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Data Communication

Data Communication is the exchange of data betⁿ 2 devices via some form of transmission medium such as a wire cable.

Components

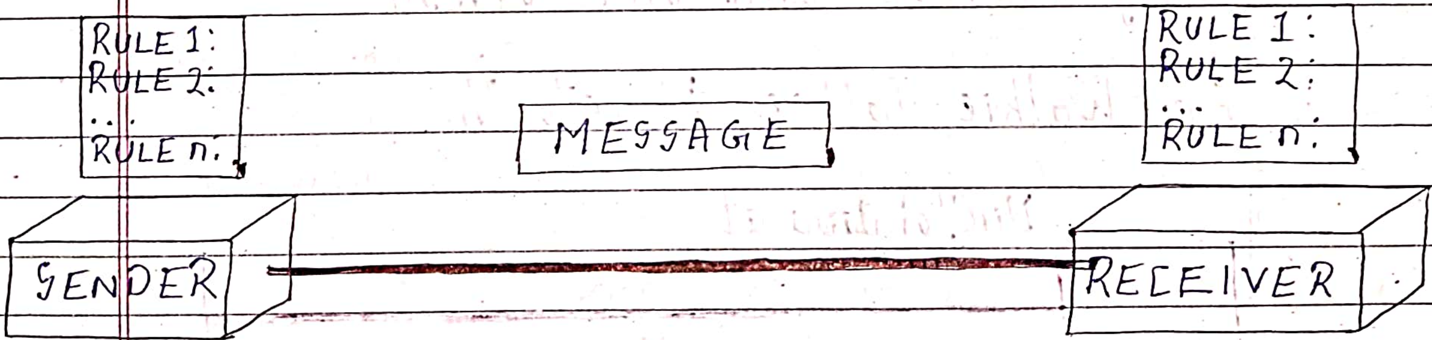
1) Message :- It is the information (data) to be communicated. Includes text, numbers, pictures, audio & video.

2) Sender :- It is the device that sends the data message.

3) Reciever :- It is the device that recieves the message.

4) Medium :- It is the physical path by which a message travels from sender to reciever. Can be wired or wireless.

5) Protocol :- It is a set of rules that govern data communications.



Data Flow

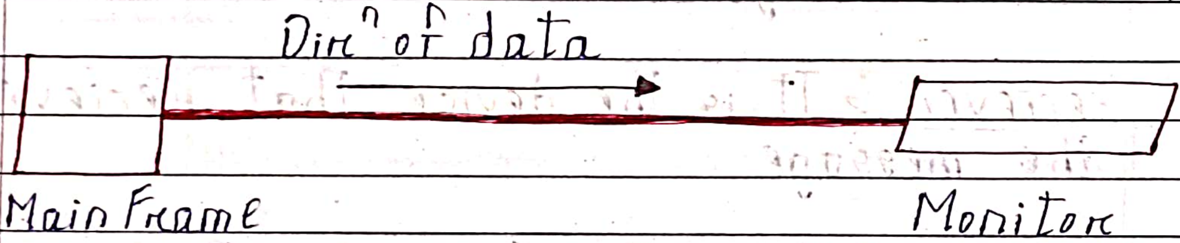
DATA FLOW

SIMPLEX — HALF-DUPLEX — FULL-DUPLEX

Simplex :

⇒ Communication is unidirectional.
⇒ Only one of the 2 devices can transmit ; the other can only recieve.

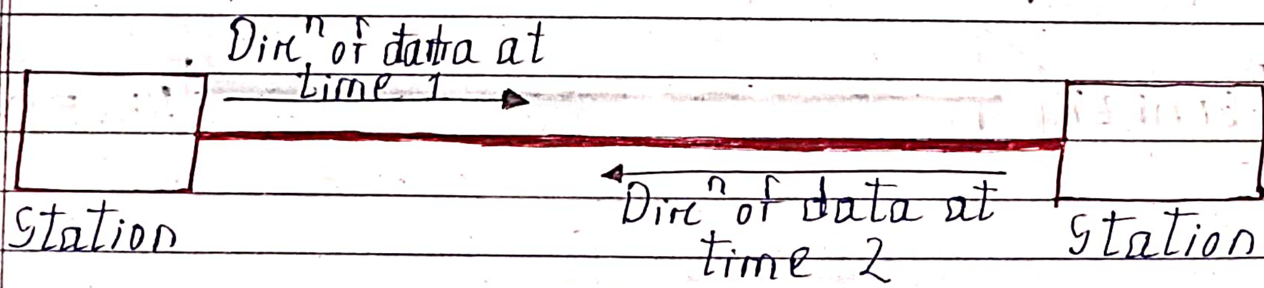
Eg. keyboards, Traditional Monitors



Half-Duplex :

⇒ Each station can both transmit & recieve, but not at the same time.
⇒ When one device is sending, the other can only recieve, and vice versa.

Eg. Walkie-Talkie, Bluetooth.

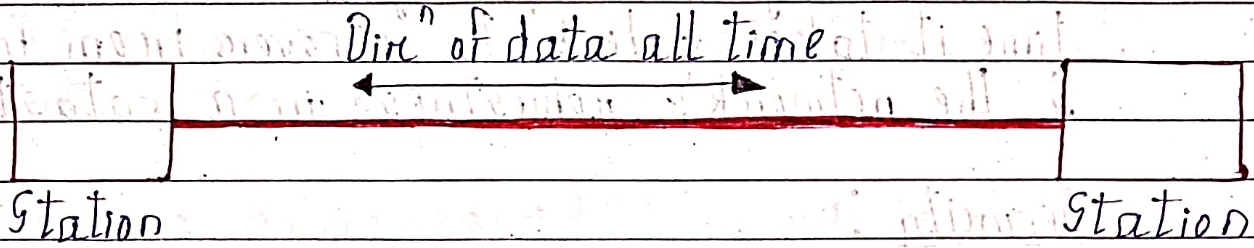


Full Duplex :

⇒ Both stations can transmit & recieve simultaneously.

⇒ Here the capacity of channel is getting shared by the signals travelling in both the dirⁿs.

Eg. Mobile network



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Networks

A network is the connection of set of devices capable of communication. A device can be a host such as desktop, laptop OR a connecting device such as router, switch etc.

Network Criteria

i) Perfomance :

⇒ Depends on the no. of users, the type of transmission medium, capabilities of connected hardware & the efficiency of the software.

⇒ Measured in terms of delay & throughput.

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NOTE : Transit Time is the amount of time required for a message to travel from one device to another.
Response Time is the elapsed time betⁿ an inquiry & a response.

Reliability :

Measured by the frequency of failure, the time it takes a link to recover from failure & the network's robustness in a catastrophe.

Security :

Data protection against loss of data due to errors or malicious users.

Types of Connections

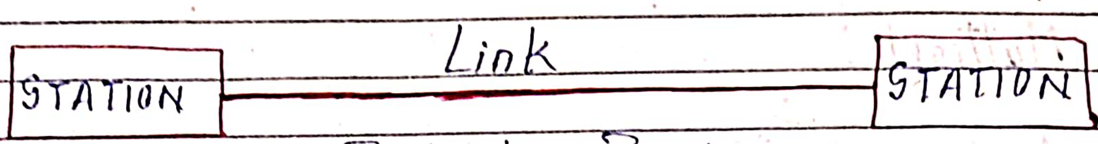
1) Point-to-Point :

=> A direct communication link betⁿ 2 devices.

=> The capacity of the link is reserved for the 2 connected devices.

=> Simpler to implement & usage.

=> Eg. Phone call betⁿ 2 people.
Direct connection betⁿ a computer & a printer.



Point-to-Point

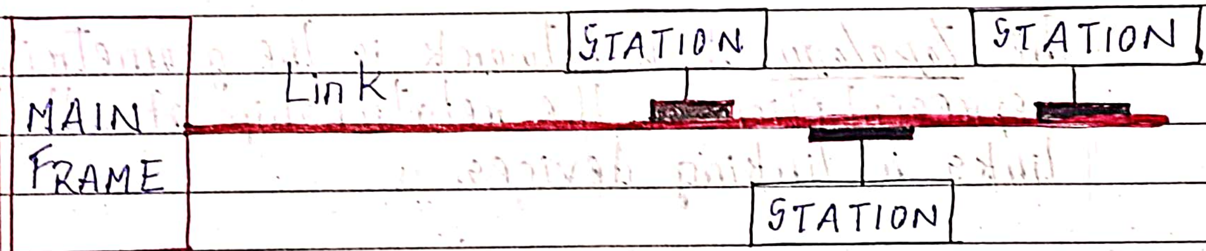
2) Multipoint:

=> A single communication link is shared by multiple devices.

=> The capacity of the link is shared among all the connected devices.

=> Complex as compared to point-to-point.

=> Eg. Conference ~~to~~ call where multiple participants join a single line.



Multipoint

Types of Transmission

1) Unicast:

=> A communication where a message is sent from one sender to one reciever.

=> Data is send to a single recipient.

2) Multiset:

⇒ A communication where a message is sent from one sender to a group of recievers.

⇒ Data is sent to a group of recipients.

3) Broadcast:

⇒ A communication where a message is sent from one sender to all the recievers.

⇒ Data is sent to all the recipients in a network.

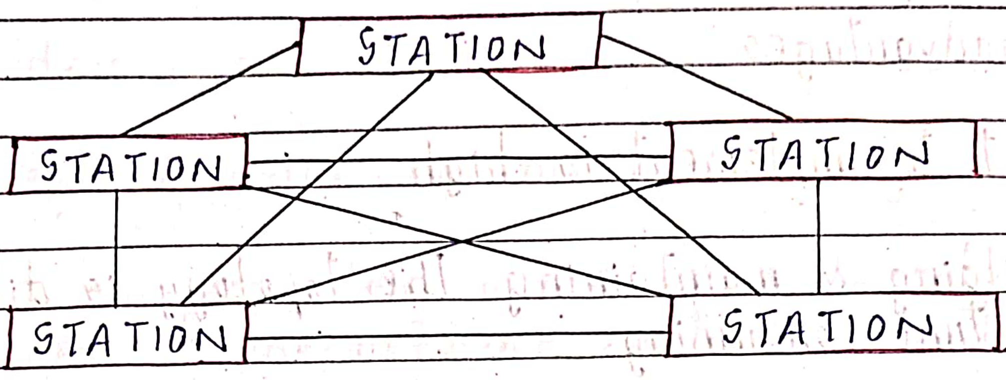
■ **Topology**

The Topology of a network is the geometric representation of the relationship of all the links & linking devices.

Topology
- Mesh
- Star
- Bus
- Ring

1) Mesh Topology

⇒ Every device has a dedicated point-to-point link to every other device.
Dedicated means that the link carries traffic only betⁿ the 2 devices it connects.



For a fully connected mesh network with n nodes, each node required (n-1) nodes to get connected with other nodes.

∴ So, total no. of physical links =

$\boxed{n(n-1)}$ For simplex

$\boxed{\frac{n(n-1)}{2}}$ For duplex

∴ The total no. of I/O ports required = $\boxed{n(n-1)}$

Advantages

⇒ Can handle high amounts of traffic, because multiple devices can transmit simultaneously.

⇒ A failure of one device does not cause a break in the transmission of data.

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Disadvantages

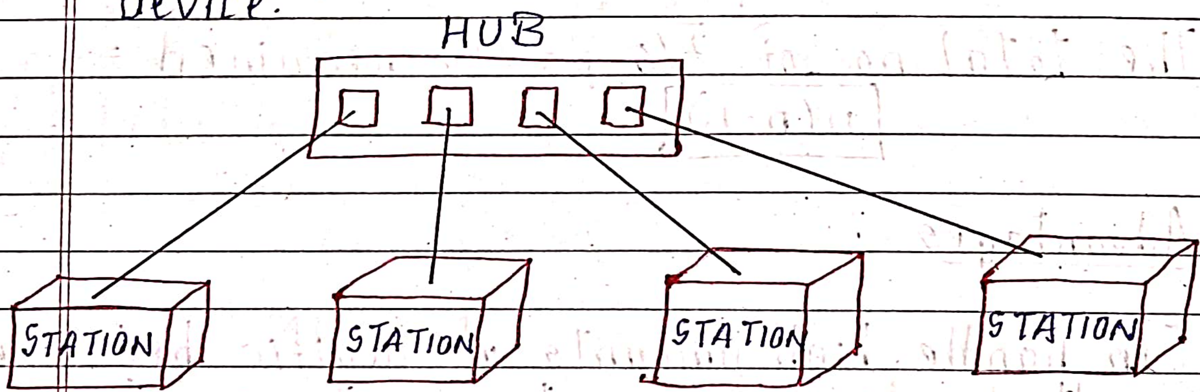
=> Cost to implement is high.

=> Building & maintaining the topology is difficult & time consuming.

2) Star Topology

=> Each device has a dedicated point-to-point link only to a central controller, known as hub.

=> The controller acts as an exchange. If one device wants to send data to another, it sends the data to the controller, which then relays the data to other connected device.



Each device needs only one link & one I/O port to connect it to any no. of others

Advantages

⇒ less expensive than mesh topology.

⇒ If one computer on the network fails, the rest of the network continues to func^n normally.

⇒ Requires less cable than a mesh, each node must be linked to a ~~special~~ central hub.

Disadvantages

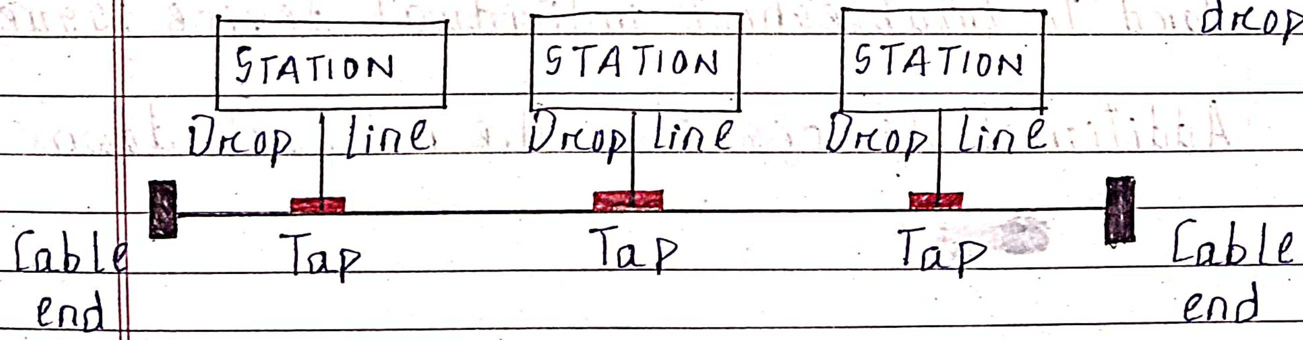
⇒ Can have higher cost to implement.

⇒ If the hub fails, the entire network goes down & all computers are disconnected from the network.

3) Bus Topology

⇒ It is a multipoint connection network. One long cable acts as a backbone to link all the devices in a network.

⇒ Nodes are connected to bus cable by taps & drop lines.



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⇒ A drop line is a connection running betⁿ the device & the main cable.

⇒ A tap is a connector that either splices into the main cable or punctures the sheating of a cable to create a contact with the metallic core.

NOTE As a signal travels along the backbone, some of its energy is transformed into heat. Thus, it becomes weaker as it travels further. For this reason there is a limit on the no. of taps a bus can support & on the dist. betⁿ those taps.

Advantages

⇒ Requires less cable length than star topology.

⇒ Easiest network topology for connecting computers in a linear fashion.

Disadvantages

⇒ If main cable is damaged, the network fails.

⇒ Hard to troubleshoot individual device issues.

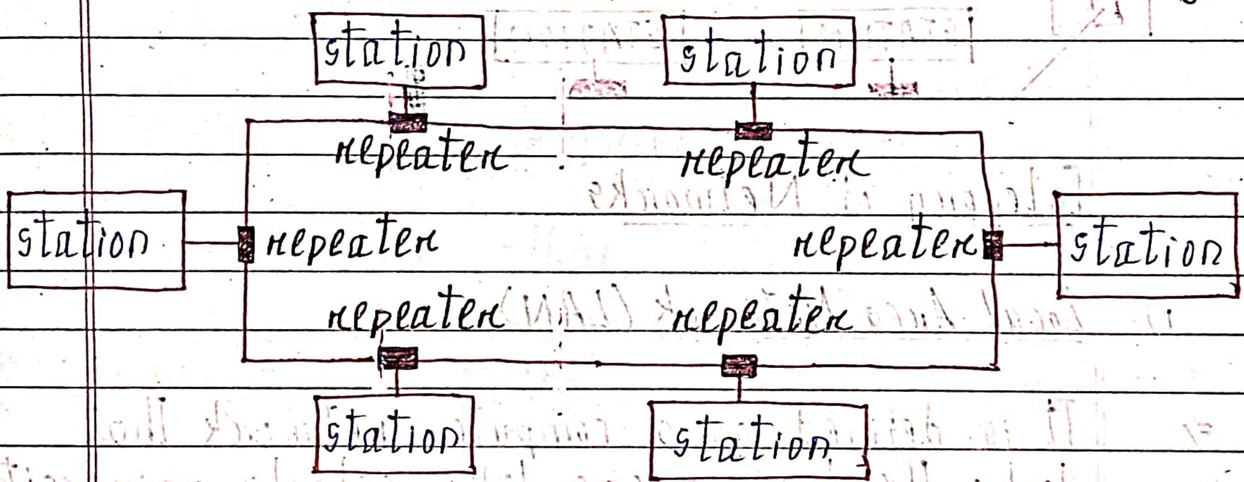
⇒ Additional devices slow the network down.

4) Ring Topology

⇒ Each device has a dedicated point-to-point connections with only the 2 devices on either side of it.

⇒ A signal is passed along the ring in one dirⁿ, from device to device, until it reaches its destination.

⇒ Each device in the ring incorporates a repeater. When a device recieves a signal intended for another device, its repeater regenerates the bits & passes them along.



Advantages

⇒ All data flows in one dirⁿ, reducing the chance of packet collisions.

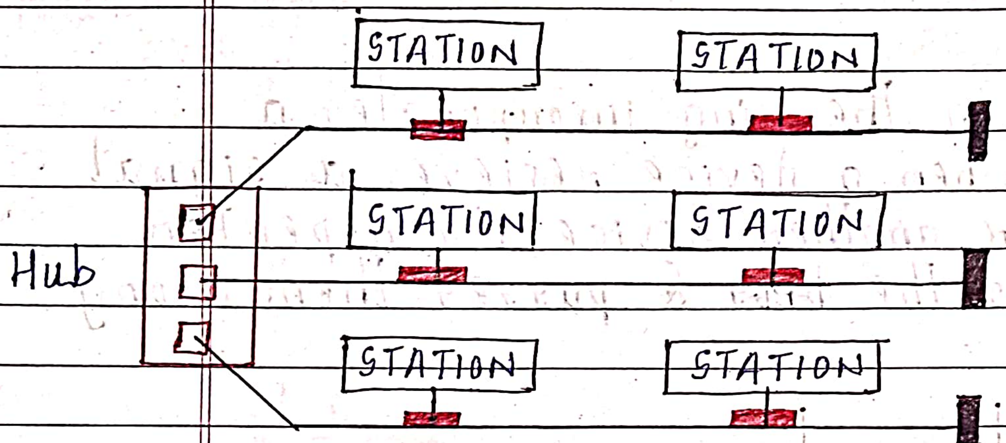
⇒ Easy to install & configure.

Disadvantages

=> The entire network will be impacted if one workstation shuts down.

=> Slower than star topology.

5) Hybrid Topology



Category of Networks

1) Local Area Network (LAN)

=> It is defined as a computer network that links the local areas like schools, universities, organisations etc.

Characteristics

=> Owned by a private owner.

=> Very easy to design & troubleshoot.

=> Wired network.

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- Data transfer rate is 10 to 100Mbps.
- A central database is used to connect the LAN networks.
- Bandwidth is high.

Eg. College, School etc.

2) Metropolitan Area Network (MAN)

- It is defined as the computer network that links the metropolitan areas.

Characteristics

- Might be public or private owner.
- Larger network than LAN.
- Connected through modem or cables/wires.
- Data transfer rate is 44-155 Mbps.
- Maintenance cost is difficult.
- Bandwidth is less.

Eg. Television Network

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3) Wide Area Network (WAN)

⇒ It is defined as the telecommunications network that covers a large geographical area.

Characteristics

⇒ Ownership might be private or public.

⇒ Connected through broadband services, 3G or 4G internet services etc.

⇒ Speed is less i.e. 150 Mbps.

⇒ Maintenance cost is difficult.

⇒ Bandwidth is relatively low.

Eg. Brodband & internet throughout the country.

▪ Protocols

⇒ A protocol is a set of rules that govern data communication.

⇒ It defines what is communicated, how it is communicated & when it is communicated.

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Key Elements of Protocol

1) Syntax

It refers to the structure or format of the data i.e. the order in which address of the sender, address of reciever & message bits are to be represented.

2) Semantics

It refers to the meaning of each section of bits.
It knows about the action to be taken based on the interpretation of data.

3) Timing

It refers to 2 characteristics:
i) when data should be send.
ii) how fast they can be send.

- ## Network Models

⇒ A network is a combⁿ of hardware & software that sends data from one location to another.

⇒ Hardware consists of physical equipment that carries signals from one point to another

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⇒ The software consists of instⁿ sets that make possible the services that we expect from a network.

OSI MODEL :

⇒ OSI stands for Open System Interconnection.

⇒ It is an open std. for all communication systems.

⇒ Established by ISO (International Standard Organisation) in the late 1970s.

⇒ Purpose is to show how to facilitate communication betⁿ diff. systems without requiring changes to the logic of the underlying hardware & software.

⇒ Consists of 7 separate but related layers, each of which defines a part of the process of moving info across a network.

7 APPLICATION

6 PRESENTATION

5 SESSION

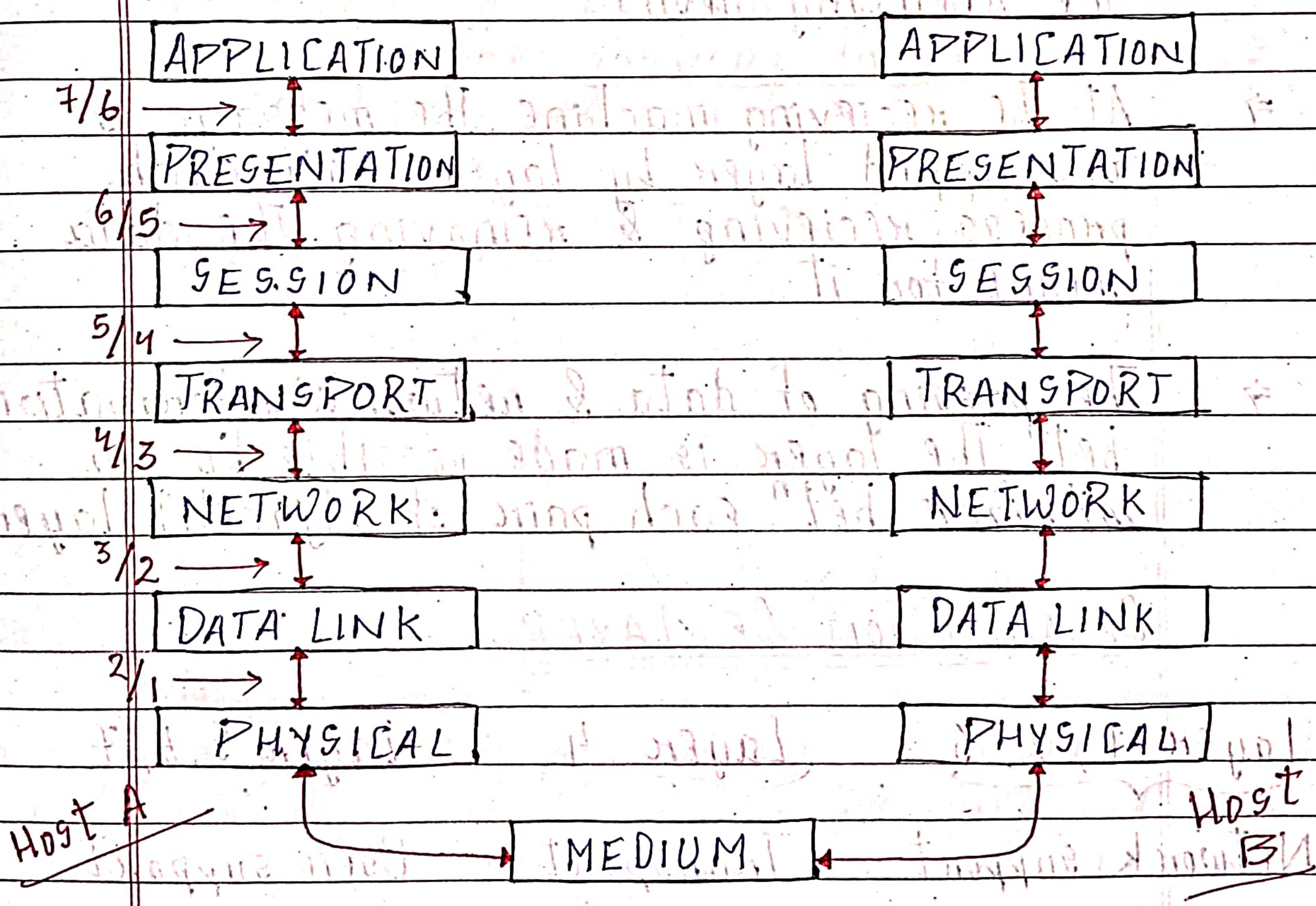
4 TRANSPORT

3 NETWORK

2 DATA LINK

1 PHYSICAL

INTERACTION BETWEEN LAYERS



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- ⇒ Device A sends a stream of bits to device B through intermediate tasks.
- ⇒ Intermediate nodes usually involve only the first 3 layers (physical, data link & network layer) of OSI model.
- ⇒ Each layer in the sending device adds its own info to the message it recieves from the layer above it & passes the whole package to the layer just below it.
- ⇒ At layer 1, the entire passage is converted to a form that can be transmitted to the recieving device.
- ⇒ At the recieving machine, the message is unwrapped layer by layer, with each process recieving & removing the data meant for it.
- ⇒ The passing of data & network information bet^n the layer is made possible by an interface bet^n each pair of adjacent layers.

ORGANISATION OF LAYER

Layer 1, 2, 3	Layer 4	Layer 5, 6, 7
Network support	Transport	User support

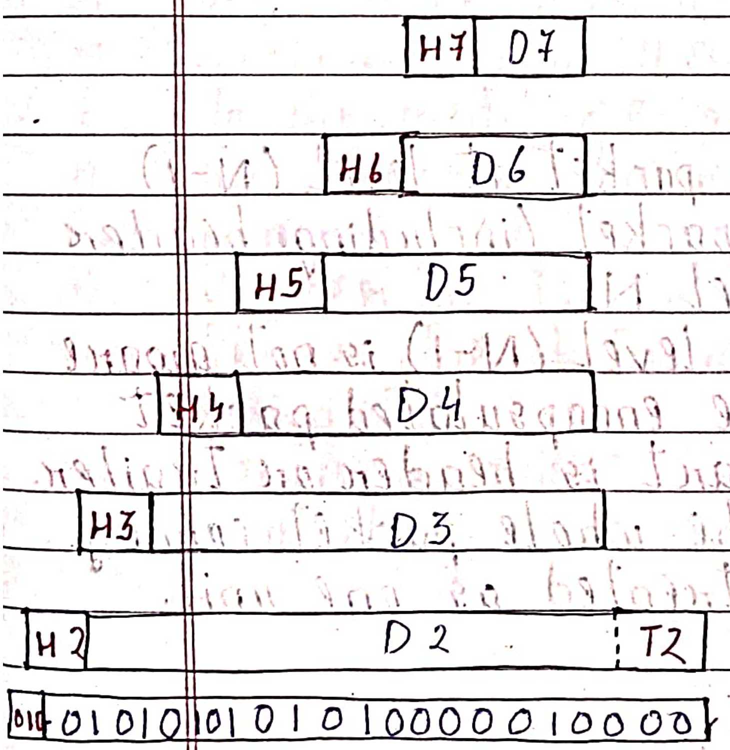
Network Support layer :- deals with the physical aspects of moving data from one device to another.

User Support layer :- Allow the system to exchange & make use of information among unrelated software systems.

Transport layer :- Links the 2 sub groups & ensures that the lower layers have transmitted is in a form that the upper layer can use.

The upper OSI layers are almost always implemented in software. The lower layers are a combⁿ of hardware & software, except for the physical layer which is mostly hardware.

Data Exchange Using The OSI Model



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⇒ The process starts at layer 7, then moves from layer to layer in descending sequential order.

⇒ At each layer, a header or a trailer can be added to the data unit.

⇒ After passing through the physical layer, data unit is changed into an EM signal & transported along a physical link.

⇒ Upon reaching its destn, the signal passes into layer 1 & is transformed back into digital form. The data units then move back up through the OSI layers.

⇒ At each block when data reaches the next higher level, the header & trailer attached to it at the corresponding sending layer are removed.

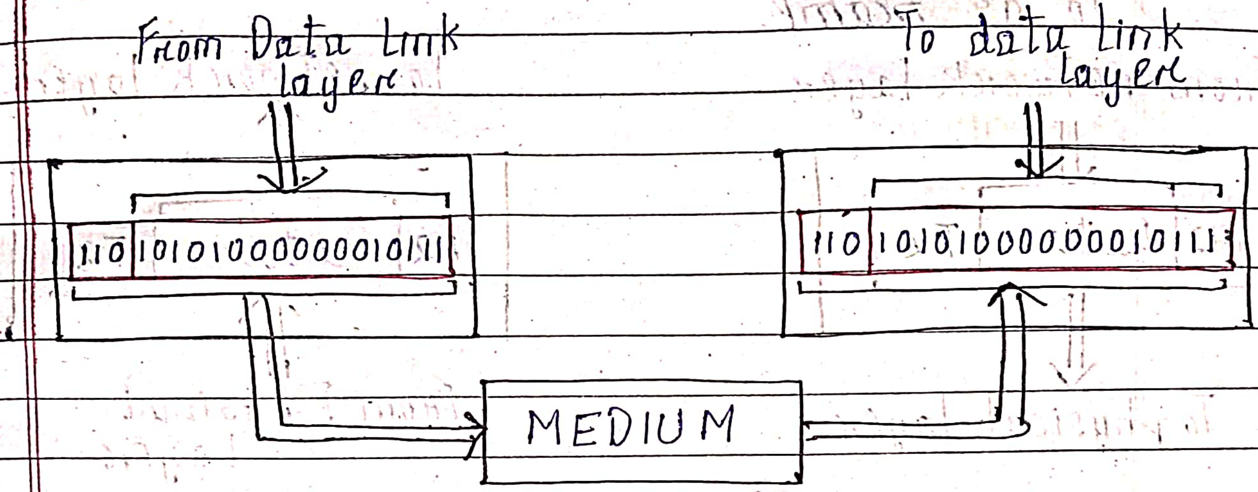
Encapsulation

The data portion of a packet at level (N-1) carries the whole packet (including header & trailer) from level N.
Encapsulation means level (N-1) is not aware of which part of the encapsulated packet is data & which part is header or trailer.
For layer (N-1), the whole packet coming from layer N is treated as one unit.

LAYERS IN THE OSI MODEL

1) Physical Layer

Responsible for movements of individual bits from one node to next.



The physical layer is concerned for the following :-

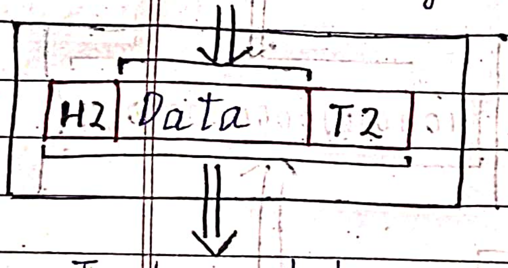
=> Defines the dirⁿ of transmission betⁿ 2 devices.
=> Defines the physical topology of the network.
=> Concerned with the connection of devices to the media i.e. point-to-point OR multipoint
=> The sender & the reciever clocks must be synchronised.
=> Defines the type of transmission.
=> Defines the data rate i.e. the duration of a bit
=> Defines how the 0s & 1s are changed to signals.

2) <u>Data link Layer</u>

⇒ Responsible for the node-to-node delivery of the message.

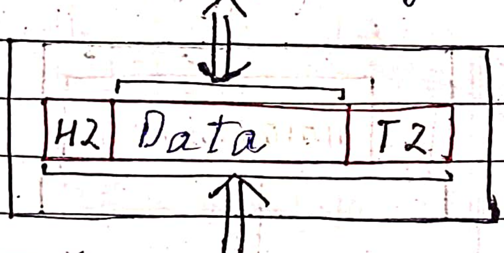
⇒ Packet in the data link layer is referred to as frame.

From network layer



To physical layer

To network layer



From Physical Layer

Other responsibilities include the following:

⇒ <u>Framing</u>: Divides the stream of bits into manageable data bits called frames.

⇒ <u>Physical Addressing</u>: Adds header to the frame to define the sender's/reciever's address.

⇒ <u>Flow control</u>: The data rate must be const. on both sides else the data may get corrupted.

⇒ <u>Error control</u>: Provides the mechanism of error control in which it detects & retransmits damaged/lost frames.

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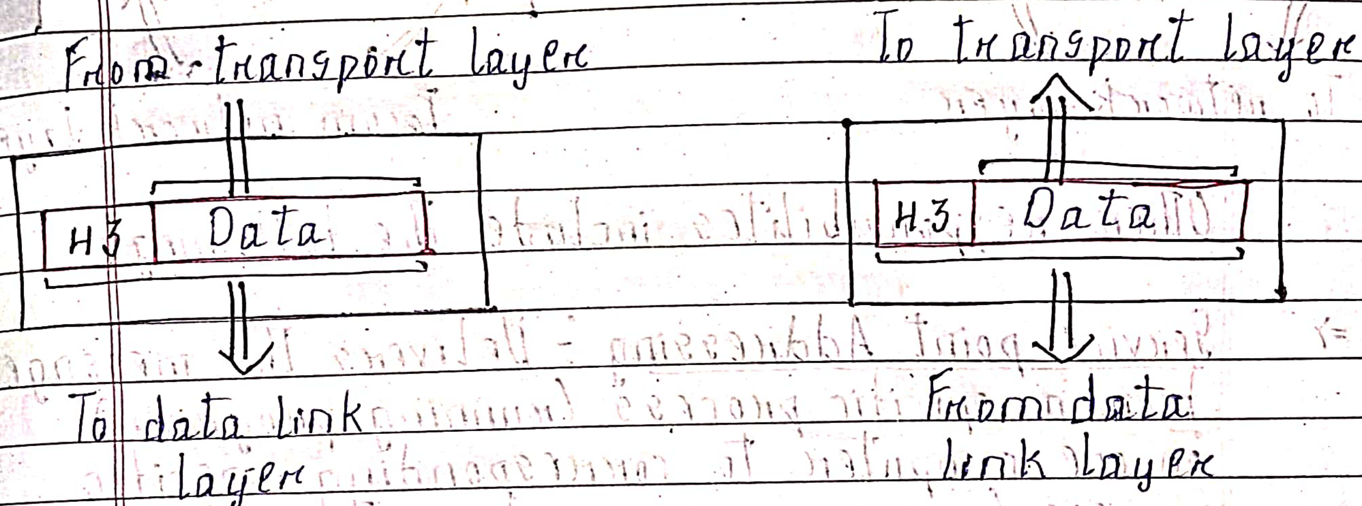
⇒ Access Control : Data link layer protocols are necessary to determine which device has control over the link at a given time in multipoint connection scenario.

3) Network Layer

⇒ Responsible for the delivery of individual data packets from the source host to the dest^n host.



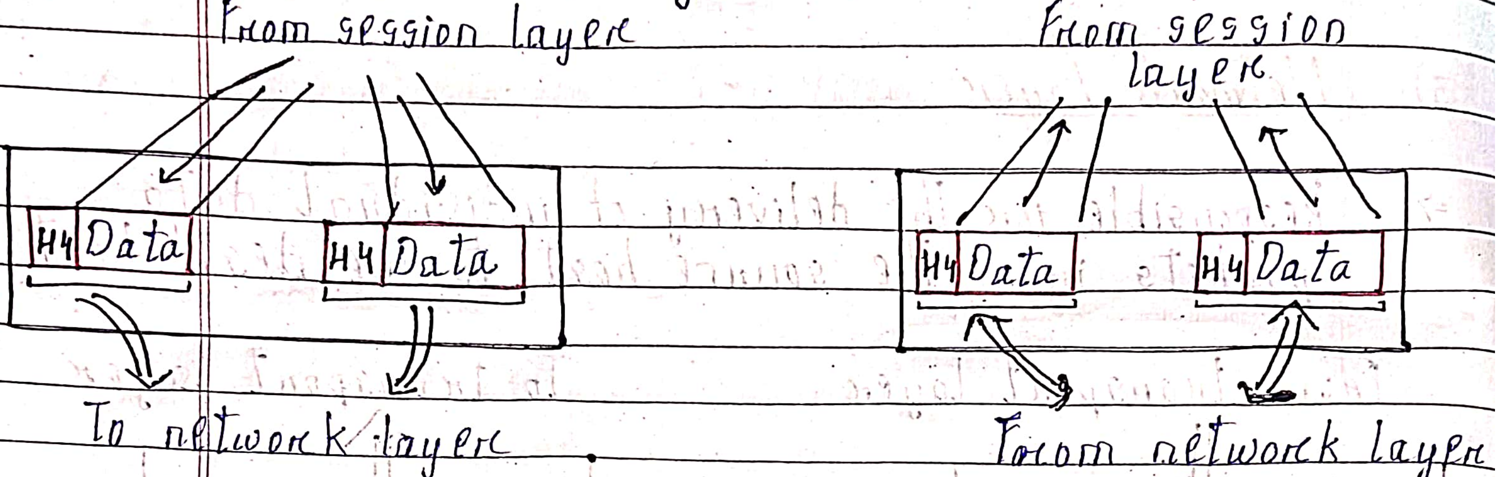
Responsibilities of network layer are follows :-

⇒ Routing :- The network layer protocols determine which route is suitable from source to dest^n.

⇒ Logical Addressing :- To identify each device inter-network uniquely, the network layer defines an addressing scheme. The sender & reciever's IP Addresses are placed in the header by the network layer.

4) Transport layer

=> Responsible for process-to-process delivery of the entire message.



Other responsibilites include the following:

=> Service-point Addressing : Delivers the message from a specific process (running program) on one computer to corresponding specific process (running program) on the other computer. The header include a type of address called service point address (port address).

=> Segmentation & Reassembly : Message is divided into transmittable segments with each segment containging sequence no. (sender's side) These no.s enable the transport layer to assemble the message correctly upon arriving at the destⁿ & to identify & detect that were lost in transmission.

⇒ Connection control : Can be either connectionless OR connection oriented.
A connectionless transport layer treats each segment as an independent packet & delivers it to the transport layer at the destⁿ machine.
A connection-oriented transport layer makes a connection with the transport layer at the destⁿ machine first before delivering the packets.

⇒ Flow control : Performed end to end rather than across a single link.

⇒ Error control : Performed process-to-process rather than across a single link.

5) Session Layer

⇒ It is the network dialog controller. It establishes, maintains, & synchronizes the interaction among communicating systems.

⇒ Responsible for dialog control & synchronization

⇒ Dialog control : Allows 2 systems to enter into a dialog. Allows communication betⁿ 2 processes to take place in either half-duplex OR full-duplex.

⇒ Synchronization : Allows a process to add check-points, or synchronization points, to a stream of data.

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6) Presentation Layer

=> Concerned with the syntax & semantics of the information exchanged betn 2 systems.

=> Responsible for translation, compression & encryption.

7) Application Layer

=> Enables the user, whether human or software, to access the network.

=> It ~~suppo~~ provides user interfaces & support for diff. services.

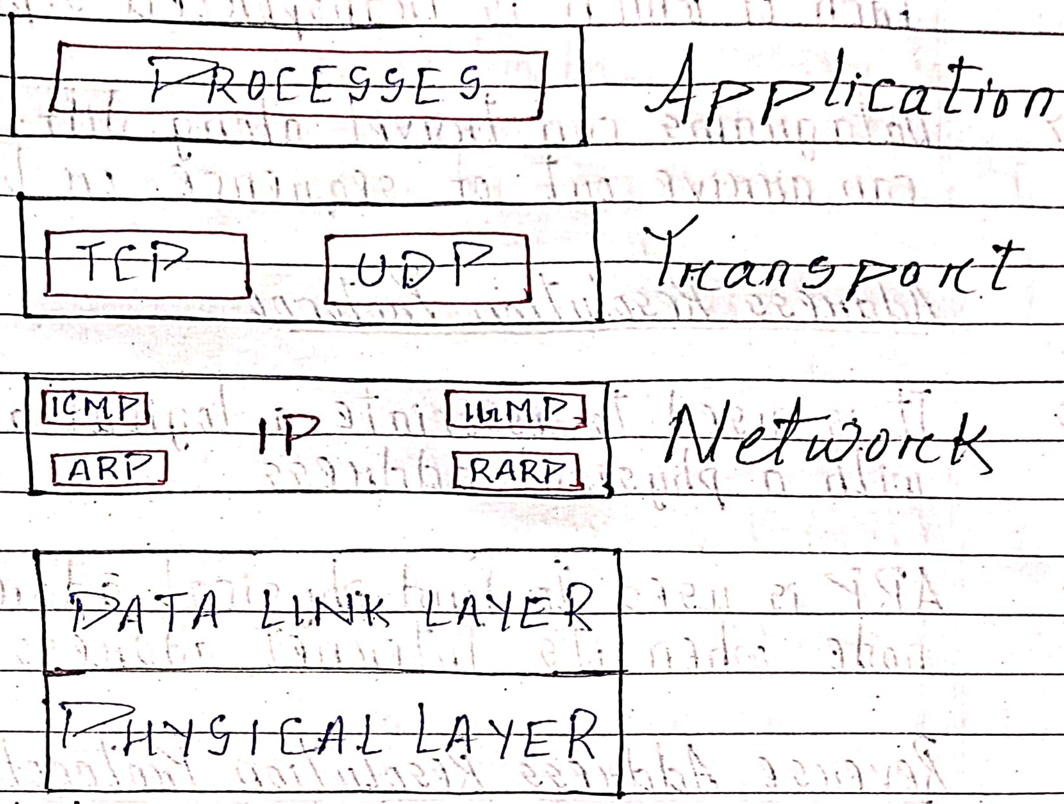
TCP/IP Protocol

=> TCP/IP is a hierarchial protocol made up of interactive modules, & each of them provides specific functionality.

Here, hierarchial means that each upper layer protocol is supported by two or more lower-level protocols.

=> Consists of 5 layers :-
1) Physical
2) Data Link
3) Network
4) Transport
5) Application

Func^n's of TCP/IP Protocol



1) Network Layer

=> It defines how the data should be sent physically through the network.

=> Responsible for the transmission of the data bet^n 2 devices on the same network.

Internetworking Protocol (IP)

=> It is an unreliable & connectionless protocol - a-best-effort delivery service. The term best effort means that the IP provides no error checking & tracking.

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=> IP Transports data in packets called datagrams each of which is transported separately.

=> Datagrams can travel along diff. routes & can arrive out of sequence or be duplicated.

Address Resolution Protocol

=> It is used to associate a logical address with a physical address.

=> ARP is used to find physical address of the node when its Internet address is known.

Reverse Address Resolution Protocol

RARP allows a host to discover its Internet address when it knows only its physical address.

Internet Control Message Protocol

ICMP is a mechanism used by hosts & gateways to send notifications of datagram problems back to the sender. Sends query & error reporting messages.

Internet Group Message Protocol

IGMP is used to facilitate the simultaneous transmission of a message to a group of recipients.

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2) Transport Layer

=> Represented by two protocols: TCP & UDP

* User Datagram Protocol

It is a process to process protocol that adds only port addresses, checksum error control, & length information to the data from the upper layer.

Transmission Control Protocol

=> Provides full transport layer services to applications.

=> At the sending end of each transmission, TCP divides a stream of data into smaller units called segments.

=> Each segment includes a sequence no. for reordering after receipt, together with an acknowledgement no. for the segments recieved. Segments are carried across the internet inside of IP datagrams.

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Addressing

Addresses

Physical Address	Logical Address	Port Address	Specific Address

Physical Address

- ⇒ Also known as The MAC address.
- ⇒ It is used by The data link layer & is The lowest level of addresses.
- ⇒ It is The address of The node which is defined by its LAN or WAN.
- ⇒ Size → 48 bits (6 bytes).

Logical Address

- ⇒ Also known as The IP address.
- ⇒ It is an universal addressing system. It is used in The Network Layer.
- ⇒ Size → 32 bits.

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Data And Signals

Analog Data

Analog data are cts & take cts values.

Analog Signal

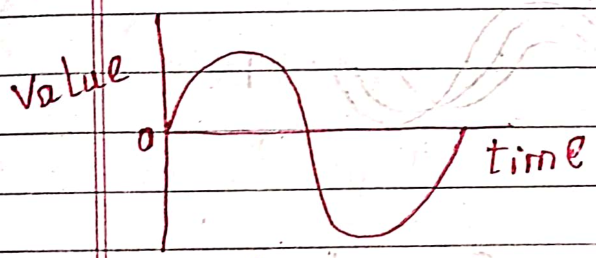
Analog signals are those signals which is cts in both time & value.

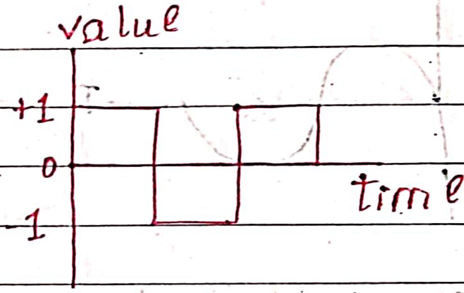
Digital Data

Digital data have discrete states & take discrete values.

Digital Signal

Digital signals are those signals which is discrete in both time & value.





Analog signal

Digital signal

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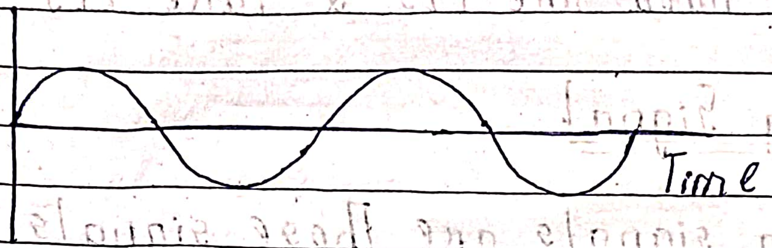
Periodic Analog Signals

A periodic signal consists of continuously repeated time.

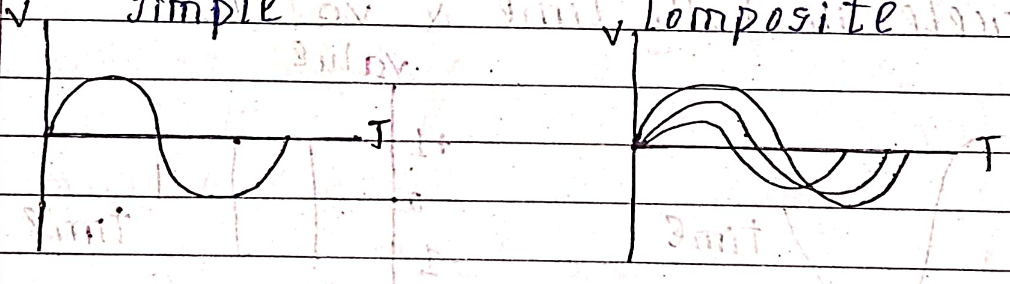


Aperiodic Signals

An aperiodic signal has no repetitive pattern. Signal changes continuously & constantly without a pattern or cycle that repeats over time.

Analog

Simple | Composite



Characteristics of Analog Signal

1) Amplitude
2) Period
3) Frequency
4) Phase

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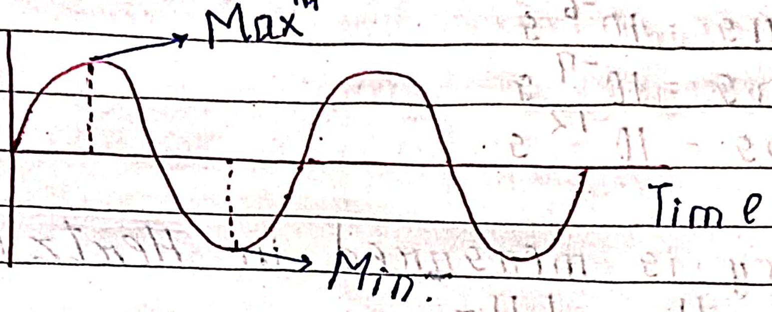
1) <u>Amplitude</u>

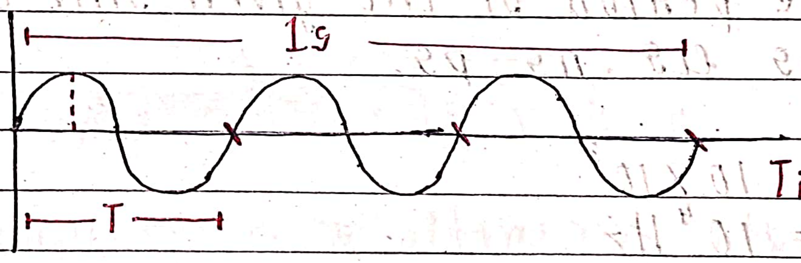
=> Height of the signal



=> Unit → volt, watt, ampere

2) <u>Period</u>

=> Amount of time it takes a signal to complete one cycle. Denoted by T.



3) <u>Frequency</u>

=> No. of cycles per second.

Mathematically,

$$\boxed{f = \frac{1}{T}}$$

where f = Frequency
T = Time period

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Period is measured in second (s).

$s = 1s$
$ms = 10^{-3} s$
$\mu s = 10^{-6} s$
$ns = 10^{-9} s$
$ps = 10^{-12} s$

Frequency is measured in Hertz (Hz).

$Hz = 1 Hz$
$kHz = 10^{3} Hz$
$MHz = 10^{6} Hz$
$GHz = 10^{9} Hz$
$THz = 10^{12} Hz$

Q- Given a sine wave of frequency 10 kHz. Express the time period of the given sine wave in s, ms, μs, ns, ps.

A- $10 kHz = 10 \times 10^{3}$
$= 10^{4} Hz$

$$T = \frac{1}{f} = \frac{1}{10^{4}} = 10^{-4} s$$

$1 s = 10^{3} ms$
$10^{-4} s = 10^{3} \times 10^{-4}$
$= 10^{-1} = 0.1 ms$

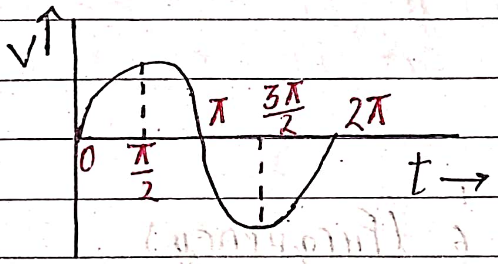
$1 \mu s = 10^{6} \mu s$
$10^{-4} s = 10^{6} \times 10^{-4}$
$= 10^{2} = 0.01 \mu s$

NOTE Frequency is the rate of change w.r.t. time
Time ↑ = Frequency ↓
Time ↓ = Frequency ↑
If
signal doesn't change → frequency → 0
signal change instant → frequency → ∞

4) Phase

⇒ Describes the posⁿ of the waveform relative to time 0.

⇒ Measured in degrees OR radians.



Q- A sine wave is offset 1/6 of a cycle w.r.t time 0. What is its phase.

A- $360 \times \frac{1}{6} = 60^\circ$

5) Wavelength

It is the dist. covered by a signal in 1 time period. Denoted by λ.

$\lambda = \frac{\text{Speed}}{\text{Frequency}} \Rightarrow \boxed{\lambda = \frac{c}{f}}$

Time And Frequency Domains

A complete sine wave in The time domain can be represented by one single spike in The frequency domain.

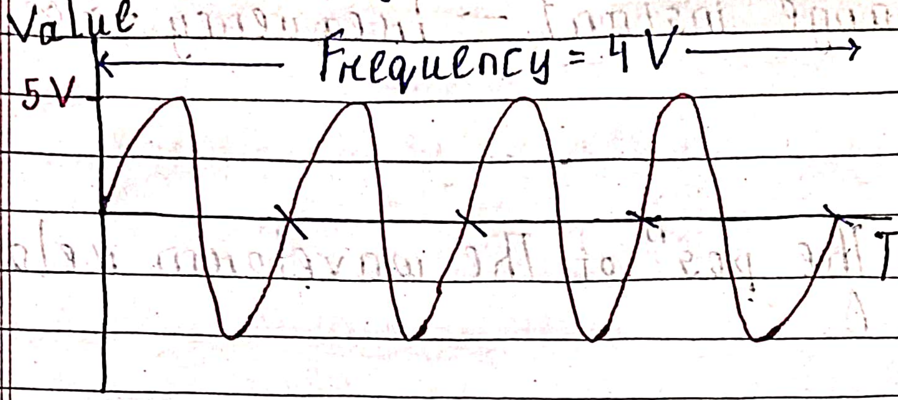


Fig. Time Domain

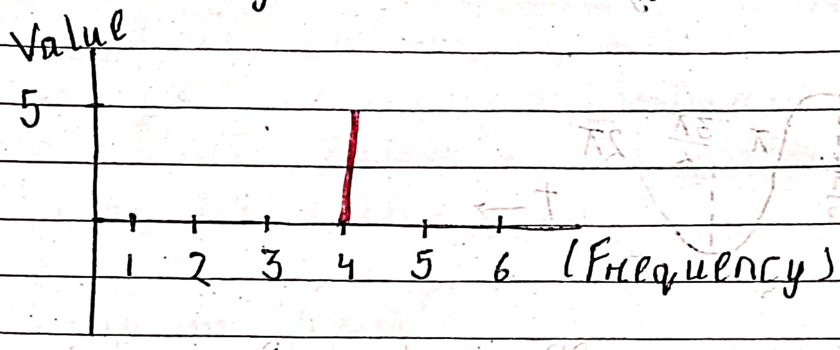


Fig. Frequency domain

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Composite Signal

⇒ It is a combⁿ of simple sine waves with diff frequencies, amplitude & phases.

⇒ If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies.

⇒ If the composite signal is nonperiodic, the decomposition gives a combⁿ of sine waves with cts frequencies.

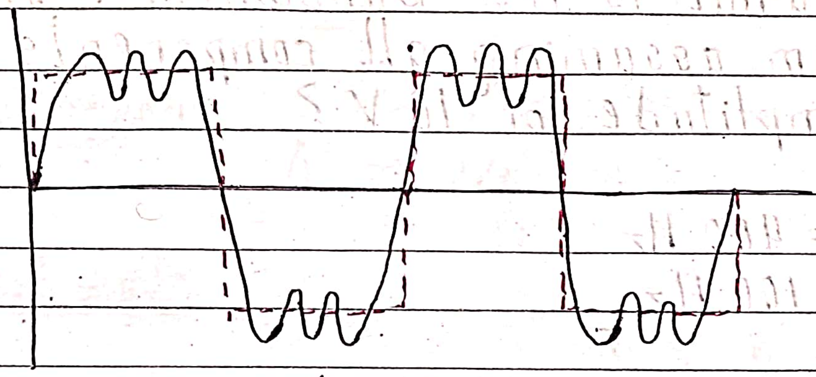

Fig. Composite Periodic Signal

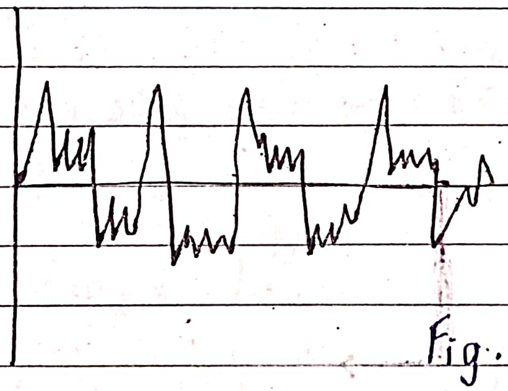

Fig. Non periodic Signal

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6) **Bandwidth**

⇒ It is the difference betⁿ the highest & lowest frequencies contained in that signal.

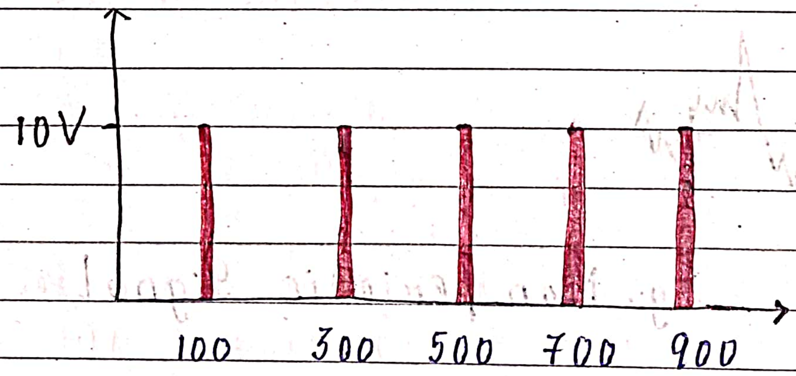
$$\boxed{B = f_h - f_l}$$

where f_h = highest frequency
f_l = lowest frequency

Q- If a periodic signal is decomposed into 5 sine waves with frequencies of 100, 300, 500, 700 & 900 Hz, what is its Bandwidth? Draw the spectrum assuming all components have a max^m amplitude of 10 V?

A- Given $f_h = 900$ Hz
$f_l = 100$ Hz

$B = 900 - 100$
$= 800$ Hz



Q- A periodic signal has a bandwidth of 20 Hz. The highest frequency is 60 Hz. What is the lowest frequency?

A- Given $B = 20\ Hz$
$f_h = 60\ Hz$

$B = f_h - f_l$
$\Rightarrow f_l = f_h - B$
$= 60 - 20$
$= 40\ Hz$

Digital Signals

Represent 1 → +ve voltage
0 → zero voltage

Bit rate

It is the no. of bit intervals per second.
OR
It is the no. of bit sent in 1 sec. & is usually expressed in bits per second (bps)

NOTE If a signal has 'L' levels it has $\log_2 L$ bits.

Q- A digital signal has 8 levels. How magny bits needed per level?

A- No. of bits per level $= \log_2 8 = 3$ bits

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NOTE Page → 24 lines
1 line → 80 char } Avg.
1 char → 8 bits

Transmission Impairment

The signal at the beginning of the medium is not same as the signal at the end of the medium.

Impairment causes

Attenuation Distortion Noise

i) Attenuation

⇒ It 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 use to amplify the signal.

⇒ To show the loss or gain of energy the unit 'decibel' is used.

$$dB = 10 \log_{10} \frac{P_2 \text{ (output)}}{P_1 \text{ (input)}}$$

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Q- A signal travels through a transmission medium & its power is reduced to half. What is its attenuation.

A- $10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{0.5 P_1}{P_1}$

$= 10 \log_{10} 0.5$

$= 10 (-0.3)$

$= -3 \text{ dB} \rightarrow$ loss of 3 dB

Q- If the signal at the beginning of a cable with -0.3 dB/km has a power of 2 mW, what is the power of the signal at 5 km?

A- Loss in the cable $= 5 \times (-0.3)$

$= -1.5 \text{ dB}$

$\text{dB} = 10 \log_{10} \frac{P_2}{P_1} = -1.5$

$\Rightarrow \frac{P_2}{P_1} = 10^{-0.15} = 0.71$

$\Rightarrow P_2 = 0.71 P_1$

$= 0.7 \times 2$

$= 1.4 \text{ mW}$

iii) Distortion

$\Rightarrow$ It means that the signal changes its form or shape.

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⇒ Signal components at the reciever have phases diff. from what they had at the sender. The shape of the composite signal is thus not the same.

iii) <u>Noise</u>

⇒ There are diff. types of noise :-

a) <u>Thermal</u> :- random noise of electrons in the wire creates an extra signal.

b) <u>Induced</u> :- from motors & appliances, devices act are transmitter antenna & medium as recieving antenna.

c) <u>Crosstalk</u> :- same as above but betn 2 wires.

d) <u>Impulse</u> :- Spikes that result from power lines lightning etc.

<u>Signal-to-Noise Ratio (SNR)</u>

⇒ The signal-to-noise ratio is defined as

$$\boxed{SNR = \frac{\text{avg. signal power}}{\text{avg. noise power}}}$$

SNR ↑ signal is less corrupted by noise
SNR ↓ signal is more corrupted by noise

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

Q:- The power of signal is 10 mW & the power of the noise is 1 µW. What are the values of SNR & SNR_{dB}?

A:- $SNR = \frac{10 \text{ mW}}{1 \text{ µW}}$

$= \frac{10 \times 10^{-3}}{10^{-6}} = 10^4$

$SNR_{dB} = 10 \log_{10} 10000$

$= \underline{\underline{40}}$

NOTE For a noiseless channel

$SNR = \frac{\text{signal power}}{0} = \infty$

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

- **Digital Transmission**

We must transform data into signals to send them from one place to another.

⇒ Data stored in a computer are in the form of 0's & 1's to be carried out from one place to another, data are usually converted to digital signals. This is called digital-to-digital conversion or encoding digital data into a digital signal.

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⇒ Sometimes, we need to convert an analog signal i.e. voice in a telephone conversation, into a digital signal for several reasons such as to decrease the effect of noise. This is called analog to digital conversion or digitilizing an analog signal.

We want to send a digital signal coming out of a computer through a medium designed for an analog signal. The example is to send data from one place to another place using the public telephone line from a computer. This is called digital to analog conversion or modulating a digital signal.

An analog signal is sent over long dist. using analog medium. The example is voice or music from a radio station which is naturally an analog signal is transmitted through the air. This is called analog to analog conversion or modulating an analog signal.

Digital to Digital Conversion

Line Coding

Converts a sequence of bits to a digital signal.

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NOTE: A data element is the smallest entity that can represent a piece of information about the bit.
A signal element is the shortest unit of a digital signal.

data element → carried
signal element → carriers

The data rate defines the no. of data elements sent in 1 sec.
Unit → bits per second (bps)
The signal rate is the no. of signal elements in 1 sec.
Unit → baud.

The signal rate can be expressed by:-

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

where c → case factor
N → data rate.
r → ratio of no. of data elements carried by signal element.

Line Coding

- Unipolar
- Polar
  - NRZ
    - NRZ-L
    - NRZ-I
  - RZ
  - Biphase
    - Manchester
    - Differential Manchester
- Bipolar
  - AMI
  - pseudo ternary

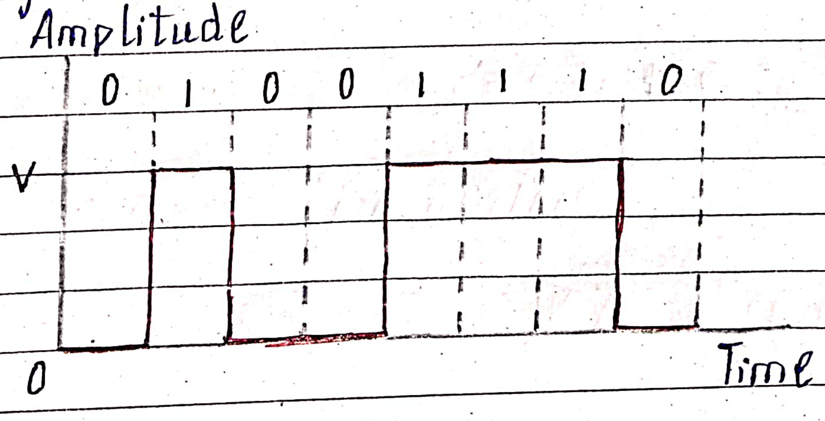
Unipolar

⇒ All signal levels are on one side of the time axis i.e. either above or below.

⇒ NRZ → Non return to zero.
The signal level does not return to zero during a symbol transmission.

⇒ 0 → 0 level
1 → +V

Eg. 01001110



Polar

NRZ :

=> Implemented with 2 voltages:-

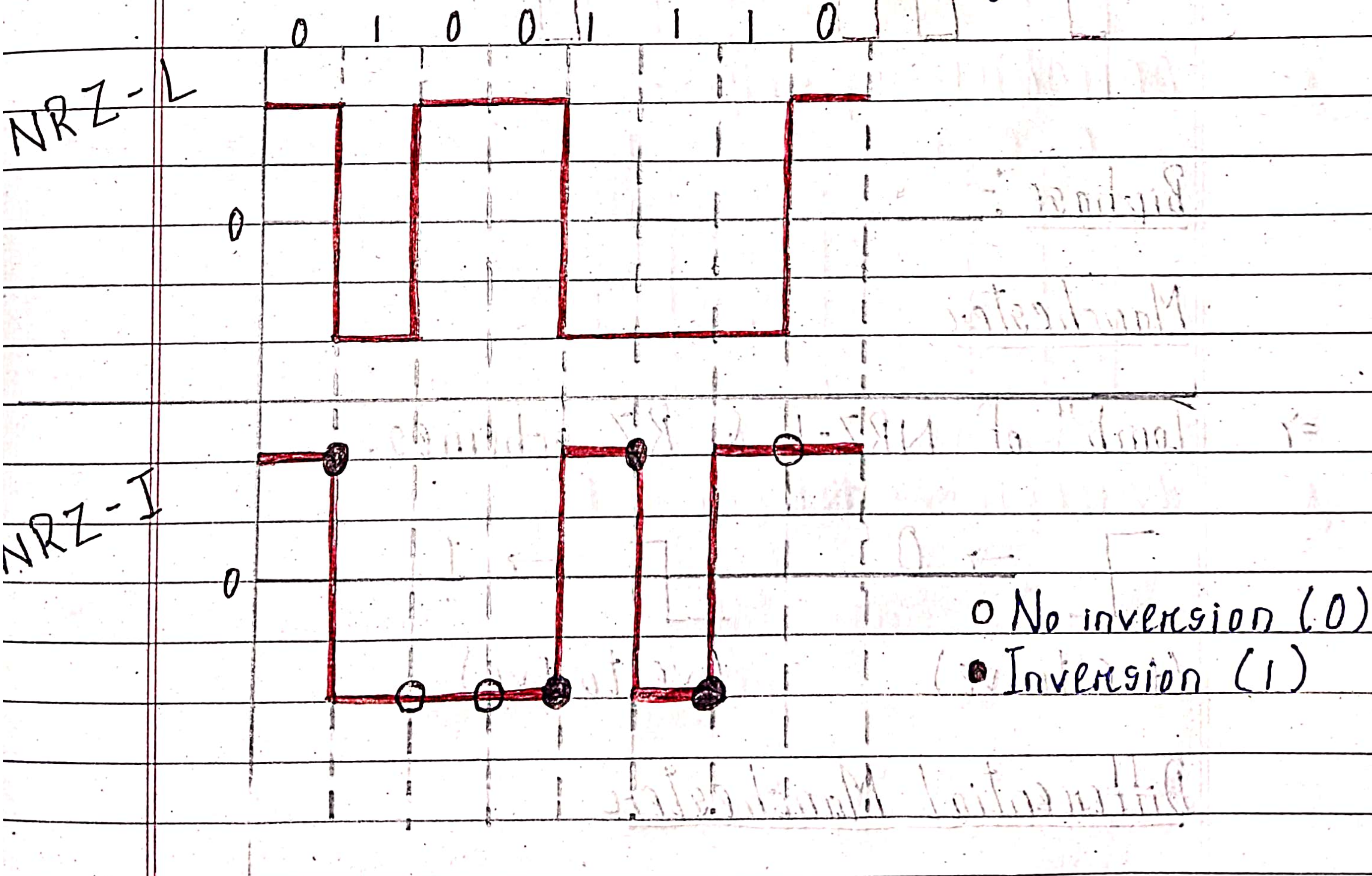
$0 \rightarrow +V$

$1 \rightarrow -V$

=> It has 2 versions:-

i) NRZ-level (NRZ-L): $0 \rightarrow +ve\ (+V)$
$1 \rightarrow -ve\ (-V)$

ii) NRZ-Inversion (NRZ-I): $0 \rightarrow$ no change
$1 \rightarrow$ change



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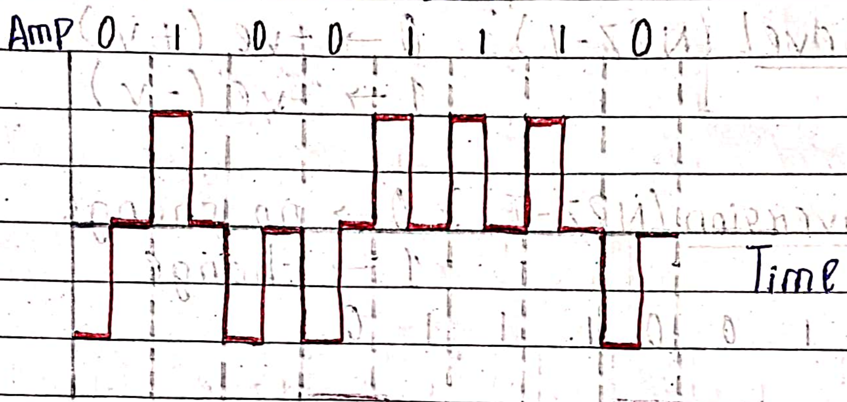
NOTE In NRZ-L The level of the voltage determines The value of bit.
In NRZ-I The lack of inversion OR The inversion determines The value of bit.

RZ :-

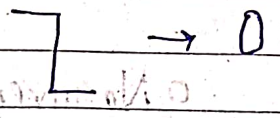
⇒ Uses 3 voltage values :- +, 0, -.
0 → -ve to zero
1 → +ve to zero.

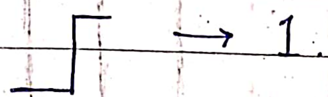


Biphase :-

Manchester

⇒ Comb^n of NRZ-L & RZ schemes.





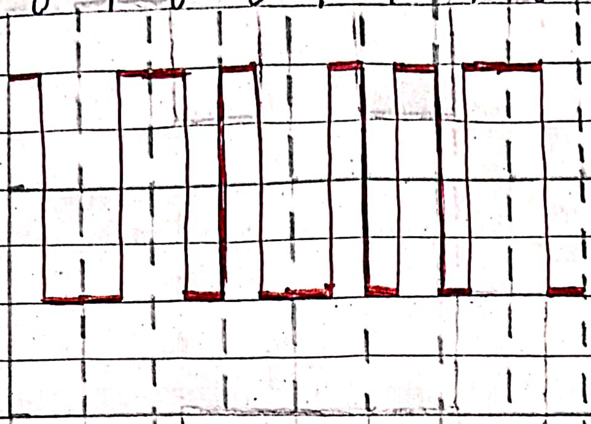
Differential Manchester

⇒ Comb^n of NRZ-I & RZ schemes

0 → change of state
1 → no change

0 1 0 0 1 1 1 0

Manchester



Differential Manchester

- No inversion (1)
- Inversion (0)

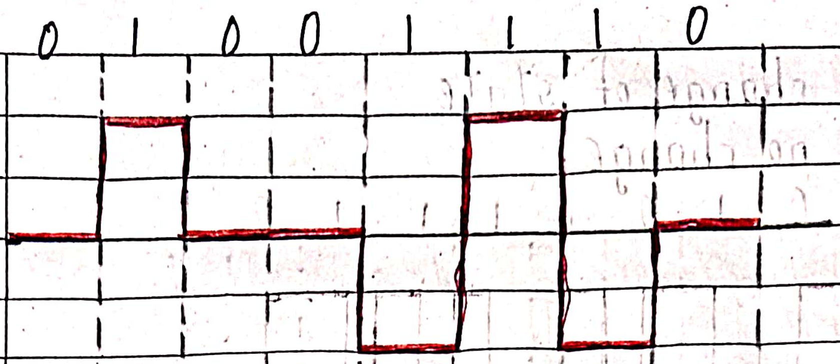
Bipolar

AMI & Pseudoternary :

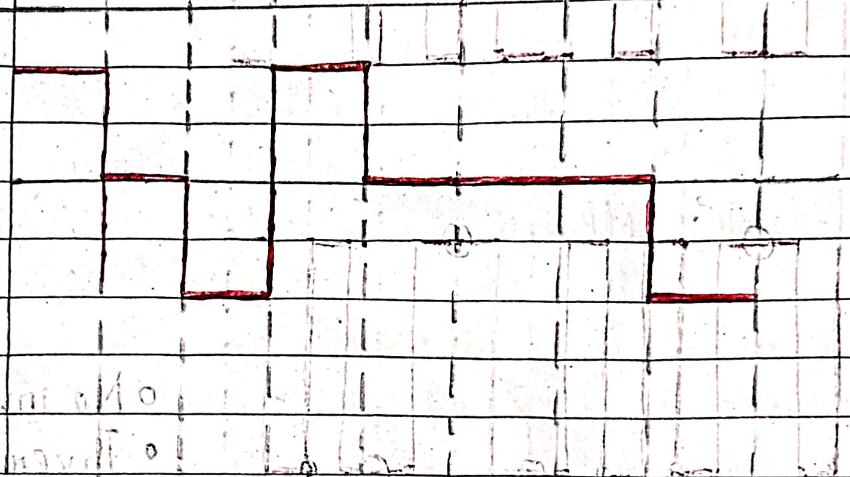
⇒ Uses 3 symbols :- 0, +, -
  0 → voltage level (0)
  1 → alternate +ve then -ve

⇒ Pseudoternary is the reverse of AMI

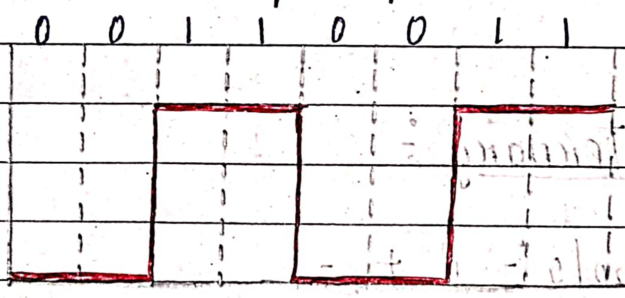
AMI



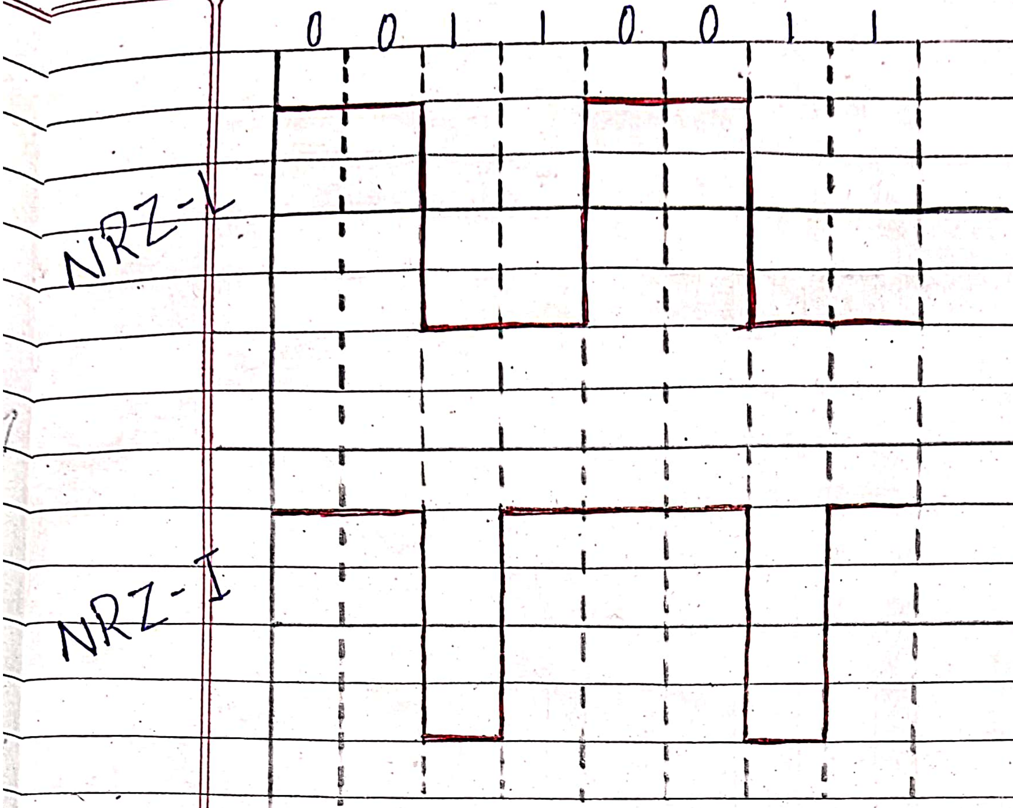
Pseudo ternary



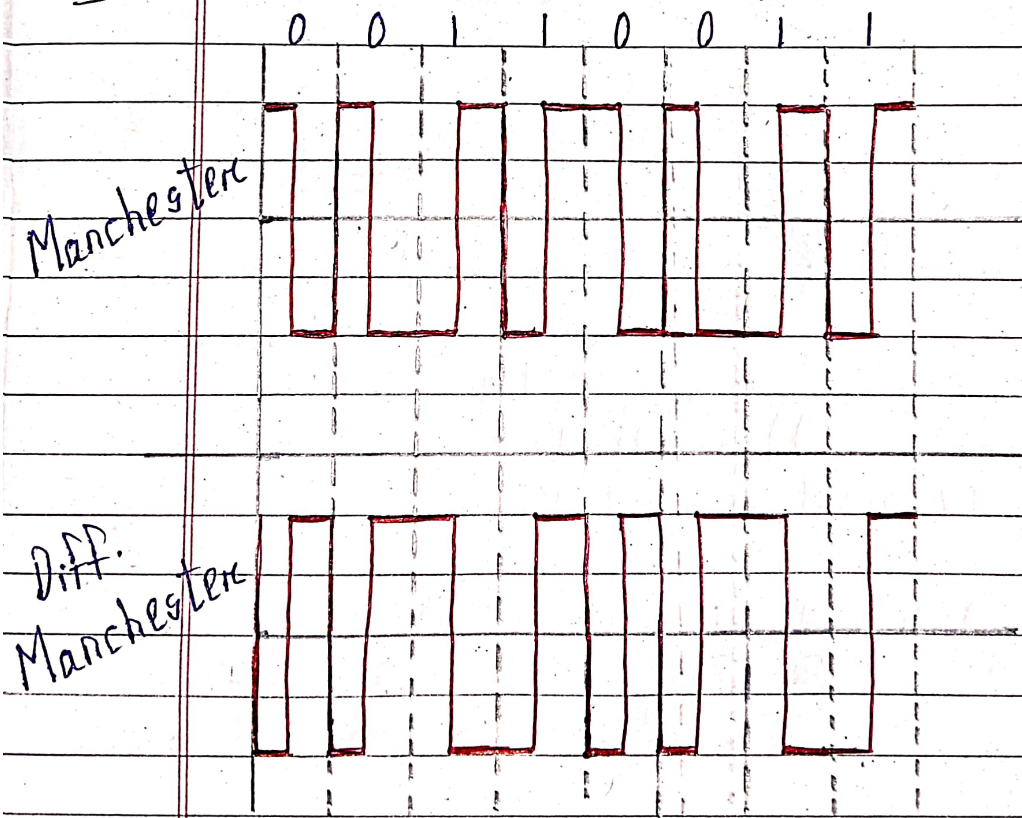
Q- 00110011 → ~~p~~unipolar



Q- 00110011 → NRZ-L & NRZ-I

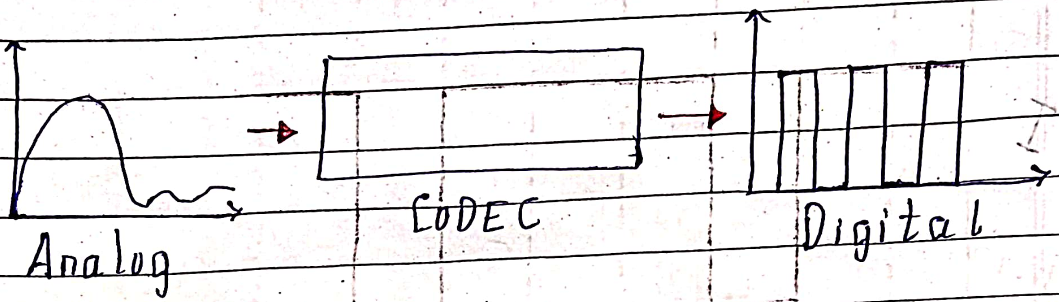


Q- 00110011 → Manchester & differential manchester



Analog to Digital Conversion

To send human voice over a long dist. we need to digitize it since digital signals are less prone to noise. This is called analog to digital conversion OR digitizing an analog signal.

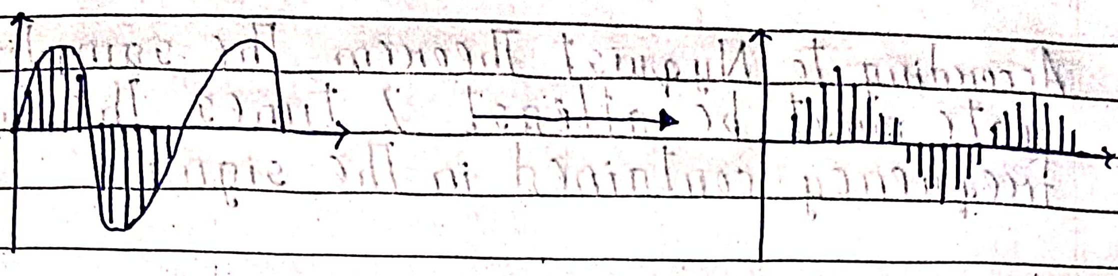


In A/D conversion we are representing the information contained in a cts wave form as a series of digital pulses. That is one's or zero's.

Pulse Amplitude Modulation

⇒ 1st step in A/D conversion is called *Pulse Amplitude Modulation (PAM)*. This technique takes an analog signal, sample it & generates a series of pulses based on the result of the sampling.

⇒ The term sampling means measuring the amplitude of the signal at equal intervals. PAM is the foundation of an important A/D conversion method called *Pulse code Modulation (PCM)*



PCM (Pulse Code Modulation)

⇒ PCM modifies the pulses created by PAM to create a completely digital signal.

⇒ PCM first quantizes the PAM pulse.

Quantization

⇒ It is a method of assigning integral values in a specific range to the sample instances.

⇒ Each value is translated into its 7 bits binary equivalent the 8th bit that is the MSB indicates the signed value.

How to find Sampling Rate ?

Nyquest → scientist

If highest frequency (HF) = x Hz

$$\boxed{\text{Sampling Rate} = 2 \times H.F = 2 \times x}$$

$$\boxed{\text{Bit rate} = \text{sampling rate} \times \text{No. of bits per sec}}$$

According to Nyquist Theorem, The sampling rate must be atleast 2 times The highest frequency contained in The signal.

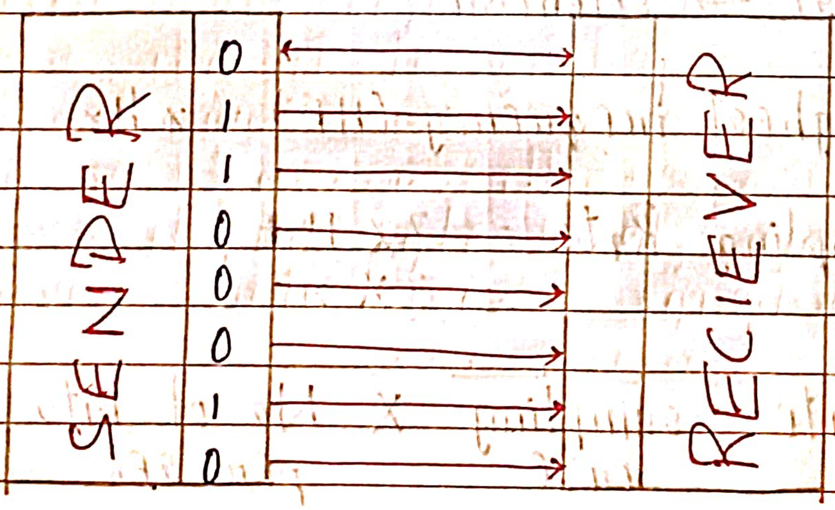
Digital Data Transmission

- Data Transmission
  - Parallel
  - Serial
    - Asynchronous
    - Synchronous

Parallel Transmission

⇒ Binary Data may be organised into group of n bits. It consists of 0's & 1's. By grouping we can sent That n bits at a time instead of 1. This is called Parallel Transmission.

⇒ The mechanism for a parallel Transmission is a concept That uses 'n' wires to send 'n' bits at one Time.



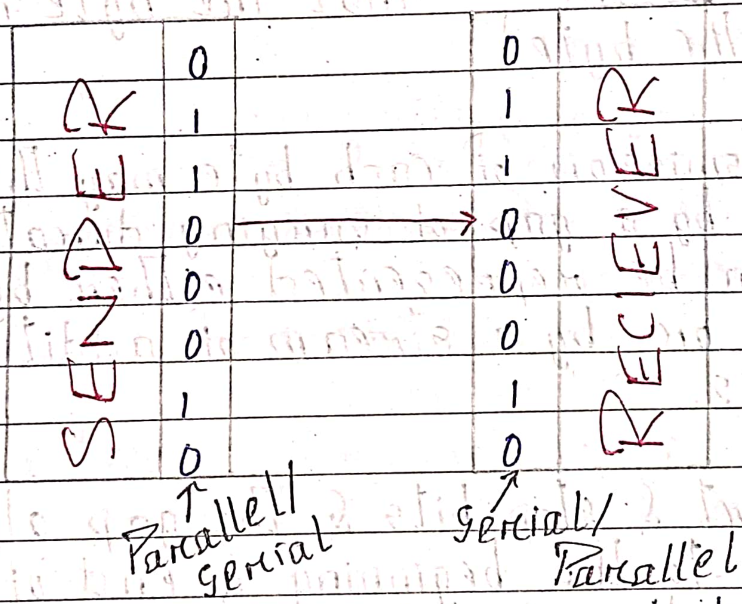
For 8 bits, 8 wires are bundled in a cable & are used for trans-mission.

Advantage :- Speed (increase the transform speed by a factor of n)

Disadvantage :- Cost (requires n connection lines just to transmit the data which is expensive)

Serial Transmission

⇒ In serial transmission, one bit follows another so we need only 1 communication channel rather than n to transmit data within 2 communicating devices.



Advantage :- Only 1 communication channel (reduces the cost by a factor of n)

1) Asynchronous Transmission

It is so named because the timing of the signal is not important. Information is recieved & translated by agreed upon the patterns. Pattern are based on grouping the bit stream into bytes.

The sending system handles each group independently, relaying it to the link whenever ready, without regards to a timer.

Bit 0 → start bit (To alert the reciever
(Used at beginning to the arrival of a
of each byte) new group)

Bit 1 → stop bit (To let the reciever know
(appened to the That the byte is finished)
end of the byte)

The transmission of each byte may then be followed by a gap of varying duration. This gap can be represented either by an idle channel or by a stream of additional stop bits.

The start & stop bits & the gap alert the reciever to the beginning & end of each byte & allow it to synchronize with the data stream.

This mechanism is called 'Asynchronous' because at the byte level, sender & reciever don't have to synchronized.

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The add^n of start & stop bits & the insertion of gaps make the transmission slower.

Eg: The connector of a terminal to a computer.

2) Synchronous Transmission

In this case, the bit stream is combined into longer frames which may contain multiple bytes.

In this mode, bits are sent one after other with start / stop bits or gaps.

It is the responsibility of the reciever to group the bits. Data are transmitted as an unbroken stream of 0's & 1's & the reciever separate that stream into bytes or characters.

Timing becomes very important thus the accuracy of the recieved information is completely dependent on the ability of the recieving device to keep an accurate count of the bits as they come in.

~~The~~ Advantage : Speed (No extra bits or gaps are there in the data stream).

2) Digitall To Analog Conversion

D/A modulation is The process of changing one of The characteristics of an analog signal based on The information in a digital signal (i.e. 0's & 1's).

Eg. Transmitting data from one computer to another using The public telephone lines.

D/A Conversion

ASK FSK PSK

QAM

ASK → Amplitude Shift keying
FSK → Frequency Shift keying
PSK → Phase Shift keying
QAM → Quadrature Amplitude Modulation (ASK + PSK)

Carrier Signal

In analog transmission, The sending device produces a high frequency signal That act as a basis for The information signal, This is called carrier signal.

Sender :- Modulating signal + Carrier signal = modulated signal

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The recieving device is tune to the frequency of the carrier signal that it expect from the sender. Digital signal is then modulated on the carrier signal by modifying one or more of its characteristics i.e. Amplitude, frequency, phase.

This kind of modification is called Modulation / shift keying & the information signal is called modulating signal.

i) ASK (Amplitude Shift keying)

⇒ In ASK the strength of the carrier signal is varies to represent binary 1 or 0. Both frequency & phase remains const while the amplitude changes.

⇒ Peak Duration → Period of time that define 1 bit.

⇒ The peak ~~ampltit~~ amplitude of the signal during each bit duration is const & it's value depends on the bits 0 or 1.

⇒ The speed of transmission using ASK is limited by the physical characteristics of the transmission medium.

⇒ Noise usually affects the amplitude. Thus, ASK is the modulating method most affected by noise.

Bandwidth for ASK :

$$\boxed{B = (1+d) * N_{baud}}$$

where N_{baud} = Baud rate

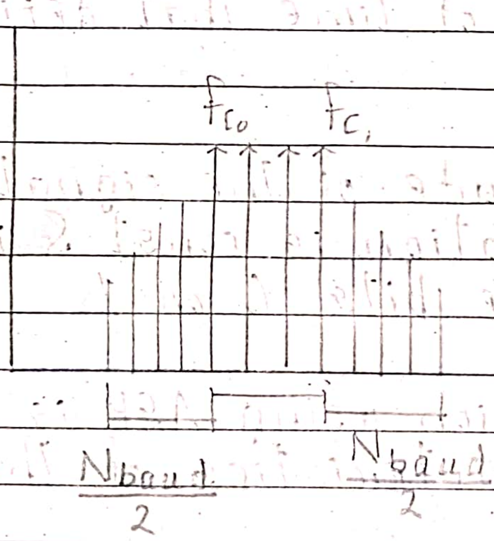
d = const. factor lies betn 0 & 1

ii> FSK (Frequency Shift keying)

=> In FSK, frequency of the carrier signal is varied to represent by binary 1 or 0. Here both amplitude & phase remain const.

=> FSK avoids most of the noise problems of ASK.

Bandwidth for FSK



$$B = 2(f_{c_1} - f_{c_0}) + N_{baud}$$

$f_{c_1} - f_{c_0} \longrightarrow$ diff in the carrier frequency

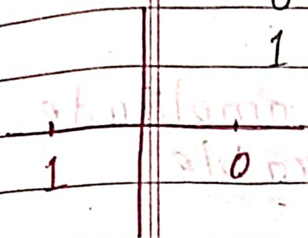
$$\frac{N_{baud}}{2} + \frac{N_{baud}}{2} = N_{baud}$$

iii> PSK (Phase Shift keying)

=> In PSK, the phase of the carrier is varying to represent by binary 1 or 0. Here both amplitude & frequency remain const.

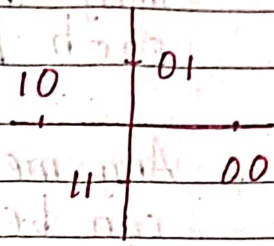
2 PSK

0 → 0°
1 → 180°



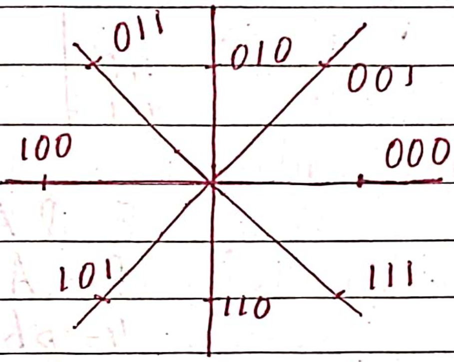
4 PSK

00 → 0°
01 → 90°
10 → 180°
11 → 270°



8 PSK

000 → 0°
001 → 45°
010 → 90°
011 → 135°
100 → 180°
101 → 225°
110 → 270°
111 → 315°



Bandwidth for PSK

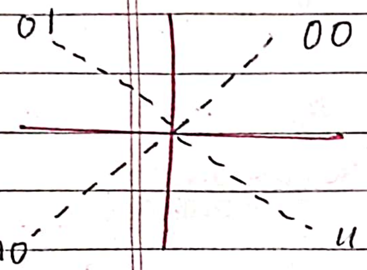
Minimum Bandwidth → same as ASK.

=> The max^m bite rate in PSK is potentially much greater than that of ASK. So, with this bit rate the bandwidth can be 2 or more times greater.

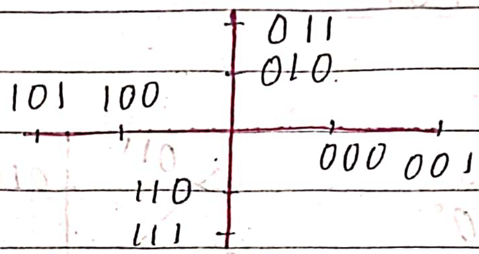
iv) <u>QAM</u>

It means combining ASK & PSK in such a way that we have max^m contrast bet^n each bit, dibit, tribit etc.

Any measurable no. of changes in amplitude can be combined with any measurable changes phases.



4 QAM
1 - Amp
4 - Phase



8 QAM
2 - Amp
4 - phases

In both cases the no. of amplitude shift is less than no. of phase shift.

<u>Bandwidth for QAM</u>

Same as that required for ASK & PSK transmission.

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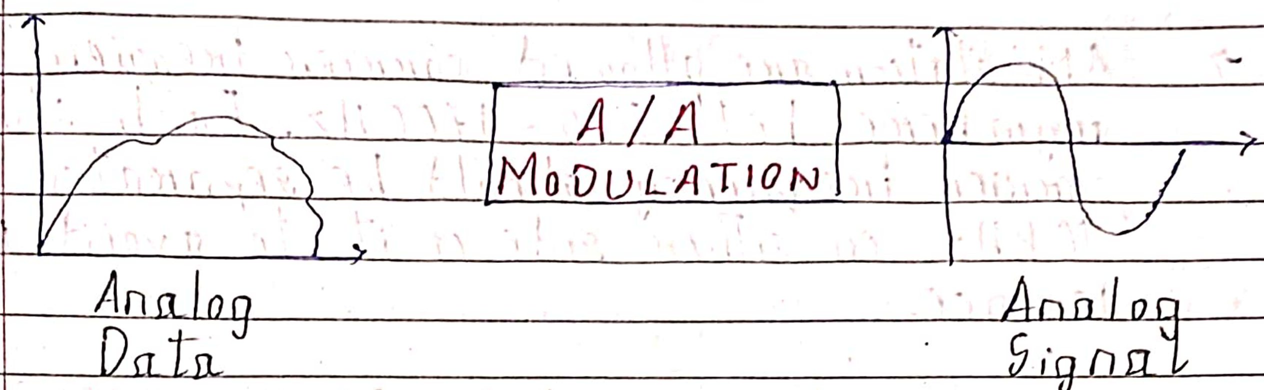
3) Analog to Analog Transmission



A/A conversion is the representation of analog information by an analog signal.
Eg. Radio.

It can be accomplished in 3 ways:-
1) AM (Amplitude Modulation)
2) FM (Frequency Modulation)
3) PM (Phase Modulation)

1) AM

In AM transmission the carrier signal is modulated so that its amplitude varies with the change in amplitude of the modulating signal.

AM Bandwidth

The bandwidth of an AM signal is twice the bandwidth of the modulating signal.

$$\boxed{BW_T = 2 \times BW_M}$$

AM Band Allocation

⇒ AM station are allowed carrier frequency anywhere betn 530 - 1700 Hz. Each station carrier frequency should be separated by 10 kHz on either side of it to avoid interference.

⇒ BW of audio signal ⟶ 5 kHz
AM radio station requires min. B.W of 10 kHz

NOTE FCC (Federal Communication Commission) allows 10 kHz for each AM station.

2) FM

⇒ In FM transmission the frequency of carrier signal is modulated to follow the changing voltage level i.e. Amplitude of the modulating signal

⇒ The peak amplitude & phase of the carrier signal remain const. but as the amplitude of the information signal changes, the frequency of the carrier changes.

FM Bandwidth

$$\boxed{BW_T = 10 \times BW_m}$$

10 times the BW of the modulating signal

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BW of stereo Audio → 15 kHz
FM station requires a BW of 150 kHz.
FCC requires min. BW of 200 kHz

3) PM

⇒ In PM transmission the phase of the carrier signal is modulated to changing the voltage level i.e. amplitude of the modulating signal.

⇒ The peak amplitude & frequency of the carrier signal remain const. As the amplitude of the information signal changes, the phases of the carrier changes.

Q- Calculate the BW require for each of the following AM station. This regard FCC rules.
i) modulating signal with a BW of 4 kHz.
ii) modulating signal with a BW of 8 kHz.
iii) modulating signal with frequencies of 2000 - 3000 Hz.

A- i) $2 \times 4 = 8$ kHz
ii) $8 \times 2 = 16$ kHz
iii) $B = (3000 - 2000)$
$= 1000 \times 2 = 2000$ Hz.

Error Detection & Correction

Types of Errors

i) Single bit error : It means that only 1 bit of a given data unit is changed from 1 to 0 or from 0 to 1.

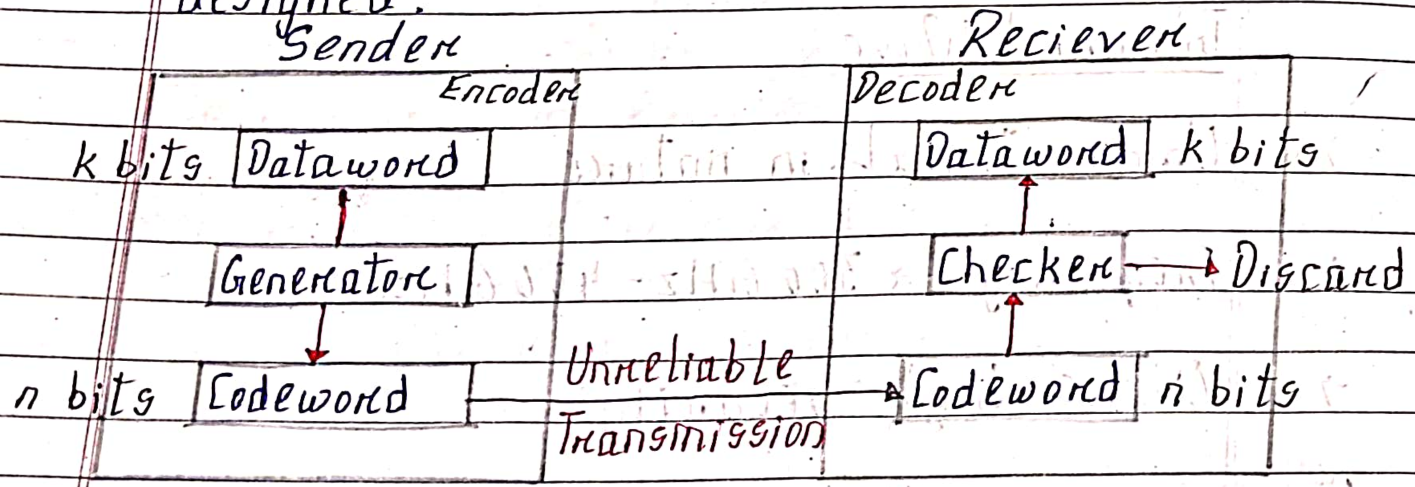
ii) Burst error : It means that 2 or more bits in the data unit have changed from 1 to 0 or from 0 to 1.

Redundancy

The concept of detecting & correcting errors is called redundancy.

Error Correction

An error detecting code can detect only the types of errors for which it is designed.



Error detection methods are:
i) VRC (Vertically Redundancy check)
ii) LRC (Longitudinal Redundancy check)
iii) CRC (Cyclic Redundancy check)
iv) Checksum

i) VRC

⇒ In VRC, a redundant bit that is called parity bit is added to every data unit so that the total no. of 1's become even.

⇒ When the data unit reached its destⁿ, the reciever put all 8 bits through an even parity funcⁿ checking, if the reciever found an even ~~func~~ no. But if the reciever found that the total no. of 1's is odd then it shows an error & thus, the whole unit rejected.

Eg. APPLE

a = 97 1100001 → 11000011
p = 112 1110000 → 11100001
p = ~~108~~ 112 1110000 → 11100001
l = 108 11011000 Even parity
e = 101 11001010 Even parity

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Advantage : It can detect all single bit errors. It can also detect burst error as long as the no. of bits is change to odd.

Disadvantage : It can't detect error where the total no. of bits are even. where the 2 bits of data unit are changed.

ii) LRC

=> LRC verifies the accuracy of store trans-mitted data using parity bit.

=> It's a redundancy check applied to a parallel group of bit streams. The data to be transmitted is divided into transmission blocks into which the additional check data is inserted.

Q- Consider a message word
10110110 01000101 11101001
Determine the decision of checker unit of reciever when
i) There is no error in the recieved code word.
ii) There are 3 bits in error due to burst error of length 5-bits.
iii) There are 8 bits in error due to burst error of length 12 bits.

A- Assuming The block size as 8 bits, The LRC can be calculated as follows :-

10110110
01000101 Perform XOR operations
11101001

$\boxed{00011010}$ → LRC.

Now, The recieved code word is :-
10110110 01000101 11101001 00011010

NOTE If The recieved code word doesn't contain any errors Then Their XOR operations will give 0 as result.

i) 10110110
01000101
11101001
00011010

00000000

It will accept The recieved code word.

ii) 10110110
11101001
0
00011010 → 00001111

00010101

It will go for rejecting code & wants to retransmites it.

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iii) 1 0 1 1 0 1 1 0
01000101 → 0 0 1 0 1 1 0 0
1101001 → 1 0 0 0 0 1 0 1
0 0 0 0 1 1 0 1

0 0 0 1 0 0 1 0

It will go for rejecting the code & want to retransmites it.

⇒ An LRC can detect easily n bits having n bits of burst error. However if 2 bits in one data units are damaged & 2 bits exactly the same position in another data unit are changed then an LRC checker will not detect the error.

iii) <u>CRC</u>

⇒ Let m be the highest power of x in g(x).

⇒ Append 'm' no. of zeroes to the func^n f(x) to get M(x).

⇒ Divide $\frac{M(x)}{g(x)}$ using modulo-2 division.

<u>Modulo-2</u>

0 - 0 = 0
1 - 0 = 1
1 - 1 = 0
0 - 1 = 1

⇒ Let R(x) be remainder.

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⇒ Add $R(x)$ to $M(x)$ to get $T(x)$

⇒ The reciever divides $T(x)$ by $g(x)$. If the remainder is 0. Then the reciever will accept the ~~…~~ fram, else it discard the frame.

Q- Data word = 100100.
key = $x^3 + x^2 + 1$
Find the recieved code word.

A- $f(x) = 100100$
$g(x) = x^3 + x^2 + 1 \rightarrow 1101$
m = 3

$x^3 + x^2 + \cancel{x^1} + 1$
1 1 0 1

$M(x) = 100100000$

```
          111101
1101 ) 100100000
       1101
        1000
        1101
         1010
         1101
          1110
          1101
           0110
           0000
            1100
            1101
             001  → R(x)
```

```
  100100000
+       001
  100100001
```
$\underbrace{100100001}_{CRC}$

```
          111101
1101 | 100100001
       1101↓
        1000
        1101↓
         1010
         1101↓
          1110
          1101↓
           0110
           0000↓
            1101
            1101
             000   accepted
```

iv) <u>Checksum</u>

=> For data detection by checksums, data is divided into fixed sized frames.

=> The sender adds the frames using 1's complement arithmetic to get the sum. It then complements the sum to get the checksum & sends it along with the data frames.

=> The reciever adds the incoming frames along with the checksum using 1's complement arithmetic to get the sum & then complement it.

=> If the result is 0, the recieved frames are accepted; otherwise they are discarded

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Q- The given data packet of 16 bits is :-
10101001 00111001

The chekksum is of 8 bits. Determine the data pattern sent by the sender including checksum bits. Also determine the decision of the checker unit of reciever node if the recieved data pattern is :-

i) There is no error.
ii) There is burst error of length 5 that affects 4 bits.

A-
```
  10101001
  00111001
  --------
  11100010
1's complement
  00011101
```

The recieved code is
10101001 00111001 00011101

i)
```
  10101001
  00111001
  00011101
  --------
  11111111
1's complement
  00000000
```

The recieved code doesn't have any error.

ii> 1010100001 → 10101010
00111001 → 01011001
00011101

```
      1 1
  1 1 1 1 1 1 1
    1 0 1 0 1 0 1 0
    0 1 0 1 1 0 0 1
    0 0 0 1 1 1 0 1
  -----------------
  1 0 0 0 0 0 0 0 0
                 +1
  -----------------
    0 0 0 0 0 0 0 1
```

1's complement → 11011110

The recieved code has error & it has to retransmites it.

Hamming Code (Error Correction)

9	8	7	6	5	4	3	2	1
D_9	P_8	D_7	D_6	D_5	P_4	D_3	P_2	P_1

Parity pos^n is fixed.

D_7 D_6 D_5 P_4 D_3 P_2 P_1

⇓

Hamming code

Even

$P_1 = 1, 3, 5, 7, 9, 11$
$P_2 = 2, 3, 6, 7, 10, 11$
$P_3 = 4, 5, 6, 7.$
$P_4 = 8, 9, 10, 11$

Always check for even parity

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Q- A communication system employs (7, 4) hamming code for error detection. If a message sequence is 1101, find the transmitted code.
Show how the parity bits indicate the pos^n of an error in the recieved code if 3rd bit from RHS is recieved in error.

A-

D_7	D_6	D_5	P_4	D_3	P_2	P_1
1	1	0		1		

$P_1 = 0$
$P_2 = 1$
$P_4 = 0$

Hamming code
1100110

Let the 3rd bit is error. so now the code will be

D_7	D_6	D_5	P_4	D_3	P_2	P_1
1	1	0	0	0	1	0

$P_1 = w$ $\quad$ $w = 1$
$P_2 = x$ $\quad$ $x = 1$
$P_4 = y$ $\quad$ $y = 0$

$$\begin{matrix} y & x & w \\ 0 & 1 & 1 \end{matrix} \longrightarrow 3$$

$\therefore$ The 3rd pos^n in the data is error.

DATA LINK CONTROL

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1) Line Discipline

coordinates the link system. It determines which device can send & when it can send.

2) Flow Control

coordinates the amount of data that can be sent before recieving acknowledgement.

3) Error control

allows the reciever to inform the sender to any frames lost OR damaged in transmission & coordinates the retransmission of these frames by the sender.

1) <u>Line Discipline</u>

Can be done in 2 ways :-

i) ENQ / ACK
ii) Poll / Select

ENQ → Enquiry
ACK → Acknowledgment
NAK → -ve ACK

i) <u>ENQ / ACK</u>

⇒ Used for point-to-point communication

<u>How it Works?</u>

⇒ The initiator first transmits a frame called <u>ENQ</u> asking if the reciever is ~~able~~ available to recieve data.

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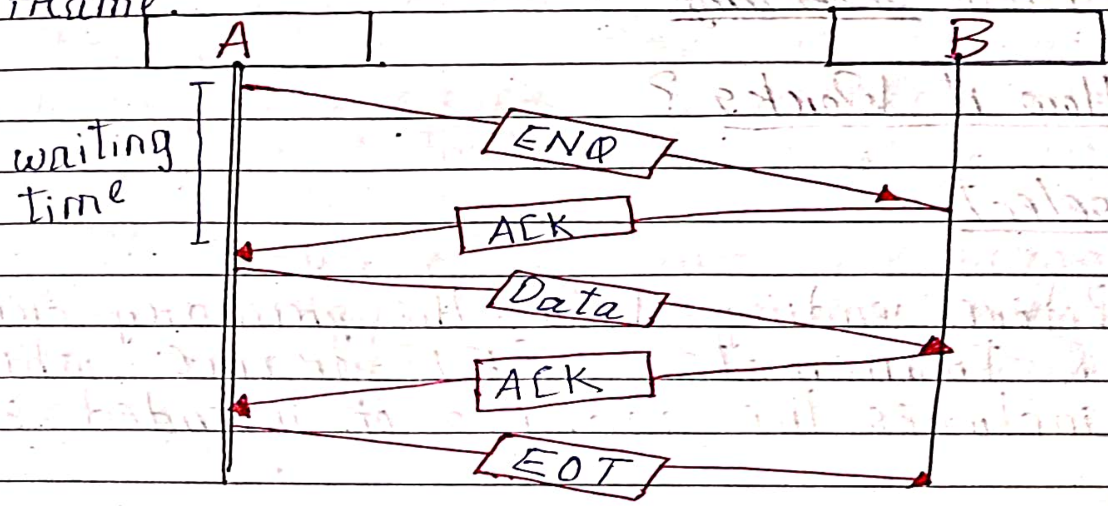
=> The reciever must answer either with an ACK frame (if it is ready) or with a NAK frame (if it is not ready).

=> If neither an ACK nor a NAK is recieved within a specified time limit, the initiator assumes that the ENQ frame was lost in transit, disconnects, & sends a replacement.
An initiating system ordinarily makes 3 such attempts to establish a link before giving up

=> If the response is -ve → initiator disconnects & begin the process at another time.

=> If the response is +ve → initiator is free to send the data.

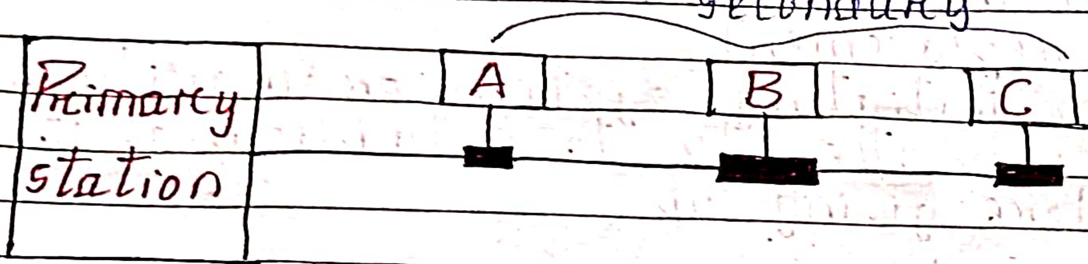
=> Once all the data have been transmitted. The sending system finishes with EOT frame.



ii) <u>Poll / Select</u>

=> Works with multi-point connections.

=> The primary decides which of the several secondary nodes has the right to use the channel. Thus, it is the initiator of a session.



=> If the primary wants to recieve the data, it asks the secondary, if they have anything to send. This func^n is called <u>Polling</u>.

=> If the primary wants to send data, it tells the secondary to get ready to recieve the data frame. This func^n is called <u>selecting</u>.

<u>How it Works?</u>

<u>select</u>

=> Before sending data, the primary creates & transmits a SEL frame which includes the address of intended secondary

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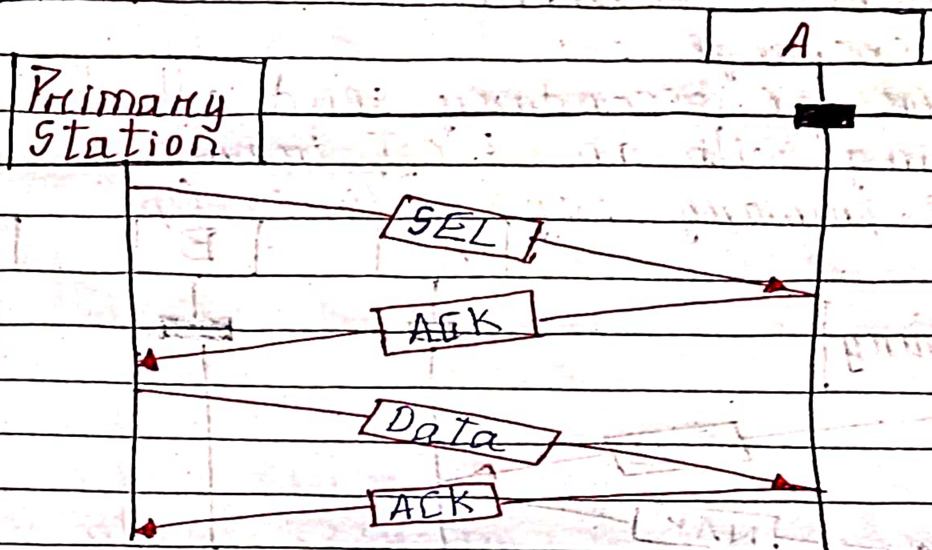
=> If the secondary is aware & running, it returns an ACK from to the primary

=> The primary then sends one or more data frames.



poll

=> When the primary is ready to recieve data, it must ask (Poll) each secondary device in turn if it has anything to send.

=> When the 1st secondary is approached, it responds either with a NAK frame or with a data frame

=> If the response is -ve → the primary then polls the 2nd secondary in the same way until it finds one with data to send.

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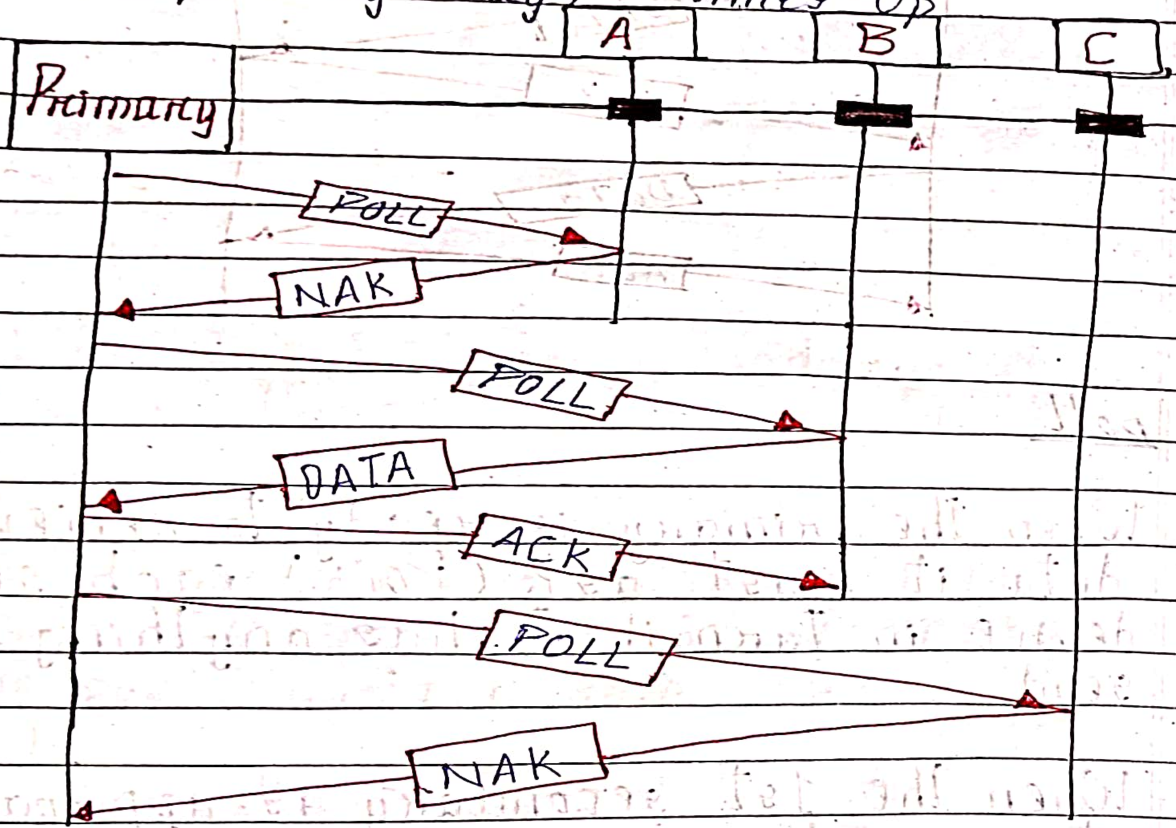
⇒ When the response is +ve → The primary reads the frame & returns an ACK frame.

⇒ There are 2 possibilities of terminating the exchange :-
i) either the secondary send all of its data, timing with an EOT frame.
ii) The primary says "Times Up"



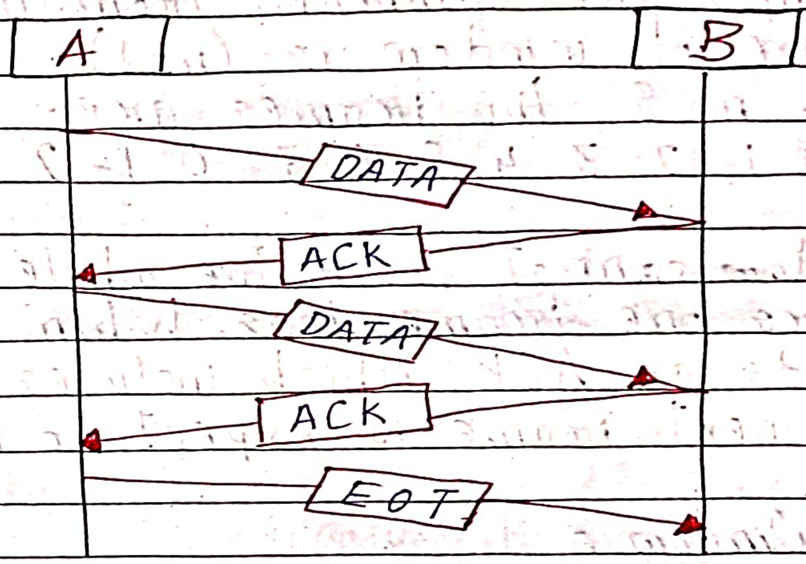
2) Flow Control

Can be done using 2 methods :-
i) stop and wait
ii) sliding window

ii) stop-and-wait

=> The sender sends one frame & waits for an acknowledgement before sending the next frame.

=> This process gets repeated until the sender transmits an EOT frame.



iii) sliding Window

=> The sender can transmit several frames before needing an ACK. So, the channel capacity can be used efficiently.

=> The reciever acknowledges only some of the frames, using a single ACK frame to confirm the reciept of multiple data frames.

⇒ The sliding window refers to imaginary boxes at both the sender & reciever.

⇒ This window can hold frames at either end & provides the upper limit on the no. of frames that can be transmitted before requiring an ACK.

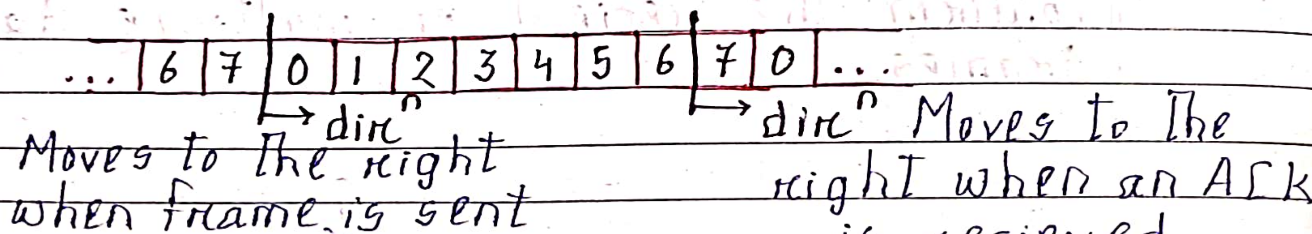
⇒ The frames are numbered from 0 to (n-1). The size of window is (n-1).
For eg. n = 8, the frames are -
0, 1, 2, 3, 4, 5, 6, 7, 0, 1, 2, ...

⇒ The window cannot cover the whole module. It covers one frame less. When the reciever sends an ACK which includes the no. of the next frame is expect to recieve.

<u>Sender Window :-</u>

⇒ As the frames are next out, the left boundary of the window moves inward, shrinking the size of the window.

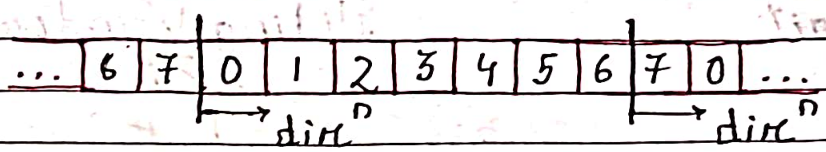
⇒ Once the ACK arrives, the window expands to allow in a no. of new frames equal to the no. of frames acknowledged by that ACK.



Reciever Window :

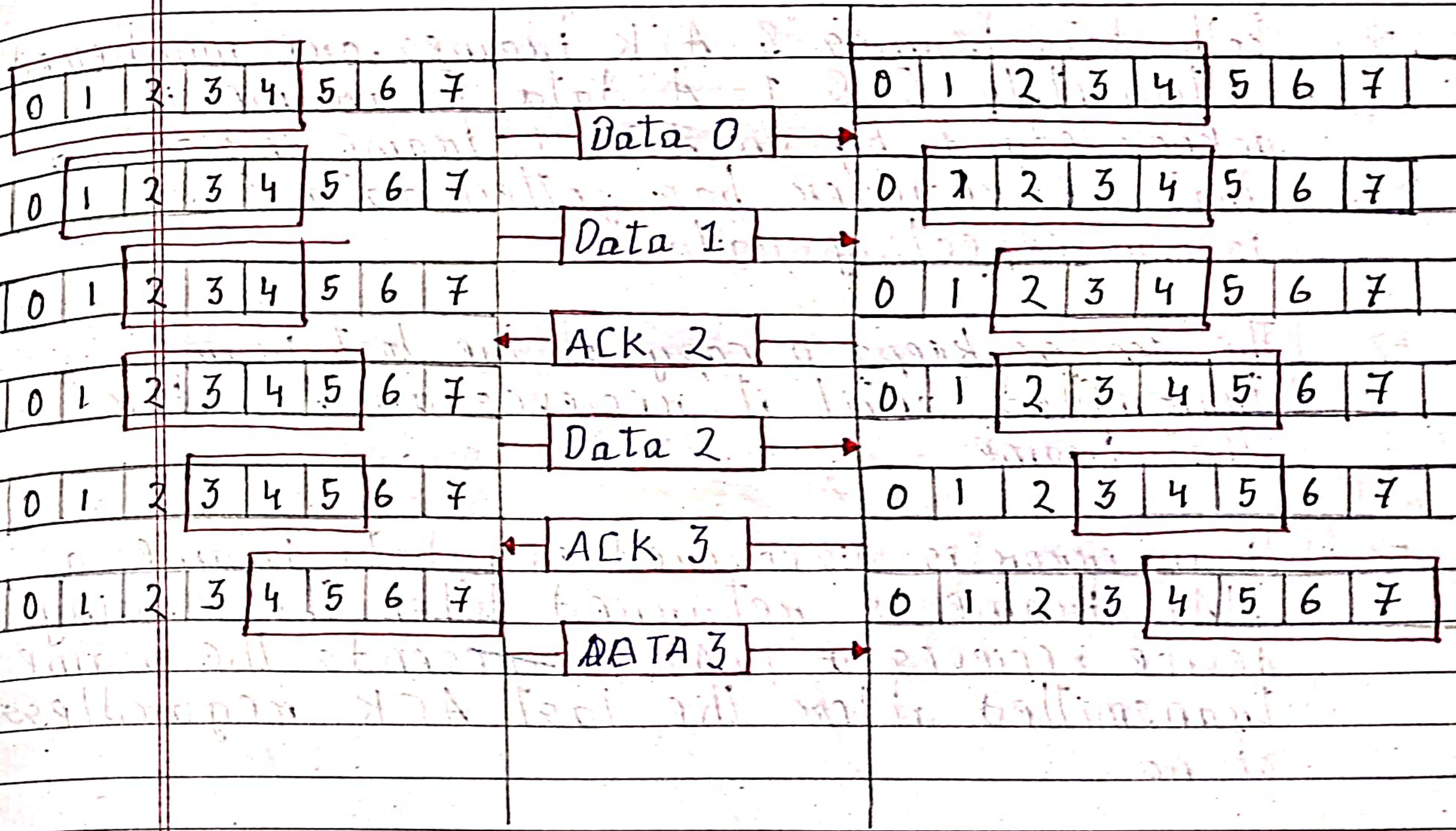
=> As new frame comes in, the size of the reciever window shrinks, i.e. left wall moves to the right.

=> As soon as ACK is sent, the window expands to include places for a no. of frames equal to the no. of frames acknowleged.



Moves to right when frame is recieved

Moves when an ACK is sent



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3) **Error Control**

Whenever an error is detected by the reciever node a NAK is returned & the specified frames are retransmitted. This process is called automatic repeat request (ARQ)

Error Control

- Stop-and-wait ARQ
- Sliding Window ARQ
  - Go-Back-n
  - Selective repeat

Stop-and-wait ARQ

=> Both data frames & ACK frames are numbered alternately 0 & 1. A data 0 frame is acknowledged by an ACK 1 frame, indicating that the reciever has gotten data 0 & is now expecting data 1.

=> The sender keeps a copy of the last frame transmitted until it recieves an ACK for that frame

=> If an error is discovered in a data frame, a NAK frame is returned. When the sending device recieves a NAK, it resends the frame transmitted after the last ACK, regardless of no.

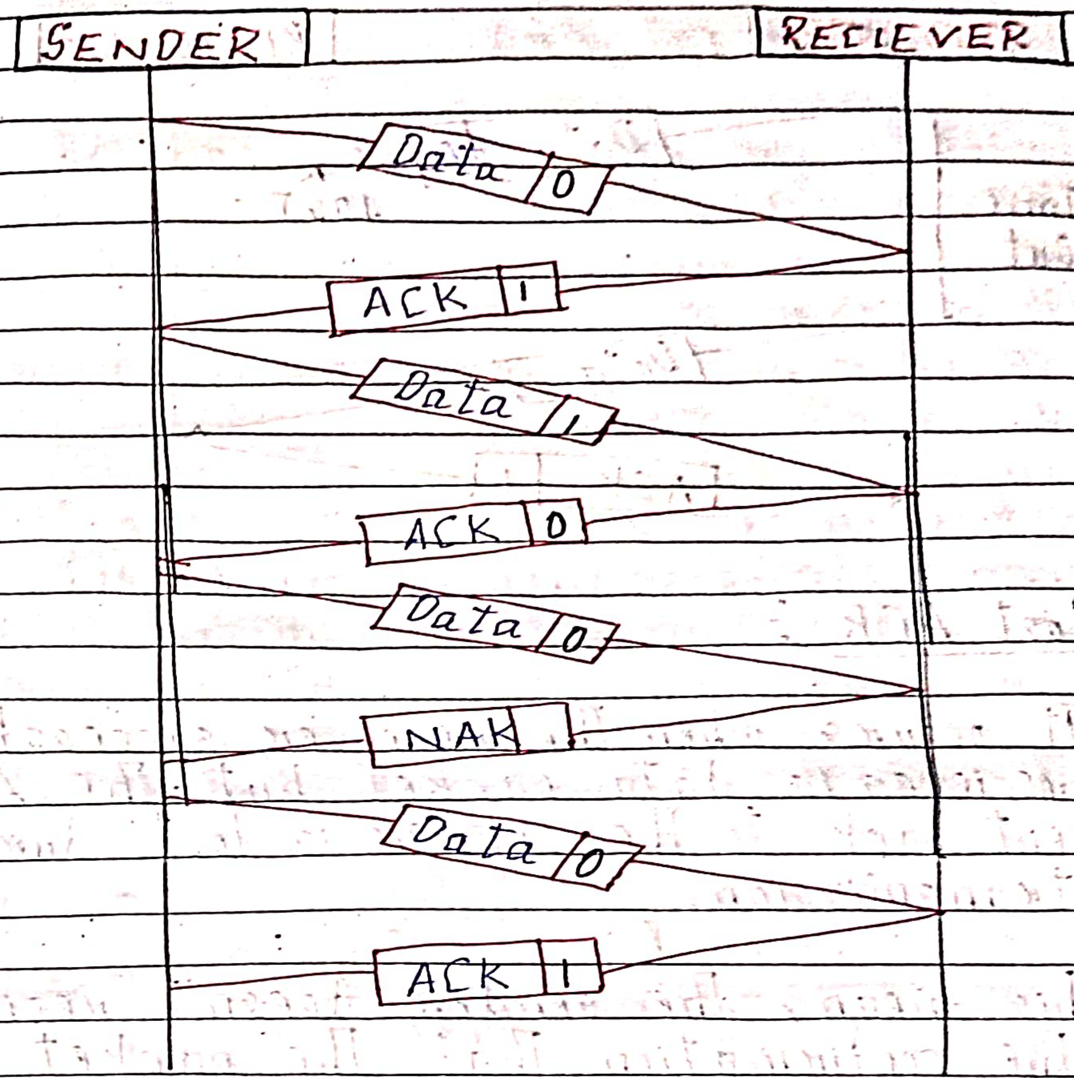
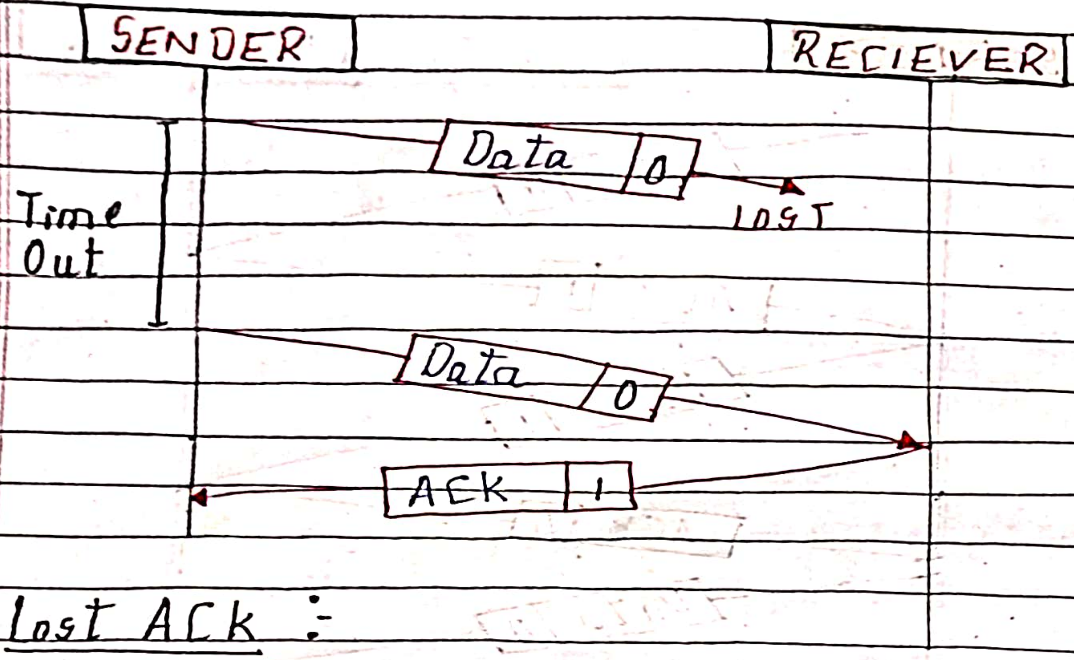


Fig. Damaged Corrupted Frame

Lost data frame :-

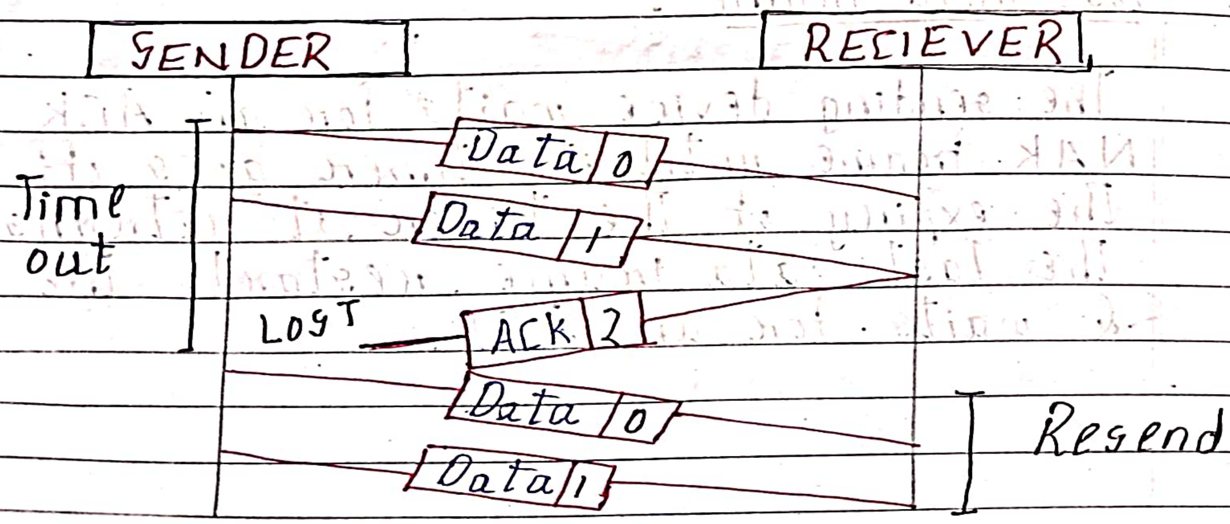
The sending device waits for an ACK or NAK frame until its timer goes off. After the expiry of the timer, it retransmits the last data frame, restarts the timer & waits for an ACK.



Lost ACK :-

⇒ It occurs when the reciever successfully recieves a data packet but the ACK sent back to the sender is lost during transmission.

⇒ This means the sender doesn't recieve the confirmation that the packet was delivered, leading it to assume the data packet was lost & initiate a retransmission



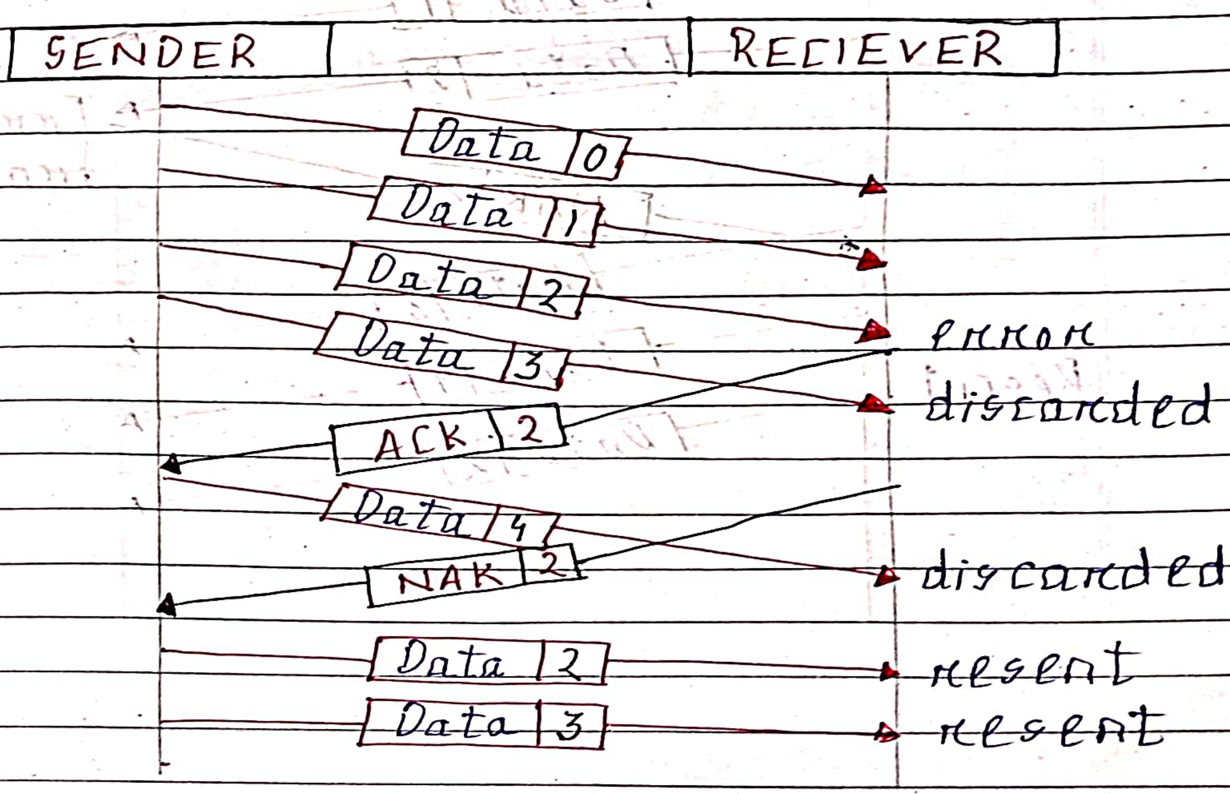
Go-Back-n ARQ

If one frame is lost or damaged, all frames sent since the last frame acknowledged are retransmitted.

Damaged Frame :-

=> As soon as the reciever discovers an error, it transmits a NAK frame to the sender & stops accepting subsequent frames until the damaged frame has been replaced correctly.

=> After recieving the NAK, the sending device goes back to frame & retransmits all the frame.

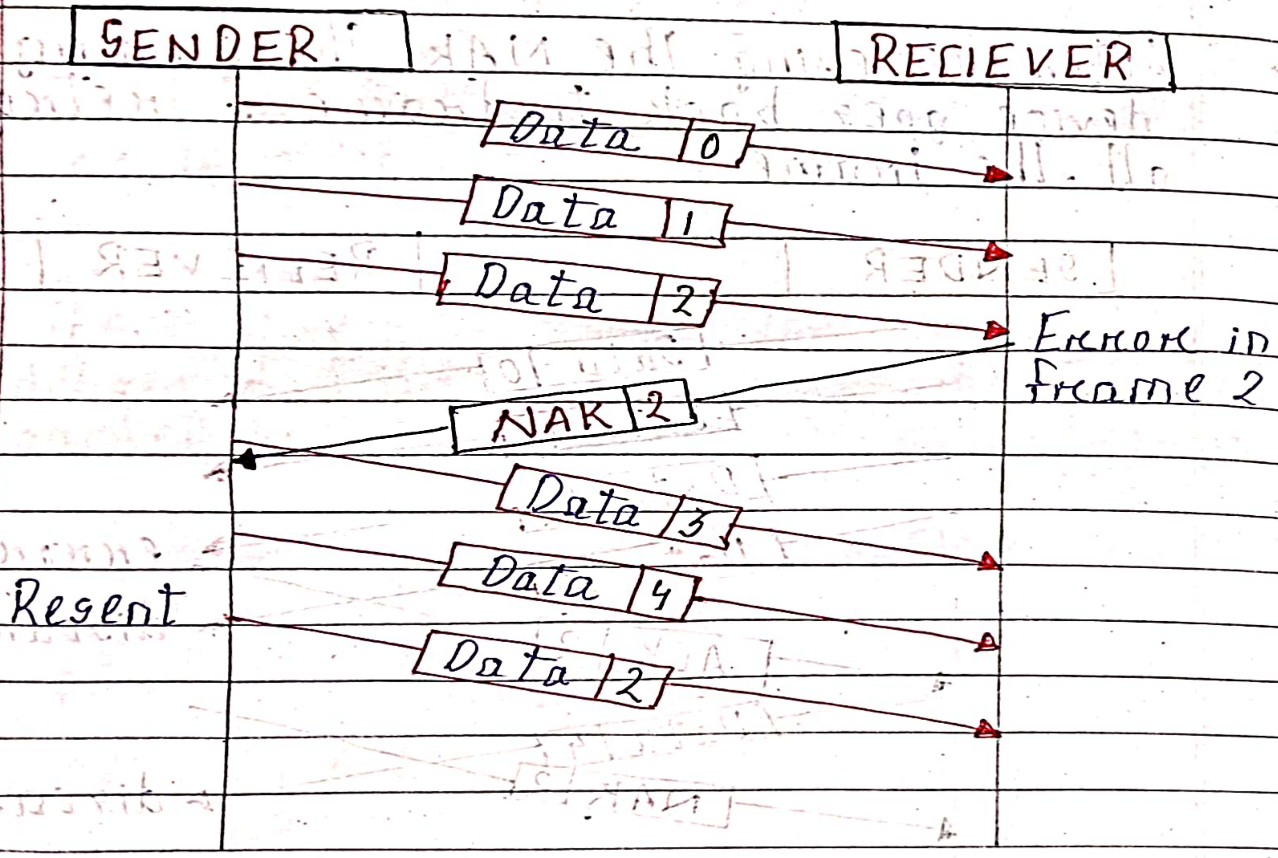


Selective-repeat ARQ

⇒ Only the specific damaged or lost frame is retransmitted.

⇒ If a frame is corrupted in transit, a NAK is returned & the frame is resent out of sequence.

⇒ The recieving device must be able to sort the frames it has & insert the retransmitted frame into its proper place in the sequence.

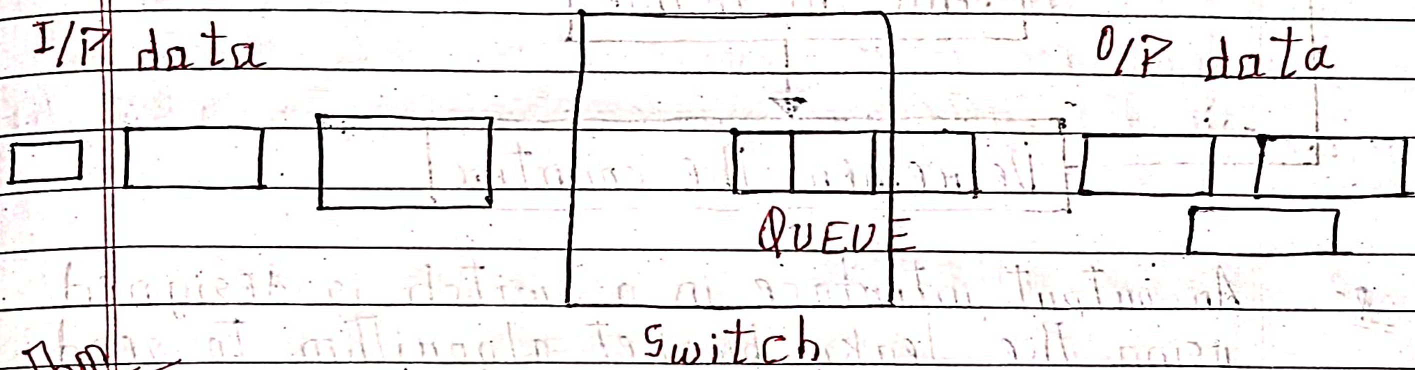


Congestion Control

When too many packets are present in the network it causes packet delay & loss of packet which degrades the perfomance of the system. This situation is called congestion.

To control the congestion, leaky bucket algorithm is used.

Leaky Bucket Algorithm

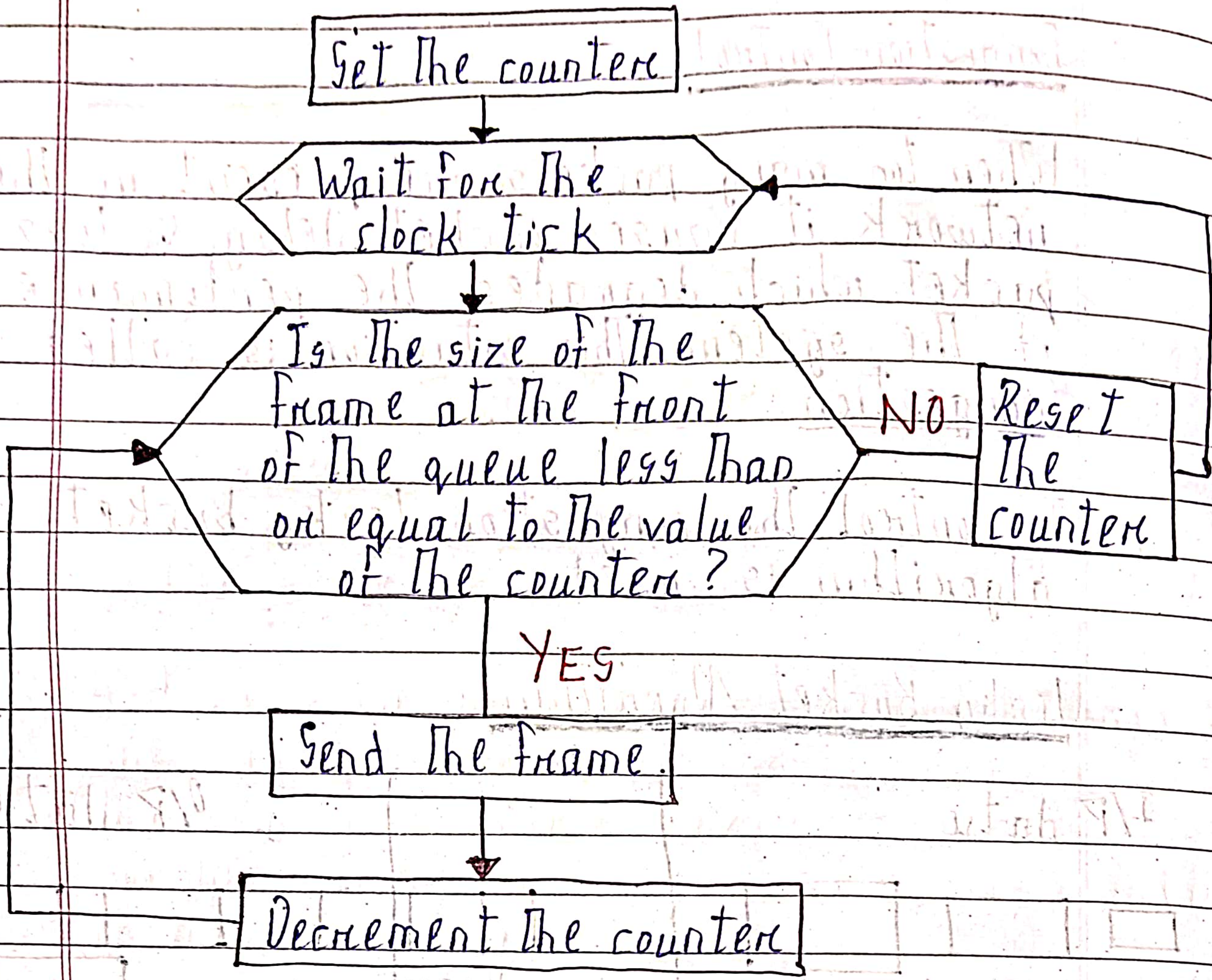


Algorithm

1) Initialize the counter to 'n' at the tick of the clock.

2) If n > size of the packet, send the packet & decrement the counter by the packet size.

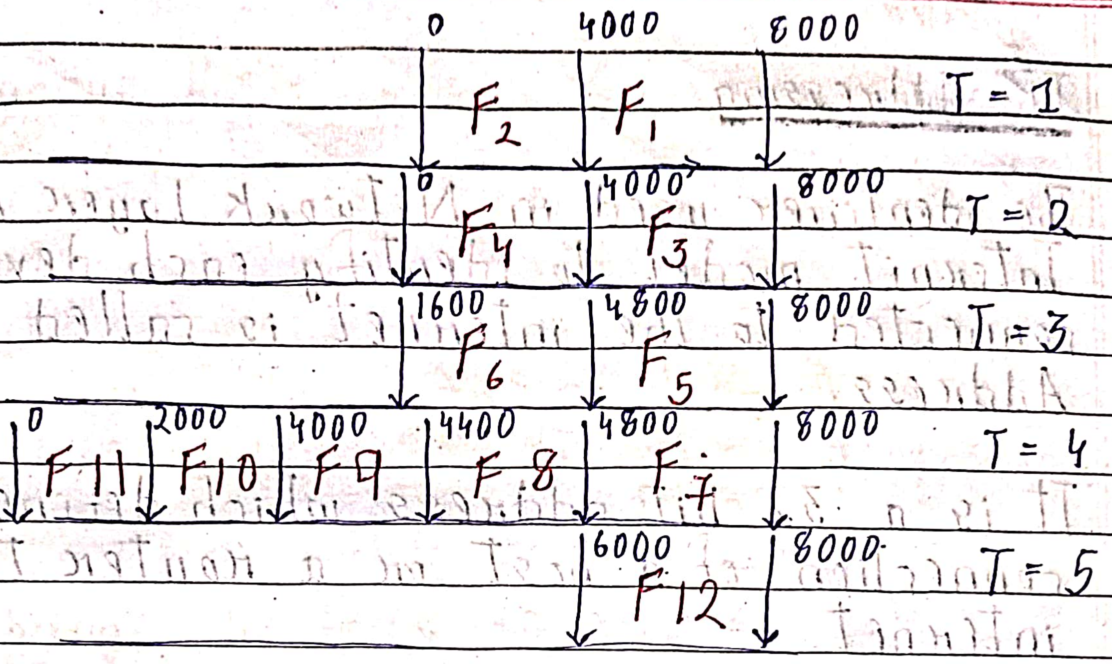
3) Repeat the counter & go to step 1.



Q- An output interface in a switch is designed using The leaky bucket algorithm to send 8000 bytes per second. If The following frames are recieved in sequence, so The frames That are sent during each second;

Frames 1, 2, 3, 4 → 4000 bytes each
Frames 5, 6, 7 → 3200 bytes each
Frames 8, 9 → 400 bytes each
Frames 10, 11, 12 → 2000 bytes each

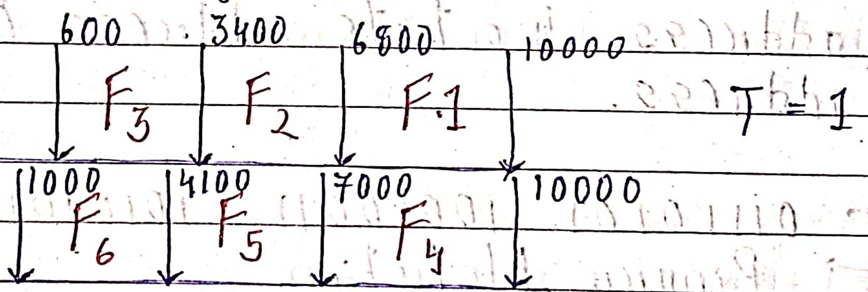
A-



Q- An output interface in a switch is designed using the leaky bucket algorithm to send 10000 bytes per second. If the following frames are recieved in sequence then show the frames that are sent during each second

Frame 1 → 3200 bytes
Frame 2 → 3400 bytes
Frame 3 → 2800 bytes
Frame 4 → 3000 bytes
Frame 5 → 2900 bytes
Frame 6 → 3100 bytes

A-



IP Addressing

⇒ The identifier used in Network Layer of The Internet model to identify each device connected to The internet is called IP Address.

⇒ It is a 32 bit address which defines The connection of a host or a router to The internet.

⇒ 2 devices on The internet can never have The same address at The same time However, if a device has 2 connection to The internet Through 2 networks Then it has 2 IP addresses.

Binary Notation

An IP address referred to as a 32 bit address, 4 octate address OR 4 byte address.

01110101 10010011 10101010 11110000
↳ Binary Notation

117.147.170.240
↳ Dotted Decimal Notation

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Q- Change The following IP address from binary to dotted decimal notation.

1) 10000001 00001011 00001011 11101111
129 . 11 . 11 . 239

2) 11111001 10011011 11111011 00001111
249 . 155 . 251 . 15

Q- Change The Following dotted notation to binary.

1) 111.56.45.78
01101111. 00111000. 00101101 01001110

2) 75.45.34.78
01001101 00101101 00100010 01001110

Classful Addressing

The address pair is divided into 5 ~~pairs~~: classes :-
A, B, C, D, E

Bytes		1st	2nd	3rd	4th (MSB)
A	→	0			
B	→	1	0		
C	→	1	1	0	
D	→	1	1	1	0
E	→	1	1	1	1