Chapter One

Data Communication Basics

ALEBACHEW D.

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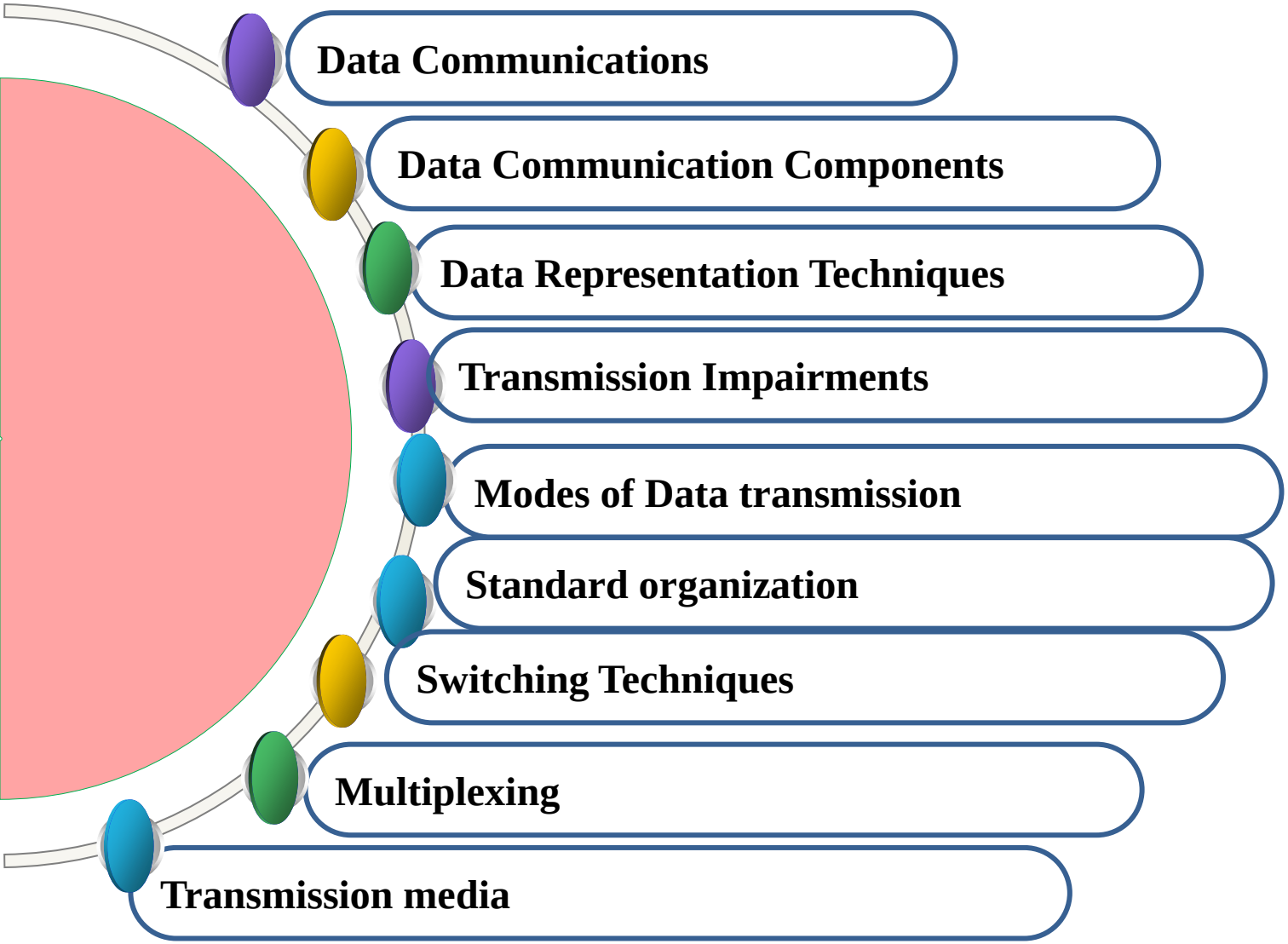
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Data Communications

- **Data communications**
  - is the exchange of data between two devices via some form of transmission medium such as a wire cable.
  - For data communications to occur, the communicating devices must be part of a communication system made up of a combination of hardware (physical equipment) and software (programs).
- The effectiveness of a data communications system depends on four fundamental characteristics:
  - **Delivery**
  - **Accuracy**
  - **Timeliness and**
  - **Jitter**

Data Communications

1. Delivery

- The system must deliver data to the correct destination.
- Data must be received by the intended device or user and only by that device or user.

2. Accuracy

- The system must deliver the data accurately.
- Data that have been altered in transmission and left uncorrected are unusable.

3. Timeliness

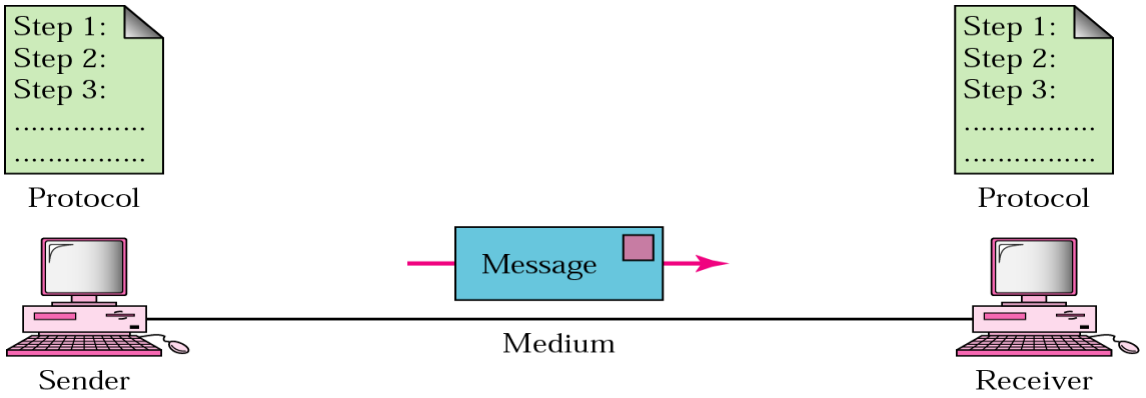
- The system must deliver data in a timely manner.
- Data delivered late are useless.
- In the case of video and audio, timely delivery means delivering data as they are produced, in the same order that they are produced, and without significant delay.
- This kind of delivery is called real-time transmission.

4. Jitter

- Jitter refers to the variation in the packet arrival time.
- It is the uneven delay in the delivery of audio or video packets.
- For example, let us assume that video packets are sent every 30 ms. If some of the packets arrive with 30-ms delay and others with 40-ms delay, an uneven quality in the video is the result.

Data Communication Components

- **There are five components in data communication system.**
  - **Message**
  - **Sender**
  - **Receiver**
  - **Transmission Medium and**
  - **protocol**



Data Communication Components

1. **Message**: the information (data) to be communicated

   (text, numbers, pictures, sound, video - or combinations)

2. **Sender**: the device that sends the message

   computer, video camera, …

3. **Receiver**: the device that receives the message.

   computer, workstation, television …

4. **Medium**: the physical path by which a message travels from sender to receiver.

   twisted pair cable, coaxial cable, fiber optic cable and radio waves

5. **Protocol**: a set of rules that govern data communications.

Without a protocol, two devices may be connected but not communicating, Just as a person speaking French cannot be understood by a person who speaks only Japanese.

Data Representation Techniques

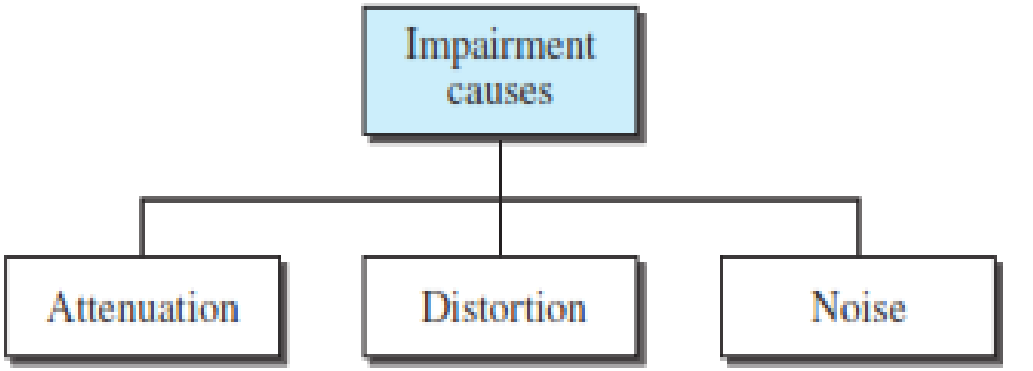
- Information today comes in different forms such as text, numbers, images, audio, and video.
- **Text**
  - Text is represented as a bit pattern, a sequence of bits (0s or 1s).
  - Different sets of bit patterns have been designed to represent text symbols.
  - Each set is called a code, and the process of representing symbols is called coding.
  - Unicode and ASCII code
- **Numbers**
  - Numbers are also represented by bit patterns.
  - However, a code such as ASCII is not used to represent numbers; the number is directly converted to a binary number to simplify mathematical operations.
- **Images:** also represented by bit patterns.
  - an image is composed of a matrix of pixels (picture elements), where each pixel is a small dot.
  - The size of the pixel depends on the resolution.
  - For example, an image can be divided into 1000 pixels or 10,000 pixels. In the second case, there is a better representation of the image (better resolution), but more memory is needed to store the image.

Data Representation Techniques

- **Audio**
  - refers to the recording or broadcasting of sound or music.
  - It is continuous, not discrete.
  - Even when we use a microphone to change voice or music to an electric signal, we create a continuous signal.
- **Video**
  - refers to the recording or broadcasting of a picture or movie.
  - Video can either be produced as a continuous entity (e.g., by a TV camera), or it can be a combination of images, each a discrete entity, arranged to convey the idea of motion.

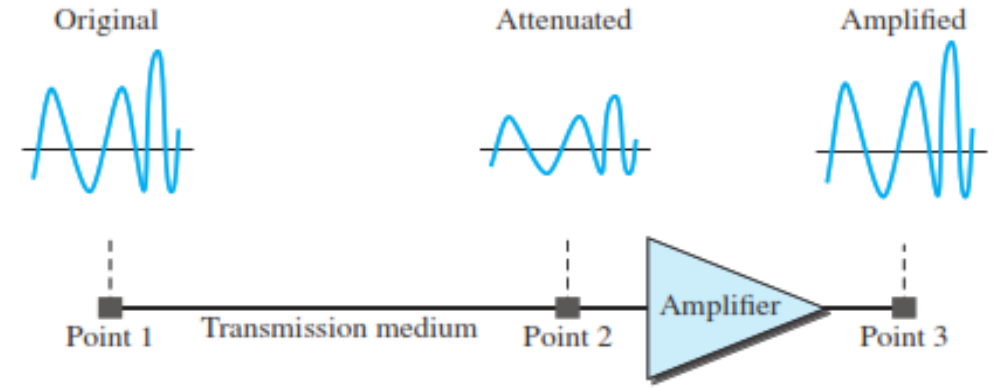
Transmission Impairment

- **Signals travel through transmission media, which are not perfect.**
- **The imperfection causes signal impairment. This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium.**
- **What is sent is not what is received.**
- **Three causes of impairment are attenuation, distortion, and noise.**



Transmission Impairment

- Attenuation
  - means a loss of energy
  - When a signal travels through a medium, it loses some of its energy in overcoming the resistance of the medium.
  - That is why a wire carrying electric signals gets warm, if not hot, after a while.
  - To compensate for this loss, amplifiers are used to amplify the signal.



Transmission Impairment

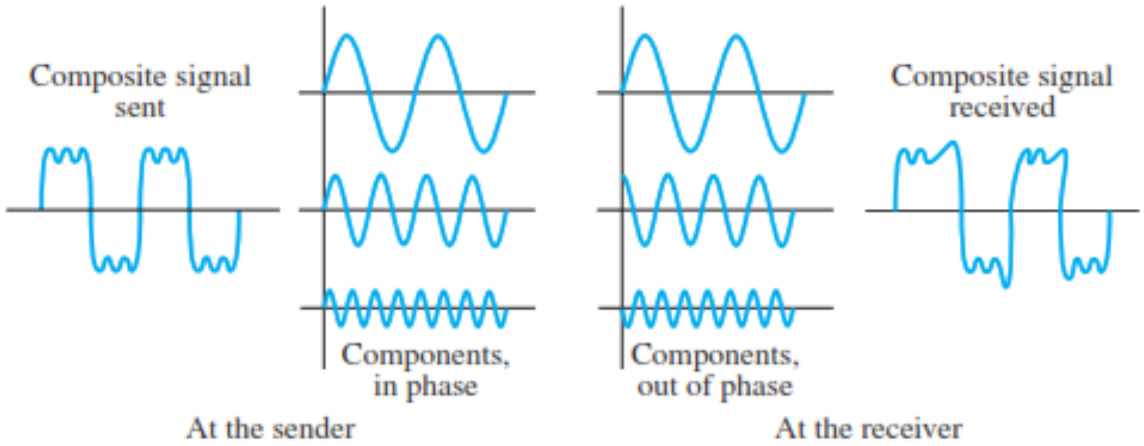
- Attenuation
  - To show that a signal has lost or gained strength, engineers use the unit of the decibel.
  - The decibel (dB) measures the relative strengths of two signals or one signal at two different points.
  - Note that the decibel is Negative if a signal is attenuated and Positive if a signal is amplified.

$$\mathrm{dB} = 10 \log_{10} \frac{P_2}{P_1}$$

  - Variables P1 and P2 are the powers of a signal at points 1 and 2, respectively.

Transmission Impairment

- Distortion
  - means the 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 destination.
  - Differences in delay may create a difference in phase if the delay is not exactly the same as the period duration.

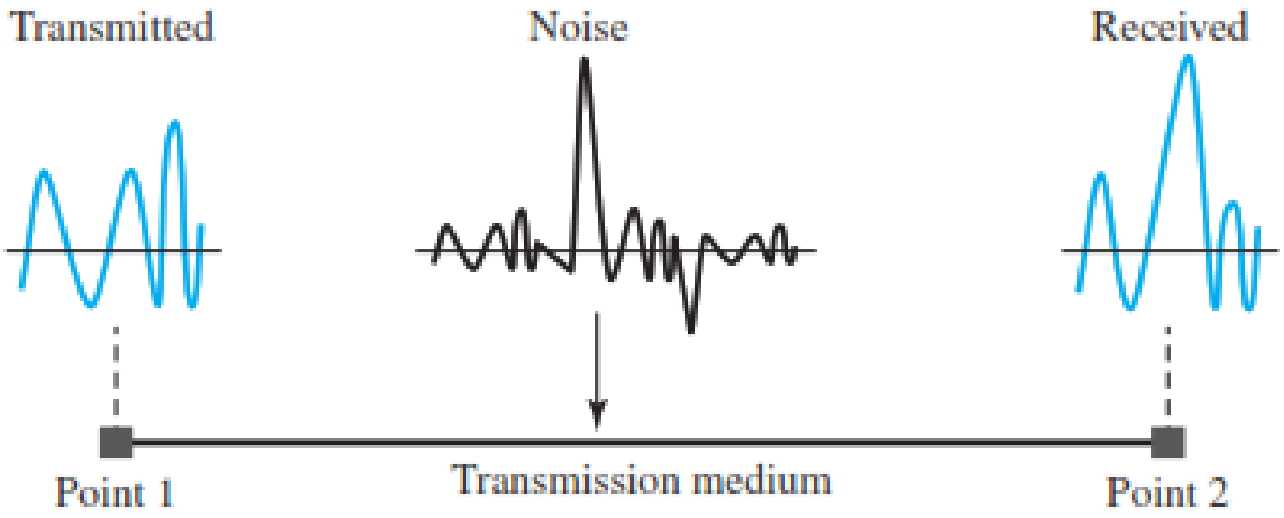


Transmission Impairment

- Noise:
  - For any data transmission event, the received signal will consist of the transmitted signal, modified by the various distortions imposed by the transmission system, plus additional unwanted signals that are inserted somewhere between transmission and reception.
  - Undesired signals are referred to as noise.
  - Types of Noise:
    - Thermal Noise
    - Induced Noise
    - Crosstalk and
    - Impulse Noise may corrupt the signal.
  - Thermal noise is the random motion of electrons in a wire, which creates an extra signal not originally sent by the transmitter.
  - Induced noise comes from sources such as motors and appliances. These devices act as a sending antenna, and the transmission medium acts as the receiving antenna.

Transmission Impairment

- Noise
  - Crosstalk is the effect of one wire on the other. One wire acts as a sending antenna and the other as the receiving antenna.
  - Impulse noise is a spike (a signal with high Energy in a very short time) That comes from power lines, lightning, and so on.



Transmission Impairment

- Noise
  - Example 1:

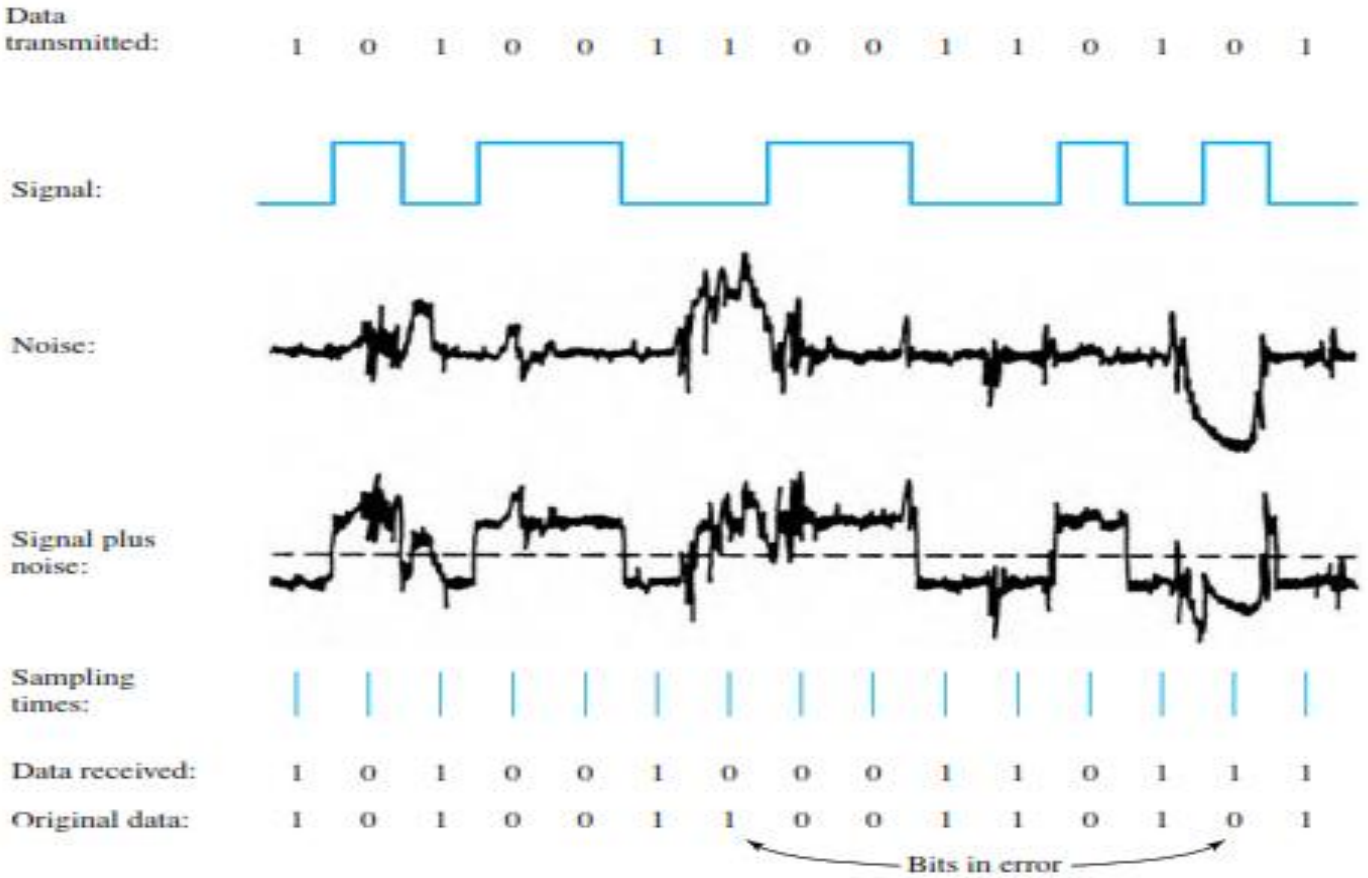
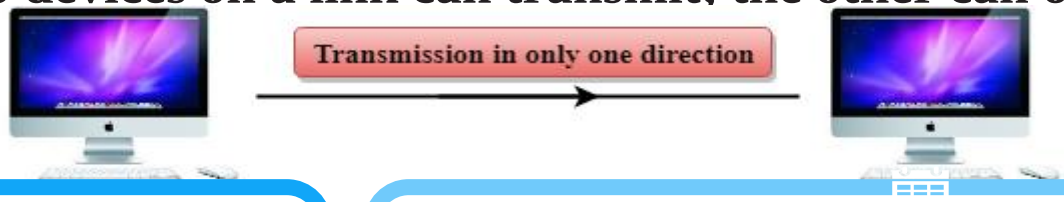


Figure 3.16 Effect of Noise on a Digital Signal

Transmission Modes

- Data transmission modes can be characterized in the following **three types** based on the **direction of exchange of information**:
- **Simplex**
  - **The communication is unidirectional (send data in one direction)**
  - **Only one of the two devices on a link can transmit; the other can only receive**
  - **Eg. radio**



Advantage

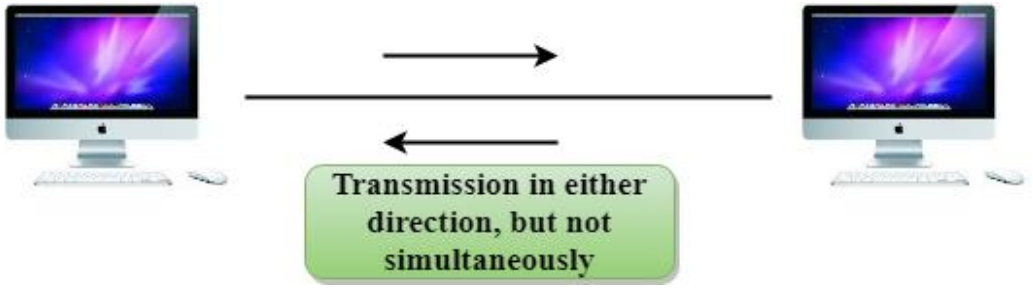
- The station can utilize the entire bandwidth

Dis advantage

- **No inter-communication between devices.**

Cont…

- **Half-duplex**
  - **Each station can both transmit and receive, but not at the same time.**
  - **When one device is sending, the other can only receive, and vice versa**
  - **Eg. Walkie-talkies**



Advantage

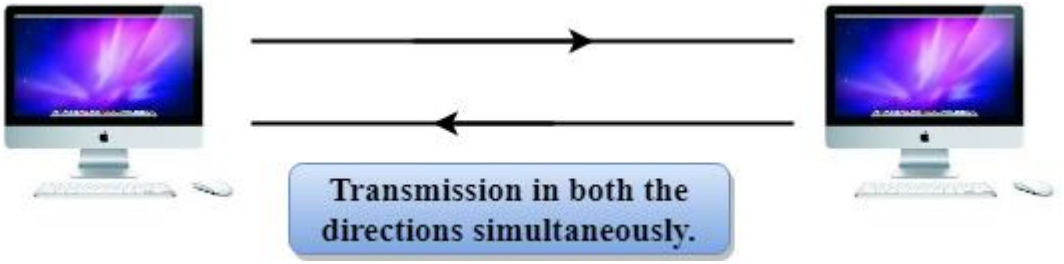
- Both the devices can send and receive the data and also can utilize the entire BW of the communication channel during the transmission of data

Dis advantage

- when one device is sending the data, then another has to wait, this causes the **delay** in sending the data at the right time.

Cont…

- **Full-duplex (*duplex*)**
  - ***both stations can transmit and receive simultaneously***
  - ***Eg* telephone**



Advantage

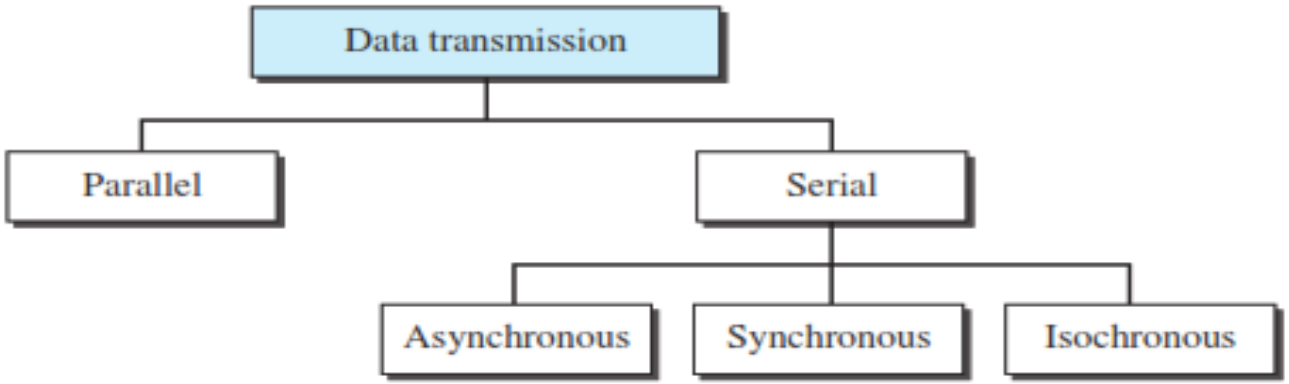
- No delays in communication as both can send and receive data simultaneously.

Dis advantage

- **No proper bandwidth** utilization as the same line is used for sending and receiving data at the same time.

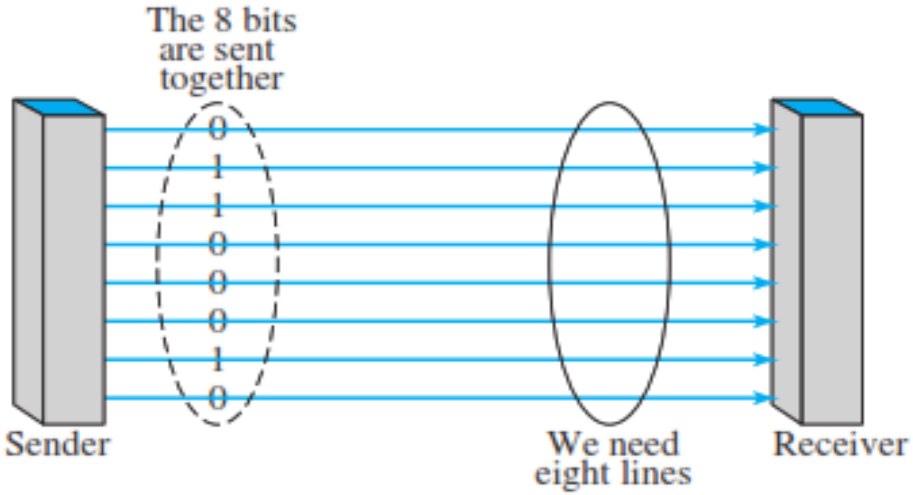
Transmission Modes

- **The transmission medium may be capable of sending only a single bit in unit time or multiple bits in unit time.**
- **According to the number of bits sent across a link can be accomplished in either parallel or serial mode.**
- **In parallel mode**
  - **multiple bits are sent with each clock tick.**
- **In serial mode**
  - **1 bit is sent with each clock tick.**
  - **There are three subclasses : asynchronous, synchronous, and isochronous**



Transmission Modes

- **In parallel Transmission**
  - Binary data, consisting of 1s and 0s, may be organized into groups of *n bits each.*
  - Computers produce and consume data in groups of bits much as we conceive of and use spoken language in the form of words rather than letters.
  - By grouping, we can send data *n bits at a time instead of 1*.
  - The mechanism is simple one: Use *n wires* to send *n bits at one time*.
  - *That way each bit has its own wire, and all n bits of one* group can be transmitted with each clock tick from one device to another

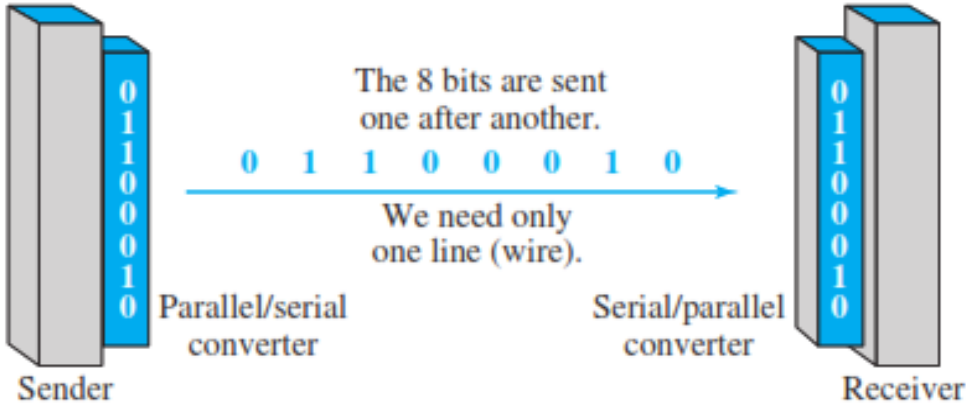


Advantage:
speed
Disadvantage:
cost
Can't travel long distances

Example: Printer connection

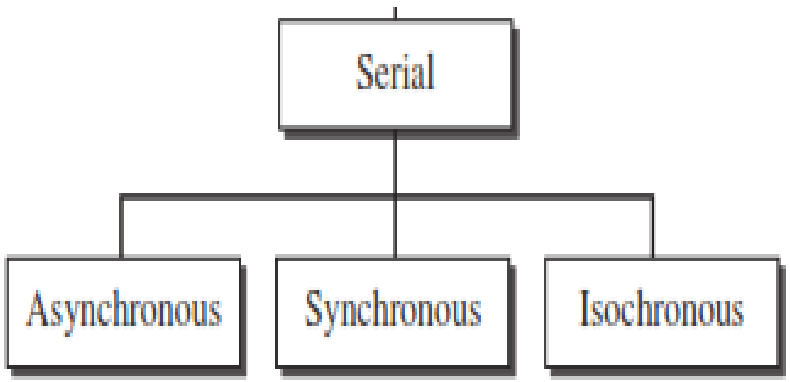
Transmission Modes

- **In Serial Transmission**
  - In serial transmission one bit follows another, so we need only one communication Channel rather than *n* to transmit data between two communicating devices



  - **Advantage**:
    - Reduces the cost of transmission
    - Travels long distances
    - Example: telephone wires

- Serial transmission occurs in one of three ways:
  - Asynchronous
  - Synchronous and
  - Isochronous

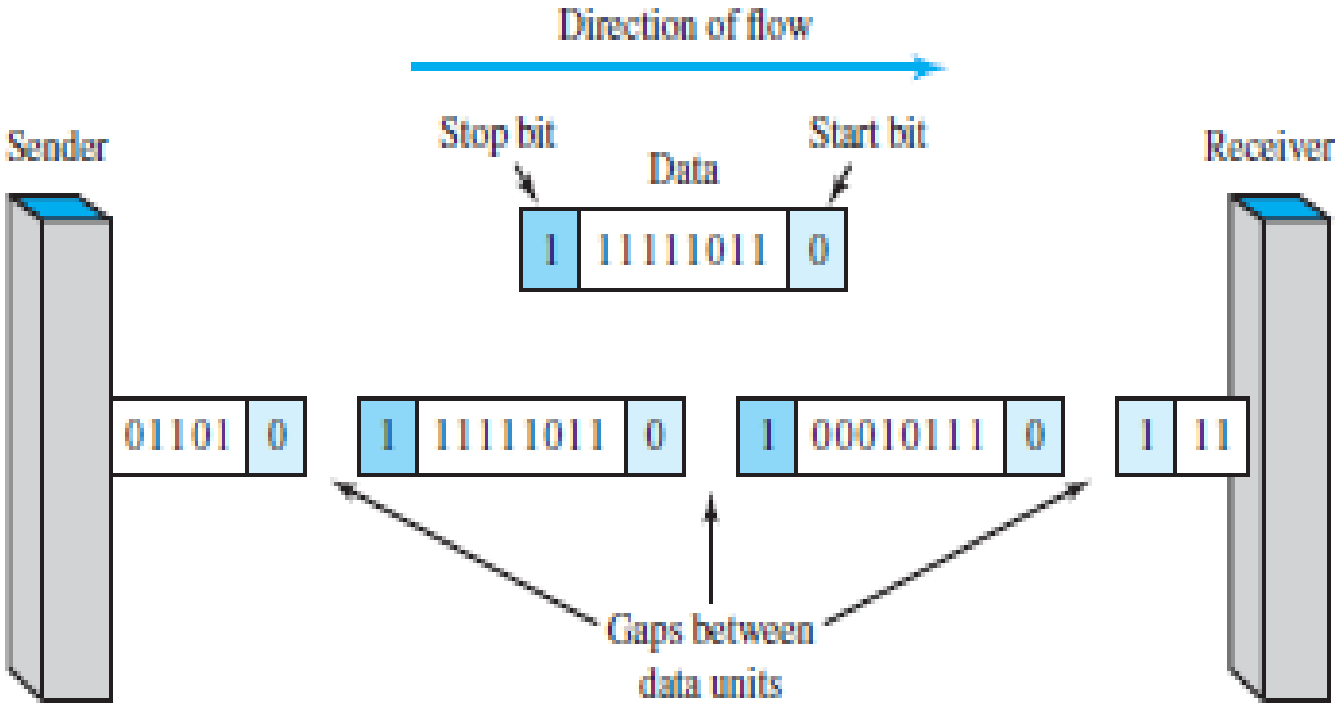


Transmission Modes

- **Asynchronous transmission**
  - **Asynchronous transmission is so named because the timing of a signal is unimportant.**
  - **Patterns are based on grouping the bit stream into bytes.**
  - **Each group, usually 8 bits, is sent along the link as a unit.**
  - The start bit is indicated by 0 and stop bit is indicated by 1.
  - **There may be a gap between bytes.**
  - **Asynchronous here means "asynchronous at the byte level," but the bits are still synchronized; their durations are the same**

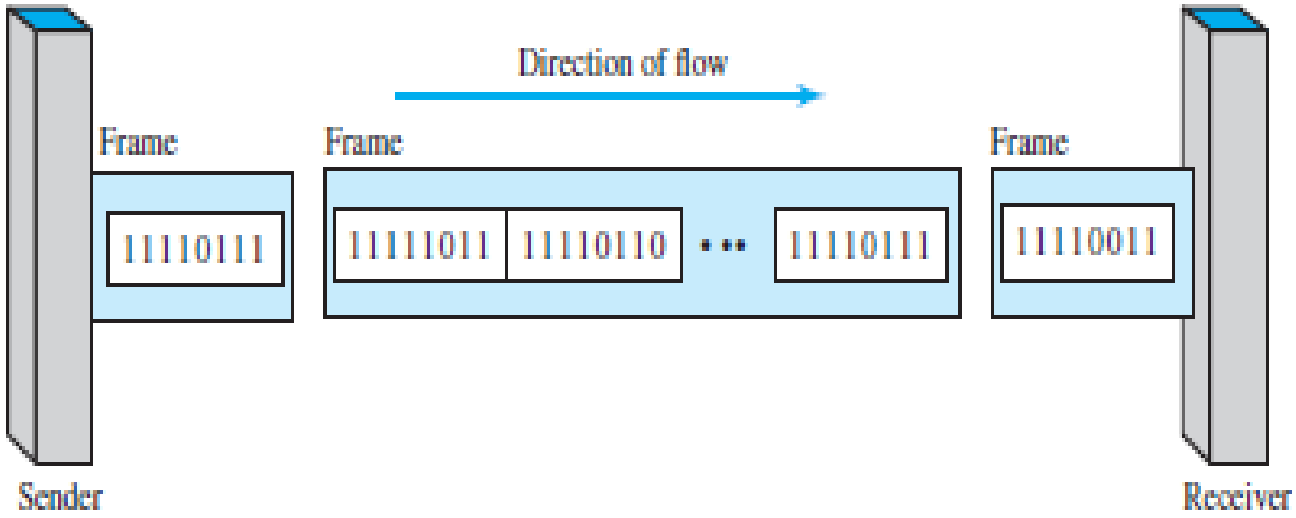
Transmission Modes

- **Asynchronous transmission**
  - **Example:** the connection of a keyboard to a computer is asynchronous transmission. A user types only one character at a time, types extremely slowly in data processing terms, and leaves unpredictable gaps of time between characters.



Transmission Modes

- **Synchronous transmission**
  - **The bit stream is combined into longer "frames," which may contain multiple bytes.**
  - **We send bits one after another without start or stop bits or gaps. It is the responsibility of the receiver to group the bits.**
  - **Synchronous transmission is faster than asynchronous transmission.**



Transmission Modes

- **Isochronous transmission**
  - In real-time audio and video, in which uneven delays between frames are not acceptable, synchronous transmission fails.
  - Example: TV images are broadcast at the rate of 30 images per second; they must be viewed at the same rate.
  - If each image is sent by using one or more frames, there should be no delays between frames.
  - For this type of application, synchronization between characters is not enough; the entire stream of bits must be synchronized.
  - The **isochronous transmission** guarantees that the data arrive at a fixed rate.

no	Parameter	Parallel transmission	Serial transmission
1	Number of wire required to transmit N bits	N wire	1 wire
2	Number of bits transmitted simultaneously	N bits	1 bits
3	Speed of data transfer	Fast	slow
4	Cost	Higher due to more number of conductor	Low, since only one wire is used
5	Application	Short distance communication such as computer to printer communication	Long distance computer to computer communication.

Standard Organizations for Data Communications

- An association of **organizations, governments, manufacturers and users** form the standards organizations and are responsible for developing, coordinating and maintaining the standards.
- The primary standards organizations for data communication are:
  - ✓ International Standard Organization (ISO)
  - ✓ International Telecommunications Union Telecommunication Sector (ITU-T)
  - ✓ Institute of Electrical and Electronics Engineers (IEEE)
  - ✓ American National Standards Institute (ANSI)
  - ✓ American National Standards Institute (ANSI)
  - ✓ Electronics Industry Association (EIA)

Switching Techniques

- In large networks, there may be more than one path for transmitting data from sender to receiver.
- Selecting a path that data must **take out of the available options** is called switching.
- There are two popular switching techniques
  - **circuit switching** and **packet switching**.
    - Circuit Switching
- Dedicated path is established for data transmission

Cont…

- **Packet Switching**

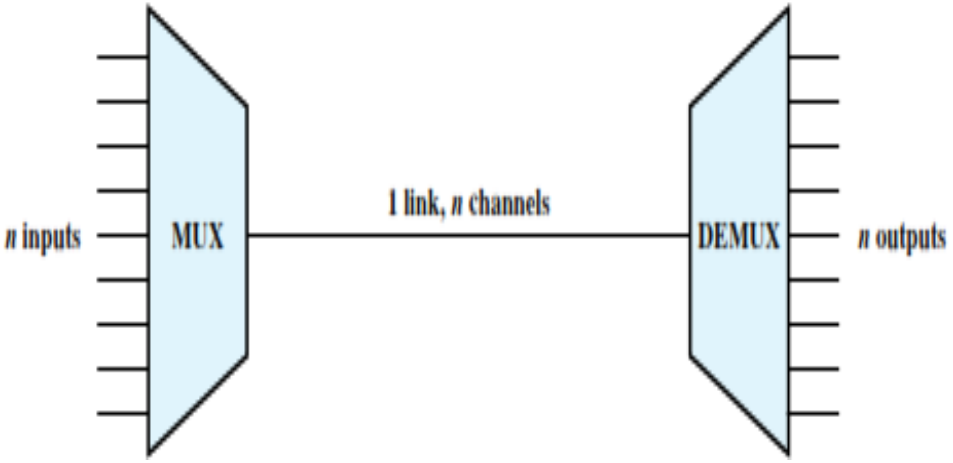
- data is broken down into **small packets** with each packet having source and destination addresses, travelling from one router to the next router.
- These data chunks or "**packets**" allow for faster, more efficient data transfer.

Circuit Switching	Packet Switching
In circuit switching there are 3 phases: **i) Connection Establishment.** **ii) Data Transfer.** **iii) Connection Released.**	In Packet switching directly data transfer takes place.
In circuit switching, each data unit know the entire path address which is provided by the source.	In Packet switching, each data unit just know the final destination address intermediate path is decided by the routers.
In Circuit switching, data is processed at source system only	In Packet switching, data is **processed at all intermediate node** including source system.
It is not a store and forward technique.	It is a **store and forward** technique.
Transmission of the data is done by the source.	Transmission of the data is done not only by the source, but also by the intermediate routers.
there is a physical path between the source and the destination	there is **no physical path** between the source and the destination

Multiplexing

- Allows multiple signals to be transmitted simultaneously across a single data link.
- In a multiplexed system, n lines share the bandwidth of one link.
- A way of transmitting various signals over a media or single line.
- In the figure, link refers to the physical path. It merges a number of low speed signals to send high speed link .
- The entire process can be done using a device **MUX**(N input and 1 output) & **DEMUX** (used at receiving end and 1 input and N output).

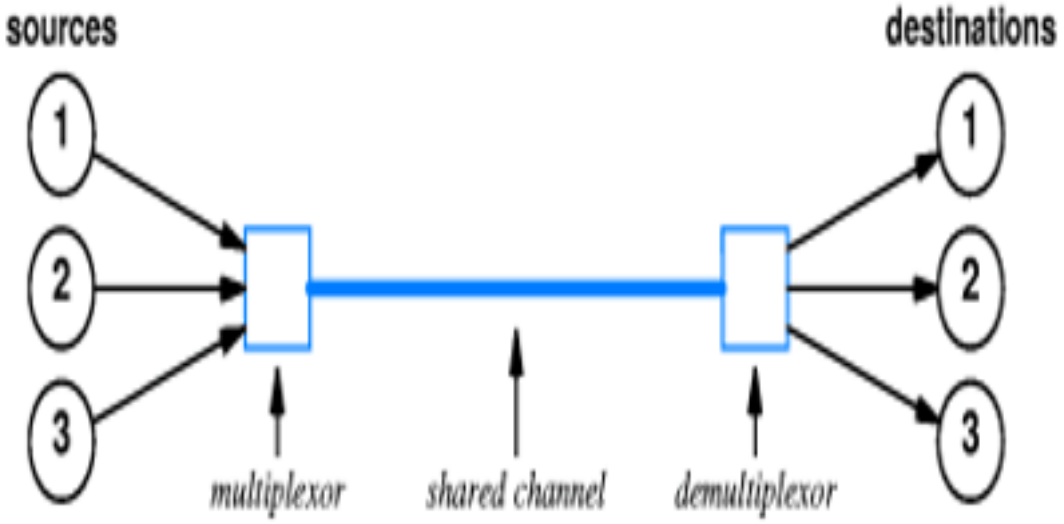
Multiplexing



- For each type of multiplexing:
  - **Multiplexer** (mux))
    - is a device that combines several signals into a single channel.
    - **to accept data from more than one source, and transmit it over the shared channel.**
  - **Demultiplexer** (demux)
    - separates the combined signals and regenerates them in original form
    - **accepts data from the shared channel, and sends it on to its correct destination.**

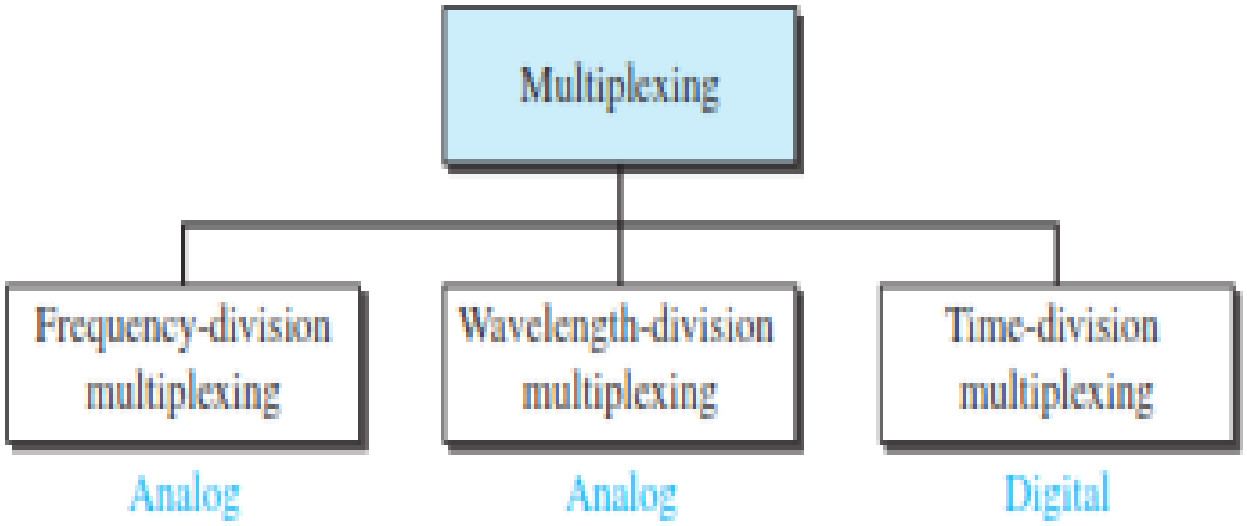
Multiplexing

- Multiplexing/Demultiplexing: Used when many sources communicate with many destinations through one communication line.

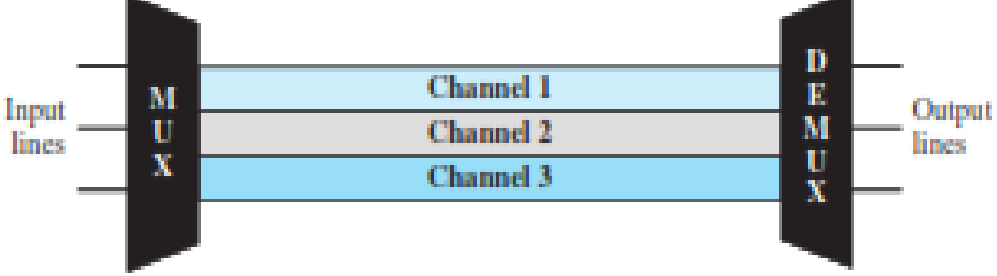


Multiplexing

- There are three basic multiplexing techniques:
  - **Frequency-division multiplexing**
  - **Wavelength-division multiplexing** and
  - **Time-division multiplexing.**
- The first two are techniques designed for analog signals, the third, for digital

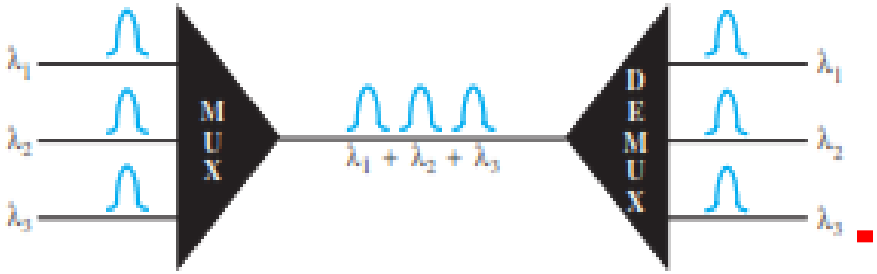


Multiplexing



- **Frequency-Division Multiplexing**
  - is an **analog multiplexing technique that combines analog signals**
  - Used in telephone companies in 20th century in long distance connections for multiplexing number of voice signals.
  - 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.

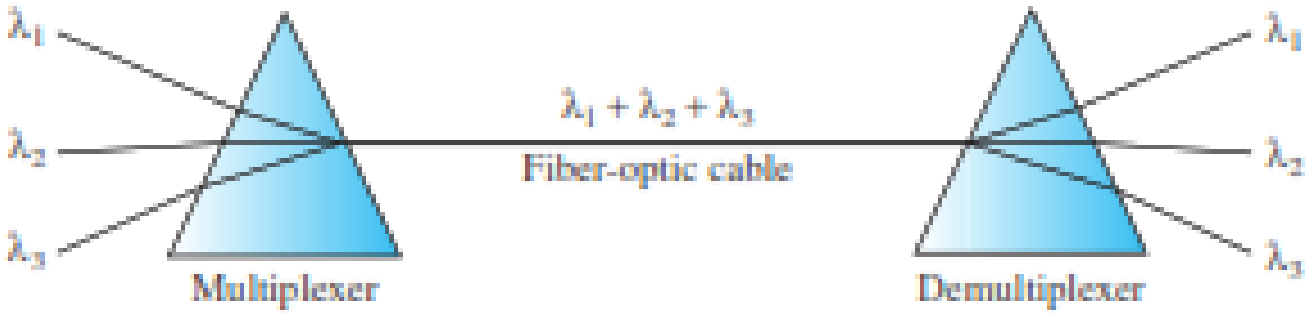
Multiplexing



- **Wavelength-Division Multiplexıng**
  - **is an analog multiplexing technique to combine optical signals.**
  - **is designed to use the high-data-rate capability of fiber-optic cable.**
  - **WDM is conceptually the same as FDM, except that the multiplexing and demultiplexing involve optical signals transmitted through fiber-optic cables/channels.**
  - **The idea is the same: We are combining different signals of different frequencies. The difference is that the frequencies are very high.**

Multiplexing

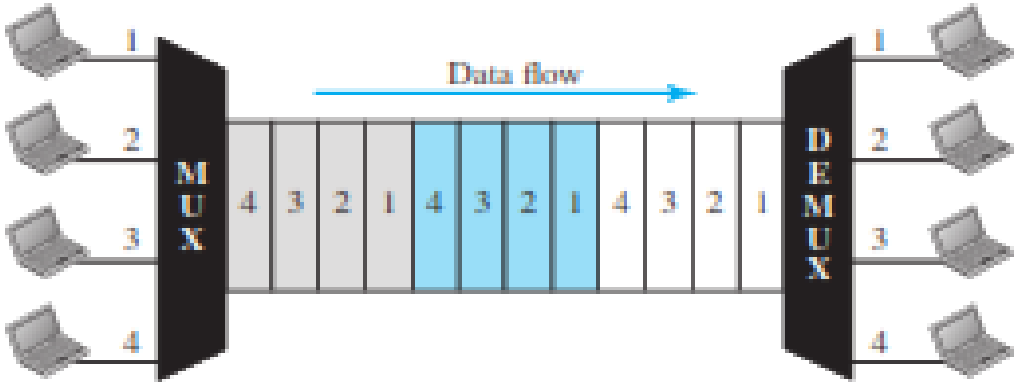
- **Wavelength-Division Multiplexing**



  - **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.**

Multiplexing

- **Time-Division Multiplexing**
  - **TDM is a digital multiplexing technique for combining several low-rate channels into one high-rate one.**
  - **is a digital process that allows several connections to share the high bandwidth of a link.**
  - **Instead of sharing a portion of the bandwidth as in FDM, time is shared.**
  - **Sectioned by time rather than by frequency**



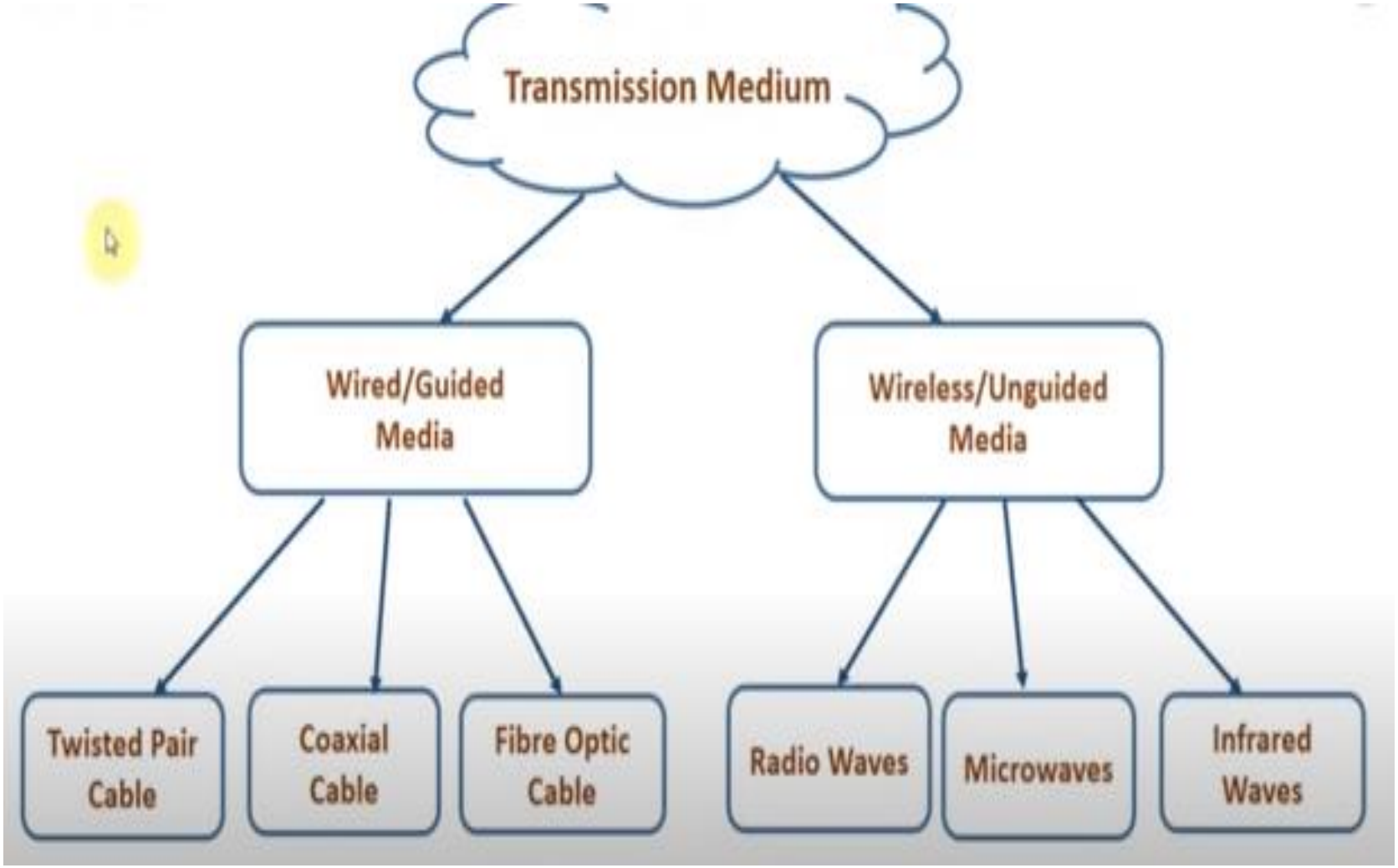
Multiplexing

- **Time-Division Multiplexing**
  - **It is a communication process that transmits two or more streaming digital signals over a common channel.**
  - **Divides time into slices called *time slots*.**
  - **In TDM incoming signals are divided into equal fixed length time slots.**
  - **After MUX these signals are transmitted over a shared medium and reassembled into their original format after DEMUX.**
  - **Both MUX and DEMUX are synchronized timely & at the same time switch toward the next channel.**
  - **TDM can be used with both digital and analogue transmission.**

Transmission media

- The transmission medium is the physical path between transmitter and receiver in a data transmission system.
- It is included in the physical layer of the OSI protocol hierarchy.
- Transmission media is a means by which a communication signal is carried from one system to another

Categories of Transmission Media



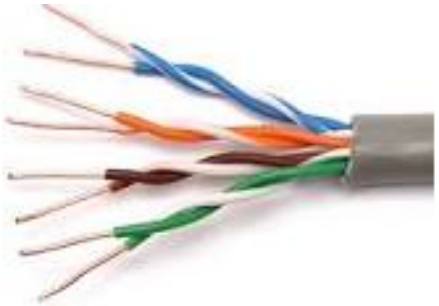
Categories of Transmission Media

- **Two basic categories of transmission Media:**
  - **Guided**
  - **Unguided**

  Guided – uses a cabling system that guides the signals along a specific path.
  - **Also known as bound media**
    - **E.g. Fiber Optics, Twisted Pair, Coaxial Cable etc…**

  Unguided – consists of a means for the data signals to travel but nothing to guide them along a specific path - wireless
  - **Also called unbound media**
    - **Example: Radio wave, Satellite, etc.**

Wired /Guided Media



- Twisted pair, Coaxial and Fiber optic
  - Twisted pair cabling comes in two varieties:
    - Shielded and Unshielded Twisted pair cable
  - Unshielded twisted pair (UTP) is the most popular and is generally the best option for school networks
  - The cable has four pairs of wires inside the jacket.
  - Each pair is twisted with a different number of twists per inch to help eliminate interference from adjacent pairs and other electrical devices.
  - The tighter the twisting, the higher the supported transmission rate and the greater the cost per foot.

Cont…

- **UTPs are cheaper, more flexible, and easier to install.**
- **The Electronic Industries Association (EIA) has developed standard to grade UTP cable by quality; Category 1 as the lowest quality and category 6 as the highest quality.**

Type	Use
Cat 1	Voice Only (Telephone Wire)
Cat 2	Data to 4 Mbps (LocalTalk) both voice and data.
Cat 3	Data to 10 Mbps. standard cable for most telephone systems
Cat 4	Data to 20 Mbps
Cat 5	Data to 100 Mbps (Fast Ethernet)
Cat5e	Data to 1Gbps (ether, FastE, GigEtr)
Cat6	Data to 1Gbps (Ether, FastE, GigEtr) with improved performance and reliability.
Cat6a	Upto 10Gbps(GigEthr,10G Ethernet(55 Meter))
cat7	Upto 10Gbps(GigEthr,10G Ethernet(100 Meter))

Unshielded Twisted Pair Connector

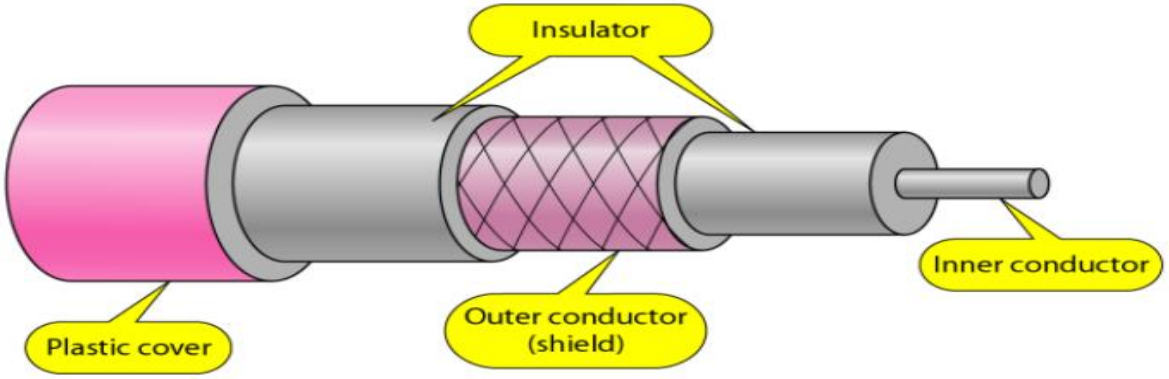
- **The standard connector for unshielded twisted pair cabling is an RJ-45 connector.**
- **RJ stands for Registered Jack, implying that the connector follows a standard borrowed from the telephone industry.**

Shielded Twisted Pair (STP) Cable

- **A disadvantage of UTP is that it may be susceptible to radio and electrical frequency interference.**
- **Shielded twisted pair (STP) is suitable for environments with electrical interference;**
- **however, the extra shielding can make the cables quite bulky.**
- **Shielded twisted pair is often used on networks using Token Ring topology.**
  - **Susceptible means disposed, vulnerable**

Coaxial Cable

- **Coaxial cabling has a single copper conductor at its center.**
- **is difficult to install, it is highly resistant to signal interference.**
- **it can support greater cable lengths between network devices than twisted pair cable.**
- **The two types of coaxial cabling: Thick coaxial and Thin coaxial.**
- **Read About: Thick coaxial and Thin coaxial.**

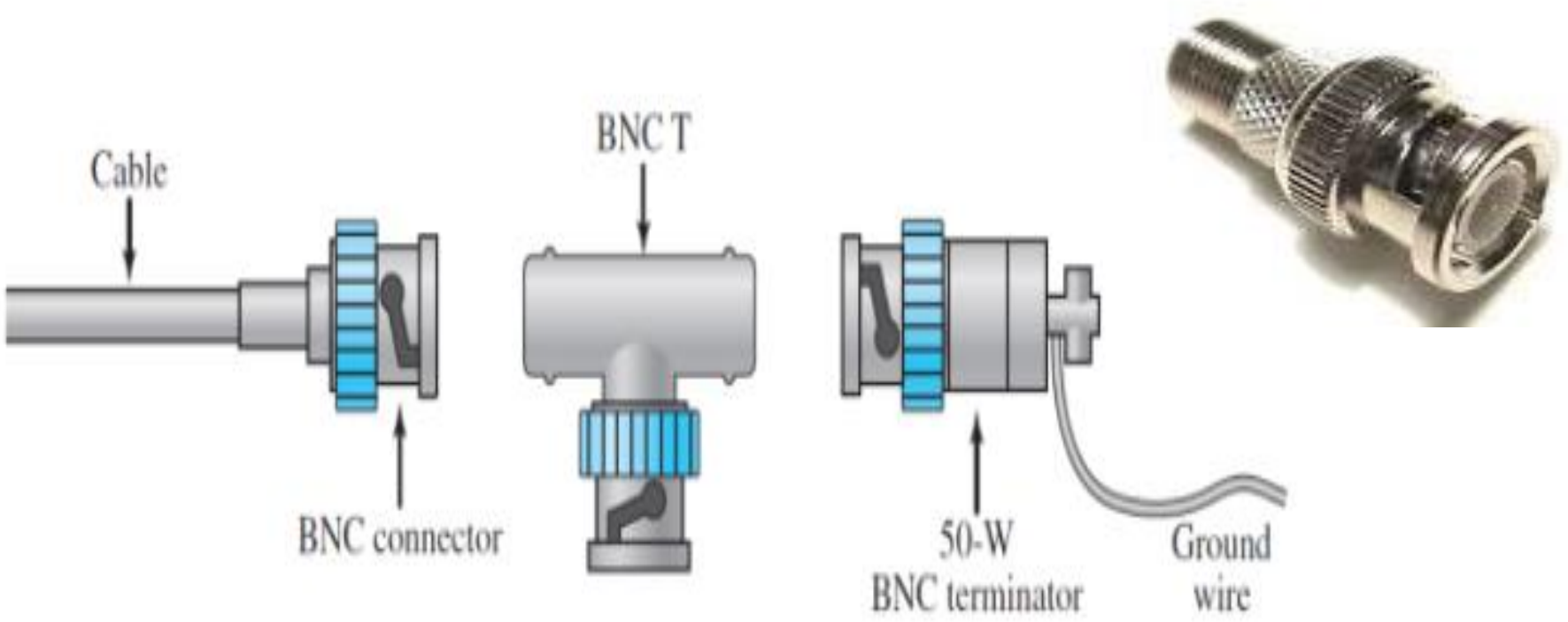


Coaxial Cable Connectors

- **The most common type of connector used with coaxial cables is the Bayone-Neill-Concelman (BNC) connector .**
- For LANs, coaxial cable offers several advantages. It can be run longer distances than UTP cable without the need for repeaters
- Television distribution
    - Ariel to TV
    - Cable TV
- Long distance telephone transmission
  - Can carry 10,000 voice calls simultaneously
- Short distance computer systems links

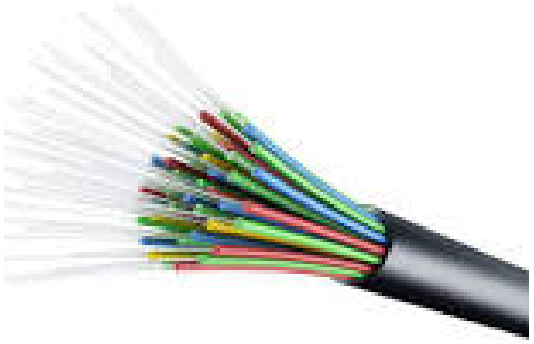
Cont…

Three popular types of these connectors: the BNC connector, the BNC T connector, and the BNC terminator.



Fiber Optic Cable

- **consists of a center glass core surrounded by several layers of protective materials.**
- **It transmits light rather than electronic signals eliminating the problem of electrical interference.**
- It is made of glass or plastic and transmits signals in the form of light



- **Fiber optic cable has the ability to transmit signals over much longer distances than coaxial and twisted pair.**
- **It also has the capability to carry information at vastly greater speeds.**
- **This capacity broadens communication possibilities to include services such as video conferencing and interactive services.**
- **The cost of fiber optic cabling is comparable to copper cabling; however, it is more difficult to install and modify.**

Fiber Optic Connector

- The most common connector used with fiber optic cable is an ST connector(Straight Tip).
- It is barrel shaped, similar to a BNC connector.

Specification	Cable Type	Maximum length
10BaseT	Unshielded Twisted Pair	100 meters
10Base2	Thin Coaxial	185 meters
10Base5	Thick Coaxial	500 meters
10BaseF	Fiber Optic	2000 meters
100BaseTX	Shielded Twisted Pair	220 meters

Cont…

Advantage

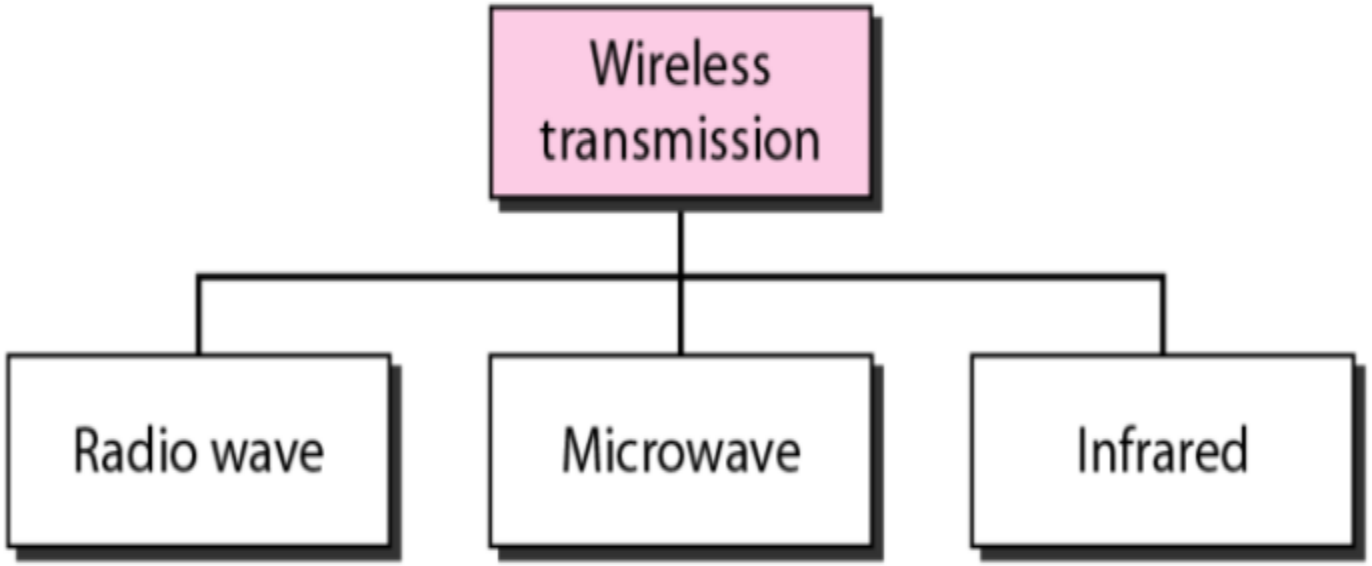
- ✓ Higher bandwidth.
- ✓ Less signal attenuation.
- ✓ Immunity to electromagnetic interference.
- ✓ High security.
- ✓ Light weigh

Disadvantage

- ✓ Installation and maintenance
- ✓ Unidirectional light propagation
- ✓ High Cost

UNGUIDED MEDIA: WIRELESS

- Unguided media transport electromagnetic waves without using a physical conductor.
- This type of communication is often referred to as wireless communication.



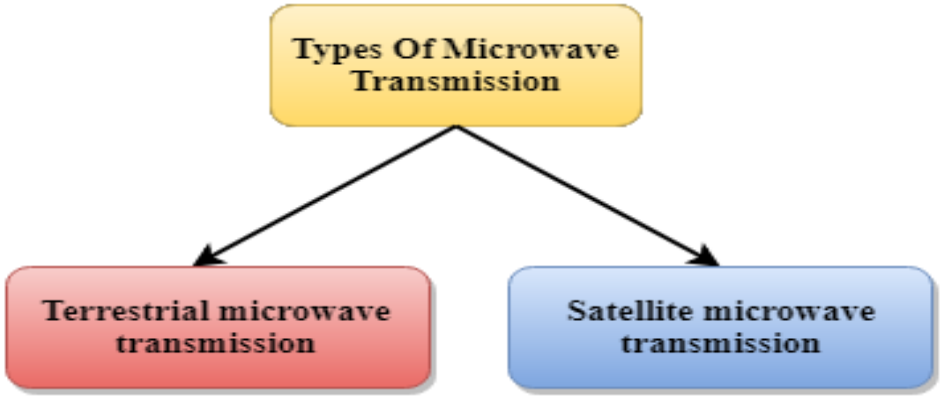
Radio Waves

- Radio waves are the electromagnetic waves that are **transmitted in all the directions of free space.**
- Radio waves are **omnidirectional,** i.e., the signals are propagated in all the directions.
- The range in frequencies of radio waves is from **3Khz to 1 Ghz**.
- In the case of radio waves, the sending and receiving antenna are not aligned, i.e., the wave sent by the sending antenna can be received by any receiving antenna.
- **Useful for multicasting** when there is one sender and many receivers.
- Can penetrate through walls
- Example: **FM radio, police radio and Television**

Microwaves

- Are radio waves that provide high speed signal transmission
- Range form 1GHZ to 300 GHz
- Useful for unicast communication like Telephone, Satellite networks and Wireless LAN.
- Can not penetrate walls
- Uses directional antennas (point to point communication)

Microwave



Terrestrial Microwave

– **is a technology that transmits the focused beam of a radio signal from one ground-based microwave transmission antenna to another.**

Microwaves

Satellite Microwaves

- This transmission system uses satellites for broadcasting and receiving of signals.
- Satellite communication is more reliable nowadays as it offers more flexibility than cable and fiber optic systems.
- We can communicate with any point on the globe by using satellite communication.
- The satellite accepts the signal that is transmitted from the earth station, and it amplifies the signal.
- The amplified signal is retransmitted to another earth station.

Infrared Waves

- The communication rage is **limited**
- Short range communication in a closed area using line of sight propagation
- It **cannot penetrate the walls**
- Due to short range, its considered to be most secured transmission media
- **Example**: Tv remote, car remote, AC remote, wireless speaker

Thank You