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ISO 9314-2

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Information processing systems — Fibre Distributed Data Interface (FDDI) —

Part 2 :
Token Ring Media Access Control (MAC)

Systèmes de traitement de l'information — Interface de données distribuées sur fibre (FDDI) —

Partie 2 : Mécanisme d'accès au support de l'anneau à jeton (MAC)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 9314-2 was prepared by Technical Committee ISO/TC 97, *Information processing systems.*

ISO 9314 consists of the following parts, under the general title *Information processing systems — Fibre Distributed Data Interface (FDDI) —*

- *Part 1: Token Ring Physical Layer Protocol (PHY)*
- *Part 2: Token Ring Media Access Control (MAC)*
- *Part 3: Token Ring Physical Layer, Medium Dependent (PMD)*

Introduction

This part of ISO 9314 on the FDDI media access control is intended for use in a high-performance multistation network. This protocol is designed to be effective at 100 Mbit/s using a Token ring architecture and fibre optics as the transmission medium over distances of several kilometres in extent.

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Information processing systems - Fibre Distributed Data Interface (FDDI) -

Part 2: Token Ring Media Access Control (MAC)

1 Scope

This part of ISO 9314 specifies the Media Access Control (MAC), the lower sublayer of the Data Link Layer (DLL), for Fibre Distributed Data Interface (FDDI).

FDDI provides a high-bandwidth (100 Mbit/s), general-purpose interconnection among computers and peripheral equipment using fibre optics as the transmission medium in a ring configuration. FDDI can be configured to support a sustained transfer rate of approximately 80 Mbit/s (10 Mbyte/s). It may not meet the response time requirements of all unbuffered high speed devices. FDDI establishes the connection among many stations distributed over distances of several kilometres in extent. Default values for the FDDI were calculated to accommodate rings of up to 1 000 physical links and a total fibre path length of 200 km (typically corresponding to 500 stations and 100 km of dual fibre cable).

FDDI consists of

(a) A Physical Layer (PL), which provides the medium, connectors, optical bypassing, and driver/receiver requirements. PL also defines encode/decode and clock requirements as required for framing the data for transmission on the medium or to the higher layers of the FDDI. For purposes of this part of 9314, references to the PL are made in terms of the Physical Layer entity designated PHY.

(b) A Data Link Layer (DLL), which is divided into two sublayers:

(1) A Media Access Control (MAC) which provides fair and deterministic access to the medium, address recognition, and generation and verification of frame check sequences. Its primary function is the delivery of frames, including frame insertion, repetition, and removal. The definition of MAC is contained in this part of ISO 9314.

(2) A Logical Link Control (LLC) which provides a common protocol to provide the required data assurance services between MAC and the Network Layer.

(c) A Station Management (SMT)[1] which provides the control necessary at the station level to manage the processes under way in the various FDDI layers such that a station may work co-operatively on a ring. SMT provides services such as control of station initialization, configuration management, fault isolation and recovery, and scheduling procedures.

[1] SMT will form the subject of a future part of ISO 9314.

The MAC definition contained herein is designed to be as independent as possible from bo the physical medium and the speed of operation. Concepts employed in ISO 8802-5, dealir with Token Ring MAC operation have been modified to accommodate the higher FDDI speed while retaining a similar set of services and facilities.

ISO 9314 specifies the interfaces, functions, and operations necessary to ensure interoperabili between conforming FDDI implementations. This part of ISO 9314 provides a function description. Conforming implementations may employ any design technique that does n violate interoperability.

2 Normative references

The following standards contain provisions which, through reference in this text, constitu provisions of this part of ISO 9314. At the time of publication, the editions indicated we valid. All standards are subject to revision, and parties to agreements based on this part ISO 9314 are encouraged to investigate the possibility of applying the most recent editions the standards listed below. Members of IEC and ISO maintain registers of currently val International Standards.

ISO 8802-2: ----[1], *Information processing systems - Local Area Networks - Part 2: Logic Link Control (LLC).*

ISO 8802-5: ----[1], *Information processing systems - Local Area Networks - Part 5: Tok Ring Access Method and Physical Layer specification.*

ISO 9314-1: 1989, *Information processing systems - Fibre Distributed Data Interface (FDDI) Part 1: Token Ring Physical Layer Protocol (PHY).*

ISO 9314-3: ----[1], *Information processing systems - Fibre Distributed Data Interface (FDDI) Part 3: Token Ring Physical Layer, Medium Dependent (PMD).*

3 Definitions

For the purposes of this part of ISO 9314, the following definitions apply:

3.1 asynchronous: A class of data transmission service whereby all requests for servic contend for a pool of dynamically allocated ring bandwidth and response time.

3.2 capture: The act of removing a Token from the ring for the purpose of Fran transmission.

3.3 claim token: A process whereby one or more stations bid for the right to initialize tl ring.

3.4 entity: An active functional agent within an Open System Interconnection (OSI) layer sublayer, including both operational and management functions.

3.5 fibre optics: The technology whereby optical signals from light-generating transmitters a propagated through optical fibre waveguides to light-detecting receivers.

[1] To be published.

3.6 frame: A PDU transmitted between co-operating MAC entities on a ring, consisting of a variable number of octets and control symbols.

3.7 Media Access Control (MAC): The Data Link Layer responsible for scheduling and routing data transmissions on a shared medium Local Area Network (e.g., an FDDI ring).

3.8 nonrestricted token: A Token denoting the normal mode of asynchronous bandwidth allocation, wherein the available bandwidth is time-sliced among all requesters.

3.9 octet: A data unit composed of eight ordered bits (a pair of data symbols).

3.10 Physical (PHY): The Physical Layer responsible for delivering a symbol stream produced by an upstream MAC Transmitter to the logically adjacent downstream MAC Receiver in an FDDI ring.

3.11 physical connection: The full-duplex physical layer association between adjacent physical layer entities (in concentrators, repeaters, or stations) in an FDDI ring.

3.12 primitive: An element of the service interface presented by an entity.

3.13 Protocol Data Unit (PDU): The unit of data transfer between communicating peer layer entities. It may contain control information, address information, data (e.g., an SDU from a higher layer entity), or any combination of the three. The FDDI MAC PDUs are Tokens and Frames.

3.14 receive: The action of a station in accepting a Token, Frame, or other symbol sequence from the incoming medium.

3.15 repeat: The action of a station in receiving a Token or Frame from the adjacent upstream station and simultaneously sending it to the adjacent downstream station. The FDDI MAC may repeat received PDUs (Tokens and Frames), but does not repeat the received symbol stream between PDUs. While repeating a Frame, MAC may copy the data contents and modify the control indicators as appropriate.

3.16 restricted token: A Token denoting a special mode of asynchronous bandwidth allocation, wherein the bandwidth available for the asynchronous class of service is dedicated to a single extended dialogue between specific requesters.

3.17 ring: Two or more stations connected by a physical medium wherein information is passed sequentially between active stations, each station in turn examining or copying and repeating the information, finally returning it to the originating station.

3.18 Service Data Unit (SDU): The unit of data transfer between a service user and a service provider.

3.19 services: A set of functions provided by one OSI layer sublayer entity, for use by a higher layer or sublayer entity or by management entities.

3.20 station: An addressable logical and physical attachment in a ring, capable of transmitting, receiving, and repeating information. An FDDI station has one or more PHY entities, one or more MAC entities, and one SMT entity.

3.21 Station Management (SMT): The supervisory entity within an FDDI station that monitors and controls the various FDDI entities including PMD, MAC, and PHY.

3.22 symbol: The smallest signalling element used by MAC, i.e., the PHY SDU. The symt set consists of 16 data symbols and 8 control symbols. Each symbol maps to a speci sequence of five code bits as transmitted by the Physical Layer.

3.23 synchronous: A class of data transmission service whereby each requester preallocated a maximum bandwidth and guaranteed a response time not to exceed a speci delay.

3.24 token: An explicit indication of the right to transmit on a shared medium. On a Tok Ring, the Token circulates sequentially through the stations in the ring. At any time, it may held by zero or one station. FDDI uses two classes of Tokens: restricted and nonrestrictec

3.25 transmit: The action of a station in generating a Token, Frame, or other symt sequence and placing it on the outgoing medium.

4 Conventions and abbreviations

4.1 Conventions

The terms SMT, MAC, LLC, and PHY, when used without modifiers, refer specifically to t local entities. The term LLC unless otherwise qualified refers to any local user of MAC da services, other than SMT, including ISO 8802-2.

Low lines (e.g., requested_service_class) are used as a convenience to mark the name signals, functions, etc., that might otherwise be misinterpreted as independent individual words they were to appear in text.

The use of a period (e.g., MA_UNITDATA.request) is equivalent to the use of low lines exce that a period is used as an aid to distinguish modifier words appended to an antecede expression.

4.1.1 Addressing

my short address (MSA): 16-bit Individual Address of this station (0 = Null).

my long address (MLA): 48-bit Individual Address of this station (0 = Null). If a stati does not implement 48-bit addressing then MLA=0.

short addresses: Set of 16-bit station Addresses including MSA if not Null, the 16-l Broadcast Address (all ones), and any other 16-bit Group Addresses recognized by this statio

long addresses: Set of 48-bit Station Addresses including MLA if not Null, the 48-l Broadcast Address (all ones), and any other 48-bit Group Addresses recognized by tl station.

If a station does not implement 48-bit addressing, then MLA = 0.

When claiming the Token (i.e., the transmitter is in Claim Token state), if the station transm with 16-bit addressing, then MLA = 0; conversely, if the station transmits with 48-l addressing, then MSA = 0.

4.1.2 Timing values and timers:

All timing values are expressed as the unsigned twos complements of the target, or remaining, time in octets, i.e., the numerically greater magnitude represents the shortest time remaining. This definition is for reference purposes only and does not prescribe the implementation, except where these timing values appear in Protocol Data Units on the ring. These timing values are not all used simultaneously in the state machines; consequently, the implementation need not materialize them when they are not needed.

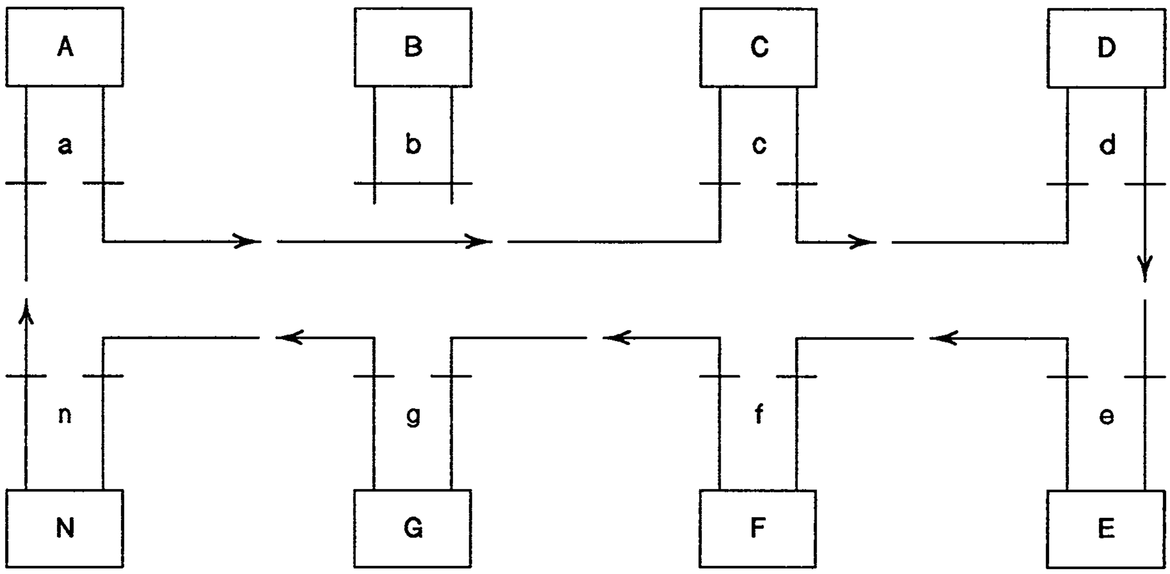
For the purpose of the description contained in this part of ISO 9314, all timers are assumed to be initialized with the unsigned twos complement of the target, or remaining, time in octets. Timers are further assumed to count upward if enabled, expiring when an overflow occurs. All timer comparisons are expressed on the basis of elapsed time. These conventions are only for the convenience of documenting this part of ISO 9314 and do not prescribe implementation.

4.2 Abbreviations

Error_Ct	Count of reportable frame errors
Frame_Ct	Count of all frames received
Late_Ct	Count of TRT expirations (Token Lateness)
Lost_Ct	Count of PDUs detected as lost
A_Flag	Indicates Destination Address match in last received frame
C_Flag	Indicates successful copying of last received frame
E_Flag	Indicates error detected in last received frame
H_Flag	Indicates Higher Source Address received
L_Flag	Indicates Lower Source Address received
M_Flag	Indicates My Source Address received
N_Flag	Indicates next station addressing
R_Flag	Indicates the Token_class of the last valid Token received was restricted
A_Max	Maximum signal acquisition time
D_Max	Maximum ring latency time
F_Max	Maximum frame time
I_Max	Maximum station physical insertion time
L_Max	Maximum Transmitter Frame set-up time
M_Max	Maximum number of MAC entities allowed on the ring
S_Min	Minimum safety timing allowance
T_Bid_Rc	Bidding TTRT received by this station in Claim Frames
T_Bid_Tx	Bidding TTRT transmitted in this station's Claim Frames
T_Init	Ring initialization time
T_Max	Maximum TTRT to be supported by this station
T_Min	Minimum TTRT to be supported by this station
T_Neg	Negotiated TTRT during Claim process (in receiver)
T_Opr	Operative TTRT for this station (in transmitter)
T_Pri	Set of n priority Token rotation time thresholds
T_Pri(n)	Element n of the set T_Pri
T_React	Worst Case time to react to a station insertion or removal
T_Req	Requested TTRT for this station's synchronous traffic
T_Resp	Worst case time to recover a Token
THT	Token-Holding Timer
TRT	Token-Rotation Timer
TTRT	Target Token Rotation Time
TVX	Valid-Transmission Timer

5 General description

A Token ring consists of a set of stations serially connected by a transmission medium form a closed loop (see figure 1). Information is transmitted sequentially, as a stream symbols, from one active station to the next. Each station generally regenerates and repe each symbol and serves as the means for attaching one or more devices to the ring for purpose of communicating with other devices on the ring. A given station (the one that access to the medium) transmits information on to the ring, where the information circula from one station to the next. The addressed destination station(s) copies the information a passes. Finally, the station that transmitted the information effectively removes it from ring.



——Physical Medium   A,B,C,D,E,F,G, ... N - Ring Stations
a,b,c,d,e,f,g ... n - Bypass Function

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

Figure 1 - Token ring configuration example

A station gains the right to transmit its information on to the medium when it detects a To passing on the medium. The Token is a control signal comprised of a unique symbol seque that circulates on the medium following each information transmission. Any station, u detection of a Token, may capture the Token by removing it from the ring. The station n then transmit one or more frames of information. At the completion of its informa transmission, the station issues a new Token, which provides other stations the opportunity gain access to the ring.

A Token-holding timer, or equivalent means, limits the length of time a station may (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. The classes of service may be synchronous (typically used for applications such as real-time voice), asynchronous (typically used for interactive applications), or immediate (used for extraordinary applications such as ring recovery). The allocation of ring bandwidth occurs by mutual agreement among users of the ring.

Error detection and recovery mechanisms are provided to restore ring operation in the event that transmission errors or medium transients (e.g., those resulting from station insertion or removal) cause the access method to deviate from normal operation. Detection and recovery for these cases utilizes a recovery function that is distributed among the stations attached to the ring.

The media access method as specified herein is not intended to place constraints on the logical link control or higher level protocols employed to effect data transfer.

6 Services

This clause specifies the services provided by MAC and the services required by MAC. The intent is to allow higher-level protocol(s) (e.g., ISO 8802-2) to operate correctly with this MAC. How many of the services described in this clause are chosen for a given implementation is up to that implementer; however, a set of MAC services shall be supplied sufficient to satisfy the higher level protocol(s) being used. The services as defined herein do not imply any particular implementation, or any interface. Services described are

(a) MAC services provided to the local LLC entity, or other MAC users (indicated by MA_ prefix).

(b) Services required from the local PHY entity by MAC (indicated by PH_ prefix).

(c) MAC services provided to the local SMT entity (indicated by SM_MA_ prefix).

6.1 MAC-to-LLC services

This subclause specifies the services provided by the Medium Access Control (MAC) to allow the local LLC entity to exchange LLC service data units with peer LLC entities. These services are also used for implementer frames. The following primitives are defined:

MA_UNITDATA.request
MA_UNITDATA.indication
MA_UNITDATA_STATUS.indication
MA_TOKEN.request

The description of each primitive includes a description of the information that is passed between the LLC and MAC entities.

6.1.1 MA_UNITDATA.request

This primitive defines the transfer of one or more Service Data Units (SDUs) from a local LLC entity to a single peer LLC entity, or to multiple peer LLC entities in the case of group addresses.

6.1.1.1 Semantics of the primitive

MA_UNITDATA.request (
FC_value (1),
destination_address (1),
M_SDU (1),
requested_service_class (1),
stream (1),
FC_value (2),
destination_address (2),
M_SDU (2),
requested_service_class (2),
stream (2),
.
.
.
FC_value (n),
destination_address (n),
M_SDU (n),
requested_service_class (n),
stream (n),
Token_class
)

Each set of FC_value, destination_address, M_SDU, requested_service_class and strea parameters specifies one frame for transmission and is referred to as a subrequest.

The FC_value parameter supplies the Frame Control (FC) field to be transmitted as part (the frame.

The destination_address parameter may specify either an individual or a group MAC addres It shall contain sufficient information to create the DA (Destination Address) field that included in the frame by MAC. Address length is determined by the L bit of the associate FC_value parameter (see 7.3.3).

Each M_SDU parameter specifies an LLC service data unit as received at the MAC interfac to be transmitted by MAC. There is sufficient information associated with the M_SDU f MAC to determine the length of the service data unit. Associated with each M_SDU is requested_service_class parameter.

Requested_service_class may be either Synchronous or Asynchronous. If asynchronous, th requested_Token_class and the priority level may optionally be specified.

Stream is a parameter that, if set, shall cause multiple M_SDUs to be transmitted as a resu of the MA_UNITDATA.request. Stream, when reset, indicates that this M_SDU is the last or associated with this MA_UNITDATA.request. The frames shall be transmitted in the ord presented by this primitive regardless of the associated requested_service_class. If TR (Token-Rotation Timer) has expired (Late_Ct not= 0) or if a frame is encountered that cann be transmitted because of its associated requested_service_class and the current value (THT (Token-Holding Timer), then transmission is terminated and a Token is issued as define by the Token_class parameter. A MA_UNITDATA_STATUS.indication is subsequently returne to LLC. If the transmission_status is successful, MAC may initiate transmission of th remaining frames on the next permitted access opportunity or, alternatively, MAC may requi reissuance of a new MA_UNITDATA.request.

Token_class specifies the class of Token that MAC shall issue following transmission of the associated SDUs (i.e., at the end of the request), if no other request is pending that can be honoured. With requests for synchronous service the Token_class shall be the Token_class that was captured; with requests for asynchronous service it may be either restricted or nonrestricted. If no SDUs were specified by the MA_UNITDATA.request, then MAC shall immediately issue the requested class of Token.

6.1.1.2 When generated

This primitive is generated by the local LLC entity whenever data is to be transferred to a peer LLC entity or entities or a Token is to be generated. This may be in response to a request from higher layers of protocol or from data generated internally to LLC.

6.1.1.3 Effect of receipt

The receipt of this primitive shall cause MAC to append all MAC-specific fields, including DA, SA (Source Address), and any fields that are unique to the medium access method, and pass the properly formed frames to the lower layers of protocol for transfer to peer MAC entity or entities.

NOTE - This primitive is the normal means of requesting the transfer of data. The capture of a Token is implicit in this primitive and therefore it is not necessary to issue an MA_TOKEN.request primitive in conjunction with it.

6.1.2 MA_UNITDATA.indication

This primitive defines the transfer of data from MAC to the local LLC entity.

6.1.2.1 Semantics of the primitive

```
MA_UNITDATA.indication          (
                                FC_value,
                                destination_address,
                                source_address,
                                M_SDU,
                                reception_status
                                )
```

The FC_value parameter specifies the value of the frame's FC (Frame Control) field. The destination_address parameter may be either an individual or a group address as specified by the DA field of the incoming frame. The source_address parameter is an individual address as specified by the SA field of the incoming frame. The M_SDU parameter shall specify the MAC service data unit as received by the local MAC entity.

The reception_status parameter indicates the success or failure of the incoming frame. It consists of the following elements:

(a) Frame validity: FR_GOOD, FR_BAD

If a FR_BAD is reported, the reason for the error shall also be reported. The reason shall be one of the following:

(1) **Invalid FCS:** Calculated FCS (Frame Check Sequence) does not match the received FCS

(2) **Length Error:** The frame did not have a valid data length

(3) **Internal Error:** An internal error has occurred that prevents MAC fro transferring to LLC a frame that has been acknowledged by the setting of the (address recognized) and C (frame copied) indicators.

(b) Frame Status:

The received E (error detected), A, C, and, optionally, any other Indicator values.

6.1.2.2 When generated

The MA_UNITDATA.indication primitive shall be generated by MAC to indicate to the local LL entity the arrival of an LLC frame addressed to this station.

6.1.2.3 Effect of receipt

The effect of receipt of this primitive by the LLC entity is not specified.

6.1.3 MA_UNITDATA_STATUS.indication

This primitive shall provide an appropriate response to MA_UNITDATA.request primitiv signifying the success or failure of the request.

6.1.3.1 Semantics of the primitive

```
MA_UNITDATA_STATUS.indication        (
                                      number_of_SDUs,
                                      transmission_status,
                                      provided_service_class
                                      )
```

The number_of_SDUs parameter reports the number of M_SDUs transmitted on a give access opportunity as a result of this request.

The transmission_status parameter shall be used to pass information back to the loc requesting LLC entity. It shall be used to indicate the success or failure of the previo associated MA_UNITDATA.request. If the MA_UNITDATA.request primitive specified more th one M_SDU, then the transmission_status parameter may apply to all of the SDUs transmitte indicating if all were acknowledged, via the A and C indicators, by a peer MAC entity. In th case, the resolution of the transmission_status is implementer defined.

The provided_service_class parameter specifies the service class that was provided for t transfer.

6.1.3.2 When generated

This primitive shall be generated by MAC in response to an MA_UNITDATA.request primiti from the local LLC entity.

6.1.3.3 Effect of receipt

The effect of receipt of this primitive by LLC is unspecified.

NOTE - In the event of multiple outstanding requests, additional information may be needed in order for LLC to associate the response with the appropriate request. The association may be implied by the requests being serviced in a first-in-first-out (FIFO) manner. Alternatively, MAC may maintain multiple queues of requests, at least one for each class_of_service implemented, servicing each of these queues in a FIFO manner. It is assumed that if the addressed peer MAC entity, or entities, acknowledge receipt of the frame(s) (by setting the A and C indicators), then either the frame(s) will be delivered, or an internal error will be reported, to the corresponding LLC entity, or entities, via an MA_UNITDATA.indication.

6.1.4 MA_TOKEN.request

This primitive is used by LLC to request the capture of the next Token.

6.1.4.1 Semantics of the primitive

```
MA_TOKEN.request                    (
                                    requested_Token_class
                                    )
```

Requested_Token_class may be either restricted or nonrestricted. The priority level may also be specified if multiple levels of priorities are implemented.

6.1.4.2 When generated

This primitive may be generated by the local LLC entity when data of a time critical nature is to be transferred.

6.1.4.3 Effect of receipt

The receipt of this primitive shall cause MAC to capture the next usable Token based on the requested_Token_class parameter. MAC then enters State T2 (Transmit Data) and transmits Idle symbols until an MA_UNITDATA.request primitive is received from LLC unless TRT expires first, in which case MAC shall issue another Token of the same Token_class as was captured.

NOTE - This primitive may be used for time critical operations to minimize the effects of ring latency. This mode of operation may cause longer than usual preambles preceding a frame, thus wasting ring bandwidth; therefore it should not be used for transfers of data on the FDDI ring that are not time critical.

6.2 PHY-to-MAC services

This subclause specifies the services provided at the interface between the MAC and PHY entities to allow MAC to exchange MAC protocol data units with peer MAC entities. Additional detail is provided in the FDDI Physical Layer Protocol standard (ISO 9314-1) concerning conditions that generate these primitives and PHY actions upon receipt of MAC generated primitives.

The following primitives are defined:

PH_UNITDATA.request
PH_UNITDATA.indication
PH_UNITDATA_STATUS.indication[1)]
PH_INVALID.indication

---

1) This PHY-to-MAC primitive is not used in this part of ISO 9314 on FDDI MAC.

The description of each primitive includes a description of the information that is passe between the MAC and PHY entities. All PHY service data units have the duration of on symbol period.

These services shall be "synchronous", e.g., each PH_UNITDATA.indication causes exactly on PH_UNITDATA.request. Depending upon the current internal configuration of the station, th PH_UNITDATA.request may be returned to the same PHY, or to a different PHY.

6.2.1 PH_UNITDATA.request

This primitive defines the transfer of data from MAC to the local PHY entity.

6.2.1.1 Semantics of the primitive

```
PH_UNITDATA.request                    (
                                       PH_Request(symbol)
                                       )
```

The symbol specified by PH_Request(symbol) shall be one of the following: J, K, T, R, S, I, o n, where n is any of the 16 data symbols specified in the FDDI Physical Layer Protocc standard (ISO 9314-1).

6.2.1.2 When generated

MAC shall send PHY one PH_UNITDATA.request for each PH_UNITDATA.indication receive from PHY.

6.2.1.3 Effect of receipt

The effect of receipt of this primitive by PHY is not specified.

6.2.2 PH_UNITDATA.indication

This primitive defines the transfer of data from the PHY entity to MAC.

6.2.2.1 Semantics of the primitive

```
PH_UNITDATA.indication                 (
                                       PH_Indication(symbol)
                                       )
```

The symbol specified by PH_Indication(symbol) shall be one of the following: J, K, T, R, S, n, Q, H, or V.

6.2.2.2 When generated

The PHY entity sends MAC a PH_UNITDATA.indication every time PHY decodes a symbol This indication is sent once every symbol period.

6.2.2.3 Effect of receipt

Upon receipt of this primitive, MAC shall accept a symbol from PHY, process it, and generat a corresponding PH_UNITDATA.request to PHY.

6.2.3 PH_UNITDATA_STATUS.indication

This primitive has local significance and shall provide an appropriate response to the PH_UNITDATA.request primitive signifying acceptance of the symbol specified by the PH_UNITDATA.request and willingness to accept another symbol.

6.2.3.1 Semantics of the primitive

```
PH_UNITDATA_STATUS.indication          (
                                        transmission_status
                                        )
```

The transmission_status parameter shall be used to signify the transmission completion status.

6.2.3.2 When generated

PHY sends PH_UNITDATA_STATUS.indication to MAC in response to every PH_UNITDATA.request received. The purpose of the PH_UNITDATA_STATUS.indication is to synchronize the MAC data output with the data rate of PHY.

6.2.3.3 Effect of receipt

The receipt of this primitive shall enable MAC to send another PH_UNITDATA.request to PHY.

6.2.4 PH_INVALID.indication

This primitive is generated by the Physical Layer and asserted to MAC to indicate that PHY is unable to present a valid symbol stream to MAC.

6.2.4.1 Semantics of the primitive

```
PH_INVALID.indication          (
                                PH_Invalid
                                )
```

The PH_Invalid parameter shall indicate that PHY is unable to present a valid symbol stream to MAC.

6.2.4.2 When generated

The Physical Layer generates this primitive whenever it detects that the symbol stream is invalid.

6.2.4.3 Effect of receipt

Receipt of this primitive by MAC shall cause the MAC receiver to signal FO_Error, or if the ending delimiter has already been received, FR_Received, to the MAC transmitter and enter State R0. Depending upon the state exited on the transition to R0, actions relative to incrementing Frame_Ct, Error_Ct and Lost_Ct are taken as appropriate. FO_Error or FR_Received causes the MAC transmitter to enter State T0.

6.3 MAC-to-SMT services

This subclause specifies the services provided at the interface between the station management (SMT) entity and MAC. This interface is used by the local SMT entity to monitor and control the operation of MAC. Additional detail is provided in SMT concerning conditio that generate these primitives and SMT actions upon receipt of MAC-generated primitives.

The following primitives are defined:

SM_MA_INITIALIZE_PROTOCOL.request
SM_MA_INITIALIZE_PROTOCOL.confirm
SM_MA_CONTROL.request
SM_MA_STATUS.indication
SM_MA_UNITDATA.request
SM_MA_UNITDATA.indication
SM_MA_UNITDATA_STATUS.indication
SM_MA_TOKEN.request

The description of each primitive includes a description of the information that is passe between the MAC and the SMT entities.

6.3.1 SM_MA_INITIALIZE_PROTOCOL.request

This primitive has local significance and is used by SMT to change operational parameters MAC; however, it is not necessary to change these parameters while MAC is operational in th ring.

6.3.1.1 Semantics of the primitive

```
SM_MA_INITIALIZE_PROTOCOL.request    (
                                      individual_MAC_address (16 bit),
                                      individual_MAC_address (48 bit),
                                      group_MAC_addresses,
                                      T_Min_value,
                                      T_Max_value,
                                      TVX_value,
                                      T_Req_value,
                                      T_Neg_value,
                                      T_Pri_value,
                                      indicate_for_own_frame,
                                      indicate_for_rcv_only_good_frame
                                      )
```

The individual_MAC_address is the octet string that MAC shall use as its individual addres Both a 16-bit and a 48-bit address may be supplied.

Each group_MAC_address is an octet string that MAC shall use as a group address.

T_Max_value specifies the maximum target Token rotation time (TTRT).

TVX_value specifies the value of TVX (Valid_Transmission Timer) to be used.

T_Min_value specifies the minimum target Token rotation time (TTRT) to be supported.

T_Req_value specifies the requested TTRT for asynchronous traffic.

T_Neg_value specifies the negotiated TTRT for asynchronous traffic.

T_Pri_value specifies a set of priority Token rotation time thresholds.

The indicate_for_own_frame parameter specifies that MAC shall also receive and indicate to SMT frames that it has transmitted.

The indicate_for_rcv_only_good_frames parameter is the value MAC shall use to decide whether to generate MA_UNITDATA.indication and SM_MA_UNITDATA.indication primitives only on frames that are good, or alternatively on all frames.

All parameters of this primitive are optional. If a parameter is omitted, MAC shall use the most recently provided value for this parameter or, if no value has been previously provided, the default value for the parameter.

6.3.1.2 When generated

This primitive is generated by SMT whenever it requires MAC to reconfigure.

6.3.1.3 Effect of receipt

Receipt of this primitive shall cause MAC to establish the values of its addresses, timers, and other initialization parameters. Upon completion of this primitive, MAC shall generate a SM_MA_INITIALIZE PROTOCOL.confirm.

6.3.2 SM_MA_INITIALIZE_PROTOCOL.confirm

This primitive is used by the MAC to inform SMT that the SM_MA_INITIALIZE_PROTOCOL.request is complete.

6.3.2.1 Semantics of the primitive

```
SM_MA_INITIALIZE_PROTOCOL.confirm        (
                                         status
                                         )
```

The status parameter indicates the success or failure of the SM_MA_INITIALIZE_PROTOCOL.request.

6.3.2.2 When generated

This primitive shall be generated by MAC upon completion of a SM_MA_INITIALIZE_PROTOCOL.request.

6.3.2.3 Effect of receipt

The effect of receipt of this primitive by SMT is not specified.

6.3.3 SM_MA_CONTROL.request

This primitive has local significance and is used by the local SMT entity to control the operation of MAC.

6.3.3.1 Semantics of the primitive

```
SM_MA_CONTROL.request                    (
                                         control_action,
                                         beacon_information,
```

requested_status
requested_condition
)

The control_action parameter shall include the following: Reset, Beacon, Present_Statu: Reset_Counters, Interrupt_Upon_Conditions, or Send_Bad_FCS.

The beacon_information parameter shall contain the DA field and the Information field for us in the Beacon Frame if the control_action parameter specifies Beacon.

The requested_status parameter shall include the following: current values of all counter: current values of all timers, R_Flag (Token class restricted) value, current Receiver stat machine state, and current Transmitter state machine state.

The requested_condition parameter shall include one or more of the following: capture c Token, receipt of frame, and passing of the Token.

6.3.3.2 When generated

This primitive is generated by SMT to cause MAC to take the action specified by th control_action parameter.

6.3.3.3 Effect of receipt

Receipt of this primitive by MAC shall cause it to take the following actions:

(a) If the control_action parameter is Reset or Beacon, then MAC shall

(1) Generate the MAC_Reset signal.

(2) Enter Receiver State R0 (Listen).

(3) Enter Transmitter State T0 (Transmit IDLE).

(b) If the control_action parameter is Beacon, then, following the above, State T (Transmit Beacon) shall be entered in the Transmitter state machine. The Beacon Frame shall be constructed using the beacon_information parameter.

(c) If the control_action parameter is Present_Status, then MAC shall present the statu to SMT as indicated by the requested_status parameter.

(d) If the control_action parameter is Reset_Counters, then MAC shall reset all counter:

(e) If the control_action parameter is Interrupt_Upon_Condition, then MAC shall sign: SMT when any of the requested_conditions are detected.

(f) If the control_action parameter is Send_Bad_FCS, then MAC shall send bad FC with a specific frame to be transmitted.

6.3.4 SM_MA_STATUS.indication

This primitive is used by MAC to inform the local SMT entity of errors and significant statu changes.

6.3.4.1 Semantics of the primitive

SM_MA_STATUS.indication (
Status_report
)

The status_report parameter shall specify appropriate status including the following:

(a) Any change of Ring_Operational status

(b) Receipt of My_Claim, Higher_Claim, or Lower_Claim

(c) Receipt of My_Beacon or Other_Beacon

(d) Expiration of TVX

(e) Expiration of TRT and Late_Ct not= 0

(f) Receipt of PH_Invalid causing the Receiver to enter State

(g) Receipt of MAC_Reset causing the Receiver to enter State R0

(h) Overflow of Frame_Ct, Error_Ct, or Lost_Ct

(i) Receipt of a frame with the Destination Address equal to this station's individual address and the received A Indicator set

(j) Recognition that this station's transmitted frame was lost in the course of its circulation around the ring

(k) Any time the R_Flag goes from Reset to Set

(l) Any time a station sets Ax but does not set Cx

(m) Receipt of a Token if the MAC Transmitter is in State T2 (Transmit Data) or T3 (Issue Token)

(n) Expiration of TRT whilst in MAC Transmitter State T4 (Claim Token) or T5

(o) Occurrence of any condition specified in a previously received SM_MA_CONTROL.request (interrupt_upon_condition)

6.3.4.2 When generated

This primitive shall be generated by MAC when any of the listed reportable conditions are detected.

6.3.4.3 Effect of receipt

The effect of receipt of this primitive by SMT is not specified.

6.3.5 SM_MA_UNITDATA.request

This primitive defines the transfer of one or more SMT Service Data Units (SDU) from the local SMT entity. Any defined PDU format may be sent.

6.3.5.1 Semantics of the primitive

SM_MA_UNITDATA.request (
FC_value (1),
destination_address (1),
M_SDU (1),
requested_service_class (1),
stream (1),
FC_value (2),
destination_address (2),
M_SDU (2),
requested_service_class (2),
stream (2),
.
.
.
FC_value (n),
destination_address (n),
M_SDU (n),
requested_service_class (n),
stream (n),
Token_class
)

Each set of FC_value, destination_address, M_SDU, requested_service_class, and strea parameters specifies one frame for transmission and is referred to as a subrequest.

The FC_value parameter supplies the FC field to be transmitted as part of the frame.

The destination_address parameter may specify either an individual or a group MAC addres It shall contain sufficient information to create the DA field that is appended to the frame t MAC. Address length is determined by the L bit of the associated FC_value parameter.

Each M_SDU parameter specifies an SMT service data unit as received at the MAC interfac to be transmitted by MAC. There is sufficient information associated with the M_SDU f MAC to determine the length of the service data unit. Associated with each M_SDU is requested_service_class parameter.

Requested_service_class may be either Synchronous, Asynchronous, or Immediate. asynchronous, the requested_token_class and the priority level may optionally be specified. not specified, the default value is assumed. Immediate, if specified, shall cause the frame be sent immediately without waiting for receipt of a Token.

Stream is a parameter that if set shall cause multiple M_SDUs to be transmitted as a rest of the same SM_MA_UNITDATA.request. Stream, when reset, indicates that this SDU is tl last one associated with this SM_MA_UNITDATA.request. The frames shall be transmitted the order presented by this primitive regardless of the associated requested_service_clas If TRT has expired (Late_Ct not= 0) or if a frame is encountered which cannot t transmitted because of its associated requested_service_class and the current value of TH then transmission is terminated and a Token is issued as defined by the Token_cla: parameter. A SM_MA_UNITDATA_STATUS.indication is subsequently returned to SMT. If tl transmission_status is successful, then MAC may initiate transmission of the remaining fram(on the next permitted access opportunity or alternatively, MAC may require reissuance of new SM_MA_UNITDATA.request.

Token_class specifies the class of Token that MAC shall issue following the transmission of the associated SDUs (i.e., at the end of the request), if no other request is pending that can be honoured. With requests for synchronous service the Token_class shall be the Token_class that was captured; with requests for asynchronous service it may specify either none, restricted or nonrestricted. If no SDUs were specified by the SM_MA_UNITDATA.request, then MAC shall immediately issue the requested class of Token.

6.3.5.2 When generated

This primitive shall be generated by SMT whenever data is to be transferred to a peer SMT entity or entities, or a Token is to be generated.

6.3.5.3 Effect of receipt

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

NOTE - The capture of a Token is implicit in this primitive and therefore it is not necessary to issue an SM_MA_TOKEN.request primitive in conjunction with it.

6.3.6 SM_MA_UNITDATA.indication

This primitive defines the transfer of data from MAC to the local SMT entity or entities in the case of group addresses. This primitive shall be able to report any SMT or MAC frame addressed to the station.

6.3.6.1 Semantics of the primitive

```
SM_MA_UNITDATA.indication          (
                                    FC_value,
                                    destination_address,
                                    source_address,
                                    M_SDU,
                                    reception_status
                                    )
```

The FC_value parameter specifies the value for the frame's FC field. The destination_address parameters may be either in individual or a group address as specified by the DA field of the incoming frame. The source_address parameter is an individual address as specified by the SA field of the incoming frame. The M_SDU parameter shall specify the MAC service data unit as received by the local MAC entity.

The reception_status parameter indicates the success or failure of the incoming frame. It consists of the following elements:

(a) Frame Validity: FR_GOOD, FR_BAD

If a FR_BAD is reported, the reason for the error shall also be reported. The reason shall be one of the following:

(1) **Invalid FCS** Calculated FCS does not match the received FCS.

(2) **Length Error** The frame did not have a valid data length.

(3) **Internal Error** An internal error has occurred that prevents MAC froı transferring to SMT a frame that has been acknowledged by the setting of the A an C indicators.

(b) Frame Status: The received E, A, C, and, optionally, any other indicator values.

6.3.6.2 When generated

The SM_MA_UNITDATA.indication primitive shall be generated by MAC to indicate the arriva of a MAC or SMT frame addressed to this station at the local MAC entity. If so initialize (see 6.3.1, SM_MA_INITIALIZE_PROTOCOL.request), then MAC shall also generate this primitiv upon receipt of frames that it has transmitted. This allows examination of elements of th reception_status for a transmitted frame following circulation around the ring.

6.3.6.3 Effect of receipt

The effect of receipt of this primitive by the SMT entity is not specified.

6.3.7 SM_MA_UNITDATA_STATUS.indication

This primitive shall provide an appropriate response to the SM_MA_UNITDATA.request primitiv generated by the SMT entity signifying the success or failure of the request.

6.3.7.1 Semantics of the primitive

```
SM_MA_UNITDATA_STATUS.indication      (
                                       number_of_SDUs,
                                       transmission_status,
                                       provided_service_class
                                       )
```

The number_of_SDUs parameter reports the number of M_SDUs transmitted on a give access opportunity as a result of this request.

The transmission_status parameter shall be used to pass information back to the loca requesting SMT entity. It shall be used to indicate the success or failure of the previou associated SM_MA_UNITDATA.request. If the SM_MA_UNITDATA.request primitive specifie more than one M_SDU, then the transmission_status parameter may apply to all of the SDU transmitted, indicating if all were acknowledged, via the A and C indicators, by a peer MA entity. In this case, the resolution of the transmission_status is implementer defined.

The provided_service_class parameter specifies the service class that was provided for th transfer.

6.3.7.2 When generated

This primitive shall be generated by the MAC entity in response to a SM_MA_UNITDATA.request primitive from the local SMT entity.

6.3.7.3 Effect of receipt

The effect of receipt of this primitive by SMT is unspecified.

NOTE – In the event of multiple outstanding requests, additional information may be needed i order for SMT to associate the response with the appropriate request. The association ma be implied by the requests being serviced in a FIFO manner. Alternatively, MAC may maintai multiple queues of requests, at least one for each class_of_service implemented, servicing eac of these queues in a FIFO manner. It is assumed that if the addressed peer MAC entity, or entities, acknowledge receipt of the frame(s) (by setting the A and C indicators), then either the frame(s) will be delivered, or an internal error will be reported, to the corresponding SMT entity, or entities, via an SM_MA_UNITDATA.indication.

6.3.8 SM_MA_TOKEN.request

This primitive is used by SMT to request the capture of the next Token.

6.3.8.1 Semantics of the primitive

```
SM_MA_TOKEN.request          (
                             requested_Token_class
                             )
```

Requested_Token_class may be either restricted or nonrestricted. The priority level may also be specified if multiple levels of priorities are implemented.

6.3.8.2 When generated

This primitive may be generated by the local SMT entity when data of a time critical nature is to be transferred.

6.3.8.3 Effect of receipt

The receipt of this primitive shall cause MAC to capture the next usable Token based on the requested_Token_class parameter. MAC then enters State T2 and transmits Idle symbols until an SM_MA_UNITDATA.request primitive is received from SMT unless TRT expires first, in which case MAC shall issue another Token of the same Token_class as was captured.

NOTE - This primitive may be used for time critical operations to minimize the effects of ring latency. This mode of operation may cause longer than usual preambles preceding a frame, thus wasting ring bandwidth; therefore it should not be used for transfers of data on the FDDI ring that are not time critical.

7 Facilities

7.1 Symbol set

Peer MAC entities on the ring communicate via a set of fixed-length symbols. These symbols are passed across the MAC-to-Physical interface via the primitives defined as part of the FDDI services.

7.1.1 Line states

Line States indicate the condition of the medium between transmissions. Line States are indicated by sequences of the following symbols as defined in the FDDI Physical Layer Protocol standard (ISO 9314-1).

7.1.1.1 Quiet (Q)

The Quiet symbol indicates the absence of activity on the medium.

7.1.1.2 Halt (H)

The Halt symbol indicates a forced logical break in activity on the medium.

7.1.1.3 Idle (I)

The Idle symbol indicates the normal condition of the medium between transmissions. provides a continuous fill pattern to establish and maintain clock synchronization.

7.1.2 Control symbols

7.1.2.1 Starting Delimiter (SD) A Starting Delimiter (SD) delineates the starting boundary of data transmission sequence. During normal ring operation, the Starting Delimiter follows the idl state. The Starting Delimiter may also succeed or pre-empt a previous transmission. Th Starting Delimiter sequence consists of the unique symbol sequence (J,K) that may b recognized independently of previously established symbol boundaries.

7.1.2.1.1 Initial SD symbol (J)

The J symbol is the first symbol of a sequential Starting Delimiter symbol pair.

7.1.2.1.2 Final SD symbol (K)

The K symbol is the last symbol of a sequential Starting Delimiter symbol pair.

7.1.2.2 Ending Delimiter (ED)

An Ending Delimiter consisting of one or more T symbols terminates all normal data transmissio sequences. The T symbol is not necessarily the last symbol in a transmission sequence, sinc an Ending Delimiter may be followed by one or more Control Indicator symbols. Endin Delimiters and optional Control Indicators shall be transmitted as a balanced symbol sequenc consisting of an even number of symbols. When no Control Indicators are present, thi sequence consists of a pair of T symbols.

7.1.2.3 Control Indicators

Control Indicators indicate logical conditions associated with a data transmission sequenc They may be independently altered by repeating stations without altering the normal data the transmission sequence. A sequence of Ending Delimiter and Control Indicator symbols sha be balanced, i.e., consist of an even number of symbols. An Ending Delimiter followed by a odd number of Control Indicators is a balanced symbol sequence; however, an Ending Delimite followed by an even number of Control Indicators is balanced by adding a final Endin Delimiter.

7.1.2.3.1 Reset (R)

The Reset Symbol indicates a logical "off" or "false" condition.

7.1.2.3.2 Set (S)

The Set Symbol indicates a logical "on" or "true" condition.

7.1.3 Data symbols (0-F), (n)

A Data Symbol conveys one symbol of arbitrary binary data within a transmission sequenc The elements of the 16 Data Symbols are denoted by the set of hexadecimal digits (0-F). nonspecific member of the set is denoted by the character *n*.

7.1.4 Violation symbol (V)

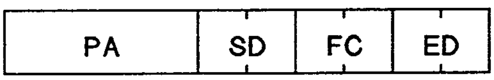
The Violation Symbol indicates a condition of activity on the medium which does not conform to any other symbol in the symbol set.

7.2 Protocol Data Units

Two Protocol Data Unit (PDU) formats are used by MAC: Tokens and Frames. In the following discussion, the figures depict the formats of the PDUs in the order of transmission on the medium, with the left-most symbol transmitted first.

Fields defined as numeric values are represented as unsigned magnitudes. Operations that require comparison of fields or symbols, perform that comparison upon those fields as depicted, with the first symbol transmitted (depicted as the left-most symbol) compared first and, for the purpose of comparison, considered most significant.

7.2.1 Token

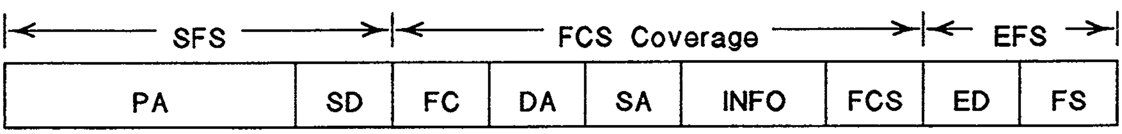


PA = Preamble (16 or more symbols)
SD = Starting Delimiter (2 symbols)
FC = Frame Control (2 symbols)
ED = Ending Delimiter (2 symbols)

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

The preamble is transmitted by the Token originator as a minimum of 16 symbols of Idle. Physical Layers of subsequent repeating stations may change the length of the Idle pattern consistent with Physical Layer clocking requirements. Thus repeating stations may see a variable length preamble that is shorter or longer than the originally transmitted preamble. Tokens shall be recognized and acted upon when received with a preamble of zero or greater length, independent of previously established symbol boundaries. If a valid token is received but cannot be repeated (owing to ring timing or latency constraints), the station shall issue a new token.

7.2.2 Frame



SFS = Start of Frame Sequence
PA = Preamble (16 or more symbols)
SD = Starting Delimiter (2 symbols)
FC = Frame Control (2 symbols)
DA = Destination Address (4 or 12 symbols)
SA = Source Address (4 or 12 symbols)
INFO = Information (0 or more symbol pairs)
FCS = Frame Check Sequence (8 symbols)
EFS = End of Frame Sequence
ED = Ending Delimiter (1 symbol)
FS = Frame Status (3 or more symbols)

The frame format is used for transmitting both MAC and LLC messages to the destinatic station(s). It may or may not have an information field. The Media Access Control sha control the maximum frame length as required by the Physical Layer. For the purpose (counting frame length, all of the above fields, excluding the preamble, are counted. Th Physical Layer of FDDI requires limiting the maximum frame length to 9 000 symbols includir four symbols of the preamble.

7.3 Fields

The following is a detailed description of the individual fields contained within PDUs.

7.3.1 Preamble (PA)

The PA of a frame shall be transmitted by the frame originator as a minimum of 16 symbo of Idle. Physical Layers of subsequent repeating stations may change the length of the Idl pattern consistent with Physical Layer clocking requirements. Thus, repeating stations may se a variable length preamble that is shorter or longer than the originally transmitted preamble. given MAC implementation is not required to be capable of copying frames received with les than 12 symbols of preamble; however, if it cannot correctly repeat such a frame then it sha not repeat any part of the frame (including the starting delimiter).

7.3.2 Starting Delimiter (SD)

J	K

J = J symbol
K = K symbol

A frame or Token shall start with these two symbols. No frame or Token is considered vali unless it starts with this explicit sequence.

7.3.3 Frame Control (FC)

C L F F	Z Z Z Z

C = Class bit
L = Address Length Bit
FF = Format Bits
ZZZZ = Control Bits

The Frame Control field defines the type of the frame and associated control functions.

7.3.3.1 Frame class bit

The Frame Class Bit indicates the class of service as follows:

C = 0 indicates an asynchronous frame
C = 1 indicates a synchronous frame

7.3.3.2 Frame address length bit

The Frame Address Length bit indicates the length of both MAC addresses (DA and SA) a follows:

L = 0 indicates 16 bit addresses
L = 1 indicates 48-bit addresses

7.3.3.3 Frame format bits

The FF in conjunction with the CL and ZZZZ bits, indicate the frame type as follows:

CLFF	ZZZZ to ZZZZ	
0X00	0000	Void frame
1000	0000	Nonrestricted Token
1100	0000	Restricted Token
0L00	0001 to 1111	Station management frame
1L00	0001 to 1111	MAC frame
CL01	r000 to r111	LLC frame
CL10	r000 to r111	Reserved for implementer
CL11	rrrr	Reserved for future standardization

Where: X is either a 0 or 1 bit
r is reserved for future standardization and should be set to zero.

void: Void frames are logically not frames and their content shall be ignored. Fields in a PDU with FC = Void have no meaning except that a station shall reset TVX and strip a void frame if the SA field matches that station's address.

token: All stations shall interpret the Token, if valid. Two classes, restricted and nonrestricted, of Tokens are specified.

station management: These frames contain Station Management (SMT) information. The contents of the Control Bits have meaning for the Station(s) addressed by the DA field.

medium access control: If the Frame Type Bits indicate a MAC frame, all stations shall interpret the Control Bits (ZZZZ) for MAC significance. If ZZZZ is not equal to 0000, all stations shall interpret and, if necessary, act on the control bits. The information field contents of MAC frame is at least 32 bits long and shall be acted on by an appropriate management entity of the station(s).

reserved for implementer: Designates a frame that contains implementation-dependent information. The format is undefined except that it shall have DA and SA field, shall be an integral number of octets (i.e., pairs of Data Symbols), and shall end with a valid End of Frame Sequence.

logical link control: If the Frame Type Bits indicate an LLC frame, the contents of the Control Bits have meaning for the station or stations identified by the Destination Address.

7.3.3.4 Control bits

The following values for the Control Bits, when used with the associated CLFF bits, have been defined. All other values are reserved for future assignment.

MAC Beacon Frame (1L00 0010): This frame is transmitted for the purpose of indicating that corrective action is required and shall be interpreted by a station independent of the DA (DA = 0 or a value supplied by SMT, e.g., upstream neighbour). This frame is sent as a result of serious ring failure (e.g., loss of signal or jabbering station transmitting in violation of the MAC protocol). This frame is useful in localizing the fault.

MAC Claim Frame (1L00 0011): This frame is transmitted on the ring during error recovery fo the purpose of determining the station that shall create the Token and initialize the ring an shall be interpreted by a station independent of the DA (DA = SA). When a statio determines that the ring is not properly functioning, it enters the Claim Token state. While i this state the station sends Claim Frames and inspects the source address of the Clair Frames it receives. If the source address matches its own address (MA), it has claimed th Token and shall then generate a new Token.

SMT Next Station Addressing Frame (0L00 1111): This frame is a Next Station Addressin Frame and is to have the C Indicator set only by the next addressed station on the rin The next addressed station is distinguished by the fact that it receives the frame with the Indicator reset.

NOTE - The use of this frame will be specified in a future part of ISO 9314 on SMT.

LLC Frame (0L01 rPPP): This frame is an LLC information frame used for asynchronou transmission. The last three Control bits (PPP) indicate the frame's priority, with PPP=111 bein the highest asynchronous priority and PPP=000 being the lowest asynchronous priority. Th control bit labelled r is reserved and should be set to zero.

LLC Frame (1L01 rrrr): This frame is an LLC information frame used for synchronou transmission. The control bit labelled r is reserved and should be set to zero.

Implementor Frame (CL10 rXXX): This frame is an implementor defined frame. The control bi labelled r is reserved and should be set to zero. The remaining control bits, XXX, ar implementor defined.

7.3.4 Destination and source addresses

Each frame shall contain two address fields: the Destination (station) Address and the Sourc (station) Address, in that order. Addresses may be either 16 or 48 bits in length; however, a stations shall have 16-bit address capability.[1)]

A station with only 16-bit address capability shall be capable of functioning in a ring wit stations concurrently operating with 48-bit addresses. To do so, the 16-bit address statio shall be capable of

(a) Repeating frames with 48-bit addresses.

(b) Recognizing the 48-bit broadcast address of all ones.

(c) Reacting correctly to Claim Frames with 48-bit addresses.

(d) Reacting correctly to Beacon Frames with 48-bit addresses.

A station using 48-bit addresses shall have a minimum 16-bit address capability such that th 48-bit address station shall

(a) Have a fully functional 16-bit individual address.

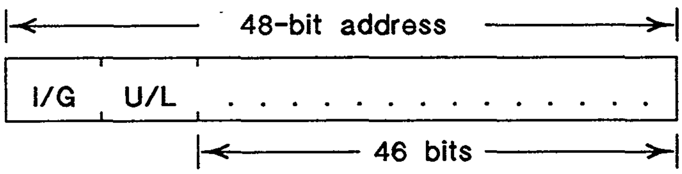
(b) Recognize the 16-bit broadcast address of all ones.

---

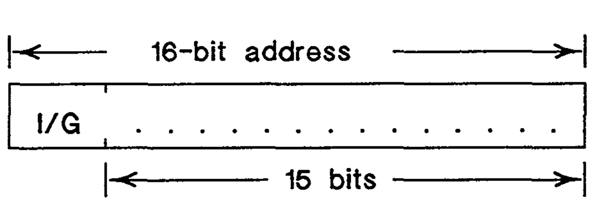
1) This subclause is the intended subject of a future amendment to require that 48-bit addresse are mandatory and 16-bit addresses are optional.

7.3.4.1 Destination address

The Destination Address identifies the station(s) for which the frame is intended. The first bit(s) transmitted in the destination address are control bits: one for individual or group addresses, and in the case of 48-bit addresses, the other for universally or locally administered addresses.



I/G = Individual or Group Bit
U/L = Universal or Local Bit



I/G = Individual or Group Bit

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

0 = individual address, 1 = group address

Individual addresses identify a particular station on the ring and shall be distinct from all other individual station addresses on the same ring (in the case of Local Administration), and from the individual addresses of other ring stations on a global basis (in the case of Universal Administration).

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

Broadcast Address: The group address consisting of all 1's shall constitute a broadcast address, denoting the set of all stations on a given ring.

Null Address: An address of all zeros, known as the null address shall not be interpreted by a station as its address.

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

0 = universally administered, 1 = locally administered

Universal Administration: With this method, each individual address is distinct from all other individual addresses on a global basis. The procedure for administration of these addresses is not specified in the FDDI standard.

Local Administration: Individual station addresses are administration by a local authority.

7.3.4.2 Source address

The Source Address shall be the individual_MAC_address to identify the station originating the frame and shall have the same format and length as the destination address in the given frame. The individual/group bit shall be set to 0.

7.3.5 Information (INFO) field

The INFO Field contains zero, one, or more data symbol pairs whose meaning is determined by the FC field and whose interpretation is made by the destination entity, e.g., MAC, LLC, or SMT. The length of the INFO field is variable, but is limited however by the maximum PDU length restriction of 9 000 symbols for all PDU fields including four symbols of the preamble.

7.3.5.1 Order of transmission

The Service Data Units (SDUs) passed between LLC and MAC are assumed to be ordered sequences of octets. The MAC entity subdivides these octets into data symbol pairs with the most significant data symbol of each pair to be transmitted first. The ordering of these data symbol sequences shall be preserved through all MAC entities and the associated PHY entities.

7.3.5.2 MAC supervisory frames

The Information Field for MAC supervisory frames shall be at least four octets in length. The first four octets shall be as follows:

Claim Frame - The bid for Target Token rotation time expressed as the twos complement of desired Target Token rotation time in octets.

Beacon Frame - The first octet is Beacon Type and the next three octets are reserved for future assignment.

Beacon Type	
0000 0000	Unsuccessful Claim
0000 0001 to 1111 1111	Reserved for future assignment

7.3.6 Frame Check Sequence (FCS)

This subclause specifies the generation and checking of the FCS field. This field is used to detect erroneous data bits within the frame as well as erroneous addition or deletion of bits to the frame. The fields covered by the FCS field include the FC, DA, SA, INFO, and FCS fields. Annex B provides further information on the generation and use of the FCS.

7.3.6.1 Definitions

F(x): A degree k-1 polynomial that is used to represent the k bits of the frame covered by the FCS sequence (see 7.2.2). For the purposes of the FCS, the coefficient of the highest order term shall be the first bit transmitted.

L(x): A degree 31 polynomial with all of the coefficients equal to one, i.e.,

$$L(x) = X^{31} + X^{30} + X^{29} + \ldots + X^2 + X + 1.$$

G(x): The standard generator polynomial

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

R(x): The remainder polynomial that is of degree less than 32.

P(x): The remainder polynomial on the receive checking side that is of degree less than 32.

FCS: The FCS polynomial that is of degree less than 32.

Q(x): The greatest multiple of G(x) in $[x^{32}F(x)+X^{k}L(x)]$.

Q*(x): $x^{32}Q(x)$.

M(x): The sequence that is transmitted.

M*(x): The sequence that is received.

C(x): A unique polynomial remainder produced by the receiver upon reception of an error-free sequence. This polynomial has the value.

$$C(X) = X^{32}L(X)/G(X)$$

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

7.3.6.2 FCS Generation equations

The equations that are used to generate the FCS sequence from F(x) are as follows:

$$FCS = L(X)+R(X) = R\$(X) \qquad (1)$$

where R$(X) is the one's complement of R(X)

$$[X^{32}F(X)+X^{k}L(X)]/G(X)=Q(X)+R(X)/G(X) \qquad (2)$$

$$M(x) = x^{32}F(x) + FCS \qquad (3)$$

NOTE – All arithmetic is modulo 2. In equation (1), adding L(x) (all ones) to R(x) simply produces the one's complement of R(x); thus this equation is specifying that the R(x) is inverted before it is sent out. Equation (3) simply specifies that the FCS is appended to the end of F(x).

7.3.6.3 FCS checking

The received sequence M*(x) may differ from the transmitted sequence M(x) if there are transmission errors. The process of checking the sequence for validity involves dividing the received sequence by G(x) and testing the remainder. Direct division, however, does not yield a unique remainder because of the possibility of leading zeros. Thus a term L(x) is prepended to M*(x) before it is divided. Mathematically, the received checking is shown in equation (4).

$$X^{32}[M^{*}(X)+X^{k}L(X)]/G(X)=Q^{*}(X)+P(X)/G(X). \qquad (4)$$

In the absence of errors, the unique remainder is the remainder of the division

$$P(X)/G(X)=X^{32}L(X)/G(X)=C(X). \qquad (5)$$

7.3.7 Ending Delimiter (ED)

The symbol T is the ending of Tokens and frames. Ending delimiters and optional Contro Indicators shall form a balanced symbol sequence, i.e., be transmitted in pairs so as tc maintain octet boundaries. This shall be accomplished by adding a trailing T symbol as required.

7.3.7.1 Token ending delimiter

The Ending Delimiter of a Token shall consist of two consecutive T symbols.

ED	
T	T

T = Terminate Symbol

7.3.7.2 Frame ending delimiter

The Ending Delimiter field of a frame shall consist of a single T symbol.

ED
T

T = Terminate Symbol

7.3.8 Frame Status (FS)

The Frame Status field (FS) shall consist of an arbitrary length sequence of Control Indicato symbols (R and S) that follows the Ending Delimiter of a frame. It ends if any symbol othe than R or S is received. A trailing T symbol, if present, shall be repeated as part of the FS field. The first three Control Indicators of the Frame Status field are mandatory, indicating Error Detected (E), Address Recognized (A), and Frame Copied (C). The use of additiona trailing Control Indicators in the Frame Status field is optional and is implementer defined Although the use of optional trailing Control Indicators in the Frame Status field is undefined by the FDDI standard, all conforming FDDI stations shall repeat the entire Frame Status field.

E	A	C				
R/S	R/S	R/S	R/S	R/S	...	T

T = Terminate Symbol
R = Reset Symbol
S = Set Symbol

7.3.8.1 Error detected indicator (E)

The error detected indicator (E) is transmitted as R by the station that originates the frame All stations on the ring inspect repeated frames for errors. If an error is detected and the received E indicator was not Set, then an error is counted. The E indicator is set to S by a repeating station when either an error to be counted is detected or the received E indicato is S.

7.3.8.2 Address recognized indicator (A)

The address recognized indicator is transmitted as R by the station that originates the frame. If another station recognizes the destination address as its own individual or group address it sets the A indicator to S; otherwise, a repeating station transmits this indicator as received.

7.3.8.3 Frame copied indicator (C)

The frame copied indicator is transmitted as R by the station that originates the frame. If another station recognizes the destination address as its own and copies the frame (into its receive buffer), it sets the C indicator to S; otherwise, a repeating station transmits this indicator as received.

7.4 Timers

Each station shall maintain three timers to regulate the operation of the ring. The values of these timers are locally administered. They may vary from station to station on the ring, provided that the applicable ring limits are not violated.

The term Reset, when applied to timers, shall mean that the timer is reset to its initial value and (re)started. The terms disabled and enabled refer to stopping and starting the timers, respectively.

7.4.1 Elements of timer calculation

The following parameters are used for the purpose of timer calculation. Because the MAC timer values are also a function of the attached Physical Layer(s) parameters, appropriate parameters and concepts as related to the Physical Layer are assumed as described in this subclause.

D_Max = 1,617 ms (default)
      = Maximum Ring Latency

D_Max is the maximum latency (circulation delay) for a Starting Delimiter (SD) to travel around the ring as expressed in time. D_Max consists of the total ring cable delay plus the total station latency of all stations. As defined, D_Max allows for a wide variety of topologies, for example;

(a) A total path length equal to a maximum of 200 km contributing a maximum of 1,017 ms to the D_Max term when calculated at approximately 5 085 ns/km. This 200 km limit on the path length allows for a total cabled ring length of 100 km, which accommodates the round trip path length that exists between single-attachment connections as well as the total cable length for trunks formed by dual-attachment connections in a wrap configuration.

NOTE - The description of dual-attachment connections, single-attachment connections, and wrap configurations will be contained in a future part of ISO 9314 on SMT.

(b) A total number of physical connections equal to 1 000, which for all stations repeating a frame contributes a maximum of 0,600 ms to the D_Max term when calculated on the basis of 600 ns (15-symbol) latency per physical connection. The 600 ns maximum is a default maximum Start Delimiter latency allowed for conforming FDDI equipment including the latency (delay) introduced by both the MAC entity and its associated physical connection(s). This calculation assumes that all physical connections are at their maximum Start Delimiter latency, which includes the maximum elasticity buffer delay in the Physical Layer when the elasticity buffer processes a transition from Idle_Line-State to Active_Line-State (i.e., a JK is received in ILS).

M_Max = 1 000 (default)
= Maximum Number of MAC entities

M_Max equals the maximum number of MAC entities allowed on the ring. Note that M_Max may be additionally limited by the constraints imposed by D_Max; for example, in the case where two Physical Layers are used with one MAC to create a Class A connection.

I_Max = 25,0 ms
= Maximum Station Physical Insertion Time

I_Max is the maximum station physical insertion time contributed by the Physical Layer(s).

A_Max = 1,0 ms
= Maximum Signal Acquisition Time

A_Max consists of the sum of the maximum allowed clock and DC balance signal acquisition time contributed by the attached Physical Layer(s).

Token_Time = 0,000 88 ms
= Token Length

Token_Time consists of the time required to transmit a Token (6 symbols) and its Preamble (16 symbols). Token capture and retransmission time is assumed to be on the order of a few symbols and not significant to MAC timer calculations.

L_Max = 0,003 5 ms
= Maximum Transmitter Frame set-up time

L_Max consists of the maximum set up time permitted for a station to begin transmission of the first and subsequent frames after the capture of a Token.

NOTE - L_Max determines the maximum length of the preamble that may normally precede a frame when it is initially transmitted. Considerations of performance make it desirable to transmit the minimum length of preamble possible. If a station exceeds L_Max, then it should issue a well-formed void frame to allow all MAC receivers to reset TVX.

F_Max = 0,361 ms
= Maximum Frame Time

F_Max consists of the time required to transmit a maximum length frame (9 000 symbols) and its Preamble (16 symbols).

Claim_FR = 0,002 56 ms
= Claim Frame Length

Claim_FR consists of the time required to transmit a Claim Frame and its Preamble (16 symbols). A minimum length Claim Frame using long (48 bit) addresses is assumed.

S_Min = 0,364 5 ms
= Minimum Safety Timing Allowance

S_Min consists of the minimum safety timing allowance for the recovery from random noise on the ring. S_Min consists, at a minimum, of one frame of maximum length (F_Max), which may be permuted by noise plus the L_Max that is required to place the first frame on to the ring after capturing a Token.

7.4.2 Token-Holding Timer (THT)

Each station shall have a timer THT, called the Token-Holding Timer, that controls how long the station may transmit asynchronous frames. A station may initiate a transmission of an asynchronous frame if timer THT has not expired and is less than the T_Pri (see 8.1.4.2) associated with the frame to be transmitted. Timer THT is initialized with the current value of timer TRT (see 7.4.4) when the Token is captured.

7.4.3 Valid-Transmission Timer (TVX)

Each station has a timer TVX, called the Valid-Transmission Timer, to recover from transient ring error situations. The timeout value of TVX is determined such that:

$$\begin{aligned} TVX &> Max(D\_Max,\ F\_Max) + Token\_Time + F\_Max + S\_Min \\ &> 2{,}35 \text{ ms} \end{aligned}$$

The default value for TVX shall be at least 62 500 symbol times (2,50 ms). Note that a value of 2,621 44 ms may be derived conveniently from the symbol clock (i.e., with with a 16 bit counter) and thus may be used by conforming FDDI MAC entities as the default value of TVX.

7.4.4 Token-Rotation Timer (TRT)

Each station shall have a timer TRT, called the Token-Rotation Timer, used to control ring scheduling during normal operation and to detect and recover from serious ring error situations. TRT is initialized with different values during different phases of ring operation. Whenever TRT expires, it is reinitialized to the current value of T_Opr, and Late_Ct is incremented.

T_Opr, controlled by the transmit state machine of MAC, is the operative timeout value of TRT. T_Opr is negotiated between stations to a value that is between T_Min and T_Max for all stations on the ring as part of the Claim Token bidding process (see 8.4.5), which occurs during ring initialization. Thus T_Opr affects the operating characteristics of the ring. Each station uses a value T_Req, between its T_Min and T_Max values, to negotiate for the lowest value of T_Opr, such that the lowest value of T_Req becomes T_Opr for the ring. Note that because of the nature of the timed Token rotation protocol, the Token may be received up to one T_Opr late. Thus a station requiring a guaranteed response time should set its T_Req to one-half of the required response time.

The minimum value of TRT, called T_Min, affects the interoperability of stations on the ring. If the negotiated value of T_Opr is less than a station's T_Min, then that station is unable to operate correctly on the ring. The default value of T_Min shall not be greater than 100 000 symbol times (4,0 ms) yielding a guaranteed maximum latency of 8,0 ms.

The maximum value of TRT, called T_Max, shall be several times the maximum ring initialization time to permit stable ring recovery, where:

$$T\_Max > K \times T\_Init \quad \text{(default K=4)}$$

$$T\_Max > M \times T\_React + N \times T\_Resp \quad \text{(default M=2 and N=6)}$$

The default value for T_Max shall be at least 4 125 000 symbol times (165 ms). Note that a value of 167,772 16 ms may be derived conveniently from the symbol clock (i.e., with a 22 bit counter) and may be used by conforming FDDI MAC entities as the default value of T_Max.

NOTE - The time spent in States T0, T4, and T5 of the Transmitter state machine during ring recovery is directly dependent on the choice of the T_Max parameter if there is a fault and thus the T_Max value should not be set to the maximum value supported by this part of ISO 9314 (i.e., with a 32-bit counter) unless specifically required by the user.

T_Init is measured from the time the ring is free of spurious noise. It consists of two components where

$$T\_Init = T\_React + T\_Resp < 40{,}58 \text{ ms}$$

In the absence of noise,

$$T\_React < I\_Max + D\_Max + A\_Max + TVX < 30{,}24 \text{ ms}$$

NOTE - TVX is the actual value of TVX used (2,621 44 ms assumed).

$$T\_Resp < ((3 \times D\_Max) + (2 \times M\_Max \times Claim\_FR) + S\_Min) < 10{,}34 \text{ ms}$$

7.4.5 Late Counter (Late_Ct)

The number of TRT expirations since MAC was reset or a Token (restricted or nonrestricted) was received shall be accumulated as the value Late_Ct to assist Station Management in the isolation of serious ring errors and to provide fair bandwidth sharing for users of the asynchronous data service provided by MAC.

Late_Ct is set to one when the station is initialized or reset and is incremented, whenever TRT expires. After the ring has become operational (Ring_Operational), Late_Ct is cleared (to zero) whenever the transmitter is notified by the receiver of the arrival of a valid Token (restricted or nonrestricted) and the Late_Ct is incremented on each expiration of TRT.

7.5 Frame counts

To aid in problem determination and fault location, the MAC entity in each station shall maintain counts of all frames received and of all frames received with one or more errors that were previously undetected.

To be counted as a frame, a frame sequence shall be terminated by a frame ending delimiter (T symbol). Frame sequences terminated by stripping actions (Idle symbols) or the reception of invalid symbols shall not be counted as frames received. Full detail on Receiver actions for receiving and counting frames is provided in 8.3.

7.5.1 Frame_Ct

This is the count of all frames received.

7.5.2 Error_Ct

This is the count of error frames that were detected by this station and no previous station. Frames received with the Frame Status Error Indicator set (Er = S) are not counted as error frames by a station, since they should already have been counted by the station that set the Error Indicator.

7.5.3 Lost_Ct

Lost_Ct is a count of all instances in which MAC is in the process of receiving a frame or Token and an error is detected such that the credibility of PDU reception is placed in doubt. In these instances, MAC shall increment the Lost_Ct and strip the rest of the frame from the ring, replacing it with Idle symbols. The Lost_Ct is not incremented in subsequent stations that recognize the remnant as a stripped frame because it is followed by an Idle symbol.

8 Operation

This clause specifies the operation of the MAC entity of a FDDI Token Ring Station.

8.1 Overview

This subclause provides a descriptive overview of MAC operation. The formal specifications are contained in subsequent subclauses (8.2 to 8.4).

Access to the Physical medium (the ring) is controlled by passing a Token around the ring. The Token gives the downstream station (receiving relative to the station passing the Token) the opportunity to transmit a frame or a sequence of frames. If a station wants to transmit, it strips the Token from the ring before the Frame Control field of the Token is repeated. After the captured Token is completely received, the station shall begin transmitting its eligible queued frames.

After transmission, the station issues a new Token for use by a downstream station.

Stations that are not transmitting merely repeat the incoming symbol stream. While repeating the incoming symbol stream, the station determines whether the information is intended for this station. This is done by matching the DA to its own address or a relevant group address. If a match occurs, subsequent received symbols, up to the FCS, are processed by the MAC or sent to the LLC.

8.1.1 Frame transmission

Upon a request for Service Data Unit (SDU) transmission, MAC constructs the Protocol Data Unit (PDU) or frame from the SDU by placing the SDU in the INFO field of the frame. The SDU remains queued by the requesting entity awaiting the receipt of a Token that may be used to transmit it.

Upon reception and capture of an appropriate Token, the station begins transmitting its queued frame(s) in accordance with the rules of Token holding.

During transmission, the FCS for each frame is generated and appended to the end of the PDU.

8.1.2 Token transmission

After transmission of the frame(s) is completed, the station immediately transmits a new Token.

Optionally, the station may wait to see one or more frames return, up to the number it has sent during that Token holding time, before issuing the Token. The station shall check to see if the station's address has returned in the SA field, as indicated by the M_FLAG. If it has not been returned, the station shall transmit Idle symbols. On notification that the FC, DA, and SA have been returned, or immediately if it chooses not to wait, the station shall transmit a new Token. Note that this optional Token handling method shall not be used with normal data transmission because it results in significant performance degradation. However, this method may be used for various Station Management functions.

8.1.3 Frame stripping

Each transmitting station shall be responsible for stripping from the ring the frames that it originated. This is accomplished by stripping the remainder of each frame whose Source Address matches the station's address from the ring and replacing it with Idle symbols.

This process of stripping leaves remnants of frames, consisting of the PA, SD, FC, DA and SA fields, followed by Idle symbols, because the decision to strip a frame is based upon recognition of the station's address in the SA field, which cannot occur until after the initial part of the frame has already been repeated. These remnants cause no ill effects because various criteria, including recognition of an Ending Delimiter (ED), have to be met to indicate a frame. To the level of accuracy required for statistical purposes, these remnants can be distinguished from error or lost frames because they are always followed by the Idle symbol. Remnants are removed from the ring when they encounter a transmitting station.

8.1.4 Ring scheduling

Transmission of normal PDUs (i.e., PDUs formed from SDUs) on the ring is controlled by a Timed Token Rotation protocol. This protocol supports two major classes of service:

(a) **synchronous:** Guaranteed bandwidth and response time

(b) **asynchronous:** Dynamic bandwidth sharing

The synchronous class of service is used for those applications whose bandwidth and response time limits are predictable in advance, permitting them to be preallocated (via SMT). The asynchronous class of service is used for those applications whose bandwidth requirements are less predictable (e.g., bursty or potentially unlimited) or whose response time requirements are less critical. Asynchronous bandwidth is instantaneously allocated from the pool of remaining ring bandwidth that is unallocated, unused, or both.

Within each station, the MAC Transmitter maintains a Token-Rotation Timer (TRT) to control ring scheduling. A Target Token Rotation Time (TTRT) is negotiated during ring initialization via the Claim Token process. The MAC Receiver saves the most recently received TTRT bic (T_Bid_Rc) and passes the final negotiated TTRT value (T_Neg) to the MAC transmitter where it becomes the operative TTRT (T_Opr) upon successful ring initialization. TRT shall be reset each time an early Token arrives at a station. A Token arriving before TRT reaches TTRT (i.e., an early Token) may be used for both synchronous and asynchronous transmissions. A Token arriving after TRT reaches TTRT (i.e., a late Token) may be used only for synchronous transmissions. Different mechanisms are used to limit the length of a station's synchronous and asynchronous transmissions. However, in no case is a station intended to hold the Token longer than TTRT.

This protocol guarantees an average TRT (or average synchronous response time) not greater than TTRT, and a maximum TRT (or maximum synchronous response time) not greater than twice TTRT.

8.1.4.1 Synchronous transmission

Each station has a known allocation of synchronous bandwidth, i.e., the maximum time that the station may hold the Token without THT being enabled. Synchronous bandwidth is expressed as a percentage of TTRT, i.e., a station would require a 100% allocation to transmit for a time equal to TTRT before issuing a Token.

Allocation of synchronous bandwidth is established by SMT, using SMT PDUs. Initially, each station has a zero allocation, and it uses the SMT protocol to change its allocation. A station may "remember" its allocation across ring reinitialization, provided that there has not been a TTRT change or a major ring reconfiguration (e.g., no Beacon frames have been received). The sum of all stations' current allocations should not exceed the maximum usable synchronous bandwidth of the ring, expressed as:

TTRT - (D_Max + F_Max + Token_time) (see 7.4.1)

Support for synchronous transmission is optional, and is not required for interoperability.

8.1.4.2 Asynchronous transmission

Asynchronous bandwidth is controlled by a two-tier allocation mechanism, enforced by two classes of Tokens:

(a) **nonrestricted token:** Asynchronous bandwidth is time-sliced among all requesters.

(b) **restricted token:** Asynchronous bandwidth is dedicated to a single extended dialogue between specific requesters.

The ring begins operation in nonrestricted Token mode. This is the normal mode of operation. It supports fair access at a frame granularity. In this mode multiple levels of asynchronous priority may optionally be distinguished by a station. For each implemented priority level (*n*), a threshold value (T_Pri(*n*)) is established, forming a set of threshold values (T_Pri). A nonrestricted Token may only be captured for transmission of a frame of priority *n* when the current Token-Rotation Timer (TRT) is less than the associated priority threshold value (T_Pri(*n*)). By setting lower threshold values for lower priority levels, transmission of lower priority frames is deferred when the ring is more heavily loaded (i.e., TRT exceeds the threshold).

Whenever an early Token is captured, the current value of TRT shall be saved in an asynchronous Token-Holding Timer (THT), and TRT shall be reset to time the next Token rotation. THT is enabled (running) during asynchronous transmission. The difference between its current value and the target value (TTRT) reflects the remaining asynchronous bandwidth available to this station. An asynchronous frame of priority *n* may only be transmitted if THT is less than the associated priority threshold value (T_Pri(*n*)). Multiple asynchronous priority levels is an implementation option. If they are not implemented, then all asynchronous frames shall have an effective threshold value = TTRT.

Restricted Token mode is entered when a station wishes to initiate an extended dialogue requiring substantially all of the unallocated ring bandwidth (e.g., an extended burst data transfer from a high-speed device). The management of the extended dialogue (e.g., decisions to initiate, continue and terminate the dialogue) shall be the responsibility of higher-level protocols. The initiating station captures a nonrestricted Token, transmits its initial dialogue frame(s), then issues a restricted Token. The addressed destination station(s) receive the initial dialogue frame(s), enter restricted mode, and exchange restricted Tokens for the duration of the dialogue (typically many times TTRT). Restricted Token mode is terminated when the terminating station captures a restricted Token, transmits its final dialogue frame(s), then issues a nonrestricted Token.

Restricted Token mode supports fair access at a dialogue granularity, in that each contending extended dialogue initiator has equal opportunity to initiate new dialogues (deterministically, if the initiator is also the terminator). Restricted Token mode prevents any asynchronous transmission (including SMT normal background protocols, e.g., Neighbour Identification) other than the current extended dialogue, because normal asynchronous transmission cannot use restricted

Tokens and any new extended dialogue may only begin with a nonrestricted Token. However, synchronous transmission may proceed normally in restricted Token mode, because either class of Token may be used.

Use of THT in restricted Token mode is not required, since the dialogue consists of a deterministic sequence of exchanges, and frame-granular fairness to other traffic has been pre-empted. Ignoring THT is sometimes useful in that it extends to restricted Token mode service the bandwidth and response time guarantees of synchronous service, and may be used in conjunction with MA_TOKEN.request to minimize the effect of ring latency. However, if THT is ignored, the station shall not intrude on the aggregate synchronous bandwidth allocation (known to SMT).

To ensure fairness and detect potential hang conditions during restricted Token mode operation SMT should negotiate and monitor a maximum restricted Token mode time. If restricted Token mode operation exceeds this time, SMT should abort the extended dialogue via the SMT protocol and interface.

Support for restricted Token mode transmission is optional, and is not required for interoperability. An implementation of restricted Token mode may support ignoring THT, but is not required to.

8.1.5 Ring monitoring

The MAC monitoring functions are distributed among all stations on a ring. Each station continuously monitors the ring for invalid conditions requiring ring (re)initialization. Ring (re)initialization is a consequence of either inactivity or incorrect activity on the ring. Ring inactivity is typically detected by expiration of the Valid-Transmission Timer (TVX) in the MAC Receiver. Incorrect ring activity is typically detected by counting successive expirations of the Token-Rotation Timer (TRT) with the Late Counter (Late_Ct) in the MAC Transmitter, or by SMT processes.

8.1.5.1 Claim Token process

Any station detecting a requirement for ring (re)initialization shall initiate the Claim Token process. In this process one or more stations bid for the right to initialize the ring by continuously transmitting Claim Frames. Each station also looks for incoming Claim Frames and compares the received bid with the station's own bid. Any station receiving a lower bid shall (re)enter the bidding, while any station receiving a higher bid shall yield. Conflicting bids shall be resolved by an arbitration hierarchy as follows:

(a) The bid with the lowest Target-Token Rotation Time (TTRT) has precedence (i.e., the numerically highest T_Bid value).

(b) Given equal T_Bid values, the bid with the longest address has precedence (i.e. FC.L = 1 > FC.L = 0).

(c) Given equal T_Bid and L values, the bid with the highest address has precedence (i.e., the numerically highest SA value).

The Claim Token process completes when one station receives its own Claim Frames after the frames have passed around the ring. At this point the ring is "filled" with that station's Claim Frames and all other stations have yielded. The winning station proceeds to initialize the ring (see 5.1.5.2). These rules permit a given installation to give certain stations preferential status in ring recovery, but do not require it.

Each station times the Claim Token process by setting the Token-Rotation Timer (TRT) to a large value (T_Max) that is sufficient to permit stable ring recovery. TRT shall be reset to this value upon entering leaving the Claim Token process, but shall not be reset once a station has left the Claim Token process until the ring becomes operational (see 8.1.5.2). If TRT expires while a station is in the Claim Token process, the Claim Token process has failed to recover the ring. At this point, intervention that is external to MAC may be required, and the station shall initiate the Beacon process (see 8.1.5.3). If TRT expires after a station has left the Claim Token process and is waiting for some other station to initialize the ring, this station shall re-enter the Claim Token process. This mechanism ensures that spurious Beacon or pre-emptive Claim Frames will not persist on the ring, since at least one Beacon or Claim Frame has to be received to leave the Claim Token process.

8.1.5.2 Initialization process

Within each station, the Boolean variable Ring_Operational indicates the current operating status of the ring. Ring_Operational is cleared whenever the station initiates or detects the Claim or Beacon processes on the ring, and when it receives a MAC_Reset request from SMT (see 6.3.3). Whenever Ring_Operational is cleared (including subsequent MAC_Resets), any (SM_)MA_UNITDATA.request or (SM_)MA_TOKEN.request currently being serviced is aborted, no Token is issued, and an abnormal confirm status is returned to the requester.

Ring initialization begins when one station successfully completes the Claim Token process. That station proceeds to initialize the ring. First, it sets the operative TTRT value (T_Opr) to the negotiated TTRT value (T_Neg) (which should be the same as its requested TTRT value (T_Req) since this station won the bidding). Then it resets its Token-Rotation Timer (TRT). Finally it issues an initial nonrestricted Token.

The purpose of the initial rotation of the Token is to align both the TTRT values and the TRT timers in all stations on the ring. Since Ring_Operational is clear, no station may capture the initial Token or transmit frames. In each station upon receipt (and repeating) of the initial Token, T_Opr shall be set to T_Neg, TRT shall be reset, Late_Ct shall be set = 1, and Ring_Operational shall be set. These actions permit synchronous transmission on the second Token rotation while inhibiting asynchronous transmission. Beginning with the second Token rotation, each station correctly accumulates current synchronous bandwidth utilization (as opposed to allocated limits) in TRT, and asynchronous transmission is possible on the third and subsequent Token rotations (see 8.1.4.2).

8.1.5.3 Beacon process

When a station detects that the Claim Token process has failed, or upon request from SMT (see 6.3.3), that station initiates the Beacon process. In this case, the ring has probably been physically interrupted, and may have been globally reconfigured (e.g., one logical ring may have been partitioned into two, or two logical rings may have been joined into one). Some form of intervention that is external to MAC has been or should be invoked to restore the logical ring. The purpose of the Beacon process is to signal to all remaining stations that a significant logical break has occurred and to provide diagnostic or other assistance to the restoration process (via SMT).

Upon entering the Beacon process, a station continuously transmits Beacon Frames. A station yields to Beacon Frames received from an upstream station. Consequently, if the logical break persists, the Beacon Frames of the station immediately downstream from the break are normally propagated. If a station in the Beacon Process receives its own Beacon Frames, it assumes that the logical ring has been restored, and it initiates the Claim Token process to recover the ring quickly.

As with the Claim Token process, a station shall reset TRT upon entering the Beacon process, but not upon receipt of individual Beacon or Claim frames. If TRT expires after a station has left the Beacon process, this station shall enter the Claim Token process to remove spurious Beacon Frames. In conjunction with the normal frame-stripping function, these rules ensure that the ring can be recovered efficiently and reliably when the logical break is restored. However, they result in a brief interruption of Beacon Frame propagation through stations not immediately downstream of a logical break once every T_Max. This phenomenon does not compromise MAC, and it is easily filtered in the SMT Beacon processing logic.

8.2 Structure

MAC consists of two co-operating asynchronous processes, the MAC Receiver and the MAC Transmitter, within each station. Both of these processes operate on the symbol stream, and they are synchronized by global MAC variables (e.g., T_Opr) and signals (e.g., Token, Claim Frame, and the like).

The need for separate Receiver and Transmitter processes arises from the requirement that certain functions (specifically, recognition of MAC frames, own address detection, and capture of the Frame Status) shall be performed concurrently with, and asynchronously to the states of, the Transmitter. In cases where identical functions are needed by both processes (e.g., delimiter recognition and input validation), they have been placed in the Receiver with appropriate signals sent to the Transmitter. These signals may be replaced by their corresponding functions in the Transmitter.

It is also desirable that a station be capable of self monitoring, both to facilitate loop-back testing and to avoid compromising ring integrity unnecessarily; thus the error detection functions are specified in the Receiver while the recovery functions are specified in the Transmitter.

The MAC processes are defined as co-operating state machines. It is assumed that time elapses only within discrete states, and that state transitions are logically instantaneous. It follows that actions requiring one or more symbol times to complete shall be performed within states; however, when these actions are associated with a specific transition, they may be described as part of that transition. In all such cases the actions occur prior to the associated transition. Actions described as part of a state occur each time the state is entered. Thus, when a triggering event occurs externally to a state machine, the state machine shall perform the following event-processing sequence as a logically atomic operation:

(a) Evaluate all conditions within the current state.

(b) If the conditions for a state transition are satisfied, then

(1) Perform the transition actions in the current state.

(2) Enter the new state.

(3) Perform the entry actions (if any) for the new state.

(4) If an immediate transition from the new state is possible, then repeat the sequence beginning with step 1.

(c) If the conditions for in-state actions are satisfied, then the specified actions shall be performed.

The major triggering event to the MAC Receiver is the occurrence of a PH_UNITDATA.indication. The Receiver shall perform its event processing sequence, using the input symbol presented with the PH_UNITDATA.indication as a parameter for condition evaluation. Upon completion of the event processing sequence in the Receiver, both the input symbol and any associated event signals generated by Receiver actions shall be forwarded to the MAC Transmitter.

Event propagation from the MAC Receiver to the MAC Transmitter shall incur a conceptual propagation delay representing the internal MAC repeat delay of the station. The input symbol and any associated event signals generated by the Receiver actions experience identical propagation delay between Receiver and Transmitter. Consequently, they arrive at the Transmitter at the same conceptual time, but in the order that they were generated by the Receiver.

The major triggering event to the MAC Transmitter is the arrival of an input symbol, together with any associated event signals, from the MAC Receiver; i.e., for each input symbol the Transmitter shall generate a corresponding output symbol. The Transmitter performs its event-processing sequence, but uses the input symbol forwarded from the Receiver as a parameter for condition evaluation only when it is potentially repeatable; i.e., within the Repeat State. Upon completion of the event processing sequence in the Transmitter, a PH_UNITDATA.request with the appropriate output symbol is generated as an in-state action in the resultant Transmitter state. In the Repeat State, the output symbol shall typically be the input symbol from the Receiver; in all other states, the input symbol is discarded and a new output symbol is generated.

It is also assumed that the contents of specific fields in received and transmitted frames are only known to MAC during the lifetime of the frames. Any values to be remembered shall be saved in MAC variables.

The MAC state machines are specified both with text and with state diagrams. In the state diagrams, states are shown as vertical staffs and state transitions as horizontal arrows, with the triggering event or condition above the shaft and any action beneath the shaft. In the event of any discrepancy, the state diagrams and attached notes shall take precedence over text.

8.3 Receiver

This subclause describes the detailed MAC Receiver operation as shown in figure 2.

The MAC Receiver process receives and validates information from the ring, selects those portions that are relevant to its station, detects ring errors and failures, and reports them via appropriate signals. The Receiver scans the input from PHY (PH_Indication), looking for valid frames (FR) and Tokens (TK). Each frame whose Destination Address (DA) matches one of the Station_Addresses shall be passed to the appropriate entity (LLC, MAC, or SMT) with the frame validity status. MAC frames shall be processed by the Receiver after validation. A Valid-Transmission Timer (TVX) shall be maintained to detect ring failures. Appropriate signals shall be generated for the Transmitter process, and the current T_Bid_Rc and T_Neg and Frame Status Indicators, A_Flag, C_Flag, and E_Flag shall be saved for the transmitter. Counts of all frames (Frame_Ct) and bad frames (Error_Ct and Lost_Ct) shall also be maintained for SMT.

8.3.1 Token and frame validity criteria

For purposes of classifying and taking action as the result of a received Token or frame, the following criteria are applied:

(a) Token

(1) Has a Starting Delimiter (JK).

(2) Has an FC = 1X00 0000.

(3) Has no additional Data Symbols (*n*).

(4) Has a Token Ending Delimiter (TT).

(b) Frame (included in Frame_Ct)

(1) Has a Starting Delimiter (JK).

(2) Has an FC other than 1X00 0000.

(3) Has zero or more additional Data Symbols (*n*).

(4) Has an Ending Delimiter (T).

(c) Format Error (included in Lost_Ct)

(1) Has a Starting Delimiter (JK).

(2) Has zero or more Data Symbols (*n*).

(3) Is not a Token.

(4) Is not a Frame.

(5) Ends with a symbol other than Idle (I) as its first nondata symbol.

(d) Void (may or may not physically be a frame, but logically is not, i.e., contains n information)

(1) Has a Starting Delimiter (JK).

(2) Has an FC = 0X00 0000.

(e) Valid Data Length

(1) Is an integral number of Data Symbol pairs (octets) between Starting and Endin Delimiters.

(2) Is a minimum number of octets between Starting and Ending Delimiters as show in table 1.

(f) Valid Frame[1]

(1) Is a Frame.

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[1] The list of valid frame criteria is the intended subject of a future amendment to also require tha the received E indicator be reset, and in addition, to require that MAC repeat the E indicator as se for all cases where it is not received as reset.

(2) Has a Valid Data Length.

(3) Has an FC = 0X00 0000 or XX10 XXXX, or has correct FCS.

(g) Frame Error (set E_Flag)

(1) Is a Frame.

(2) Is not a Valid Frame.

(h) Locatable Error (included in Error_Ct)

(1) Is a Frame Error.

(2) The Error Detected Indicator either was not received or was received as Reset (Er=R).

Table 1 - Interpretation of FC field

FC	Interpretation	Minimum Octets
CLFF ZZZZ to ZZZZ		
XX00 0000	Void or Token	1
0000 0001 to 1111	SMT frame	9
0100 0001 to 1111	SMT frame	17
1000 0001 to 1111	MAC frame	13
1100 0001 to 1111	MAC frame	21
X001 XXXX	LLC frame	9
X101 XXXX	LLC frame	17
X010 XXXX	Implementer frame	9
X110 XXXX	Implementer frame	17
X011 XXXX	Reserved	9
X111 XXXX	Reserved	17

8.3.2 State R0: LISTEN

When a MAC Receiver is initialized, it enters the Listen State. In this state, the receiver waits for a valid symbol from PHY, and the Valid-Transmission Timer (TVX) is disabled.

A PH_Indication(I) represents the start of signalling reception upon which clock synchronization may be established. A transition to the Listen State represents a potential discontinuity in the processing of the input symbol stream.

R(00): Physical Reset: A transition to State R0 occurs if a MAC_Reset signal (see 6.3.3.3) is received. On this transition, the negotiated TTRT (T_Neg) shall be set to the maximum TTRT supported by this station (T_Max).

R(01): Signal Start: If PH_Indication(I) is received from PHY, the Valid-Transmission Timer (TVX) shall be reset and enabled, and a transition to State R1 occurs.

8.3.3 State R1: AWAIT_SD (Await Starting Delimiter)

In this state, the receiver looks for a valid start of a frame or Token (PH_Indication(J)] Input received during other receiver states is not excluded, since invalid input in those state: may prove to be valid starting delimiters upon return to this state. The test for RC_Star only occurs in this state.

R(10a): Physical Reset: A transition to State R0 occurs if a MAC_Reset signal is received On this transition, the negotiated TTRT (T_Neg) shall be set to the maximum TTRT supporte(by this station (T_Max).

R(10b): Reset: A transition to State R0 occurs if a PH_Invalid is received from PHY.

R(12): Start Receive: If PH_Indication(J) is received, a transition to State R2 occurs. On thi: transition, the RC_Start signal is generated. The address recognized (A_Flag), frame copie((C_Flag), error detected (E_Flag), next station addressing (N_Flag), higher source addres: (H_Flag), lower source address (L_Flag), and my source address (M_Flag) flags shall b(cleared.

8.3.4 State R2: RC_FR_CTRL (Receive Frame Control Field)

In this state, the receiver scans the received symbols for a start of frame or start of Toke sequence consisting of the start delimiter followed by two data symbols (JKnn). Th(appropriate valid header exit is chosen based upon the received frame control fielc Valid_FCS_Rc is reset in preparation for checking the incoming frame.

R(20a): Physical Reset: A transition to State R0 occurs if a MAC_Reset signal is receivec On this transition, the negotiated TTRT (T_Neg) shall be set to the maximum TTRT supporte(by this station (T_Max).

R(20b): Reset: A transition to State R0 occurs if PH_Invalid is received from PHY. On thi: transition, the FO_Error signal shall be generated and the Lost_Ct shall be incremented.

R(21a): Frame Strip: A transition to State R1 occurs if PH_Indication(I) is received from PH\ or if PH_Indication (K) is not the next symbol received after transition R(12). On thi: transition, the FR_Strip signal shall be generated.

R(21b): Format Error: This transition to State R1 occurs if a symbol sequence other than I o nn is received from PHY after receipt of the K symbol. On this transition, the FO_Erro signal shall be generated and the Lost_Ct shall be incremented.

If the transition R(21a) or R(21b) is caused by the receipt of another J symbol, such as th(sequences JJ, JKJ, or JKnJ, and the Receiver is capable of processing a Start of Fram(sequence with a zero-length Preamble, then the transition to State R1 and back to State R: shall be considered as taking zero time, such that the second J symbol is interpreted as th(potential start of a valid frame sequence.

R(23): Start of Frame: After a starting delimiter and FC field (JKnn) have been received; ; transition to State R3 occurs if the received FC field (FCr) indicates a frame start (i.e., no Token). If the FC field indicates a next station addressing frame, then the N_Flag shall b(set.

R(25): Start of Token: After a starting delimiter and FC field (JKnn) have been received ; transition to State R5 occurs if a possible Token is being received.

8.3.5 State R3: RC_FR_BODY (Receive Frame Body)

In this state the receiver scans the received Destination Address (DA) and Source Address (SA) and takes actions as appropriate. Also, in this state the receiver scans the remainder of the frame up to the reception of an Ending Delimiter (T symbol) and checks FCS. If a Claim Frame is indicated by the FC field, the receiver scans the INFO field and takes actions as appropriate.

Destination Address received actions (DA_Actions) shall be as follows:

(a) No actions are taken if the FC field indicates a Void Frame.

(b) If the L Bit received (Lr), contained in the FC field, is equal to zero, indicating a 16-bit address, and if the Destination Address received (DAr) is contained in the set of this station's Short Addresses, then the A_Flag is set and the frame is passed to the appropriate entity (LLC, MAC, or SMT) as indicated by the Frame Control field received (FCr).

(c) If the L Bit received (Lr), contained in the FC field, is equal to one, indicating a 48-bit address, and if the Destination Address received (DAr) is contained in the set of this station's Long Addresses, then the A_Flag is set and the frame is passed to the appropriate entity (LLC, MAC, or SMT) as indicated by the Frame Control field received (FCr).

Source Address received actions (SA_Actions) shall be as follows:

(a) If the L Bit received (Lr) is equal to zero, indicating a 16-bit address, then

(1) If the Source Address received (SAr) is equal to this station's My Short Address (MSA) but not zero, then

- My Address received flag (M_Flag) is set.
- FR_Strip signal is generated.

(2) If this station's My Long Address (MLA) is equal to zero and SAr is greater than this station's MSA, then the Higher Address received flag (H_Flag) is set.

(3) Otherwise, when SAr is not equal to zero, then the Lower Address received flag (L_Flag) is set.

(b) If Lr is equal to one, indicating a 48-bit address, then

(1) If the Source Address received (SAr) is equal to this station's My Long Address (MLA) but not zero, then

- My Address received flag (M_Flag) is set.
- FR_Strip signal is generated.

(2) If SAr is greater than this station's MLA, then the Higher Address received flag (H_Flag) is set.

(3) Otherwise, when SAr is not equal to zero, then the Lower Address received flag (L_Flag) is set.

Claim-Token-received actions (CT_Actions) shall be as follows:

(a) If the Frame Control Field received indicates that this frame is a MAC Claim Frame (FC = 1L00 0011), then the first four octets of this frame's INFO field contains the bidding TTRT received (T_Bid_Rc) from the upstream station. If the T_Bid_Rc is

(1) Greater than this station's requested TTRT (T_Req), then

- H_Flag is set.
- M_Flag is cleared.
- L_Flag is cleared.

(2) Less than this station's requested TTRT (T_Req), then

- L_Flag is set.
- M_Flag is cleared.
- H_Flag is cleared.

(3) Equal to this station's requested TTRT (T_Req), then no flag actions are taken and

- L_Flag is unchanged.
- M_Flag is unchanged.
- H_Flag is unchanged.

(b) Finally, if the L_Flag is still set then the FR_Strip signal is generated.

R(30a): Physical Reset: A transition to State R0 occurs if a MAC_Reset signal is received. On this transition, the negotiated TTRT (T_Neg) shall be set to the maximum TTRT supported by this station (T_Max).

R(30b): Reset: A transition to State R0 occurs if a PH_Invalid is received from PHY. On this transition, the FO_Error signal shall be generated and the Lost_Ct shall be incremented.

R(31a): Frame Strip: A transition to State R1 occurs if PH_Indication(I) is received from PHY. On this transition, the FR_Strip signal shall be generated.

R(31b): Format Error: This transition to State R1 occurs if a symbol other than I or data is received before an Ending Delimiter (T). On this transition, the FO_Error signal shall be generated and the Lost_Ct shall be incremented.

R(34): ED Received: A transition to State R4 occurs and Frame_Ct shall be incremented if PH_Indication(T) is received. If the received frame has a valid data length and the FCS is good, or if FCr indicates a Void or Implementer frame, then the Valid-Transmission Timer (TVX) shall be reset and if the A_Flag has been set and no error was detected in the interface to the receiving entity (Valid_Copy), then the frame-copied indicator (C_Flag) shall be set. If the received frame does not have a valid data length, or the FCS check is bad and FCr does not indicate a Void or Implementer frame, then the E_Flag shall be set and the A_Flag, M_Flag, H_Flag and L_Flag shall be cleared.

8.3.6 State R4: RC_FR_STATUS (Receive Frame Status)

In this state the receiver scans for trailing control indicator symbols (R or S) representing the Error Detected, Address Recognized, and Frame Copied control indicators. The condition for transfer to State R1 is satisfied upon detection of the first subsequent symbol that is not a control indicator. If that symbol is a T symbol, it is a candidate for being repeated by the MAC transmitter as the last symbol of frame status. If that symbol is not a T symbol, it shall not be considered to be part of frame status and therefore shall not be repeated by the MAC transmitter.

NOTE - One way to align the timing of the above conditions so that the MAC transmitter need not be sensitive to what is occurring is to implement a substate within State R4 which is entered only upon detection of a trailing T symbol. The MAC receiver would then transition to State R1 at the next symbol boundary, regardless of what symbol is presented. While in this substate, if either condition for transition to State R0 is satisfied, that transition (40a or 40b) would still continue to take precedence.

While in this state, if the received A indicator (Ar) is reset, and if the N_Flag is set indicating a next station addressing frame, then the N_Flag shall be cleared, allowing the transmitter to set the C Indicator (Cx). The transmitter shall, however, still repeat the C Indicator as set if the received value is set.

R(40a): Physical Reset: A transition to State R0 occurs if a MAC_Reset signal is received. On this transition, the negotiated TTRT (T_Neg) shall be set to the maximum TTRT supported by this station (T_Max).

R(40b): Reset: A transition to State R0 occurs if PH_Invalid is received from PHY. On this transition, the FR_Received signal shall be generated and, if the E_Flag is set and the Error Detected Indicator (Er) either was not received or was received as Reset, then the Error_Ct shall be incremented.

R(41a): My Claim: After reception of the received Frame Status field (FSr), a transition to State R1 occurs. If the received Frame Control field indicates a Claim Frame (FCr = Claim) and a successful claim comparison is made, then T_Neg shall be set equal to T_Bid_Rc, My_Claim shall be generated, and the R_Flag shall be reset. The comparison for establishing My_Claim requires that the address length bit contained in the FC field (FC.L), the Source and Destination Address fields (SA and DA), and the MAC information field (including T_Bid_Rc) match this station's transmitted values.

R(41b): Higher Claim Received: After FSr, a transition to State R1 occurs. If the received Frame Control field indicates a Claim Frame (FCr = Claim) and a successful higher claim comparison is made, then T_Neg shall be set to T_Bid_Rc, Higher_Claim shall be generated, and the R_Flag shall be reset. The comparison for establishing Higher_Claim shall be made in the following order; first on the T_Bid_Rc field, second on the address length bit contained in the FC field, and finally on the address field itself.

R(41c): Lower Claim Received: After FSr, a transition to State R1 occurs. If the received Frame Control field indicates a Claim Frame (FCr = Claim) and a successful lower claim comparison is made, then Lower_Claim shall be generated and the R_Flag shall be reset. The comparison for establishing Lower_Claim shall be made in the following order; first on the T_Bid_Rc field, second on the address length bit contained in the FC field, and finally on the address field itself.

R(41d): My Beacon Received: After FSr, a transition to State R1 occurs. If the received Frame Control field indicates a Beacon Frame and a successful address comparison (SA=MA) is made, then My_Beacon shall be generated, T_Neg shall be set to T_Max, and the R_Flag shall be reset.

R(41e): Other Beacon Received: After FSr, a transition to State R1 occurs. If the received Frame Control field indicates a Beacon Frame, an unsuccessful address comparison (SA not= MA) is made, and no errors were detected (not E_Flag), then Other_Beacon shall be generated, T_Neg shall be set to T_max and the R_Flag shall be reset.

R(41f): Frame Received: After FSr, a transition to State R1 occurs. If none of the conditions for transitions R(41a) through R(41e) are satisfied, then transition R(41f) shall be taken and FR_Received shall be generated. On this transition, if the E_Flag is set and the Error Detected Indicator (Er) either was not received or was received as Reset, then the Error_Ct shall be incremented.

8.3.7 State R5: CHECK_TK (Check Token)

In this state, the receiver looks for a valid Token ending delimiter (TT). Both T symbols shall be repeated by the MAC transmitter when the token is being repeated by the station.

NOTE - To align the timing of the above condition to the symbol being repeated in a fashion consistent with the repeating of the symbols of frame status in State R4, a substate should be implemented within State R5, which is entered upon detection of the second T symbol. The MAC receiver would then transition to R1 via 51c at the next symbol boundary, regardless of what symbol is presented. While in this substate, if either condition for transition to State R0 is satisfied, that transition (50a or 50b) would still continue to take precedence.

R(50a): Physical Reset: A transition to State R0 occurs if a MAC_Reset signal is received. On this transition, the negotiated TTRT (T_Neg) shall be set to the maximum TTRT supported by this station (T_Max).

R(50b): Reset: A transition to State R0 occurs if a PH_Invalid is received from PHY. On this transition, the FO_Error signal shall be generated and the Lost_Ct shall be incremented.

R(51a): Frame Strip: A transition to State R1 occurs if PH_Indication(I) is received from PHY. On this transition, the FR_Strip signal shall be generated.

R(51b): Format Error: This transition to State R1 occurs if any symbol other than I or T is received. On this transition, the FO_Error signal shall be generated and the Lost_Ct shall be incremented.

R(51c): Token Received: A transition to State R1 occurs if a correct Token Ending Delimiter (TT) is received. If the Token_class of the received Token is nonrestricted, then the R_Flag shall be cleared and TVX shall be reset; otherwise, if the the R_Flag is not already set, then the R_Flag shall be set and an SM_MA_Status.indication should be optionally generated to permit SMT to monitor the duration of the restricted Token dialogue. In restricted Token mode, TVX shall not be reset unless a valid Frame is received. In any case, the Token_Received (TK_Received) signal shall be generated for the Transmitter.

8.4 Transmitter

This subclause describes the overall MAC Transmitter operation as shown in figure 3.

The MAC Transmitter process repeats information from other stations on the ring, inserts information from its own station into the ring, and co-operates with other stations to co-ordinate priorities for use of the ring. It operates on the input symbol stream from PHY (PH_Indication) and produces the output symbol stream to PHY (PH_Request). The Transmitter repeats the received frames until it needs and receives a usable Token. Then it transmits its own data, passes the Token, and resumes repeating. The Transmitter also transmits Claim Frames when required to recover the ring. The operation of the Transmitter is synchronized by the signals generated by the Receiver; the Transmitter also uses the Frame Status

(A_Flag), C_Flag, and E_Flag) values saved by the Receiver. The Transmitter maintains the current operating value of the ring Target Token Rotation Time (T_Opr) and the Token-Rotation Timer (TRT) to ensure correct ring scheduling.

8.4.1 State T0: TX_IDLE (Transmitter Idle)

When a MAC transmitter is initialized, it enters the TX_Idle state. In this state the transmitter sends continuous Idle symbols (I). The Transmitter reverts to this state between repeated frames and Tokens, to capture a Token, and to strip frames that have circulated the ring.

T(00): Reset: A transition to State T0 occurs when transmitter reset is required. Reset shall be required when any of the following conditions occurs:

(a) An SM_MA_CONTROL.request (Reset or Beacon) is received from SMT, resulting in MAC_Reset.

(b) A Claim Frame with a higher precedence is received (Higher_Claim).

(c) A Beacon Frame with another station's Source Address is received (Other_Beacon).

The operational Target Token Rotation Time (T_Opr) shall be set to its maximum value (T_Max). If the ring was operational (Ring_Operational) before the reset occurred or the Token is not already late (Late_Ct=0), then the Token-Rotation Timer (TRT) shall be reset to T_Opr, the Token shall be indicated as late by setting Late_Ct equal to one, and Ring_Operational shall be cleared. Finally the transition to State T0 occurs.

This transition shall take precedence over the recovery transition if their respective conditions occur simultaneously.

T(01): Receive Start: A transition to State T1 occurs after the receiver detects the beginning of a starting delimiter (RC_Start signal). RC_Start received during other transmitter states is not necessarily ignored, since transitions to the TX_Idle State may immediately encounter the receiver start condition upon return to the TX_Idle State, i.e., the TX_Idle State may be traversed in zero time; however, the reaction to RC_Start only occurs in the TX_Idle state.

T(02): Usable Token Received: A transition to State T2 occurs when the receiver signals the receipt of a valid Token (TK_Received), the Token is usable. A Token is usable when the ring is operational (Ring_Operational) and either:

(a) The station has a synchronous request queued for transmission, or

(b) The Token is early (Late_Ct=0) and all of the following conditions exist:

(1) The station has an asynchronous request queued.

(2) The requested Token class was received (R_Flag).

(3) THT is to be ignored (Ignore_THT) or the Token Rotation Timer (TRT) is less than the requested priority threshold value (T_Pri(Request_Priority)).

At this point, the Token has been successfully captured. The Token-Holding Timer (THT) is disabled. If the Token is early (Late_Ct=0), then the Token-Rotation Timer (TRT) value is saved in THT and TRT is reset. Otherwise, THT is set to its expired value and Late_Ct is cleared, allowing TRT to retain the accumulated lateness. Finally, the transition to State T2 occurs.

A single TK_Received signal shall cause at most one transition in the Transmitter, i.e., thi transition cannot immediately follow T(10b).

T(03): Token Received and Not Usable: A transition to State T3 occurs when the Receive signals the receipt of a valid Token (TK_Received) and the Token is not usable (see T(02) At this point, the Token has been inadvertently captured (due to a short ring or other timin window) and shall be reissued. If the ring is already operational (Ring_Operational), and if th Token is early (Late_Ct=0), the Token-Rotation Timer (TRT) shall be reset to the Targe Token Rotation Time (T_Opr); otherwise, Late_Ct shall be cleared, allowing TRT to retain th accumulated lateness. If the ring is not already operational, T_Opr shall be set to the fin negotiated Target Token Rotation Time (T_Neg), TRT is reset to the new value of T_Op Late_Ct is set equal to one and Ring_Operational is set. Finally, the transition to State T occurs.

A single TK_Received signal shall cause at most one transition in the Transmitter, i.e., thi transition cannot immediately follow T(10b).

T(04): Recovery: A transition to State T4 occurs when ring recovery is required. Recover shall be required when any of the following conditions occurs:

(a) The Valid-Transmission Timer (TVX) expires.

(b) TRT expires and the Token is already late (Late_Ct>0).

(c) The ring is operational (Ring_Operational) with a Target Token Rotation Time greate than this station's requested Target Token Rotation Time (i.e., in twos complemen T_Opr<T_Req).

(d) A Claim Frame with a lower precedence is received (Lower_Claim).

(e) A Beacon Frame is received with this station's Source Address (My_Beacon).

The T_Opr shall be set to its maximum value (T_Max), TRT shall be reset to the new valu of T_Opr, Ring_Operational shall be cleared, and the transition to State T4 occurs.

The recovery transition conditions are asynchronous to the normal operation of the Transmitte Therefore these conditions may occur at the same time as the conditions for some othe transition. If this happens the other transition shall take precedence. However, the recover transition conditions (e.g., timer expiration) shall be "remembered" unless the pre-emptin transition causes them to be cleared (e.g., timer reset).

T(05): Beacon Requested: A transition to State T5 occurs if a SM_MA_CONTROL.reques (Beacon) was received. TRT shall be reset to T_Opr.

8.4.2 State T1: REPEAT (Repeat)

In this state the transmitter generally repeats the input symbol stream; however, the receive trailers may be modified and certain frames may be aborted. The transmitter normally return to the Idle state between frames (FR_Received or TK_Received). If a usable Token i detected, then the transmitter returns to the Idle State before the FC field of the Token i repeated and thus the Token is stripped from the ring. The repeat action shall also b stopped for any frame where the Source Address field equals the station address (M_Flag thereby stripping it from the ring, and whenever a format error (FO_Error) is detected by th receiver.

While in this state, the Transmitter may alter the values of individual control indicators in the repeated Frame Status field (FS_Actions). If the E_Flag or A_Flag are set, then the corresponding E or A indicators shall be set rather than repeated. If the C_Flag is set and the N_Flag is clear, then the C indicator shall be set rather than repeated. If the N_Flag is set, this station is not the next station addressed within the group, so it shall not alter the C indicator even if it successfully copied the Frame. The processing of subsequent indicators by an addressed station (A_Flag set) is unspecified; however, a nonaddressed station shall repeat them unaltered.

The Frame Status field is variable in length; consequently, some control indicators may inadvertently be destroyed by transmission noise on the ring. If a given indicator is not correctly received, the Receiver shall not scan for subsequent indicators. The implementer may choose to restore lost indicators in certain cases. For example, the E indicator can always be restored to the set condition based on the value of E_Flag, whereas the A and C indicators shall only be restored to the set condition if the corresponding FS_Actions cause them to be set, rather than repeated.

T(10a): Token Capture: A transition to State T0 occurs before the Frame Control (FC) field of a Token is repeated, if the Token is usable. A Token is usable when the ring is operational (Ring_Operational) and either:

(a) The station has a synchronous request queued for transmission, or

(b) The Token is early (Late_Ct=0) and all of the following conditions exist:

(1) The station has an asynchronous request queued.

(2) The requested Token class was received (R_Flag).

(3) THT is to be ignored (Ignore_THT) or the Token Rotation Timer (TRT) is less than the requested priority threshold value (T_Pri(Request_Priority)).

At this point, an attempt is made to capture the Token by stripping it from the ring. Note that this transition may occur before the first symbol of the FC field is repeated, and shall occur before the last symbol of the FC field is repeated. The Receiver shall subsequently signal successful Token capture (TK_Received) if a valid Token was received.

T(10b): Token Repeated: A transition to State T0 occurs after a Token is repeated. If the ring is already operational (Ring_Operational), and if the Token is early (Late_Ct=0), then the Token-Rotation Timer (TRT) shall be reset to the Target Token Rotation Time (T_Opr); otherwise, Late_Ct shall be cleared, allowing TRT to retain accumulated lateness. If the ring is not already operational, then T_Opr shall be set to the final negotiated Target Token Rotation Time (T_Neg), TRT shall be reset to the new value of T_Opr, Late_Ct shall be set to 1, and Ring_Operational shall be set. Finally, the transition to State T0 occurs.

A single TK_Received signal shall cause at most one transition in the Transmitter; i.e., this transition cannot immediately precede T(02) or T(03).

T(10c): Strip: A transition to State T0 occurs if the Receiver detects a strip condition (FR_Strip) or if a format error (FO_Error) is detected.

T(10d): Reset: A transition to State T0 occurs when transmitter reset is required. Reset shall be required when any of the following conditions occurs:

(a) An SM_MA_CONTROL.request (Reset or Beacon) is received from SMT, resulting in a MAC_Reset.

(b) A Claim Frame with a higher precedence is received (Higher_Claim).

(c) A Beacon Frame with another station's Source Address is received (Other_Beacon).

The operational Target Token Rotation Time (T_Opr) shall be set to its maximum value (T_Max). If the ring was operational (Ring_Operational) before the reset occurred or the Token is not already late (Late_Ct=0), then the Token-Rotation Timer (TRT) shall be reset to T_Opr, the Token shall be indicated as late by setting Late_Ct equal to one, and Ring_Operational shall be cleared. Finally the transition to State T0 occurs.

This transition shall take precedence over the recovery transition if their respective conditions occur simultaneously.

T(10e): **Frame Repeated:** A transition to State T0 occurs after a frame is repeated.

T(14): **Recovery:** A transition to State T4 occurs when ring recovery is required. Recovery shall be required when any of the following conditions occurs:

(a) The Valid-Transmission Timer (TVX) expires.

(b) TRT expires and the Token is already late (Late_Ct>0).

(c) The ring is operational (Ring_Operational) with a Target Token Rotation Time greater than this station's requested Target Token Rotation Time (i.e., in twos complement T_Opr<T_Req).

(d) A Claim Frame with a lower precedence is received (Lower_Claim).

(e) A Beacon Frame with another station's Source Address is received (My_Beacon).

The T_Opr shall be set to its maximum value (T_Max), TRT shall be reset to the new value of T_Opr, Ring_Operational shall be cleared, and the transition to State T4 occurs.

The recovery transition conditions are asynchronous to the normal operation of the Transmitter. Therefore these conditions may occur at the same time as the conditions for some other transition. If this happens the other transition shall take precedence. However, the recovery transition conditions (e.g., timer expiration) shall be "remembered" unless the pre-empting transition causes them to be cleared (e.g., timer reset).

8.4.3 State T2: TX_DATA (Transmit data)

In this state the transmitter transmits one or more data frames, the total being limited by the TTRT and the amount of data queued for transmission; for synchronous data by this station's synchronous bandwidth allocation, and for asynchronous data by the values of the Token-Holding Timer and the asynchronous priority thresholds, if any. Before transmitting each frame, if the requested service class for the frame is asynchronous, then Token-Holding Timer (THT) shall be enabled; otherwise, THT shall be disabled.

T(20): **Reset:** A transition to State T0 occurs when transmitter reset is required. Reset shall be required when any of the following conditions occurs:

(a) An SM_MA_CONTROL.request (Reset or Beacon) is received from SMT, resulting in a MAC_Reset.

(b) A Claim Frame with a higher precedence is received (Higher_Claim).

(c) A Beacon Frame with another station's Source Address is received (Other_Beacon).

The operational Target Token Rotation Time (T_Opr) shall be set to its maximum value (T_Max). If the ring was operational (Ring_Operational) before the reset occurred or the Token is not already late (Late_Ct=0), then the Token-Rotation Timer (TRT) shall be reset to T_Opr, the Token shall be indicated as late by setting Late_Ct equal to one, and Ring_Operational shall be cleared. Finally the transition to State T0 occurs.

This transition shall take precedence over the recovery transition if their respective conditions occur simultaneously.

T(22): Another Frame: A transition to State T2 occurs after the Frame Status (FS) is transmitted if another Frame can be transmitted. Upon completion of the current frame another frame can be transmitted if TRT has not expired (Late_Ct=0) and either:

(a) A synchronous request is queued whose next frame transmission would not exceed the station's synchronous bandwidth allocation (not checked by MAC), or

(b) An asynchronous request is queued and both of the following conditions exist:

(1) The requested Token class was received (R_Flag).

(2) THT is to be ignored (Ignore_THT) or the Token Holding Timer (THT) is less than the requested priority threshold value (T_Pri(Request_Priority)).

T(23): Done: A transition to State T3 occurs at the end of a completed Frame if there are no more Frames that may be transmitted as described in transition T(22). This transition shall also be taken if TRT expires while the Transmitter is waiting to transmit another frame (e.g., during Frame setup time or while waiting for the Stream indicator (see 6.1.1)).

T(24): Recovery: A transition to State T4 occurs when ring recovery is required. Recovery shall be required when any of the following conditions occurs:

(a) The Valid-Transmission Timer (TVX) expires.

(b) TRT expires and the Token is already late (Late_Ct>0).

(c) The ring is operational (Ring_Operational) with a Target Token Rotation Time greater than this station's requested Target Token Rotation Time (i.e., in twos complement, T_Opr<T_Req).

(d) A Claim Frame with a lower precedence is received (Lower_Claim).

(e) A Beacon Frame with this station's Source Address is received (My_Beacon).

The T_Opr shall be set to its maximum value (T_Max), TRT shall be reset to the new value of T_Opr, Ring_Operational shall be cleared, and the transition to State T4 occurs.

The recovery transition conditions are asynchronous to the normal operation of the Transmitter. Therefore, these conditions may occur at the same time as the conditions for some other transition. If this happens, the other transition shall take precedence. However, the recovery transition conditions (e.g., timer expiration) shall be "remembered" unless the pre-emptin(transition causes them to be cleared (e.g., timer reset).

8.4.4 State T3: ISSUE_TK (Issue Token)

In this state, a new Token is issued. This state is entered after the station has complete(its data transmission or has been successful in claiming the Token. The class of Token issue(after a successful Claim Token bidding process shall be nonrestricted.

T(30a): Reset: A transition to State T0 occurs when transmitter reset is required. Rese shall be required when any of the following conditions occurs:

(a) An SM_MA_CONTROL.request (Reset or Beacon) is received from SMT, resulting in ; MAC_Reset.

(b) A Claim Frame with a higher precedence is received (Higher_Claim).

(c) A Beacon Frame with another station's Source Address is received (Other_Beacon).

The operational Target Token Rotation Time (T_Opr) shall be set to its maximum valu((T_Max). If the ring was operational (Ring_Operational) before the reset occurred or th(Token is not already late (Late_Ct=0), then the Token-Rotation Timer (TRT) shall be reset t(T_Opr, the Token shall be indicated as late by setting Late_Ct equal to one, an(Ring_Operational shall be cleared. Finally the transition to State T0 occurs.

This transition shall take precedence over the recovery transition if their respective condition occur simultaneously.

T(30b): Token Issued: A transition to State T0 occurs after the transmitter has issued th(ending delimiter of the Token.

T(34): Recovery: A transition to State T4 occurs when ring recovery is required. Recover shall be required when any of the following conditions occurs:

(a) The Valid-Transmission Timer (TVX) expires.

(b) TRT expires and the Token is already late (Late_Ct>0).

(c) The ring is operational (Ring_Operational) with a Target Token Rotation Time greate than this station's requested Target Token Rotation Time (i.e., in twos complemen T_Opr<T_Req).

(d) A Claim Frame with a lower precedence is received (Lower_Claim).

(e) A Beacon Frame with this station's Source Address is received (My_Beacon).

The T_Opr shall be set to its maximum value (T_Max), TRT shall be reset to the new valu of T_Opr, Ring_Operational shall be cleared, and the transition to State T4 occurs.

The recovery transition conditions are asynchronous to the normal operation of the Transmitte Therefore, these conditions may occur at the same time as the conditions for some othe transition. If this happens, the other transition shall take precedence. However, the recover transition conditions (e.g., timer expiration) shall be "remembered" unless the pre-emptin transition causes them to be cleared (e.g., timer reset).

8.4.5 State T4: CLAIM_TK (Claim Token)

Before entering this state, the Target Token Rotation Time (T_Opr) shall be set to its maximum value (T_Max), the Token-Rotation Timer (TRT) shall be reset to the new value of T_Opr, and the Ring_Operational Indicator shall be cleared. Each station on the ring is now forced to bid for a Target Token Rotation Time (TTRT). The station shall attempt to recover the ring by continuously transmitting Claim Frames with the bid in the INFO field (T_Bid_Tx) equal to this station's requested Target Token Rotation Time (T_Req) (if none, then T_Bid_Tx shall be set to T_Max) until Claim arbitration is resolved, a Beacon Frame is received, TRT expires, or a reset signal is received from PHY.

Claim arbitration is resolved in favour of this station if a successful My_Claim Frame comparison is received. If a Claim Frame successfully circulates the ring (a station recognizes SA as its own address), then My_Claim is asserted and that station shall issue a nonrestricted Token to restart ring operation.

If TRT expires while the station is issuing Claim Frames, MAC ring recovery has failed. The station shall start to issue Beacon Frames indicating a serious ring failure. The comparison for establishing a Higher_Claim or Lower_Claim shall be made in the following order; first on the T_Bid_Rc field, second on the address length bit contained in the FC field, and finally on the address field itself. If a Lower_Claim Claim Frame is received, the station shall continue to send its own Claim Frames. If a Higher_Claim Claim Frame is received, a transition shall be made to State T1 and subsequent received Claim Frames shall be repeated.

Reset_Required shall cause the station to revert to an idle and frame repeat mode.

T(40): Reset: A transition to State T0 occurs when transmitter reset is required. Reset shall be required when any of the following conditions occurs:

(a) An SM_MA_CONTROL.request (Reset or Beacon) is received from SMT, resulting in a MAC_Reset.

(b) A Claim Frame with a higher precedence is received (Higher_Claim).

(c) A Beacon Frame with another station's Source Address is received (Other_Beacon).

TRT shall be reset to T_Opr.

T(43): Successful Claim: A transition to State T3 occurs if the station receives its own (My_Claim) Claim Frame. The Target Token Rotation Time of the ring (T_Opr) shall be recorded from the INFO field of My_Claim Claim Frame by this station (and by every other station on the ring). Then TRT shall be reset and the Late_Ct shall be cleared. Finally, the transition to State 3 occurs.

T(45): Failed: A transition to State T5 is made if TRT expires while the station is issuing Claim Frames. The Beacon type shall be set to Unsuccessful Claim and the Beacon DA shall be set to NULL.

8.4.6 State T5: TX_BEACON (Transmit Beacon)

This state is entered if the station's attempt at ring recovery by issuing Claim Frames fails, or upon request from SMT. This action normally occurs if there is a physical interruption in the ring or SMT has detected a global ring reconfiguration. In this state, a station continuously transmits Beacon Frames. The net effect of having any station receiving a Beacon Frame revert to an idle and repeat mode, is that the only station persisting in issuing Beacon Frames shall be the station transmitter immediately downline from the ring interruption. This state ma also be entered upon command by SMT (see SM_MA_CONTROL.request).

T(50): Reset: A transition to State T0 occurs when transmitter reset is required. Reset sha be required when either of the following conditions occurs:

(a) An SM_MA_CONTROL.request (Reset or Beacon) is received from SMT, resulting in MAC_Reset.

(b) A Beacon Frame with a another station's Source Address is receive (Other_Beacon).

TRT shall be reset to T_Opr.

T(54): Fixed: A transition to State T4 occurs if the station receives its own Beacon Frame: The station shall attempt to recover the ring. The TRT shall be reset and a transition t State 4 occurs.

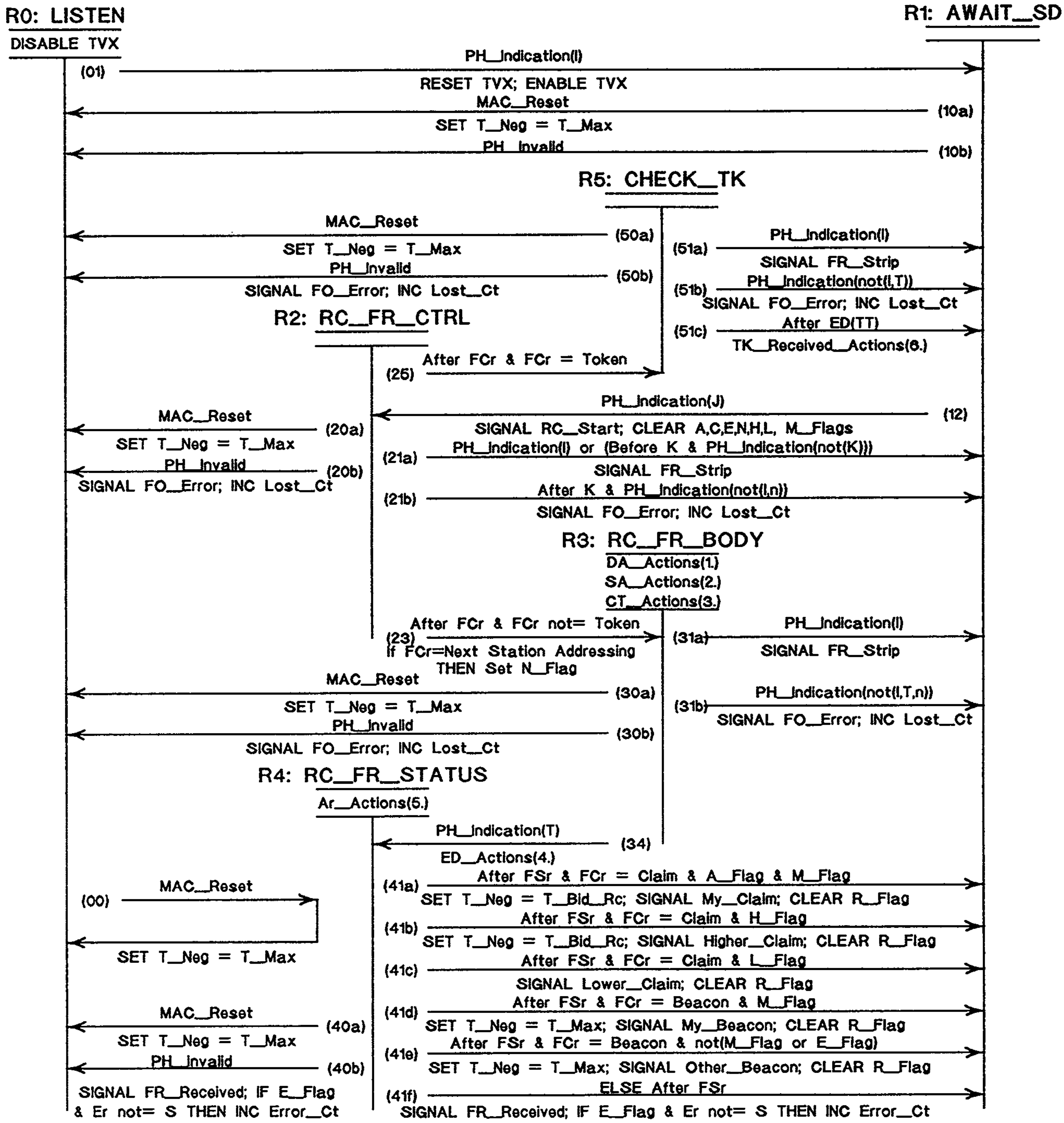

Figure 2 - MAC receiver state diagram (part 1 of 2)

RECEIVER FOOTNOTES

```
1. DA_Actions:
     After DAr
      IF FCr not= Void
         THEN IF Lr = 0 & DAr is contained in the set of Short_Addresses or
                 Lr = 1 & DAr is contained in the set of Long_Addresses
                 THEN SET A_Flag; Copy_Frame

2. SA_Actions:
     After SAr
      IF (Lr = 0 & SAr = MSA & MSA > 0) or
         (Lr = 1 & SAr = MLA & MLA > 0)
         THEN SET M_Flag; SIGNAL FR_Strip
         ELSE IF Lr = 0 & SAr > MSA & MLA = 0 or
                 Lr = 1 & SAr > MLA
                 THEN SET H_Flag
                 ELSE IF SAr > 0
                         THEN SET L_Flag

3. CT_Actions:
     After 4_Info_Octets
      IF FCr = Claim
         THEN IF T_Bid_Rc not= T_Req
                 THEN CLEAR M_Flag;
                      IF T_Bid_Rc > T_Req
                         THEN IF L_Flag
                                 THEN SET H_Flag; CLEAR L_Flag
                         ELSE IF H_Flag
                                 THEN SET L_Flag; CLEAR H_Flag
              IF L_Flag
                 THEN SIGNAL FR_Strip

4. ED_Actions:
     INC Frame_Ct;
     IF Valid_Data_Length & (Valid_FCS_Rc or (FCr = Void or Implementer))
        THEN RESET TVX;
             IF A_Flag & Valid_Copy
                THEN SET C_Flag
        ELSE SET E_Flag;
             CLEAR A_Flag, H_Flag, M_Flag, L_Flag

5. Ar_Actions:
     After Ar
      IF Ar = R
         THEN CLEAR N_Flag

6. TK_Received_Actions:
     IF Token_class = Restricted
        THEN IF not R_Flag
                THEN SET R_Flag; Notify SMT
        ELSE RESET TVX; CLEAR R_Flag
     SIGNAL TK_Received
```

Figure 2 - MAC receiver state diagram (part 2 of 2)

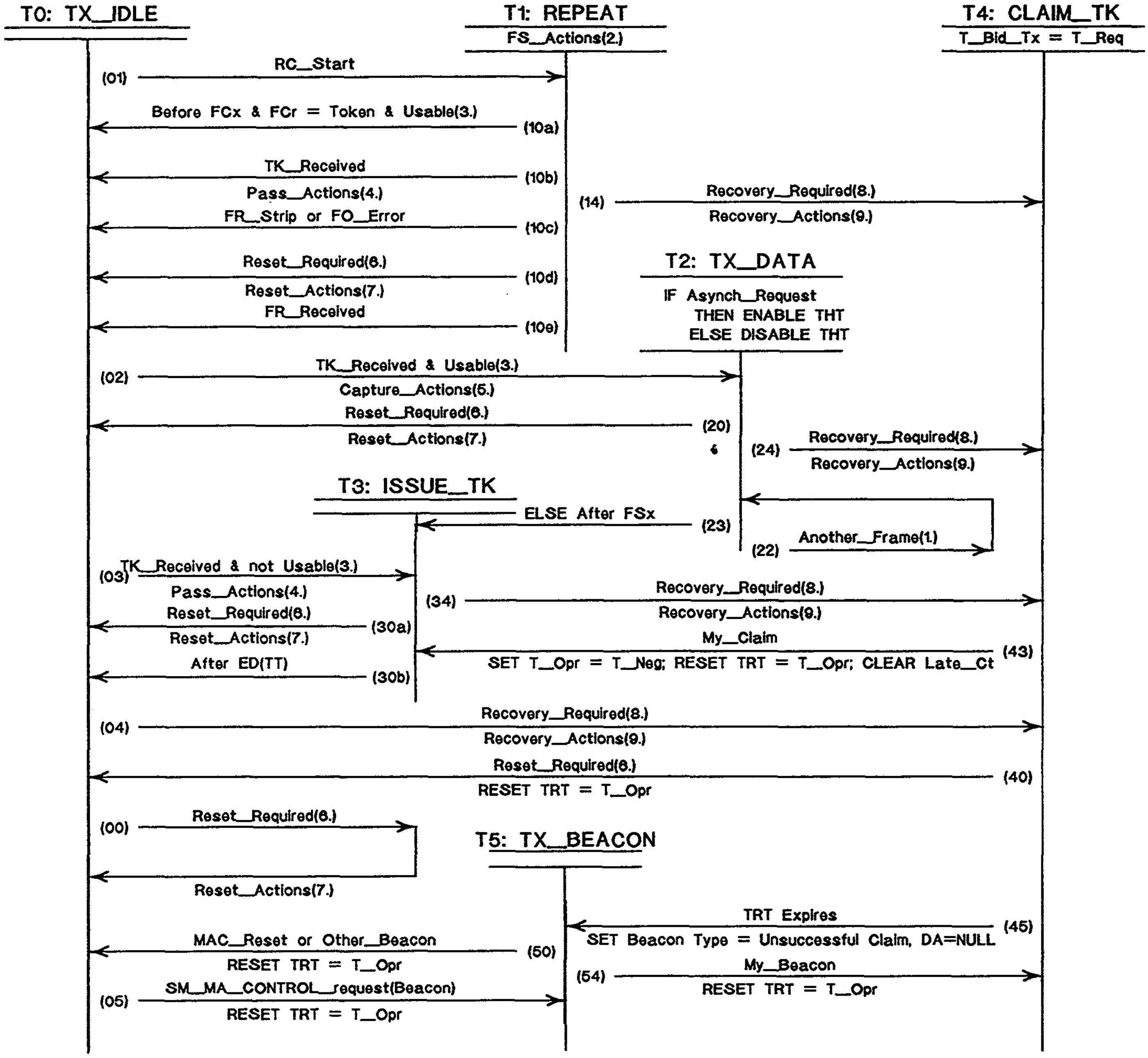

Figure 3 - MAC transmitter state diagram (part 1 of 2)

TRANSMITTER FOOTNOTES

```
1. Another_Frame:
        After FSx & Late_Ct=0 & (Synch_Request or
        (Asynch_Request & Requested_TK_Class = R_Flag &
        (Ignore_THT or THT < T_Pri(Request_Priority))))

2. FS_Actions:
        Before Ex
           IF E_Flag THEN SET Ex = S ELSE SET Ex = Er
        Before Ax
           IF A_Flag THEN SET Ax = S ELSE SET Ax = Ar
        Before Cx
           IF C_Flag & not N_Flag THEN SET Cx = S ELSE SET Cx = Cr

3. Usable_Token:
        Ring_Operational & (Synch_Request or
        (Asynch_Request & Late_Ct = 0 & Requested_TK_Class = R_Flag &
        (Ignore_THT or TRT < T_Pri(Request_Priority))))

4. Pass_Actions:
        IF Ring_Operational
           THEN IF Late_Ct=0
                   THEN RESET TRT=T_Opr
                   ELSE CLEAR Late_Ct
           ELSE SET T_Opr=T_Neg; RESET TRT=T_Opr;
                SET Late_Ct=1; SET Ring_Operational

5. Capture_Actions:
        DISABLE THT;
        IF Late_Ct=0
           THEN SET THT=TRT; RESET TRT=T_Opr
           ELSE SET THT=expired; CLEAR Late_Ct

6. Reset_Required:
        MAC_Reset or Higher_Claim or Other_Beacon

7. Reset_Actions:
        SET T_Opr=T_Max;
        IF Ring_Operational or Late_Ct=0
           THEN RESET TRT=T_Opr; SET Late_Ct=1;
                CLEAR Ring_Operational

8. Recovery_Required:
        TVX Expires or (TRT Expires & Late_Ct > 0) or
        (Ring_Operational & T_Opr < T_Req) or
        Lower_Claim or My_Beacon

9. Recovery_Actions:
        SET T_Opr=T_Max; RESET TRT=T_Opr; CLEAR Ring_Operational

10. TRT_Actions:
        In all states, IF TRT expires
                          THEN Increment Late_Ct; RESET TRT=T_Opr
```

Figure 3 - MAC transmitter state diagram (part 2 of 2)

Annex A

(informative)

Addressing Hierarchical Structuring for Locally-Administered Addresses

A.1 General structure

The following structure provides for a Token-ring LAN divided into multiple rings, with one or more MAC-level relay stations interconnecting the rings. Structuring MAC addresses in a hierarchical fashion may 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 may exchange frames without any intermediary MAC-level relay entity. Stations on a ring may communicate with stations with different ring numbers 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 destination address partitioning recommended for this purpose is

(1) 16-bit hierarchical form

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

(2) 48-bit locally administered 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:

Individual and Group Addresses: For destination addresses, the first bit transmitted (I/G) distinguishes individual from group addresses:

0 = individual address
1 = group address

For source addresses, the first bit transmitted (I/G) is reserved for future standardization. It shall be set to zero on transmission, and shall be ignored on stripping.

This ring: The ring number field is set to all zeros or to the ring number of this ring, if known.

All stations, this ring: The ring number field is set to all zeros or to the ring number of this ring, if known; the station subaddress field is set to all ones

Hierarchical Structuring for Locally-Administered Addresses

All rings: The ring number field is set to all ones

A.2 Group addressing modes

Two formats for group addressing are defined within the structure of hierarchical addressing (as described above), using the first bit of the station subaddress field:

0 = bit-significant mode, 1 = conventional group mode

Bit-significant mode: This mode specifies that each bit in the station subaddress field represents a single group address. For 16-bit addresses, 7 bit-significant address may be defined in this mode; for 48-bit addresses, 31 bit-significant addresses may be defined.

Stations that are to copy frames destined for many different functions may implement a bit-significant mask, to facilitate the copying of frames with bit-significant destination addresses. Such a mask could have a bit set to 1 for each bit-significant address for which the station wishes to copy frames.

For example:

Function K has bit-significant address B'0010000'.
Function P has bit-significant address B'0000010'.
Ring station Y has bit-significant mask B'0010010'.
implying that station Y may copy frames destined for both functions K and P.

Conventional group mode: This mode specifies that the remaining bits in the station subaddress field represent a single group address. For 16-bit addresses, this allows about 2**7 group addresses in conventional group mode; for 48-bit addresses, this allows about 2**31 group addresses in conventional mode.

The four options are illustrated below:

(1) 16-bit hierarchical form, bit-significant mode.

1	7-bit ring number	0	up to 7 bit-significant addresses

(2) 48-bit locally administered hierarchical form, bit-significant mode

1	1	14-bit ring number	0	up to 31 bit-significant address

(3) 16-bit hierarchical form, conventional group media

1	7-bit ring number	1	7-bit, conventional group addresses

(4) 48-bit locally administered hierarchical form, conventional group mode

1	1	14-bit ring number	1	31-bit, conventional group address

Annex B

(informative)

Frame Check Sequence

B.1 Description

The transmission integrity of a received message is determined by the use of a frame check sequence (FCS). The FCS is generated by a transmitter, positioned within a frame in accordance with the diagram in 7.2.2., and inspected by a receiver.

The definitions of the constants and variables used in this annex are given in 7.3.6.1.

The FCS generation algorithm used is the 32-bit standard algorithm. (See clause B.5 for further information.) The procedure for using the FCS assumes the following:

(a) The k bits of data that are being checked by the FCS can be represented by a polynomial F(x) of degree k-1. Examples:

(1) F(x) = 10100100 = $X^7+X^5+X^2$

(2) F(x) = 000...010100100 = $X^7+X^5+X^2$

(3) F(x) = 101001 = $X^5+X^3+ 1$

In general, leading zeros do not affect F(x) while trailing zeros add a factor of X^n where n is the number of trailing zeros.

(b) For the purpose of generating the FCS, the first bit transmitted of the fields covered by the FCS is the coefficient of the highest term of F(x), regardless of the actual meaning of those fields.

(c) There exists a generator polynomial G(x) (see 7.3.6).

(d) There exists a polynomial L(x) equal to 32 ones (see 7.3.6).

B.2 Generation of the FCS

The FCS is defined as the ones complement of a remainder of R(x) obtained from the modulo two division of

$x^{32}F(x)+x^kL(x)$

by the generator polynomial G(x).

FCS = L(x)+R(x) = R\$(x) (B1)

where R\$(X) is the ones complement of R(X)

$[X^{32}F(X)+X^kL(X)]/G(X)=Q(X)+R(X)/P(X)$ (B2)

The multiplication of F(x) by x^{32} corresponds to shifting the message F(x) left by 32 places to provide space for the FCS to be added.

The addition of the $x^kL(x)$ term is equivalent to inverting the first 32 bits of F(x). This may be accomplished in a shift register implementation by presetting the shift register to all ones. This term is included to detect erroneous addition or deletion of zero bits at the leading edge of the message.

The complementing of R(x) by the transmitter before transmission ensures that the transmitted sequence has a property that permits the receiver to detect addition or deletion of trailing zeros that may appear as a result of errors.

At the transmitter, the FCS is added to the $x^{32}F(x)$ term resulting in a total transmitted message.

$$M(x) = x^{32}F(x)+FCS \qquad (B3)$$

B.3 Checking the FCS

In the receiver, a process nearly identical to the generation process is used to check the received sequence. The received sequence M*(x) is added to $x^kL(x)$. Then the sum is multiplied by x^{32} and divided by G(x). This yields

$$D(X)=X^{32}[M^*(X)+X^kL(X)]/G(X) \qquad (B4)$$

If there are no errors, M*(x) = M(x), and we may substitute (B3) into (B4):

$$D(X)=X^{32}[X^{32}F(X)+FCS+X^kL(X)]/G(X) \qquad (B5)$$

We may now substitute (B1) and (B2) into (B5), to yield

$$D(X)=X^{32}[Q(X)+R(X)/G(X) + R\$(X)/G(X)] \qquad (B6)$$

Thus by adding them together we get all ones or L(x):

$$R(x) + R\$(x) = L(x) \qquad (B7)$$

Substituting (B7) into (B6),

$$D(X)= X^{32}[Q(X)+L(X)/G(X)]=Q^*(X)+P(X)/G(X) \qquad (B8)$$

Taking the remainder,

$$P(X)/G(X)=X^{32}L(X)/G(X)= C(X) \qquad (B9)$$

in the absence of any errors. If there were an error, then M*(x) not= M(x) and a different remainder would be calculated.

B.4 Implementation

The mathematical derivation and proof of the FCS algorithm shown above is not suggestive of an appropriate implementation. For this reason one method of implementing the FCS generation and checking using shift registers is described here. It utilizes "ones presetting" at both the sender and receiver. The receiver checks for the residual c(x) to indicate an error-free reception.

A feedback shift register is used to accomplish the division by G(x). This 32 bit register is accessed via the three signals Input, Output, and Control. When Control=one, Input bits are shifted into the feedback register and also fed back to the Output. When Control=zero, the feedback paths are disabled and the shift register shifts the complement of its contents to Output. This is shown in figure B.1.

Before FCS generation at the transmitting end, initialization logic (not shown) presets the shift register to all ones. Control is then held at one while the sequence to be checked is shifted into the input. Meanwhile, the same bits are emerging at output to be transmitted. When the last bit of the data field has been processed, Control is set to zero and the complemented FCS is shifted out for transmission, high order bit first.

FCS checking in the receiver begins with the shift register loaded to all ones. Control is then held at one while the received bits are shifted into Input. When the last bit of the input sequence has been processed, the shift register will contain the sequence C(x) if no errors occurred during transmission.

B.5 Related standards

Additional information on the FCS may be found in the following standards:

(a) American National Standard for Advanced Data Communication Control Procedures (ADCCP), ANSI X3.66-1979 (Section 12 and Annex D).

(b) Telecommunications; Synchronous Bit Oriented Data Link Control Procedures (Advanced Data Communications Control Procedures), FED-STD-1003A.[1]

[1] Available from GSA Specification Section, 7 & D Street, S. W., Washington, DC 20407

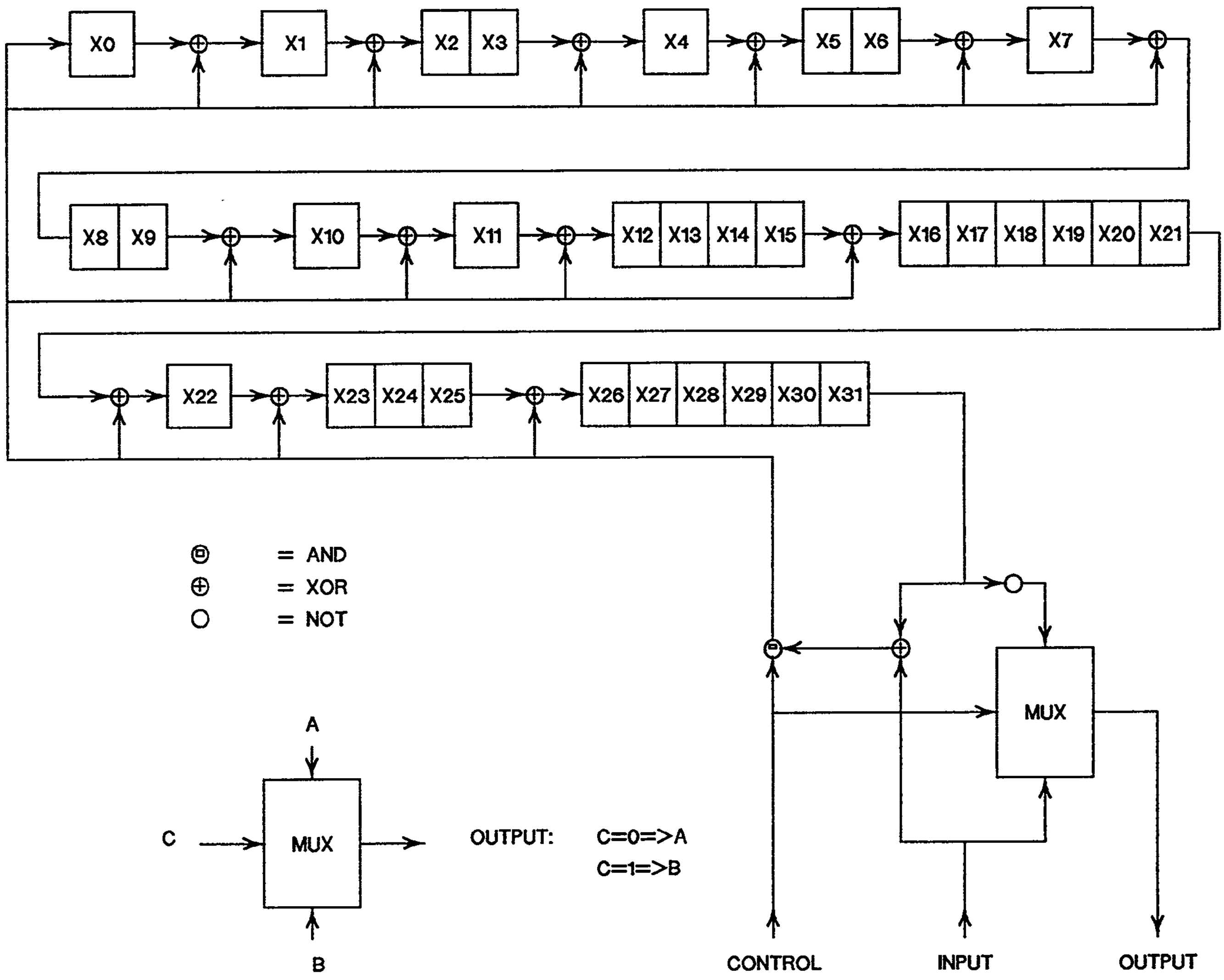

Figure B.1 - FCS implementation example

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UDC 681.3 : 621.39 : 666.189.21 : 666.22

Descriptors : data processing, information interchange, network interconnection, optical fibres, computer interfaces, communication procedure.

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