Data Communication

UNIT-2

Multiplexing

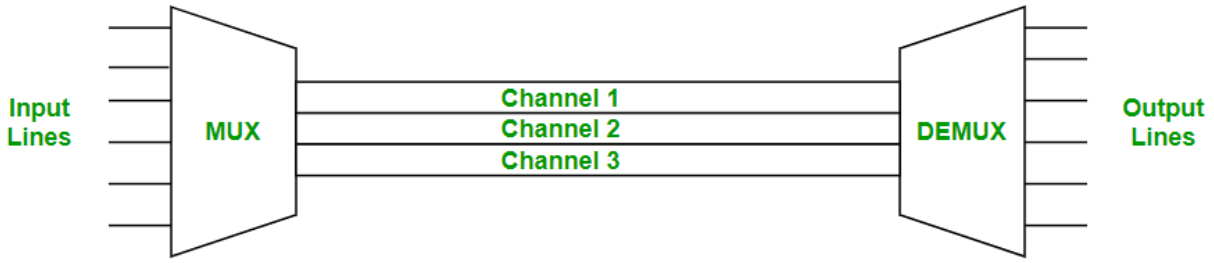
Multiplexing is the sharing of a medium or bandwidth. It is the process in which multiple signals coming from multiple sources are combined and transmitted over a single communication/physical line.

Types of Multiplexing

There are main three types of Multiplexing:

1. Frequency Division Multiplexing (FDM)
2. Time-Division Multiplexing (TDM)
3. Wavelength Division Multiplexing (WDM)

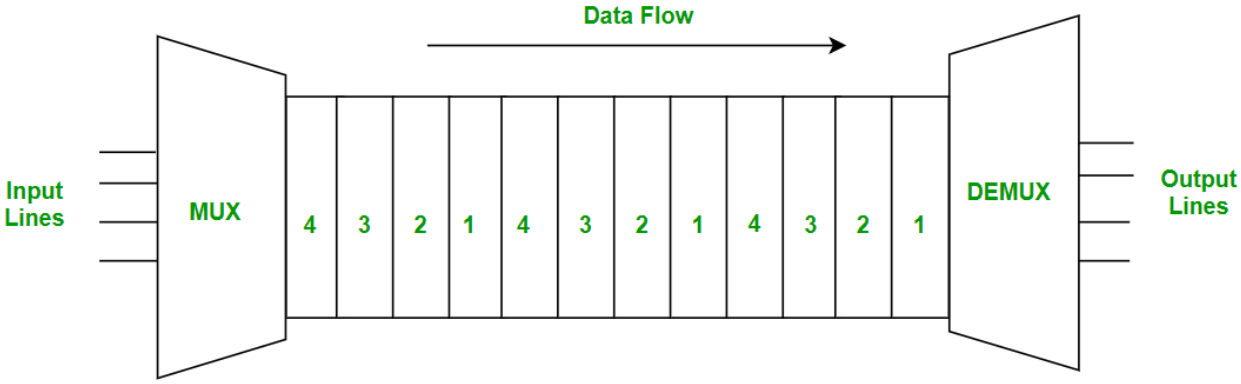
Frequency division multiplexing is defined as a type of multiplexing where the bandwidth of a single physical medium is divided into a number of smaller, independent frequency channels. Frequency Division Multiplexing is used in radio and television transmission. In FDM, we can observe a lot of inter-channel cross-talk, due to the fact that in this type of multiplexing the bandwidth is divided into frequency channels. In order to prevent the inter-channel cross talk, unused strips of bandwidth must be placed between each channel. These unused strips between each channel are known as guard bands.



2. Time Division Multiplexing:

Time-division multiplexing is defined as a type of multiplexing wherein FDM, instead of sharing a portion of the bandwidth in the form of channels, in TDM, time is shared. Each connection occupies a portion of time in the link.

In Time Division Multiplexing, all signals operate with the same frequency (bandwidth) at different times.

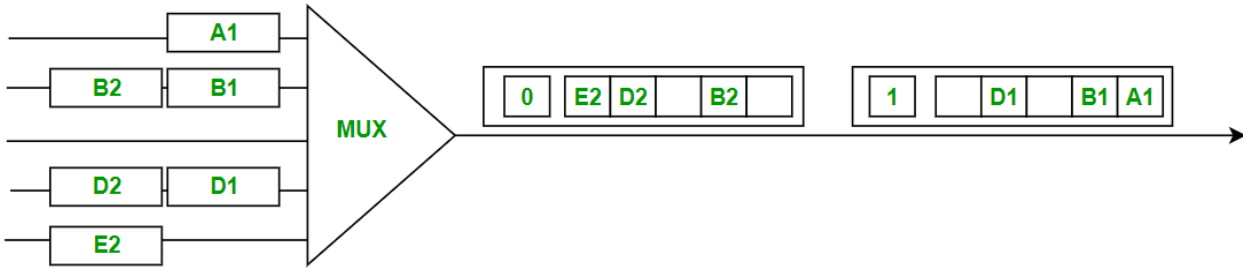


Synchronous TDM:

Synchronous TDM is a type of Time Division Multiplexing where the input frame already has a slot in the output frame. Time slots are grouped into frames. One frame consists of one cycle of time slots.

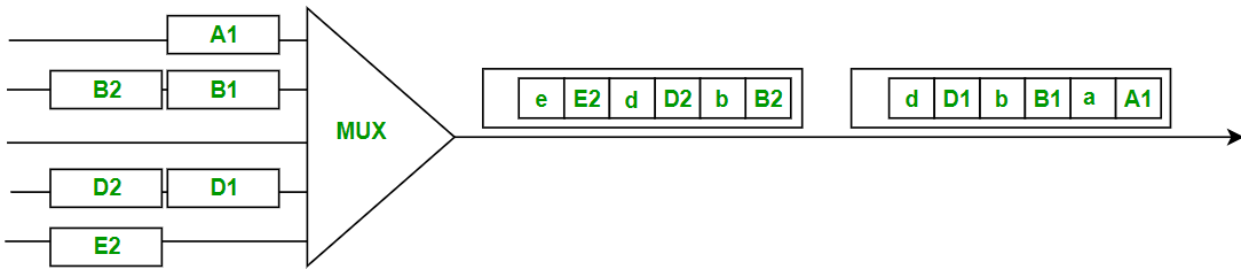
Synchronous TDM is not efficient because if the input frame has no data to send, a slot remains empty in the output frame.

In synchronous TDM, we need to mention the synchronous bit at the beginning of each frame.



Statistical TDM:
Statistical TDM is a type of Time Division Multiplexing where the output frame collects data from the input frame till it is full, not leaving an empty slot like in Synchronous TDM.

In statistical TDM, we need to include the address of each particular data in the slot that is being sent to the output frame.



Statistical TDM is a more efficient type of time-division multiplexing as the channel capacity is fully utilized and improves the bandwidth efficiency.

3. Wavelength Division Multiplexing:
Wavelength Division Multiplexing (WDM) is a multiplexing technology used to increase the capacity of optical fiber by transmitting multiple optical signals simultaneously over a single optical fiber, each with a different wavelength. Each signal is carried on a different wavelength of light, and the resulting signals are combined onto a single optical fiber for transmission. At the receiving end, the signals are separated by their wavelengths, demultiplexed and routed to their respective destinations.

Wavelength Division Multiplexing is used on fiber optics to increase the capacity of a single fiber. It is an analog multiplexing technique. Optical signals from the different sources are combined to form a wider band of light with the help of multiplexers. At the receiving end, the De-multiplexer separates the signals to transmit them to their respective destinations.

North American Digital Multiplexing Hierarchy

The American Telephone and Telegraph Company's (AT&T's) North American Digital Hierarchy for multiplexing digital signals into a single higher-speed pulse stream suitable for transmission on the next higher level of the hierarchy. To upgrade from one level in the

hierarchy to the next higher level, a special device called muldem (multiplexer/ demultiplexer) is required.

Muldems can handle bit-rate conversions in both directions.

The muldem designations (M12, M23, and so on) identify the input and output digital signals associated with that muldem.

The DS-1 may be further multiplexed or line encoded and placed on specially conditioned cables called T1 lines.

[Digital Signal 1: DS1 A digital telephone standard used in the United States, Canada, and Japan. DS1 can transmit up to 24 voice and data calls over telephone lines.]

The DS-2, DS-3, DS-4 and DS-5 digital signals are placed on T2, T3, T4M, or T5 lines, respectively.

Digital signals are routed at central locations called digital cross-connects.

A digital cross-connect (DSX) provides a convenient place to make patchable interconnects and to perform routine maintenance and troubleshooting. Each type of digital signals (DS-1, DS-2, and so on) has its own digital switch (DSX-1, DSX-2, and so on). The output from a digital switch may be upgraded to the next higher level of multiplexing or line encoded and placed on its respective T lines (T1, T2, and so on).

T1 Digital Carrier System

The T1 carrier system multiplexes binary code-words corresponding to samples of each of the 24 channels in a sequence.

A segment containing one codeword (corresponding to one sample) from each of the 24 channels is called a FRAME.

Each frame has 24x8 = 192 data bits and takes 125μs.

As mentioned previously, sampling rate used for voice = 8000 samples/sec.

Every sample is represented by 8 bits.

Therefore,

Data rate of 1 voice channel = 8x8000 = 64kbps.

In the T1 system 24 voice channels are multiplexed in time.

Data rate of a T1 stream should be = 24x64kbps = Mbps

At the receiver it is also necessary to know where a frame starts in order to separate information bits correctly. For this purpose, a Framing bit is added at the beginning of each frame.

Framing Bits: Indicate start of frames.

Total number of bits/ frames = 193

the actual data rate = 1.544Mbps

European Time-Division Multiplexing

In Europe, a different version of T carrier lines is used called E lines. A high-speed digital communications link that enables the transmission of voice, data, and video signals at a rate of Mbps

a) Initially designed for transmission of 30 telephone channels

b) Basis for design: PCM voice digitizing using 64 kbps for each channel.

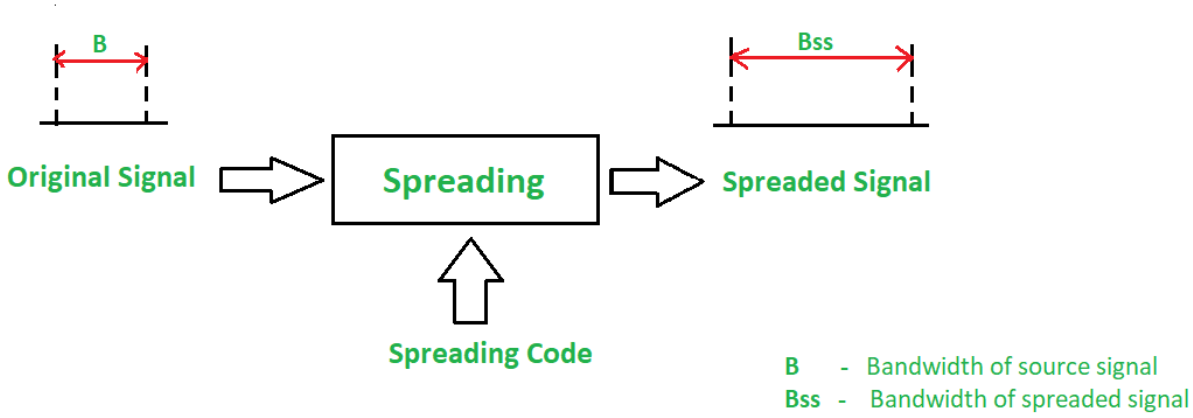
The E1 frame consists of 32 8-bit channels (timeslots) 32 time slots X bits = 256 bits/frame time slots E1 frames are transmitted at the rate of 8,000 frames/s256 bits X 8,000 frames = 2,048 kbps or Mbps frame second

T Carrier Systems
T carriers are used for the transmission of PCM-encoded time division multiplexed digital signals
T1 Carrier System
Transmission of 24, 64-kbps channels, T1 line speed Mbps.
Lengths from about 1 mile to over 50 miles.
Binary eight zero substitution, B8ZS ( ) or ( )
T2 Carrier System
Transmission of 94, 64-kbps channels, T2 line speed Mbps.
Lengths up to 500 miles.
Binary six zero substitution, B6ZS (0-+0+-) or (0+-0-+)
T3 Carrier System
Transmission of 672, 64-kbps channels, T3 line speed Mbps.
Binary three zero substitution, B3ZS
T4M Carrier System
Transmission of 4032, 64-kbps channels, T4 line speed Mbps.
Lengths up to 500 miles
T5 Carrier System
Transmission of 8064, 64-kbps channels, T5 line speed Mbps.

Spread Spectrum

The increasing demand for wireless communications has problems due to limited spectrum efficiency and multipath propagation. The use of spread spectrum communication has simplified these problems. In the spread spectrum, signals from different sources are combined to fit into **larger bandwidth**.

Most stations use air as the medium for communication, stations must be able to share the medium without an interception and without being subject to jamming from a malicious intruder. To achieve this, spread-spectrum techniques add redundancy means it uses **extended bandwidth** to accommodate signals in a protective envelope so that more secure transmission is possible. The spread code is a series of numbers that looks random but are actually a pattern. The original bandwidth of the signal gets **enlarged** (spread) through the spread code as shown in the figure.



Spread Spectrum

Principles of Spread Spectrum process:

1. To allow redundancy, it is necessary that the bandwidth allocated to each station should be much larger than needed.
2. The spreading process occurs after the signal is created by the source.

Conditions of Spread Spectrum are:

1. The spread spectrum is a type of modulation where modulated signal BW is much larger than the baseband signal BW i.e. spread spectrum is a wide band scheme.
2. A special code (pseudo noise) is used for spectrum spreading and the same code is to be used to despread the signal at the receiver.

Characteristics of the Spread Spectrum are:

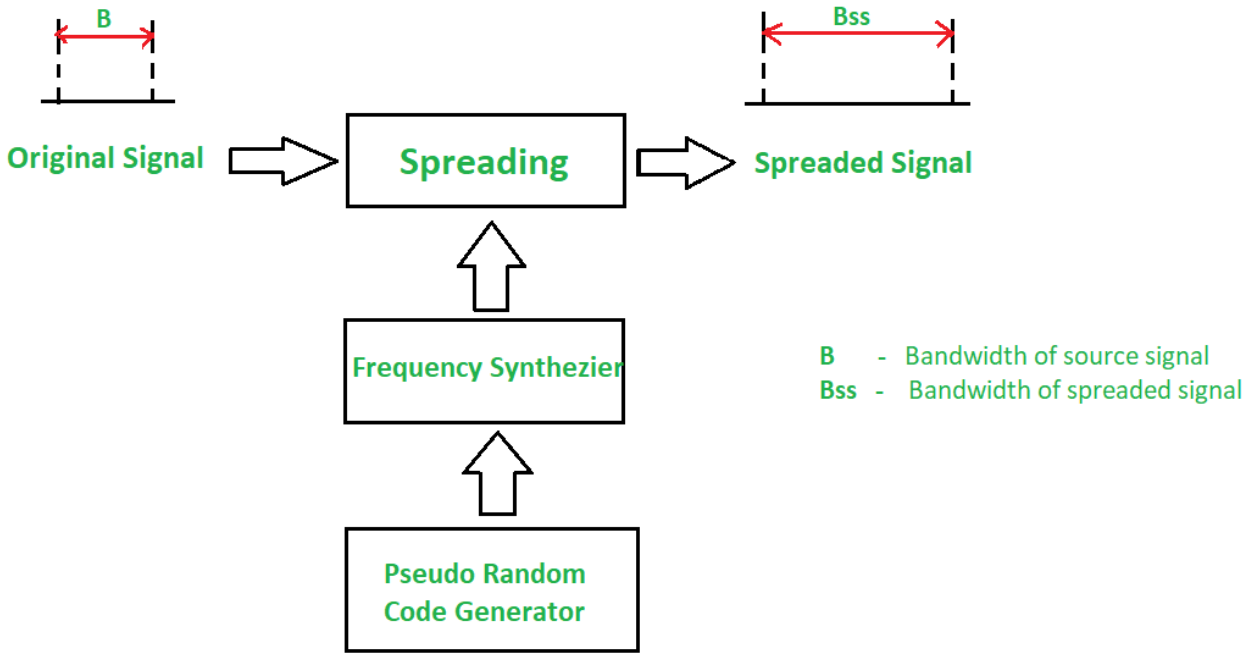
1. Higher channel capacity.
2. Ability to resist multipath propagation.
3. They cannot easily intercept any unauthorized person.
4. They are resistant to jamming.
5. The spread spectrum provides immunity to distortion due to multipath propagation.
6. The spread spectrum offers multiple access capabilities.

Two types of techniques for Spread Spectrum are:

1. Frequency Hopping Spread Spectrum (FHSS)
2. Direct Sequence Spread Spectrum (DSSS)

Frequency Hopping Spread Spectrum (FHSS):

In Frequency Hopping Spread Spectrum (FHSS), different carrier frequencies are modulated by the source signal i.e. M carrier frequencies are modulated by the signal. At one moment signal modulates one carrier frequency and at the subsequent moments, it modulates other carrier frequencies. The general block diagram of FHSS is shown in the below figure.



Frequency Hopping Spread Spectrum

A pseudorandom code generator generates Pseudo-random Noise of some pattern for each hopping period $\mathbf{T}_h$. The frequency corresponding to the pattern is used for the hopping period and is passed to the frequency

synthesizer. The synthesizer generates a carrier signal of that frequency. The figure above shows the spread signal via FHSS.

Advantages of FHSS:

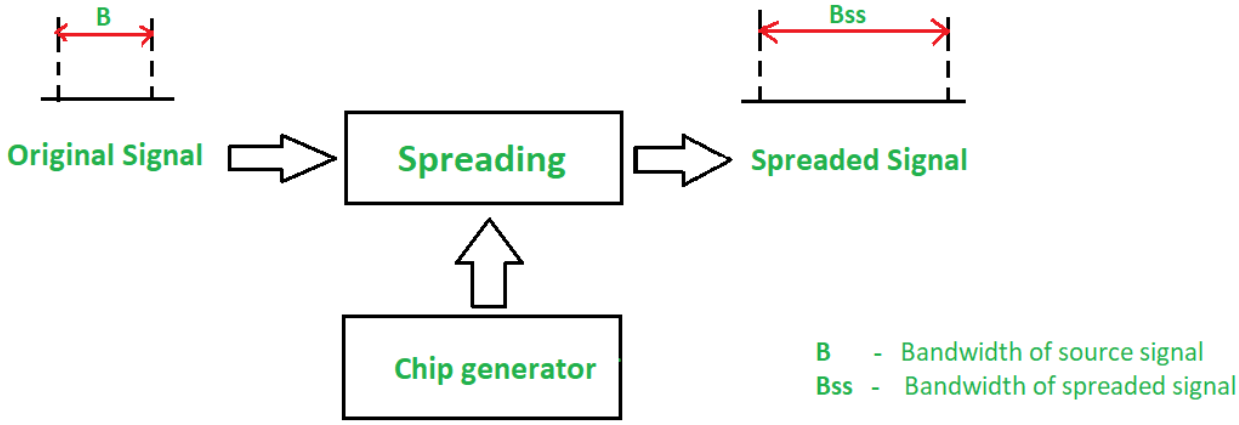
- Synchronization is not greatly dependent on distance.
- Processing Gain is higher than DSSS.

Disadvantages of FHSS:

- The bandwidth of the FHSS system is too large (in GHz).
- Complex and expensive Digital frequency synthesizers are required.

Direct Sequence Spread Spectrum (DSSS):

In DSSS, the bandwidth of the original signal is also expanded by a different technique. Here, each data bit is replaced with n bits using a spreading code called **chips,** and the bit rate of the chip is called as **chip-rate**. The chip rate is n times the bit rate of the original signal. The below Figure shows the DSSS block diagram.



Direct Sequence Spread Spectrum

In wireless LAN, the sequence with n = 11 is used. The original data is multiplied by **chips** (spreading code) to get the spread signal. The required bandwidth of the spread signal is 11 times larger than the bandwidth of the original signal.

Advantages of DSSS:

- The DSSS System combats the jamming most effectively.
- The performance of DSSS in presence of noise is superior to FHSS.
- Interference is minimized against the signals.

Disadvantages of DSSS:

- Processing Gain is lower than DSSS.

- Channel Bandwidth is less than FHSS.
- Synchronization is affected by the variable distance between the transmitter and receiver.

Terminal Handling

A **Terminal controller** is a device that collects traffic from a set of terminals and directs them to a concentrator.

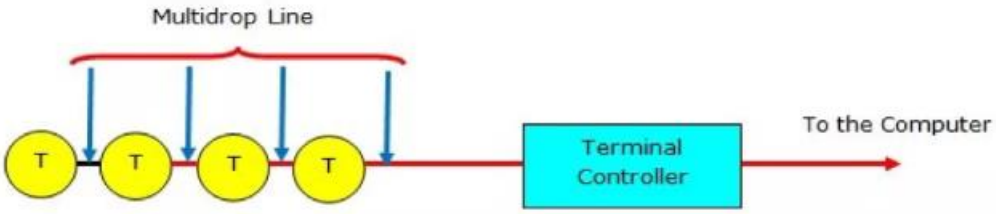
- For many applications the cost of communication lines exceeds the cost of the equipment connected by those lines. In an attempt to reduce communication costs, many networks provide a way for multiple terminals to share a single communication line. The conceptual model is that of fig, in which a **terminal controller** accepts input from a cluster of terminals, and funnels the output onto one line, as well as the reverse operation. In fig.(a), all the terminals are wired onto the same *multidrop line*, whereas in fig, each terminal has its own *point-to-point line* to the controller.
- Terminal controller can be divided into two general classes, multiplexers and concentrators. A *multiplexer* is a device that accepts input from a collection of lines in some static, predetermined sequence, and outputs the data onto a single output line in the same sequence. As each output time slot is dedicated to a specific input line, there is no need to transmit the input line numbers. The output line must have the same capacity as the sum of the input line

In TDM when a terminal has no traffic, an output time slot is wasted. The output slots are filled in strict rotation. If there are no data, dummy characters are used. It is not possible to skip a time slot, because the receiving end keeps track of which character came from which terminal by its position in the output stream. Initially, the multiplexer and the computer synchronize themselves. Both know that the order to be used. The data themselves carry no identification of their origin. If the multiplexers skipped a time slot when there were no data from a terminal, the receiver would get out of phase and interpret the origin of succeeding characters incorrectly.
If each terminal has traffic only a small fraction of the time, TDM makes inefficient use of the output line capacity.

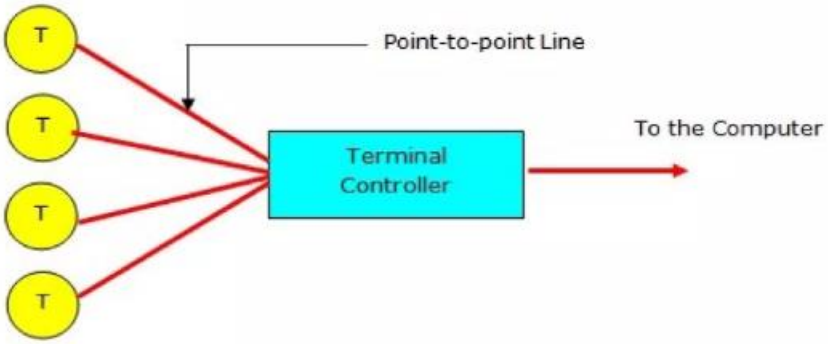
When the actual traffic is far below the potential traffic, most of the time slots on the output line are wasted. Consequently, it is often possible to use an output line with less capacity than the sum of the input lines. This arrangement is called ***concentration***.

The general approach is to only transmit actual data and not dummy characters. However, this strategy introduces the problem of telling the receiver which character came from which input line. One solution to this problem is to send two output characters for each input character – the terminal number and the data.

Concentrators using this principle are often referred to as ***statistical multiplexers*** or ***ATDMS*** (Asynchronous Time Division Multiplexers), in contrast with the true (synchronous) multiplexers, or ***STDMS***, although strictly speaking, a statistical multiplexer that had as much output capacity as input capacity would not be a concentrator.



(b) A Terminal Controller using One Multidrop Line



(a) A Terminal Controller using Point-to-point Lines

Concentrator

- In telecommunication, the term **concentrator** has the following meanings:
- In data transmission, a functional unit that permits a common path to handle more data sources than there are channels currently available within the path. A concentrator usually provides communication capability between many low-speed, usually asynchronous channels and one or more high-speed, usually synchronous channels. Usually different speeds, codes, and protocols can be accommodated on the low-speed side. The low-speed channels usually operate in contention and require buffering.

A device that connects a number of links with only one destination, the main function of this device is to make a kind of load balancing between two or more servers connected together, data distribution is done according to the server processing rate.
A patch panel or other component in the cable plant where cable runs converge.
ISP used concentrators to enable modem dialling; this kind of concentrator is sometimes called a modem concentrator or a remote access concentrator. The term "access concentrator" is also used to describe similar provider edge equipment used in computer networks that doesn't rely on modems anymore, e.g.

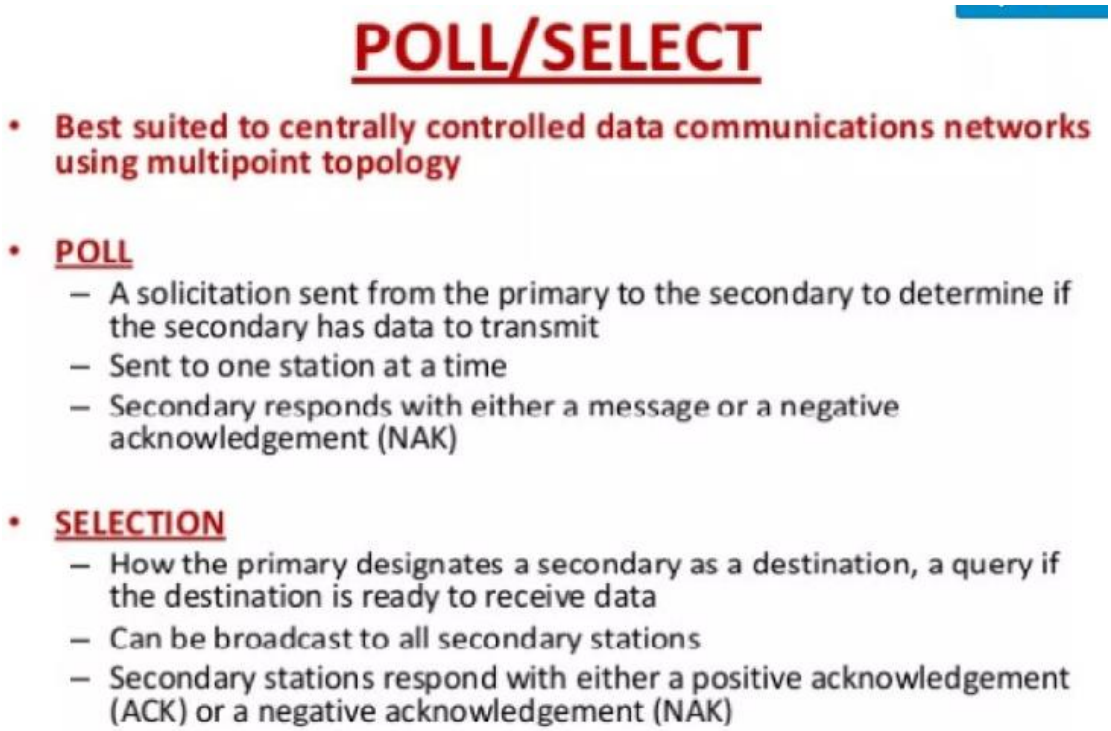
Polling

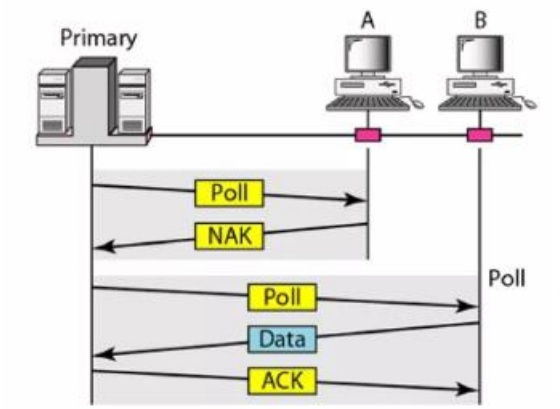
Polling is a technique that continuously checks a peripheral device to see if it has data to transfer. In a computer network, polling is a master/slave arrangement where a central computer sends a message to a specific terminal. The terminal responds with an acknowledgment before the data transfer begins.

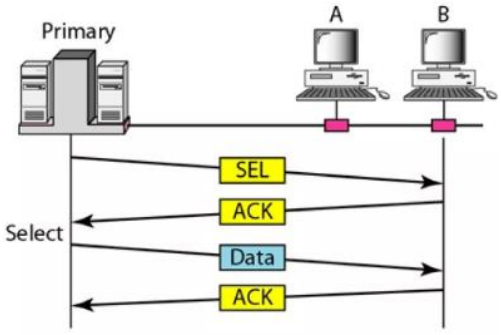
In a wireless network, polling is strictly centralized. If one terminal can be heard by all others, it can poll all other terminals. The central terminal, also known as the Base Terminal (BS), can poll the other terminals using schemes like round-robin, random address, or reservation.

Polling has several advantages:

- The maximum and minimum access time and data rates on the channel are fixed and predictable.
- It has maximum efficiency.
- It has maximum bandwidth.
- No slot is wasted in polling.
- There is assignment of priority to ensure faster access from some
- secondary.




Primary
A
B
Poll
NAK
Poll
Poll
Data
ACK

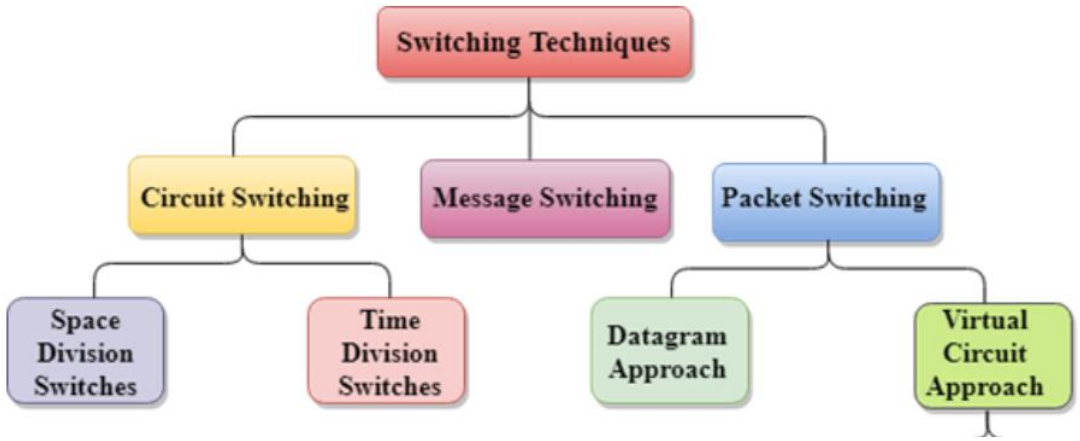

Primary
A
B
SEL
ACK
Select
Data
ACK

Switched communication networks

Switched communication networks are those in which data transferred from source to destination is routed between various intermediate nodes. Switching is the technique by which nodes control or switch data to transmit it between specific points on a network. There are 3 common switching techniques:

1. Circuit Switching
2. Packet Switching
3. Message Switching

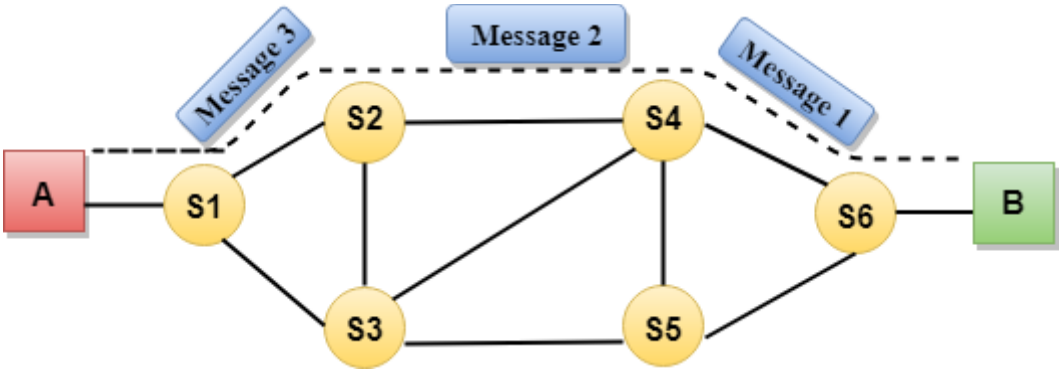
Classification Of Switching Techniques



- Circuit switching is a switching technique that establishes a dedicated path between sender and receiver.
- In the Circuit Switching Technique, once the connection is established then the dedicated path will remain to exist until the connection is terminated.
- Circuit switching in a network operates in a similar way as the telephone works.
- A complete end-to-end path must exist before the communication takes place.
- In case of circuit switching technique, when any user wants to send the data, voice, video, a request signal is sent to the receiver then the receiver sends back the acknowledgment to ensure the availability of the dedicated path. After receiving the acknowledgment, dedicated path transfers the data.
- Circuit switching is used in public telephone network. It is used for voice transmission.
- Fixed data can be transferred at a time in circuit switching technology.

Communication through circuit switching has 3 phases:

- Circuit establishment
- Data transfer
- Circuit Disconnect



Advantages Of Circuit Switching:

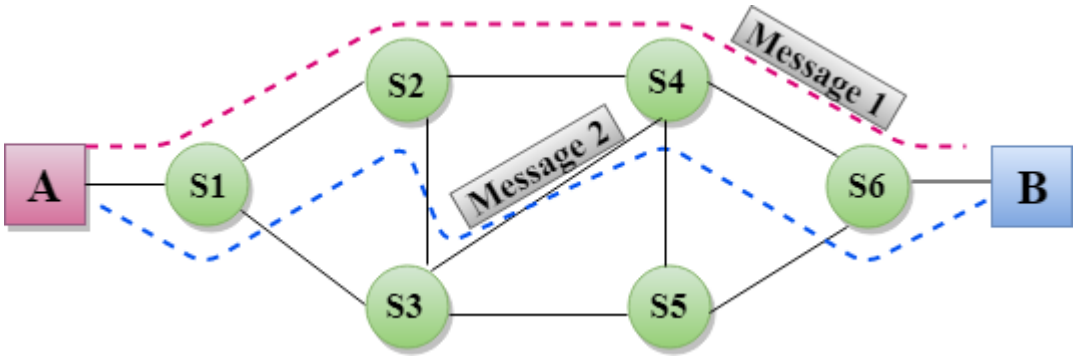
- In the case of Circuit Switching technique, the communication channel is dedicated.
- It has fixed bandwidth.

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.

Message Switching

- Message Switching is a switching technique in which a message is transferred as a complete unit and routed through intermediate nodes at which it is stored and forwarded.
- In Message Switching technique, there is no establishment of a dedicated path between the sender and receiver.
- The destination address is appended to the message. Message Switching provides a dynamic routing as the message is routed through the intermediate nodes based on the information available in the message.
- Message switches are programmed in such a way so that they can provide the most efficient routes.
- Each and every node stores the entire message and then forward it to the next node. This type of network is known as **store and forward network.**
- Message switching treats each message as an independent entity.



Advantages Of Message Switching

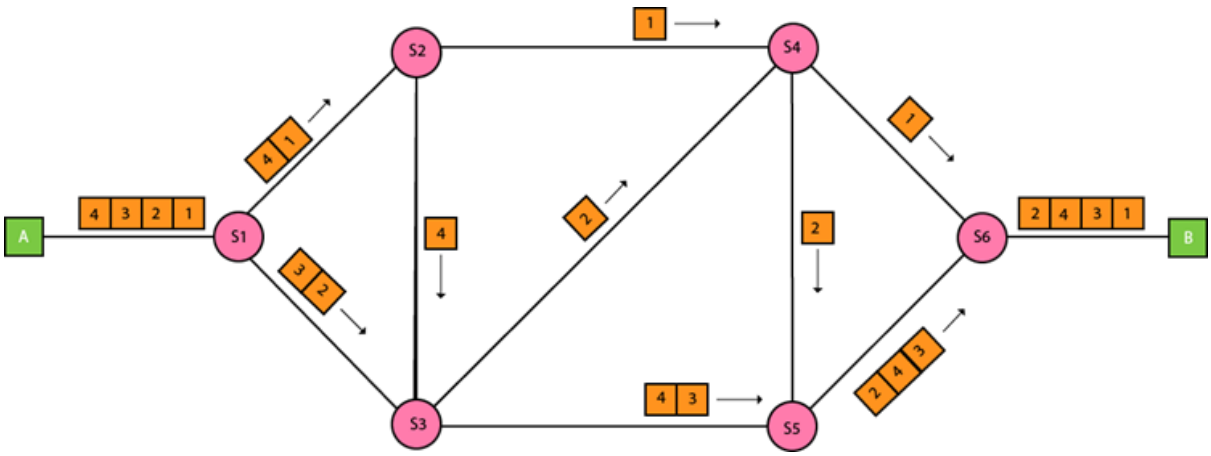
- Data channels are shared among the communicating devices that improve the efficiency of using available bandwidth.
- Traffic congestion can be reduced because the message is temporarily stored in the nodes.
- Message priority can be used to manage the network.
- The size of the message which is sent 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.

Packet Switching

- The packet switching is a switching technique in which the message is sent in one go, but it is divided into smaller pieces, and they are sent individually.
- 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.



Approaches Of Packet Switching:

There are two approaches to Packet Switching:

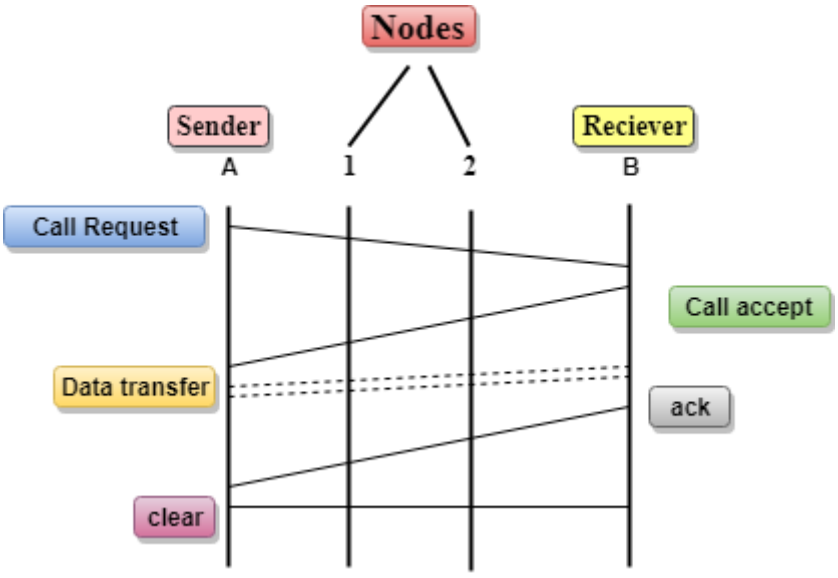
Datagram Packet switching:

- It is a packet switching technology in which packet is known as a datagram, is considered as an independent entity. Each packet contains the information about the destination and switch uses this information to forward the packet to the correct destination.
- The packets are reassembled at the receiving end in correct order.
- In Datagram Packet Switching technique, the path is not fixed.
- Intermediate nodes take the routing decisions to forward the packets.
- Datagram Packet Switching is also known as connectionless switching.

Virtual Circuit Switching

- Virtual Circuit Switching is also known as connection-oriented switching.
- In the case of Virtual circuit switching, a preplanned route is established before the messages are sent.
- Call request and call accept packets are used to establish the connection between sender and receiver.
- In this case, the path is fixed for the duration of a logical connection.

Let's understand the concept of virtual circuit switching through a diagram:



- In the above diagram, A and B are the sender and receiver respectively. 1 and 2 are the nodes.
- Call request and call accept packets are used to establish a connection between the sender and receiver.
- When a route is established, data will be transferred.
- After transmission of data, an acknowledgment signal is sent by the receiver that the message has been received.
- If the user wants to terminate the connection, a clear signal is sent for the termination.
- Differences b/w Datagram approach and Virtual Circuit approach

Datagram approach	Virtual Circuit approach
Node takes routing decisions to forward the packets.	Node does not take any routing decision.
Congestion cannot occur as all the packets travel in different directions.	Congestion can occur when the node is busy, and it does not allow other packets to pass through.
It is more flexible as all the packets are treated as an independent entity.	It is not very flexible.

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.