Wired LAN

Ethernet

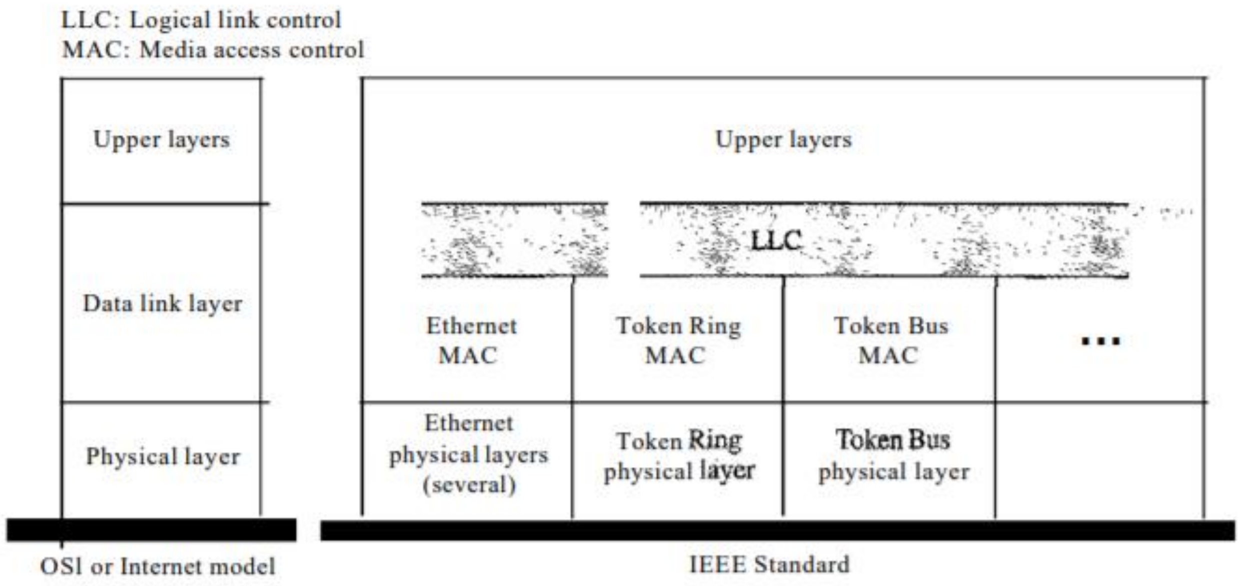
Introduction

❑ IEEE STANDARDS

➢ In 1985, the Computer Society of the IEEE started a project, called Project 802, to set standards to enable intercommunication among equipment from a variety of manufacturers. Project 802 does not seek to replace any part of the OSI or the Internet model. Instead " it is a way of specifying functions of the physical layer and the data link layer of major LAN protocols ". The standard was adopted by the American National Standards Institute (ANSI). In 1987, the International Organization for Standardization (ISO) also approved it as an international standard under the designation ISO 8802. The IEEE 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 .

Introduction

Figure 13.1 *IEEE standardfor LANs*



LLC

- Data Link Layer
- Logical link control (LLC) functions :
  - Flow control .
  - Error control .
  - Part of the framing duties .

- The LLC provides one single data link control protocol for all IEEE LANs .

LLC

- Framing LLC defines a protocol data unit (PDU) that is some what 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 .

LLC

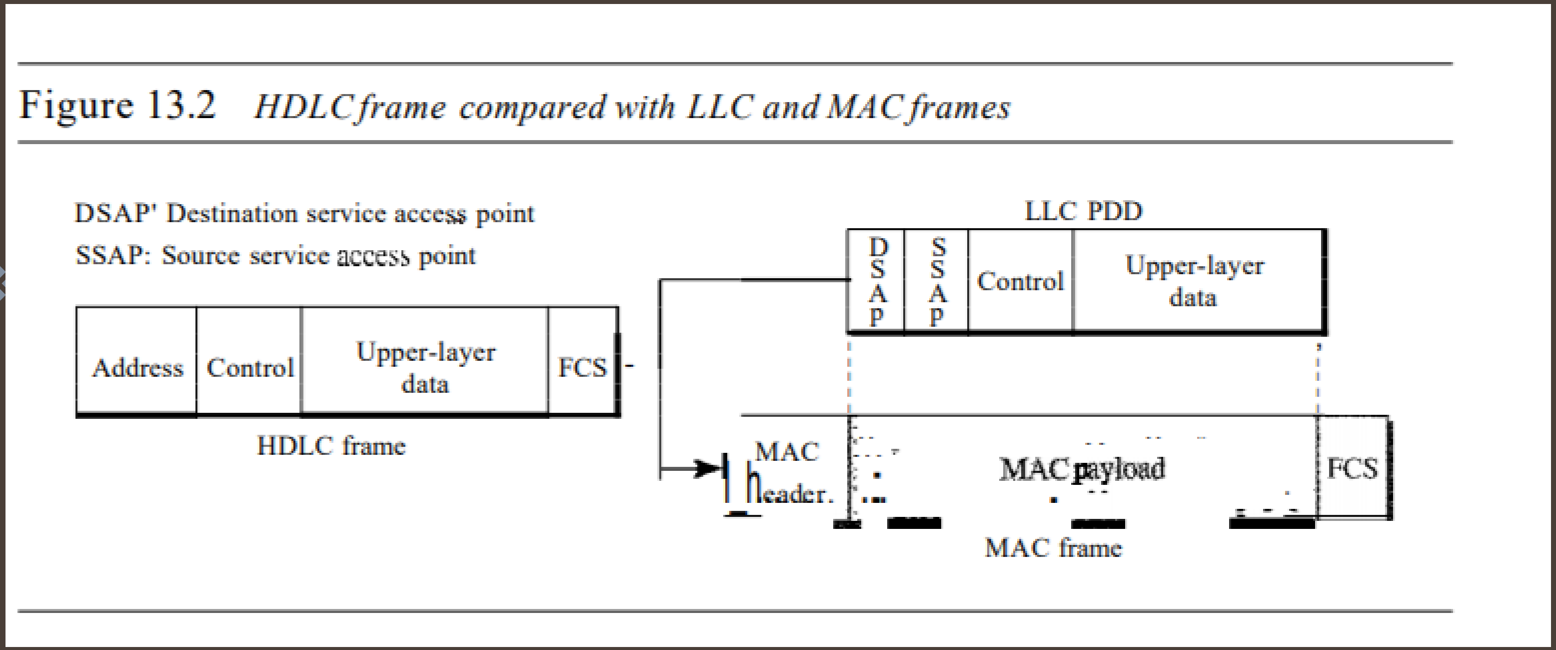


Figure 13.2 HDLC frame compared with LLC and MAC frames
DSAP' Destination service access point
SSAP: Source service access point
Address
Control
Upper-layer data
FCS
HDLC frame
LLC PDD
DSAP
SSAP
Control
Upper-layer data
MAC header
MAC payload
FCS
MAC frame

MAC

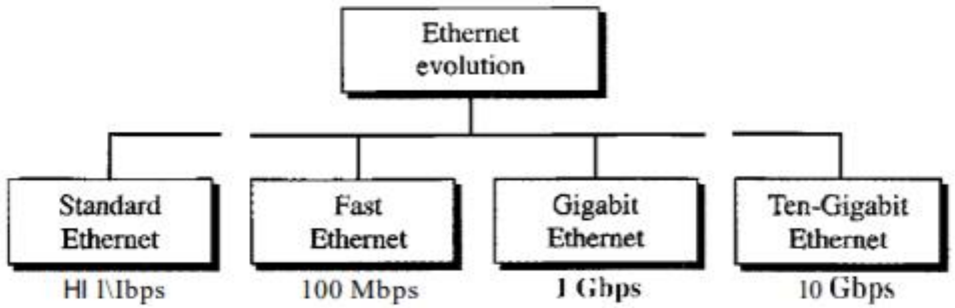
- IEEE Project 802 has created a sublayer called media access control that defines the specific access method for each LAN. For example, it defines CSMA/CD as the media access method for Ethernet LANs and the token passing method for Token Ring and Token Bus LANs. As we discussed in the previous section, 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 .

STANDARD ETHERNET

❑ 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 (1 Mbps), Fast Ethernet (100 Mbps), Gigabit Ethernet (1Gbps), and Ten-Gigabit Ethernet (10 Gbps), as shown in Figure below .

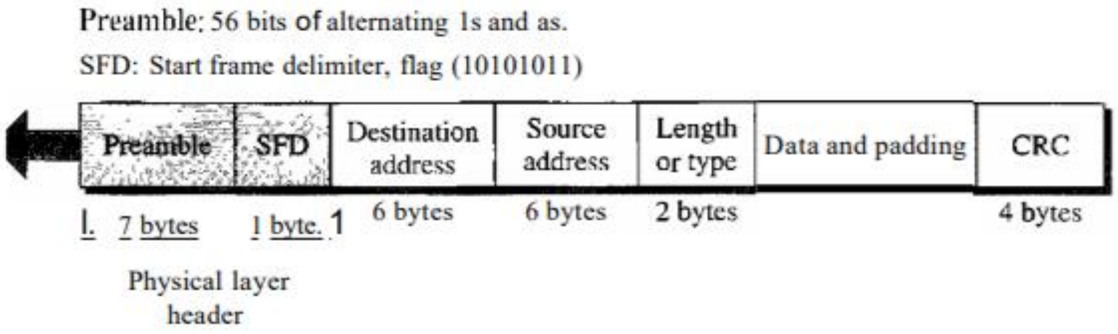
Figure 13.3 *Ethernet evolution through four generations*



STANDARD ETHERNET

- 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 Figure below .

Figure 13.4 *802.3 MAC frame*



STANDARD ETHERNET

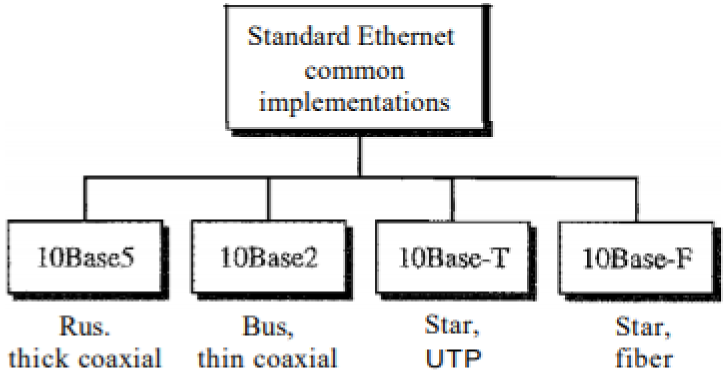
- Preamble : contains 7 bytes (56 bits) of alternating 0s and 1s that alerts the receiving system to the coming frame and enables it to synchronize its input timing. The 56-bit pattern allows the stations to miss some bits at the beginning of the frame. The preamble is actually added at the physical layer and is not (formally) part of the frame .
- Start frame delimiter (SFD) : The SFD warns the stations that this is the last chance for synchronization .
- Destination address (DA) : The DA field is 6 bytes and contains the physical address of the destination station 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 .

STANDARD ETHERNET

- 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.
- Data. This field carries data encapsulated from the upper-layer protocols . It is a minimum of 46 and a maximum of 1500 byte .
- CRC : The last field contains error detection information in this case a CRC 32

STANDARD ETHERNET

Figure 13.8 *Categories ofStandard Ethernet*



STANDARD ETHERNET

- 10Base5 : Thick Ethernet or Thick net is The first implementation .
- The nickname derives from the size of the cable .
- 10Base5 use a bus topology with an external transceiver (transmitter/receiver) connected via a tap to a thick coaxial cable .
- The transceiver is responsible for transmitting , receiving , and detecting collisions .
- This means that collision can only happen in the coaxial cable .
- The maximum length of the coaxial cable must not exceed 500m .
- If a length of more than 500m is needed we should use repeaters .

STANDARD ETHERNET

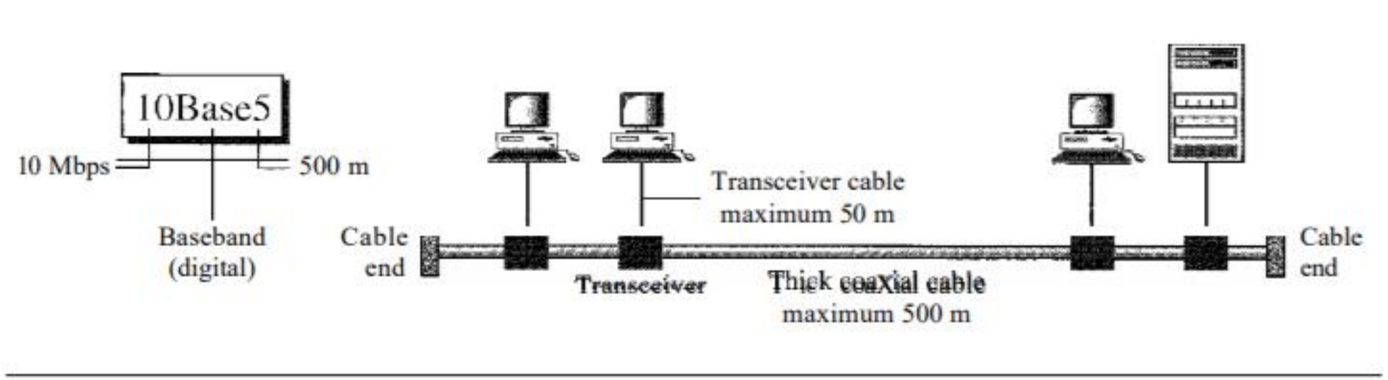


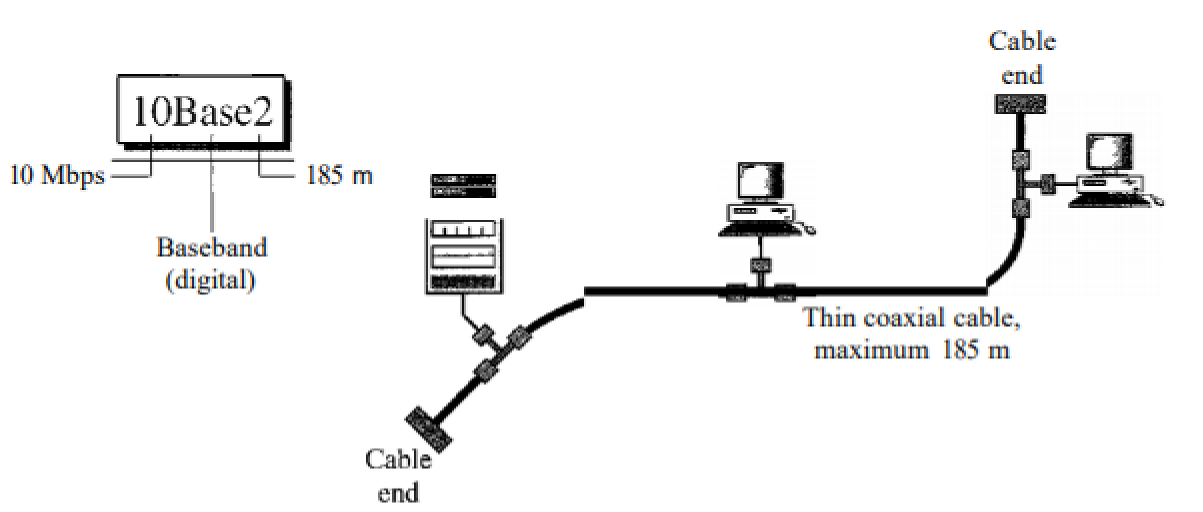
Figure 13.10 *IOBase5 implementation*

STANDARD ETHERNET

- 10Base2 : Thin Ethernet or Cheaper net is The second implementation .
- 10 Base2 uses a bus topology .
- The cable is much thinner and more flexible .
- 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 .
- 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 and the tee connections are much cheaper than taps.
- Installation is simpler because the thin coaxial cable is very flexible .
- The length of each segment cannot exceed 185 m (close to 200 m) due to the high level of attenuation in thin coaxial cable .

STANDARD ETHERNET

Figure 13.11 *lOBase2 implementation*

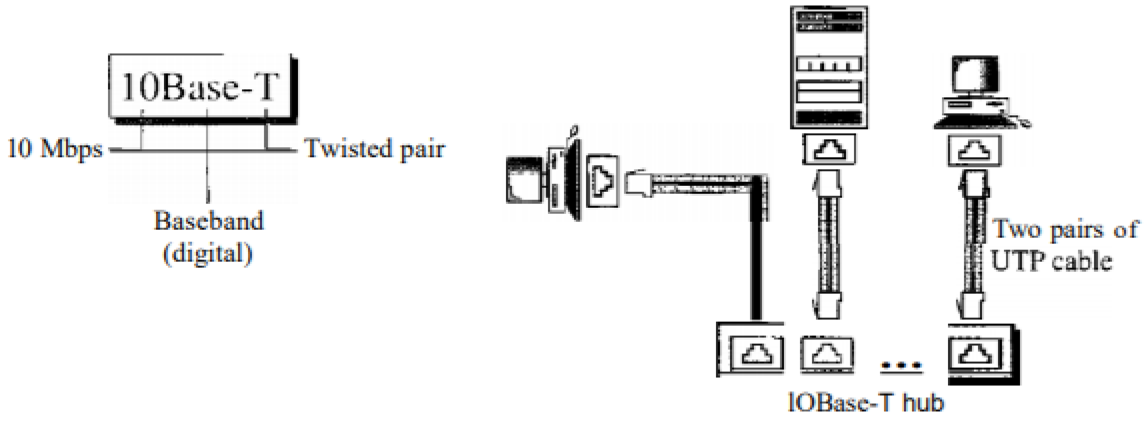


STANDARD ETHERNET

- 10Base-T : Twisted-Pair Ethernet The third implementation .
- 1OBase-T uses a physical star topology.
- The stations are connected to a hub via two pairs of twisted cable .
- 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 .
- The maximum length of the twisted cable here is defined as 100 m, to minimize the effect of attenuation in the twisted cable .

STANDARD ETHERNET

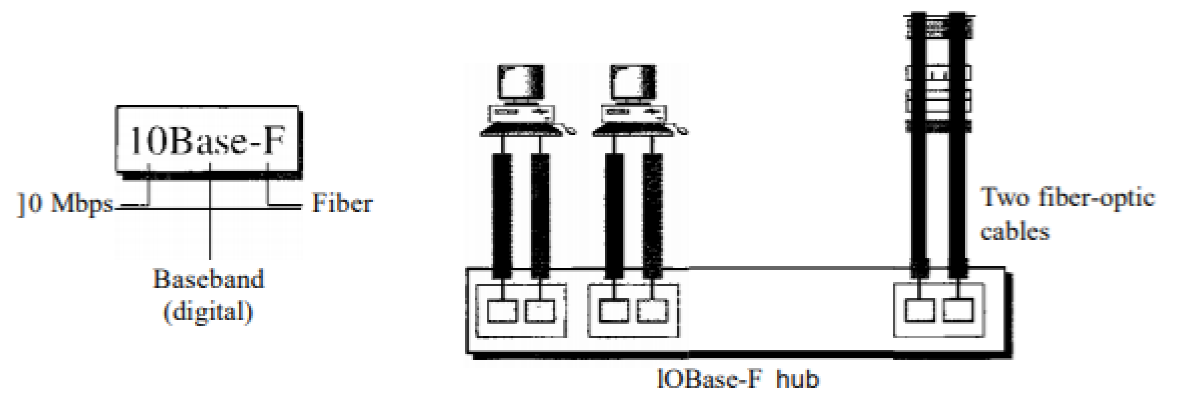
Figure 13.12 *IOBase-T implementation*



STANDARD ETHERNET

- 10Base-F : Fiber Ethernet Although there are several types of optical fiber 10-Mbps Ethernet, the most common is called 10Base-F.
- 10Base-F uses a star topology to connect stations to a hub .
- The stations are connected to the hub using two fiber-optic cables .

Figure 13.13 *IOBase-F implementation*



STANDARD ETHERNET

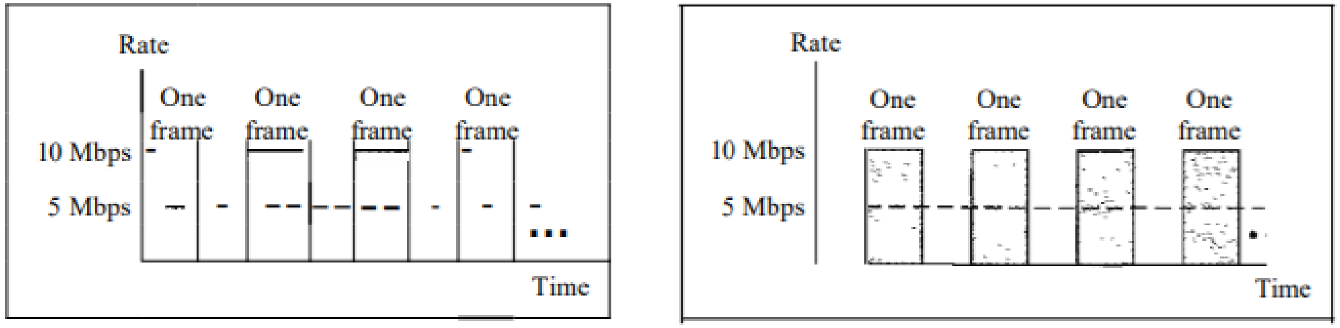
- CHANGES IN THE STANDARD
- The 10-Mbps Standard Ethernet has gone through several changes before moving to the higher data rates . These changes actually opened the road to the evolution of the Ethernet to become compatible with other high-data-rate LANs. We discuss some of these changes in this section.

STANDARD ETHERNET

- Bridged Ethernet 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 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. Figure 13.14 shows the situation .

STANDARD ETHERNET

Figure 13.14 *Sharing bandwidth*



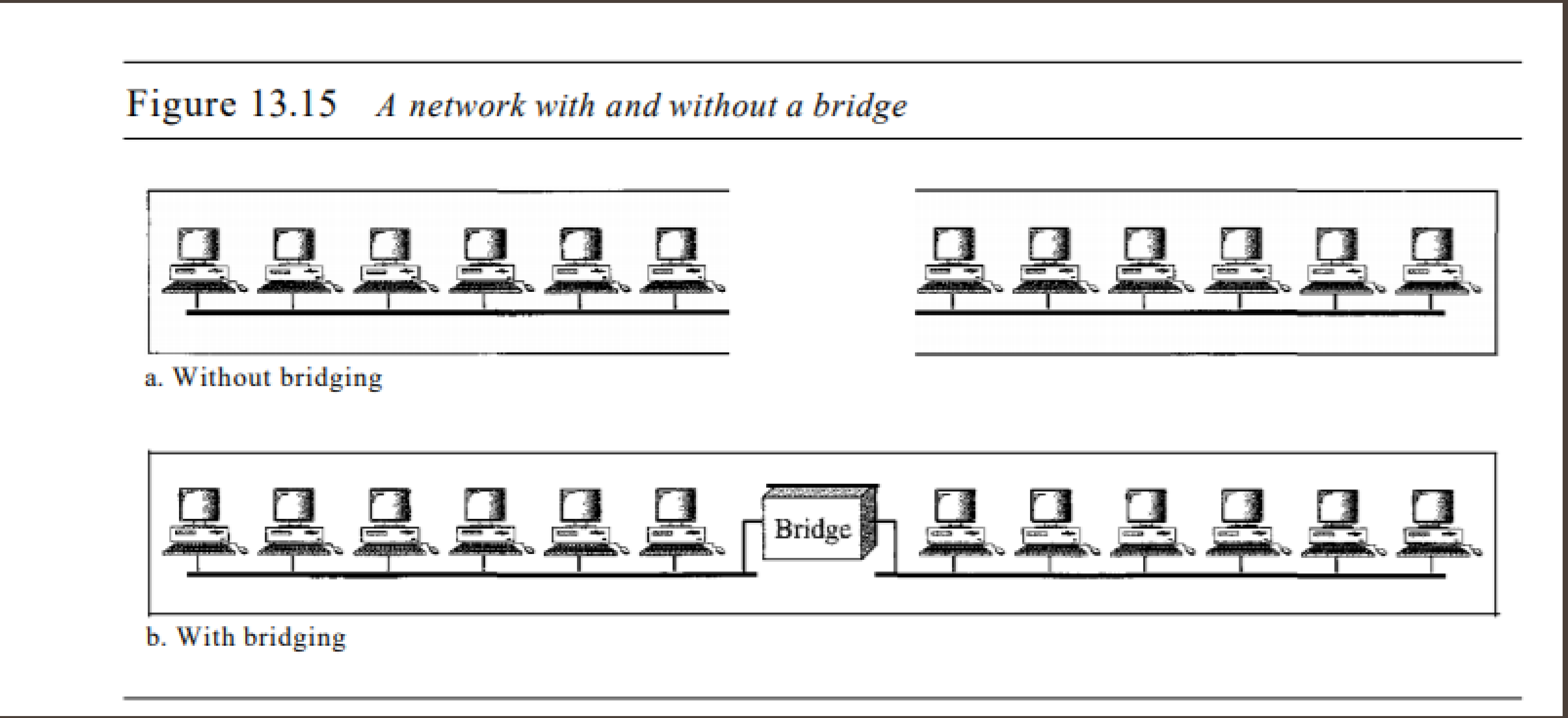
a. First station

b. Second station

STANDARD ETHERNET

- The bridge can help here. A bridge divides the network into two or more networks . Bandwidth-wise, each network is independent .
- For example, in Figure 13.15, 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. It is obvious that if we further divide the network, we can gain more bandwidth for each segment. For example, if we use a four-port bridge, each station is now offered 10/3 Mbps, which is 4 times more than an unbridged network .

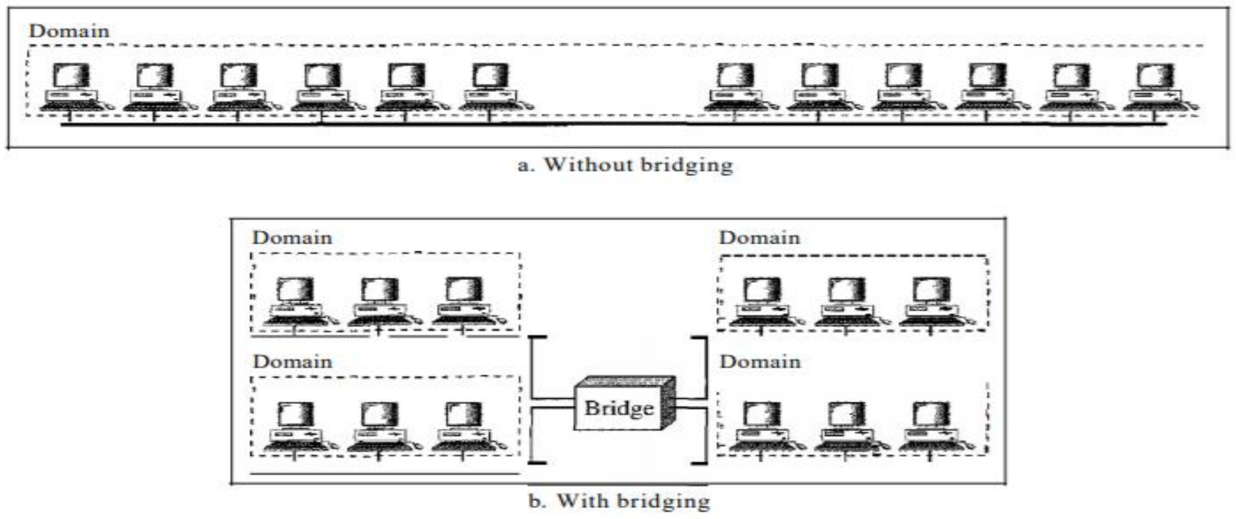
STANDARD ETHERNET



STANDARD ETHERNET

- Separating Collision Domains Another advantage of a bridge is the separation of the collision domain. Figure 13.16 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 .

Figure 13.16 *Collision domains in an unbridged network and a bridged network*



STANDARD ETHERNET

Table 13.1 *Summary ofStandard Ethernet implementations*

Characteristics	*lOBase5*	*lOBase2*	*lOBase-T*	*IOBase-F*
Media	Thick coaxial cable	Thin coaxial cable	2UTP	2 Fiber
Maximum length	500m	185 m	100m	2000m
Line encoding	Manchester	Manchester	Manchester	Manchester

Fast Ethernet

- Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel . 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 :
- Upgrade the data rate to 100 Mbps .
- Make it compatible with Standard Ethernet .
- Keep the same 48-bit address .
- Keep the same frame format .
- Keep the same minimum and maximum frame lengths .

Fast Ethernet

- MAC Sublayer

- Access method half-duplex and full-duplex .
- In half-duplex the stations are connected via a hub . in the full-duplex 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 fullduplex Fast Ethernet there is no need for CSMA/CD .

Fast Ethernet

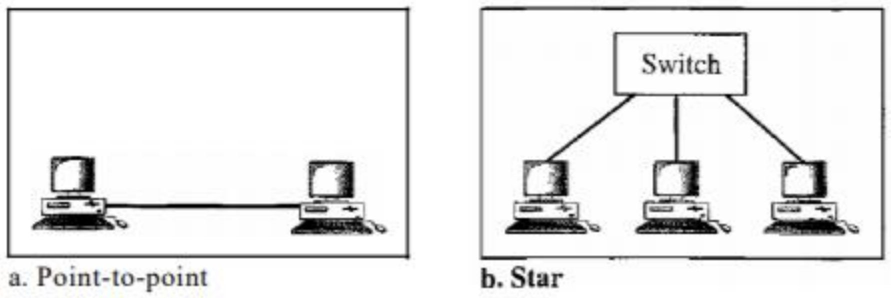
- MAC Sublayer
- Autonegotiation : A new feature added to Fast Ethernet is called autonegotiation. It allows a station or a hub a range of capabilities.
- It was designed particularly for the following purposes :
  - To allow incompatible devices to connect to one another. For example, a device with 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 .

Fast Ethernet

❖ Physical layer

➢ 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 .

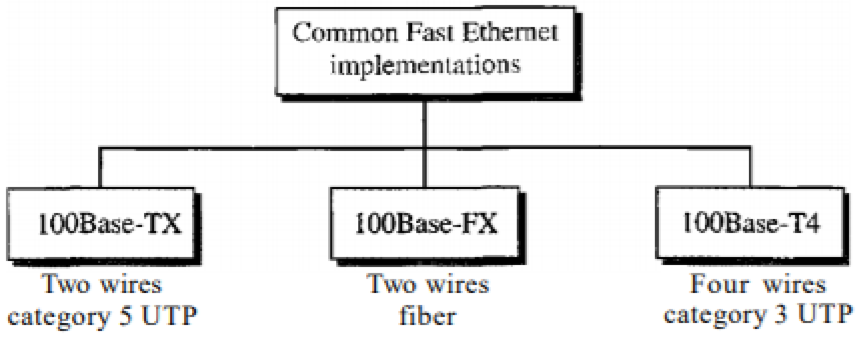
Figure 13.19 *Fast Ethernet topology*



Fast Ethernet

- 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 (lOOBase-TX) or fiber-optic cable (lOOBase-FX). The four-wire implementation is designed only for category 3 UTP (looBase-T4) .

Figure 13.20 *Fast Ethernet implementations*



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. lOOBase-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 Os and 1s .This creates a data rate of 125 Mbps, which is fed into MLT-3 for encoding.

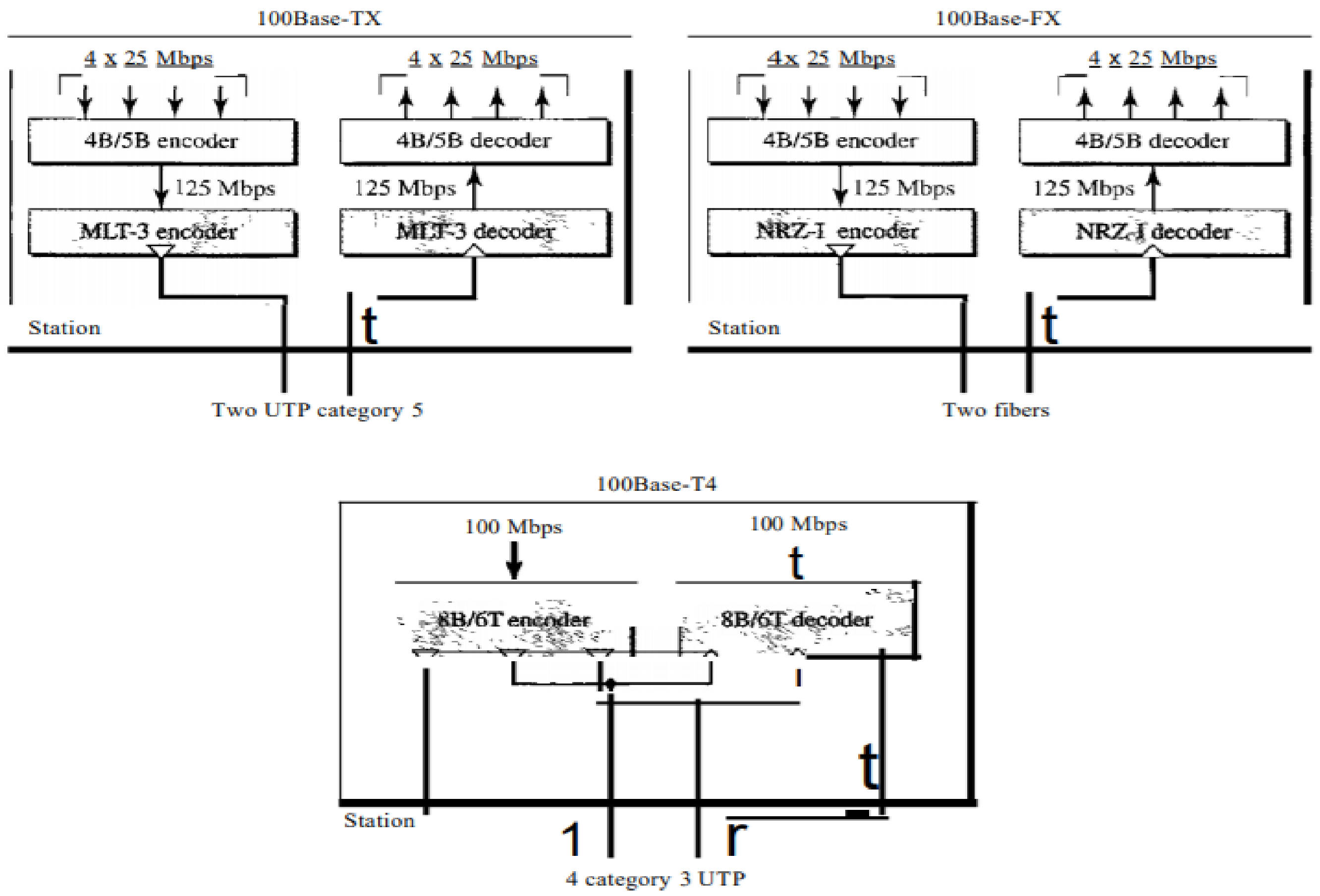
- lOOBase-FX uses two pairs of fiber-optic cables. Optical fiber can easily handle high bandwidth requirements by using simple encoding schemes. The designers of 100Base-FX selected the NRZ-I encoding scheme for this implementation. However, NRZ-I has a bit synchronization problem for long sequences of Os (or Is, based on the encoding) . To overcome this problem, the designers used 4B/5B .

Fast Ethernet

- Encoding
  - block encoding as we described for 1OOBase-TX. The block encoding increases the bit rate from 100 to 125 Mbps, which can easily be handled by fiber-optic cable. A 1OOBase-TX network can provide a data rate of 100 Mbps, but it requires the use of category 5 UTP or STP cable. This is not cost-efficient for buildings that have already been wired for voice-grade twisted-pair . A new standard, called lOOBase-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.

Fast Ethernet

Figure 13.21 *Encoding for Fast Ethernet implementation*



Fast Ethernet

Table 13.2 *Summary ofFast Ethernet implementations*

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

Gigabit

- 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 :
  - Upgrade the data rate to 1 Gbps .
  - Make it compatible with Standard or Fast Ethernet .
  - Use the same 48-bit address .
  - Use the same frame format .
  - Keep the same minimum and maximum frame lengths .
  - To support auto negotiation as defined in Fast Ethernet .

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

- 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, as we discussed before. This means that CSMAlCD 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 .

Gigabit

- Half - Duplex

- 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. However, as we saw before, the maximum length of the network in this approach is totally dependent on the minimum frame size. Three methods have been defined: traditional, carrier 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 11100 shorter in Gigabit Ethernet than in lO-Mbps Ethernet, the slot time for Gigabit Ethernet is 512 bits x 111000 JlS, which is equal to 0.512 JlS. 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.

Gigabit

- Half - Duplex

- 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.

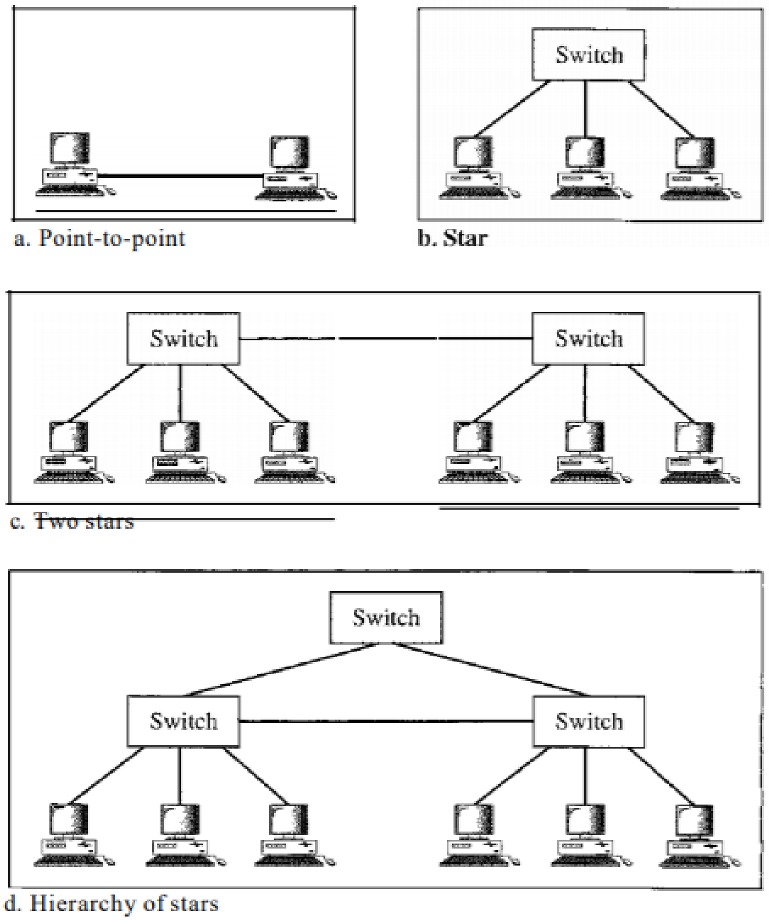
- Frame Bursting Carrier extension is very inefficient if we have a series of short frames to send; each frame carries redundant data. To improve efficiency, frame bursting was proposed. Instead of adding an extension to each frame, multiple frames are sent. However, to make these multiple frames look 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. In other words, the method deceives other stations into thinking that a very large frame has been transmitted.

Gigabit

- Topology
- Gigabit Ethernet is designed to connect two or more stations .
- If only two stations the type of connections is 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 .

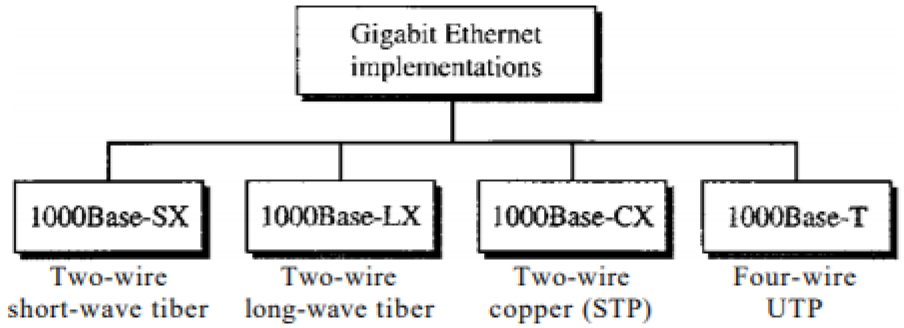
Gigabit

Figure 13.22 *Topologies of Gigabit Ethernet*



Gigabit

Figure 13.23 *Gigabit Ethernet implementations*



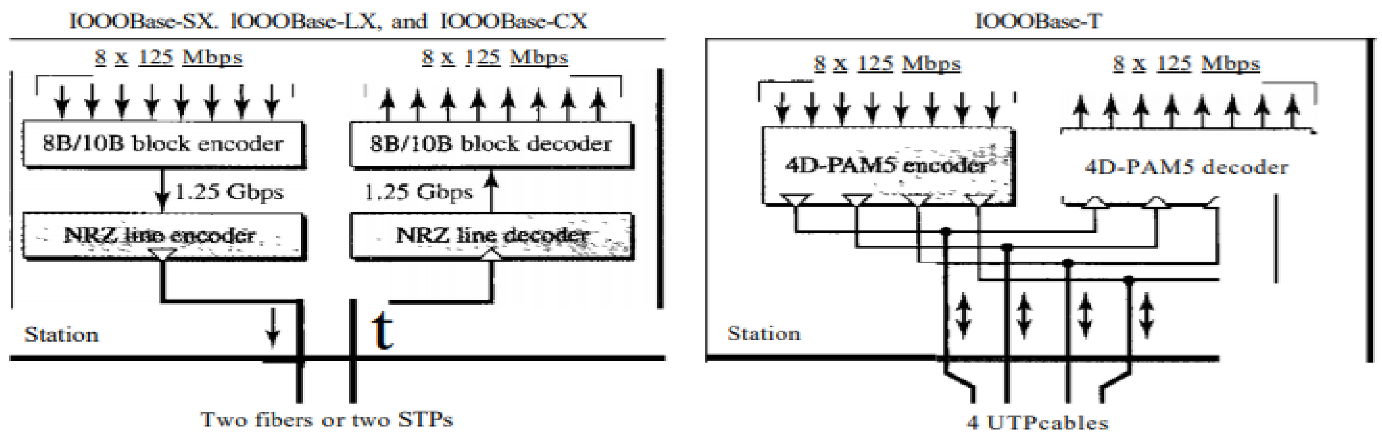
Gigabit

- Encoding
- Gigabit cannot use Manchester encoding scheme because it involves a very high bandwidth (2Gbaud) .
- The two-wire implementations use an NRZ scheme .
- NRZ does not self-synchronize properly. To synchronize bits, particularly at this high data rate, 8BIl OB block encoding .
- This block encoding prevents long sequences of Os or Is 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.

Gigabit

- 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 .

Figure 13.24 *Encoding in Gigabit Ethernet implementations*



Gigabit

Table 13.3 *Summary of Gigabit Ethernet implementations*

Characteristics	*lOOOBase-SX*	*lOOOBase-LX*	*lOOOBase-CX*	*lOOOBase-T*
Media	Fiber short-wave	Fiber long-wave	STP	Cat 5 UTP
Number of wires	2	2	2	4
Maximum length	550m	5000m	25m	100m
Block encoding	8B/lOB	*8B/lOB*	8B/lOB	
Line encoding	NRZ	NRZ	NRZ	4D-PAM5

Ten – Gigabit

- 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 :

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

Ten – Gigabit

❖ 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 : lOGBase-S, lOGBase-L, and lOGBase-E .

Table 13.4 *Summary ofTen-Gigabit Ethernet implementations*

Characteristics	*lOGBase-S*	*lOGBase-L*	*lOGBase-E*
Media	Short-wave S50-nrn rnultimode	Long-wave 131O-nrn single mode	Extended 1550-mrn single mode
Maximum length	300m	lOkm	40km

Done …

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2018