby state (STATE S4).

(A05). If a Remove Ring Station MAC frame is received, transition is made to STANDBY MONITOR Bypass state (STATE S0). The option of an active monitor ignoring the Remove Ring Station PDU is permitted.

4.2.4.2 STATE A1: TRANSMIT FILL (Transmit Fill). This state exists to assure that all purge frames have been stripped from the ring before transmitting a new token.

(A11). When timer TRR expires, a token is transmitted with P equal to Rr, and M and R equal to 0. P is stacked as Sx and a zero is stacked as Sr, timers TVX and TAM are reset, and transition made to Active Monitor STATE A0.

4.2.4.3 STATE A2: TX PURGE (Transmit Purge). In this state, purge MAC frames are continuously transmitted to purge the ring before transmitting a new token.

(A21). If the station receives a FR_PRG whose SA equals the station's address and with a subvector equal to UNA, timer TRR is reset and transition is made to Transmit Fill state (STATE A1).

(A22). If timer TNT expires while waiting for receipt of the station's SA or if a BCN or CL_TK with SA not equal to MA is received, the latency buffer shall be deleted, timers TNT, TSM, and TER reset, Active Monitor Error PDU queued, and transition made to STANDBY MONITOR Standby state (STATE S4).

The option of ignoring the receipt of BCN or CL_TK (SA≠MA) and not queuing an ACTIVE_ERROR_PDU on transition is permitted.

5. Physical Layer

The following sections define physical layer (PHY) specifications. These include data symbol encoding and decoding, symbol timing, and reliability.

Throughout this section, the word *repeater* is used to mean the repeater part of a station or a separate unit.

5.1 Symbol Encoding. The PHY encodes and transmits the four symbols presented to it at its MAC interface by the MAC.

The symbols exchanged between MAC and PHY are shown below. (Specific implementations are not constrained in the method of making this information available.)

0 = binary zero
1 = binary one
J = non-data-J
K = non-data-K

As shown in Fig 5-1, the symbols are transmitted to the medium in the form of differential Manchester encoding that is characterized by the transmission of two signal elements per symbol.

In the case of the two data symbols, binary one and binary zero, a signal element of one polarity is transmitted for one half the duration of the symbol to be transmitted, followed by the contiguous transmission of a signal element of the opposite polarity for the remainder of the symbol duration. This provides two distinct advantages:

(1) The resulting signal has no dc component and can readily be inductively or capacitively coupled and
(2) The forced *mid-bit* transition conveys inherent timing information on the channel.

In the case of differential Manchester encoding, the sequence of signal element polarities is completely dependent on the polarity of the trailing signal element of the previously transmitted data or non-data bit symbol. If the symbol to be transmitted is a binary zero, the polarity of the leading signal element of the sequence is opposite to that of the trailing element of the previous symbol and, consequently, a transition occurs at the bit symbol boundary as well as mid-bit. If the symbol to be transmitted is a binary one, the algorithm is reversed and the polarity of the leading signal element is the same as that of the trailing signal element of the previous bit. Here there is no transition at the bit symbol boundary.

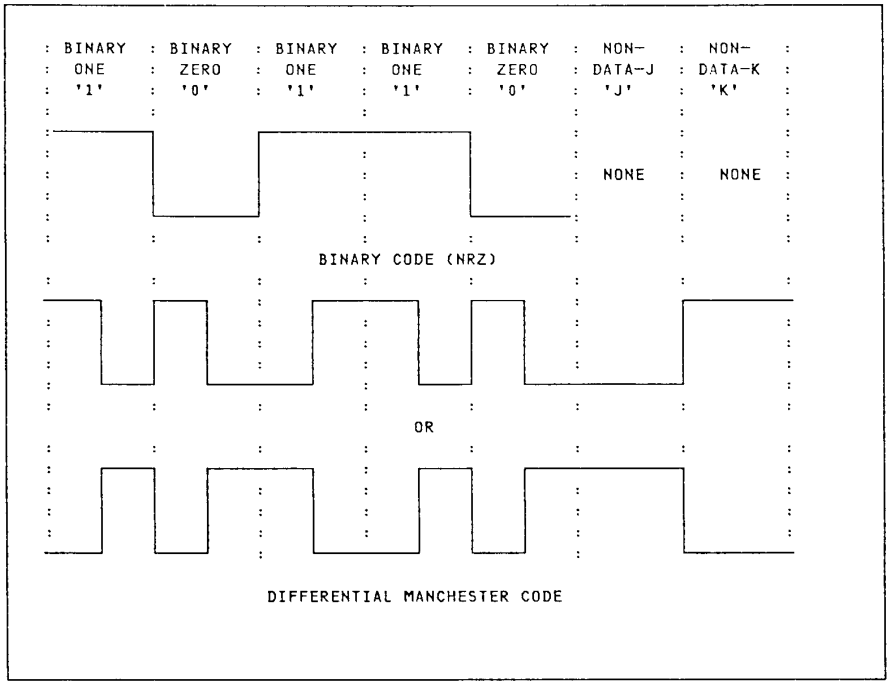


Fig 5-1
Example of Symbol Encoding

The non-data symbols, J and K, depart from the above rule in that a signal element of the same polarity is transmitted for both signal elements of the symbol and there is, therefore, no mid-bit transition. A J symbol has the same polarity as the trailing element of the preceding symbol, whereas a K symbol is the opposite polarity to the trailing element of the preceding symbol. The transmission of only one non-data symbol introduces a dc component on the ring. To avoid an accumulating dc component, non-data symbols are normally transmitted as a pair of J and K symbols. (By its nature, a K symbol is opposite to the polarity of the preceding symbol.)

5.2 Symbol Decoding. Received symbols shall be decoded using an algorithm that is the inverse of the one described for symbol encoding, and the decoded symbols shall be presented at the MAC interface.

If the PHY receives more than four signal elements of the same polarity in succession, it shall introduce a change of polarity (that is, a transition) at the end of the fourth signal element in the received bit stream and continue to introduce a transition each signal element time until a transition is received from the ring. The resulting bit stream is then decoded and the symbols presented to the MAC interface.

In a similar manner, during periods of loss-of-clock synchronization or underrun/ overrun of the latency buffer, the PHY shall generate a transition each signal element time, decode the new bit stream, and present the resulting symbols to the MAC interface.

5.3 Data Signalling Rates. The data signalling rates shall be within ±0.01% of 4 or 6 Mbit/s.

5.4 Symbol Timing. The PHY shall recover the symbol timing information inherent in the transitions between levels of the received signal. It minimizes the phase jitter in this recovered timing signal to provide suitable timing at the data signalling rate for internal use and for the transmission of symbols on the ring. The rate at which symbols are transmitted is adjusted continuously in order to remain in phase with the received signal.

In normal operation there is one station on the ring that is the active monitor. All other stations on the ring are frequency and phase locked to this station. They extract timing from the received data by means of a phase-locked loop. The phase-locked loop design shall be based on the requirement to accommodate a combined total of at least 250 stations and repeaters on the ring. The timing requirements to meet this total are defined in Section 7.

An additional requirement is placed on the time to acquire frequency and phase lock. Whenever a station is inserted into the ring or loses phase lock with the upstream station, it shall, upon receipt of a signal from the upstream station that is within specification, acquire phase lock within 1.5 ms.

5.5 Latency Buffer. The latency buffer is provided by the active monitor. It serves two distinct functions.

5.5.1 Assured Minimum Latency. In order for the token to continuously circulate around the ring when all stations are in repeat mode, the ring must have a latency (that is, time, expressed in number of bits transmitted, for a signal element to proceed around the entire ring) of at least the number of bits in the token sequence, that is, 24. Since the latency of the ring varies from one system to another and no a priori knowledge is available, a delay of at least 24 bits shall be provided by the active monitor.

5.5.2 Phase Jitter Compensation. The source timing or master oscillator of the ring shall be supplied by the active monitor station. All other stations in the ring track the frequency and phase of the incoming signal they receive. Although the mean data signalling rate around the ring is controlled by the active monitor station, segments of the ring can operate instantaneously at speeds slightly higher or lower than the frequency of the master oscillator. The cumulative effect of these variations in speed are sufficient to cause variations in the latency of the ring. Based on the jitter specifications in Section 7, the total latency variation shall not exceed B bits. The parameter values are

Data rate =	4	16	Mbit/s
B =	3	15	bits

An elastic buffer with a length of n bits shall be added to the fixed 24 bit buffer. This maintains constant ring latency. The parameter values are

Data rate =	4	16	Mbit/s
n ≥	6	32	bits

Note that additional latency may be required by the physical design of the receiver logic and circuitry to provide the full elasticity.

The resultant buffer shall be initialized to 24 + n/2 bits. If the received signal at the active monitor station is slightly faster than the master oscillator, the buffer will expand, as required, to maintain a constant total latency. If the received signal is slow, the buffer will contract to maintain a constant latency. Constant total latency is a requirement to avoid adding or dropping bits from the data stream.

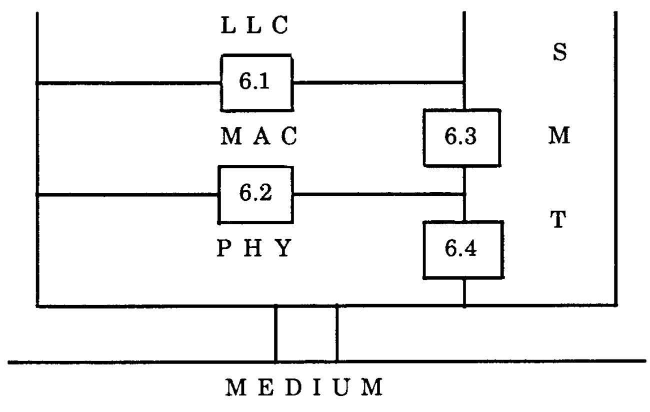
6. Service Specifications

This section specifies the services provided

(1) By MAC to LLC;
(2) By PHY to MAC;
(3) By MAC to SMT;
(4) By PHY to SMT.

The services are described in an abstract way and do not imply any particular implementation or any exposed interface.

The diagram below serves as a guide to the subsections (6.1 through 6.4) that define the services provided.



6.1 MAC to LLC Service. This section specifies the services required of the MAC by LLC to allow the local LLC entity to exchange LLC data units with peer LLC entities.

Work is in progress to produce a single service specification that is common to all of the MACs. When this is available it will be referenced in this document.

6.1.1 Interactions. The following primitives are defined for the LLC to request service from MAC:

MA-UNITDATA request
MA-UNITDATA indication
MA-UNITDATA-STATUS indication

6.1.2 Detailed Service Specifications. All primitives are specified in an exemplary form only. Each service shall name the particular primitive and the required information that is passed between LLC and MAC.

6.1.2.1 MA-UNITDATA request. This primitive defines the transfer of a MAC SDU from a local LLC entity to a single-peer LLC entity, or multiple-peer LLC entities in the case of group addresses.

Semantics of the Service Primitive

```
MA-UNITDATA request    (
                       destination_address,
                       source_address,
                       data,
                       priority,
                       service_class
                       )
```

The destination_address parameter may specify either an individual or a group MAC entity address. The source_address parameter shall specify an individual MAC entity address. Together they shall contain sufficient information to create the DA and SA fields that are appended to the frame by the local MAC entity as well as any lower level address information. The data parameter specifies the MAC SDU to be transmitted by the MAC entity. There is sufficient information associated with data for the MAC entity to determine the length of the data unit. The priority parameter specifies the priority (Pm) desired for the data unit transfer. The service_class parameter specifies the class of service desired for the data unit transfer.

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

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

Additional Comments. The priority as specified in the priority parameter is one of 8 levels.

6.1.2.2 MA-UNITDATA indication. This primitive defines the transfer of data from the MAC entity to the LLC entity or entities in the case of group addresses.

Semantics of the Service Primitive

```
MA-UNITDATA indication (
                         destination_address,
                         source_address,
                         data,
                         priority
                         service_class
                         )
```

The destination_address parameter may be either an individual or a group address as specified by the DA field of the incoming frame. The source_address parameter must be an individual address as specified by the SA field of the incoming frame. The data parameter shall specify the MAC SDU as received by the local MAC entity. The priority parameter specifies the priority (Pm) desired for the data unit transfer. The service_class parameter specifies the class of service desired for the data unit transfer.

When Generated. The MA-UNITDATA indication primitive shall be generated by the MAC entity to the LLC entity or entities to indicate the arrival of an LLC frame at the local MAC entity. Such frames shall be reported only if they are validly formed and their DA designates the local MAC entity, or the SA designates the local MAC entity if the station was so initialized (see 6.3.2.1).

Effect of Receipt. The effect of receipt of this primitive by the LLC is dependent upon the validity and content of the frame.

Additional Comments. If the local MAC entity is designated by the destination_address parameter of an MA-UNITDATA request primitive, the indication primitive shall also be invoked by the MAC entity to the local LLC entity. This full duplex characteristic of MAC may be due to unique function capabilities within MAC or full duplex characteristics of the lower layers; for example, all frames transmitted to the broadcast address shall invoke MA_UNITDATA indication primitives at all stations in the network including the station that generated the request.

6.1.2.3 MA-UNITDATA-STATUS indication. This primitive has local significance and shall provide an appropriate response to the LLC MA-UNITDATA request primitive signifying the success or failure of the request.

Semantics of the Service Primitive

```
MA-UNITDATA-STATUS indication (
                                destination_address,
                                source_address,
                                transmission_status,
                                provided_priority,
                                provided_service_class
                                )
```

The destination_address parameter shall be either an individual or group MAC entity address as specified in the associated MA-UNITDATA request primitive. The source_address parameter shall be an individual MAC entity address as specified in the associated MA-UNITDATA request primitive. The transmission_status parameter shall be used to pass status information back to the local requesting LLC entity. It shall be used to indicate the success or failure of the previous associated MA-UNITDATA request. The provided_priority parameter specifies the priority that was provided to the data unit transfer. The provided_service_class parameter specifies the service class that was provided for the data unit transfer.

When Generated. This primitive shall be generated by the MAC entity in response to an MA-UNITDATA request primitive from the local LLC entity.

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

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

6.2 PHY To MAC Service. The services provided by the PHY allow the local MAC entity to exchange MAC data units with peer MAC entities and to report certain status changes.

6.2.1 Interactions. The following primitives are defined for the MAC to request service from the PHY:

PH-UNITDATA request
PH-UNITDATA indication
PH-STATUS indication

6.2.2 Detailed Service Specifications. All primitives are specified in an exemplary form only. Each service shall name the particular primitive and the required information that shall be passed between MAC and PHY.

6.2.2.1 PH-UNITDATA request. This primitive defines the transfer of data from a local MAC entity to the station's PHY.

Semantics of the Service Primitive

```
PH-UNITDATA request      (
                          symbol
                          )
```

The symbol specified shall be one of the following:

0 = binary zero
1 = binary one
J = non-data-J
K = non-data-K

When Generated. The MAC shall send the PHY a PH-UNITDATA request every time MAC has a symbol to output.

Effect of Receipt. Upon receipt of this primitive, the PHY entity shall encode and transmit the symbol.

Additional Comments. None.

6.2.2.2 PH-UNITDATA indication. This primitive defines the transfer of data from PHY to the MAC entity.

Semantics of the Service Primitive

```
PH-UNITDATA  indication  (
                          symbol
                          )
```

The symbol specified shall be one of the following:
0 = binary zero
1 = binary one
J = non-data-J
K = non-data-K

When Generated. The PHY shall send MAC a PH-UNITDATA indication every time PHY decodes a symbol. This indication is sent once every symbol period.

Effect Of Receipt. Upon receipt of this primitive the MAC accepts a symbol from the PHY.

Additional Comments. None.

6.2.2.3 PH_STATUS indication. This primitive is used by PHY to inform MAC of errors and significant status changes.

Semantics of the Service Primitive

```
PH-STATUS  indication  (
                        burst_error_detected
                        )
```

Upon detection of a burst error PHY shall begin generating fill and passing it to MAC (on the PH_UNITDATA indication), to correct detected silence on the medium.

When Generated. Upon detection of a burst error.

Effect of Receipt. The receipt of this indication MAC shall increment the burst error counter.

Additional Comments. None.

6.3 MAC to SMT Service. This section specifies the abstract entities (parameters, events, and actions) that characterize local interactions between MAC and SMT. These interactions consist of reporting errors, parameter values when requested, and other events. This service specification complies with ISO Management Architecture, ISO/DIS 7499 Part 4, OSI Management Framework [5].

6.3.1 Overview of MAC Services. The entities (parameters, events, and actions) communicable between MAC and SMT. The MAC abstract entities consist of

(1) Parameters within MAC read or written by SMT.
(2) Actions initiated by SMT that cause changes within MAC.
(3) Events within MAC that are passed to SMT.

6.3.1.1 General Service Definition. The primitives that are used to read and write parameters, cause an action, and report an event are:

(1) LM_GET_VALUE — This primitive reads the value of one or more MAC parameters.
(2) LM_SET_VALUE — This primitive writes the value of one or more MAC parameters.
(3) LM_ACTION — This primitive generates an action or a state change in MAC.
(4) LM_EVENT — This primitive passes an indication of events within MAC to SMT.

6.3.1.2 Required Versus Optional Services. The support of the parameters, events, and actions accessible through the primitives is mandatory unless indicated otherwise.

6.3.2 MAC Attributes. The attributes of a resource indicate its state (present or past) and control its operation (in the future). The MAC attributes are divided into groups in which they can be accessed by SMT using the Token-Ring MAC to SMT interface. Attributes may be generally classified as

(1) MAC Characteristics — Operational information that describes some aspect of the resource's capabilities. In general, characteristics affect the operation of the resource at some future time. Characteristics may be specifically defined to be read-only or read-write with respect to remote management access.

(2) MAC Status — Dynamic operation about the resource's present state. Status attributes are read-only.

(3) MAC Statistics — Information about the resource's past behavior. Statistical attributes are typically a form of an event log, such as counters. The only type of statistics defined for this standard are counters that are read-only with no reset control.

6.3.2.1 Characteristics. Characteristics are the reference data of a resource that may be either necessary or useful to operate or manage the resource.

Address Group. This group identifies the various MAC addresses related to the reporting node. The following indicates the parameters reported, the section that defines the parameters, and their access.

```
AddressGroup :: = SEQUENCE {
  individualMACaddress    [0] IMPLICIT OCTET STRING,  – 3.2.4.2
                          read-only
  functionalAddresses     [1] IMPLICIT OCTET STRING,  – 3.3.2.8
                          read-write
  groupMACaddress         [2] IMPLICIT OCTET STRING,  – 3.3.2.9
                          read-only
  una                     [3] IMPLICIT OCTET STRING,  – 3.3.2.15
                          read-only
  ringNumber              [4] IMPLICIT OCTET STRING,  – 3.3.2.11
                          read-write
  physicalDrop            [5] ANY,                    – 3.3.2.13
                          read-write
  privateAddressParm      [6] ANY OPTIONAL }          – see below
                          either
```

privateAddressParm — Allows vendor specific address group parameter. This parameter can be of any type and can be read-only or read-write.

Attachments Group. This group identifies the various functions that are or can be within the node (applications, the box the node is in, etc). The following indicates the parameters reported, the section that defines the parameter, and their access.

```
AttachmentsGroup :: = SEQUENCE {
  functionalAddresses        [0] IMPLICIT OCTET STRING,  – 3.3.2.8
                             read-write
  authorizedFunctionClass    [1] IMPLICIT OCTET STRING,  – 3.3.2.3
                             read-write
  authorizedAccessPriority   [2] IMPLICIT INTEGER,       – 3.3.2.2
                             read-write
  productInstanceID          [3] ANY,                    – 3.3.2.14
                             read-only
  privateAttachParm          [4] ANY OPTIONAL }          – see below
                             either
```

privateAttachParm — Allows for vendor-specific attachment group parameter. This parameter can be of any type and can be read-only or read-write.

6.3.2.2 Status. A status attribute is one that indicates something about the current state of the resource. A status attribute is distinguished from a characteristic in that it is modified internally by the resource rather than by an external management entity. Status attributes are read-only.

State Group. The status group identifies the status of the station. The following indicates the parameters reported, the section that defines the parameter, and their access.

```
StateGroup :: = SEQUENCE {
  macVersionNumbers      [0] ANY,               – 3.3.2.17   read-only
  macStatus              [1] ANY,               – 3.3.2.18   read-only
  errorReportTimerValue  [2] INTEGER            – 3.3.2.7    read-write
  privateStateParm       [3] ANY OPTIONAL }     see below    read-only
```

privateStateParm — Allows for vendor-specific state group paramter. This parameter can be of any type.

6.3.2.3 Statistics. Statistics are attributes that contain a record of events over some period of time. The statistics defined for this standard are counters with no reset control. Access to the counterValue parameter is read-only.

Isolating Error Counters Group. The isolating error counters group lists the counters and their values. These errors are those that can be isolated to a particular fault domain (indicatring station, its UNA, and the wire between them or an individual station). The isolating error counters are reported to the REM by stations on its local ring using the Error message. The counters in this group are reported as kept and reported by the REM. When a counter reaches its maximum value, an event (Counter Threshold Reached) is reported and the counters are reset to 0. The following indicates the parameters reported and the section that defines the parameter.

```
IsolatErrorsGroup :: = SEQUENCE {
  lineError              [0] IMPLICIT INTEGER,            – 3.8.1
  burstError             [1] IMPLICIT INTEGER,            – 3.8.3
  acError                [2] IMPLICIT INTEGER,            – 3.8.4
  abortTransError        [3] IMPLICIT INTEGER OPTIONAL,   – 3.8.5
  internalError          [4] IMPLICIT INTEGER,            – 3.8.2
  privateErrorCounters   [5] ANY OPTIONAL }               – see below
```

privateErrorCounters — This is to allow vendor-specific isolating error counters. This parametrer can be of any type.

Non-Isolating Error Counters Group. The non-isolating Error Counters Group lists the counters and their values. These errors are those that cannot be isolated to a particular fault domain. The non-isolating error counters are reported to the REM by stations on its local ring using the Error message. The counters in this group are reported as kept and reported by the REM. When a counter reaches its maximum value, an event (Counter Threshold Reached) is reported and the counters are reset to 0. The following indicates the parameters reported and the section that defines the parameter.

```
NonIsolatErrorsGroup :: = SEQUENCE {
  lostFrameError         [0] IMPLICIT INTEGER,      – 3.8.6
  receiveCongestion      [1] IMPLICIT INTEGER,      – 3.8.7
  frameCopiedError       [2] IMPLICIT INTEGER,      – 3.8.8
  tokenError             [3] IMPLICIT INTEGER,      – 3.8.10
  privateErrorCounters   [4] ANY OPTIONAL }         – see below
```

privateErrorCounters — This is to allow vendor-specific non-isolating error counters. This parameter can be of any type.

6.3.3 MAC Transients. Transients are information units that concern the dynamic actions of a resource. There are two types of transients: actions and event reports. These transients are described in the next two sections.

6.3.3.1 MAC Actions. The following list describes the various actions defined for token ring.

```
TokenRingMACaction :: = CHOICE {
  remove              [0] IMPLICIT NULL,        – see below
  disconnect          [1] IMPLICIT NULL,        – see below
  privateAction       [2] ANY OPTIONAL }        – see below
```

The remove action is used to request the station to remove from the ring.
The disconnect action is used to request the station to insert in the ring.
The privateAction provides for vendor-specific actions.

6.3.3.2 MAC Events. An event report is an information unit that is used to inform SMT of a significant activity in the operation of the resource. A description of the events defined for token rings follows.

Enter Active State. This event is generated by the CRS when it receives a Report New Active Monitor message from a station. The following indicates the information included with the event reported and the section that defines the information.

```
EnterActiveState :: = SEQUENCE {
  ringNumber              [0] IMPLICIT OCTET STRING,    – 3.3.2.11
  activeMonitorAddress    [1] IMPLICIT OCTET STRING,    – 3.2.4.2
  una                     [2] IMPLICIT OCTET STRING,    – 3.3.2.15
  physicalDrop            [3] ANY,                      – 3.3.2.13
  productinstanceID       [4] ANY }                     – 3.3.2.14
```

Active Monitor Error. The Active Monitor Error event is generated when the REM receives a Report Active Monitor Error message from the new active monitor. The following indicates the information included with the event reported and the section that defines the information.

```
ActiveMonitorError :: = SEQUENCE {
  ringNumber          [0] IMPLICIT OCTET STRING,    – 3.3.2.11
  stnMACaddress       [1] IMPLICIT OCTET STRING,    – 3.2.4.2
  una                 [2] IMPLICIT OCTET STRING,    – 3.3.2.15
  Error Code          [3] IMPLICIT OCTET STRING,    – 3.3.2.6
  physicalDrop        [4] ANY }                     – 3.3.2.13
```

Report Station in Ring. The Report Station in Ring event is generated when the Ring Parameter Server receives a Request Initialization message from a station. The following indicates the information included with the event reported and the section that defines the information.

```
ReportStationInRing :: = SEQUENCE {
  ringNumber                [0] IMPLICIT OCTET STRING,  – 3.3.2.11
  insertingStnMACaddress    [1] IMPLICIT OCTET STRING,  – 3.2.4.2
  una                       [2] IMPLICIT OCTET STRING,  – 3.3.2.15
  productinstanceID         [3] ANY,                    – 3.3.2.14
  macVersionNumber          [4] ANY }                   – 3.3.2.17
```

Configuration Change. The Configuration Change event is generated when the CRS receives a Report SUA Change message from a station. The following indicates the information included with the event reported and the section that defines the information.

```
ConfigurationChange :: = SEQUENCE {
  ringNumber          [0] IMPLICIT OCTET STRING,   – 3.3.2.11
  stnMACaddress       [1] IMPLICIT OCTET STRING,   – 3.2.4.2
  una                 [2] IMPLICIT OCTET STRING,   – 3.3.2.15
  physicalDrop        [3] ANY }                    – 3.3.2.13
```

Neighbor Notification Incomplete. The Neighbor Notification Incomplete event is generated when the RPS receives a Report Neighbor Notification Incomplete message from the active monitor. The following indicates the information included with the event reported and the section that defines the information.

```
NeighborNotification ::= SEQUENCE {
  ringNumber                 [0] IMPLICIT OCTET STRING,    – 3.3.2.11
  activeMonitorMACaddress    [1] IMPLICIT OCTET STRING,    – 3.2.4.2
  saOfLastAMPorSMPframe      [2] IMPLICIT OCTET STRING }   – 3.3.2.19
```

Counter Threshold Reached. The counter threshold reached event is generated when a threshold or the maximum value is reached. The counters are reset after this event is reported. The following indicates the information included with the event reported and the section that defines the information.

```
CounterThresholdReached ::= SEQUENCE {
  ringNumber                  [0] IMPLICIT OCTET STRING,         – 3.3.2.11
  stnMACaddress               [1] IMPLICIT OCTET STRING,         – 3.2.4.2
  una                         [2] IMPLICIT OCTET STRING,         – 3.3.2.15
  isolatErrorCntrsGroup       [3] IMPLICIT IsolatErrorsGroup     – 6.3.2.3
  nonIsolatErrorCntrsGroup    [4] IMPLICIT NonIsolatErrorsGroup  – 6.3.2.3
  physicalDrop                [5] ANY }                          – 3.3.2.13
```

Beaconing Condition on Ring. The beaconing condition on ring event is generated by the REM when its attached ring has beaconed or is beaconing (its station is in state S5). The following indicates the information included with the event reported and the section that defines the information.

```
BeaconingConditionOnRing :: = SEQUENCE {
  ringNumber          [0] IMPLICIT OCTET STRING,     – 3.3.2.11
```

stnMACaddress	[1] IMPLICIT OCTET STRING,	– 3.2.4.2
una	[2] IMPLICIT OCTET STRING,	– 3.3.2.15
beaconType	[3] IMPLICIT OCTET STRING,	– 3.3.2.4
ringStatus	[4] IMPLICIT OCTET STRING,	– see below
physicalDrop	[5] ANY }	– 3.3.2.13

ringStatus — This indicates the status of the ring indicated by one of the following. This parameter is 2 octets in length.

–X'0000' : Normal
–X'0001' : Temporary Beaconing — a beaconing condition existed on the ring specified. Both stations in the fault domain (identified in this indication) remain in the ring.
–X'0002' : Temporary Beaconing — a beaconing condition existed on the ring specified. One of the stations in the fault domain (identified in this indication) has been removed as part of the recovery process.
–X'0003' : Temporary Beaconing — a beaconing condition existed on the ring specified. Both stations in the fault domain (identified in this indication) have been removed as part of the recovery process.
–X'0004' : Permanent Beaconing — the ring specified has been beaconing long enough for both the beaconer and its upstream neighbor to remove and test. At this point manual intervention is needed to recover the error.

Ring Station Removed. The Ring Station Removed event is generated by the CRS when it issues a Remove Ring Station message to a station. The CRS must then query the station to ensure it has removed from the ring before creating this event. The following indicates the information included with the event reported and the section that defines the information.

RingStationRemoved :: = SEQUENCE {

ringNumber	[0] IMPLICIT OCTET STRING,	– 3.3.2.11
stnMACaddress	[1] IMPLICIT OCTET STRING }	– 3.2.4.2

Private Event. This is to allow vendor-specific events.

6.4 PHY to SMT Service. This section specifies abstract entity actions for PHY that characterize local interactions between PHY and SMT. This service specification complies with ISO Management Architecture, ISO/DIS 7499 Part 4, OSI Management Framework [5].

6.4.1 Overview of PHY Management Service. The PHY abstract entities consist of *actions* initiated through SMT that cause changes within PHY.

6.4.1.1 General Service Definition. The following primitive is used to cause an action and report an event.

LM_ACTION — This primitive generates an action or a state change in PHY.

6.4.1.2 Required Versus Optional Services. The following sections define specific events and actions in PHY. The support of the events and actions accessible through the primitives is mandatory unless indicated otherwise.

6.4.2 PHY Transients. Transients are information units that concern the dynamic actions of a resource. These transients are described as follows.

6.4.2.1 PHY Actions. The following are the various PHY actions defined for token ring.

```
TokenRingPHYaction :: = CHOICE {
  remove           [0] IMPLICIT NULL,        – see below
  insert           [1] IMPLICIT NULL,        – see below
  privateAction    [2] ANY OPTIONAL }        – see below
```

remove — The remove action is used to request the station to remove from the ring.

insert — The insert action is used to request the station to enter the ring.

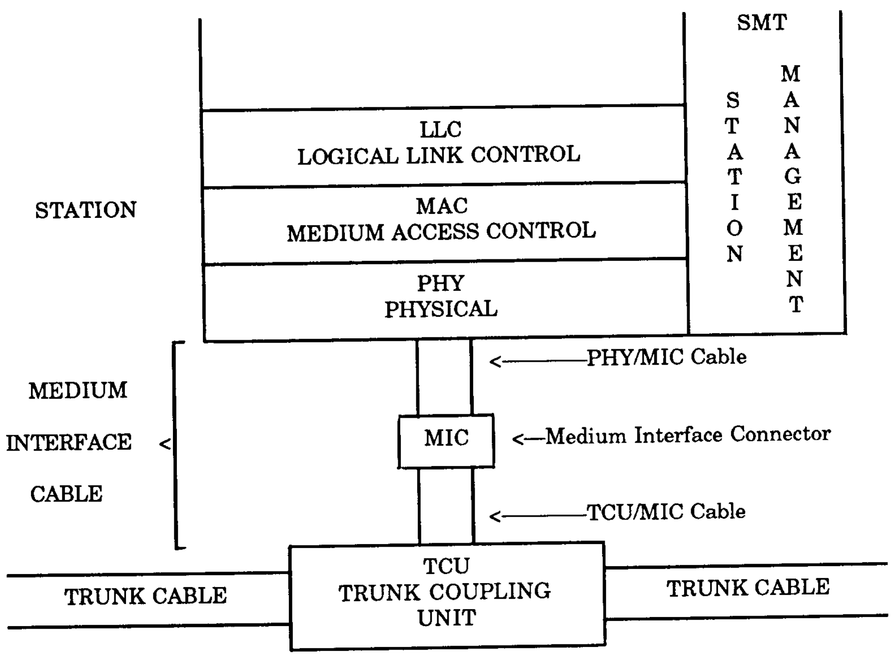
privateAction — This is to allow for vendor-specific actions in PHY.

7. Station Attachment Specifications

7.1 Scope. This section specifies the functional, electrical, and mechanical characteristics of balanced, baseband, shielded twisted pair attachment to the trunk cable of a token ring.

7.2 Overview. The function of the trunk cable medium is to transport data signals between successive stations of a baseband ring local area network. This communications medium consists of a set of TCUs interconnected sequentially by trunk cable links. Each TCU is connected to a TCU/MIC cable to which a station may be connected. The relationship between these embodiments and the LAN model are shown in Fig 7-1.

Fig 7-1
Partitioning of PHY and Medium



Repeaters may be used, where required, to extend the length of a trunk link beyond limits imposed by normal signal degradation due to link impairments. These repeaters serve to restore the amplitude, shape, and timing of signals passing through them. The repeater's regenerative functions have the same characteristics as a repeating station on the ring and must be included in the count of the number of stations supported by the ring.

The medium interface cable shown in Fig 7-1 may be as shown or may include multiple sections of cable joined by connectors identical to the MIC. By definition, the MIC is the connector at which all transmitted and received signal specifications shall be met. It may be attached to the station directly or on a *pig tail.*

7.3 Coupling of the Station to the Ring. The connection of the station to the trunk cable medium shall be via a shielded cable containing two balanced, Z = 150 ± 15 Ω twisted pairs. The cable impedance must be maintained over the frequency range of 2–20 MHz. The station transmitter shall deliver the specified signal at the MIC, and the station receiver shall have sufficient sensitivity and distortion margin to operate properly with the appearance of the specified signal levels and distortion at this interface point. The shield of the cables shall be connected to the shield terminal of the MIC.

An exemplary implementation of the connection, in bypass mode, of the station to the ring is shown in Fig 7-2.

7.4 Ring Access Control. Station insertion into the ring is controlled by the station. The mechanism for effecting the insertion or bypass of the station resides in the TCU. The station exercises control of the mechanism via the media interface cable using a *phantom* circuit technique. The phantom circuit impresses a dc voltage on the medium interface cable. This dc voltage is transparent to the passage of station-transmitted symbols, hence the name *phantom.* The voltage impressed is used within the TCU to effect the transfer of a switching action to cause the serial insertion of the station in the ring. Cessation of the phantom drive causes a switching action that will bypass the station and cause the station to be put in a looped *(wrapped)* state. This loop may be used by the station for off-line self-testing functions.

The phantom drive circuit is designed such that the station may detect open-wire and certain short-circuit faults in either the receive pair or transmit pair of signal wires. This is done by detecting dc current imbalance in two separate phantom circuits. In order to do this the transformers (or their equivalent) in the TCU and the station must provide two coils that are dc-isolated but ac signal coupled to each other. Circuits attached between the transmit pair and the receive pair of conductors shall be designed such that a line-to-line dc current balance is maintained within each pair.

7.4.1 Current and Voltage Limits. Ring access shall be controlled with a voltage on MIC pin B with respect to pin G and a voltage on MIC pin O with respect to pin R.

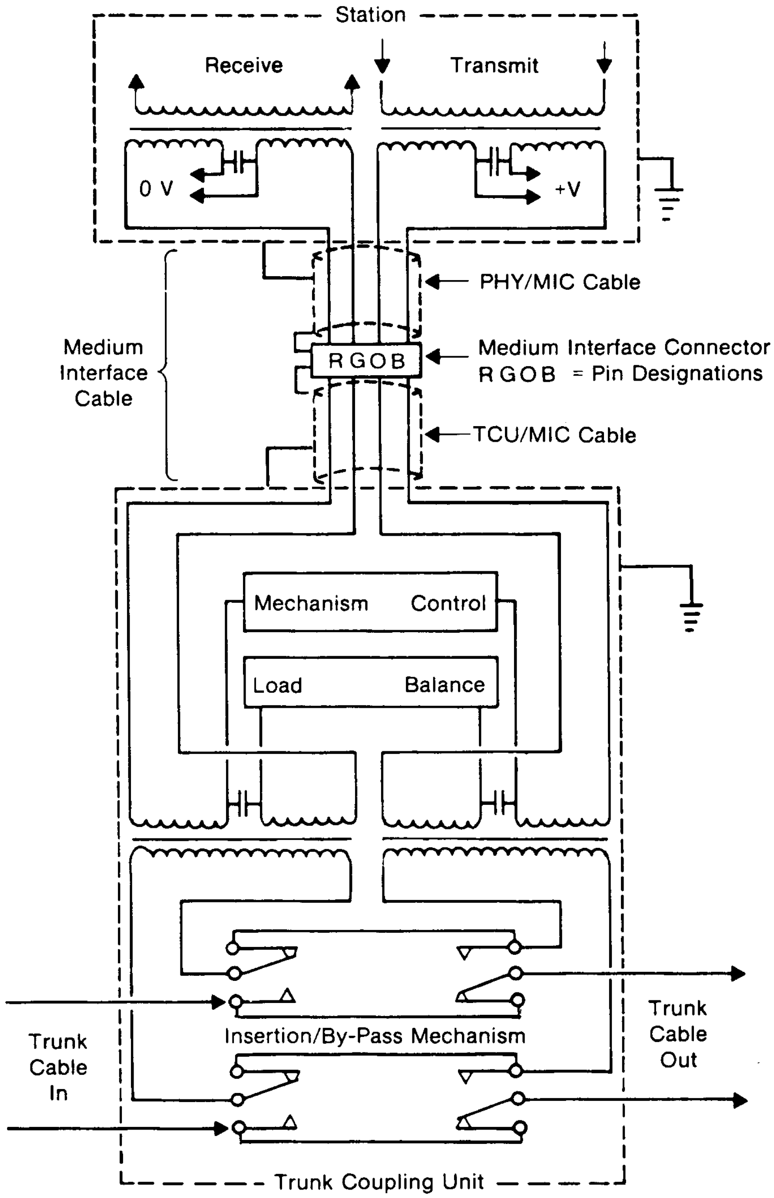


Fig 7-2
Example of Station Connection to the Medium

Insertion shall be effected with a voltage of 4.1–7.0 V for a current less than 1 mA and 3.5–7.0 V for a current between 1–2 mA.

Bypass shall be effected with a voltage of less than 1 V.

The MIC, as described later, will automatically short-circuit pin R to pin O and pin G to B when it is withdrawn. Therefore, the station shall provide means to assure that the short-circuit current will not exceed 20 mA.

The static load provided by the TCU between pins B and O and pins R and G shall have a resistance between 2.9 kΩ and 5.3 kΩ and shall be matched within 5%.

7.4.2 Insertion/Bypass Transfer Timing. The insertion/bypass mechanism shall break the existing circuit before establishing the new circuit. The maximum time that the ring trunk circuit is open shall not exceed 5 ms.

7.5 Signal Characteristics. There are three segments associated with PHY: the transmitter, including all components in the transmission path up to the transmitter MIC; the channel, including the installed cabling, connectors, and coupling units; and the receiver, including all components following the receive MIC. Each segment is specified independently to assure compabilhility among different implementations. The specifications in this section do not address ring access control.

Several specifications are derived from limits on the total ring accumulation of error and not on any single lobe. Statistical limits have been used for these specifications to allow greater freedom of design.

7.5.1 The Transmitter. All specifications are made at the media interface connector with a 150 Ω resistive termination. The requirements on the transmitter presented here do not include the phantom drive signaling simultaneously impressed on the wires. The transmitted signal must be a differential signal centered around ground with a peak-to-peak amplitude between 3.0 V and 4.5 V. Transmit asymmetry (TA) is defined with respect to any valid Manchester data stream. The stream consists of periods of high voltage (greater than ac ground) and low voltage (less than ac ground), with the high and low times each nominally one or two unit invervals long. TA, defined only where adjacent up and down times are the same number of UIs, is one half the maximum time difference between the adjacent high and low periods measured at the ac zero crossings. TA shall have an average (μ) and a standard deviation (σ) among stations such that

data rate	=	4	16	Mbit/s
$\lvert \mu \rvert$	<	3	1	ns
$\lvert \mu \rvert + 3\sigma$	<	11	3	ns

The transmitter waveform shall have the characteristics of a square wave transmitter, as defined above, driving a bandpass filter meeting the following specifications:

data rate	=	4	16	Mbit/s
high-pass pole	<	30	50	kHz
single low-pass pole	>	14	*	MHz
double low-pass pole	=	*	30±5	MHz with Q=0.7±0.2
no other low-pass poles	<	25	64	MHz
no more than two additional low-pass poles	<	*	100	MHz

*This parameter is not applicable at this operating speed.

However, in order to meet certain national emmision standards, it may be necessary to implement a more stringent bypass filter whose high frequency characteristics are

frequency	4	8	16	24	28	32	36	40	48	MHz
max atten	1.0	1.0	1.0	3.5	10	–	–	–	–	dB
min atten	–	–	–	–	–	2	5	10	20	dB
max delay*	0	0	2	7	13	–	–	–	–	ns
min delay*	–1.5	0	0.5	1.0	1.0	–	–	–	–	ns

*Delay is measured relative to the delay of the 8 MHz component of the signal and a straight line interpolation is assumed between the specified frequencies.

The low-frequency characteristics are the same for either bandpass filter. Filters complying to either specification above will interoperate on the same token ring.

7.5.2 The Channel. The channel described here is defined as the test channel for transmitter and receiver operation. The channel is treated as a two-port device, the ports being at the media interface connectors for the transmitting and receiving stations. Two sets of specifications are set for the channel: the first specifies transfer functions to limit the allowable phase distortion produced by the channel, and the second specifies a minimum received signal level.

The channel is characterized as a network with a square-root-frequency attenuation (SQA) plus a flat attenuation (ATT) plus rational poles. There shall be no rational poles between F3 and F4 and no more than two rational poles between F4 and F5. The parameter values are

data rate	=	4	16	Mbit/s
SQA	≤	22	19	dB
ATT	≤	15	15	dB
F3	=	50	50	kHz
F4	=	16	45	MHz
F5	=	50	75	MHz

SQA is measured with a 4 MHz sine wave for 4 Mbit/s operation, and with a 16 MHz sine wave for 16 Mbit/s operation. The total attenuation shall be limited in amount by the minimum eye-height requirement shown in Fig 7-3.

When driven by any allowable transmitter and any valid data pattern over any allowable channel, the received signal shall have an eye opening of greater than V1 mV, peak-to-peak, over the center 1/3 of the half-bit time as shown in Fig 7-3, where the eye is triggered from the transmitter clock.

This eye shall be measured after a passive equalizer having an input impedance of 150 Ω, poles, P1 and P2, and a zero, Z1. The parameter values are

data rate	=	4	16	Mbit/s
V1	=	50	150	mV
P1	=	2.7	10.3	MHz
P2	=	16.0	25.0	MHz
Z1	=	0.54	2.4	MHz

7.5.3 The Receiver. Requirements on the receiver are divided into four items. The first, maximum data-correlated jitter output, limits the response of the timing recovery to data-induced phase error. The second, maximum un correlated jitter output, limits the amount of phase error due to internal noise. These first two requirements determine the amount of accumulated jitter that following stations must track and that the elastic buffer in the active monitor must remove. The third requirement, maximum jitter bandwidth, limits the rate of change of output phase that must in turn be tracked by following stations. Finally, the fourth, jitter tolerance, tests the capability of the station to correctly receive data in the presence of jitter.

Input jitter is composed of two components, the output jitter of the previous station and the jitter associated with the transmission of that data between stations. Define the output jitter of the previous station as "transferred jitter." Output jitter is measured at the recovered clock used to latch transmitted data. These clocks will generally not be available to users of the station and therefore must be probed during development testing or acquired indirectly via the transmitted data. The level and spectrum of the received data for these tests is the entire range of values produced by using any transmitter and channel within their specifications. All jitter specifications have the dimensions of unit intervals (UIs), and are based on peak-to-peak measurements. A UI is one data sampling clock cycle; e.g., 125 ns for a 4 Mbit/s signal.

7.5.3.1 Correlated Jitter. Correlated jitter is the portion of the total jitter that is related to the data pattern. The maximum correlated jitter occurs for a worst-case data pattern, usually a data stream that switches between all zeros and all ones. Measurements of worst-case correlated jitter are made with zero transferred jitter and an input data stream consisting of alternating strings of ones and zeros to allow measurement of transient phase effects. The output phase is specified both raw (unfiltered), to limit the data/clock alignment er-

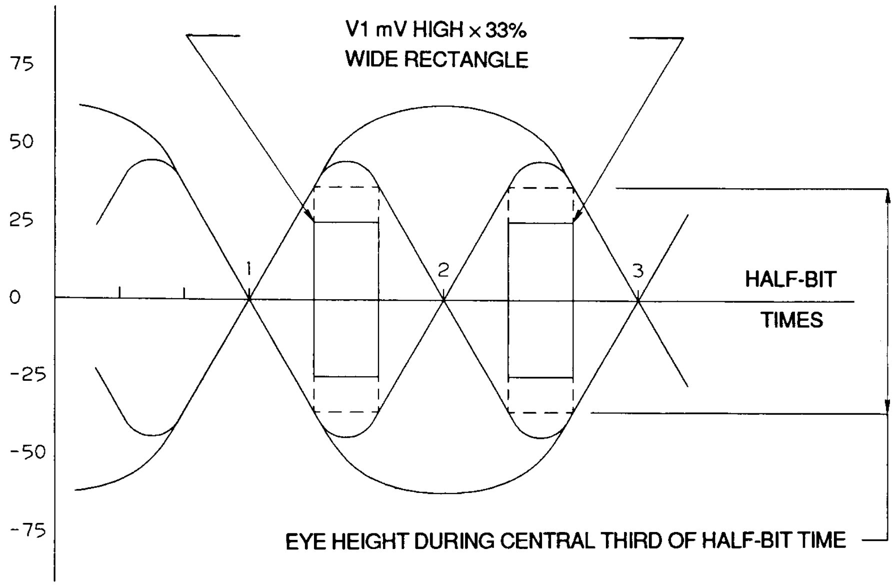


Fig 7-3
Receive Signal Eye Pattern

ror in the following station, and filtered, to limit the total accumulated jitter of the ring.

Unfiltered correlated jitter (UCJ) in the table below is measured in UIs. When the jitter, that is the phase response, is low pass filtered by a single pole at F6, the correlated jitter output shall have an average across stations of less than mFCJ UI with a standard deviation of σFCJ. The parameter values are

data rate	=	4	16	Mbit/s
F6	=	125	500	kHz

For a normal channel with SQA (square root attenuation) ≤ SQA1, the parameter values are

data rate	=	4	16	Mbit/s
SQA1	=	13	19	dB
UCJ	=	0.07	0.12	UI
mFCJ	=	0.016	0.07	UI
σFCJ	=	0.014	0.05	UI

For a normal channel with SQA1 ≤ SQA ≤ SQA2, the parameter values are

data rate	=	4	16	Mbit/s
SQA2	=	22	19	dB
UCJ	=	0.18	0.12	UI
mFCJ	=	0.016	0.07	UI
σFCJ	=	0.014	0.05	UI

7.5.3.2 Uncorrelated Jitter. Uncorrelated jitter output is defined as the average of two measurements, one with an input data stream of all zeros, and the other with all ones. Both measurements are done with zero transferred jitter over an interval of 30 seconds. The average of the two measurements shall be less than UJA UI. The parameter values are

data rate	=	4	16	Mbit/s
UJA	=	0.095	0.16	UI

7.5.3.3 Jitter Bandwidth. A nominal phase lock loop bandwidth of 90 kHz at 4 Mbit/s operation and 980 kHz at 16 Mbit/s operation has been chosen as the design objective. Specifications are set for the maximum bandwidth, defined below, as well as the minimum bandwidth, defined in the following section, 7.5.3.4.

Jitter bandwidth specifies the maximum bandwidth of the phase-locked loop. Jitter bandwidth is defined in terms of the rate of change of the phase of the clock responding to an input phase step. The phase of the clock can be measured from the phase of the transmit data (with the station transmitting off its recovered clock). To filter out high-frequency jitter, the following restriction must be met. With a jitter input consisting of a phase step of magnitude less than 0.33 UI, the output phase will take at least T1 μs to go through the 10% to 90% interval of its phase change. The parameter values are

data rate	=	4	16	Mbit/s
T1	=	1.0	0.2	μs

7.5.3.4 Jitter Tolerance. Tolerance to jitter is measured by detecting errors in a pseudo-random bit stream. The transferred jitter is sinusoidal; its magnitude at each frequency is increased until errors occur. The receiver must operate within its specifications with transferred jitter up to TJL UI for frequencies less than FL. The receiver must also operate with jitter less than TJH UI for frequencies greater than FH. Between those limits, (jitter in UI) × (frequency in kHz) is a constant. The parameter values are

data rate	=	4	16	Mbit/s
TJL	=	5.5	30	UI
FL	=	2.0	1.8	kHz
TJH	=	0.2	0.2	UI
FH	=	55	270	kHz

7.5.4 Error Rate. The station shall provide an output with an error rate of less than or equal to 10^{-9} when the signal-to-noise ratio (S/N) at the output of the equalizer specified in 7.5.2 is greater than or equal to 22 dB. S/N, measured in dB, is defined as 20 log ($^1/_2$ minimum eye height during the central third of the half-bit time + rms noise).

7.6 Reliability. The MAC, PHY, and connecting cable up to and including the MIC of each station shall be designed to minimize the probability of causing communication failure among other stations attached to the local network. The mean time to the occurrence of such a failure shall be at least one million hours of operation without requiring manual intervention to restore the network to operational status.

7.7 Safety Requirements. All stations meeting this standard shall conform to one of the following standards:

(1) IEC Publication 380 (1985) [2][3]
(2) IEC Publication 435 (1983) [3]
(3) IEC Publication 950 (1986) [4]

All exposed materials shall meet appropriate flammability requirements. Low smoke and fume materials shall be used as mandated by local requirements.

7.8 Electromagnetic Emanation. Equipment shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR Publication 22 (1985) [1].

7.9 Medium Interface Connector (MIC). Fig 7-4 shows an isometric view of the MIC as it would be oriented when it is wall mounted. It has four signal contacts with a ground contact and is hermaphroditic in design so that two identical units will mate when oriented 180 degrees with respect to each other.

Electrical Characteristics

crosstalk rejection	> 62 dB @ 100 kHz to 4 MHz
crosstalk rejection	> 50 dB @ 100 kHz to 16 MHz
connector insertion loss in a 150 Ω impedance line	< 0.1 dB @ 100 kHz to 16 MHz
dc contact resistance	
pins	20 mΩ average, 100 mΩ maximum
shield	25 mΩ average, 100 mΩ maximum
self-shorting path	40 mΩ average, 100 mΩ maximum
carry current	≥ 0.1 A
voltage proof contact-contact	≥ 750 V dc

[3] The numbers in brackets correspond to those of the references listed in 1.4.

Mechanical Characteristics

contact force	0.5 – 1.0 N
insertions	> 1000

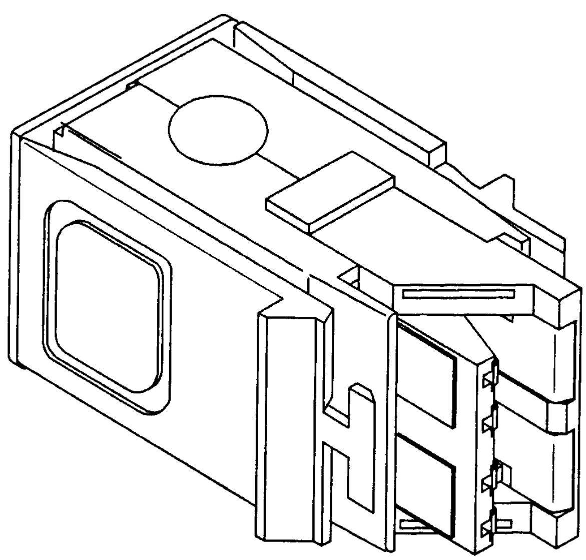
surface treatment (compatible with the following):
point-of-pin contact — plating with 3 μm of hard gold
point-of-shield contact — plating with 5 μm of tin

The mechanical mateability of the connector is subject to standardization by IEC.

7.9.1 Medium Interface Connector—Contactor Detail. Figure 7-5 shows the details of the signal and ground contactors. When the connector is disconnected, pin R shall be shorted to pin O and pin G shorted to pin B for automatic looping capability. Only those dimensions that are essential to mating are shown.

7.9.2 Medium Interface Connector—Locking Mechanism Detail. Figure 7-6 shows the locking mechanism of the connector. Only those dimensions that are essential to mating are shown.

Fig 7-4
Medium Interface Connector—Isometric View



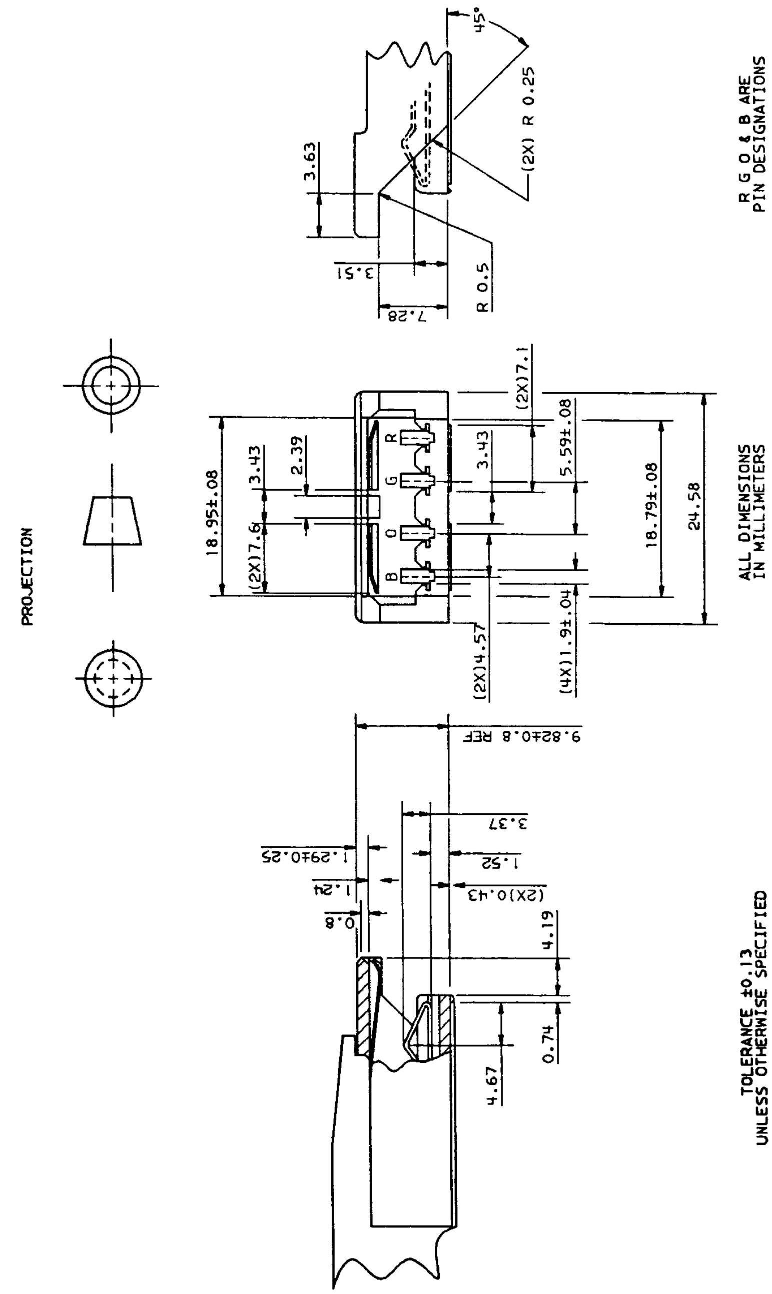


Fig 7-5
Medium Interface Connector—Contactor Detail

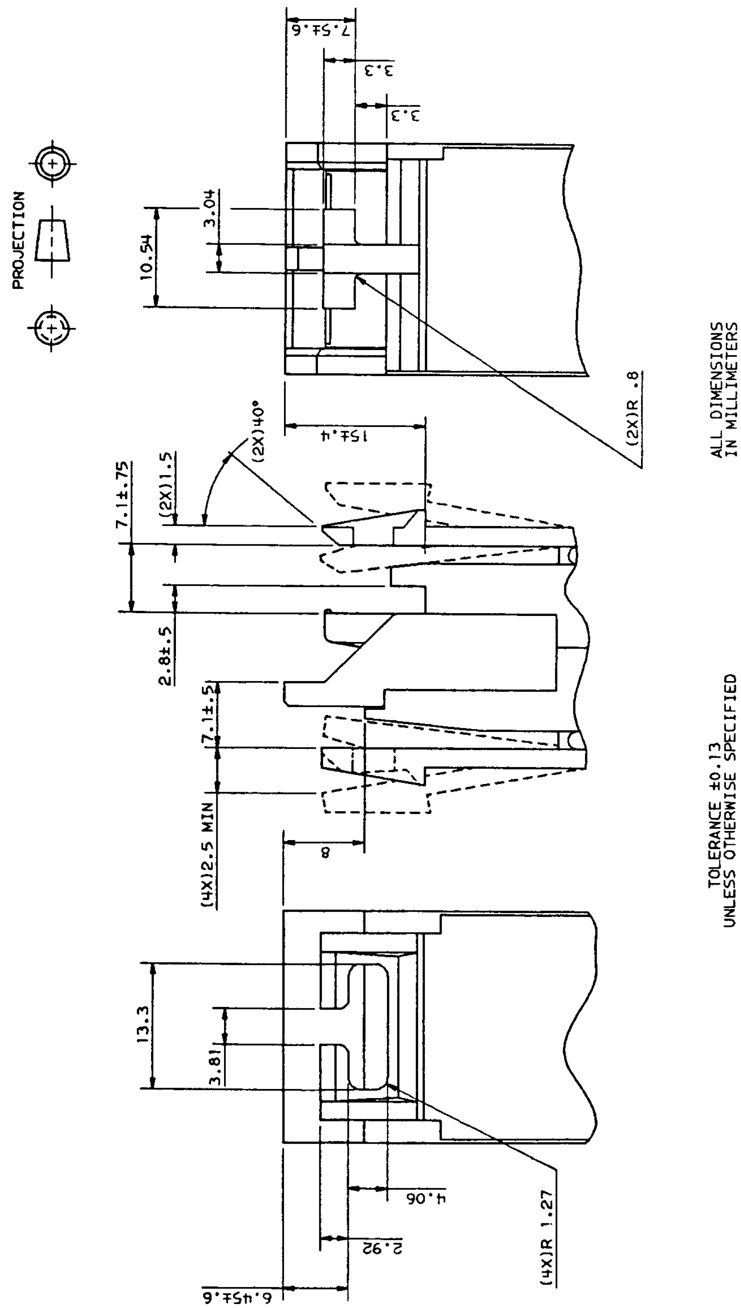


Fig 7-6
Medium Interface Connector—Locking Mechanism Detail

Appendices

(These Appendices are not a part of IEEE Std 802.5-1989, Token Ring Access Method and Physical Layer Specifications, but are included for information only.)

Appendix A
Address Structuring

IEEE Recommended Practice. This appendix presents the preferred procedures for the hierarchical structuring for locally administered addresses.

General Structure. The following structure provides for a token ring LAN divided into multiple rings, with one or more MAC-level relay stations for interconnecting the rings. Structuring MAC addresses in a hierarchical fashion can facilitate the operation of these relay stations.

A ring is defined as the collection of all stations of a LAN that have the same ring number and that can exchange frames without any intermediary MAC-level relay entity. Stations on a ring can communicate with stations with different ring numbers only through a MAC-level relay or some other intermediary.

A hierarchical address permits a MAC-level relay station to recognize frames that require forwarding to other rings by applying a straightforward algorithm to the frames to be forwarded.

The source and DA partitioning recommended for this purpose is

(1) 16-bit hierarchical form

I/G	7-bit ring number	8-bit station subaddress

(2) 48-bit hierarchical form

I/G	1	14-bit ring number	32-bit station subaddress

In addition to the definitions of broadcast address and null address, the following addressing conventions are recommended:

This ring. The ring number field is set to all 0's or to the ring number of this ring, if known.

All stations, this ring. The ring number field is set to all 0's or to the ring number of this ring, if known; the station subaddress field is set to all 1's.

All rings. The ring number field is set to all 1's.

Appendix B
LLC Type 3 Support

IEEE Recommended Practice. This appendix presents the preferred procedures for token ring support of LLC Type 3 for real time applications.

Overview. This appendix describes the characteristics and options that are recommended in token ring networks to ensure optimum support for LLC Type 3 in real time applications. Token ring networks employing LLC Type 3 procedures typically will do so in order to support real time requirements. For the purposes of this appendix, *real time* implies an ability for any station in a network to respond to any other station in the network in less than 10 ms.

Token Ring Implementation Issues. Token ring networks supporting LLC Type 3 shall have the following characteristics:

(1) All stations shall limit maximum packet lengths to the order of 100 octets. Longer frames can be supported if the priority mechanism is employed for LLC Type 3 messages provided these longer frames are sent at lower priority than the LLC Type 3 frames.

(2) LLC Type 3 requests and response packets shall be 16–40 octets.

(3) The maximum number of stations on a ring shall be less than 128.

(4) Only a portion of the stations on the ring shall generate traffic at any point in time—LLC Type 3 or background traffic. A number less than 32 generally meets this requirement.

(5) The length of the ring shall be kept short, less than 2 km unless ETR is employed. For networks using ETR, the ring length can be increased up to 20 km with satisfactory operation.

Station Implementation Issues. Token ring stations implementing LLC Type 3 messages shall

(1) Have the ability to employ the MAC priority mechanism.

(2) Be able to receive, recognize, and respond to an LLC Type 3 message with minimum delay. For the meximum quantities expressed in this appendix, a value of 1 ms or less to receive a request, generate, and transmit the response is required for a successful implementation.

(3) Be able to use the ETR operation in long rings with high utilization.

IEEE Training Programs on Local Area Networks

The IEEE will soon launch newly developed training programs on Local Area Networks (LANs). The IEEE standards for LANs deal with the Physical and Data Link Layers as defined by the International Organization for Standardization (ISO) Open Systems Interconnection Reference Model. If you're involved in the design of LANs, make sure you have the complete IEEE LAN series, and participate in our LAN Training Programs. Some of the topics covered will be:

- Twisted Pair Medium
- Token-Passing Ring Medium
- Network security
- Interconnection compatibility between stations and data processing equipment

IEEE Training Programs in Computer Software Engineering

Throughout the year, the IEEE sponsors training programs on computer engineering. Special team discounts are available and IEEE sponsored training programs may also be brought to your plant. These programs include:

- User Documentation
- Reviews and Audits
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- Project Management Planning
- Configuration Management
- Verification and Validation
- Quality Assurance
- Requirements Specifications

POSIX

The IEEE also will soon launch new POSIX training programs based on IEEE Std 1003.1-1988, Standard Portable Operating System Interface for Computer Environments.
Some of the topics covered will be:

- Standard operating system interface and environment based on the UNIX* Operating System documentation
- Portability of applications software at the source-code level
- Systems procurement and evaluation
- Open software environment

For details on our Computer Engineering Training Programs, and for more information on our new LAN Training Programs, write or call: IEEE Manager of Standards Training Programs, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331 USA, 1-800-678-IEEE.

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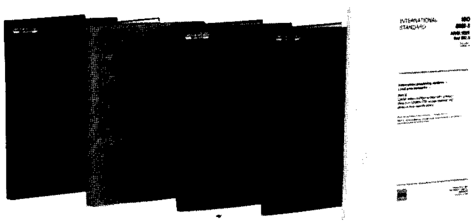
IEEE Standards for Local Area Networks



IEEE Standards for Local Area Networks (LANs) deal with the Physical and Data Link as defined by the International Organization for Standardization (ISO) Open Systems Interconnection Reference Model.

■ Logical Link Control
ANSI/IEEE Std 802.2-1985 (ISO/DIS 8802-2)
(Product Number: SH09712)

This standard describes the functions, features, and protocol of the Logical Link Control (LLC) Sublayer in the LAN protocol; the LLC Sublayers Interface Service Specifications to the Network Layer, the Medium Access Control (MAC) Sublayer, and the LLC Sublayer Management Function; and peer-to-peer procedures that are defined for the transfer of information and control between any pair of Data Link Layer service access points on a Local Area Network.

■ Information Processing Systems— Local Area Networks—Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications (ISBN 1-55937-005-X)
ISO 8802-3 : 1989 (ANSI/IEEE 802.3-1988)
(Product Number: SH11726)

The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) media access method is the means by which two or more stations share a common bus transmission medium. This is a comprehensive standard for LANs employing CSMA/CD as the access method. ISO 8802-3 : 1989 encompasses several media types and techniques for signal rates from 1 Mb/s to 20 Mb/s. It provides the necessary specifications and related parameter values for a 10 Mb/s baseband implementation.

This standard describes the large-scale separation of the system into two parts: the Media Access Control (MAC) Sublayer of the Data Link Layer, and the Physical Layer.

These layers correspond closely to the lowest layers of the ISO Model for Open System Interconnection (OSI).

ISO 8802-3 : 1989 also contains the ISO approved version of supplement ANSI/IEEE Std 802.3a, Type 10BASE2 Coaxial Medium Specification.

■ Supplements to CSMA/CD
ANSI/IEEE Std 802.3b, c, d, e-1989 Edition
(Product Number: SH12351)

This volume contains four IEEE supplements* to ISO 8802-3 : 1989 (ANSI/IEEE Std 802.3-1988)

- 802.3b Type 10BROAD36 Medium Specification
- 802.3c Repeater Unit Specification
- 802.3d MAU and Baseband Medium Specification for Vendor Independent Fiber Optic IRL (continuation of 802.3c)
- 802.3e Type I BASE5 Twisted Pair Medium Specification (Section 12)

ISO 8802-3 : 1989, Sections 1-7, form the base specification for these supplements. Supplements b and e are specifications for an alternate medium to be used in the CSMA/CD Access Method. Supplement c completes the necessary specification for a Repeater Unit implementation.

**ISO 8802-3 : 1989 addenda pending.*

■ Token-Passing Bus Access Method and Physical Layer Specifications
ANSI/IEEE Std 802.4-1985 (ISO/DIS 8802-4)
(Product Number: SH09720)

This standard deals with all elements of the Token-Passing Bus access method and its associated physical signaling and media technologies. It deals exclusively with broadcast type shared media. On a broadcast medium every station may receive all signals transmitted. Media of the broadcast type are usually configured as a physical bus.

IEEE 802.4 has been developed to achieve compatible interconnection of stations by way of a Local Area Network using the Token-Passing Bus access method. It specifies electrical and physical characteristics of the transmission medium; electrical signaling method used; frame formats transmitted; actions of a station upon receipt of a data frame; and services provided at the conceptual interface between the Medium Access Control Sublayer and the Logical Link Control Sublayer above it.

■ Token Ring Access Method and Physical Layer Specifications (ISBN 1-55937-012-2)
IEEE Std 802.5-1989
(Product Number: SH12609)

This standard specifies the formats and protocols used by the Token-Passing Ring Medium Control (MAC) Sublayer, the Physical Layer, and the means of attachment to the Token-Passing Ring physical medium. It will aid in the compatible interconnection of data processing equipment by way of a Local Area Network using the Token-Passing Ring access method. Std 802.5-1985 defines frame format, including delimiters, frame check sequence, MAC protocol, symbol encoding and decoding, symbol timing, and latency buffing.

ISBN 1-55937-012-2

IEEE Std 802.5b-1991

LOCAL AND METROPOLITAN AREA NETWORKS

802.5 SUPPLEMENTS

IEEE Recommended Practice for Use of Unshielded Twisted Pair Cable (UTP) for Token Ring Data Transmission at 4 Mb/s

IEEE

IEEE Std 802.5b-1991
(Supplement to IEEE Std 802.5-1989)

IEEE Standards for
Local and Metropolitan Area Networks:

Supplement to Token Ring Access Method and Physical Layer Specifications

Recommended Practice for Use of Unshielded Twisted Pair Cable (UTP) for Token Ring Data Transmission at 4 Mb/s

Sponsor

Technical Committee on Computer Communications of the IEEE Computer Society

Approved June 26, 1991

IEEE Standards Board

Abstract: This supplement describes the recommended practice for using unshielded twisted pair cables (UTP) for transmitting data at 4 Mb/s. It covers signal characteristics, unshielded twisted pair transmission characteristics, medium interface connection, cable routing, bit error rate, safety, and reliability.

The Institute of Electrical and Electronics Engineers, Inc.
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ISBN 1-55937-146-3

October 18, 1991 *SH14548*

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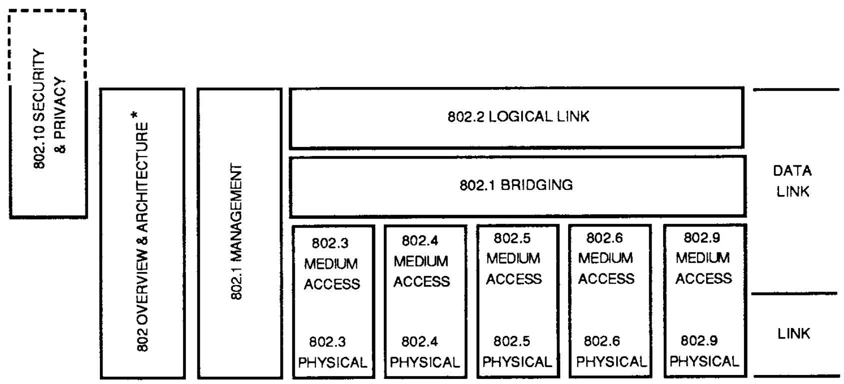
Foreword

(This Foreword is not a part of IEEE Std 802.5b-1991, Recommended Practice for Use of Unshielded Twisted Pair Cable (UTP) for Token Ring Data Transmission at 4 Mb/s.)

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



* Formerly IEEE Std 802.1A.

This family of standards deals with the physical and data link layers as defined by the ISO Open Systems Interconnection Basic Reference Model (ISO 7498:1984). The access standards define several types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The standards defining these technologies are as follows:

- IEEE Std 802†: Overview and Architecture. This standard provides an overview to the family of IEEE 802 Standards. It is a part of the 802.1 scope of work.
- IEEE Std 802.1D: MAC Bridging. Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.

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

- IEEE Std 802.1E: System Load Protocol. Specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.
- ISO 8802-2 [ANSI/IEEE Std 802.2]: Logical Link Control.
- ISO/IEC 8802-3 [ANSI/IEEE Std 802.3]: CSMA/CD Access Method and Physical Layer Specifications.
- ISO/IEC 8802-4 [ANSI/IEEE Std 802.4]: Token Bus Access Method and Physical Layer Specifications.
- IEEE Std 802.5: Token Ring Access Method and Physical Layer Specifications.
- IEEE Std 802.6: Metropolitan Area Network Access Method and Physical Layer Specifications.

In addition to the family of standards are technical advisory groups as follows:

- IEEE Std 802.7: Broadband Technical Advisory and Physical Layer Topics and Recommended Practices.
- P802.8: Fiber Optic Technical Advisory and Physical Layer Topics.

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

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated to this standard within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Information on the current revision status of this standard may be obtained by contacting

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Paula M. Kelty
IEEE Standards Project Editor

Contents

IEEE Standards for
Local and Metropolitan Area Networks:

Supplement to Token Ring Access Method and Physical Layer Specifications

Recommended Practice for Use of Unshielded Twisted Pair Cable (UTP) for Token Ring Data Transmission at 4 Mb/s

1. Introduction

This supplement to IEEE Std 802.5-1989, IEEE Standards for Local Area Networks: Token Ring Access Method and Physical Layer Specifications, describes the recommended practice for using unshielded twisted pair cables (UTP) for transmitting data at 4 Mb/s. A standard to support token ring over unshielded twisted pair is a subject for future study.

1.1 Scope. There are many applications where UTP can be successfully used if noise sources are controlled as recommended in this document. The need to use existing wiring, or to minimize short-term installation costs, makes the decision to use UTP for 4 Mb/s token ring operation an appropriate business decision for many installations.

When UTP is used in the channel, the resulting token ring operation will be limited. The limitations include a maximum attach capability of 72 stations instead of 250. In addition, the error rate performance is highly dependent upon noise sources that may interfere with ring operation. Guidance is provided to help minimize ring error rate.

The transmit and receive waveforms are different from those described in 7.5 of IEEE Std 802.5 due to the need for media filters to prevent excessive electromagnetic radiation from the UTP and to control common-mode noise. The characteristics at the media filter are defined in Section 3. It is an element in the transmission signal path and is matched to the token ring transmitter and receiver. Since a media filter may be designed for a particular transmitter/receiver, it may not be suitable for use with other stations due to electromagnetic radiation compliance. Therefore, interchangeability of stand-alone UTP media filters across attaching stations is not assured by this practice.

1.2 Overview. Within this document, UTP will be used to mean 100 Ω unshielded twisted pair cable. This type of cable has previously been called telephone wire. Token ring operation using UTP media, while not conforming to IEEE Std 802.5, will provide satisfactory operation in many applications when used according to these recommendations. In many applications, the use of UTP as the lobe media (the wire used for transmission from the user areas to the trunk coupling unit) is viable and will lead to satisfactory ring operation using stations that conform to IEEE Std 802.5. However, this operation is not part of that standard.

A consequence of using UTP for token-ring application is the modification of the transmitted waveforms to limit electromagnetic radiation and NEXT (near-end crosstalk) noise. Many countries have regulations limiting high-frequency energy radiated from telephone cables as well as electronic equipment. Since UTP cables do not limit this radiation as well as shielded cables, the high frequency content of the Manchester signals that are transmitted on the UTP must be limited by the media filter. In addition, the filtering also limits the amount of high-frequency components that can be coupled by crosstalk into adjacent pairs in a cable sheath. Limitation of the high-frequency crosstalk reduces the incident noise into the receiver from the station's transmitter. That transmitted signal, which may be at maximum signal strength, propagates along the wires adjacent to the twisted pair connected to the receiver.

This recommended practice specifies the data transmission performance characteristics of the filter/station combination for station interoperability. Radiation-limiting characteristics of the media filter are not specified. Equipment should comply with local and national codes for limiting electromagnetic interference.

1.3 References

[1] ANSI/ICEA S-80-576-1988, Telecommunications Wire and Cable for Wiring of Premises.[1]

[2] EIA/TIA-568 (1991), Commercial Building Wiring Standard.[2]

[3] IEC 189-2 (1981), Low-frequency cables and wires with p.v.c. insulation and p.v.c. sheath. Part 2: Cables in pairs, triples, quads and quintuplets for inside installations.[3]

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[1] This ICEA publication is available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA. (For information about a future revision, contact ICEA, P.O. Box 411, South Yarmouth, MA 02664, USA.)

[2] EIA publications are available from Global Engineering, 1990 M Street NW, Suite 400, Washington, DC 20036, USA.

[3] IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10035, USA.

[4] ISO 8877:1987, Information processing systems—Interface connector and contact assignments for ISDN basic access interface located at reference points S and T.[4]

[4] ISO publications are available from ISO, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10035, USA.

2. Signal Characteristics

Except for those specifications addressed below, the media specified in Section 3 and the safety considerations addressed in Section 7, all sections of the Physical Layer remain unchanged.This includes symbol encoding and decoding, symbol timing, buffering, ring-access control, and electromagnetic radiation.

The signal characteristics for transmission on a UTP system listed below can be met by a conformant station combined with a media filter as part of the transmitter and receiver interface to the UTP media. The relevant characteristics of the filter are not specified alone, but combined with the function of the transmitter and receiver. The methodology was selected to allow each manufacturer maximum flexibility in filter design while maintaining interoperability requirements. The required filtering of the Manchester signals will be performed by the media filter, which may perform any of the following:

(1) Differential-mode filtering;
(2) Common-mode filtering;
(3) Impedance matching.

2.1 Overview. The Physical Layer is divided into three segments: the transmitter, including all components in the transmission path up to the first medium interface connection; the channel, including the installed cabling, connectors, and coupling units; and the receiver, including all components following the last medium interface connection. Each segment is specified independently to assure compatibility among different suppliers. The specifications in this section do not address ring-access control.

The interfaces between the three segments are defined at themedium interface connections, which are the UTP interfaces nearest the attaching stations, usually a wall-mounted jack mated to a modular plug. The media filter is included in the transmitter and receiver segments. The connectors are defined in Section 4. The interfaces are defined for 100 Ω loads and therefore will have a voltage transformation with respect to the shielded 150 Ω system.

The physical and logical size of a network of token rings using UTP can be extended with bridges, repeaters, etc. Lobe lengths, attachment limits, and required number of repeaters may be different for UTP networks incorporating these choices than for rings using strictly data grade media (DGM).

2.2 The Transmitter. The transmitter includes all the components in the transmission path up to the first medium interface connection. Phantom drive signaling requirements, measured in the UTP case at the first medium interface connection on the TCU side of the media filter, are unchanged from those specified for shielded twisted pair. The transmitter interface to the UTP media will be at the output of the media filter specified below. The transmit asymmetry, TA, is defined in 7.5.1 of IEEE Std 802.5.

2.2.1 Differential Output Voltage. The transmitter output is specified at the medium interface connection with a 100 Ω resistive termination. The transmitted signal should be a differential signal centered around ground with a peak-to-peak (p-p) amplitude between 2.5 and 3.7 V. (These levels are equivalent to 3.0–4.5 V p-p into a 150 Ω load.) The transmitter waveform should have the characteristics of a signal that is the result of passing a square wave signal through a bandpass filter with a high-pass 3 dB point below 30 kHz, and one or two low-pass poles having a combined 3 dB point above 4.6 MHz. The 3 dB points are measured with respect to the passband loss, whichshould be less than 0.5 dB over the range 100 kHz to 1 MHz. The amplitude of the positive and negative transmitted levels should be balanced within 5%.

2.2.2 Media Filter. The transmitter should contain a media filter that is used to interface with the UTP media. (The receiver is not required to have a media filter.) When a conformant station is used, a media filter is required. This filter, when combined with any output filter that is provided by the conformant station, should provide the transmitter waveform specified above. The filter should match the media as described below.

2.2.3 Differential Output Impedance. The differential output impedance should be such that any reflection, due to differential signals incident upon the transmitter from the UTP channel, which has a characteristic as specified in Section 3, should be at least 12 dB below the incident signal over the frequency range of 1–8 MHz. This return loss is defined as follows:

$$RL = 20 \log (| Z_t + Z_c | / | Z_t - Z_c |)$$

where

Z_t = impedance looking into the transmitter
Z_c = characteristic impedance of the UTP

2.2.4 Common-Mode Rejection. The transmitter should have a balanced output to minimize the conversion of common-mode noise to differential noise. For common-mode input noise in the frequency range 1 kHz to 8 MHz, the reflected differential-mode noise should be at least 40 dB below the input common-mode noise. The differential output voltage and output jitter characteristics should be met in the presence of a common-mode ac voltage of 20 V p-p at all frequencies from 60 Hz to 8 MHz.

2.3 Channel. The channel is treated as a two-port device, the ports being at the UTP interface connectors for the transmitting and receiving stations. As described in 7.5.3 of IEEE Std 802.5, the channel characteristics are specified in order to verify transmitter and receiver interoperability. The channel is characterized as a network with a square-root-frequency attenuation (SQA), plus a flat attenuation (ATT), plus rational poles. The flat attenuation should not exceed 6 dB. There should be no rational poles between 50 kHz and 16 MHz. The maximum channel attenuation is defined by the minimum eye size required by the receiver.

When the channel is driven by a transmitter described in 2.2, and any valid data pattern, the signal at the output of the passive equalizer attached to the receiver end of the channel should have an eye height greater than 82 mV p-p over the center 1/3 of the half-bit time as shown in Fig 7-3 of IEEE Std 802.5. (This voltage level is equivalent to a 100 mV eye after the 100–150 Ω transformation.)

The eye trigger should be provided by the transmitter clock. The eye should be measured at the output of the passive equalizer described in 7.5.3 of IEEE Std 802.5, which has poles at 2.7 MHz and 16 MHz, a zero at 0.54 MHz, and an input impedance of 100 Ω.

NOTE: The voltage of 100 mV compared to the minimum eye opening of the 50 mV p-p in 7.5.3 of IEEE Std 802.5 provides additional noise margin for UTP operation.

2.4 The Receiver. Definitions of the following elements can be found in 7.5.4 of IEEE Std 802.5. Specifications for uncorrelated jitter, jitter bandwidth, and jitter tolerance are not altered by UTP transmission.

2.4.1 Differential Input Voltage. Referring to 7.5.2, Fig 7.3, of IEEE Std 802.5, the receiver should operate properly whenever the received eye as measured through the reference equalizer is greater than 82 mV p-p over the center third of the half-bit time. The eye is based on the reception of a pseudo-random signal and is triggered from the transmitter clock.

2.4.2 Differential Input Impedance. The receiver should be matched to the transmission media. The differential input impedance should be such that any reflection, due to differential signals incident upon the receiver from the UTP channel, which has a characteristic as specified in Section 3, should be at least 12 dB below the incident signal over the frequency range of 1–8 MHz. This return loss is defined as follows:

$$RL = 20 \log (|Z_r + Z_c| / |Z_r - Z_c|)$$

where

Z_r = input impedance of the receiver
Z_c = characteristic impedance of the UTP

2.4.3 Common-Mode Rejection. The receiver should operate in the presence of an ac common-mode voltage of 20 V p-p at all frequencies between 60 Hz and 8 MHz.

2.4.4 Correlated Jitter. The correlated jitter output, as defined in 7.5.3.1 of IEEE Std 802.5, should be less than 0.063 UI. (A unit interval (UI) is equal to 125 ns.) This specification corresponds to unfiltered correlated jitter (UCJ) being less than 0.063 UI, and no specification on filtered correlated jitter.

2.4.5 Uncorrelated Jitter. Uncorrelated jitter specified in 7.5.3.2 of IEEE Std 802.5, is not altered by the UTP media.

2.4.6 Jitter Bandwidth. The jitter bandwidth specified in 7.5.3.3 of IEEE Std 802.5 is not altered by the UTP media.

2.4.7 Jitter Tolerance. Jitter tolerance specified in 7.5.3.4 of IEEE Std 802.5 is not altered by the UTP media.

3. Unshielded Twisted Pair Cable (UTP) Transmission Characteristics

This section recommends the transmission parameters for the UTP. Two transmission parameters that affect token ring performance are attenuation and crosstalk. Since a significant number of UTP token ring network applications will use existing in-place cable, these recommended transmission parameters have taken into account the characteristics of this cable to ensure that it may be utilized. The following specifications can generally be met by 0.4–0.5 mm (24 to 22 AWG) UTP.

3.1 Attenuation. The following attenuation characteristics are recommended maximum limits and permit cables with better characteristics to be used.

Frequency (MHz)	Maximum Attenuation (dB/kft @ 20 °C)
1.0	8.0
4.0	16.0
10.0	30.0

3.2 Near-end Crosstalk (NEXT) Attenuation. The recommended minimum near-end differential crosstalk attenuation between the two twisted pairs used in a token ring network application is shown below.

Frequency (MHz)	Minimum Crosstalk Attenuation (dB @ 20 °C)
1.0	41.0
4.0	32.0
10.0	26.0

3.3 Cable Physical Configuration. The cable should have a minimum of two twists per foot. In addition, to avoid periodic repetitions of the twist lengths of pairs within the cable, the twist length of individual pairs should be unique and not integral multiples of a common length.

3.4 Differential Characteristic Impedance. The magnitude of the differential characteristic impedance at 4 MHz of each twisted pair should be $100 \pm 15\ \Omega$.

3.5 Supporting Media Standards. For new installations, UTP with attenuation and crosstalk characteristics no worse than those specified in EIA/TIA-568 [2],[5] should be used. This referenced publication provides telecommunication cabling guidelines for commercial building and specifications for a variety of media, including 100 Ω UTP. Existing cable should conform to ANSI/ICEA S-80-576 [1], IEC 189-2 [3], or EIA/TIA-568.

[5] The numbers in brackets correspond to those of the references listed in 1.3.

4. Medium Interface Connection

Since the primary connector used with UTP is the modular connector, it is recommended for medium interface connection. Both the 6-pin and 8-pin wall connectors are recommended for all UTP token ring applications. (When a UTP cable is used for both voice and token ring signals, the voice is normally connected to a separate jack.) For the 6-pin and 8-pin connectors, the convention at the wall outlet is as follows:

	←6-PIN JACK→						←8-PIN JACK→							
Terminal No.	1	2	3	4	5	6	1	2	3	4	5	6	7	8
Designator	U	Tx	Rx	Rx	Tx	U	U	U	Tx	Rx	Rx	Tx	U	U

NOTES: (1) Designators U are unassigned and not used by token ring.
(2) The physical dimensions of the 8-pin jack are specified in ISO 8877 [4].

Careful attention must be paid to the wiring, insuring that both transmit "Tx" terminals and the receive "Rx" terminals are each assigned to separate UTP pairs. Continuity of the pairs must be maintained from the wall outlet to the telephone connecting blocks in the telephone closet. Testing the continuity of the UTP link before attaching the station is recommended. The following signal wiring continuity should be observed in wiring stations to the ring using UTP media and modular connectors:

Station Signal Assignment	6-Pin Jack (Pin No.)	8-Pin Jack (Pin No.)	Data Connector Code	TCU Pin Function
Tx	2	3	B	Rx
Rx	3	4	R	Tx
Rx	4	5	G	Tx
Tx	5	6	O	Rx

NOTE: The station transmit and receive circuits are connected to the TCU receive and transmit circuits, respectively.

5. Cable Routing

Telephone wiring practices have a significant effect on the capability of a UTP wiring system to accommodate token ring signals. For satisfactory transmission, in addition to conforming with the specifications in the previous sections, the following conditions should be met:

(1) The UTP cable should be free of splices, stubs, and bridge taps.
(2) The wiring run from the TCU to the wall outlet should pass through no more than two connecting blocks (sometimes referred to as "punchdown blocks").
(3) When token-ring signals are carried in cables that are routed through floor ducts, the ducts should be properly grounded.
(4) Cables should be routed away from all sources of interference.These include power lines, motors, radio interference, fluorescent lights, and heavy machinery.
(5) For transmission between TCUs, UTP should not be used.
(6) Where there are both UTP and DGM lobes on the same ring, attach limits are based on a maximum ring count of 72 stations.
(7) Token-ring signals should not be routed through UTP cables that exit a building or which are adjacent to cables either exiting a building or exposed to direct lightning strikes and power surges.
(8) UTP cables that contain token-ring signals should contain no more than one wire pair carrying analog voice signals and one wire pair carrying digital data signals.
(9) For single wiring closet rings, lobe lengths should not exceed 100 meters of 22 or 24 gauge wire from attaching device to the TCU.

Where possible it is recommended that a dedicated UTP cable be used for token ring signals. If this practice is followed, the crosstalk noise due to other signals in the cable is minimized and a lower error rate is realizable.

NOTE: The transmission distances supported by UTP for token ring operation are 1/3 to 1/2 those supported by DGM. In addition, simultaneous use of multi-pair UTP for token ring and other high-speed data with telephone service may further limit the the token ring drive distance and increase the system error rate.

6. Bit Error Rate

The error rate of the token ring is a function of both the environmental electrical noises and the noise generated by signals on the wire pairs in the same cable sheath as the lobe pairs carrying the token ring signals. This includes the self-crosstalk noise from the node transmit signal. Since the UTP is not shielded, the error rate of the UTP lobe system is not guaranteed in the presence of the noise generated outside the token ring. When environmental electrical noise is encountered that may cause excessive errors, it is recommended to use DGM in those locations. UTP should not be used for interconnecting TCUs in separate wiring closets.

Although the error rate of 10^{-9} cannot be guaranteed, with careful planning an acceptable error rate can be achieved in most office environments.

7. Safety

7.1 Precautionary Notes. Token ring equipment attached to UTP media may be subject to voltages that are not present with the use of DGM, and should be designed assuming these voltages may be present. Implementers are urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate standards regarding the attachment of DTEs to UTP telephone media.

7.2 Telephony Voltages. During installation and maintenance of the UTP cable plant, care should be taken to ensure that the UTP media cable conductors do not make electrical contact with non-network conductors or ground. Use of unshielded twisted pair will often bring the token ring wiring into close proximity with other wiring through the sharing of conduit, cable trays, wiring closets, etc. Due to the lack of shielding, this may expose the token ring and attached equipment to potentially damaging voltages through inductive coupling of impulses, electrostatic discharge, and high-voltage breakdown events (lightning). Equipment vendors are urged to provide installation guidelines that will do the following:

(1) Alert installers and users to this exposure.
(2) Suggest means to minimize the exposure to risks of this type.
(3) Suggest techniques that will minimize damage should such an event occur.

The use of building wiring brings with it the possibility of wiring errors that may connect telephony voltages to token ring equipment. Other than voice signals, the primary voltages that may be encountered are the "battery" and ringing voltages. Although there is no universal standard, the following maximums apply:

(A) Battery voltage to an on-hook telephone line is about 56 Vdc applied to the line through a balanced 400 Ω source impedance.
(B) Battery voltage to the off-hook telephone line is about 56 Vdc applied through a balanced 400 Ω source impedance. Most of this voltage is dropped across this impedance due to the relatively low impedance of an off-hook telephone.
(C) Ringing voltage is a composite signal consisting of an ac component and a dc component.The ac component can be up to 175 V p-p at 20–60 Hz, with a100 Ω source impedance. The dc component is 56 Vdc with a 300–600 Ω source impedance. Large spikes can occur at the start and end of each ring cycle as well as when the telephone instrument goes off-hook.

8. Reliability

The reliability of the UTP cabling system and connectors are a function of the individual components and associated cabling practices and are not covered by this practice. (See 7.6 of IEEE Std 802.5 and Section 5 of this document for reliability using DGM.)

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