



Draft for Development

CSMA/CD Local area networks

Part 2. Guidance for implementors

Projet à développer

Réseaux locaux CSMA/CD (à accès multiple avec exploration de signaux porteurs
et à détection de collision)

Partie 2. Guide destiné aux techniciens de la matérialisation

Vornorm

CSMA/CD-lokale Netzwerke

Teil 2. Richtlinien für Hersteller

Foreword

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

This Draft for Development complements DD 98 : Part 1 by giving guidance to implementors, and is identical to the Technical Guide on CSMA/CD which was previously available from the Department of Trade and Industry.

Information on related standards and Drafts for Development is given in the introduction to DD 98 : Part 1.

Terminology and conventions. The text of Technical Guide TG 101/2 has been approved as suitable for publication as a Draft for Development without deviation. Some terminology and certain conventions are not identical with those used in Drafts for Development; attention is drawn especially to the following.

Wherever the words 'IEEE Standard 802.3' appear they should be read as 'DD 98 : Part 1'.

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

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

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

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

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

PREFACE

The Institute of Electrical and Electronic Engineers Committee 802 (IEEE 802) has produced a family of standards for Local Area Networks. Various definitions exist, but essentially a LAN is a data communications network in a limited geographic area with the following major characteristics :

- o high-speed data transmission, most often in excess of 1 Mbit/s (1 million bits per second).
- o privately-owned transmission media wholly on the premises of the owner (ie not crossing a public-right-of-way).
- o providing access to a heterogeneous mix of data processing machines including (personal) computers, office systems and word processors, cluster controllers and terminal devices.

The relationship among the IEEE 802 family members is as shown below :

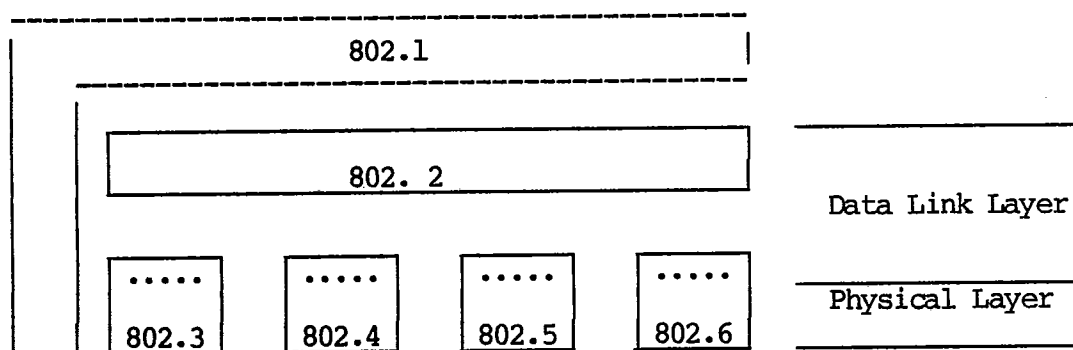


Figure 1. Family of IEEE 802 Local Area Network Standards

The IEEE 802 family of standards is directed at the Physical and Data Link Layers as defined by the International Standards Organisation (ISO) in their Open System Interconnect Reference Model (OSI RM). It should be understood that for communications between data terminal equipments to be meaningful, equivalent function to that specified in all the layers of the OSI RM must also be supplied. As the figure shows, the IEEE 802 standard defines four types of media access techniques with their associated physical media, each appropriate for particular applications or system cost objectives. These four standards are :

- o IEEE Standard 802.3, a bus using the Carrier-Sense Multiple-Access with Collision Detection (CSMA/CD) media access technique.
- o IEEE Standard 802.4, a bus using the token passing media access technique.
- o IEEE Standard 802.5, a ring using the token passing media access technique.
- o IEEE Standard 802.6, a metropolitan area network.

The common Logical Link Control Standard (LLC), IEEE 802.2, is intended to be used in conjunction with all four media access standards.

A companion document, IEEE 802.1, describes the relationship among these standards and their relationship to the ISO OSI RM in more detail. It also explains the relation of the IEEE 802 Standards to higher layer protocols, and discusses internetworking and networking management issues.

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1. INTRODUCTION

This introductory section briefly describes how business needs and technological developments have converged to produce a new set of communication systems known as Local Area Networks (LANs). The creation of a CSMA/CD LAN is presented together with an overview of standardisation activities in the area of Open Systems Interconnection.

1.1 Background

With the continuing decline in the cost of data processing, we have witnessed a dramatic increase in the number of independent computer systems - systems used in such applications as scientific computing, process control, word processing and personal computing. Whilst the majority of these machines possess local processing ability, they rely upon making numerous external transactions. The proliferation of such machines leads to a requirement for suitable communications networks - particularly LANs that can interconnect locally distributed data processing systems.

Various definitions exist for a LAN, however they all meet the following broad set of requirements :

- o data rate in the range 1-20 Mbit/s
- o geography spanning at least 1km (typically within a building or a small set of buildings)
- o the ability to support several hundred independent devices
- o high integrity (ie good error characteristics, reliable + resilient)
- o fair access offered to all users
- o efficient use of shared resources, particularly the network itself
- o simplicity in implementation (ie ease of installation, attachment + maintenance, graceful growth)
- o low cost

Surveys have indicated that the majority of information generated by most establishments is destined for internal consumption, and normally only 20% or less is transmitted externally. Such figures support the need for high performance, local communications networks. External communications could take place via telecommunications media (Wide Area Networks, or WANs), and the LAN-WAN junction could be formed by a Gateway. This Gateway unit will absorb any speed difference between LAN and WAN, and implement any protocol conversion that may be necessary.

Surveys also report on a growing requirement to freely and simply interconnect Data Processing Units from various vendors. This level of interconnection can be realised with existing interface standards (for example CCITT V24), however the performance (and cost) goals can clearly not be achieved.

Recent developments in data communications and transmission technology are now creating a series of high performance and cost effective Local Area Network systems. The development of a layered architecture standard is also easing the task of protocol design and implementation (ISO Reference Model for Open Systems Interconnection).

The CSMA/CD Access Method is probably the most publicised. Developments in CSMA/CD networks date back to 1972 when an experimental system known as 'Ethernet' was demonstrated by the Xerox Corporation. This system has since been enhanced in performance and functionality, and an extensive Ethernet system has been operating at the Xerox Research Laboratories in California for some considerable time. Xerox experience with their Ethernet system has been encouraging [8].

Xerox made a specification for Ethernet available to the public in September 1980. The Xerox specification, known as the 'Bluebook', became the basis for ECMA and IEEE Standards for CSMA/CD LAN. The first standard for CSMA/CD LAN was issued in Europe by ECMA in August 1982, however by the time IEEE had ratified its standard in June 1983, some minor technical differences had emerged between the two. ECMA therefore harmonised its standard (actually a set of three documents) with IEEE and reissued versions became available in January 1984. IEEE Standard 802.3 has been submitted to ISO with the support of ECMA, and is now being processed as an International Standard.

It must be noted that both ECMA and IEEE Standards for CSMA/CD LAN specify only lower-level protocols. For meaningful communication to take place between two Data Processing Entities, a series of higher-level protocols are required to be implemented. Most of these higher level protocols are already subject to standardisation.

In summary, the migration to office automation requires the interconnection of a wide variety of communication device types. Business needs to be able to 'mix + match' devices from various manufacturers. Requirements and technology are converging to provide cost-effective implementations, and a very sanitary approach to information processing (informatics) is being taken. The commercial impetus to realise these concepts may be observed in the energy which has been focussed on standardisation and the capital injected into products (particularly siliconisation).

1.2 OSI Reference Model in Relation to IEEE 802.3

All types of communication, regardless of path length or speed, requires the definition of a protocol in order to be meaningful. In practice, data communications must be subjected to flow + sequence control; messages must contain addressing information and be routed accordingly; and some messages will require acknowledgement for example.

A large body of reference work already exists to define these functions, [1] is a recent example. The International Standards Organisation (ISO) has sponsored the definition of a Reference Model for Open Systems Interconnection [2] to facilitate communications between systems which have been independently designed and implemented.

It is not the purpose of this document to describe the entire communication process in detail, suffice it to say that a LAN essentially has the same communications needs as a traditional WAN, differing only in how the physical connection is managed. The relationship between the IEEE 802.3 LAN architecture and the ISO OSI-RM is depicted in Figure 2. IEEE Standard 802.3 specifies formats and protocols equivalent to those specified in the OSI-RM at the Physical and Data Link Layers.

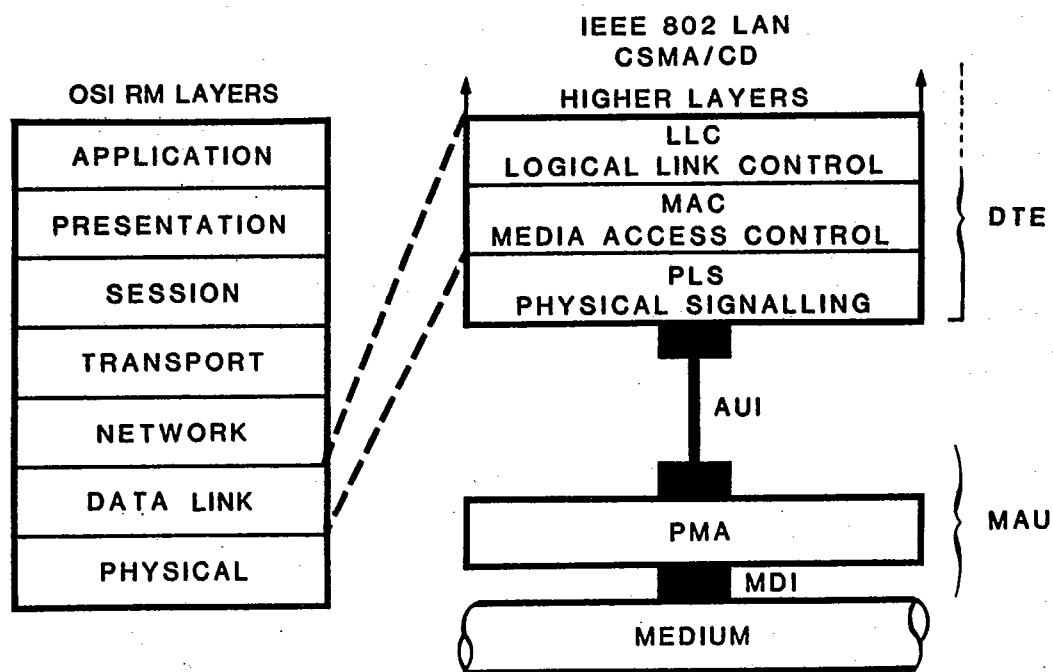


Figure 2 Relationship of OSI Reference Model to LAN Model

2. OVERVIEW OF IEEE 802.3 CSMA/CD ACCESS METHOD

This section describes the theory of operation of the CSMA/CD system defined in IEEE Standard 802.3. Tradeoffs are discussed and rationale behind network sizing is presented. Detailed overviews of the Media Access Sublayer and Physical Layer specifications are given in sections 3 and 6 respectively.

2.1 Operation

The access method known as Carrier Sense, Multiple Access with Collision Detection, or CSMA/CD, enables truly distributed control of a shared communications medium. With this approach there is no fixed pre-allocation of time slots or fixed sharing of frequency bands. A station wishing to transmit is said to 'contend' for use of the common, shared communications channel until it acquires access. Once a station acquires access to the channel, it then transmits a data packet. Access to the communications channel is equally fair to all stations - there is no prioritisation.

Before acquiring the channel, stations first check whether the network is busy. If a station detects activity (ie Carrier Sense), it will defer transmission of its data packet until the communications channel becomes silent. Immediately silence is detected, the deferring station begins to transmit.

During transmission, the transmitting station listens for a collision (other transmitters attempting to use the channel simultaneously). Normally, collisions will occur within a short time interval following start of transmission, and after this interval all stations will detect carrier and defer transmission. This interval is referred to as the collision window or slot time, and is a function of the end-to-end propagation delay of the network. If no collisions occur during this time, a transmitter has acquired the channel and continues to transmit, however collision monitoring still takes place in the unlikely event of a malfunction somewhere in the network.

If a station detects a collision, the transmission of the remainder of the data packet is immediately aborted. To ensure that all stations on the network are able to detect collision activity, any station detecting a collision will invoke a collision enforcement procedure that briefly jams the channel. Each transmitter involved in the collision then schedules its data packet for retransmission at some later time. This scheduling procedure causes each station involved in a collision to backoff for a random delay period. Random retransmission attempts will help resolve contention and therefore reduce the number of repeated collisions. In order to maintain channel stability during high load conditions, a controlled retransmission strategy is used - whereby the mean of the random retransmission delay is increased as a function of the channel load.



Stations accept data packets, or frames, addressed to them, and discard any that are found to be in error. Deference reduces the probability of collision, and collision detection allows the timely retransmission of a data packet. It is impossible, however, to guarantee that all packets transmitted will be delivered successfully (as with any network). Transient, electromagnetic interference could, for example, lead to corruption of data being conveyed by the communications medium. Under very high load conditions which may occur periodically, the channel may be momentarily lost due to collision activity, and the number of transmission attempts made by a particular station could reach its specified maximum. It must be noted that the latter scenario is a statistically unlikely event.

The realisation of a CSMA/CD LAN is shown in Figure 3. This figure shows a multiple segment configuration which could contain the maximum end-to-end propagation delay permitted by the standard. An overview of the specified CSMA/CD LAN is as follows :

The communications channel comprises coaxial trunk segments and local branch cables. Individual segments are constrained to 500 metres due to signal degradation, however the trunk may be extended by the use of repeater units. The repeater regenerates the transmission signals in both amplitude and time domains and is logically transparent to the communications channel; signals and collision events are transferred from segment to segment as if the repeater did not exist. A repeater unit may be used to extend the topology of the network into three physical dimensions, and may also be used to couple remote segment to a network via an Inter-Repeater Link as shown in figure 3.

Stations are connected to the coaxial trunk medium with the assistance of Medium Attachment Units (MAUs) and branch cables. The MAU, which is sometimes referred to as a transceiver, performs transmission, reception and collision detection. The circuitry in this remote unit is normally powered by the attached station via its branch cable. Of particular importance are the two compatibility interfaces, incorporated at the MAU; one with the coaxial trunk cable, the other with the branch cable. Both interfaces are fully specified in the standard and the branch cable compatibility interface applies equally to the station interface. The MAU is attached to the trunk cable via conventional coaxial connectors, or alternatively via a novel auto-insertion tap connector. Use of a passive communication medium and a reliable MAU design ensures excellent network reliability. Reliability is further enhanced by the use of an anti-jabber feature within each MAU. The anti-jabber function will truncate illegally long transmissions (as described in Section 5.2.4 of this document).

A station wishing to transmit will have its data encapsulated with address fields, etc (as described in section 2.3) and then transfer the resultant packet to the MAU, encoded serially as Manchester Biphase data and flowing at a data rate of 10 Mbit/s. The MAU will in turn impress this data onto the trunk cabling

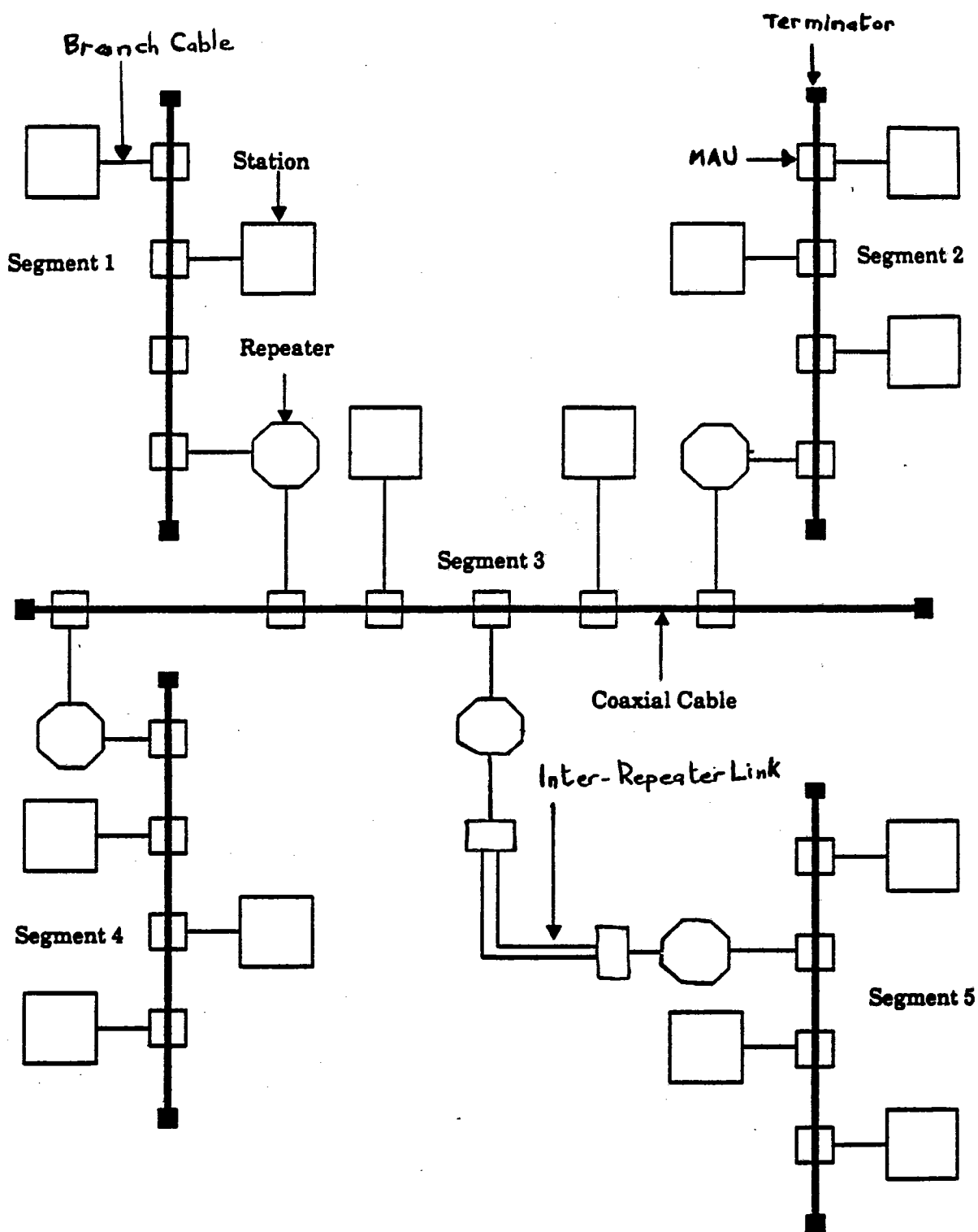


Figure 3. CSMA/CD Baseband LAN Configuration

system as **baseband** transmission. The message is broadcast on the communications channel and listened to by all MAUs (and hence stations) that are powered at the time of transmission. Once a station has recognised its own address within a data packet 'header', it will decapsulate the packet, check the integrity of the frame and store it locally for subsequent processing should it check OK. Any requirement for acknowledgement is dealt with by higher protocol layers.

2.2 Tradeoffs

As the various definitions imply, a LAN must offer good service at low cost. The essential features of 'good service' are quick access to the medium, with high throughput and extensive coverage. Unfortunately these requirements are contradictory; for example, a LAN possessing extensive geographical coverage (ie long end-to-end length) could clearly not offer rapid access due to the propagation delays involved. Time to access the communications medium may be improved by constraining the length of the data packet, however this creates inefficiency due to the fixed overheads of addressing, etc.. Alternatively, the packet length may be compressed in time by increasing the data rate on the medium. Whilst no reduction in the size of the data field is necessary, increased data rates inevitably require a tradeoff in coverage and generally lead to higher costs, or both. LAN efficiency can be improved by transmitting packets whose duration is long in relation to the 'flight' time, so clearly a contradiction exists in attempting to achieve extensive coverage and rapid access to the medium.

Tradeoffs must be made in the LAN specification in order to meet the general set of requirements presented in Section 1.1 in a cost-effective manner. Obviously we must make optimum use of technology, but we must also ensure that a broad application base results to ensure the success of the product being specified. Listed below is the rationale behind the setting of parameter values contained within Section 4.4 of IEEE Standard 802.3.

Data Rate is set at 10 Mbit/s. This is felt to be a comfortable limit in copper, baseband transmission technology. 500 metre transmission distances are cost effective with coaxial cable. A LAN operating at a 10 Mbit/s data rate has a considerable advantage over a LAN operating at say 1 Mbit/s data rate regarding the efficient transport of longer data packets. This is particularly important in an application where a high proportion of data files are being transferred within the network (ie. based on current storage technology - streaming rates, etc.). A data rate of 20 Mbit/s is technologically possible, however cost and cable length tradeoffs become unattractive.

Note: Whilst IEEE Standard 802.3 suggests that other data rates are for 'further study', 10 Mbit/s is felt to be optimum on both cost and performance grounds. Other data rates may not therefore be given the consideration suggested in the standard. Additional reasons for this are contained in Section 7 of this document.

Slot Time is set a 512 bit times, or 51.2uS at 10 Mbit/s data rate. This is probably the most important parameter in the entire CSMA/CD LAN specification.

Slot time is a multi purpose parameter which describes the contention behaviour of the network. It serves as an upper bound on the collision window and limits the frame fragment size produced by a collision. It also acts as the scheduling quantum for collision retransmission.

The slot time must define the maximum period of time taken for a transmitting station to establish whether or not it has acquired the communications medium. This will be an accumulation of propagation delays in cables, MAUs, repeaters, and the physical signalling circuitry incorporated within the station itself. Slot time is determined by the maximum propagation delay present within the network and must take account of the time taken for a transmission to propagate from one end of the network to the other, followed by a (likely) transmission commencing at the remote end of the network just prior to the reception of the initial transmission, and then for the resulting collision to propagate back to the original point of transmission.

The value of slot time chosen enables the geographic coverage of the CSMA/CD LAN to be acceptable. In practice, some 2500 metres of coaxial trunk cable and an adequate number of repeaters may be connected in line. Detailed bit budgets are contained in Section 6.1 of this document.

Min Frame Size is set at 512 bits, or 64 octets. This enables a frame to 'span' a maximum length network, and ensures proper operation of the collision detection procedure. This parameter is equivalent in length (or time) to the network slot time and corresponds to 46 octets of data (after decapsulation).

Max Frame Size is set at 1518 octets. This is a fairly arbitrary maximum, which corresponds to approximately 1mS of transmission time at a data rate of 10 Mbit/s. This parameter is constrained in order to prevent 'hogging' of the communications medium, and to ease implementation (ie storage + processing).

Jam Size is set at 32 bits. This enforces a collision for a period of time that is sufficiently long to 'flood' a single segment. Note that the jam time of 3.2 uS at 10 Mbit/s data rate just exceeds the propagation delay of 500 metres of coaxial cable (2.165 uS) plus several bits of delay inherent in the MAUs.

Inter Packet Gap is set at 9.6 μ S. This parameter is a period of silence that follows each transmission, and enables MAUs and DTE circuitry to recover in time for the next transmission which could be different in phase and slightly different in frequency (data rate). 9.6 μ S is a comfortable period of recovery for the signal transmission circuitry, the data decoder, and the data processing logic operating at a data rate of 10 Mbit/s.

Address Size is set at either 16 or 48 bits for both Source and Destination. A 48 bit address field is equivalent to approximately 10^{14} , or a thousand billion unique address locations and is confidently expected to be sufficient. Remember that the earth's population is currently one thousand million.

Backoff Limit is set at 10. This parameter determines the extent to which the station will backoff after it has been involved in repeated collisions. Backoff time will be doubled after each successive collision associated with the same transmission attempt. The binary exponential characteristics of the backoff timer will be truncated after 10 transmission attempts to Slot Time $\times 2^{10}$ seconds (52.5 mS at a data rate of 10 Mbit/s).

Attempt Limit is set at 16. This is a limit in the number of transmission attempts a station may make after repeated collisions. If the number of permitted transmission attempts is exceeded, this event is reported as an error and the station will terminate transmission activity. Note that the station will backoff for exponentially increasing periods of time until ten transmission attempts have been observed, it will then use that maximum backoff period for the remaining six attempts. This particular algorithm, and the specified limits, have been shown to be very effective in resolving contention and maintaining high levels of throughput in a network [8].

2.3 Frame Structure

Figure 4 shows the eight fields of a frame : the preamble, start of frame delimiter, source and destination addresses, a length field to indicate the length of the following field which contains the LLC data to be transmitted and a field that contains padding if required, and a frame check sequence (FCS) field containing a cycle redundancy check value to detect transmission errors.

Of the eight fields contained in the frame, all are fixed except the LLC data and PAD fields, which may contain an integral number of octets between the minimum and maximum values specified. The specified frame size limits refer to that portion of the frame from the destination address field to the FCS field inclusively.

Detailed description of the MAC frame is presented in Section 3 of this document.

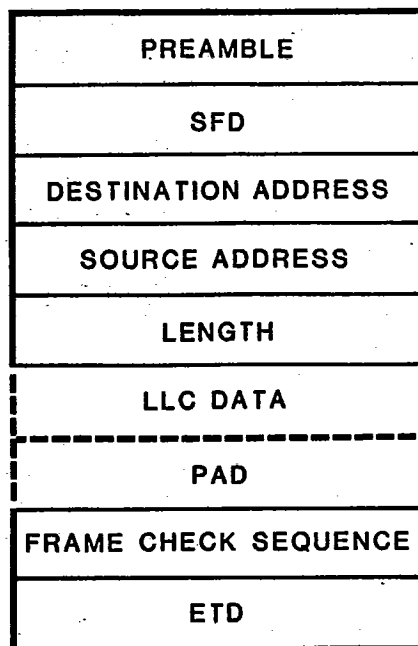


Figure 4 CSMA/CD Frame Structure

Each frame is preceded by a short preamble sequence to enable receiving stations to acquire frequency and phase synchronisation to the Manchester-encoded signal. The preamble is followed by a start of Frame delimiter, which is unique code to identify the beginning of the MAC frame. The completion of a frame is simply indicated by silence. Details of these Physical Layer entities are given in Section 4 of this document.

2.4 Specification

IEEE Standard 802.3 comprises no less than three styles of specification for the CSMA/CD LAN. It is important to understand the reasons for this apparent triplication :

Standard Text : The MAC sublayer and Physical Layer are fully specified in conventional text throughout the body of the standard. These specifications are presented as a basis for implementation.

Formal Specification : A procedural model for the CSMA/CD access method is presented in Section 4.2 of the standard. The model is written in Pascal and is intended to serve as the primary definition of the MAC sublayer. This procedural model must be referred to whenever there is any ambiguity concerning the definition of some aspect of the access method.

State Diagrams : A set of state diagrams is presented in Appendix 4A of the standard to support the formal specification of the Medium Access sublayer. A second set of state diagrams is presented in Section 6.3 of the standard to support the functional specification of the Physical layer.

The state diagrams are intended to be descriptive (graphical) rather than definitive.

2.5 Network Management

Some Network Management (NMT) requirements for the CSMA/CD LAN are still under consideration by the standards committee, who expect to publish an addition to IEEE Standard 802.3 during the latter half of 1984. A list of NMT parameters is presented in Appendix D of this document.

A number of NMT features are specified in the standard, particularly those incorporated within the Physical Layer. The MAU contains two such features; one is known as **Signal Quality Error Test**, or **SQE Test**, the other is known as **Jabber**. **SQE Test** is an automatic simulation of collision activity shortly after each transmission. No signal is injected into the communications medium during this event - it is purely for self test purposes to inform the station of the status of the collision detection function. This particular feature is sometimes known as 'heartbeat' (for obvious reasons). The **Jabber** facility is intended to protect the network from a malfunctioning station and therefore enhances the reliability of communications generally. **Jabber** achieves this by automatically truncating illegally long transmissions (see Section 5.2.4 of this document).

Most NMT parameters are concerned with activity within the MAC sublayer, in particular collision statistics and deviation from specified formats and boundary conditions of fields and frames. A more detailed overview of NMT is presented in Section 6.3 of this document.

3. THE MEDIA ACCESS CONTROL SUBLAYER

This section presents the Service Specification which exists between the MAC sublayer and the LLC sublayer. A detailed description of the MAC frame structure is also presented with commentary.

3.1 Service Specification

The MAC service specification for CSMA/CD LAN is contained in Section 2 of IEEE Standard 802.3. The services are described in an abstract way and do not imply any particular implementation, or any exposed interface. The services provided by the MAC sublayer allow the local LLC sublayer entity to exchange LLC data with peer (ie remote) sublayer entities. Optional support may be provided for resetting the MAC sublayer entity to known state.

The specified services are as follows:

MA_DATA request: LLC requests MAC to transfer data to peer LLC(s). The LLC Data Unit (LLCDU) will contain sufficient information for the MAC sublayer to construct Destination Address and Length Fields. The LLCDU will also contain information relating to the service class required.

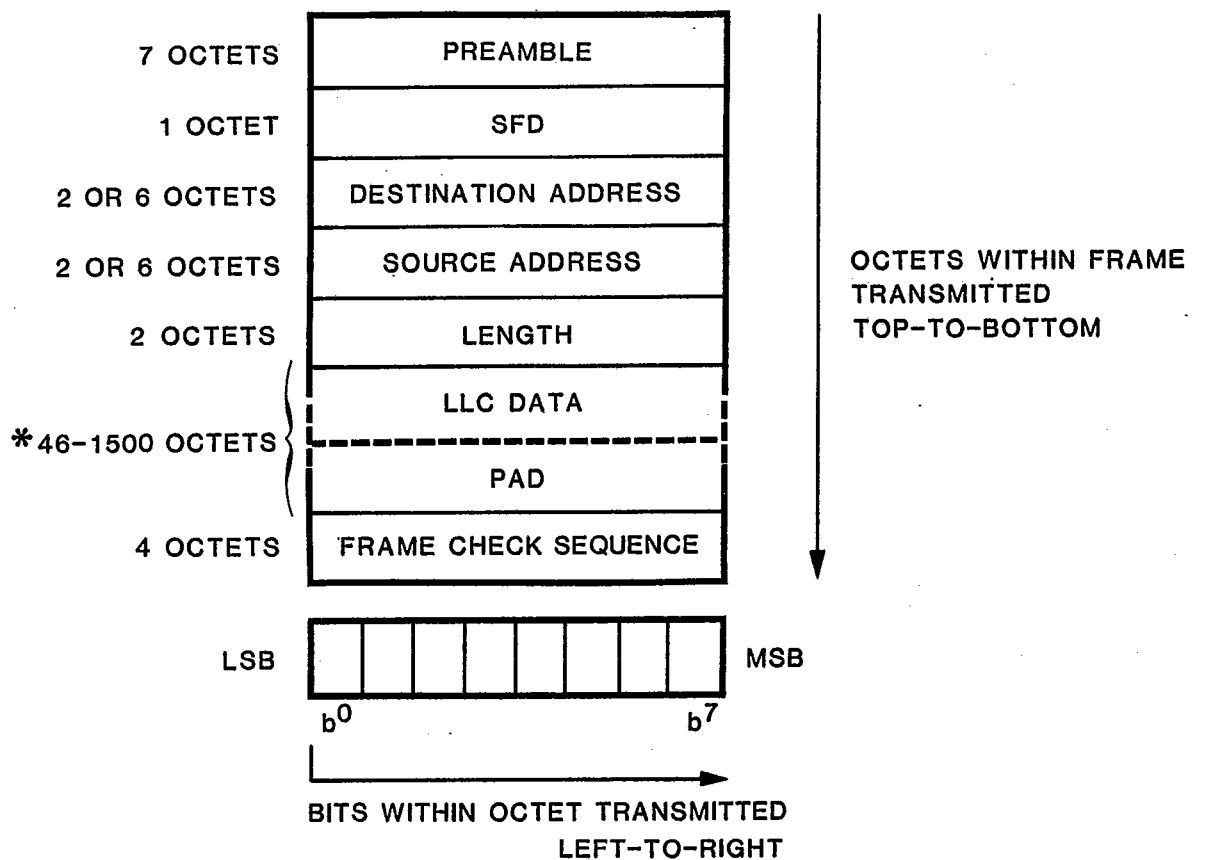
MA_DATA confirm: MAC provides an appropriate response to LLC to signify the success (or failure) of an MA_DATA request. Failure may, for example, be due to excessive collisions associated with the previous MA_DATA request.

MA_DATA indicate: MAC indicates to LLC the arrival of a valid frame which has been received without error, and the Destination Address designates the local MAC entity. Indication is associated with transfer of data from MAC to LLC.

3.2 MAC Frame Format

The structure of the MAC frame is shown in fig.5. IEEE Standards show the MAC frame to comprise SFD and Preamble fields, however it may be argued that both of these entities belong in the Physical Layer.

Relative to fig. 5, the octets of a frame are transmitted from top to bottom, and the bits of each octet are transmitted from left to right. Section 3 of the standard contains a detailed specification of the CSMA/CD MAC frame, a summary of which is contained below.



* WHEN 6 OCTET ADDRESSING IS USED

Figure 5 MAC Frame Format

3.2.1 Preamble Field

The preamble field is a 7 octet field which is used to allow the Physical Signalling (PLS) circuitry to synchronise, or reach its 'steady state'. Refer to Section 4.7.1 of this document for details.

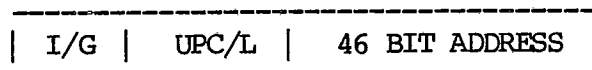
3.2.2 SFD Field

The Start of Frame Delimiter (SFD) field is the sequence 10101011. It immediately follows the preamble pattern and indicates the start of a MAC frame. It is worth noting that the first seven bits of this octet are an extension of the Preamble sequence (10 recurring), the detection of sequence '11' therefore indicates start of frame.

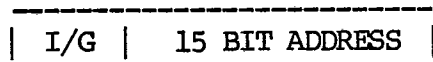
3.2.3 Addressing Fields

Each MAC frame contains two address fields; the **Destination Address** field and the **Source Address** field, in that order. The representation of each address field is shown in fig. 6 and is described below.

48 BIT ADDRESS FORMAT



16 BIT ADDRESS FORMAT



I/G = 0 Individual Address
 I/G = 1 Group Address
 UPC/L = 0 Globally Administered Address
 UPC/L = 1 Locally Administered Address

Figure 6. Address Field Format

Field Size: Each address is permitted by the standard to contain either 16 or 48 bits, with the constraint that the size of source and destination address fields must be identified for all stations on a particular LAN. The 16 bit address field option has been specified to reduce the framing overheads when dealing with very short packets, and does not have the universal appeal associated with the 48 bit field. It is worth noting that a 16 bit address field option is not specified in the ECMA standard for CSMA/CD (ECMA 82), nor the original 'Bluebook' specification for Ethernet.

Multicast: The first bit (LSB) in the Destination Address is used to indicate whether the frame being transmitted is intended for an individual destination or for a number of destinations. A '0' indicates an individual address and a '1' indicates a multicast address. There are two kinds of multicast address -

Group address: An address associated by higher level convention with a group of logically related stations.

Broadcast address: A distinguished, predefined address which always denotes the set of all stations on a given LAN. This is specified by all '1's in the address field, irrespective of size.

Local/Global: The second bit in the 48 bit Destination Address field is used to distinguish between locally or globally administered addresses. For global (ie communications network wide) addressing, this bit is set to '0'. For local (ie sub network) addressing, the

bit is set to '1'. Note that for broadcast addresses, this bit is set to '1'. The use of local and global addressing enables selective filtering of frames to be carried out by Bridges or Gateways when forming connections between sub-networks. Selective filtering could reduce the traffic levels in a communications network and constrain frames to a particular sub-network for security purposes.

3.2.4 Length Field

The Length field is a 2 octet field whose value indicates the number of LLC data octets in the Data field. If this value is less than the specified minimum, the residue will be made up from Pad bits. The Length field is transmitted and received high order octet first.

3.2.5 Data + Pad Fields

The Data field conveys LLC data with full transparency in the sense that any arbitrary sequence of octet values may appear up to the maximum limit specified. If the Data field is less than the specified minimum, pad bits are inserted in the Pad field in order to make the combination of Data + Pad fields conform to the MAC protocol requirements.

Limits of Data field length are dependent upon the size of Address field adopted. Assuming that the 6 octet Address field is used, the range of allowable frame lengths (ie 64 to 1518 octets) imposes a limit on the size of the Data field of 46-1500 octets. If the LLC Data field is then less than 46 octets in length, the remainder will be made up from pad bits.

Upon receipt of a frame, the MAC sublayer will only accept the number of data octets identified by the Length field. For this reason the contents of the Pad field are irrelevant and unspecified. If the number of data octets does not match the number indicated in the Length field, or should not be an integral number the MAC sublayer may invoke NMT.

3.2.6 FCS Field

A cyclic redundancy check (CRC) is used by both the transmit and receive algorithms to protect the integrity of the frame. This CRC value is contained in the Frame Check Sequence (FCS) field as a 4 octet (32 bit) value. The value is computed as a function of the contents of the Address, Length, Data and Pad fields, and does not include Preamble or SFD. The definition of encoding is given in Section 3.2.8 of the Standard.

The 32 bit CRC is acknowledged to be a very powerful error check for frames limited to around 1500 octets in length. Should an FCS error be detected by a receiving station, the MAC sublayer will communicate this event to NMT and the frame will be aborted. Depending upon the LLC class of service specified by the source station, an invalid frame may either be 'lost' (ie in the case of a datagram), or alternatively non-acknowledgement will lead to a repeat transmission of that frame.

4. THE PHYSICAL LAYER

This section presents the Service Specification which exists between the Physical Layer and the MAC sublayer. A detailed description of the Physical Layer components is also presented with commentary.

4.1 Service Specification

The Physical Layer Service Specification for CSMA/CD LAN is contained in Section 5 of IEEE Standard 802.3. The services are described in an abstract way and do not imply any particular implementation. The services provided by the Physical Layer allow the local MAC sublayer entity to exchange data bits with peer (ie remote) MAC sublayer entities.

The specified services are as follows:

PH_DATA request: MAC requests PHY to transfer data to peer MAC(s). This event is associated with single bit transfer, and causes the PHY to encode and transmit the bit or to cease transmission.

PH_DATA confirm: PHY provides an appropriate response to MAC to signify the success (or failure) of the PH_DATA request. This event informs MAC that PHY is ready to accept another data bit for transmission.

PH_DATA indicate: PHY indicates to MAC the transfer of a data bit.

PH_CARRIER indicate: PHY indicates the status of the Medium to MAU. Indication implies reception activity at the MAU; it could also imply a Signal Quality Error(SQE) from the MAU.

PH_SIGNAL indicate: PHY indicates the presence of a signal error to MAC. Indication implies collision activity on the Medium, as detected by the MAU. Alternatively, indication could be reporting the result of SQE Test.

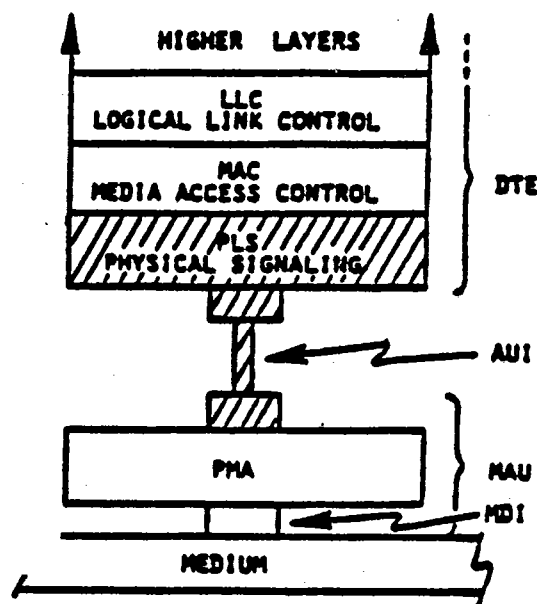
4.2 Physical Sublayers

The Physical Layer is partitioned into two separate entities which reside in different location. The physical separation enables the practical realisation of the 'trunk and branch' topography adopted for CSMA/CD LAN. Details of the Physical Layer Components are presented in Section 4.3 of this document, and an overview of the functionality of each 'sublayer' is given below. Fig. 7 shows the partitioning of the Physical Layer.

Physical Signalling: The Physical Signalling (PLS) sublayer provides data encoding and decoding (Manchester Biphase) and the transmission and reception service required to operate the Access Unit Interface (AUI). The PLS sublayer is resident within a DTE.

Medium Attachment Unit: The Medium Attachment Unit (MAU) provides the means of attachment to the Coaxial Cable Medium. The MAU is located remote from a station and forms the junction with the Medium. The purpose of the MAU is to perform transmission, reception and collision detection. The MAU also enables a station to be connected to different types of Media by offering alternative Medium Dependent Interface (MDIs). The station interface is fixed.

Access Unit Interface: The Access Unit Interface (AUI) connects the MAU to a station via a cable, connectors and signalling system that is totally defined in the standard. The AUI has a 'compatibility' interface with the station and a MAU.



AUI = ATTACHMENT UNIT INTERFACE
 MAU = MEDIUM ATTACHMENT UNIT
 MDI = MEDIUM DEPENDENT INTERFACE
 PMA = PHYSICAL MEDIUM ATTACHMENT

Fig. 7. Physical Layer Partitioning.

4.3 Frame Delimiters

The MAC frame (ie first bit of destination address to last bit of frame check sequence) is bound by delimiters for identification purposes. The Start Frame Delimiter (SFD) is the sequence 10101011 as previously described in Section 3.2.2 of this document. Completion of the frame is indicated by the End Transmission Delimiter (ETD), which is also known as Idle (IDL). This is a period of silence or a logic 'high' on the medium.

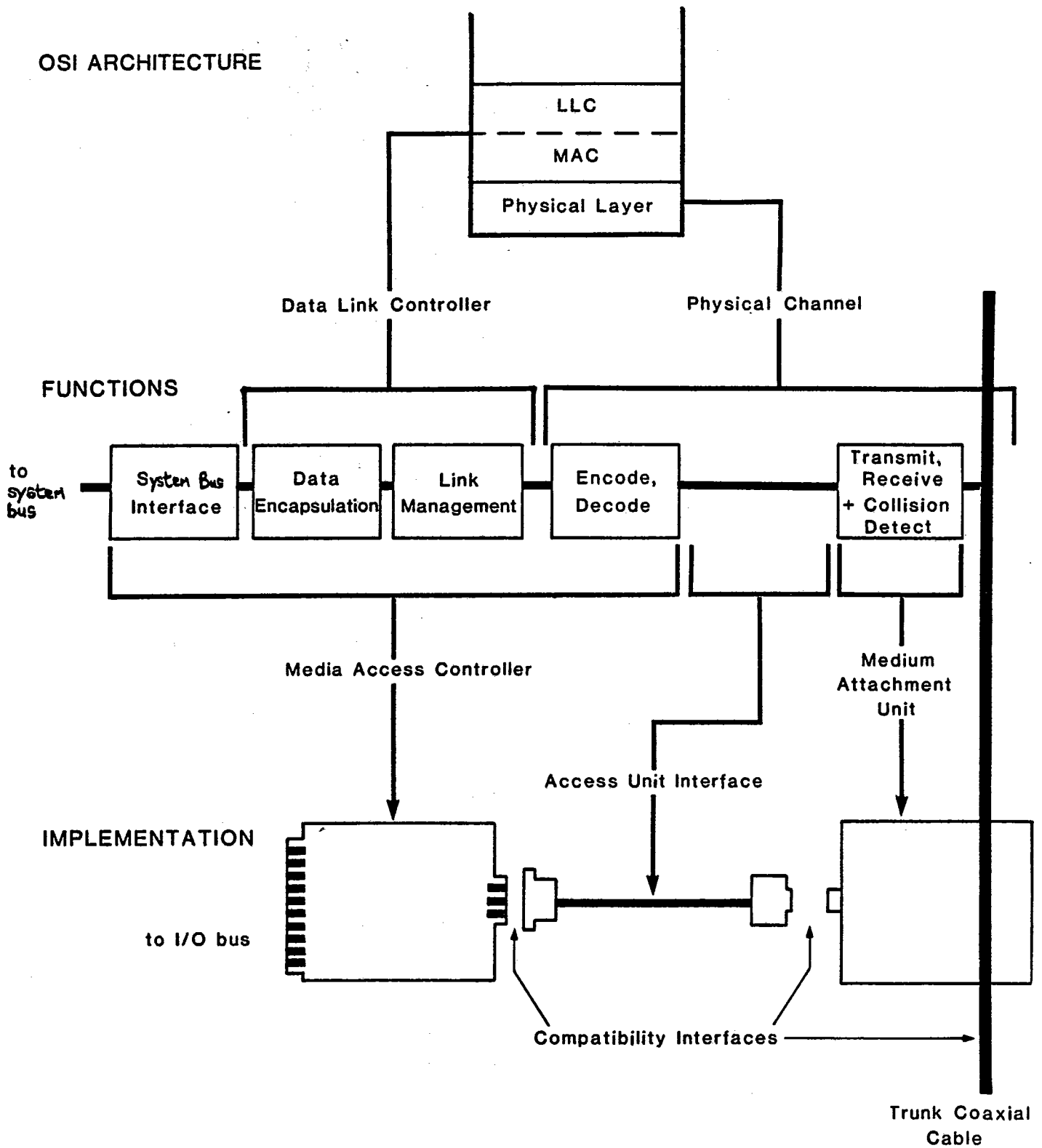


Figure 8 Architecture, Functions and Implementation of CSMA/CD LAN

4.4 Carrier Sense Function

Signal activity (ie carrier) on the coaxial cable medium is sensed by the MAU and reported to the Physical Signalling sublayer (PLS), which is implemented within the station. PLS contains a Carrier Sense Function, which performs the task of notifying the MAC sublayer everytime there is a change in carrier status.

It is necessary for the Carrier Sense Function to ignore the SQE Test sequence generated by the attached MAU (as described in Section 4.5.1). A Carrier Inhibit Timer is therefore used to 'blank out' the SQE test signal. This timer has a value of 4 μ S minimum, 8 μ S maximum, and is triggered by the removal of Carrier Sense indication (ie end of transmission). The Carrier Sense Function is inhibited during this period.

4.5 Physical Components

Fig 8 shows the architecture, functionality and implementaiton of the CSMA/CD LAN. A description of the Physcial components is given below. For detailed specifications, refer to Sections 6 and 7 of IEEE Standard 802.3. For implementation commentary see Section 5 of this document.

4.5.1 Medium Attachment Unit

The Medium Attachment Unit (MAU) for the standard, baseband, trunk coaxial cable is fully specified in Section 7 of the standard. Other MAUs will be identified in future for alternative media.

A Model of the MAU is shown in Fig. 9.

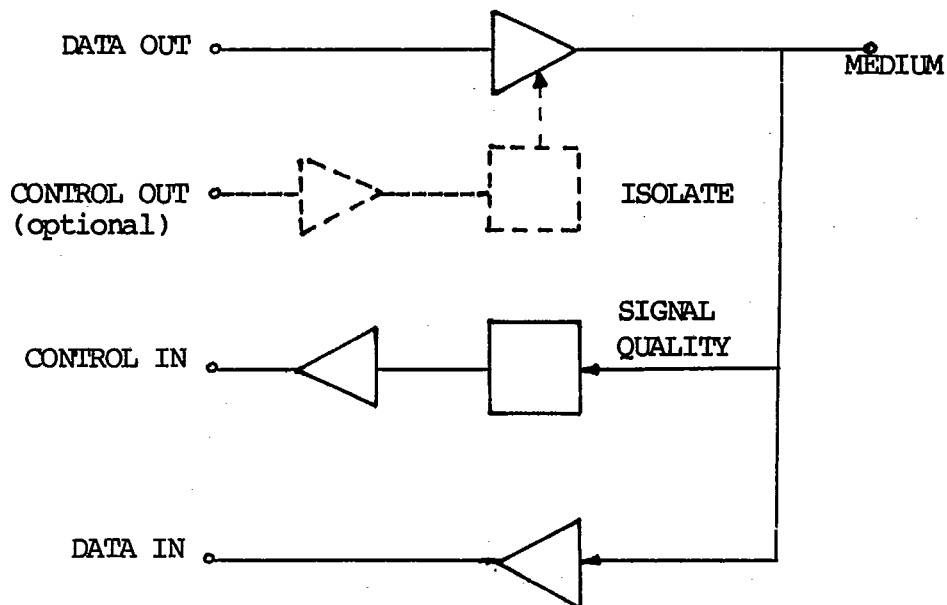


Fig. 9 Medium Attachment Unit Model

The MAU essentially performs data transmission and reception with the coaxial cable medium. All data used for transmission is Manchester Biphase encoded within the station. Data for transmission by the MAU is conveyed via a DATA OUT circuit, and data received by the MAU is passed to a station via a DATA IN circuit.

The MAU also detects the presence of Signal Quality Errors (SQEs) on the medium and reports such events to the attached station via the CONTROL IN circuit (this is sometimes known as the collision presence circuit). Signal Quality Errors are defined as follows:

'Improper' Signals: The exact nature of 'improper signals' on the medium is undefined. It could, for example, be caused by a malfunctioning MAU, or by a break or short in the medium. The nature and scope of 'improper' signal detection is left to the MAU Manufacturer.

Collisions: SQE indication is normally used to report collisions on the medium to an attached station. 'Collisions' are defined as simultaneous transmission attempts from two or more MAUs. IEEE Standard 802.3 allows the MAU to possess either receive-based or transmit-based collision detection (CD) techniques. Receive-based CD is when the detecting MAU is not involved in the collision event (ie it was not transmitting at the time). Transmit-based is when the detecting MAU was involved in the collision event. The standard specifies that in the case of transmit-based CD, the MAU must detect a collision between three or more transmissions.

SQE Test: A short test sequence takes place within the MAU to check the correct functioning of the CD circuitry (detailed below).

An optional fourth circuit may be provided between the MAU and a station to isolate the transmit function in the case of a fault. This optional circuit is call CONTROL OUT. The signaling used for the control circuits is described in Section 4.5.2.

The MAU contains features which enhance the reliability of a network. These features are presented below:

SQE Test: After the completion of each transmission, the MAU will activate as much of the SQE detection circuitry as possible without placing signals on the medium. The MAU will indicate the successful completion of a simulated collision by sending a very short burst of 10 MHz signal to the station. Because of the nature of this feature, it is sometimes refered to as 'heartbeat'.

Jabber: In order to prevent a malfunction in any MAU, AUI or DTE to the medium from 'hogging' the network by transmitting illegally long (or continuous) frames, an inhibit timer is specified. This timer, known as Jabber, has the nominal value of 20mS to 150mS, after which time a transmission is terminated. Jabber reset is discussed in Section 5.2.4 of this document.

Monitor: The Monitor function enables a station to 'disconnect' (optional) the MAU transmitter from the communications medium in the unlikely case of a MAU Malfunction. Note that a MAU is still able to 'monitor' signals from the medium, and detect Signal Quality Errors while the MAU is in this mode of operation.

IEEE Standard 802.3 contains a complete specification for the interface between a MAU and the coaxial cable medium (ie signal levels, timing, phase distortion and connector). This particular junction in the network is known as the Medium Dependent Interface (MDI), which is also one of two compatibility interfaces.

Note: This compatibility interface enables the MAU to be a multivendored network component.

4.5.2 Access Unit Interface

The Access Unit Interface (AUI) represents the umbilical chord between a station and its remotely sited MAU. The AUI comprises a screened multiway cable, connectors, and the means of signaling across the interface circuits - it may be up to 50 metres in length. The AU Interface performs the following functions:

- o conveys data from the station to a MAU for transmission on the medium.
- o relays data received from the medium by a MAU to its attached station.
- o carries the SQE signal from a MAU to the attached station.
- o connects electrical power from a station to the MAU circuitry.
- o optionally accomodates a control interface for a station to isolate the MAU transmitter.

The cable construction and connector specifications are completely specified in Section 6 of the Standard. The signalling used across the interface is also completely specified in order to establish the junction between AUI cable assembly and both MAU and station as a compatibility interface.

Note: This compatibility interface is fundamental in the formation of networks comprising multivendored data processing equipment (ie stations). It also allows the use of alternative media (and MAUs) as discussed in Section 7 of this document.

Implementation commentary is presented in Section 5.2.3. of this document.

Fig. 9 shows the signal circuits present in the AU Interface. All data conveyed by the DATA IN and DATA OUT circuits is Manchester Biphase encoded (as described in Section 4.5.3. below). The signalling used in the control circuits is more simple. The encoded symbols used in this signalling mechanism are CS0, CS1, and IDL. These symbols are defined as:

CS0 - a bit of frequency equal to the data rate (ie 10 MHz).

CS1 - a bit stream of frequency equal to half of that of the data rate (ie 5 MHz).

IDL - a state of 'inactivity' which always begins with a 'high' signal level.

The set of control signals used in the AU Interface are presented below. Mandatory signals are highlighted.

CONTROL OUT CIRCUIT

SIGNAL	MESSAGE	DESCRIPTION
IDL	Normal (0)	Instructs the MAU to enter (remain in) normal mode (ie to transmit + receive as required).
CS1	MAU Request (0)	Requests that the MAU should be made available to a station.
CS0	Isolate (0)	Instructs the MAU to enter (remain in) monitor mode (as described in the previous sections).

CONTROL IN CIRCUIT

SIGNAL	MESSAGE	DESCRIPTION
IDL	MAU Available	Indicates that the MAU is ready to output data.
CS1	MAU Not Available (0)	Indicates that the MAU is not ready to output data.
CS0	Signal Quality Error	Indicates that the MAU has detected an error on input data.

Very few (if any) implementations of the AU Interface will use the optional control signals offered in the standard. The reasons for this are presented in the previous section relating to the MAU.

4.5.3 Encoder/Decoder

As previously stated, Manchester Biphase encoding is used for all data being conveyed across the local AU Interface and across the medium itself. Manchester Biphase encoding is a binary signaling mechanism that combines data and clock into bit-symbols. Each bit symbol is divided into two halves with the second half containing the binary inverse of the first half; a transition always occurs in the centre of each bit-symbol. During the first half of the bit symbol, the encoded signal is the logical complement of the bit value being encoded. Thus a Clocked Data Zero, or CD0, is represented by a HI in the first half of the bit-symbol, and a LO in the second half. A Clocked Data One, or CD1, will be the inverse of this. Examples of Manchester Biphase waveforms are shown in Fig. 10.

The IDL (Idle) signal is also encoded (refer to previous section). Since IDL always starts with a HI signal level, an additional transition will be added to the data stream if the last bit sent was a zero. This transition cannot be confused with clocked data (CD0 or CD1) since the transition will occur at the start of a bit cell. There will be no transition in the centre of the bit cell. The IDL condition, as sent by a driver, must be maintained for a minimum of 2 bit times. The IDL condition must then be detected within 1.6 bit times at the receiving device.

Recovery of timing implicit in the data is easily accomplished due to the wealth of binary transitions guaranteed to be in the encoded waveform, independent of the data sequence. A phase-locked loop or equivalent mechanism maintains continuous tracking of the phase of the information on the Data In circuit. The Preamble sequence enables the data communications components to reach 'steady state' before receiving and decoding data. This sequence of transitions (described in 3.2.1) forms a square wave of frequency equal to half the data rate (ie 5 MHz). Phase locking to the preamble sequence is made easier by the fact that

transitions occur only at the centre of the bit cells (and is therefore unique).

Commentary on implementation of the encoder/decoder function is presented in Section 5.2.2 of this document.

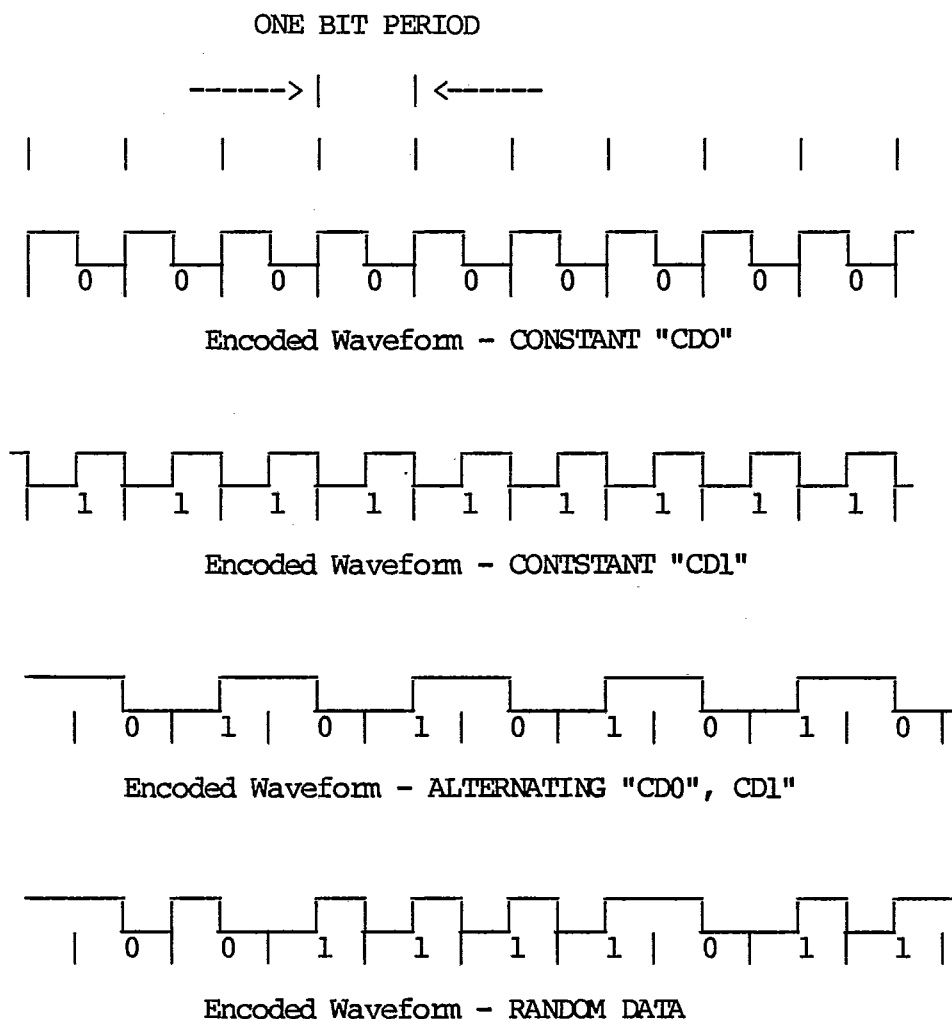


Fig 10. Examples of Manchester Biphase Encoding

4.5.4 Medium

The communications medium specified in Section 7 of IEEE Standard 802.3 is a coaxial cable of special design. This cable is used in baseband transmission mode so as to simplify the design of data communications components.

The specified trunk coaxial cable system is a constant impedance transmission line which is terminated at each end by its characteristic impedance. Otherwise known as a segment, it comprises cable, connectors and terminators and may be up to 500 metres in length. A cable segment accommodates a maximum of 100 MAUs which may be attached by coaxial connectors (ie. connected in series), or alternatively by a penetration (i.e. tap) connector. The construction and dimensions of the coaxial cable