24 07 2019

MODULE -I

Data

The word 'data' refers to information presented in whatever form is agreed upon by the parties creating and using the data.

Data Communication

Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable.

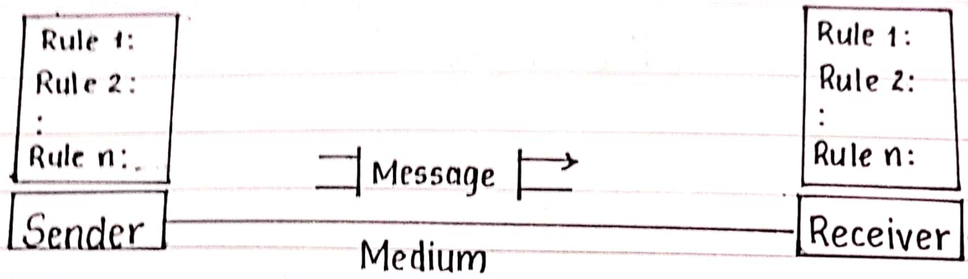
The effectiveness of a data communication system depends on four fundamental characteristics. They are:

- Delivery : Data must be received by the intended device or user and only by that device or user.
- Accuracy : Data that have been altered in transmission and left uncorrected are unusable.
- Timeliness : Data delivered late are useless.
- Jitter : Jitter refers to the variation in the packet arrival time.

Components of Data Communication.

A data communications system has five components :

- Message : It is the information to be communicated.
- Sender : It is the device that sends the data message.
- Receiver : It is the device that receives the message.
- Transmission Medium : It is the physical path by which a message travels from sender to receiver.
- Protocols : It is a set of rules that govern data communication.

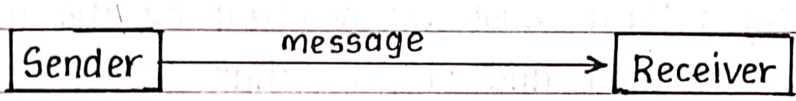


Data Flow

Communication between two devices can be simplex, half-duplex and full-duplex.

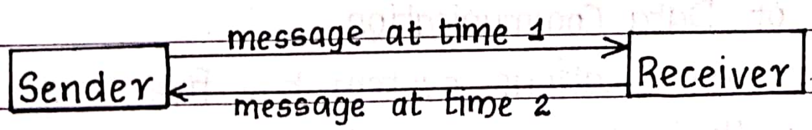
- **Simplex**

In simplex mode, the communication is unidirectional. Only one of the two devices can transmit; the other can only receive.
Eg: Radio, keyboards etc.



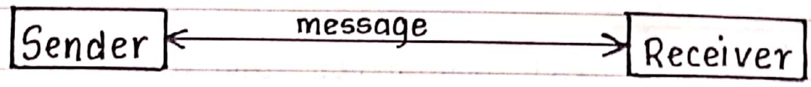
- **Half-Duplex**

In half-duplex mode, 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, Citizens band radios etc.



- **Full-Duplex**

In full-duplex mode, both stations can transmit and receive simultaneously.
Eg: Telephones



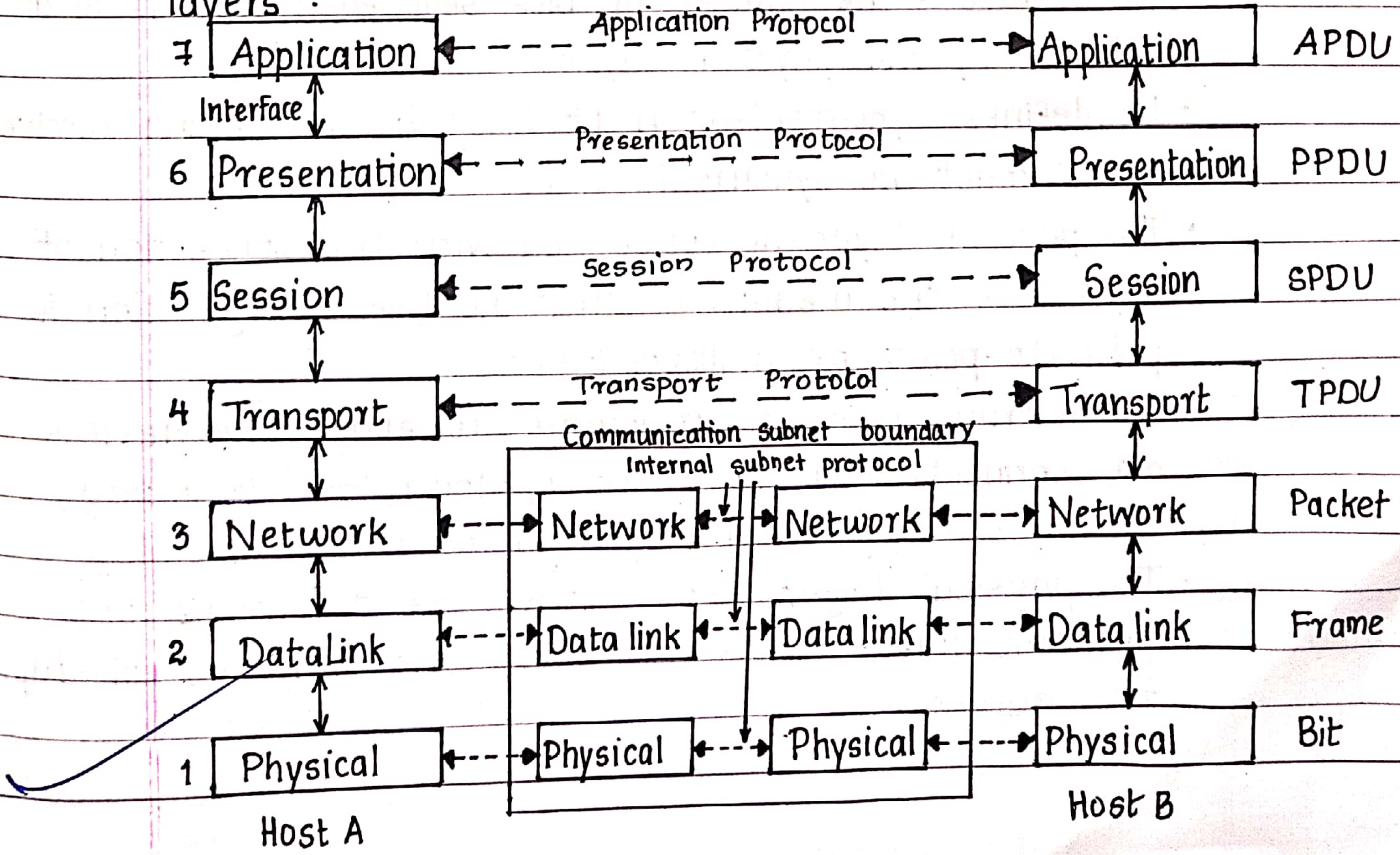
Network Models

1. The OSI Reference Model
2. The TCP/IP Protocol Suite

The OSI Reference Model

The OSI model is based on a proposal developed by the International Standards Organization (ISO) as a first step toward international standardization of the protocols used in the various layers. The model is also called the ISO OSI (Open Systems Interconnection) Reference Model because it deals with connecting open systems (systems that are open for communication with other systems).

The OSI Model consists of seven seperate but related layers.



The Physical Layer

The Physical Layer coordinates the functions required to carry a bit stream over a physical medium. It deals with the mechanical and electrical specifications of the interface and transmission medium. It also defines the procedures and functions that physical devices and interfaces have to perform for transmission to occur.

The physical layer is also responsible for :

- This layer is responsible for movements of individual bits from one hop to the next.
- Deals with the physical characteristics of interfaces and medium. It also defines the type of transmission medium.
- The physical layer data consists of a stream of bits (sequence of 0s and 1s) with no interpretation. The physical layer defines the type of encoding - how 0s and 1s are changed to signals.
- Data rate - the number of bits sent each second - is also defined by the physical layer.
- It defines synchronization of bits. The sender and receiver clocks must be synchronized.
- The physical layer is concerned with the connection of devices to the media (Whether the line configuration is point-to-point or multipoint).
- It defines physical topology. Whether the devices are connected using star topology, bus topology, mesh topology, ring topology or hybrid topology.
- The physical layer also defines the directions of transmission between two devices : Simplex, half-duplex, Full-duplex.

The Data Link Layer

The Data Link layer transforms the physical layer, a raw transmission facility, to a reliable link. It makes the physical layer appear error-free to the upper layer (network layer).

The responsibilities of the datalink layer are :

- Moving frames from one hop to the next. (Hop - every individual device in a network).
- Framing : The data link layer divides the stream of bits received from the network layer into manageable data units called frames.
- Physical Addressing : If frames are to be distributed to different systems on the network, the data link layer adds a header to the frame to define the sender and/or receiver of the frame.
- Flow control : If the rate at which the data are absorbed by the receiver is less than the rate at which data are produced in the sender, the datalink layer imposes a flow control mechanism to avoid overwhelming the receiver.
- Error control : The data link layer adds reliability to the physical layer by adding mechanisms to detect and retransmit damaged or lost frames. It also uses a mechanism to recognize duplicate frames. Error control is normally achieved through a trailer added to the end of the Frame.
- Access control : When two or more devices are connected to the same link, datalink layer protocols are necessary to determine which device has control over the link at any given time.

The Network Layer

The network layer is responsible for the source-to-destination delivery of a packet, possibly across multiple networks. The network layer ensures that each packet gets from its point of origin to final destination.

Other responsibilities of the network layer are :

- Logical Addressing : The physical addressing implemented by the data link layer handles the addressing problem locally. If a packet passes the network boundary, we need another addressing system to help distinguish the source and destination systems. The network layer adds a header to the packet coming from the upper layer that, among other things, includes the logical addresses of the sender and receiver.
- Routing : When independent networks or links are connected to create internetworks or a large network; the connecting devices (called routers or switches) route or switch the packets to their destination.

The Transport Layer

The transport layer is responsible for process-to-process delivery of the entire message.

Responsibilities of the transport layer are :

- Service-point addressing / Port addressing : The transport layer gets the entire message to the correct process on the computer.
- Segmentation and reassembly : A message is divided into transmittable segments, with each segment containing a sequence number. These numbers enable the transport layer to reassemble the message correctly upon

arriving at the destination and to identify and replace packets that were lost in transmission.

- Connection Control : The transport layer can be either connectionless or connection oriented.
- Flow Control : Flow control at this layer is performed end-to-end rather than across a single link.
- Error control : The sending transport layer makes sure that the entire message arrives at the receiving transport layer without error (damage, loss or duplication).

The Session Layer

The session layer is the network dialog controller. It establishes, maintains and synchronizes the interaction among communicating systems.

Responsibilities of the session layer are :

- Dialog Control : It allows the communication between two processes to take place in either half-duplex or full-duplex mode.
- Synchronization : It allows a process to add checkpoints or synchronization points to a data stream for the fast recovery of lost data.

The Presentation Layer

The presentation layer is concerned with the syntax and ~~syntax~~ semantics of the information exchanged between two systems.

Responsibilities of the presentation layer are :

- Translation : The presentation layer at the sender changes the information from its sender-dependent format into a common format. The presentation layer at the receiver changes the common format into its receiver-dependent format.

- Encryption : Encryption means that the sender transforms the sender transforms the original information to another form and sends the resulting message out over the network. Decryption reverses the original process to transform the message back to its original form.
- Compression : Data compression reduces the number of bits contained in the information.

The Application Layer

The application layer enables the user, whether human or software, to access the network. It provides user interfaces and support for services such as electronic mail, remote file access and transfer, shared database management, and other types of distributed information services.

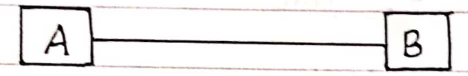
Specific services provided by the application layer are.

- Network virtual terminal : A network virtual terminal is a software version of a physical terminal, and it allows a user to log on to a remote host.
- File transfer, access and management : This application allows a user to access files in a remote host, to retrieve files from a remote computer for use in the local computer, and to manage or control files in a remote computer locally.
- Mail Services : This application provides the basis for e-mail forwarding and storage.
- Directory services : This application provides distributed database sources and access for global information about various objects and services.

Types of Connections

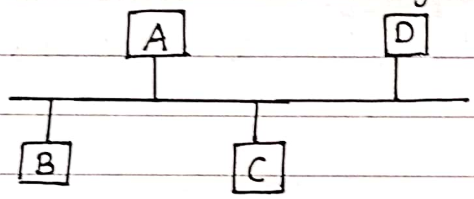
- **Point-to-point**

A point-to-point connection provides a dedicated link between two devices. The entire capacity of the link is reserved for transmission between those two devices.



- **Multipoint or multidrop**

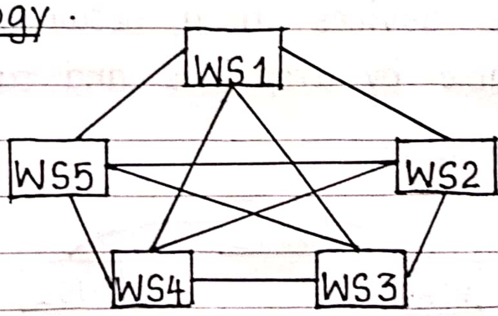
A multipoint connection is one in which more than two specific devices share a single link.



Physical Topology

The term 'physical topology' refers to the way in which a network is laid out physically. There are four basic topologies possible: mesh, star, bus and ring.

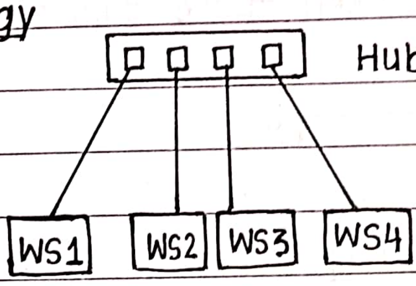
- **Mesh Topology.**



In a mesh topology, every device has a dedicated point-to-point link to every other device. To find the number of physical links in a fully connected mesh network with 'n' nodes, we need

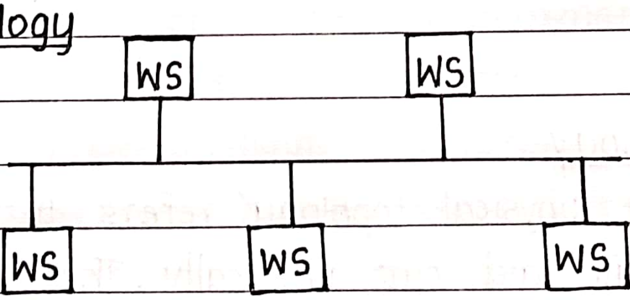
$$\boxed{n(n-1)/2}$$

- Star Topology



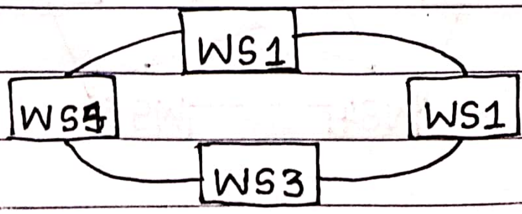
In a star topology, each device has a dedicated point-to-point link only to a central controller, usually called a hub.

- Bus Topology



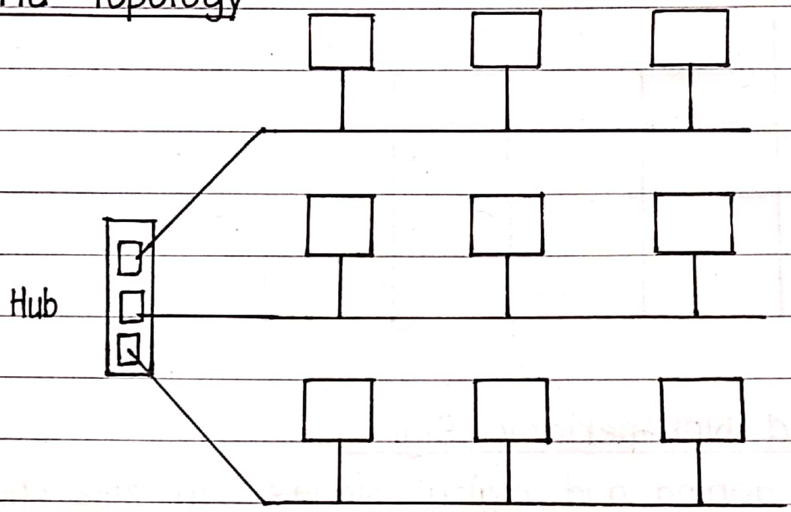
In a bus topology, one long cable acts as a backbone to link all the devices in a network. Nodes are connected to the bus cable by drop lines and taps.

- Ring Topology



In a ring topology, every device has a dedicated point-to-point connection with only the two devices on either side of it.

• <u>Hybrid Topology</u>



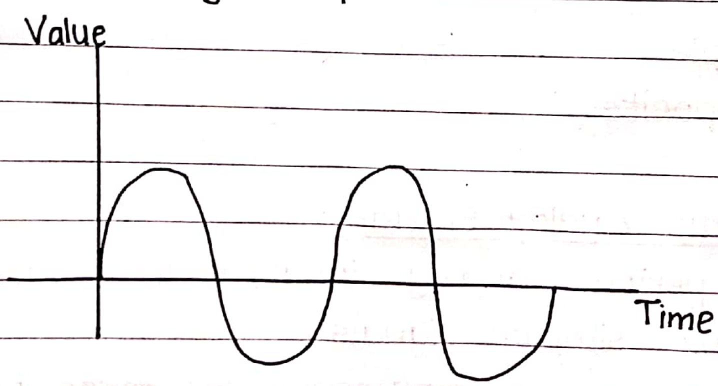
Combination of star and bus.

Combination of two or more topologies is called hybrid topology.

<u>Signals</u>

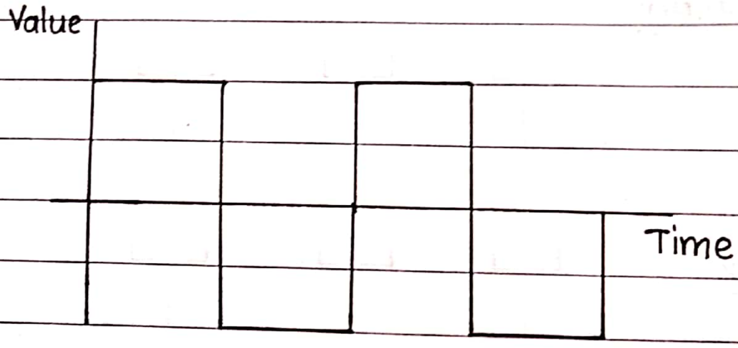
• <u>Analog Signal</u>

An analog signal has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path.



• Digital Signal

A digital signal can have only a limited number of defined values. Although each value can be any number, it is often as simple as 1 and 0.



Periodic and Non-periodic Signals.

Both analog and digital signals can take one of two forms: periodic or nonperiodic.

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.

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

Periodic Analog Signals

Periodic analog signals can be classified as:

- Simple
- Composite.

• Simple Periodic Analog Signal

A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals.

A sine wave can be represented by three parameters:

the peak amplitude, the frequency and the phase.

i) Peak Amplitude

The peak amplitude of a signal is the absolute value of its highest intensity, proportional to the energy it carries. For electric signals, peak amplitude is normally measured in volts.

ii) Period and Frequency

Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle.

Frequency refers to the number of periods in 1 second. Frequency is the inverse of period and vice-versa.

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

iii) Phase

The term 'phase' describes the position of the waveform relative to time 0. Phase is measured in degrees or radians.

Wavelength

Wavelength is the distance a simple signal can travel in one period. It depends on both the frequency and the medium.

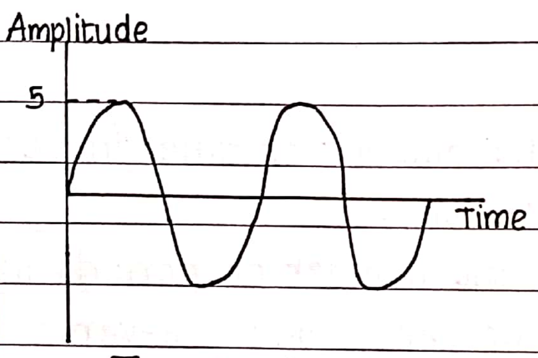
$$\text{Wavelength} = \text{propagation speed} \times \text{period}$$

$$= \frac{\text{propagation speed}}{\text{frequency}}$$

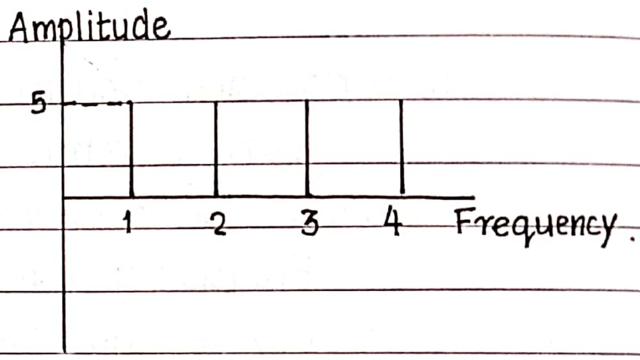
Time and Frequency Domains

The time-domain plot shows changes in signal amplitude with respect to time. Phase is not explicitly shown on a time-domain plot.

A frequency-domain plot is concerned with only the peak value and frequency. Changes of amplitude during one period are not shown.



Time-domain plot.



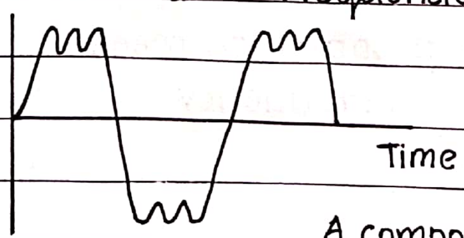
Frequency-domain plot.

- **Composite Signals**

A composite period analog signal is composed of multiple sine waves.

According to Fourier Analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

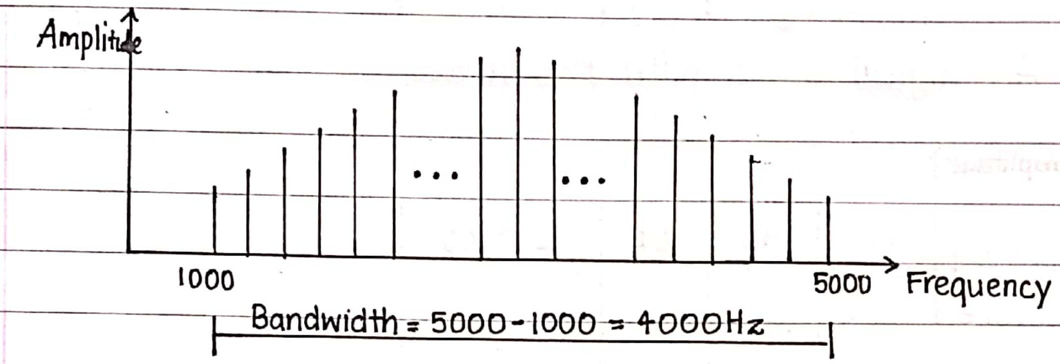
A composite signal can be periodic or non-periodic. If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies: if the composite signal is non-periodic, the decomposition gives a combination of sine waves with continuous frequencies.



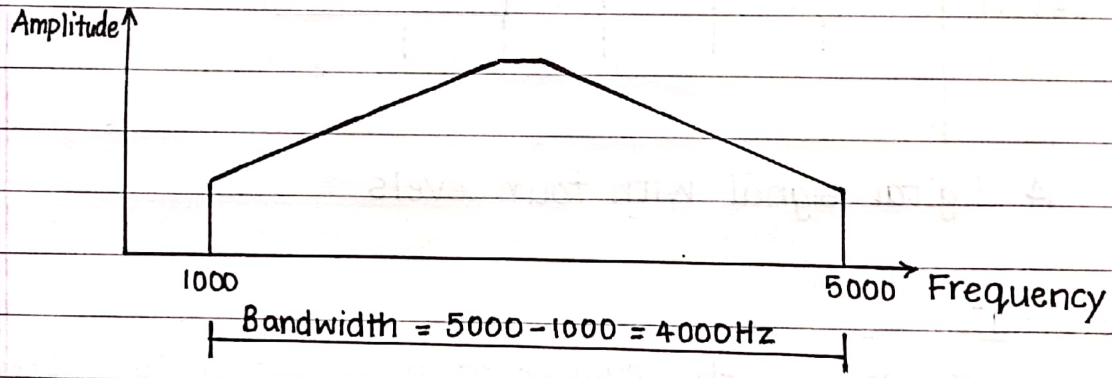
A composite periodic signal.

Bandwidth

The range of frequencies contained in a composite signal is its bandwidth. The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.



a. Bandwidth of a periodic signal.

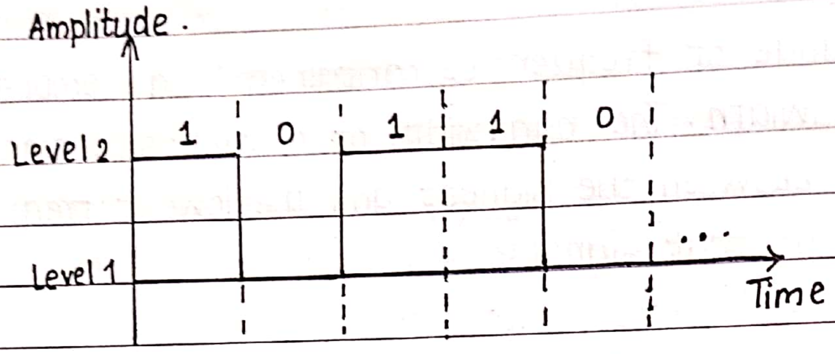


b. Bandwidth of a non-periodic signal.

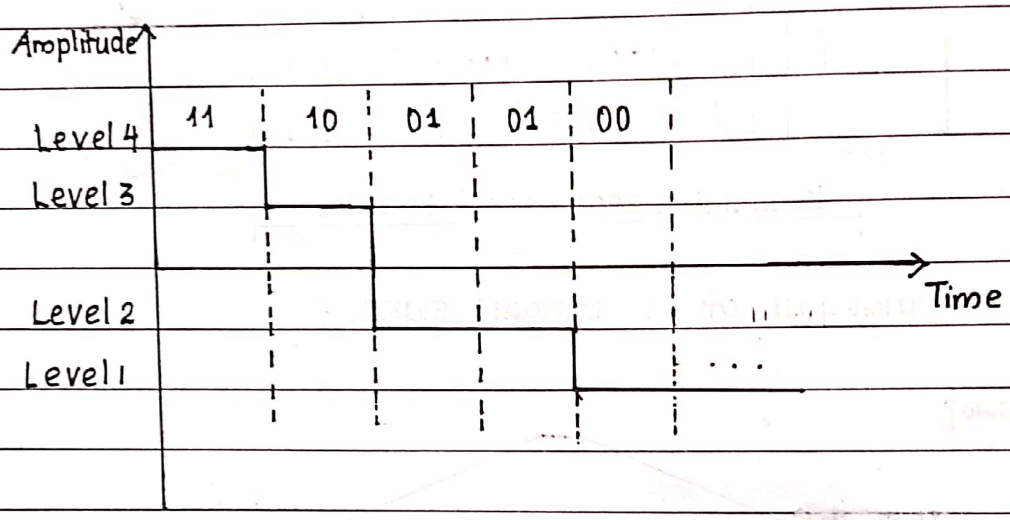
Digital Signal

A digital signal is a signal that is being used to represent data as a sequence of discrete values; at any given time it can only take on one of a finite number of values.

$$\text{No. of bits per level} = \log_2 \text{no. of level.}$$



A digital signal with two levels.



A digital signal with four levels.

Bit Rate

Bit rate is the number of bits sent in 1s, expressed in bits per second (bps).

Bit Length

Bit length is the distance one bit occupies on the transmission medium.

Bit length = propagation speed x bit duration.

Ref : Behrouz A Forouzan - Data Communications and Networking.

Scanned by CamScanner

Baseband Transmission

Baseband transmission means sending a digital signal over a channel without changing the digital signal to an analog signal. It requires a low-pass channel, a channel with a bandwidth that starts from zero.

Baseband transmission of a digital signal that preserves the shape of the digital signal is possible only if we have a low-pass channel with an infinite bandwidth or very wide bandwidth.

Broadband Transmission (Using modulation)

Broadband transmission or modulation means changing the digital signal to an analog signal for transmission. Modulation allows us to use a bandpass channel - a channel with a bandwidth that does not start from zero.

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.

The causes of impairment are :

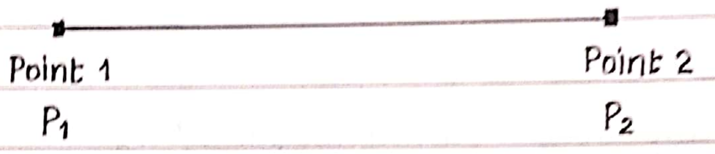
- Attenuation
- Distortion
- Noise

• Attenuation.

Attenuation means a loss of energy. 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 to amplify the signal.

Decibel

To show that a signal has lost or gained strength, engineers use the unit of decibel. The decibel (dB) measures the relative strengths of two signals or one signal at two different points.

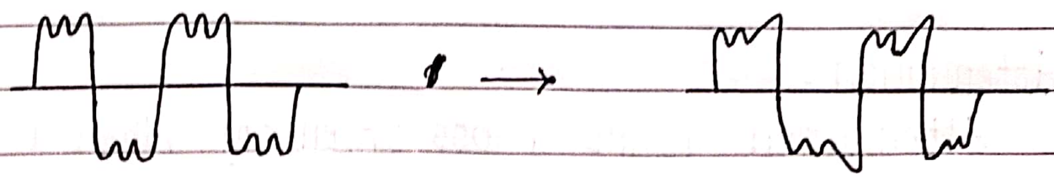


$$dB = 10\log_{10} \frac{P_2}{P_1}$$

- If a signal is attenuated, dB is negative.
- If a signal is amplified, dB is positive.

• Distortion.

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



At the sender At the receiver

• Noise

Any signal that is transmitted other than the required signal is noise. It can be classified as thermal noise, induced noise, crosstalk and impulse noise.

i) Thermal Noise

It is the random motion of electrons in a wire which creates an extra signal not originally transmitted by the sender.

To find the amount of thermal noise found in bandwidth of 1Hz,

$$\boxed{N_0 = kT}$$

where k = Boltzmann's constant (1.3803×10^{-23} J/K)

T = Temperature in Kelvin.

To find the thermal noise present in bandwidth of 'W' watts.

$$\boxed{N = kTW}$$

$$N \text{ in dB} = 10\log_{10} kTW$$

$$= 10\log k + 10\log T + 10\log W$$

$$= -228.6 \text{ dBW} + 10\log T + 10\log W.$$

What is the thermal noise for a channel of bandwidth 300Hz and temperature 27°C.

$$N \text{ in dB} = -228.6 \text{ dBW} + 10\log 300 + 10\log 300$$

$$= \underline{\underline{-179.057 \text{ dBW}}}$$

ii) Induced Noise

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.

iii) Crosstalk

Crosstalk is the effect of one wire on another wire. One wire acts as a sending antenna and the other as the receiving antenna.

iv) Impulse Noise

Impulse noise is a spike (a signal with high energy in a very short time) that comes from power lines, lightning and so on. For digital data, a large amount of bit error occurs for a small amount of spike.

Signal-to-Noise Ratio

The signal-to-noise ratio is defined as

$$SNR = \frac{\text{average signal power}}{\text{average noise power}}$$

• High SNR means that the signal is less corrupted by noise.
• Low SNR means that the signal is more corrupted by noise.

$$SNR_{dB} = 10\log_{10} SNR.$$

Data Rate Limits

Data rate depends on three factors.

1. The bandwidth available
2. The level of signals we use
3. The quality of the channel (the level of noise)

Two theoretical formulas were developed to calculate the data rate: one by Nyquist for a noiseless channel, another by Shannon for a noisy channel.

Noiseless Channel : Nyquist Bit Rate

For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate.

$$\text{Bit rate} = 2 \times \text{bandwidth} \times \log_2 L$$

where L is the no. of signal levels used.

Noisy Channel : Shannon Capacity

For a noisy channel, Shannon capacity defines the theoretical highest data rate

$$\text{Capacity} = \text{bandwidth} \times \log_2 (1 + SNR)$$

- The value of $\log_2(1+SNR)$ is 2 for an ideal case.

What is the channel capacity for a channel of bandwidth 300Hz and signal to noise ratio 3 dB ?

$$SNR_{dB} = 10 \log_{10} SNR$$

$$3/10 = \log_{10} SNR$$

$$SNR = \text{antilog}(3/10)$$

$$= 1.995$$

$$\text{Channel capacity} = \text{bandwidth} \times \log_2 (1+SNR)$$

$$= 300 \times \log_2 (2.995)$$

$$= 474.76 \text{ bps}.$$

Ref: Behrouz. A. Forouzan

Study the work of Shannon and Nyquist on channel capacity. Each places an upper limit on the bit rate of the channel. How these approaches are related ?.

Transmission Media

A transmission medium can be broadly defined as anything that can carry information from source to destination.

In data communication, the transmission medium is usually freespace, metallic cable, or fibre-optic cable. The information is usually a signal that is the result of a conversion of data from another form.

In telecommunication, transmission media can be divided into 2 broad categories: guided and unguided.

Guided Media

It includes twisted-pair cable, coaxial cable and fibre-optic cable. It provides a conduit from one device to another. A signal travelling along any of these media is directed and contained by the physical limits of the medium.

Unguided Media.

It is free space. It transports electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication.

Twisted-Pair Cable.

A twisted-pair cable consists of 2 conductors (normally copper), each with its own plastic insulation, twisted together. One of the wires is used to carry signals to the receiver and the other is used only as a ground reference. The receiver uses the difference between two.

If the two wires are parallel, the effect of unwanted signal is not the same in both wires because they are at different locations relative to the noise or crosstalk sources. This results in a difference at the receiver. By twisting the pairs, a balance is maintained. Twisting makes it probable that both wires are equally affected by external influences. This means that the receiver receives no unwanted signal.

There are 2 types of twisted pair cables - shielded and unshielded.

The most common twisted pair cable used in communications is referred to as unshielded twisted pair (UTP). IBM has also produced a version of twisted pair cable for its use called shielded twisted pair (STP). STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductor. STP is more bulkier and expensive.

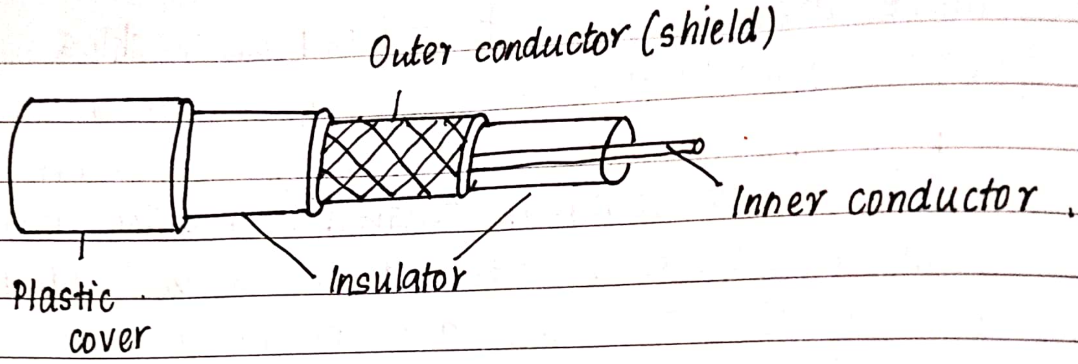
Electronic Industries Association (EIA) has developed standards to classify unshielded twisted-pair cable into 7 categories.

LANs such as 10 Base-T and 100 Base-T used twisted pair cables.

UTP connectors are RJ-45 female and RJ-45 male.

Coaxial Cable.

It carries signals of higher frequency ranges than those in twisted pair, in part because the two media are constructed quite differently coaxial cable has a coaxial core conductor of solid or stranded wire enclosed in an insulating sheath, which is in turn encased in an outer conductor of metal foil, braid or combination of the two. The outer metallic wrapping serves both as a shield against noise and as the second conductor which complements the circuit.



The three popular types of connectors are the BNC connector, BNC T connector and BNC terminator.

BNC connector - end of the cable to a device, such as a TV set.

BNC-T connector - used in ethernet networks to branch out to a connection to a computer or other device.

BNC terminator - end of the cable to prevent reflection of signal.

Ref : Data Communications and Networking by Behrouz A Forouzan.

Assignment.

Difference between Nyquist bit rate and Shannon capacity is that Shannon's capacity needs Nyquist rate to complete the calculation of capacity with a given bandwidth.

Nyquist rate tells us that inorder to reconstruct

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a baseband signal with bandwidth W from sampling, we need to sample the signal at 2W rate. This is meant for noiseless channel. Nyquist bit rate formula defines the theoretical maximum bit rate

$$R = 2B * \log_2 L$$

B - bandwidth
L - no. of signal level
R - bit rate/second.

But Shannon's capacity theorem needs to specify more distribution. Under Gaussian noise.

$$C = W\log_2(1 + S/N)$$

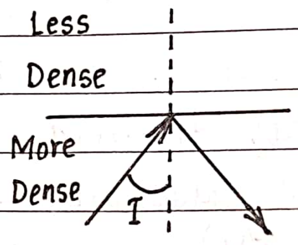
C - capacity of channel
W - bandwidth.
S/N - SNR.

The Nyquist formula tells how many signal levels we need, while in Shannon's formula, there is no indication of the signal level, which means no matter how many levels we have, we cannot achieve a data rate higher than the capacity of channel. The formula gives us the upper limit of capacity of the channel and thus defines a characteristics of channel method of transmission.

Ref: Bernard Sklar.

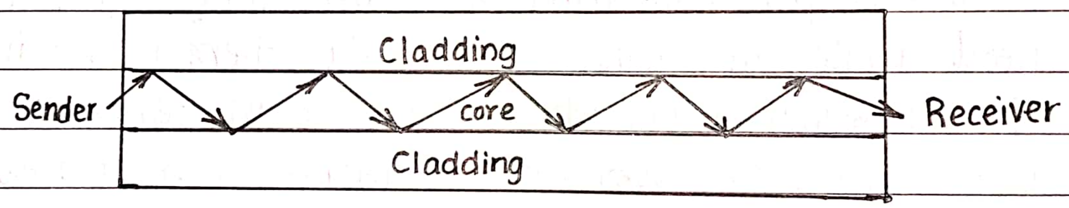
Fiber-Optic Cable

A fibre optic cable is made of glass or plastic and transmits signals in the form of light. It transmits light along its axis by the process of total internal reflection (TIR).



If the angle of incidence (I) is greater than the critical angle, the ray reflects and travels again in the denser medium.

Optic fibers use reflection to guide light through a channel. A glass or plastic core is surrounded by a cladding of less dense glass or plastic.



The difference in the density of the core and cladding must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted onto it.

Propagation Modes.

Fibre-optic cable has two propagation modes.

- Multimode
- Single mode.

- **Multimode**

In multimode, multiple beams from a light source move through the core in different paths. Multimode can be implemented in two forms - step index or graded index.

i) Multimode Step-Index fiber

In multimode step-index fiber, the density of the core remains constant from the centre to the edges. A beam of light moves through this constant density in a straight line until it reaches the interface of the core and the cladding.

ii) Multimode Graded-Index fiber

In multimode graded-index fiber, the density of the core is highest at the center and gradually decreases to its lowest at the edge.

- Single-Mode

In single-mode, a highly focused source of light is used that limits beams to a small range of angles, all close to the horizontal. Single-mode can ~~onlo~~ be implemented in only one form - single-mode step-index fiber.

Fiber-Optic Cable Connectors.

There are three types of connectors for fiber-optic cable.

1) Subscriber Channel (SC) connector
- Used for cable TV.
- Uses a push/pull locking system.

ii) Straight Tip (ST) Connector.
- Used for connecting cable to networking devices.

- Uses a bayonet locking system and it is more reliable than SC.

iii) MT-RJ Connector.

- It is a connector that is the same size as RJ45.

Advantages of Optic Fiber.

Fiber optic cable has several advantages over metallic cable.

- Higher bandwidth : Fiber-optic cable can support dramatically higher bandwidth than either twisted pair or coaxial cable.
- Less signal attenuation : Transmission distance is significantly greater than that of other guided media.
- Immune to electromagnetic interference.
- Resistance to corrosive materials.
- Light weight.
- Greater immunity to tapping.

Disadvantages of Optic Fiber.

There are some disadvantages in the use of optical fiber.

- Installation and maintenance : Since fiber-optic cable is a relatively new technology, its installation and maintenance require expertise that is not yet available everywhere.
- Unidirectional light propagation : Two fibers are required for a bidirectional communication.
- Fiber-optic cables are more expensive than other guided media.

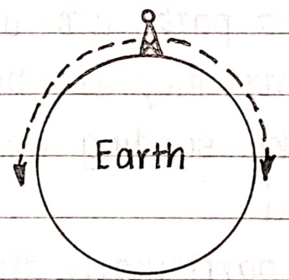
Unguided Media

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

Unguided signals can travel from the source to destination in several ways.

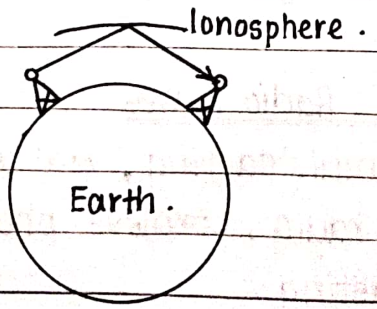
i) Ground Propagation.

- Radio waves travel through the lowest portion of the atmosphere, hugging the earth.
- These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the planet.
- Distance depends on the amount of power in the signal.



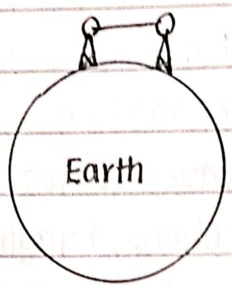
ii) Sky Propagation.

- Higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to earth.
- Allows greater distance with lower output power.



iii) Line-of-sight propagation.

- Very high-frequency signals are transmitted in straight lines directly from antenna to antenna.
- Antennas must be directional, facing each other.



Radio Waves

Electromagnetic waves ranging in frequencies between 3kHz and 1GHz ~~is Radio~~ are normally called radio waves. Radio waves, for the most part, are omnidirectional. When an antenna transmits radio waves, they are propagated in all directions. This means that the sending and receiving antennas do not have to be aligned.

Radio waves, particularly those waves that propagate in the sky mode, can travel long distances which makes it a good candidate for long-distance broadcasting such as AM radio.

Radio waves, particularly those of low and medium frequencies, can penetrate walls. Therefore, an AM radio can receive signals inside a building but we cannot isolate a communication to just inside or outside a building.

Applications of Radio waves.

- Used for multicasting, AM and FM radio, television, maritime radio, cordless phones and paging are examples of multicasting.

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Microwaves

Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves.

Microwaves are unidirectional. When an antenna transmits microwaves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned.

Characteristics of Microwave propagation.

- Microwave propagation is line-of-sight. Repeaters are often needed for long distance communication.
- Very high-frequency microwaves cannot ~~be~~ penetrate walls.
- Wider subbands can be assigned and a high data rate is possible.
- Use of certain portions of the band requires permission from authorities.

Applications of Microwaves.

- Used for unicast (one-to-one) communication such as cellular telephones, satellite networks and wireless LANs.

Infrared Waves

Electromagnetic waves with frequencies from 300 GHz to 400 THz are called infrared waves. They can be used for short-range communication.

Infrared waves, having high frequencies cannot penetrate walls. This advantageous characteristic prevents interference between one system and another.

Applications of Infrared Waves.

- Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

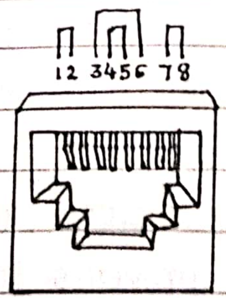
Ref : Data Communications and Networking by Behrouz . A · Forouzan .

Thumpher

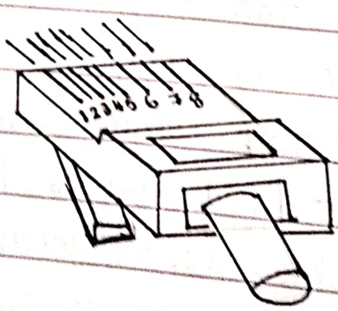
UTP Categories

UTP Category	Data Rate	Max. length	Cable type	Application
CAT1	Upto 1Mbps	–	Twisted pair	Old Telephone Cable
CAT2	Upto 4Mbps	–	Twisted pair	Token Ring Networks.
CAT3	Upto 10Mbps	100m	Twisted pair	Token Ring & 10 Base-T Ethernet
CAT4	Upto 16Mbps	100m	Twisted pair	Token Ring Networks
CAT5	Upto 100Mbps	100m	Twisted pair	Ethernet, FastEthernet, Token ring
CAT5e	Upto 1Gbps	100m	Twisted pair	Ethernet, FastEthernet, Gb Ethernet
CAT6	Upto 10Gbps	100m	Twisted pair	Gb Ethernet, 10G Ethernet (55m)
CAT6a	Upto 10Gbps	100m	Twisted pair	Gb Ethernet, 10G Ethernet (55m)
CAT7	Upto 10Gbps	100m	Twisted pair	Gb Ethernet, 10G Ethernet (100m)

UTP Connectors



RJ-45 Female

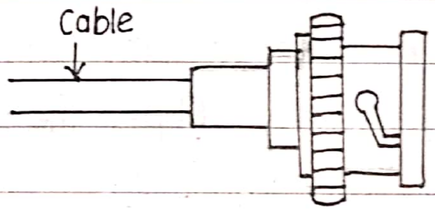


RJ-45 Male.

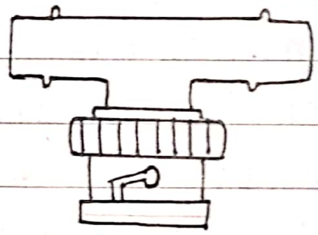
Categories of Coaxial Cable

Category	Impedance	Use
RG-59	75Ω	Cable TV
RG-58	50Ω	Thin Ethernet
RG-11	50Ω	Thick Ethernet

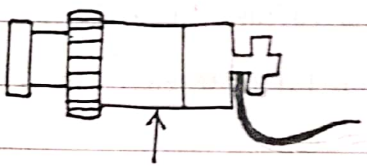
Coaxial Cable Connectors



← BNC Connector.



← BNC T Connector



← 50Ω BNC Terminator.

Ground wire.

Digital-to-Digital Conversion.

Line Coding

Line coding is the process of converting digital data to digital signal. Line coding converts a sequence of bits to a digital signal. At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal.

Data Element

A data element is the smallest entity that can represent a piece of information. Eg: bit.

Signal Elements.

A signal element is the shortest unit (timewise) of a digital signal. They carry data elements.

Data Rate Versus Signal Rate.

Data rate defines the number of data elements (bits) sent in 1s. The unit is bits per second (bps). The data rate is sometimes called the bit rate.

Signal rate is the number of signal elements sent in 1s. The unit is baud. The signal rate is sometimes called the pulse rate, the modulation rate or the baud rate.

Our goal in data communications is to increase the data rate while decreasing the signal rate. Increasing the data rate increases the speed of transmission; decreasing the signal rate decreases the bandwidth requirement.

Relationship between data rate and signal rate.

It depends on the value of r. 'r' is the number of data elements carried by each signal element. We can formulate the relationship between data rate and signal rate as.

$$\boxed{S = c \times N \times \frac{1}{r}}$$

where N is the data rate

c is the case fator.

S is the number of signal elements.

Maximum Data Rate

Maximum data rate can be determined if the bandwidth of the channel is given.

$$\boxed{N_{max} = \frac{1}{c} \times B \times r}$$

Baseline Wandering.

In decoding a digital signal, the receiver calculates a running average of the received signal power. This average is called the baseline. The incoming signal power is evaluated against this baseline to determine the value of the data element. A long string of 0s and 1s can cause a drift in the baseline. This is called baseline wandering. This makes it difficult for the receiver to decode correctly. A good line coding scheme needs to prevent baseline wandering.

DC Components.

When the voltage level in a digital signal is constant for a while, the spectrum creates very low frequencies. These frequencies around zero, called DC components, presents problems for a system that cannot pass low frequencies or a system that uses electrical coupling. For these systems, we need a coding scheme with no DC component.

Self-synchronization.

To correctly interpret the signals received from the sender, the receiver's bit intervals must correspond exactly to the sender's bit intervals. A self-synchronizing digital signal ~~that ale~~ includes timing information in the data being transmitted. This can be achieved if there are transitions in the signal that alert the receiver to the beginning, middle or end of the pulse. If the receiver's clock is out of synchronization, these points can reset the clock.

Line Coding Schemes.

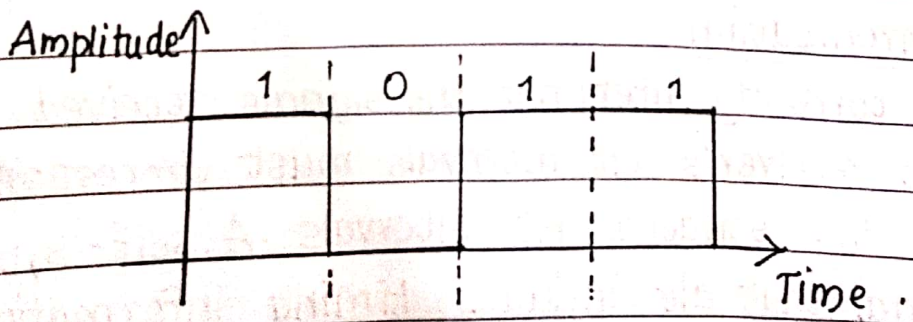
We can roughly divide line coding schemes into five broad categories.

Line Coding	
Unipolar	NRZ
Polar	NRZ, RZ, biphase (Manchester & dif M)
Bipolar	AMI and pseudoternary
Multilevel	2B/1Q, 8B/6T and 4D-PAM5
Multitransition	MLT-3.

Unipolar Scheme.

In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below.

- **Non-Return-to Zero (NRZ)**
  - Positive voltage defines bit 1
  - Zero voltage defines bit 0.
  - It is called NRZ because the signal does not return to zero at the middle of bit



Polar Schemes

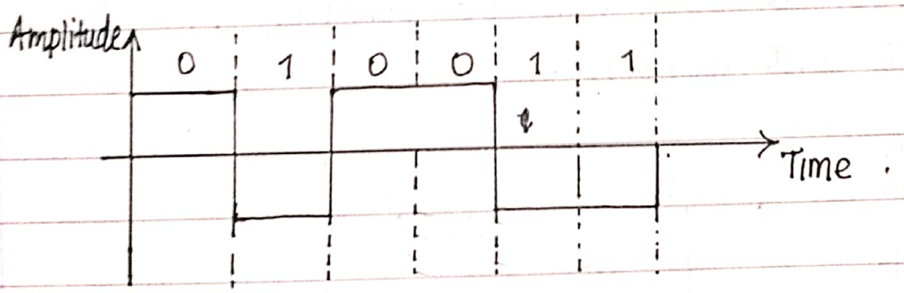
In polar schemes, the voltages are on the both sides of time axis.

- **Non-Return-to Zero (NRZ)**
  - In polar NRZ encoding, we use two levels of voltage
  - There are two versions of polar NRZ.
    - NRZ-L
    - NRZ-I

NRZ-Level (NRZ-L)

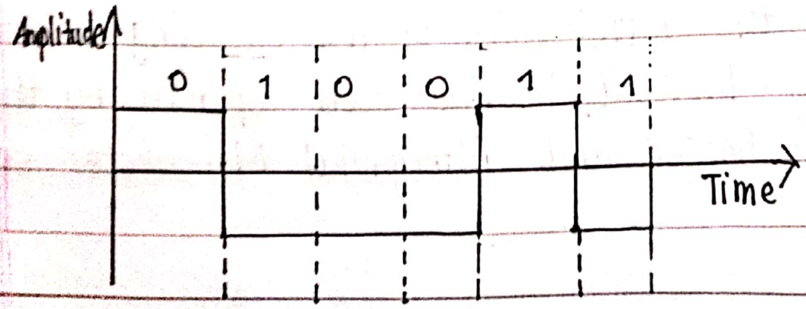
In NRZ-L, the level of the voltage determines the value of bit.

0 = high level 1 = low level.



NRZ-Invert (NRZ-I)

In NRZ-I, the change or the lack of ~~inversion~~ change in the level of the voltage determines the value of bit. If there is no change, the bit is 0; if there is change, the bit is 1.



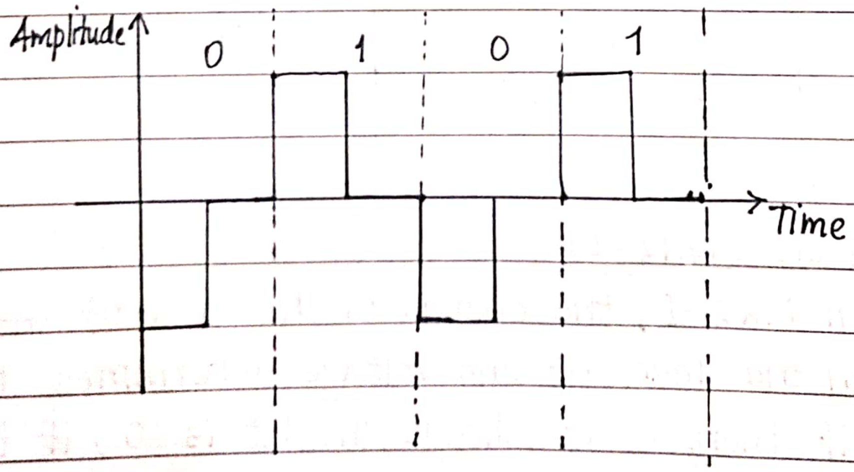
Return-to-Zero (RZ)

The main problem with NRZ encoding occurs when the sender and receiver clocks are not synchronized. The receiver does not know when one bit has ended and the next bit is starting. One solution for this is Return-to-Zero Scheme.

RZ scheme uses three values: positive, negative and zero. In RZ, the signal changes not between bits, but during bits.

Disadvantages of RZ scheme.

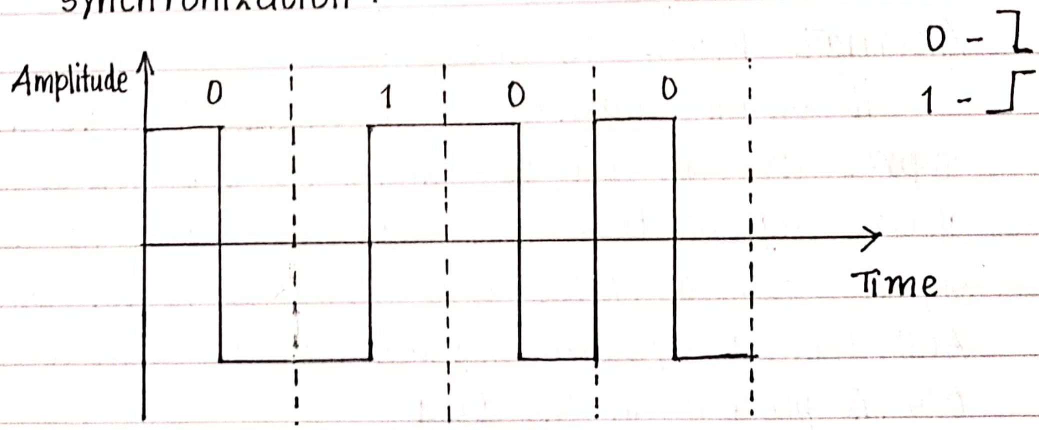
- It requires two signal changes to encode a bit and therefore occupies greater bandwidth.
- A sudden change of polarity can result in the interpretation of all 0s as 1s and all 1s as 0s.
- RZ uses three levels of voltage, which is more complex to create and discern.



Because of the deficiencies of RZ encoding scheme, it is not used today. Instead, it has been replaced by the better performing Manchester and differential Manchester schemes.

Biphase

- **Manchester Scheme**.
  - The idea of RZ (transition at middle of bit) and the idea of NRZ-L are combined into Manchester scheme.
  - In Manchester encoding, the duration of the bit is divided into two halves.
  - The voltage remains at one level during the first half and moves to the other level during the second half.
  - The transition at the middle of the bit provides synchronization.



- **Differential Manchester Scheme**.
  - Differential Manchester scheme combines the idea of RZ and NRZ-I.
  - There is always a transition at the middle of the bit, but the bit values are determined at the beginning of the bit
  - If the next bit is 0, there is a transition; if the next bit is 1, there is none.

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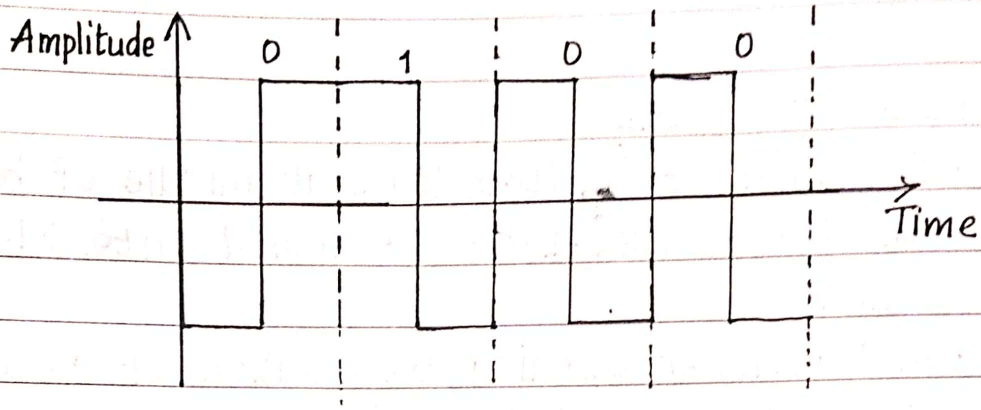
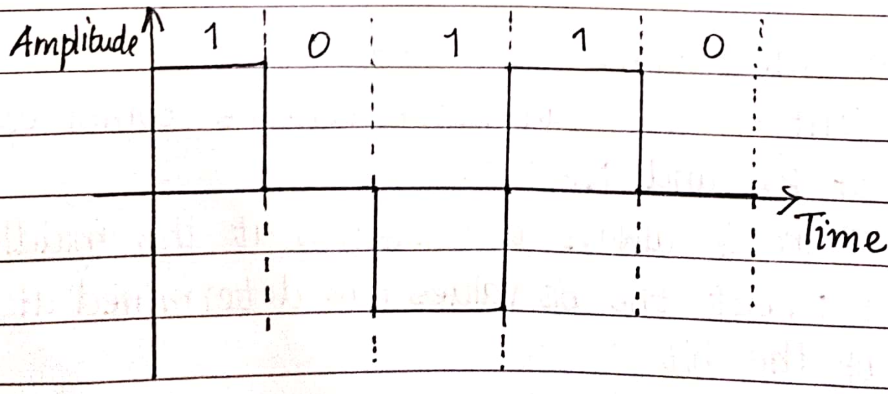


Bipolar Schemes .

In bipolar encoding, there are three voltage levels : positive, negative and zero .

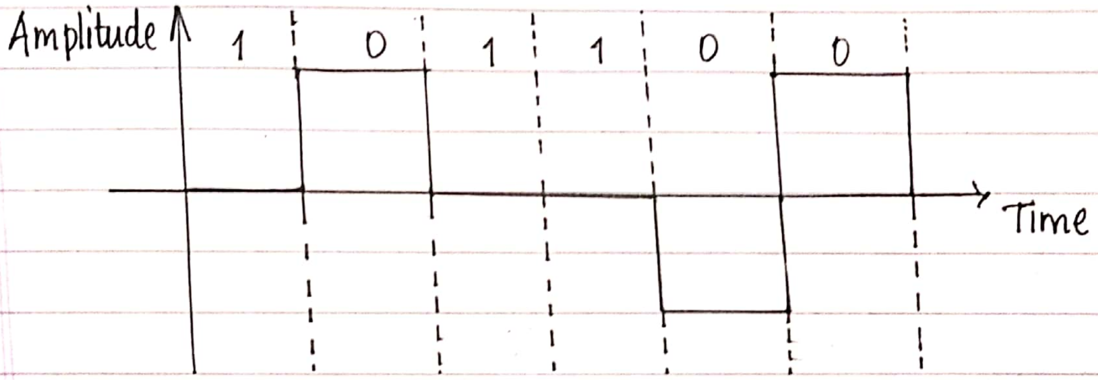
Alternate Mask Inversion (AMI)

It means alternate 1 inversion . A neutral zero voltage represents the bit 0 . Binary 1's are represented by alternating positive and negative voltage . It has the same signal rate as NRZ but there is no DC component . AMI has a synchronization problem when a lay sequence of 0's is present in the data .



Pseudo ternary.

A variation of AMI encoding is called pseudoternary. in which the 1 bit is encoded as a zero voltage and the 0 bit is encoded as alternating positive and negative voltages. They have the same signal rate as NRZ but there is no DC component.



Ref: Data Communications and Networking by Behrouz. A. Forouzan.