Computer Networks

If only 2 computers connected it is called as data communication.

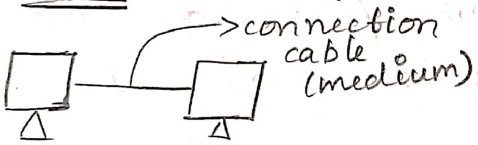
If more than 2 computers connected then it is called computer network(not internet)

Group of networks interconnected is called internet

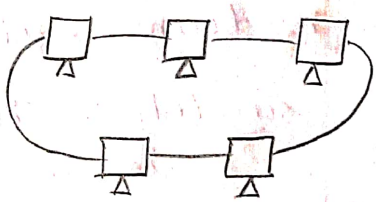
Network:

Collection of two or more computers, that link together and communicate with each other, to enable sharing of information, data and resources.

data communication

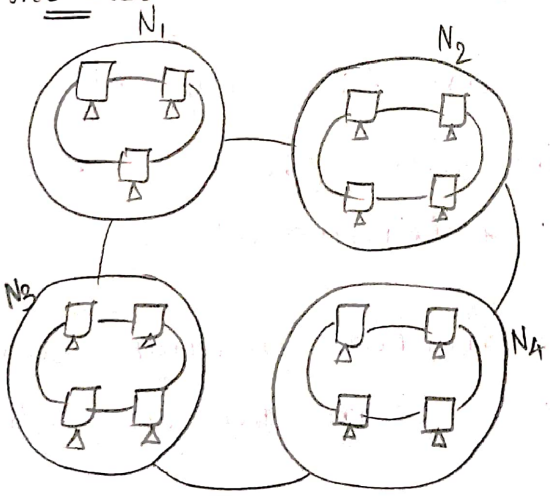


network



interconnection of computer

Internet



interconnection of network

medium (or) cable (or) wire (or) link

msg
↓
segment
↓
Packets
↓
frame
↓
1's or 0's
↓
signal
↓
it only gets transferred.

Resources:
servers, mainframes, modems, routers, smartphones, webcam and printers

Uses and benefits of computer network
- File sharing
- Hardware sharing
- Application sharing
- User communication
- network gaming
- voice over IP(VOIP)

IP:
with wire → guided medium
without wire → unguided medium
} → connection of two devices

Data communication:
The exchange of data between two devices via some form of transmission medium such as a wire cable.

switch → it is for connecting devices in a single(home) network.

single network → can be setup by using components devices, cable, protocol, data, switch (or) Forwarders (or) intermediators.

(all PC are connected through switches) → network
(All switches are connected through router) → internet

Switch

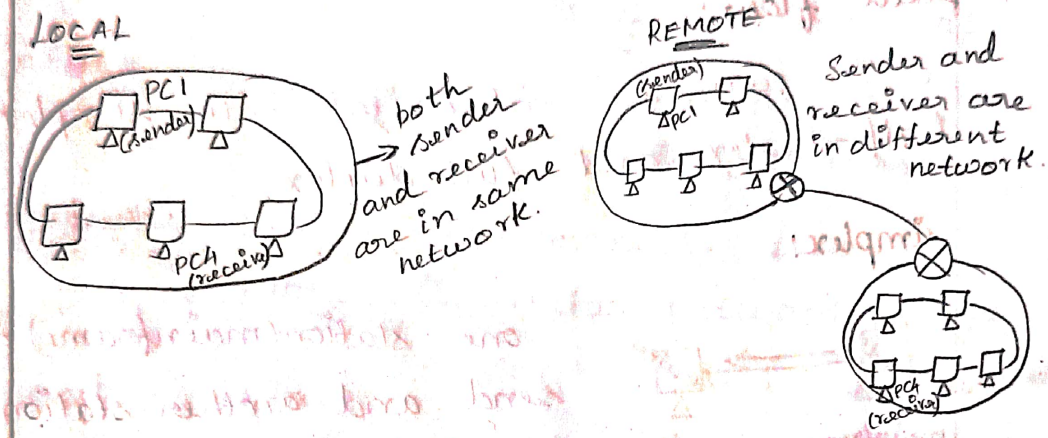
router

switch and router are network connecting devices.

Types of data communication:

Local → devices are in same geographical area.

remote → communication between two or more devices not located in same geographical area.



Fundamental characteristics of data communication.

Delivery → data to correct destination

accuracy → data delivery should be accurate

Timelines → deliver data in timely manner

Jitter → Variation in packet arrival time.

delay time

Personal computer → workstation/node/ end device/ host

PC connected to network or server

when PC connected to internet

Transmitter → medium

Protocol:

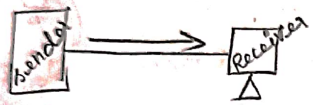
represent the agreement between the communicating devices.

(without protocol, two devices can be connected, but can't be communicated)

Data flow:

It can be categorized into simplex, half-duplex and full duplex.

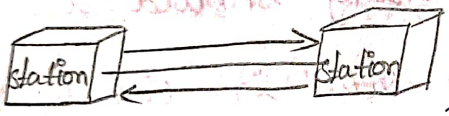
simplex:



mainframe monitor

one station (mainframe) can send and another station (monitor) can only receive (msg transfer only in single dir

half duplex:



each station can send and receive data, but not at a same tim
eg:- chatting

full duplex:

both station can send and receive data at a same time.
eg:- Telephone call

Network:

Network is a set of devices connected by communication links.

node → end device

link → medium, cable, air, ...

wireless → microwave, radiowave, infrared

eg:- satellite eg:- mobile phone

eg:- laser point

unguided ← medium

tower (Boy station)

medium

Telephone line → Twisted pair cable

LAN cable, lap charging cable → cohosial cable

Long distance transmission → Fibre optic cable

connecting device: microwave, infrared, radiowave → unguided medium

switch → connect same network devices (only two layer)

router → all different networks are connected to router (3 layers)

gateway → used to connect two or more dissimilar network (7 layer) ↓ more secured

hub → 1 layer

Access point:

* Access point is used to connect the end device wirelessly same as switch but access point is wireless.

* Creates wireless local area network (WLAN)

* The access point connects end devices wirelessly and the access point is connected to the router or switch or hub using wire.

Wi-fi card:

Wireless fidelity.

using wi-fi the end devices are connected to the access point wirelessly

network criteria:

Performance

Reliability

security

Performance:

*measured using transmit time and response time.

- Transit time → time for a message to travel from one device to another (source → destination)
- Response time → elapsed time between an inquiry and a response. (destination → source)

before jitter and latency these are calculated

*Performance is dependent on following factors:

- The number of users
- Type of transmission medium
- capability of connected network
- efficiency of software

Parameters for measuring network Performance.

1. Bandwidth (capacity of the link)
   *maximum capacity of medium to transmit message.
2. Latency (Delay)
   *time taken to reach the destination and also to the sender. (complete delay until it reaches the destination)

the delay in the complete data transaction.

3. Throughput
   *minimum capacity of message to travel through link.
4. Jitter → packet variation
   *Packet delay variance.
   *delay between each packets
   *different packets of data face different delays in the network.

Bandwidth (bits per second)

Bandwidth is the maximum amount of data that can be transmitted through a link. It refers to the overall capacity of a network link.

measuring using bps

kbPS	- kilo bits per second	kilo (1kb/s = 1000b/s)
MbPS	- Mega bits per second	mega (1Mb/s = 1000kb/s
GbPS	- Giga bits per second	giga (1Gb/s = 1000Mb/s
TbPS	- tera bits per second	Tera (1Tb/s = 1000Gb/s)

convert bits and bytes:

8 bits = 1 byte

1024 bytes = 1 KB

1024 KB = 1 MB

1024 MB = 1 GB

1024 GB = 1 TB

1. convert 5KB to bits

$1024 \times 5 = 5120$ bytes

$5120 \times 8 = 40960$ bits

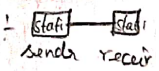
1 byte = 8 bits

physical structures:

Type of connection:

1. Point-to-point:

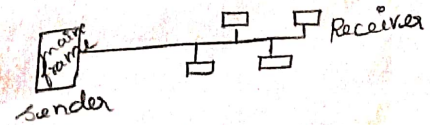
Two end devices are connected directly to each other, a data is transmitted between two devices without any intermediate devices. eg:



2. Multipoint:

Single cable connects more than 2 devices.

eg:-



Network topologies:

Network topology defines the layout, virtual shape or structure of network.

Topology defines the way hosts are connected to the network.

Types of topology:

1. Mesh topology

Network:

LAN → data surrounded within the same network

WAN → data send to other network

Based on the geographical location

Protocol:

It is set of rules for data communica

The key elements are,

* Syntax
* Semantics
* timing

* without protocol only connection will be established the devices can't be communicated

Syntax:

Structure

Says how to read the bits

Semantics:

meaning of each section of bits

group of bits → bit pattern, each bit patter do some task

Timing:

when and where the data should be sent

at which speed the data should be sent.

Standards

Two categories

1. De facto → not approved by an organization body but approved.
2. De jure → recognized officially.

If any product or anything is officially recognized by ISO, ITU-T, ANSI, IEEE, EIA then it is called De jure.

Internet:

* internet

two or more networks that can communicate with each other.

* Internet

collaboration of hundreds of interconnected networks.

internet service providers
* Jio
* Airtel
* BSNL
* Vodafone

Internet backbone:
A set of high-speed networks that carry internet traffic.
These networks are provided by companies such as AT&T, GTE and IBM

Internet connection:
Phone modem → converts data to analog audio signal and also vice versa.
Digital subscriber line → transfer digital data(0's & 1's) to and from phone company's central office.
cable modem
Broadband → ~~the connection~~ when our SIM card is connected to its company then it called broadband

Data transfer rate: → fix to cable
The capacity of cable is called data transfer rate.
The speed with which data is moved from one place on a network to another.
(The network performance is measured by throughput
Jitter and bandwidth)

data transfer → bits → download speed, uploading speed.
storage → bytes

Computer Network Models

⇒ First the sender send the letters with From and To address and put in the post office.

⇒ Take all the received letters in the

encrypt → original message converted to duplicate message.

1. OSI model
2. TCP/IP model

use of OSI layer:

to guide technology vendors and developers.

provide a teaching tool

OSI → open system interconnection

↓

approved by ISO.

It divides the task into seven tasks

Each layer will do only their work.

Seven layers! (should always be in order don't change the order)

directly communicate with the medium ← 1. physical

Mac address is provided ← 2. Data link (error detection and correction)

3. Network (provides path)

only in this IP address is provided ← 4. Transport (delivery)

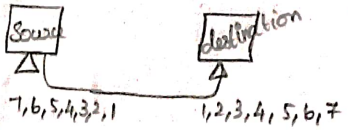
5. Session (dialogue controller)

6. Presentation (compression, convert to machine code)

sender ↑ ↓ destination

7. Application

source to destination → 7 to 1



Mac → medium access control

To access internet minimum 3 layer is needed

Layer 1: Physical Layer:

* no protocol
* In this layer information (data) is converted into bits
* bits converted to signals
* medium selection (guided or unguided medium)

Functions:

* Bit synchronization
  clock is used to synchronize the bit pattern.
* Bit rate
  no. of bits transferred per second between source to destination.

eg:- hub, repeater, modem, cable etc...

* Selecting of topology.
* data flow (Transmission mode selection)

Data Link Layer - Layer 2: (DLL) → adds mac address

* converts bits to frames (destination side) or packets to frames (source side)
* It is responsible for error detection and correction.
* Flow control
* Protocols - ARP, RARP, PPP, Ethernet, Wifi etc..

only 2 layer functionality

ARP - address resolution protocol
PPP - point-to-point protocol
RARP - Reverse address resolution protocol)

The protocol's of that layer can only be used for that particular layer because these protocols have only that layer functionality

physical address (or) mac address (or) ethernet address

The DLL is divided into two sublayers:

1. Media access control - It says how many devices can access (use) a particular network. controlling how many devices can connect per medium.

2. Logical link control.

Responsible for error checking and frame synchronization.

Layer 3 : Network Layer : → adds IP address

* converts segments to packets
* It adds IP address of source and destination into the packet
* Handles network traffic (Data rate)
* This layer adds sequence number to each packet.

Protocol - IP, ICMP, IGMP, IPsec,

ICMP - Internet control message protocol
IGMP - Internet Group management protocol
IPsec - Internet protocol security

Layer 4 : Transport Layer : (uses for data delivery

* Segmentation takes place
* uses TCP and UDP protocols
* TCP - gives the guarantee of transmission
UDP - does not gives the guarantee of transmission of data
* responsible for retransmission
* sends acknowledgement for successful and unsuccessfull message delivery.

* Protocols - TCP, UDP, SCTP, DCCP etc...

TCP - Transmission control protocol
UDP - User datagram Protcol.

SCTP - Stream control transmission protocol

DCCP - Datagram congestion control protocol.

Layer 5 : Session Layer: (dialogue controller)

create session between client & server

It means any activity performed within start time and stop time is called session.

transit time + acknowledgement time is called round trip time.

responsible for dialog control means for keeping track of whose turn it is to transmit (session)

response for managing connection & terminating connection.

Presentation layer : Layer 6 (ASCII conversion)

1. Types of network address.

IP address – Network layer

Mac address – Datalink layer

Port address – Transport layer

Mail address – Application layer

app → Interact with users

Sender

Receiver

Application layer	Application layer data	Hello	Application layer
Presentation layer	Presentation header	PH Hello	Presentation layer
Session layer	Session header	SH Hello	Session layer
Transport layer	Transport header	TH SH PH Hello	Transport layer
Network layer	Network header	NH TH SH PH Hello	Network layer
Datalink layer	Datalink header	DH NH TH SH PH Hello	Datalink layer
Physical layer		100.1.1.1.1.0.1.0.1.0.0.1.1	physical layer

data moved to network media

data received from network media

Network media

In sender side the header files are added before the original data

In the receiver side the header files are removed in each stage

(The headers files are the providing information like IP, MAC, port etc... in each layer) ✓.

TCP/IP Model.

* used to interconnect various defense department computer network.
* It is internet architecture.

5 layers

1. Application — combined of presentation, session and application
2. Transport — Transport
3. Internet — network
4. Network interface — datalink
5. Hardware devices — Physical

Both are same.

datagram or datapacket

Application presentation Session	SMTP FTP (↓ TCP) TELNET DNS SNMP NFS RPC TFTP → UDP
Transport	TCP UDP
Network	ICMP IGMP ARP RARP
Datalink layer	
Physical layer	

no protocols

DHCP = Dynamic host configuration protocol.

OSPF = open shortest path First.

Encapsulation:

data moves from upper layer to lower layer

each layer includes a bundle of information called a header along with the actual data.

Decapsulation:

the data is moving from lower layer to upper layer, each layer removes the headers.

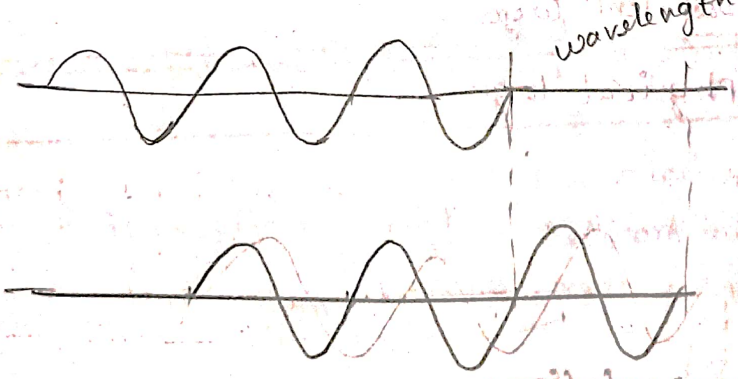
units of period and frequency:

Unit	Equivalent		
Seconds	1S	Hertz(HZ)	1HZ
Milliseconds	10^{-3}S	KiloHertz	

Wavelength:

Wavelength is a another characteristic of a signal travelling through a transmission medium.

It binds the frequency of a simple sine wave to the propagation speed of the medium



Frequency

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

ex:
The period of the signal is 100ms. What is its frequency in kilohertz?

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

$f = \frac{1}{T} = \frac{1}{10^{-1}}\,Hz = 10\,Hz$

$= 10 \times 10^{-3}\,KHz$

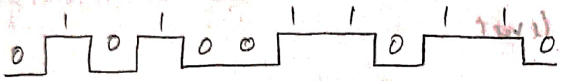
$\boxed{f = 10^{-2}\,KHz}$

(Amplitude and voltage are same)

Bit interval and wavelength are same.

Digital data & signal:

Bit interval → time required to send one single bit.



0 and 1's are data

 → signal

0 → no voltage (0V)

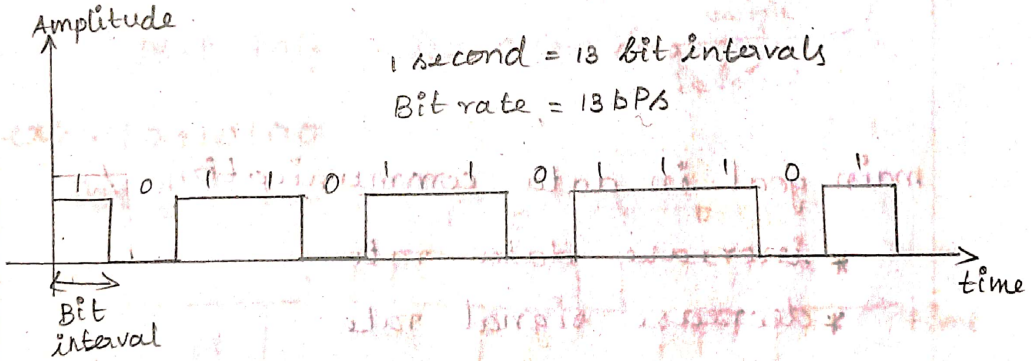
1 → positive voltage (+V)

Bit rate → no. of bits transferred per second.

Baud rate → no. of digital signals transferred per second

mega = 10^6
nano = 10^{-9}
milli = 10^{-3}

ex: 1011011011101



Digital to digital conversion:

To convert digital data to digital signal there are 3 techniques

They are, 1. Line coding
2. Block coding
3. Scrambling

Line Coding:

It is the process of converting digital data to digital signal.

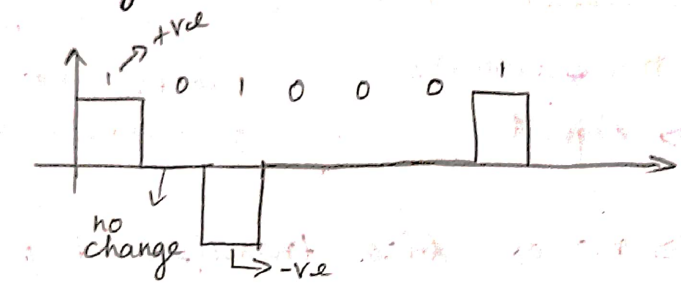
Sender ⇒ digital data $\xrightarrow{\text{encoded}}$ signal

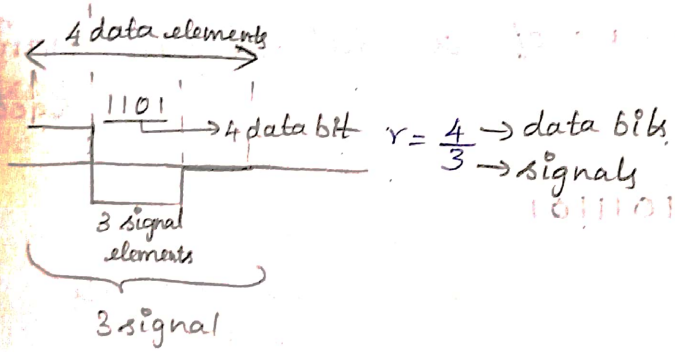
receiver ⇒ digital signal $\xrightarrow{\text{decoded}}$ data

Two signal level

two data levels

Three signal level





main goal in data communication

* increase data rate
* decrease signal rate

*worst case → ↑ signal rate

*best case → Min signal rate

Relationship between data rate and signal rate.

$S = c \times N \times \frac{1}{r}$ baud ← total $\frac{\text{no. of bits}}{\text{no. of signal}}$

S ← no. of signal element

c ↓ case factor

N → data rate

ex:1

baud rate? $C = 1/2$

$S = C \times N \times \frac{1}{r} = \frac{1}{2} \times 100{,}000 \times \frac{1}{1} = 50000$ baud

$= 50$ kbaud

Unipolar - NRZ

0 → no change

1 → +ve

Bipolar → NRZ, RZ, manchester, differential manchester

NRZ → 0 → +ve

1 → -ve

RZ → 1 bit

Polar RZ:

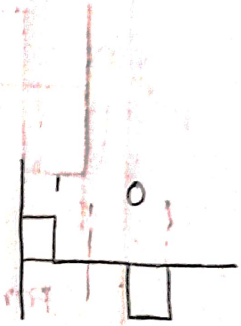
Symbol 0 → $-\frac{A}{2}, \frac{T_B}{2}$

$0, \frac{T_A}{2}$

1 bit → divided to 2 levels

symbol 1 → $\frac{A}{2}, \frac{T_B}{2}$

$0, \frac{T_A}{2}$



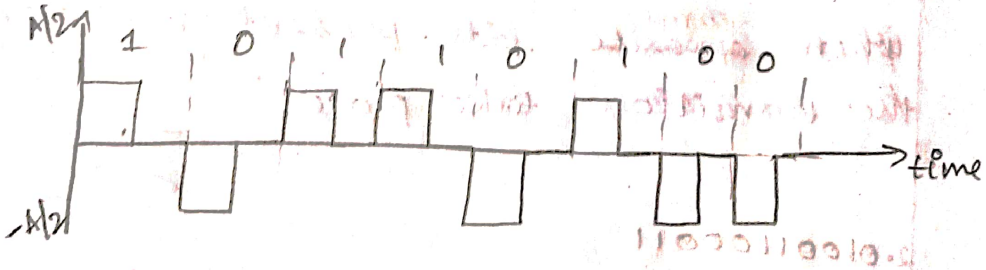
0 → 1st half pulse $-A/2$

next half pulse 0 (no change)

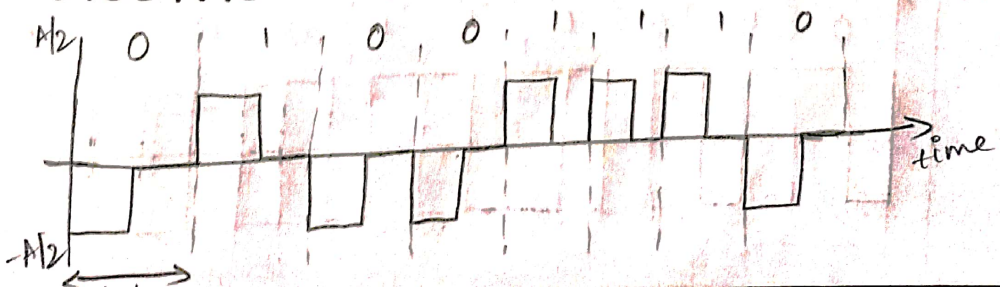
1 → 1st half pulse $+A/2$

next half pulse 0 (no change)

ex:- 1. 10110100



2. 01001110

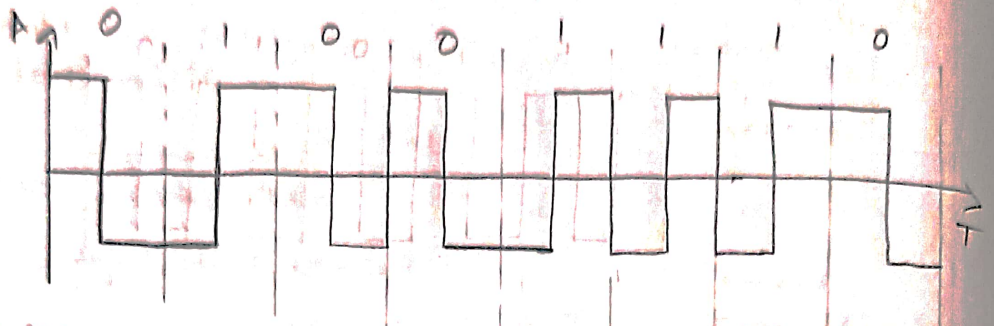


Manchester

1 bit divided to 2 levels

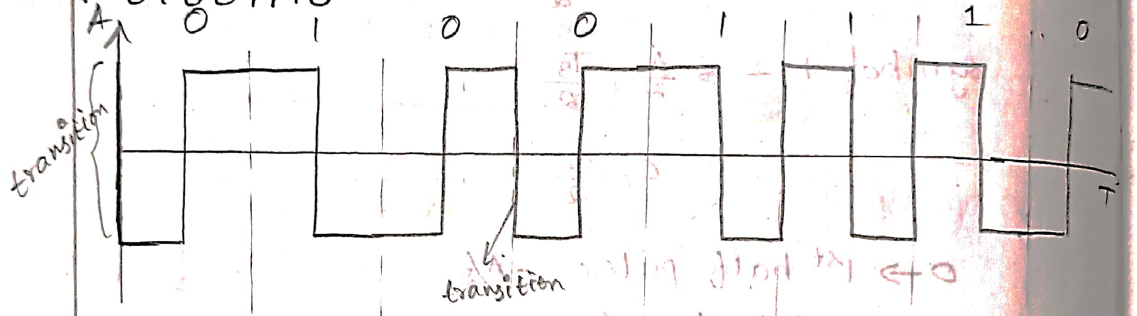
example:

1. 01001110



Differential Machester: → RZ + NRZ

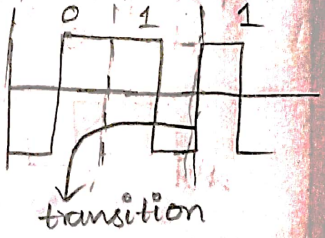
1. 01001110



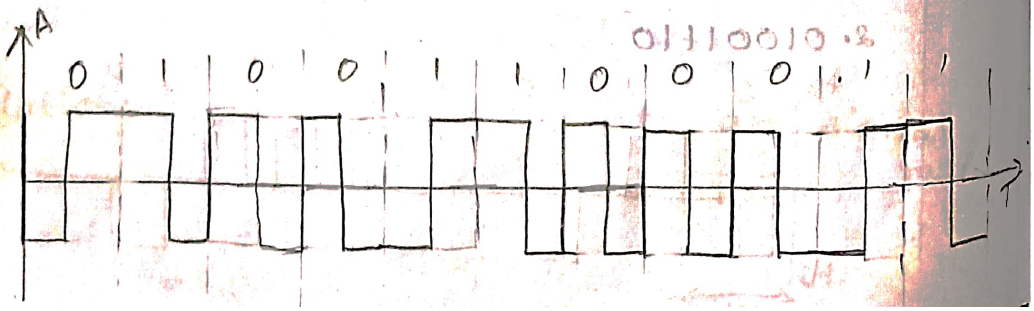
For differential Manchester, if 0 is at 1st bit then it should start from no chang

* If next bit is 0 → transition present
* If next bit 1 → no transition

when ~~same/opposite~~ bits present next next then the transition takes place



2. 01001100011



Baseline Wandering:

While decoding in receiver side there will be a sequence of 0's or 1's comes then it is called Baseline Wandering.

Line coding scheme prevents baseline wandering.

DC components:

when a voltage level in a digital signal is constant for a while, the spectrum

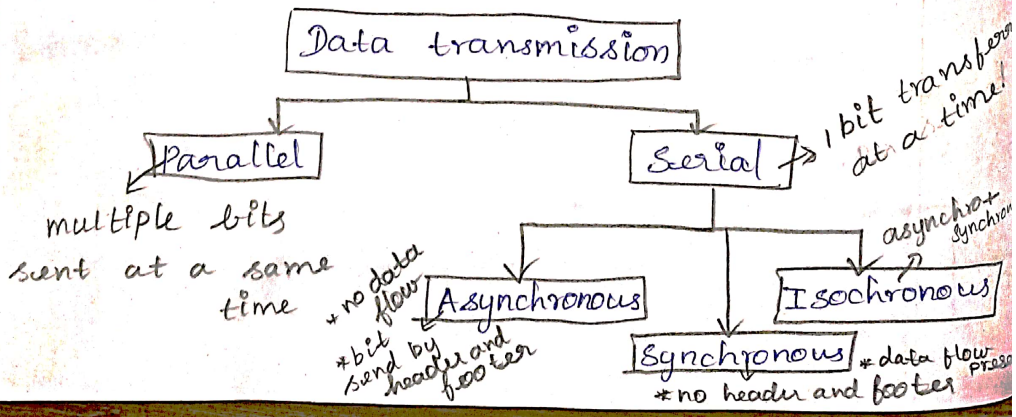
Self Synchronization:

If the receiver clock is faster or slower. The bit intervals are not matched and the receiver might misintrupt the signal.

Data Transmission mode.

It refers to the movement of data in form of bits between two or more digital devices.

Data bus used to transmit data in the form of bits



Parallel transmission:

All the bits of data are transmitted simultaneously on separate communication line

advantage: speed

disadvantage: costly

Serial transmission:

Data transmitted as a single bit at a time using a fixed time interval for each bit.

advantage: less transmission line cost.

Transmission Media:

It is a communication channel carries the information from the sender to the receiver.

1. Guided Media (Wired)
   1. Twisted-pair cable < unshielded / shielded
   2. Coaxial cable < Baseband / Broadband
   3. Fibre-optic cable
2. Unguided Media (Wireless)
   1. Radio Waves (Tower to destination)
   2. Micro waves (satellite to tower)
   3. Infrared (laser light, remote)

characteris
advan
disadvan

Guided Media

Twisted-pair and coaxial cable use metallic conductors to transfer.

Fiber-optic transmits signals in a form of light.

Twisted-pair transmission characteristics

* analog - need amplifiers every 5km to 6km.
* needs a repeater for every 2-3km.
* limited distance
* limited bandwidth
* limited datarate 60MHz.

1. Unshielded twisted pair
2. Shielded twisted pair.

UTP ⇒ ordinary telephone wire
cheapest, easier to install
Suffers froms external EM interface.

STP ⇒ Metal braid/sheething that reduce interference.

Near and cross talk:

Coupling of signal from one pair to another.

Guided media - UTP

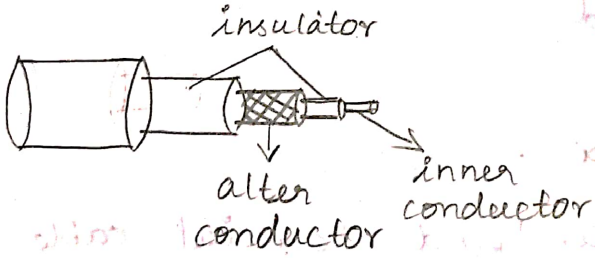
Applications:

Telephone lines connecting subscribers to the central office.

DSL Lines-

LAN - 10 Base-T and 100 Base-T

Guided media - Coaxial cable:



BNC ⇒ Bayone-Neil-Concelman

It is used to connect the end of the cable to a device.

Applications:

⇒ Analog telephone networks

⇒ Cable TV networks

⇒ 10 base 2.

Guided - media Fiber optic cable.

Antenna:

* It converts electrical power into electromagnetic waves & vice versa.

Radiation pattern:

* Power radiated in all directions

* not same performance in all directions - as seen in a radiation pattern diagram.

* Isotropic antenna is a theoretical.

Amplifier:

* It is an electronic device that increases that voltage, current mobile to base station → radiowave

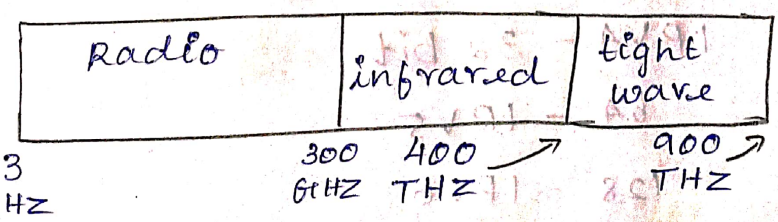
* satellite to dish → unguided media, microwaves.

below 2 MHz Groundwave preparation.

sky wave propagation - 2 to 30 MHz

line of sight (above 30 MHz)

Electromagnetic spectrum for wireless connection:



Broadcast Radio:

Omidirectional several out signals in all directions

antenna transmits radio waves

radio is 8KHZ to 300GHZ

use broadcast radio,

30MHZ - 1GHZ for: FM radio, UHF & VHF televi

suffers from multipath interference

unguided media: Microwave

1 - 300GHZ → frequency

unicast communication cellular phones

IEEE 802.1 is used to provide an authentication mechanism to device wishing to attach to a LAN or WLAN.

IEEE 802.2 - specifies the general interface between the network layer and the datalink layer.

IEEE 802.11 → wireless LAN.

IEEE 802.4 → token passing LAN's.

IEE 802 → collection of networking standards that cover the physical and data link layer specification for ethernet/wireless.

For synchronization we are using Bit Stuffing.

It synchronizes → end delimeter

IPV4 - 32 bits

64 - IPV5

128 - IPV6

Input stream:

01101111111100111110111111111100000

converted bit stuffed stream

011011111011001111100111111011000000

UNIT-2

DATA LINK LAYER (bits converted to frames)

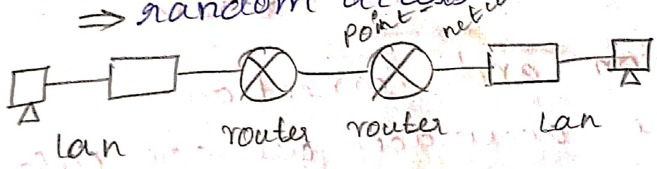
DLL:

In the OSI model, the data link layer is 2nd layer.

nodes → hosts, routers etc...

2PDU is a frame encapsulates datagram

⇒ error detection
⇒ retransmission
⇒ flow control
⇒ random access



Three types of address:

Unicast: one-one communication

Multicast: one-many communication

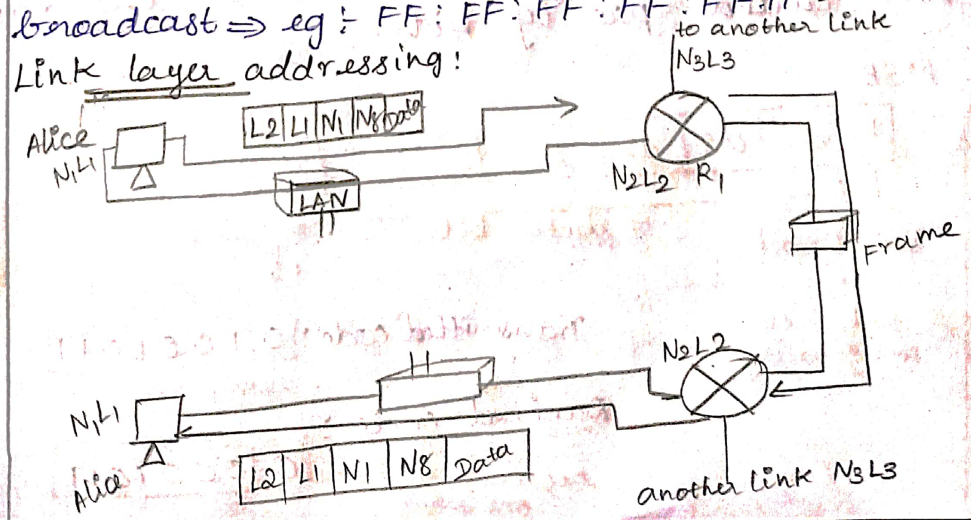
Broadcast: one-all communication.

unicast ⇒ eg: A3:34:45:11:92:R1 → odd

multicast ⇒ eg: A2:35:44:10:92:F1 → even

broadcast ⇒ eg: FF:FF:FF:FF:FF:FF → all are "ff"

Link layer addressing:



Address resolution protocol (ARP)

it maps an IP address to a logical link (MAC) address.

ARP accepts an IP address, from the IP protocol, maps the address to the corresponding link-layer address, and pass it to the data link layer.

request → broadcast
reply → unicast

PACKET FORMAT (ARP packet)

0	8	16	31
Hardware type		Protocol type	
Hardware length	protocol length	operation request, reply	
Source hardware address			
Source protocol address			
Destination hardware address (empty in request)			
destination protocol address.			

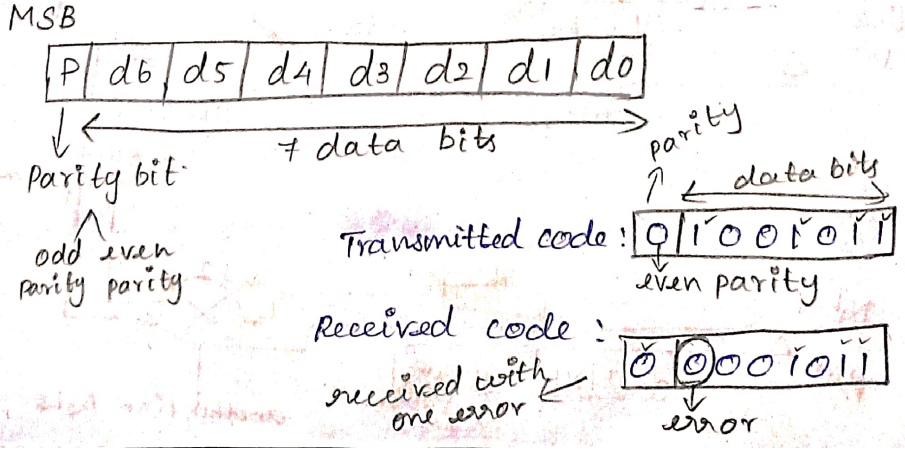
Error detection and Correction:

* to achieve accuracy we are calculation reliability

1. parity code 2. checksum
3. Cyclic Redundancy check (CRC)
4. Hamming code.

data bits + parity bits = code word.

* to detect and correct the errors, additional bits are added to the data bits called parity bits.



Types of errors:

1. single bit 2. multi bit 3. burst error

eg:- 1 → 0
0 → 1

Redundancy: Redundant Bits are added by the sender and removed by the receiver

Error correction can be handled in two ways

1. Backward error correction:

Once error is discovered the receiver requests the sender to retransmit the entire data.

2. Forward error correction:

In this case, receiver uses the ecc which automatically corrects the errors.

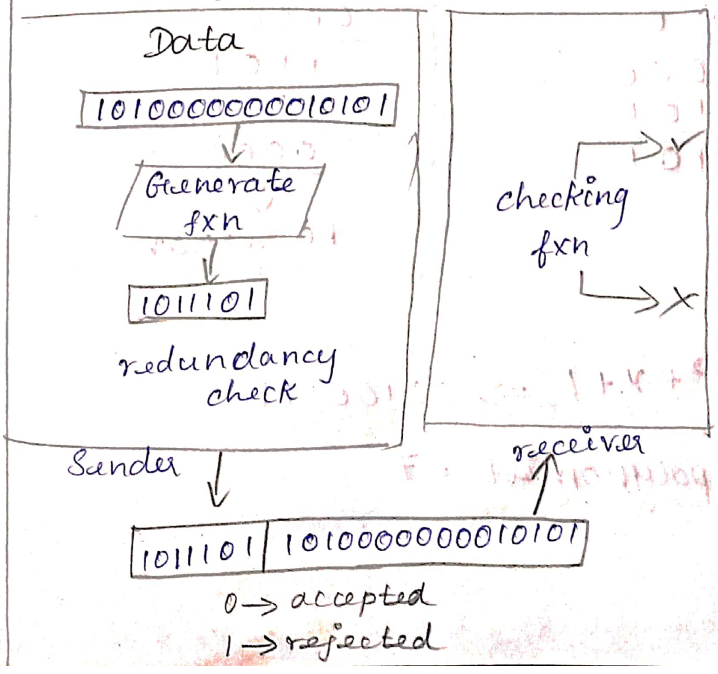
Coding Scheme:

1. Block coding 2. Convolution coding
3. Scrambling

Block code:

* In block codes, in fixed size blocks of bits, the message is contained.
* In this, the redundant bits are added for correction and detecting errors.
* In block coding, we divide our message into blocks, each of k bits called message blocks.

Redundancy:



L → length of CRC divisor

1. CRC divisor = 1011 data limits = 1001

$L = n - 1$

$n = L + 1 = 4 + 1 = 5$

$r = n \% 2 = 5 \% 2 = 3$

Step 2:

```
      1010
1011 | 1001110
       1011
       -----
       00101
        0000
       -----
        1011
        1011
       -----
       00000
        0000
       -----
           0   → remainder
```

Step 1:

```
      1010
1011 | 1001000
       1011↓
       -----
       00100
        0000↓
       -----
       01000
        1011↓
       -----
       00110
        0000
       -----
       0110   → remainder (3 bits)
```

⇒ no error → because remainder is 0.

2. data = 10110 CRC divisor = 1101

length of CRC divisor

$L = n - 1$

$n = L + 1 = 4 + 1 = 5$

$r = 5 \% 2 = 3$

```
      11001
1101 | 10110000
       1101
       -----
       01100
        1101
       -----
       00010
        0000
       -----
        0100
        0000
       -----
        1000
       - 1101
       -----
         101
```

```
      10110101
1101 | 10110101
       1101↓
       -----
       01100
        1101↓
       -----
       00011
        0000↓
       -----
       00110
        0000
       -----
        1101
        1101
       -----
        0000
```

↓ no error

Polynomial:

$x^7 + x^5 + x^2 + x + 1 \Rightarrow 10100111$

degree of polynomial = 7

CheckSum:

can be applied to message of any length.

Error detection by checksums:

data is divided into fixed sum sized frames or segments

Sender's end: add's 1st complement to get the sum.

procedure:

while sending the values are added and kept.

After it get received in the receiver side the total of the sending should be equal to the sum of values in receiver end.

If not, then the bits (data) are not accepted.

eg:-

1.

Sender	Receiver
7 ⇒ 0111	7
11 ⇒ 1011	11
12 ⇒ 1100	12
0 ⇒ 0000	0
6 ⇒ 0110	6
	36

✓ (36 = 36) data will be accepted.

Sender side 36

Step 1:

```
 0111 (7)
 1011 (11)
10010
   →1
 0011
```

Step 2:

```
 0011
 1100 (12)
 1111
```

Step 3:

```
 1111
 0000 (0)
 1111
```

Step 4:

```
 1111
 0110 (6)
10101
   →1
 0110 (36)
```

If there is a carry add it to the answer itself.

Step 5:

take 1st complement: 1001

check sum: 1001

decimal: 9

Sender side data: 0111 1011 1100 0000 0110 1001 (checksum)

Receiver side:

```
  0111 (7)
  1011 (11)
 1)0010
    1
 ------
  0011
  1100 (12)
 ------
  1111
  0000 (0)
 ------
  1111
  0110 (6)
 ------
1)0101
    1
 ------
  0110
```

Step 5: 0110 → check sum came from sender side.
1001
1111

1st complement ⇒ 0000

If all the bits are 0, then accept the data otherwise the data won't be accepted.

2. 1001 1100 1010 0011 . Find the checksum.

Sender:

```
  1001
  1100
 ------
1)0101
    1
 ------
  0110
  1010
 ------
1)0000
    1
 ------
  0001
  0011
 ------
  0100
```

take 1st complement : 1011

check sum: 1011

3. 11001100, 10101010, 11110000 and 11000011

```
   11001100
   10101010
  ----------
1)01110110
           1
  ----------
   01110111
   11110000
  ----------
1)01100111
           1
  ----------
   01101000
   11000011
  ----------
1)00101011
           1
  ----------
   00101000
```

take 1's complement : 11010011

check sum : 11010011

Sender / Receiver

```
   00101100
   11010011
  ----------
   11111111
```

1's complement ⇒ 00000000

All bits are 0, the data will be accepted.

2m Hamming distance:

metric for comparing two data strings.

eg:-

1. 11011001 and 10011101

Step1: Take X-OR

```
  11011001
  10011101
  ---------
  01000100   => 2 one's are present.
```

Step2: Write no. of 1 present in the output bits

d(11011001, 10011101) = 2//

2. 01110110 , 11110001, 01100110

```
  01110110
  11110001
  ---------
  10000111
  01100110
  ---------
  11100001   => 4 one's are present.
```

d(01110110, 11110001, 01100110) = 4//

Hamming Code:

11	10	9	8	7	6	5	4	3	2	1
d	d	d	r	d	d	d	r	d	r	r

redundancy bits

HDLC :

High level data-link control

bit-oriented protocol

It implements stop and wait protocol. → flow control and error control.

1st sends one frame then wait until the acknowledge comes from the receiver then only it sends the next frame.

It implements ARQ mechanisms (Automatic repeat request)

↳ error control mechanism

↳ retransmission of frame.

only one frame can be send at a time

configurations and transfer mode:

two common transfer modes

Normal response mode (NRM)

Asynchronous balanced mode.

NRM

1 primary station and many secondary stations

The secondary stations are controlled by primary stations (by sending commands)

HDLC - Three types of frames:

1. Information frames (I-frames)

original data present ← Piggybacking technique

↳ Stop and wait protocol.

2. Supervisory frames (S-frames) → only control frames.

3. Unnumbered frames (U-frames)

↳ system management frames are present

Flag field:

Flag set at the beginning and end of the frame.