# 2. THE PHYSICAL LAYER

## 2.1. FUNCTION OF PHYSICAL LAYER

Physical layer is the lowest layer of the OSI reference model. It is responsible for sending bits from one computer to another. This layer deals with the setup of physical connection to the network and with transmission and reception of signals.

Functions of Physical Layer

Following are the various functions performed by the Physical layer of the OSI model.

1. Representation of Bits: Data in this layer consists of a stream of bits. The bits must be encoded into signals for transmission. i.e. 0's and 1's are changed to signal.
2. Data Rate: This layer defines the rate of transmission which is the number of bits per second.
3. Synchronization: It deals with the synchronization of the transmitter and receiver. The sender and receiver are synchronized at bit level.
4. Line Configuration: This layer connects devices with the medium: Point to Point configuration and Multipoint configuration.
5. Topologies: Devices must be connected using the following topologies: Mesh, Star, Ring and Bus.
6. Transmission Modes: Physical Layer defines the direction of transmission between two devices: Simplex, Half Duplex, Full Duplex.
7. Deals with baseband and broadband transmission.**Baseband** technology transmits a single data **signal**/stream/channel at a time while **broadband** technology transmits multiple data signals/streams/channels simultaneously at the same time.

***Design Issues with Physical Layer***

The **Physical Layer** is transmitted raw bits over a communication channel.

Making sure that when one side sends a 1 bit, it is received by the other side as a

1 bit and not as a 0 bit.

The design issues here mostly deal with electrical, mechanical and timing interfaces.

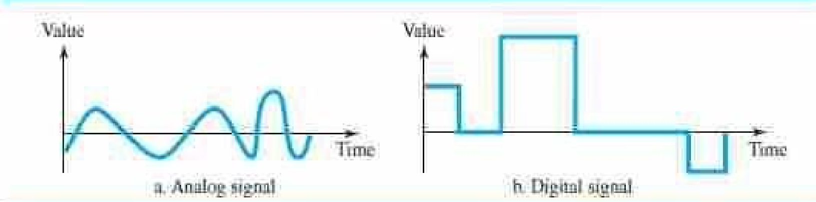
## 2.2. Data and Signals: Analog and Digital signals, Transmission Impairment, Data Rate Limits, Performance

The term analog **data** refers to information that is continuous; digital data refers to information that has discrete states. To be transmitted, data must be transformed to electromagnetic **signals**.

**Analog and Digital signals:**

| Analog Signals | Digital Signals |
|---|---|
| • Continuous signals | • Discrete signals |
| • Represented by sine waves | • Represented by square waves |
| • Human voice, natural sound, analog electronic devices are few examples | • Computers, optical drives, and other electronic devices |
| • Continuous range of values | • Discontinuous values |
| • Records sound waves as they are | • Converts into a binary waveform. |
| • Only be used in analog devices. | • Suited for digital electronics like computers, mobiles and more. |

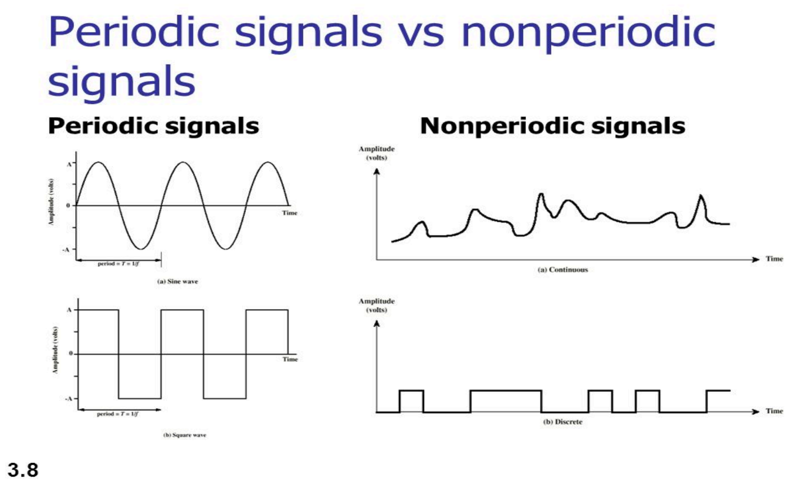
Figure 3.2 *Comparison of analog and digital signals*




***Analog and digital signals can take one of two forms:*** periodic or non-periodic

***Periodic Signal:*** A periodic signal completes a pattern within a measurable time frame, called a period, and repeats that pattern over subsequent identical periods. The completion of one full pattern is called a cycle.

***Non-periodic signal:*** A non-periodic signal changes without exhibiting a pattern or cycle that repeats over time.




**Period** refers to the amount of time, in seconds, a signal needs to complete 1 cycle. **Frequency** refers to the number of periods in I s.

**f= 1/T and t= 1/F**

## Transmission Impairment

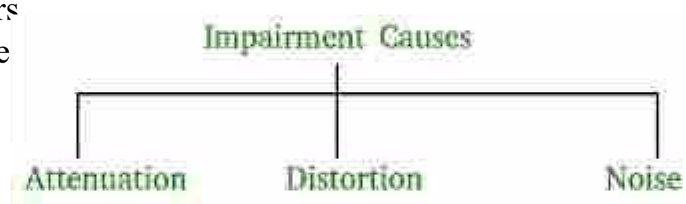
When a signal transmits from one transmission medium to other, the signal that is received may differ from the signal that is transmitted, due to various transmission impairments.

*Consequences:*

- For analog signals: degradation of signal quality
- For digital signals: bit errors

The most significant impairments include

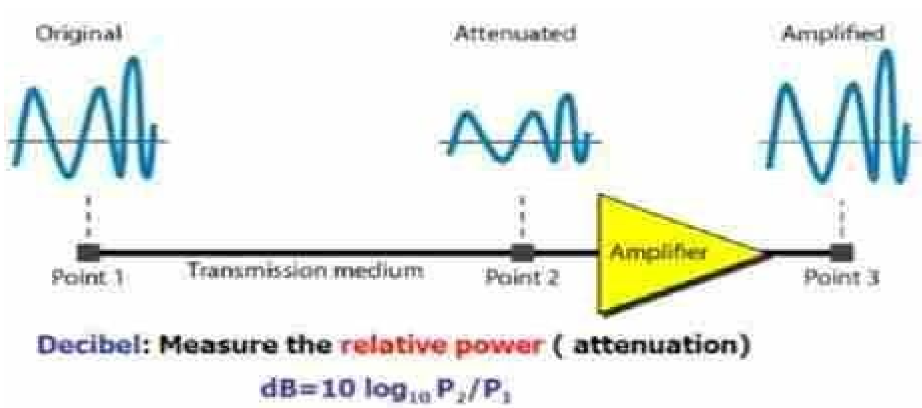
- ✔ **Attenuation**
- ✔ **Distortion**
- ✔ **Noise**




## Attenuation

**Attenuation** refers to loss of energy by a signal time.

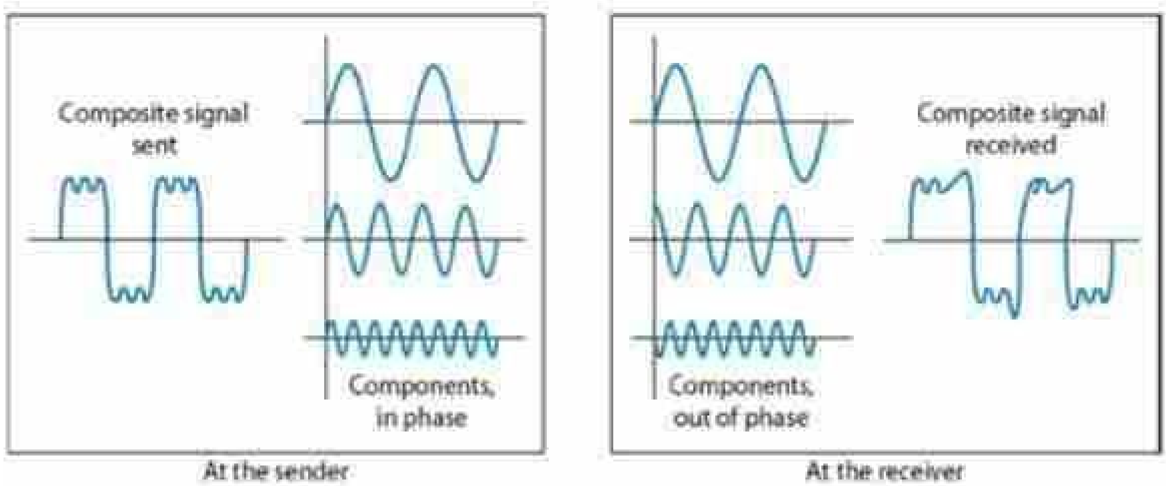
When a signal, simple or composite , travels through a medium ,it loses some of its energy in overcoming the resistance of the medium.
To compensate for this loss, amplifiers are used.




- Attenuation is measured in **decibels(dB)**.
- It measures the relative strengths of two signals or one signal at two different point.
- **P1** is power at the sending end and **P2** is power at the receiving end.

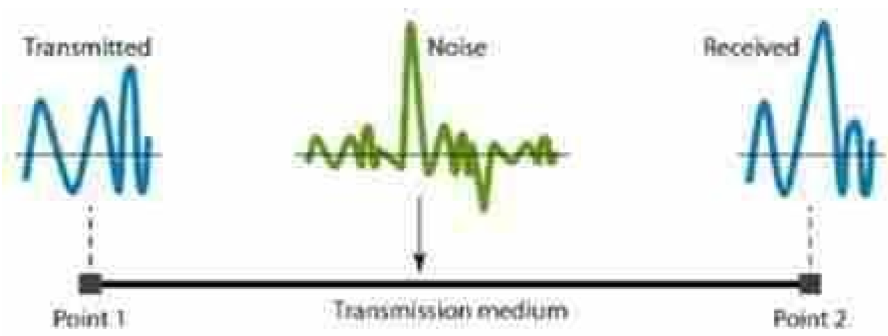
## Distortion

Distortion means signal changes its form or shape.
Distortion can occur in a composite signal made of different frequencies.
Each signal component has its own propagation speed through a medium and therefore its own delay in arriving at the final signal.




**Noise**

The random or unwanted signal that mixes up with the original signal is called noise. Several types of noise such as thermal noise, induced noise , crosstalk noise, Impulse noise may corrupt the signal.




***Induced*** *noise comes from sources such as motors and appliances. These devices act as sending antenna and transmission medium act as receiving antenna.*
***Thermal*** *noise is movement of electrons in wire which creates an extra signal.*
***Crosstalk*** *noise is when one wire affects the other wire.*
***Impulse*** *noise is a signal with high energy that comes from lightning or power lines.*

***SNR (Signal to NOISE ratio)*** *is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise.*

SNR = AVG SIGNAL POWER / AVG NOISE POWER

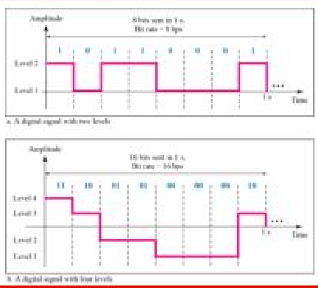
**Data rate Limits**

Data rate governs the speed of data transmission.
A very important consideration in data communication is how fast we can send data, in bits per second, over a channel.

**Data rate depends upon 3 factors:**

1. The bandwidth available
2. Number of levels in digital signal

**Figure 3.16** *Two digital signals: one with two signal levels and the other with four signal levels*




3.1

3. The quality of the channel – level of noise

**Two theoretical formulas** were developed to calculate the data rate:

1. **No**iseless Channel: **N**yquist Bit Rate
2. Noisy Channel: Shannon Capacity

1. **Noiseless Channel: Nyquist Bit Rate**

$$\textbf{BitRate} = 2 * \textbf{Bandwidth} * \log_2(L)$$

Where, **Bandwidth** is the bandwidth of the channel,
**L** is the number of signal levels used to represent data, and
**BitRate** is the bit rate in bits per second.

Bandwidth is a fixed quantity, so it cannot be changed. Hence, the data rate is directly proportional to the number of signal levels.

**Problems:**

**Q1 :** Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. What can be the maximum bit rate?

**Output1 :** BitRate = $2 * 3000 * \log_2(2) = 6000$bps

**Q2 :** We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?

**Output2 :** $265000 = 2 * 20000 * \log_2(L)$
=> $\log_2(L) = 6.625$
=> $L = 2^{6.625} = 98.7$ levels

2. **Noisy Channel: Shannon Capacity**

In reality, we cannot have a noiseless channel; the channel is always noisy.
Shannon capacity is used, to determine the theoretical highest data rate for a noisy channel:

$$\textbf{Capacity} = \textbf{Bandwidth} * \log_2(1 + \textbf{SNR})$$

Where, B**andwidth** is the bandwidth of the channel,
**SNR** is the signal-to-noise ratio, and
**Capacity** is the capacity of the channel in bits per second.

Bandwidth is a fixed quantity, so it cannot be changed. Hence, the channel capacity is directly proportional to the power of the signal, as **SNR = (Power of signal) / (power of noise).**

*The signal-to-noise ratio (S/N) is usually expressed in decibels (dB) given by the formula:*

**10 * log10(S/N)**

**so for example a signal-to-noise ratio of 1000 is commonly expressed as:**

⇨ **10 * log10(1000) = 30 dB.**

***Note: The Shannon capacity gives us the upper limit; the Nyquist formula tells us how many signal levels we need.***

**Q2. Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as - ??**

**Sol.** $C = B \times \log_2 (1 + SNR)$

$\Rightarrow C = B \times \log_2 (1 + 0)$

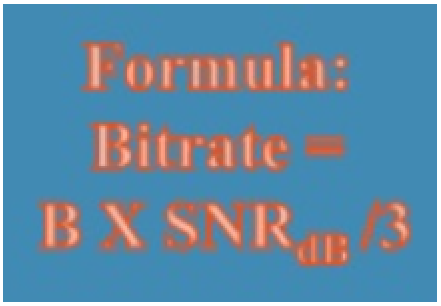
$\Rightarrow C = 0$

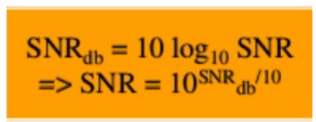
**This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel with any bandwidth.**

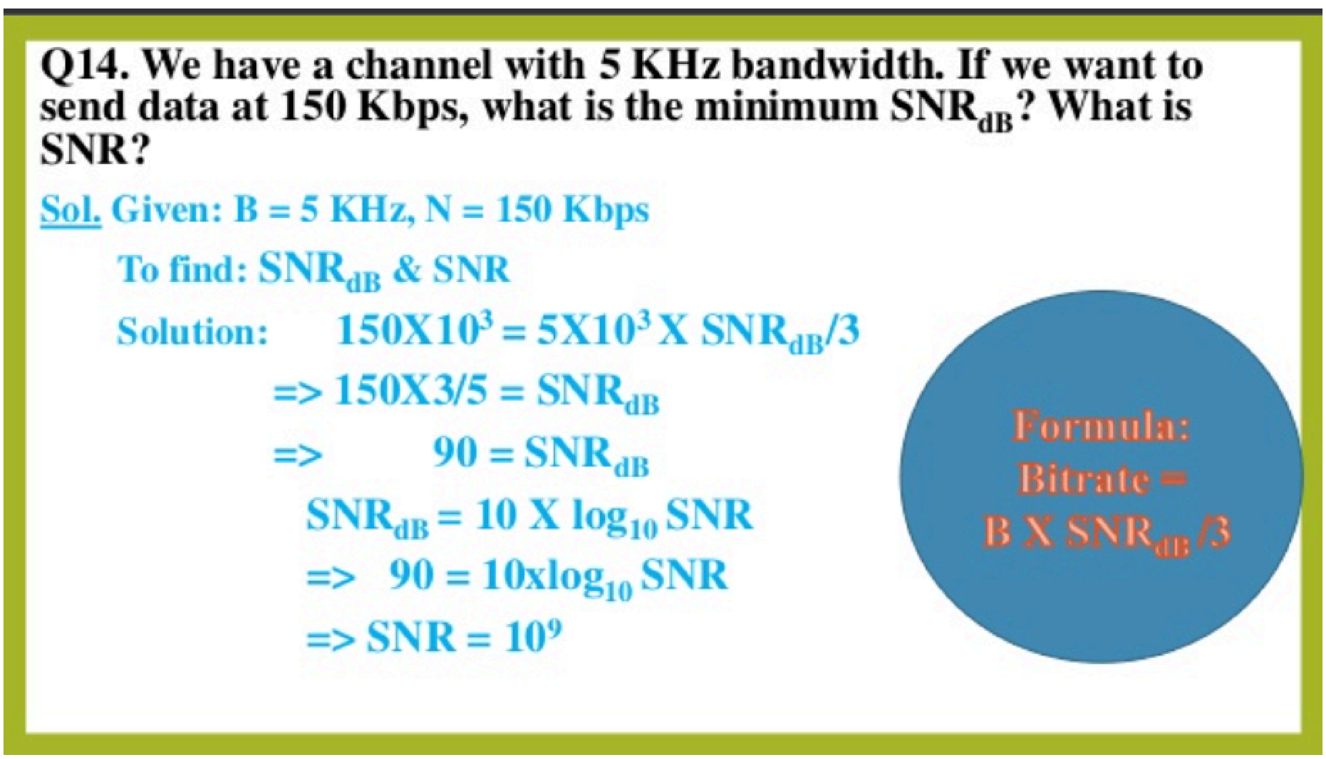
**Problems:**

**Q1 :** A telephone line normally has a bandwidth of 3000 Hz (300 to 3300 Hz) assigned for data communication. The SNR is usually 3162. What will be the capacity for this channel?

**Output1** : => C = 3000 * log2(1 + SNR) = 3000 * 11.62 = 34860 bps



**PERFORMANCE:**

1. Bandwidth
2. Throughput
3. Latency (Delay)
4. Bandwidth Delay Product
5. Jitter

**Bandwidth**

**Bandwidth is the maximum rate of data transfer across a given path.**

- One characteristic that measures network-performance is bandwidth.
- Bandwidth of analog and digital signals is calculated in separate ways:

***(2) Bandwidth of an Analog Signal (in hz)***

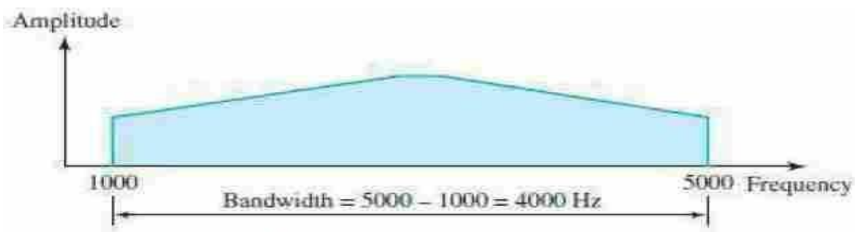



Figure 3.13 *The bandwidth of signals*

**In figure 3.13,** the signal has a minimum frequency of F1 = 1000Hz and maximum frequency of F2 = 5000Hz.
Hence, the bandwidth is given by F2 - F1= 5000 - 1000 = 4000 Hz

***(3) Bandwidth of a Digital Signal (in bps)***

For example: The bandwidth of a Fast Ethernet is a maximum of 100 Mbps. (This means that this network can send 100 Mbps).

**Throughput**

• The throughput is a measure of **how fast we can actually send data through a network.**

*In other words,*

1) The throughput is an actual measurement of how fast we can send data.

***Example 1.18***

A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

**Solution**

We can calculate the throughput as

$$\text{Throughput} = (12{,}000 \times 10{,}000) / 60 = 2 \text{ Mbps}$$

***Latency (Delay)***

The latency defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.

$$\text{Latency} = \text{propagation time} + \text{transmission time} + \text{queuing time} + \text{processing delay}$$

**Propagation time** is defined as the time required for a bit to travel from source to destination.

$$\text{Propagation time} = \text{Distance} / (\text{Propagation Speed})$$

**Example 1.19**

What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be $2.4 \times 10^8$ m/s in cable.

## Solution

We can calculate the propagation time as

$$\textbf{Propagation time} = (12{,}000 \times 10{,}000) / (2.4 \times 2^8) = 50 \text{ ms}$$

**Queuing-time** is the time needed for each intermediate-device to hold the message before it can be processed.

(Intermediate device may be a router or a switch)

- ☂ the queuing-time is not a fixed factor. This is because
  - i) Queuing-time changes with the load imposed on the network.
  - ii) When there is heavy traffic on the network, the queuing-time increases.
- ☂ An intermediate-device
  - → queues they arrived messages and
  - → processes the messages one by one.
- ☂ If there are many messages, each message will have to wait.

**Processing Delay** ☂ Processing delay is the time taken by the routers to process the packet header.

***Bandwidth Delay Product***

**Two performance-metrics of a link are 1) Bandwidth and 2) Delay**

- The bandwidth-delay product is very important in data-communications.
-

☂ Let us assume,

Bandwidth of the link = 1 bps Delay of the link = 5s.
bandwidth-delay product is 1 x 5 = 5.

Thus, there can be maximum 5 bits on the line.

☂ There can be no more than 5 bits at any time on the link.

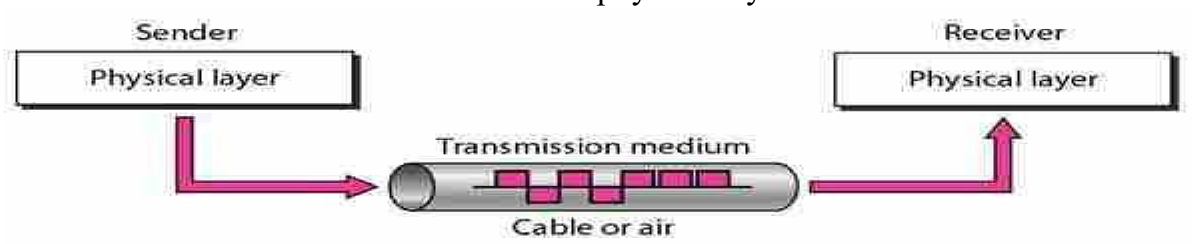
***Case2:*** *The following figure shows case 2 (Figure 3.33).*

***Jitter***

• Another performance issue that is related to delay is jitter.
• We can say that jitter is a problem
→ if different packets of data encounter different delays and
→ if the application using the data at the receiver site is time-sensitive (for ex: audio/video).

## 2.3. DATA TRANSMISSION MEDIA:GUIDED, UNGUIDED AND SATELLITE

**Transmission media** are actually located below the physical layer and are directly controlled by the physical layer. The following figure shows the position of transmission media in relation to the physical layer.




### TRANSMISSION MEDIA

These are the means by which a communication signal is carried from one system to another. These media can carry information from a source to a destination. The transmission media can usually be free space such as: satellite, microwave, radio and infrared systems, metallic cables such as: twisted pair, or coaxial cable, or fiber-optic cable.

In telecommunication, transmission media can be divided into two broad categories:

i. Guided transmission media
ii. Unguided transmission media

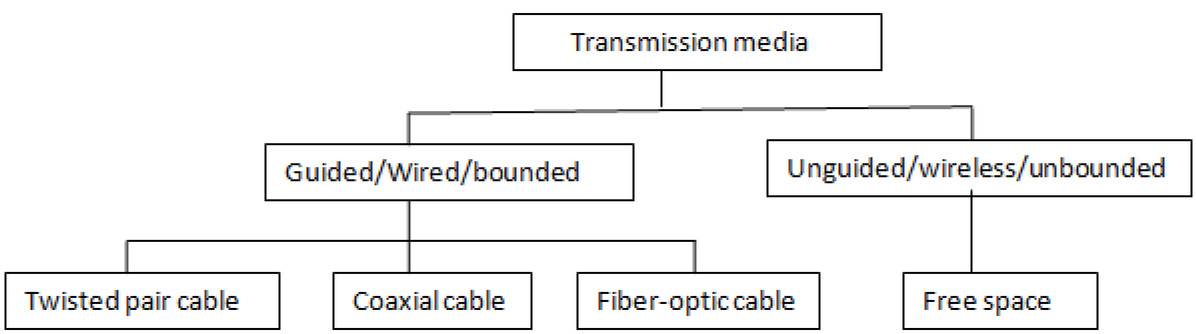



**Fig: Classes of transmission media**

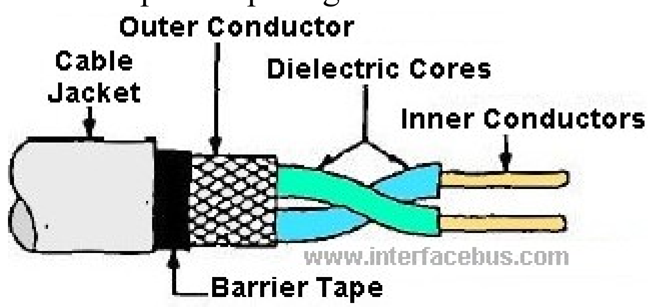
### Guided Transmission Media

Guided Transmission media uses a cabling system that guides the data signals along a specific path. They provide the physical path way for the transmission of the data from the source to the destination. The data signals travelling along any of these media is directed and contained by the physical limits of the medium. Twisted-pair and coaxial cable use metallic (copper) conductor that accept and transport signals in the form of electric current. Optical fiber is a cable that accepts and transport signals in the form of light. Guided Media are also known as Bound media or wired media.

a. **Twisted Pair Cable**

**Twisted pair** cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purposes of canceling out electromagnetic interference (EMI) from external sources; for instance, electromagnetic radiation from unshielded twisted pair (UTP) cables, and crosstalk between neighboring pairs.
This cable is the most commonly used and is cheaper than others. It is lightweight, cheap, can be installed easily, and they support many different types of network. Some important points:

- Its frequency range is 0 to 3.5 kHz.
- Typical attenuation is 0.2 dB/Km @ 1kHz.
- Typical delay is 50 µs/km.
- Repeater spacing is 2km.




Twisted Pair is of two types :

- Unshielded Twisted Pair (UTP)
- Shielded Twisted Pair (STP)

**Unshielded Twisted Pair Cable**
It is the most common type of telecommunication when compared with Shielded Twisted Pair Cable which consists of two conductors usually copper, each with its own colour plastic insulator. Identification is the reason behind colored plast
ic insulation.
**Shielded Twisted Pair Cable**
This cable has a metal foil or braided-mesh covering which encases each pair of insulated conductors. Electromagnetic noise penetration is prevented by metal casing. Shielding also eliminates crosstalk .
It has same attenuation as unshielded twisted pair. It is faster the unshielded and coaxial cable. It is more expensive than coaxial and unshielded twisted pair.

b. **Coaxial Cable**

Coaxial is called by this name because it contains two conductors that are parallel to each other. Copper is used in this as centre conductor which can be a solid wire or a standard one. It is surrounded by PVC installation, a sheath which is encased in an outer conductor of metal foil, braid or both.
Outer metallic wrapping is used as a shield against noise and as the second conductor which completes the circuit. The outer conductor is also encased in an insulating sheath. The outermost part is the plastic cover which protects the whole cable.
Here the most common coaxial standards.

- 50-Ohm RG-7 or RG-11 : used with thick Ethernet.
- 50-Ohm RG-58 : used with thin Ethernet
- 75-Ohm RG-59 : used with cable television
- 93-Ohm RG-62 : used with ARCNET.

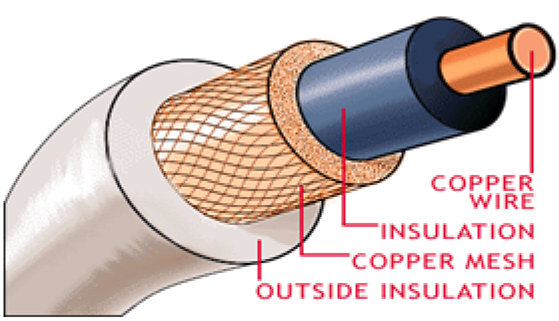
RG- Radio guide

***Advantages:***

- Bandwidth is high
- Used in long distance telephone lines.
- Transmits digital signals at a very high rate of 10Mbps.
- Much higher noise immunity
- Data transmission without distortion.
- They can span to longer distance at higher speeds as they have better shielding when compared to twisted pair cable

***Disadvantages:***

- Single cable failure can fail the entire network.
- Difficult to install and expensive when compared with twisted pair.




**C) Fiber Optic Cable**

These are similar to coaxial cable. It uses electric signals to transmit data. At the centre is the glass core through which light propagates.
In multimode fibers, the core is 50microns, and In single mode fibers, the thickness is

8 to 10 microns.

The core in fiber optic cable is surrounded by glass cladding with lower index of refraction as compared to core to keep all the light in core. This is covered with a thin plastic jacket to protect the cladding. The fibers are grouped together in bundles protected by an outer shield.

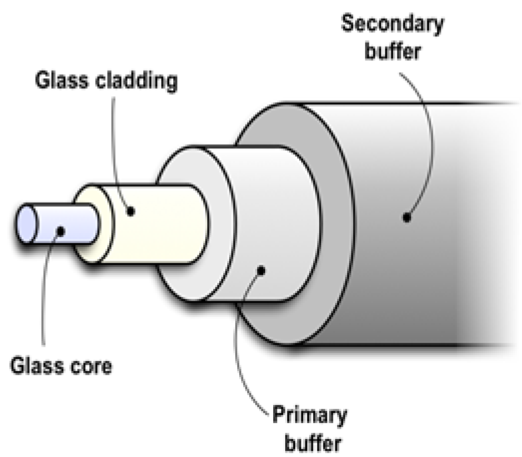
Fiber optic cable has bandwidth more than **2 gbps (Gigabytes per Second)**

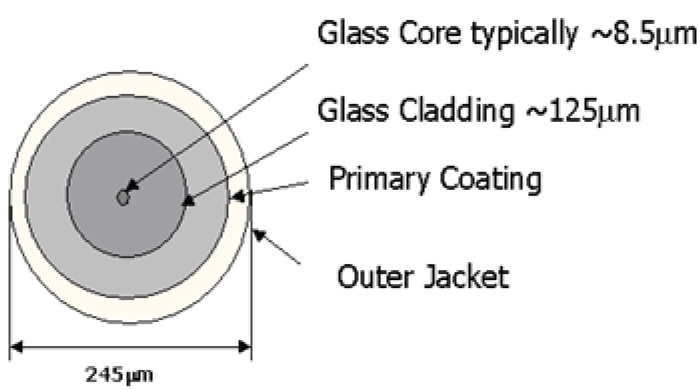
***Advantages:***

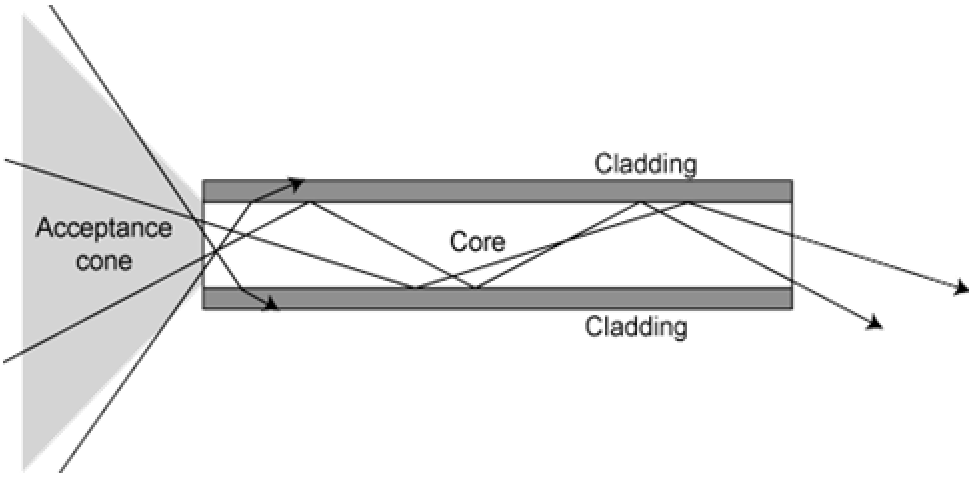
- Provides high quality transmission of signals at very high speed.
- These are not affected by electromagnetic interference, so noise and distortion is very less.
- Used for both analog and digital signals.

***Disadvantages:***

- It is expensive
- Difficult to install.
- Maintenance is expensive and difficult.






1. **Unguided Media:**

It is also referred to as Wireless or Unbounded transmission media.No physical medium is required for the transmission of electromagnetic signals.

Features:

- Signal is broadcasted through air
- Less Secure
- Used for larger distances

***There are 3 major types of Unguided Media:***

**(i) Radiowaves –**

These are easy to generate and can penetrate through buildings. The sending and receiving antennas need not be aligned. Frequency Range:3KHz – 1GHz. AM and FM radios and cordless phones use Radiowaves for transmission.
Further Categorized as (i) Terrestrial and (ii) Satellite.

**(ii) Microwaves –**

It is a line of sight transmission i.e. the sending and receiving antennas need to be properly aligned with each other. The distance covered by the signal is directly proportional to the height of the antenna. Frequency Range:1GHz – 300GHz. These are majorly used for mobile phone communication and television distribution.

**(iii) Infrared –**

Infrared waves are used for very short distance communication. They cannot penetrate through obstacles. This prevents interference between systems. Frequency Range:300GHz – 400THz. It is used in TV remotes, wireless mouse, keyboard, printer, etc.

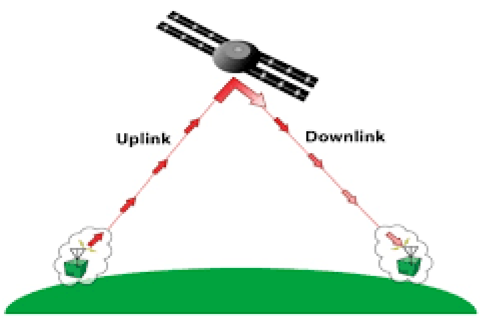
**Satellites:**

A satellite is an object that revolves around another object. For example, earth is a satellite of The Sun, and moon is a satellite of earth.

A **communication satellite** is a **microwave repeater station** in a space that is used for telecommunication, radio and television signals.

How a Satellite Works

**Uplink frequency** is the frequency at which ground station is communicating with satellite. The satellite transponder converts the signal and sends it down to the second earth station, and this is called **Downlink frequency**.



Satellite Communication Basics

The satellites **receive** and **retransmit** the signals back to earth where they are received by other earth stations in the coverage area of the satellite. **Satellite's footprint** is the area which receives a signal of useful strength from the satellite.

Satellite Frequency Bands

The satellite frequency bands which are commonly used for communication are the **C band, Ku-band,** and **Ka- band**.

| | |
|---|---|
| HF Band | 3 to 30 MHz |
| VHF Band | 30 to 300 MHz |
| UHF Band | 300 to 1000 MHz |
| L Band | 1 to 2 GHz |
| S Band | 2 to 4 GHz |
| C Band | 4 to 8 GHz |
| X Band | 8 to 12 GHz |
| Ku Band | 12 to 18 GHz |
| K Band | 12 to 27 GHz |
| Ka Band | 27 to 40 GHz |

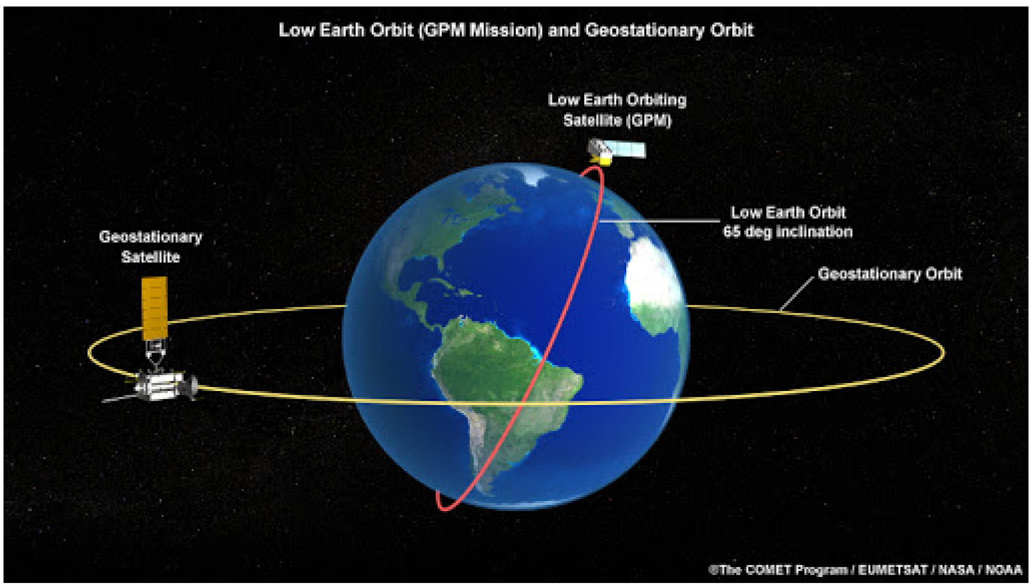
Earth Orbits

A satellite when launched into space, needs to be placed in certain orbit to provide a particular way for its revolution, so as to maintain accessibility and serve its purpose whether scientific, military or commercial. Such orbits which are assigned to satellites, with respect to earth are called as **Earth Orbits**.

The important kinds of Earth Orbits are −

- Geo-synchronous Earth Orbit
- Geo-stationary Earth Orbit
- Medium Earth Orbit
- Low Earth Orbit

| Abbreviation | Orbit Name | Altitude [km] |
|---|---|---|
| LEO | Low Earth Orbit | 160 to 2000 |
| MEO | Medium Earth Orbit | 2000 to <35786 |
| GSO | Geosynchronous Orbit | 35786 |
| GEO | Geostationary Equatorial Orbit | 35786 |



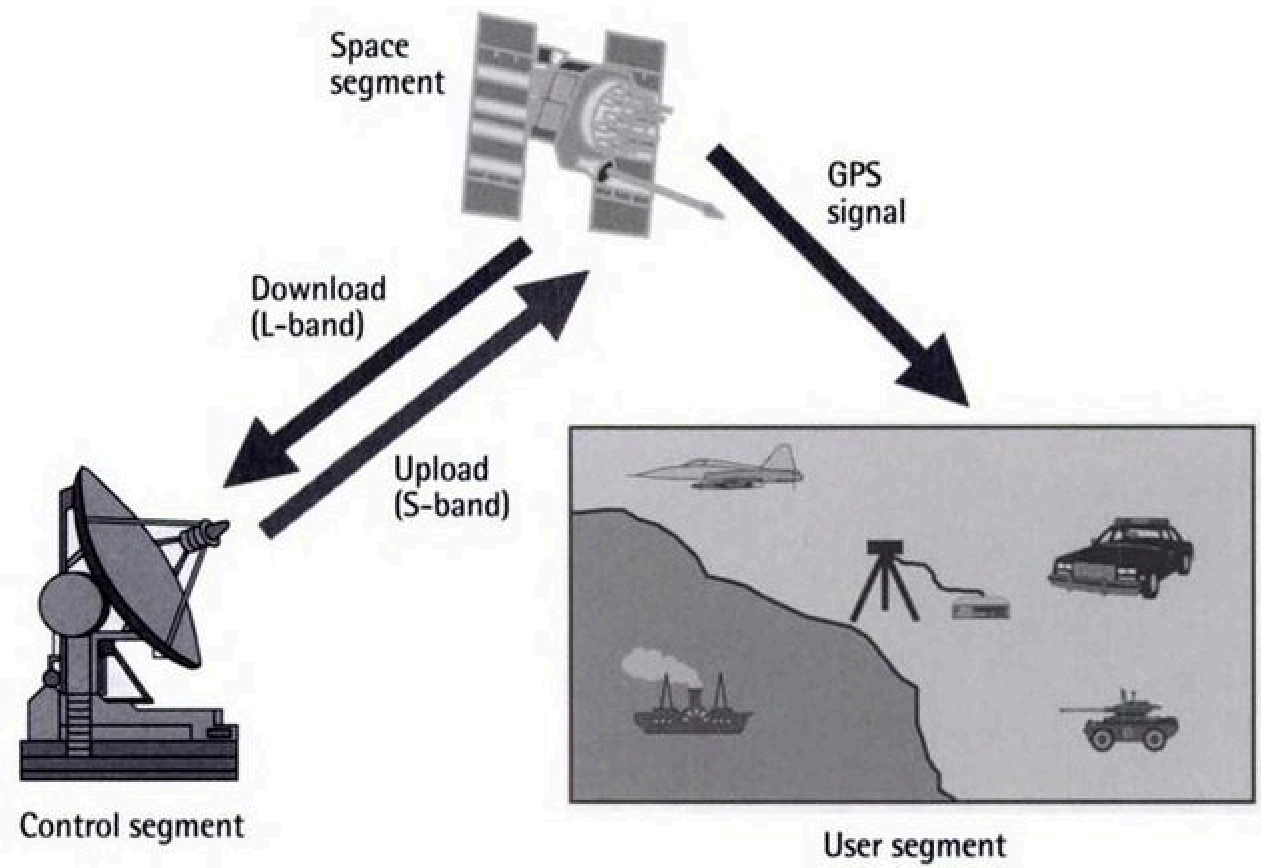

| Parameter | LEO | MEO | GEO |
|---|---|---|---|
| Satellite Height | 500-1500 km | 5000-12000 km | 35,800 km |
| Orbital Period | 10-40 min. | 2-8 hours | 24 hours |
| Number of Satellites | 40-80 | 8-20 | 3 |
| Satellite Life | Short | Long | Long |
| Number of Handoffs | High | Low | Least(none) |
| Gateway Cost | Very expensive | Expensive | Cheap |
| Propagation Loss | Least | High | Highest |

**Satellite Network Segments**

Satellite networks have three major segments:

i. **Space segment**—The space segment is the actual design of the satellite and the orbit in which it operates. Satellites are launched into specific orbits to cover the parts of the earth for which coverage is desired.
ii. **Control segment**—The control segment defines the frequency spectrum over which satellites operate and the types of signaling techniques used between the ground station and the satellite to control those communications.

iii. **Ground segment**—The ground segment is the earth station—the antenna designs and the access techniques used to enable multiple conversations to share the links up to the satellite.




**Advantages and Disadvantages of Satellite**

The **advantages** of satellite include the following:

- Access to remote areas
- Coverage of large geographical areas
- Point to multipoint communication
- High bandwidth
- Transmission cost is independent of distance.

The **disadvantages** of satellite include the following:

- High initial cost
- Propagation delay
- Environmental interference problems

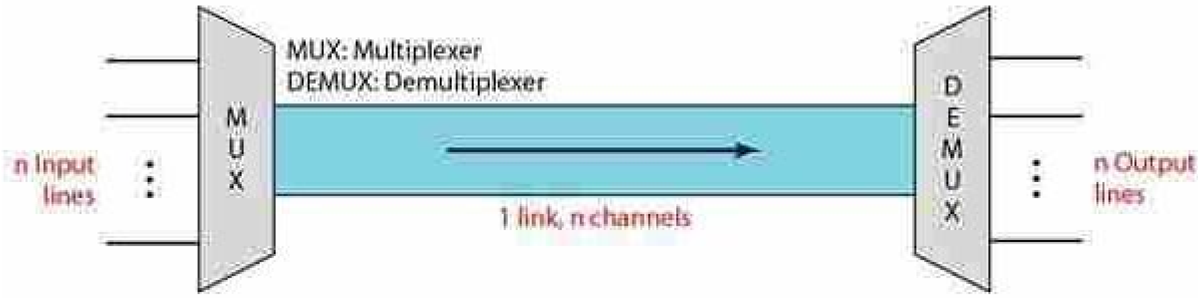
- Licensing requirements
- Regulatory constraints in some regions
- Danger posed by space debris, solar flare activity, and meteor showers

## 2.4. Bandwidth Utilization: Multiplexing and Spreading

### Multiplexing

Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link. **Multiplexing** (or muxing) is a way of sending multiple signals or streams of information over a communications link at the same time in the form of a single, complex signal; the receiver recovers the separate signals, a process called demultiplexing (or demuxing).

The following figure shows the basic format of a multiplexed system. The lines on the left direct their transmission streams to a multiplexer (MUX), which combines them into a single stream (many-toone). At the receiving end, that stream is fed into a demultiplexer (DEMUX), which separates the stream back into its component transmissions (one-to-many) and directs them to their corresponding lines.

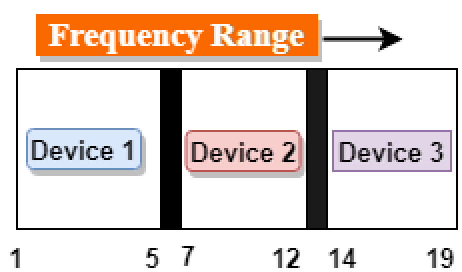



*The three basic multiplexing techniques are*

1. ***Frequency-division multiplexing***
2. ***Time-division multiplexing.***
3. ***Wavelength-division multiplexing***

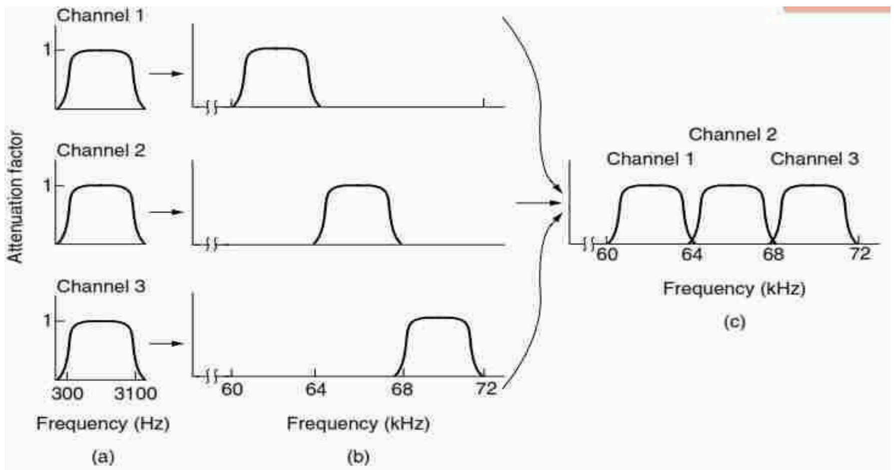
## Frequency Division Multiplexing

- **Frequency Division Multiplexing** is a technique in which the available bandwidth of a single transmission medium is subdivided into several channels.



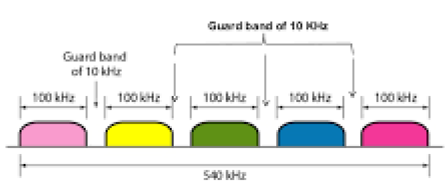

- In the above diagram, **a single transmission medium is subdivided into several frequency channels, and each frequency channel is given to different devices.** Device 1 has a frequency channel of range from 1 to 5.
- The input signals are translated into frequency bands by using modulation techniques, and they are combined by a multiplexer to form a composite signal.
- The main aim of the FDM is to subdivide the available bandwidth into different frequency channels and allocate them to different devices.

- Using the modulation technique, the input signals are transmitted into frequency bands and then combined to form a composite signal.
- The carriers which are used for modulating the signals are known as **sub-carriers**. They are represented as f1,f2..fn.
- **FDM** is mainly used in radio broadcasts and TV networks.




Detailed example is shown in above figure. There are three voice-grade telephone channels multiplexed using FDM. When many channels are multiplexed together, 4000Hz(4KHz) is allocated per channel. The excess is called a **guard band**. It keeps the channels well separated. First the voice channels are raised in frequency, each by a different amount. Then they can be combined because no two channels now occupy the same portion of the spectrum. Notice that even though there are gaps between the channels thanks to the guard bands which well separates two frequency even if there is some overlapping.

Figure 6.7 *Example 6.2*




## Time-Division Multiplexing.:

- **In Frequency Division Multiplexing Technique, all signals operate at the same time with different frequency, but in case of Time Division Multiplexing technique, all signals operate at the same frequency with different**

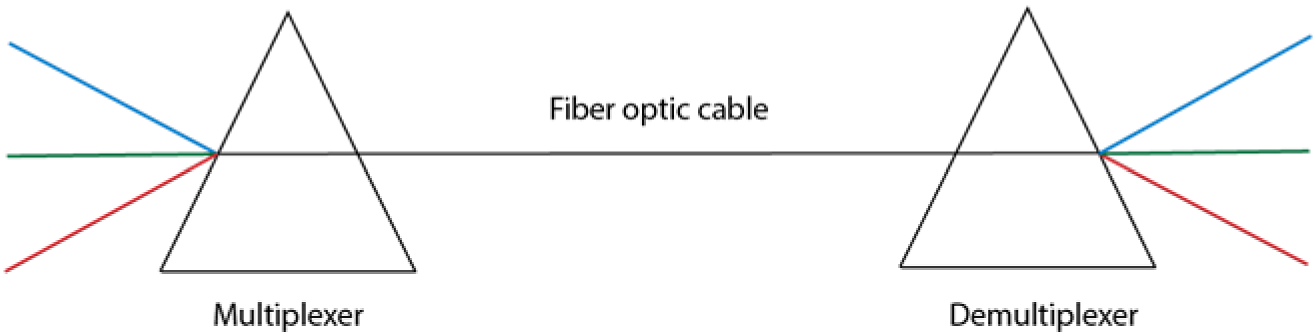
**time.**

- In Time Division Multiplexing technique, the total time available in the channel is distributed among different users. Therefore, each user is allocated with different time interval known as a Time slot at which data is to be transmitted by the sender.
- A user takes control of the channel for a fixed amount of time.
- In Time Division Multiplexing technique, data is not transmitted simultaneously rather the data is transmitted one-by-one.
- In TDM, the signal is transmitted in the form of frames. Frames contain a cycle of time slots in which each frame contains one or more slots dedicated to each user.
- It can be used to multiplex both digital and analog signals but mainly used to multiplex digital signals.
- **Examples** of utilizing **TDM** include digitally transmitting several telephone conversations over the same four-wire copper cable or fiber optical cable in a **TDM** telephone network

**Wavelength-Division Multiplexing**

- Wavelength Division Multiplexing is same as FDM except that the optical signals are transmitted through the fibre optic cable.
- WDM is used on fibre optics to increase the capacity of a single fibre.
- It is used to utilize the high data rate capability of fibre optic cable.
- It is an analog multiplexing technique.
- **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.

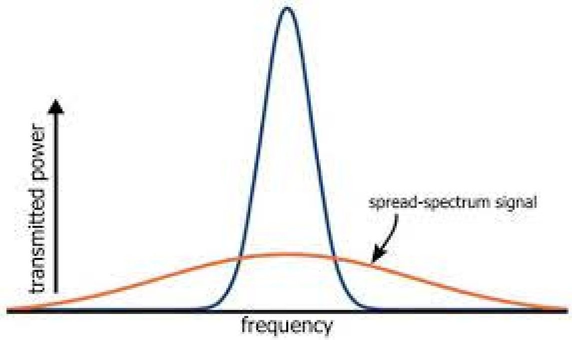



In this method, we combine multiple light sources into one single light at the multiplexer and do the reverse at the demultiplexer.
The combining and splitting of light sources are easily handled by a prism.
Recall from basic physics that a prism bends a beam of light based on the angle of incidence and the frequency.
Using this technique, a multiplexer can be made to combine several input beams of light, each containing a narrow band of frequencies, into one output beam of a wider band of frequencies.
A demultiplexer can also be made to reverse the process.

**Spread Spectrum Techniques**

Spread-Spectrum techniques are methods by which a signal (e.g. an electrical, electromagnetic) generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth.

These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference, noise and jamming, to prevent detection.

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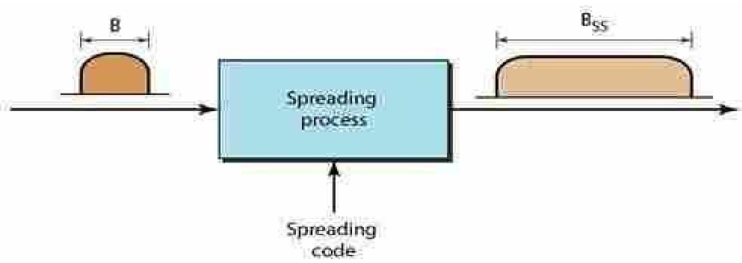
Spread spectrum is designed to be used in wireless applications (LANs and WANs). In wireless applications, all stations use air (or a vacuum) as the medium for communication. Stations must be able to share this medium without interception by an eavesdropper and without being subject to jamming from a malicious intruder.

To achieve these goals, spread spectrum techniques add redundancy, they spread the original spectrum needed for each station. If the required bandwidth for each station is B, spread spectrum expands it to Bss such that Bss >> B. The expanded bandwidth allows the source to wrap its message in a protective envelope for a more secure transmission.



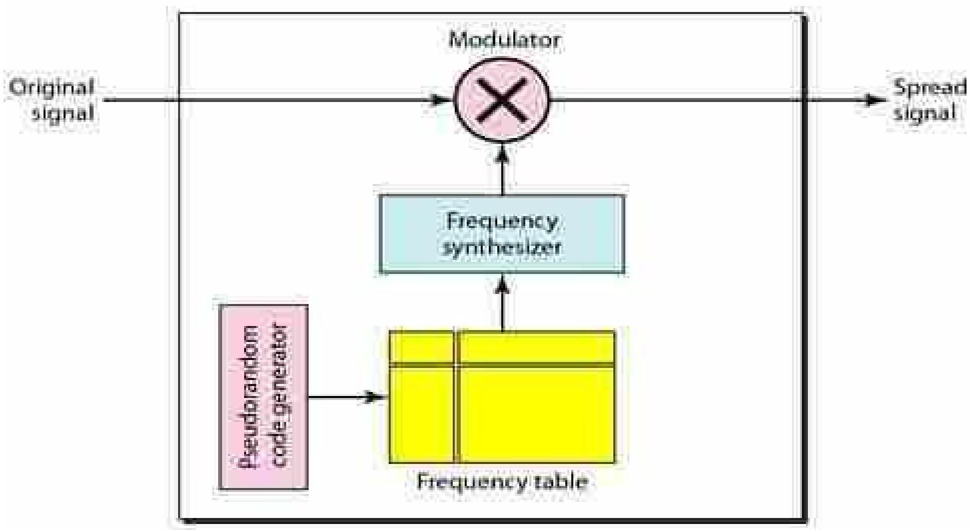

***There are two techniques to spread the bandwidth:***

**Frequency Hopping Spread Spectrum (FHSS)**

The Frequency Hopping Spread Spectrum (FHSS) technique uses different carrier frequencies (frequency that has been altered (modulated) to "carry" data)that are modulated by the source signal.

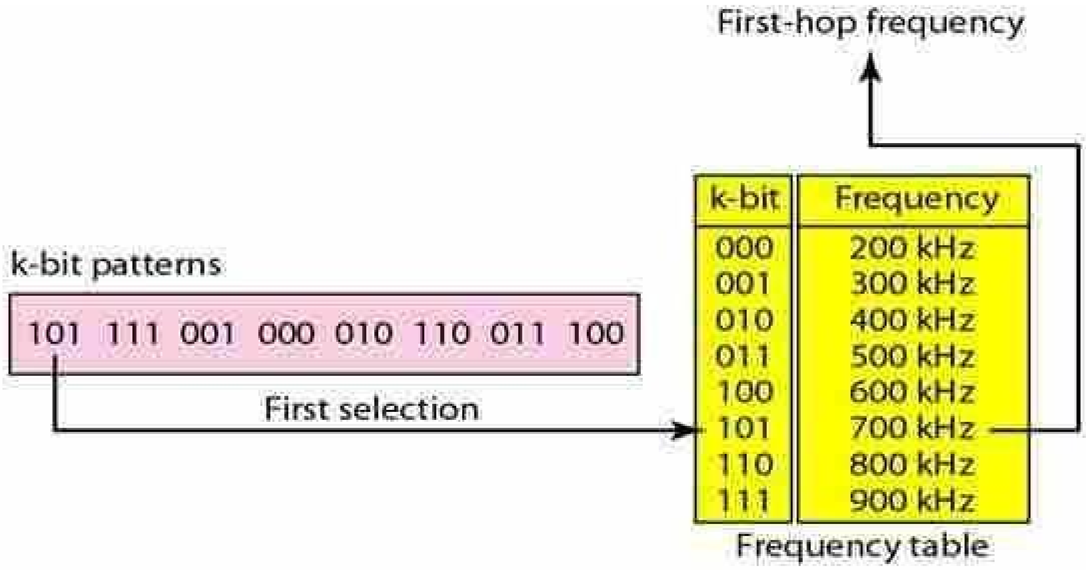
The bandwidth occupied by a source after spreading is BpHSS >> B.

The following figure shows the general layout for FHSS. A pseudorandom code generator, called pseudorandom noise (PN), creates a k-bit pattern for every hopping pe


Modulator
Original signal
Spread signal
Frequency synthesizer
Pseudorandom code generator
Frequency table

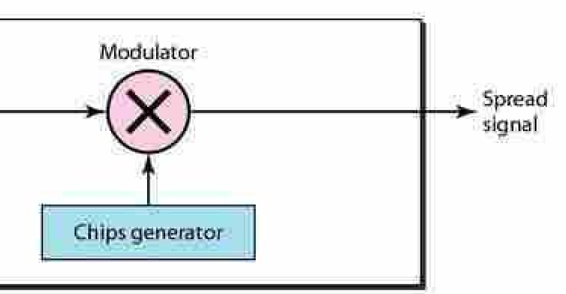
riod

**For E xample** M is 8 and k is 3. The pseudorandom code generator will create eight different 3-bit patterns. These are mapped to eight different frequencies in the frequency table as shown in the following figure.




The pattern for this station is 101, 111, 001, 000, 010, all, 100. Note that the pattern is pseudorandom it is repeated after eight hoppings. This means that at hopping period 1, the pattern is 101. The frequency selected is 700 kHz, the source signal modulates this carrier frequency.

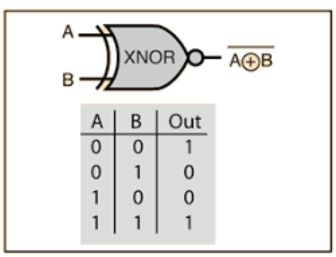
The second k-bit pattern selected is 111, which selects the 900-kHz carrier; the eighth pattern is 100, the frequency is 600 kHz. After eight hoppings, the pattern repeats, starting from 101 again.

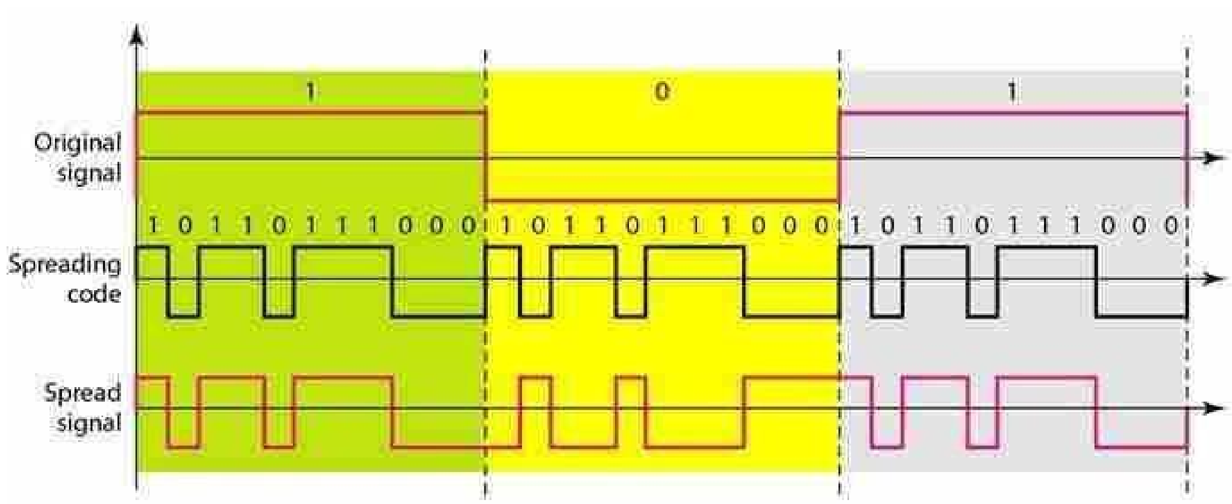



**Direct Sequence Spread Spectrum (DSSS).**

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.

In the figure, the spreading code is having the pattern 10110111000 (in this case).




## 2.5. SWITCHING: CIRCUIT SWITCHING, PACKET SWITCHING AND MESSAGE SWITCHING

- **Switching** is the process to forward packets coming in from one port to a port leading towards the destination.

- When data comes on a port it is called **ingress**, and when data leaves a port or goes out it is called **egress**.
- A communication system may include a number of switches and nodes.

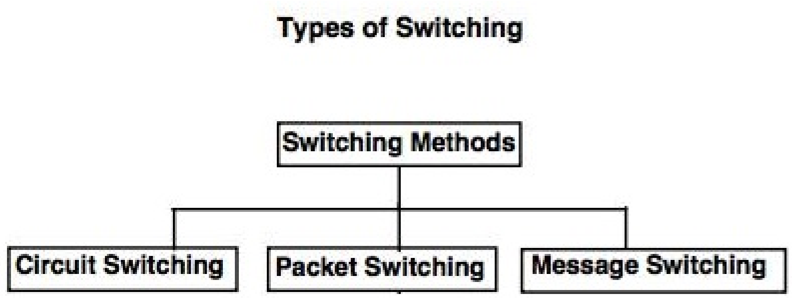
***At broad level, switching can be divided into two major categories:***

**Connectionless:** The data is forwarded on behalf of forwarding tables. No previous handshaking is required and acknowledgements are optional.

**Connection Oriented:** Before switching data to be forwarded to destination, there is a need to pre- establish circuit along the path between both endpoints. Data is then forwarded on that circuit. After the transfer is completed, circuits can be kept for future use or can be turned down immediately.

- In large networks, there can be multiple paths from sender to receiver. The switching technique will decide the best route for data transmission.
- Switching technique is used to connect the systems for making one-to-one communication.

**Classification Of Switching Techniques**




**Circuit Switching**

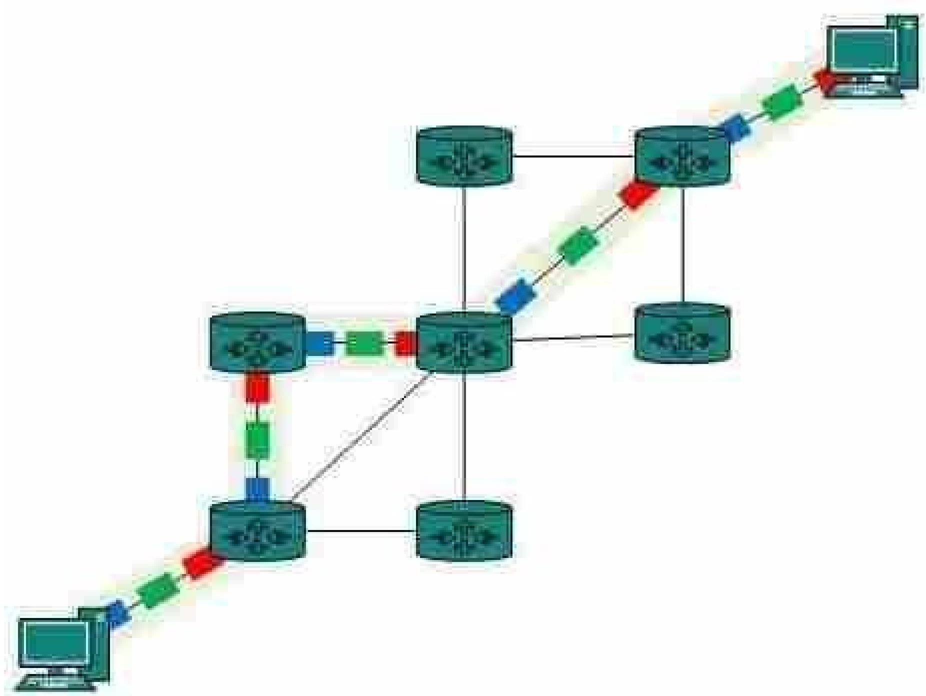
- When two nodes communicate with each other over a **dedicated communication path**, it is called circuit switching.
- There 'is a need of **pre-specified route** from which data will travels and no other data is permitted.
- In circuit switching, to transfer the data, circuit must be **established** so that the data transfer can take place.
- Circuits can be **permanent or temporary.**

- 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



Circuit switching was designed for voice applications. Telephones are the best suitable example of circuit switching. Before a user can make a call, a virtual path between caller and caller is established over the network.

**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.

Example

The defining **example** of a **circuit-switched** network is the early analog telephone network. When a call is made from one telephone to another, **switches** within the telephone exchanges create a continuous wire **circuit** between the two telephones, for as long as the call lasts.

**Message Switching**

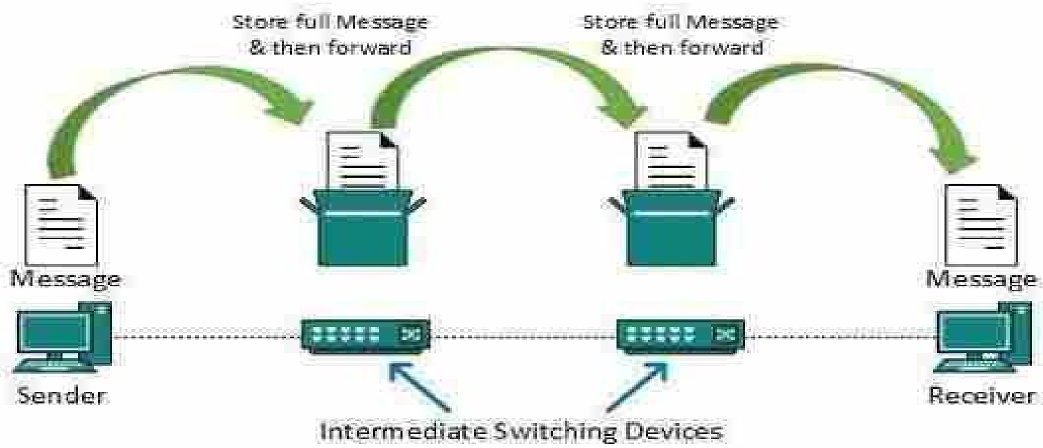
- Message Switching is a switching technique in which a message is transferred as a complete unit and routed through intermediate nodes at which it is stored and forwarded.
- In Message Switching technique, there is no establishment of a dedicated path between the sender and receiver.
- The destination address is appended to the message.
- Message 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 forwards 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.

**They provide 2 distinct and important characteristics:**

**Store and forward –** The intermediate nodes have the responsibility of transferring the entire message to the next node. Hence, each node must have storage capacity.

**Message delivery –** This implies wrapping the entire information in a single message and transferring it from the source to the destination node.

A switch working on message switching, first receives the whole message and buffers it until there are resources available to transfer it to the next hop. If the next hop is not having enough resources to accommodate a large size message, the message is stored and the switch waits.


Store full Message
& then forward
Store full Message
& then forward
Message
Message
Sender
Receiver
Intermediate Switching Devices

This technique was considered a substitute for circuit switching. As in circuit switching the whole path is blocked for two entities only. Message switching is replaced by packet switching. Message switching has the following drawbacks:

Every switch in the transit path needs enough storage to accommodate the entire message.
Because of store-and-forward technique and waits included until resources are available, message switching is very slow.
Message switching was not a solution for streaming media and real-time applications.

**Advantages Of Message Switching**

- As message switching is able to store the message for which communication channel is not available, It helps in reducing the traffic congestion in network.
- In message switching, the data channels are shared by the network devices.
- It makes the traffic management efficient by assigning priorities to the messages.

**Disadvantages Of Message Switching**

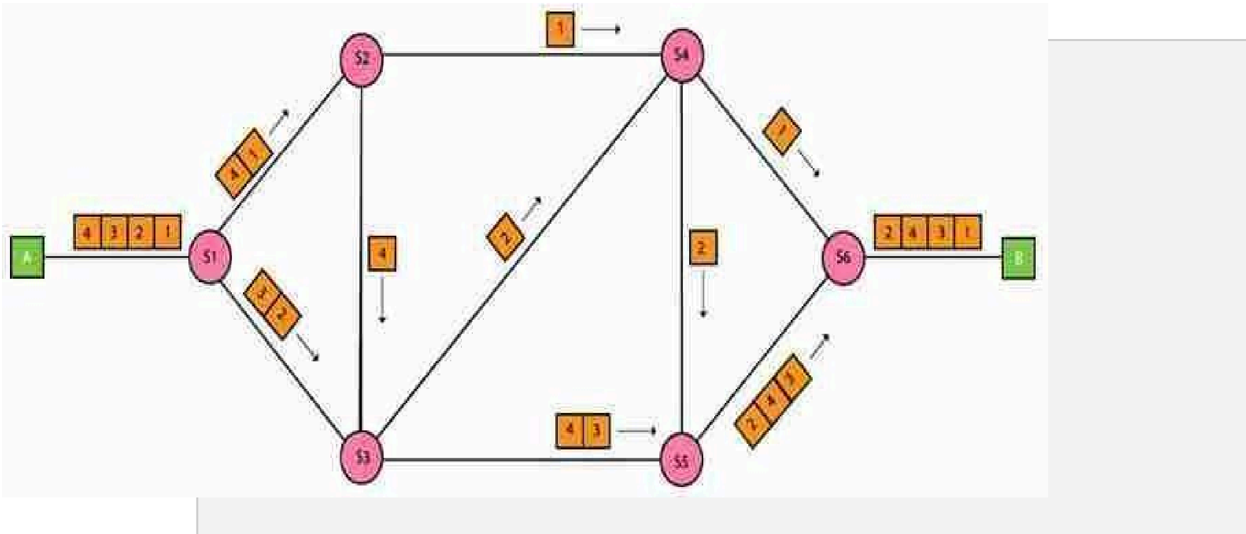
1. Message switching cannot be used for real time applications as storing of messages causes delay.
2. In message switching, message has to be stored for which every intermediate devices in the network requires a large storing capacity.

**Applications** –

The store-and-forward method was implemented in **telegraph** message switching centers.For example, in most electronic mail systems the delivery process is based on message switching, while the network is in fact either circuit-switched or packet-switched.

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.




**Packet switching** is used in the Internet and most local area networks. The Internet is implemented by the Internet Protocol Suite using a variety of Link Layer technologies. For **example**, Ethernet and Frame Relay are common. Newer mobile phone technologies (e.g., GSM, LTE) also use **packet switching**.

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.
- It 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.

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
- Reliable
- Efficient

**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.

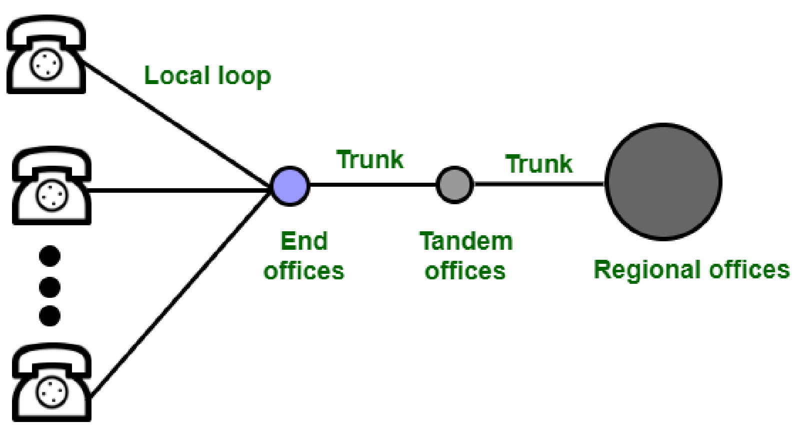
## 2.6. TELEPHONE , MOBILE AND CABLE NETWORK FOR DATA COMMUNICATION

### TELEPHONE NETWORK

Telephone Network is used to provide voice communication. Telephone Network uses Circuit Switching. Originally, the entire network was referred to as a plain old telephone system (POTS) which uses analog signals. With the advancement of technology, i.e. in the computer era, there comes a feature to carry data in addition to voice. Today's network is both analogous and digital.

**Major Components of Telephone Network:** There are three major components of the telephone network:

1. Local loops
2. Trunks
3. Switching Offices



End office- A local **office** (or end **office**) was a **switching** centre that connected directly to the customers' telephone instruments.
Tandem offices-A tandem office was one that served a cluster of local offices.

**Local Loops:** Local Loops are the twisted pair cables that are used to connect a subscriber telephone to the nearest end office or local central office. For voice purposes, its bandwidth is 4000 Hz. It is very interesting to examine the telephone number that is associated with each local loop. The office is defined by the first three digits and the local loop number is defined by the next four digits defines.

**Trunks:** It is a type of transmission medium used to handle the communication between offices. Through multiplexing, trunks can handle hundreds or thousands of connections. Mainly transmission is performed through optical fibers or satellite links.

**Switching Offices:** As there is a permanent physical link between any two subscribers. To avoid this, the telephone company uses switches that are located in switching offices. A switch is able to connect various loops or trunks and allows a connection between different subscribes.

**Advantages of Telephone Network:**

- It is a circuit-switched network.
- There is no transmission delay as any receiver can be selected.
- It is cheap in price because it is a widely spread network.

**Disadvantages of Telephone Network:**

- It requires a large time for connection.
- It has a low transmission speed.

**Applications of Telephone Network:**

- It helps to connect people.
- It is used by business organizations to advertise their products.
- It is also used around the world for recreational purposes.

## CABLE NETWORKS

The cable network started as a video service provider, but it has moved to the business of Internet access. This network can be used to provide high -speed access to the Internet.
Cable television, generally, any system that distributes television signals by means of coaxial or fibre- optic cables. The term also includes systems that distribute signals solely via satellite.
Cable-television systems originated in the United States in the late 1940s and were designed to improve reception of commercial network broadcasts in remote and hilly areas.
During the 1960s they were introduced in many large metropolitan areas where local television reception is degraded by the reflection of signals from tall buildings.

***Commonly known as community antenna television*** (CATV), these cable systems use a "community antenna" to receive broadcast signals (often from communications satellites), which they then retransmit via cables to homes and establishments in the local area subscribing to the service.

1. **Traditional Cable Networks**

   Communication in the traditional cable TV network is unidirectional.

**Figure 9.14** ***Traditional cable TV network***

**Figure 9.15** ***Hybrid fiber-coaxial (HFC) network***

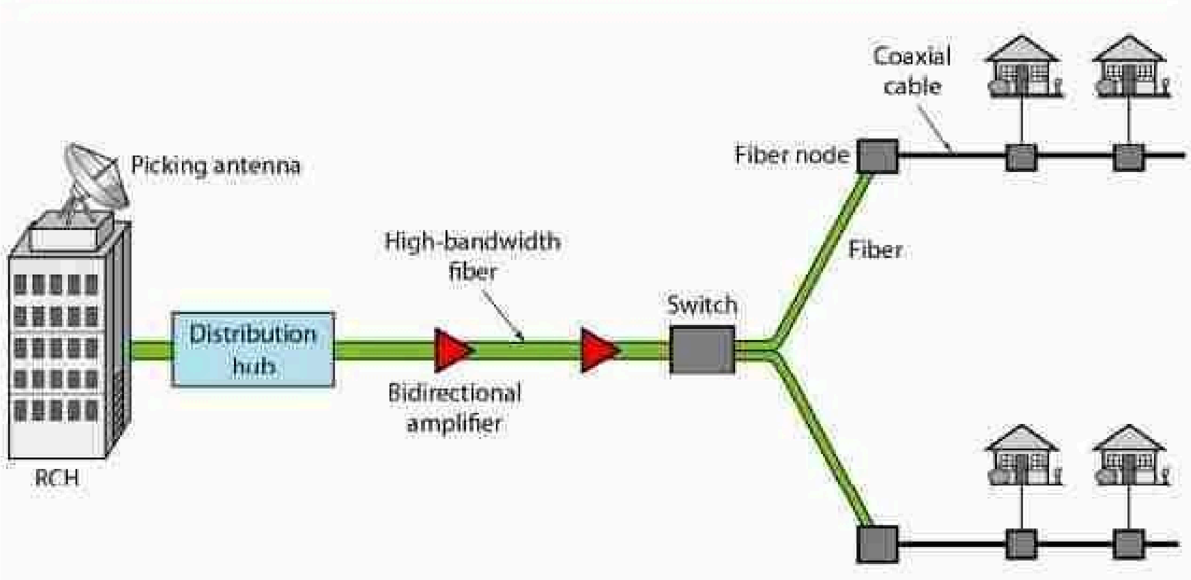


**Figure 9.17** ***Cable modem (CM)***

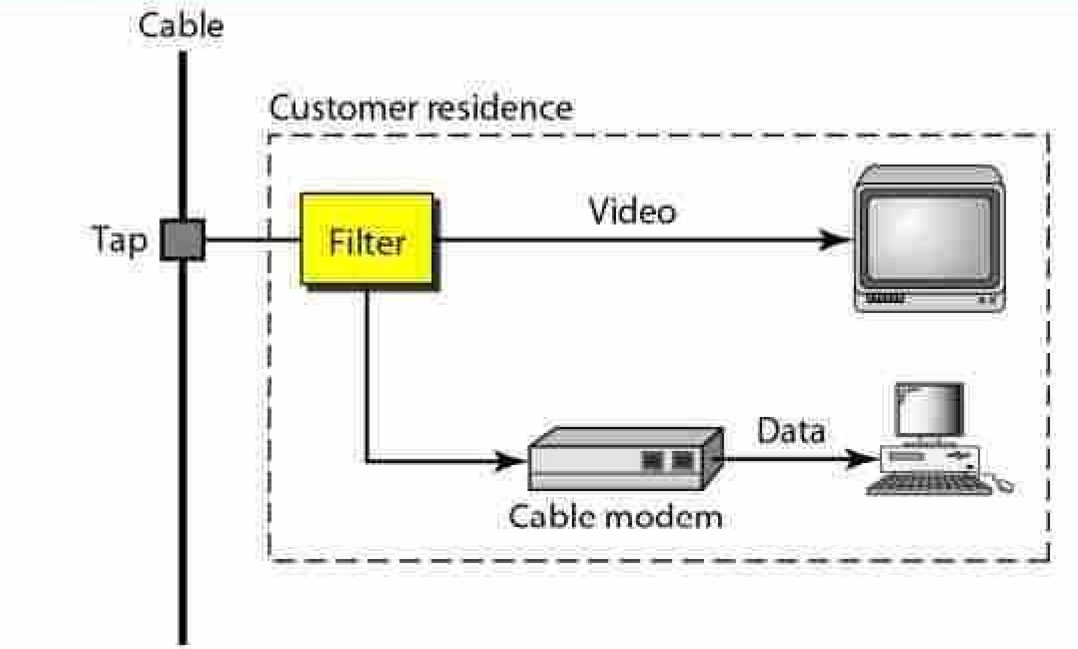
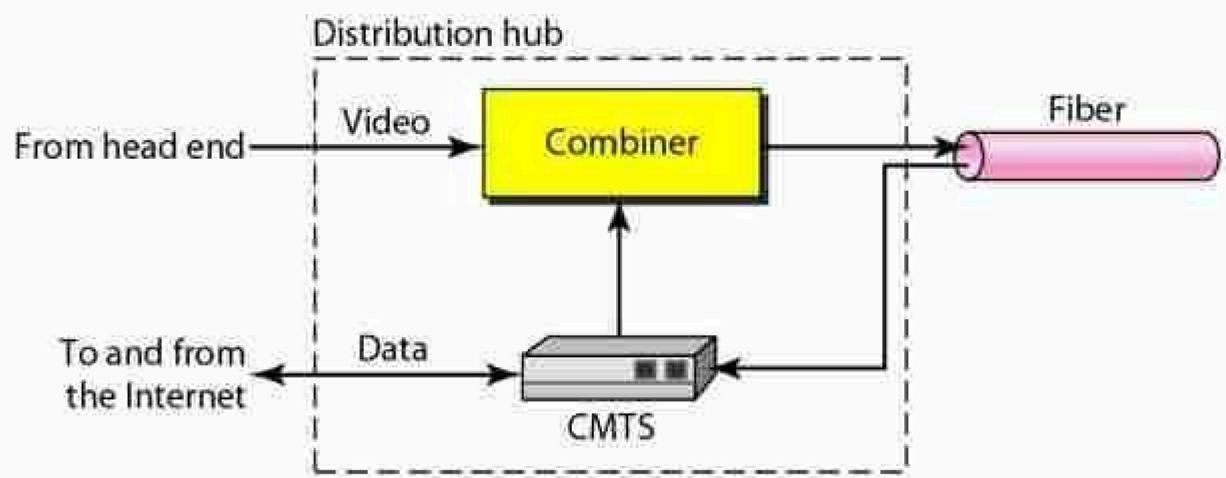



**Figure 9.18** ***Cable modem transmission system (CMTS)***



## Mobile

Mobile Data is the term used by many to describe the use of wireless data communications using radio waves to send and receive information. This is part of the much broader mobile technology arena.

**Benefits of using mobile data communications**

Mobile Data technology lets your key staff operate more efficiently when they are out of the office. It can help you:

- Carry out tasks remotely, which would normally be done on a computer in the office,
- Communicate with people at remote locations,
- Work with data that is held in the office, even when you are in a different location,
- Communicate a message
- Create an electronic audit trail of messages sent/received
- Keep in touch with the office anytime and from anywhere.

**Choosing the appropriate mobile data technology**

The technology choices are many and varied and can be divided into two main categories

- The choice of wireless data network
- The type of device

Wireless data networks exist in such number and variety as to be difficult to categories and compare.

Some wireless data networks run over wireless voice networks, such as mobile telephone networks. **GPRS and 3G** are examples.

There are cost implications on the type of data network you use for you mobile data solution. The variables involved in calculating the data transmission costs include;

- The amount of data to be transmitted
- The frequency of the data transmissions
- The type of connection, e.g. permanent always on or occasional - as and when needed.

GSM

GSM stands for Global System for Mobile communications. GSM is one of the most widely used digital wireless telephony system.

GSM technology uses TDMA (Time Division Multiple Access) to support up to eight calls simultaneously. It also uses encryption to make the data more secure.

The frequencies used by the international standard is 900 MHz to 1800 MHz However, GSM phones used in the US use 1900 MHz frequency and hence are not compatible with the international system.

CDMA

CDMA stands for Code Division Multiple Access. It was first used by the British military during World War

**II.** After the war its use spread to civilian areas due to high service quality. **WLL**

WLL stands for Wireless in Local Loop. It is a wireless local telephone service that can be provided in homes or offices.

GPRS

GPRS stands for General Packet Radio Services. It is a packet based wireless communication technology that charges users based on the volume of data they send rather than the time duration for which they are using the service.

GPRS is the mobile communication protocol used by second (2G) and third generation (3G) of mobile telephony. It pledges a speed of 56 kbps to 114 kbps, however the actual speed may vary depending on network load.