BACHELOR OF COMPUTER APPLICATIONS

SEMESTER 3

DCA2104

BASICS OF DATA COMMUNICATION

Unit 13

Wired LANs

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1. INTRODUCTION

This unit introduces the concept of wired LANs. There are several technologies associated with LAN, such as ethernet, token ring, token bus, FDDI and ATM LAN. Among that ethernet is the dominant technology. Ethernet is a family of frame-based computer networking technologies for local area networks (LANs). The name came from the physical concept of the ether. It defines a number of wiring and signaling standards for the Physical Layer of the OSI networking model as well as a common addressing format and media access control at the data link layer.

In this unit, we are going to discuss IEEE standards designed to regulate the manufacturing and inter connectivity between different LANs. In the next section we will describe how an Ethernet LAN functions. In the last section, we will define the terms fast Ethernet, gigabit Ethernet and how they function.

1.1 Objectives

After studying this unit, you should be able to:

- *Describe IEEE standards*
- *Explain standard ethernet*
- *Describe changes in the standard*
- *Explain fast ethernet*
- *Describe gigabit ethernet*

2. IEEE STANDARDS

The relationship of the 802 Standard to the traditional OSI model is shown in the figure 13.1. The IEEE (Institute of Electrical and Electronics Engineers) has subdivided the data link layer into two sublayers: logical link control (LLC) and media access control (MAC). IEEE has also created several physical layer standards for different LAN protocols.

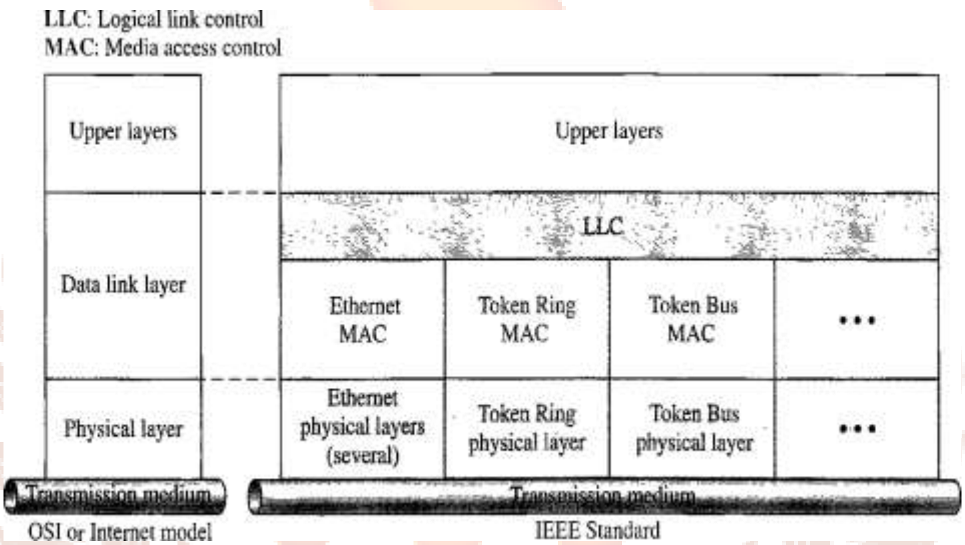


Fig 13.1: Standards for LAN protocols

Data Link Layer

The data link layer in the IEEE standard is divided into two sublayers: LLC and MAC.

a) ***Logical Link Control (LLC):***

In IEEE Project 802, flow control, error control, and part of the framing duties are collected into one sublayer called the logical link control. Framing is handled in both the LLC sublayer and the MAC sublayer.

The LLC provides one single data link control protocol for all IEEE LANs. In this way, the LLC is different from the media access control sublayer, which provides different protocols for different LANs. A single LLC protocol can provide interconnectivity between different LANs because it makes the MAC sub layer transparent.

Framing: LLC defines a protocol data unit (PDU) that is somewhat similar to that of HDLC. The header contains a control field like the one in HDLC; this field is used for flow and error control. The two other header fields define the upper-layer protocol at the source and destination that uses LLC. These fields are called the destination service access point (DSAP) and the source service access point (SSAP). The other fields defined in a typical data link control protocol such as HDLC are moved to the MAC sublayer. In other words, a frame defined in HDLC is divided into a PDU at the LLC sublayer and a frame at the MAC sublayer, as shown in figure 13.2.

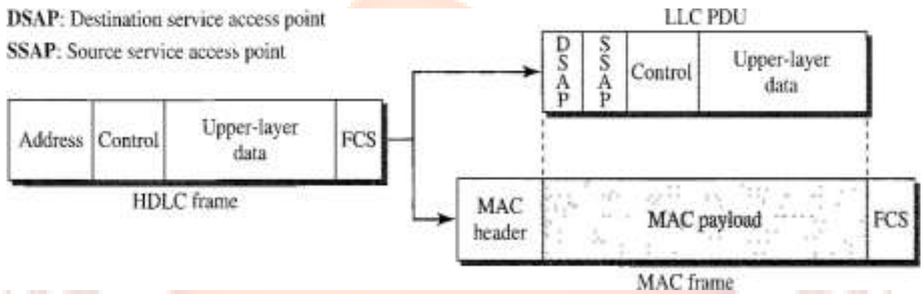


Fig 13.2: LLC and MAC sub layer

Need for LLC: The purpose of the LLC is to provide flow and error control for the upper-layer protocols that actually demand these services. For example, if a LAN or several LANs are used in an isolated system, LLC may be needed to provide flow and error control for the application layer protocols. However, most upper-layer protocols such as IP do not use the services of LLC.

b) Media Access Control (MAC):

IEEE Project 802 has created a sublayer called media access control that defines the specific access method for each LAN. For example, it defines CSMA/CD as the media access method for Ethernet LANs and the token- passing method for Token Ring and Token Bus LANs. Part of the framing function is also handled by the MAC layer.

In contrast to the LLC sublayer, the MAC sublayer contains a number of distinct modules; each defines the access method and the framing format specific to the corresponding LAN protocol.

Physical Layer

The physical layer is dependent on the implementation and type of physical media used. IEEE defines detailed specifications for each LAN implementation. For example, although there is only one MAC sublayer for Standard Ethernet, there is a different physical layer specification for each Ethernet implementations.

SELF ASSESSMENT QUESTIONS – 1

1. Data link layer is divided into two sublayers. They are______and___________.
2. In IEEE Project 802, flow control, error control, and part of the framingduties are collected into one sublayer called________________________.

3. STANDARD ETHERNET

The original Ethernet was created in 1976 at Xerox's Palo Alto Research Center (PARC). Since then, it has gone through four generations: Standard Ethernet (10 Mbps), Fast Ethernet (100 Mbps), Gigabit Ethernet (1 Gbps), and Ten-Gigabit Ethernet (10 Gbps), as shown in the figure 13.3.

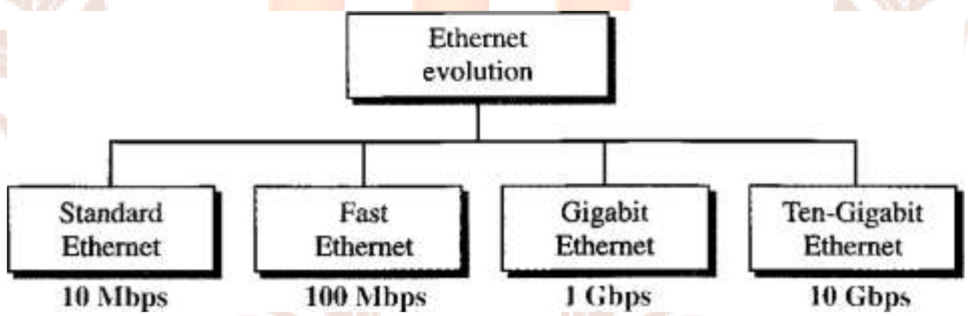


Fig 13.3: Ethernet Generations

MAC Sublayer

In Standard Ethernet, the MAC sublayer governs the operation of the access method. It also frames data received from the upper layer and passes them to the physical layer.

Frame Format:

The Ethernet frame contains seven fields: preamble, SFD, DA, SA, length or type of protocol data unit (PDU), upper-layer data, and the CRC. Ethernet does not provide any mechanism for acknowledging received frames, making it what is known as an unreliable medium. Acknowledgments must be implemented at the higher layers. The format of the MAC frame is shown in the figure 13.4.

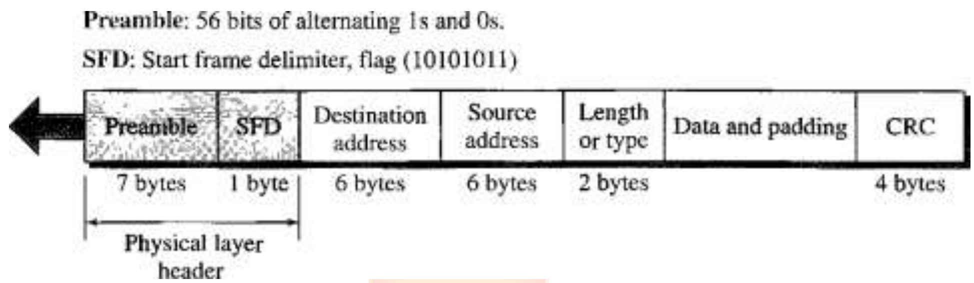


Fig 13.4: Format of MAC

- ***Preamble.*** The first field of the 802.3 frame contains 7 bytes (56 bits) of alternating 0s and 1s that alerts the receiving system to the coming frame and enables it to synchronize its input timing. The pattern provides only an alert and a timing pulse. The 56-bit pattern allows the stations to miss some bits at the beginning of the frame. The preamble is actually added at the physical layer and is not (formally) part of the frame.
- ***Start frame delimiter (SFD).*** The second field (1 byte: 10101011) signals the beginning of the frame. The SFD warns the station or stations that this is the last chance for synchronization. The last 2 bits is 11 and alerts the receiver that the next field is the destination address.
- ***Destination address (DA).*** The DA field is 6 bytes and contains the physical address of the destination station or stations to receive the packet.
- ***Source address (SA).*** The SA field is also 6 bytes and contains the physical address of the sender of the packet.
- ***Length or type.*** This field is defined as a type field or length field. The original Ethernet used this field as the type field to define the upper-layer protocol using the MAC frame. The IEEE standard used it as the length field to define the number of bytes in the data field.
- ***Data.*** This field carries data encapsulated from the upper-layer protocols. It is a minimum of 46 and a maximum of 1500 bytes.
- ***(Cyclic redundancy check) CRC***. The last field contains error detection information, in this case a CRC-32.

Frame Length:

Ethernet has imposed restrictions on both the minimum and maximum lengths of a frame, as shown in figure 13.5.

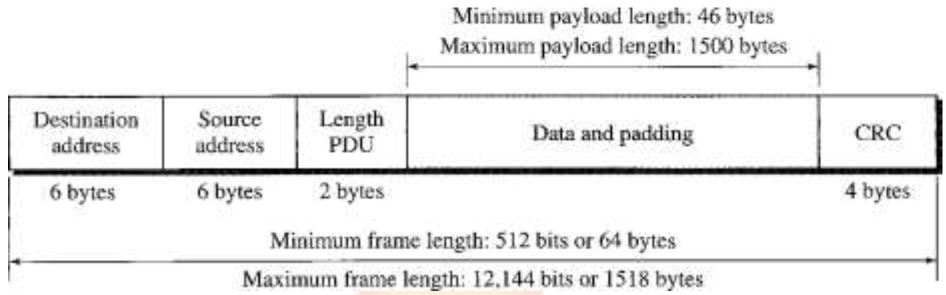


Fig 13.5: Frame length

The minimum length restriction is required for the correct operation of CSMA/CD. An Ethernet frame needs to have a minimum length of 512 bits or 64 bytes. Part of this length is the header and the trailer. If we count 18 bytes of header and trailer (6 bytes of source address, 6 bytes of destination address, 2 bytes of length or type, and 4 bytes of CRC), then the minimum length of data from the upper layer is 64 - 18 = 46 bytes. If the upper-layer packet is less than 46 bytes, padding is added to make up the difference.

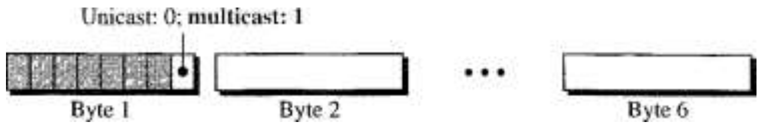
The standard defines the maximum length of a frame (without preamble and SFD field) as 1518 bytes. If we subtract the 18 bytes of header and trailer, the maximum length of the payload is 1500 bytes. The maximum length restriction has two historical reasons. First, memory was very expensive when Ethernet was designed: a maximum length restriction helped to reduce the size of the buffer. Second, the maximum length restriction prevents one station from monopolizing the shared medium, blocking other stations that have data to send.

Addressing:

Each station on an Ethernet network (such as a PC, workstation, or printer) has its own network interface card (NIC). The NIC fits inside the station and provides the station with a 6-byte physical address. As shown in the figure, the Ethernet address is 6 bytes (48 bits), normally written in hexadecimal notation, with a colon between the bytes.

$$\underbrace{06:01:02:01:2C:4B}_{\text{6 bytes = 12 hex digits = 48 bits}}$$

Unicast, Multicast, and Broadcast Addresses: A source address is always a unicast address--the frame comes from only one station. The destination address, however, can be unicast, multicast, or broadcast. The following figure shows how to distinguish a unicast address from a multicast address. If the least significant bit of the first byte in a destination address is 0, the address is unicast; otherwise, it is multicast.



A unicast destination address defines only one recipient; the relationship between the sender and the receiver is one-to-one. A multicast destination address defines a group of addresses; the relationship between the sender and the receivers is one to-many. The broadcast address is a special case of the multicast address; the recipients are all the stations on the LAN. A broadcast destination address is forty-eight 1s.

Access Method: CSMA/CD

Standard Ethernet uses 1-persistent CSMA/CD

Slot Time: In an Ethernet network, the round-trip time required for a frame to travel from one end of a maximum-length network to the other plus the time needed to send the jam sequence is called the slot time.

Slot time = round-trip time + time required to send the jam sequence

The slot time in Ethernet is defined in bits. It is the time required for a station to send 512 bits. This means that the actual slot time depends on the data rate; for traditional 10-Mbps Ethernet it is 51.2μs.

Slot Time and Collision: The choice of a 512-bit slot time was not accidental. It was chosen to allow the proper functioning of CSMA/CD. To understand the situation, let us consider two cases.

In the first case, we assume that the sender sends a minimum-size packet of 512 bits. Before the sender can send the entire packet out, the signal travels through the network and reaches the end of the network. If there is another signal at the end of the network (worst case), a collision occurs. The sender has the opportunity to abort the sending of the frame and to send a jam sequence to inform other stations of the collision. The roundtrip time plus the time required to send the jam sequence should be less than the time needed for the sender to send the minimum frame, 512 bits. The sender needs to be aware of the collision before it is too late, that is, before it has sent the entire frame.

In the second case, the sender sends a frame larger than the minimum size (between 512 and 1518 bits). In this case, if the station has sent out the first 512 bits and has not heard a collision, it is guaranteed that collision will never occur during the transmission of this frame. The reason is that the signal will reach the end of the network in less than one-half the slot time. If all stations follow the CSMA/CD protocol, they have already sensed the existence of the signal (carrier) on the line and have refrained from sending. If they sent a signal on the line before one-half of the slot time expired, a collision has occurred and the sender has sensed the collision. In other words, collision can only occur during the first half of the slot time, and if it does, it can be sensed by the sender during the slot time. This means that after the sender sends the first 512 bits, it is guaranteed that collision will not occur during the transmission of this frame. The medium belongs to the sender, and no other station will use it. In other words, the sender needs to listen for a collision only during the time the first 512 bits are sent.

Slot Time and Maximum Network Length: There is a relationship between the slot time and the maximum length of the network (collision domain). It is dependent on the propagation speed of the signal in the particular medium. In most transmission media, the signal propagates at 2 x 108 m/s (two-thirds of the rate for propagation in air). For traditional Ethernet, we calculate

$$\text{MaxLength} = \text{PropagationSpeed} \times \frac{\text{SlotTime}}{2}$$

$$\text{MaxLength} = (2 \times 10^{8}) \times (51.2 \times 10^{-6} / 2) = 5120 \text{ m}$$

Of course, we need to consider the delay times in repeaters and interfaces, and the time required to send the jam sequence. These reduce the maximum-length of a traditional Ethernet network to 2500 m, just 48 percent of the theoretical calculation. MaxLength = 2500 m.

Physical Layer

The Standard Ethernet defines several physical layer implementations; four of the most common, are shown in figure 13.6.

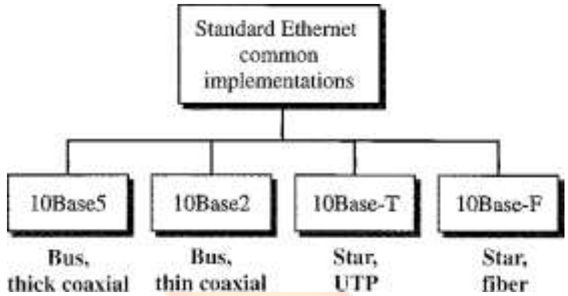


Fig 13.6: Standards for Physical Layer

Encoding and Decoding:

All standard implementations use digital signaling (baseband) at 10 Mbps. At the sender, data are converted to a digital signal using the Manchester scheme; at the receiver, the received signal is interpreted as Manchester and decoded into data. The figure 13.7 shows the encoding scheme for Standard Ethernet.

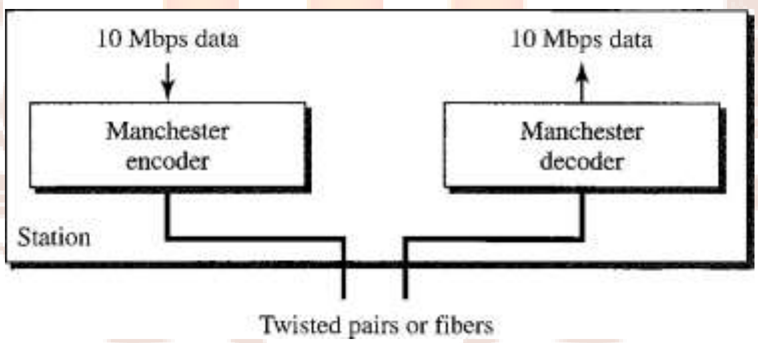


Fig 13.7: Encoding and decoding

10Base5: Thick Ethernet

10Base5 was the first Ethernet specification to use a bus topology with an external transceiver (transmitter/receiver) connected via a tap to a thick coaxial cable as shown in figure 13.8. The transceiver is responsible for transmitting, receiving, and detecting collisions.

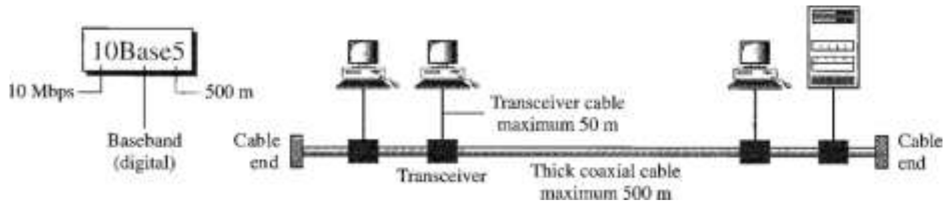


Fig 13.8: 10Base5 Thick Ethernet

The transceiver is connected to the station via a transceiver cable that provides separate paths for sending and receiving. This means that collision can only happen in the coaxial cable.

The maximum length of the coaxial cable must not exceed 500 m, otherwise, there is excessive degradation of the signal. If a length of more than 500 m is needed, up to five segments, each a maximum of 500-meter, can be connected using repeaters.

10Base2: Thin Ethernet

10Base2 also uses a bus topology, but the cable is much thinner and more flexible as shown in figure 13.9. The cable can be bent to pass very close to the stations. In this case, the transceiver is normally part of the network interface card (NIC), which is installed inside the station.

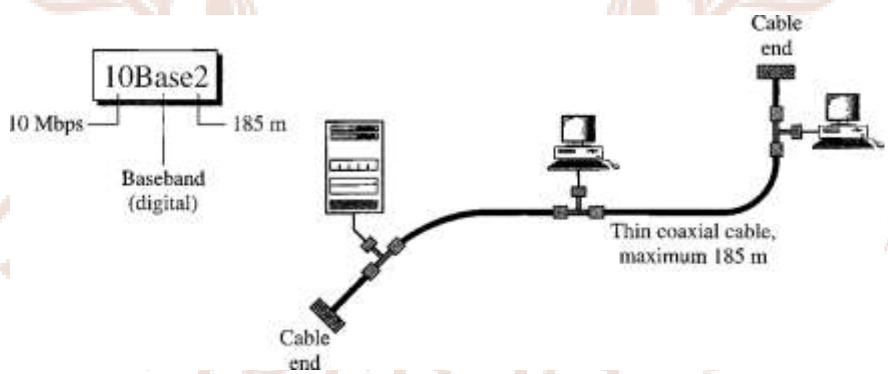


Fig 13.9: 10Base2 Thin Ethernet

Note that the collision here occurs in the thin coaxial cable. This implementation is more cost effective than 10Base5 because thin coaxial cable is less expensive than thick coaxial and the tee connections are much cheaper than taps. Installation is simpler because the thin coaxial cable is very flexible. However, the length of each segment cannot exceed 185 m (close to 200 m) due to the high level of attenuation in thin coaxial cable.

10Base- T: Twisted-Pair Ethernet

The third implementation is called 10Base-T or twisted-pair Ethernet. 10Base-T uses a physical star topology. The stations are connected to a hub via two pairs of twisted cable as shown in figure 13.10.

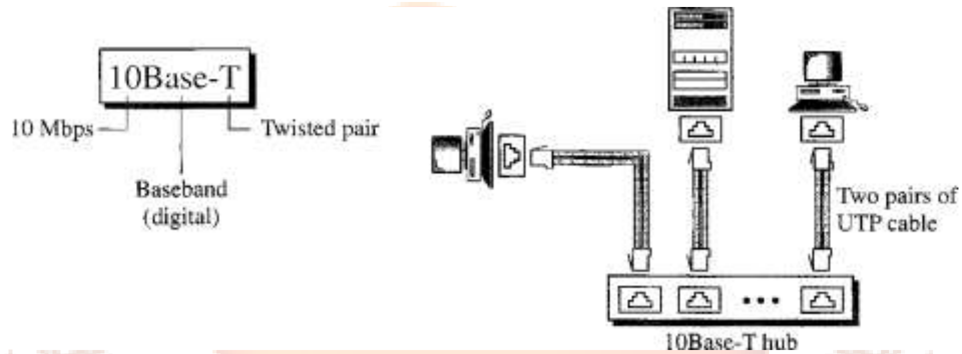


Fig 13.10: 10Base-T Twisted –pair Ethernet

Note that two pairs of twisted cable create two paths (one for sending and one for receiving) between the station and the hub. Any collision here happens in the hub. Compared to 10Base5 or 10Base2, we can see that the hub actually replaces the coaxial cable as far as a collision is concerned. The maximum length of the twisted cable here is defined as 100 m, to minimize the effect of attenuation in the twisted cable.

10Base-F: Fiber Ethernet

10Base-F uses a star topology to connect stations to a hub. The stations are connected to the hub using two fiber-optic cables as shown in figure 13.11.

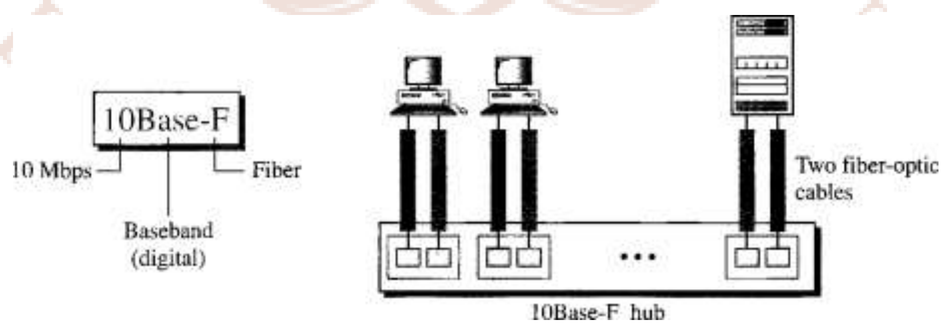


Fig 13.11: 10 Base-F Fiber Ethernet

SELF ASSESSMENT QUESTIONS – 2

3. 100 Mbps ethernet is also known as____________________.
4. Which of the following ethernet is 10 Mbps ethernet?
   a) Standard ethernet
   b) Fast ethernet
   c) Gigabit ethernet
   d) Ten-gigabit ethernet
5. The first field of the 802.3 frame is_________________field.
6. The__________________address is a special case of the multicast address.
7. 10Base5 was the first ethernet specification to use __________________ topology.
8. 10Base2 ethernet is also known as_______________________.
9. 10Base-F uses________________________topology to connect stations to ahub.

4. CHANGES IN THE STANDARD

The first step in the Ethernet evolution was the division of a LAN by bridges. Bridges have two effects on an ethernet LAN: They raise the bandwidth and they separate collision domains.

Raising the Bandwidth: As shown in figure 13.12, in an unbridged Ethernet network, the total capacity (10 Mbps) is shared among all stations with a frame to send; the stations share the bandwidth of the network. If only one station has frames to send, it benefits from the total capacity (10 Mbps). But if more than one station needs to use the network, the capacity is shared. For example, if two stations have a lot of frames to send, they probably alternate in usage. When one station is sending, the other one refrains from sending. We can say that, in this case, each station on average sends at a rate of 5 Mbps.

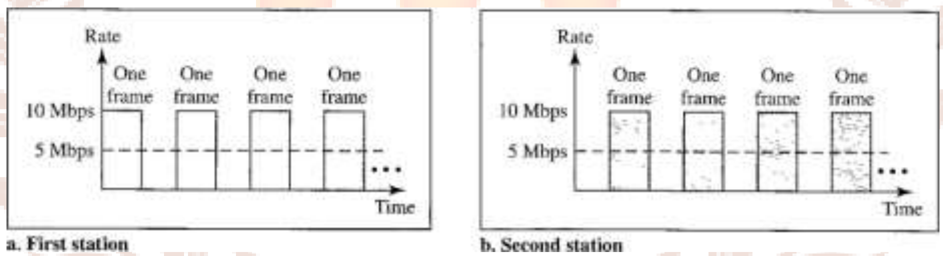


Fig 13.12: Raising Bandwidth

4.1 Bridged Ethernet

A bridge divides the network into two or more networks. Bandwidth-wise, each network is independent. For example, in the figure 13.13, a network with 12 stations is divided into two networks, each with 6 stations. Now each network has a capacity of 10 Mbps. The 10-Mbps capacity in each segment is now shared between 6 stations (actually 7 because the bridge acts as a station in each segment), not 12 stations. In a network with a heavy load, each station theoretically is offered 10/6 Mbps instead of 10/12 Mbps, assuming that the traffic is not going through the bridge.

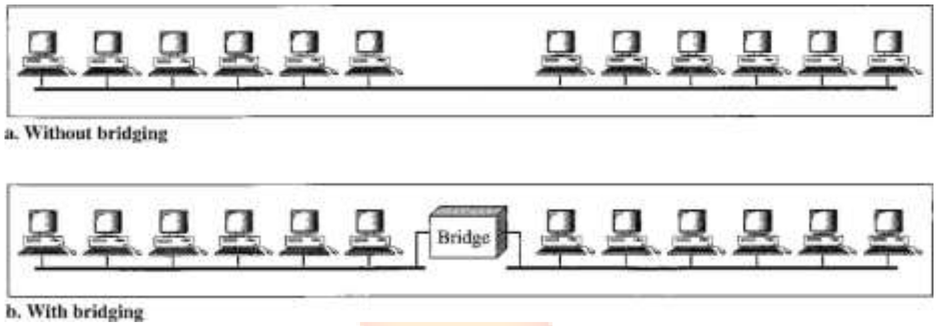


Fig 13.13: Usage of Bridge

Separating Collision Domains: Another advantage of a bridge is the separation of the collision domain. The figure 13.14 shows the collision domains for an unbridged and a bridged network. You can see that the collision domain becomes much smaller and the probability of collision is reduced tremendously. Without bridging, 12 stations contend for access to the medium; with bridging only 3 stations contend for access to the medium.

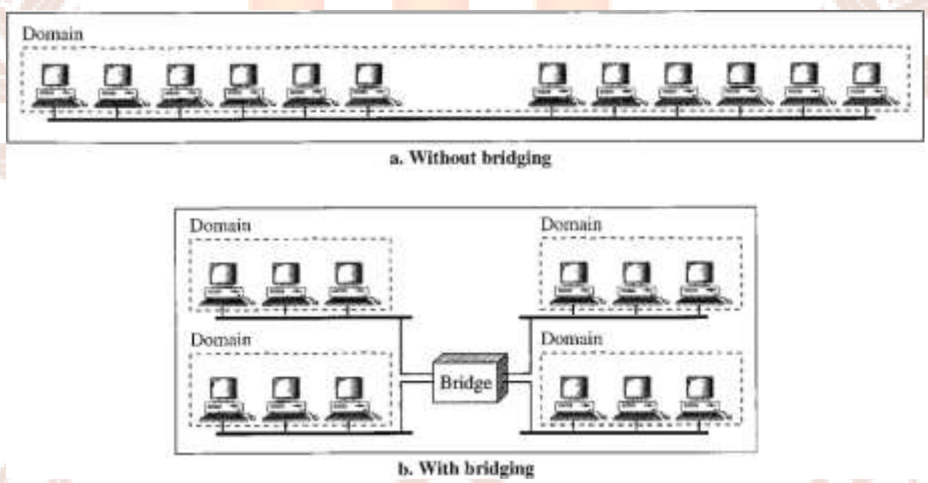


Fig 13.14: Collision Domain

4.2 Switched Ethernet

The idea of a bridged LAN can be extended to a switched LAN. Instead of having two to four networks, why not have N networks, where N is the number of stations on the LAN. In other words, if we can have a multiple- port bridge, why not have an N-port switch? In this way, the bandwidth is shared only between the station and the switch (5 Mbps each). In addition, the collision domain is divided into N domains as shown in figure 13.15.

A layer 2 switch is an N-port bridge with additional sophistication that allows faster handling of the packets. Evolution from a bridged Ethernet to a switched Ethernet was a big step that opened the way to an even faster Ethernet.

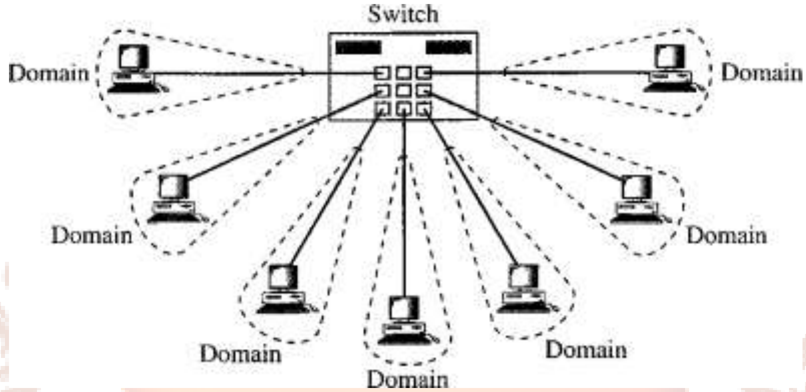


Fig 13.15: Switched Ethernet

4.3 Full-Duplex Ethernet

One of the limitations of 10Base5 and 10Base2 is that communication is half-duplex (10Base-T is always full-duplex); a station can either send or receive, but may not do both at the same time. The next step in the evolution was to move from switched Ethernet to full-duplex switched Ethernet. The full-duplex mode increases the capacity of each domain from 10 to 20 Mbps. The figure 13.16 shows a switched Ethernet in full-duplex mode. Note that instead of using one link between the station and the switch, the configuration uses two links: one to transmit and one to receive.

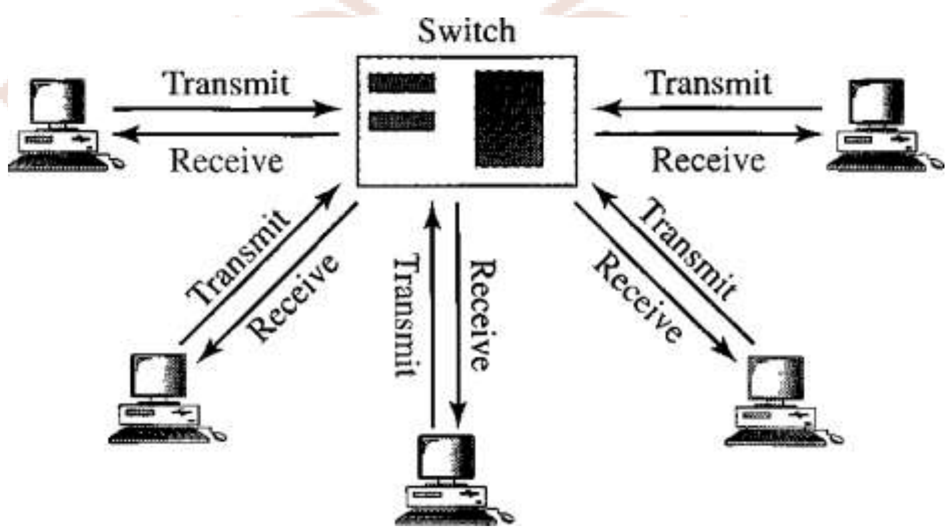


Fig 13.16: Full–Duplex Ethernet

No need for CSMA/CD: In full-duplex switched Ethernet, there is no need for the CSMA/CD method. In a full-duplex switched Ethernet, each station is connected to the switch via two separate links. Each station or switch can send and receive independently without worrying about collision. Each link is a point-to-point dedicated path between the station and the switch. There is no longer a need for carrier sensing; there is no longer a need for collision detection. The job of the MAC layer becomes much easier. The carrier sensing and collision detection functionalities of the MAC sublayer can be turned off.

MAC Control Layer: Standard Ethernet was designed as a connectionless protocol at the MAC sublayer. There is no explicit flow control or error control to inform the sender that the frame has arrived at the destination without error. When the receiver receives the frame, it does not send any positive or negative acknowledgment.

To provide for flow and error control in full-duplex switched Ethernet, a new sublayer, called the MAC control, is added between the LLC sublayer and the MAC sublayer.

SELF ASSESSMENT QUESTIONS – 3

10. The________________________mode increases the capacity of each domain from 10 to 20 Mbps.
11. Standard Ethernet was designed as a connectionless protocol at the _________________sublayer.

5. FAST ETHERNET

Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel (or Fibre Channel, as it is sometimes spelled). IEEE created Fast Ethernet under the name 802.3u. Fast Ethernet is backward- compatible with Standard Ethernet, but it can transmit data 10 times faster at a rate of 100 Mbps. The goals of Fast Ethernet can be summarized as follows:

1) Upgrade the data rate to 100 Mbps.
2) Make it compatible with Standard Ethernet.
3) Keep the same 48-bit address.
4) Keep the same frame format.
5) Keep the same minimum and maximum frame lengths.

MAC Sublayer

A main consideration in the evolution of Ethernet from 10 to 100 Mbps was to keep the MAC sublayer untouched. However, a decision was made to drop the bus topologies and keep only the star topology. For the star topology, there are two choices, as we saw before: half duplex and full duplex. In the half-duplex approach, the stations are connected via a hub; in the full-duplex approach, the connection is made via a switch with buffers at each port.

The access method is the same (CSMA/CD) for the half-duplex approach; for full-duplex Fast Ethernet, there is no need for CSMA/CD. However, the implementations keep CSMA/CD for backward compatibility with Standard Ethernet.

Autonegotiation:

A new feature added to Fast Ethernet is called autonegotiation. It allows a station or a hub a range of capabilities. Autonegotiation allows two devices to negotiate the mode or data rate of operation. It was designed particularly for the following purposes:

- To allow incompatible devices to connect to one another. For example, a device with a maximum capacity of 10 Mbps can communicate with a device with a 100 Mbps capacity (but can work at a lower rate).
- To allow one device to have multiple capabilities.
- To allow a station to check a hub's capabilities.

Physical Layer

The physical layer in Fast Ethernet is more complicated than the one in Standard Ethernet. Some of the features of this layer are as follows.

Topology:

Fast Ethernet is designed to connect two or more stations together. If there are only two stations, they can be connected point-to-point. Three or more stations need to be connected in a star topology with a hub or a switch at the center as shown in figure 13.17.

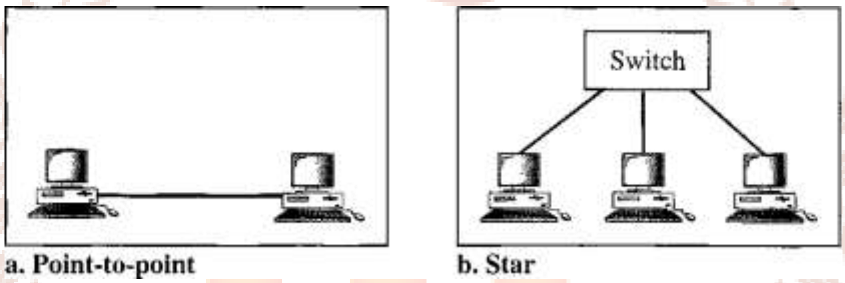


Fig 13.17: Fast Ethernet Topology

Implementation:

Fast Ethernet implementation at the physical layer can be categorized as either two-wire or four-wire. The two-wire implementation can be either category 5 UTP (100Base-TX) or fiber-optic cable (100Base-FX). The four- wire implementation is designed only for category 3 UTP (100Base-T4) as shown in figure 13.18.

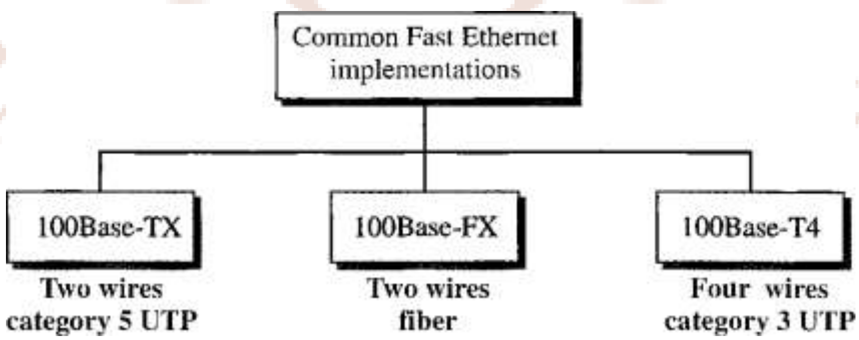


Fig 13.18: Types of Fast Ethernet

Encoding:

Manchester encoding needs a 200-Mbaud bandwidth for a data rate of 100 Mbps, which makes it unsuitable for a medium such as twisted-pair cable. For this reason, the Fast Ethernet designers sought some alternative encoding/decoding scheme. However, it was found that one scheme would not perform equally well for all three implementations. Therefore, three different encoding schemes were chosen as shown in figure 13.19.

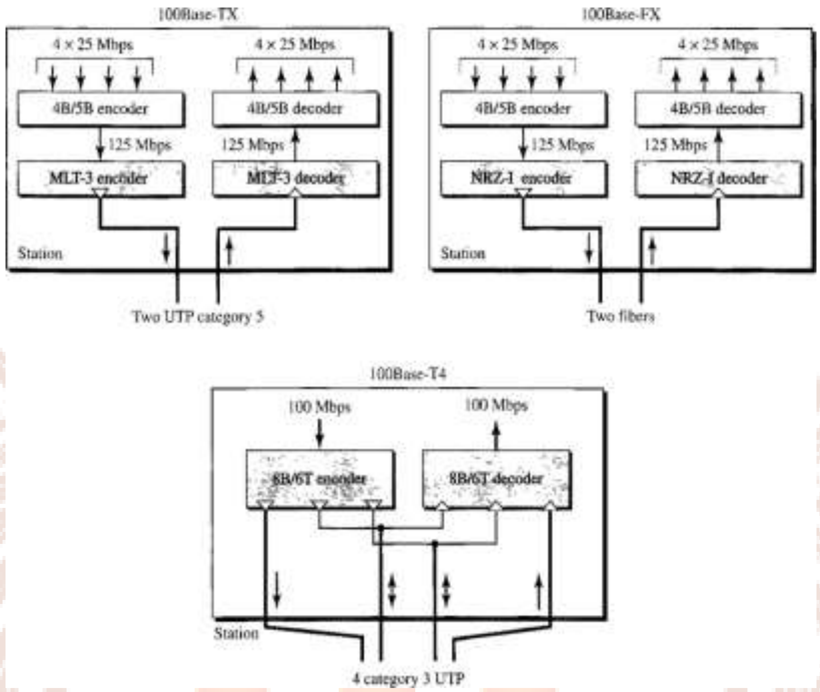


Fig 13.19: Encoding

100Base-TX uses two pairs of twisted-pair cable (either category 5 UTP or STP). For this implementation, the MLT-3 scheme was selected since it has good bandwidth performance. However, since MLT-3 is not a self- synchronous line coding scheme, 4B/5B block coding is used to provide bit synchronization by preventing the occurrence of a long sequence of 0s and 1s. This creates a data rate of 125 Mbps, which is fed into MLT-3 for encoding.

100Base-FX uses two pairs of fiber-optic cables. Optical fiber can easily handle high bandwidth requirements by using simple encoding schemes. The designers of 100Base-FX selected the NRZ-I encoding scheme for this implementation. However, NRZ-I has a bit synchronization problem for long sequences of 0s (or 1s, based on the encoding). To overcome this problem, the designers used 4B/5B block encoding as we described for 100Base-TX. The block encoding increases the bit rate from 100 to 125 Mbps, which can easily be handled by fiber-optic cable.

100Base-T4 was designed to use category 3 or higher UTP. The implementation uses four pairs of UTP for transmitting 100 Mbps. Encoding/decoding in 100Base-T4 is more complicated. As this implementation uses category 3 UTP, each twisted-pair cannot easily handle more than 25 Mbaud. In this design, one pair switches between sending and receiving. Three pairs of UTP category 3, however, can handle only 75 Mbaud (25 Mbaud) each. We need to use an encoding scheme that converts 100 Mbps to a 75 Mbaud signal. 8B/6T satisfies this requirement. In 8B/6T, eight data elements are encoded as six signal elements. This means that 100 Mbps uses only (6/8) x 100 Mbps, or 75 Mbaud. Summary of fast Ethernet is shown in Table 13.1

Table 13.1: Fast Ethernet Summary

Characteristics	*100Base-TX*	*100Base-FX*	*100Base-T4*
Media	Cat 5 UTP or STP	Fiber	Cat 4 UTP
Number of wires	2	2	4
Maximum length	100 m	100 m	100 m
Block encoding	4B/5B	4B/5B	
Line encoding	MLT-3	NRZ-I	8B/6T

SELF ASSESSMENT QUESTIONS – 4

12. ________________________ Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel.
13. IEEE created Fast Ethernet under the name_________________.
14. 100Base-FX uses two pairs of___________cables.

6. GIGABIT ETHERNET

The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps). The IEEE committee calls the Standard 802.3z. The goals of the Gigabit Ethernet design can be summarized as follows:

1) Upgrade the data rate to 1 Gbps.
2) Make it compatible with Standard or Fast Ethernet.
3) Use the same 48-bit address.
4) Use the same frame format.
5) Keep the same minimum and maximum frame lengths.
6) To support autonegotiation as defined in Fast Ethernet.

MAC Sublayer

Gigabit Ethernet has two distinctive approaches for medium access: half- duplex and full-duplex. Almost all implementations of Gigabit Ethernet follow the full-duplex approach.

Full-Duplex Mode:

In full-duplex mode, there is a central switch connected to all computers or other switches. In this mode, each switch has buffers for each input port in which data are stored until they are transmitted. There is no collision in this mode. This means that CSMA/CD is not used. Lack of collision implies that the maximum length of the cable is determined by the signal attenuation in the cable, not by the collision detection process.

Half-Duplex Mode:

Gigabit Ethernet can also be used in half-duplex mode, although it is rare. In this case, a switch can be replaced by a hub, which acts as the common cable in which a collision might occur. The half-duplex approach uses CSMA/CD. The maximum length of the network in this approach is totally dependent on the minimum frame size. Three methods have been defined: traditional, carder extension, and frame bursting.

Traditional: In the traditional approach, we keep the minimum length of the frame as in traditional Ethernet (512 bits). However, because the length of a bit is 1/100 shorter in Gigabit Ethernet than in 10-Mbps Ethernet, the slot time for Gigabit Ethernet is 512 bits x 1/1000 gs, which is equal to 0.512 gs. The reduced slot time means that collision is detected

100 times earlier. This means that the maximum length of the network is 25 m. This length may be suitable if all the stations are in one room, but it may not even be long enough to connect the computers in one single office.

Carrier Extension: To allow for a longer network, we increase the minimum frame length. The carrier extension approach defines the minimum length of a frame as 512 bytes (4096 bits). This means that the minimum length is 8 times longer. This method forces a station to add extension bits (padding) to any frame that is less than 4096 bits. In this way, the maximum length of the network can be increased 8 times to a length of 200 m. This allows a length of 100 m from the hub to the station.

Frame Bursting: Carrier extension is very inefficient if we have a series of short frames to send; each frame carries redundant data. To improve efficiency, frame bursting was proposed. Instead of adding an extension to each frame, multiple frames are sent. However, to make these multiple frames look like one frame, padding is added between the frames (the same as that used for the carrier extension method) so that the channel is not idle.

Physical Layer

The physical layer in Gigabit Ethernet is more complicated than that in Standard or Fast Ethernet. Some features of this layer are:

Topology:

Gigabit Ethernet is designed to connect two or more stations. If there are only two stations, they can be connected point-to-point. Three or more stations need to be connected in a star topology with a hub or a switch at the center. Another possible configuration is to connect several star topologies or let a star topology be part of another as shown in figure 13.20.

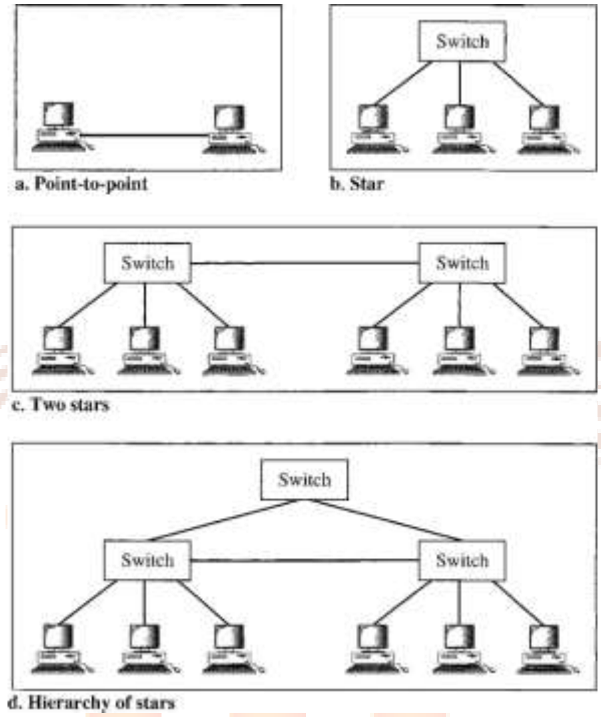


Fig 13.20: Giga Ethernet Topology

Implementation:

Gigabit Ethernet can be categorized as either a two-wire or a four-wire implementation. The two-wire implementations use fiber-optic cable (1000Base-SX, short-wave, or 1000Base-LX, long-wave), or STP (1000Base-CX). The four-wire version uses category 5 twisted-pair cable (1000Base-T). In other words, we have four implementations, as shown in figure 13.21.

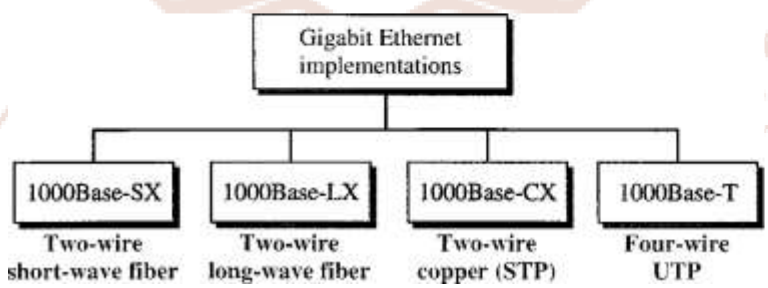


Fig 13.21: Types of Giga Ethernet

Encoding:

The figure 13.22 shows the encoding/decoding schemes for the four implementations.

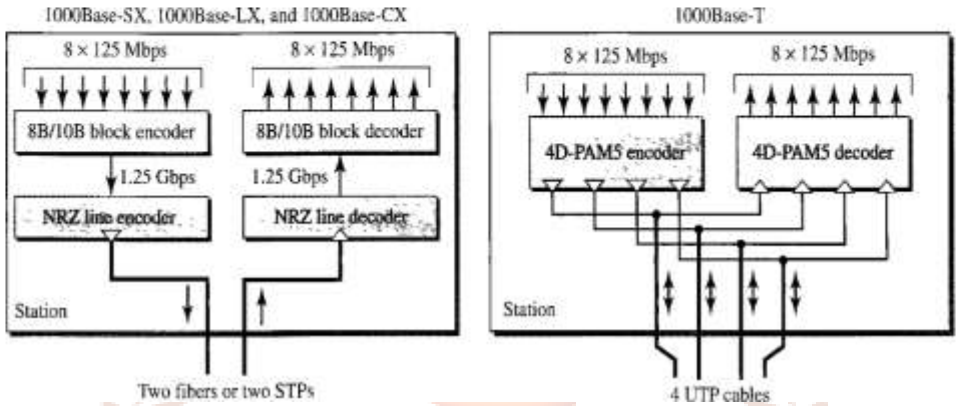


Fig 13.22: Giga Ethernet Encoding

Gigabit Ethernet cannot use the Manchester encoding scheme because it involves a very high bandwidth (2 GBaud). The two-wire implementations use an NRZ scheme, but NRZ does not self-synchronize properly. To synchronize bits, particularly at this high data rate, 8B/10B block encoding is used. This block encoding prevents long sequences of 0s or ls in the stream, but the resulting stream is 1.25 Gbps. Note that in this implementation, one wire (fiber or STP) is used for sending and one for receiving.

In the four-wire implementation it is not possible to have 2 wires for input and 2 for output, because each wire would need to carry 500 Mbps, which exceeds the capacity for category 5 UTP. As a solution, 4D-PAM5 encoding is used to reduce the bandwidth. Thus, all four wires are involved in both input and output; each wire carries 250 Mbps, which is in the range for category 5 UTP cable.

Ten-Gigabit Ethernet

The IEEE committee created Ten-Gigabit Ethernet and called it Standard 802.3ae. The goals of the Ten-Gigabit Ethernet design can be summarized as follows:

1) Upgrade the data rate to 10 Gbps.
2) Make it compatible with Standard, Fast, and Gigabit Ethernet.
3) Use the same 48-bit address.
4) Use the same frame format.
5) Keep the same minimum and maximum frame lengths.
6) Allow the interconnection of existing LANs into a metropolitan area network (MAN) or a wide area network (WAN).
7) Make Ethernet compatible with technologies such as Frame Relay and ATM.

MAC Sublayer

Ten-Gigabit Ethernet operates only in full duplex mode which means there is no need for contention; CSMA/CD is not used in Ten-Gigabit Ethernet.

Physical Layer

The physical layer in Ten-Gigabit Ethernet is designed for using fiber-optic cable over long distances. Three implementations are the most common: 10GBase-S, 10GBase-L, and 10GBase-E.

SELF ASSESSMENT QUESTIONS – 5

15. Gigabit Ethernet cannot use the Manchester encoding schemebecause it involves a very high bandwidth. (True/False).
    (a)True (b) False
16. The IEEE committee created Ten-Gigabit ethernet and called it as ____________________ Standard.

7. SUMMARY

Let us recapitulate the important concepts discussed in this unit:

- The IEEE (Institute of Electrical and Electronics Engineers) has subdivided the data link layer into two sublayers: logical link control (LLC) and media access control (MAC).
- In IEEE Project 802, flow control, error control, and part of the framing duties are collected into one sublayer called the logical link control.
- IEEE Project 802 has created a sublayer called media access control that defines the specific access method for each LAN.
- 10Base5 was the first Ethernet specification to use a bus topology with an external transceiver (transmitter/receiver) connected via a tap to a thick coaxial cable.
- 10Base2 also uses a bus topology, but the cable is much thinner and more flexible.
- The third implementation is called 10Base-T or twisted-pair Ethernet.
- 10Base-F uses a star topology to connect stations to a hub.
- A bridge divides the network into two or more networks.
- One of the limitations of 10Base5 and 10Base2 is that communication is half-duplex.
- The full-duplex mode increases the capacity of each domain from 10 to 20 Mbps.
- Gigabit Ethernet has two distinctive approaches for medium access: half-duplex and full-duplex. Almost all implementations of Gigabit Ethernet follow the full-duplex approach.

8. TERMINAL QUESTIONS

1. Describe IEEE standards.
2. Explain different standard ethernet specifications.
3. Write short note on bridged ethernet.
4. Differentiate between switched ethernet and full duplex ethernet.
5. Explain fast ethernet.
6. Describe gigabit ethernet.

9. ANSWERS

Self-Assessment Questions

1. Logical link control, media access control
2. Logical link control (LLC)
3. Fast ethernet
4. (a) standard ethernet
5. Preamble
6. Broadcast
7. Bus
8. Thin ethernet
9. Star
10. Full duplex
11. MAC
12. Fast ethernet
13. 802.3u
14. Fiber-optic
15. (a) true
16. 802.3ae

Terminal Questions

1. The IEEE (Institute of Electrical and Electronics Engineers) has subdivided the data link layer into two sublayers: logical link control (LLC) and media access control (MAC). IEEE has also created several physical layer standards for different LAN protocols. (Refer section 2 for detail).

2. 10Base5 was the first Ethernet specification to use a bus topology with an external transceiver (transmitter/receiver) connected via a tap to a thick coaxial cable. 10Base2 also uses a bus topology, but the cable is much thinner and more flexible (Refer section 3 for detail).
3. A bridge divides the network into two or more networks. Bandwidth-wise, each network is independent. (Refer section 4.1 for detail).
4. In switched ethernet, instead of having two to four networks, we have N networks, where N is the number of stations on the LAN. The next step in the evolution was to move from switched Ethernet to full-duplex switched Ethernet. The full-duplex mode increases the capacity of each domain from 10 to 20 Mbps. (Refer section 4.2 and 4.3 for detail).
5. Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel (or Fibre Channel, as it is sometimes spelled). IEEE created Fast Ethernet under the name 802.3u. (Refer section 5 for detail)
6. The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps). The IEEE committee calls the Standard 802.3z. (Refer section 6 for detail)

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