Unit-3

Multiplexing and Switching

Multiplexing is a technique used to combine and send the multiple data streams over a single medium. The process of combining the data streams is known as multiplexing and hardware used for multiplexing is known as a multiplexer. Multiplexing technique is widely used in telecommunications in which several telephone calls are carried through a single wire. Multiplexing originated in telegraphy in the early 1870s and is now widely used in communication. George Owen Squier developed the **telephone carrier multiplexing** in 1910.

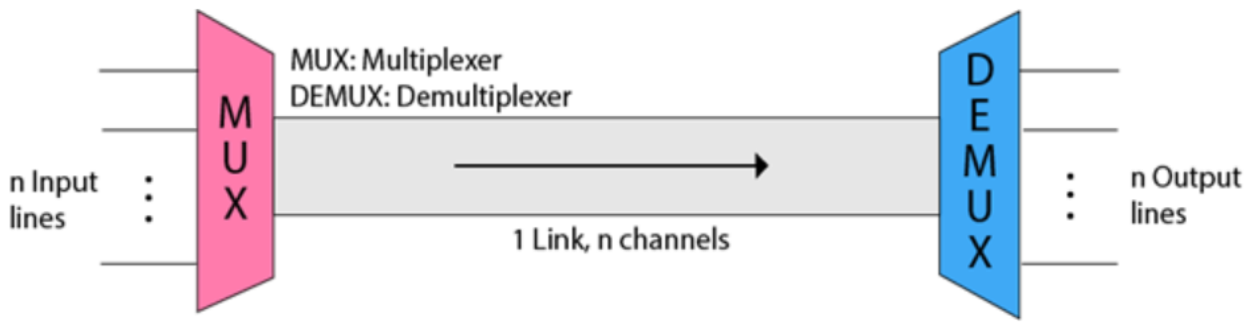


Figure: Concept of multiplexing

Multiplexing is achieved by using a device called Multiplexer (**MUX**) that combines n input lines to generate a single output line. Multiplexing follows many-to-one, i.e., n input lines and one output line.

Demultiplexing is achieved by using a device called Demultiplexer (**DEMUX**) available at the receiving end. DEMUX separates a signal into its component signals (one input and n outputs). Therefore, we can say that demultiplexing follows the one-to-many approach.

Why multiplexing?

- The transmission medium is used to send the signal from sender to receiver. The medium can only have one signal at a time.
- If there are multiple signals to share one medium, then the medium must be divided in such a way that each signal is given some portion of the available bandwidth. For example: If there are 10 signals and bandwidth of medium is100 units, then the 10 unit is shared by each signal.
- When multiple signals share the common medium, there is a possibility of collision. Multiplexing concept is used to avoid such collision.
- Transmission services are very expensive.

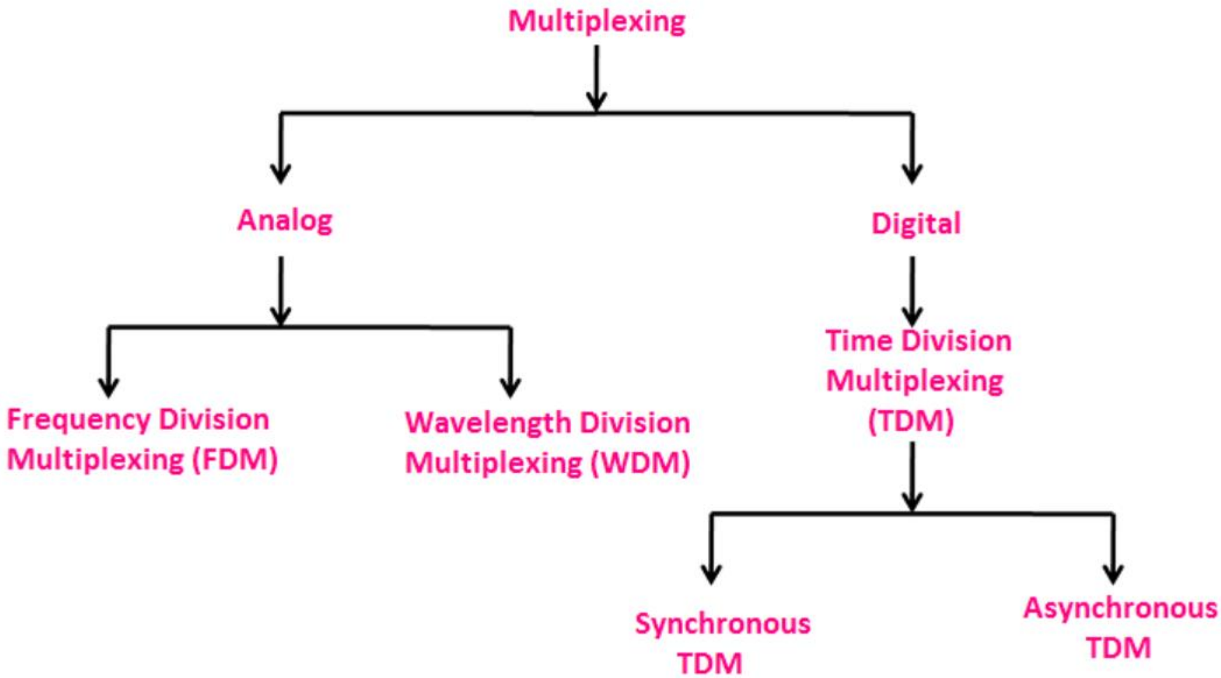


Figure: Types of Multiplexing

Analog multiplexing

The process of combining multiple analog signals into one signal is called analog multiplexing. It multiplexes the analog signals according to their frequency or wavelength.

Multiplexing requires that the multiple signals be kept apart so that they do not overlap with each other and thus can be separated at the receiving end. This can be achieved by separating the signal in frequency.

There are two types of analog multiplexing:

- Frequency division multiplexing
- Wavelength division multiplexing

Frequency division multiplexing

Frequency division multiplexing is an analog technique. It is the most popular multiplexing technique. We use this technique extensively in TV and radio transmission. This technique combines multiple signals into one signal and transmitted over the communication channel. Frequency division multiplexing is also known as FDM.

In this technique, the bandwidth of the communication channel should be greater than the combined bandwidth of individual signals.

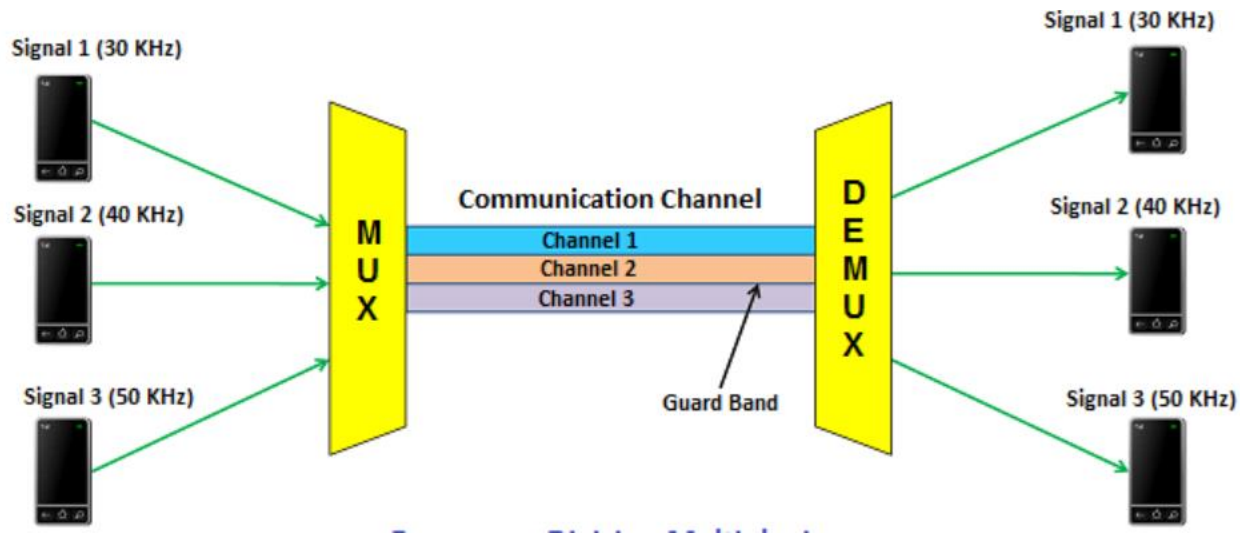


Figure: Frequency Division Multiplexing

The frequency division multiplexing divides the bandwidth of a channel into several logical sub-channels. Each logical sub-channel is allotted for a different signal frequency. The individual signals are filtered and then modulated (frequency is shifted), in order to fit exactly into logical sub-channels.

In this technique, each logical sub-channel (individual signal frequency) is allotted to each user. In other words, each user owns a sub-channel.

Each logical sub-channel is separated by an unused bandwidth called Guard Band to prevent overlapping of signals. In other words, there exists a frequency gap between two adjacent signals to prevent signal overlapping. A guard band is a narrow frequency range that separates two signal frequencies.

How FDM System works

The below figure shows the schematic diagram of an FDM system. The transmitter end contains multiple transmitters and the receiver end contains multiple receivers. The communication channel is present between the transmitter and receiver.

At transmitter end, each transmitter sends a signal of different frequency. In the below figure, the transmitter 1 sends a signal of 30 kHz, transmitter 2 sends a signal of 40 kHz, and transmitter 3 sends a signal of 50 kHz. These signals of different frequencies are then multiplexed or combined by using a device called multiplexer. It then transmits the multiplexed signals over a communication channel.

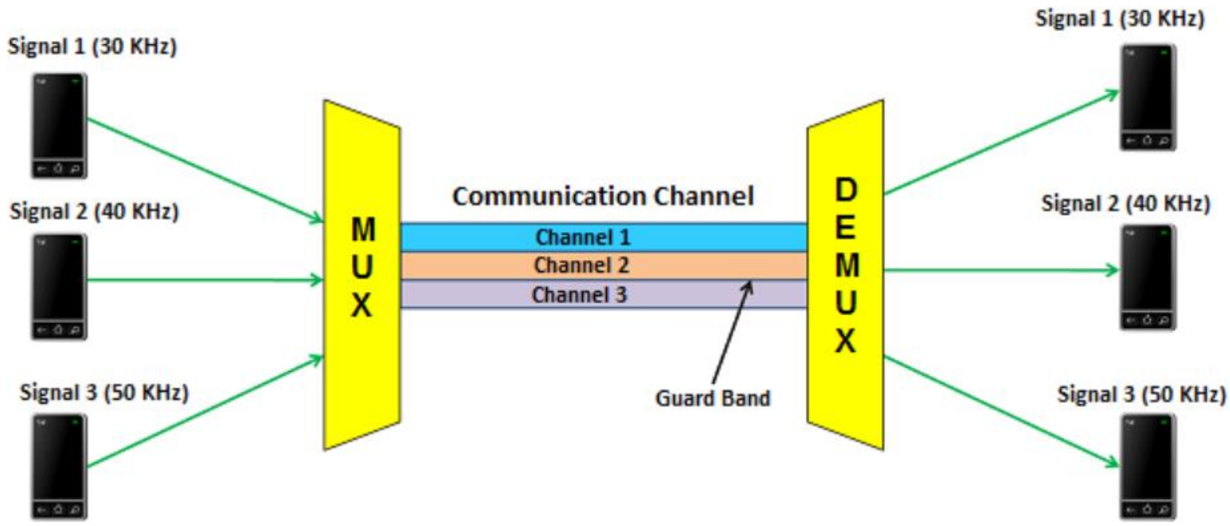


Figure: Frequency division multiplexing

At the receiver end, the multiplexed signals are separated by using a device called demultiplexer. It then sends the separated signals to the respective receivers. In the above figure, the receiver 1 receives signal of 30 kHz, receiver 2 receives signal of 40 kHz, and receiver 3 receives signal of 50 kHz.

Advantages of FDM

- It transmits multiple signals simultaneously.
- In frequency division multiplexing, the demodulation process is easy.
- It does not need Synchronization between transmitter and receiver.

Disadvantages of FDM

- FDM technique is used only when low-speed channels are required.
- It suffers the problem of crosstalk.
- A Large number of modulators are required.
- It requires a high bandwidth channel

Applications of FDM

- FDM is commonly used in TV networks.
- It is used in FM and AM broadcasting. Each FM radio station has different frequencies, and they are multiplexed to form a composite signal. The multiplexed signal is transmitted in the air.

Wavelength multiplexing

Wavelength division multiplexing is an analog technique. It is the most important and most popular method to increase the capacity of an optical fiber. We know that wavelength and frequency are inversely proportional to each other (I.e. longer wavelength means low frequency and shorter wavelength means high frequency). Therefore, the working principle of wavelength division multiplexing is similar to frequency division multiplexing. The only difference is in wavelength division multiplexing optical signals are used instead of electrical signals. In wavelength division multiplexing, optical signals are transmitted through fiber optic cables.

Wavelength division multiplexing is a technology in which multiple optical signals (laser light) of different wavelengths or colors are combined into one signal and is transmitted over the communication channel. Thus multiple signals are transmitted simultaneously over a single communication channel.

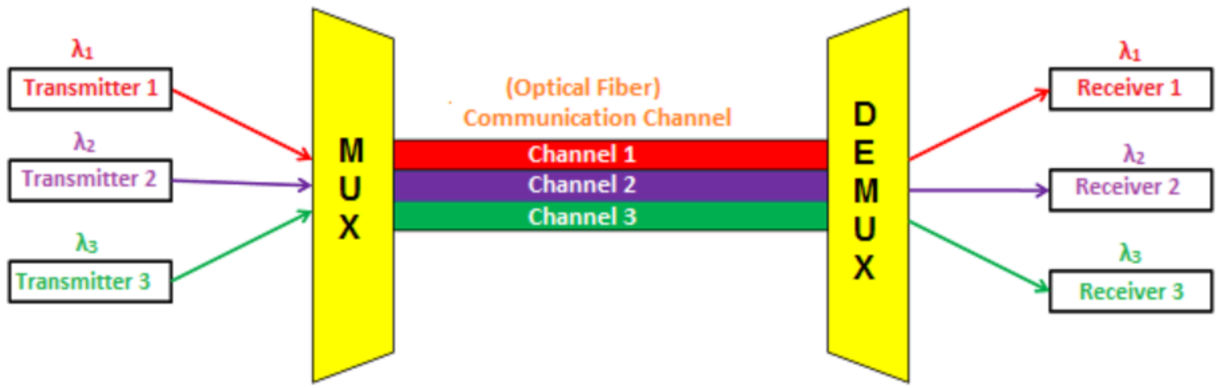


Figure: Wavelength Division Multiplexing

In wavelength division multiplexing, the communication channel is a fiber optic cable. Wavelength division multiplexing is also known as WDM. A demultiplexer at the receiver end separates the optical signal wavelengths or colors.

In this technique, the bandwidth of the communication channel should be greater than the combined bandwidth of individual signals.

The wavelength division multiplexing divides the bandwidth of a channel into several logical sub-channels according to its wavelength. It allots each logical sub-channel for a different light color or optical signal wavelength. The individual signals are filtered and then modulated (wavelength is shifted), to fit exactly into logical sub-channels.

In this technique, each logical sub-channel (individual signal wavelength) is allotted to each user. In other words, each user owns a sub-channel.

The main advantage of WDM system is that you only need to upgrade the multiplexer and demultiplexer at each end; you no need to buy more fibers which are more expensive.

Wavelength division multiplexing enables bi-directional communication and multiplication of optical signal capacity.

How WDM Works

The transmitter end contains multiple optical transmitters and the receiver end contains multiple optical receivers. The communication channel (optical fiber) is present between the transmitter and receiver. It is used to utilize the high data rate capability of fibre optic cable.

Optical signals from different source are combined to form a wider band of light with the help of multiplexer. At the receiving end, demultiplexer separates the signals to transmit them to their respective destinations. Multiplexing and Demultiplexing can be achieved by using a prism.

Prism can perform a role of multiplexer by combining the various optical signals to form a composite signal, and the composite signal is transmitted through a fibre optical cable.

At transmitter end, each transmitter sends an optical signal of different wavelength or color. These optical signals of different wavelengths or colors are then multiplexed or combined by using a device called multiplexer.

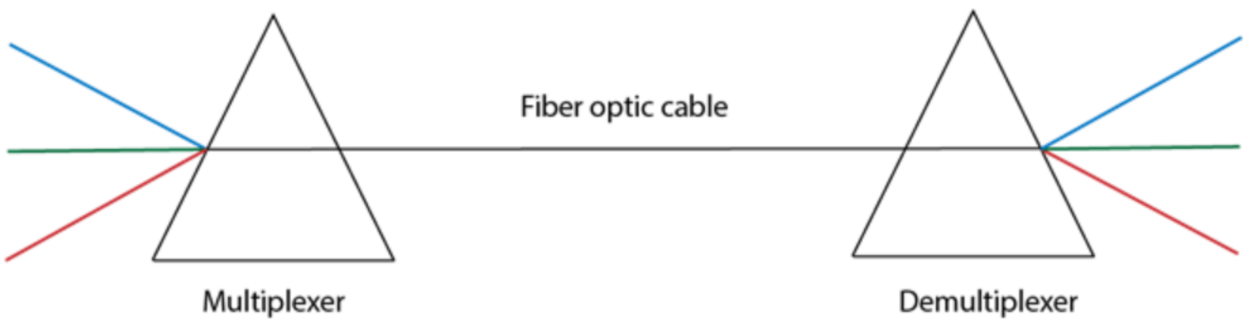


Figure: Wavelength Division Multiplexing

The multiplexed signals are then transmitted over a single communication channel (optical fiber). In between the transmitter and receiver, optical amplifiers are used to compensate the optical signal loss caused during the transmission.

At the receiver end, the multiplexed signals are separated by using a device called demultiplexer. The separated signals are then sent to the respective receivers.

Advantages of Wavelength Division Multiplexing

- WDM allows transmission of data in two directions simultaneously
- Low cost
- Greater transmission capacity
- High security
- Long distance communication with low signal loss

Digital Multiplexing

The process of combining multiple digital signals into one signal is called digital multiplexing.

Time division multiplexing

Time Division Multiplexing is a technique in which multiple signals are combined and transmitted one after another on the same communication channel.

At the receiver side, the signals are separated and received. Each signal is received by a user at a different time.

Time Division Multiplexing is also simply referred to as TDM. It is the digital multiplexing technique.

In frequency division multiplexing, all signals of different frequencies are transmitted simultaneously. But in time division multiplexing, all signals operate with the same frequency are transmitted at different times.

In frequency division multiplexing, the sharing of a channel is done on the basis of frequency. But in time division multiplexing, the sharing of a channel is done on the basis of time.

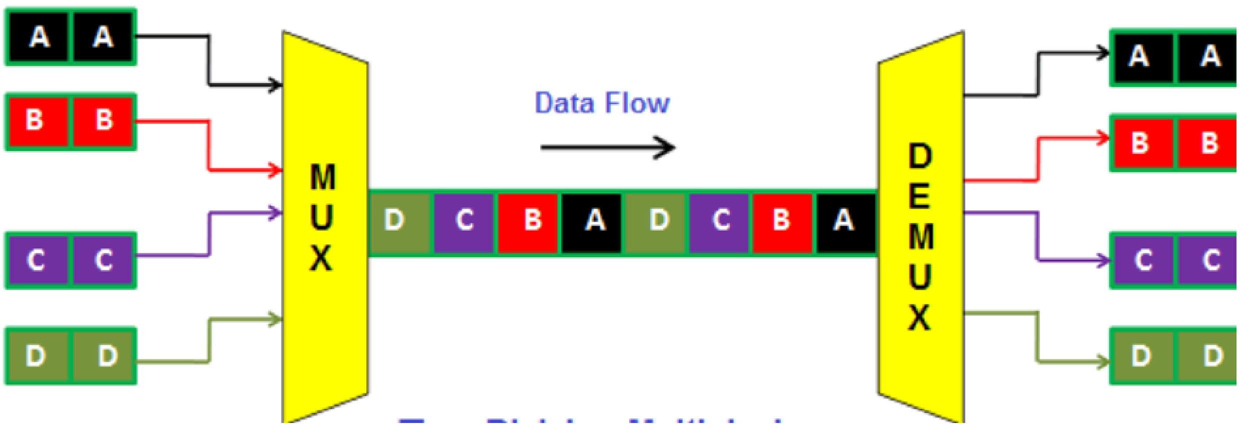


Figure: Time Division Multiplexing

In time division multiplexing, each user is allotted a particular time interval called time slot during which data is transmitted. The time interval (time slot) allotted to each receiver (user) is so small that the receiver will not detect that some time was used to serve another receiver (user).

In time division multiplexing, all signals are not transmitted simultaneously; instead, they are transmitted one after another. For example, as shown in the above figure, at first, we send signal A. Then after second signal B and then after third signal C and finally, we send last signal D. Thus, each user occupies an entire bandwidth for a short period of time.

The time division multiplexing technique is used to multiplex analog signals or digital signals. However, the time division multiplexing is more suitable for digital signal multiplexing.

In time division multiplexing, the bandwidth capacity of the communication channel should be greater than the multiple input signals.

Types of TDM

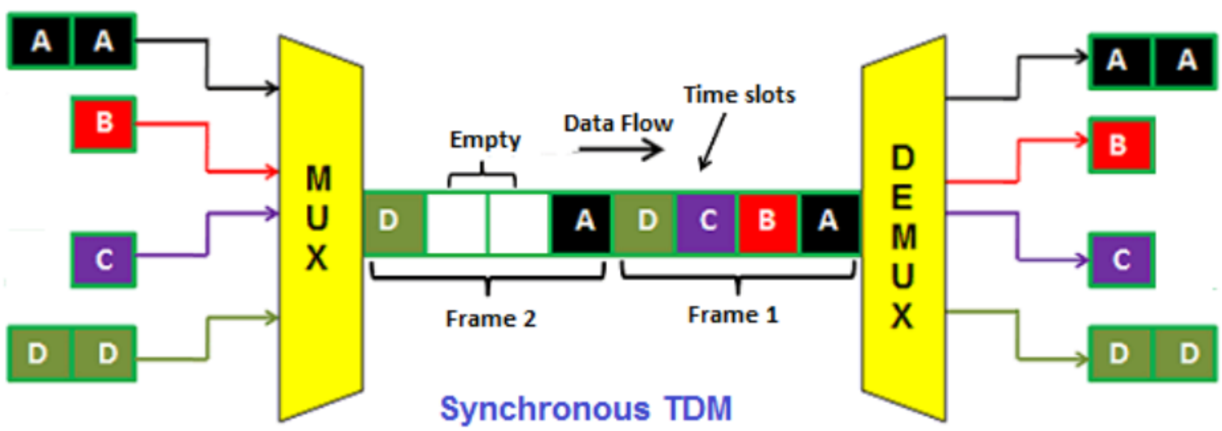
Time Division Multiplexing is mainly classified into two types:

- Synchronous TDM (Time Division Multiplexing)
- Asynchronous TDM (Time Division Multiplexing)

Synchronous TDM

In synchronous time division multiplexing, each device (transmitter) is allotted with a fixed time slot, regardless of the fact that the device (transmitter) has any data to transmit or not. The device has to transmit data within this time slot. If the device (transmitter) does not have any data to send then its time slot remains empty.

As shown in the below figure, the various time slots are arranged into frames and each frame consists of one or more time slots dedicated to each device (transmitter). For example, if there are 3 devices, there will be 3 slots in each frame. Similarly, if there are 5 devices, there will be 5 slots in each frame.



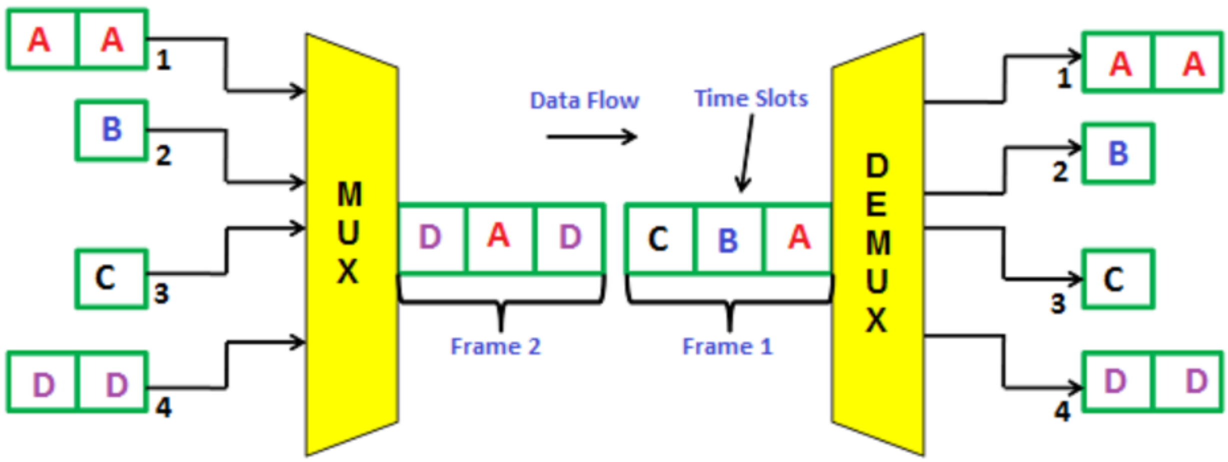
The above figure shows 4 devices (transmitter A, transmitter B, transmitter C, and transmitter D) that have 4 dedicated time slots (time slot A, time slot B, time slot C and time slot D). The transmitter A data is sent at time slot A, transmitter B data is sent at time slot B, transmitter C data is sent at time slot C and transmitter D data is sent at time slot D. In the time frame 2, the transmitter B and C does not have any data to send so the time slot B and C remains empty.

The main drawback of synchronous time division multiplexing is that the channel capacity is not fully utilized. Hence, the bandwidth goes wasted.

Asynchronous TDM

In Asynchronous time division multiplexing, the time slots are not fixed (I.e. time slots are flexible). The asynchronous TDM is also known as statistical time division multiplexing.

In synchronous TDM, the number of time slots is equal to the number of devices (transmitters). But in Asynchronous TDM, the number of time slots is not equal to the number of devices (transmitters). The time slots in asynchronous TDM are always less than the number of devices (transmitter). For example, if we have X devices and Y time slots. Y should always be less than X (I.e. Y < X).



Asynchronous TDM

In asynchronous time division multiplexing, time slots are not fixed to a particular device; instead, they are allotted to any of the devices that have data to send.

In the above figure, it is shown that the number of devices are 4 and time slots are 3. The timeframe 1 (all slots) is completely filled with data from devices A, B, and C. The timeframe 1 has only 3 time-slots. So the data from device D is filled in the next timeframe (I.e. timeframe 2) in timeslot 1. The data from devices A and D will be filled in timeslots 2 and 3 in timeframe 2.

In asynchronous time division multiplexing, the multiplexer scans all the devices (transmitters) and accepts input only from the devices that have actual data to send and fills all the frames, and then sends it to the receiver.

If there is not enough data to fill all the slots in a frame, then the partially filled frames are transmitted. In most of the cases, all the time slots in frames are completely filled.

Advantages of TDM

1. Full bandwidth is utilized by a user at a particular time.
2. The time division multiplexing technique is more flexible than frequency division multiplexing.
3. In time division multiplexing, the problem of crosstalk is very less.

Disadvantages of TDM

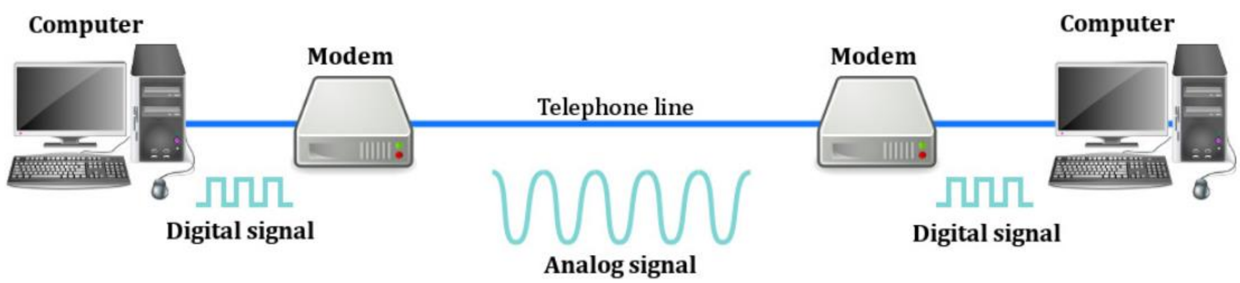
- In time division multiplexing, synchronization is required.

Difference between FDM and TDM

FDM	TDM
1. Each sending device produces signals which modulate at distinct carrier frequencies.	1. Each frame consists of a set of time slots, and portions of each source is assigned a time slot per frame.
2. It is preferred for analog signal.	2. It is preferred for digital signal.
3. Synchronization is not required	3. Synchronization is required.
4. FDM circuitry is very complex.	4. TDM circuitry is very simple to build.
5. FDM suffers from the Cross Talk immunity due to band pass filter.	5. TDM is not sensitive for Cross Talk (Noise immunity)
6. FDM requires guard band for its operations.	6. TDM requires syn pulse for its operations
7. FDM is less efficient compared to TDM.	7. TDM is more efficient and widely used technique in multiplexing.
8. FDM is used in TV and radio broadcasting.	8. TDM is used in pulse code modulation.

Modem

A modem is a hardware networking device that converts data to a signal so it can be easily sent and received over a phone line, cable, or satellite connection. Computer information is stored digitally, whereas information transmitted over telephone lines is transmitted in the form of analog waves. A modem converts between these two forms.



Modulation

Modulation is the process by which carrier signal varies in accordance with the message signal. Modulation technique is used to change the signal characteristics. Modulation enables the transfer of information on an electrical signal to a receiving device that demodulates the signal to extract the blended information.

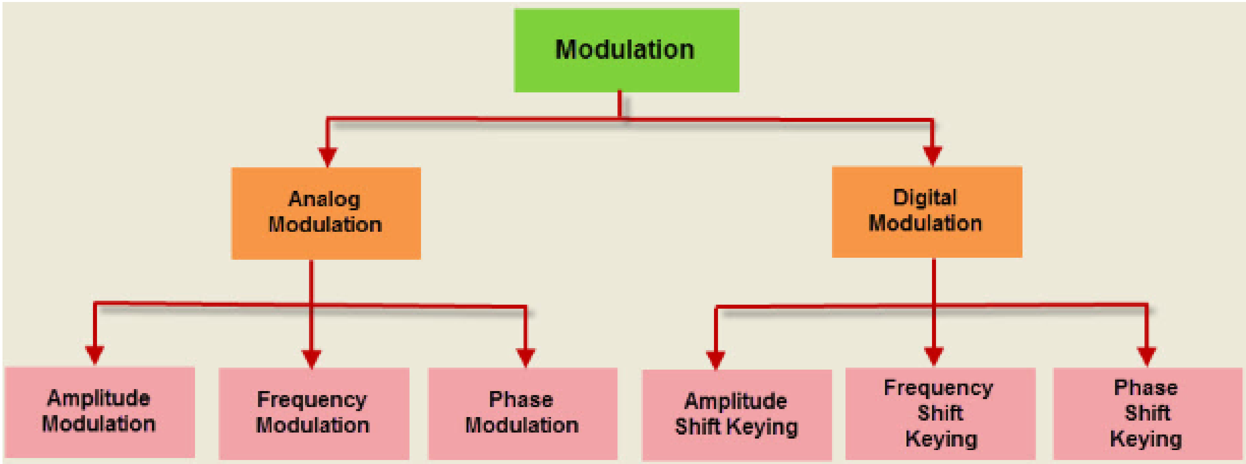


Figure: Types of modulation

Analog Modulation

In analog modulation, analog signal (sinusoidal signal) is used as a carrier signal that modulates the message signal or data signal. The general function Sinusoidal wave's is shown in the figure below, in which, three parameters can be altered to get modulation – they are amplitude, frequency and phase; so, the types of analog modulation are:

- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Phase Modulation (PM

Amplitude Modulation (AM)

In the amplitude modulation, amplitude of carrier signal wave is varied in accordance with the modulating or message signal by keeping the phase and frequency of the signals constant. The carrier signal frequency would be greater than the modulating signal frequency. Amplitude modulation is first type of modulation used for transmitting messages for long distances by the mankind. The AM radio ranges in between 535 to 1705 kHz which is great. But when compared to frequency modulation, the Amplitude modulation is weak, but still it is used for transmitting messages. Bandwidth of amplitude modulation should be twice the frequency of modulating signal or message signal. If the modulating signal frequency is 10 kHz then the Amplitude modulation frequency should be around 20 kHz. In AM radio broadcasting, the modulating signal or message signal is 15 kHz. Hence the AM modulated signal which is used for broadcasting should be 30 kHz.

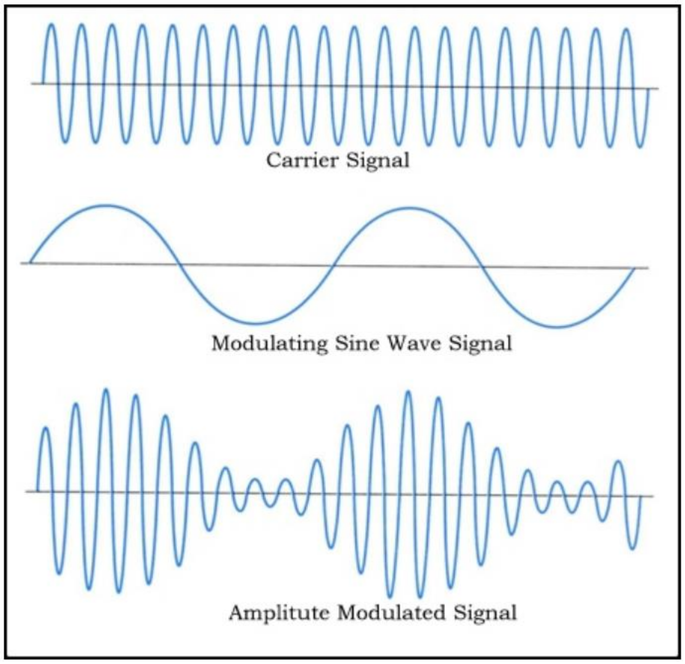


Figure: Amplitude modulation

Advantages

- Because of amplitude modulation wavelength, AM signals can propagate longer distances.
- For amplitude modulation, we use simple and low cost circuit; we don't need any special equipment and complex circuits that are used in frequency modulation.
- The Amplitude modulation receiver will be wider when compared to the FM receiver. Because, atmospheric propagation is good for amplitude modulated signals.
- Bandwidths limit is also big advantage for Amplitude modulation, which doesn't have in frequency modulation.
- Transmitter and receiver are simple in Amplitude modulation. When we take a demodulation unit of AM receiver, it consists of RC filter and a diode which will demodulate the message signal or modulating signal from modulated AM signal, which is unlike in Frequency modulation.
- Zero crossing in Amplitude modulation is equidistant.

Disadvantages

- Adding of noise for amplitude modulated signal will be more when compared to frequency modulated signals. Data loss is also more in amplitude modulation due to noise addition. Demodulators cannot reproduce the exact message signal or modulating signal due to noise.
- More power is required during modulation because Amplitude modulated signal frequency should be double than modulating signal or message signal frequency. Due to this reason more power is required for amplitude modulation.

- Sidebands are also transmitted during the transmission of carrier signal. More chances of getting different signal interfaces and adding of noise is more when compared to frequency modulation. Noise addition and signal interferences are less for frequency modulation. That is why Amplitude modulation is not used for broadcasting songs or music.

Applications

- Used to carry message signals in early telephone lines.
- Used in Navy and Aviation for communications as AM signals can travel longer distances.
- Widely used in amateur radio.

Frequency Modulation (FM)

The process of carrier signal frequency is varied according to the message signal or modulation signal frequency by keeping the amplitude constant is called frequency modulation.

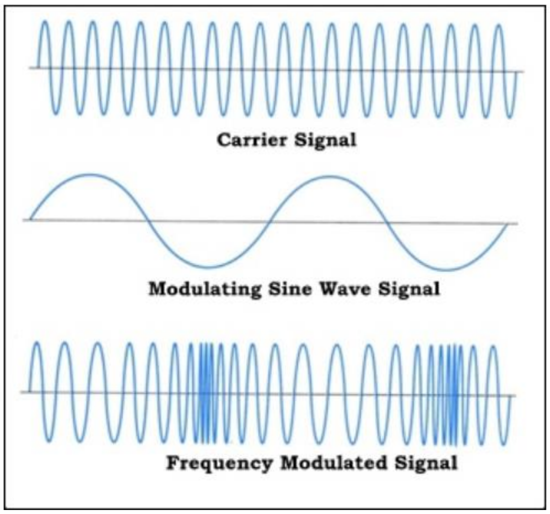


Figure: Frequency Modulation

Advantages

- Frequency modulation has more noise resistivity when compared to other modulation techniques. That's why they are mainly used in broadcasting and radio communications. And we are all well aware that radio communication use mainly frequency modulation for transmission. We know that noise will occur mainly to the amplitude of the signal. In frequency modulation, amplitude is made constant and only frequency is varied, so we can easily find out the noise in the amplitude by using a limiter.
- The frequency modulation is having greater resistance to rapid signal strength variation, which we will use in FM radios even while we are travelling and frequency modulation is also mainly used in mobile communication purposes.
- For transmitting messages in frequency modulation, it does not require special equipment's like linear amplifiers or repeaters and transmission levels or higher when compared to other

modulation techniques. It does not require any class C or B amplifiers for increasing the efficiency.

- Transmission rate is good for frequency modulation when compared to other modulation that is frequency modulation can transmit around 1200 to 2400 bits per second.
- Frequency modulation has a special effect called capture effect in which high frequency signal will capture the channel and discard the low frequency or weak signals from interference.

Disadvantages

- In the transmission section, we don’t need any special equipment but in the reception, we need more complicated demodulators for demodulating the carrier signal from message or modulating signal.
- Frequency modulation cannot be used to find out the speed and velocity of a moving object. Static interferences are more when compared to phase modulation. Outside interference is one of the biggest disadvantages in the frequency modulation. There may be mixing because of nearby radio stations, pagers, construction walkie-talkies etc.
- To limit the bandwidth in the frequency modulation, we use some filter which will again introduce some distortions in the signal.
- Transmitters and receiver should be in same channel and one free channel must be there between the systems.

Applications

- Frequency modulation is used in radio’s which is very common in our daily life.
- Frequency modulation is used in audio frequencies to synthesize sound.
- For recording the video signals by VCR systems, frequency modulation is used for intermediate frequencies.
- Used in applications of magnetic tape storage.

Phase modulation (PM)

In this type of modulation, the phase of the carrier signal varies in accordance with the message signal. When the phase of the signal is changed, then it affects the frequency. So, for this reason, this modulation is also comes under the frequency modulation.

Generally, phase modulation is used for transmitting waves. It is an essential part of many digital transmission coding schemes that underlie a wide range of technologies like GSM, WiFi, and satellite television.

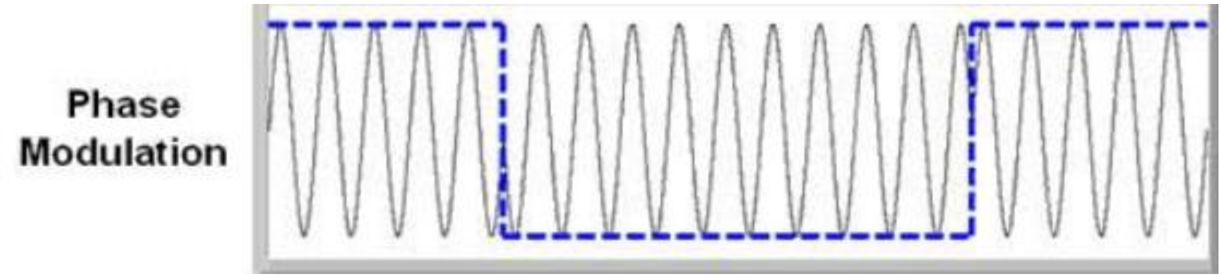


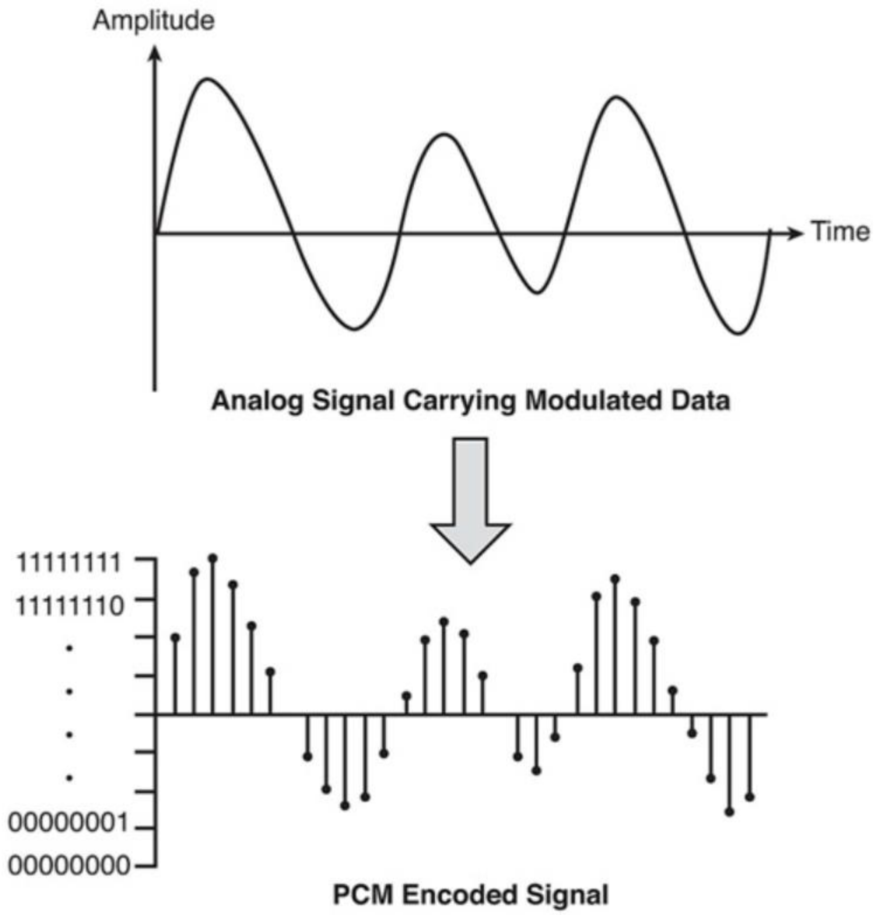
Figure: Phase modulation

Like FM, PM minimizes various types of interference to broadcast reception at frequencies below 30 MHz. The two techniques are commonly used together. FM cannot be applied during the amplification of a sound signal in broadcasting, and so PM is used instead. PM is also utilized in some microwave radio relays and in certain kinds of telegraphic and data-processing systems. Other important applications of PM include communications between mobile radio units employed by the police and military.

Analog to Digital Modulation

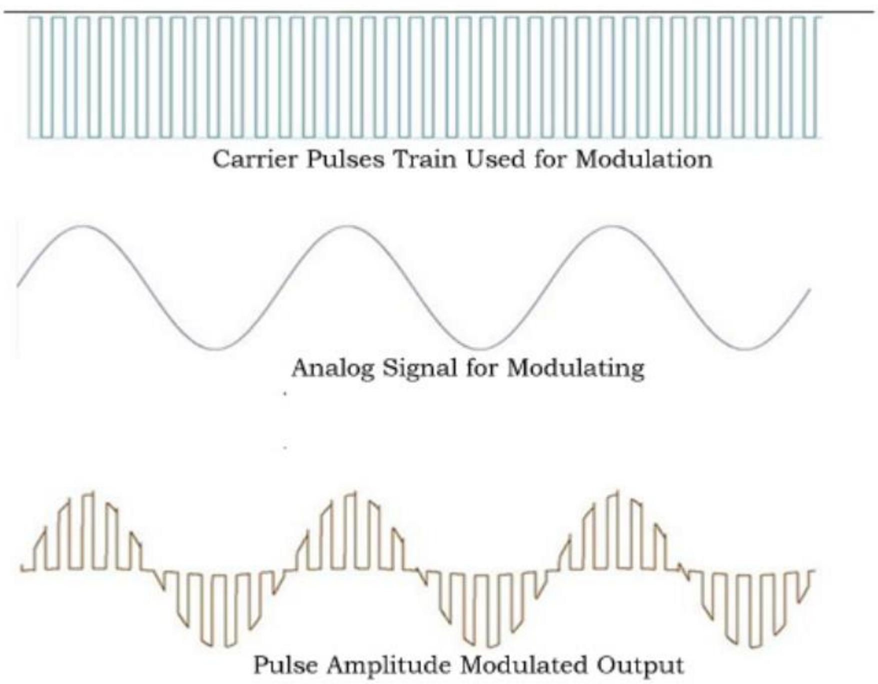
Pulse Code Modulation (PCM)

In the pulse code modulation, Analog Signal is reconstructed to digital signal for ease of transmission by using the analog signal samples. In technical terms, PCM will transmit the analog in a digital from, whose signal is sampled at regular intervals of time and quantized at same quantum levels to digital code. We know that digital code is nothing but binary code which consists of 1's and 0's that is logic1 and logic0. So we will transmit the digital data in the form of 1's and 0's. When the signal is received by the receiver, demodulator in the receiver will demodulate the binary signal back into pulses with same quantum levels like in modulator and these pulses are again used for regenerating the required analog signal.



Pulse Amplitude Modulation (PAM)

In pulse amplitude modulation, the amplitude of regular interval of periodic pulses or electromagnetic pulses is varied in proposition to the sample of modulating signal or message signal. This is an analog type of modulation. In the pulse amplitude modulation, the message signal is sampled at regular periodic or time intervals and this each sample is made proportional to the magnitude of the message signal. These sample pulses can be transmitted directly using wired media or we can use a carrier signal for transmitting through wireless.



Pulse Position Modulation (PPM)

In the pulse position modulation, the position of each pulse in a signal by taking the reference signal is varied according to the sample value of message or modulating signal instantaneously. In the pulse position modulation, width and amplitude is kept constant. It is a technique that uses pulses of the same breath and height but is displaced in time from some base position according to the amplitude of the signal at the time of sampling. The position of the pulse is 1:1 which is propositional to the width of the pulse and also propositional to the instantaneous amplitude of sampled modulating signal. The position of pulse position modulation is easy when compared to other modulation. It requires pulse width generator and monostable multivibrator.

Pulse width generator is used for generating pulse width modulation signal which will help to trigger the monostable multivibrator, here trial edge of the PWM signal is used for triggering the monostable multivibrator. After triggering the monostable multivibrator, PWM signal is converted into pulse position modulation signal. For demodulation, it requires reference pulse generator, flip-flop and pulse width modulation demodulator.

Pulse Duration Modulation (PDM) or Pulse Width Modulation (PWM)

In pulse width modulation or pulse duration modulation, the width of the pulse carrier is varied in accordance with the sample values of message signal or modulating signal or modulating voltage. In pulse width modulation, the amplitude is made constant and width of pulse and position of pulse is made proportional to the amplitude of the signal.

Switching

Switching is the technique by which nodes control or switch data to transmit it between specific points on a network. It defines the connection technique between sender and receiver along with format of data used during communication.

Types of switching

1. **Circuit switching**

   Circuit-switching is the real-time connection-oriented system. In Circuit Switching a dedicated channel (or circuit) is set up for a single connection between the sender and recipient during the communication session. In telephone communication system, the normal voice call is the example of Circuit Switching. The telephone service provider maintain a unbroken link for each telephone call. Circuit switching is pass through three phases that are circuit establishment, data transfer and circuit disconnect.

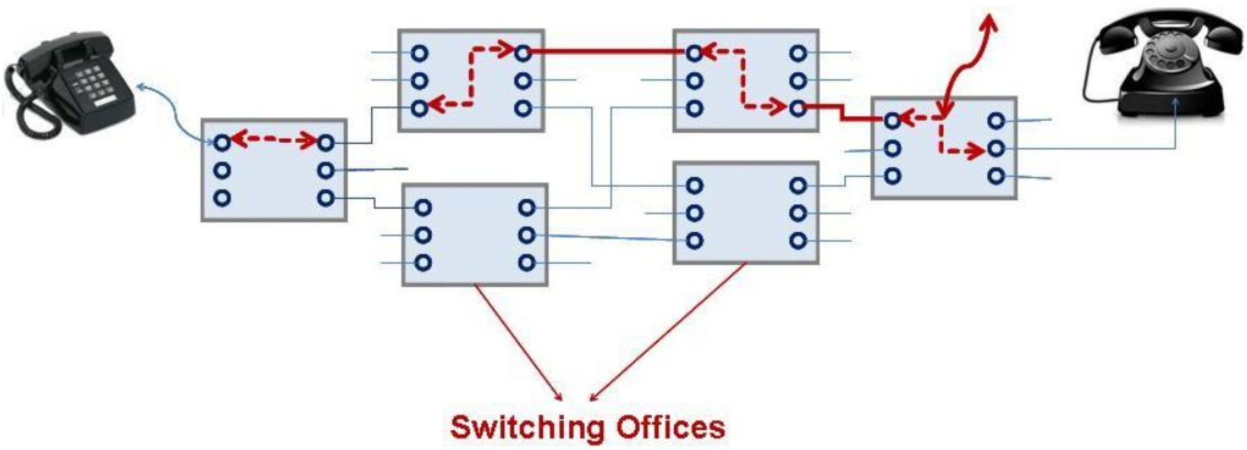


Figure: Circuit switching

Advantages of Circuit Switching:

- In the case of Circuit Switching technique, the communication channel is dedicated.
- It has fixed bandwidth.

Disadvantages of Circuit Switching:

- Once the dedicated path is established, the only delay occurs in the speed of data transmission.
- It takes a long time to establish a connection approx 10 seconds during which no data can be transmitted.
- It is more expensive than other switching techniques as a dedicated path is required for each connection.
- It is inefficient to use because once the path is established and no data is transferred, then the capacity of the path is wasted.

- In this case, the connection is dedicated therefore no other data can be transferred even if the channel is free.

2. Message switching

Message Switching is a switching technique in which a message is transferred as a complete unit and routed through intermediate nodes. In this method, if a station wishes to send a message to another station, it first appends the destination address to the message. After this, the message is transmitted from the source to its destination either by store and forward or broadcast method.

In store and forward method, the message is transmitted from the source node to an intermediate node. The intermediate node stores the complete message temporarily, inspects it for errors, and transmits it to the next node, based on an available free channel and its routing information. The actual path taken by the message to its destination is dynamic, because the path is established as it travels along. When the message reaches a node, the channel on which it came is released for use by another message.

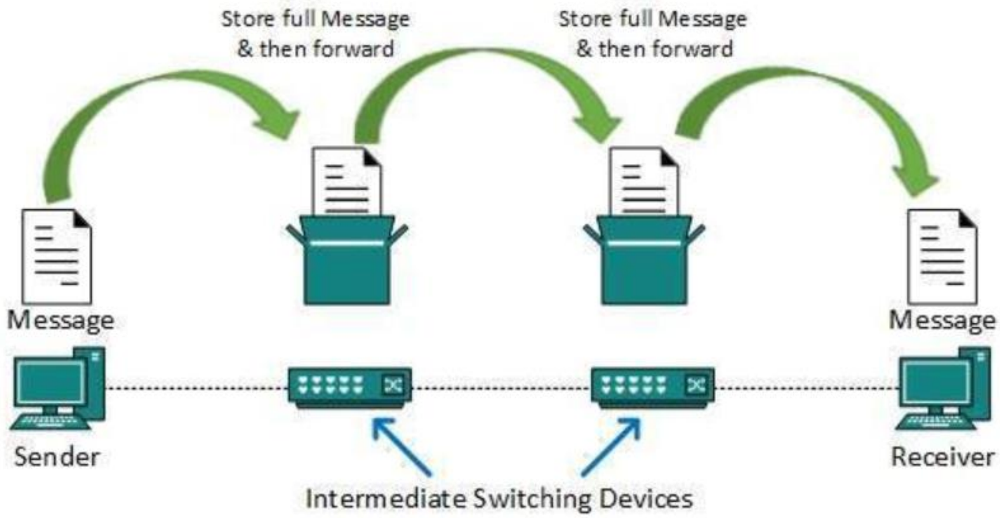


Figure: Message Switching

In the broad cast method, the message is broadcast over a common medium, which is known as broadcast channel. All the stations check the destination address of each message as they pass by, and accept only those addressed to them. The routing delays inherent in store and forward method are eliminated in this method.

Advantages of Message Switching

- Data channels are shared among the communicating devices that improve the efficiency of using available bandwidth.

- Traffic congestion can be reduced because the message is temporarily stored in the nodes.
- Message priority can be used to manage the network.
- The size of the message which is sent over the network can be varied. Therefore, it supports the data of unlimited size.

Disadvantages of Message Switching

- The message switches must be equipped with sufficient storage to enable them to store the messages until the message is forwarded.
- The Long delay can occur due to the storing and forwarding facility provided by the message switching technique.

3. Packet Switching

The message splits into smaller pieces known as packets and packets are given a unique number to identify their order at the receiving end. Every packet contains some information in its headers such as source address, destination address and sequence number. Packets will travel across the network, taking the shortest path as possible. All the packets are reassembled at the receiving end in correct order. If any packet is missing or corrupted, then the message will be sent to resend the message. If the correct order of the packets is reached, then the acknowledgment message will be sent.

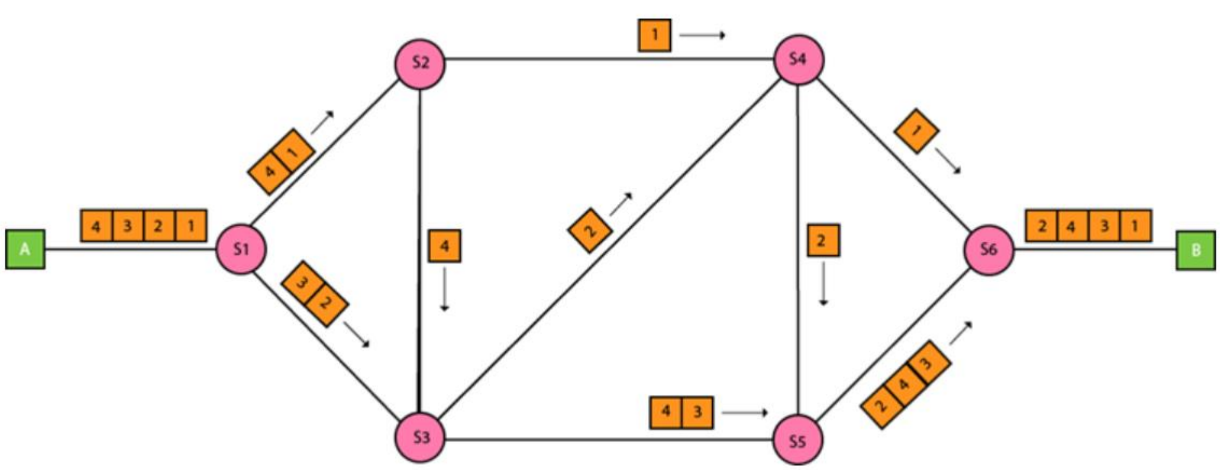


Figure: Packet switching

Advantages of Packet Switching:

- **Cost-effective:** In packet switching technique, switching devices do not require massive secondary storage to store the packets, so cost is minimized to some extent. Therefore, we can say that the packet switching technique is a cost-effective technique.
- **Reliable:** If any node is busy, then the packets can be rerouted. This ensures that the Packet Switching technique provides reliable communication.
- **Efficient:** Packet Switching is an efficient technique. It does not require any established path prior to the transmission, and many users can use the same communication channel simultaneously, hence makes use of available bandwidth very efficiently.

Disadvantages of Packet Switching:

- Packet Switching technique cannot be implemented in those applications that require low delay and high-quality services.
- The protocols used in a packet switching technique are very complex and requires high implementation cost.
- If the network is overloaded or corrupted, then it requires retransmission of lost packets. It can also lead to the loss of critical information if errors are nor recovered.

Network Devices

1. **Repeater** – A repeater operates at the physical layer. Its job is to regenerate the signal over the same network before the signal becomes too weak or corrupted so as to extend the length to which the signal can be transmitted over the same network. An important point to be noted about repeaters is that they do not amplify the signal. When the signal becomes weak, they copy the signal bit by bit and regenerate it at the original strength. It is a 2 port device.

2. **Hub** – A hub is basically a multiport repeater. A hub connects multiple wires coming from different branches, for example, the connector in star topology which connects different stations. Hubs cannot filter data, so data packets are sent to all connected devices. In other words, collision domain of all hosts connected through Hub remains one. Also, they do not have intelligence to find out best path for data packets which leads to inefficiencies and wastage.

Types of Hub

- **Active Hub :-** These are the hubs which have their own power supply and can clean , boost and relay the signal along the network. It serves both as a repeater as well as wiring center. These are used to extend maximum distance between nodes.
- **Passive Hub :-** These are the hubs which collect wiring from nodes and power supply from active hub. These hubs relay signals onto the network without cleaning and boosting them and can't be used to extend distance between nodes.

3. **Bridge –** A bridge operates at data link layer. A bridge is a repeater, with add on functionality of filtering content by reading the MAC addresses of source and destination. It is also used for interconnecting two LANs working on the same protocol. It has a single input and single output port, thus making it a 2 port device.

Types of Bridges

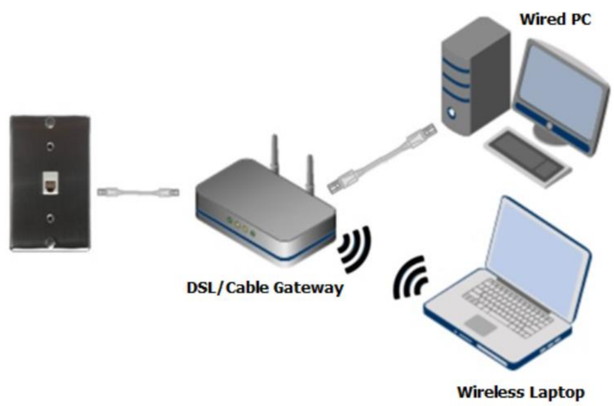
Transparent Bridges :- These are the bridge in which the stations are completely unaware of the bridge's existence i.e. whether or not a bridge is added or deleted from the network , reconfiguration of the stations is unnecessary. These bridges makes use of two processes i.e. bridge forwarding and bridge learning.

Source Routing Bridges :- In these bridges, routing operation is performed by source station and the frame specifies which route to follow. The hot can discover frame by sending a special frame called discovery frame, which spreads through the entire network using all possible paths to destination.

4. **Switch –** A switch is a multi-port bridge with a buffer and a design that can boost its efficiency (large number of ports imply less traffic) and performance. Switch is data link layer device. Switch can perform error checking before forwarding data that makes it very efficient as it does not forward packets that have errors and forward good packets selectively to correct port only. In other words, switch divides collision domain of hosts, but broadcast domain remains same.

5. **Routers –** A router is a device like a switch that routes data packets based on their IP addresses. Router is mainly a Network Layer device. Routers normally connect LANs and WANs together and have a dynamically updating routing table based on which they make decisions on routing the data packets. Router divide broadcast domains of hosts connected through it.

6. **Gateway –** A gateway, as the name suggests, is a passage to connect two networks together that may work upon different networking models. They basically works as the messenger agents that take data from one system, interpret it, and transfer it to another system. Gateways are also called protocol converters and can operate at any network layer. Gateways are generally more complex than switch or router.



7. **Brouter –** It is also known as bridging router is a device which combines features of both bridge and router. It can work either at data link layer or at network layer. Working as router, it is capable of routing packets across networks and working as bridge, it is capable of filtering local area network traffic.

8. **Network Interface Card-** A network interface (or NIC card) is a printed circuit board that fits into the expansion slot on the motherboard of a computer or on the peripheral device to the network device to the network through the hub or switch. These days, network cards are integrated within the mother board. These types of integrated cards are called in network interface cards.

   Network interface cards work on layer 2 of the OSI model. The network interface cards are identified with the MAC address. The MAC address of a NIC card is globally unique. The MAC address contains manufacturer ID and NIC card ID.