ECMA

EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

STANDARD ECMA-89

LOCAL AREA NETWORKS

TOKEN RING TECHNIQUE

September 1983

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114 Rue du Rhône – 1204 Geneva (Switzerland)

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BRIEF HISTORY

This Standard ECMA-89 is one of a series of Standards for Open Systems Interconnection.

Open Systems Interconnection Standards are intended to facilitate homogeneous interconnection of heterogeneous information processing systems.

The Standard is within the framework for the co-ordination of Standards for Open Systems Interconnection which is defined by ISO 7498. It is based on the practical experience of ECMA member companies world-wide, and the results of their active participation in the current work of ISO, CCITT and IEEE, and the national Standards Bodies in Europe and the USA. It represents a pragmatic and widely based consensus.

This is one of a series of Standards to be developed and published by ECMA in the field of Local Area Networks. These ECMA Standards refer to several LAN Techniques:

- Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
- Token Techniques (Bus, Ring)

Accepted as Standard ECMA-89 by the General Assembly of ECMA of June 16-17, 1983.

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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 ECMA-89

- defines the frame format, including delimiters, addressing, and frame check sequence, and introduces timers, frame counts, and priority stacks (see Section 3);

- defines the medium access control protocol; the prose description of the algorithms is supplemented with finite-state machines and state tables (see Section 4);

- describes the services provided by the medium access control sublayer to the Network Management, Logical Link Control sublayer and to the Physical Layer; these services are defined in terms of service primitives and associated parameters (see Section 5);

- defines the physical control functions of symbol encoding and decoding, symbol timing and latency buffering (See Section 6);

- defines the shielded twisted pair attachment of the DTE to the medium including the definition of the medium interface connector (see Section 7 and Appendix A).

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.

1.2 References

ISO/7498	Data Processing-Open Systems Interconnection - Basic Reference Model.
ECMA-57	Safety Requirements for Data Processing Equipment
ECMA-71	HDLC Selected Procedures
ECMA-72	Transport Protocol
ECMA-80	Local Area Networks - CSMA/CD Baseband - Coaxial Cable System

ECMA-81	Local Area Networks - CSMA/CD Baseband - Physical Layer
ECMA-82	Local Area Networks - CSMA/CD Baseband - Link Layer
ECMA-90	Local Area Networks - Token Bus
ECMA TR/14	Local Area Networks Layer 1 to 4 Architecture and Protocols
IEC 364	Requirements for Electrical Installations

1.3 Definitions

For the purposes of this Standard the following definitions apply.

1.3.1. Broadcast Transmission

A transmission addressed to all DTEs.

1.3.2. Data Terminal Equipment (DTE)

The functional unit of the data station which serves as the data source, or data sink, or both and provides for the data communications control functions to be performed in accordance with the link protocol.

1.3.3. 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 zero is represented by a polarity change at the start of the bit time. A one is represented by no polarity change at the start of the bit time. Differential Manchester encoding is polarity independent.

1.3.4. Logical Link Control (LLC)

That part of the Link Layer which supports media independent data link functions, and uses the services of the medium access control sublayer to provide services to the Network Layer.

1.3.5. Medium

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

1.3.6. Medium Access Control (MAC)

The part of the DTE that supports the medium access control functions of the station.

1.3.7. Medium Interface Connector (MIC)

The connector at which the transmit and the receive signals specifications are met.

1.3.8. Network Management (NMT)

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

1.3.9. 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 medium access control sublayer.

1.3.10. Protocol Data Unit (PDU)

Information delivered as a unit between peer entities which may contain control information, address information, or data.

1.3.11. Repeater

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

1.3.12. Ring Latency

In a token 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 DTE connected to the token ring.

1.3.13. Service Data Unit (SDU)

Information delivered as a unit between adjacent entities which may also contain a PDU of the upper level.

1.3.14. Token

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

1.3.15. Trunk Cable

The transmission cable which interconnects two trunk coupling units.

1.3.16. Trunk Coupling Unit (TCU)

A physical device which enables a DTE to connect to a trunk cable. The trunk coupling unit contains the means inserting the DTE into the ring or, conversely, by-passing the DTE.

1.4. Conformance

Equipment conforming to this Standard shall implement the provisions specified in sections 3, 4, 6 and 7.

There is no conformance requirement for the layer services defined in section 5.

2. GENERAL DESCRIPTION

This Standard specifies the formats and protocols used by the token-passing ring medium access control (MAC) sublayer, the Physical Layer (PHY), and the means of attachement to the token-passing ring physical medium. The local Area Network Model and its relationship to the Open System Interconnection (OSI) Reference Model of the International Organization for Standardization (ISO) is illustrated in Figure 1.

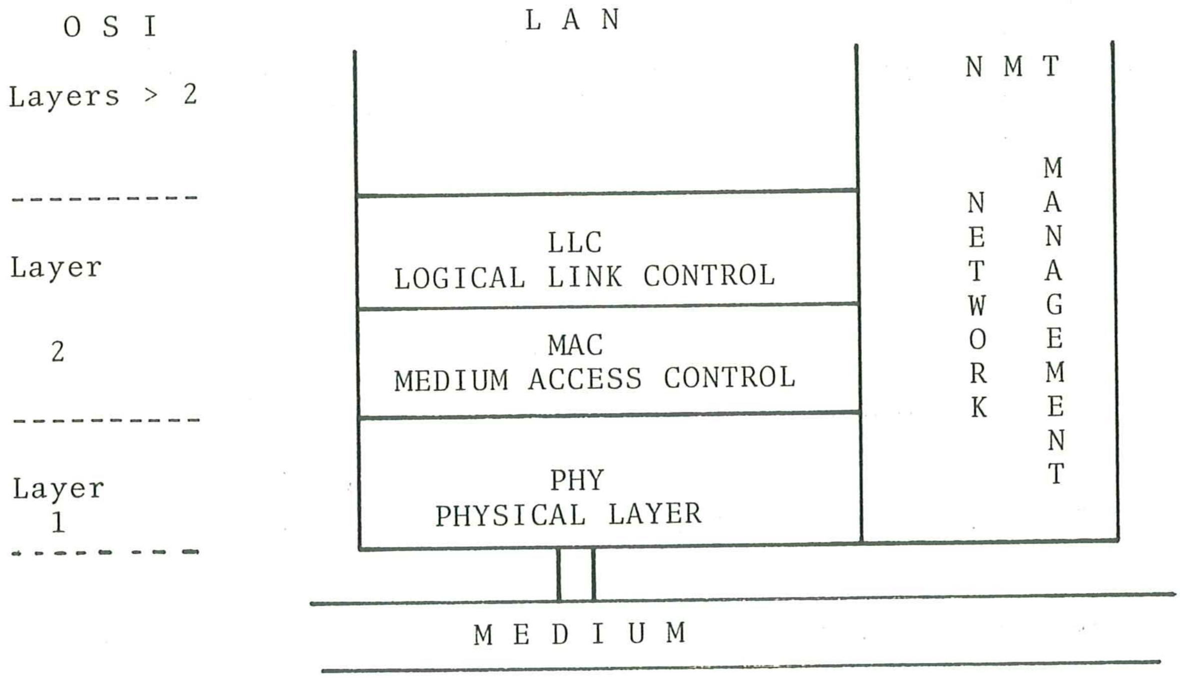
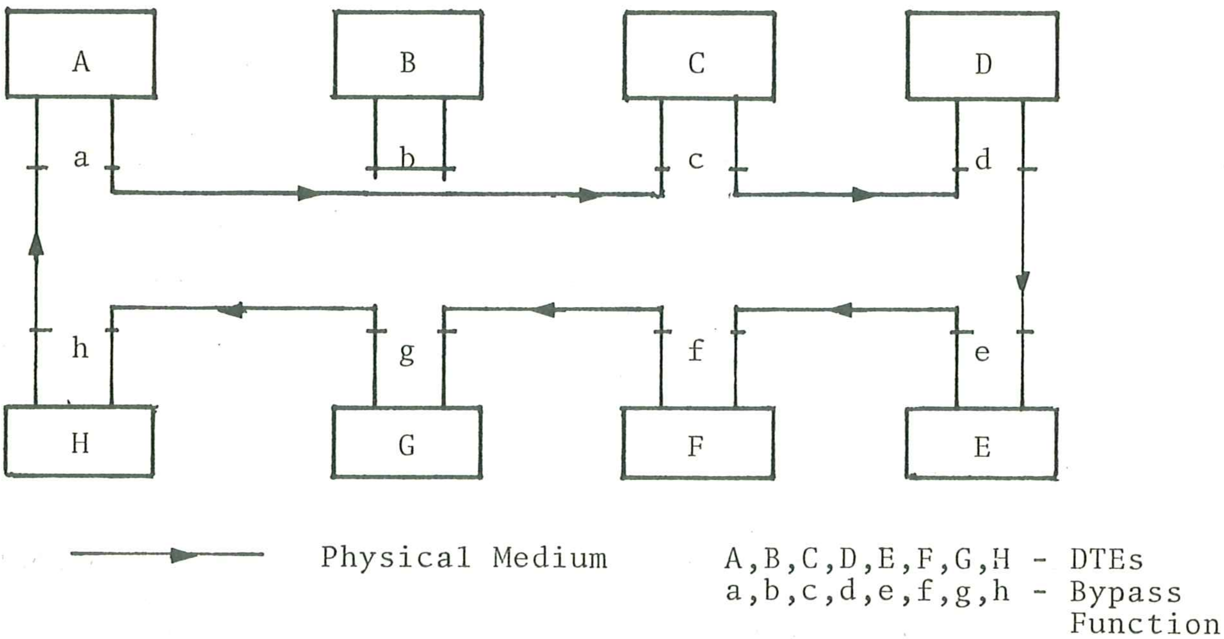


Fig. 1 Relation of OSI Reference Model TO LAN Model

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

A DTE gains the right to transmit its information onto the medium when it detects a token passing on the medium. The token is a control signal comprising a unique signalling sequence that circulates on the medium following each information transfer. Any DTE, upon detection of a token, may capture the token by modifying it to a start of frame sequence and appending appropriate control and statuts fields, address fields, information field, frame check sequence and the frame ending delimiter. At the completion of its information transfer and after checking for proper operation, the DTE initiates a new token, which provides other DTEs the opportunity to gain access to the ring.



All DTEs are active except B (b illustrated in bypass mode)

Fig. 2 Token Ring Configuration

A token-holding timer, or equivalent means, controls the length of time a DTE may 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, e.g., 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 (e.g., those resulting from DTE 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 centralized in a specific DTE with back-up capability in the other DTEs which are attached to the ring.

The token access method as specified does not place constraints on the DTE that has access to the medium relative to the logical link control or higher level protocols employed to effect data transfer.

3. FORMATS AND FACILITIES

3.1. Token and Frame Formats

There are two formats used : token 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.

3.1.1. Token Format

SD	AC	ED

SD = Starting Delimiter (1 octet)

AC = Access Control Field (1 octet)

ED = Ending Delimiter (1 octet).

The token is the means by which the right to transmit is passed from one DTE to another.

3.1.2. Frame Format

SD	AC	FC	DA	SA	INFO	FCS	ED	FS

|—— *F C S coverage* ——| (from FC through FCS)

SD = Starting Delimiter (1 octet)
AC = Access Control (1 octet)
FC = Frame Control (1 octet)
DA = Destination Address (6 octets)
SA = Source Address (6 octets)
INFO = Information (0 - 4099 octets)
FCS = Frame check Sequence (4 octets)
ED = Ending Delimiter (1 octet
FS = Frame Status (1 octet)

The frame format is used for transmitting both Medium Access Control (MAC) and Logical Link Control (LLC) messages to the destination DTE(s). It may or may not have an information field.

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 = Binary ZERO

(For a discussion of non-data symbols, see Section 6).

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 indicate the priority of a token and therefore which DTEs are allowed to use the token. In a multiple-priority system, DTEs use different priorities depending on the priority of the PDU to be transmitted.

Priorities increase from 000 to 111. For purposes of comparing priority values, the priority shall be transmitted most-significant bit first, e.g., 110 has higher priority than 011 (left-most bit transmitted first).

3.2.2.2. Token Bit

The Token Bit is set to ZERO in a token and to ONE in a frame. When a DTE with a PDU to transmit detects a token which has a priority equal to, or less than, the PDU to be transmitted it changes the token to a start of frame and transmits the PDU.

3.2.2.3. Monitor Bit

The Monitor Bit shall be set to ZERO in all frames and tokens transmitted. The active monitor inspects and modifies this bit. All other DTEs ignore and repeat this bit.

3.2.2.4. Reservation Bits

The Reservation Bits allow DTEs with high priority PDUs to indicate in repeated frames that the next token be issued at the requested priority. The precise protocol for setting these bits is described in Section 4.

3.2.3. <u>Frame Control</u> (FC)

F F	Z Z Z Z Z Z

FF = Frame Type Bits
ZZZZZZ = MAC Control Bits

The Frame Control field defines the type of the frame and certain MAC supervisory and information frame functions.

3.2.3.1. Frame Type Bits

The Frame Type Bits indicate the type of the frame as follows :

00	=	MAC frame (contains a MAC PDU)
01	=	LLC frame (contains an LLC PDU)
10 or 11	=	frame type, including the FCS, is undefined (reserved for future use)

Medium Access Control Frames

If the Frame Type Bits indicate a MAC frame, all DTEs shall interpret the MAC Control Bits zzzzzz for MAC significance. If zzzzzz = 000000, the frame contains only information for the addressee (s) and other DTEs shall do no further processing of the frame. If zzzzzz ≠ 000000, then all DTEs must interpret and, if necessary, act on the contents of the MAC Control Bits whether or not they are the addressee(s) of the frame.

Logical Link Control Frames

If the Frame Type Bits indicate an LLC frame, the contents of the MAC Control Bits have meaning for the DTE or DTEs identified by the Destination Address.

3.2.3.2. MAC Control Bits

The following values for the MAC Control Bits have been defined. All other values are reserved for future use.

MAC Information Frame (00 000000)

This frame is used to convey MAC Control PDUs that are intended only for the DTEs identified by the destination address. The type of control PDU being transmitted is indicated in the information field.

Beacon MAC Supervisory Frame (00 000010)

This frame is addressed to all DTEs on the ring for the purpose of indicating that corrective action is required. The transmission of Beacon is covered in the Monitor Finite State Machine.

Claim Token MAC Supervisory Frame (00 00011)

This frame is addressed to all DTEs on the ring during error recovery for the purpose of determinating the DTE that will become the active monitor. When a DTE which is a stand-by monitor mode determines that there is no active monitor operating on the ring, it enters a "claiming token" state. While in this state the DTE sends claim token supervisory frames and inspects the source address of the claim token supervisory frames it receives. If the source address matches its own (MA) address fields, it has claimed the token and enters active monitor mode.

Purge MAC Supervisory Frame (00 000100)

This frame is transmitted by the active monitor and is addressed to all DTEs on the ring. It is transmitted following claiming the token or to perform reinitialization of the ring following the detection of an M bit set to ONE or the expiration of timer TVX.

LLC Frame (01 rrryyy)

This frame is an LLC frame. The first three Control bits (rrr) are reserved. They are set to ZERO in all transmitted frames and ignored upon reception. The last three Control bits (yyy) indicate the frame's priority (PM) i.e., the highest priority at which the frame can be transmitted.

3.2.4. Destination and Source Address Fields

Each frame shall contain two address fields : the Destination (DTE) Address and the Source (DTE) Address, in that order. Both source and destination addresses are six octets in length.

3.2.4.1. Destination Address

The Destination Address identifies the DTE(s) for which the frame is intended. Included in the destination address are two bits : one for individual or group addresses, the other for universally or locally administered addresses.

Individual and Group Addresses

The first bit transmitted of the destination address distinguishes individual from group addresses.

ZERO = individual address   ONE = group address

Individual addresses identify a particular DTE on the LAN and shall be distinct from all other individual DTE addresses on the same LAN.

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

Broadcast Address

The group address consisting of 48 ONEs shall constitute a broadcast, denoting the set of all DTEs on a given LAN.

Null Address

An address of 48 ZEROs, known as the null address, shall not be assigned as a DTE address.

Address Administration

There are two methods of administering addresses : locally or through a "universal" authority. The second bit transmitted of the destination address indicates whether the address has been assigned by a universal or local administrator :

ZERO = universally administered.
ONE = locally administered

Universal Administration

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

Local Administration

Individual DTE addresses are administered by a local (to the LAN) authority.

3.2.4.2. Source Address Field

The Source Address identifies the DTE originating the frame and has the same format and length as the destination address in a given frame. The individual/group bit shall be set to ZERO.

In the Claim Token or Purge processes for the purpose of comparing Source Address to Station Address values, the Source Address bits shall be considered received in the order of most-significant to least-significant bit.

3.2.5. Information (INFO) Field

The INFO Field contains zero, one or more octets that are meaningful to either the MAC or LLC.

3.2.5.1. Preservation of Bit Order

The Service Data Units (SDUs) passed between LLC and MAC are assumed to be ordered sequences of bits. The ordering of these bit sequences will be preserved through the MAC sublayer and between MAC and PHY.

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 ONEs complement of the sum (modulo 2) of the following :

1. The remainder of $X^{12} (X^{31} + X^{30} + X^{29} + \ldots + X^{2} + X + 1)$ divided (modulo 2) by G (X), where R is the number of bits in the Frame Control, Addresses, and Information fields.

   and

2. The remainder after the multiplication by X^{32} and then division (modulo 2) by the standard generator polynomial 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, the initial remainder of the division is preset to all ONEs at the transmitter, (term 1 above), and is then modified by division of the FC, DA, SA and INFO fields by the generator polynomial (term 2). The ONE's complement of this remainder is transmitted, high-order bit first, as the frame check sequence.

At the receiver, the initial remainder is preset to all ONEs and the serial incoming bits covered by the FCS, when divided by the generator polynomial, results in a unique non-ZERO remainder value in the absence of transmission errors. The unique remainder value for the 32-bit frame check sequence is the polynomial

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

where the X^{31} term is received first.

3.2.7. Ending Delimiter (ED)

J K 1 J K 1	I	E

J = Non-data-J, K = Non-data-K, 1 = Binary One
I = Intermediate Frame Bit
E = Error Detected Bit

The transmitting DTE shall transmit the delimiter as shown. Receiving DTEs shall consider the ending delimiter valid if the first six symbols J K 1 J K 1 are received correctly. The I bit may be set to ONE to indicate that this is an intermediate frame in a multiple frame transmission. The E bit of the delimiter is set to ZERO by the originator of the frame. No frame or token is considered valid unless it ends with this explicit six-bit sequence.

In a token, the E and I bits are transmitted as ZERO.

3.2.7.1. Intermediate Frame Bit (I Bit)

The I bit may be set to a ONE to indicate that this is an intermediate (or first) frame of a multiple frame transmission. A ZERO indicates the last frame. Any transmitting DTE not using this technique for stripping its transmitted frames will set it to ZERO in all frames.

3.2.7.2. Error Detected Bit (E Bit)

The Error Detected Bit (E) is set to ZERO by the DTE that originates the frame. All DTEs on the ring monitor repeated frames for errors. If an error is detected and the received E bit was ZERO, the transmitted E bit is set to ONE and an error is reported.

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

Reserved Bits - These bits are reserved for future standardization. They will be transmitted as ZEROs, however, their value will be ignored by the receivers.

3.2.8.1. Address Recognized (A) Bits and Frame Copied (C) Bits

The A and C bits are set to ZERO by the DTE originating the frame. If another DTE recognizes the destination address as its own address or relevant group address it sets the A bits to ONE. If it copies the frame (into its receive buffer), it also sets the C bits to ONE. This allows the originating DTE to differentiate among three conditions :

1. DTE non-existent/non-active
2. DTE exists but frame not copied
3. Frame copied.

The A and C bits are set without regard to the value of the E bit. Only the values that are 00rr 00rr, 10rr 10rr and 11rr 11rr are considered valid. All other values are undefined.

Note 1: If a destination DTE detects that the A bits have already been set, and the DA is not a group address, it indicates a possible duplicate address problem. The second condition (DTE existent but frame not copied) allows the originating DTE to log the instances when, for example, congestion has prevented a destination DTE from copying the frame. The action to be taken upon detection of a duplicate address is an item for future study.

3.2.9. Abort Sequence

SD	ED

This sequence is used for the purpose of terminating the transmission of a frame prematurely. This indicates that an invalid token was used as the start of frame sequence of an error has occured in the originating DTE. The abort sequence can occur anywhere in the data stream, i.e., receiving DTEs must be able to detect an abort sequence even if it does not occur on octet boundaries. The E and I bits of the ED are transmitted as ZERO.

3.3. Timers

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

3.3.1. Token-Holding Timer (THT)

Each DTE shall have a timer THT, called the Token-Holding timer, that controls how long the DTE can transmit frames. A DTE may initiate transmission of a frame if such transmission can be completed before timer THT expires. Its value is dependent on transmission speed and number of DTEs among others. The default value of THT shall be 40'000 bit times.

3.3.2. Return-To-Repeat Timer (TRR)

Each DTE shall have a timer TRR, called Return-to-Repeat timer, to ensure that under all conditions, the DTE will return to Repeat State. TRR has a value greater than the maximum ring latency. The maximum ring latency is given by the signal propagation delay around a maximum-length ring plus the sum of all DTE latencies. The default value of TRR shall be 10'000 bit times.

3.3.3. Valid-Transmission Timer (TVX)

Each DTE shall have a timer TVX, called Valid-Transmission timer, to recover from various token related error situations. The value of TVX shall be the value of THT plus TRR.

3.3.4. No-Token Timer (TNT)

Each DTE shall have a timer TNT, called No-Token timer, to recover from various token related error situations. TNT shall have a value equal to the value of TRR plus n times the value of THT (where n is the maximum number of DTEs on the ring). The default value of TNT shall be 4'000'000 bit times.

3.4. Flags

Flags are used to "remember" the occurence of a particular event. They will be set when the event occurs and reset when that knowledge is no longer needed.

3.5. Frame Counts

To aid problem determination and fault location the MAG entity in each DTE will report to NMT :

- Each frame passing through which contains a frame error.
- Each frame passing through without a frame error.

See Section 4.2 for more details on frame error reporting.

3.6. Priority Registers and Stacks

The values of received priorities and reservations on tokens and frames are stored in registers as Pr and Rr. The previously stored values are discarded.

When a DTE responds to a request it has received for a higher-priority token, it notes the value of the priority bits in the token that it used to create the frame starting sequence. It also notes the value of the priority bits in the token it transmitted. These values are stored in stacks as Sr and Sx, respectively.

When a token is received whose priority is equal to the Sx value, the stacked Sx is removed (popped) from the stack and the token changed to a start of frame sequence followed by ZEROs which is subsequently terminated by the transmission of a new token.

The value of the priority bits in the new token and the operation of the registers and stacks are 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. See Section 6 for more details. Note that the token management is structured so that only one latency buffer will be active in a normally functioning ring.

4. TOKEN RING PROTOCOLS

This section specifies the procedure used in the Medium Access Control (MAC) sublayer.

4.1. Overview

The following provides a descriptive overview of frame transmission and reception. The formal specifications of the operations are given in the FSM (Finite State Machine) later in this section.

Access to the Physical medium (the ring) is controlled by passing a token (token bit set to ZERO) around the ring. The token gives the downstream (receiving) DTE (relative to the DTE passing the token) the opportunity to transmit a frame or a sequence of frames. If a DTE wants to transmit, it sets the token bit in the arriving token to ONE and appends its own data "on the fly". After transmission, the DTE issues a new token for use by a downstream DTE.

DTEs with no data to transmit merely repeat the incoming signal stream. While repeating the incoming signal stream, the DTE transfers a copy of the incoming signal to its own buffer and determines whether the information is intended for this DTE. This is done by matching the DA to its own address or a relevant group address. If a match occurs, subsequent octets up to the FCS which are received are processed by the MAC or sent to the LLC.

4.1.1. Frame Transmission

Upon a request for frame transmission, MAC constructs the frame from LLC data or network management requests and prefixes FC, DA and SA fields. It is then queued awaiting the receipt of a token that can be used to transmit it. Such a token must have a priority less than or equal to he priority of the PDU(s) to be sent. If a frame or a token that cannot be used "passes", then the DTE will request a token of the appropriate priority. Upon detection of the token, it is changed to a beginning of a frame by changing the token bit.

At this time, the DTE 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 data.

4.1.2. Token Transmission

After initiating transmission of the frame(s), the DTE checks to see if the DTEs address has returned in the SA field. If it has not been seen after completion of transmission, then the DTE transmits fill. On notification that the AC, FC, DA, and SA have returned, the DTE transmits a token.

Note 2 : Fill may be either ZEROs, ONEs or any combination thereof.

4.1.3. Reception

At the receiving DTE, the MAC sublayer decodes the destination address to determine if the frame is destined for this DTE. If so, and the frame is an LLC frame, the DA, SA, INFO and the value of the frame priority as received in the FC field are forwarded to the LLC. Otherwise, the frame is processed by the MAC sublayer.

4.1.4. Frame Removal

Each transmitting DTE is responsible for removing from the ring at least all start of frame sequences which it originated.

4.1.5. Priority Operation

The priority bits and the reservation bits contained in the Access Control Field work together to match the service priority of the ring to the highest priority frame that is ready for transmission. The current ring service priority is indicated by the priority bits of the Access Control field.

When a DTE is not able to seize a token, requests for a token at a specified priority are indicated by setting the reservation bits of the Access Control field of a frame or token. The value of the reservation bits may be increased by any DTE to match the priority of a PDU that is ready for transmission. This may be continued until a usable token is seized.

If a token holder receives a frame with the reservation bits set to a priority higher than the current ring service priority, then that DTE issues a new token which it will be at the higher priority. Upon doing this the DTE remembers the old service priority by stacking it as Sr (Stacked Received Priority) and it also remembers the new token priority by stacking it as Sx (Stacked Transmitted Priority). The higher priority frame or frames then use the higher priority token. Eventually, perhaps after priority changes by other DTEs, a token with priority Sx returns to the former token holder. That DTE, upon recognizing a token with priority Sx, returns the service priority of the ring to either Sr (its former value) or Rr (the value requested) whichever is higher. This is done by issuing a new token at the appropriate priority.

At this point, Sx, which was popped from the stack, is discarded. Sr will also be discarded if it equals the priority of the token issued. If a token was issued at Rr, the Rr is stacked as Sx.

As indicated above changes of service priority may be nested. Reservations higher than the current service priority or the stacked receive priority will cause a token to be issued at the reservation priority. A complete description of the priority mechanism is defined by the finite state machines.

4.2. Operational Specification

The basic operation of the ring is described in this section.

The MAC receives from the Physical Layer (PHY) a serial stream of four symbols which are :

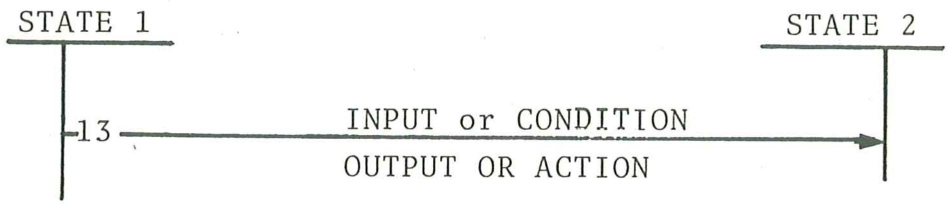
0 = Binary ZERO	1 = Binary ONE
J = Non Data Bit-J	K = Non Data Bit-K

See Section 6 for a detailed description of these symbols.

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

In turn, MAC stores values, sets flags and performs certain internal actions (as noted in the Receive Action Table) and generates tokens, frames, fill or flipping bits and delivers them to the Physical Layer in the form of a serial stream of the 0, 1, J and K symbols.

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 (e.g.,13) and the arrow indicating the direction of transition. Input(s) are above and the output(s) below the transition line.

ABBREVIATIONS and MNEMONICS

P	= Priority	FR	= Frame
Pm	= PDU Priority	MA	= My (DTE's) Address
Pr	= Received Priority	DA	= Destination Address
R	= Reservation	SA	= Source Address
Rr	= Received Reservation	PDU	= Protocol Data Unit
Sr	= Stacked Received Priority	TK	= Token
Sx	= Stacked Transmitted Priority	TX	= Transmit
E	= Error Detected Bit	TRR	= Return-to-Repeat Timer
A	= Address Recognized Bit	THT	= Token Holding Timer

C = Frame Copied Bit
M = Monitor Bit

& = AND
V = OR
/ = the greater of

TNT = No Token Timer
TVX = Valid Transmission Timer
ED = Ending Delimiter
FS = Frame Status (Field)

TK (P = x, M = y, R = z) = Token with P = x, M = y and R = z
FR (P = x, M =y, R = z) = Frame with P = x, M = y and R = z

4.2.1. Receive Actions

The various internal actions that are taken as a result of an input received from the ring are summarized in the Receive Action table. They are explained as follows :

(R-A) Report Good Frames

If while in operational State 0 (Repeat), the frame that was repeated on the ring was errorless a good frame event is reported. A good frame is one that (1) is bounded by a valid SD and ED, (2) is an integral number of octets in length, (3) with the exception of the SD and ED, is composed of only ZERO and ONE bits, (4) has good FCS and (5) is a minimum of 20 octets (including SD and ED) in length.

(R-B) Report Frame Error

If while in operational State 0 (Repeat), the E bit is set to ONE on the frame that is being repeated on the ring, a frame error event is reported. (See transition 02B).

(R-C) Priority Level Error

If while in any operational state, there is a transmit priority stacked (Sx) and a frame or a token is received with a priority less than the value of Sx an error has occured. Therefore, the stacks are cleared.

(R-D) Another Address Received

If while in any operational state the source address that is received is not equal to the DTE's individual address the MA flag is set to ZERO (MA-FLAG=0). Note that the MA flag is set without regard to whether the frame is good or bad.

REF	OPERATIONAL STATE & INPUT	ACTION
R-A	STATE 0 & RECEIVE GOOD FRAME	REPORT FR_OK
R-B	STATE 0 & SET E=1	REPORT FR_ERROR
R-C	STATE ALL & (FR(P<Sx) v TK(P<Sx)	CLEAR STACKS
R-D	STATE ALL & RECEIVE SA≠MA	SET MA_FLAG=0
R-E	STATE ALL & RECEIVE SA=MA	SET MA_FLAG=1
R-F	STATE ALL & RECEIVE (TOKEN v FRAME)	STORE (Pr, Rr)

Figure 3 Receive Action Table

(R-E) My Address Received

If while in any operational state the source address that is received is equal to the DTE's individual address the MA flag is set to ONE.

(R-F) Access Control Field Received

While in any operational state upon the receipt of an access control field (AC) in a token or a frame the value of the priority bits will be stored as Pr and the reservation bits stored as Rr and the previously stored Pr and Rr discarded.

4.2.2. Operational Finite-State Machine

The operational finite-state machine is explained as follows :

4.2.2.1. State 0 : REPEAT (Repeat State)

When a DTE is powered on, it enters Repeat State. In Repeat State, the bits which are received are, in general, repeated on the line to the next DTE. Certain bits and fields in the repeated bit stream may be modified and certain actions taken without changing state. Transition is made to State 1 TX DATA_FR (Transmit Data Frame(s) when there are one or more Protocol DATA Units (PDUs) queued for transmission and the conditions for transmission are satisfied. Transition is made to State 4 TX ZEROS & MOD STACKS (Transmit ZEROs and Modify Stacks) for the purpose of modifying the priority stack.

(01) Usable Token Received

If a PDU is enqueued for transmission and a token is received whose priority (P) is equal to or less than the PDU priority (Pm) the DTE changes the token to a start of frame (by changing the Token Bit from ZERO to ONE, sets R and M to ZERO, initiates the transmission of the enqueued PDU, resets the Token Holding Timer, sets the MA flag to ZERO and makes a transision to State 1.

(02) Bit Flipping Loop

A number of actions can be taken without changing state. These actions are shown in the Bit Flipping Loop State Table and are explained as follows.

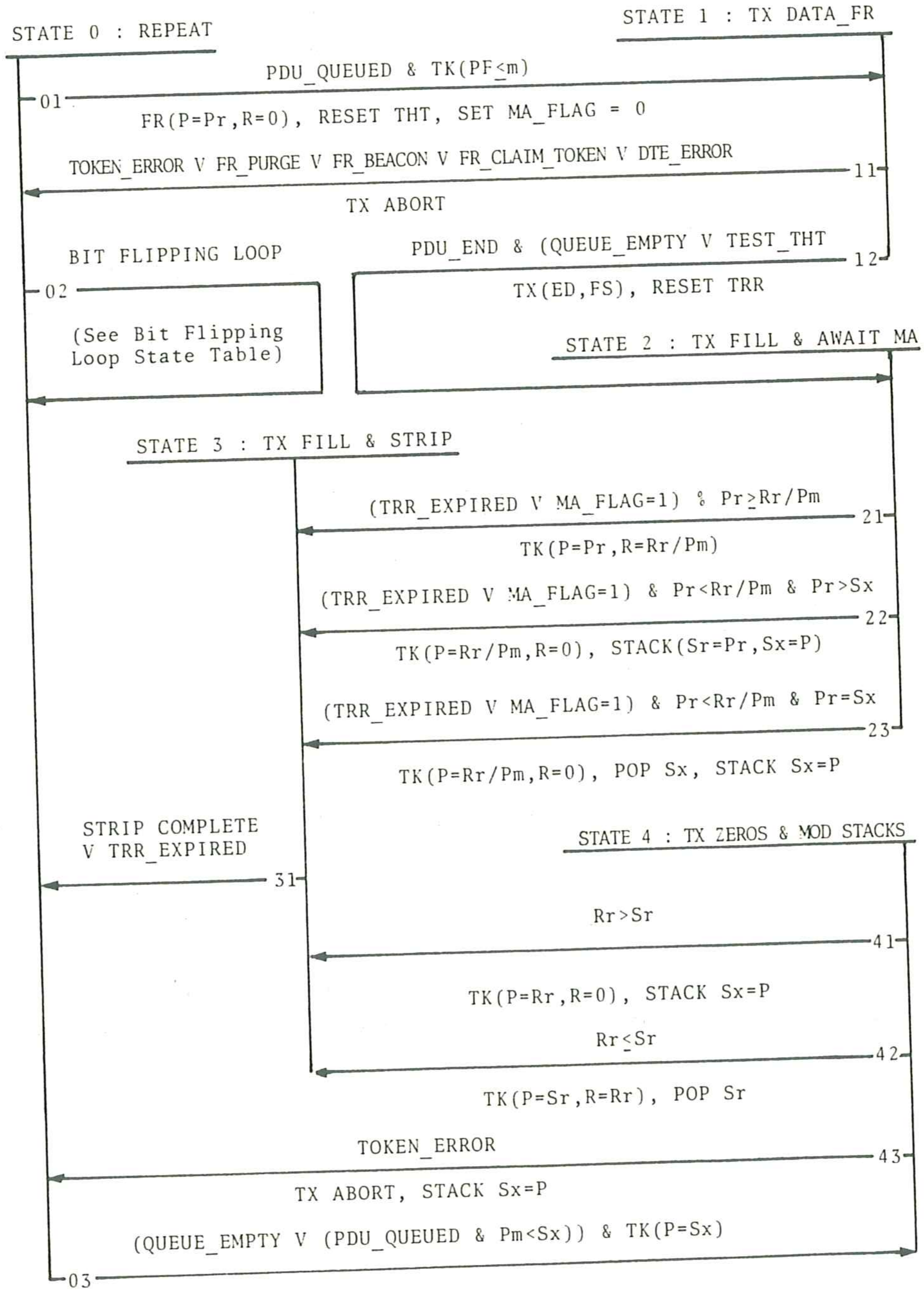


Fig. 4 Operational Finite-State Machine Diagram

REF	INPUT	OUTPUT
02A	PDU_QUEUED & (FR(R<Pm) V TK(P Pm,R Pm))	SET R=Pm
02B	FR_WITH_ ERROR & E=0	SET E=1
02C	DA = MA	SET A=1
02D	FR_COPIED	SET C=1
02E	SA = MA	TX ABORT, REPORT ERROR
02F	>2 CONSECUTIVE J SYMBOLS	TX ZERO

Figure 5. Bit Flipping Loop State Table

(02A) Request Usable Token

If there is a PDU queued for transmission with priority Pm, the reservation R is 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.

(02B) Frame Error

If the frame that is being repeated is not a good frame and the received E (error) bit was ZERO, the E bit is set to ONE. (See Receive Action Table description for definition of a good frame).

(02C) Own Address Detected

If the DTE detected its own address or relevant group address in the destination address field, the A bits in the FS field are set to ONE.

(02D) Frame Copied

If the DTE copies the frame from the ring, the C bits in the FS field are set to ONE.

(02E) Frame Corruption

If a frame is received that contains a source address that is the same as the repeating DTE's address (MA = My Address), an abort sequence will be transmitted as soon as possible. This condition will occur if a DTE has reverted to repeat state before it has received at least a portion of its last transmitted frame. This will also occur when two or more DTEs have the same address.

(02F) Multiple J Symbols

The first two J symbols that are received are repeated as J symbols. However, any additional consecutively received J symbols will be repeated as ZEROs.

(03) Re-stack Operation

If there are no frames enqueued with priority (Pm) equal to, or greater than, the stacked transmit priority (Sx) and a token is received with priority (P) equal to the stacked transmit priority (Sx), the following actions are taken. The token is changed to a start of frame by changing the T bit from ZERO to ONE., the Sx popped from the stack, timer TRR reset and a transition made to State 4. If there is no Sx value stacked, the test P=Sx is considered being false.

4.2.2.2. State 1 : TX DATA FR (Transmit Data Frame(s))

While in this state, the DTE transmits one or more frames. The first and all subsequent PDUs that are transmitted must have a Pm equal to, or greater than, the priority of the token that was used. On the receive side, as noted in the Receive Action Table, the DTE is monitoring the receive data for the value of the priority and reservation bits, its DTE address, which was transmitted in the source address field, and the ending delimiter.

(11) Abort State 1 - Error Recovery Action

If after changing a token to a start of frame, the DTE detects that the token did not end properly (with RRR, JK1JK1) or if a Beacon, Purge or Claim Token frame is received, or if an error has occurred within the DTE, the transmission is terminated immediately with an Abort Sequence and transition is made to State 0.

(12) End of Frame Transmission

If the transmission of the PDU is completed and there are no more PDUs to transmit at this priority or above (QUEUE_EMPTY) or if transmission of an additional frame could not be completed before THT expires (TEST_THT), the ED and FS are transmitted, timer TRR reset and transition made to State 2.

4.2.2.3. State 2 : TX FILL & AWAIT MA (Transmit Fill and Await My Address)

If a source address equal to the DTE's address has not been received (i.e. MA_FLAG = 0) the DTE will transmit fill until MA_FLAG = 1 or TRR expires. If upon entering State 2 MA_FLAG is already set to ONE no fill will be transmitted and transition will be made directly to State 3, via transitions 21, 22 or 23.

(21) Token Transmission, Same Priority

If both the stored value Rr and a queued PDU priority (Pm) are less than, or equal to, the stored value Pr, a token is transmitted with the P equal to Pr and R equal to the greater of Rr or Pm and transition made to State 3.

(22) Token Transmission, Higher Priority and Pr>Sx

If the Rr or an enqueued PDU priority (Pm) is greater than the Pr, and the stacked priority (Sx) is less than the received priority (pr), a token is transmitted with the P equal to the greater of Rr or Pm and R equal to ZERO. Pr is stacked as Sr and P is stacked as Sx and a transition made to State 3. If there is no Sx value stacked, the test Pr>Sx is considered being true.

(23) Token Transmission, Higher Priority and Pr = Sx

If the Rr or an enqueued PDU priority (Pm) is greater than the Pr, and the stacked priority (Sx) equals the received priority (Pr), a token is transmitted with the P equal to the greater of Rr or Pm and R equal to ZERO. Sx is popped from the stack and a new value P is stacked as Sx and a transition made to State 3. If there is no Sx value stacked, the test Pr=Sx is considered being false.

4.2.2.4. State 3 : TX FILL & STRIP (Transmit Fill and Strip)

(31) Strip Complete

In this state, fill will be transmitted until at least a portion of the last frame transmitted is received. This stripping action may continue up to the receipt of the Frame Status field of the last transmitted frame or until TRR expires, which ever occurs first. If upon entering State 3 TRR has already expired no fill will be transmitted, and transition will be made directly to State 0.

The method employed to determine which frame is the last frame in a multi-frame transmission is not specified by this Standard. Various methods may be employed such as time outs, counting frames, or utilization of the I bit in the ED to distinguish the end of an intermediate frame from the ending of the last frame transmitted.

4.2.2.5. State 4 : TX ZEROS & MOD STACK (Transmit ZEROs and Modify Stack)

A continuous string of ZEROs is transmitted immediately following the AC of the frame until the internal logic of the DTE can perform the necessary functions to transmit a token.

(41) Reservation Request > Stack

If Rr is greater than the stacked Sr, a token with its priority P set to Rr and its reservation R set to ZERO is transmitted, P is stacked as Sx and a transition made to State 3.

(42) Reservation Request < Stack

If Rr is equal to, or less than, the stacked Sr, a token with P equal to Sr and an R equal to Rr is transmitted, Sr is popped from the stack and transition is made to State 3.

(43) Token Recognition Error

If after changing a token to a frame, the DTE detects that the token did not end properly (with RRR, JK1JK1), the transmission is terminated immediately with an Abort Sequence, Pr is stacked as Sx and transition is made to State 0.

4.2.3. Monitor Specification

The function of the monitor is to recover from various error situations such as no token circulating, persistently circulating priority token, and persistently circulating frame.

In normal operation there is only one active monitor in a ring at any point in time.

The operation of the monitor is explained as follows :

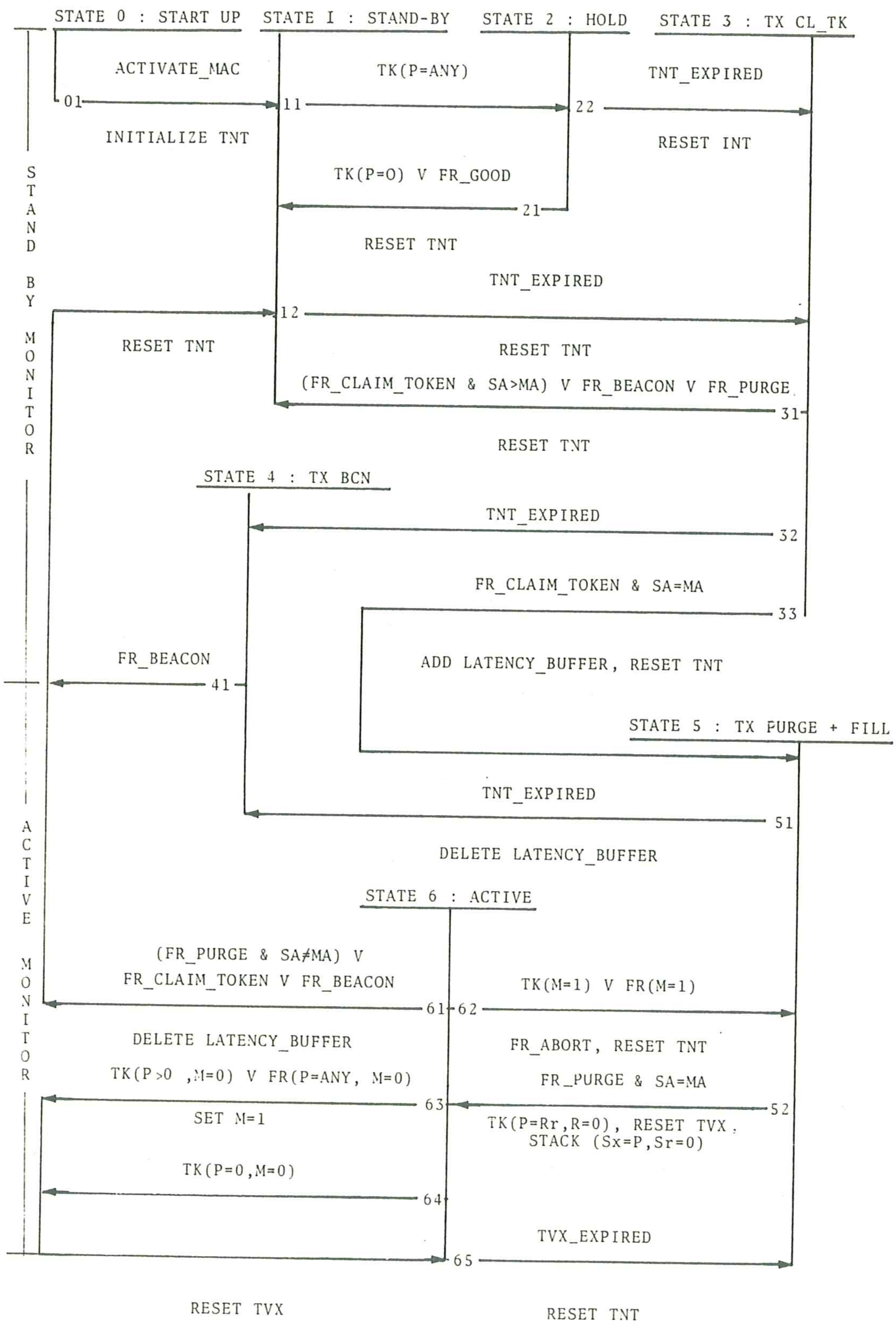


Fig. 6 Monitor Finite-State Machine Diagram

4.2.3.1. <u>State 0 : Start Up</u>

<u>(01) Activate</u>

Upon powering up and activation of MAC, timer TNT is initialized and transition made to State 1.

4.2.3.2. <u>State 1 : Stand-By</u>

In this state the monitor is in stand-by mode and monitoring the ring to ascertain that there is a properly operating active monitor on the ring. It does so by observing the tokens and frames as they are repeated on the ring. If there are no tokens or frames, or only frames, or only priority tokens rotating on the ring the stand-by monitor will timeout and initiate claiming token as follows.

<u>(11)</u>

Any token, regardless of the priority, will cause a transition to State 2.

<u>(12)</u>

However, if no token has been seen for period TNT the timer will expire and transition will be made to State 3 after resetting TNT.

4.2.3.3. <u>State 2 : Hold</u>

<u>(21)</u>

If either a token with a priority of ZERO or a good frame is received transition will be made back to State 1 after resetting TNT.

<u>(22)</u>

However, if TNT expires, timer TNT will be reset and transition will be made to State 3.

4.2.3.4. State 3 : TX Claim_Token (Transmit Claim Token)

In this state, Claim Token MAC Supervisory frames are transmitted.

(31)

If a Claim Token frame is received in which the source address is greater than the DTE's address or a Beacon MAC Supervisory frame or Purge MAC Supervisory frame is received timer TNT is reset and transition made to State 1.

(32)

However, if TNT expires transition is made to State 4.

(33)

Or, if the DTE receives a Claim Token frame with a source address equal to the DTE's address, the bid for active monitor has been won. The latency buffer is inserted in the ring, TNT reset and transision made to State 5.

4.2.3.5. State 4 : TX BCN (Transmit Beacon)

(41)

Beacon MAC Supervisory frames will continue to be transmitted until Beacon frames are received at which time TNT is reset and transition made to State 1.

4.2.3.6. State 5 : TX Purge + Fill (Transmit Purge + Fill)

In this state one Purge frame followed by Fills is transmitted until one of the following events occurs.

(51)

If TNT expires while waiting for receipt of the DTE's source address (transition 52), the latency buffer is deleted and transition is made to State 4.

(52)

If the DTE receives a Purge frame the Source Address of which equals the DTE's address, a token is transmitted with P equal to Rr and R equal to ZERO, P is stacked as Sx and a ZERO is stacked as Sr, timer TVX is reset and transition made to State 6.

4.2.3.7. State 6 : Active

(61)

If a Purge frame with an address not equal to the monitor's address or a Claim Token or Beacon frame is received, the latency buffer is deleted, TNT reset, and transition made to State 1.

(62)

If a frame or a token is received with the M bit set to ONE the frame is aborted, TNT reset and transition made to State 5.

(63)

The M bit is set to ONE on a token the M bit of which is set to ZERO and the priority of which is greater than ZERO or a frame the M bit of which is set to ZERO, and timer TVX reset.

(64)

Receipt of a token the M bit of which is set to ZERO and the priority of which is ZERO will cause timer TVX to be reset.

(65)

If TVX expires, TNT is reset and transition made to State 5.

4.2.4. Relationship of Operational and Monitor FsMs

When the monitor FSM enters State 3, 4 or 5 (Transmit Claim Token, Transmit Purge or Transmit Beacon) activity of the Operational FSM is suspended. Upon exiting States 3 or 4 to Monitor State 1

(Stand-by) or exiting State 5 to Monitor State 6 (Active) activity of the Operational FSM shall be resumed in Operational State 0 (Repeat).

5. MEDIUM ACCESS CONTROL SERVICE SPECIFICATIONS

5.1. Medium Access Control-To-Logical Link Control Sublayer

This section specifies the services provided by the MAC sublayer to the LLC sublayer.

5.1.1. Overview

The Services provided by the MAC sublayer allow the local LLC sublayer entity to exchange LLC PDUs with peer LLC sublayer entities.

5.1.1.1. Interactions

The primitives are :

MA_DATA.request	(mandatory)
MA_DATA.response	(optional)
MA_DATA.indicate	(mandatory)
MA_RESET.request	(optional)
MA_RESET.response	(optional)

5.1.1.2. Basic Services and Options

The Service primitives are mandatory or optional as indicated above.

5.1.2. Specifications

The primitives and parameters are specified in an abstract sense and specify the information that will be available to and from the receiving sublayer.

5.1.2.1. MA_DATA.request

Function

This is to transfer data from a local LLC sublayer to one or more peer LLC sublayer entities.

Semantics

MA_DATA.request <destination address, m_sdu>

<destination address> may specify either an individual or a group MAC address.

<m_sdu> specifies the MAC service data unit to be transmitted by the MAC sublayer.

When Generated

Generated by the LLC sublayer to request transmission of a frame.

Effect on Receipt

The MAC sublayer will append the MAC sublayer specified fields and pass it as a properly formed frame to the physical layer for transmission to the peer MAC sublayer entity or entities.

5.1.2.2. MA_DATA.response <transmission status>

<transmission status> indicates to the LLC sublayer the success or failure of the MA_DATA. request. The types of failure that is associated with this primitive is implementation dependent.

When Generated

Generated is response to a MA_DATA.request.

Effect on Receipt

Unspecified.

5.1.2.3. MA_DATA.indicate

Function

This is to transfer data from a local MAC sublayer to the LLC sublayer.

Semantics

MA_DATA.indicate < destination_address, source_address, m_sdu >

< destination_address > may be either a individual or group address.

< source_address > the source address in the incoming frame.

< m_sdu > indicates the MAC service data unit.

When Generated

To indicate to the LLC sublayer the reception of frame.

Effect on Receipt

Unspecified.

5.2. Medium Access Control Sublayer-To-Physical Layer

This section specifies the services provided by the MAC sublayer to the Physical Layer.

5.2.1. Overview

Described below are the services provided by the Physical Layer. They are for the transmission and reception of symbols, each with a duration of one bit-period.

5.2.1.1. Interactions

The primitives are :

PHY.request
PHY.indication
PHY.response

PHY.request is used to put a symbol on the medium.

PHY.indication is used to indicate the reception of a symbol and timing information from the medium.

PHY.response conveys to the MAC sublayer timing information and acknowledgment of the previous PHY.request.

5.2.1.2. Basic Services and Options

All services are required in all implementations.

5.2.2. Specifications

The primitives and parameters are specified in an abstract sense and specify the information that will be available to and from the receiving layer.

5.2.2.1. PHY.request

Function

This is to request service.

Semantics

PHY.request < symbol >

< symbol > may specify one of the following :

0 = Binary Zero, 1 = Binary One, J = Non-data-J,
K = Non-Data-K.

When Generated

The MAC sublayer is telling the physical layer that a specific symbol is to be transmitted.

Effect on Receipt

The physical layer encodes and transmits the symbol. It then signals its acceptance with a PHY.response.

Constraints

On rings, J and K symbols are always requested in pairs and occur only in delimiters. The first six symbols of those frame delimiters are either :

J K 0 J k 0 or J K 1 J K 1

Additional Comments

The response to this request is a timed response made once per transmit bit-period. Consequently, it is repeated only once per transmit bit-period.

5.2.2.2. PHY.indication

Functions

This is for service indication

Semantics

PHY.indication < symbol >

< symbol > specifies one of the following :

0 = Binary ZERO, 1 = Binary ONE, J = Non-Data-J, K = Non-Data-K.

When Generated

To indicate the symbol received.

Effect on Receipt

Unspecified.

Additional Comments

This indication is a timed indication made once per receive bit-period. Consequently, it is only repeated once per receive bit-period.

5.2.2.3. PHY.response

Function

This is for service response.

Semantics

PHY.response < acceptance status >

< acceptance status > indicates the success or failure of the execution of the request.

When Generated

In response to a PHY.request.

Effect on Receipt

If the received status was active, then the MAC sublayer can make another request within the next bit-period.

Additional Comments

Active indicates that the symbol was transmitted. It does not imply reception.

5.3. Medium Access Control Sublayer-To-Network Management

This section specifies the service provides at the boundary between the Network Management and the MAC sublayer. Use of the service primitives if for further study.

5.3.1. Overview

This section describes informally the MAC sublayer to Network Management services.

5.3.1.1. Local Administrative Services

These services are for :

- resetting the MAC entity and selecting the MAC entity's MAC sublayer address,
- specifying the time constants appropriate for the network,
- determining if the MAC sublayer should be a member of the ring, and if the corresponding Physical Layer should be connected to the medium,
- getting error statistics.

5.3.1.2. Connectionless Data Transfer Service

This service if for the network management to perform MAC sublayer management functions without establishing a point-to-point connection.

5.3.2. Specification

The primitives and their parameters are specified in an abstract sense. Specified is the information that must be available to the receiving entity. There are non constraints in the method of making this information available. The MAC sublayer may also provide local response mechanisms for all request type primitives. The basic services are :

MA_INITIALIZE_PROTOCOL.request
MA_INITIALIZE_PROTOCOL.response

MA_GO_ON_LINE.request
MA_GO_ON_LINE.response
MA_GO_OFF_LINE.request
MA_GO_OFF_LINE.response

MA_ERROR_REPORT.request
MA_ERROR_REPORT.response

MA_CDATA.request
MA_CDATA.indication
MA_CDATA.response

5.3.2.1. MA_INITIALIZE_PROTOCOL.request

Function

This is to request protocol initialization. It also serves as a RESET for the entire MAC sublayer.

Semantics

MA_INITIALIZE_PROTOCOL.request < individual_MAC_address, Group_MAC_address >

< Individual_MAC_Address > is the octet string the MAC sublayer will use as its individual address.

< Group_MAC_address > is the octet string the MAC sublayer will use as its group address.

When Generated

Network management wants the MAC sublayer to reset and reconfigure.

Effect on Receipt

The MAC sublayer will reset, establish its individual and/or group MAC sublayer address, select the desired protocol, and generate a MA_PROTOCOL_INITIALIZE.response.

5.3.2.2. MA_INITIALIZE_Protocol.response

Function

This is the response for protocol initialization.

Semantics

MA_INITIALIZE_PROTOCOL.response < status >

< status > indicates the success or failure of the initialization request.

When Generated

After the MAC sublayer has processed an MA_INITIALIZE_PROTOCOL.request.

Effect on Receipt

Unspecified.

5.3.2.3. MA_GO_ON_LINE.request

Function

The network management uses this to specify that the MAC sublayer should be a member of the ring.

Semantics

MA_GO_ON_LINE.request.

When Generated

To request that the MAC sublayer take the actions necessary for ring membership.

Effect on Receipt

The MAC sublayer records the status and, if different from its current status, takes appropriate action.

Additional Comments

Only the MAC sublayer's actual ring membership condition is affected.

5.3.2.4. MA_GO_ON_LINE.response

Function

This is the response for a request to go on line.

Semantics

MA_GO_ON_LINE.response < status >

< status > indicates the success or failure of the request.

When Generated

In response to a MA_GO_ON_LINE.request.

Effect on Receipt

Unspecified.

5.3.2.5. MA_GO_OFF_LINE.request

Function

The network management uses this to specify that the MAC sublayer should disconnect from the ring.

Semantics

MA_GO_OFF_LINE.request

When Generated

Passed from the network management to the MAC sublayer to disconnect the DTE from the ring.

Effect on Receipt

The MAC sublayer takes appropriate action.

Additional Comments

Only the MAC's ring membership is affected.

5.3.2.6. MA_GO_OFF_LINE.response

Function

This is in response to the request to go off line.

Semantics

MA_GO_OFF_LINE.response < status >

< status > indicates the success or failure of the request.

When Generated

In response to a MA_GO_OFF_LINE.request.

Effect on receipt

Unspecified.

5.3.2.7. MA_ERROR_REPORT.request

Function

This is for requesting error statistics.

Semantics

MA_ERROR_REPORT.request

When Generated

The network management wants the MAC sublayer's error statistics.

Effect on Receipt

The MAC sublayer generates an MA_ERROR_REPORT.response.

5.3.2.8. MA_ERROR_REPORT.response

Function

This is for error statistics reporting.

Semantics

MA_ERROR_REPORT.response < error_report >

< error_report > specifies the error statistics. Details are implementation specific.

5.3.2.9. MA_CDATA.request

Function

To request a connectionless data transfer service of the MAC sublayer.

Semantics

MA_DATA.request < request_class, special-control,
access_control, destination_address,
source_address, m_sdu >

< request_class > determines which request class governs transmissions.

< special_control > specify the generation of special symbol sequences. Typical examples might be token or abort delimiters. It may also invoke special frame actions, such as not appending an FCS to the frame (for FCS logic-test purposes). The specifics of this parameter are implementation defined.

< access_control > specifies any value for the frame's AC (access control) octet. It is recommended that the values specified be different from those used in the operational protocols.

< destination_address > may specify either an individual or a group MAC sublayer address.

< m_sdu > specifies the MAC service data unit to be transmitted.

When Generated

The network management wants the MAC sublayer to compose and transmit a specific symbol sequence.

Effect on Receipt

The MAC sublayer composes and transmits the frame as specified.

5.3.2.10. MA_CDATA.indication

Function

This is the indication of a connectionless data transfer service.

Semantics

MA_CDATA.indication < request_class,
special_status, access_control,
destination_address,
source_address, m_sdu >

< request_class > reports which request class governed transmission.

< special_status > specifies any special attribute of the received frame, such as invalid_FCS, etc. The specifics of this parameter are implementation determined.

< access_control > is the AC (access control) octet received.

< destination_address > and < source_address > specify the DA and SA fields received.

< m_sdu > is the MAC service data unit received.

When Generated

The MAC sublayer passes this to the network management after receiving a frame. In general, such frames are reported only when their destination address designates the local MAC sublayer. However, specific implementations may use this mechanism to report any or all frames.

Effect on Receipt

Unspecified.

5.3.2.11. MA_CDATA.response

Function

This is the response to a connectionless data transfer service request.

Semantics

MA_CDATA.response < request_class, status >

< request_class > is the request class used for transmission.

< status > indicates the status of the previous MA_CDATA.request.

When Generated

To indicate the status of the previous transfer request.

Effect on Receipt

Unspecified.

Additional Comments

Success indicates that the previous < m_sdu > was transmitted. It does not imply reception.

6. PHYSICAL LAYER

The following sections define Physical Layer 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 DTE or a separate unit.

6.1. Symbol Encoding

The Physical Layer encodes and transmits the four symbols presented to it at its MAC interface by the MAC sublayer.

The symbols exchanged between the MAC and PHY layers 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.

The symbols are transmitted to the medium in the form of Differential Manchester coding which is characterized by the transmission of two line signal elements per said 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 (i.e., the symbol duration is equal to the reciprocal of the data signalling rate, including tolerances), 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 :

- the resulting signal has no DC component and can readily be transformer or capacitively coupled and

- the forced "mid-bit" transition conveys inherent timing information on the channel.

In the case of Differential Manchester coding, the sequence of line signal element polarities is completely dependent on the polarity of the trailing signal element of the previously transmitted data or non-data symbol (bit). 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. Il this case, there is no transition at the bit (symbol) boundary.

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 element of the symbol and there is therefore no mid-bit transition. 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. In addition, as previously noted in Section 4, two consecutive J symbols may be transmitted under abnormal circumstances). Refer to Figure 7 for an example of symbol encoding.

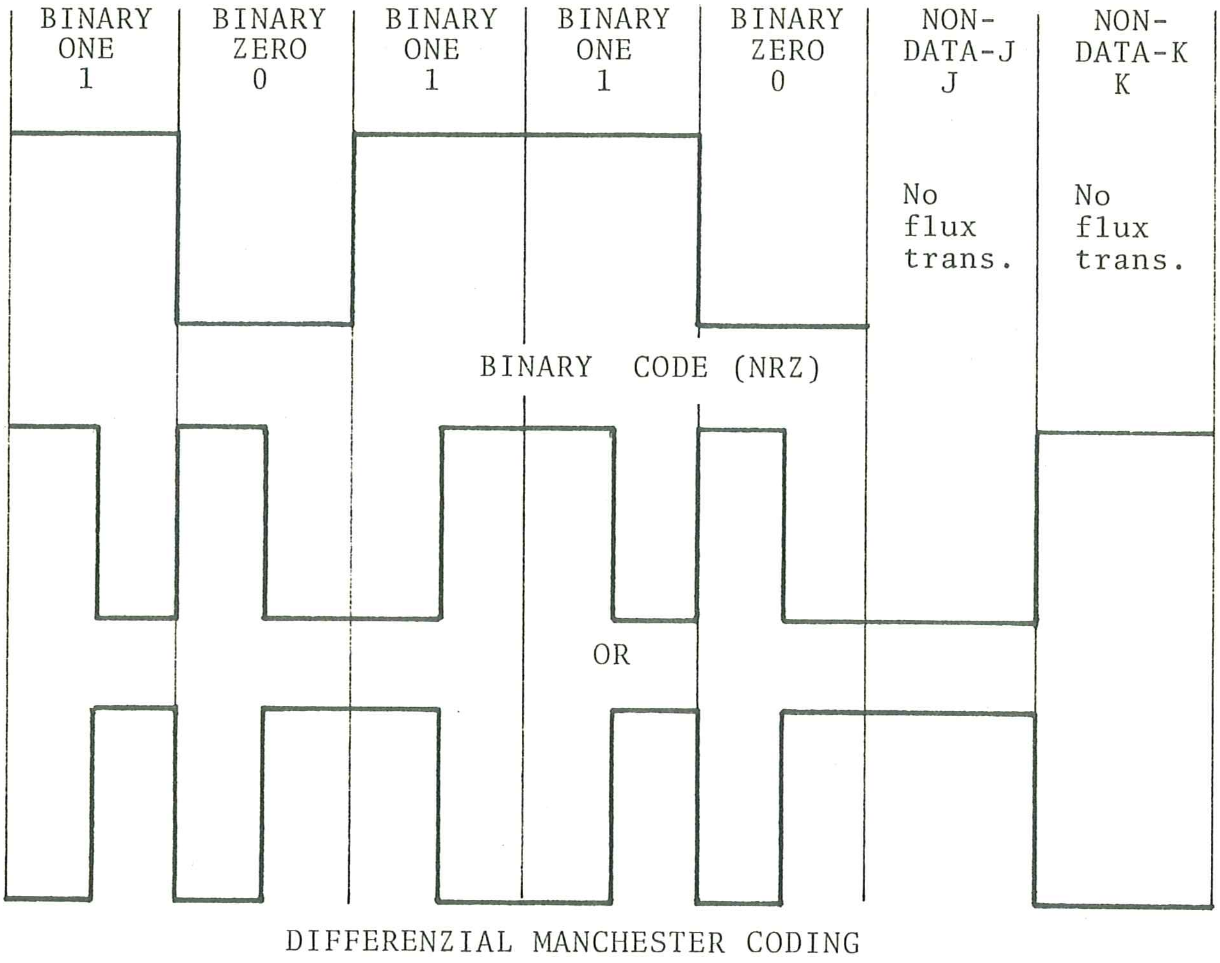


Fig. 7 Example of Symbol Encoding

6.2. Symbol Decoding

Received symbols shall be decoded using an algorithm which is the inverse of the one described for symbol encoding and the decoded symbols are presented at the PHY to MAC interface.

During periods of loss of clock synchronization, under-run or over-run of the latency buffer, the Physical Layer will present the symbol J at the MAC interface.

6.3. Data Signalling Rates

The Physical Layer, when operating with a shielded, twisted pair Medium Interface Cable will transmit data at signalling rates of 1 or 4 Mbit/s with a tolerance of ±0,01%.

6.4. Symbol Timing

The Physical Layer shall recover the symbol timing information inherent in the transitions between levels of the received signal. It shall minimize 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 plase with the receive signal.

There is one DTE on the ring that is the active monitor. All other DTEs on the ring are frequency and phase-locked to this DTE. They extract timing from the received data by means of a phase-locked loop. The phase-locked loop design shall meet the following requirements :

1. Il shall limit the dynamic alignment jitter at any DTE in the ring to 3-sigma value of 10^{o}.

2. Whenever a DTE is inserted into the ring or loses phase lock with the upstream DTE, it shall, upon receipt of a signal which is within specification, (re)acquire phase lock within 1,5 ms.

3. It shall accommodate at least 250 repeaters on the ring.

4. It shall operate with a receive signal as specified in Section 7.

5. It shall operate with a jitter power spectral density of 2,5 X 10^{-25} 5^{2}/Hz which may have been added by the medium interface cable and medium, to the output of the upstream DTE.

6.5. The Latency Buffer

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

The ring protocol requires that a token is able to circulate around the ring continuously until it is seized by a DTE which needs to transmit. A DTE which is transmitting cannot repeat any signals appearing at its input. It is therefore imperative that the leading signal elements of a transmitted token not return (around the ring) to the source until the source has completed the transmission and has entered repeat mode since the transmission would otherwise be mutilated. The latency of the ring (i.e., time, expressed in number of bits transmitted, for a signal element to proceed around the entire ring) must then be, at least, equal to the number of bits in the token, viz. 24. Since ring latency varies from one system to another and no a priori knowledge is available, a buffer of at least 24 bits is provided to guarantee a minimum ring latency to protect the token.

The phase-locked loops (PLLLs) which recover timing information at the individual DTEs around the ring are oscillators which track the frequency and phase of an incoming signal. Therefore, while the mean data signalling rate around the ring is controlled by a crystal oscillator, segments of the ring can, instantaneously, operate at speeds slightly higher or lower than this crystal frequency. This creates no problem on the ring since each receiver PLL tracks the PLL of its upstream DTE and the slight variations go unnoticed.

However, the ring closes at the active monitor where the crystal oscillator is located. The cumulative variations in speed are sufficient to cause effective variations of up to ± 3 bits in the latency of the ring on a continuing basis. Since the active monitor also contains a phase-locked loop to recover timing from the received data, no difficulty is experienced in receiving the incoming data correctly, but since it uses the crystal oscillator to transmit, certain bits would be dropped (not retransmitted) or others duplicated if corrective action were not taken.

The corrective action is to add elasticity to the latency buffer. An elastic buffer with a length of 6 bits (12 signal elements) is added to the fixed 24-bit buffer. The resulting 30-bit buffer is initialized to 27 bits. If the received signal is slightly faster than the crystal, the buffer will expand, as required, to 28, 29 or 30 bits to avoid loss of data. If the received signal is slow, the buffer will contract to 26, 25 or 24 bits to avoid duplication of data. Since the mean received data rate is controlled by the crystal, the mean buffer length will be 27 bits.

6.6. Reliability

The Physical Layer of each DTE shall be designed such that the mean time between failure of any repeater which causes cessation of normal ring operation shall be at least one million hours.

6.7. Electromagnetic Susceptibility

Sources of interference from the environment include, but are not limited to, electromagnetic fields, electrostatic discharge and transient voltages between earth connections.

The DTE hardware shall meet its specifications when operating in the following electromagnetic fields : -

- ambient plane wave field of -

  2 V/m from 10 kHz to 30 MHz
  5 V/m from 30 MHz to 1 GHz.

- interference voltage of 0,25 V/ns to 1 V/ns peak slope, between the Medium Interface Cable shield and the DTE earth connection; e.g. 3,95 V to 15,8 V peak at a frequency 1% different from the data signalling rate.

7. DTE ATTACHMENT SPECIFICATIONS - SHIELDED TWISTED PAIR

7.1. Scope

This section specifies the functional, electrical and mechanical characteristics of balanced, baseband, shielded twisted pair attachement to the Trunk Cable medium of a token ring network.

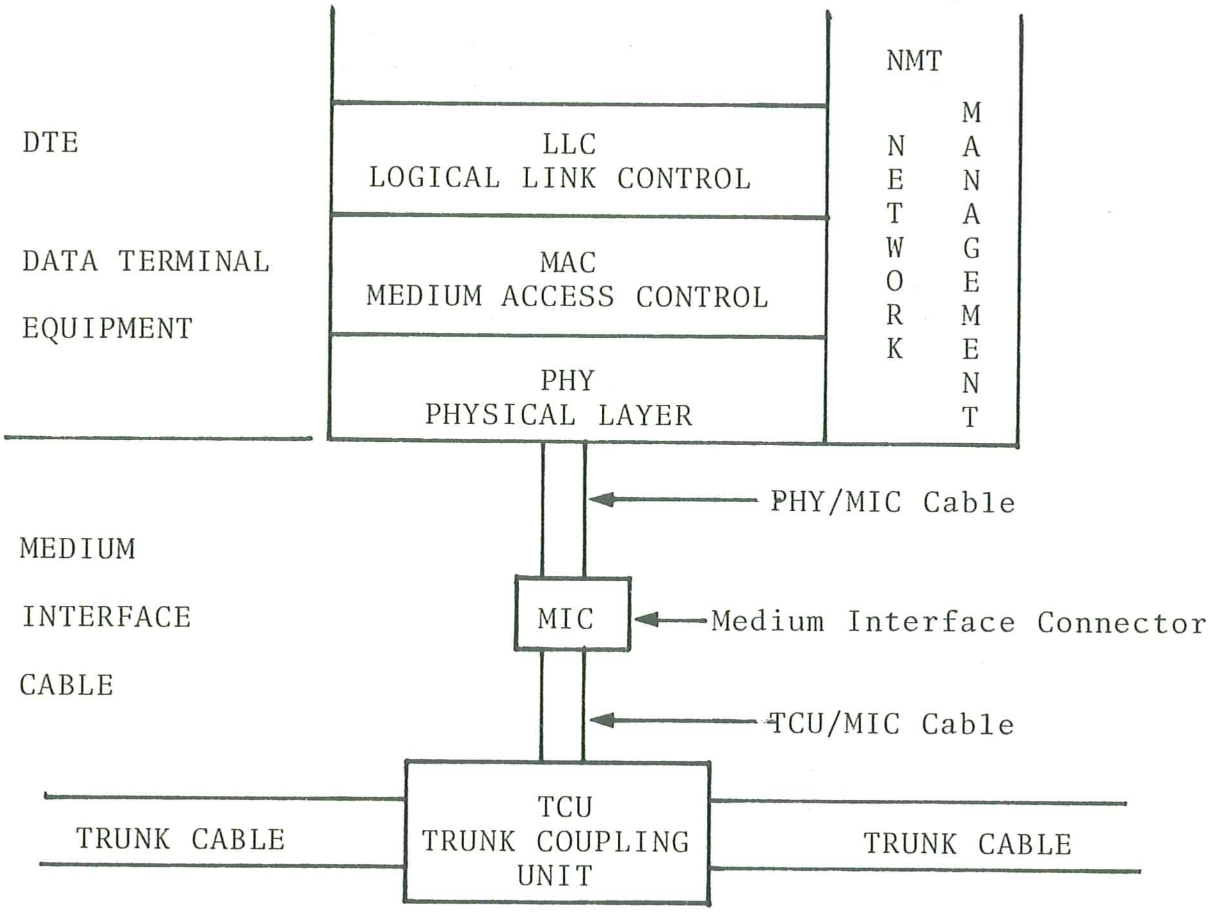


Fig. 8 Partitioning of the Physical Layer and Medium

7.2. Overview

The function of the Trunk Cable medium is to transport data signals between successive DTEs of a baseband ring local area network. This communications medium consists of a set of Trunk Coupling Units (TCUs) containing the insertion/by-pass functional units interconnected sequentially by Trunk Cable links. Each insertion/by-pass unit is connected to a Medium Interface Cable to which a DTE may be connected. The relationship between these embodiments and the LAN model shown in Figure 8.

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 repeaters' receive and transmit functions have the same characteristics as an active DTE on the network and must be included in the count of the number of DTEs supported by the ring.

The Medium Interface Cable shown in Figure 8 may be as shown or may include multiple sections of cable joined by connectors identical to the Medium Interface Connector (MIC). By definition, the MIC at which the transmit and receive signal specifications must be met is the connector designated by the DTE manufacturer and may be attached to the DTE directly or on a cable which is permanently mechanically fixed to the DTE. All wiring done from the TCU to this specified MIC, including wiring from a receptacle to the MIC must be included as part of the medium.

7.3 Coupling of DTE to the Trunk Cable Medium

The Connection of the DTE to the Trunk Cable Medium shall be via shielded cable containing two balanced, 150 Ohm ± 15 Ohm twisted pairs. The DTE transmitter must be able to deliver the specified signal at the MIC, and the DTE receiver must 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 of the DTE to the Trunk Cable Medium is shown in Figure 9.

7.4 Ring Insertion and Bypass Control

DTE insertion into the ring is controlled by the DTE. The mechanism for effecting the insertion or by-pass of the DTE resides in the TCU. The DTE exercises control of the mechanism via the Medium Interface Cable using a phantom circuit technique. Through the phantom circuit a DC voltage is impressed on the Medium Interface Cable. This DC voltage does not affect the symbols transmitted to a TCU from the DTE.

The voltage impressed is used within the TCU to effect a switching action causing the insertion of the DTE into the ring. Cessation of the DC voltage on the phantom circuit causes a switching action which will by-pass the DTE and cause the DTE to be put into a looped ("wrapped") state. This loop may be used by the DTE for off line self testing functions.

The phantom circuit is designed such that the DTE 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 DTE must provide two coils which are isolated but AC signal coupled to each other.

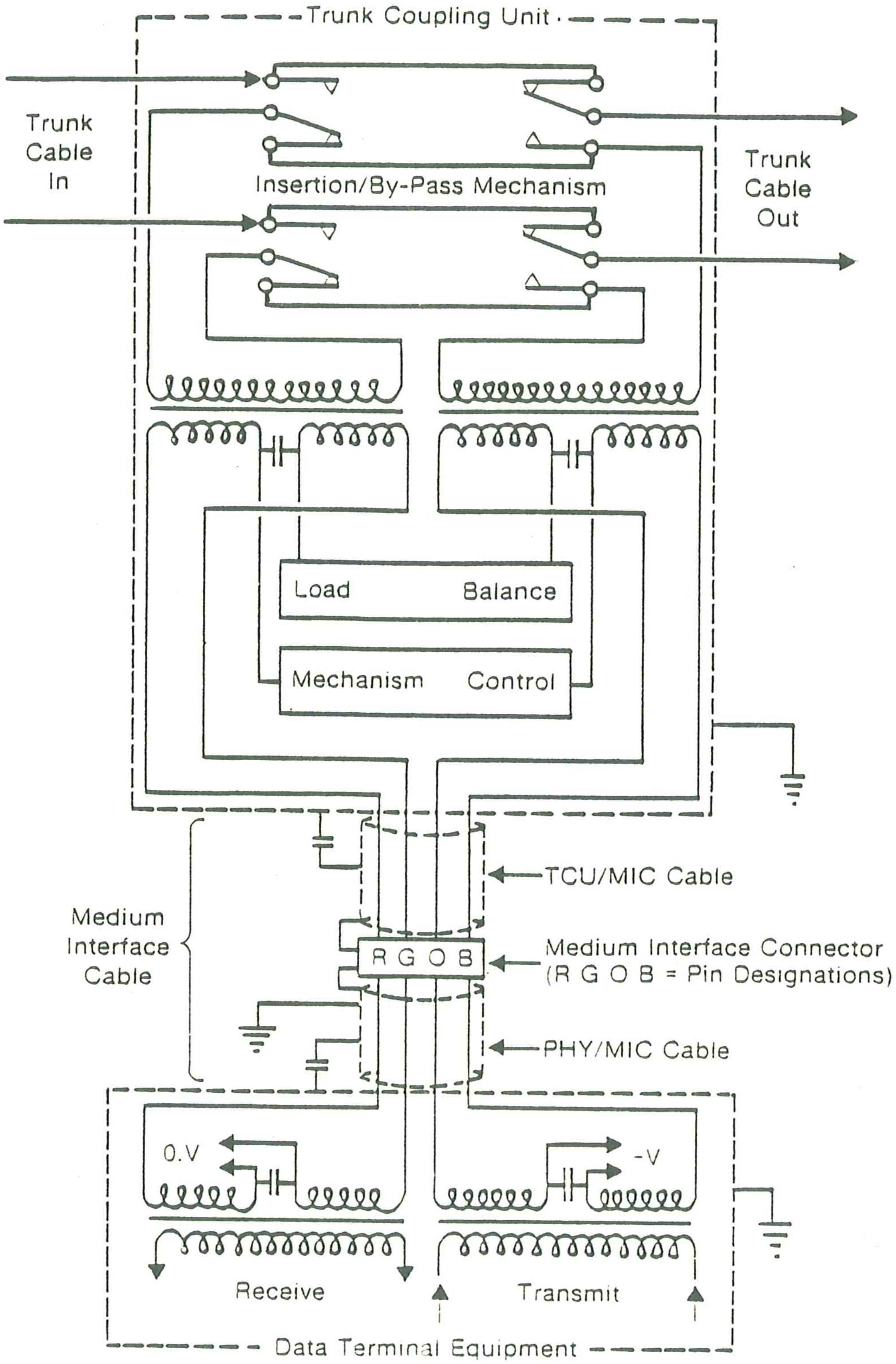


Fig. 9 Example of DTE Connection to the Medium

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

The point of measurement of the voltage and current limits is at the MIC (Medium Interface Connector).

Insertion shall be effected with a voltage of 4,1 V to 7,0 V on MIC pin B and O with return on pin G and R respectively within the current range of 0,65 mA to 2,0 mA.

By-pass shall be effected when a voltage of less than 1 V is present on MIC pin B and O with respect to pins R and G.

A load with a DC resistance within 5% of the insertion/by-pass mechanism resistance shall be presented by the TCU on pins G and O.

The operating voltage supplied by the DTE on MIC pins B and O shall be within 1% of each other over the operating current range of 0,65 mA to 2,0 mA.

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 DTE shall provide means to assure the short circuit current will not exceed 20 mA.

7.4.2 Insertion/By-pass Timing

The insertion/by-pass mechanism will open 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

7.5.1 Transmitted Signals

Data Signalling Rates

The data signalling rates are 1 or 4 Mbit/s. The permitted tolerance for each signalling rate is ± 0,01%.

Signal Jitter

Maximum cumulative deviation of a transmitted signal element transition from the ideal transition (i.e. timing distortion and "jitter") measured at the MIC shall have a 3 sigma value of 10^{o}.

Signal Level

The magnitude of the transmitted signal, measured at the MIC, with a 150 Ohm resistive termination, shall be 3,0 V to 4,5 V, peak-to-peak. The amplitude of the positive and the negative transmitted levels shall be balanced within 5%.

Rise-/Fall Times

During transitions of the transmitted signals between alternating binary states, the differential voltage measured across a 150 Ohm ± 15 Ohm test load at the MIC shall be such that the voltage changes between the 10% and 90% points of the output signal within a time interval which shall not be greater than 25 ns. In addition the harmonic content of the transmitted signal generated by a pattern of all ZEROs or all ONEs shall meet the following requirement:

- 2nd and 3rd harmonics: each at least 10 dB below fundamental
- 4th and 5th harmonics: each at least 15 dB below fundamental
- 6th and 7th harmonics: each at least 20 dB below fundamental
- all higher harmonics : each at least 25 dB below fundamental.

7.5.2 Received Signals

Signal distortion is caused by the cable characteristics; the cable attenuation is proportional to the square root of the frequency.

Note 3 : This characteristic is well known and can be found in many reference text books. Specifically, the form of the characteristic is in Reference Data for Radio Engineers page 574, 4th edition published by ITT).

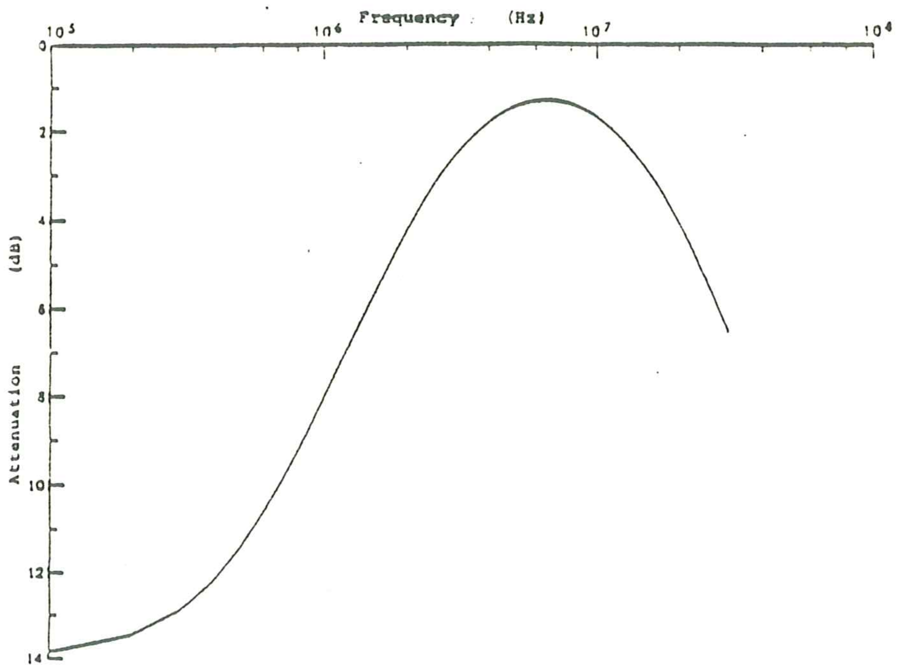


Fig. 10 Receive Filter Characteristics for 4 Mbit/s Operation

In addition, flat (non-distorting) attenuation may be caused by the transmission medium, especially TCUs and connectors. In some configurations the total attenuation may vary from 0 dB to 29 dB at 4 MHz (at 1 MHz for 1 Mbit/s data rate) including flat attenuation not exceeding 26 dB at 4 MHz (at 1 MHz for 1Mbit/s data rate). The total acceptable attenuation may be limited to less than 29 dB based on the actual noise level at the MIC and the required error rate of the LAN. The error rate required of a LAN shall be established by mutual agreement among the users of the LAN.

In order to specify meaningful measurements at the MIC, all received signals and noise will be specified at the output of an equalizing filter. The filter is a 2-pole 1-zero device. For 4 Mbit/s ring operation the filter should have poles at 2,7 MHz and 16 MHz, and zero at 540 kHz each with a tolerance of ± 5%. (For 1 Mbit/s operation, the frequency values are all divided by 4). A plot of the characteristics of the filter is shown in Figure 10.

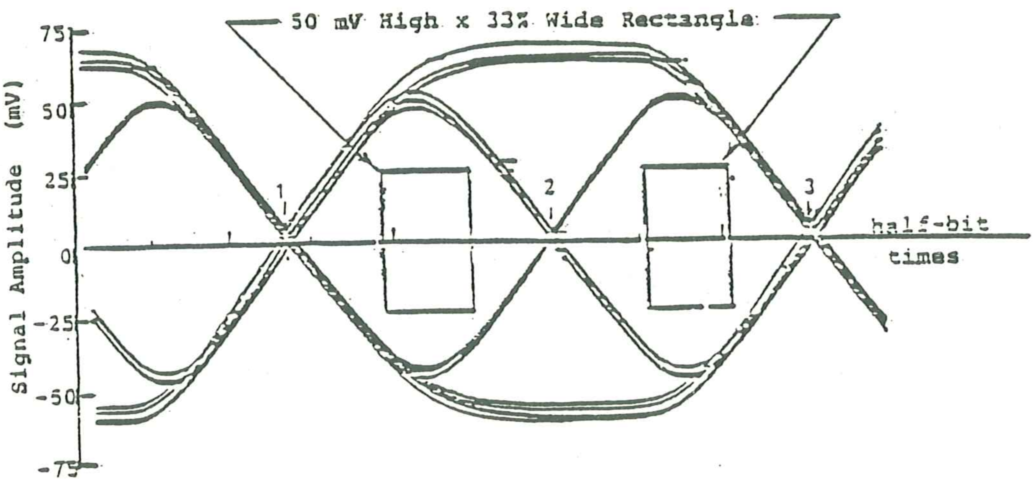


Fig. 11 Receive Signal Eye Pattern

Signal Level

The receive signal at the output of the filter with a 150 Ohm ± 15 Ohm resistive termination shall have at least a magnitude of 25 mV during the central third of the half bit time. Figure 11 is the characteristic "eye" pattern of the received signal when viewed on an oscilloscope. A compliant signal should an opening such that a rectangular area of 50 mV high (2 x 25 mV) and a width of 33% of the half bit time will fit, symmetrically, within the eye as shown in Figure 11.

Error Rate

The DTE shall provide an output with an error rate of $\leq 10^{-9}$ when the S/N (signal-to-noise ratio) at the output of the specified filter is $\geq$ 22 dB S/N, measured in dB, is defined as 10 log (1/2 minimum eye height during the central third of the half bit time divided by RMS noise).

7.6 Medium Interface Connector

Access to the medium shall be via a connector with four contacts plus ground. It shall have self short circuiting ability from pin R to pin O and pin G to pin B for automatic looping capability when the connector is disconnected. The design of the connector shall be hermaphroditic so that two identical units will mate when oriented 180° with respect to each other.

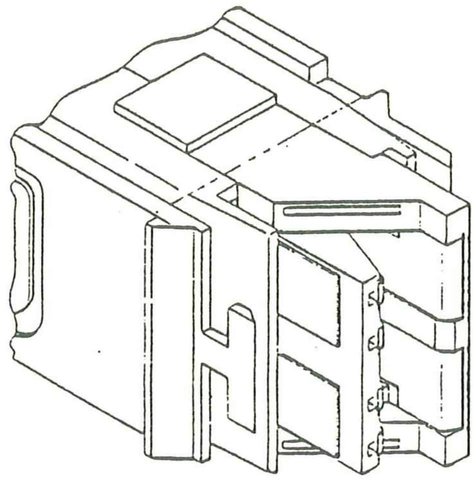
Detail specification of the interface is shown in Appendix A.

7.7 Reliability

The Medium Interface Cable, the Medium Interface Connector and the by-pass mechanism, which comprise the means of connecting the DTE to the Trunk Cable, should be designed to minimize the probability of total network failure. They should be designed to provide a mean time between failure of at least one million hours of operation without causing communication failure among other DTEs attached to the ring.

APPENDIX A

MEDIUM INTERFACE CONNECTOR SPECIFICATION



Shown above is an isometric drawing of the Medium Interface Connector (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.

Section A.1 illustrates the details of the signal and ground contractors. When the connector is disconnected pin R is shorted to pin 0 and pin G shorted to pin B. Section A.2. illustrates the locking mechanism of the connector.

Only those dimensions that are essential to mating are shown.

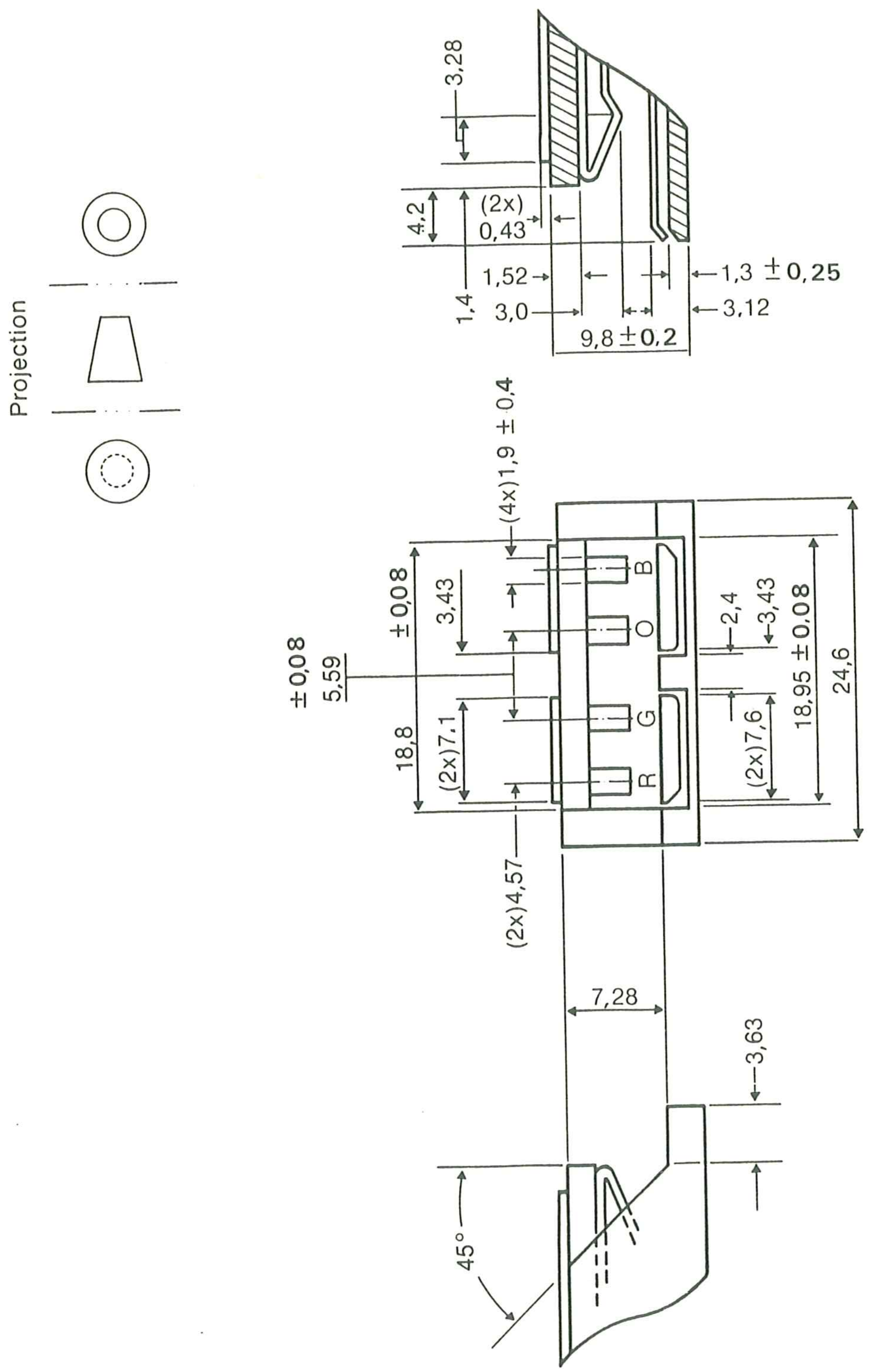
ELECTRICAL CHARACTERISTICS	CONDITION	VALUE
Crosstalk rejection	DC to 4 MHz	> 65 dB
Connector Insertion Loss in a 150 ohm impedance line	DC to 4 MHz	< 0,1 dB

ELECTRICAL CHARACTERISTICS	CONDITION	VALUE
DC contact resistance		
Pins and shield	E ≤ 20mV x	≤ 26 mohm
Self shorting path	E ≤ 20mV x	≤ 60 mohm
x connection according to IEC 130-14		
Carry current		≥ 0,1 A
Voltage proof contact-contact		≥750 V dc

MECHANICAL CHARACTERISTICS	VALUE
Contact force	0,5 - 1,0 N
Insertions	> 2000
Life span	> 15 years

Surface treatment (compatible with the following) :

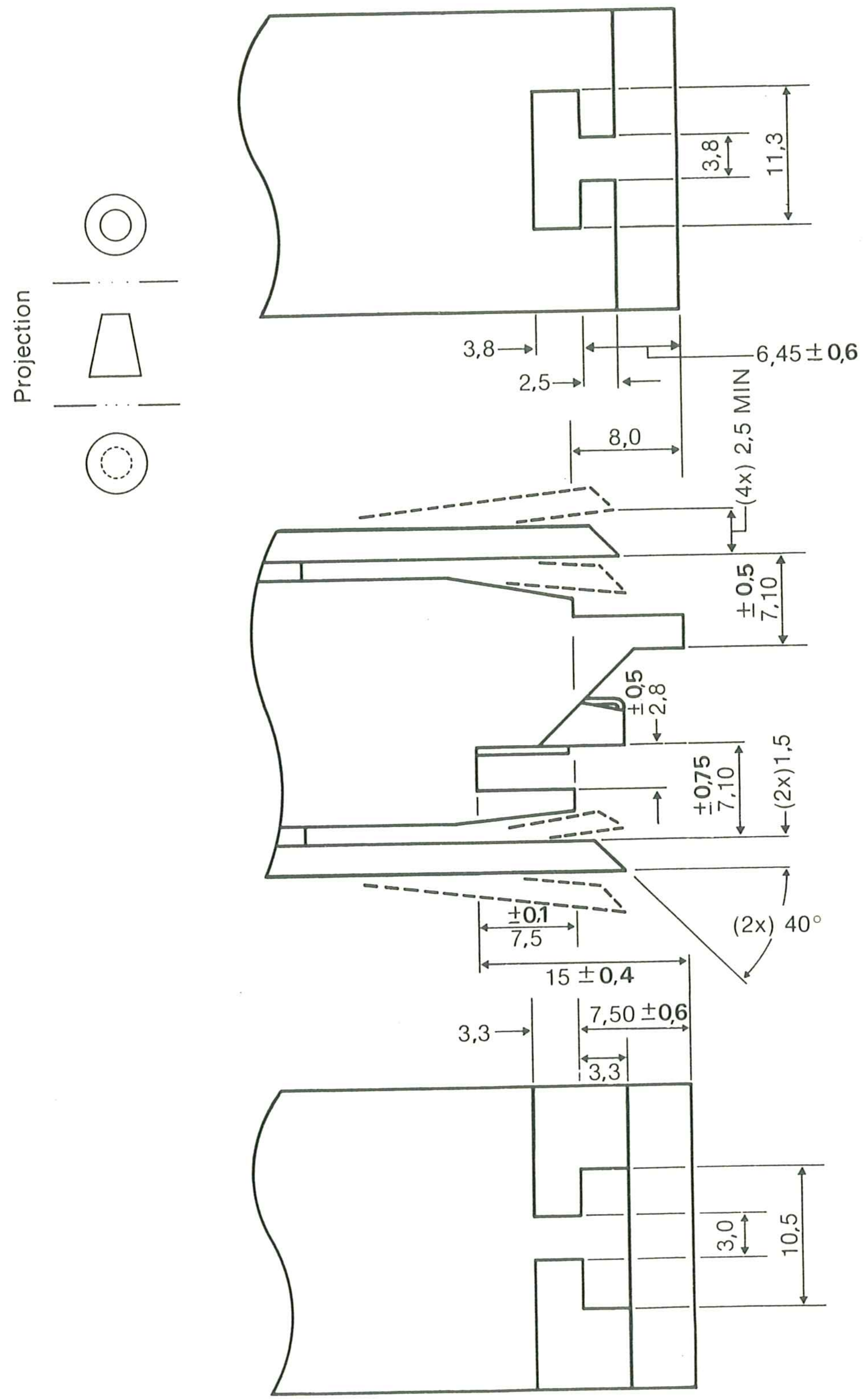
Point of pin contact - Plating with 0,75 um of gold
Point of shield contact - Plating with 0,75 um of tin



- Tolerance ±0,13
Unless Otherwise Specified

- All Dimensions
In Millimeters

- R, G, O & B Are
Pin Designations



Tolerance ±0,13
Unless Otherwise Specified

All Dimensions
In Millimeters