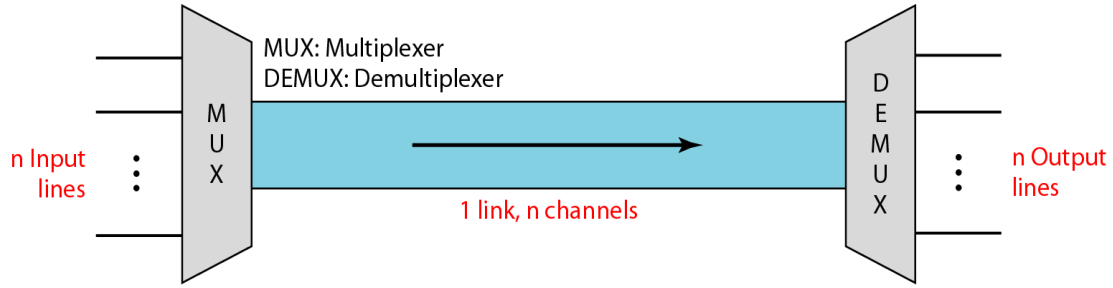
Chapter No: 3

MULTIPLEXING AND SWITCHING

Multiplexing and De-multiplexing

- To combine multiple signals (analog or digital) for transmission over a single line or media.
- A common type of multiplexing combines several low-speed signals for transmission over a single high-speed connection.
- **Multiplexing** is done by using a device called **Multiplexer** (MUX) that combines ***n*** input lines to generate ***one*** output line i.e. (**many to one**). Therefore multiplexer (MUX) has several inputs and one output.
- At the receiving end, a device called **Demultiplexer** (DEMUX) is used that separates signal into its component signals. So DEMUX has ***one*** input and ***several*** outputs.



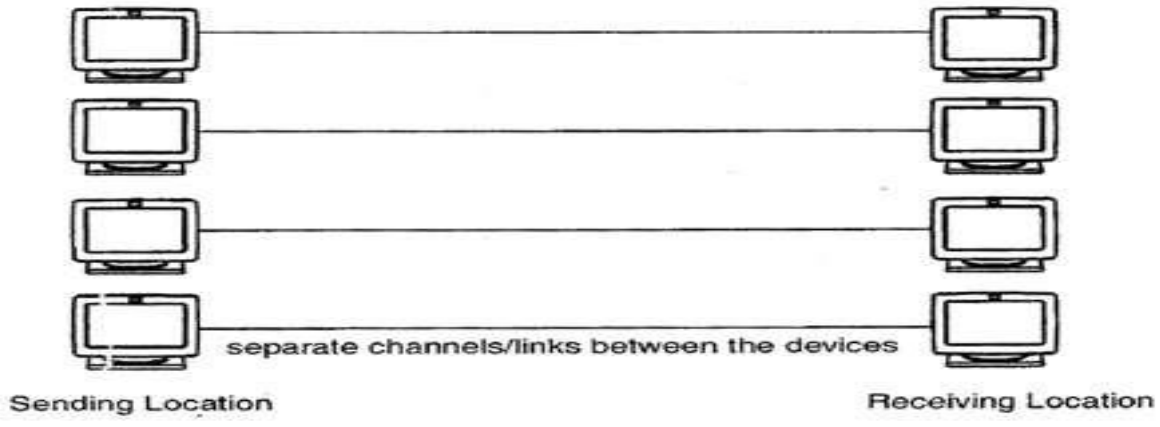
Concept of Multiplexing

- ☐ As shown in fig multiplexer takes 4 input lines and diverts them to single output line.
- ☐ The signal from 4 different devices is combined and carried by this single line.
- ☐ At the receiving side, a demultiplexer takes this signal from a single line & breaks it into the original signals and passes them to the 4 different receivers.

Multiplexing

Advantages of Multiplexing

- ☐ If no multiplexing is used between the users at two different sites that are distance apart, then separate communication lines would be required as shown in fig.
- ☐ This is not only costly but also become difficult to manage. If multiplexing is used then, only one line is required. This leads to the reduction in the line cost and also it would be easier to keep track of one line than several lines.
- ☐ More than one signal can be sent over a single medium.
- ☐ The bandwidth of a medium can be utilized effectively.

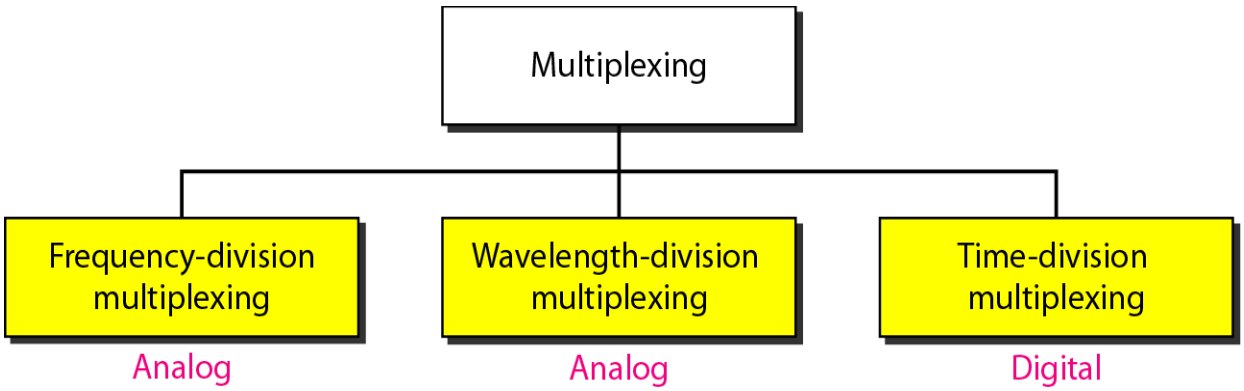


No multiplexing used

Why to use Multiplexing?

- 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.

Types of Multiplexing



Question: Define Multiplexing. State its Types. (2 marks)
Answer:

- Multiplexing is the process in which multiple data streams, coming from different sources, are combined and transmitted over a single data channel or data stream.
- The following three major multiplexing techniques:
  - Frequency division multiplexing
  - Wavelength division multiplexing
  - Time division multiplexing
  -

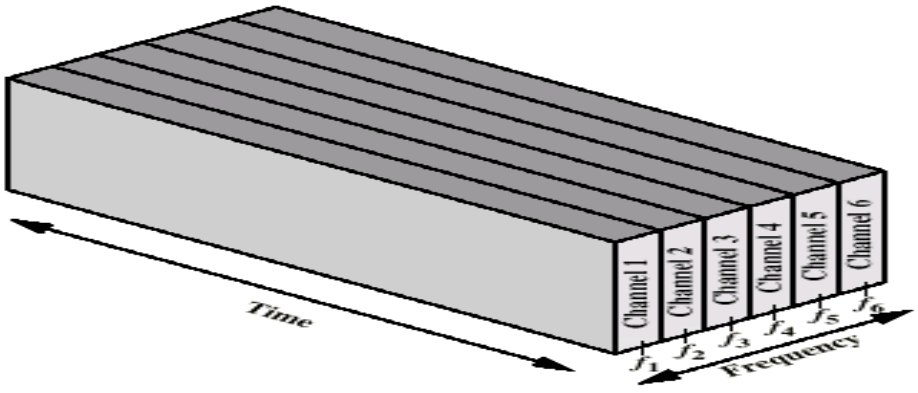
Question: State advantages of multiplexing. (2 Marks)
Answer: Advantages of multiplexing:

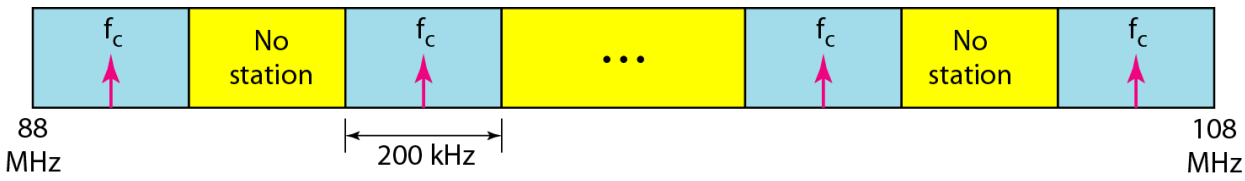
1. Simple and easy
2. Large capacities and scalable.
3. Signals from different sources can be sent together through a single common channel.
4. Signals may have varying speed.

Frequency Division Multiplexing (FDM)

- **Frequency-Division Multiplexing (FDM**) is a scheme in which numerous signals are combined for transmission on a single communications line or channel.
- It is analog technique. Each signal is assigned a different frequency (sub channel) within the main channel.
- FDM requires that the bandwidth of a link should be greater than the combined bandwidths of the various signals to be transmitted. Thus each signal having different frequency forms a particular logical channel on the link and follows this channel only. These channels are then separated by the strips of unused bandwidth called guard bands. These guard bands prevent the signals from overlapping as shown in Fig.
- In FDM, signals to be transmitted **must be analog signals**. Thus digital signals need to be converted to analog form, if they are to use FDM.

- A typical analog Internet connection via a twisted pair telephone line requires approximately three kilohertz (3 kHz) of bandwidth for accurate and reliable data transfer.
- Twisted-pair lines are common in households and small businesses. But major telephone cables, operating between large businesses, government agencies, and municipalities, are capable of much larger bandwidths.





FDM Process

- In FDM, signals generated by each sending device modulate different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link.
- Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal.
- These bandwidth ranges are the channels through which the various signals travel.
- Channels can be separated by strips of unused bandwidth **guard bands** to prevent signals from overlapping.
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Figure: Multiplexing Process :

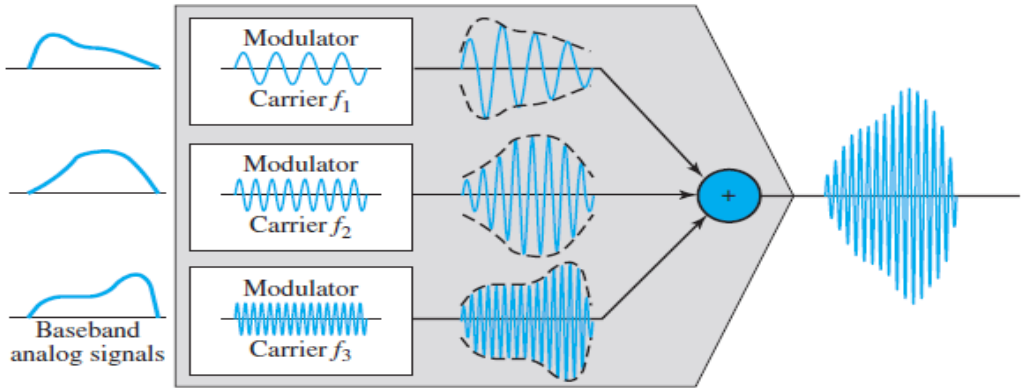
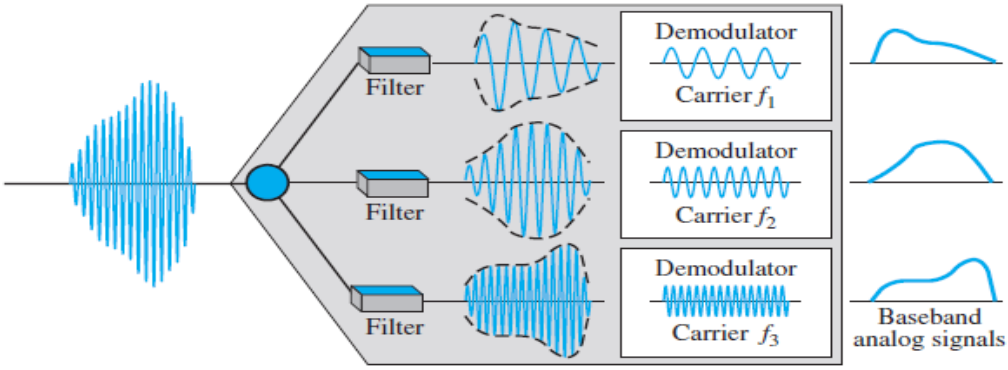


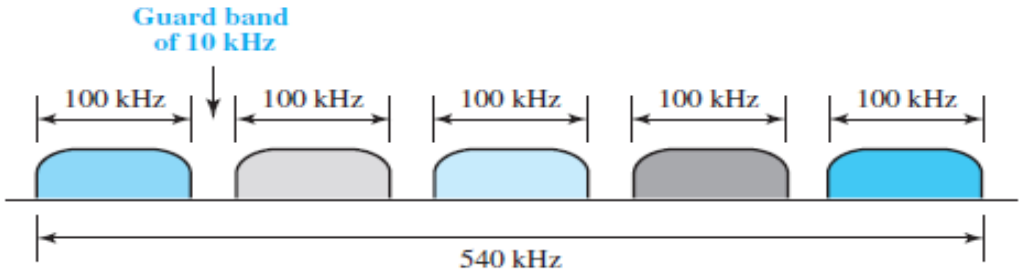
Figure: De-multiplexing Process:



Question: Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference? (4 Marks)

Answer:

- **For five channels, we need at least four guard bands. This means that the required bandwidth is at least**
  - **$5 \times 100 + 4 \times 10 = 540$ kHz**



Question: Five channels each with 200kHz bandwidth are multiplexed using FDM. Find minimum bandwidth of the link if guard band of 10kHz is used. (4Marks)

Answer:

- Five channels each with 200 kHz bandwidth are multiplexed using FDM.
- For five channels, we need at least four guard bands.
- Guard Bands of 10 KHz is used.
- This means that the required bandwidth is at least :
    - **5*200+4*10=1040 KHz.**

Advantages of FDM:

1. A large number of signals (channels) can be transmitted simultaneously.
2. FDM does not need synchronization between its transmitter and receiver for proper operation.
3. Demodulation of FDM is easy.
4. Due to slow narrow band fading only a single channel gets affected.

Disadvantages of FDM:

1. The communication channel must have a very large bandwidth.
2. Intermodulation distortion takes place.
3. Large number of modulators and filters are required.
4. FDM suffers from the problem of crosstalk.
5. All the FDM channels get affected due to wideband fading.

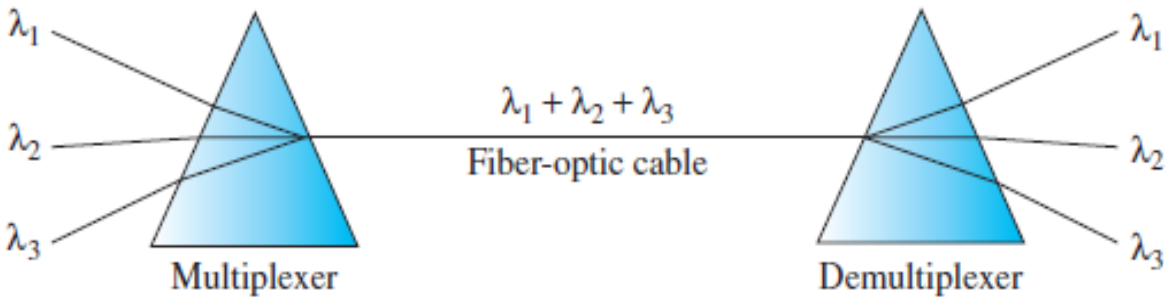
Applications of FDM

- FDM is used for FM & AM radio broadcasting.
- FDM is used in television broadcasting.
- First generation cellular telephone also uses FDM.

Wavelength-Division Multiplexing

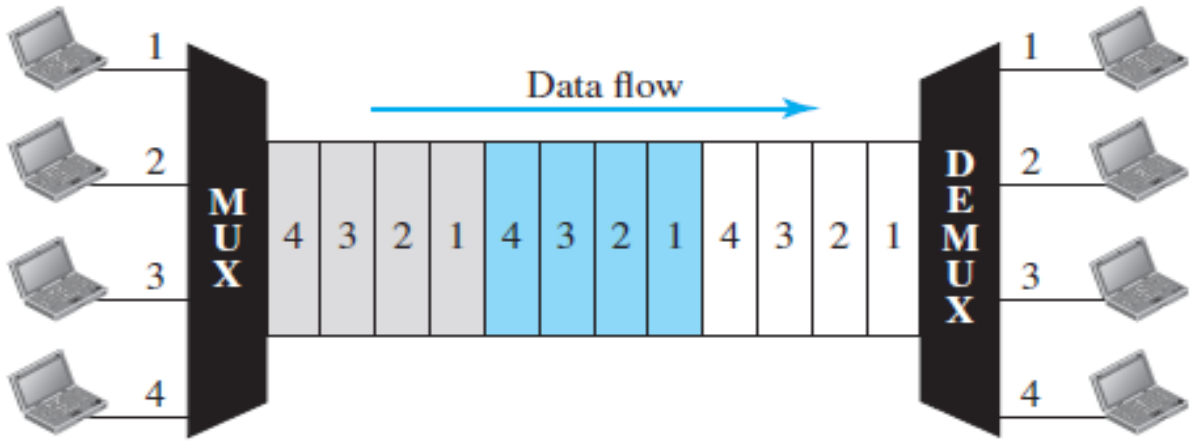
- Wavelength-division multiplexing (WDM) is designed to use the high-data-rate capability of fiber-optic cable.
- The optical fiber data rate is higher than the data rate of metallic transmission cable, but using a fiber-optic cable for a single line wastes the available bandwidth.
- WDM is conceptually the same as FDM, except that the multiplexing and Demultiplexing involve optical signals transmitted through fiber-optic channels. The difference is that the frequencies are very high.
- WDM is an analog multiplexing technique.
- In WDM different signals are *optical or light* signals that are transmitted through optical fiber.

- Various light waves from different sources are combined to form a composite light signal that is transmitted across the channel to the receiver.
- At the receiver side, this composite light signal is broken into different light waves by Demultiplexer.
- The Combining and the Splitting of light waves is done by using a PRISM. Prism bends beam of light based on the angle of incidence and the frequency of light wave.



Time Division Multiplexing (TDM):

- **TDM** is the digital multiplexing technique.
- **In TDM**, **the channel/link is divided** on the **basis of time**.
- Total time available in the channel is divided between several users. Each user is allotted a particular a time interval called time slot or time slice during which the data is transmitted by that user.
- Thus each sending device **takes control of entire bandwidth** of the channel for fixed amount of time.
- Each user is allotted a particular time interval **called *time slot* or *slice.***
- In TDM the data rate capacity of the transmission medium should be greater than the data rate required by sending or receiving devices.
- All the signals to be transmitted are not transmitted simultaneously. Instead, they are transmitted one-by-one. Thus each signal will be **transmitted for a very short time**. One cycle or frame is said to be complete when all the signals are transmitted once on the transmission channel.
- The TDM system can be used to multiplex analog or digital signals, however it is **more suitable for the digital signal multiplexing**.
- The TDM signal in the form of frames is transmitted on the common communication medium.



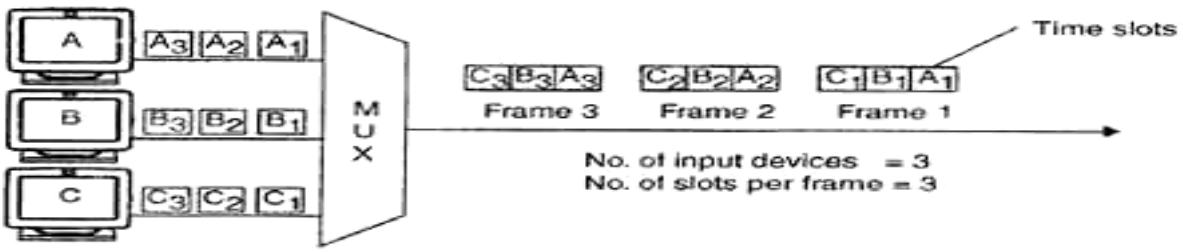
Types of TDM

1. **Synchronous TDM and**
2. **Statistical (Asynchronous) TDM**

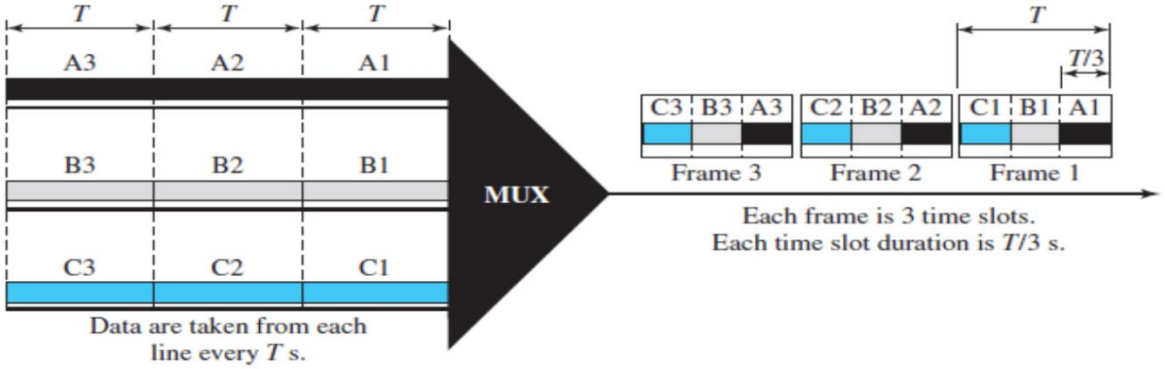
Question: Explain process of synchronous time division multiplexing with its advantages. (4 Marks)

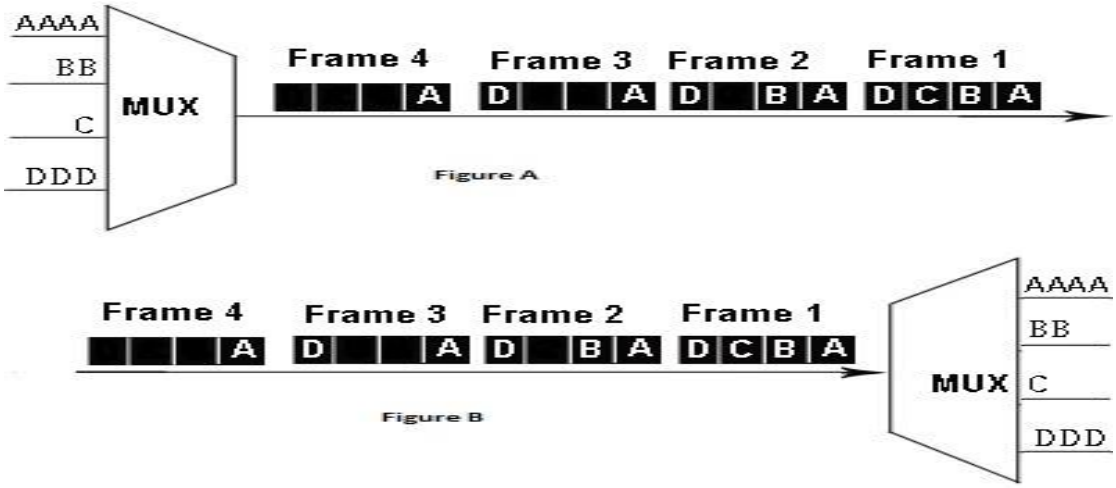
1. Synchronous TDM (STDM)

- In synchronous TDM, **each device is given same time slot** to transmit the data over the link, irrespective of the fact that the device has any data to transmit or not. Hence the name Synchronous TDM.
- Synchronous TDM requires that the total speed of various input lines should not exceed the capacity of path.
- Each device places its data onto the link when its **time slot** arrives *i.e.* each device is given the possession of line turn by turn.
- If any device does not have data to send then its **time slot remains empty**.
- The various time slots are organized into **frames** and each frame consists of one or more time slots dedicated to each sending device.
- If there are *n* sending devices, there will be *n* slots in frame *i.e.* one slot for each device. As show in fig, there are 3 input devices, so there are 3 slots in each frame.
- If there is no data to be transmitted, the buffer will be empty but still the turn of the node will come.



Synchronous TDM





Advantages of Synchronous TDM :

- Relatively simple
- An order of data is maintained
- No addressing information is required, channel capacity should be large.
- Commonly used with ISDN (Integrated Services Digital Network).

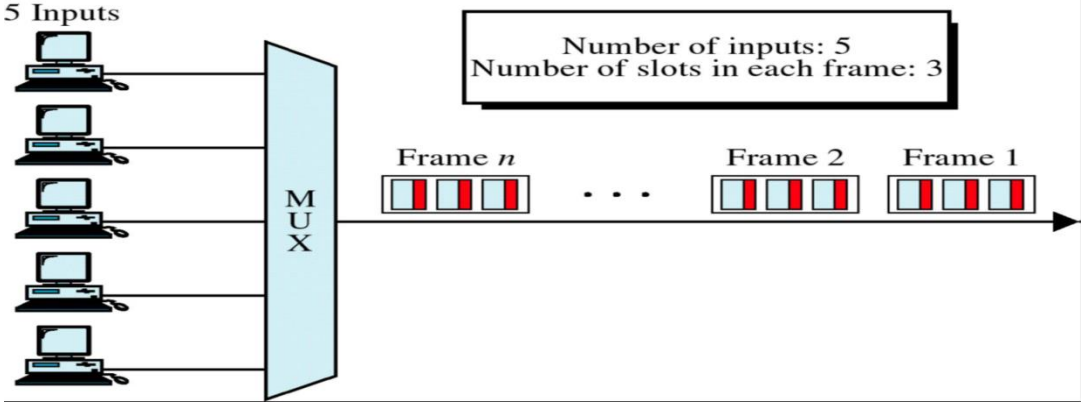
Disadvantages of Synchronous TDM :

1. The channel capacity cannot be fully utilized. Some of the slots go empty in certain frames.
2. The capacity of single communication line that is used to carry the various transmission should be greater than the total speed of input lines.

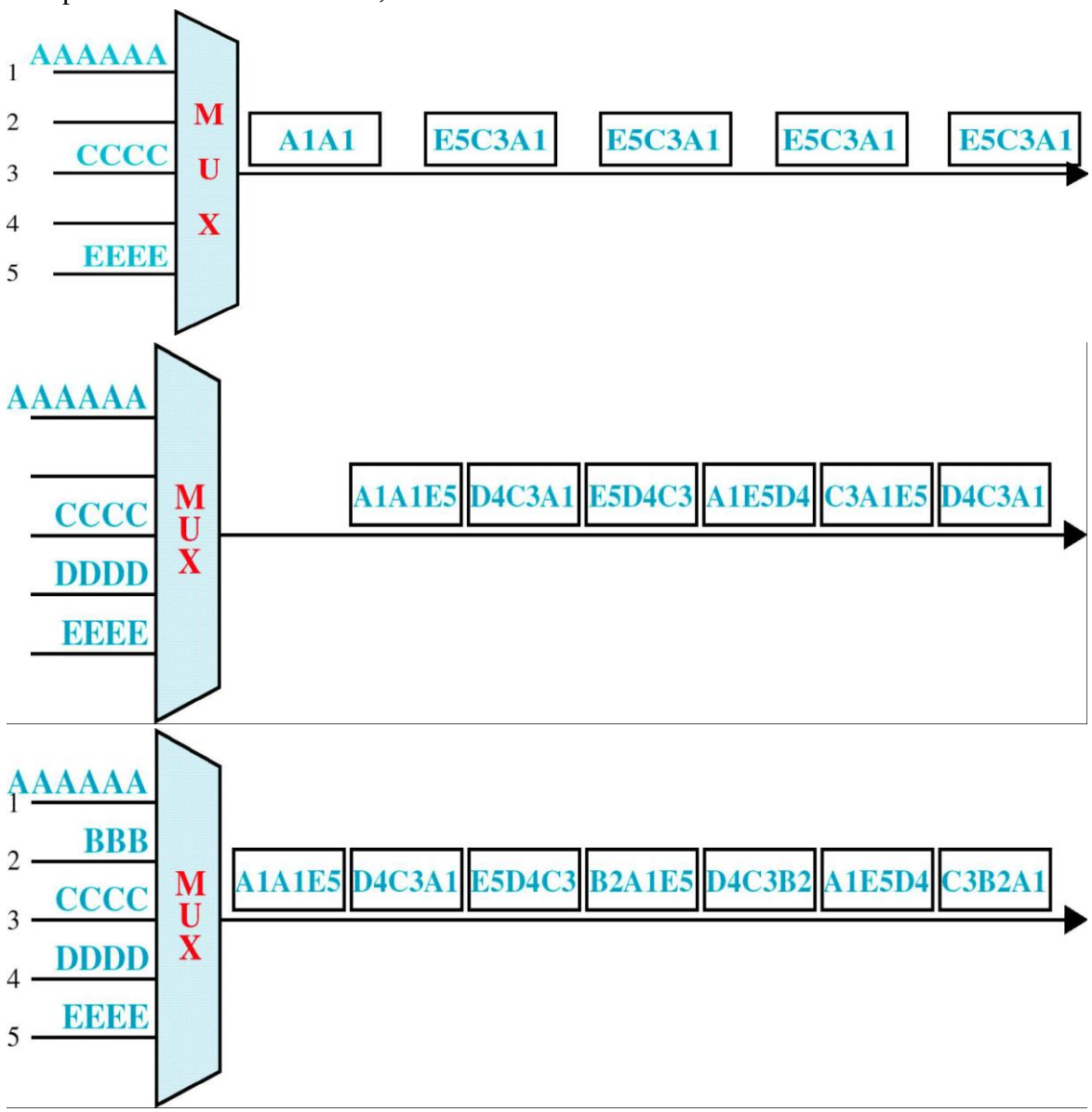
2. Asynchronous TDM or statistical TDM

Question: Explain the process of asynchronous TDM with example.

- It is also known as **statistical** time division multiplexing.
- Asynchronous TDM is called so because is this type of multiplexing, **time slots are not fixed** *i.e.* the slots are flexible. Here, the total speed of input lines can be greater than the capacity of the path.
- In synchronous TDM, if we have *n* input lines then there are *n* slots in one frame. But in asynchronous it is not so. If we have *n* input lines then the frame contains not more than *m* slots, with *m* less than *n (m < n).*
- The number of time slots in a frame is based on a statistical analysis of number of input lines.



- In this system slots are not predefined, the slots are allocated to any of device that has data to send.
- The multiplexer scans the various input lines, accepts the data from the lines that have data to send, fills the frame and then sends the frame across the link.
- If there are not enough data to fill all the slots in a frame, then the frames are transmitted partially filled.
- Asynchronous Time Division Multiplexing is depicted in fig. Here we have five input lines and three slots per frame. In **Case 1**, only three out of five input lines place data onto the link *i.e.* number of input lines and number of slots per frame are same. In **Case 2**, four out of five input lines are active. Here number of input line is one more than the number of slots per frame.
- In **Case 3**, all five input lines are active. In all these cases, multiplexer scans the various lines in order and fills the frames and transmits them across the channel.
- The distribution of various slots in the frames is not symmetrical. In case 2, device 1 occupies first slot in first frame, second slot in second frame and third slot in third frame.



Advantages of TDM :

1. Full available channel bandwidth can be utilized for each channel.
2. lnter modulation distortion is absent.
3. TDM circuitry is not very complex.
4. The problem of crosstalk is not severe.

Disadvantages of TDM :

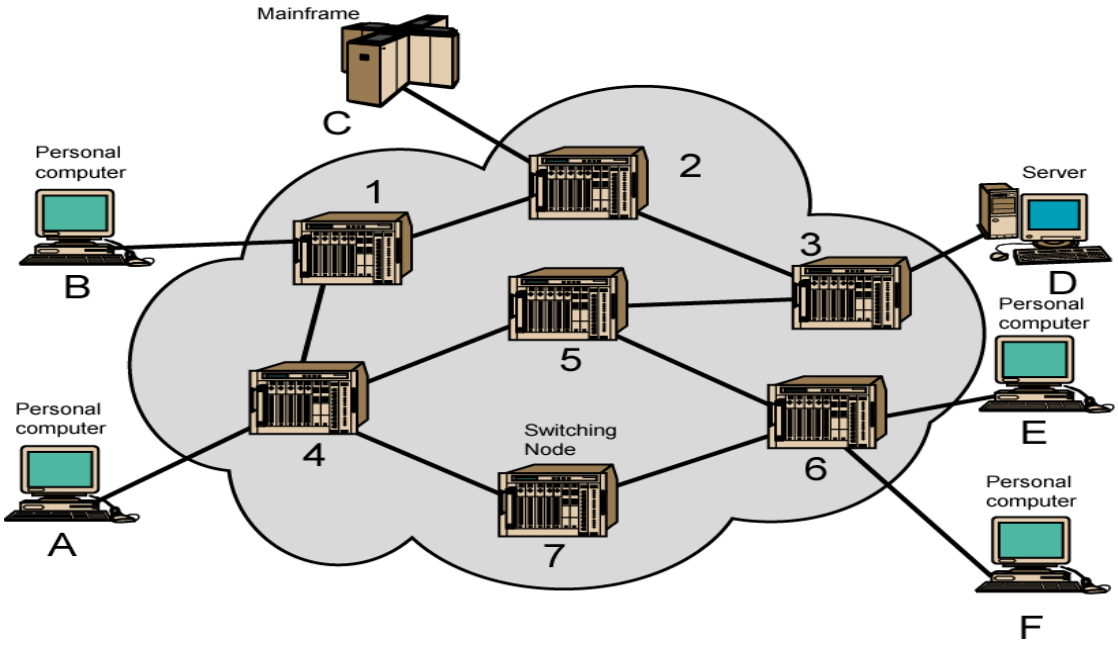
1. Synchronization is essential for proper operation.
2. Due to slow narrowband fading, all the TDM channels may get wiped out.

Comparison of FDM and TDM

PARAMETER	TDM	FDM
Definition	TDM is the transmission technique in which different signal are transmitted over a common channel and each signal occupies entire range of bandwidth in the time domain.	FDM is the transmission technique in which different signal are transmitted over a common channel and each signal occupies different slot within that bandwidth of the frequency domain.
Stands For	Time-Division Multiplexing	Frequency-Division Multiplexing
Useful for	TDM can be used for both Analog and Digital signals.	FDM can be used for Analog signals only.
Synchronization	TDM requires Synchronization.	not required Synchronization.
Circuit	circuitry is very simple to built.	FDM circuitry is very complex.
Cross Talk	TDM is not sensitive for Cross Talk (Noise Immunity)	FDM suffers from the cross talk immunity due to Bandpass Filter.
Requirement	TDM requires sync pulse for its operation.	FDM requires Guard bands for its operation.
Effiecient	TDM is more efficient and is widely used technique in multiplexing.	FDM is less efficient compared to TDM.
Applications	TDM is used in Pulse code modulation.	FDM is used in TV and RADIO broadcasting.

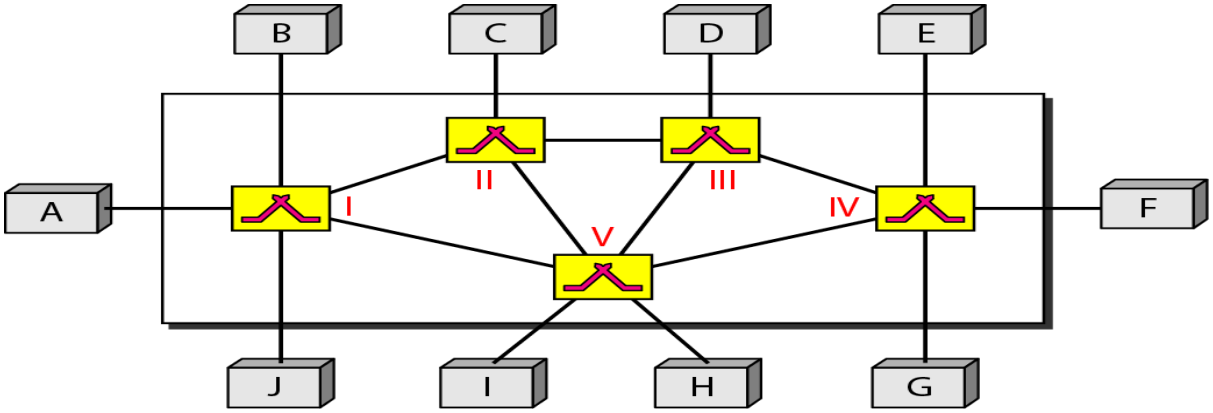
Switched network

- Transmission of data beyond a local area, communication is typically achieved by transmitting data from source to destination through a network of intermediate switching nodes.
- Networks are used to interconnect many devices or stations.
- The stations may be computers, terminals, telephones, or other communicating devices.
- Long distance transmission between stations is typically done over a network of **switching nodes**.
- **Switching nodes** do **not concern with content of data**. **Their purpose is to** provide a switching facility that will **move the data from node to node** until they reach their destination (the end device).
- In a switched communications network, data entering the network from a station are **routed** to the destination by being switched from node to node.

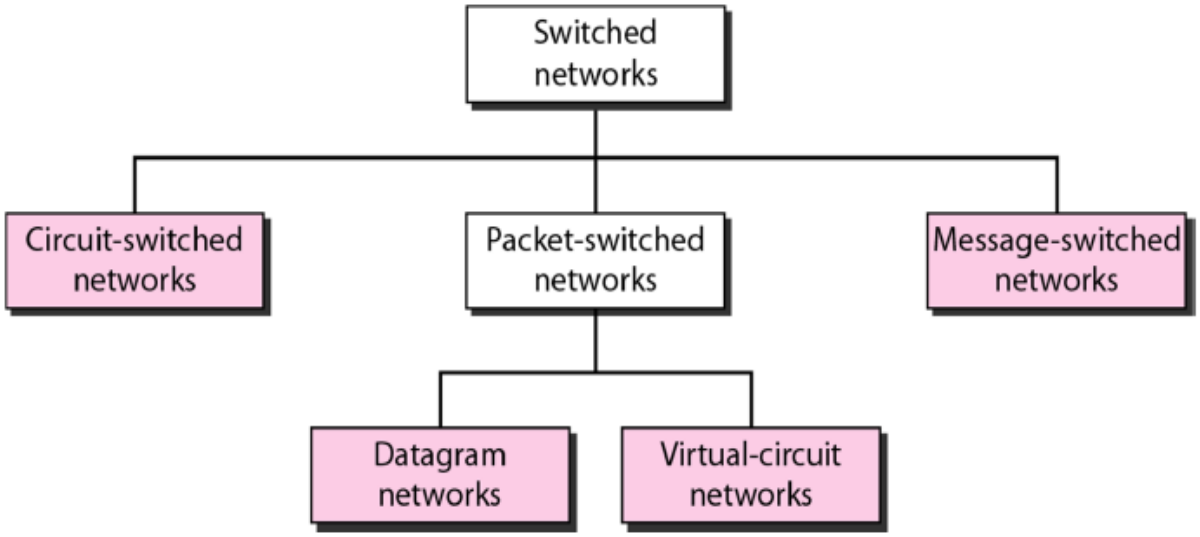


Switching Nodes:

- Nodes may connect to other nodes, or to some stations.
- Network is usually partially connected
    - there is not a direct link between every possible pair of nodes.
- However, some redundant connections are desirable for reliability

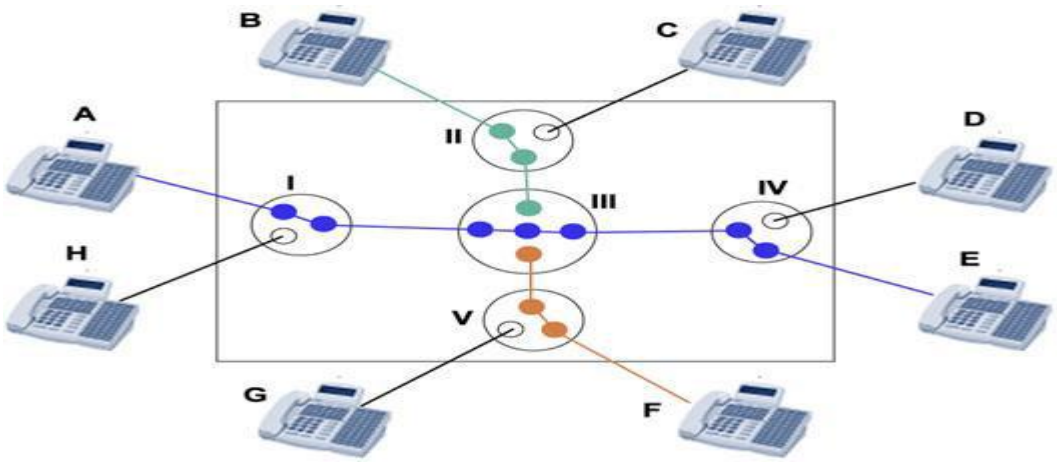


Types of Switching



Circuit Switching

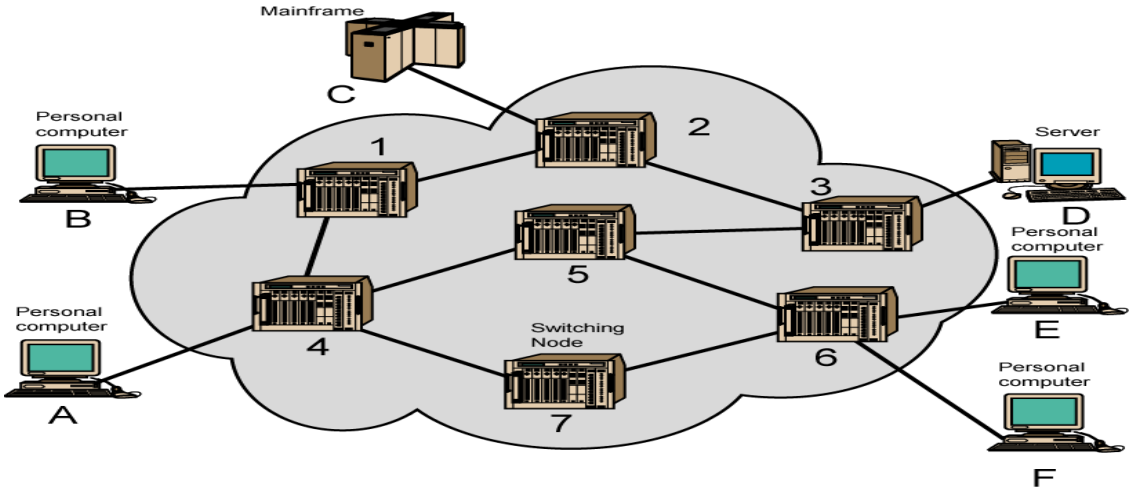
- Circuit Switching is used in public telephone networks.
- Telephone network provides telephone service which involves the two way, real-time transmission of voice signals across a network.
- The network connection allows electrical current and the associated voice signal to flow between the two users.
- These networks are **connection oriented** because they require setting up of a connection before the actual transfer of information can take place.
- The transfer mode of a network that involves setting up a dedicated end to end connection is called **Circuit Switching.**
- Communication via circuit switching has **three phases:**
    1. **Circuit establishment (link by link)**
        - Routing & resource allocation (FDM or TDM)
    2. **Data transfer**
    3. **Circuit disconnect**
        - Deallocate the dedicated resources



Phases of Operation in Circuit Switching

Communication via Circuit switching takes place over three phases of operation:

1. **Circuit Establishment** – In a circuit switching network, before any signal is transmitted, it is necessary to establish an end-to-end link. The node to node links are usually multiplexed by using FDM or TDM.



   - For example consider above figure, station A sends a request to node-4 requesting a connection to station E.
   - Typically, the link from A to 4 is a dedicated line node 4 must find the next route leading to E node 4 selects the link to node 5 and so on then sends a message requesting connection to E.
   - Thus, a dedicated path has been established from A-4-5-6-E

2. **Data Transfer** -After establishing a connection actual transfer of information can take place. It can be analog or digital depending on the nature of network.
   - Data can now be transmitted from A through the network to E.
   - The path is A-4 link, internal switching through 4, 4-5 channel, internal switching through 5, 5-6 channel, internal switching through 6, 6-E link. Generally, the connection is full duplex.

3. **Circuit disconnect (Teardown) :** After some time the connection between two users is terminated usually by the action of one or two stations.Signals must be propagated to nodes 4, 5, and 6 to deallocate the dedicated resources.

Advantages :

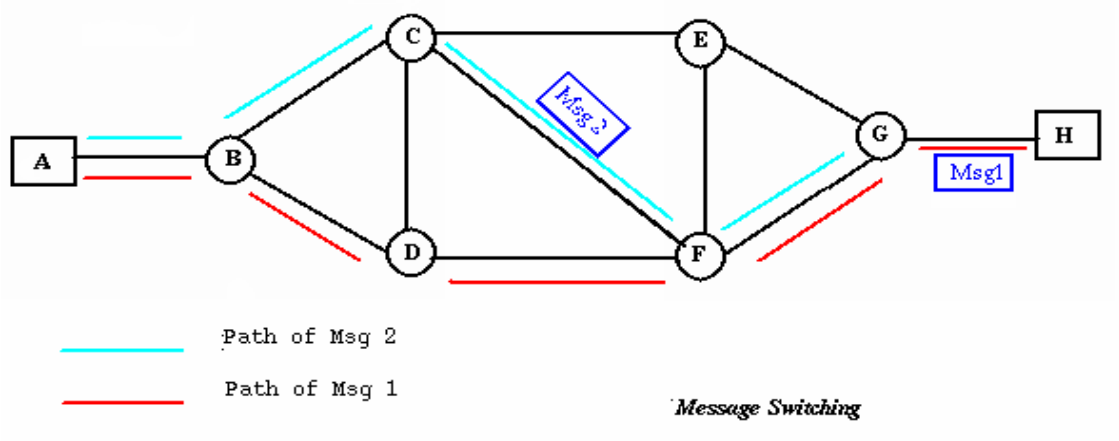
- The dedicated transmission channel provides a guaranteed data rate.
- Because of dedicated path there is no delay in data flow.
- This method is **suitable for long continuous transmission**.

Disadvantages :

- Since the connection is dedicated it cannot be used to transmit any other data even if the channel is free.
- Dedicated channels require more bandwidth.
- It takes more time to establish connection.

Message Switching

- With message switching there is no need to establish a dedicated path between two stations.
- When a station sends a message, the destination address is appended to the message.
- The message is then transmitted through the network, in its entirety, from node to node.
- Each node receives the entire message, stores it in its entirety on disk, and then transmits the message to the next node.
- This type of network is called a store-and-forward network.



- A message-switching node is typically a computer.
- The device needs sufficient secondary-storage capacity to store the incoming messages.
- A time delay is introduced using this type of scheme due to store- and-forward time, plus the time required to find the next node in the transmission path.

Advantages:

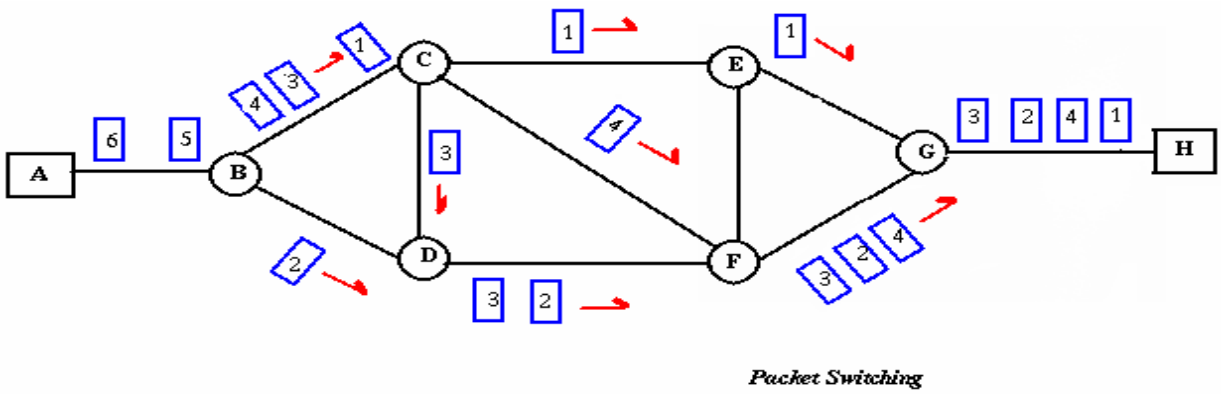
- Channel efficiency can be greater compared to circuit switched systems, because more devices are sharing the channel.
- Traffic congestion can be reduced, because messages may be temporarily stored in route.
- Message priorities can be established due to store-and-forward technique.
- Message broadcasting can be achieved with the use of broadcast address appended in the message.

Disadvantages

- Message switching is not compatible with interactive applications.
- Store-and-forward devices are expensive, because they must have large disks to hold potentially long messages.

Packet Switching

- In Packet Switching, messages are broken up into **packets**, each of which includes a header with source, destination and intermediate node address information.
- *Packet switching* can be seen as a solution that tries to combine the advantages of message and circuit switching.
- There are two methods of packet switching:
    - **Datagram and**
    - **virtual circuit.**
- In packet switching methods, a message is broken into small parts, called packets.
- Each packet is tagged with appropriate source and destination addresses.
- Since packets have a strictly defined maximum length, they can be stored in main memory instead of disk, therefore access delay and cost are minimized.
- Also the transmission speeds, between nodes, are optimized.
- With current technology, packets are generally accepted onto the network on a first-come, first-served basis.



Packet Switching

Advantages:

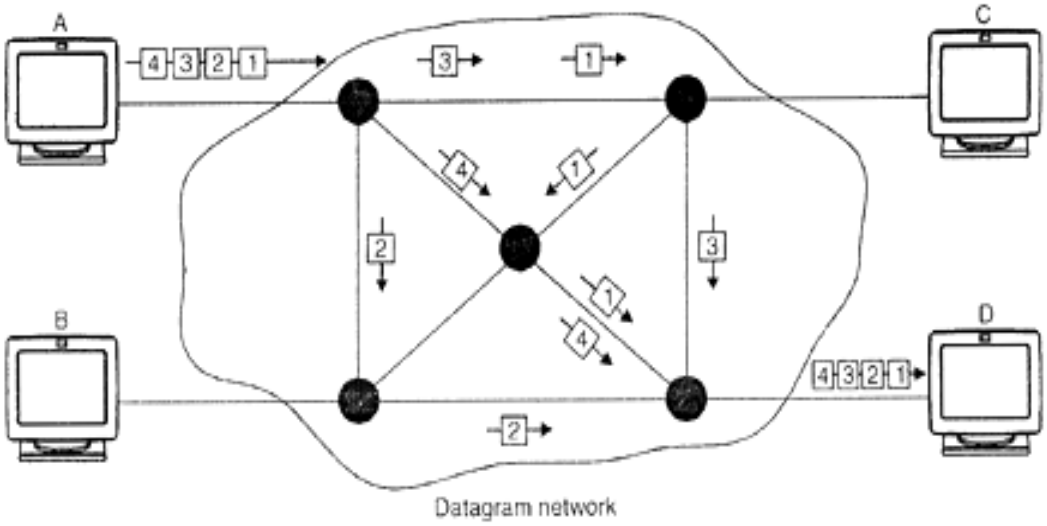
- Better utilization of the network segments in terms of the usage of the network path.
- If a certain link goes down during the transmission, the remaining packets can be sent through another route.
- Since many users can share transmission resources efficiently, the cost of intermittent data communication is reduced.

Disadvantages:

- Variable transmission delays caused by packet processing and packet queues at packet switches.
- Some packet-switching networks support variable packet sizes; this contributes to longer packet processing times at packet switches.
- Sometimes packet may not arrive at their destination in the order in which they were originally transmitted

Datagram packet Switching

- Each message is divided into a stream of packets. Each packet is separately addressed and treated as an independent unit with its own control instructions.
- The switching devices route each packet independently through the network, with each intermediate node determining the packet's next route segment.
- Before transmission starts, the sequence of packets and there are established by the exchange of control information between the sending terminal, the network and the receiving terminal.
- Resources are not allocated for any packet so there is no reserved bandwidth.
- The switches in datagram network are referred to as **routers**.
- No dedicated connection is established between the sender and the receiver, so this network is called as **connectionless** network.
- Datagram packet switching operates at network layer



Datagram packet switching

Advantages:

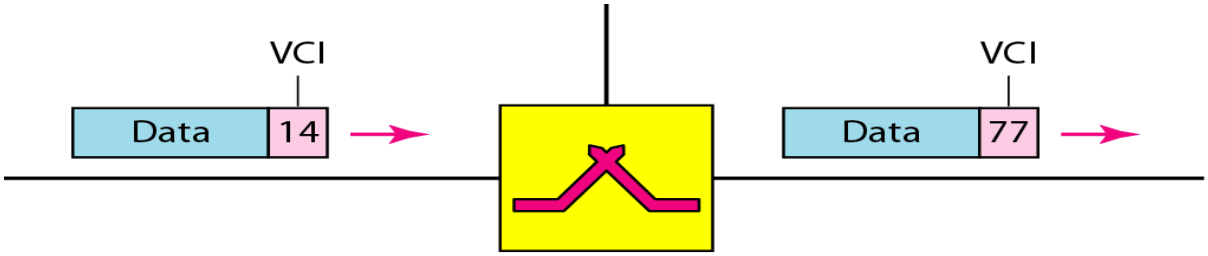
- No call setup phase required.
- More flexible because routing can be used to avoid congested port of the network.
- Cheaper in cost.

Disadvantages:

- Packets are forwarded slowly as compare to the Virtual circuit approach.

Virtual Circuit Packet Switching

- It establishes a logical connection between the sending and receiving devices called **Virtual circuit**.
- The sending device starts the conversation by communicating with the receiving device and agreeing as communication parameters, such as maximum message size and the path to be taken.
- Once this virtual circuit is established; the two devices use it for the rest of the conversation.
- All packets travel through the logical connection established between the sending device and the receiving device.
- Similar to circuit switched network, there are **setup** and **teardown** phases along with the **data transfer** phase.
- Virtual circuit is established in the data link layer.
- Virtual Circuit Identifier(VCI) is a small number which is used by a frame between two switches.



Three phases of communication

- A source and destination have to undergo three phases to communicate between each other, they are:

1. Set up
2. Data Transfer
3. Teardown

- **Set up Phase:**
  - In the Set up phase a switch creates an entry for a virtual circuit by following two approaches-

i) Permanent Virtual Circuit (PVC)
ii) Switched Virtual Circuit (SVC)

i) Permanent Virtual Circuit (PVC) –

- The PVC is like a leased telephone line between two parties. One party can pick up the phone and talk to the other one without dialing.
- A source and destination choose to have a PVC between them.
- Then the corresponding table entries are recorded for all the switches.

ii) Switched Virtual Circuit (SVC) –

- In SVC a temporary connection is established between the source and destination.
- This connection exists only when the data is to be transferred.

- When source A wants to establish a virtual circuit with destination B then the following two steps are to be followed :
  1. Set up Request 2. Acknowledgement

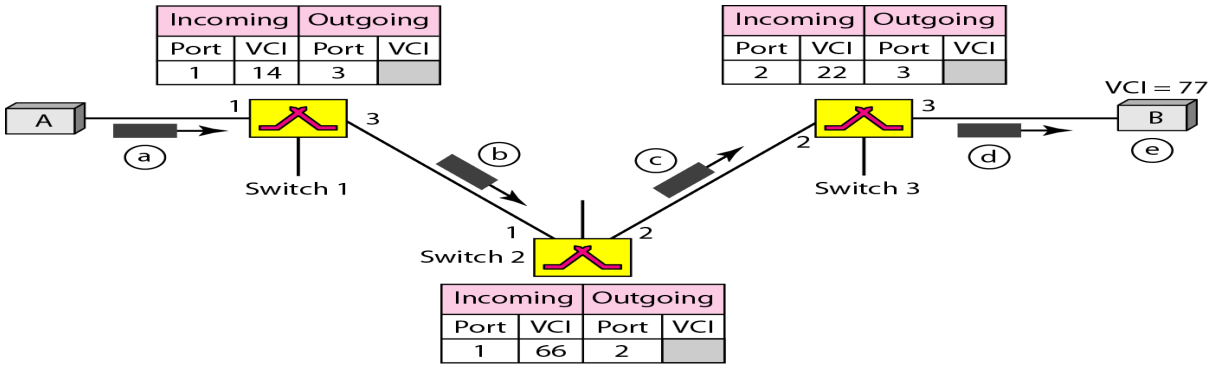


Figure: Setup request in a virtual-circuit network

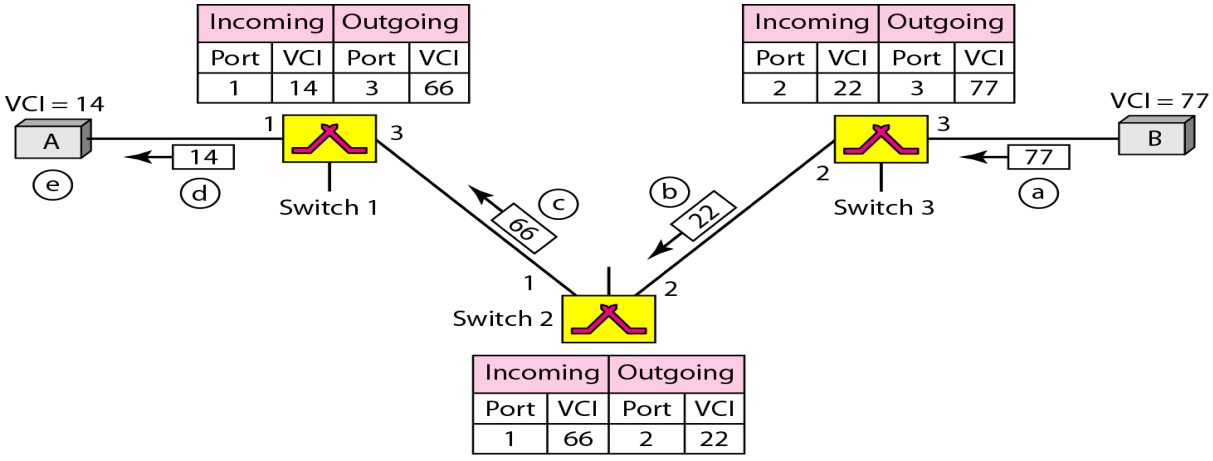


Figure: Setup acknowledgment in a virtual-circuit network

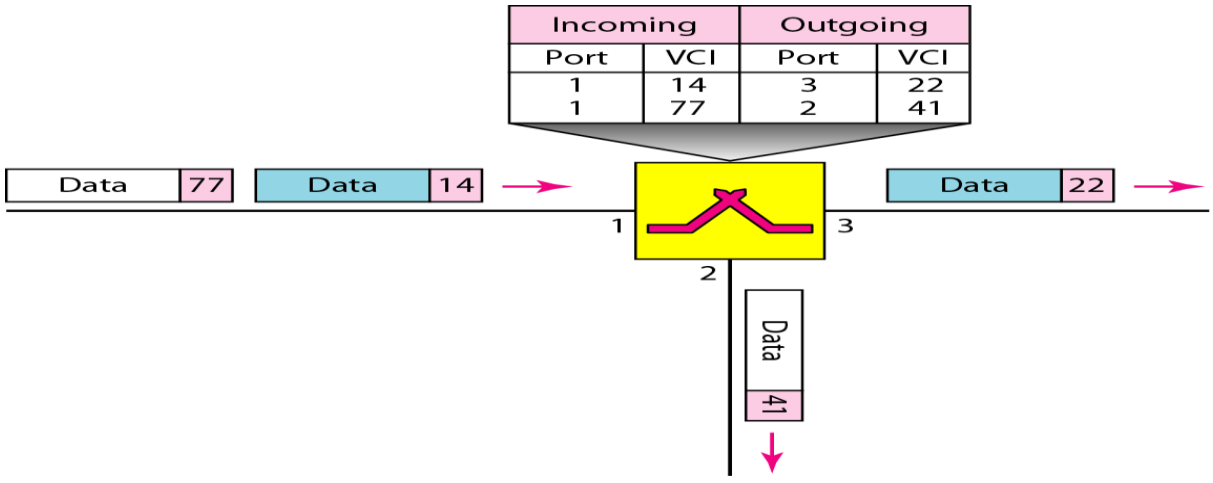


Figure: Switch and tables in a virtual-circuit network

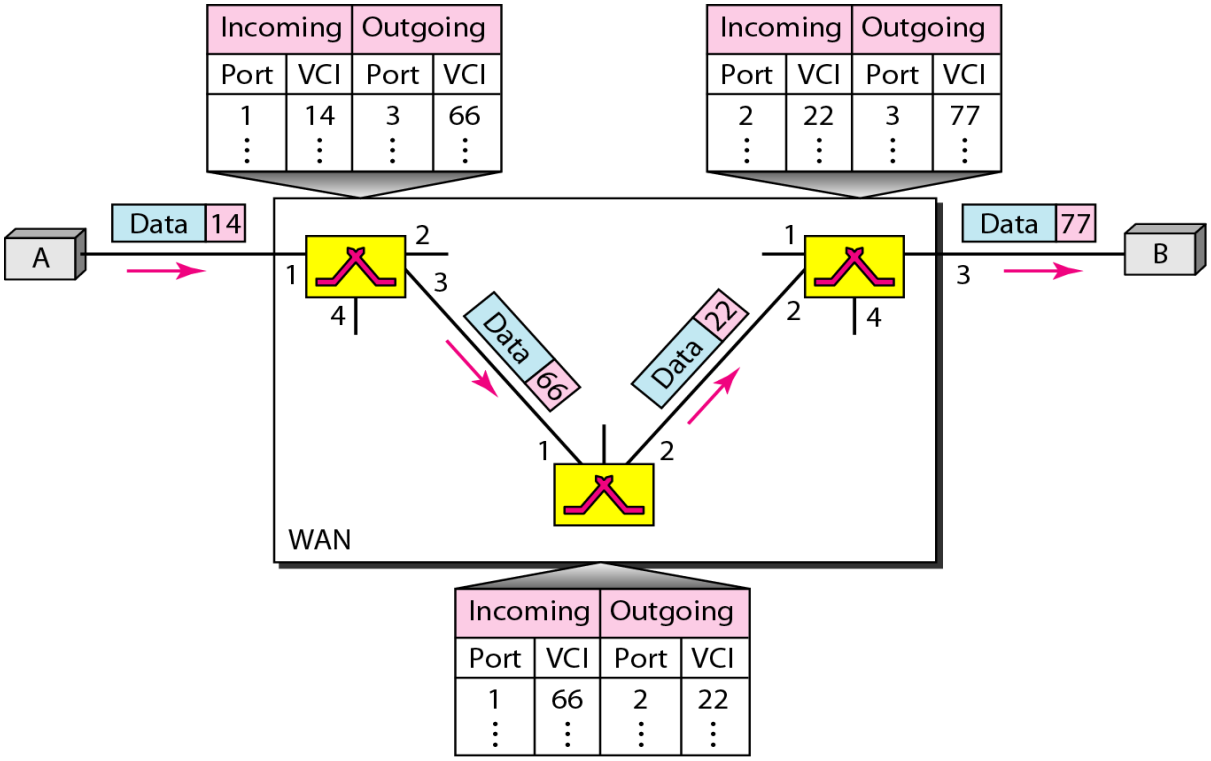


Figure: Source-to-destination data transfer in a virtual-circuit network

Advantages of Virtual circuit Switching:

- Virtual circuit provides packet sequencing and error control.
- Packet forwarding is fast and quick.
- Multiple packets send by the same source to same destination.

Disadvantages of Virtual circuit Switching:

- Loss of a node losses all circuits through that node so its less reliable.
- Less flexible than other approaches.
- Cost is high than Datagram approach

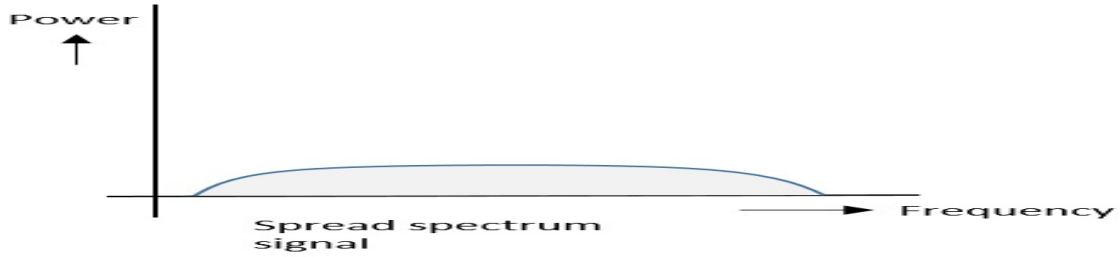
Comparison of Datagram approach and Virtual Circuit Packet Switching:

Sr. No.	Datagram approach	Virtual circuit packet switching
1.	In this approach each packet is considered as a totally independent packet from all others.	In this approach preplanned route established before any packet sent.
2.	More flexible because of routing can be used to avoid congested port of the network.	Less flexible.
3.	Slow in packet forwarding.	Packets are forwarded quickly.
4.	More Reliable	Less reliable because loss of node losses all circuit through that node.

Spread Spectrum

- Spread spectrum is an increasingly important form of encoding for wireless communications. It is used to transmit either analog or digital data, using an analog signal.
- The basic idea of spread spectrum is to modulate the signal so as to increase significantly the bandwidth (spread the spectrum) of the signal to be transmitted.
- It was initially developed for military and intelligence requirements. The use of spread spectrum makes jamming and interception more difficult and provides improved reception.
- The first type of spread spectrum developed is known as **frequency hopping**. A more recent type of spread spectrum is **direct sequence**. Both of these techniques are used in various wireless communications standards and products.

➢ The spread spectrum signals have the signal strength distributed as shown in the following frequency spectrum figure.



➢ Following are some of its features −

- Band of signals occupy a wide range of frequencies.
- Power density is very low.
- Energy is wide spread.

➢ With these features, the spread spectrum signals are highly resistant to interference or jamming.

General Model of Spread Spectrum System

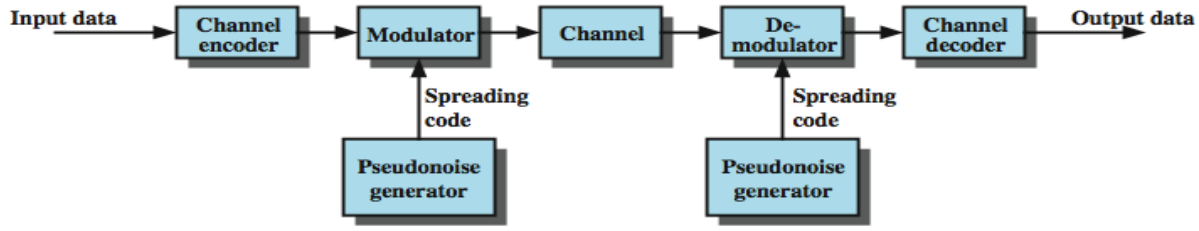


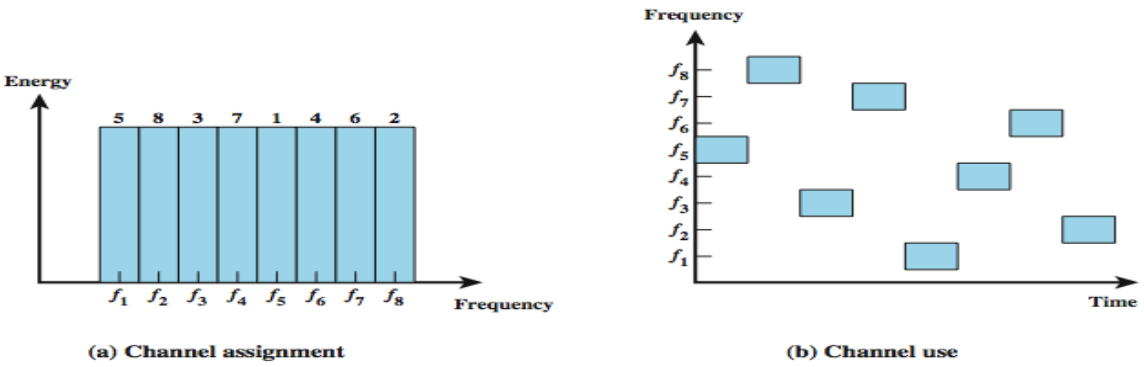
Figure highlights the key characteristics of any spread spectrum system. Input is fed into a channel encoder that produces an analog signal with a relatively narrow bandwidth around some center frequency. This signal is further modulated using a sequence of digits known as a spreading code or spreading sequence. Typically, but not always, the spreading code is generated by a pseudo noise, or pseudorandom number, generator. The effect of this modulation is to increase significantly the bandwidth (spread the spectrum) of the signal to be transmitted. On the receiving end, the same digit sequence is used to demodulate the spread spectrum signal. Finally, the signal is fed into a channel decoder to recover the data.

Frequency Hopped Spread Spectrum (FHSS)

- This is frequency hopping technique, where the users are made to change the frequencies of usage, from one to another in a specified time interval, hence called as frequency hopping.
- For example, a frequency was allotted to sender 1 for a particular period of time. Now, after a while, sender 1 hops to the other frequency and sender 2 uses the first frequency, which was previously used by sender 1. This is called as frequency reuse.
- The frequencies of the data are hopped from one to another in order to provide a secure transmission. The amount of time spent on each frequency hop is called as Dwell time.
- With frequency-hopping spread spectrum (FHSS), the signal is broadcast over a seemingly random series of radio frequencies, hopping from frequency to frequency at fixed intervals.
- A receiver, hopping between frequencies in synchronization with the transmitter, picks up the message.
- Would-be eavesdroppers hear only unintelligible blips. Attempts to jam the signal on one frequency succeed only at knocking out a few bits of it.

Example:

- Following Figure shows an example of a frequency-hopping signal.
- A number of channels are allocated for the FH signal. Typically, there are 2^k carrier frequencies forming 2^k channels.
- The spacing between carrier frequencies and hence the width of each channel usually corresponds to the bandwidth of the input signal.
- The transmitter operates in one channel at a time for a fixed interval; for example, the IEEE 802.11 standard uses a 300-ms interval. During that interval, some number of bits (possibly a fraction of a bit, as discussed subsequently) is transmitted using some encoding scheme.
- A spreading code dictates the sequence of channels used. Both transmitter and receiver use the same code to tune into a sequence of channels in synchronization.



(a) Channel assignment (b) Channel use

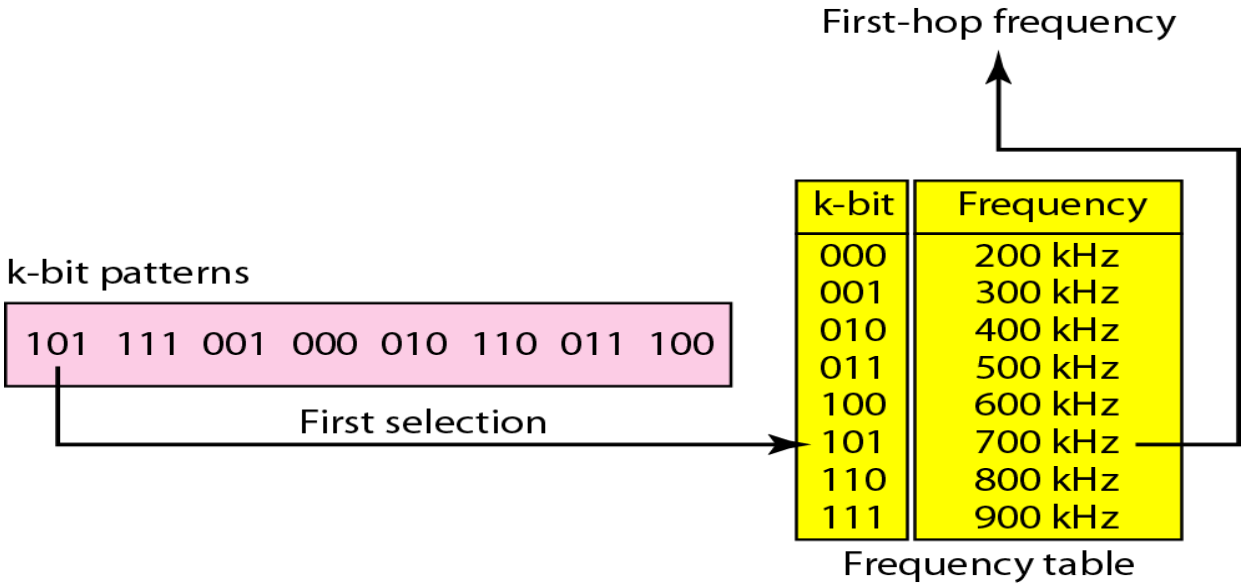


Figure: Frequency Selection

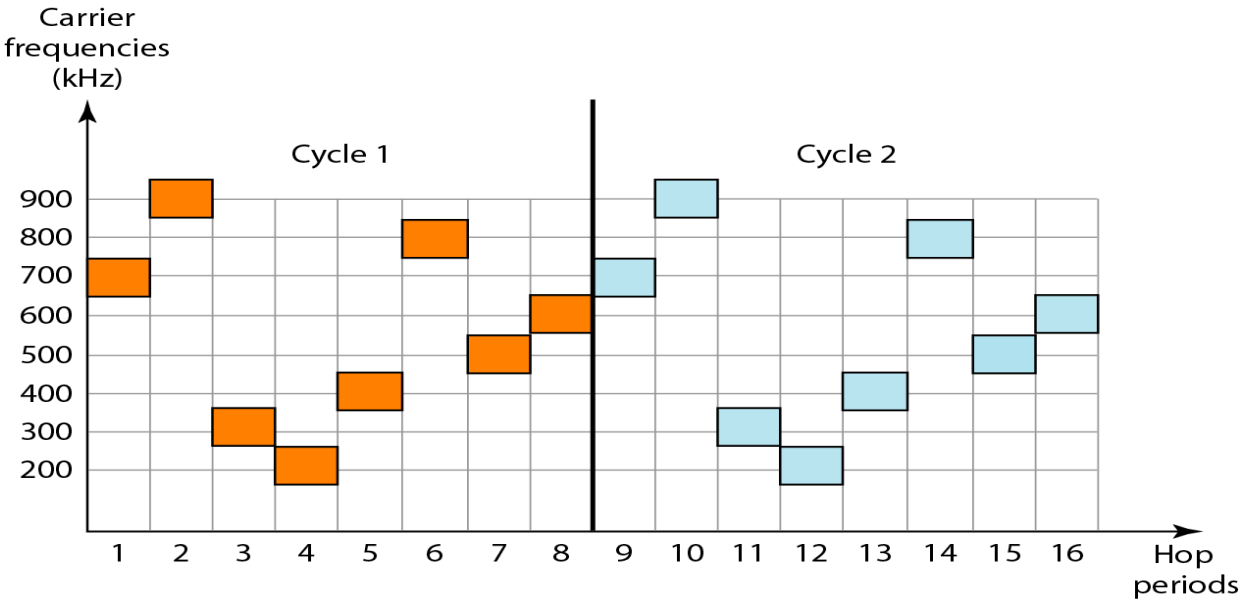


Figure: FHSS Cycle

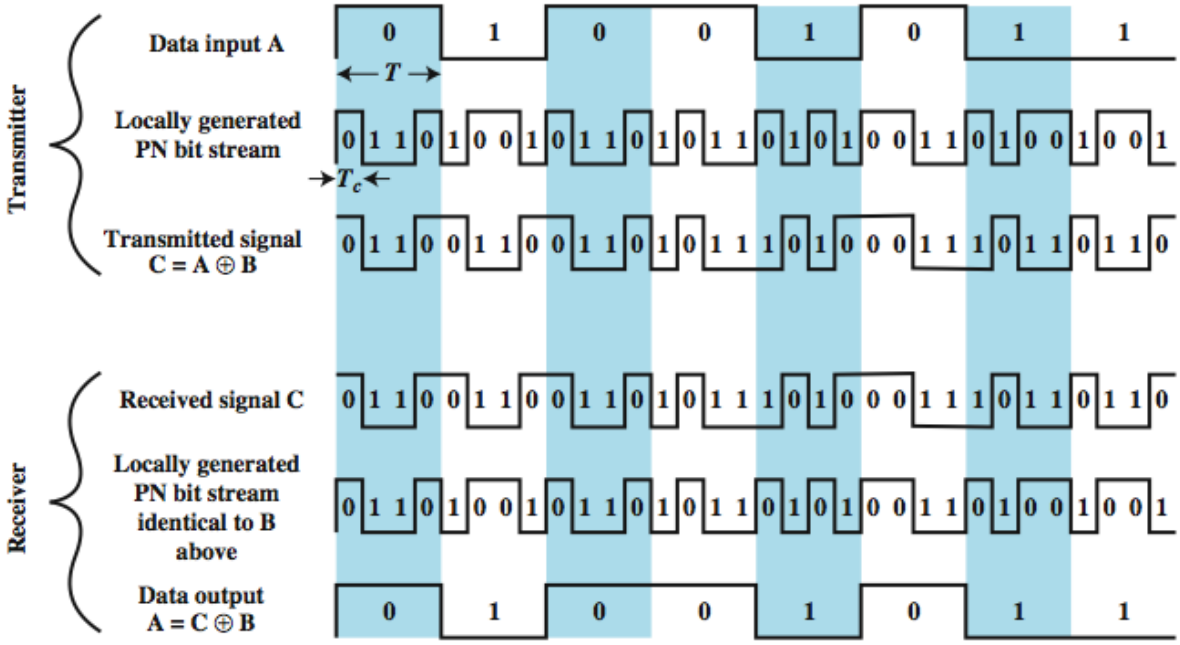
Direct Sequence Spread Spectrum (DSSS)

- Whenever a user wants to send data using this DSSS technique, each and every bit of the user data is multiplied by a secret code, called as **chipping code**.
- This chipping code is nothing but the spreading code which is multiplied with the original message and transmitted. The receiver uses the same code to retrieve the original message.
- With direct sequence spread spectrum (DSSS), each bit in the original signal is represented by multiple bits in the transmitted signal, using a spreading code. The spreading code spreads the signal across a wider frequency band in direct proportion to the number of bits used. Therefore, a 10-bit spreading code spreads the signal across a frequency band that is 10 times greater than a 1-bit spreading code.

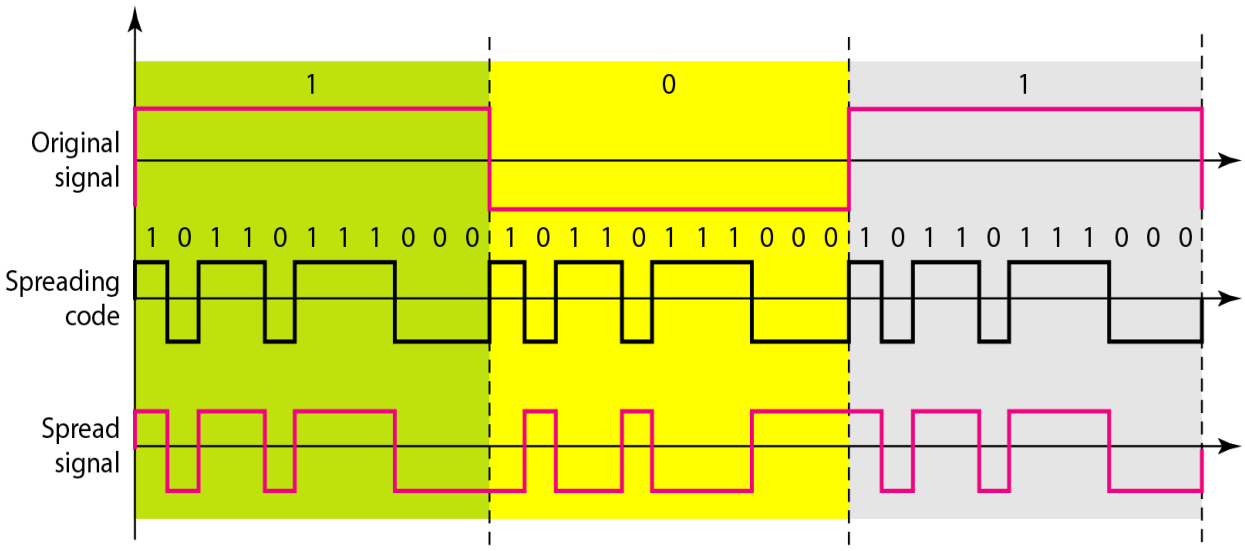
Direct Sequence Spread Spectrum Example

One technique with direct sequence spread spectrum is to combine the digital information stream with the spreading code bit stream using an exclusive-OR (XOR).

Figure shows an example. Note that an information bit of one inverts the spreading code bits in the combination, while an information bit of zero causes the spreading code bits to be transmitted without inversion. The combination bit stream has the data rate of the original spreading code sequence, so it has a wider bandwidth than the information stream. In this example, the spreading code bit stream is clocked at four times the information rate.



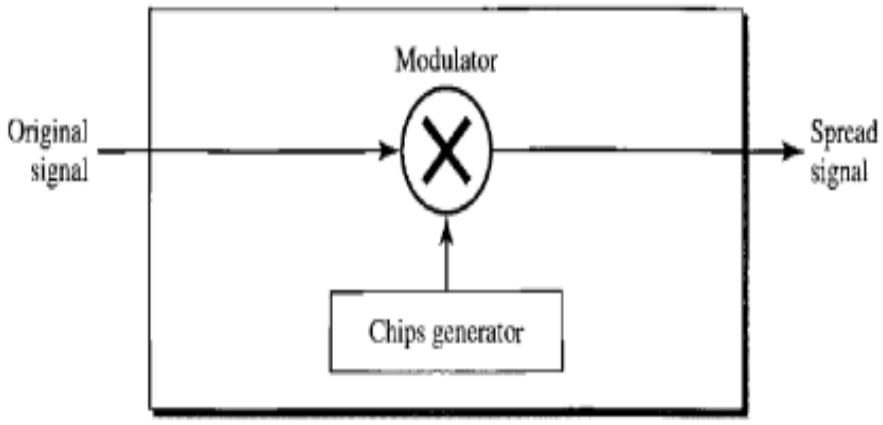
Another Example:



FHSS	DSSS / CDMA
Multiple frequencies are used	Single frequency is used
Hard to find the user's frequency at any instant of time	User frequency, once allotted is always the same
Frequency reuse is allowed	Frequency reuse is not allowed
Sender need not wait	Sender has to wait if the spectrum is busy
Power strength of the signal is high	Power strength of the signal is low
Stronger and penetrates through the obstacles	It is weaker compared to FHSS
It is never affected by interference	It can be affected by interference
It is cheaper	It is expensive
This is the commonly used technique	This technique is not frequently used

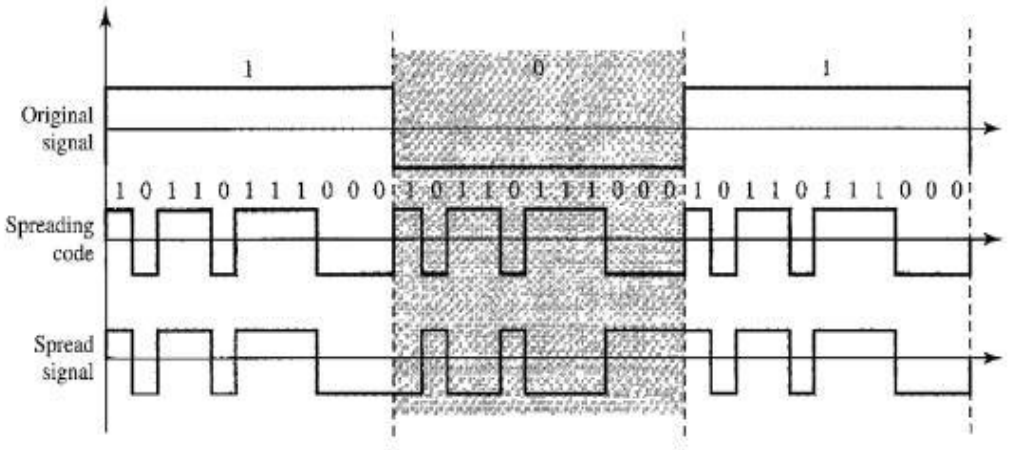
Question: Explain DSSS mechanism with neat diagram.

- The direct sequence spread spectrum (DSSS) technique also expands the bandwidth of the original signal, but the process is different.
- In DSSS, we replace each data bit with n bits using a spreading code. In other words, each bit is assigned a code of n bits, called chips, where the chip rate is n times that of the data bit.



- As an example, let us consider the sequence used in a wireless LAN,the famous Barker sequence where n is 11. We assume that the original signal and the chips in the chip

generator use polar NRZ encoding. Figure shows the chips and the result of multiplying the original data by the chips to get spread signal.



Question: Compare DSSS with FHSS.

Compare	DSSS	FHSS
Definition	PN sequence of large bandwidth is multiplied with narrow band data signal.	Data bits are transmitted in different frequency slots which are changed by PN sequence.
Modulation method	M-ary FSK	BPSK
Acquisition time	Short	Long
Effect of distance	More	Less