Topics:

1. Data Communications
2. Network
3. Topology
4. Network Types

① Data Communications

Data - information presented in whatever form is agreed upon by the parties creating and using the data.

Telecommunication - communication at a distance.

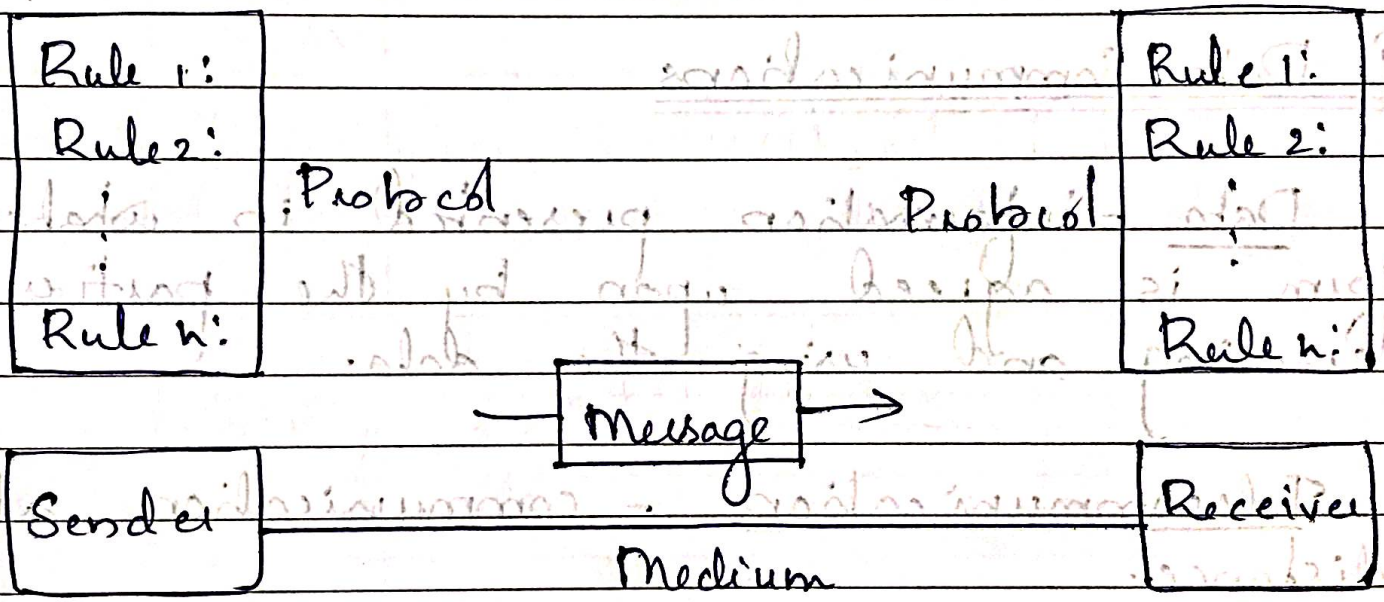
Data communications are the exchange of data between 2 devices via some form of transmission medium.

Characteristics

- Delivery - Reach intended user.
- Accuracy - No alteration

- Timeliness - Real time transmission
- Jitter - variation in packet arrival time. (speed of network)

Components of a data communication System



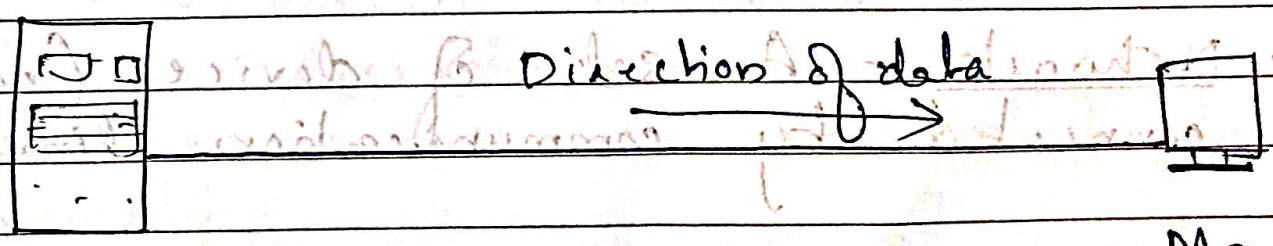
1. Message
2. Sender
3. Receiver
4. Transmission medium
5. Protocol

Data Representation

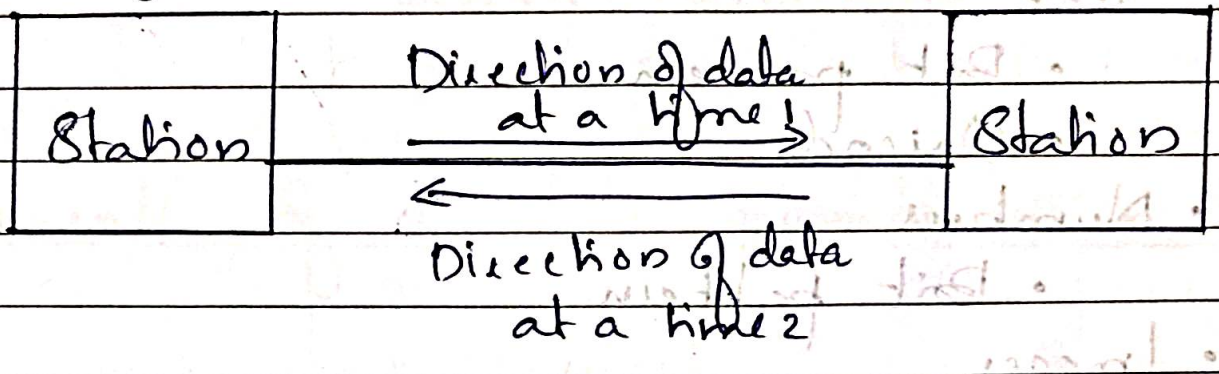
- Text
  - Bit pattern
  - Unicode
- Numbers
  - Bit pattern
- Images
  - Pixels - bit pattern 00, 01, 10, 11
  - RGB / YCM (2^8)
- Audio
  - Continuous
- Video
  - Continuous entity / combination of entity

Data flow (simplex, half-duplex, full-duplex)

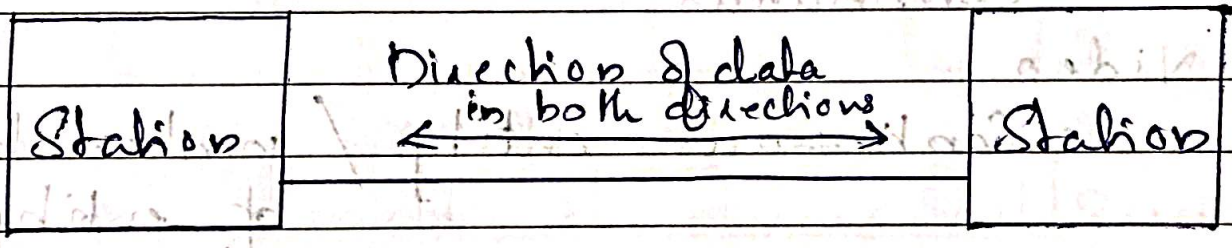
(a) Simplex



(b) Half - duplex



(c) Full - duplex (Bidirectional : Data flow)
(Both transmission takesplace in both direction)



(2) Networks

- Network - A set of devices (nodes) connected by communication links.

Node - It is a medium of data transmission, It can be a computer, printer or any other devices capable of sending or receiving data generated by other nodes on the network.

Link - It can be a cable, air, optical fibre or any transmission media.

Network Criteria

> Performance
  > Depends on Network Elements
  > Measured in terms of Delay & Throughput.

> Reliability
  > Failure rate of network components
  > Measured in terms of availability / robustness

> Security
  > Data protection against corruption/ loss of data due to:
    - Errors
    - Malicious users

> Type Of Connection

> Point to point - single transmitter & receiver.

> Multipoint - multiple recipients of single transmission.

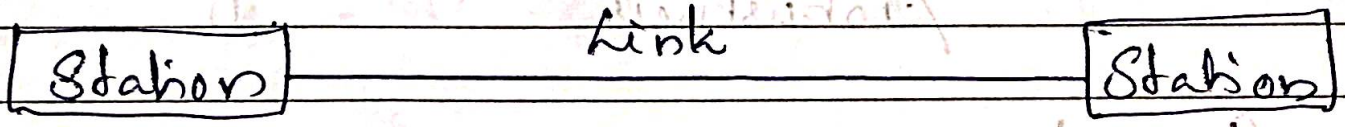
> Physical Topology

> Connection of devices

> Type of transmission - unicast, multicast, broadcast.

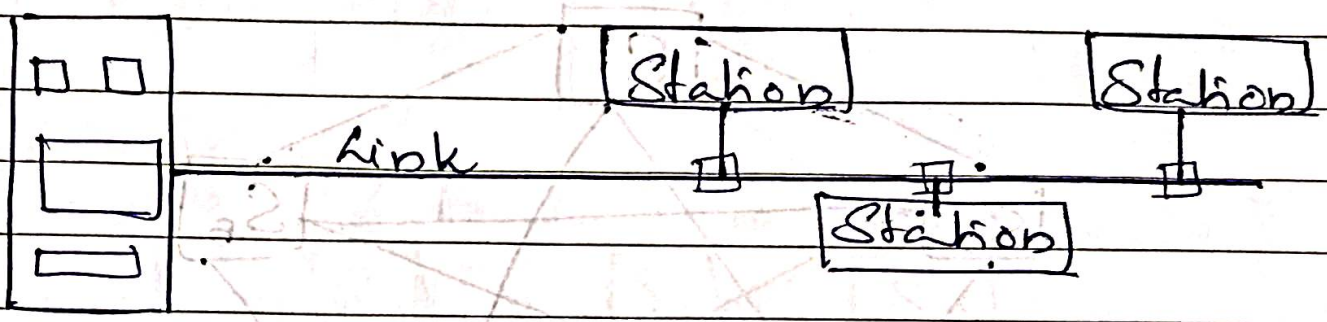
Types of connections : point-to-point & multipoint.

(a) Point to Point :



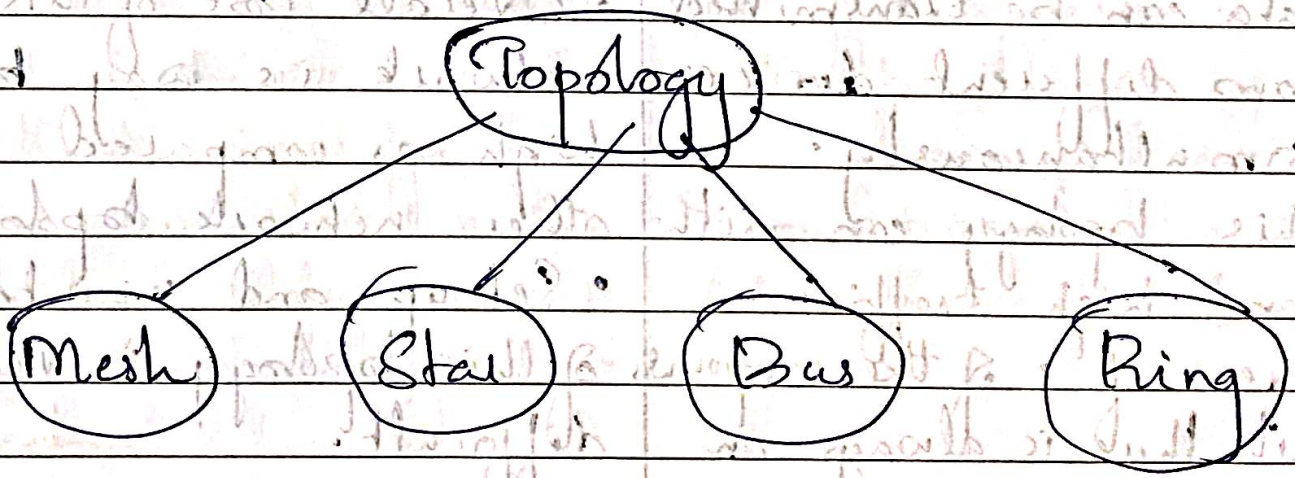
Eg: Normal call

(b) Multipoint

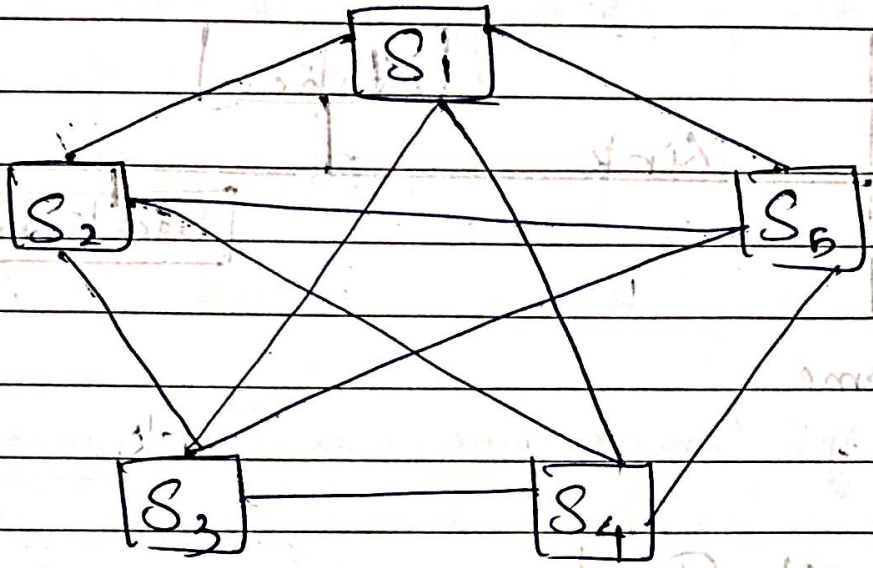


eg: Conference call.

(3) Categories Of Topology

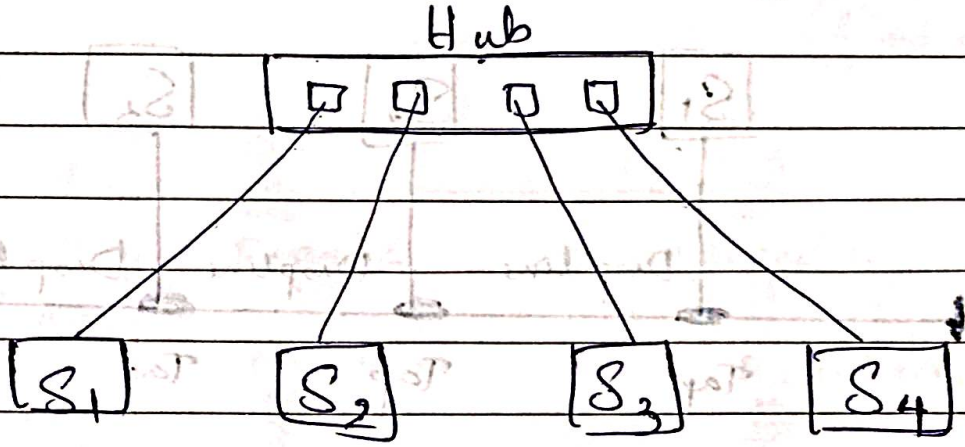


① Fully Connected Mesh Topology (5 devices)



Adv.	Dis Adv
• Data can be transmitted from different devices simultaneously.	• Overall cost of this network is way too high as compared to other network topologies.
• This topology can withstand high traffic.	• Set-up and maintenance of this topology is very difficult.
• Even if 1 of the components fails there is always an alternative present.	• More cabling is required as compared to bus, star & ring topology.
• Each can carry it own data load.	• Complicated.
• Provides security & privacy.	• Connections not fully utilized

② Star Topology Connecting 4 stations



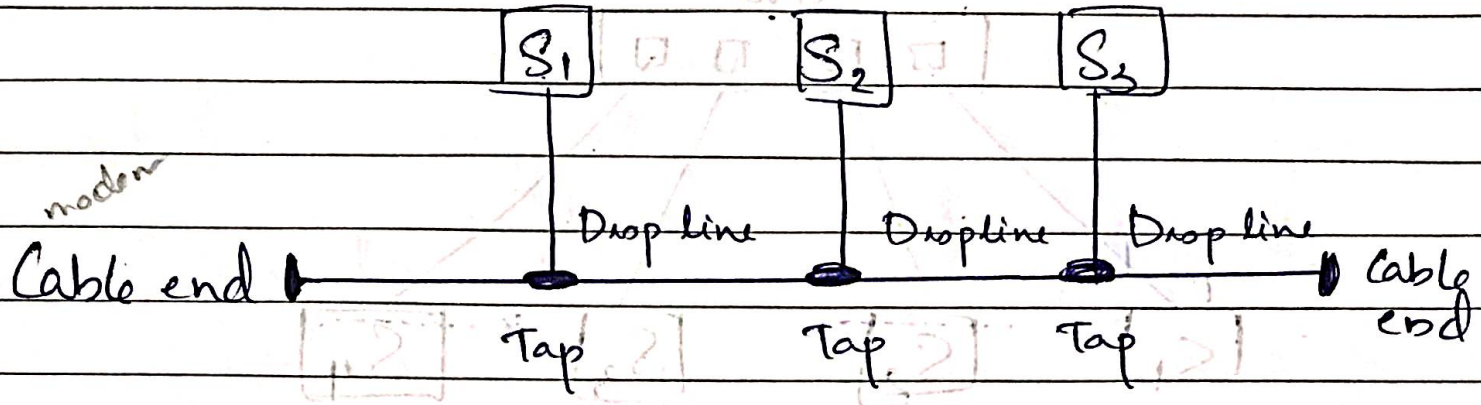
adv

- A new node can be easily connected to the existing network by connecting it with unused port of hub.
- If the is fault in cable connected with computer, only the particular computer get affected.
- Less cables required than Mesh Topology ∴ Affordable by small organization also

disadv

- If Hub or switch get faulty, all computer connected to it will be get affected.
- Traffic increased when computers are simultaneously sending data to each other.

(3) Bus Topology connecting 3 stations



adv	disadv
• Easy to connect computer or peripheral to a linear bus.	• Entire network shuts down if there is a break in the main cable.
• Uses less cables than mesh topology.	• Difficult to identify the problem if the entire network shut down.
• Don't need any special device like Hub or Switch.	• Terminators are required at both ends of the back bone cable.

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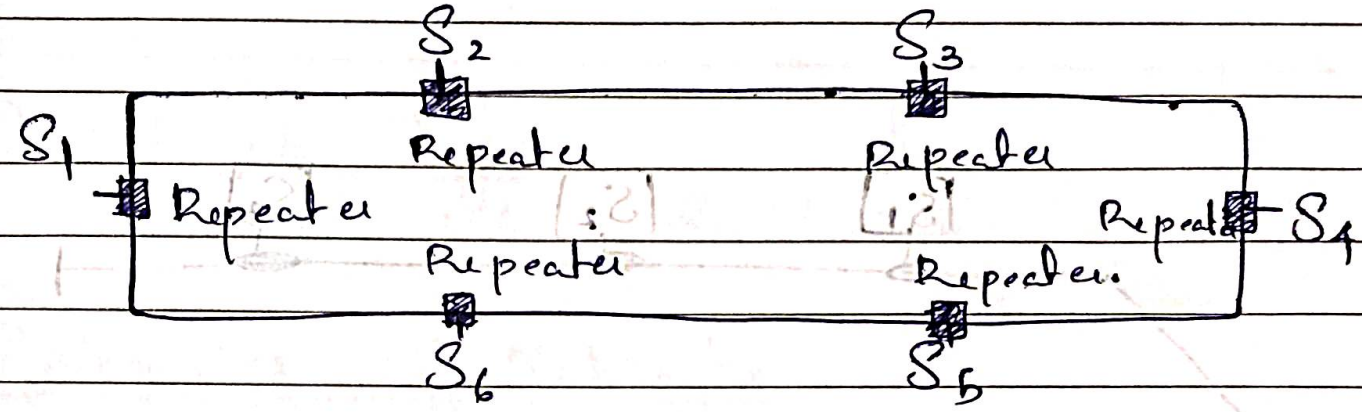
(4) Ring Topology Connecting 6 stations (Unidirectional)



adv

- Each node gets to send the data when it receives an empty token. This helps to reduces chances of collision.
- The transmission of data is relatively simple as packets travel in one direction only.
- Every computer serves as a repeater to boost signals & send it to the next node along with the token & data.

disadv

- Each packet of data must pass through all the computers between source & destination. This makes it slower.
- If one workstation or port goes down, the entire network gets affected.
- Difficult to add & remove devices once the network has been setup.
- Data sharing accomplished through one direction only

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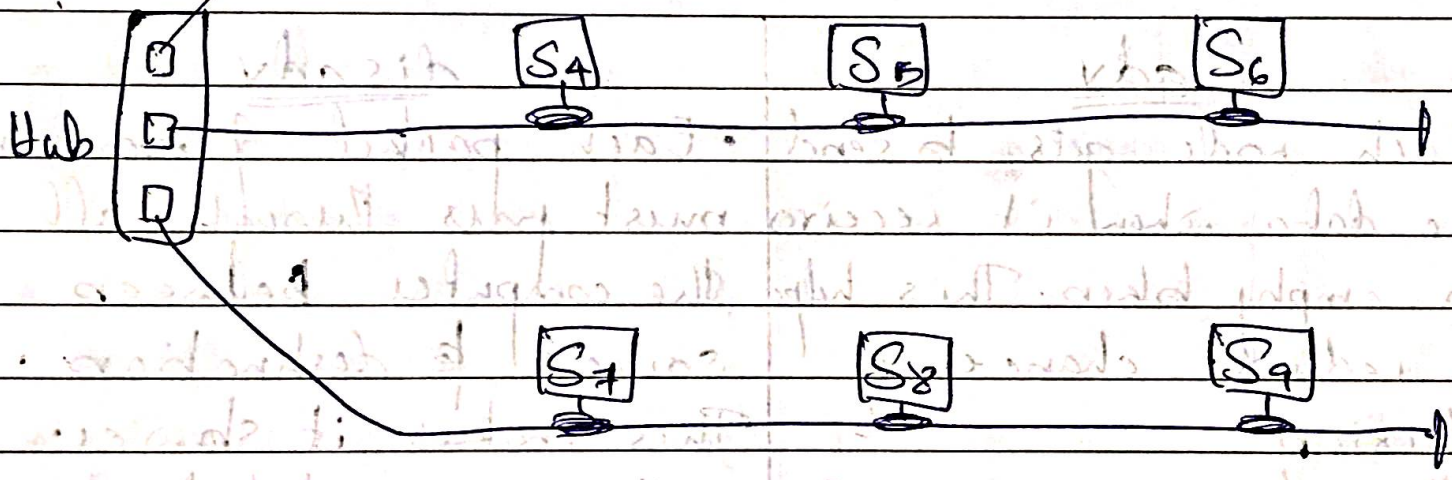
⑤ Hybrid Topology :- A star backbone with 3 bus networks



- Very largely used topology
- Combination of star & bus topology.

Topics:

(5) Network Models
(6) OSI reference model

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(4) Network Types

> LAN, WAN, Switching

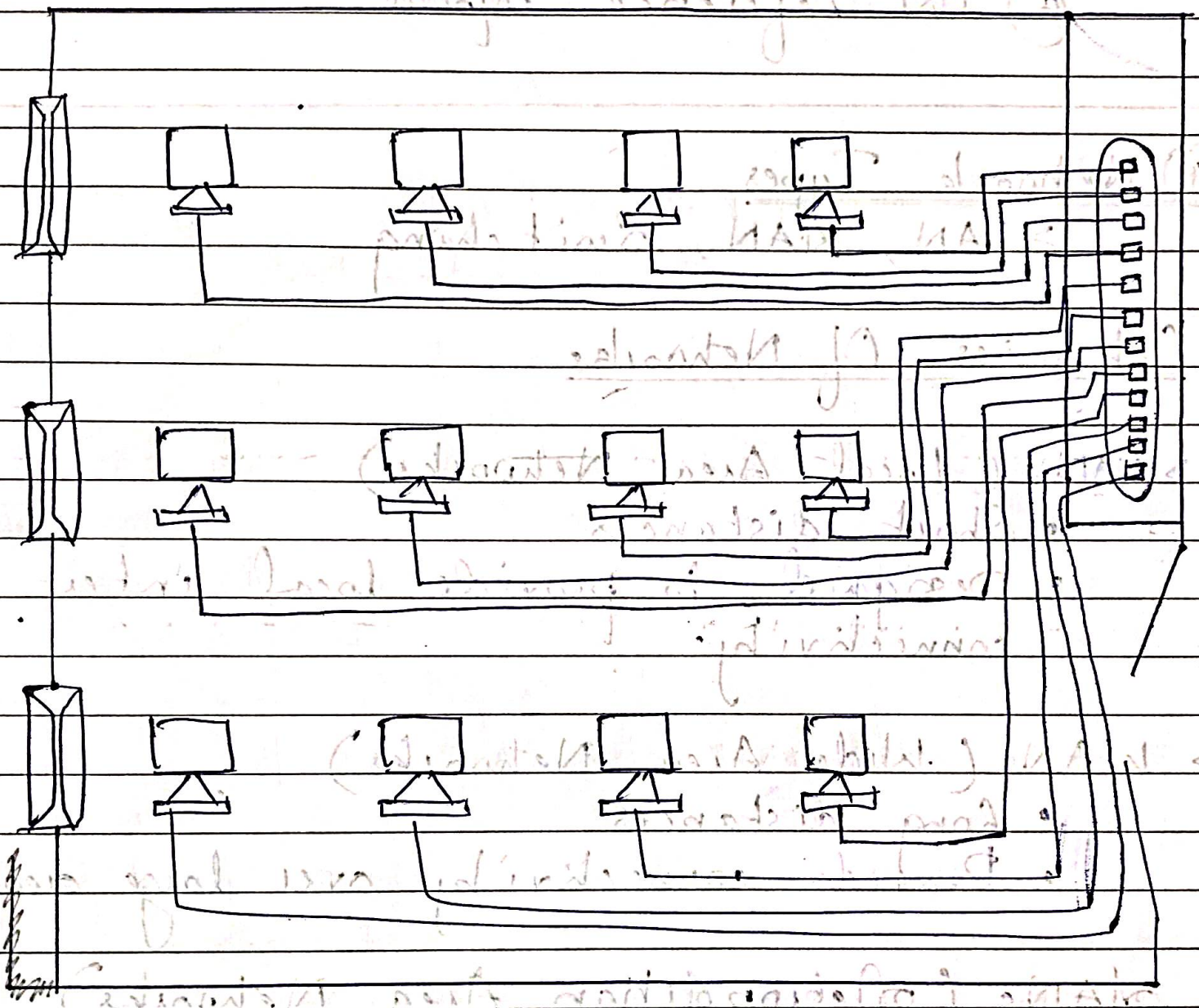
Categories Of Networks

> LANs (Local Area Networks)
- Short distances
- Designed to provide local interconnectivity.

> WANs (Wide Area Networks)
- Long distances
- Provide connectivity over large areas

> MANs (Metropolitan Area Networks)
- Provide connectivity over areas such as a city, a campus.

An isolated LAN connecting 12 computers to a hub in a closet.



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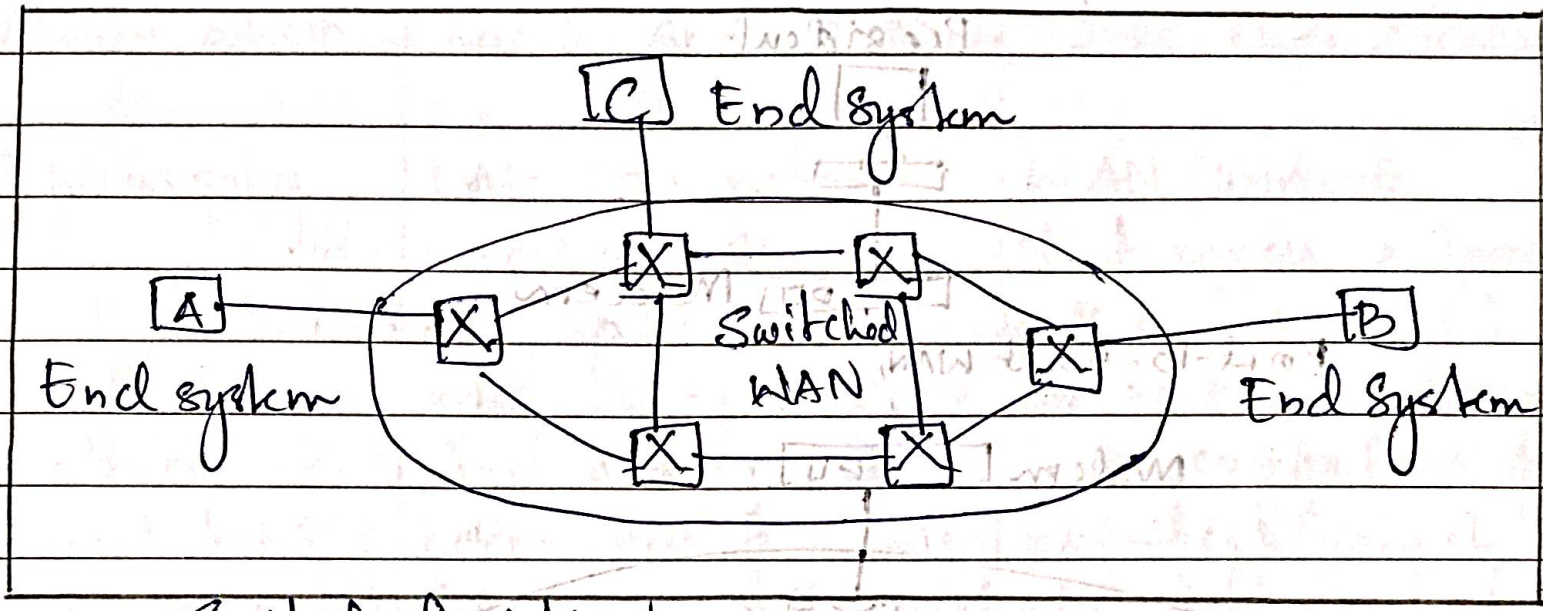
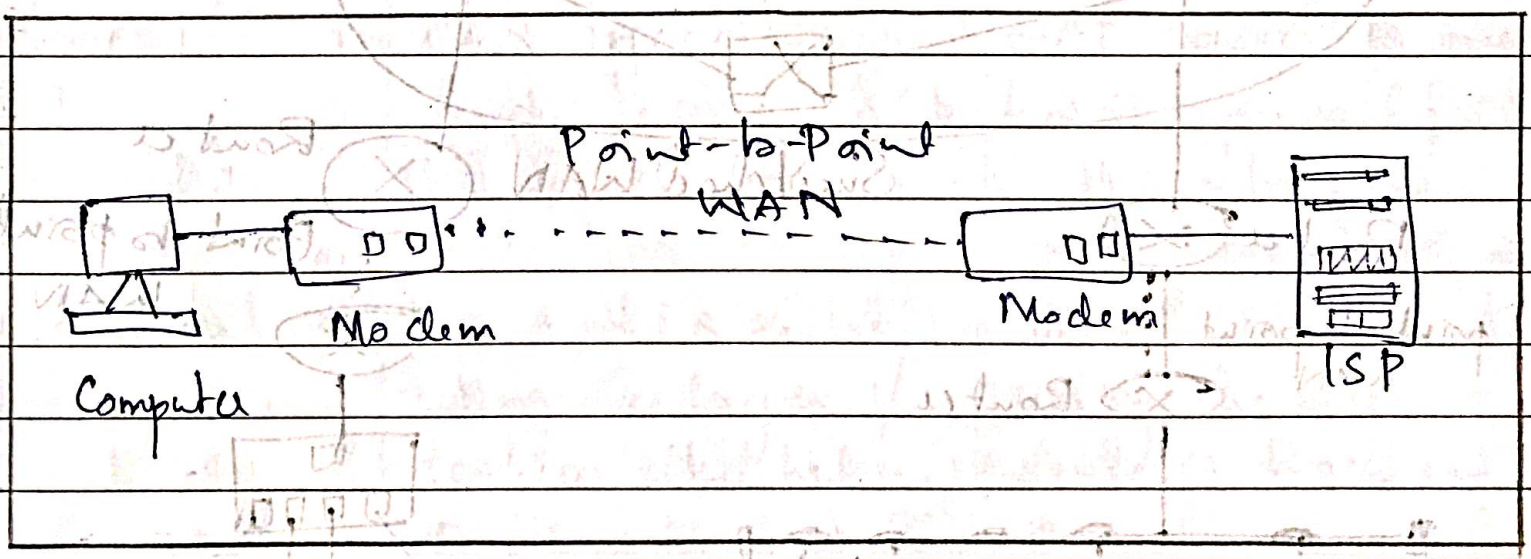
WANs : a switched WAN and a point-to-point WAN

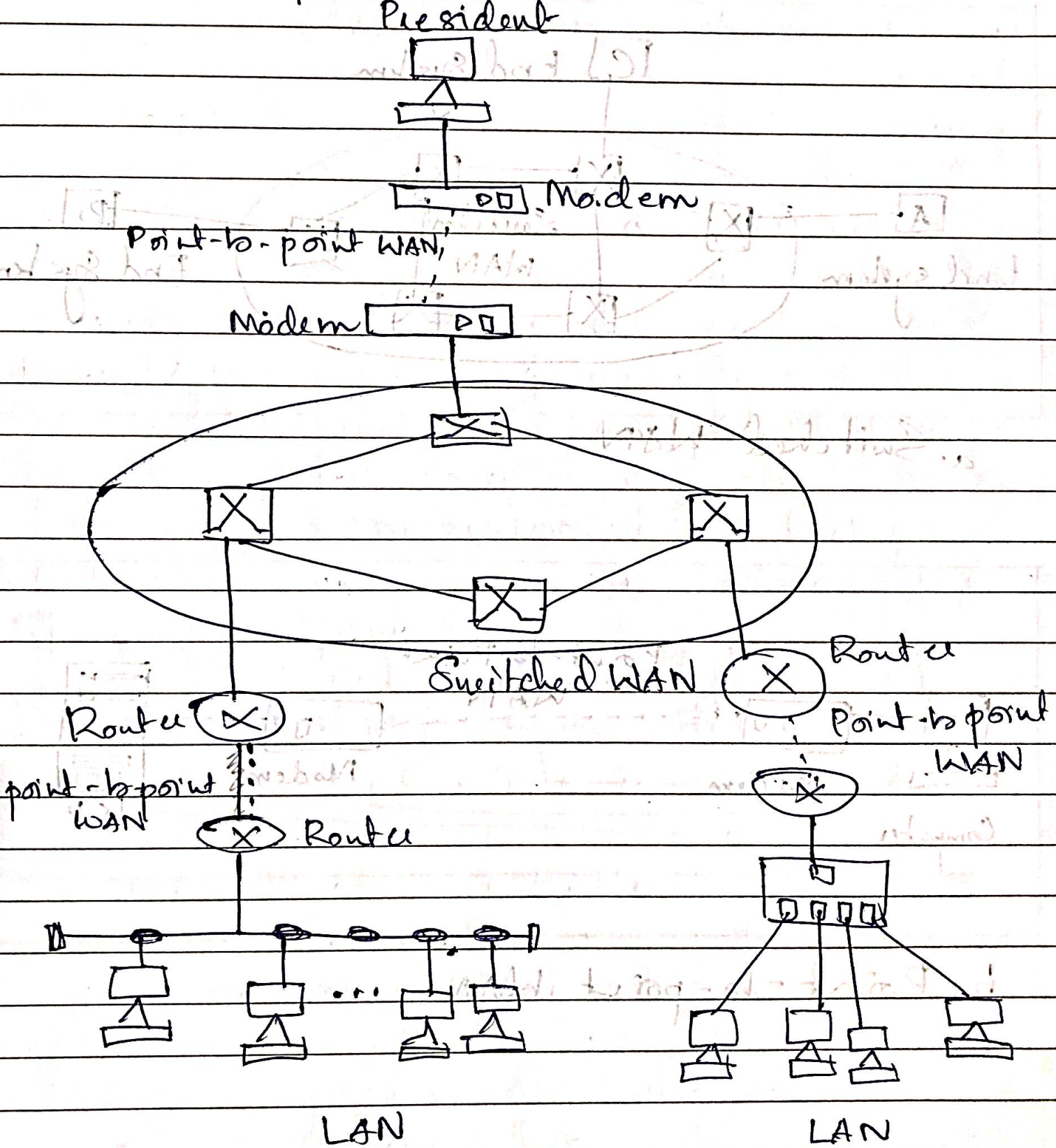


a. Switched WAN



b. Point-to-point WAN ...

A heterogeneous network made of four WANs & two LANs



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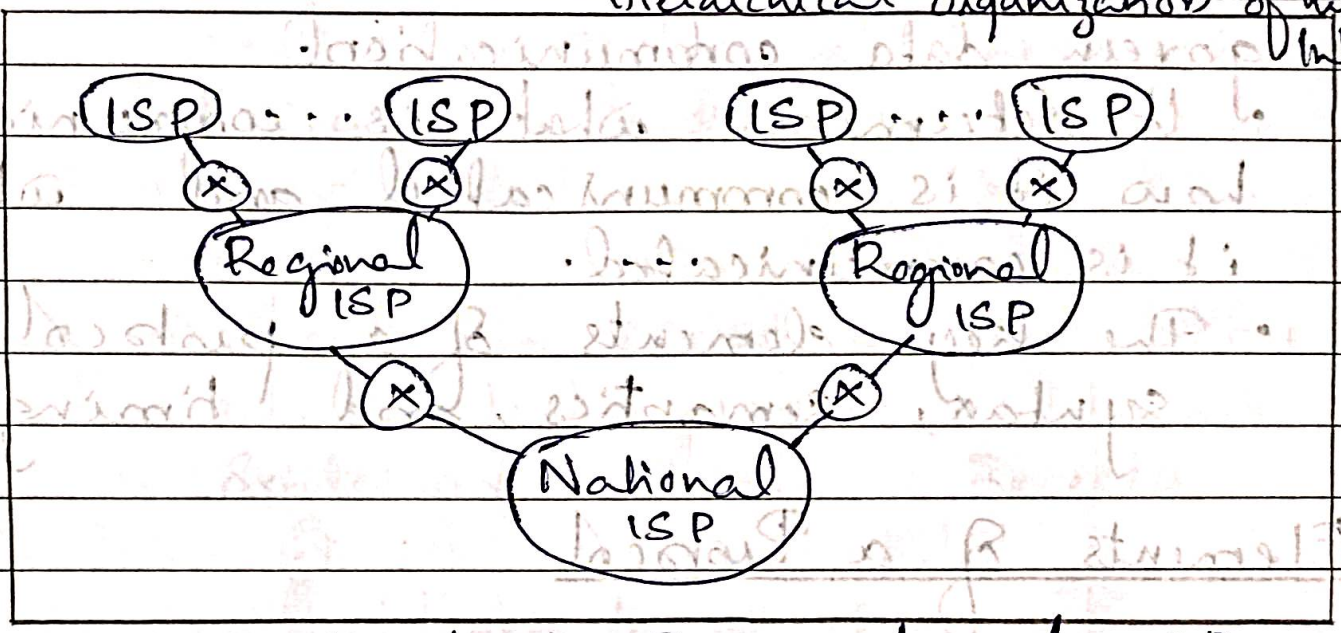
Parameter	LAN	WAN
Abbreviation for	Local Area Network	Wide Area Network
Philosophy	LAN is a network covering a small geographic area & connecting various end devices like computers & printers. LAN may be limited to a home, office, schools or building.	WAN (Wide A. is a network that covers a broad area and used to connect end devices like computers & printers which are distributed across long distance
Speed	LAN speed is high, upto 1/10 Gbps	WAN speed is much low, generally 100 mbps In few cases upto 10 or 50 mbps
Components	The LAN is build using the layer 1/2 devices like hubs, switches, bridges and layer 3 devices like Core/layer 3 switch. These devices connect to computers, servers & printers etc.	The WAN is build using the layer 3 devices Routers & multi-layer switches.

Ownership & management	LAN is owned, operated, managed & monitored by a customer.	WAN is owned, operated managed & monitored by multiple Service providers hence exist under distributed ownership.
Example	Network inside an office space.	Internet is the best example of WAN
Security	More Secured	Less Secured.
Technology	Ethernet & Token Rings are 2 primary technologies used in LAN environment	MPLS, ATM, Frame relay & ISDN are examples of WAN technologies.
COST (CAPEX & OPEX)	Less expensive to setup & operate	More expensive.
Coverage	Coverage across small geographical are like limited to office area or customer building.	WAN is has extremely large geographical area. It is not limited to one country.
Congestion	Less congested	More congested
Physical layer connectivity (Fiber)	Generally Copper & Fiber medium is used in LAN setup. Multimode Fiber is preffered in LAN environment.	Generally Fiber mediums used in WAN termination Singlemode Fiber is preferred in WAN environment.

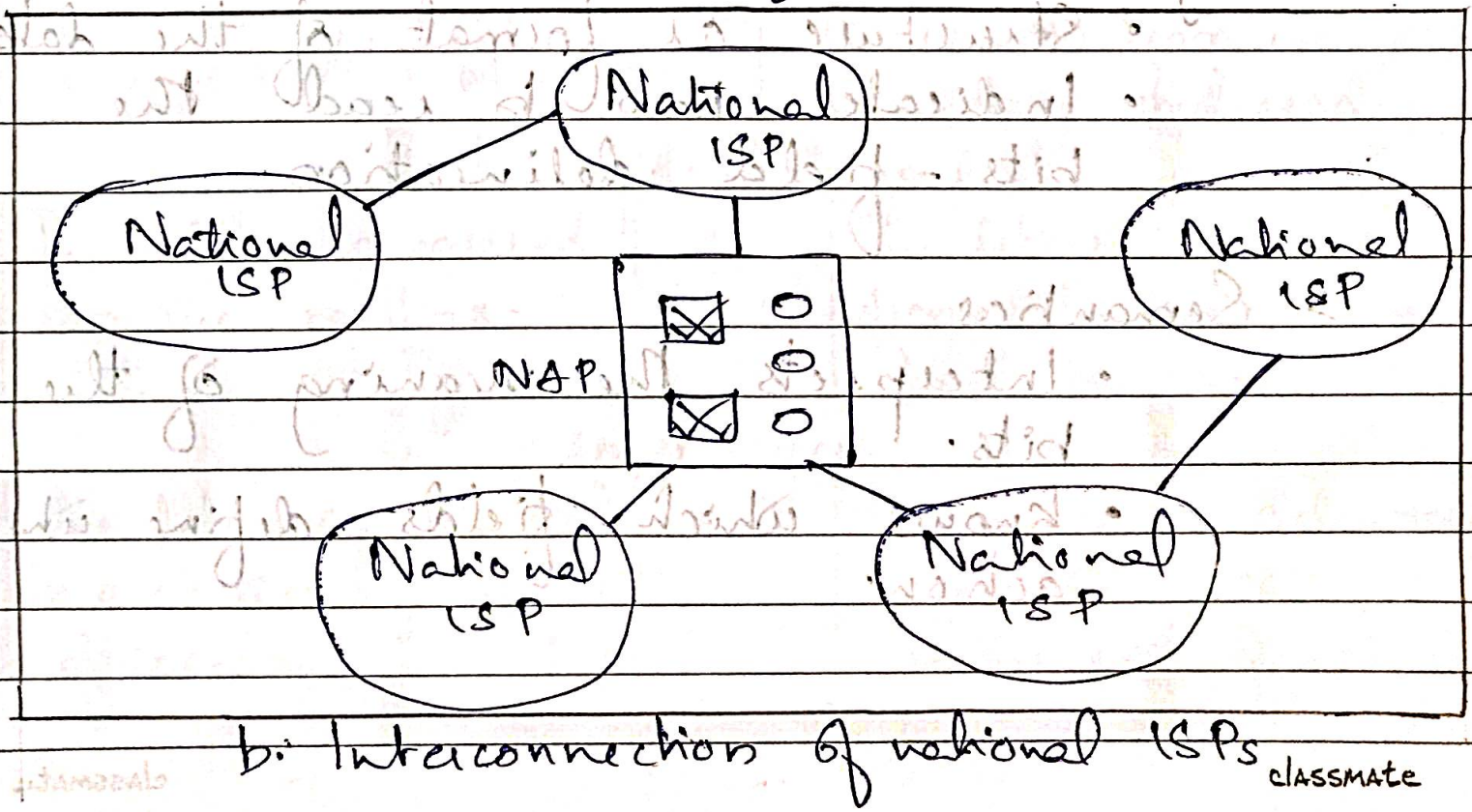
The Internet

When two or more networks are connected they make an internetwork or internet.

Hierachical organization of the Internet



a. Structure of a national ISP



b. Interconnection of national ISPs

Protocols (Rules)

- A protocol (aggreement) is synonymous with rule.
- It consists of a set of rules that goverm data communication.
- It determines what is communicated, how it is communicated and when it is communicated.
- The key elements of a protocol are syntax, semantics, and timing.

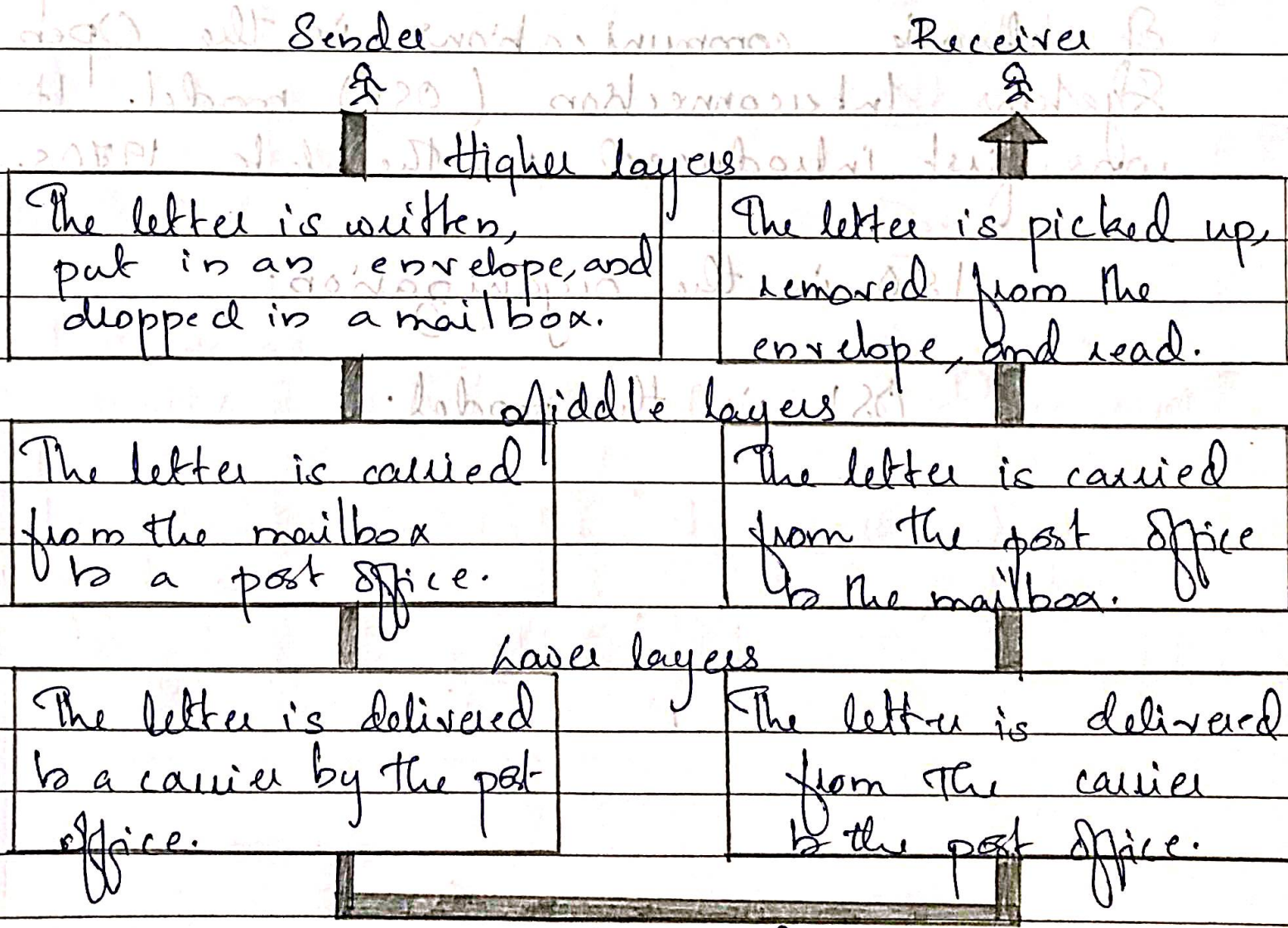
Elements of a Protocol

> Syntax
  - Structure or format of the data
  - Indicates how to read the bits - field delineation.

> Semantics
  - Interprets the meaning of the bits.
  - knows which fields define what action.

> Timing
- When data should be sent & what
- Speed at which data should be sent or speed at which it is being received.

Task involved in sending a letter



The OSI model

- Established in 1947, the International Standards Organization (ISO) is a multinational body dedicated to worldwide agreement on international standards.

- An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model. It was first introduced in the late 1970s.

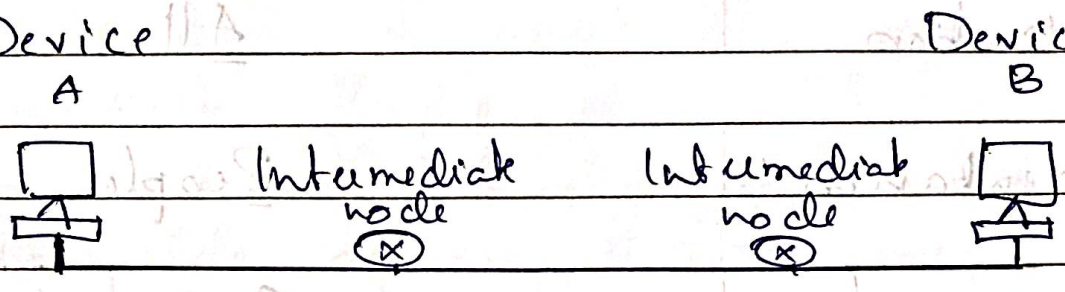
ISO is the organization.

OSI is the model.

Seven layers of the OSI model

7	Application	All
6	Presentation	People
5	Session	Seem
4	Transport	To
3	Network	Need
2	Data link	Domino
1	Physical	Pizza

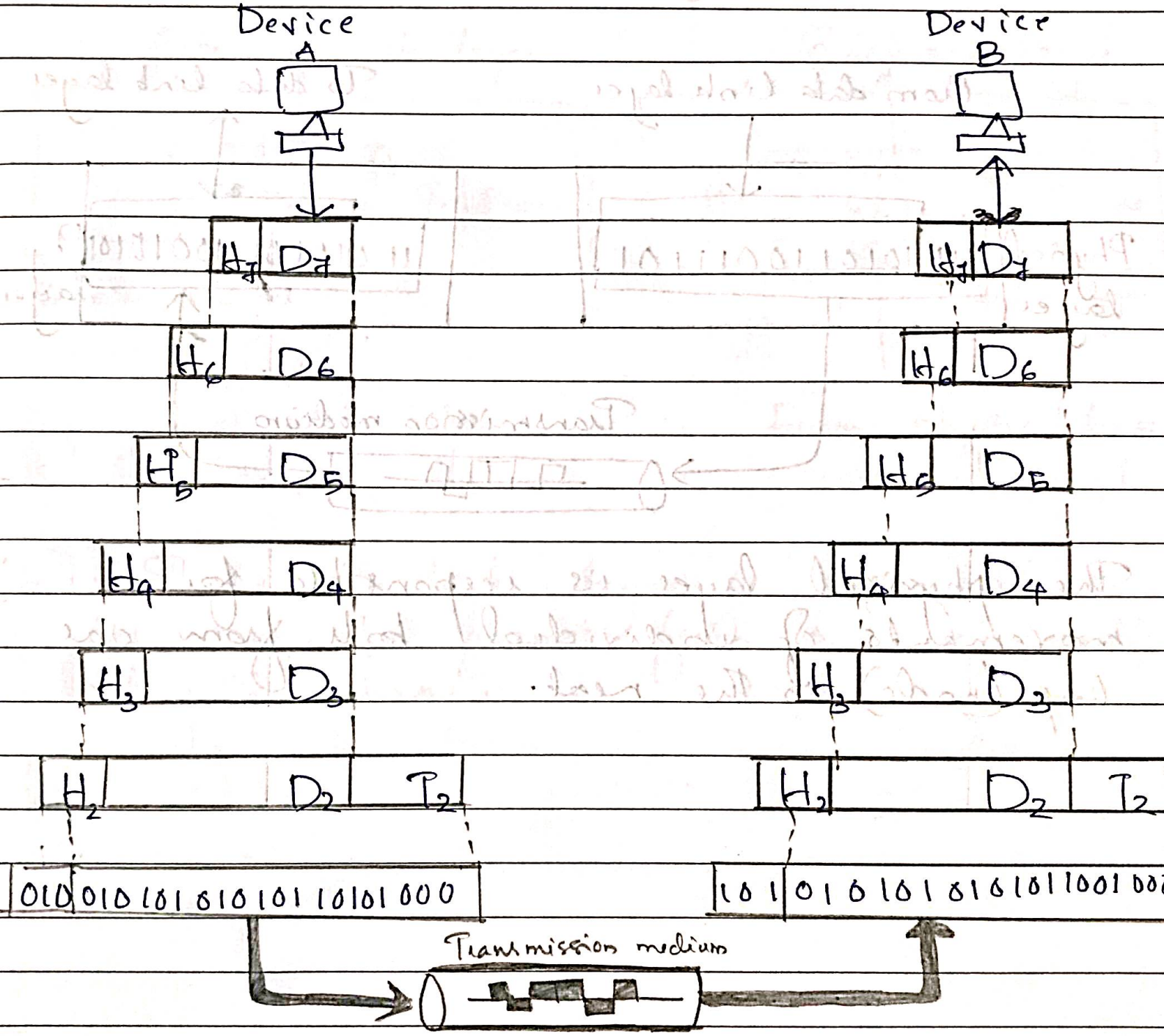
The interaction between layers in the OSI model.



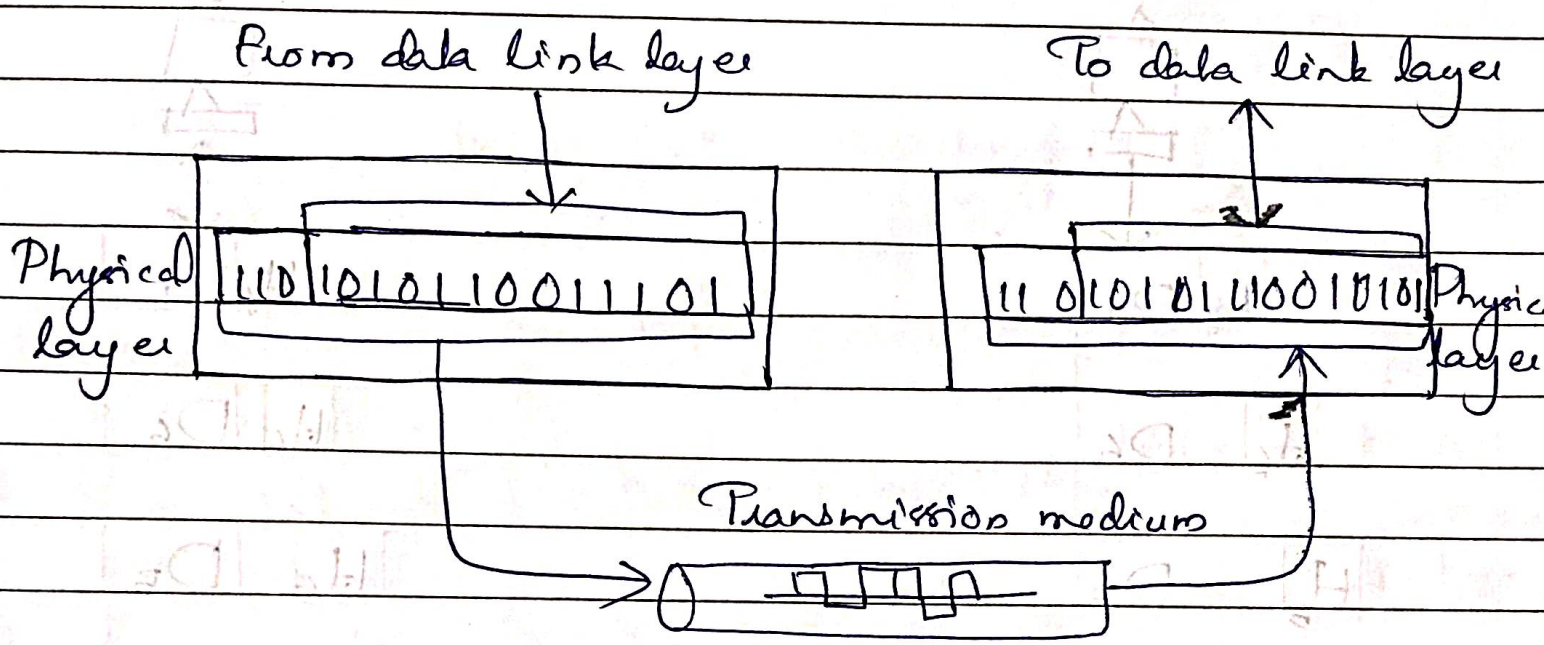
7	Application	Peer to peer protocol (7th layer)	Application	7
	7-6 interface		7-6 interface	
6	Presentation	Peer to peer protocol (6th layer)	Presentation	6
	6-5 interface		6-5 interface	
5	Session	Peer to peer protocol (5th layer)	Session	5
	5-4 interface		5-4 interface	
4	Transport	Peer to peer protocol (4th layer)	Transport	4
	4-3 interface		4-3 interface	
3	Network	3rd	Network 3rd Network 3rd	Network 3
	3-2 interface		3-2 interface	
2	Data link	2nd	Data link 2nd Data link 2nd	Data link 2
	2-1 interface		2-1 interface	
1	Physical	bit	Physical bit Physical 1st	Physical 1

Physical communication

An exchange using the OSI model

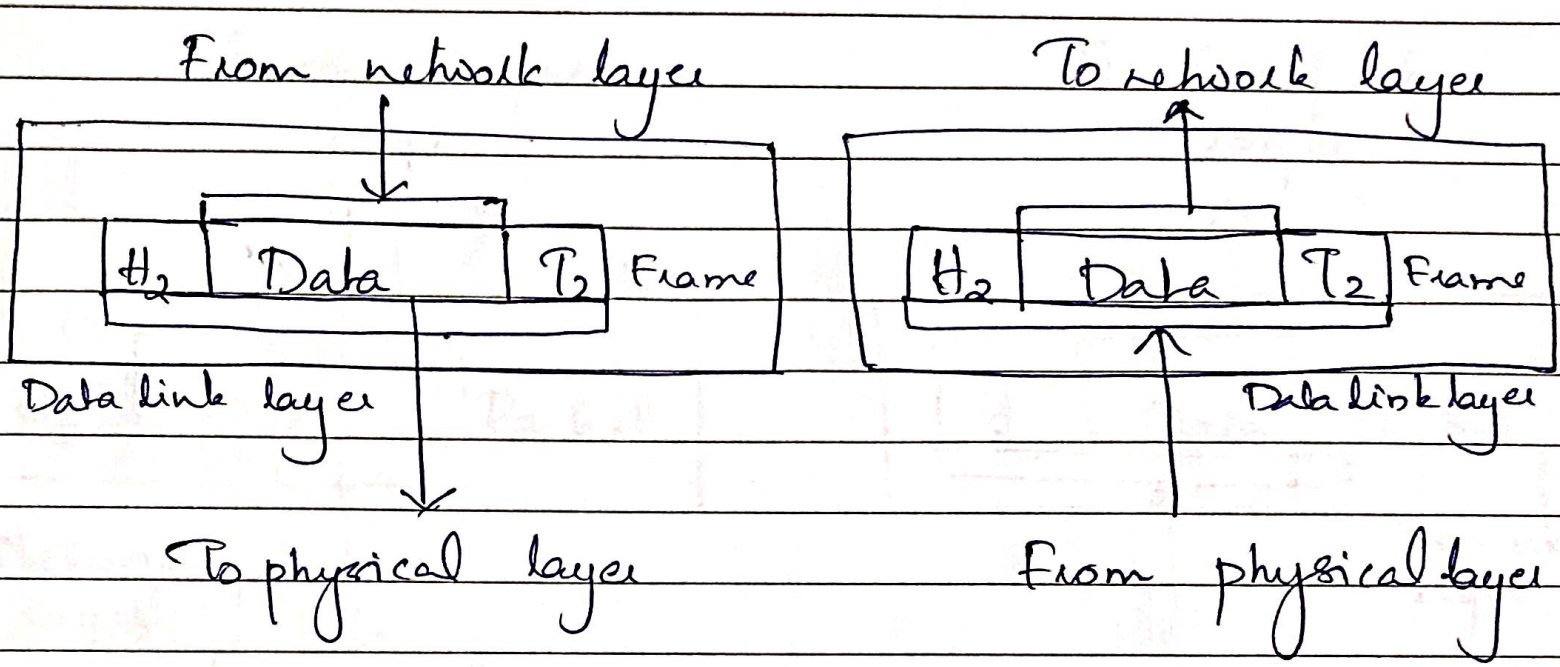


Physical layer



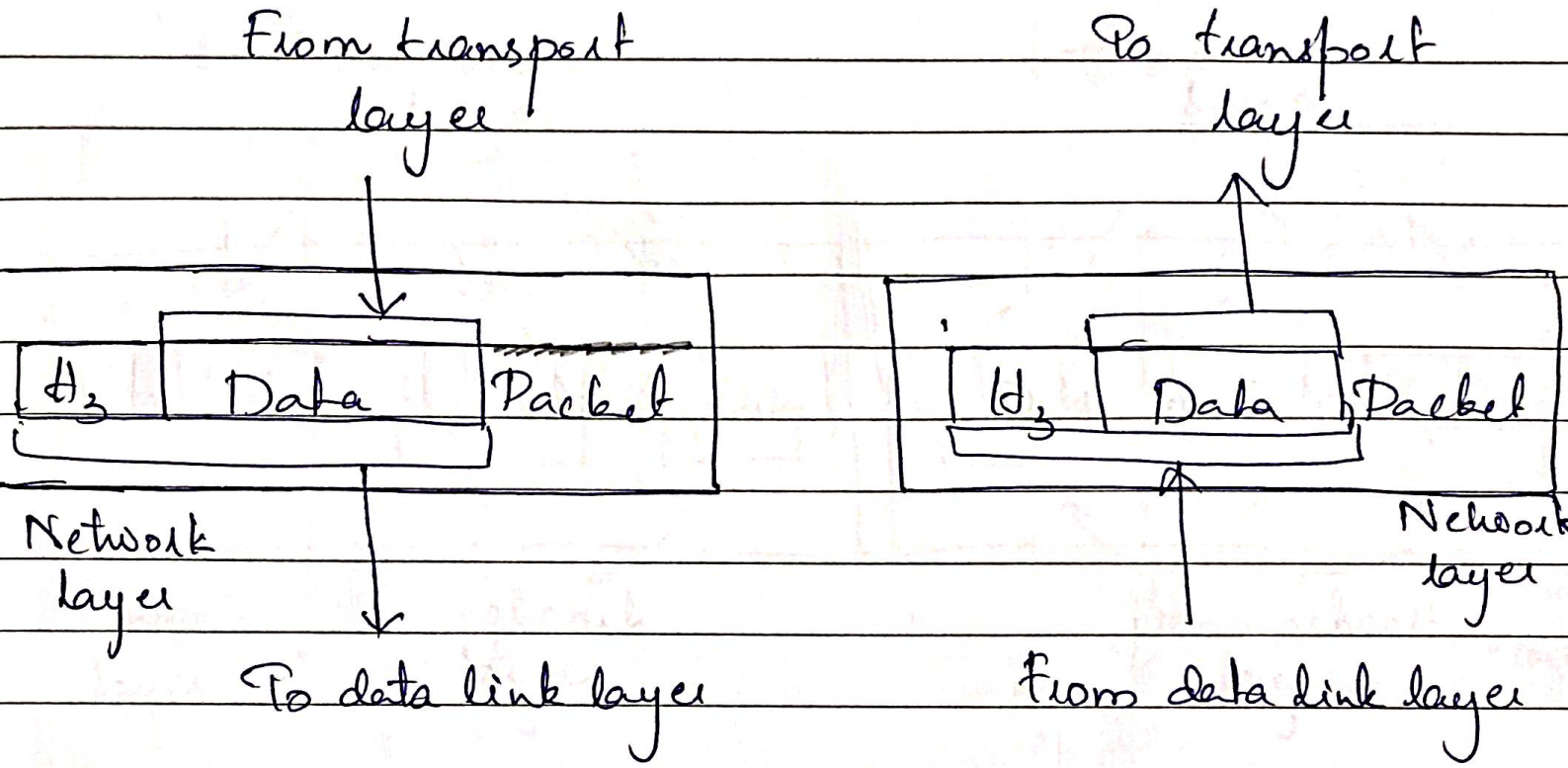
The physical layer is responsible for movements of individual bits from one hop (node) to the next.

Data link layer



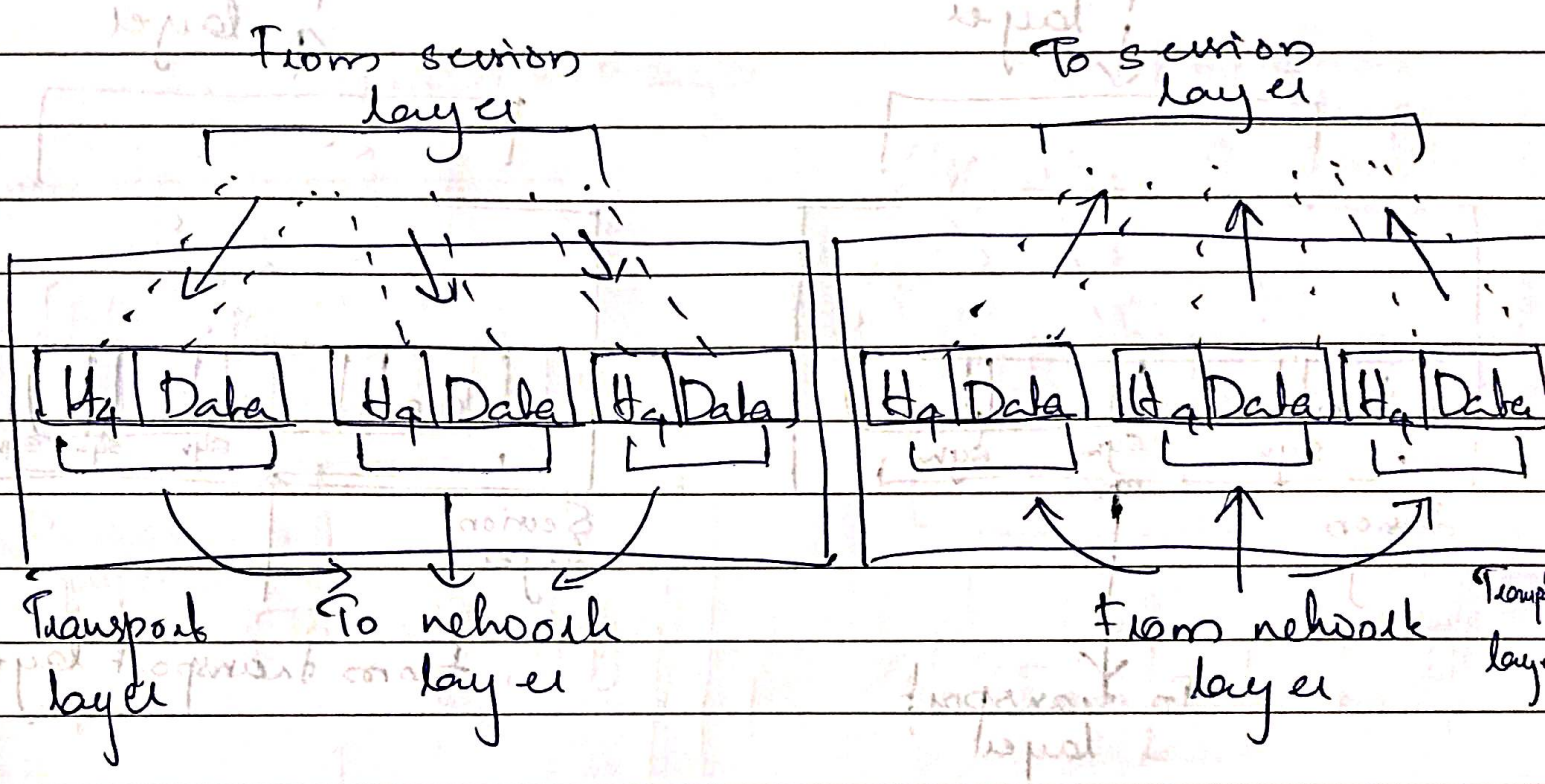
The data link layer is responsible for moving frames from one hop (node) to the next.

Network layer



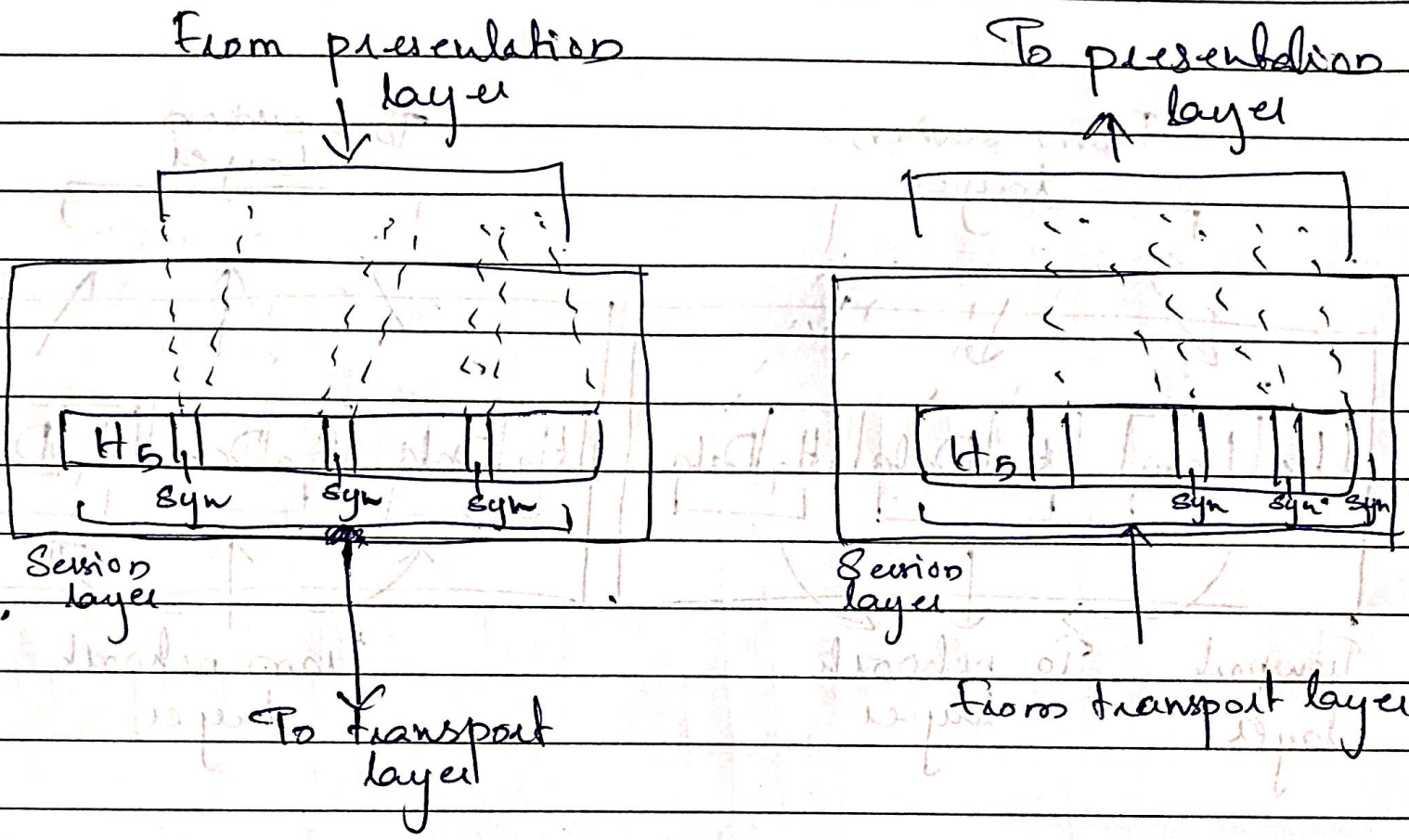
The network layer is responsible for the delivery of individual packets from the source host to the destination host.

Transport layer



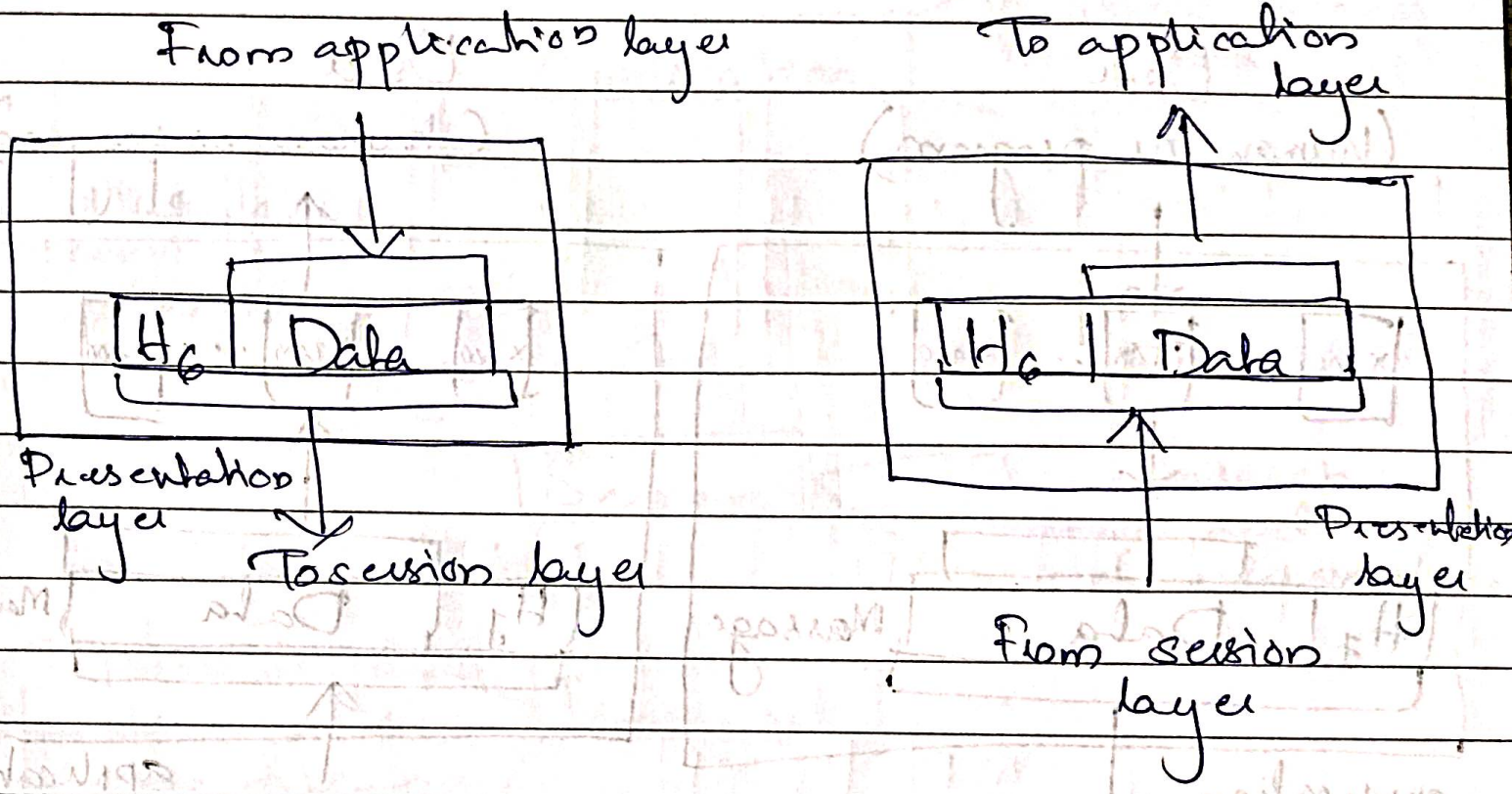
The transport layer is responsible for the delivery of a message from one process to another.

Session layer



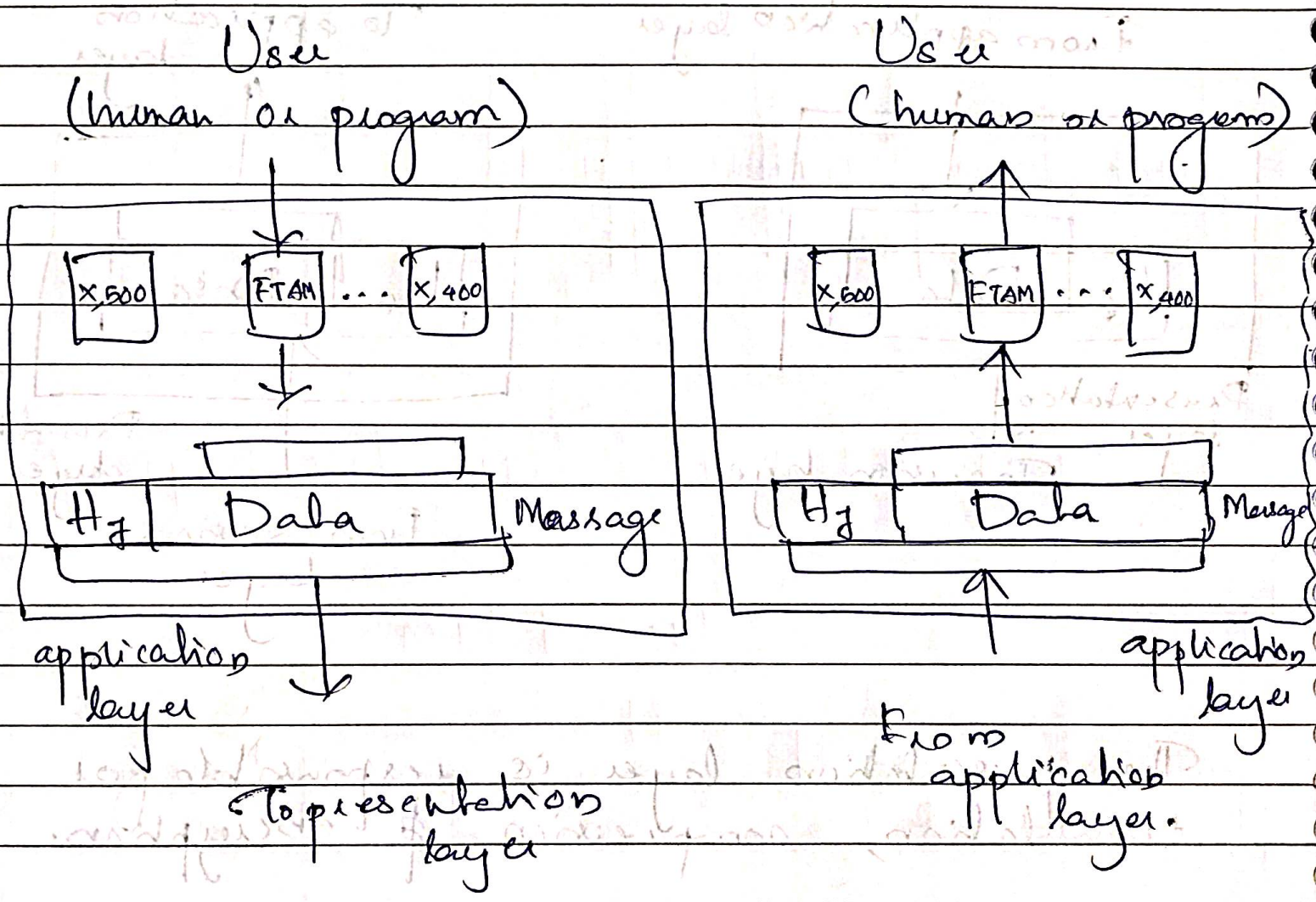
The session layer is responsible for dialog control & synchronization.

Presentation layer



The presentation layer is responsible for translation, compression & encryption.

Application layer



The application layer is responsible for providing services to the user.

Summary of layers

Application — To allow access to network resources.

Presentation — To translate, encrypt & compress data

Session — To establish manage and terminate sessions

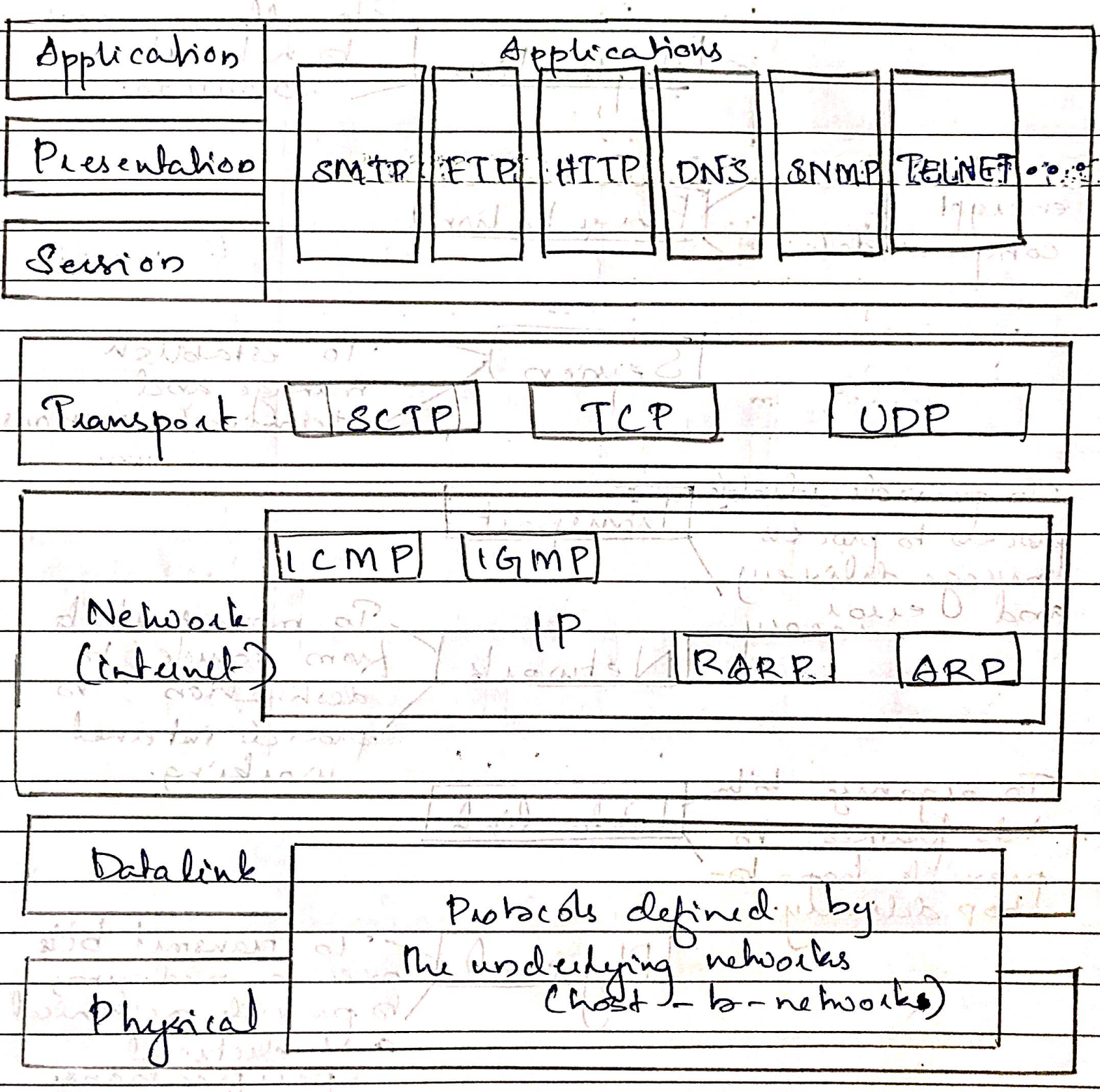
Transport — To provide reliable process to process message delivery and error recovery

Network — To move packets from source to destination; to provide internet working.

Data link — To organize bits into frames; to provide hop-to-hop delivery.

Physical — To transmit bits over a medium. to provide mechanical and electrical specifications.

TCP/IP & OSI model



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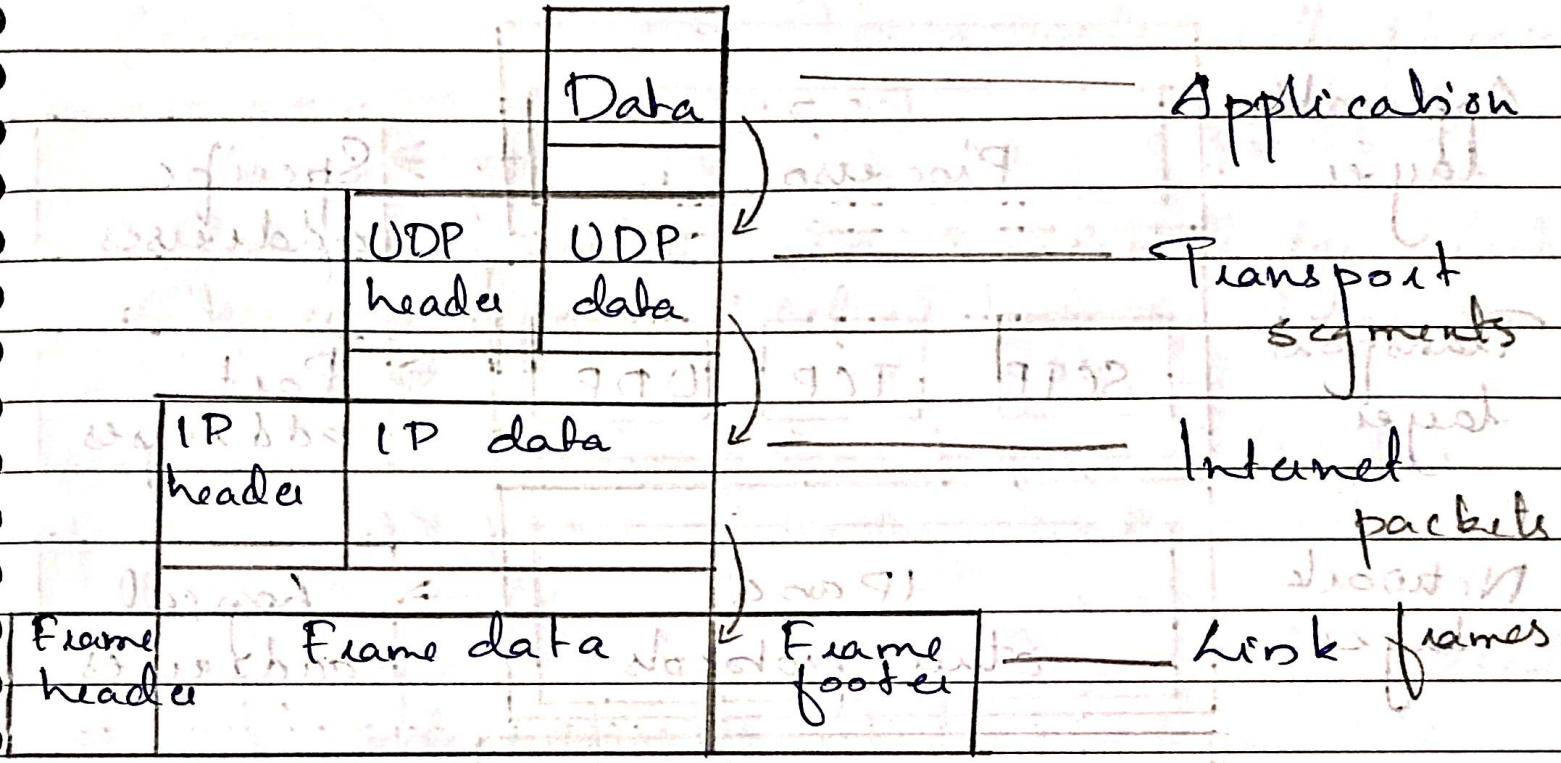
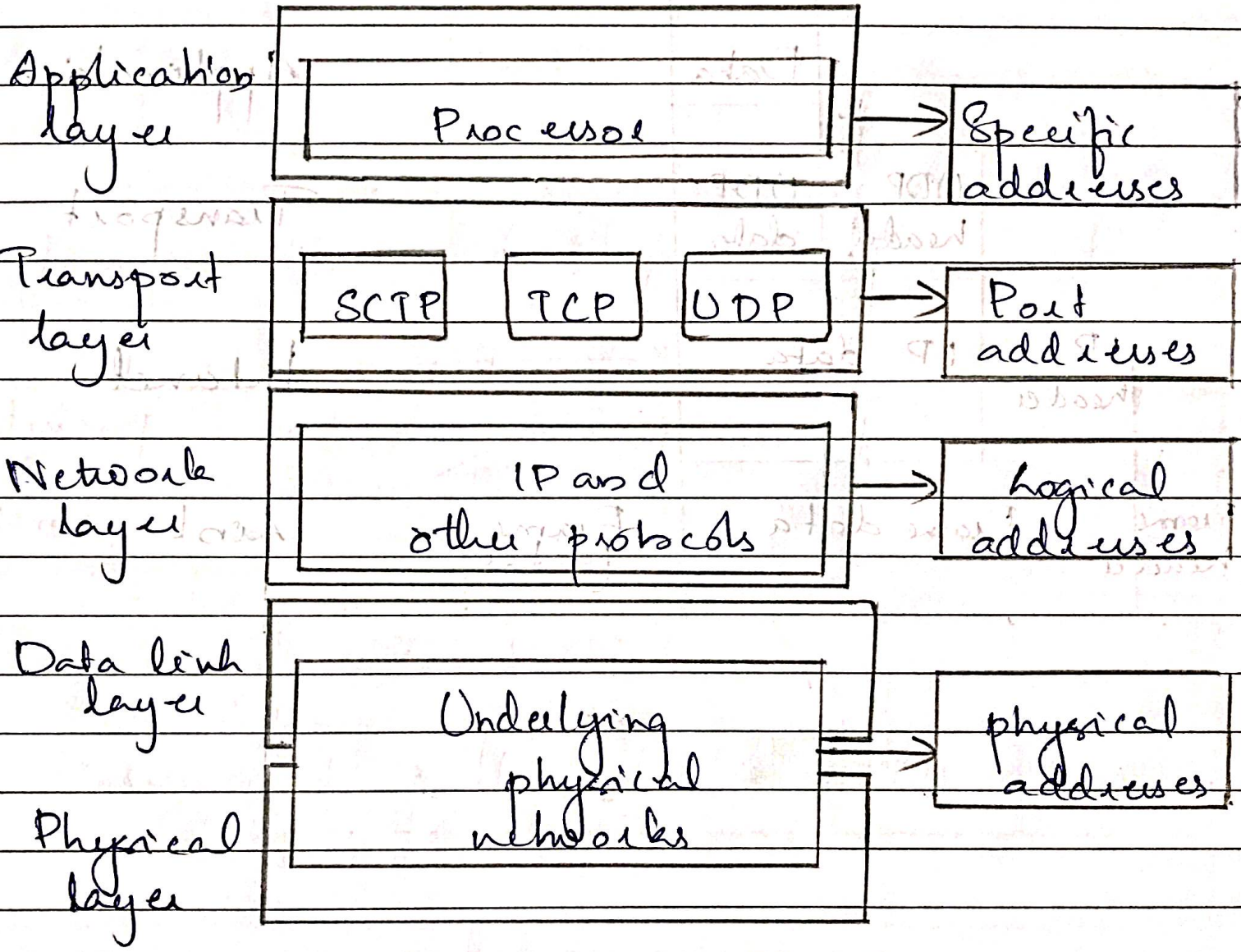
Sender's end Receiver's end

Encapsulation & Decapsulation



Relationship of layers & addresses in TCP / IP



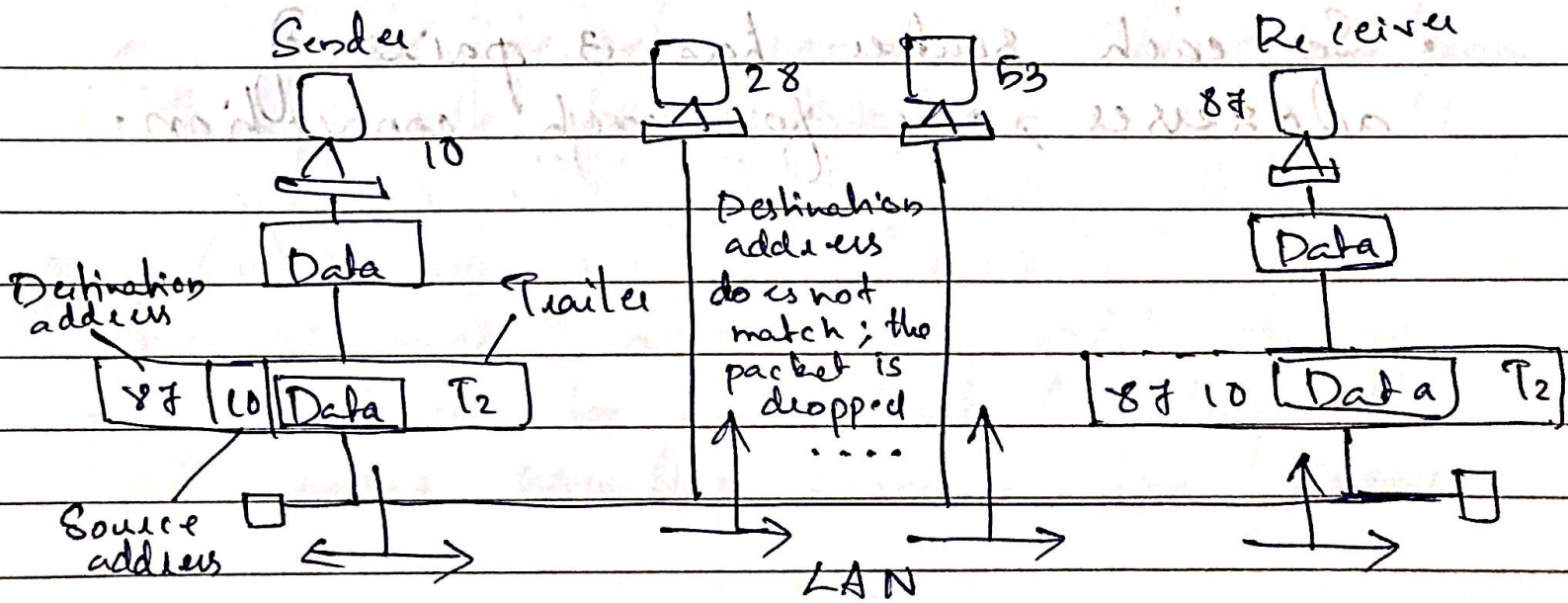
checksum

Physical addresses

- A node with physical address 10 sends (sender) a frame to a node with physical address 87 (receiver).
- The two nodes are connected by a link (bus topology LAN).

07:01:02:01:2C:4B

A 6-byte (12 hexadecimal digits) physical address.



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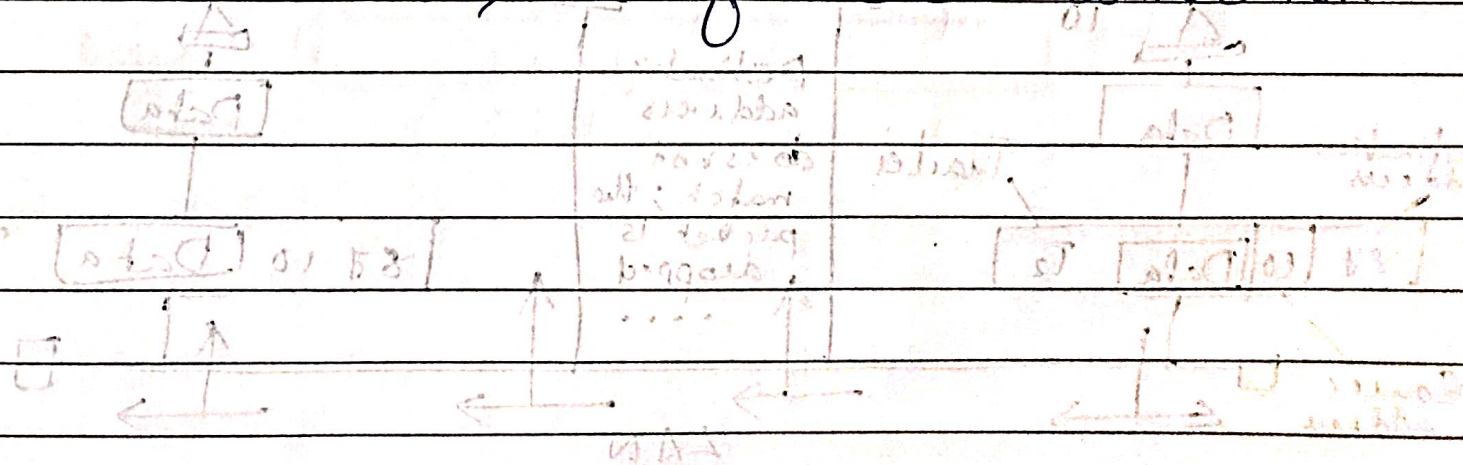
IP address: a part of an internet with two routers connecting 3 LANs

- Each device (computer or router) has a pair of addresses (logical and physical) for each connection.
- Each computer is connected to only one link and ∴ has only one pair of addresses.
- Each router, however, is connected to three networks.
- So each router has 3 pairs of addresses, one for each connection.



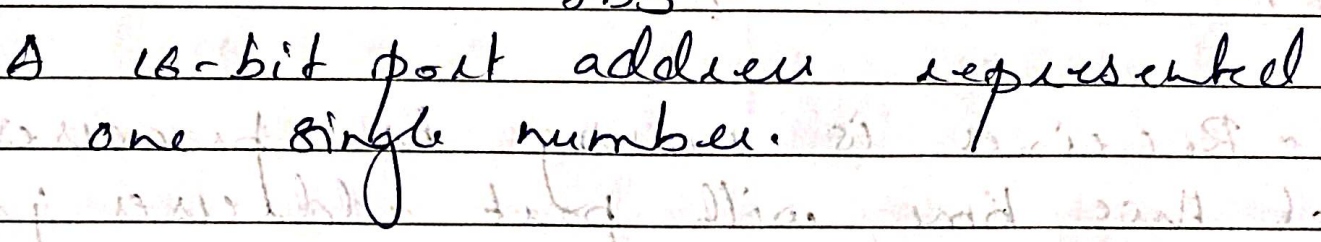
Port addresses

- Sender is running 3 processes at this time with port addresses a, b & c.
- Receiver is running two processes at this time with port addresses j and k.
- Process a needs to communicate with process j.

Note that although physical addresses change from hop to hop, logical & port addresses remain the same from the source to destination.

wrong The physical addresses will change from hop to hop, but the logical addresses usually remain the same.

A port address is a 16-bit address represented by one decimal number as shown.

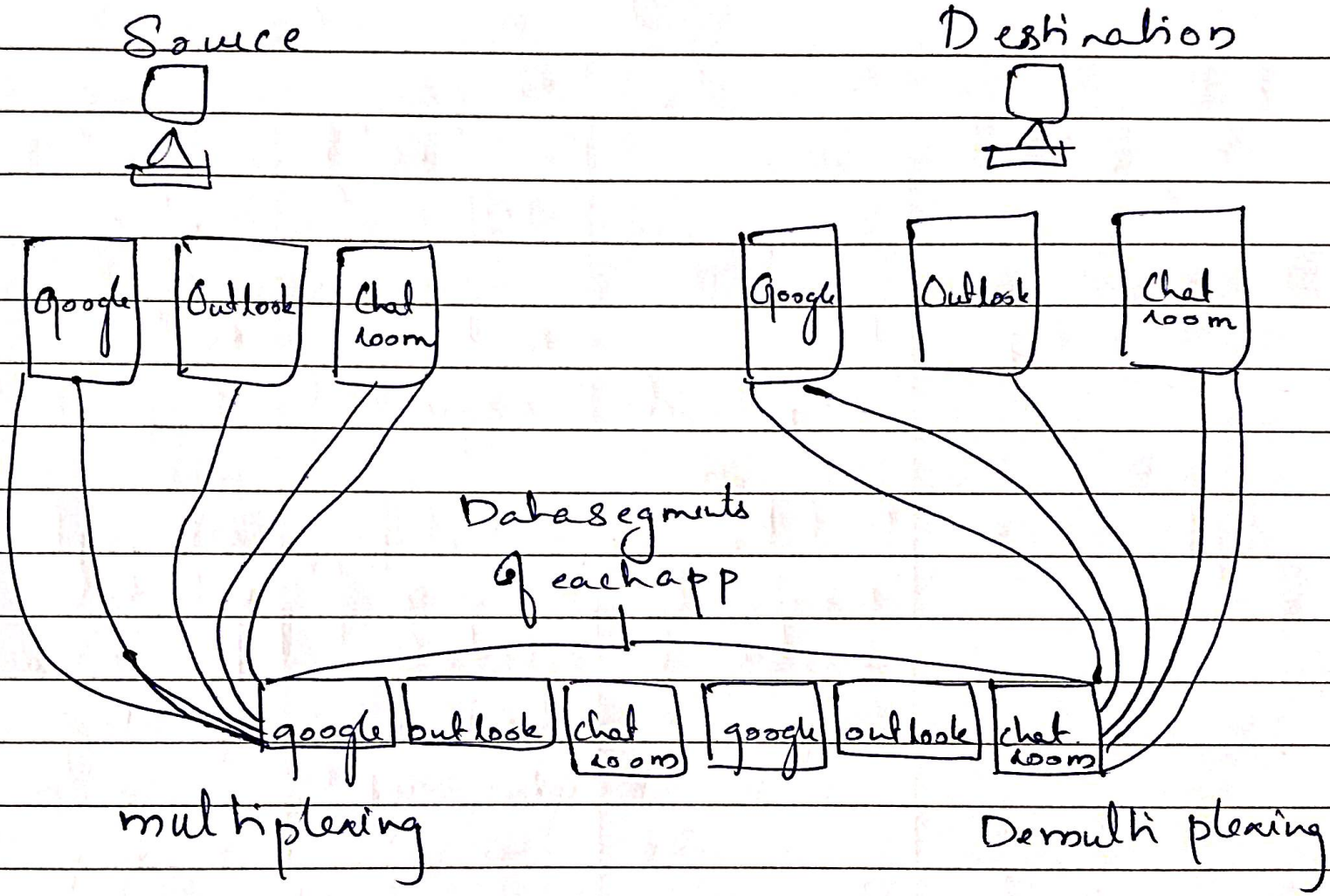


A 16-bit port address represented as one single number.

Application - Specific Addresses

- Applications have user-friendly addresses that are designed for that specific application.
- Examples:
  - e-mail address (xyz@rajagiri.edu)
  - The Universal Resource Locator (URL) (www.rajagiri.edu)

Multiplexing / demultiplexing



Parameter	Circuit Switching	Packet Switching	Message Switching
Path followed by packets	It is always same	May or may not be different.	May or may not be same.
Call setup	It is required.	Not required	Not required.
Application	Real time transfer of voice signal.	Internet for datagram & reliable stream service b/w computers	Telegraph network for transmission of telegrams.
Layer used for implementation	It is implemented at physical layer.	Virtual circuit network is implemented at data link layer and datagram network at network layer.	

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Data & Signals

Data

Informations sending from sender to receiver.

Signals

The form which data is sending

* like a building blocks of computer networks.
* All the data transmitted over channel can either be in analog form or digital form.
* Data are manipulated in the signal form suitable for the transmission channel.
* Like data elements, signals can also either in analog form or digital form.
  - Analog data converted into analog signal form, for example Telephone.
  - Digital data converted to analog signal form, for example modem.
  - Analog data converted to digital signal form, for example codec.

- Digital data converted to digital signal form, for example digital transmitter.

Data Vs Signal

Parameters	Data	Signal
• What is it?	Data is the information we want to transmit	Signal is the waveform format used to send data over channel
• Function	Acts as payload of carrier	Acts as carrier which carries data or payload
• Measurement quantity	Bits rate in bps or Kbps or Mbps or Gbps.	Signal rate or baud rate in Baud, k Baud or Mbaud

• Affecting data communication parameters	Speed, Higher the bit rate higher is the speed.	Bandwidth, lower the signal rate, lower is the bandwidth.
• Format	Analog (continuous) or Digital form (Binary or discrete)	Analog (Electric, EM or Optical) or digital form (i.e. pulse such as NRZ or RZ)

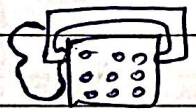
To be transmitted, data must be transformed to electromagnetic signals.

Analog & Digital Data

- Data can be analog or digital.
- The term analog data refers to information that is continuous; digital data refers to information that has discrete states.

- Analog data take on continuous values.
- Digital data take on discrete values.

Analog Data

Voice (Sound Waves) →  → Analog Signal

Handphone

Digital Data

Binary Voltage Pulses → Modem → Analog Signal

Analog Data

Analog Signal → [CODEC] → Digital Signal

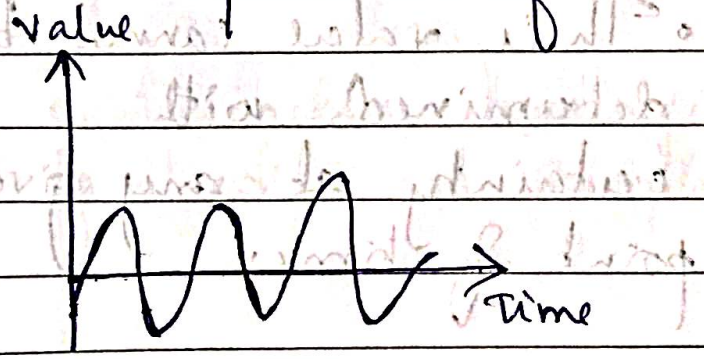
Digital Data

Digital Data → [Digital Transmitter] → Digital Signal

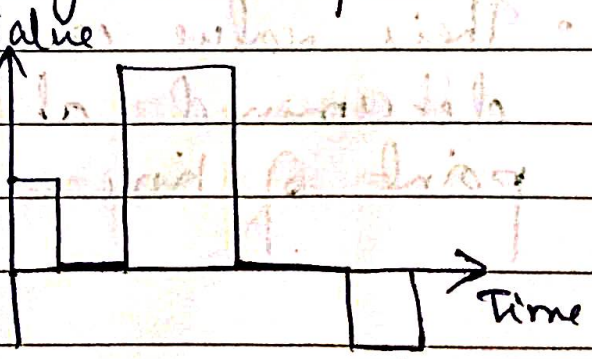
Analog & Digital Signals

- Signals can be analog or digital.
- Analog signals can have an infinite number of values in a range.
- Digital signals can have only a limited number of values.

Comparison of analog & digital signals



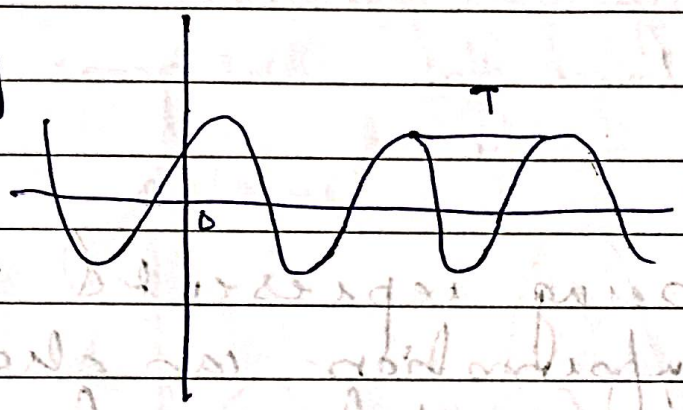
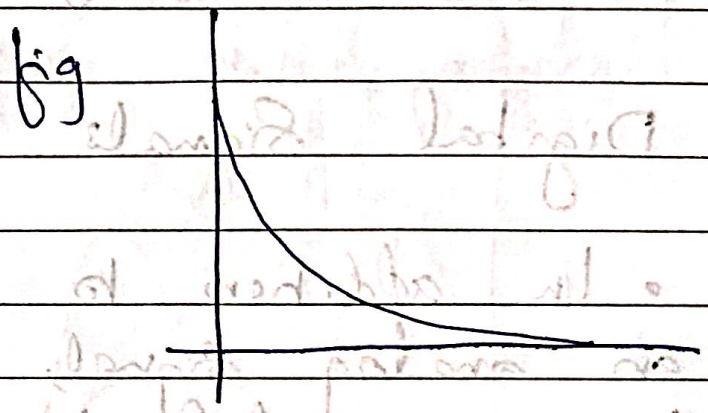
a. Analog signal



b. Digital signal

Periodic Vs Non-Periodic Signals

Periodic Signal	Aperiodic Signal
• A signal which repeats itself after a specific interval of time is called periodic signal.	• A signal which does not repeat itself after a specific interval of time is called a periodic signal.
• A signal that repeats its pattern over a period is called periodic signal.	• A signal that does not repeats its pattern over a period is called aperiodic signal or non periodic
• They can be represented by a mathematical equation.	• They cannot be represented by any mathematical equation.
• Their value can be determined at any point of time.	• Their value cannot be determined with certainty at any given point of time.

• They are deterministic signals.	• They are random signals
• Example : Sine cosine square sawtooth etc	• Example : sound signals from radio, all types of noise signals.
fig 	fig 

Periodic Analog Signals

- In data communications, we commonly use periodic analog signals and non-periodic digital signals.

- Periodic analog signals can be classified as simple or composite.

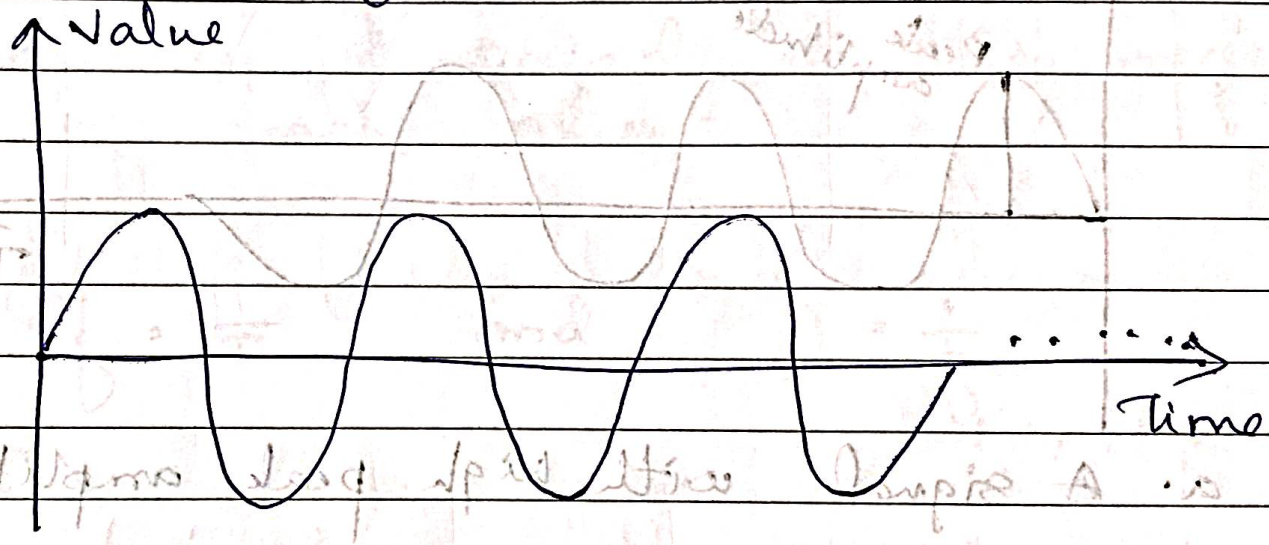
- A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals.
- A composite periodic analog signal is composed of multiple sine waves.

Digital Signals

- In addition to being represented by an analog signal, information can also be represented by a digital signal.
- For example, a 1 can be encoded as a +ve voltage and a 0 as zero voltage.
- A digital signal can have more than two levels.
- In this case, we can send more than 1 bit for each level.

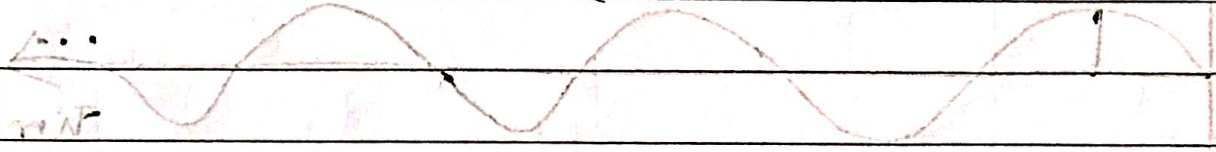
A sine wave

- Simple periodic analog signal cannot be decomposed into simpler signals.
- Composite periodic analog signal is composed of multiple sine waves.



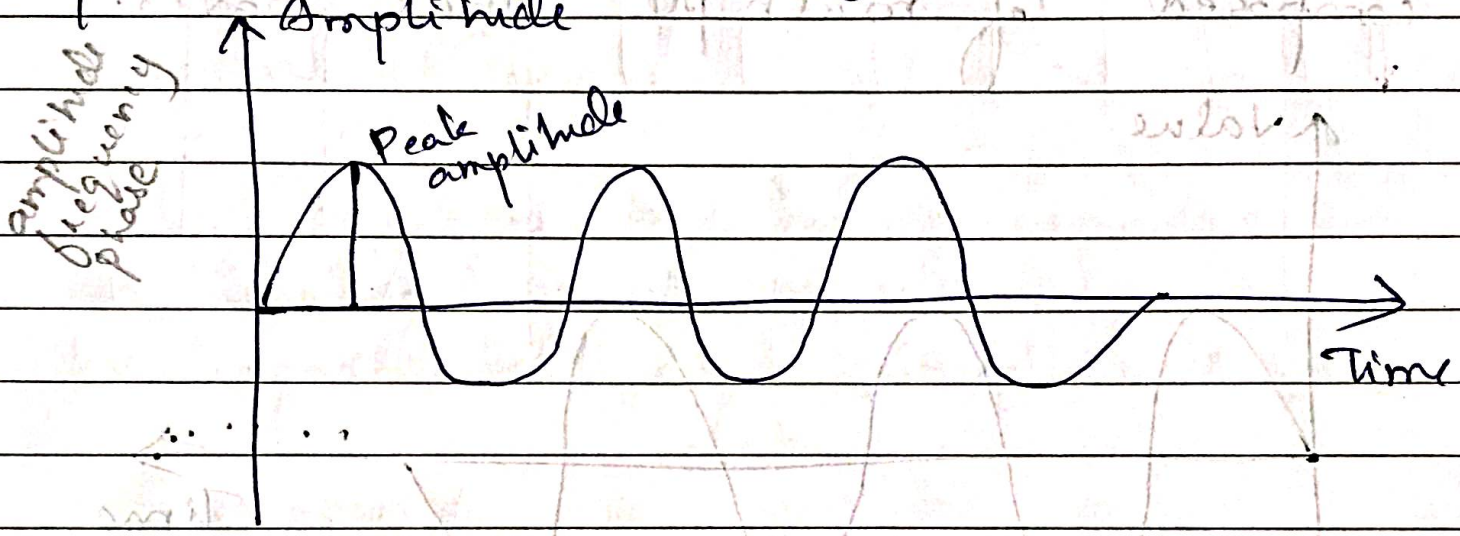
Parameters:

- Peak amplitude
- Frequency
- Phase

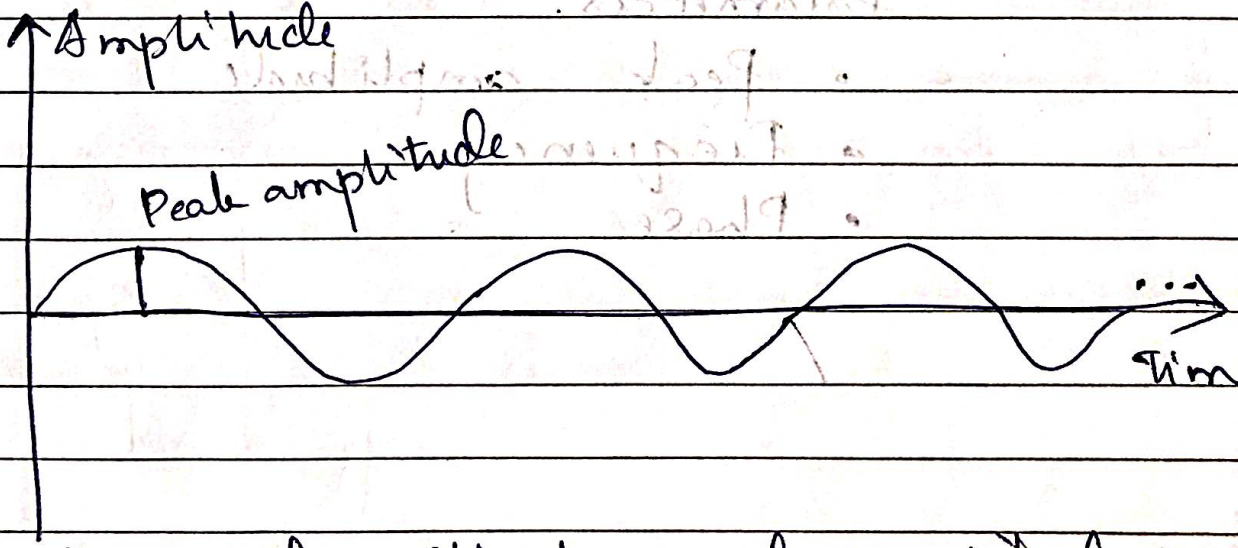


Two signals with the same phase & frequency but different amplitudes

Peak amplitude of a signal is the absolute value of its highest intensity, proportional to energy it carries.



a. A signal with high peak amplitude



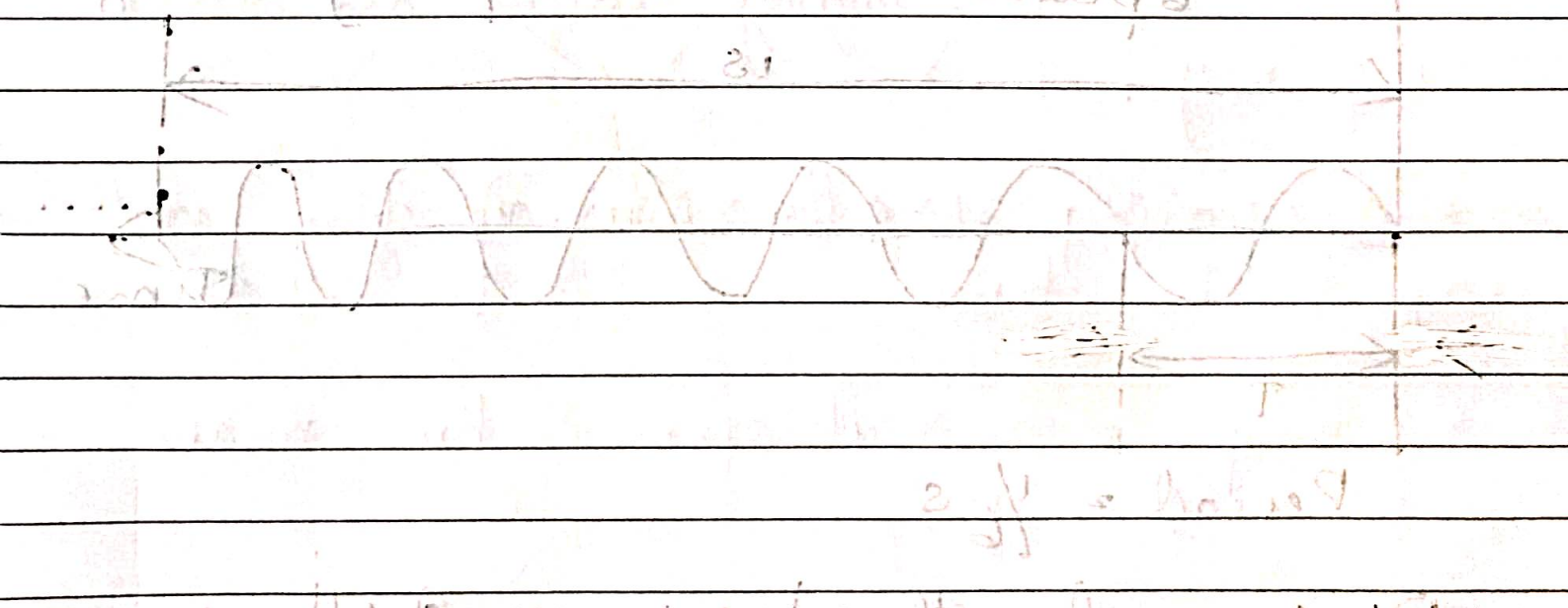
b. A signal with low peak amplitude

Period & Frequency

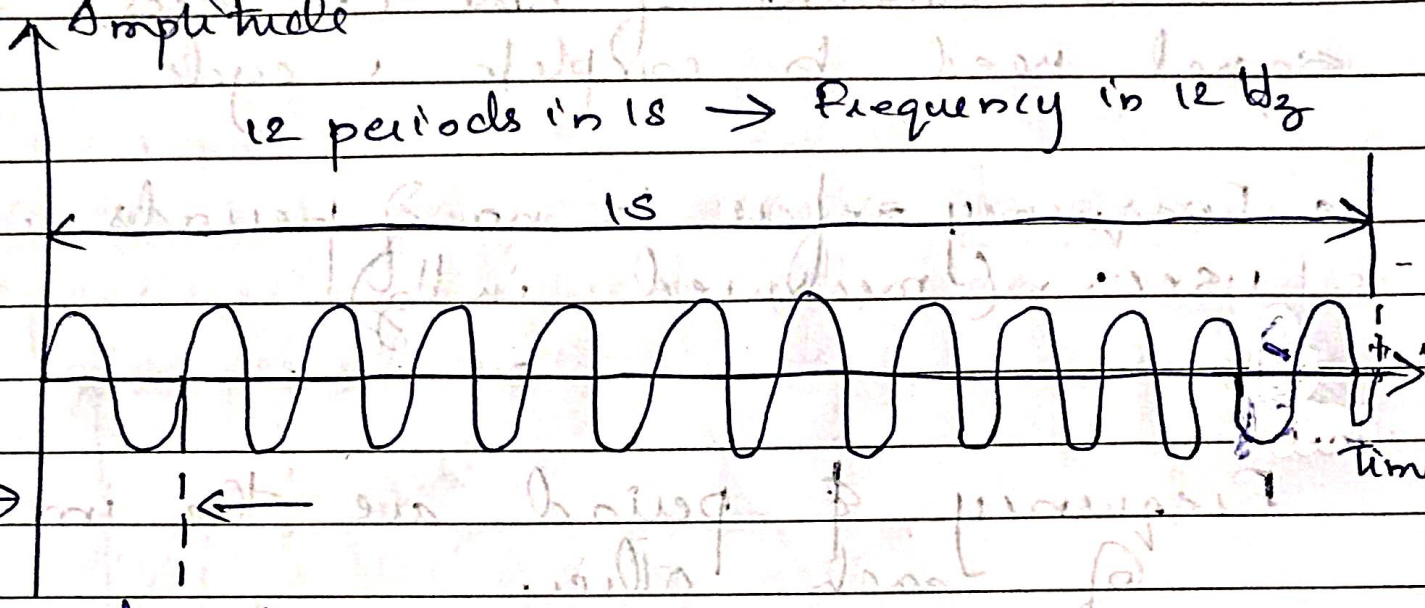
- Period - amount of time (in secs) a signal need to complete 1 cycle
- Frequency refers to no. of periods in 1 sec. (measured in Hz)

Frequency & period are the inverse of each other.

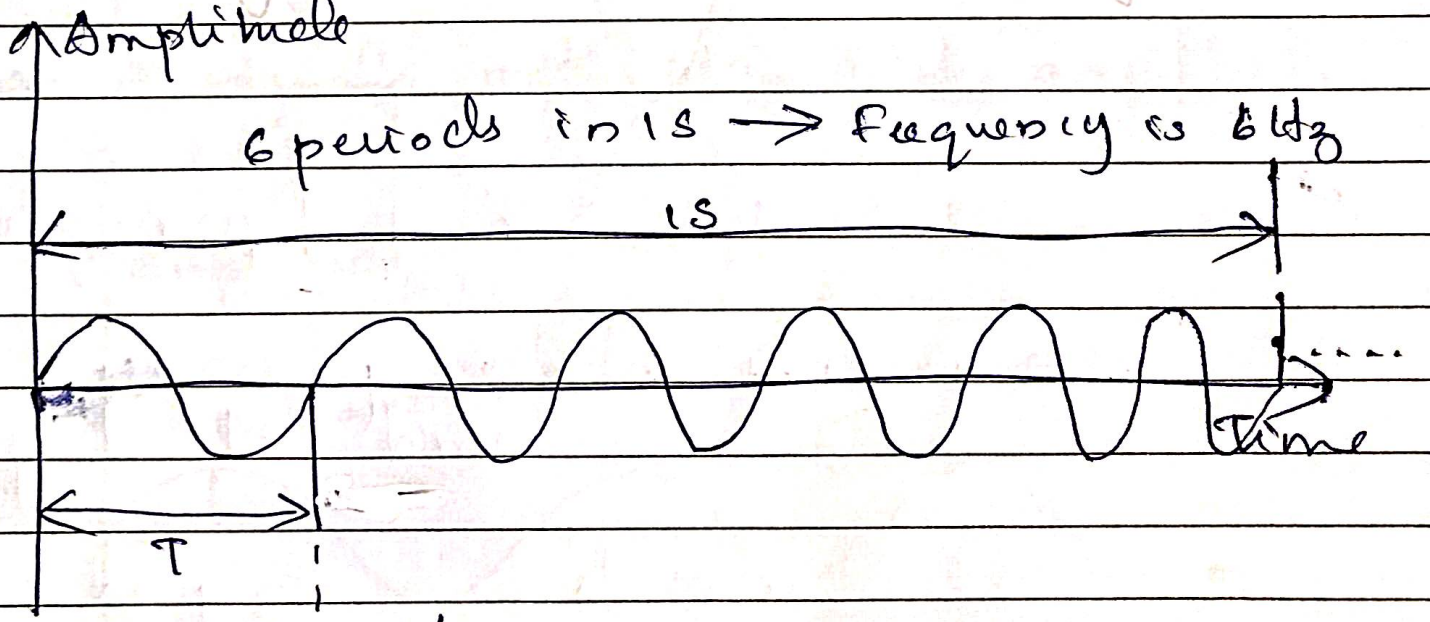
$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$



Two signals with the same amplitude & phase but different frequencies.



a) A signal with a frequency of 12 Hz



b) A signal with a frequency of 6 Hz

Units of period & frequency

Unit	Equivalent	Unit	Equivalent
Seconds (s)	1 s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	Kilohertz (kHz)	10^{3} Hz
Microseconds (μs)	10^{-6} s	Megahertz (MHz)	10^{6} Hz
Nanoseconds (ns)	10^{-9} s	Gigahertz (GHz)	10^{9} Hz
Picoseconds (ps)	10^{-12} s	Terahertz (THz)	10^{12} Hz

The power we use at home has a frequency of 60 Hz.

The period of this sine wave can be determined as follows:

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166\ s = 0.0166 \times 10^{3}\ ms = 16.6\ ms$$

The period of a signal is 100ms. What is its frequency in kilohertz?

Solution

First we change 100ms to seconds, and then we calculate the frequency from the period. ($1\ Hz = 10^{-3}\ kHz$)

$$100ms = 100 \times 10^{-3}\ s = 10^{-1}\ s$$

$$f = \frac{1}{T} = \frac{1}{10^{-1}}\ Hz = 10\ Hz = 10 \times 10^{-3}\ kHz = 10^{-2}\ kHz$$

Frequency

- Frequency is the rate of change with respect to time.
- Change in a short span of time means high frequency.

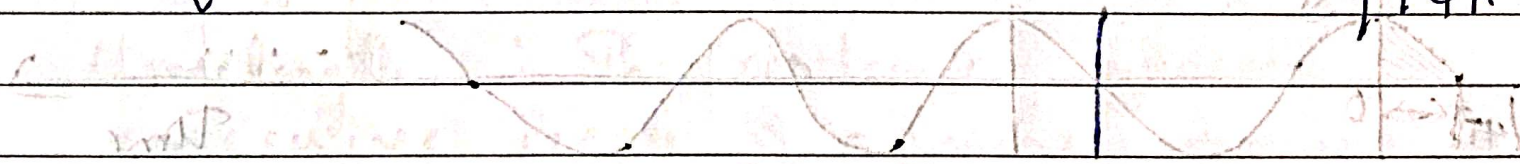
- Change over a long span of time means low frequency.

If a signal does not change at all, its frequency is zero.

If a signal changes instantaneously, its frequency is infinite.

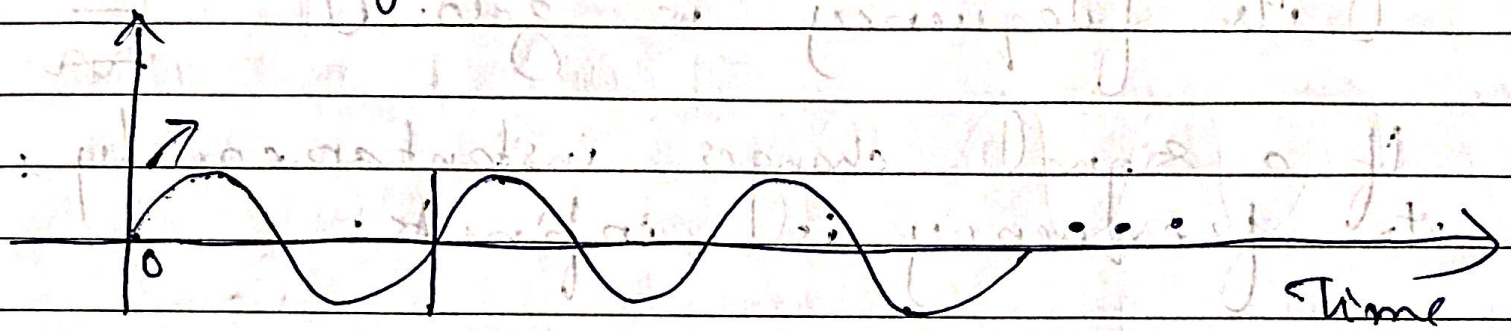
Phase

Phase describes the position of the waveform relative to time 0.

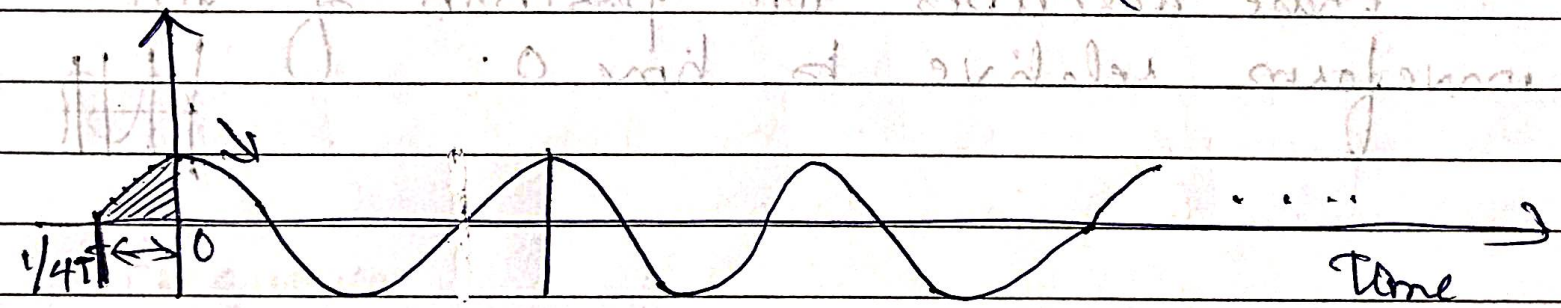


Three sine waves with the same amplitude & frequency, but different phases.

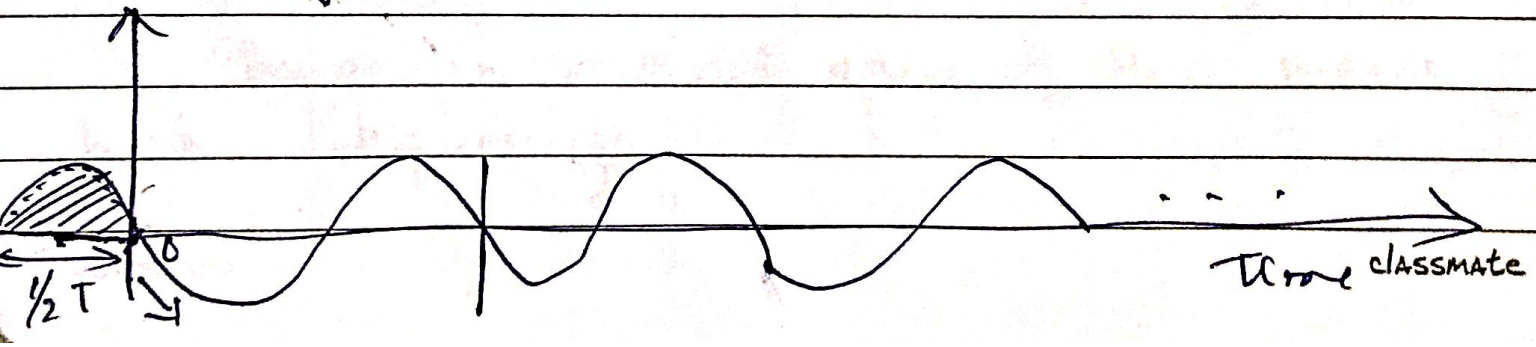
a. 0 degrees



b. 90 degrees



c. 180 degrees



A sine wave is offset 1/6 cycle with respect to time 0. What is its phase in degrees and radians?

Solution

We know that 1 complete cycle is 360°. Therefore, 1/6 cycle is

$$\frac{1}{6} \times 360 = 60° = 60 \times \frac{2\pi}{360} \text{ rad} = \frac{\pi}{3} \text{ rad}$$

$$= 1.046 \text{ rad}$$

Wavelength & period

Wavelength : The distance between successive crests of a wave, especially points in a sound wave or electro-magnetic wave.

Wavelength is usually measured in meter(m)

Signals & Communication

> A single-frequency sine wave is not useful in data communications.

> We need to send a composite signal, a signal made of many simple sine waves.

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

Composite Signals & Periodicity

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

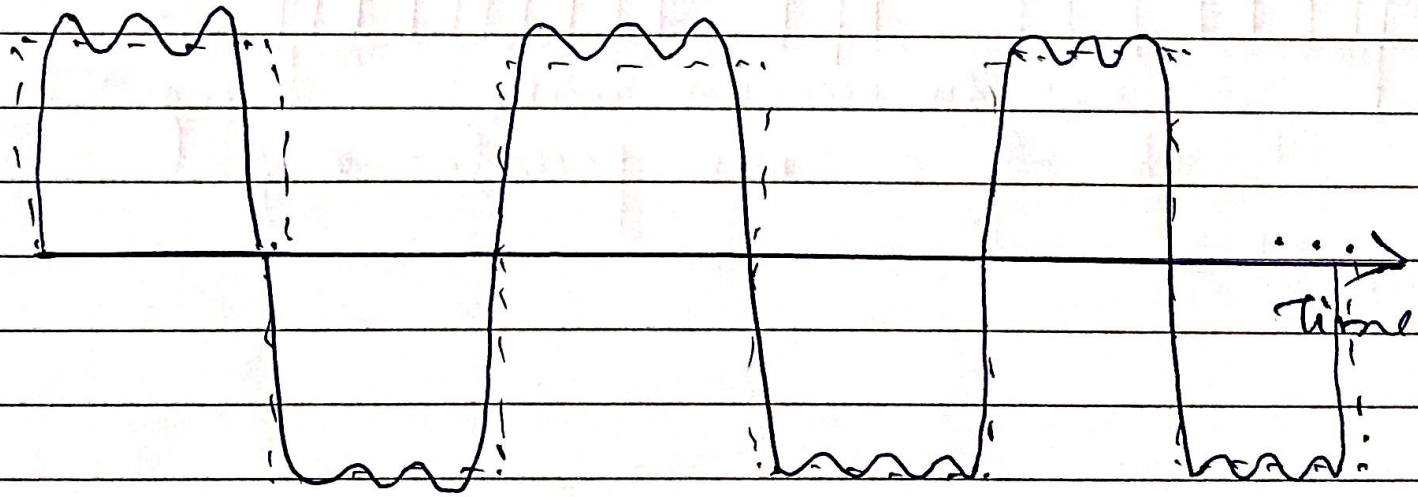
> If the composite signal is non-periodic, the decomposition gives a combination of sine waves with continuous frequencies.

eg. periodic composite signal with frequency f

- Not typical of those found in data communications.

- We can consider it to be 3 alarms systems, each with a different frequency.

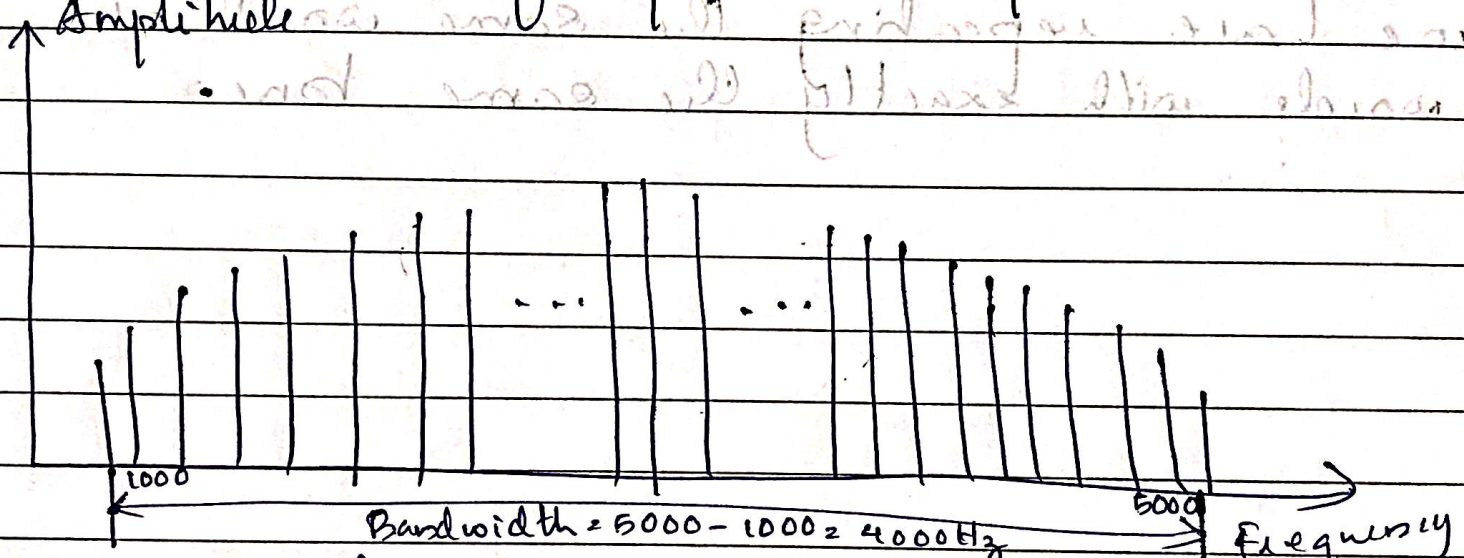
- The analysis of this signal can give us a good understanding of how to decompose signals.



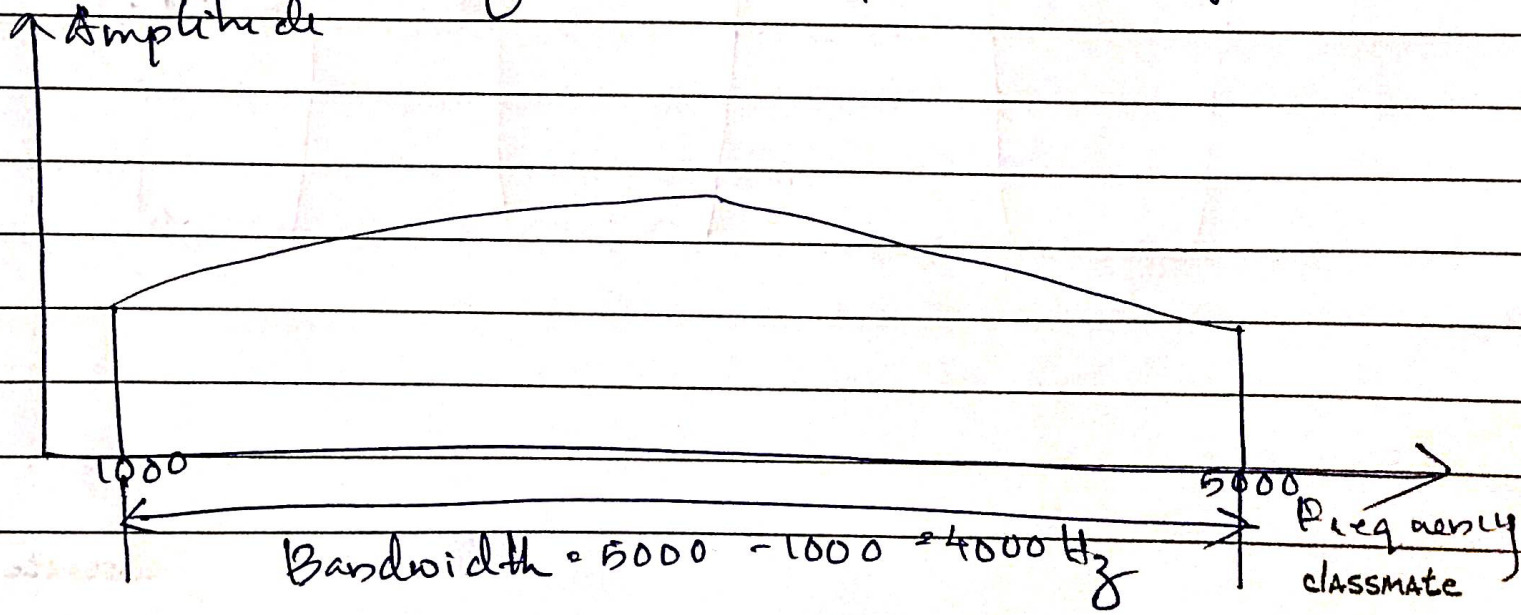
Bandwidth & Signal Frequency

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

a. Bandwidth of a periodic signal



b. Bandwidth of a non-periodic signal



Eg. 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 maximum amplitude of 10 V.

Solution

Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then

$$B = f_h - f_l = 900 - 100 = 800 \text{ Hz}$$

The spectrum has only five spikes at 100, 300, 500, 700 and 900 Hz.