Module 5

Broadcast Communication Networks

Lesson 3

IEEE CSMS/CD based LANs

Specific Instructional Objectives

At the end of this lesson, the students will become familiar with the following concepts:

- Explain the basic characteristics of LANs
- Explain the operation of IEEE 802 LANs
    - 802.3 - CSMA/CD-based (Ethernet)

5.3.1 Introduction

A LAN consists of shared transmission medium and a set of hardware and software for interfacing devices to the medium and regulating the ordering access to the medium. These are used to share resources (may be hardware or software resources) and to exchange information. LAN protocols function at the lowest two layers of the OSI reference model: the physical and data-link layers. The IEEE 802 LAN is a shared medium peer-to-peer communications network that broadcasts information for all stations to receive. As a consequence, it does not inherently provide privacy. A LAN enables stations to communicate directly using a common physical medium on a point-to-point basis without any intermediate switching node being required. There is always need for an access sublayer in order to arbitrate the access to the shared medium.

The network is generally owned, used, and operated by a single organization. This is in contrast to Wide Area Networks (WANs), which interconnect communication facilities in different parts of a country or are used as a public utility. These LANs are also different from networks, such as back plane buses, that are optimized for the interconnection of devices on a desktop or components within a single piece of equipment.

Key features of LANs are summarized below:

- Limited geographical area – which is usually less than 10 Km and more than 1 m.
- High Speed – 10 Mbps to 1000 Mbps (1 Gbps) and more
- High Reliability – 1 bit error in 10^{11} bits.
- Transmission Media – Guided and unguided media, mainly guided media is used; except in a situation where infrared is used to make a wireless LAN in a room.
- Topology – It refers to the ways in which the nodes are connected. There are various topologies used.
- Medium-Access Control Techniques –Some access control mechanism is needed to decide which station will use the shared medium at a particular point in time.

In this lesson we shall discuss various LAN standards proposed by the IEEE 8.2 committee with the following goals in mind:

- To promote compatibility
- Implementation with minimum efforts
- Accommodate the need for diverse applications

For the fulfillment of the abovementioned goals, the committee came up with a bunch of LAN standards collectively known as IEEE 802 LANs as shown in Fig. 5.3.1. To satisfy diverse requirements, the standard includes CSMA/CD, Token bus, Token

Ring medium access control techniques along with different topologies. All these standards differ at the physical layer and MAC sublayer, but are compatible at the data link layer.

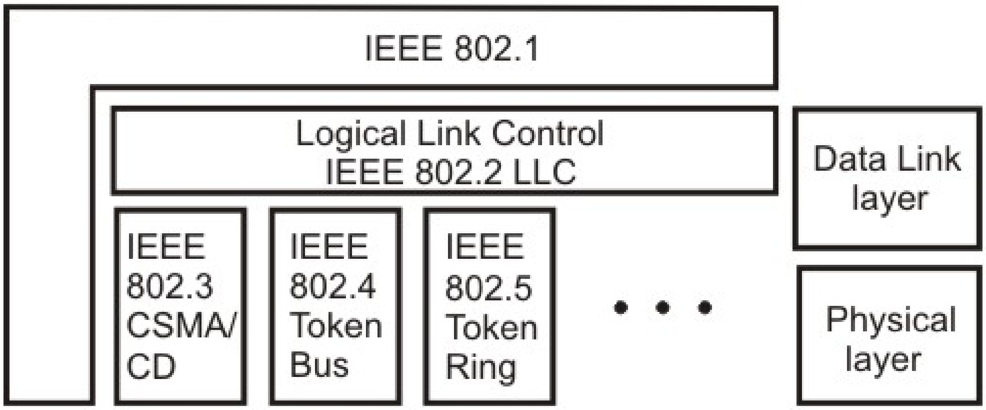


Figure 5.3.1 IEEE 802 Legacy LANs

The **802.1** sublayer gives an introduction to set of standards and gives the details of the interface primitives. It provides relationship between the OSI model and the 802 standards. The **802.2** sublayer describes the **LLC** (logical link layer), which is the upper part of the data link layer. LLC facilitate error control and flow control for reliable communication. It appends a header containing sequence number and acknowledgement number. And offers the following three types of services:

- Unreliable datagram service
- Acknowledged datagram service
- Reliable connection oriental service

The standards 802.3, 802.4 and 802.5 describe three LAN standards based on the CSMA/CD, token bus and token ring, respectively. Each standard covers the physical layer and MAC sublayer protocols. In the following sections we shall focus on these three LAN standards.

5.3.2 IEEE 802.3 and Ethernet

5.3.2.1 Ethernet - A Brief History

The original Ethernet was developed as an experimental coaxial cable network in the 1970s by Xerox Corporation to operate with a data rate of 3 Mbps using a carrier sense multiple access collision detection (CSMA/CD) protocol for LANs with sporadic traffic requirements. Success with that project attracted early attention and led to the 1980 joint development of the 10-Mbps Ethernet Version 1.0 specification by the three-company consortium: Digital Equipment Corporation, Intel Corporation, and Xerox Corporation.

The original IEEE 802.3 standard was based on, and was very similar to, the Ethernet Version 1.0 specification. The draft standard was approved by the 802.3 working group in 1983 and was subsequently published as an official standard in 1985 (ANSI/IEEE Std.

802.3-1985). Since then, a number of supplements to the standard have been defined to take advantage of improvements in the technologies and to support additional network media and higher data rate capabilities, plus several new optional network access control features. From then onwards, the term *Ethernet* refers to the family of local-area network (LAN) products covered by the IEEE 802.3 standard that defines what is commonly known as the CSMA/CD protocol. Three data rates are currently defined for operation over optical fiber and twisted-pair cables:

- 10 Mbps—10Base-T Ethernet
- 100 Mbps—Fast Ethernet
- 1000 Mbps—Gigabit Ethernet

Ethernet has survived as the major LAN technology (it is currently used for approximately 85 percent of the world's LAN-connected PCs and workstations) because its protocol has the following characteristics:

- It is easy to understand, implement, manage, and maintain
- It allows low-cost network implementations
- It provides extensive topological flexibility for network installation
- It guarantees successful interconnection and operation of standards-compliant products, regardless of manufacturer

5.3.2.2 Ethernet Architecture

Ethernet architecture can be divided into two layers:

- **Physical layer:** this layer takes care of following functions.
  - Encoding and decoding
  - Collision detection
  - Carrier sensing
  - Transmission and receipt
- **Data link layer:** Following are the major functions of this layer.
  - Station interface
  - Data Encapsulation /Decapsulation
  - Link management
  - Collision Management

The Physical Layer:

Because Ethernet devices implement only the bottom two layers of the OSI protocol stack, they are typically implemented as network interface cards (NICs) that plug into the host device's motherboard, or presently built-in in the motherboard. Various types cabling supported by the standard are shown in Fig. 5.3.2. The naming convention is a concatenation of three terms indicating the transmission rate, the transmission method, and the media type/signal encoding. Consider for example, 10Base-T. where 10 implies transmission rate of 10 Mbps, Base represents that it uses baseband signaling, and T refers to twisted-pair cables as transmission media. Various standards are discussed below:

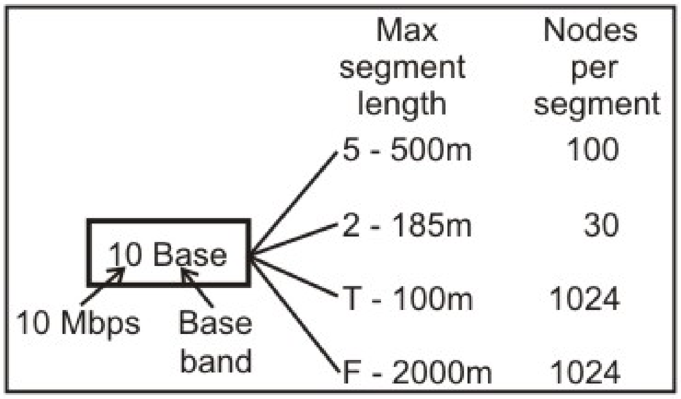


Figure 5.3.2 Types of medium and convention used to represent them

10Base-5: It supports 10 Mbps baseband transmission. The standard specifies 0.5 inch coaxial cable, known as *yellow cable* or *thick Ethernet*. The manner of interfacing a computer is shown in Fig. 5.3.3. Each cable segment can be maximum 500 meters long (which is indicated by **5** in the convention). Up to a maximum of 5 cable segments can be connected using repeaters, with maximum length 2500 meters. At most 1024 stations is allowed on a single LAN. Some other characteristics for this media are:

- ***Tap***: Not necessary to cut a cable to add a new computer
- ***Transceiver***: It performs send/receive, collision detection, provides isolation
- ***AUI***: Attachment Unit Interface is directly placed on the cable after *vampire wire tap* on the cable
- ***AUI drop Cable:*** This cable is used to interface the network interface unit of the computer with the AUI.

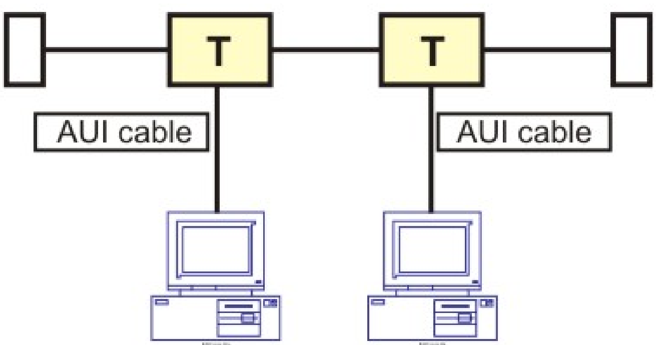
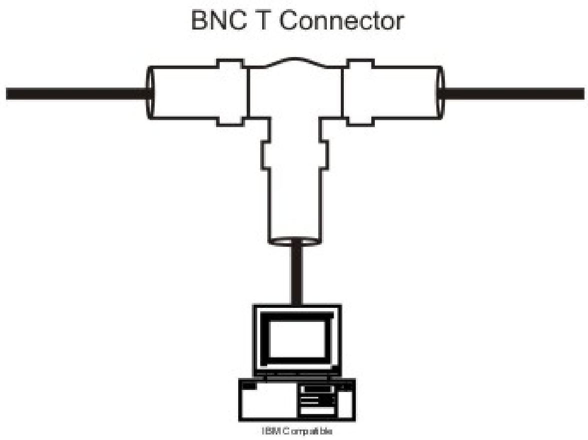


Figure 5.3.3 Interfacing a Computer in 10Base-5 standard

10Base-2: It also supports 10 Mbps baseband transmission. The standard specifies 0.25 inch coaxial cable known as *cheapernet* or *thin Ethernet*. Each cable segment can be maximum 185 meters long. Up to a maximum of 5 cable segments can be connected using repeaters, with maximum length of 925 meters. The interfacing mechanism of a computer is shown in Fig. 5.3.4. It may be noted that in this case there is no need for AUI drop cable, which is required in case of 10Base-5 standard.



Some other characteristics are:

- Use for office LAN/ departmental LAN
- BNC connector is used to interface a computer
- Drop cable is not required

Figure 5.3.4 Interfacing a computer in 10Base-2 standard

10Base-T: This standard supports 10 Mbps baseband transmission and uses 24AWG Unshielded Twisted Pair (UTP) cable of both Cat-3 and Cat-5 category cables. A HUB functions as a multi-port repeater with stations connected to it with RJ45 connector. Maximum length of a cable segment is 100 meters. It uses star topology as shown in Fig. 5.3.5. This allows easy to maintenance and diagnosis of faults. As a consequence, this is the most preferred approach used for setting up of a LAN.

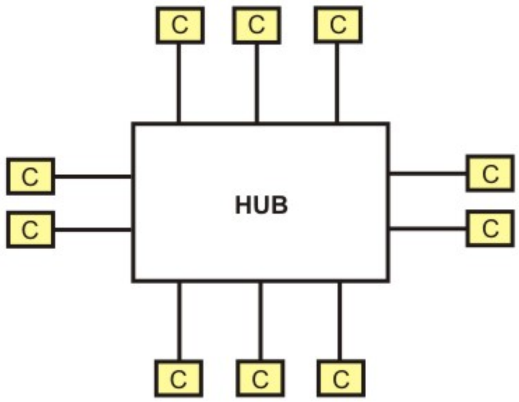


Figure 5.3.5 Interfacing a computer in 10Base-T standard

10Base-F: It allows long distance connections using optical fiber. The topology is same as 10Base-T, but the medium is a pair of optical fiber instead of twisted-pair of wire. It has the following divisions:

- 10BaseFP → A passive-star topology, up to 1 Km link
- 10BaseFL → An asynchronous point-to-point link, up to 2 Km
- 10BaseFB → A synchronous point-to-point link, up to 2 Km with 15 cascaded repeaters

5.3.2.3 Encoding for Signal Transmission

IEEE 802.3 standard uses *Bi-phase Manchester encoding*, which we have already discussed in Sec. 2.3.1. This encoding scheme provides several advantages against the problem, which one may face in such a scenario. In baseband transmission, the frame information is directly impressed upon the link as a sequence of pulses or data symbols that are typically attenuated (reduced in size) and distorted (changed in shape) before they reach the other end of the link. The receiver's task is to detect each pulse as it arrives and then to extract its correct value before transferring the reconstructed information to the receiving MAC.

Filters and pulse-shaping circuits can help restore the size and shape of the received waveforms, but additional measures must be taken to ensure that the received signals are sampled at correct time in the pulse period and at same rate as the transmit clock:

- The receive clock must be recovered from the incoming data stream to allow the receiving physical layer to synchronize with the incoming pulses.
- Compensating measures must be taken for a transmission effect known as baseline wander.

Clock recovery requires level transitions in the incoming signal to identify and synchronize on pulse boundaries. The alternating 1s and 0s of the frame preamble were designed both to indicate that a frame was arriving and to aid in clock recovery. However, recovered clocks can drift and possibly loose synchronization if pulse levels remain constant and there are no transitions to detect (for example, during long strings of 0s).

Fortunately, encoding the outgoing signal before transmission can significantly reduce the effect of both these problems, as well as reduce the possibility of transmission errors. Early Ethernet implementations, up to and including 10Base-T, all used the Manchester encoding method. Each pulse is clearly identified by the direction of the mid-pulse transition rather than by its sampled level value.

Unfortunately, Manchester encoding requires higher baud rate (twice the data rate) that make it unsuitable for use at higher data rates. Ethernet versions subsequent to 10Base-T all use different encoding procedures that include some or all of the following techniques:

- **Using forward error-correcting codes**: An encoding in which redundant information is added to the transmitted data stream so that some types of transmission errors can be corrected during frame reception.
- **Expanding the code space**: A technique that allows assignment of separate codes for data and control symbols (such as start-of-stream and end-of-stream delimiters, extension bits, and so on) and that assists in transmission error detection.

5.3.2.4 The Ethernet MAC Sublayer

The MAC sublayer has two primary responsibilities:

- Data encapsulation, including frame assembly before transmission, and frame parsing/error detection during and after reception
- Media access control, including initiation of frame transmission and recovery from transmission failure

5.3.2.5 The Basic Ethernet Frame Format

The IEEE 802.3 standard defines a basic data frame format that is required for all MAC implementations, plus several additional optional formats that are used to extend the protocol's basic capability. The basic data frame format contains the seven fields shown in Fig. 5.3.6.

- **Preamble (PA)**: It consists of 7 bytes. The PA is an alternating pattern of ones and zeros that tells receiving stations that a frame is coming, and that provides a means to synchronize the frame-reception portions of receiving physical layers with the incoming bit stream.

- **Start-of-frame delimiter (SFD)**: It consists of 1 byte. The SFD is an alternating pattern of ones and zeros, ending with two consecutive 1-bits indicating that the next bit is the left-most bit in the left-most byte of the destination address.

7	1	6	6	2	46-1500		4	
PA	**SFD**	**DA**	**SA**	**LEN**	**LLC PDU**	**PAD**	**FCS**	**IEEE 802.3**

8	6	6	2	46-1500		4
PA	**DA**	**SA**	**Type**	**DATA**	**PAD**	**FCS**

PA: Preamble --- 10101010s for synchronization
SFD: Start of frame delimiter --- 10101011 to start frame
DA: Destination MAC address
SA: Source MAC address
LEN: Length --- number of data bytes
Type: Identify the higher-level protocol
LLC PDU + Pad: minimum 46 bytes, maximum 1500
FCS: Frame Check Sequence --- CRC-32

Figure 5.3.6 Ethernet Frame Format

- **Destination address (DA)**: It onsists of 6 bytes. The DA field identifies which station(s) should receive the frame. The left-most bit in the DA field indicates whether the address is an individual address (indicated by a 0) or a group address (indicated by a 1). The second bit from the left indicates whether the DA is globally administered (indicated by a 0) or locally administered (indicated by a 1). The remaining 46 bits are a uniquely assigned value that identifies a single station, a defined group of stations, or all stations on the network as shown in Fig. 5.3.7..

I/G = 0 in case of individual address
= 1 in case of group address
U/L = 0 in case of global administered address
= 1 in case of local administered address
Unicast: Defines a single destination
Broadcast: FFFFFFFFFFFF each station on the network receive and accept frames
Multicast: A group address defines multiple recipient

Figure 5.3.7 Ethernet MAC Address

- **Source addresses (SA)**: It consists of 6 bytes. The SA field identifies the sending station. The SA is always an individual address and the left-most bit in the SA field is always 0.

- **Length/Type**: It consists of 4 bytes. This field indicates either the number of MAC-client data bytes that are contained in the data field of the frame, or the frame type ID if the frame is assembled using an optional format. If the Length/Type field value is less than or equal to 1500, the number of LLC bytes in the Data field is equal to the Length/Type field value. If the Length/Type field value is greater than 1536, the frame is an optional type frame, and the Length/Type field value identifies the particular type of frame being sent or received.

- **Data**: It is a sequence of *n* bytes of any value, where *n* is less than or equal to 1500. If the length of the Data field is less than 46, the Data field must be extended by adding a filler (a pad) sufficient to bring the Data field length to 46 bytes.
- **Frame check sequence (FCS):** It **c**onsists of 4 bytes. This sequence contains a 32-bit cyclic redundancy check (CRC) value, which is created by the sending MAC and is recalculated by the receiving MAC to check for damaged frames. The FCS is generated over the DA, SA, Length/Type, and Data fields.

5.3.2.6 Other important issues

There are some more important issues, which are briefly discussed below.

- **Inter-frame Gap:** There is mandatory requirement of 9.6 ms interval between two frames to enable other stations wishing to transmit to take over after a frame transmission is over. In other words, a 96 bit-time delay is provided between frame transmissions.

- **How are collisions detected?** A station sends frame and continues to sense the medium. If the signal strength sensed by a station exceeds the normal signal strength, it is treated as collision detection.

- **What the station does?** The transmitting station sends a jamming signal after collision is detected.
  - 32-bit jam signal: 10101010 --- 10101010
  - 48-bit jam signal: 10101010 --- 10101010

The jam signal serves as a mechanism to cause non-transmitting stations to wait until the jam signal ends.

- **Minimum Frame Size:** A frame must take more than 2τ time to send, where τ is the propagation time for preventing the situation that the sender incorrectly concludes that the frame was successfully sent. This slot time is 51.2μsec corresponding to 512 bit = 64 bytes. Therefore the minimum frame length is 64 bytes (excluding preamble), which requires that the data field must have a minimum size of 46 bytes.

Fill In The Blanks

1. The **802.2** standard describes the ____________, which is the upper part of the data link layer.
2. **LLC offers** three types services: Unreliable datagram service, ________________ and _______________.
3. IEEE 802 bundle also includes a MAN standard IEEE 802.6 which is also known as ______________.
4. 100Base-T2 means _______________________________
5. 100 Mbps, baseband, long wavelength over optical fiber cable will be abbreviated as ________________
6. Ethernet uses __________ encoding

Answers:

1. **LLC** (logical link layer)
2. Acknowledged datagram service, Reliable connection oriental service
3. Distributed Queue Dual Bus (DQDB)
4. 100 Mbps, baseband, over two twisted-pair cables
5. 1000Base F
6. Bi-phase Manchester

Short question Answers

Q-1 What are the goals in mind of IEEE 802 committee?
Ans: IEEE 802 committee has few goals in mind, namely

- To promote compatibility
- Implementation with minimum efforts
- Accommodate diverse applications

Q-2. List the functions performed by the physical layer of 802.3 standard?
Ans. Functions of physical layer are:

i) Data encoding/decoding (To facilitate synchronization and efficient transfer of signal through the medium).
ii) Collision detection (It detects at the transmit side)
iii) Carrier sensing (Channel access senses a carrier on the channel at both the transmit and receive sides)
iv) Transmit/receive the packets (Frame transmitted to all stations connected to the channel)
v) Topology and medium used (Mediums are co-axial cable, twisted pair and fiber optic cable)

Q-3. Why do you require a limit on the minimum size of Ethernet frame?
Ans. To detect collision, it is essential that a sender continue sending a frame and at the same time receives another frame sent by another station. Considering maximum delay

with five Ethernet segments in cascade, the size of frame has been found to be 64 bytes such that the above condition is satisfied.

Q-4. What are the different types of cabling supported by Ethernet standard?

Ans. Types of cabling are:

i) 10 BASE 5 - Maximum cable length is 500 meters using 4” diameter coaxial cable.

ii) 10 BASE 2 - Maximum cable length is 185 meters using 0.25” diameter CATV cable.

iii) 10 BASE T - Maximum cable length is 100 meters using twisted-pair cable (CAT-3 UTP).

iv) 10 BASE FL - Maximum cable length is 2 Km using multimode fiber optic cable (125/62.5 micrometer).