OSI Model — 7 layer model.

	Layer	
	Application.	message.
	Presentation	
	Session	
(Port to Port Delivery.)	Transport	segment
(Source to Dest. Delivery.)	Network	Packet
(Hop to Hop Delivery.)	Data Link	frame
	Physical	bits

Noiseless channels
(1) Simplest
(2) Stop & wait.

Noisy channel
(1) Stop & wait ARQ
(2) Go back N
(3) Selective Repeat ARQ.

Stop and wait ARQ :
uses mod-2 arithmetic as it has either 0 or 1 as data packets.

Go back N ARQ :

Sender window of size $= 2^m - 1$
and reciever window size $= 1$

Selective Repeative ARQ

Sender window size $= 2^m - 1$
Reciever window size $= 2^m - 1$

basic formulas

① $a = \frac{t_p}{t_{fr}}$

② $t_p = \frac{Dist}{Sp}$ (time for propagation)

③ $t_{fr} = \frac{msg}{Bandwidth}$

Utilizations

⇒ Stop & wait ; $U = \frac{1}{1+2a}$; $a \geq 1$

⇒ Go back N ARQ ; $U = \frac{W}{1+2a}$; ~~W <~~ $W \geq 2a+1$

Throughput

$= U \times Bandwidth$

pipeling speed

$$S = \frac{n t_n}{K t_p + (n-1) t_p}$$

for token Ring :-

$$U = \frac{1}{\text{Max}[1, a] + \frac{a}{M}}$$

{ M : No. of stations }

CSMA / Ethernet

Vulnerable time = propagation time (t_p)

In CSMA/CD ;

$$\boxed{t_{fr} \geq 2 t_p}$$

- Ethernet follows CSMA/CD.

Ethernet :-

- Types
  - standard ethernet : 10 Mbps
  - fast ethernet : 100 Mbps
  - Gigabit ethernet : 1 Gbps
  - Ten Gigabit ethernet : 10 Gbps

MAC Frame :

Min = 64 bytes

Max = 1518 bytes

Preamble	SFD	Destination Address	Source Address	length	Data & Padding	CRC
7 byte	1 byte	6 byte	6 byte	2 byte	1500 bytes (max) ↕ 46 bytes (min)	4 byte

$$\boxed{t_{fr} \geq 2 t_p}$$

CSMA/CD is not suitable for high ~~performance~~ propagation delay n/w like satellite n/w.

flag:- 0 → No fragments

1 → More fragments.

HLEN		Total length
	flag	Offset

HLEN : Header length

1 B = 4 WORDS

eg:- HLEN = 20 B
then divide by 4.

∴ 5 words ⟹ (0101) words.

DATA LINK LAYER:-

IPV4
(32-bits)

IPV6
(128-bits)

		Range	No. of Hosts	
Class A :	0	0 - 127	2^{24}	: used in large org.
class B :	10	128 - 191	2^{16}	: used in mid-size org.
class C :	110	192 - 223	2^{8}	: used in small org
Class D :	1110	224 - 239	2^{28}	: Multicast
Class E :	1111	240 - 255	2^{28}	: Reserved.

Transport Layer :-

(1) UDP : User Datagram Packet

- connection - less service
- unreliable
- suitable for multicasting
- suitable for some route updating protocols like : RIP.

– It is suitable for multimedia file transfer, UDP is suitable.

(2) TCP : Transmission Control Protocol

- Connection - oriented protocol
- Reliable
- process to process communication.

eg:- ATM

- TCP connection is suitable / used by :-

(1) FTP
(2) SMTP
(3) HTTP
(4) IMAP
(5) POP
(6) TELNET

		Port NO.		
FTP	:	20 (Data)	;	21 (control)
TELNET	:	23		
SMTP	:	25		
DNS	:	53		
HTTP	:	80		

~~Toekat~~ Token Bucket

$$\underbrace{C}_{\text{token bucket capacity}} + \underbrace{\rho}_{\text{token arrival rate}}\underbrace{S}_{\text{Burst length}} = \underbrace{M}_{\text{Max. output rate (M bytes/sec)}}S$$

Deffie-Hellman Algo

Alice | **Bob**

$R_1 = g^x \bmod p$ | $R_2 = g^y \bmod p$

R_1 | R_2

$K_1 = (R_2)^x \bmod p$ | $K_2 = (R_1)^y \bmod p$

$$\boxed{K = g^{xy} \bmod p}$$ ⇒ shared Key.

RSA:-

* Sending a msg. ⇒ $C = (M)^e \bmod n$
* Recieving a msg ⇒ $M = (C)^d \bmod n$

⇒ $M = (M)^{ed} \bmod n$

Ques:- Consider a selective repeat sliding window protocol that uses a frame size of 1KB to send data on a 1.5 Mbps link with a one-way delay of 50 msec.
To achieve a link utilization of 60%, the minimum no. of bits required to represent the sequence number field is ____ ?

Sol^n:-

$M = 1KB = 10^3 \times 8$ Mb

$B = 1.5$ Mbps

$T_p = 50$ ms

$U = 60\%$

For SR protocol $\Rightarrow$ $U = \frac{W}{1+2a}$

$a = \frac{t_p}{t_{fr}}$

$t_{fr} = \frac{M}{B} = \frac{8 \times 10^3}{1.5 \times 10^6}$

$t_{fr} = 5.3$ ms

$a = \frac{500}{5.3} = 9.43$

$\frac{60}{100} = \frac{W}{1+2a}$

$\frac{60}{100} = \frac{W}{1+2(9.43)}$

$\frac{60}{100} = \frac{W}{1+18.86}$

$\frac{60}{100} = \frac{W}{19.86}$

$W = \frac{60}{100} \times \frac{1986}{100}$

$W = \frac{1986 \times 6}{1000} = 11.9 \approx 12$

$\therefore \quad W = 2^{m-1} \qquad \left[2^{m-1} = \frac{2^m}{2^1} \right]$

$\Rightarrow \quad 12 = \frac{2^m}{2}$

$24 = 2^m$

$2^5 = 32$

$m = 5$

Ques:- Suppose that a stop and wait protocol used bit rate on 64 Kbit/sec and 20 msec propagation delay. Assume that transmission time for the acknowledgement and processing time at nodes is negligible. Then min. frame size in bytes to achieve 50% utilization?

Sol^n:- $t_p = 20 \text{ msec} = 20 \times 10^{-3} \text{ sec}$

$B = 64 \text{ Kbit/sec} = 64 \times 10^3 \text{ bit/sec}$

$U = 50\%$

$M = ?$

For stop & wait protocol – $U = \frac{1}{1+2a}$

$$\frac{\cancel{50}^{1}}{\cancel{100}_{2}} = \frac{1}{1+2\left(\frac{t_p}{t_{fr}}\right)}$$

$$a = \frac{t_p}{t_{fr}}$$

$$t_{fr} = \frac{M}{B}$$

$$\frac{1}{2} = \frac{1}{1 + 2\left[\dfrac{\dfrac{20\times10^{-3}}{1}}{\dfrac{M}{64\times10^{3}}}\right]}$$

$$\frac{1}{2} = \frac{1}{1 + 2\left[\dfrac{20\times10^{-3}\times 64\times10^{3}}{M}\right]}$$

$$\frac{1}{2} = \frac{1}{1 + 2\left[\dfrac{20\times64}{M}\right]}$$

$$\cancel{M=}\quad 1 + 2\left[\frac{20\times64}{M}\right] = 2$$

$$2\left[\frac{20\times64}{M}\right] = 2-1$$

$$\frac{20\times64}{M} = \frac{1}{2} \quad\Rightarrow\quad M = 2560 \text{ bits}$$

$$M = \underline{\underline{320 \text{ bytes}}}$$

Ques:- A link has transmission speed of 10^6 bit per sec. It ~~reduces~~ uses data packets of size 1000 bytes. Efficiency of stop & wait protocol in this set up is exactly 25%. one way tp = ____? in msec.

Ans:- $\boxed{tp = 12 \text{ msec}}$

Ques:- Consider a network connecting two systems located 8000 Km apart.

$$B = 500 \times 10^6 \text{ bits/sec}$$

$$\text{Speed} = 4 \times 10^6 \text{ m/sec.}$$

It is needed to design Go back N sliding window protocol. Avg packet size is 10^7 bits. Network is to be used to its full capacity. Then min. size in bits of sequence number fields is ____?

Ans:- $\boxed{8}$

Capacity of channel/link

1. Half Duplex ⇒ Bandwidth * tp = capacity

2. full duplex ⇒ 2 * Bandwidth * tp = capacity

In case of Stop & wait ⟶ its like non-pipelining.

Thin pipe is useful for Stop & wait rather than thick pipe.

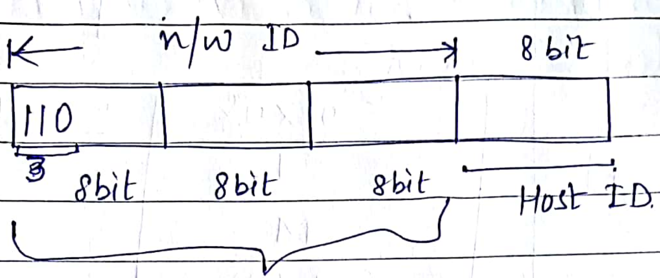
when capacity is low

when capacity is more.

• efficiency of stop & wait is more in case of thin pipe.

Ques. In IPV4 Addressing the no. of network allowed under class C address is ______ ?

Soln:-



for class C :

$(8+8+8)-3$

$24-3$

21

Ans:- ∴ 2^{21} networks.

$$\text{Efficiency} = \eta = \frac{1}{1+2a} = \frac{1}{1+2\times\frac{t_p}{t_{fr}}}$$

$$= \frac{1}{1+\left(\frac{2*t_p*B}{M}\right)} = \frac{1}{1+\left(\frac{\text{capacity}}{M}\right)}$$

Error Control in Data Link

CRC Code :- Cyclic Redundancy Check.

Generate CRC Code for a frame 1101011011 using the generator $G(x) = x^4 + x + 1$.

$G(x) = x^4 + x^1 + 1$

$$\begin{array}{ccccc} \square^4 & \square^3 & \square^2 & \square^1 & \square^0 \\ 1 & 0 & 0 & 1 & 1 \end{array}$$

generator ← 1 0 0 1 1

$G(x)$ is of 5 bits.

∴ append $\underbrace{(5-1)}_{4 \text{ bits}}$ bits to frame.

⇒ 1101011011<u>0000</u>

```
            110000101
10011 ) 11010110110000
       -10011
        10011
       -10011
        0000010110
            -10011
             10100
            -10011
              1110  → Remainder
```

Thus, transmitted frame is

<u>11010110111110</u>

10011) 11010110111110 (11010110111110

Remainder ⇒ 000

∴ <u>no error</u>

Q. A 4-stage pipeline has the stage delays as 150, 120, 160 and 140 ns respectively. Registers that are used between the stages have delay of 5ns.
Assuming const clocking rate the total time required to process 1000 data items on this pipeline is—

t_n

4×1000

4000

Sol^n:

$k = 4$ $\quad n = 1000$

$t_p = (150 + 120 + 160 + 140) + (5 \times 4)$

$= 590$ ns

$S = \frac{n\, t_n}{(k+n-1)\, t_p}$

$S = \frac{t_n}{t_p}$

$1 = \frac{1000 \times t_n}{(4 + 1000 - 1)\, 590}$

$1003 \times 590 = 1000\, t_n$

$t_n = \frac{1003 \times 590}{1000}$

$\frac{4000}{590}$

$S = \boxed{6.78}$

$6.78 = 1000 \times t_n$

---

micropipeling — finest level of pipelining. — conducted at logic gate level.

$2 < k < 15$

macropipeling — conducted at processor level.

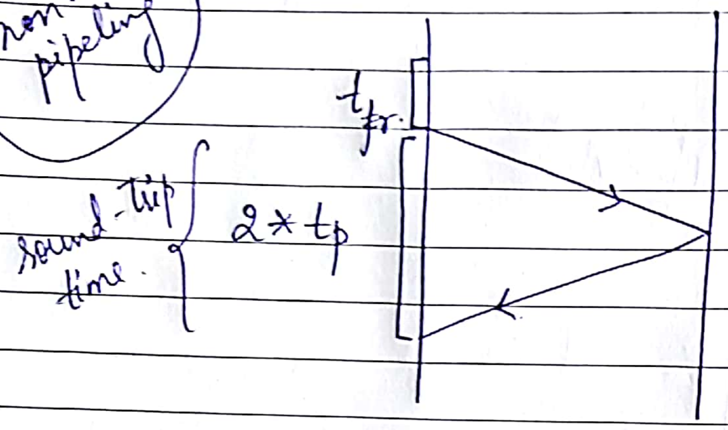
pipeline throughput = no. of operations per unit time.

Efficiency of linear stage pipeling $= \frac{n}{k + (n-1)}$

[redacted] [redacted]

Stop & wait → pipeling // capacity of a link.

non-pipeling



$t_t = t_{fr}$ = transmission time

t_{fr} sec ——— 1 packet

1 sec ——— $\frac{1}{t_{fr}}$ packet

$t_{fr} + 2 * t_p$ ——— $\frac{t_{fr} + 2 * t_p}{t_{fr}}$ packets

$$\frac{t_{fr}}{t_{fr}} + \left(\frac{2 t_p}{t_{fr}}\right)$$

$= (1 + 2a)$ packets

These many packets can be sent by stop & wait.

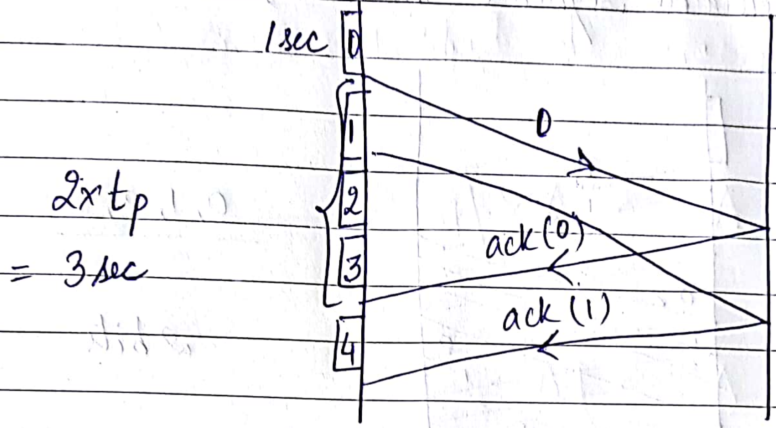
Efficiency of stop & wait can be ↑ by increasing no. of packets sent.

$\eta = \frac{1}{1+2a}$ || In Stop & wait

Instead of $(1+2a)$ → 1 packet is sent.

Scanned by CamScanner

Why stop & wait → sliding window protocol?



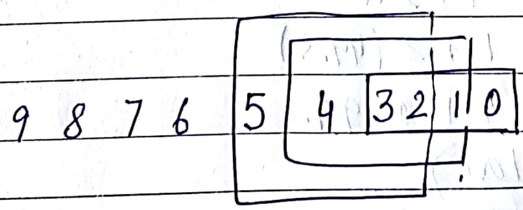
* when we try to implement pipeling technique in stop & wait → it becomes sliding window.

eg:- $t_p = 1.5$ sec

$t_{fr} = 1$ sec.

$t_{fr} + 2t_p = 1+3 = 4$ sec

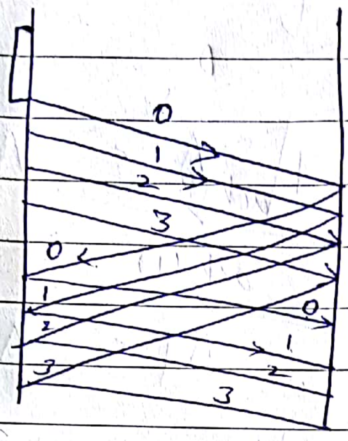
∴ we can have window size / buffer of size = 4.



$W_{sender} = 1 + 2a$

now the sequence number of packets is infinite. 0, 1, 2, 3, 4 — so on.

In order to determine sequence number;



$\underline{0, 1, 2, 3}$

2 bits

$W_s = 1 + 2a$

min seq $= 1 + 2a$

bits ~~seq~~ sequence no. field

$= \lceil \log_2 (1+2a) \rceil$

$W_s = \min(1+2a, 2^n)$ packets

eg:- $t_{fr} = 1\,msec$

$t_p = 49.5\,msec$

find sender window size ?

Sol^n:-

$W_s = 1 + 2a$

$1 + 2(49.5)$

$= 1 + 99.0$

$W_s = \underline{\underline{100}}$

Scanned by CamScanner

Error Handling

Error Detection

- CRC
- checksum
- Data re-transmission
- Parity
  - Vertical
  - Horizontal

Error correction

- Hamming Code
-

Hamming Code

disadv :- To send a data of 1KB, we would have to add 0.5 KB redundant data.
- more time for computation.

practically we rarely use Hamming code.

- caculate redundant bit

$$2^r > m + r + 1$$

$r \rightarrow$ redundant bit
$m \rightarrow$ data bit.

data 1011001 $m = 7$ bits

$\therefore r = 4$ bits

total $= m + r = 7+4 = 11$ bits

11	10	9	8	7	6	5	4	3	2	1
1	0	1	R_4	1	0	0	R_3	1	R_2	R_1

Scanned by CamScanner

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

1 1 0 1 0 1 1 0 0 0 1 1 0 0 1

P_1 P_2 P_4 P_8

check 1 no. skip 1 no. even Parity

Parity P_1 → ? 0 0 1 0 1 0 1 → 1 ✓

check 2, skip 2.

P_2 → ~~? 0 0 1 0~~ ~~? 0 1 1 0 1 1~~ ⇒ ? 0 1 1 0 1 0 1 → 0

check 4, skip 4

P_4 → ? 0 1 1 1 0 0 1 → 0

P_8 → ? 0 0 0 1 0 0 1 → 1

P_2, P_4 & P_8 are wrong

∴ $2+4+8 = 14^{th}$ is wrong.

∴ At position 14 → it should be '1' instead of '0'

Multiple Access

⇒ Data Link layer is divided into 2 functionality-oriented sublayers.

Data Link Control
Multiple-Access Resolution

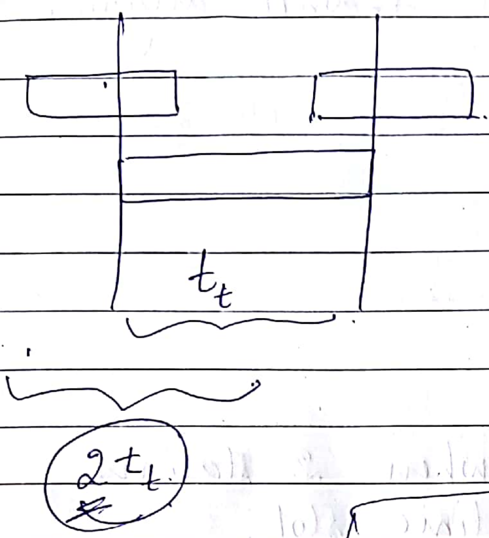
ALOHA

1) Transmit Data Anytime
2) No carrier sense
3) Collisions are possible.
4) Acknowledgements are there in Aloha
5) No collision Detection
6) Retransmission takes place.
   ↳ RT takes place after some random time called as (back off time)

Aloha ← Pure
 \ Slotted Aloha.

Pure.

vulnerable time $\rightarrow t_t$.



$$\boxed{\eta = G * e^{-2G}}$$

G : No. of stations who wants to transmit in t_t

to find max value of efficiency we differentiate

$$\frac{d\eta}{dG} = 0 \Rightarrow G = \frac{1}{2}.$$

At $G = \frac{1}{2}$, we get max eff.

$$\eta_{max} = \frac{1}{2} * e^{-\cancel{2}\cdot\frac{1}{\cancel{2}}}$$

$$= \frac{1}{2} * e^{-1}$$

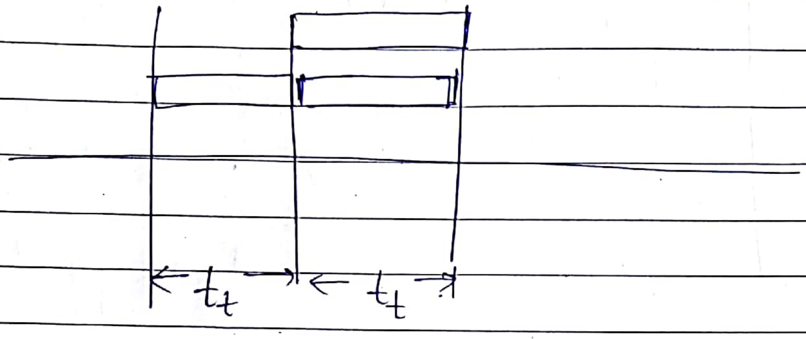
$$= \frac{1}{2e} \approx \frac{0.5}{e}$$

It means in 2 time slots ($2t_t$) one station transmit

$$\eta_{max} = \frac{0.5}{e} = 0.184 = 18.4\%$$

Effective Bandwith = Bandwidth * η

Slotted Aloha :- • every station has slots.
• No station can trasmit anytime.



• Only chance of collision is when 2 stations transmits in same time slot.

$\therefore$ vulnerable time = $1\ t_t$

$$\eta = G * e^{-G}$$

$$\frac{d\eta}{dG} = 0 \Rightarrow G = 1$$

$$\therefore \eta_{max} = 1 * e^{-1} = \frac{1}{e} = 0.368$$

$$\eta_{max} = 36.8\%$$

Q. Explain different types of Aloha!

Q. Why/how the η of slotted Aloha is double the pure Aloha?

Q. Derive the η of pure & slotted Aloha with their difference in vulnerable time?

Q: In slotted Aloha, data is transmitted at ~~500 Kbps~~ a Bandwidth of 220. find effective bandwidth?

Data Rate Limits

Data rate depends on :-

① Bandwidth available (B)
② level of signals used. (0, 1) $[2^1, 2^2, --- 2^n]$
③ Quality of channel (level of noise)

Noisy channel — Shanon Capacity
Noiseless channel — Nyquist Bit rate.

Capacity of system

- The bit rate of a system increases with ↑ in the number of signal levels we use to denote a symbol.
- A symbol can consist of 1 bit or 'n' bits.

- The no. of signal levels = 2^n
- As the no. of levels goes up, the spacing b/w level decreases. which increases the probability of an error occuring in the presence of transmission impairments.

Nyquist Th.:-

- It gives the upper bound for the bit rate of a transmission system by calculating the bit rate directly from the number of bits in a symbol and the Bandwidth of the system.

- Nyqn Th states that for noiseless channel

$$C = 2B \log_2 2^{\boxed{n}}$$

n — no. of levels.

C — Capacity in bps

B — BW in Hz.

eg:- Consider a noiseless channel with BW of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as —

$B = 3000\ Hz$.

$L = 2$.

$2^n = L$

$\therefore n = 1$.

Bit Rate $= 2\ B \log_2 (L) \rightarrow$ no. of levels.

$= 2 \times 3000 \times \log_2 (2)$

$= 6000$ bps. ≈ 6 Kbps.

eg:- Same question for 4 signal levels.

$2^n = L$

$L = 4$

$B = 3000\ Hz$

$2^2 = 4 \Rightarrow n = 2$

Bitrate = 265000 bps

eg:- We need to send 265 kbps over a noiseless channel with a BW of 20 KHz. How many signal levels do we need?

Sol:- Bit Rate $= 2\ B \log_2 L$

$265000 = 2 * 20 \times 1000 * \log_2 L$

$\log_2 L = 6.625$

$L = 2^{6.625} \approx 98.7$ levels.

$\because$ level is in power of 2.

$2^6 = 64$

$2^7 = 128$

Shanon Th — Noisy channel

$$C = B \log_2 (1 + SNR)$$

It is in dB (decibels)

SNR = Signal to Noise Ratio.

eg: Consider an extremely noisy channel in which the value of the ~~noise~~ signal to noise ratio is almost zero.
In other words, the noise is so strong that the signal is faint. For this channel the capacity 'C' is calculated as —

Sol. $SNR \approx 0$

$$C = B \log_2 (1 + SNR)$$

$$B \log_2 (1 + 0)$$

$$B \log_2 (1)$$

$$C = B * 0$$

$$C = 0$$

eg:- We can calculate the theoritical highest bit rate of a regular telephone line.

A telephone line has BW of 3000. SNR ratio is usually 3162. for this Capacity of channel is

Ans.

$$C = B \log_2 (1+SNR)$$

$$3000 \log_2 (1 + 3162)$$

$$C = 34860 \text{ bps.}$$

Q: A channel has a Bandwidth of 1 MHz. SNR for this channel is 63. Calculate Bit rate and no. of levels required.

$BW = 1MHz = 10^6 Hz.$

using shanon Th.

$$\text{Bit rate} = BW \log_2 (1+SNR)$$

$$= 10^6 \log_2 (1+63)$$

$$= 10^6 \log_2 (64)$$

$$= 10^6 \log_2 (2^6)$$

$$= 6 \times 10^6 \text{ bps}$$

using nyquist.

$$\text{Bit rate} = 2 * BW * \log_2 L$$

$$6 \times \cancel{10^6} = 2 * \cancel{10^6} \log_2 L$$

$$\log_2 L = 3 \Rightarrow \log_2 (2^3) = 3$$

$L = 8$

$L = 8$ //.