→ Computer Networks

☆ Larry & Peterson ~~Book~~

☆ A.S. Tannenbaum - A6

☆ William Stalings : Data & Computer Communication ~~B3~~ B3 } References

☆ Routing in Internet : Christian Hutina

☆ Internetworking with TCP/IP : Volume 1 & Volume 2 } Lab

☆ Unix Network Programming : Richard Stevens

☆ Beej's Guide → Online

☆ A computer network is an interconnection of autonomous devices.

- autonomous → don't control ~~[?]~~ (unless allowed)
- devices → any electronic device
- interconnection → (the link that makes ~~able~~ both receiver / sender able to exchange meaningful data)

☆ Advantages of Computer Networks:

* Data Sharing

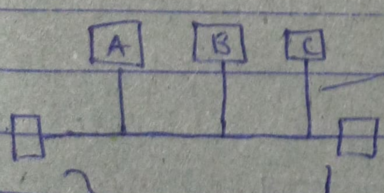
* Resource Sharing

☆ Classification

- → Point to Point
- → Multipoint (Shared) ~~Peer to Peer~~

* Multipoint network uses medium access control protocol of type (802.X).

* Bus topology



→ Medium Access ~~CA~~ Control Protocol is used to avoid mixing.

→ Mixing of information will take place

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★ Packet Switching (Postal) (Unreliable)
→ Loss of data or ~~and~~ unordered data is possible

★ Circuit Switching (Old Phone Calls) (Reliable)

★ Connection Oriented (Reliable) Connection Established Connection ~~Maintenc~~ Maintanence " Termination * TCP ensures connection oriented reliable	★ Connection less * Provided by UDP

~~Transpor~~
Transport
Connection less (CL) ← → CO (Connection Oriented)
Packet Switching — Circuit Switching

★ TCP/IP Reference Model

Application
Transport ← Port Number
Network ← IP address
Data Link ← Physical Address (LLC, MAC)
Physical

↓ Sublayers
LLC = Logical Link Control
MAC = Medium Access Control
↓
Mandatory in multi-point network only

* Network layer (i) It provides routing
↳ ensuring delivery from source to destination
↓
similar to postal services
(ii) fair allocation of resources. (Equal distribution)
(iii) Addressing (Provides logical address through ~~IP4/IP6~~ IPV_4/IPV_6)

* Network Layer provides connectionless, best effort, packet switching data layer delivery services to the ~~up~~ upper layer.

- Packets may reach out of order at the destination
- Some packets may be lost
- Packets may follow efficients path to reach the destination
- Unexpected high delay is possible

18/08/22

(CN)

⇒ Computer Networks

* Responsibilities of the Transport Layer:

(i) It ~~provide~~ provides reliable connection ~~layer~~ oriented service to upper layer protocol (TCP).

(ii) It ~~provides~~ extends best effort connectionless services offered by the network ~~layer~~ layer (UDP)

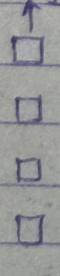
* Applications that require reliable services are file transfer, email, etc. (TCP)
* Applications that can use ~~UP~~ UDP (do not ~~reqr~~ require ~~reliabili~~ reliability or can tolerate delay) are video playing, & voice calls.

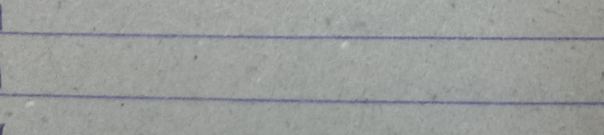
(iii) It is also providing an address which is logical in nature and known as port number.
↓ (A 16-bit address)

* Port Number is used to demultiplex incoming data to the processors.

* Socket ⟶ : Socket bind (ip, port number)
Argument 1: ip, Argument 2: port number
↓ end point of communication (can send or recieve data)

Port No. → (Distribution on main tabs of browser)
Network layer
IP



* 

→ Presentation } obsolete
→ Session } → Present in OSI model

CN CN

n(network), h (host)

* Presentation layer
  - n to h s
  - n to h l
  - h to n s
  - h to n l

* Responsibilities of data link layer:

(i) Ensure framing: It is either done by MAC or LLC or other DLL model.

(ii) Error control

(iii) Flow control (Using LLC)

*

* MAC ensures collision doesn't take place

* (iv) Global address ~~(+t)~~ (Using MAC or LAC) (Also known as Physical Address)

Presentation notation :- 9A : 4b : 23 : 46 : 2 : A : 36

Real address is in the form of binary string.

→ Physical Layer

~~(i)~~ Services are:

(i) Converts ~~to~~ bits into signals and vice-versa.

(ii) Defines the medium of communication (in wired network: type of wire) ~~#~~ and (in wireless network: frequency band)

How the connection is established? → which interface is ~~used~~ used?

frequency band → ISM band (License exempted) → (WLAN); Licensed Band (2G) → (Requires permission)

type of wire → Coaxial Cable, Twisted Pair, Fibre

Coaxial Cable → Thin, Thick (Unit = Ω)

Twisted Pair → Shielded, Unsheilded → (Used in LAN)

Fibre → Single mode, Multi-mode

(iv) Decides (serial or parallel), (simplex or duplex) (halfplex)

parallel → (Printer to Computer)

simplex → (single direction; duplex → dual direction)

halfplex → (Can afford both directions → but only one side at once)

☆ Topology (Set to deploy the network) :

(i) Bus (IEEE 802.4)

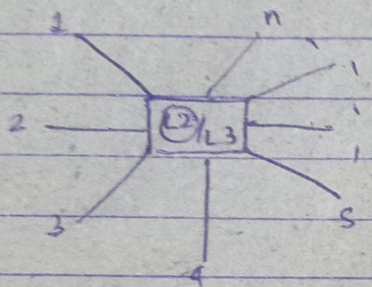
(ii) Star :

(iii) Ring

(iv) Tree

(v) Mesh (Have to convert to tree for ease)

☆ Star Topology

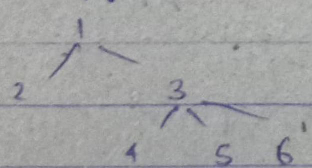


IEEE 802.3

* L2 switch just transfers data to all the systems (broadcast)
* L3 switch just delivers on the destination. ✓ (Best option)

☆ Ring Topology (IEEE 802.5)
↓
- Ring token

☆ Tree Topology



Routing has to be done from parent to child

→ Communication Model

Source ⟶ ~~Trans~~ Transciever $\xrightarrow{\text{Repeater/Amplifier}}$ Digital/Analog Channel (Wire/Wireless) ⟶ Transceiver ⟶ Destination

↑ Noise

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* Signal is an electrical and electromagnetic encoding of data.

$s(t) = \sum A_n \sin(\omega_n t + \phi_n) + \sum A_m \cos(\omega_m t + \phi_m)$

~~* Cont :-~~

→ Socket Programming

Write C Program for both

Server $\xrightarrow[\text{Socket (IP, Port Number)}]{\text{So}}$ Client

* Server

socket() → bind() → listen() → accept() → send() → recv() → close()

Client

socket() → connect() → recv() ~~receive()~~ → ~~receive()~~ send() → close()

~~send()~~ → ~~close~~

* socket() returns ~~an~~ integer values with three parameters (domain, type, protocol).
  (→ int type)

that is: server-socket = socket (domain, type, ~~proto~~ protocol).

- domain → ~~IP4 IPV4 / IV~~ → IPV4 / IPV6 → AF-INET, AF-INET 6
- type → TCP / UDP → SOCK-STREAM, SOCK-DGRAM
- protocol → 0

Example server-socket = socket (AF_INET, SOCKSTREAM, 0)

(int type)

* bind = (server-socket, (struct sockaddr*) &server-address, ~~size of~~ size of (server-address))

* listen = (server-socket, backlog)
  backlog → capacity of the server

* send (client-socket, server message, size of (server-message))

25/08/22 (CN)

~~Communication means~~

* To transfer the data, signals are transferred ~~th~~ over wired or wireless network
* A signal is physical representation of data, ~~what~~ which will be a function of ~~a time~~ time and space.

☆ Bandwidth (B) = $f_{max} - f_{min}$ ~~Hz~~ Hz

☆ Spectrum (S)

B = S = Set of frequencies allowed by the regulatory authorities to use for a particular communication system.

* Bandwidth & Spectrum are similar, but spectrum is defined for wireless medium.

☆ Data Rate : bits/sec over the bandwidth/spectrum.

↓

(Channel capacity)

☆ Baud Rate: Number of symbols transferred per second.

☆ Nyquist Theorem: If an arbitary signal passes through a channel of bandwidth 'H', the signal can occupy 'V' $\underbrace{\text{discrete level}}_{\text{symbols}}$, then the maximum data rate obtained over the channel will be:

$\boxed{C = 2H\log_2 V}$: C = data rate in bits/~~second~~ second. (theoretical)

This equation holds true in ideal conditions.

* It also states that the signal can be completely reconstructed by taking 2H sample per second.

☆ Signal to Noise Ratio ~~H~~ (SNR) = $\frac{\text{Signal Power}}{\text{Noise Power}}$

$$(SNR)_{dB} = 10\log_{10}\left(\frac{\text{Signal Power}}{\text{Noise Power}}\right)$$

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★ Sennon's Result

For a noisy channel of bandwidth 'H' Hz, SNR, the maximum data rate can ~~be~~ be represented by:

$\boxed{C = H\log_2(1+SNR) \text{ bits/second}}$

Ques → A typical telephone channel with bandwidth 3400 Hz at 40dB SNR, what is the maximum acheivable data rate ?

first convert to standard form

Ans → ~~$C = 3400\log_2(1+40)$~~

$(SNR)_{dB} = 10\log_{10}(SNR)$

$\cancel{40}^{4} = \cancel{10}\log_{10}(SNR)$

$10^4 = SNR$

$C = 3400\log_2(10^4)$

Ques → Suppose there is a noiseless channel of 4000 Hz, at what ~~sample~~ time rate, the samples should be ~~collect~~ collected at the receiving end, to reconstruct the symbol?

Ans → $\frac{1}{4000\times2} = 125\,\mu s$

~~Ques~~ Ques → Baud rate of a channel is ~~2500 Baud~~ 2400 Baud, one symbol can represented by 2Hz, V = 16. What is the maximum acheivable data rate?

Ans → $C = 2H\log_2 V$

$= 2H\log_2(16)$

$= 8H$

~~$= 8\times(2\times(2400\times16))$~~ t

~~$= 8\times1200\,(2000$~~

$= 8\times(2400\times2)$

$= 8\times4800$

~~$= 51200$~~

$= 38400$ ~~H~~ bits/second

1 symbol → 2Hz

2400 symbol → (2×2400) Hz

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→ Multiplexing
★ FDM
} (To complete)

→ Transmission Media

Guided (Wired)

Unguided (Wireless)

★ Twisted Pair

* $10^4 - 10^8$ Hz
* Data rate : Order of ~~Mbps~~ Mbps (1 - 1000 ~~K~~ Mbps)
* Distance : ~~10 kms~~ 1 - 10 km

★ Untwisted

* ~~Da~~ $10^4 - 10^8$ Hz
* Data rate : Mbps to ~~Gq~~ Gbps
* Distance : 10 kms

★ Coaxial Cable

* 100 kHz - 1 GHz
* Data rate : Order of ~~Gq~~ Gbps
* Distance : 10 kms

★ Fibre Cables

* $10^{14} - 10^{15}$ Hz
* Data Rate : 100 - 1000 ~~Gbps~~ Gbps
* Distance : ~~Up~~ Upto 100 kms

★ Radio Waves (FM and AM radio)

* $10^4 - 10^8$ Hz
* Distance : 100 kms

★ Microwave k

* $10^8 - 10^{10}$ Hz
* Distance : Order of 10 kms

(Increasing Data Rate)

★ Infrared ~~(Rem~~ (Remote controls)

* $10^{11} - 10^{14}$ Hz
* Distance : ~~10~~ 100 ~~m~~ m

★ Visible Light

* 10^{14} Hz.
* Distance : 100 m

Increasing Coverage

(Increasing Penetration Power)

* Penetration Power

→ Parameters

~~Bas~~ Basic : { Amplitude, Frequency, Phase

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Derived : $\begin{cases} T = \frac{1}{f} \text{ (Period)} \\ \lambda = \frac{c}{f} \end{cases}$

Ques → Operating frequency is 2.5 GHz, find the wavelength ; (c = signal speed).

Ans → $\lambda = \frac{c}{f}$

$= \frac{3 \times 10^8 \times 10}{2.5 \times 10^9}$

$= \frac{3}{25}$

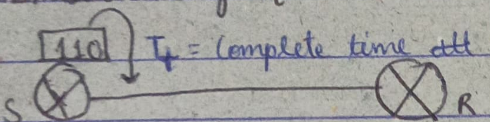
$= 0.12$ ~~sec~~ m

CN Tutorial

★ Delays

(i) Transmission Delay (T_t)

T_t = Complete time ~~att~~ to load all the data on the transmission line

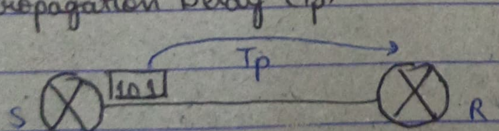


* Depends on bandwidth, data size

$\downarrow$ ~~x~~B $\downarrow$ BL

* $T_t = \frac{L}{B}$

(ii) Propagation Delay (T_p)



T_p = Time till delivery of the last bit from the ~~receiver~~ sender's end.

* Depends on velocity (V), distance (d)

$\boxed{T_p = \frac{d}{V}}$

(Round Trip Time)

★ RTT = $T_t + T_p + T_q + T_{processing}$ or $\boxed{RTT = 2T_p}$

T_q ↓ Queing Delay

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Ques → Consider a P-P link of ~~4 km~~ 4 km length, ~~at~~ at what bandwidth would the ~~pro~~ propagation delay equal to transmission delay for 100 byte packet at a speed of $2\times10^8\ ms^{-1}$?

Ans → $T_t = T_p$

$S \xrightarrow{4km} R$

$\Rightarrow \frac{L}{B} = \frac{d}{V}$

$\Rightarrow \frac{\cancel{4\times10^3}\ 100}{B} = \frac{\cancel{4}\times10^3\ 2}{\cancel{2}\times10^8\ 10^5}$	$\Rightarrow \frac{8\ 100}{B} = \frac{4\times10^3}{2\times10^8}$
$\Rightarrow B = 50\times10^5$	$\Rightarrow B = \frac{1}{2}\times10^7$
$\Rightarrow B = 5\times10^6\ Hz$	
$= 5MHz$	$\Rightarrow B = 5\times10^6$ ~~mt~~ ~~M~~ B B/s

(ii) if 512 bytes packet is transferred

Ans → $\frac{512}{B} = 20\mu s$

$B = \frac{512\ bytes}{20\mu s}$

$= 25.6\ MB/s$

Ques → Calculate the total time required to send 1000 KB file? (Assume packet size 1 KB and an RTT of 50 ms and an intial 2×RTT for "handshaking", before data sent; Bandwidth of 1.5 Mbps).

Ans → $T = (100\ ms) + \frac{(50\times1000)}{1.5\ Mbps}$ $\frac{1.5 Mbps}{50\times1000}$ $\frac{(50\times1000)\times10}{1.5\times10^6\ 10^4\times10^3}$

$= 100\ ms + \left(\frac{1}{30}\right)\frac{1}{10^3}$

50 50×1000

$\frac{1000}{1.5\times10^6}$ 3

$= 100\ ms + 0.3\ 3ms\ \frac{}{10^3}$

$\frac{\cancel{10000}\ 2000}{15\ \ 3}$ $\frac{100}{30}$ 0.3

$= \cancel{1ms}\ 103\ ms$

0.003

$\frac{2}{3}\times50$ 3 ms

$\frac{100}{3} = 33.33\mu$

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Total time $= T_t + T_p + 2RTT$

$= \frac{L}{B} + \frac{RTT}{2} + 2RTT$

$= \frac{1000 \times 10^{3} \times 8}{1.5 \times 10^{6}} + 25ms + 50ms$

$= 5455\ ms$

iii) If $RTT = 8\ ms$, $B = 10\ Mbps$

Ans → Total time $= T_t + T_p + 2RTT$

$= \frac{L}{B} + \frac{RTT}{2} + 2RTT$

$= \frac{\cancel{1000} \times 10^{3} \times 8}{10 \times \cancel{10^{6}}} + 4 + 16$ ms

$= (20) + (0.8)s$

$= 0.020 + 0.8s$

$= 0.820$

Ques → Consider a network with average source and destination 20km apart and one way delay of 100 μsec. At what data rate does the RTT equals to T_t for a 1KB packet?

Ans → $\cancel{RTT = T_t + T_p +}$ $\quad \cancel{T_t = \frac{L}{B} = \frac{20 \times 10^{3}}{1 \times 10\ 100\ \mu s}}$

20km

S D

$\cancel{\frac{L}{B} = 100\ \mu s}$ $\quad \frac{1}{B} = 100\ \mu s$ $\quad$ 1 KB $\quad \cancel{\frac{20\ km}{100\ \mu s} \frac{20 \times 10^{3}\ m}{100 \times 10^{-6}\ s}}$

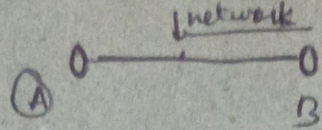
$\cancel{B = 100\ \frac{20\ km}{100\ \mu s}}$ $\quad \cancel{T_t = \frac{L}{B} = \frac{1KB (10^{3})}{B}}$ $\quad = \frac{2 \times 10^{4} \times 10^{6}}{10^{2}}$

$\cancel{\frac{L}{B} = 2 \times \left(\frac{d}{V}\right)}$ 100 $\quad \cancel{\frac{10^{3}}{B} = 2 \times 10^{3} (20 \times 10^{3})}$ $\quad \cancel{= 4 \times 10^{8}\ ms^{-1}}$

$\frac{1}{B} = 2 \times$

100

$\boxed{4}$



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Ans → $B = RTT = 2 \times T_p$

$= 2 \times 100\,\mu s$

$\frac{1 \times 10^3 \times 8}{B} = 200\,\mu s$

$B = \frac{10^3 \times 8}{200 \times 10^{-6}}$

$= \frac{10^3 \times 8}{2 \times 10^{-4}}$

$= \frac{10^7 \times 8}{2}$

$= 40$ Mbps

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⇒ Computer Networks

★ Encoding Techniques

These techniques are used to ~~dt~~ generate digital signals.

Parameters (To be checked)

(i) Clocking

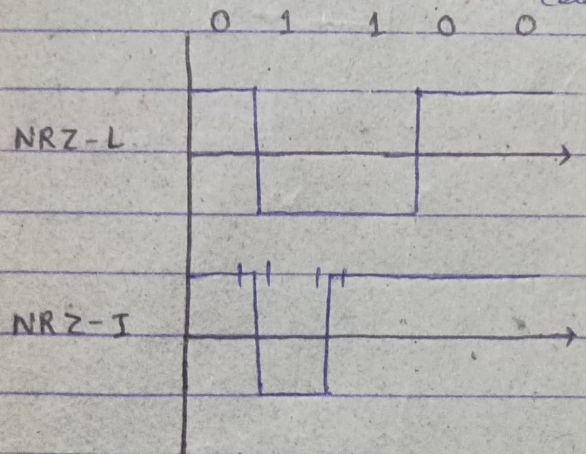
(ii) Power of Error Detection

(iii) Cost And Complexity

(iv) Net DC Component

(1) NRZ (Not Return to Zero)
- NRZ - L
  - 0 (High)
  - 1 (Low)
- NRZ - I (Differential Encoding)
  - 0 (No transition)
  - 1 (Transition)

} Both at the start of bit position



* Advantages of Differential Encoding

~~Easy to~~ (i) Easy to implement

(ii) It ~~s~~ make good use of bandwidth, signal rate is equal to bit rate, since lesser size of samples is required.

Parameters for NRZ:

(i) Insufficient clocking information is present.

(ii) Poor error detection, since no fixed sequence is found.

(iii) Net DC component can be present.

Hence, NRZ ; used for magnetic purposes, but not for communication systems.

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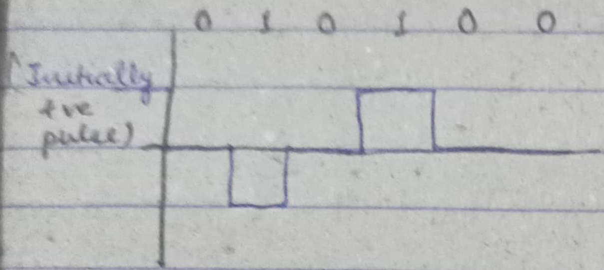
(2) Multilevel Binary Series
- Bipolar AMI (Alternate Mark Inversion) — 0: Represented by 0V signal; 1: Alternate +ve & -ve voltage
- Pseudoternary — (Reverse of the Bipolar AMI)



(Bipolar AMI)

Parameters :-

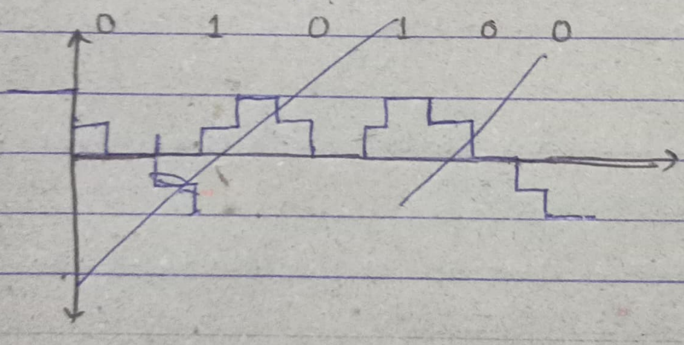
* All conditions are satisfied except the clocking problem.

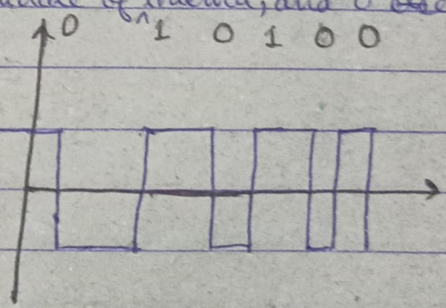
(Biphase Series) → 3, 4

(3) Manchester Encoding (Used in Ethernets)

* 1 is represented by high to low transition at the middle of bit interval, and '0' vice versa.

*





(4) Differential Manchester (Use IEEE 802.5 for this, also called Token Ring)

* '0' is represented by transition at the start of the bit transition, '1' is represented by no transition.
* There has to be transition at the middle of the bit interval.

* Parameters for Biphase series:

All conditions are satisfied except poor bandwidth utilisation.

(5) ~~Block~~ Block Encoding (Uses NRZ-I for generating the signal)
→ 4B/5B : ~~then NR~~ 4B = 5B Code
→ 8B/10B : 8B = 10 B Code

* 5 bit codes are selected such that, it doesn't have, not more than 1 leading 0, and not more than 2 trailing zeroes. Therefore, code will never have 3 consecutive zeroes. Resultant code is transmitted using NRZ-I. Similarly process is for 8B/10B.
* 8B/10B is used for fibre channel & Giganet.
* Dictionary of codes is required.
* Better utilization of bandwidth than others and all the other parameters are ~~also~~ also good, hence it is used for communication systems.

☆ Long Distance Digital Communication
(1) B8ZS (Bipolar AMI with 8 Zero Substitution)
(2) HDB3 (High Density Binary with 4 Zero Substitution)

* Rules for HDB3 :-
(i) Signals are generated using Bipolar AMI but every sequence of 8 zeroes will be replaced as per the following rules:-
(ii) If the last voltage pulse preceeding 8 zeroes was +ve, then, 8 zeroes will be replaced by 000±0∓.
(iii) Otherwise it will be 000∓0±.
The above replacement will cause two code violation, and whenever ~~rece receiver~~ receiver detects two ~~vot~~ violation, then it will replace 8 zeroes by

→ Modulation Techniques
Used for generating
Parameters :
(i) SNR (ii) Data Rate (iii) Available Bandwidth

(1) ASK $\begin{cases} 0: A\sin 2\pi f_c t \\ 1: 0 \end{cases}$

(2) FSK $\begin{cases} 0: A\sin 2\pi f_{c_1} t \\ 1: A\sin 2\pi f_{c_2} t \end{cases}$ $(f_{c_2} = 2 f_{c_1})$

(3) PSK $\begin{cases} 0: A\sin 2\pi f_c t + 0 \\ 1: A\sin 2\pi f_c t + \cancel{\phi}\pi \end{cases}$

* ASK is used over voice grade line, provides data rate upto 1200 bits/second.
* Lesser acceptable error than ASK, same data rate as ASK, used for radio transmission.
* Higher Frequencies ~~on~~ can be used on LAN to provide better data rate.
* with FSK more than 2 frequencies can be used, and the scheme becomes multiple frequency shift scheme.

* (4) ~~Q~~ QAM (Quadrature Amplitude Modulation Technique) : Combination of ASK & PSK

(5) Multiple shift Key

* MSK (Minimum Shift Key)
* ~~& GSK (Gaussian~~ GMSK (Gaussian Minimum Shift Key)

Special pre-computation avoid sudden phase shift, hence the signals have minimum shift, depending upon the bit values (even, odd), the higher or lower frequency, original or inverted signal is generated.

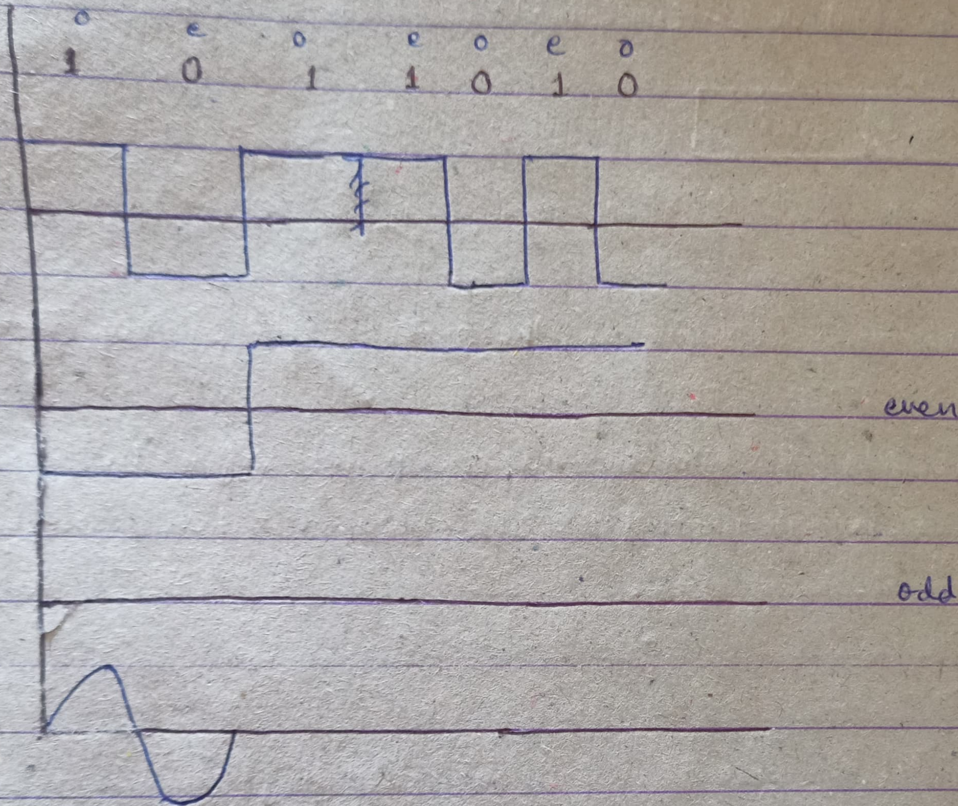
* Rules :- (for MSK)

even	0	1	0	1
odd	0	0	1	1
signal	h	l	~~hl~~ l	h

– – + +

opposite phase   same phase

→ Computer Networks



→ Data link Layer

☆ Framing Protocols
- Byte Oriented
  - Sentinal (BISYNC)
  - Byte Counting (DDCMP)
- Bit Oriented
  - Sentinal (HDLC) ~~(HPLC)~~

★ BISYNC

8	8	8	16	8		8	16
SYN	SYN	SOH	Header	STX	data	ETX	CRC

CRC ↓ used for error detection

8 -> All are 8 bit standard ASCII characters.

★ DDCMP

8	8	8	14	42	Variable	16
SYN	SYN	Class	Count	Header	Data	CRC

★ ~~HPLC~~ ~~HDLC~~ ~~EOF~~ ~~PP~~ PPP (Dial Up ~~Con~~ Connection)

8	8	8	16		16	8
Flag	Address	Control	Protocol	Data	Check Sum	Flag

★ Byte Stuffing

Since ASCII characters are used as frame delimators, the problem is when they occur within the data.

Solution: Sender stuff an "DLE" character into the data stream just before the occurrence of special characters, receiver unstuff the DLE character before passing the frame to the upper layer protocol.

★ Bit Stuffing

Each frame begins & ends with a special bit pattern called flag (which is 7 in hex).

Whenever, sender encounter, 5 consecutive 1's in the data stream, it stuffs a 0 ~~after~~ after it.

When, receiver encounters the above pattern, ~~it~~ it destuff 0 bit before passing the frame to the upper ~~lay~~ layer protocol.

If the receiver sees 5 consecutive 1's followed by a 1, then it will check next bit, if the next bit is zero, it is marked as ~~end~~ end of the frame, if the next bit is 1, then

then it will be concluded that the frame received an error.

☆ HDLC

8	16		16	8
Flag	Header	Body	CRC	Flag

~~Ded~~ ~~Dial~~ Dial Up Connection

→ Error Control
- Detection (Wired)
  - Bit Error
  - Burst Error
- Correction (Wireless)

☆ Parity Check

: Not suitable for Communication

Applied on word : 8/16/32 .....

☆ Parameters
- Power of error detection
- Number of extra bit required

☆ Two dimensional Parity Check : More power of error detection

* It can catch all errors from 1 to 3 bit and most of the 4 bit error.
* Greater number of bits required } Not acceptable (Not used for communication)

☆ ~~Check~~ Check Sum

* Transmission ~~Sid~~ Side:

(i) ~~*~~ Message is divided into words (8, 16, 32 ... bits).

(ii) Add all the ~~1's~~ words using 1's complement arithmetic.

(iii) Take 1's complement of the result and call it checksum.

(iv) ~~Place checksum in the res~~ Add it to the signal and transmit it.

Receiver Side:

(i) Divide the message into words including the checksum

(ii) Calculate the overall sum alongwith checksum using 1's complement arithmetic.

(iii) Take 1's complement of the result.

(iv) If the result is all 0, then ~~accept~~, ~~else~~ accept, else discard.

Example:

			Checksum
10110110	10000011 11	11000011	00000 010

* It can detect all the odd bits error and most of the 2 bit and 4 bit error.
* Since checksum is fixed size (8-bit), it can ~~detect~~ be used for communication purpose.