ECMA

EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

STANDARD ECMA-90

LOCAL AREA NETWORKS
TOKEN BUS TECHNIQUE

September 1983

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1. GENERAL

1.1 Scope

For the purpose of compatibility interconnection of data processing equipment via a Local Area Network using the Token Bus access method, this Standard ECMA-90:

- specifies the electrical and physical characteristics of the transmission Network ;
- specifies the electrical characteristics of the connection between Data Terminal Equipment DTE and the transmission Network ;
- specifies the functions of the Physical Layer ;
- specifies the services provided at the conceptual interface between Medium Access Control sublayer and the Logical Link Control sublayer above it ;
- specifies the functions within the Medium Access Control sublayer.

1.2 References

ISO/7498	:	Data Processing - Open System Intercommunication Basic Reference Model
IEC 364	:	Regulation for Electrical Installations
ECMA 72	:	Transport Protocol
ECMA 57	:	Safety Requirements for Data Processing Equipment
ECMA TR/14	:	Local Area Network-Layers 1 to 4, Architecture and Protocol

1.3 Definitions

For the purpose of this Standard the following Definitions apply :

1.3.1 Bidirectional Broadband Amplifier

An assembly of amplifiers and filters which amplifies and re-equalizes in the Forward direction all signals received in the higher frequency portion of the broadband spectrum and simultaneously amplifies and re-equalizes in the Reverse direction all signals received in the lower frequency portion of the broadband spectrum.

1.3.2 Broadcast Medium

The class of media in which all DTEs are capable of receiving a signal transmitted by any other DTE.

1.3.3 Collision

The result of multiple transmissions overlapping in the transmission Medium creating noise.

1.3.4 Data Terminal Equipment (DTE)

The source and sink for all communication on the network. This includes all equipment attached to the Medium including the means of connection.

1.3.5 Drop Cable

A coaxial cable which connects the DTE to the Broadband Medium.

1.3.6 Forward

The direction of transmission originating at the head-end of a broadband cable system and relayed "outbound" by the system's Bidirectional Broadband Amplifiers to the DTEs.

1.3.7 MAC Service Data Unit (MSDU)

A unit of information which is exchanged at the conceptual interface between the Logical Link Control sublayer and the Medium Access Control sublayer.

1.3.8 Multi-Level Duobinary AM/PSK

A form of Duobinary AM/PSK modulation which uses more than two distinct amplitude levels (in this specification independent of phase) to represent information.

This document covers a three level Duobinary AM/PSK system capable of signalling at about 1 bit/Hz.

1.3.9 Multicast

An addressing mode in which a given frame is targeted to a group of logically related Stations.

1.3.10 Power Splitter

A module which electrically and mechanically couples one Trunk Cable to other Trunk Cables, providing a branching topology for the broadband Medium.

A Power Splitter splits the power in the Forward channel spectrum among the outgoing Trunks and combines any signalling received in the Reverse channel spectrum.

It passes AC power between the Trunk Cables and contains only passive electrical components (R, L, C).

1.3.11 Remodulator

The unit located at the head-end of a Token Passing broadband bus Local Area Network which receives in a Reverse channel the signals transmitted by DTEs and rebroadcasts those signals back to DTEs in a corresponding Forward channel.

1.3.12 Reverse

The direction of transmission originating at the DTE of a broadband network, terminating at the Remodulator and relayed "inbound" by the system's Bidirectional Broadband Amplifiers.

1.3.13 Slot-Time

It is the maximum time any Station need wait for an immediate medium access level response from another Station. The value of the Slot-Time is the sum of the round trip propagation delay for the network (which includes twice the worst case Station reaction time) plus a safety margin.

1.3.14 Splitter

A version of the Power Splitter used to couple Drop Cables together.

It does not pass AC power between the Drop Cables.

1.3.15 Station

A member or potential member of the logical ring which is identified by a unique individual address.

1.3.16 Tap

A module which electrically and mechanically couples the Trunk Cable to Drop Cables, passes AC power between input and output Trunk Cable sections and isolates the power from Drop Cable sections.

It splits the rf power in the Forward channel spectrum asymmetrically, with the bulk of the power passed to the outgoing Trunk Cable and only a small percentage going to the Drop Cables, and combines with similar asymmetry any signalling received in the Reverse channel spectrum. It contains only passive electrical components (R,L,C).

1.3.17 Token Bus

The generic term for a class of Medium Access Control procedures which allows multiple Stations to access a Broadcast channel in a deterministic way preventing Collision by passing a medium access right (Token) from Station to Station in a logical ring manner.

1.3.18 Trunk cable

The main coaxial cable of a broadband network which may carry AC power with RF signalling.

1.4 Conformance

Equipment conforming to this Standard shall implement the provisions specified in section 3, 4, 5, 6, 7 and 8.

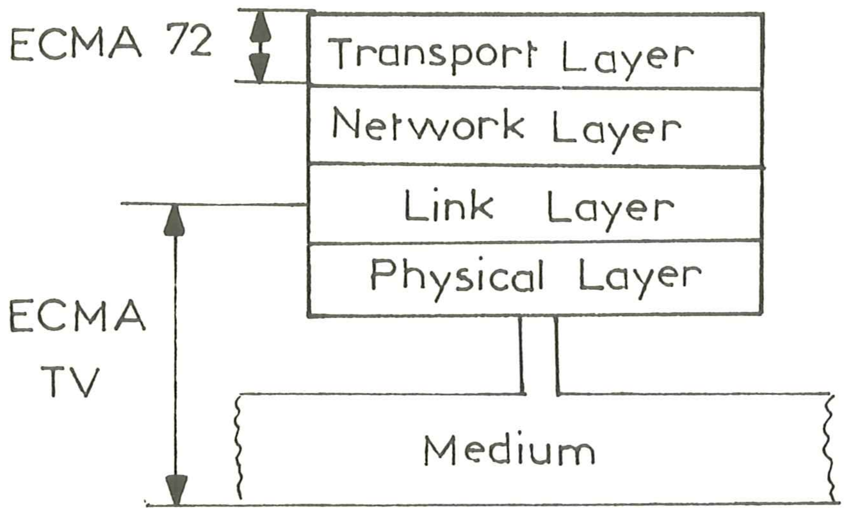
In these sections the functions marked "Optional" are not mandatory in an implementation but any that are retained shall be clearly mentioned in the product specifications.

Though Equipment with or without the Optional functions should work together, the benefits carried by these functions could be seriously reduced if not all DTEs support these functions.

2. GENERAL DESCRIPTION

ECMA TR/14 discusses the relationship between this Standard and other ECMA Standards for Local Area Network interconnection.

This relationship is illustrated diagramatically as following :



Access to the broadcast Medium is provided by sequentially passing control from Station to Station in a logically circular fashion.

The access control mechanism determines when the Station has the right to access the shared medium by recognizing and accepting the Token from the predecessor Station and it determines when the Token must be passed to the successor Station.

The logical chain around which the Token is passed from Station to Station can be created, extended or repaired after loss of Stations.

The mechanisms for chain maintenance are also described.

2.1 Network configuration

2.1.1 Topology

Broadband CATV networks take the form of branched topologies using CATV components such as :

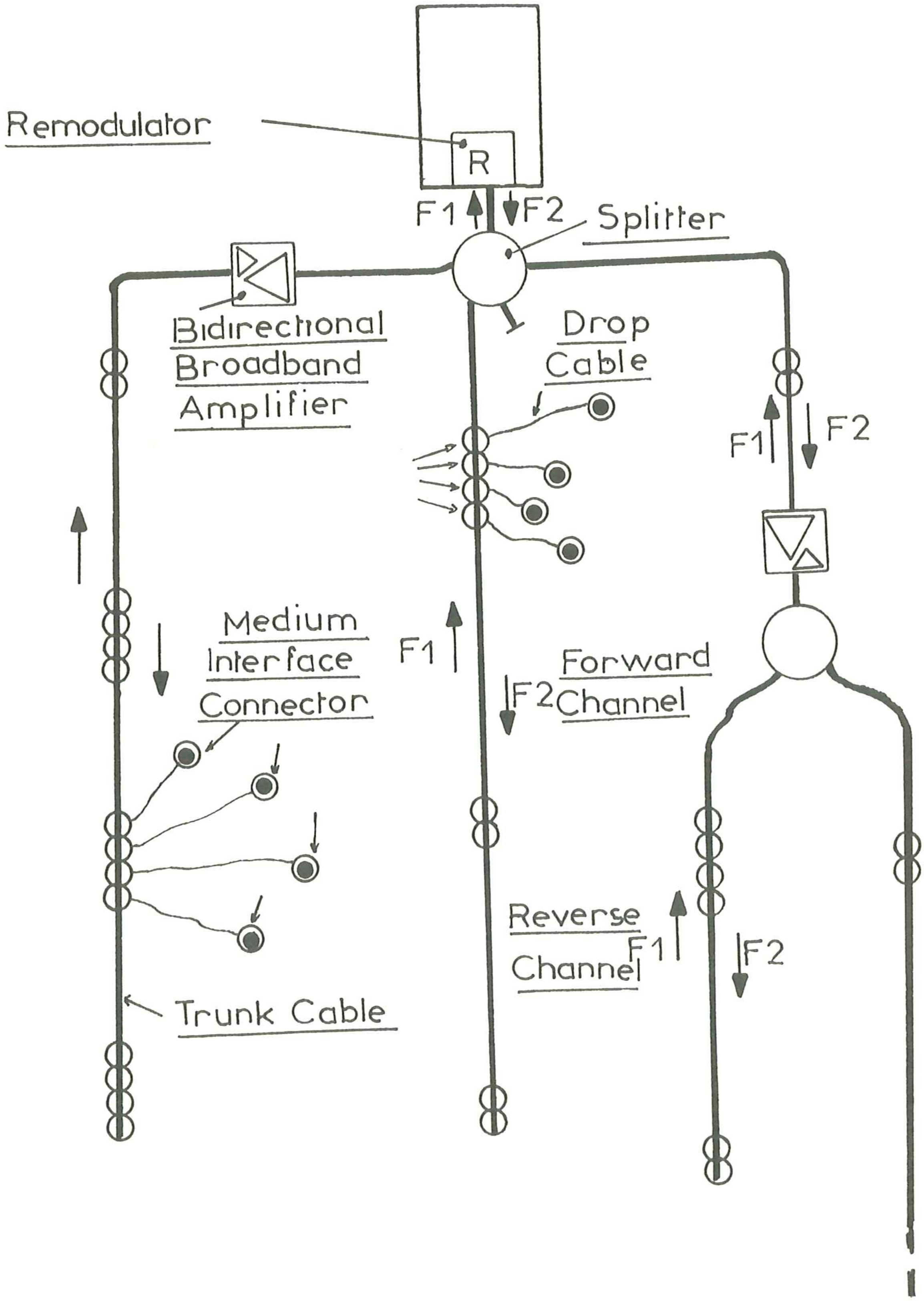
- F connectors
- Low loss coaxial cable
- Taps
- Splitters
- Bidirectional Broadband Amplifiers
- Remodulator

Broadband networks can be constructed using flexible coaxial cable and passive Taps.

Larger configurations require Bidirectional Broadband Amplifiers and power supplies, together with semi-rigid Trunk Cable and flexible Drop Cables.

Each Broadband Local Area Network comprises a Remodulator which must be "upstream" from all of the DTEs, but need not actually be at the head end of the entire transmission network. It is only necessary that the Remodulator be closer to the root of the tree-shaped transmission network than any DTEs of its network.

Network Configuration



2.1.2 Signal Loss Budget Considerations

When installing a transmission network the placement of Bidirectional Broadband Amplifiers and Splitters must take into account :

- Each DTEs minimum transmit level and receive level specifications (see section 3.3.2 and 5.5).
- The current and anticipated future placement of DTEs and Bidirectional Broadband Amplifiers.
- The presented signal level, noise floor, signal-to-noise ratio and intermodulation distortion specifications (see section 3.3).

2.2 Channel allocation

Two frequency channels shall be allocated for each Local Area Network of a broadband network :

- One Forward channel is reserved for the transfer of data from the Remodulator.
- One Reverse channel is reserved for the transfer of data from any DTE to the Remodulator.

2.3 Physical layer characteristics

2.3.1 Symbol Transmission and Reception

Successive symbols presented to the Physical Layer entity at its MAC service interface are applied to an encoder which produces as output a three-symbol 0, 2, 4 code.

The encoder includes a scrambler which is applied to consecutive zero and one input symbols to reduce the possibility of generating repeated data patterns.

That output is then applied to a modulator which uses a Duobinary signal shaping process to produce a Multi-Level Duobinary AM/PSK signal within the designated channel where the level corresponds directly with the relative numeric value of the associated symbol.

The signal is then AC coupled to the broadband network Medium and conveyed in the Reverse channel to the Remodulator.

Each receiver is AC coupled to the broadband network. The received signal is filtered to eliminate noise from other channels and the transmitted symbol is deduced from the amplitude of the filtered signal. That deduced symbol is then decoded by an inverse of the encoding process and the resultant decoded symbols are presented at the MAC service interface.

2.3.2 Remodulator

In an actual single-cable broadband network, DTEs do not transmit and receive on the same frequency channel.

One central device, designated Remodulator receives on the Reverse channel and transmits on the Forward channel.

All of the DTEs transmit on the Reverse channel and receive on the Forward channel. Thus the system really consists of a pair of directionnal channels, with the Reverse channel having many transmitters and one receiver and the Forward channel having one transmitter and many receivers.

To allow DTEs to communicate the Remodulator serves as a relay device, its medium access sublayer entity interprets the symbols received in the Reverse channel and retransmits them in the Forward channel.

During normal operation the Remodulator transmits continuously. The DTEs in the Local Area Network determine the exact transmit and receive data rate from this continuous Forward channel signal. To support this process, the Remodulator encodes the symbol "Silence" as explicit signalling rather than turning off its transmitter as the DTEs do.

2.4 Access method characteristics

The essence of the Token access method is :

. A Token controls the right of access to the transmission Medium, the Station which holds (possesses) the Token has momentary control over the Medium.

. The Token is passed by Stations residing on the Medium. As the Token is passed from Station to Station a logical ring is formed.

. Steady-state operation consists of a data transfer phase and a Token transfer phase.

- Ring maintenance function within the Stations provide for ring initialization, lost Token recovery, new Station addition to logical ring and general housekeeping of the logical ring.

The ring maintenance functions are replicated among all the Token using Stations on the network.

2.4.1 Elements of Access Procedure

Specific responsibilities of the Medium Access Control sublayer for broadcast Medium involve managing ordered access to the logical ring, providing a means for admission and deletion of Stations (adjustment of ring membership), and handling fault recovery.

The faults considered here are possible lost and multiple Tokens under network exception conditions (e.g. line hits). Successful recovery involves the reestablishement of a single Token in the network.

Recovery of information contained in lost frames is not provided by this sublayer.

Some basic observations are useful in understanding the operation of Tokens on a Broadcast Medium :

- Stations are connected in parallel to the Medium. Thus, when a Station transmits, other Stations can interfere with the first Station's transmission but cannot predictably alter its contents.

- When a Station transmits, it may assume that all other Stations hear something (though not necessarily what was transmitted).

- When a Station receives a valid frame (properly formed and delimited and containing a correct frame check sequence), it may infer that some Station transmitted the frame, and therefore, that all Stations heard something.

- When a Station receives something other than a valid frame (i.e. noise), it may make no inference about what the other Stations on the Medium might have heard.

- Not all Stations need be involved in Token passing (only those who desire to initiate transmission).

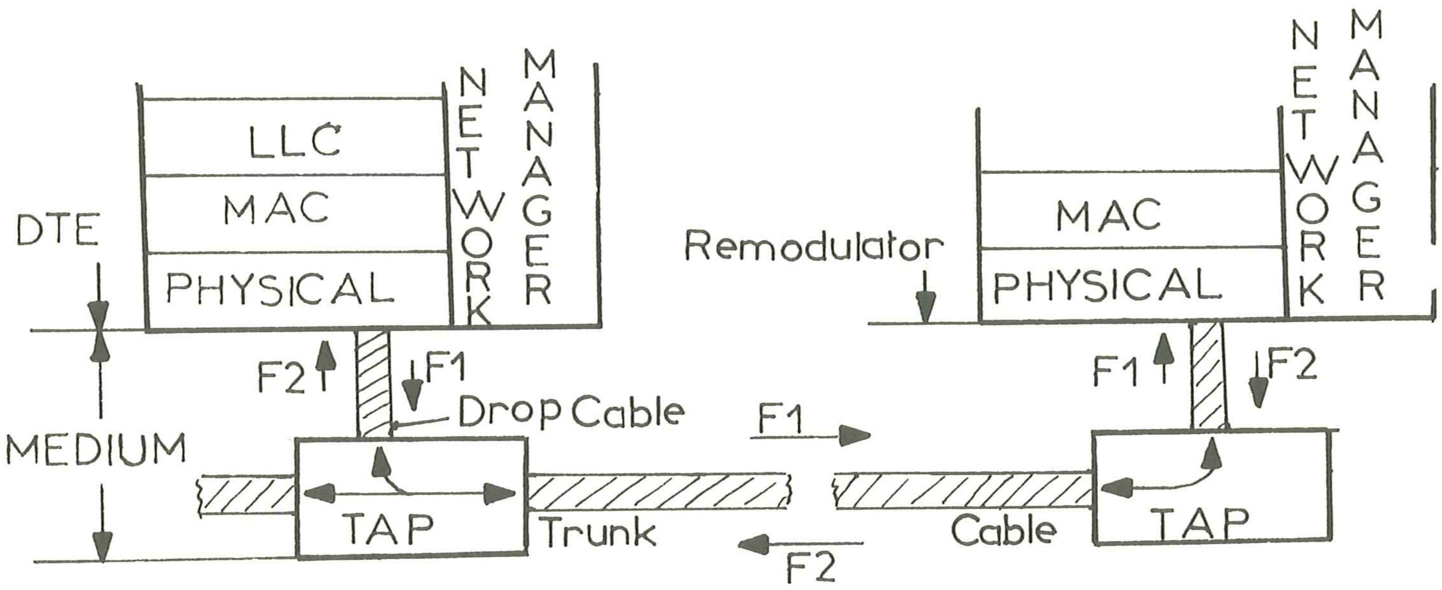
. Multiple Tokens and lost Tokens may be detected by any Station. There are no special "monitor" Station that perform Token recovery functions.

. Due to spatial separation, Stations cannot be guaranteed to have a common perception of the system state at any instant (the medium access protocol described herein accounts for this).

3. BROADBAND BUS MEDIUM SPECIFICATION

3.1 General

This section describes the services offered by the Medium. The relationship between the Medium and Physical Layer is illustrated below.



Physical Hardware Partitioning

3.1.1 Object

The object of this section is to specify the interface to a transmission Medium which.

1) provides the transmission Medium necessary for communication between Local Network DTEs employing the ECMA Local Area Network Token Bus access method and a Token-Passing Broadband Bus Physical Layer ;

2) provides a Medium which can be shared by multiple Local Area Networks and by totally unrelated applications (such as voice, data and analog video) ;

3) provides for high network availability ;

4) provides for ease of installation and service in a wide range of environments ;

5) permits use of existing components mass-produced for the cable TV industry, and of the corresponding set of installation practices, where feasible.

3.1.2 Compatibility Considerations

This Standard applies to Media which are designed to operate as conventional Bidirectional CATV - Broadband coaxial cable networks.

Such networks use commonly available CATV Taps, Connectors, Bidirectional Broadband Amplifiers, power supplies and coaxial Cable.

This specification applies to a single Trunk network in which two-way communication usually is accomplished through the use of Bidirectional Broadband Amplifiers whose filters permit differing parts of the available cable spectrum to be transmitted in each direction.

The use of a coaxial broadband network permits the assignment of different frequency bands to multiple simultaneous applications. For example, a portion of the cable spectrum can be used by Local Area Networks while other portions are used for point to point or multi-point data links and others are used to convey television and audio signals.

With the proper selection of signal levels and proper equipment design all of the applications can be propagated without deleterious interference.

3.2 DTE/Remodulator connection to the medium

- The connection of the DTE or Remodulator to the broadband Medium shall be made by a 75 Ohm coaxial Drop Cable terminated in a male F series 75 Ohm connector ; this connector shall mate with a female F series 75 Ohm connector mounted on the DTE or Remodulator.

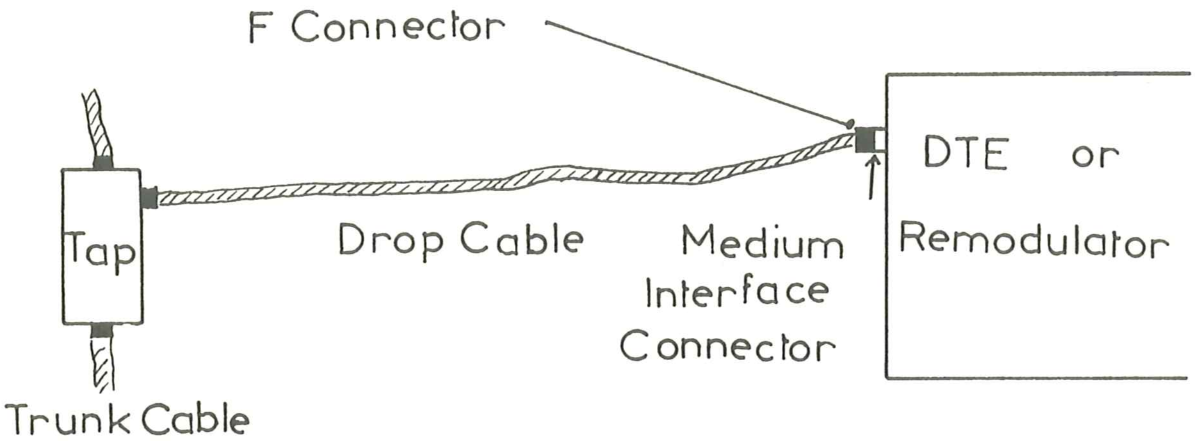
- In addition to this coupling, the screen(s) of the coaxial Drop Cable shall be connected to the shell of the terminating male F connector. The impedance of that connection shall be less than 0,1 Ohm over the range 0 to 450 MHz. Also the contact impedance between the shell of that male F series connector and the outer barrel of a mated female F series connector shall be less than 0,1 Ohm over the range 0 to 450 MHz.

- The DTE shall be AC coupled to the centre conductor of the 75 ohm Broadband Medium.

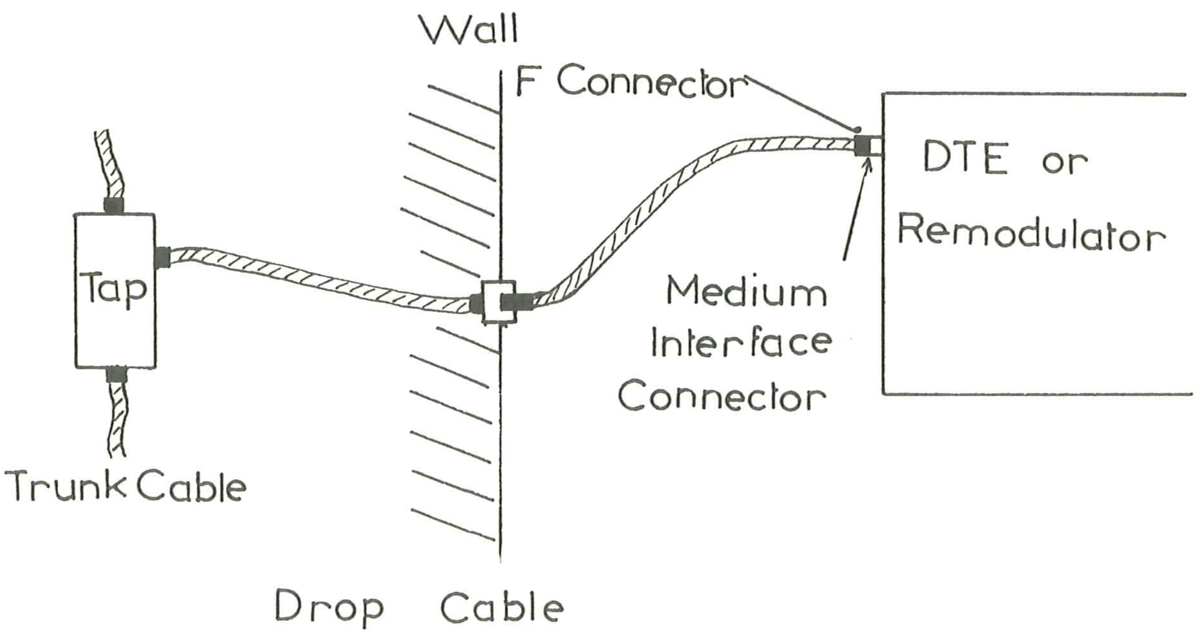
- Unless otherwise mandated by the Safety Requirements, the AC breakdown voltage of the insulation shall be at least 500V AC rms.

- Two kind of Medium Interface Connections (MIC) are possible :

  a) The Station is directly connected to the nearest Tap inserted into the Trunk Cable via a Drop Cable without a wall outlet.



  b) The Station is connected to a wall outlet via a Medium Interface Cable which is part of the Drop Cable.



<u>In both cases all signal characteristics between Medium and Physical Layer are specified at the DTE/Remodulator medium interface connector.</u>

The Medium Layer services accept from any DTE and deliver to any DTE of the Broadband Medium physical signals as specified in sections 3 and 5 of this Standard.

It is the responsibility of the transmission network designer to select the Medium components which are required to conform to this Standard.

3.3 Electrical specification

All measurements specified in the following paragraphs are to be made at the DTE or Remodulator Medium Interface connector. Unless otherwise indicated these measurement shall be made across that central portion of the channel actually used for signalling.

3.3.1 Characteristic Impedance

The characteristic impedance of the Broadband Medium shall be 75 Ohm ± 2 Ohms.

3.3.2 Signal Level

When receiving the signal of a single DTE or Remodulator whose transmit level has been adjusted as specified in section 5.5 the Broadband Medium shall present that signal to the connected Remodulator or DTE at an amplitude of between +50 dBμV and +70 dBμV.

The maximum short term variation of that level with respect to a reference signal of constant mean amplitude provided at any DTE or Remodulator site shall be no more than ± 1dB/minute (e.g. due to the temperature changes in outdoor installations).

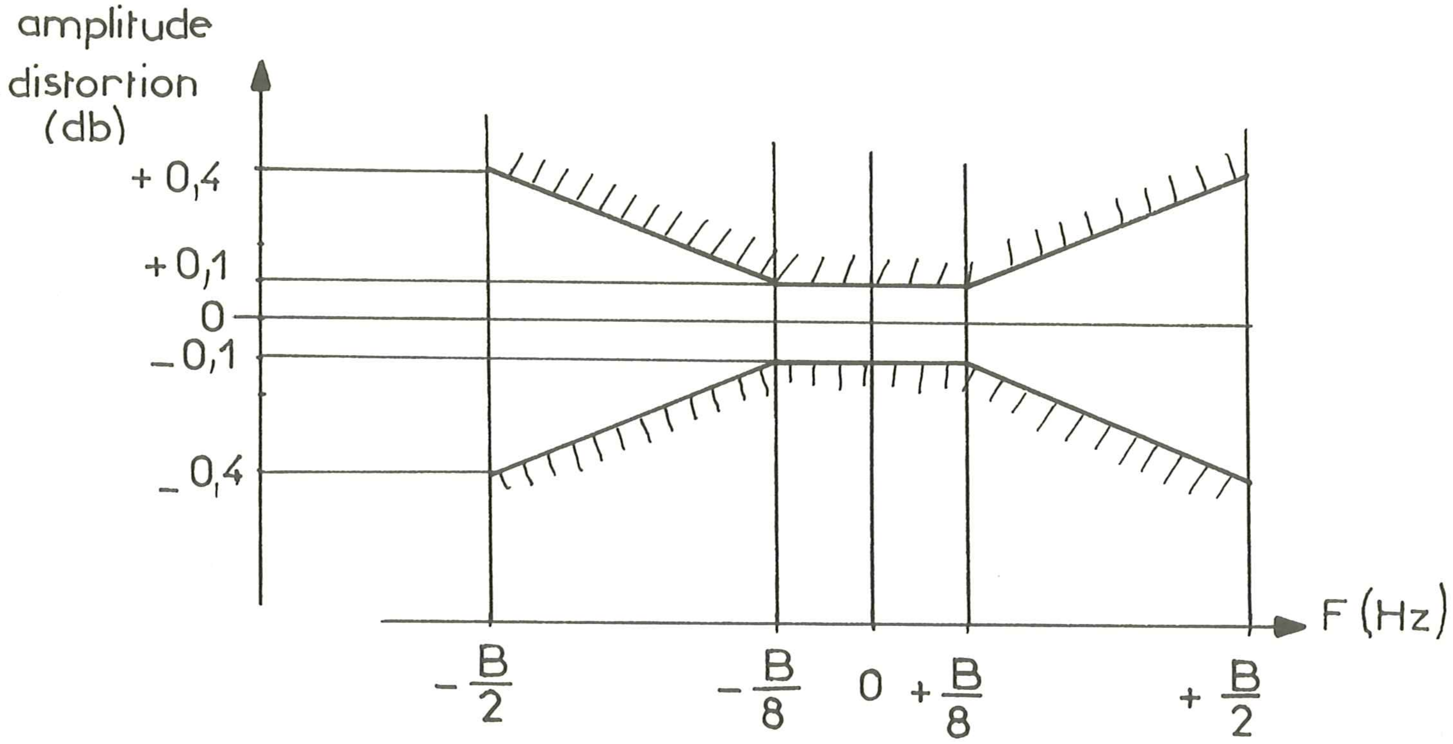
3.3.3 Distortion

Bidirectional Broadband Amplifiers are the primary cause of amplitude and phase distortion on the Broadband Medium.

3.3.3.1 Amplitude Distortion

Over any directional channel used for a Token-Passing Broadband Bus Local Area Network, the Amplitude Distortion shall fall within the limits as specified below :

$$PAD = \begin{cases} \pm 0{,}1 & , \quad 0 \leqslant |F| \leqslant \frac{B}{8} \\ \pm 0{,}6\,\frac{F}{B} & , \quad \frac{B}{8} \leqslant |F| \leqslant \frac{B}{2} \end{cases}$$



Where :

B : Denotes the bandwidth of the channel in Hz (6 MHz)

F : Denotes the frequency variation in Hertz relative to the centre of the signalling band.

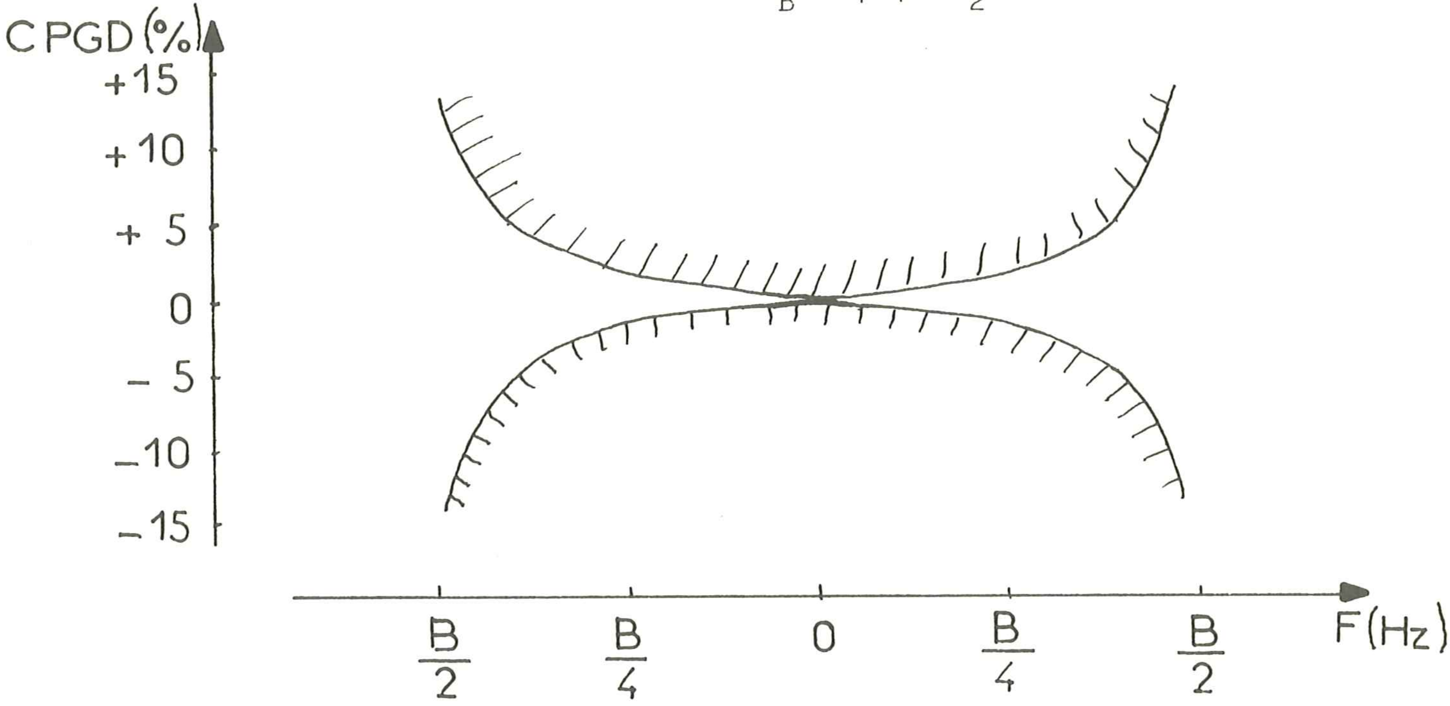
and

PAD : Denotes the maximum channel permissible Amplitude Distortion relative to the centre of the signalling band, measured as a fraction of 1/B seconds.

3.3.3.2 Group - Delay Distortion

Over any directional channel used for a Token-Passing Brodband Bus Local Area Network the Group - Delay Distortion shall fall within the limits as specified below :

$$CPGD = \pm\ 10\ \log_{10}\ \cos\left(\frac{\pi F}{B}\right),\quad |F| \leq \frac{B}{2}$$



where :

B : Denotes the bandwidth of the channel (6 MHz) in Hz

F : Denotes the frequency variation in Hertz relative to the centre of the signalling band

and

CPGD : Denotes the maximum channel permissible Group Delay Distortion relative to the centre of the signalling band, measured as a percentage of 1/B seconds.

3.3.4 Signal to Noise (S/N) Level

It is recommended that the rms Signal to Noise Level be at least +40 dB.

In no case shall it be worse than +26 dB.

3.3.5 Third - Order Distortion

The composite triple beat due to all the signals on the cable except those provided by this DTE shall be less than +3 dBµV.

3.3.6 Power Handling Capability

The 50 or 60 Hz AC power commonly carried on Broadband Trunk Cables shall not be carried on the Drop Cable which connects directly to the DTE or Remodulator.

The total rf signal's power over the entire cable spectrum, as presented to the DTE or Remodulator, shall be less than 1/4 watt.

3.3.7 Cable Terminator Characteristics

The reflection from a 75 Ohm resistive cable terminator shall be less than -36 dB.

3.4 Reliability of the medium

All Medium Equipment should be designed such that the aggregate probability of that Equipment causing a communication failure at more than one DTE connected to the Medium is less than 10^{-4} per hour of operation.

4. PHYSICAL LAYER SERVICES

This section describes the services provided by the Physical Layer to the Link Layer above.

The services provide for the transmission and reception of symbols, each with a duration of one bit-period.

They provide the means by which co-operating MAC entities can co-ordinate their transmissions and exchange information via the shared communications Medium.

4.1 Bad signal indication

The Physical Layer shall assert a Bad Signal Indication whenever the received symbol or sequence of symbols do not belong to the possible set of transmitted symbols or sequence of symbols (i.e. reception of more than 22 consecutive ONE).

4.2 Signal element input indication

The Physical Layer shall send a Signal Element Input Indication containing one signal element to the Link Layer whenever the Physical Layer receives the element from the Medium.

The signal element shall have the following values :

Zero : corresponds to a binary ZERO

One : corresponds to a binary ONE

Non-Data : used in delimiters, always sent in pairs

Pad-Idle : received preamble/inter - frame - idle

Silence : silence (or signalled pseudo-silence) received for a duration of one bit-period

4.3 Signal element output request

The Physical Layer shall send a Signal Element Output Request to the Link Layer whenever the Physical Layer requires another signal element to transmit on the medium.

This request shall be sent once per bit time.

4.4 Signal element output response

The Link Layer shall send a Signal Element Output Response to the Physical Layer in response to a Signal Element Output Request when the Link Layer has a signal element to transmit.

The possible values shall be the following :

Zero : corresponds to a binary ZERO

One : corresponds to a binary ONE

Non-Data : used in delimiters, always sent in pairs

Pad-Idle : send preamble/inter - frame - idle

Silence : silence (or signalled pseudo silence) for the duration of one bit-period.

5. BROADBAND BUS PHYSICAL LAYER SPECIFICATION

This section specifies the functional and electrical characteristics of the Physical Layer.

5.1 Data signalling rate

The Standard Data Signalling Rate shall be 5Mbit/s ± 0,01 %.

The exact rate in any given Local Area Network shall be as determined by the network Remodulator.

The use of other data signalling rates is for further study.

5.2 Data scrambler

In order to reduce the probability of long transmitted sequences of identical symbol codes and to randomize spectral components of the transmitted modulation, the symbolic binary data transmitted between the six-symbol frame delimiter sequences shall be pseudo-randomized by dividing the equivalent message polynomial by the generating polynomial $1 + X^{-6} + X^{-7}$.

The coefficients of the quotient of this division are taken in descending order.

Additionally the Data Scrambler shall be reinitialized (preset to all ONE) at each Non-Data symbol.

Appendix C describes the logical arrangements of such a Data Scrambler and corresponding Descrambler.

5.3 Symbol encoding

The Physical Layer shall transmit symbols presented to it at the output of the Data Scrambler.

The possible symbols are Zero, One, Non-Data, Pad-Idle, and Silence.

Each of these symbols is encoded into a different three-symbol 0, 2, 4.

The encoding action to be taken for each of the input symbol is :

Silence : All DTEs shall encode silence as the symbol 0 and shall cease transmission while transmitting only Silence.

The Remodulator shall encode successive Silence symbols as successive codes of the repeating sequence 2 2 0 4 always restarting with the first 2 of the sequence for each new period of transmitted Silence.

Pad-Idle : Consecutive Pad-Idle symbols shall be encoded as successive symbols of the repeating sequence 4 0 always restarting the sequence for each new period of Pad-Idle.

Non-Data : Each Non-Data symbols shall be encoded as a 2. The Start frame Delimiter sequence shall be encoded :

2 2 0 2 2 0 0 0

and the End frame Delimiter sequence shall be encoded :

2 2 4 2 2 4 0 or 4 0 or 4

Additionally the encoder shall start to maintain a sense of octet alignment, with the next output symbol considered to be the first of a new octet.

Zero and : Each Zero and One symbol shall be encoded as follows :

1) The Data Scrambler symbol shall be converted to one of the three-symbol output codes via the following correspondence :

Zero = 0

One = 4

2) Consecutive octets of three-symbol output codes, starting with the pair of octets immediately following the six-symbol frame Delimiter sequences, shall be inspected to determine whether both octets consist of the identical symbol code ; if they do then the last three output codes in the second octet shall be altered before transmission as follows :

0 0 0 shall be replaced by 4 2 2

4 4 4 shall be replaced by 0 2 2

The method for octet inspection is the following:

With respect to the modem's sense of octet alignment,if the last octet as transmitted by the modem and the current octet are all the identical symbol, then the last three occurences of that symbol in the current octet shall be replaced as specified prior to transmission.

5.4 Baseband modulation

The three symbol coded signal shall be converted to an appropriately-shaped signal whose amplitude is determined by the output symbol code as follows (where MAX is the amplitude of the largest signal element) :

$\underline{0}$ = 0 amplitude

$\underline{2}$ = 0,5 of MAX

$\underline{4}$ = MAX

The equivalent baseband signal shaping function shall be based upon the partial response pulse often referred to as Duobinary or class 1 partial response whose time function is defined by :

$$g(t) = \frac{4}{\Pi} \cdot \frac{\cos\left(\frac{\Pi t}{T}\right)}{1 - \left(2\frac{t}{T}\right)^2}$$

Where 1/T denotes the data signalling rate.

<u>Shaping Process Description</u>

Every bit time, a pulse of the shape defined here before shall be sent to the modulator. This pulse shall be of either positive or negative polarity according to the polarity of the last shaped signal and to the value of the current symbol to be transmitted.

The transmission of adjacent pairs of <u>Non-Data</u> symbols can be synthesized by omitting one pulse. The pulse following the omission can be of either polarity accordingly to the last shaped signal transmitted.

The following table gives the polarity of the current shaped signal accordingly to the polarity of the last one and to the value of the current symbol to be transmitted.

Last Shapped Signal Polarity	Current Symbol	Current Shapped Signal Polarity
-	0	+
+	0	-
-	4	-
+	4	+
-	First 2 of a pair	Signal Omission
+	First 2 of a pair	Signal Omission
-	Second 2 of a pair	+
+	Second 2 of a pair	-

The amplitude of the modulated signal is then directly the resultant amplitude of the consecutive shaped pulses being transmitted and will be :

+ MAX or - MAX	for a One Symbol
0	for a Zero Symbol
+ 0,5 MAX or - 0,5 MAX	for a Non-Data Symbol

5.5 Line signal in RF band

Unless otherwise specified, all power and voltage level specifications are in rms and dBµV rms, based on transmissions of random data patterns. Measurements for voltage levels and power ratios may be made using a data pattern of unscrambled One symbols, with a correction factor of + 3 dB over equivalent measurements using random data.

5.5.1 AM/PSK Modulation

The equivalent baseband modulation shall be applied to an rf carrier centred in the assigned channel (e.g. 3 MHz from each channel edge of a 6 MHz channel) and the resultant modulated carrier shall be coupled to the Broadband Bus Medium.

The negative levels of the baseband signal correspond to phase reversals of the rf carrier.

The receiver need not detect this phase, as only the amplitude information is significant the line signal shall correspond to a double-sideband signal with its carrier frequency at the mid-point frequency of the channel ± 100 kHz.

NOTE 1: Channel allocation for Local Area Network is for further study.

5.5.2 Transmitted signal level

The output level of the transmitted signal into a 75 Ohm resistive load shall be adjustable over the range from +90 dBuV to +110 dBuV with adjustment performed either manually, or upon command through the Physical Layer entity's Network Manager Interface or both.

The granularity (Step-size) of this adjustment shall be at most 2 dB, and once set, the actual variance from the set transmitter level shall be at most ±2 dB.

The residual or leakage transmitter-off output signal shall be at least 60 dB below that of the modulated signal.

5.5.3 Frequency Response

The amplitude of the theoretical line signal pulse spectrum, corresponding to a single coded 4 appearing at the output of the multi-symbol signal coder, is to be cosine-shaped in the frequency domain as indicated below with MAXIMA at the channel mid-point and 0 at +2,5 MHz from that mid-point.

$$\left| G(f) \right| = \begin{cases} 2T \cos(\pi f t) & , \; |f| \leq \dfrac{1}{2T} \\ 0 & , \; |f| > \dfrac{1}{2T} \end{cases}$$

$$\angle G(f) = \begin{cases} -\pi f T & , \; |f| \leq \dfrac{1}{2T} \\ 0 & , \; |f| > \dfrac{1}{2T} \end{cases}$$

Respectively, where 1/T denotes the data signalling rate.

- The transmitted power, independently of the data transmitted, in that portion of frequency spectrum that is outside the channel bandwidth shall meet or exceed the relative attenuation specified in the equation below :

$$RA = \min \left(60{,}35 + 10 \log_{10} B + 80 \left| \frac{MF - NCEF}{B} \right| \right)$$

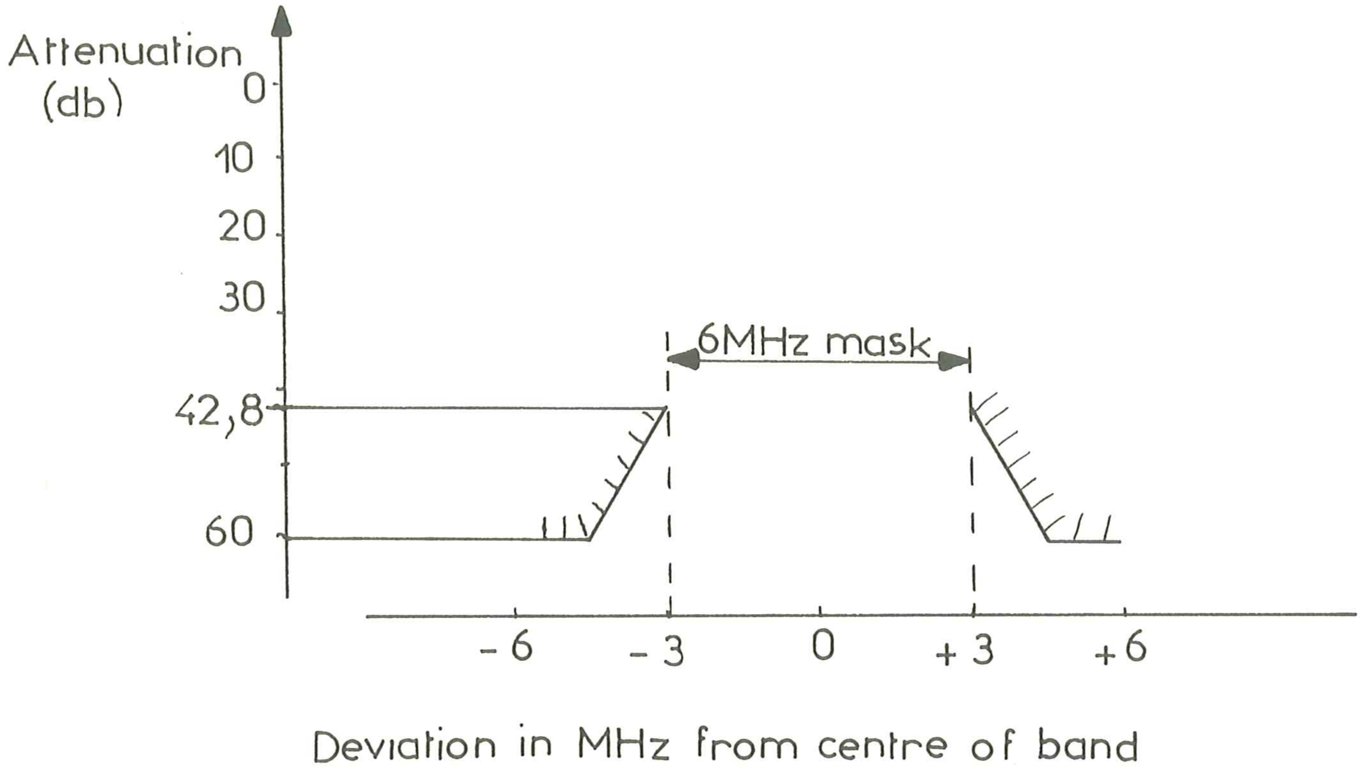
Where :

RA is the attenuation relative to total transmitted power in dB measured in any 30 kHz band.

B is the channel bandwidth in MHz.

MF is the measurement frequency in MHz and NCEF is the frequency in MHz of the nearest edge of the channel.

Transmit spectrum Mask



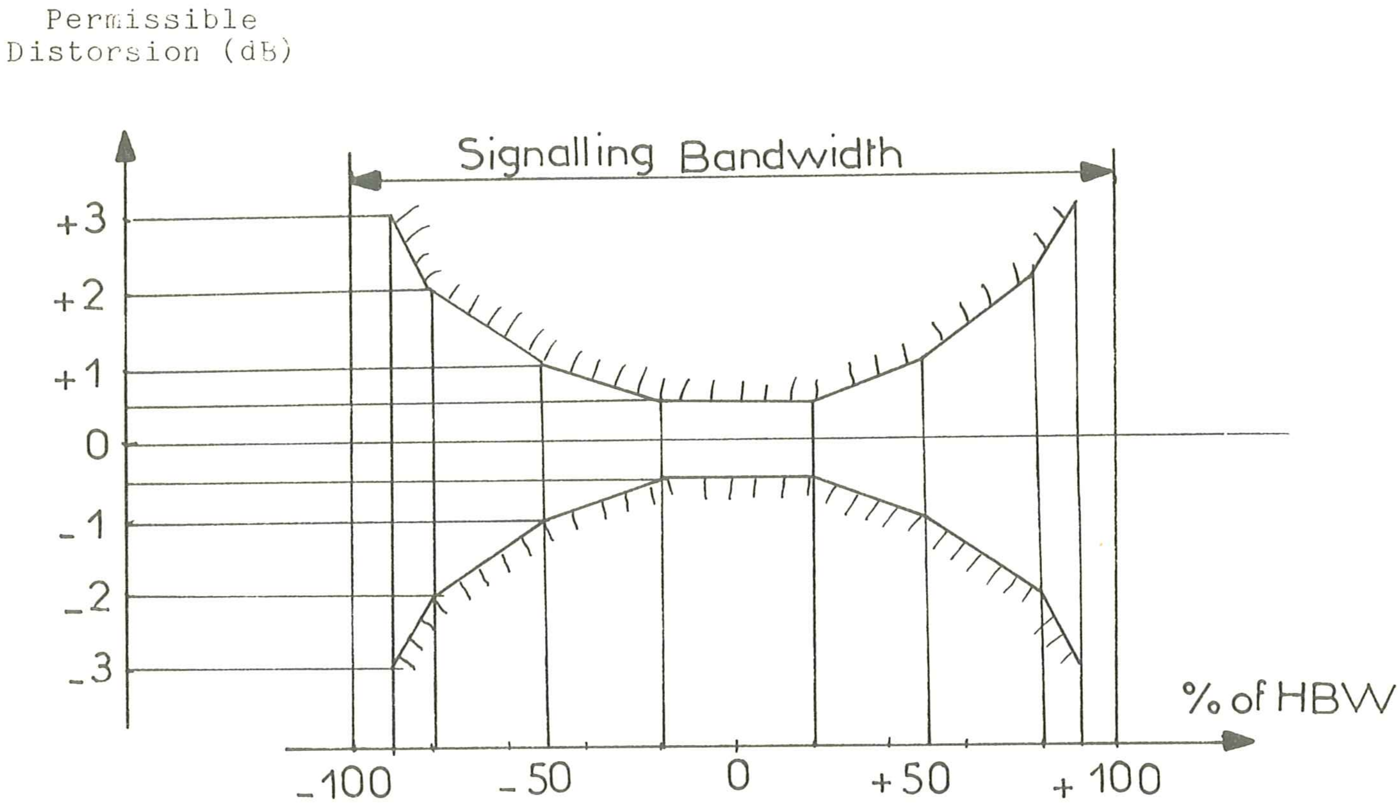
5.5.4 Amplitude Distortion

In the 5 MHz signalling band centred at the actual rf carrier frequency, the Amplitude Distortion of the real spectrum relative to the theoretical spectrum as defined in 5.5.3 above shall fall within the limits specified by the following table and figure.

Breakpoints of Amplitude Distortion limits

DISTANCE FROM BAND CENTRE % OF HBW	PERMISSIBLE DISTORTION FROM THEORITICAL SPECTRUM (IN FREQUENCY DOMAIN) (dB)
± 20 %	± 0,5
± 50 %	± 1,0
± 80 %	± 2,0
± 90 %	± 3,0
± 100 %	at least 20 dB attenuation

At the band edges, where the theoretical spectrum has Zeros (infinite attenuation), the actual signal amplitude shall be attenuated by at least 20 dB with respect to the signal amplitude at the centre of the band.



5.5.5 Group Delay Distortion

In the 5 MHz signalling band centred at the actual rf carrier frequency, the Group Delay Distortion relative to the centre of the band shall fall within the limits specified by the following equation.

$$\text{SPGD} = \pm\, 90 \log_{10} \cos(\Pi f t), \quad |f| \leq \frac{1}{2T}$$

Where :

1/T denotes the data signalling rate and SPGD denotes the Station Permissible Group Delay distortion relative to the centre of the signalling band, measured as a percentage of T.

5.6 Jabber function (Optional)

The Physical Layer shall provide a Jabber Function which is a self-interrupt capability to inhibit transmit data from reaching the Medium. The Jabber Function will terminate a transmission in a minimum time of 375 ms and a maximum time of 625 ms.

If the transmission is in excess of this duration the Jabber Function inhibits further data output from reaching the Medium. Reset of the Jabber Function is either achieved manually or alternatively arranged to be dependent upon the removal of the output data stream.

5.7 Receiver sensitivity and selectivity

The Physical Layer entity shall be capable of providing a bit error rate of 10^{-9} or lower, when receiving signals of average amplitude level in the range from +50 dBuV to +70 dBuV in a system with an rms in-band signal-to-noise level of +26 dB or greater.

The receiver shall reject all other channels.

5.8 Automatic gain control

The Physical Layer entity shall monitor the level of the received signal. It shall adjust its receiver gain as necessary based upon that monitoring for receivers connected to the Forward channel, this adjustment may be based upon the long-term time-averaged amplitude of the received signal.

For the Remodulator (which is receiving the Reverse channel), the initial adjustment must be made rapidly during the initial Pad-Idle sequence which begins each transmission and must be completed at least four Pad-Idle symbols before the end of that sequence.

At the end of the Pad-Idle sequence the level adjustment shall be such that the bit error rate specified in 5.7 is guaranteed during the remainder of the data frame.

In order to preset its AGC for this rapid level acquisition process, the Remodulator shall be able to detect an End of frame Delimiter or a Silence greater than 24 symbols (4,8 µs). For this purpose it is required that the Silence between two frames originated from different Stations be at least 24 symbols.

The minimum length of that Pad-Idle sequence is 16 signalling symbols for a data transfer rate of 5 Mbit/s.

5.9 Symbol timing

5.9.1 At the DTE Level

Each Physical Layer entity whose receiver is connected to the Forward channel shall recover the symbol timing information contained within the received signalling. This Recovered symbol timing shall be used for symbol transmission.

The jitter of the transmitted symbol timing relative to the symbol timing within the received signalling shall be less than 10 ns.

This jitter is directly related to the mean period between transitions within the received bit stream.

The two following types of worst case periods can be distinguished :

a) A one-time worst-case period between transitions of 22 bits (e.g. 10000000 00000000 00000001).

b) A continued worst-case period of 16 bits per solid transition (transition between 0 or 4 and 2 may not provide good clock recovery in low cost receivers, so only the transitions between 0 or 4 are considered "solid").

5.9.2 At the Remodulator Level

The Remodulator is the master clock of the complete system. Is shall originate its own transmit symbol timing. The jitter of that originated timing shall be less than 0,2 ns.

The Remodulator shall not derive its symbol timing from the received signalling.

5.10 Symbol decoding

After full wave rectification of the demodulated line signal the Physical Layer entity will determine each received signalled symbol.

Then, that symbol shall be decoded by a process inverse to that described in 5.3 and the decoded symbols shall be reported at the MAC interface.

Whenever a signalled symbol sequence is received for which the encoding process has no inverse, the Bad Signal Indication shall be asserted as long as the error condition exists.

5.11 Bad-signal detection

When signals on the Reverse channel cannot be decoded the Remodulator shall generate either Pad-Idle or Abort sequences on the Forward channel. The transmitted sequence depends on its current transmission state as follows :

a) If the Remodulator was repeating Silence as Pseudo Silence, it shall transmit Pad-Idle symbols until the fist NON-DATA symbol is to be repeated or until the received signalling disappears.

b) If the Remodulator has already detected one or more frame delimiters since the last Silence period it shall transmit Abort sequences as long as the Bad Signal Indication is received.

Abort Format :

SD	ED

Where SD and ED respectively denote a Start of frame Delimiter and an End of frame Delimiter.

5.12 Remodulator overload protection

The receive levels at the Remodulator receiver may be exceeded during periods when the distributed Token Bus protocol has more than one DTE transmitting. A Remodulator shall be designed to tolerate at least + 30 dB increase in the received signal over the maximum specified in 3.3.2.

Furthermore, the Remodulator reception part must report the presence of received signalling by asserting a Bad-Signal Indication during such period of overload.

5.13 Pseudo silence generation

As soon as a Silence has been detected on the Reverse channel (at least 24 consecutive 0 symbols) the Remodulator shall transmit continuously on the Forward channel a training and synchronization signal (Sequence 2 2 0 4) for all of the DTEs in the Local Area Network.

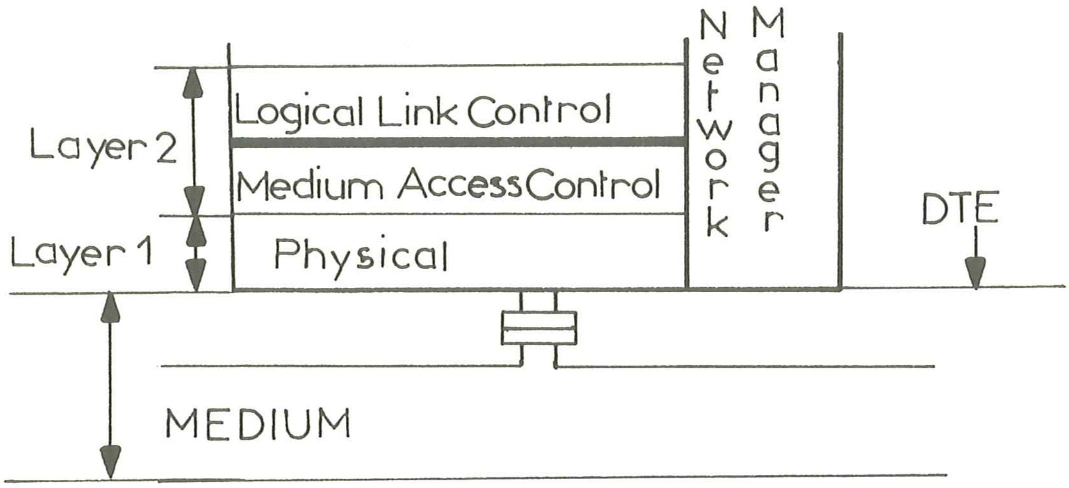
5.14 Physical layer reliability

The Physical Layer should be designed such that its probability of causing a communication failure among the DTEs connected to the Medium is less than 10^{-6} per hour. For the Remodulators this requirement is relaxed to a probability of 2.10^{-5} per hour.

6. MEDIUM ACCESS CONTROL SUBLAYER SERVICES

This section specifies the services provided to the Logical Link Control entity at the boundary between the Logical Link sublayer and the Medium Access Control sublayer of the Data Link Layer of the Reference Model.

The relationship between this specification and the other Local Area Network specifications is illustrated here below.



This Standard specifies these services in an abstract way. It does not specify or constrain the implementation entities and interfaces within a computer system.

These services are all connectionless data transfer services between peer Logical Link Control entities.

They provide the means by which peer Logical Link Control entities can exchange MAC Service Data Units (M SDU).

6.1 Overview of interactions

The primitives associated with data transfer service are :

MA - DATA. Request

MA - DATA. Indicate

An MA - DATA . Request primitive is passed to the MAC sublayer to request that an M SDU be sent.

An MA - DATA . Indicate primitive is passed from the MAC sublayer to indicate the arrival of an M SDU.

6.2 Detailled specifications of interactions with the logical link control entity

6.2.1 MA - DATA . Request

6.2.1.1 Semantics of the Service Primitive

The primitive shall provide parameters as follows:

MA - DATA . Request
(destination - address, M SDU, desired-quality)

The destination - address parameter may specify either an individual or a group MAC - entity address.

The M SDU parameter specifies the MAC Service Data Unit to be transmitted by the MAC sublayer entity.

The desired-quality specifies the quality of service.

Two parameters of desired-quality could be optionally communicated :

a) The Priority Level of the message giving a target for an acceptable Token waiting time.

b) The number of consecutive transmitted copies of the message giving an estimated probability of message delivery.

6.2.1.2 When Generated

This primitive is passed from the Logical Link Control sublayer entity to request that the MAC sublayer entity compose and transmit the specified frame on the Local Area Network.

6.2.1.3 Effect on Receipt

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

6.2.1.4 Constraints

The M SDU shall be less than 4'100 octets in length.

6.2.1.5 Additional Comments

None.

6.2.2 MA - DATA . Indicate

6.2.2.1 Semantics of the Service Primitive

The semantics of the primitive are as follows :

MA - DATA . Indicate
(destination - address, source-address, M SDU)

The destination - address parameter may be either an individual or a group address as specified by the DA field of the incoming frame.

The source-address parameter must be an individual address as specified by the SA field of the incoming frame.

The M SDU parameter specifies the MAC Service Data Unit as received by the local MAC entity.

6.2.2.2 When Generated

The MA - DATA . Indicate is passed from the MAC sublayer entity to the LLC sublayer entity or entities to indicate the arrival of a frame to the local MAC sublayer entity.

Such frames are reported only if they are validly formed, received without error, and their destination address designates the local MAC entity.

6.2.2.3 Effect on Receipt

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

6.2.2.4 Additional Comments

If the local MAC sublayer entity is a designated by the destination address parameter of an MA - DATA . Request, the Indicate primitive will also be invoked by the MAC entity to the local LLC entity at the time of M SDU transfer on the Medium.

This full duplex characteristic of the MAC sublayer may be due to unique functionality within the MAC sublayer or full duplex characteristics of the lower layers (e.g. all frames transmitted to the broadcast address will involve MA - DATA. Indicates at all Stations in the network including the Station that generated the request and this at the time of the frame transfer on the network).

7. MEDIUM ACCESS CONTROL SUBLAYER FUNCTIONS

This section specifies the functions within the Medium Access Control sublayer.

7.1 Error detection

Error detection uses current CRC technique :

- Firstly the transmitting Station generates a Frame Check Sequence (FCS) which is concatenated either to the data field or SA field of any transmitted frame.
- Secondly the receiving station executes the same operation on received frames comparing the FCS calculated, the FCS received to detect an error.

The Frame Check Sequence field contains a 4 octect (32 bit) cyclic redundancy check (CRC) value.

This value is computed as a function of the contents of all MADU fields except the Frame Check Sequence field itself.

The encoding is defined by the generating polynomial :

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

Mathematically, the CRC value corresponding to a given frame is defined by the following procedure.

1) The first 32 bits of the frame are complemented.

2) The n bits of the frame are the coefficients of a polynomial M (X) of degree n-1 (the first bit of the access control field corresponds to the X^{n-1} term and the last bit of the data or SA field corresponds to the X^0 term).

3) M (X) is multiplied by X^{32} and divided by G (X), producing a remainder R (X) of degree smaller than 31.

4) The coefficient of R (X) are a 32-bit sequence.

5) The bit sequence is complemented and the result is the CRC.

6) The 32 bits of the CRC are transmitted in the order X^{31}, X^{30}, ...X^1, X^0.

7.2 Error recovery in multicast mode (Optional)

This is an Optional function which is not mandatory to be implemented to claim compatibility with this ECMA Standard.

7.2.1 Procedure Properties

This Procedure has the following Properties :

a) It is relevant whatever the number of Stations concerned by a multicast message and does not require the knowledge of this number.

b) It is efficient whatever the distance separating two Stations.

c) There is pratically no delay between the error detection and the recovery action.

d) The added procedure overhead may be relatively low as long as the procedure is selectively used only for very reliable short datagrams such as :

. alarms
. high security level lettergram addressed to a moving entity
. synchronization events ... etc

In fact the decision to use this procedure is taken at the higher level by the source and this not systematically.

e) The procedure does not affect the global event order viewed by any Station.

It means that addressed Stations receiving multicast messages will see them in the same order.

7.2.2 Procedure Description

7.2.2.1 Transmitter Action

From the transmitter point of view the procedure consists to send in a mutual exclusive manner (contiguously) a certain number of copies (N) following the original version of the message.

The number N is specified during the MA-DATA Request primitive communication accordingly to the network bit error rate and to the desired datagram reliability.

When the Station receives a Token it enters the network access phase and then is able to transmit packets on the Medium. Multiple packets may be sent by transmitting firstly the original version (V = 0 in the LLC frame format field) and then consecutively the N requested copies (V = 1 for each copy in the LLC frame format field).

To guarantee that messages are received with the evaluated probability of loss, only one message shall be transmitted using this technique in each network access phase defined by a Token reception. Other messages which are not copied may be transmitted in the same network access phase.

7.2.2.2 Receivers Action

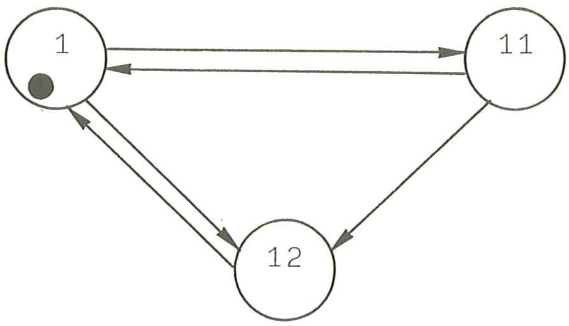
Any receiver shall follow the same procedure here after described.

The state diagram represented below shows the differents phases of this procedure.

1. Idle

11. Recovery

12. Copies Discard



S1. IDLE

In this state a Station picks up any valid original version of a packet and discards all received copies.

This action is also carried out by Station which does not support the error recovery implementation.

Any Station achieving the option shall execute the following actions :

. After picking up an original version the Station enters the "Copies - Discard" state in order to discard all the possible copies following the original version.

. If an error has been detected, the Station enters the "Recovery" state trying to find a valid copy of the transmitted message.

S11 Recovery

In this state the Station is waiting for either a valid LLC frame or a Token frame.

. If it receives either an original version of a message or a Token it will return to the Idle state picking up the message.

  The reception of an original version of a message following the detected error means that either all the copies have been lost (erroneous) or only the original version was sent.

. If it receives properly a message copy it will recover the message and will enter the "Copies - Discard" state to discard the following ones.

. Any properly received packet is taken for destination address field examination if received in this state.

S12. Copies - Discard

In this state all messages'copies are systematically discarded.

. Upon receiving either the original version of a message or a Token, the Station reenters the Idle state.

. Any properly received original version of a packet is taken for destination address field examination if received in this state.

7.3 Medium access procedures

7.3.1 General Description

7.3.1.1 Token Passing Procedure

Steady state operation (the network condition where all access linkages have been established and no error conditions present) simply requires the sending of the Token to a specific Station (hereafter refered to as the Next Station, or NS) as each finishes transmitting.

The Token (right to transmit) is passed from Station to Station in numerically descending Station address order.

Each participating Station knows the address of its predecessor (the Station it got the Token from) and its successor (who the Token shall be sent to next), in addition to its own. These values are dynamically determined and maintained by the algorithms described.

After each Station has completed other maintenance functions described next, the Station passes the Token to its successor by sending a "Token" frame.

After sending the Token frame the Station listens to make sure that its successor hears the Token frame and is active.

If the sender hears a valid frame following the Token, it assumes that its successor has the Token and is transmitting.

7.3.1.2 Token Passing Failure

In case of Token passing failure the following actions are executed.

If the sender does not hear a valid frame within one network Slot Time it assumes the successor did not hear the frame and resends the Token.

If the successor does not respond to a second Token frame, the sender assumes the successor has failed.

The sender now sends a "Who Follows" frame with its successor's address in the data field of the frame.

All Stations compare the value of the data field of a Who Follows frame with the address of their predecessor (the Station that sends them the Token).

The Station whose predecessor is the successor of the sending Station responds to the Who Follows frame by sending its address.

The Station holding the Token thereby establishes a new successor, bridging the failed Station from the logical ring.

If the sending Station hears no response to a Who Follows frame, it repeats the frame a second time.

If there is still no response, the Station now sends a "Solicit Successor" frame (see below) asking any Station in the system to respond to it.

If there are any operational Stations that can hear the request, they respond and the logical ring is re-established using the response window process discussed next.

If two attempts at soliciting a successor fail, the Station assumes that a catastrophy has occured.

Either all other Stations have failed, the Medium has broken, or the Station's own receiver has failed so that it cannot hear other Stations who have been responding to his request.

In this catastrophic condition the Station quits attempting to maintain the logical ring and simply listens for some indication of activity from other Stations.

In summary, the Token is normally passed from Station to Station using a short Token pass frame.

If a Station fails to pick up the Token, the sending Station uses a series of recovery procedures, that get increasingly drastic as the Station fails to find a successor Station.

7.3.1.3 Stations Insertion

New Stations are added to the logical ring through a controlled contention process called "response windows".

The MAC frame "Solicit Successor" indicates the opening of response windows.

All Stations in the logical ring periodically (see 7.5.4 max response window count) send Solicit Successor frames allowing new Stations to enter the ring.

The Solicit Successor frame specifies a range of Station addresses between the frame source and destination addresses.

Stations whose address falls within this range who wish to enter the ring, respond to the frame.

The Solicit Successor frame sender transmits the frame and then waits, listening for a response in the response window following the frame. The size of the response window is determined by the Slot Time and the transmission time during which a Station may respond.

Responding Stations send the frame sender requests to become the next Station in the logical ring.

If the frame sender hears a valid request frame, it allows the new Station to enter the ring by changing the address of its successor to the new Station and passing its new successor the Token.

- In any response window there exists the likelihood that more than one Station will simultaneously request ring entry.

  To minimize contention when this happens, the Token pass sequence is ordered by address.

  Minimum contention is achieved by requiring that a Station only request admission when a window is opened that spans its address.

- There are two "Solicit Successor" frames. One with a single response window and another with two response windows.

The single response window frame is sent when the Station's Successor's address is known and is less than the Station's address.

This is the normal case when the Token is being passed from higher to lower addressed Stations.

The Solicit Successor with one window frame allows only Stations whose address is in the range between the Token sender and the Token destination to respond, thus limiting the possible contenders and preserving the descending order of the access ring.

- One Station in the logical ring has its Station's address below that of its successor (e.g. the unique Station having the lowest address who must send the Token to the "top" of the address sorted ring).

  When soliciting successor, this Station must open two response windows, one for those below it, one for those above.

  Stations having an address below the sender respond in the first response window, while Stations having an address higher than the destination, respond in the second response window.

- In any response window, when the soliciting Station hears a valid Set-Successor frame, it has found a new successor.

  When multiple Stations simultaneously respond, only unrecognizable noise may be heard during the response period.

  The soliciting Station sequences through a response arbitration algorithm to identify a single responder by sending a "Resolve Contention" frame.

  The Stations which had responded to the earlier "Solicit Successor" frame and which have not yet been eliminated by the iterative resolve demanders algorithm choose a two-bit value and listen for 0, 1, 2 or 3 Slot Times as determined by that value (this value is choosen based on each Stations address, taken two bits at a time. This is further described in later sections).

If these contending Stations hear anything while listening, they eliminate themselves from the arbitration; if they hear only silence they resend their demand.

- By knowing and controlling the rate at which response windows are opened, and by virtue of the finite length of the demand resolution algorithm (described later), hard bounds on the access rate can always be calculated (determinism).

  The demand resolution cycle need be run a maximum of twenty-five times (6.8/2 + 1 or 48 address bits taken two at a time plus one random pair) for six bytes addresses and nine times (2.8/2 + 1 or 16 address bits taken two at a time plus one random pair) for two bytes addresses.

7.3.1.4 Logical Ring Initialization

Initialization is primarily a special case of adding new Stations.

The lack of a Token on the network is detected by the exhaustion of an "Inactivity" timer in a Station which causes the Station to send a "Claim Token" frame.

(This is the only time a transmission is allowed without the previous receipt of a Token).

As in the response window algorithm, the initialization algorithm realizes that more than one Station may try to initialize the network at a given instant.

This is resolved by address sorting the initializers.

- Each potential initializer sends a "Claim Token" frame having a length that is a multiple of the network Slot-Time (the multiple being 0, 2, 4 or 6 based on bits of the Station address, as in demand resolution, above).

  Each initializing Station waits one Slot Time for its own transmission to pass and then samples the state of the Medium.

If a Station senses Non-Silence, knows that some other Station(s) sent a longer length transmission.

The Station defers to the Station (s) with the longer transmission and re-enters the Idle mode.

- If Silence was detected, and unused bits remain in the address string, the Station attempting initialization repeats the process using the next two bits of its address to derive the length of the frame.

  If all bits have been used, and no carrier is sensed, the Station has "won" the initialization contest and now holds the Token.

  Once there is a unique Token in the network, the access right builds via the response window process previously described.

  The random pair of bits used at the end of the address sort algorithm ensure that two Stations with the same address (which is a fault condition) will not bring down an entire system.

  If the two Stations don't separate (random numbers come up the same), neither Station gets into the access ring.

  If they do separate (random numbers are different), one will get in.

  In the later case, the Station who doesn't get in will hear a transmission from a Station with its address and then know of the error condition.

- The distributed address sorting processes of claiming the Token and resolving demand contention must proceed from most significant to least significant address bits.

- A Station may remove itself from the logical ring any time by simply choosing not to respond to a Token passed to it, allowing the fault recovery mechanisms in the protocol to patch it out.

A more efficient method is if the Station desiring to exit the ring sends a Set-Successor frame to its predecessor (the Station it got the Token from) with the value contained in its register NS prior to passing on the Token.

The exiting Station then simply sends the Token as usual to NS, knowing it will never be returned.

Re - admission requires the demand sequence, above.

7.3.1.5 Priority Option

The token passing access method provides an Optional priority mechanism by which higher layer data frames avaiting transmission are assigned to different "Priority Levels" ranked or ordered by their desired transmission priority. This priority mechanism allows the MAC sublayer to provide eight Priority Levels to the LLC sublayer and higher level protocols. The priority of each frame is determined by the Priority Level value requested in the MA-DATA Request primitive.

The Token Bus access method distinguishes two service classes.

- The synchronous service class allows any Station belonging to this class to get the Token inside well defined periods of time (i.e. at least every 10 ms) independently of :

  . the number of In-Ring Stations
  . the load of the local network

A Station automatically shall belong to this class as soon as it accepts to transmit data frames having a Priority Level in the range from 4 to 7 (4 to 7 are called synchronous levels).

So, synchronous service class allows the transfer of frames with a Priority Level in the range from 0 to 7.

- The asynchronous service class uses the bandwidth left available by the synchronous service class without any time limit guarantee.

- Any Station having only the capability to transfer data frames with Priority Levels in the range from 0 to 3 (called asynchronous levels) belongs to this class.

In order to achieve the objective of providing synchronous access to the synchronous service class, a Ring Interrupt Priority scheme has been specified (see 7.4.).

The principle of this mechanism is the following :

a) When the Token circulation is sequential (sequential mode) any Station receiving the Token and having asynchronous levels frames in queues can transmit them accordingly to their Token Rotation Timer values.

   But the sequential circulation of the Token can be periodically interrupted to pass the Token to the synchronous service class.

b) When the Token circulation has been interrupted (interrupt mode) any Station receiving the Token and having synchronous levels frames in queues can transmit them accordingly to their Token Rotation Timer values.

   Such mechanism requires the following actions be taken :

   a) The Stations address space is divided into two subsets of consecutive addresses :

      - one is allocated to the synchronous service class,

      - the other is allocated to the asynchronous service class.

   b) A Ring Interrupt Timer located at each Station level, determines the interruption periods.

c) The sequential circulation of the Token around the established logical ring is interrupted each time a time out of the Ring-Interrupt Timer is detected, then the Token is directly passed to the highest address Station of the synchronous service class.

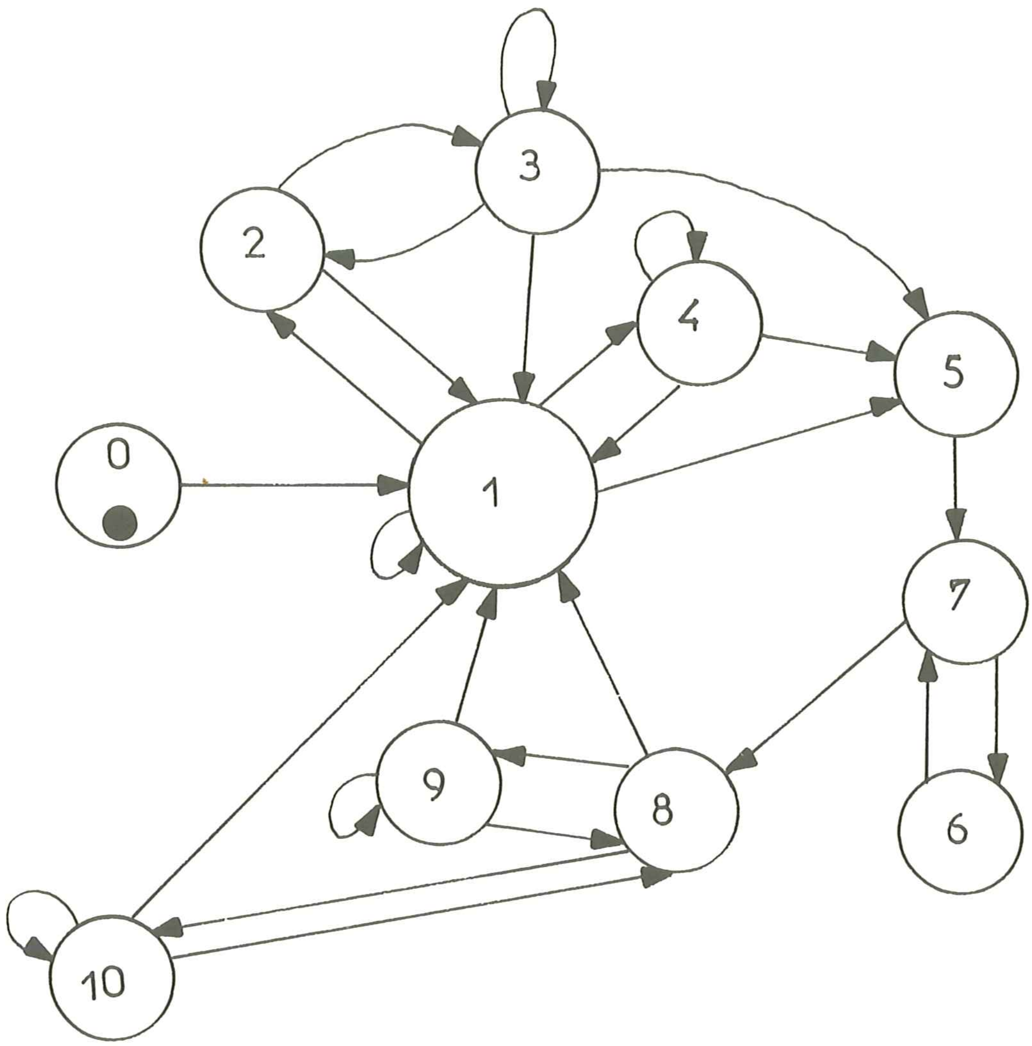
d) The Token is given back to the interrupted Station as soon as the lowest address Station of the synchronous service class has finished using it.

7.3.2 Access States

The medium access logic in a Station sequences through a number of distinct phases, called states, while participating in the Token access method.

These states are introduced in the following sub-sections with all transitions between them given in figure 7.1.

The complete state transition matrix and the formal description is given in appendix D.



0. - UNPOWERED

1. - IDLE

2. - DEMAND - IN

3. - DEMAND - DELAY

4. - CLAIM - TOKEN

5. - ACCEPT - TOKEN

6. - USE - TOKEN

7. - CHECK - PRIORITY

8. - PASS - TOKEN

9. - CHECK - TOKEN - PASS

10. - AWAIT - RESPONSE

Fig. 7.1 - MAC Finite State Machine Diagram

7.3.2.0 Unpowered

This is the virtual state the access machine is in prior to power-up.

After powering up, a Station tests itself and its connection to the Medium without transmitting on the Medium.

(Note that this "internal" self-testing is Station implementation dependent and does not affect other Stations on the network. Thus the self test procedure is not covered in this Standard).

After completing any power-up procedures, the Station enters the Idle state.

7.3.2.1 Idle

"Idle" is the most prevalent state, where the Station is listening to the Medium and not transmitting.

Received frames are processed here to insure validity (i.e, correct FCS) and dispatched to the correct handling procedure based on the value in the Frame Format field which begins each frame.

Link Level Control (LLC) frames are simply passed to the LLC sub-layer and not evaluated further for content (that is LLC'S job).

- If a MAC frame is received for which the Station must take action, the appropriate state is entered.

  For example, if a "Token" frame addressed to the Station is received, the Station first enters the "Accept-Token" state and then sequences to the "Use Token" state.

- If the Station goes for a long period of time (a defined multiple of the Slot-Time) without hearing any activity on the Medium, it may infer that recovery or restart of the logical ring is necessary.

  The Station attempts to claim the Token (enters the "Claim Token" state) and restarts it circulating around the old logical ring or the Station attempts to (re) initialize the logical ring.

7.3.2.2 Demand In

"Demand In" is entered from Demand Delay or Idle if a Resolve Contention frame is received by a Station contending for the Token.

This state is entered when multiple Stations are contending in the same response window.

The multiple contention is resolved by having each Station delay a period of time before transmitting a request for the Token to the Token holder (a Set - Successor frame).

The delay interval is chosen by taking Station's (unique) address and using two bits to determine the delay interval.

Thus Station will delay 0, 1, 2 or 3 Slot Times when entering the Demand In state before transmitting.

- In order to sort the Station so that the highest addressed Station tends to win the contention, the one's complement of the Station's address is used.

  Stations with numerically higher addresses delay shorter intervals.

  The entire contention process can take many passes of the following steps :

  . Send Set - Successor frame to Token holder

  . Listen for response

  . Hear Resolve Contention frame

  . Delay number of window times, if hear any other frames drop from contention

  . Repeat using next two bits of address

  The contention resolution process should resolve so that the contending Station with the highest address is finally heard by the Token holder and receives the Token.

However, if two Stations are assigned the same Station address, they will both sequence through the contention process using the same delays and will never resolve.

To permit resolution in this error condition, a final resolution pass is taken using a two-bit random number after the Station's address bits have all been used and the contention is still unresolved.

If both Stations chose the same random value or another error prevents resolution, then the Token holder and the contending Stations abandon the resolution process.

(Thus two Stations with the same address and the same random number value may never be able to enter the logical ring).

7.3.2.3 Demand Delay

"Demand Delay" is the state the Station enters after having sent a Set - Successor frame to the Token holder while attempting to demand into a window.

In this state the Station listens for :

1) A Token from the Token holder indicating its Set - Successor frame was heard.

2) A frame from another Station, indicating that it should drop from contention and return to the Idle state.

3) A Resolve Contention frame from the Token holder indicating that all claiming Stations should perform another step of the address sort.

If multiple Stations contend in a response window, the Token holder may hear nothing but "Collisions" (noise).

If this occurs, the Token holder sends a "Resolve Contention" frame.

All Stations currently in the Demand Delay state respond to this frame.

The responding Stations change to the Demand In state (discussed previously), send another Set - Succesor frame to the Token holder, and re-enter the Demand Delay state.

7.3.2.4 Claim Token

Entered from the Idle state after the inactivity timer expires (and TS desires to be included in the access ring).

In this state, the Station attempts to initialize or re-initialize the logical ring by sending Claim - Token frames.

To resolve multiple simultaneous Stations sending Claim - Token frames, each Station monitors the Medium as previously described in the section 7.3.1.4.

If a carrier is not heard for a Slot-Time duration, the Station broadcasts another Claim - Token frame with a length a multiple of a fraction of its address.

When the limit is reached, the Station has successfully "claimed" the Token, updates is logical - ring - state to In - Ring.

7.3.2.5 Accept Token

The state the Station enters after just receiving or claiming a Token.
If the Station does not want to remain in the logical ring, it may remove itself by sending a Set - Successor frame to its predecessor (the Station it got the Token from, as determined by the SA field) with the value of its register NS.
This patches TS out of the access ring but it still has the Token.
The Station then enters the "Check-Priority" state below.

7.3.2.6 Use Token

This is the state in which a Station can send data - units for the Station's LLC sublayer.
Each time a LLC frame or a group of LLC frames (original version plus copies in case where the error recovery in multicast mode is used) has been transmitted, the Station enters the "Check-Priority" state in order to determine whether it can continu using the Token or it has to pass it.

7.3.2.7 Check Priority

"Check Priority" controls the transmissions of LLC frames for different Priority Levels.

- In sequential mode only asynchronous level queues are considered. In this case the transmission may be globally limited by the "Token Holding" Timer or limited for each asynchronous level by means of a Token Rotation Timer asso- ciated to the Priority Level and of identical value for all Stations considering the Priority Level.

- In interrupt mode only synchronous level queues are considered. In this case the transmission may be globally limited by the "Token Holding" Timer or limited for each synchronous level by means of a Token Rotation Timer associated to the Priority Level and started when entering the interrupt mode.

Thus the three following events causing the Station to pass the token are :

a) In sequential mode, the "Ring Interrupt" Timer expired event is asserted meaning that the Token shall be passed to the synchronous service class.

b) The "Token Holding" Timer expired event is asserted meaning that the maximum amount of time allocated to the Station has been used and that the Token must be passed to the next Station.

c) The "Token Rotation" Timer expired event of the lowest Priority Level under consideration is asserted meaning that there is not more sufficiently urgent message to be transmited, leading to pass the Token to the next Station.

In any case if the Station has not any more data to transmit it must pass the Token to its successor.

7.3.2.8 Pass Token

This is the state in which a Station attempts to pass the Token to its successor.
Before passing the Token, the Station may be required to allow new Stations to enter the logical ring.

The Token holding Station does this by sending a Solicit Successors frame with one or two response windows following.

Following any new successor solicitation if the address of the successor, NS, is known, the Station performs a simple Token pass.

If the successor responds and the Station hears a valid frame, the Station has completed its Token passing obligations.

If the NS is not known, the Station sends the Token with two response windows to itself.

Since this Token has two response windows and identical source and destination addresses, it forces all Stations on the network which desire to be in the access ring (whether or not they were previously) to send a frame.

Those Stations whose address are less than the sender of the Token frame transmit in the first window ; those with addresses higher transmit in the second.

7.3.2.9 Check Token Pass

The state in which the Station waits for a reaction from the Station to which it just passed the Token.

The Station sending the Token waits one Slot Time for the Station receiving the Token to transmit.

The one Slot Time delay accounts for the time delay between receiving a frame and taking the response action.

If nothing is heard in one Slot Time, the Station sending the Token assumes the pass was unsuccessful and returns to "Pass Token" to either repeat the pass or try another strategy.

In systems with significant Medium delay, such as headended broadband systems, the Token passing Station may hear its own transmissions delayed.

In this state and several other states the Station must ignore its own transmission.

In the Check Token Pass state the Station must be careful to distinguish between frames that it has sent and frames sent by the Token recipient.

(If the Token sending Station incorrectly decides that a frame it sent was sent by the Token recipient, it may drop the Token when the recipient does not pick it up ; so the Token is lost.

If the sending Station incorrectly decides that a frame sent by the recipient was sent by itself and ignore the frame, it may cause two Tokens to be created.

Either condition is a serious error.

If the Token sending Station hears a noise burst or frame with an incorrect FCS, it cannot be sure from the source address which Station sent the frame.

The protocol treats this condition in a way to minimize the chance of the Station causing a serious error.

If a noise burst is heard, the Station sets an internal indicator and continues to listen in the Check Token Pass state for up to 4 Slot Times.

If nothing more is heard, the Station assumes it hear its own Token that had been garbled and so repeats the Token transmission.

If a valid frame is heard, the Station assumes its successor has the Token.

If a second noise burst is heard, the Station's operation is arbitrary.

The Standard currently treats a second noise burst the same as a valid frame, assuming the Token has been passed.

7.3.2.10 Await Response

The state in which the Station attempts to sequence candidate successors through a distributed contention resolution algorithm until one of those successor's Set - Successor frame is correctly received or until no successors appear.

It is entered from the "Passing Token" state whenever the Station determines it is time to open a response window or if the Station does not know its successor (as in initialization or when a Token pass fails).

The Station waits in the Await Demand state for a valid frame.

If nothing is heard for the entire duration of the windows opened, the Station goes to the Token Pass state ; either to pass the Token to its known successor or to try a different Token pass strategy.

If a Set - Successor frame is received, the Station enters the Pass Token state and sends the Token to the new successor.

If the received frame is other than a Set - Succesor frame, the Station drops the Token (since someone else must have it to be able to send any other frame type, thus a duplicate Token situation) and re-enters the "Idle" state.

- If a noise is heard during the response windows, the Station cycles through a procedure of sending "Resolve Contention" frames which open four response windows each, waiting for a distinguishable (no Collision) response in one.

  The loop repeats a maximum of max-pass-count times, each time instructing contending Stations to select a different two bits of their address to determine whic' of the four opened windows to transmit in.

7.4 Ring interrupt priority scheme (Optional)

This is an Option which is not mandatory to be implemented to claim a compatibility with this ECMA Standard.

7.4.1 General

This section describes a priority scheme allowing the transfer of synchonous messages requiring to stricly limit their maximum waiting time at the MAC level, with the transfer of asynchronous messages which have not such strong waiting time constraint.

This Ring Interrupt Priority Scheme carries with it the following advantages.

a) There is practically no overhead due to the fact that the Token is directly passed to the synchronous service class and directly returned to the interrupted Station.

b) This mechanism may guarantee to the synchronous priority levels, the reception of the Token within relatively short (1 to 10 ms) periods of time whatever the load ⌢ the local network.

7.4.2 Priority Scheme Description (see fig.7.2)

When using such a mechanism we can distinguish two Token circulation modes.

- Sequential Mode
- Interrupt Mode

7.4.2.1 Sequential Mode

While being in Sequential Mode any Station of the ring can transmit data packets having an associated Priority Level in the range of the asynchronous levels (0 to 3).

It is not mandatory that all Stations have the capability to use the 4 asynchronous levels but in the contrary a Station may only use one among four levels according to the nature of the Station.

Moreover it is not mandatory to associate a Token Rotation Timer (see 7.4.2.4) for each level of priority but in such a case the admissible transmission period of any Station per token rotation should be limited by the Token Holding Timer.

The sequential circulation of the Token can be interrupted at each Station level by means of the local Ring Interrupt Timer. In such a case the Station enters the Interrupt Mode memorizing the fact that the Token sequential circulation has been interrupted at its level.

The interrupted Station then broadcasts a "Ring Interrupt" frame and waits one Slot Time for the Station receiving the Token to transmit.

If a valid frame is heard which started during the response window, the Station assumes the Token pass is successful.

If nothing is heard in one Slot Time, the Station sending the "Ring Interrupt" frame assumes the Token pass was unsuccessful and then repeats the "Ring-Interrupt" frame.

If again nothing is heard the Station assumes that there is no synchronous service class and then reenters the Sequential Mode.

If noise or an invalid frame is heard, the Station will continue to listen for additional transmission.

7.4.2.2 Interrupt Mode

When broadcasting a "Ring-Interrupt" frame, the implicit destination of the Token is the Station of the synchronous service class having the highest address (called synchronous class head SCH).

This unique Station is capable of identifying itself because it knows that its predecessor belongs to the asynchronous service class (class bit in the frame format field of a Token frame).

When the SCH Station gets the Token it can use it and propagate it to the next Station seting the mode bit to Interrupt Mode in the frame format field of the Token frame.

While being in Interrupt Mode any Station of the synchronous service class can transmit data packets having an associated Priority Level in the range of the synchronous levels (4 to 7).

It is not mandatory that all Stations of the synchronous service class have the capability to use the 4 synchronous levels but in the contrary a Station may only use one among four levels according to the nature of the Station.

Moreover it is not mandatory to associate a Token Rotation Timer (see 7.4.2.4) for each level of priority but in such a case the admissible transmission period of any Station per Token rotation should be limited by the Token Holding Timer.
The Interrupt Mode is stopped if one of the two following conditions is true.

a) All the Token Rotation Timers associated to the synchronous levels have expired. So the first Station detecting such an occurrence shall return the Token to the interrupted Station.

b) The token holder is the Station of the synchronous service class having the lowest address (called synchronous class tail SCT) and this one has no more data to transmit. So, after identifying itself because it knows that its successor belongs to the asynchronous service class (class bit in the Frame Format field of a Solicit-Successor or of a Set Successor frame), the Station shall return the Token to the interrupted Station. The Station having the responsibility to return the Token, broadcast a "Ring-Return" frame and waits one Slot Time for the interrupted Station to reenter the Sequential Mode and transmit.

   If a valid frame is heard which started during the response window, the Station assumes the Token pass is successful.

If nothing is heard in one Slot Time, the Station sending the "Ring Return" frame assumes the Token pass was unsuccessful and then repeats the "Ring Return" frame.

If again nothing is heard, the Station assumes that the interrupted Station disappeared and then reenters the Sequential Mode passing the Token to its successor.

If noise or an invalid frame is heard, the Station will continue to listen for additional transmission.

7.4.2.3 Ring Interrupt Timer (RIT)

Every RIT is loaded with a time slice value defining a target period of time between two interruptions of the Sequential Mode and is started each time a ring interrupt is broadcast. Each Station owns a RIT which is forced in the expired condition under powering up and after winning the claim Token process.

As soon as a Token holder Station in Sequential Mode detects an expired condition of this timer, it has the responsibility to start the interrupt process.

7.4.2.4 Token Rotation Timers (TRT)

A TRT could be associated to each Priority Level with the objectif to allocate it a given portion of the total bandwidth. The TRT are not exactly used in the same manner by both service classes.

- associated to the synchronous levels the TRT are all simultaneously loaded and started each time a Ring Interrupt frame is broadcast.

- associated to an asynchronous level each TRT is individually loaded and started when its station, having the Token, checks its associated Priority Level during the message transfer phase.

In both cases TRT are loaded with a Target Token Rotation Time value and are used by each Station in the ring to check if there is enough time left, at the considered Priority Level, to send the locally queued messages of this given priority.

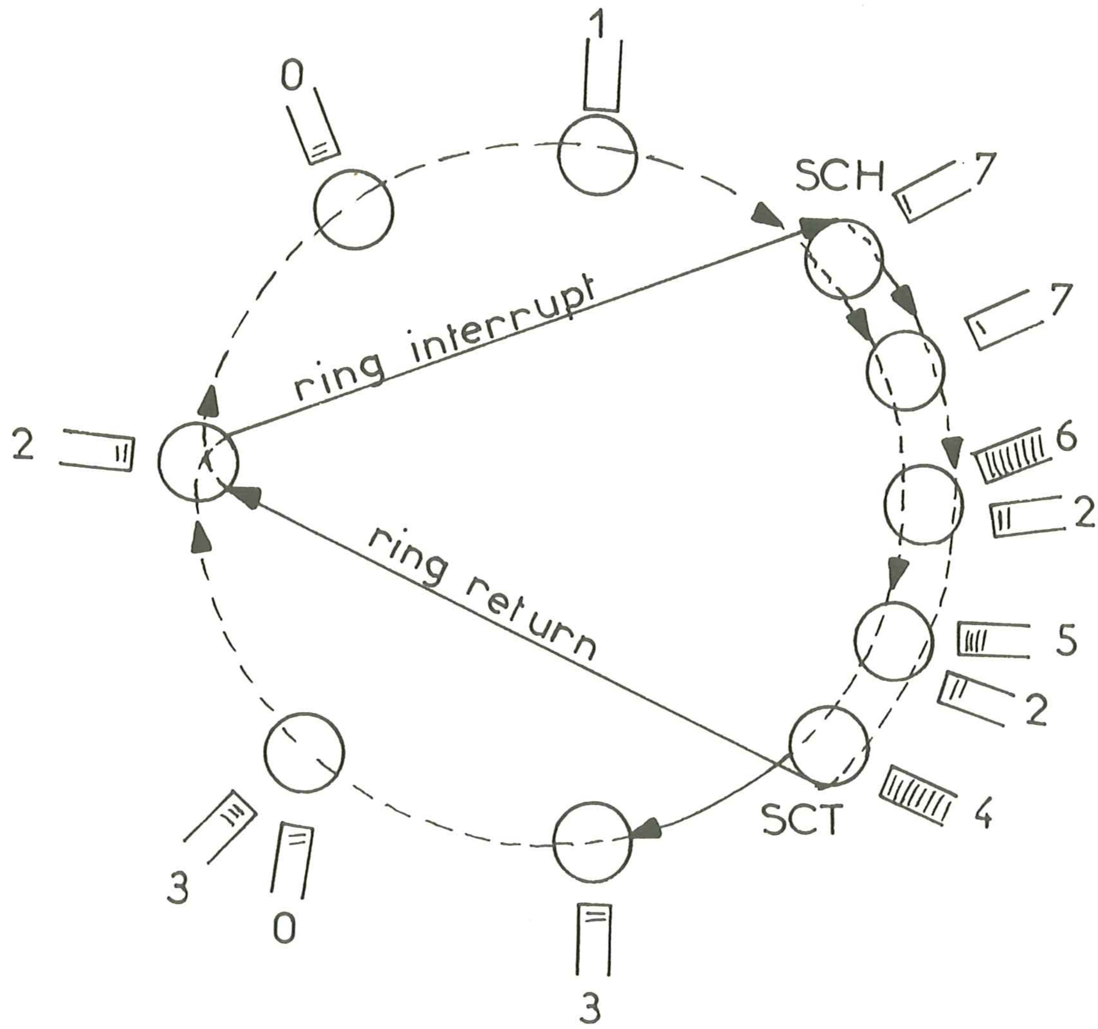


Fig. 7.2 - Ring - Interrupt Priority Scheme

7.5 Frame formats and parameters

7.5.1 Frame Structure

Three kind of frames circulating on the physical network can be distinguished at the Data Link level.

These are :

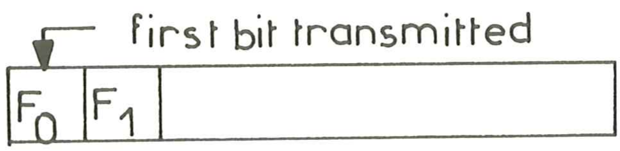
LLC frames which are directly passed to the upper layer if properly received and if the destination address is recognized by the Data Link layer as one local address.

MAC Management Frames for further study

MAC frames which are used for the logical ring initialization, administration and normal operation are transmitted, received and used only by the MAC sublayer.

All kinds of frame are structured in the same manner as described in figure 7.3.

The frames are distinguished by means of two bits (F0, F1) located in the frame format field of any frame.



F_0	F_1	Type of frame
0	0	MAC Control frame
0	1	LLC data frame
1	0	MAC Management frame
1	1	Reserved for future use

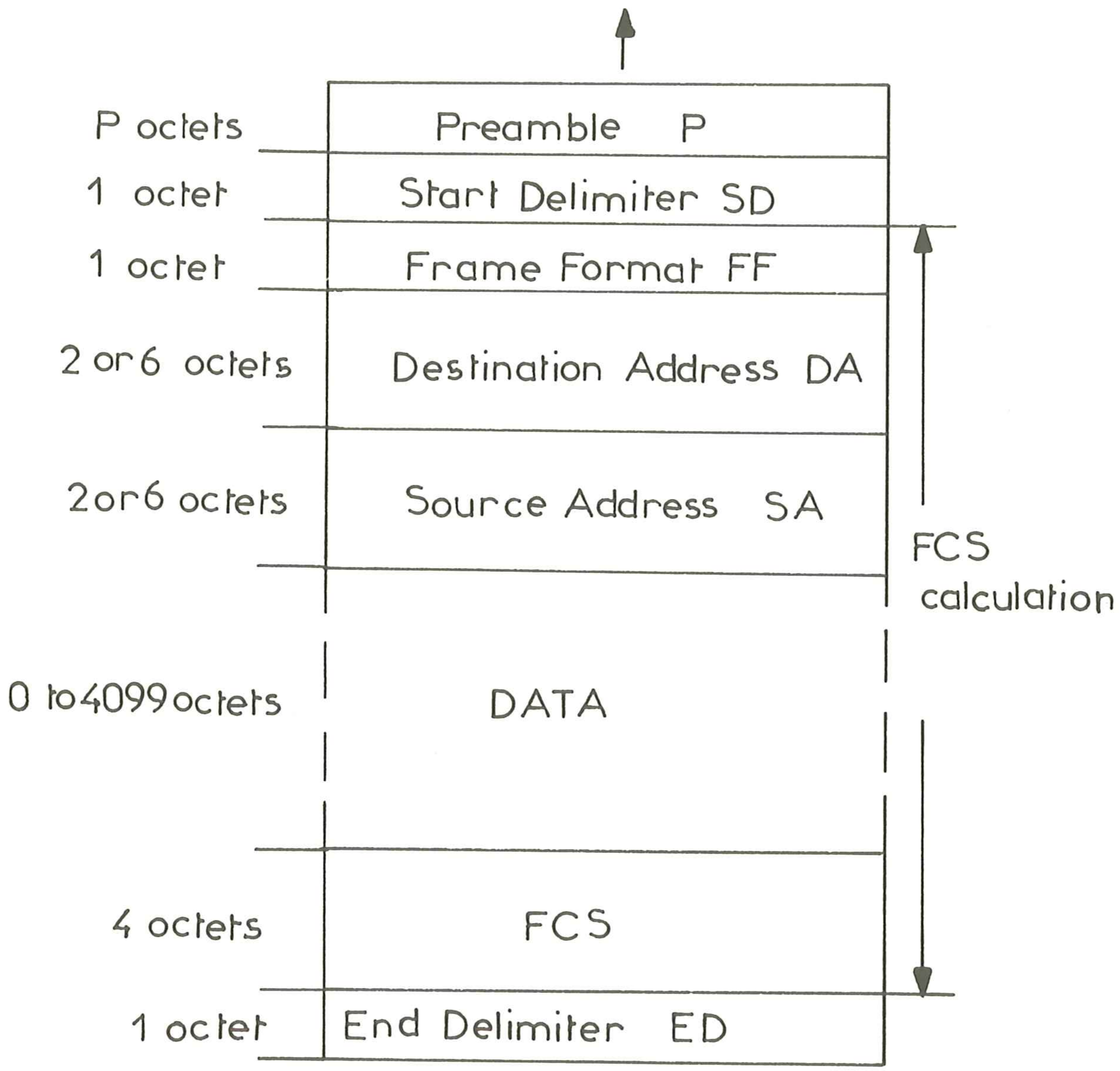


Fig. 7.3 - Frame Structure

7.5.1.0 Preamble

The Preamble pattern preceeds every transmitted frame.

Preamble is sent by MAC as an appropriate number of Pad-Idle symbols. Preamble may be decoded by the receiver as arbitrary data symbols that occur outside frame Delimitors.

Preamble is primarily used by the receiving DTE to acquire signal level and phase lock by using a known pattern (see Physical Layer section).

A secondary purpose for the Preamble is to guarantee a minimum interframe idle period to allow Stations to process the previously received frame.

This Standard requires that the duration of the Preamble must be at least 2 microseconds, regardless of data rate, and that an integer number of octets must be sent.

7.5.1.1 Frame Delimiters

The frame structure requires a Start of frame Delimiter, which begins the frame, and an End of frame Delimiter, which ends the frame and determines the position of the Frame Check Sequence.

All bits between the Delimiters are covered by the Frame Check Sequence.

The Start and End frame Delimiters consist of signalling patterns that are always distinguishable from data.

The Delimiters also contain bits of information that are not error checked.

The first six symbols of a Delimiter are a combination of Data and Non-Data symbols.

The Delimiters are coded as follows :

	First bit transmitted
Starting frame Delimiter (SD)	N N 0 N N 0 0 0
Ending frame Delimiter (ED)	N N 1 N N 1 I E

Where N = Non-Data bit
0 = Data-Zero bit
1 = Data-One bit
E = Error bit
I = Intermediate bit

The eighth ED Delimiter symbol is called ERROR (E) and a value of ONE would indicate the detection of a CRC error. The Token Bus as defined has that value be always ZERO as no Station repeats frames.

The seventh ED bit if ONE indicates that more transmission from the DTE follow, if ZERO indicates that this is the last frame transmitted.

7.5.1.2 Frame Format Field

This field is specific of the kind of frame utilized and will be more detailed in the following 7.5.2 and 7.5.3 sections.

7.5.1.3 Destination Station Address Field

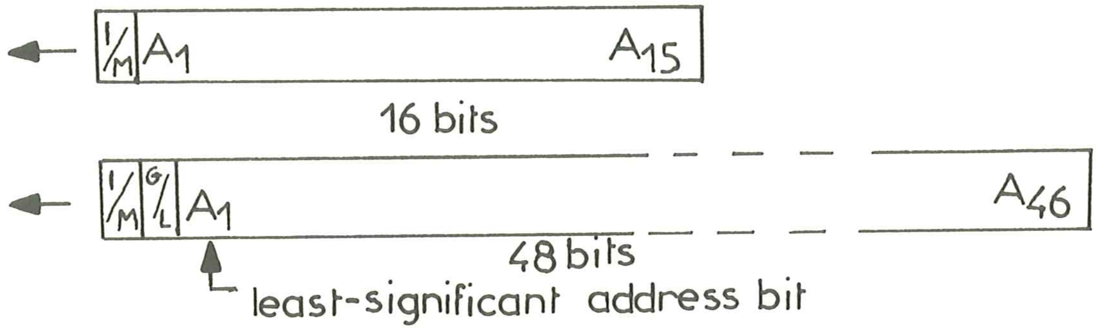
The Destination Station Address Field identifies the Station(s) for which the frame is intended.

It may be an individual address or a multicast address.

It may be a globally or locally administrated address (the I/M bit of this field is the first transmitted).

The length of this field is either 2 or 6 octets without the possibility to mix both formats on a given LAN (frequency channel of a Broadband LAN).

DA field format



I/M = 0 : Individual address, the unique address associated with a particular Station.

A Stations'individual address should be distinct from the individual address of any other Station.

I/M = 1 : Multicast address, associated with one or more Stations.

There are two kinds of multicast addresses :

- Multicast group address : an address associated by higher level convention with a group of logically related Stations.
- Broadcast address : a distinguished, predefined multicast address which always indicates the set of all Stations.

  This pattern consists of 48 ONE bits or 16 ONE bits.

G/L = 0 : Global administration, means that all individual addresses are defined to be distinct from the individual address of any other Station on any LAN

A set of multicast addresses are also defined by a global administrator so that no group of logically related Station has the same address that any other logically related Stations on any LAN.

G/L = 1 : Locally administered, each individual and multicast address in any given LAN is assigned by the local administrator of the given LAN.

A1 : Is the least significant address bit.

7.5.1.4 Source Station Address Field

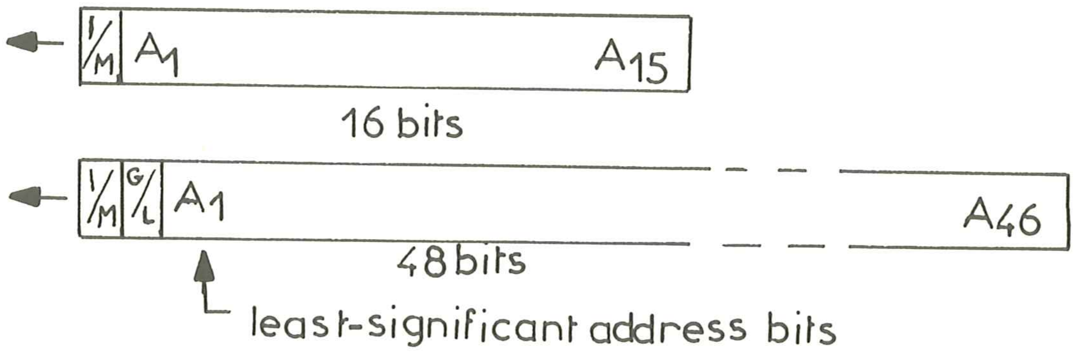
The Source Address Field specifies the Station sending the frame.

The Source Address Field is not interpreted at the Data Link Layer level.

It is specified at the Data Link level because a uniform convention for the placement of the field is crucial for most higher level protocols.

Two formats are possible but do not coexist on the same LAN (frequency channel of a Broadband LAN).

SA Field Format



The definition of G/L and A1 bits is the same as given in 7.5.1.3.

7.5.1.5 Frame Check Sequence Field

A Cyclic Redundancy Check (CRC) is used by both the transmit and receive algorithms to generate a CRC value for the FCS field.

The Token passing method uses a 32-bit CRC value that is computed as a function of the access control field, DA, SA and data field.

For more details see the section 7.1.

7.5.2 MAC Frame Format

The MAC frame is mainly distinguished from a LLC frame by the structure and meaning of the Frame Format fieldand the possible absence of the data field.

7.5.2.1 Frame Format Field Structure

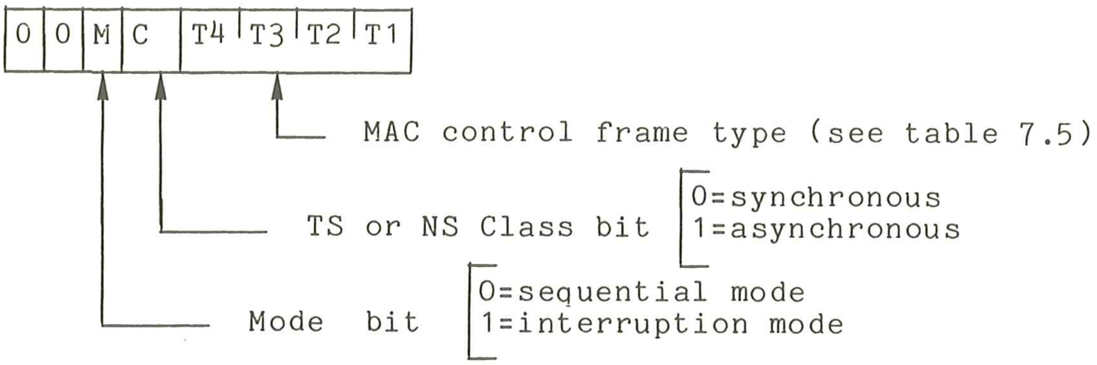


Table 7.5 - The following table summarizes the MAC frame formats

I/M = 1 means the frame is broadcast

MAC Frame Format field coding								I/M	MAC Frame Type
0	0	0	0	0	0	0	0	1	Claim-Token
0	0	M	C	0	0	0	1	0	Solicit - Successor - 1 *
0	0	M	C	0	0	1	0	0	Solicit - Successor - 2 *
0	0	0	0	0	0	1	1	1	Who - Follows
0	0	0	0	0	1	0	0	0	Resolve - Contention
0	0	M	C	1	0	0	0	0	Token *
0	0	0	1	1	0	0	0	1	Ring - Interrupt
0	0	1	0	1	0	0	0	1	Ring - Return
0	0	M	C	1	1	0	0	0	Set - Successor *

* When ECMA Priority Schema Option is not implemented M and C shall be 0 0

Remarks

1) Other codes are reserved for future study.

2) The I/M bit is the first bit of the DA field, it indicates if the frame is individually addressed or broadcasted.

7.5.2.2 Enumeration of MAC Frame Types

1 - Set Successor, with DA = the SA of the last frame received , and data-unit = the value of the Station's NS or TS register.

0 0 M C 1 1 0 0	DA	SA	new value of NS	FCS

2 - Claim-Token, with a data-unit whose value is arbitrary and whose length in octets is 0, 2, 4 or 6 times the system's Slot-Time when also measured in octets.

0 0 0 0 0 0 0 0	DA	SA	arbitrary value length=(0,2,4,6) *slot-time octets	FCS

3 - Explicit-token, with DA = the contents of the Station's NS register and a null data unit.

0 0 M C 1 0 0 0	DA	SA	FCS

4 - Ring-Interrupt, with DA = BROADCAST and a null data unit.

0 0 0 1 1 0 0 0	DA	SA	FCS

5 - Ring-Return, with DA = BROADCAST and a null data unit.

0 0 1 0 1 0 0 0	DA	SA	FCS

6 - Solicit-Successor, with DA = the content of the Station's NS register or TS and a null data unit. 1 or 2 response windows always follow this frame.

0 0 M C 0 0 0 1	DA	SA	FCS
0 0 M C 0 0 1 0			

One or two response windows

7 - Who-Follows, with DA = BROADCAST and data-unit = the value of the Station's NS register.

0 0 0 0 0 0 1 1	DA	SA	Value of NN	FCS

8 - Resolve-Contention with a null data-unit. Four response windows always follow this frame.

0 0 0 0 0 1 0 0	DA	SA	FCS

Four response windows

7.5.2.3 Order of Bit Transmission

Each octet of the access control, address and MAC information fields is transmitted low-order bit first.

The FCS is transmitted high-order bit first.

7.5.2.4 <u>Invalid Token Bus MAC Frame</u>

An invalid Token Bus MAC frame is defined as one which meets at least one of the following conditions :

- It is identified as such by the Physical Layer (for example contains Non-Data or invalid symbols).
- It is not an integral number of octets in length.
- It does not consist of one Frame Format field, two properly formed Address fields, one MAC Information field of appropriate length (dependent on the code point specified in the Frame Format field), and one FCS field, in that order.
- The Source Address field contains a group address.
- The appropriate bits of the incoming frame (exclusive of the FCS field itself) do not generate an FCS value identical to the one received.

  An implementation may also include any of the following additional conditions in the above list :

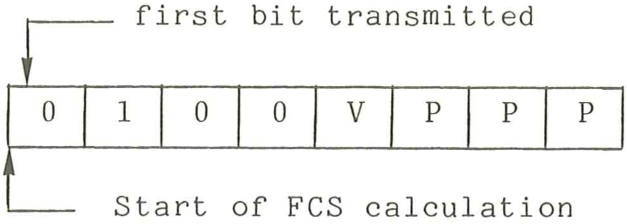
  - The frame Format Field specifies an undefined code point.

Invalid MAC frames are treated as noise.

In fact their detection is required at some points in the Token bus elements of procedure.

7.5.3 LLC Frame Format

7.5.3.1 Frame Format Field Structure



PPP = Station or service priority level
(111 = highest priority)

V:
- 0 = packet original version
- 1 = copy version

V is used for the error recovery in multicast mode Option.

7.5.3.2 LLC Frame Structure

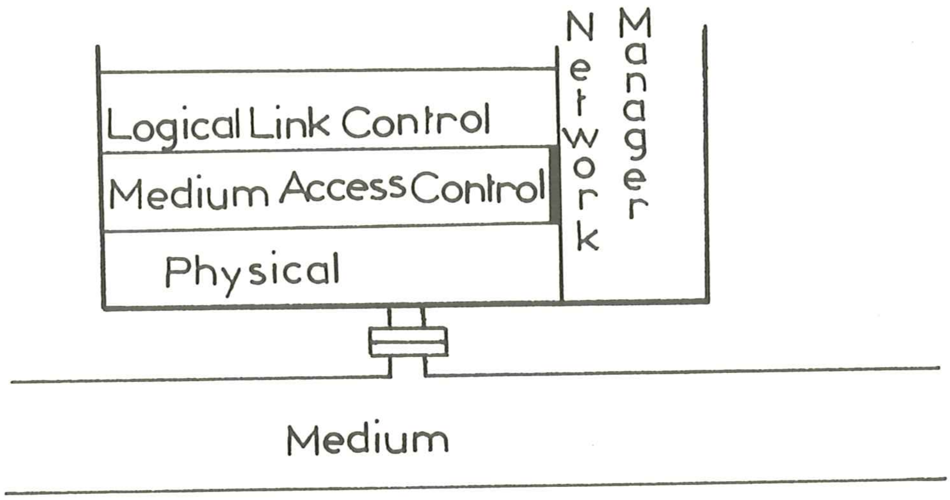
The LLC frame structure is not described in this Standard, it is an element of the LLC sublayer Standard common to all Medium Access methods.

7.5.4 Parameters

This section lists the primitives and associated parameters which shall be passed from the Network Manager to the MAC sublayer in order to make this one capable of properly executing the medium access procedure here before specified.

The following figure illustrates the relationship existing between the two concerned sublayers of the Reference Model.

This Standard does not constrain the implementation entities and interfaces within a computer system.



The minimal subset of primitives and associated parameters being mandatory is the following.

7.5.4.1 MA - INITIALIZE - PROTOCOL. Request

This primitive is passed to the MAC sublayer to reset the entire MAC sublayer and to select the MAC entity's MAC address (and implicitely the length of all MAC addresses on the network), the Token-Passing protocol appropriate for the network (e.g, Bus or Ring) and the Station's role in that network (e.g, Originate-only or Originate - and - Repeat).

After receiving such a primitive the Station is just only capable of receiving data, it is not a member of the logical ring.

7.5.4.2 MA - SET - TIMER - LIMIT. Request

This primitive is passed to the MAC sublayer to designate a protocol time constant and specify the value of that time constant.

The following timer values shall be passed during the primitive communication :

- bus Slot Time value (mandatory)
- Time Slice Between Interrupts value (mandatory if the priority scheme Option is implemented)

- Maximum Token Holding Time (mandatory).
- Target Token Rotation Time for each Priority Level used by the local Station.

7.5.4.3 MA - DESIRED - RING - MEMBERSHIP. Request

This primitive is passed to the MAC sublayer to specify whether the MAC entity should be a member of the Token-Passing logical ring.

If an IN-RING-DESIRED status is specified, the following parameters shall be passed during the primitive communication.

- Max Response Window Count : (mandatory) this value specifies how often a Station opens response windows when passing the Token.

- Definition of the Priority Level accepted by the Station.

8. ENVIRONMENTAL SPECIFICATION

8.1 Electromagnetic and electric environment

Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltage between earth connections, etc...

Several sources of interference will contribute to voltage buildup between the coaxial cable and the earth connection, if any, of the DTE.

The Medium Layer entity embodiment shall meet its specifications when operating in an ambient plane wave field of :

2 V/m from 10 kHz to 30 MHz

5 V/m from 30 kHz to 1 GHz

APPENDIX A - GUIDELINES FOR CONFIGURING THE MEDIUM

Installation and maintenance guidelines developped within the CATV industry for inter and intra facility installation of coaxial cable systems should be followed where applicable.

A.1 GENERAL

The Network is constituted by using a certain number of passive (Cable, Taps, Splitters) and active (Remodulators, Bidirectional Broadband Amplifiers) components.

The components' choice is done accordingly to several parameters such as :

- The size of the Physical Network ;
- The Environmental Constraints ;
- The cost/performance ratio ;
- The extensibility requirements etc...

CATV Networks can satisfy any kind of LAN requirements especially concerning the networks' size and the number of connection points. Realistic limits could be the following :

- A maximum distance of 5 km between the Remodulator and the farest DTE ;
- A maximum of about 10 000 DTE connected to the broadband Network.

However during the Networks' installation phase a certain number of technical questions need to be answered, the following section gives some guidelines aiming at answering these questions.

A.2 CABLE CHOICE

The choice of the cable is done taking into consideration the following parameters :

- The Network's size defines the cable attenuation characteristics ;
- The environmental constraints define the cable shielding and coating characteristics ;
- The part of the Network being considered (Trunk or Drop Cable) define the cable attenuation.

The following table gives some examples :

CABLE CLASS	COATING	DIELECTRIC DIAMETER	ATTENUATION at 230 MHz per 100 m	MINIMAL BENDING RADIUS
Indoor Drop cable	PVC	7 mm	12,9 dB	60 mm
Indoor Trunk cable	PVC	11,1 mm	5,8 dB	150 mm
Outdoor Drop cable	PE	7 mm	12,9 dB	60 mm
Outdoor Trunk cable	PE	11,1 mm	5,8 dB	150 mm

Note 1 :

As the Cable attenuation varies with the frequency, the worst case figure must be used when calculating the Network's attenuation.

A.3 NETWORK ATTENUATION CALCULATION

Not only Cable Attenuation but also Taps and Splitters Attenuation must be considered when installing the Network. For example :

- A four ports symetrical Splitter has an attenuation of about 7 dB ;

- At the Tap level two kind of losses must be taken into account :

  . Insertion loss (0,3 to 3,3 dB),

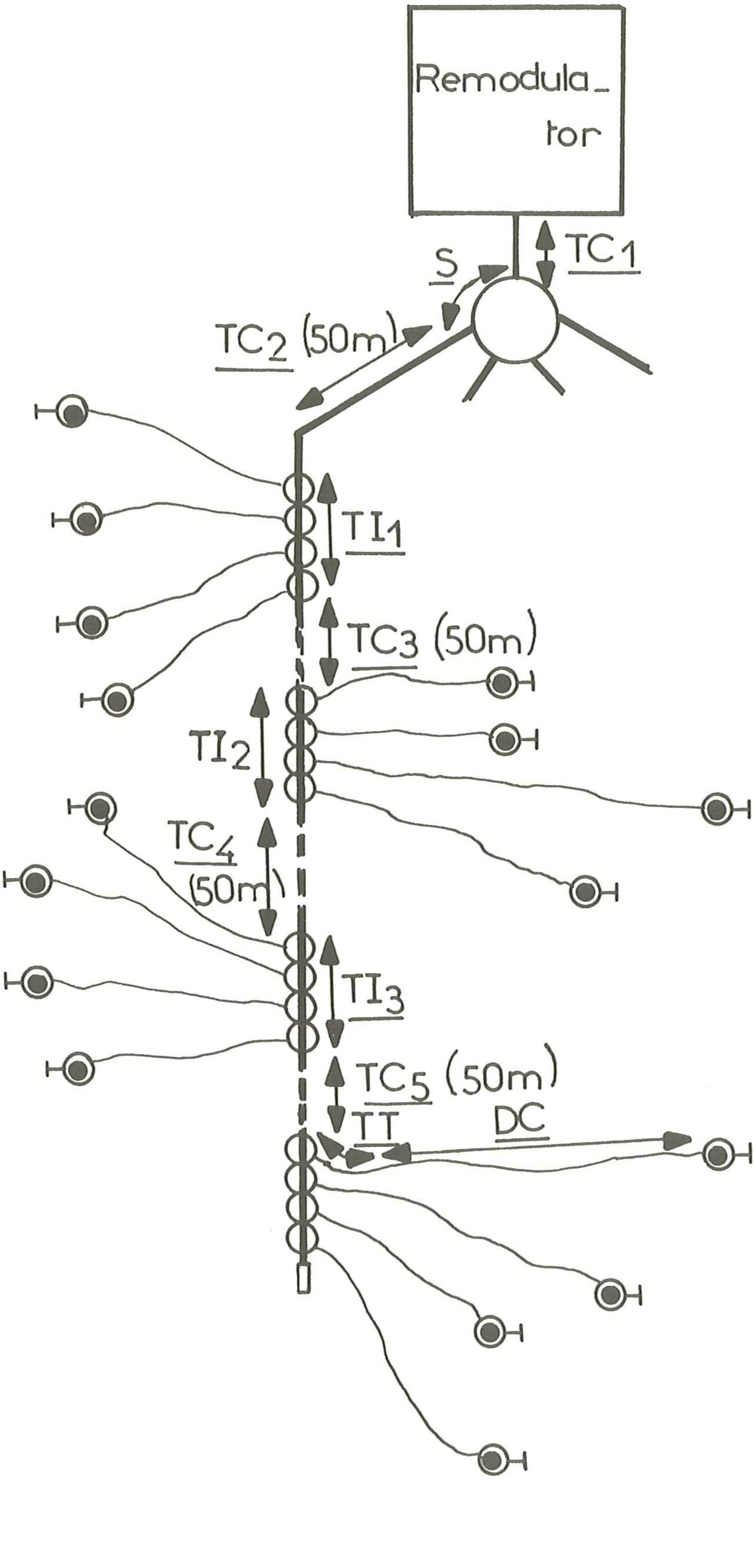
  . Transmission loss (4 to 36 dB).

The figure 1 gives an example of Network attenuation calculation at 230 MHz. In this example the following values have been taken :

Trunk Cable loss
(TC) = 5,8 dB per 100 m, hence 2,9 dB for 50 m Cable's segment

Drop Cable loss
(DC) = 12,9 dB per 100 m, hence 1,3 dB for 10 m Cable's segment

FIGURE 1


Remodula_
tor
TC1
S
TC2 (50m)
TI1
TC3 (50m)
TI2
TC4
(50m)
TI3
TC5 (50m)
TT
DC

Line Splitter - Equal 4 port splitting loss
(S) = 7 dB

Tap transmission loss
(TT) = 26 dB

Tap insertion loss
(TI) = 1 dB

The worst case attenuation figure is given by taking the total attenuation (At) between the Remodulator and the last wall outlet of the longest brunch.

Hence :

$At = TC_1 + S + TC_2 + TI_1 + TC_3 + TI_2 + TC_4 + TI_3 + TC_5 + TT + DC$

$At = 1 + 7 + 2{,}9 + 1 + 2{,}9 + 1 + 2{,}9 + 1 + 2{,}9 + 26 + 1{,}3 = \underline{49{,}9\ dB}$

A.4 AMPLIFIER INSERTION

In order to satisfy the electrical signal specification at the Medium - DTE/Remodulator Interface it may become necessary to insert Amplifier or combination of Amplifiers to compensate for the attenuation of this Network. The design of the Network, the correct choice and a well chosen location of the Amplifiers will be the basis for a CATV Network of good quality.

A Bidirectional Broadband Amplifier comprises at least a Forward amplifier module and a Reverse amplifier module. Both amplifier modules derive their power source (24V) from a power module which in turn takes its input from the Trunk cable.

All amplifiers add noise and non linear distortion in the system. According to the product specification of these amplifiers (gain, reference output level, flatness ...etc) and to the system requirements (number of channels, system attenuation...) the system designer fixes an operational input level of the amplifier allowing the best balance between noise and distortion figures.

Thus the location of Broadband amplifiers depends on this operating input level, but it is always possible by using different kind of cable and attenuator to combine this calculated figure with the real physical possibilities on the field.

Cascading Amplifiers

The maximum Bidirectional Broadband Amplifiers being cascaded depends on :

- The maximum permissible distortion level at the receiver ;
- The maximum permissible Noise level at the receiver ;
- The performance of the amplifiers, regarding distortion, noise, frequency-response, etc.... ;
- The number of channels, transported by the trunkline.

A realistic limit in the number of cascadable Bidirectional Broadband Amplifier is around 10 to 20.

APPENDIX B - INTERMODULATION DISTORTION MEASUREMENT

The important distortion products are not only harmonics of the frequencies used in the system, but also the sums and the differences of these frequencies, generated by the non-linearity of the amplifiers. In practice only the distortion products of 2 nd, and 3 rd order are involved in the calculation, the distortion product of 4 th and higher order can be neglected.

2 nd order products are $f_1 + f_2$; $f_1 - f_2$ and 2f

3 rd order products are $2f_1 \pm f_2$; $f_1 \pm f_2 \pm f_3$ and 3f

All these resulting frequencies are called intermodulation products.

In a multi-channel distribution system where all, or most, carriers are spaced at a constant frequency interval, there is a rapid build-up of third order distortion components as channels are added to the system. They cluster at the carrier frequencies. The number of these components is greatest at channels nearest the middle of this continuous incremental spectrum.

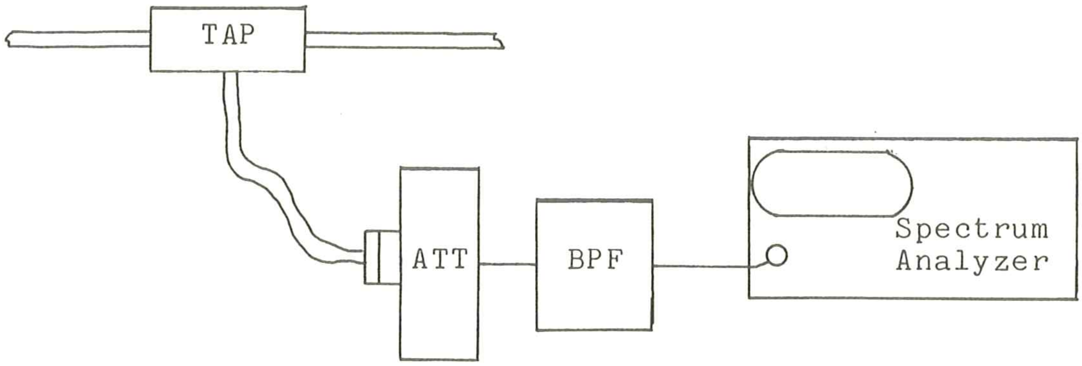
The following described test procedure is extracted from "Standard of good engineering practices for measurements on CATV systems" (NCTA 008 0477).

Test Procedure description

The following test equipment is required for this procedure.

- A spectrum analyzer with 30 KHz IF bandwidth capability ;
- A variable 75 Ohm attenuator (ATT) ;
- A bandpass filter for each channel to be tested or a tunable bandpass filter (BPF).

The following diagram shows the proper test equipment set up for this procedure.



1 - Increase the level of all channels at the Remodulator by 3 dB, except the pilot carriers.

2 - Connect the spectrum analyzer to the system as shown in the block diagram. Where possible, have 6 or 10 dB in the input attenuator.

3 - Tune the spectrum analyzer such that the channel to be measured is centered on the screen. The spectrum analyzer should be adjusted as follows, when establishing the "0" dB reference level.

IF bandwidth	300 KHz or greater
Video bandwidth	Maximum, video filter "Off"
Scan width	0,5 MHz per div.
Vertical	10dB per div.
Scan time	5ms per div. or slower

4 - In conjonction with the level controls on the analyzer, adjust the variable attenuator to establish a full screen "0" dB reference for the peak level of the RF signal under test.

5 - Have the channel under test disconnected from the system at the Remodulator and adjust the spectrum analyzer as follows :

IF bandwidth	30 KHz
Video bandwidth	10 Hz *
Scan width	50 KHz per div.
Vertical	10 dB per div.
Scan time	0,2 sec per div.

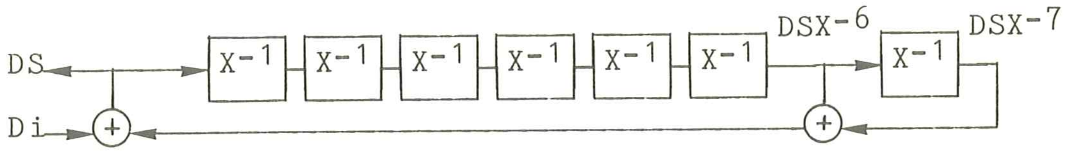
* When using a spectrum analyzer with minimum video filtering capabilities of greater than 10 Hz, the composite third order distortion display will be noisy and should be read at the middle of the trace.

6 - The display remaining on the spectrum analyzer will indicate now the level of the composite third order distortion in the region of the carrier. The number of dB below the "0" dB reference established in step 4 that the peak of the composite intersects in the screen, is the measurement of signal to composite third order distortion.

APPENDIX C - SCRAMBLING AND DESCRAMBLING PROCESS

C.1 SCRAMBLING

The message polynomial is divided by the generating polynomial $1 + X^{-6} + X^{-7}$. The coefficients of the quotient of this division are taken in descending order from the data sequence to be transmitted.



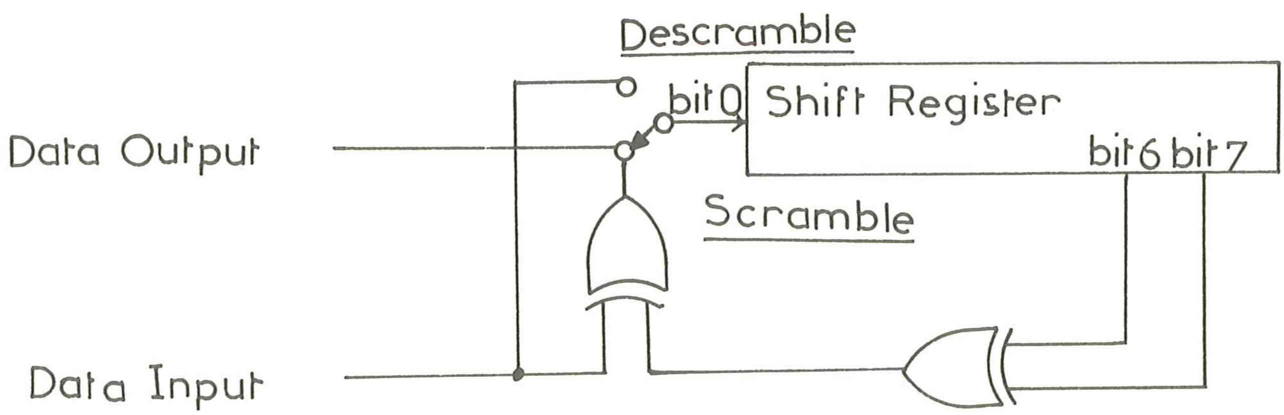
$$DS = Di + DS\ X^{-6} + DS\ X^{-7}$$
$$Di = DS\ (1 + X^{-6} + X^{-7})$$

C.2 DESCRAMBLING

At the receiver the incoming bit sequence is multiplied by the generating polynomial $1 + X^{-6} + X^{-7}$ to form the recovered message polynomial. The coefficient of the recovered polynomial, taken in descending order, forms the output data sequence.

C.3 SCRAMBLING/DESCRAMBLING PROCESS IMPLEMENTATION

The factor $1 + X^{-6} + X^{-7}$ randomizes the transmitted data over a sequence length of 127 bits. The following figure is given as an indication only, since with another technique the logical arrangement night take another form.



APPENDIX D - MAC FINITE STATE MACHINE DESCRIPTION

This Appendix defines the Medium Access Control Token Bus algorithm. It begins with a verbal description of the variables and functions used in the definition of the algorithm. The second part of the Appendix is a Formal State Machine description of the algorithm using the variables and functions discussed in the first part.

D.1 VARIABLES AND FUNCTIONS

This subsection briefly describes the variables and basic functions used in the State Machine description.

The variables and functions are grouped into categories as follows :

- Variables defined by Network Management ;
- Variables defined by Interface Machine ;
- Timers ;
- Variable defined by Receive Machine ;
- Other Internal Variables and Functions.

D.1.1 Network Management Variables

Network Management provides the MAC machine with the Station's address bit string (and thus implicitely with the length of all addresses). Other variables are derived from the address length Also supplied by Network Management is an indicator as to whether the station should remain in the logical ring when it has no data to send and the value of the network's Slot-Time parameter, expressed as a multiple of the transmission period of one octet.

D.1.1.1 TS

This Station's address. A bit string variable set to the value of the Station's 16-bit or 48-bit address.

D.1.1.2 Max-Pass-Count

An integer equal to half the Station's address length in bits, plus one. (Thus equal to 9 for 16-bit address length and 25 for 48 bit length).

The value of Max-Pass-Count limits loops in the Finite State Machine. The value is used to limit the Token contention process. After cycling through Max-Pass-Count contention cycles the process must be stopped if, due to an error, a single contender cannot be resolved.

The value of Max-Pass-Count is also used to stop the Token claiming process. After sending Max-Pass-Count claim Token frames, if no other Station is heard, a Station can Claim the Token.

The value is used to terminate the resolution process if an error prevents resolution of a successor to one station.

D.1.1.3 <u>Max-Response-Window-Count</u>

An integer within the range 2^4 to 2^8-1. The value determines how often a Station opens Response windows when passing the token. Normally, a station passes the Token with response windows on every "n" th pass of the Token, where "n" is the value of Max-Response-Window-Count.

If all Stations in the ring used the same Max-Response - Window-Count, they would all consistently open response windows on the same Token rotation. This action could lead to rapid Token rotations, where no response windows were opened, and occasional long rotations, where every Stations opened a response window before passing the Token.

To avoid all Stations in the ring having the same value of Max-Response-Window-Count, the least significant two bits of the value shall be chosen randomly. The actual value used for the Max-Response-Window-Count shall be periodically changed by each Station by re-randomizing the least significant two bits of the variable.

D.1.1.4 <u>In-Ring-Desired</u>

A boolean variable which determines the MAC machine's steady-state condition when it has no queued transmission requests. If the variable is true, the Station should be In-Ring (a participant in the Token Passing logical ring). If false, the Station should be Out-ofRing (an observer of the Token Passing logical ring).

D.1.1.5 Station's-Priority-Levels (Optional)

An array of integers in the range 0 to 7 giving the priority levels for which the Station has the capabilities (Address and Timers) required to follow the Ring Interrupt Priority scheme as specified in this ECMA TV Standard.

If all specified priority levels are in the range 0 to 3, the Station belongs to the Asynchronous Access Class.

If some specified priority levels are higher than the level 3, the station belongs to the synchronous Access Class.

D.1.1.6 Time-Slice-between-Interruption (optional) TSBI

An integer in the range of 1 to 65535 used to control how often the sequential circulation of the Token must be interrupted to satisfy the synchronous Access Class requirements.

D.1.1.7 Target-Token-Rotation-Time TTRT

An array of integers in the range 1 to 65535 used to control how long a station can transmit data at a given Priority level.

D.1.1.8 Maximum-Token-Holding-Time MTHT

An integer in the range of 1 to 65535 used to control the maximum time a Station can transmit frames during a Token holding phase.

D.1.2 Interface Machine Variables

The Interface Machine provides the Medium Access machine with queued requests for data frame transmission.

D.1.2.1 Send-Pending (Priority-Level)

A boolean variable which when true indicates that at least one frame is ready to be sent in the queue having a Priority-Level associated to the considered Send-Pending.

D.1.2.2 Any-Send-Pending (Access-Class)

A boolean variable reflecting the logical OR of all the boolean variables Send-Pending (Priority-Level) of a given access class. Any-Send-Pending is true if at least one of the pending frame queues of the considered access class is non-empty. If all queues are empty, the variable value is false.

The two boolean variable In-Ring-Desired and Any-Send-Pending determine the operation of the MAC State Machine with respect to contending for the Token and being in the logical ring as follows :

Variable state		MAC action
In-Ring-Desired	Any-Send-Pending	
False	False	Do not contend for Token. Drop out if currently in Token Passing logical ring
False	True	Contend for Token. Send data, which may empty the pending frame queues and make Any-Send-Pending false.
True	False	Contend for Token if not Sole-Active-Station. Remain in Token Passing logical ring even without data to Send.
True	True	Contend for Token. Remain in Token-Passing logical ring and send data.

D.1.3 Timers

A number of Timers are used in the description of the state machine. A Timer is expressed as a set of procedures and a boolean variable. The procedures are named "XX-Timer-Start (value)", where "XX" is the Timer name and "Value" is an integer that sets the Timer delay. "XX-TimerValue" returns the current value of the counter. The boolean variables are named "XX-Timer-expired" and have a value of false while the Timer is running and true when the Timer has expired.

The first five Timers work in integral multiples of the network Slot-Time. (The first five Timers are not used concurrently, thus they could be implemented in a single hardware Timer).

D.1.3.1 Bus-Idle-Timer

Controls how long a Station listens in the Idle state for any data on the Medium before entering the Claiming Token state and reinitializing the network. Most Stations wait 7 Slot-Times. The one Station in the network having "Lowest-Address" true waits 6 slots-Times.

The value of Max-Bus-Idle is 6 or 7 accordingly to "Lowest-Address" boolean value.

D.1.3.2 Claim-Timer

Controls how long a Station listens between sending Claim-Token frames. The Claim-Timer is always loaded with the value ONE.

If the Bus-Idle-Timer expires, a Station may transmit a Claim-Token frame and set the Claim-Timer. When the Claim-Timer expires, if no transmissions are present at that instant, the Station sends an additional Claim-Token frame and repeats the delay and transmission check. This procedure is repeated until either transmissions from another Station are heard or the value of the Claim-Pass-Count equals Max-Claim-Pass-Count.

(The length of the Claim Token frames are 0+, 2+, 4+ or 6+ Slot-Times as a function of two bits of the Station's address. Indexing through the address performs an address sort in the Claim process, leaving the Station with the highest address claiming the Token).

D.1.3.3 Response-Window-Timer

Controls how long a Station which has opened response windows listens before transmitting its next frame.

When sending a Solicit-Successor, Who-Follows or Resolve-Contention frame the Timer controls the length of time a Station solicits responses. After sending a Solicit-Successor frame, the sending Station loads the Response-Window-Timer with the number of windows opened. The Timer thus determines how long the Station remains in the await response state listening for Stations to respond. If the Timer expires and nothing is heard, the Station goes to the Pass-Token state and passes the Token to its successor.

D.1.3.4 Contention-Timer

Controls how long a Station listens in the Demand-In state after hearing a Resolve-Contention, Solicit-Successor or Who-Follows frame when the station wants to contend for the Token. If the Station hears a transmission while listening, it has lost the contention and must return to the Idle state.

If the Station hears a Solicit-Successor or Who-Follows frame it determines which response window in which to contend based on the Station's address and the SA/DA addresses in the frame. If the Station wants to contend in the first window it loads the Contention-Timer with ZERO, so the Station proceeds immediately to the Demand-In state. If the Station wants to contend in the second window, the Contention-Timer is loaded with ONE, so the Station listens during the first window.

Following receiving a Resolve-Contention frame, if the Station is contending, it loads the Contention-Timer with the one's complement of two bits selected from its own address as indexed by the Resolution-Pass-Count.

The Station thus listens zero, one, two, or three Slot-Times before again contending.

D.1.3.5 Token-Pass-Timer

Controls how long a Station listens after passing the Token to its successor.

If any frame is heard before the Token-Pass-Timer expires, the Station assumes that its successor has accepted the Token. If the Timer expires and a frame is not heard, the Station assumes its successor did not accept the Token and sequences to the next stage of the Pass Token procedure.

The remaining Timers have a granularity of n octets transmission time, rather than network Slot-Time.

They are used to implement the priority structure and limit the time during which a Station may start to transmit frames for each Priority Level.

D.1.3.6 Ring-Interrupt-Timer RIT

At each Station level this Timer is loaded with the Time-Slice-between-Interrupt value each time a broadcast Ring-Interrupt frame is received. While being in sequential mode any Station will have to pass the Token to the synchronous access class as soon as its Ring-Interrupt-Timer-expired boolean is true.

D.1.3.7 Token-Rotation-Timer TRT

A maximum of 8 Timers, one for each Priority Level. The number of Timers necessary is determined by the number of Priority Levels requiring a TRT the Station currently uses to transmit data.

For Priority Levels of the Synchronous access class the associated timers are loaded with the value of the Target-Token-Rotation-Timer each time a Ring-Interrupt frame is broadcast.

For Priority Levels of the Asynchronous access class the associated timers are loaded with the value of the Target-Token-Rotation-Time when the Station holding the token checks their respective associated Priority Levels.

D.1.3.8 Token-Hold-Timer

The residual time from the current Token-Rotation-Timer is loaded into the Token-Hold-Timer as soon as the related Priority Level queue is considered. The Station may send data frames, of this Priority Level as long as the Token-Hold-Timer has not expired.

Either if the Station does not implement the priority scheme option or if the Priority Level has not an associated TRT, the Token-Hold-Timer will be loaded with the Maximum-Token-Hold-Time as soon as the Token is received.

D.1.4 Receive Machine Variables

Output of the Receive Machine are several state variables and a data frame, described in the following paragraphs.

D.1.4.1 Rx-Data-Frame

This signal indicates that a valid frame has been received, and that the frame type is LLC-frame.

This signal is set by the Receive-Machine, read by both the Access-Control-Machine and the Interface Machine, but cleared only by the Interface-Machine.

D.1.4.2 Rx-Protocol-Frame

This signal indicates that a valid frame has been received and that the frame type is one of the MAC-Protocol-Frame types. This signal is set by the Receive-Machine and it is read and cleared by the Access-Machine.

The following parameters are given with this indication :

Rx-Frame-Id

Derived from the Frame Format Field, indicates the type of Rx-Protocol-Frame received. Values are Claim-Token, Solicit-Successor-1, Solicit-Successor-2, Who-Follows, Resolve-Contention, Token, Set-Successor, Ring-Interrupt and Ring-Return.

Rx-Frame-DA

The 2 or 6 octet Destination Address field.

Rx-Frame-SA

The 2 or 6 octet Source Address field.

Rx-Frame-Data-Unit

The data unit field of the frame.

D.1.4.3 Bus-Quiet

A boolean variable which is true whenever the physical layer is reporting that Silence is being received. False when something other than Silence is being received. Bus-Quiet is set and reset by the Receive-Machine and is only read by the Access-Control-Machine.

D.1.4.4 Noise-Burst

A boolean variable set by the Receive-Machine when Bus-Quiet goes true (the bus goes from Non-Silence to Silence) and neither Rx-Protocol-Frame nor Rx-Data-Frame where set during the transmission (i.e. no valid frame was heard). Reset by the Access-Control-Machine when the Noise-Burst condition has been processed.

D.1.5 Other Internal Variables

The following are internal to the MAC FSM.

D.1.5.1 TH

Token-Holder's address. The address of the current Token-Holder. A temporary buffer loaded from the SA field of a Token, Solicit-Successor, Who-Follows or Resolve-Contention frame. If a Set-Successor frame is sent by the Station as part of the contention process, the DA address is taken from TH.

D.1.5.2 NS

Next-Station's address. The address of a Station's successor in the logical ring. NS is set when a Station that does not know its successor hears a SolicitSuccessor frame and contends for the Token. The Stationsets NS to the value of the Destination Address field of the frame. (If the Station successfully contends in a response window, it will receive the Token and eventually pass it to the Station whose address was loaded into NS).

The NS variable is also loaded whenever the Station receives a Set-Successor frame addressed to it.

Note :

Once a Station thinks it knows the value of NS it no longer reloads NS when a contention window is opened spanning the Station's address. The reason is that under recovery conditions, Stations will send SolicitSuccessor-2 frames addressed to themselves that open response windows for all stations. If all Stations reset their NS variables at this point, any logical ring that existed would collapse.

D.1.5.3 NS-known

A boolean variable that indicates whether the Station thinks it knows the address of its successor. NS-known is set true whenever the Station receives the Token or a Set-Successor frame. Normally the Set-Successor frame follows a successful contention.

NS-Known is set false whenever the Station leaves the logical ring.

D.1.5.4 PS

Previous Station's address. The variable is set to the value of the source address of the last Token addressed to the Station.

If a "who-Follows" frame is heard the contents of the data field of the frame are compared with the contents of PS. If they are equal the Station responds to the Who-Follows request with a Set-Successor Frame.

D.1.5.5 In-Ring

A boolean variable set true when the Station receives a Token frame addressed to it or when the Station successfully completes the claiming Token process. Set false if the Station sets itself out of the ring.

D.1.5.6 Sole-Active-Station

A boolean variable used to mute Stations having defective receivers. If a Station's receiver becomes inoperative in an undetected manner, the Station otherwise would disrupt the operation of the system by continually claiming the Token and then soliciting a successor Station.

If a Sole-Active-Station variable is true, a Station is prevented from entering the claiming Token process unless it has data to send. Thus a Station with an inoperative receiver and no data to send will remain passively out of the ring.

If a Station is a member of the ring and its receiver fails, it will be unable to hear its successor claiming the Token. The Station will cycle through the Token passing recovery algorithm, quickly reaching the point where it has sent a Solicit-Successor-2 frame addressed to itself and received no response. At this point, the Station sets Sole-Active-Station true and becomes passive.

Sole-Active-Station is set false whenever the Station hears a valid frame from another Station.

D.1.5.7 Lowest Address

A boolean variable set true if the Station's successor address is greater than the Station's address. There should be only one Station in the logical ring with Lowest-Address set True.

This is the Station with the Lowest-Address of all those currently in the logical ring. When this station opens response windows after a Solicit-Successor frame, it must open two windows. The first window is used by Stations having an even lower address that wish to enter the ring. The second window is used by Stations having a higher address than the recipient of the Token, the Station currently with the highest address in the ring.

Lowest-Address is computed and set by a Station whenever NS is changed.

Lowest-Address is used for a second purpose unrelated to Token Passing. If the Token-Holding Station fails, another Station must recover the Token. The BUS-Idle-Timer is a "watchdog" Timer. If no frames are heard by a Station for an interval greater than this Timer, the claim Token process is started.

In an effort to minimize interference during the claiming process, one Station is selected to use a shorter Bus-Idle-Timer value than the other Stations. This Station recovers all lost Token failures, except ones it causes. The Station with Lowest-Address true is always unique, so it is assigned this role.

D.1.5.8 Heard

A three-state variable used in the await response state.

The states are :

Nothing

The Station has heard Nothing (except its own transmissions) since beginning the resolve process.

Collision

A Noise burst has been heard.

Successor

A valid "Set-Successor" frame has been received. At the end of the resolution period, the Station will send the Token to the Station whose address was in the Protocol Data Unit field of the frame.

D.1.5.9 Claim-Pass-Count

An integer with a range from 0 to Max-Pass-Count. Used as an index to TS to select two bits from the Station's address. The selected bits (times 2 times the slot-Time) determine the length of the information field of the Claiming frame to be sent. After each Claiming frame the value of the variable Claim-Pass-Count is incremented by one.

D.1.5.10 Contend-Pass-Count

An integer with a range from 0 to Max-Pass-Count. Used as an index to TS to select two bits from the Station's address. The one's-complement of the selected bits (times the Slot-Time) determine the length of time a Station delays in state 2, Demand-In, after receiving a Resolve-Contention frame. If no other frames are heard before the Contention-Timer expires, the Station sends a Set-Successor frame to the Token holder, increments the value of Contend-Pass-Count, goes to state 3, Demand-Delay, and waits for the Token or another Resolve Contention frame.

D.1.5.11 Resolution-Pass-Count

An integer with a range from 0 to Max-Pass-Count. Used to count the number of resolve contention passes the Token-holding Station makes. If the counter reaches the value of Max-Pass-Count, the resolution process is abandoned and the Token is passed to the Station's successor.

D.1.5.12 Response-Window-Count

An integer in the range 0 to 2^8-1. Determines when a Station must open a response window before passing the Token. Every time the Station successfully passes the Token, the counter is decremented. When the counter value reaches zero, a Solicit-Successor frame is sent and the value of the counter is reloaded from Max-Response-Window-Count. Whenever anything is heard during the response windows following the Solicit-Successor frame, the counter value is set to zero so that it will again be zero when the Station next passes the Token. Thus receipt of a Set-Successor frame during a response window causes the Station to reopen the response window before the next Token pass.

D.1.5.13 Pass-State

A multistate variable used to control the operation of the Pass-Token sub-states. The action taken in the state depends on the value of Pass-State as follows : (The actions are listed in the order taken by a Station soliciting successors and failing).

Pass-State value	Action
Solicit-Successor	Send Solicit-Successor frame. Enter Await Response state.
Pass-Token	Send Token to successor. Enter Check-Token-Pass state.
Repeat-Pass-Token	Same action as Pass-Token sub-state.
Who-Follows	Send Who-Follows frame. Enter Await-Response state.
Repeat-Who-Follows	Same action as who-Follows sub-state.
Solicit-Any	Send-Solicit-Successor-2 frame with DA=TS, opening 2 response windows that span all other Stations. Enter Await-Response state.
Miserable-Failure	Set Sole-Active-Station true and enter Idle state. This Station will not transmit again unless it has data to send or it hears a valid frame from another Station.

D.1.5.14 First-Time

A boolean variable that controls processing of Noise bursts in the Await-Response state. Set true upon entry to the state. Set false when the first noise burst is heard. If a Noise burst is heard when FirstTime is false, the Station returns to the Idle State.

D.1.5.15 SCH

Synchronous-Class-Head, a boolean variable Set true when :

This Station belongs to the synchronous access class and the Previous Station belongs to the Asynchronous access class. This is determined the first time a Token is passed to this Station.

SCH is set false as soon as this condition is detected as being not true.

D.1.5.16 SCT

Synchronous-Class-Tail, a boolean variable set true when :

This Station belongs to the Synchronous access class and the Successor Station belongs to the Asynchronous access class. This is determined when receiving a Set-Successor frame.

SCT is set false as soon as this condition is detected as being not true.

D.1.5.17 Interrupted

A boolean variable set true when the Station has been Interrupted and has successfully passed the Token to the SCH. This boolean allows the Interrupted Station to identify itself as being the Token destination when receiving a Ring-Return frame. Interrupted is set false as soon as the sequential circulation of the Token is restarted.

D.1.5.18 Mode

At each Station level Mode is a boolean variable which indicates whether the Token is circulating through the Asynchronous access class (sequential Mode) or through the Synchronous access class (Interrupt Mode). This variable is set when receiving the Token according to the Mode bit in the Frame Format field. Mode is used to identify the Priority Levels which must be considered by the Station holding the Token. Mode is also used by the SCT to determine whether the Token must be passed to its current successor (sequential Mode) or returned to the Interrupted Station (Interrupt Mode).

D.1.5.19 Change-Mode-Sub-States

When changing of circulation Mode the Interrupted Station (Sequential Interrupt) and the SCT Station (Interrupt Sequential) cycle through the following sub-states :

Change-Mode	Send either a Ring-Interrupt or a Ring-Return frame and enter the check-Token-Pass state.
Repeat-Change-Mode	Same action as Change-Mode.

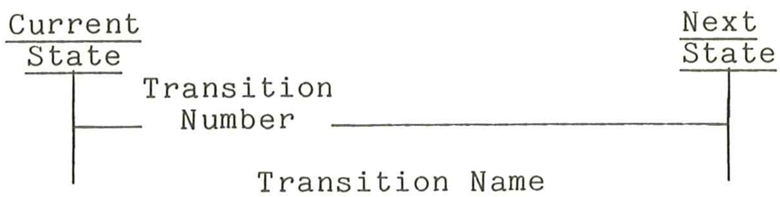
If after Repeat-Change-Mode no activity is detected on the LAN the following actions are started.

An Interrupted Station stays in Sequential Mode, deducing that there is no Synchronous access class.

A SCT also restart the Sequential Mode by passing the Token to its current successor deducing that the Interrupted Station has disappeared.

D.2 ACCESS-CONTROL-MACHINE-FORMAT-DESCRIPTION

The Access-Control-Machine (ACM) is described formally in the following section. The state transition tables present the Current-State, Transition-Name and the Next-State as following.



Below this transition description are listed first the Current-State Exit-Condition which must be true for the particular Transition to be taken and second the Action-Taken before going to the Next-State.

In order to allow a better understanding some specific comments (c) are sometimes added.

<table>
<tr><th>EXIT-CONDITION</th><th>ACTION-TAKEN</th></tr>
<tr><td colspan="2">0 → 1 Transition-Name
0 Power-Up</td></tr>
<tr><td>- Power-Ok

c : power applied to LAN interface. This state variable is controlled by hardware.</td><td>- In-Ring : = false
- NS-Known : = false
- Lowest-Address : = false
- Sole-Active-Station : = false
- Response-Window- Count : = 0

c : MAC configuration information is supplied by Network Management.

It is its responsibility to initialize the MAC sublayer on Station power-up. This includes values for :

- Slot-Time
- TS
- Max-Response-Window-Count
- TSBI
- TTRT (one per Controlled Priority Level)
- MTHT
- Interframe-Delay
- Station's-Priority-Levels
- Station's-Role
- Bus-Idle-Timer.Start (Max-Bus-Idle)</td></tr>
</table>

EXIT-CONDITION	ACTION-TAKEN
1 —— Transition-Name ——→ 1 1 New-Successor	
- Rx-Protocol-Frame AND Rx-Frame-Id=Set-Successor AND Rx-Frame-DA=TS	- NS : = Rx-Frame-Data-Unit - Lowest-Address : = (NS > TS) - NS-Known : = (NS ≠ TS) - Sole-Active-Station : = false - Bus-Idle-Timer.Start (Max-Bus Idle) - Rx-Protocol-Frame : = false - SCT : = (Successor-Class > Station-Class)
1 ——————→ 5 2 Receive-Token	
- Rx-Protocol-Frame AND Rx-Frame-Id = Token AND Rx-Frame-SA ≠ TS AND Rx-Frame-DA = TS	- In-Ring : = true - Sole-Active-Station : = false - PS : = Rx-Frame-SA - Rx-Protocol-Frame : = false - SCH : = (Predecessor-Class > Station-Class) - Mode : = Token Mode's bit
1 ——————→ 1 3 No-Demand	
- Rx-Protocol-Frame AND Rx-Frame-SA ≠ TS AND Rx-Frame-DA ≠ TS AND (IN-RING-Desired or Any-Send-Pending) AND ((Rx-Frame-Id = Solicit-Successor-1 AND Rx-Frame-SA < TS OR Rx-Frame-DA > TS) OR (Rx-Frame-Id = Solicit-Successor-2 AND Rx-Frame-SA < TS AND Rx-Frame-DA > TS))	- Sole-Active-Station : = false - Bus-Idle-Timer.Start (Max-Bus Idle) - Rx-Protocol-Frame : = false

EXIT-CONDITION	ACTION-TAKEN
1 → 2 4 Transition-Name: Entry-Demand-In	
- Rx-Protocol-Frame AND Rx-Frame-SA ≠ TS AND Rx-Frame-DA ≠ TS AND NOT NS-Known AND (In-Ring-Desired OR Any-Send-Pending) AND ((Rx-Frame-Id- = Solicit-Successor-1 AND Rx-Frame-SA > TS AND Rx-Frame-DA < TS) OR (Rx-Frame-Id = Solicit-Successor 2 AND (Rx-Frame-SA > TS OR Rx-Frame-DA < TS)))	- Contend-Pass-Count : = 0 - Response-Window-Count : = 0 - TH : = Rx-Frame-SA - NS : = Rx-Frame-DA - Lowest-Address : = (TS < NS) - Sole-Active-Station : = false - Contention-Timer-Start (Response-Delay (TS < TH)) - Rx-Protocol-Frame : = False - ALL TRT-Locally-Controlled : = expired - RIT : = expired - SCT : = (Successor Class > station class)
1 → 2 5 Repair-Demand-In	
- Rx-Protocol-Frame AND Rx-Frame-SA ≠ TS AND Rx-Frame-DA ≠ TS AND NS-Known AND (In-Ring-Desired OR Any Send-Pending) AND ((Rx-Frame-Id = Solicit-successor-1 AND Rx-Frame-SA > TS AND Rx-Frame-DA < TS) OR (Rx-Frame-Id = Solicit-successor-2 AND (Rx-Frame-SA > TS OR Rx-Frame-DA < TS)))	- Contend-Pass-Count : = 0 - Response-Window-Count : = 0 - TH : = Rx-Frame-SA - Sole-Active-Station : = false - Contention-Timer-Start (Response-Delay (TS < TH)) - Rx-Protocol-Frame : = false
1 → 2 6 Ring-Patch	
- Rx-Protocol-Frame AND Rx-Frame-Id = Who-Follows AND Rx-Frame-Data-Unit = PS AND In-Ring	- Contend-Pass-Count : = 0 - Response-Window-Count : = 0 - TH : = Rx-Frame-SA - Sole-Active-Station : = false - Contention-Timer.Start (0) - Rx-Protocol-Frame : = false

EXIT-CONDITION	ACTION-TAKEN
1 → 1 (7) Transition-Name: Own-Frame-1	
- (Rx-Protocol-Frame OR Rx-Data Frame) AND Rx-Frame-SA = TS	c : ignore own Frame - Bus-Idle-Timer.Start (Max-Bus Idle) - Rx-Protocol-Frame : = false
1 → 1 (8) Non-Idle-Bus	
Noise-Burst	- Bus-Idle-Timer.Start (Max-Bus Idle) - Noise-Burst : = false
1 → 1 (9) Start-Timer	
- In-Ring AND Rx-Protocol-Frame AND Rx-Frame-Id = Ring-Interrupt AND NOT SCH	- Ring-Interrupt-Timer.Start (TSBI) - Bus-Idle-Timer.Start (Max-Bus-Idle) - ALL synchronous-TRT-Controlled.start (TTRT)
1 → 5 (10) Ring-Interrupt	
- In-Ring AND Rx-Protocol-Frame AND Rx-Frame-Id = Ring-Interrupt AND SCH	c : The Synchronous access class head has identified itself as being the Token destination - Sole-Active-Station : = false - Rx-Protocol-Frame : = false - ALL synchronous-TRT-controlled start (TTRT)

EXIT-CONDITION	ACTION-TAKEN
1 → 5, 11: Transition-Name / Ring-Return	
Rx-Protocol-Frame AND Rx-Frame-Id = Ring-Return AND Interrupted = true	c : The asynchronous access class Interrupted Station has identified itself as being the Token destination - Sole-Active-Station : = false - Rx-Protocol-Frame : = false
1 → 1, 12: Sequential-To-Interrupt	
- In-Ring - Mode = Sequential AND Rx-Protocol-Frame AND (Rx-frame-Id = Ring-interrupt OR (Rx-Frame-Id = Token AND Frame-Mode-Bit = Interrupt))	c : update Mode and stop asynchronous TRT during the Interrupt Mode - Mode : = Interrupt - ALL Asynchronous-TRT.Stop
1 → 1, 13: Interrupt-To-Sequential	
- In-Ring - Mode = Interrupt AND Rx-Protocol-Frame AND (Rx-Frame-Id = Ring-Return OR (Rx-Frame-Id = Token AND Frame-Mode-Bit = Sequential))	c : update Mode and restart asynchronous TRT - Mode : = Sequential - ALL Asynchronous-TRT-Restart

EXIT-CONDITION	ACTION-TAKEN
1 —— 14 —— Transition-Name —— Collaspe ——→ 1	
- Bus-Idle-Timer-Expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame-OR Rx-Data-Frame) AND NOT Noise-Burst AND In-Ring AND NOT In-Ring-Desired AND NOT Any-Send-Pending	- Claim-Pass-Count : = 0 - Cdu : = Claim-Data-Unit (Claim-Pass-Count) - Send (Frame-Id ⇒ Claim-Token, DA ⇒ Broadcast, Data-Unit ⇒ Cdu) - Claim-Timer.Start (1) - Bus-Idle-Timer.Start (Max-Bus-Idle)
1 —— 15 —— No-Token ——→ 4	
- Bus-Idle-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst AND (Any-Send-Pending OR (In-Ring-Desired AND NOT Sole-Active-Station))	- Claim-Pass-Count : = 0 - Cdu : = Claim-Data-Unit (Claim-Pass-Count) - Send (Frame-Id ⇒ Claim-Token, DA ⇒ Broadcast, Data-Unit ⇒ Cdu) - Claim-Timer.Start (1)
1 —— 16 —— Idle-Station ——→ 1	
- Bus-Idle-Timer-Expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst AND (NOT Any-Send-Pending AND (NOT In-Ring-Desired OR Sole-Active-Station)) AND NOT In-Ring AND NOT NS-Known	- Lowest-Address : = false - Bus-Idle-Timer.Start (Max-Bus Idle)

EXIT-CONDITION	ACTION-TAKEN
1 —— 17 Transition-Name / Other-Heard ——→ 1	
c : The following event OTHER is asserted when either a valid Protocol-Frame or Data-Frame has been received which has not been considered herein before.	
- OTHER	- Sole-Active-Station : = false - Bus-Idle-Timer.start (Max-Bus-Idle) - Rx-Protocol-Frame : = false
2 —— 18 Continue-Contention ——→ 3	
Contention-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst	- Send (Frame-Id ⟹ Set-successor, DA ⟹ TH, Data-Unit ⟹ TS) - Contend-Pass-Count : = Contend-Pass-Count+1 - Bus-Idle-Timer.Start (Max-Bus-Idle)
2 —— 19 End-Contention ——→ 1	
Noise-Burst OR Contend-Pass-Count Max-Pass-Count	- Noise-Burst : = false - Bus-Idle-Timer.Start (Max-Bus-Idle)
2 —— 20 Unexpected-Frame-2 ——→ 1	
(Rx-Protocol-Frame OR Rx-Data Frame)	c : Drop contention and reprocess Frame in state 1 - NO ACTION

EXIT-CONDITION	ACTION-TAKEN
3 → 2, 21, Transition-Name: Contention-Delay	
- Rx-Protocol-Frame AND Rx-Frame-Id = Resolve-Contention	- Contention-Timer.Start (Contention-Delay (Contend-Pass-Count)) - Rx-Protocol-Frame : = false
3 → 1, 22, Lost-Contention	
- Rx-Protocol-Frame AND Rx-Frame-Id = Token AND Rx-Frame-DA ≠ TS	c : Token being passed to some other Station, so contention is over - Bus-Idle-Timer.Start (Max-bus-Idle) - Rx-Protocol-Frame : = false
3 → 5, 23, Won-Contention	
- Rx-Protocol-Frame AND Rx-Frame-Id = Token AND Rx-Frame-DA = TS	- In-Ring : = true - NS-Known : = True - Sole-Active-Station : = false - PS : = Rx-Frame-SA - SCH : = (Predecessor-Class > Station Class) - Mode : = Token Mode's bit - Rx-Protocol-Frame : = false

EXIT-CONDITION	ACTION-TAKEN
3 → 1 (24) Transition-Name: Unexpected-Frame-3	
(Rx-Protocol-Frame OR Rx-Data-Frame) AND Rx-Frame-Id ≠ Token AND Rx-Frame-Id ≠ Resolve-Contention AND Rx-Frame-Id ≠ Set-Successor	c : Something else is going on, so contention must be over, so go back to Idle state and reprocess the frame - NO-ACTION
3 → 3 (25) Ignore-Contenders	
Rx-Protocol-Frame AND Rx-Frame-Id = Set-Successor	c : Ignore any Set-Successor messages, from TS or others - Rx-Protocol-Frame : = false
3 → 3 (26) Ignore-Noise	
Noise-Burst	c : Ignore any unrecognizable signal streams - Noise-Burst : = false
3 → 1 (27) Long-Bus-Idle	
Bus-Idle-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst	c : Bus-Idle-Time out, so go back to Idle state immediately and process it there - NO-ACTION

EXIT-CONDITION	ACTION-TAKEN
4 —28→ 1 Transition-Name: Lose-Address-Sort	
Claim-Timer-expired AND NOT Bus-Quiet	<u>c</u> : Other stations heard so drop from contention - Bus-Idle-Timer.Start (Max-Bus-Idle)
4 —29→ 4 Continue-Address-Sort	
Claim-Timer-expired AND Bus-Quiet AND Claim-Pass-Count $<$ Max-Pass-Count	- Claim-Pass-Count : = Claim Pass-Count + 1 - Cdu : = Claim-Data-Unit (Claim-Pass-Count) - Send (Frame-Id ⇒ Claim-Token, DA ⇒ Broadcast, Data-unit ⇒ Cdu) - Claim-Timer.Start (1)
4 —30→ 5 Won-Address-Sort	
Claim-Timer-expired AND Bus-Quiet AND Claim-Pass-Count $\geq$ Max-Pass-Count	<u>c</u> : Token now claimed - In-Ring : = true

EXIT-CONDITION	ACTION-TAKEN
5 — 31 — Transition-Name: Leave-Ring → 7	
NOT In-Ring-Desired AND NS-known	- Send (Frame-Id ⟹ Set-Successor, DA ⟹ PS, Data-Unit ⟹ NS) - In-Ring : = false - Send-Pending (current-level): = false
5 — 32 — Accept-Token → 7	
In-Ring-Desired OR NOT NS-Known	Send-Pending (Current-Level) : = false
6 — 33 — Send-Asynchronous → 7	
Mode = Sequential	c : Send one LLC frame of current asynchronous access class level, plus eventually the N associated Copies (error recovery in Multicast mode option). Then go back to 7. - Send (frame-Id ⟹ LLC data, priority ⟹ Priority-level, DA ⟹ Destination Data-Unit ⟹ PDU) - Interrupted : = false

EXIT-CONDITION	ACTION-TAKEN
6 → 7 (34) Transition-Name: Send-Synchronous	
Mode = Interrupt	<u>c</u> : Send one LLC frame of current synchronous access class level, plus eventually the N associated copies (error recovery in Multicast mode option). Then go back to 7 - Send (Frame-Id ⇒ LLC data, priority ⇒ priority-Level, DA ⇒ Destination, Data-unit ⇒ PDU)
7 → 6 (35) Next-Asynchronous-level	
Sequential-Mode AND Any-Asynchronous-Send-Pending AND (THT.expired OR Send-Pending (Current-Level) = false) AND Send-Pending (Next-Level ≥ 0) AND (NOT RIT.expired OR (RIT. expired AND interrupted))	<u>c</u> : Load THT with residual from TRT of the Next asynchronous level or with Max THT - THT.start (TRT-value (Level)) - TRT.start (Level, TTRT (Level)) - Send-Pending (Current-Level): = Send-Pending (Next-Level)
7 → 6 (36) Next-Synchronous-Level	
Interrupt-Mode AND Any-Synchronous-Send-Pending AND (THT-expired OR Send-Pending (current-Level) = false) AND Send-Pending (Next-Level ≥ 4)	<u>c</u> : Load THT with residual from TRT of the Next synchronous level or with Max THT - THT.start (TRT-value (Level)) - Send-Pending (Current-Level): = Send-Pending (Next-Level)

EXIT-CONDITION	ACTION-TAKEN
7 —37→ 6 Transition-Name / Current-Level	
NOT THT expired AND Send-Pending (Current-Level) = true AND (NOT RIT expired OR (RIT expired AND Interrupted))	c : Continue sending frame of the current Priority level and checks if last one of that Level - Send-Pending (current-Level) up-date
7 —38→ 8 RIT-Expired	
Any-Send-Pending AND Sequential-Mode AND NOT Interrupted AND RIT expired	c : The Token sequential circulation has been interrupted - THT.Stop - ALL Asynchronous-TRT.Stop - Pass-State : = Change-Mode
7 —39→ 8 Pass-Token	
(NOT Any-Send-Pending OR (Send-Pending (Current-Level) = false AND NOT Send-Pending (Next-Level))) AND NS-Known AND Response-Window-Count > 0 AND (Sequential-Mode OR (Interrupt Mode AND NOT SCT)	c : Not Any Send-Pending for the considered access class, so pass Token to next-Station - Response-Window-Count : = Response-Window-Count-1 - Pass-State : = Pass-Token

EXIT-CONDITION	ACTION-TAKEN
7 → 8, 40: Transition-Name: Return-Token	
(NOT Any-Send-Pending OR (Send-Pending (Current-Level) = false AND NOT Send Pending (Next-Level))) AND NS-Known AND Response-Window-Count > 0 AND Interrupt-Mode AND SCT	c : Not Any Send-Pending for the synchronous Priority levels and the station is the synchronous class Tail - Response-Window-Count : = Response-Window-Count-1 - Pass-State : = Change-Mode
7 → 8, 41: Solicit-Successor	
(NOT Any-Send-Pending OR (Send-Pending (Current-Level) = false AND NOT Send-Pending (Next-Level))) AND NS-Known AND Response-window-Count = 0	c : Not Any Send-Pending for the considered access class, then offers entry to new stations now - Pass-State : = Solicit-Successor
7 → 8, 42: Solicit-Any	
(NOT Any-Send-Pending OR (Send-Pending (Current-Level) = false AND NOT Send-Pending (Next-Level))) AND NOT NS-known	c : Not Any-Send-Pending for the considered access class, and must find a successor - Pass-State : = Solicit-Any

EXIT-CONDITION	ACTION-TAKEN
8 │43 ──Transition-Name──► 10 Open-One-Response-Window	
- Pass-State = Solicit-Successor AND NOT Lowest-Address	c : Open 1 Response window for stations with address between TS and NS - Resolution-Pass-Count : = 0 - Heard : = Nothing - Rx-Protocol-Frame : = false - Noise-Burst : = false - Send (Frame-Id ⇒ Solicit-Successor-1, DA ⇒ NS) - Response-Window-Timer.Start (1)
8 │44 ──────► 10 Open-Two-Response-Window	
- Pass-State = Solicit-Successor AND Lowest-Address	c : Open 2 Response Window for Stations with addresses smaller or larger than any now In-Ring - Resolution-Pass-Count : = 0 - Heard : = Nothing - Rx-Protocol-Frame : = false - Noise-Burst : = false - Send (Frame-Id ⇒ Solicit-Successor-2, DA ⇒ NS) - Response-Window-Timer.Start (2)

EXIT-CONDITION	ACTION-TAKEN
8 —45→ 9 Transition-Name: Token-Pass	
- Pass-State = Pass-Token OR Pass-State = repeat-Pass-Token	- Send (Frame-Id ⟹ Token, DA ⟹ NS) - First-Time : = true - Rx-Protocol-Frame : = false - Noise-Burst : = false - Token-Pass-Timer.Start (1)
8 —46→ 9 Token-Interrupt	
- Pass-State = change-Mode OR Pass-State = Repeat-Change-Mode AND Sequential-Mode	- Send (Frame-Id ⟹ Token, DA ⟹ Broadcast) - First-Time : = true - Rx-Protocol-Frame : = false - Noise-Burst : = false - Token-Pass-Timer.Start (X)* - RIT.Start (TBSI) * with X = 1 if change-Mode and X = 3 if Repeat-Change-Mode allowing or back up SCH to take relay in case of a default of the current one
8 —47→ 9 Token-Return	
- Pass-State = Change-Mode OR Pass-State = Repeat-Change Mode AND Interrupt-Mode	- Send (Frame-Id ⟹ Token, DA ⟹ Broadcast) - First-Time : = true - Rx-Protocol-Frame : = false - Noise-Burst : = false - Token-Pass-Timer.Start (1)

EXIT-CONDITION	ACTION-TAKEN
8 —48→ 10 Transition-Name: Who-Follows-Query	
- Pass-state = Who-Follows OR Pass-State = Repeat-Who-Follows	- Resolution-Pass-Count : = 0 - Heard : = Nothing - Rx-Protocol-Frame : = false - Noise-Burst : = false - Send (Frame-Id ⇒ Who-Follows, Data-Unit ⇒ NS) - Response-Window-Timer.Start (3)
8 —49→ 10 Solicit-Any	
- Pass-State = Solicit-Any	c : Pass-Token to self with 2 Response Windows, soliciting All potential successors - Resolution-Pass-Count : = 0 - Heard : = Nothing - Rx-Protocol-Frame : = false - Noise-Burst : = false - Send (Frame-Id ⇒ Solicit-successor-2, DA ⇒ TS) - Response-Window-Timer.Start (2)
8 —50→ 1 No-Successor	
Pass-State = Miserable-Failure	c : No successor found, possible "Deaf-Receiver" Condition, assume worst case - NS-Known : = false - Lowest-Address : = false - Sole-Active-Station : = true - Bus-Idle-Timer.Start (Max-Bus-Idle)

EXIT-CONDITION	ACTION-TAKEN
9 ⟶ 8 (51) Transition-Name: Token-Pass-Failed	
Token-Pass-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst AND NOT Repeat-Change-Mode	c : Successor failed to accept and Use Token, so proceed to next Pass-Token Substate - Pass-State : = Token-Pass-Substate-Succ (Pass-State)
9 ⟶ 7 (52) Token-Interrupt-Failed	
Token-Pass-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst AND Repeat-Change-Mode AND Sequential-Mode	c : SCH failed to accept and use Token, so go back to 7 and continue the sequential Mode - ALL Asynchronous TRT.Restart - THT.Restart
9 ⟶ 8 (53) Token-Return-Failed	
Token-Pass-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst AND Repeat-Change-Mode AND Interrupt-Mode	c : Interrupted Station failed to accept and use Token, so pass Token to current successor - Mode : = Sequential - Pass-State : = Pass-Token - All Asynchronous-TRT.Restart

EXIT-CONDITION	ACTION-TAKEN
9 —54→ 9 Transition-Name: Own-Frame-9	
(Rx-Protocol-Frame OR Rx-Data-Frame) AND Rx-Frame-SA ≠ TS	- First-Time : = false - Rx-Protocol-Frame : = false
9 —55→ 1 Token-Pass-OK	
(Rx-Protocol-Frame OR Rx-Data-Frame) AND Rx-Frame-SA ≠ TS AND NOT (Change-Mode OR Repeat-Change-Mode)	c : Some Station is using the Token NO-ACTION
9 —56→ 1 Token-Interrupt-OK	
(Rx-Protocol-Frame OR Rx-Data-Frame) AND Rx-Frame-SA ≠ TS AND (Change-Mode OR Repeat-Change-Mode) AND Sequential-Mode	c : SCH is using the Token - Mode : = Interrupt - Interrupted : = true

EXIT-CONDITION	ACTION-TAKEN
9 → 1 (57) Transition-Name: Token-Return-OK	
(Rx-Protocol-Frame OR Rx-Data-Frame) AND Rx-Frame-SA ≠ TS AND (Change-Mode OR Repeat-Change -Mode) AND Interrupt-Mode	c : SCT has returned successfully the Token to the Interrupted Station - Mode : = Sequential
9 → 9 (58) Not-Sure	
Noise-Burst AND First-Time	c : Something Heard, either 1) A frame sent by Token recipient or 2) The frame sent was garbled then watch for another frame - First-Time : = false - Token-Pass-Timer.Start (4) - Noise-Burst : = false
9 → 1 (59) Token-Probably-OK	
Token-Pass-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND Noise-Burst AND NOT (Change-Mode OR Repeat-Change-Mode)	Bus-Idle-Timer.Start (Max-Bus-Idle) - Noise-Burst : = false

EXIT-CONDITION	ACTION-TAKEN
9 → 1, Transition-Name: 60 Interrupt-Probably-Ok	
Token-Pass-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND Noise-Burst AND (Change-Mode OR Repeat-Change-Mode) AND Sequential-Mode	- Bus-Idle-Timer.Start (Max-Bus-Idle) - Noise-Burst : = false - Mode : = Interrupt - Interrupted : = true
9 → 1, 61 Return-Probably-OK	
Token-Pass-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND Noise-Burst AND (Change-Mode OR Repeat) Change-Mode) AND Interrupt-Mode	- Bus-Idle-Timer.Start (Max-Bus-Idle) - Noise-Burst : = false - Mode : = Sequential

EXIT-CONDITION	ACTION-TAKEN
10 → 8 (62) Transition-Name: No-Response	
Response-Window-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst AND Resolution-Pass-Count = 0 AND Heard = Nothing	- Response-Window-Count : = Max-Response-Window-Count - Pass-State : = Token-Pass-Substate'Succ (Pass-State) <u>c</u> : The Token-Pass-Sub-State' successor is : 1) Pass-Token if NOT SCT 2) Change-Mode if SCT AND Interrupt-Mode
10 → 8 (63) Resolution-Succeeded	
Response-Window-Timer-expired AND Bus-Quiet AND Heard = Successor	- Response-Window-Count : = 0 - Pass-State : = Token-Pass-Sub State'Succ (Pass-State) <u>c</u> : The Token-Pass-Sub-State' Successor is : 1) Pass-Token if NOT SCT 2) Change-Mode if SCT AND Interrupt-Mode

EXIT-CONDITION	ACTION-TAKEN
10 → 10 (64) Transition-Name: Own-Address-10	
- (Rx-Protocole-Frame OR Rx-Data-Frame) AND Rx-Frame-SA = TS	- Heard : = Nothing - Rx-Protocol-Frame : = false
10 → 10 (65) Hear-Successor	
Rx-Protocol-Frame AND Rx-Frame-SA ≠ TS AND Rx-Frame-DA = TS AND Rx-Frame-Id = Set-Successor	- NS-Known : = true - NS : = Rx-Frame-Data-Unit - SCT : = (Successor-Class > Station-Class) - Lowest-Address : = (NS > TS) - Sole-Active-Station : = false - Heard : = Successor - Rx- Protocol-Frame : = false
10 → 10 (66) Collision	
Noise-Burst	Heard : = Collision Noise-Burst : = false

EXIT-CONDITION	ACTION-TAKEN
Transition-Name: 10 → 1 (transition 67) Unexpected-Frame-10	
(Rx-Protocol-Frame OR Rx-Data-Frame) AND (Rx-Frame-Id ≠ Set-Successor OR (Rx-Frame-Id = Set-Successor AND Rx-Frame-DA ≠ TS))	c : Some other station thinks it has the Token, so defer by dropping out Re-process the frame in state 1 NO-ACTION
10 → 10 (transition 68) Send-Resolve	
Response-Window-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst AND Heard = Collision AND Resolution-Pass-Count ⩽ Max-Pass-Count	c : Another 4 Response-Window Resolution Pass is called for - Heard : = Nothing - Resolution-Pass-Count : = Resolution-Pass-Count+1 - Send (Frame-Id ⟹ Resolve-Contention) - Response-Window-Timer.Start (4)
10 → 8 (transition 69) Resolution-Failed	
Response-Window-Timer-expired AND Bus-Quiet AND NOT (Rx-Protocol-Frame OR Rx-Data-Frame) AND NOT Noise-Burst AND ((Heard = Nothing AND Resolution-Pass-Count > 0) OR (Heard ≠ Successor AND Resolution-Pass-Count > Max-Pass-Count))	- Response-Window-Count : = 0 - Pass-State : = Token-Pass-Substate'succ (Pass-State) c : The Token-Pass-Substate-successor is : 1) Pass-Token if NOT SCT 2) Change-Mode if SCT AND Interrupt-Mode