# Data Communication and Networks.

## Course Outline

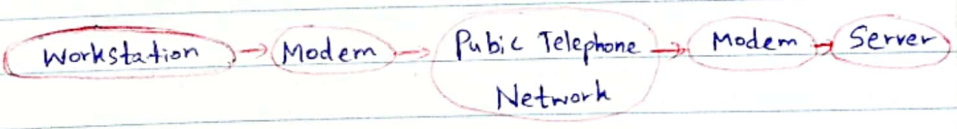
- What is Computer Networks?
- What is Internet?
- Introduction to Network Security?
- Layered Architecture.
- Error detection and Correction.
- Network Layer
- WAN technologies.

## What is Data communication?

Data communication refers to exchange of data between a source and a receiver.

A simple Model of a Data Communication system.

General bloch diagram ⟹


## What is a computer network?

The interconnection of a set of devices capable of communication.

A device can be,

- A host → large computer, desktop, laptop, workstation, cellular phone, security system.
- A connecting device → router (connects networks)
  Switch (connects devices)
  modem (modulator - demodulator)

Hardware requirements for network
- At least two computers
- Network Adaptors.
- Network Cables.
- Switch / Hub.

- A Network has to meet certain criteria for it to operate efficiently.

**Performance**
- can be mesured by.
  1) Transmit time
  2) Response time.

**Reliability**
- measured by the frequency of failure.

**Security.**
Protecting data against unauthorized access.

Performance depends on:-
- Number of users
- Type of transmission medium.
- capability of the connected hardware.
- efficiency of software

What is meant by computer networks, and explain?
A network is the interconnection of a set of devices capable of communication.

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# Physical Parts of the Network.

* **Network Adaptor** — A network interface controller is a computer hardware component that connects a computer to a computer network.

* **Cables**
networking hardware used to connect one network device to other network devices or to connect two or more computers to share printers, scanners etc.

* **Router**
A router is hardware device designed to receive, analyze and move incoming packets to another network. It may also be used to convert the packets to another network interface, drop them and perform other actions relating to a network.

* **Modem.** A hardware device that allows a computer to send and receive information over telephone line.

* **Hub** A hub is the most basic networking device that connects multiple computers or other network devices together.

* **Switch** It is a networking hardware that connects devices on a computer network.

* **What is Transmission Media.**
A transmission medium is a physical path between the transmitter and the receiver.

# Transmission Media.

- Wire (Guided / Bounded)
  - Twisted pair
    - Shielded Twisted Pair (STP)
    - Unshielded Twisted Pair (UTP)
  - Coaxial Cable
  - Fiber Optic
- Wireless (unguided / unbound)
  - Radio Transmission
  - Microwave Transmission.

* Signals being transmitted are directed and confined in a narrow pathway by using physical links.

Features:-
- High speed
- Secure
- Used for comparatively shorted distances

* No physical medium is required for the transmission of electromagnetic signals.

Features:-
- Signal is broadcasting through air.
- Used for larger distances.

## Guided Media.

### Twisted Pair Cable

- most popular networking cabling
- light weight, easy to install, inexpensive
- support many different types of network.
- supports Speed of 100 Mbps.
- made of pairs of solid or stranded copper twisted along each other.
- most commonly used in the telephone network and for communications within buildings.

### Coaxial Cable

- commonly used communication media. eg:- TV wire
- contains two conductors that are parallel to each other.
- Center conductor is usually copper.
- Used for TV distribution, long distance telephone transmission and LANs.

### Fiber Optic

- Uses electrical signals to transmit data
- Uses the concept of reflection of light through a core made up of glass or plastic.
- The core is surrounded by less dense glass or plastic covering called the cladding.
- used for transmission of large volumes of da

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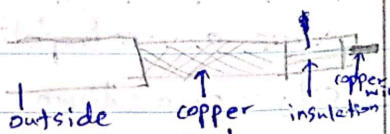
## Unshielded Twisted pair

- consists of one or more twisted pair cables.
- enclosed within an overall thermoplastic jacket which provides no electromagnetic shielding.
- more common and cost less than STP easy available.
- 100 meter limit
- Capable of high speed of LAN.
- Short distance due to attenuation.

## Shielded Twisted Pair

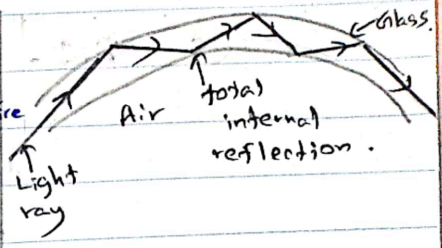
- Consists of one or more twisted pair cables.
- Has a metal braid that reduces interference.
- Medium cost
- 100 meter limit
- faster than UTP.
- More expensive than UTP
- More difficult installation.

## Coaxial cable




- Frequency characteristics superior to twisted pair
- performance limited by attenuation and noise
- Easy to wire.
- Easy to expand
- Single cable failure can take down entire network.

## Optical Fiber




- Greater capacity
- Data rates of hundreds of Gbps over tons of kilometers have been demonstrated.
- Smaller size and lighter weight
- Considerably thinner than coaxial or twisted pair cable.
- lower attenuation.
- Difficult to install and maintain
- High cost.

# Unguided Media

## Infrared Transmissions

- Archieved using transceivers that modulate non-coherant infrared light.
- Transceivers must be within line of sight of each other directly or via reflection.
- Does not penetrate walls.
- No frequency allocation issues.

## What is an Antenna?

- It is an electrical device which converts electric currents into radio waves.

- It is generally used with a radio transmitter or radio receiver.

Radio frequency, Electrical energy from Transmitter → Antenna. (converts) → electromagnetic Energy

- Electrical conductor or systems of conductors used to radiate or collect ~~Elect~~ electromagnetic energy.

- In two-way communication, the same antenna can be used for both transmission and reception.

* First Antenna → German Physicist ~~Hen~~ - Heinrich Hertz in 1888.

## Transmitter

- converts light, sound or electrical signal into microwave, radio or other electrical signals.
- An oscillating current of electrons forced through the antenna by a transmitter.
- Generates an oscillating magnetic field around the antenna elements. (metallic conductors)
- The charge of the electrons also generates an oscillating electric field along the elements.
- Above noted time, varying fields radiates away from the antenna as a moving electromagnetic wave into the space.

## Receiver Antenna.

- Converts electromagnetic signal into electrical energy.
- The oscillating electric and magnetic fields of an incoming radio wave apply force on the electrons in the ~~aktan~~ antenna elements.
- It cause them to move back and forth which generates oscillating currents in the antenna.

## Why Antenna is required?

- It is required for the communication between two parties in geographically seperated locations where the wired connectivity is not available.
- Antenna are required by any radio transmitter or receiver to couple its electrical connection to electromagnetic field.
- Radio waves are electromagnetic waves which carry signals through air at the speed of light with very minimal transmission loss.
- In some instances, the antennas are hidden.
  eg:- The antenna in AM radio
  laptops enabled with Wi Fi.

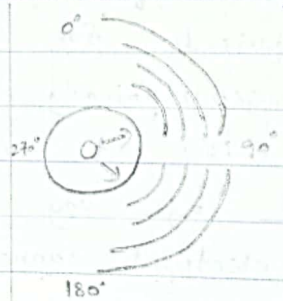
## Antenna Applications :-

- Broadcast television.
- Radio broadcasting.
- Point-to-point radio communication.
- Wireless LAN
- Radar.
- Satellite communication.
- Cell phones.

## Radiation Patterns.

Radiation pattern defines the variation of power radiated by an antenna as a function of the direction away from the antenna.

According to the applications and technology, antennas are broadly classified into 2 categories:

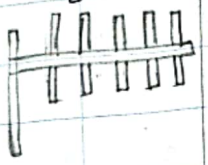

### Omni-directional Antennas

- Radiate or receive more or less in all directions
- These are employed employed when the relative position of the other station is unknown.
- Used at lower frequencies where a directional antenna would be too large

### Directional (Beam) Antennas.

- Preferentially radiate or receive in a particular direction.

# Antenna Types

| Yagi-Uda | Parabolic | Helix | Loop | Horn. |
|---|---|---|---|---|
|  |  |  |  |  |
| Unidirectional antenna | Often referred as Dish Antenna. | Omnidirectional Antenna. | Directional antenna | Unidirectional antenna. |
| Frequency range (300MHz ~ 3GHz) | Frequency range (3GHz ~ 30 GHz) | Frequency range (VHF and UHF band) | Frequency range (500 KHz ~ 1600 KHz) | Frequency range above 300 MHz |
| Narrow bandwidth | Sharp and narrow beam width | A conducting wire in the form of screw thread fed by power source | Consists of one or more complete turns of a conductor. | Gain is very high in the direction of the horn's axis |
| Higher gain | Higher directivity and gain | The feedline is connected between the bottom of the helix and ground plane | | Transmit radio waves from a waveguide out into space or collect radio waves into a waveguide for reception. |
| Higher directivity due to director and reflector | Radiates and receives signal in one direction only. | | | |
| Fixed frequency device | | | | |
| ~~Narrow~~ | Use in satellite communication / radar communication | Use in space communication / satellite communication / telemetry applications | Use in long distance Point-to-point Communication / Radio (AM-FM) reception. | Use as antennas at UHF and microwave frequencies. |

# Layered Architecture

## Why do we require Layered Architecture?

(1) Reduce the complexity of the design ~~(Devi.~~ (divide and conquer approach)
- This approach makes a design process in such a way that the unmanageable task are divided into small manageable tasks.

(2) Provides the independence of the layers, which is easier to understand and implement.

(3) Easy to modify without affecting other layers.

(4) Easy to test where each layer of the layered architecture can be analyzed and tested individually.

There are 2 layered architectures!-

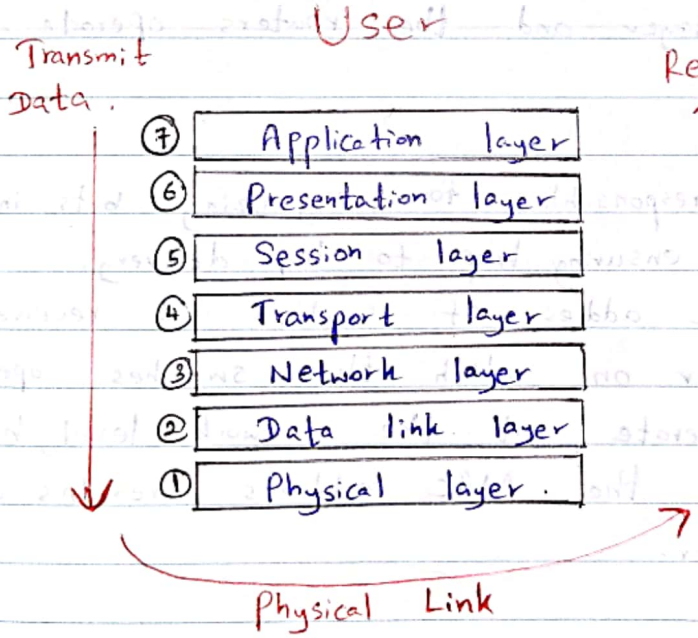
| ① OSI 7-layer architecture (Open System Interconnection) | ② TCP/IP protocol architecture (5 layers) |
|---|---|
| (7) Application (End user layer) (HTTP, FTP, IRC, SSH, DNS) | (5) Application Layer (Generates the data and requests connections) |
| (6) Presentation (Syntax layer (SSL, SSH, IMAP, FTP, MPEG, JPEG) | (4) Transport Layer (TCP/UDP) (Establishes connections with remote host) |
| (5) Session (Synch and Send to port) (API's, Sockets, Winsock) | (3) Network Layer (IP) (Transfers packets with virtual (IP) address) |
| (4) Transport (End to end connections) TCP, UDP | (2) Data link layer (MAC) (Transfers frames with physical (MAC) address) |
| (3) Network (Packets) IP, ICMP, IP, ICMP, IPSec, IGMP | (1) Physical Layer (Transmits and receives bits). |
| (2) Data link (Frames (Bridge, Ethernet, PPP, switch) | |
| (1) Physical (Physical structure (Coax, Fiber, wireless, Hubs, Registers) | |

# The OSI Model :- (Open Systems Interconnection)

- This is a tool, used by IT professionals to actually model or trace the actual flow of how data transfers in networks.

- OSI is a logical representation of how the network systems are supposed to send data or communicate to each other.

OSI model was introduced by International Organization for Standardization (ISO) in 1984.




## (01) Physical Layer

This is the layer on which the real transmission of data bits ~~makes~~ takes place through a medium.

- This layer is, as the name suggests, all the physical stuff that connects the computer together.

(1) Responsible for electrical signals, light signal, radio signals etc.
(2) Hardware layer of the OSI layer.
(3) Devices like repeater, hub, cables, Ethernet work on this layer.
(4) Protocols like RS232, ATM, FDDI work on this layer.

## (02) Data Link Layer.

- ~~The job main job of this layer is to move packets from source to destination and provide inter-networking~~
- ~~This is the layer and the routers operate on.~~
~~ST~~

- This layer is responsible for organizing bits into frames and ~~ensure~~ ensuring hop to hop delivery.
- Assign the mac address of sender and receiver.
- This is the layer on which the switches operate on. Since routers operate at the network level, hence we can ~~stay~~ say that the MAC address resides at the data link layer.

- All the computers in a specific network get plugged into a switch, so that they can communicate with each other.

- Responsible for encoding and decoding of the electrical signals into bits.
- Manages data errors from the physical layer.
- Converts electrical signals into frames.
- Devices like 'Switch' work at this layer.

## (03) Network Layer.

- This layer moves packets from source to destination and provide inter-networking.
- Since routers operate at the network ~~layer~~ level, we can say that the IP address is at the network level.
- Logical addressing (IP addressing) happens inside the Network layer.
- Network protocols like Tcp/IP, IPx, AppleTalk work at this layer.

## (03) Transport Layer.

- This layer decides how much information should be sent at a time.
- When we communicating with a website, this layer will decide how much data we ~~can~~ can transfer and receive at a given time.
- This layer provides reliable process to process message delivery and error recovery.

- Responsible for → the transparent transfer of data between end systems
  - → end-to-end error recovery and flow control.
  - → comple data transfer.

- Protocols like UDP (Video games, movies, online streaming), Tcp (www, Email, File transfer) work here.

## (04) Session Layer

- This layer maintains proper communication by establishing, manage and terminate sessions between two computers.
  eg:- • when we visit any website, our computer has to create a session with the web server of that website
- The session layer sets up, coordinates, and terminates conversations, exchanges and dialogues between the applications at each end.
- It deals with session and ~~con~~ connection coordination.
- works with APIs and NETBIOS.

## (06) Presentation Layer.

- This is the layer in which the operating system operates with the data.
- User interacts with Application layer which sends ~~the~~ the data down to presentation layer.

Responsible for →
- Data representation on your screen.
- Encryption and decryption of the data.
- Responsible for translation, Compression and Encryption data.

## (07) Application Layer.

- This is the layer that the end-user is actually interacting with.
- This layer allows access to network resources.
- This layer supports application, apps and end-user processes.
- This layer is responsible for application services for ~~file~~ file transfers, e-mail and other network software services.
- Protocols like Telnet, FTP, HTTP work on this layer.

# TCP/IP Model :-

TCP/IP Model helps you to determine how a specific computer should be connected to the internet and how data should be transmitted between them.

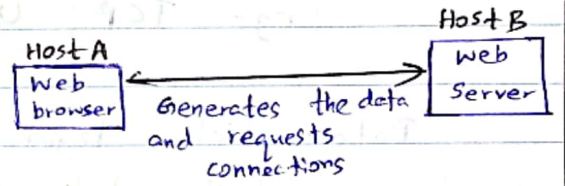
The purpose of TCP/IP model is to allow communication over large distances.

TCP/IP → Transmission Control Protocol / Internet Protocol.

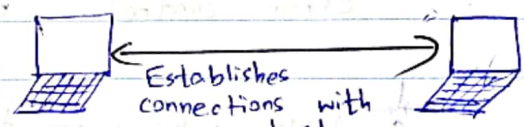
~~This model~~ TCP/IP protocol stack is specifically designed as a model to offer highly reliable and end-to-end byte stream over an unreliable internetwork.

## TCP/IP Model - New Version.

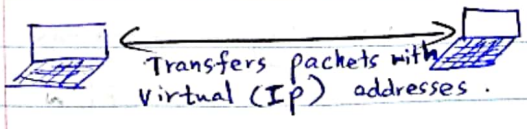
(5) Application Layer
The Application layer is the group of applications requiring network communications.



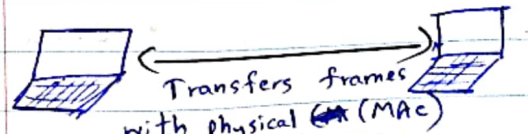

(4) Transport Layer (TCP / UDP)
Establishes the connection between applications on different hosts.



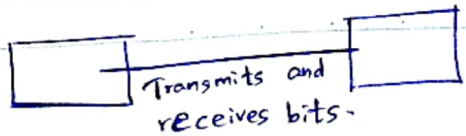

(3) Network Layer (IP).
Responsible for creating the packets that move across the network.



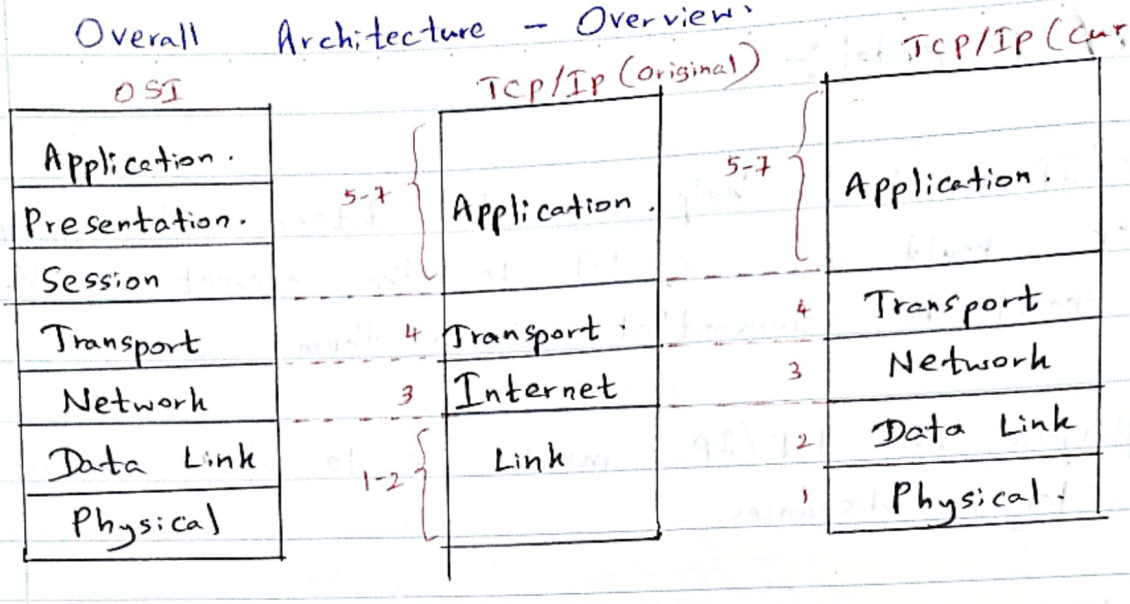

(2) Data Link Layer (MAC)
responsible for creating the frames that move across the network.




(1) Physical Layer
This layer is the trans ceiver that drives the signals on the network



## Overall Architecture – Overview:




## OSI - Model:-

~~Data Link~~

Data Link Layer

**What is a Protocol?**

A set of rules or procedures for transmitting data between electronic devices.

eg:- TCP, UDP, HTTP, ~~HTTP~~ HTTPS, FTP, SSH.

**Data Link layer is responsible for?**

implementation of point-to-point flow and ~~error~~ error control mechanism.

✳ Some requirements and objectives for effective data communication between two directly connected transmitting receiving stations are;

- Flow control.
- Frame syn chronization.
- Error control.

## Flow control:-

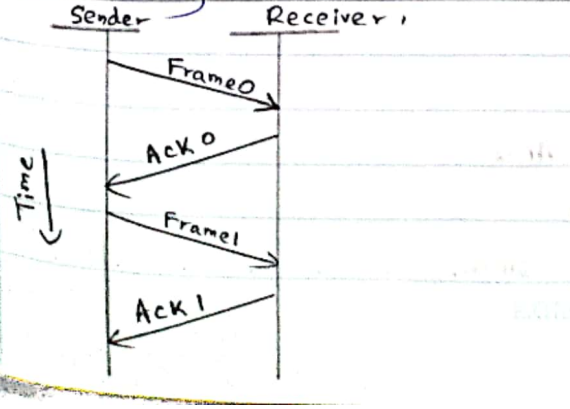
- Technique for assuring that a transmitting entity does not over-whelm a receiving entity data.
- The receiving entity typically allocates a data buffer of some maximum length for a transfer.
- In the absence of flow control, the receiver's buffer may fill up and overflow while it is processing old data.

Methods to control the flow:-

- Stop and Wait Flow Control
- Sliding Window Flow Control.

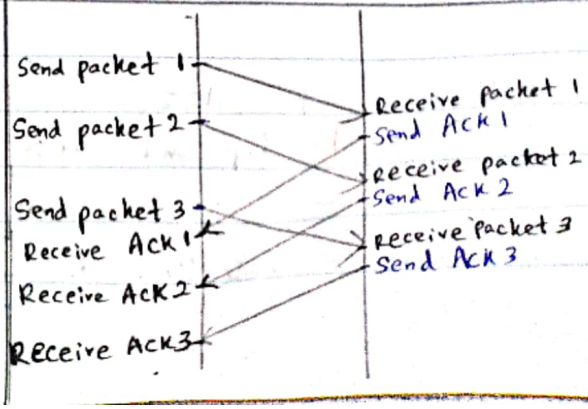
### Stop and Wait Flow Control.

- Forces the sender after transmitting a data frame to 'stop and wait' until the acknowledgement of the data frame sent is received.
- Simplest form of flow control.
- Source transmits frame.
- Destination receive frame and replies with acknowledgement (ACK)
- Source waits for ACK before sending next frame.
- Destination can stop flow by not sending ACK.




### Sliding Window Flow Control.

- Both sender and receiver agree on the number of data frames after which the ACK should be sent.
- Receiver has buffer n long.
- Transmitter sends up to n frames without ACK.
- ACK includes number of next frame expected.
- Receiver can ACK frames without permitting further transmission.



## Error Control Techniques:-

When data frame is transmitted, there is a possibility that data frame may be lost in the transit, or it is received corrupted.

Requirements for error control mechanism:-

- **Error Detection**
  The sender and receiver, either both or any, must ascertain that there is some error in the transit.

- **Retransmission after timeout.**
  If an Ack of data-frame previously transmitted does not arrive before the timeout the sender transmits the frame.

- Positive Ack → When the receiver receives a correct frame it should acknowledge it.

- Negative Ack → When the receiver receives a damaged frame or a duplicate frame, it sends a NACK.

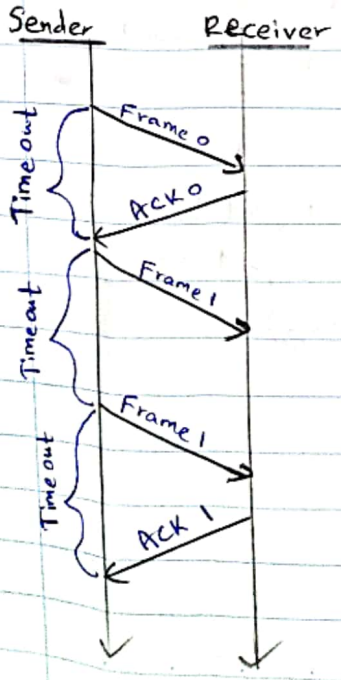
### Automatic Repeat Request (ARQ)

Collective Name for error control mechanism.

- Versions of ARQ;
  - Stop and Wait ARQ
  - Go-Back-N ARQ
  - Selective Reject ARQ.

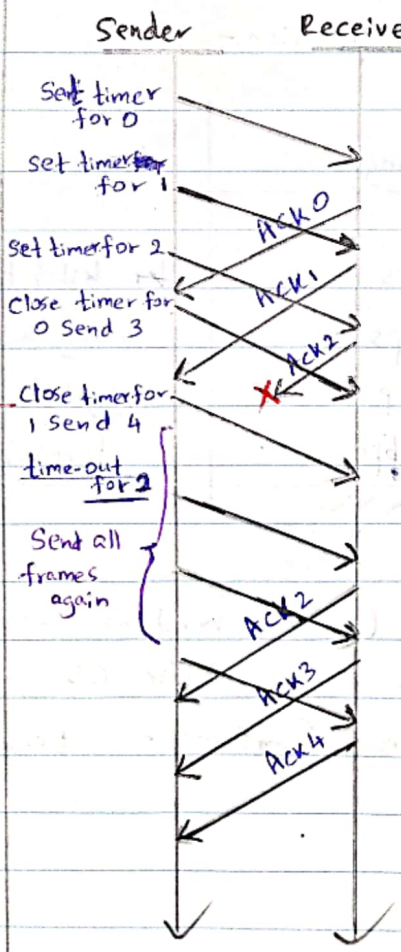
## Stop and wait ARQ

- When a frame is sent, the sender starts the timeout counter.
- If ACK of frame comes in time, the sender transmits the next frame in queue.
- If ACK does not come in time, the sender assumes that either the frame or its ACK is lost in transit.
- Sender retransmits the frame.
- If a ~~ACK is~~ negative ACK is received the sender retransmits the frame.



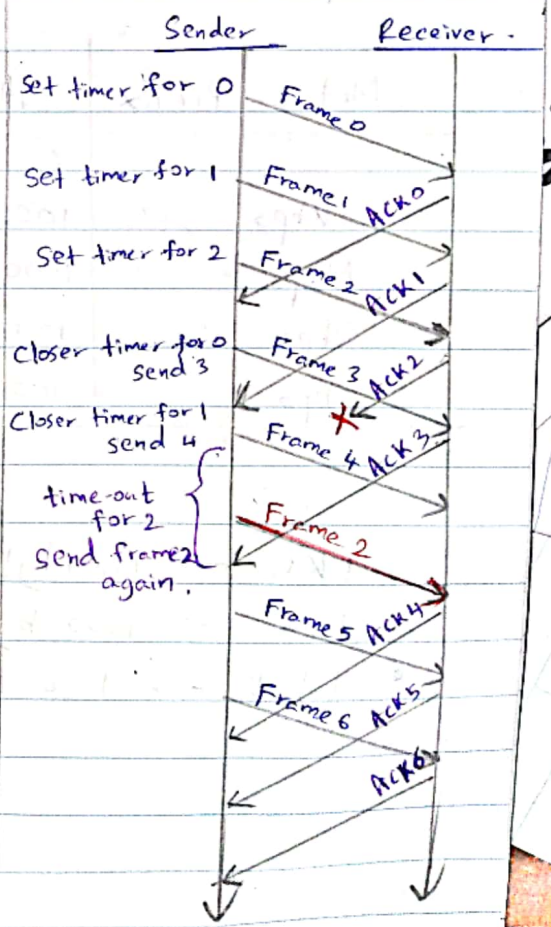

## Go-Back-N ARQ

- Stop and wait ARQ mechanism does not utilize the resources at their best, when the ~~ac~~ ACK is received, the sender sits idle and does nothing.
- Both sender and receiver maintain a window.




## Selective-Reject ARQ.

- Also called selective retransmission.
- Only rejected frames are retransmitted.
- Subsequent frames are ~~acce~~ accepted by the receiver and buffered.
- Minimize retransmission.



# Error Detection and Correction:-

8 bits = 1 Byte (B)
1024 Bs = 1 Kilobyte (KB)
1024 KBs = 1 Megabyte (MB)
1024 MBs = 1 Gigabyte (GB)
1024 GBs = 1 Terabyte (TB)
1024 TBs = 1 Petabyte (PB)
1024 PBs = 1 Exabyte (EB)
1024 EBs = 1 Zettabyte (ZB)
1024 ZBs = 1 Yottabyte (YB).

## Speed of Data transmission:-

| Metric Prefix | Meaning | |
|---|---|---|
| kbps | 1000 bps | kilobits per second. |
| Mbps | 1000 kbps | megabits per second |
| Gbps | 1000 Mbps | gigabits per second. |
| Tbps | 1000 Gbps | terabits per second. |

- 1 KB → 1024 bytes (as windows would report it)
- 1 kB → 1000 bytes (as MAc OS would report it)
- 1 KiB → 1024 bytes (unfamiliar terminology)

## What is an 'Error'?

A condition when the ~~any~~ output information does not match with the input information.

- During transmission, digital signals suffer from noise that can introduce errors in the binary bits travelling from one system to other.

## What is noise in communication?

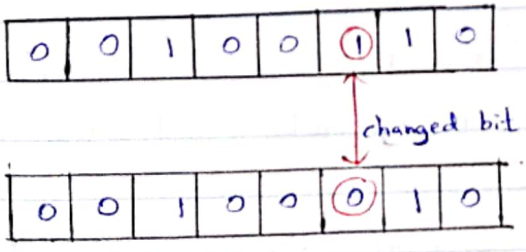
Noise ~~is~~ essentially is anything that distorts a message by interfering with the communication process.

eg:- Radio playing in the background.

## Errors

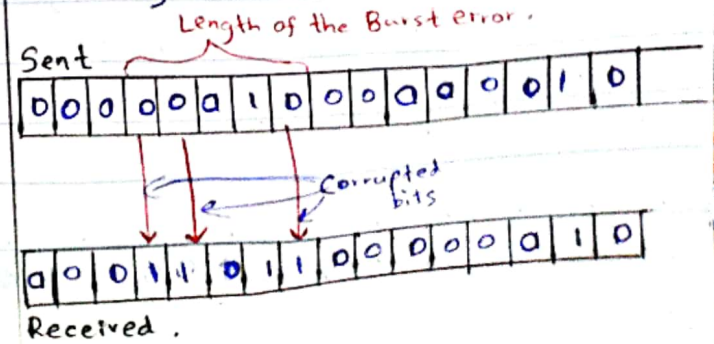
### Single bit

- only one bit of data unit is changed.
- Single bit errors can ~~happen~~ happen in parallel transmission, where all the data bits are transmitted using seperate wires.




### Burst Error -

- Two or more bits in data unit are changed from 1 to 0 or from 0 to 1 as shown in following figure.
- Not necessary, that only consecutive bits are changed.
- Length of burst error is measured from first changed bit to last changed bit.
- As shown in fig. length of burst error is 8, although some bits are unchanged in between.



## Error Detecting Codes:-

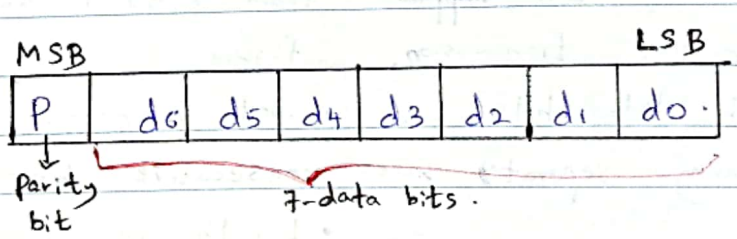
Whenever a message is transmitted, it may get scrambled by noise or data may get corrupted.

Error Detection Techniques.

- Parity Check
- Checksum.

### Parity Checking of Error Detection:-

- Simplest technique for detecting and correcting errors.
- The Most Significant Bit (MSB) of a 8-bit word is used as the parity bit and the remaining 7 bits are used as data or message bits.
- Parity can be either even or odd.



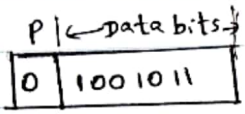

* Even parity → The number of 1's in the given word including the parity bit should be even (2, 4, 6, ...)

* Odd parity → Odd parity means the number of 1's in the given word including the parity bit should be odd (1, 3, 5 ....)

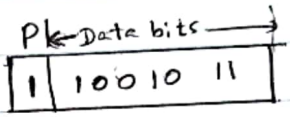
## Use of Parity Bit :-

- The parity bit can be set to 0 and 1 depending on the type of the parity required.

**For even parity,**
this bit is set to 1 or 0 such that the no. of "1 bits" in the entire word is 'even'




**For odd parity,**
this bit is set to 1 or 0 such that the no. of "1 bits" in the entire word is odd.

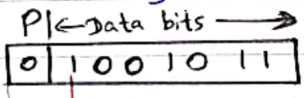



## How does the Error Detection Take Place?

Parity checking at the receiver can detect the presence of an error. if the parity of the receiver signal is different from the expected parity.

That means if it is known that the parity of the ~~transmitted~~ transmitted signal is always going to be "even" and if the received signal has an odd parity, then the receiver can conclude that the received signal is not correct.

Transmitted code




Received code with one error