UNIT – III

Media Access Control:

Data Link Layer

The data link layer is used in a computer network to transmit the data between two devices or nodes. It divides the layer into parts such as data link control and the multiple access resolution/protocol. The upper layer has the responsibility to flow control and the error control in the data link layer, and hence it is termed as logical of data link control. Whereas the lower sub-layer is used to handle and reduce the collision or multiple access on a channel. Hence it is termed as media access control or the multiple access resolutions.

Data Link Control

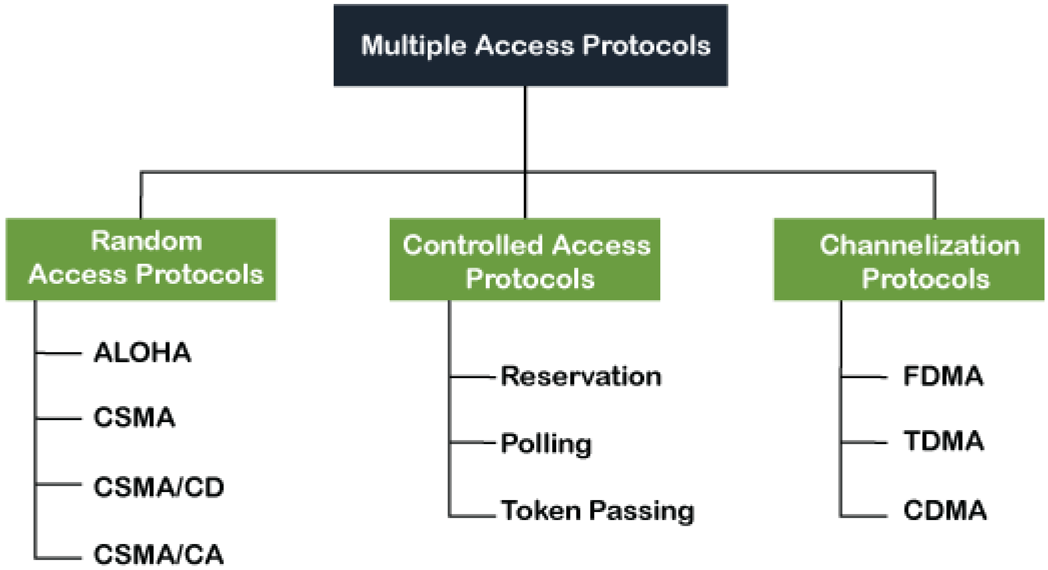
A data link layer is a reliable channel for transmitting data over a dedicated link using various techniques such as framing, error control and flow control of data packets in the computer network.

What is a multiple access protocol?

When a sender and receiver have a dedicated link to transmit data packets, the data link control is enough to handle the channel. Suppose there is no dedicated path to communicate or transfer the data between two devices. In that case, multiple stations access the channel and simultaneously transmits the data over the channel. It may create collision and cross talk. Hence, the multiple access protocol is required to reduce the collision and avoid crosstalk between the channels.

For example, suppose that there is a classroom full of students. When a teacher asks a question, all the students (small channels) in the class start answering the question at the same time (transferring the data simultaneously). All the students respond at the same time due to which data is overlap or data lost. Therefore it is the responsibility of a teacher (multiple access protocol) to manage the students and make them one answer.

Following are the types of multiple access protocol that is subdivided into the different process as:



A. Random Access Protocol

In this protocol, all the station has the equal priority to send the data over a channel. In random access protocol, one or more stations cannot depend on another station nor any station control another station. Depending on the channel's state (idle or busy), each station transmits the data frame. However, if more than one station sends the data over a channel, there may be a collision or data conflict. Due to the collision, the data frame packets may be lost or changed. And hence, it does not receive by the receiver end.

Following are the different methods of random-access protocols for broadcasting frames on the channel.

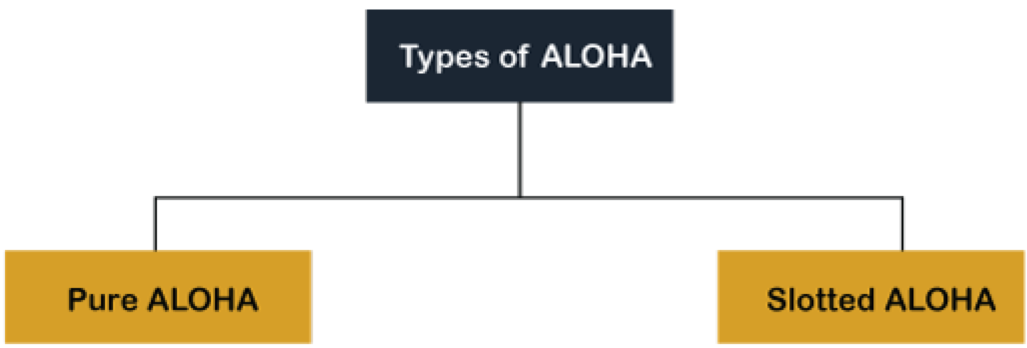
- Aloha
- CSMA
- CSMA/CD
- CSMA/CA

ALOHA Random Access Protocol

It is designed for wireless LAN (Local Area Network) but can also be used in a shared medium to transmit data. Using this method, any station can transmit data across a network simultaneously when a data frameset is available for transmission.

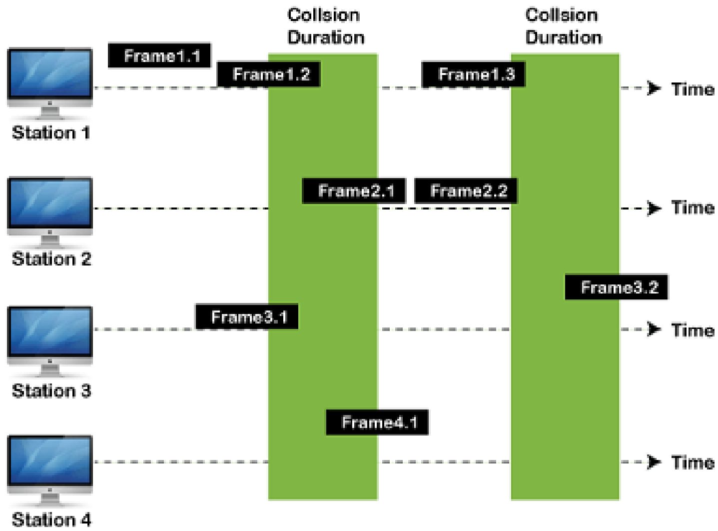
Aloha Rules

1. Any station can transmit data to a channel at any time.
2. It does not require any carrier sensing.
3. Collision and data frames may be lost during the transmission of data through multiple stations.
4. Acknowledgment of the frames exists in Aloha. Hence, there is no collision detection.
5. It requires retransmission of data after some random amount of time.



Pure Aloha

Whenever data is available for sending over a channel at stations, we use Pure Aloha. In pure Aloha, when each station transmits data to a channel without checking whether the channel is idle or not, the chances of collision may occur, and the data frame can be lost. When any station transmits the data frame to a channel, the pure Aloha waits for the receiver's acknowledgment. If it does not acknowledge the receiver end within the specified time, the station waits for a random amount of time, called the backoff time (Tb). And the station may assume the frame has been lost or destroyed. Therefore, it retransmits the frame until all the data are successfully transmitted to the receiver.

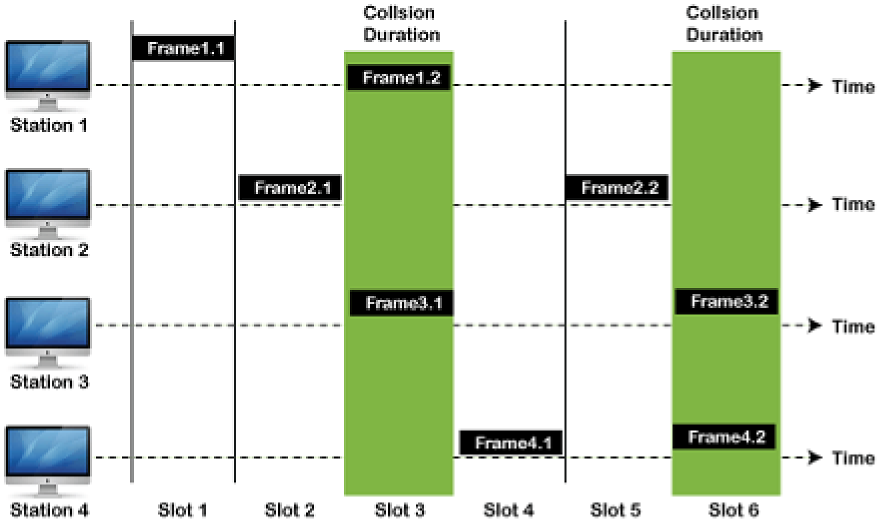


Frames in Pure ALOHA

As we can see in the figure above, there are four stations for accessing a shared channel and transmitting data frames. Some frames collide because most stations send their frames at the same time. Only two frames, frame 1.1 and frame 2.2, are successfully transmitted to the receiver end. At the same time, other frames are lost or destroyed. Whenever two frames fall on a shared channel simultaneously, collisions can occur, and both will suffer damage. If the new frame's first bit enters the channel before finishing the last bit of the second frame. Both frames are completely finished, and both stations must retransmit the data frame.

Slotted Aloha

The slotted Aloha is designed to overcome the pure Aloha's efficiency because pure Aloha has a very high possibility of frame hitting. In slotted Aloha, the shared channel is divided into a fixed time interval called slots. So that, if a station wants to send a frame to a shared channel, the frame can only be sent at the beginning of the slot, and only one frame is allowed to be sent to each slot. And if the stations are unable to send data to the beginning of the slot, the station will have to wait until the beginning of the slot for the next time. However, the possibility of a collision remains when trying to send a frame at the beginning of two or more station time slot.



Frames in Slotted ALOHA

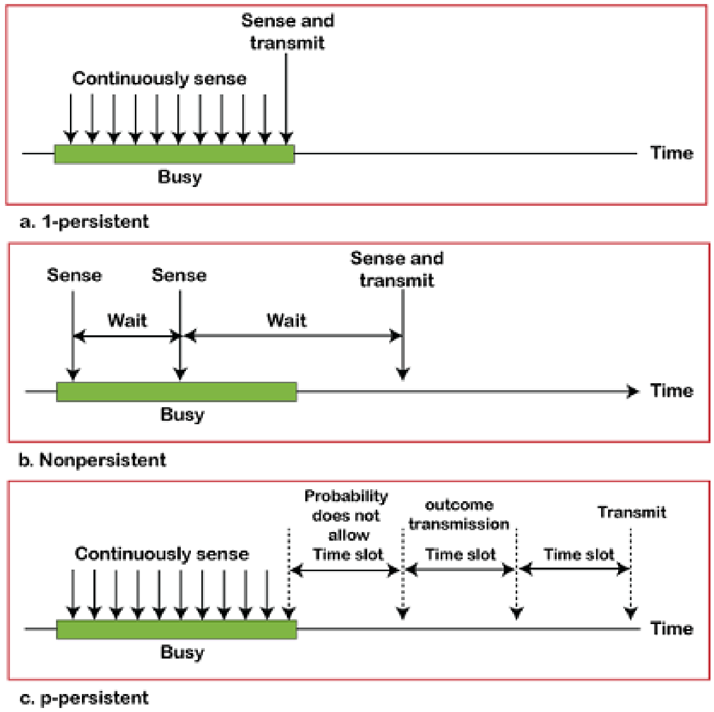
CSMA (Carrier Sense Multiple Access)

It is a carrier sense multiple access based on media access protocol to sense the traffic on a channel (idle or busy) before transmitting the data. It means that if the channel is idle, the station can send data to the channel. Otherwise, it must wait until the channel becomes idle. Hence, it reduces the chances of a collision on a transmission medium.

CSMA Access Modes

1. **Persistent:** In the 1-Persistent mode of CSMA that defines each node, first sense the shared channel and if the channel is idle, it immediately sends the data. Else it must wait and keep track of the status of the channel to be idle and broadcast the frame unconditionally as soon as the channel is idle.
2. **Non-Persistent:** It is the access mode of CSMA that defines before transmitting the data, each node must sense the channel, and if the channel is inactive, it immediately sends the data. Otherwise, the station must wait for a random time (not continuously), and when the channel is found to be idle, it transmits the frames.
3. **P-Persistent:** It is the combination of 1-Persistent and Non-persistent modes. The P-Persistent mode defines that each node senses the channel, and if the channel is inactive, it sends a frame with a P probability. If the data is not transmitted, it waits for a (q = 1-p probability) random time and resumes the frame with the next time slot.

4. **O- Persistent:** It is an O-persistent method that defines the superiority of the station before the transmission of the frame on the shared channel. If it is found that the channel is inactive, each station waits for its turn to retransmit the data.



CSMA/ CD

It is a carrier sense multiple access/ collision detection network protocol to transmit data frames. The CSMA/CD protocol works with a medium access control layer. Therefore, it first senses the shared channel before broadcasting the frames, and if the channel is idle, it transmits a frame to check whether the transmission was successful. If the frame is successfully received, the station sends another frame. If any collision is detected in the CSMA/CD, the station sends a jam/ stop signal to the shared channel to terminate data transmission. After that, it waits for a random time before sending a frame to a channel.

CSMA/ CA

It is a carrier sense multiple access/collision avoidance network protocol for carrier transmission of data frames. It is a protocol that works with a medium access control layer. When a data frame is sent to a channel, it receives an acknowledgment to check whether the channel is clear. If the station receives only a single (own) acknowledgments, that means the data frame has been successfully transmitted to the receiver. But if it gets two signals (its own and one more in which the collision of frames), a collision of the frame occurs in the shared channel. Detects the collision of the frame when a sender receives an acknowledgment signal.

Following are the methods used in the CSMA/ CA to avoid the collision:

Interframe space: In this method, the station waits for the channel to become idle, and if it gets the channel is idle, it does not immediately send the data. Instead of this, it waits for some time, and this time period is called the Interframe space or IFS. However, the IFS time is often used to define the priority of the station.

Contention window: In the Contention window, the total time is divided into different slots. When the station/ sender is ready to transmit the data frame, it chooses a random slot number of slots as wait time. If the channel is still busy, it does not restart the entire process, except that it restarts the timer only to send data packets when the channel is inactive.

Acknowledgment: In the acknowledgment method, the sender station sends the data frame to the shared channel if the acknowledgment is not received ahead of time.

B. Controlled Access Protocol

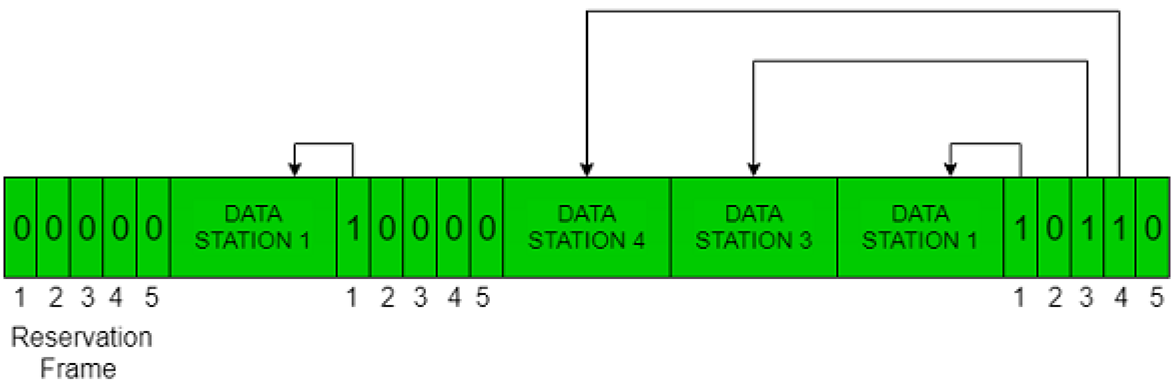
It is a method of reducing data frame collision on a shared channel. In the controlled access method, each station interacts and decides to send a data frame by a particular station approved by all other stations. It means that a single station cannot send the data frames unless all other stations are not approved. It has three types of controlled access: Reservation, Polling, and Token Passing.

Reservation

- In the reservation method, a station needs to make a reservation before sending data.
- The time line has two kinds of periods:
  1. Reservation interval of fixed time length
  2. Data transmission period of variable frames.
- If there are M stations, the reservation interval is divided into M slots, and each station has one slot.

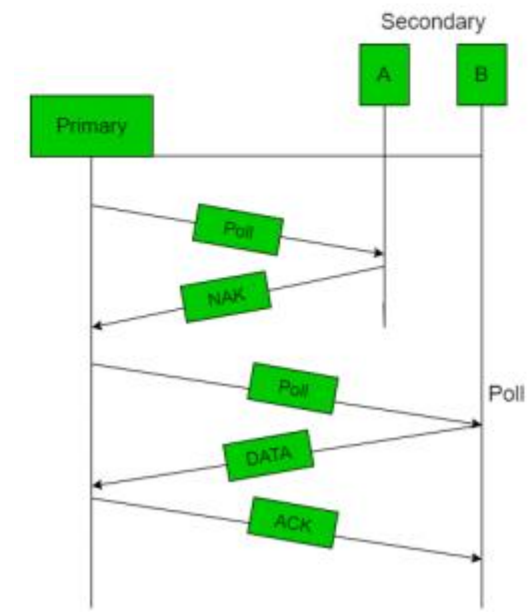
- Suppose if station 1 has a frame to send, it transmits 1 bit during the slot 1. No other station is allowed to transmit during this slot.
- In general, i th station may announce that it has a frame to send by inserting a 1 bit into i th slot. After all N slots have been checked, each station knows which stations wish to transmit.
- The stations which have reserved their slots transfer their frames in that order.
- After data transmission period, next reservation interval begins.
- Since everyone agrees on who goes next, there will never be any collisions.

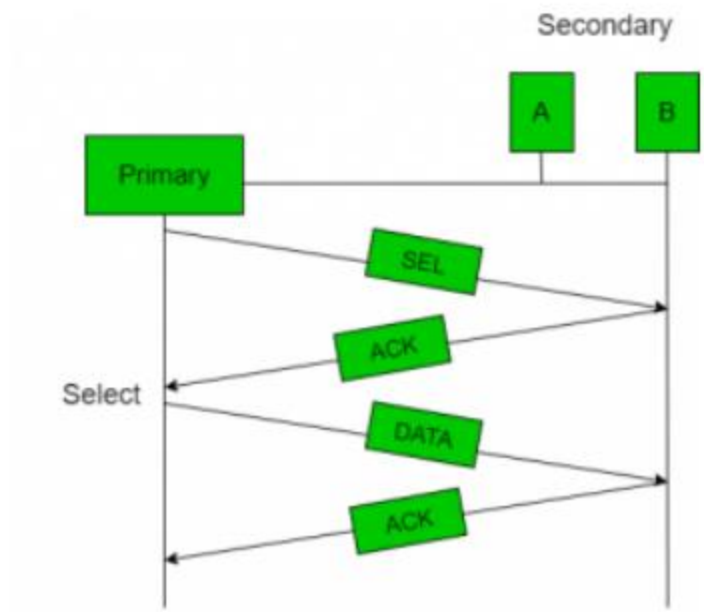
The following figure shows a situation with five stations and a five-slot reservation frame. In the first interval, only stations 1, 3, and 4 have made reservations. In the second interval, only station 1 has made a reservation.



Polling

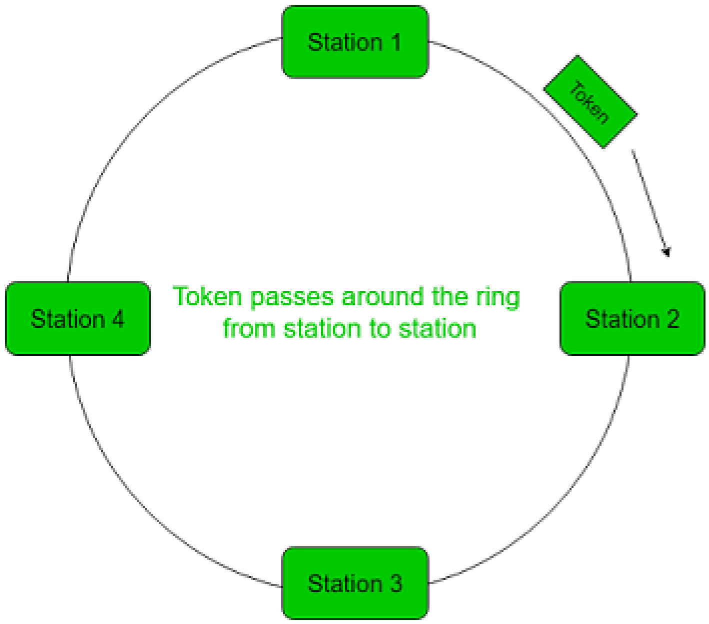
- Polling process is similar to the roll-call performed in class. Just like the teacher, a controller sends a message to each node in turn.
- In this, one acts as a primary station(controller) and the others are secondary stations. All data exchanges must be made through the controller.
- The message sent by the controller contains the address of the node being selected for granting access.
- Although all nodes receive the message but the addressed one responds to it and sends data, if any. If there is no data, usually a “poll reject”(NAK) message is sent back.
- Problems include high overhead of the polling messages and high dependence on the reliability of the controller.





Token Passing

- In token passing scheme, the stations are connected logically to each other in form of ring and access to stations is governed by tokens.
- A token is a special bit pattern or a small message, which circulate from one station to the next in some predefined order.
- In Token ring, token is passed from one station to another adjacent station in the ring whereas incase of Token bus, each station uses the bus to send the token to the next station in some predefined order.
- In both cases, token represents permission to send. If a station has a frame queued for transmission when it receives the token, it can send that frame before it passes the token to the next station. If it has no queued frame, it passes the token simply.
- After sending a frame, each station must wait for all N stations (including itself) to send the token to their neighbours and the other N – 1 stations to send a frame, if they have one.
- There exists problems like duplication of token or token is lost or insertion of new station, removal of a station, which need be tackled for correct and reliable operation of this scheme.



C. Channelization Protocols

It is a channelization protocol that allows the total usable bandwidth in a shared channel to be shared across multiple stations based on their time, distance and codes. It can access all the stations at the same time to send the data frames to the channel.

Following are the various methods to access the channel based on their time, distance and codes:

- FDMA (Frequency Division Multiple Access)
- TDMA (Time Division Multiple Access)
- CDMA (Code Division Multiple Access)
- FDMA

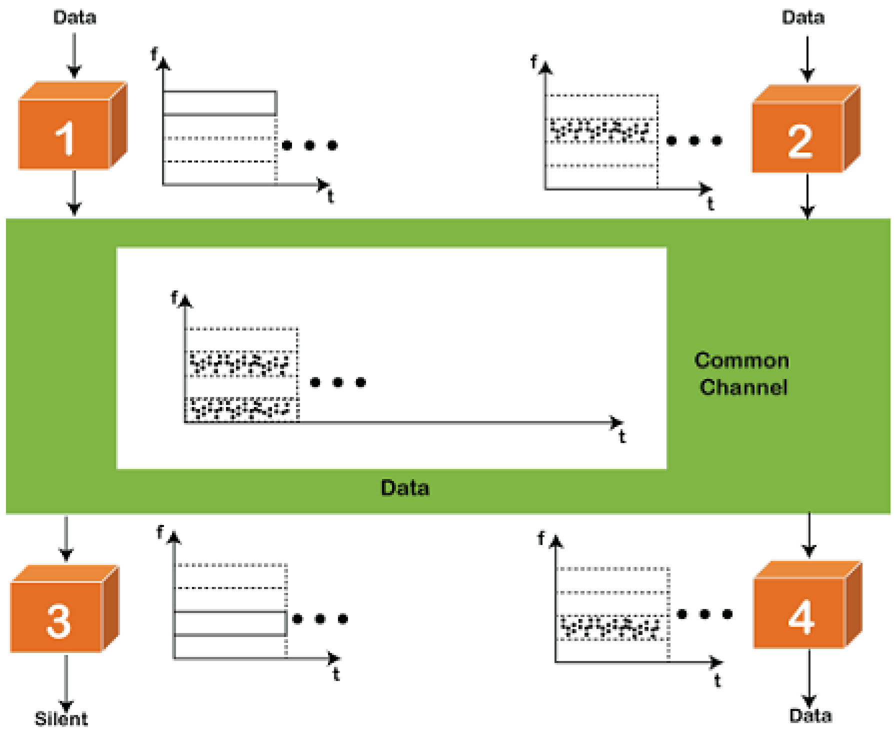
With the help of this technique, the available bandwidth is divided into frequency bands. Each station is allocated a band in order to send its data. Or in other words, we can say that each band is reserved for a specific station and it belongs to the station all the time.

Each station makes use of the bandpass filter in order to confine the frequencies of the transmitter.

In order to prevent station interferences, the allocated bands are separated from one another with the help of small guard bands.

The Frequency-division multiple access mainly specifies a predetermined frequency for the entire period of communication.

Stream of data can be easily used with the help of FDMA.



Advantages of FDMA

Given below are some of the benefits of using the FDMA technique:

- This technique is efficient when the traffic is uniformly constant.
- In case if the channel is not in use then it sits idle.
- FDMA is simple algorithmically and the complexity is less.
- For FDMA there is no restriction regarding the type of baseband or the type of modulation.

Disadvantages of FDMA

- By using FDMA, the maximum flow rate per channel is fixed and small.

2. Time-Division Multiple Access

Time-Division Multiple access is another method to access the channel for shared medium networks.

- With the help of this technique, the stations share the bandwidth of the channel in time.
- A time slot is allocated to each station during which it can send the data.
- Data is transmitted by each station in the assigned time slot.
- There is a problem in using TDMA and it is due to TDMA the synchronization cannot be achieved between the different stations.
- When using the TDMA technique then each station needs to know the beginning of its slot and the location of its slot.
- If the stations are spread over a large area, then there occur propagation delays; in order to compensate this guard, times are used.
- The data link layer in each station mainly tells its physical layer to use the allocated time slot.

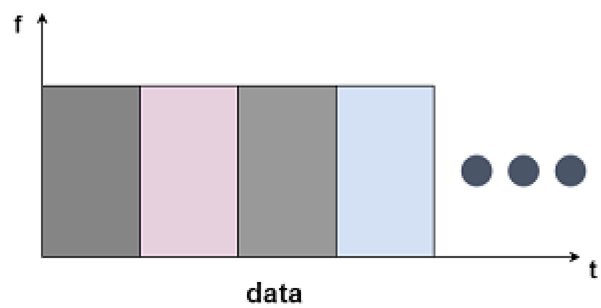


Figure: Time-Division media access.

Some examples of TDMA are as follows;

- personal digital Cellular(PDC)
- Integrated digital enhanced network.
- Universal terrestrial radio access(UTRA)

3. Code-Division Multiple Access

CDMA(code-division multiple access) is another technique used for channelization.

- CDMA technique differs from the FDMA because only one channel occupies the entire bandwidth of the link.
- The CDMA technique differs from the TDMA because all the stations can send data simultaneously as there is no timesharing.
- The CDMA technique simply means communication with different codes.

- In the CDMA technique, there is only one channel that carries all the transmission simultaneously.
- CDMA is mainly based upon the coding theory; where each station is assigned a code, Code is a sequence of numbers called chips.
- The data from the different stations can be transmitted simultaneously but using different code languages.

Advantages of CDMA

Given below are some of the advantages of using the CDMA technique:

- Provide high voice quality.
- CDMA operates at low power levels.
- The capacity of the system is higher than the TDMA and FDMA.
- CDMA is better cost-effective.

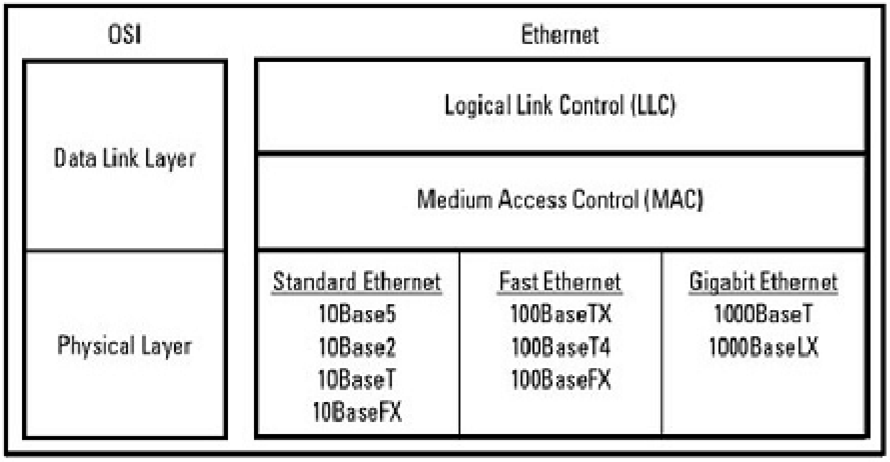
Ethernet

Ethernet is a type of communication protocol that is created at Xerox PARC in 1973 by Robert Metcalfe and others, which connects computers on a network over a wired connection. It is a widely used LAN protocol, which is also known as Alto Aloha Network. It connects computers within the local area network and wide area network. Numerous devices like printers and laptops can be connected by LAN and WAN within buildings, homes, and even small neighborhoods.

Ethernet Protocol Architecture

In the OSI network model, Ethernet protocol operates at the first two layers like the Physical & the Data Link layers but, Ethernet separates the Data Link layer into two different layers called the Logical Link Control layer & the Medium Access Control layer.

The physical layer in the network mainly focuses on the elements of hardware like repeaters, cables & network interface cards (NIC). For instance, an Ethernet network like 100BaseTX or 10BaseT indicates the cables type that can be used, the length of cables, and the optimal topology.



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 (l0 Mbps), Fast Ethernet(100 Mbps), Gigabit Ethernet (l Gbps), and Ten-Gigabit Ethernet (l0 Gbps)

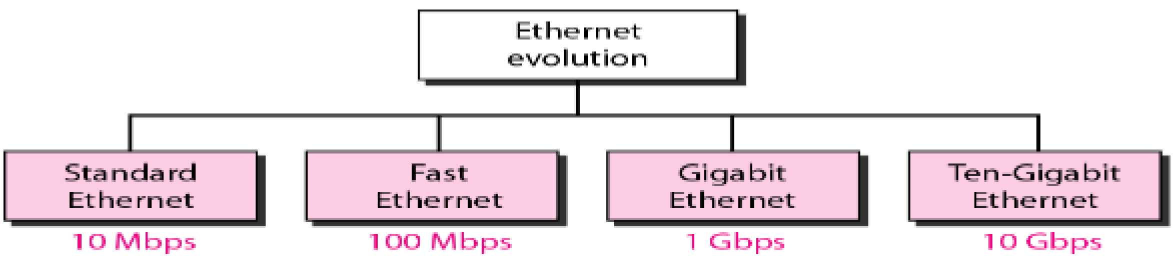


Figure: ***Ethernet evolution through four generations***

MAC Sublayer:

- MAC sublayer frames data received from the upper layer and passes them to the physical layer.

Frame Format:

- The Ethernet frame contains seven fields.
- 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

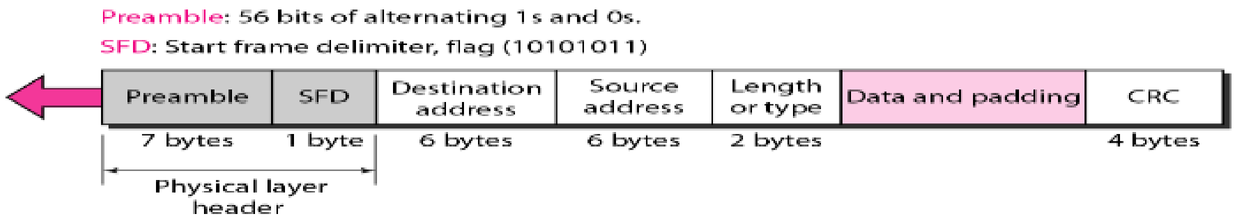
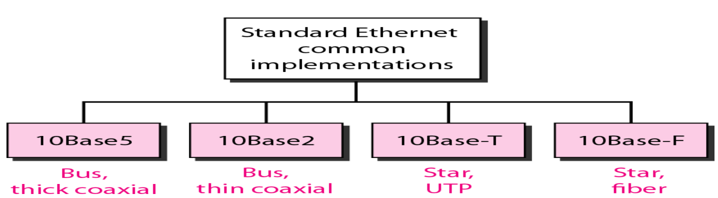


Figure: 802.3 MAC frame

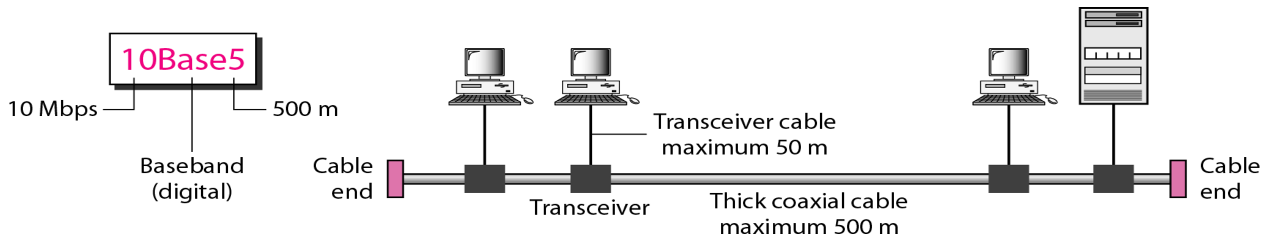
- **Preamble:** The first field of the 802.3 frame contains 7 bytes (56 bits) of alternating Os and Is that alerts the receiving system to the coming frame and enables it to synchronize its input timing.
- **Start frame delimiter (SFD):** The second field (l byte: 10101011) signals the beginning of the frame. The SFD warns the station or 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 or stations to receive the packet. We will discuss addressing shortly.
- **Source address (SA):** The SA field is also 6 bytes and contains the physical address of the sender of the packet. We will discuss addressing shortly.
- **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 bytes, as we will see later.CRC. The last field contains error detection information, in this case a CRC-32.



10Base5: Thick Ethernet:

- The first implementation is called 10Base5, thick Ethernet, or Thicknet.
- 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.

- The transceiver is responsible for transmitting, receiving, and detecting collisions. 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



10Base2:ThinEthernet

- The second implementation is called 10Base2, thin Ethernet, or Cheapernet.
- 10Base2 also uses a bus topology, but 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

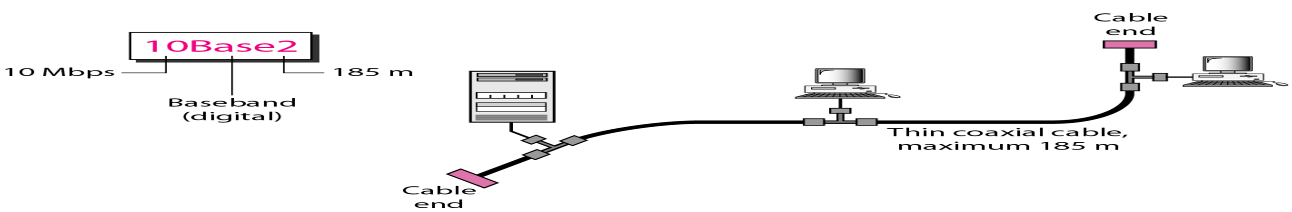
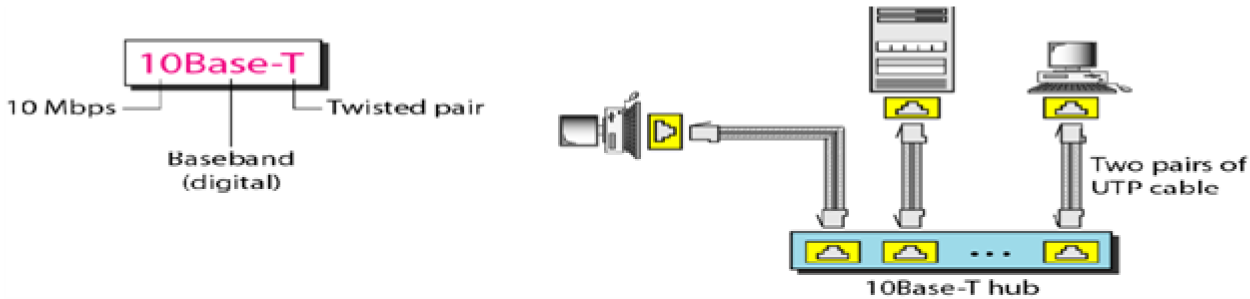


Figure: 10Base2 implementation

10Base-T: Twisted-Pair Ethernet:

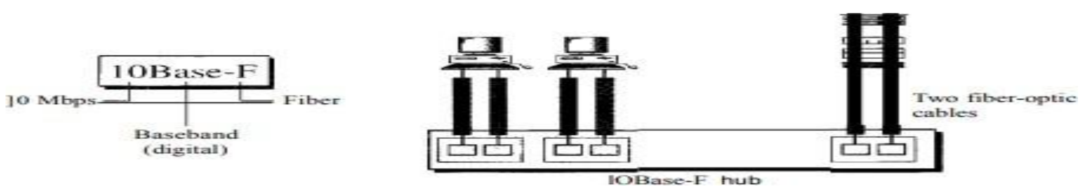
- 10 Base-T uses a physical star topology.
- Two pairs of twisted cable create two paths (one for sending and one for receiving) between the station and the hub. Any collision here happens in the hub.
- Compared to 10Base5 or 10Base2, we can see that the hub actually replaces the coaxial cable as far 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:

- 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

Characteristics	*10Base5*	*10Base2*	*10Base-T*	*10Base-F*
Media	Thick coaxial cable	Thin coaxial cable	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m
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 fasterat a rate of 100 Mbps.

Goals of Fast Ethernet:

- 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.

MAC Sublayer:

- Main consideration in the evolution of Ethernet from 10 to 100 Mbps was to keep the MAC sublayer untouched.
- **Drop 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

  Half- duplex approach:

  - The stations are connected via a hub.
  - The access method is CSMA/CD

  Full-duplex approach

  - The connection is made via a switch with buffers at each port.
  - No need for CSMA/CD

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:
  1. 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).
  2. To allow one device to have multiple capabilities.
  3. 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.

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.

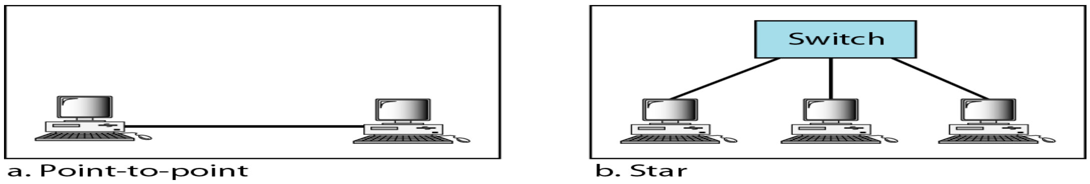


Figure: Fast Ethernet topology

Fast Ethernet Implementations:

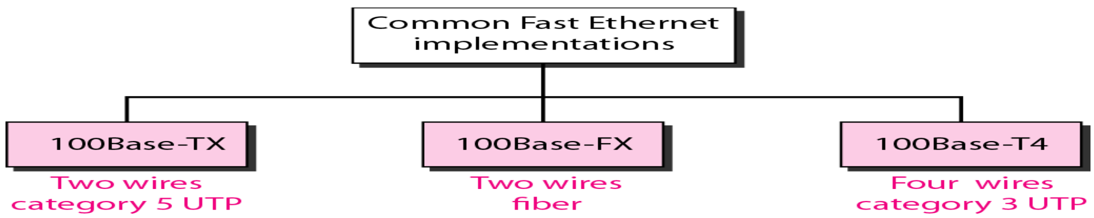


Figure: Fast Ethernet implementations

100Base-TX:

- ➢ It uses two pairs of twisted-pair cable (either category 5 UTP or STP(Shielded twisted pair).
- ➢ For this implementation, the MLT-3(Multi Level Transmit) scheme was selected since it has good bandwidth performance.
- ➢ 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.
- ➢ Uses NRZ-I(Non-Return-to-Zero Inverted) encoding scheme (bit synchronization problem.)
- ➢ To overcome this problem, 4B/5B block coding is used.

- A 100Base-TX network can provide a data rate of 100 Mbps, but it requires the use of category 5UTP or STP cable. It is cost effective.

100Base-T4:

- Uses four pairs of category 3 or higher UTP.(not cost efficient compared to Category 5)
- Transmit 100 Mbps.
- Uses 8B/6T encoding

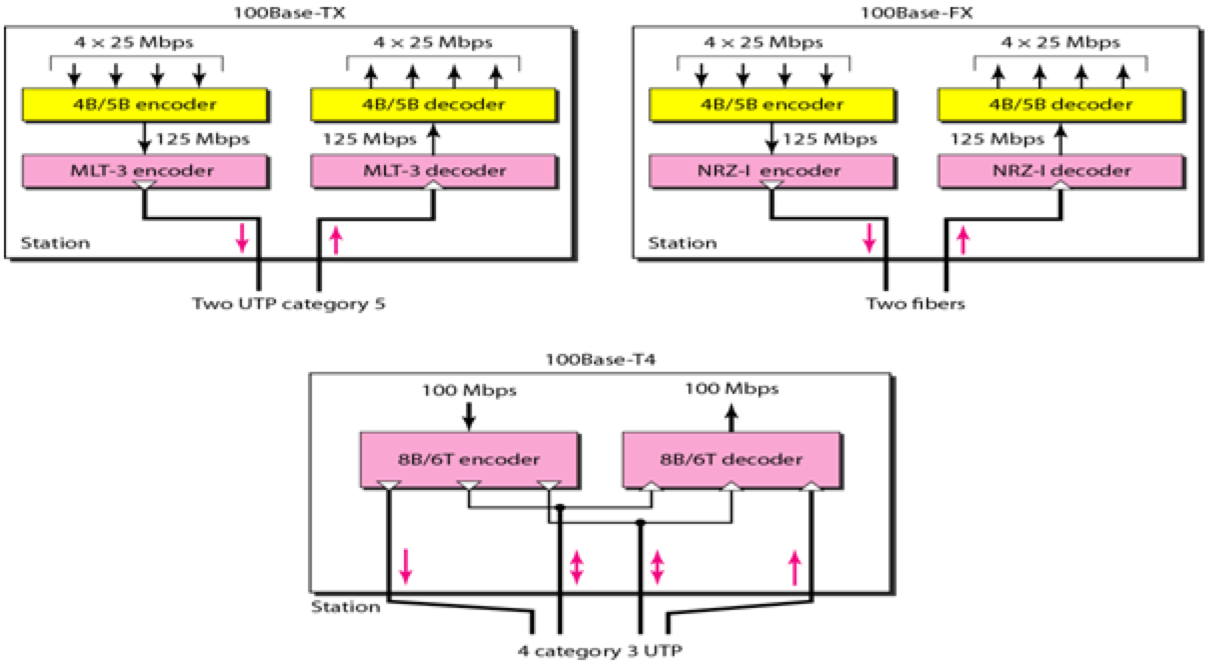


Figure: Encoding for Fast Ethernet implementation

Table for Summary for Fast Ethernet Implementations

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	100m	100m	100m
Block encoding	4B/5B	4B/5B	
Line encoding	MLT-3	NRZ-I	8B/6T

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:

Goals of gigabit Ethernet:

- 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 autonegotiation as defined in Fast Ethernet.

MAC Sublayer:-

A main consideration in the evolution of Ethernet was to keep the MAC sublayer untouched. However, to achieve a data rate 1 Gbps, this was no longer possible.

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, as we discussed before. 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. 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.

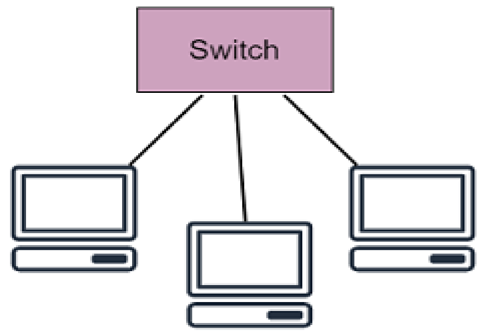
Physical Layer

The physical layer in Gigabit Ethernet is more complicated than that in Standard or Fast Ethernet. We briefly discuss some features of this layer.

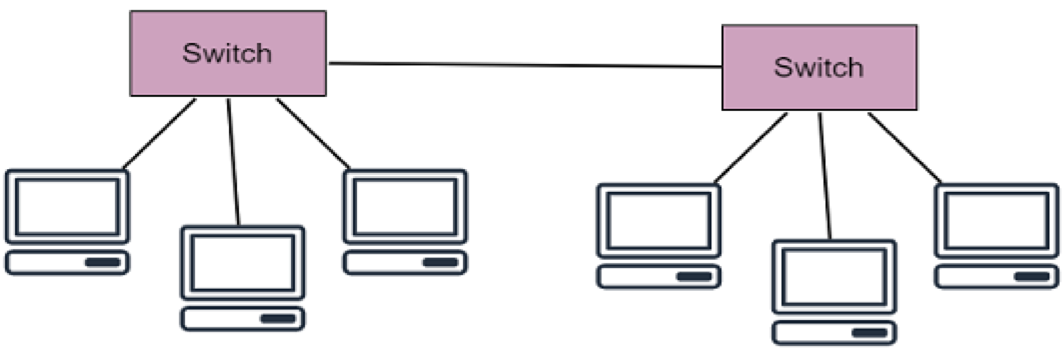
Topology:-

Gigabit Ethernet is designed to connect two or more stations

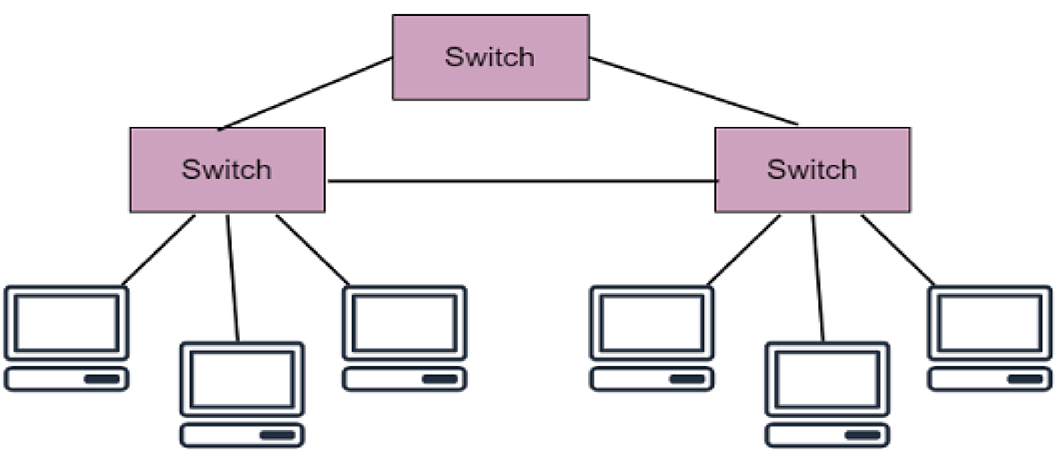
a. Point-to Point



b. Star



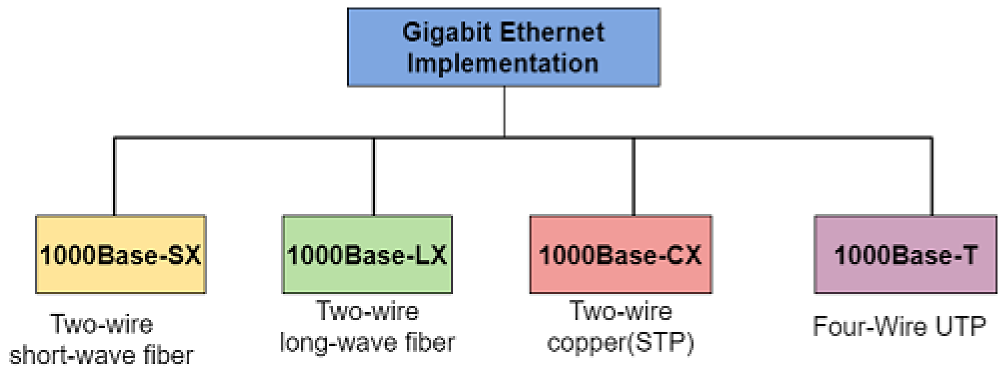
c.Two stars



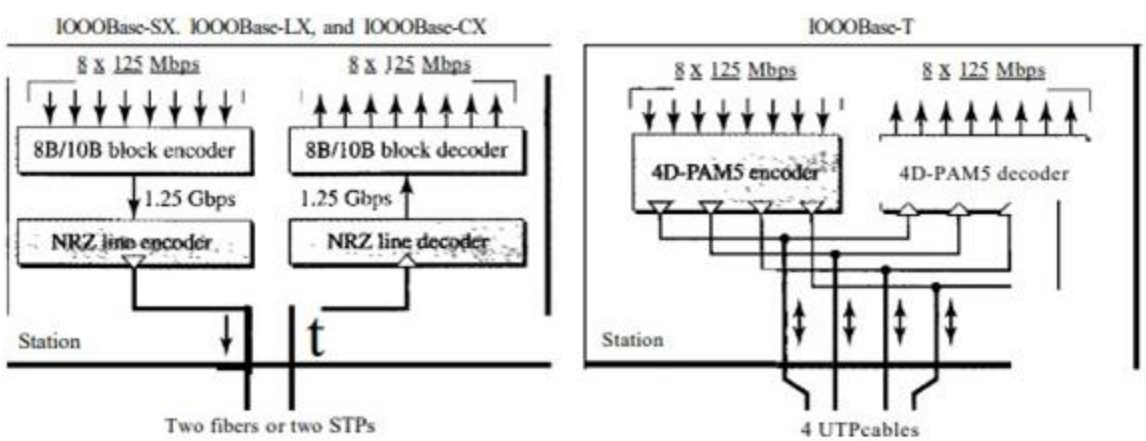
d.Hierachy of Stars

Implementation

Gigabit Ethernet can be categorized as either a two-wire or a four-wire implementation. The two-wire implementations use fiber-optic cable (1000 Base-SX, short-wave, or l000 Base-LX, long-wave), or STP (1000Base-CX). The four-wire version uses category 5 twisted-pair cable (l000 Base-T). In other words, we have four implementations. lOOOBase-T was designed in response to those users who had already installed this wiring for other purposes such as Fast Ethernet or telephone services



Encoding in Gigabit Implementations



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, 8BIl OB block encoding, discussed in Chapter 4, is used. This block encoding prevents long sequences of Os or Is in the stream, because each wire would need to carry 500 Mbps, which exceeds the capacity for category 5 UTP. As a solution, 4D-PAM5 encoding, as discussed in Chapter 4, 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.

Summary

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 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:

- 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 .

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: l0GBase-S, l0GBase-L, and l0GBase-E.

Table shows a summary of the Ten-Gigabit Ethernet implementations.

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