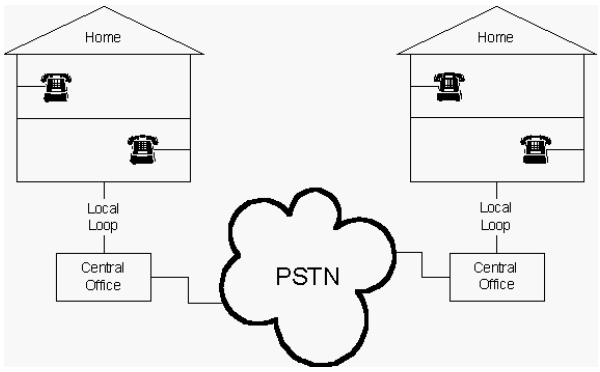
TELECOMMUNICATION

1. INTRODUCTION

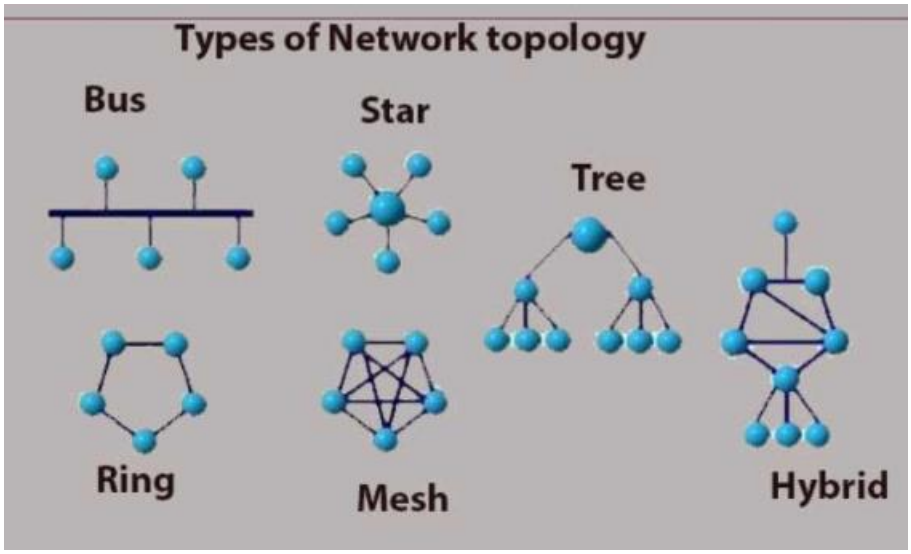
1.1 PSTN

- PSTN stands for "*Public Switched Telephone Network"*
- It forms the backbone of traditional landline telephony and is considered one of the oldest forms of communication networks
- PSTN uses copper wires to connect homes and businesses to switching centers, where calls are routed to their destination
- PSTN allows subscribers to connect by entering phone numbers, and the connection is closed after the call ends
- PSTN is reliable and doesn't require an internet connection, so it can continue to work during power outages or network crashes
- The rise of Voice over Internet Protocol (VoIP) has decreased the use of PSTN, as VoIP sends and receives voice communications over the internet
- Phones that connect to the PSTN are also known as landlines, fixed-line telephones, or PSTN



1.2 Network Topology

Network topology is the physical and logical arrangement of devices and connections in a telecommunications network. It shows how data flows between network elements, and can be thought of as a blueprint for the network



Bus Topology

- Computers are all connected to one single cable
- Only the addressee accepts and processes the message when one computer sends a signal using the cable
- Other computers on the network acknowledge the message, but disregard it
- Unidirectional data flow in bus topology makes problem identification tricky, and heavy network traffic slows it down
- While the failure of one node does not affect the network, failure of the bus system as a whole will cause the entire network to crash

Star Topology

- Each device is linked to a central controller through its dedicated point-to-point cable
- The devices communicate with a central controller that resends the message to the appropriate addressee(s)
- This central controller—also called the hub, host, or server—can be active or passive. While an active hub regenerates a signal and sends it to all the computers connected
- Star topology is easily modified by adding or deleting devices or nodes, and this process does not affect the overall network performance

Ring Topology

- Each device serves as a repeater that strengthens the signal received from the previous device
- In a ring topology, messages flow in one direction only, using tokens to pass information from one device to another. The token is a small packet that is modified with the intended message and the addressee's details
- The token helps each device identify for whom the message is intended. When a piece of information is not intended for a particular device, the token sends it to the next computer and so on, until it reaches the addressee
- Unlike the bus topology, in a ring topology the failure of one computer can affect the entire network, and adding or deleting a device disturbs the network's performance.
- Since information has to pass from one computer to another, the network is slower

Mesh Topology

- The mesh topology is a robust, fully connected topology used in a WAN, or wide area network.
- Every device has a dedicated point-to-point link to all other devices, with the result that each computer must have input/output ports.
- Dedicated P2P link system eases fault identification and isolation, and prevents traffic between computers.
- Here, data is transmitted through routing and flooding. Routing uses “the shortest path between source and destination to transmit data”, while flooding sends “data from the source to all the network nodes, but only the addressee accepts the data”.
- Mesh topology can be divided into two subtypes: full mesh and partial mesh. Each device in the workstation is directly connected to the others in the full mesh architecture. On the other hand, in the partial mesh architecture some devices are connected to the nodes with whom they exchange the most data, while others are connected to all nodes.
- Due to the quantity of required input/output ports and cabling, mesh topology is expensive.

Tree Topology

- A bus system connects numerous star topologies in a tree-branch configuration to form the tree topology.
- A single “hub” node at the top of the network is connected to several lower-level nodes via point-to-point links.

- Additionally, these lower-level nodes are linked to one or more nodes (downlines) in the following level. The “branching factor” of the tree is the fixed number of nodes connected downline

Hybrid Topology

- Hybrid topology occurs when two or more types of topologies are connected
- In a single establishment, one department of an establishment might be using a ring topology, while another department opted for a bus topology
- These two networks can connect to a star topology’s central hub. However, the architecture of the resulting arrangement does not exhibit any standard network topologies
- Hybrid topology’s robust architecture often makes it costly, since it requires extensive infrastructure, cooling, and cabling

Point-to-Point Topology

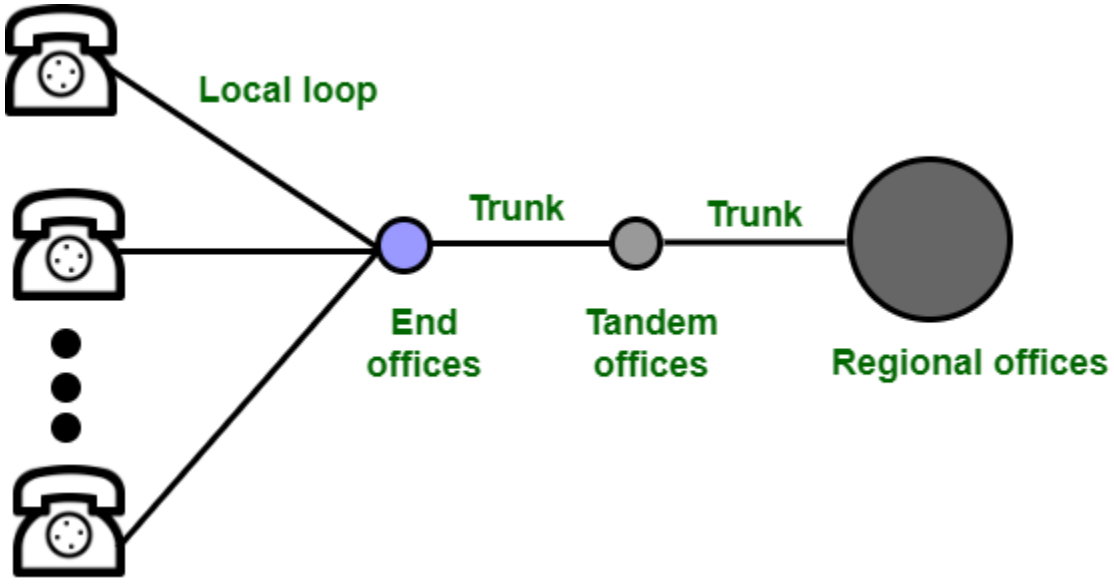
- Point-to-point is the most basic network topology and consists of a direct connection between two computers and peripheral devices. The communication medium is monopolized in this topology since it is not shared, and there is no need for a device identification mechanism.

Daisy Topology

- A daisy topology can come in linear or ring forms. Like in a ring topology, when a computer sends a message, each computer bounces the message in the chain until it reaches its destination. However, whereas the ring topology closes up through a circle of connections, a daisy topology has an endpoint that makes it easy to add new devices and nodes to the network. This topology is also known as chain topology because it connects the network devices in a sequence.

1.3 Subscriber Telephone

- In telecommunications, a subscriber is the end user of a communications service, such as a telephone, and is typically subject to a tariff.
- Subscribers can be individuals, organizations, or activities. They use end instruments, such as telephones, modems, computers, which are connected to a central office
- In a public switched telephone network (PSTN), subscriber lines are connected to a local exchange, which then communicates with trunk exchanges and main exchanges
- *"Lines within a local exchange usually have the same area code. To call a number outside the local exchange, a user must add the area code. To make an international call, a user must dial the country code"*



Local Loops:

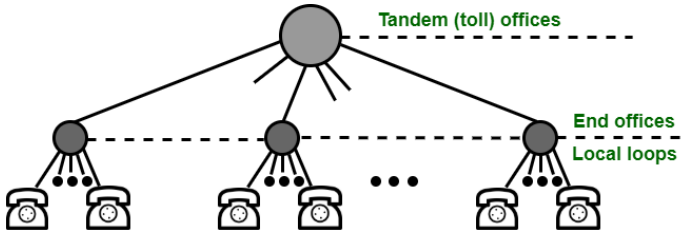
- Local Loops are the twisted pair cables that are used to connect a subscriber telephone to the nearest end office or local central office.
- For voice purposes, its bandwidth is 4000 Hz.
- It is very interesting to examine the telephone number that is associated with each local loop.
- The office is 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 (*Tandem means to connect the output of one circuit to the input of another*)



1.4 Subscriber Loop

- A subscriber loop is the part of a telecommunications system that connects a subscriber's location to a central office. It can be made up of twisted metal cables, optical fibers, or radio links.
- Subscriber loops use direct current to signal when a subscriber is requesting service or has answered. They also use Dual-Tone Multi frequency (DTMF) signaling, where callers press buttons on their keypad to send audio-frequency tones to the central office.
- *A subscriber loop carrier (SLC)* provides telephone exchange functionality for areas with high subscriber density or remote areas
- Digital subscriber line (DSL) uses Time Division Multiplexing (TDM) to provide a dedicated channel and bit rate to each subscriber
- A local loop is a simple twisted-pair cable that connects a subscriber to the public telephone network.

Digital Subscriber Line (DSL)

- The Digital Subscriber Line (DSL), originally, a digital subscriber loop is a communication medium, which is used to transfer the internet through copper wire telecommunication lines
- Along with cable internet, DSL is one of the most popular ways ISPs provide broadband internet access

Properties of DSL

- to maintain the high speed of the data being transferred
- both telephone and internet facilities by using splitters or DSL filters
- Splitter is used to split the frequency and make sure that it can’t get interrupted

Types of DSL

Symmetric DSL (SDSL)

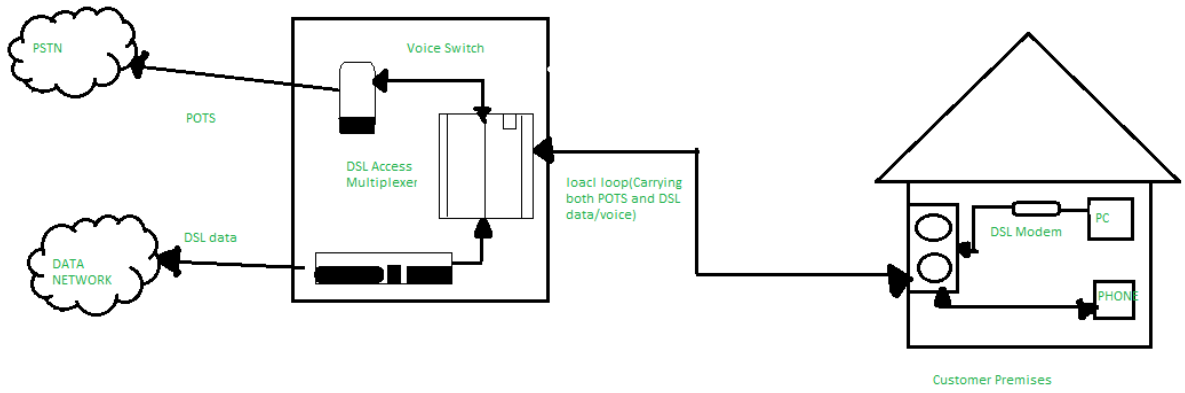
- SDSL, splits the upstream and downstream frequencies evenly, providing equal speeds to both uploading and downloading data transfer
- This connection may provide 2 Mbps upstream and downstream
- mostly preferred by small organizations

Asymmetric DSL (ADSL)

- ADSL, provides a wider frequency range for downstream transfers, which offers several times faster downstream speeds
- ADSL connection may offer 20 Mbps downstream and 1.5 Mbps upstream, it is because most users download more data than they upload
- Cheaper in cost

Very High Bit Rate DSL (VDSL)

- Very fast form of DSL
- Uses copper wire and only used for shorter distances. Can be upgraded with optical fiber for longer distances
- 3 times faster than ADSL



// yt : https://www.youtube.com/watch?v=qQYiwmamq38

(Assignment:

1. ***Digital Subscriber Line***
2. ***Comparison Analog and Digital Transmission***

)

1.5 Subscriber Loop

- A subscriber loop (also known as the local loop) is a physical connection that connects a user's premises to a central office in a telecommunication system
- It can be made up of twisted metallic cables, radio links, or optical fibers
- It serves as the access link that connects users to the larger telecommunication network, enabling services such as voice communication, internet access, and other telephony services.

Structure of the Subscriber Loop

Customer Premises Equipment (CPE): Signals are generated or received here.

Drop Wire: A pair of insulated copper wires that physically connect the subscriber's premises to the nearest distribution point (DP). Carries the electrical signal from the house to the main network.

Distribution Point (DP): A junction box or termination point for multiple subscriber lines. Located on poles, underground, or in cabinets

Feeder Cable: Connects the distribution point to the central office via a bundle of twisted-pair copper wires or fiber-optic cables

Main Distribution Frame (MDF): Located at the telephone exchange, the MDF connects incoming subscriber lines to the telecommunication switching equipment

// (Make Figure using boxes and line connections)

1.6 Telephone Conversation and Hierarchical Networks

➢ Telephone Conversation

Initiation (Dialing):

- The caller enters the recipient's phone number, initiating a connection request
- The signal is sent to the local exchange to establish the call

Signaling:

- Out-of-Band Signaling: Separate signaling channel for signaling messages. It is used for call setup, routing, and disconnection (e.g., SS7 signaling system , ISDN (- Integrated Services Digital Network))
- In-Band Signaling: Manages tones and signals on the same channel as voice data (e.g. TCP/IP)

Call Routing:

- Telephone exchange identifies the recipient's location and routes the call through switching centers in the network hierarchy

- ***Voice Transmission:***
  - Analog Transmission: Used in older systems where voice is transmitted as a continuous waveform
  - Digital Transmission: Modern systems digitize voice using codecs and transmit it as packets over IP-based networks or circuits

- ***Voice Conversion:***
  - At the Sender's Side: The microphone converts sound waves into electrical signals
  - At the Receiver's Side: The speaker converts electrical signals back into sound waves

- ***Call Termination:***
  - When either party ends the call, signaling ensures the circuit is released and resources are freed

➢ **Structure of a Hierarchical Network**

1. *Subscriber Level (Local Exchange):*
   - Connects individual subscribers to the telecommunication network
   - Handles local calls directly

2. *Tandem Exchange:*
   - Connects multiple local exchanges within a region
   - Used for routing intra-regional calls

3. *Primary Center:*
    - The first higher-level switching center
    - Routes calls between regions or local exchanges without a direct connection

4. *Secondary Center:*
    - Handles national-level traffic between primary centers
    - Ensures long-distance call management (different region / areas)

5. *International Gateway:*
    - The highest level in the hierarchy
    - Facilitates communication between different countries
    - Need to have country code

1.7 Analog and Digital Transmission

Analog Transmission

- Data is transferred with the help of analog signal in between transmitter and receiver
- Any data is converted into electric form first and after that it is passed through communication channel
- It uses a continuous signal which varies in amplitude, phase, or some other property with time in proportion to that of a variable

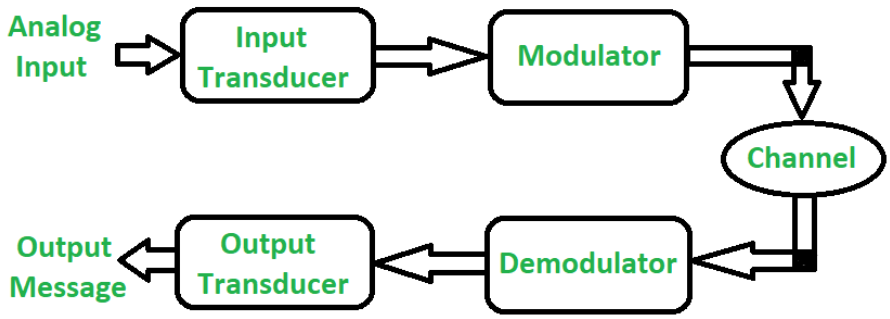
Advantages of Analog Transmission

- It is Easier in processing

- Analog Signals are best fitted to audio and video transmission
- Low cost and is portable
- It possess higher density

Disadvantages of Analog Transmission

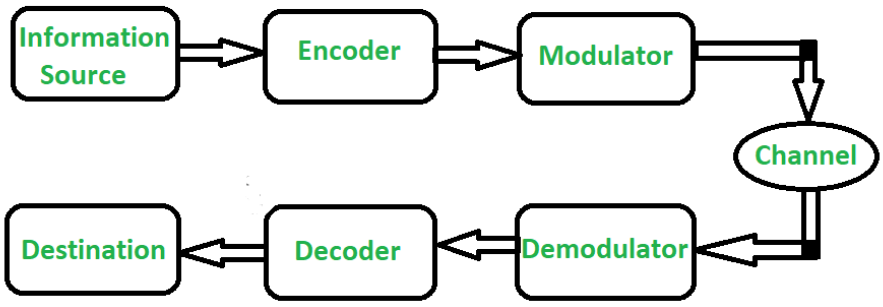
- Analog tends to possess a lower quality signal than digital
- Sensitive to external influences
- Expensive and not easily portable



Analog Communication System

Digital Transmission

- It consists of discrete values rather than continuous values
- Transfer of data occurs in the form of digital bit stream
- Digital transmission data can be broken into packets as discrete messages



Digital Communication System

Advantages of Digital Transmission

- Speed & accuracy of data transmission is quite high
- Robustness against Noise
- Error Detection and Correction
- Efficient Bandwidth Utilization
- Signal Regeneration
- Cost Efficiency in the Long Term

Disadvantages of Digital Transmission

- Power Consumption
- Dependency on Sampling Rate
- Higher Initial Cost

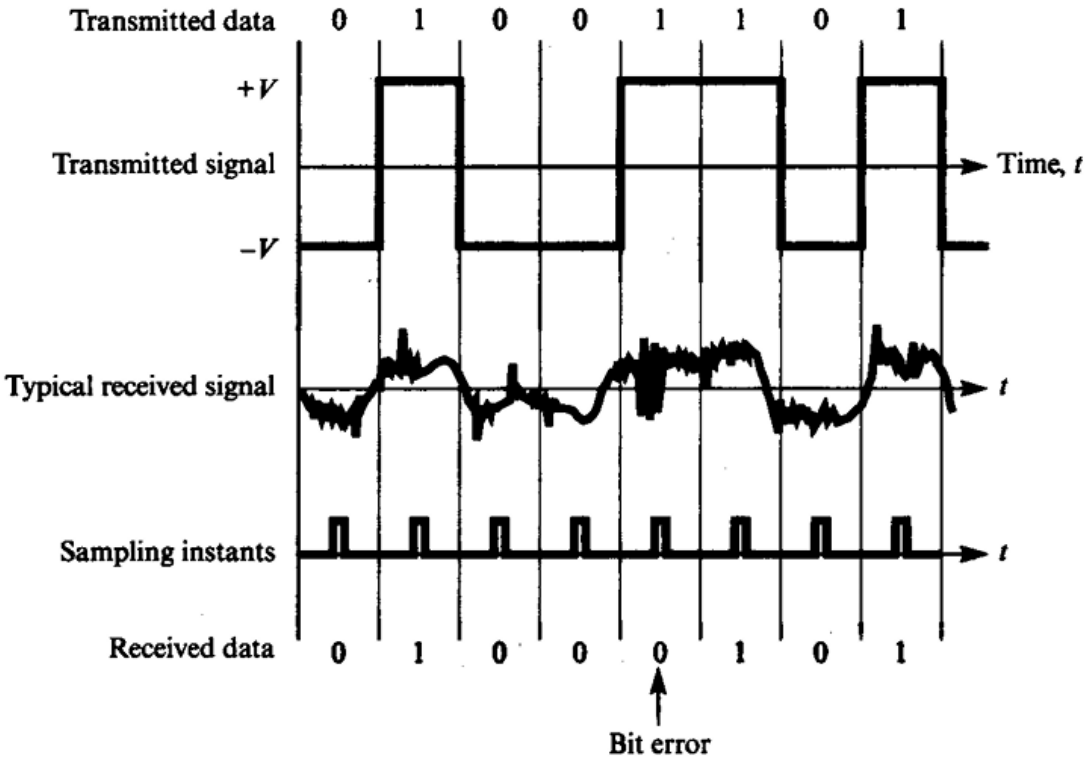
S. NO.	**ANALOG COMMUNICATION**	**DIGITAL COMMUNICATION**
1.	It uses analog signal whose amplitude varies continuously	It uses digital signal whose amplitude is of two levels either Low

	with time from 0 to 100	i.e., 0 or either High i.e., 1
2.	affected by noise highly (less noise immunity) so, error probability is high	affected by noise less (high noise immunity) so, error probability is less
3.	only limited number of channels can be broadcasted simultaneously	Can broadcast large number of channels simultaneously.
4.	coding is not possible	Coding is possible, Different coding techniques can be used to detect and correct errors
5.	having complex hardware and less flexible	having less complex hardware and more flexible
6.	low cost at initial but high at long run	High cost at initial but low at long run
7.	low bandwidth	high bandwidth
8.	Not assures an accurate data transmission	assures a more accurate data transmission
9.	AM/FM radio and analog telephony	internet and mobile networks
10.	Require modems and transducers	Requires codecs and converters
11.	Synchronization problem is hard	Synchronization problem is easier
12.	Diagram…	Diagram…

// See in internet for more…

1.8 Transmission Impairment

- to deteriorate the quality of analog signal, which means that the signal at the beginning of the medium is not the same as the signal at the end of the medium



Attenuation:

- It means loss of energy
- The strength of signal decreases with increasing distance which causes loss of energy in overcoming resistance of medium
- Amplifiers are used to amplify the attenuated signal which gives the original signal back and compensate for this loss
- Attenuation is measured in decibels (dB)

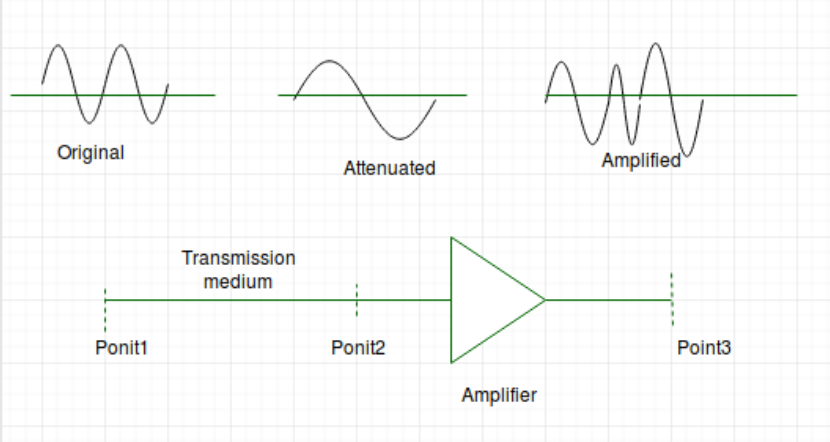
Attenuation (dB) = 10 log10 (P2/P1)

  - P1 is the power at sending end

- P2 is the power at receiving end

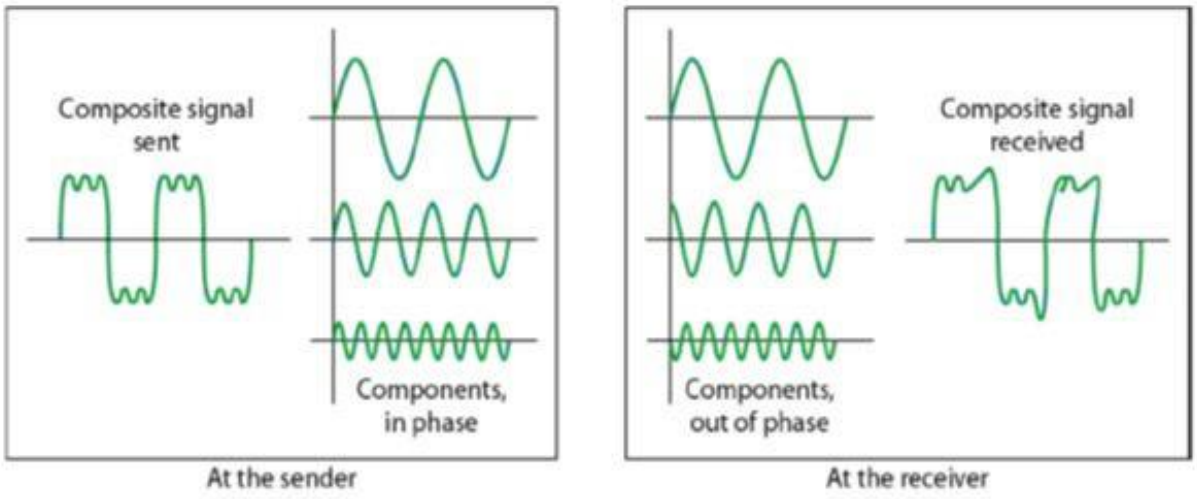
Attenuation (dB) = 20 log10 (V2/V1)

- V1 is the voltage at sending end
- V2 is the voltage at receiving end



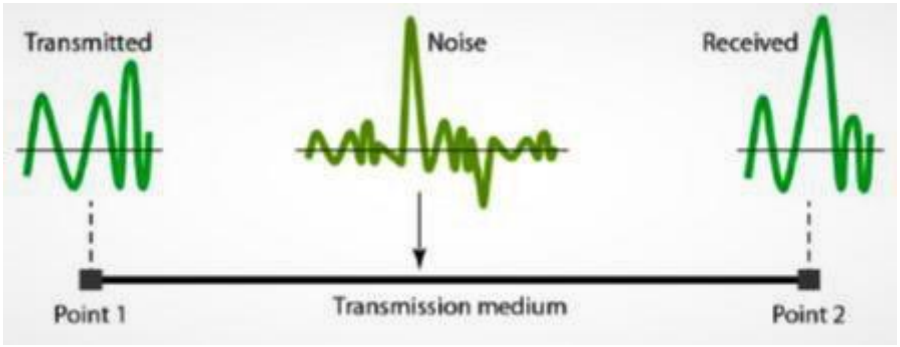
Distortion:

- ❖ It means changes in the form or shape of the signal
- ❖ This is generally seen in composite signals made up with different frequencies
- ❖ Each frequency component has its own propagation speed travelling through a medium so it delays in arriving at the final destination
- ❖ Every component arrive at different time which leads to distortion. Therefore, they have different phases at receiver end from what they had at senders end



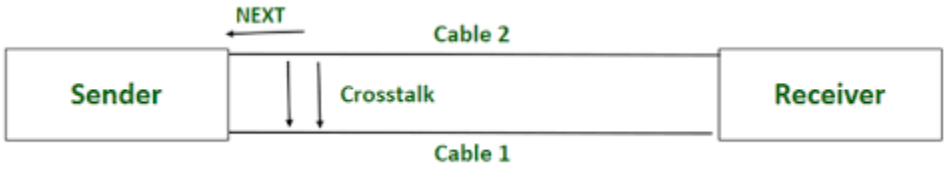
Noise:

- ❖ The random or unwanted signal that mixes up with the original signal is called noise.
- ❖ There are several types of noise such as *induced noise, crosstalk noise, thermal noise and impulse noise* which 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

❖ Crosstalk is a type of noise signal that corrupts the actual signal while transmission through the communication medium. Crosstalk noise is when one wire affects the other wire. Types of coupling in crosstalk – (***Electrostatic coupling****: It occurs when an electrostatic field generated by current flowing in a wire in close with another parallel wire generates an interference signal in that parallel wire due to the virtual capacitance built between the two wires.*
Electromagnetic coupling*: It occurs when a dynamically changing magnetic field is generated by alternating current flowing in a wire in close proximity with another parallel wire generates an interference signal in that parallel wire due to the mutual inductance between the two wires*)



❖ Thermal noise is random movement of electrons in wire which creates an extra signal. The higher the temperature of the medium or components, the greater the level of thermal noise. Some ways to reduce thermal noise

- Reduce the temperature of operation
- Reduce the value of the resistance in electrical circuits

The amount of thermal noise in 1 Hz bandwidth in an actual device is

$$Pn = kT \ (W / Hz)$$

k: Boltzmann constant, approximately (1.38×10^{-23} J/K)
T: Absolute temperature in kelvins (K) of the device or resistor.

❖ Impulse noise is a signal with high energy that comes from lightning or power lines
    - series of short, irregular pulses or spikes of power with a high amplitude
    - It's difficult to detect and analyze because it occurs occasionally

Impulse noise can be caused by a variety of sources, including:

- Lightning storms
- Voltage transients by electromechanical switching systems
- Switching of relays in electro-mechanical telephone exchanges
- Positioning a communications cable near a source of intermittent but strong electromagnetic pulses, such as an elevator motor

Signal to Noise ratio

- Ratio of the intensity of the received signal to the strength of the disturbance in the transmitter (i.e. tells you how clear a signal is)
- Used to determine the quality of transmission

$$\text{SNR} = \text{signal's power / power of noise}$$

$$= \text{Psignal / Pnoise} = \mu/\sigma$$

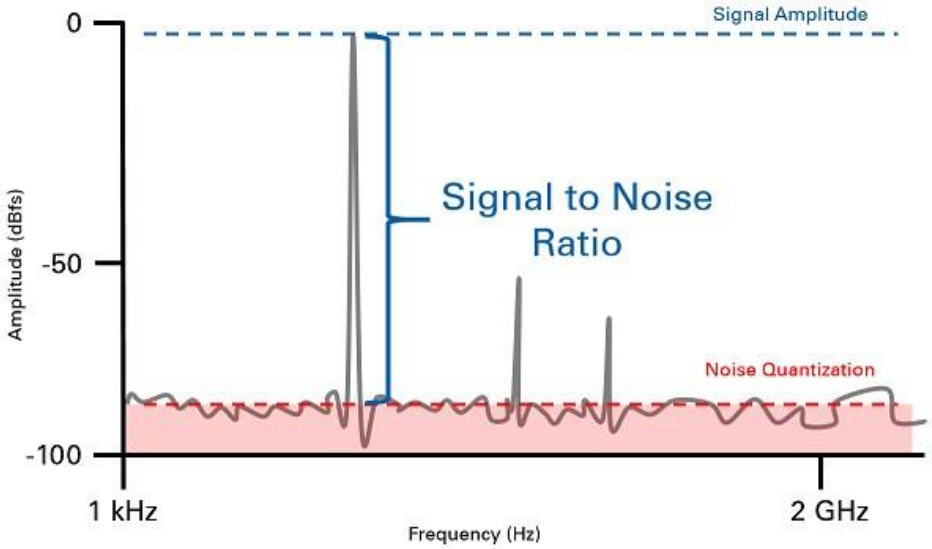
Where,

Psignal denotes the signal's power, the population mean

Pnoise denotes the power of noise, the standard deviation of data

Also,

$$(S/N)_{dB} = \text{level}_{(\text{decibel in dB})} - \text{level}_{(\text{decibel in dB})}$$



Properties of SNR:

- ✓ Measure of Quality
- ✓ Dimensionless Quantity
- ✓ Non-negative Value
- ✓ Dependence on Signal Strength
- ✓ Influence on Performance
- ✓ Effect on Detection Threshold
- ✓ Trade-off with Bandwidth

Q1. Find the SNR of the data set: 1, 4, 7, 8, and 10.

Solution:

Mean = $\mu = (1+4+7+8+10)/5$

$= 30/5$

$= 6$

Standard Deviation, $\sigma = \sqrt{((1 – 6)2 + (4 – 6)2 + (7 – 6)2 + (8 – 6)2 + (10 – 6)2)/5}$

$= \sqrt{((25 + 4 + 1 + 4 + 16)/5)}$

$= \sqrt{(50/5)}$

$= 3.16$

SNR = μ/σ

$= 6/3.16$

SNR = 1.89

❖ Echo

- phenomenon where a part of the transmitted signal reflects back to the sender after a delay, causing a duplicate of the original sound

Causes:

- Impedance mismatches in the transmission line
- Acoustic feedback from speakers and microphones (common in hands-free systems)

Solutions:

- Use of echo cancellers to suppress the reflected signal
- Proper impedance matching in transmission lines
- Acoustic isolation in devices to prevent feedback

❖ **Singing**

- Singing occurs when a feedback loop creates a sustained high-pitched tone or oscillation in the communication line

Eg. *Conference Calls in a Small Room*

- In a poorly designed conference system, the microphone picks up sound from the speaker and feeds it back into the system.
- This feedback creates a loop, and if the amplifier gain is too high, it can result in a high-pitched tone (singing).

Causes:

- Excessive amplification of signals in the circuit
- Feedback loops due to improper design of hybrid circuits or echo cancellers

❖ **Latency**

- The amount of time it takes for data to reach to its destination over internet
- It measures the time it takes for data to travel from the source to the destination and for a response to return

❖ **Jitter**

- When internet connection has inconsistent latency that results in major variation and time delay between data packet transmissions
- Jitter is the variation in delay between successive packets during data transmission, typically observed in VoIP or real-time streaming applications

Causes:

- Network congestion causing packet delays
- Variations in routing paths taken by packets
- Buffering and synchronization issues in network devices

Effects:

- Inconsistent or choppy voice quality in VoIP
- Distortion or lag in video streams
- Packet loss if delays exceed the buffer capacity

Solutions:

- Use jitter buffers to smooth out variations in packet delivery times
- Prioritize real-time traffic using Quality of Service (QoS) protocols
- Optimize network infrastructure to reduce congestion and delays

// *https://www.youtube.com/watch?v=9luJY8Yifvg*

Assignment:

(a) What is PSTN? Draw a neat diagram of PSTN hierarchy and explain the role of local and tandem exchanges. (1+4+2)

(b) Explain the transmission impairments observed in a communication system. Explain the types of devices used to control the echo. (4+4)