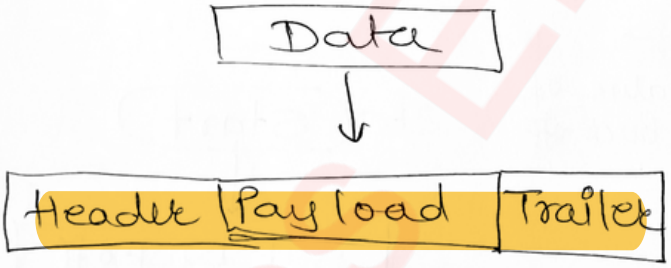
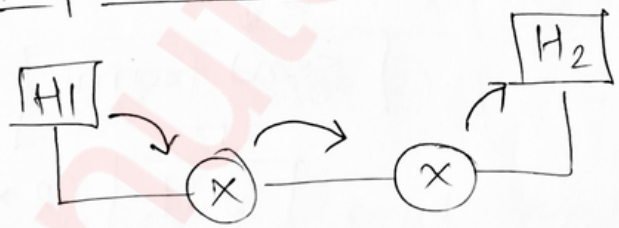
- **Data Link Layer**
  - NL↓
  - PL↑
  - Flow control
    - Stop & wait
    - Go Back N
    - selective Repeat
  - Error control
    - CRC
    - checksum
  - framing
  - Physical Addressing (MAC)
  - Access control
    - CSMA/CD/CA
    - Aloha
    - Token Ring

LLC	Logical Link Control
MAC	Media Access Control



- **Hop-to-Hop** (Node to Node)



MAC

- Access control
- Physical Addressing

LLC

- Flow control
- Error control

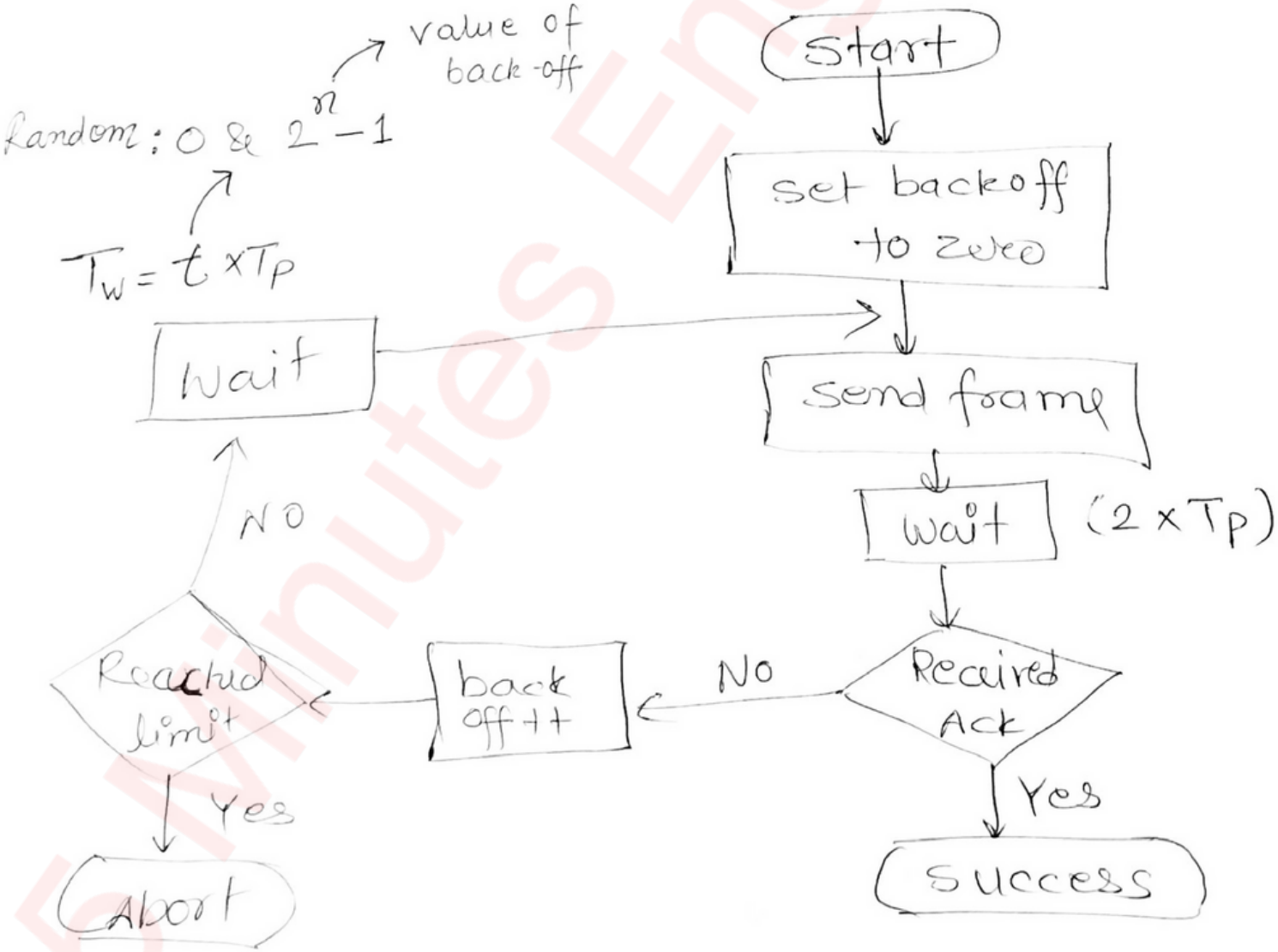
- framing -

✳ Access control

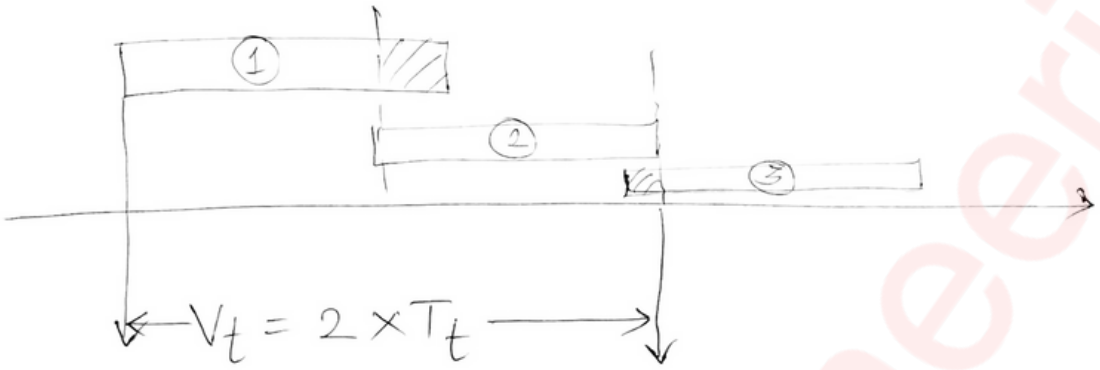
Random Access

- ALOHA
  - Pure
  - Slotted
- CSMA
- CSMA/CD
- CSMA/CA

⇒ ALOHA



- Vulnerable Time
  - ↳ Possibility of collision



↑
Because of Randomness (18%) efficiency

"But"

↳ Slotted ALOHA

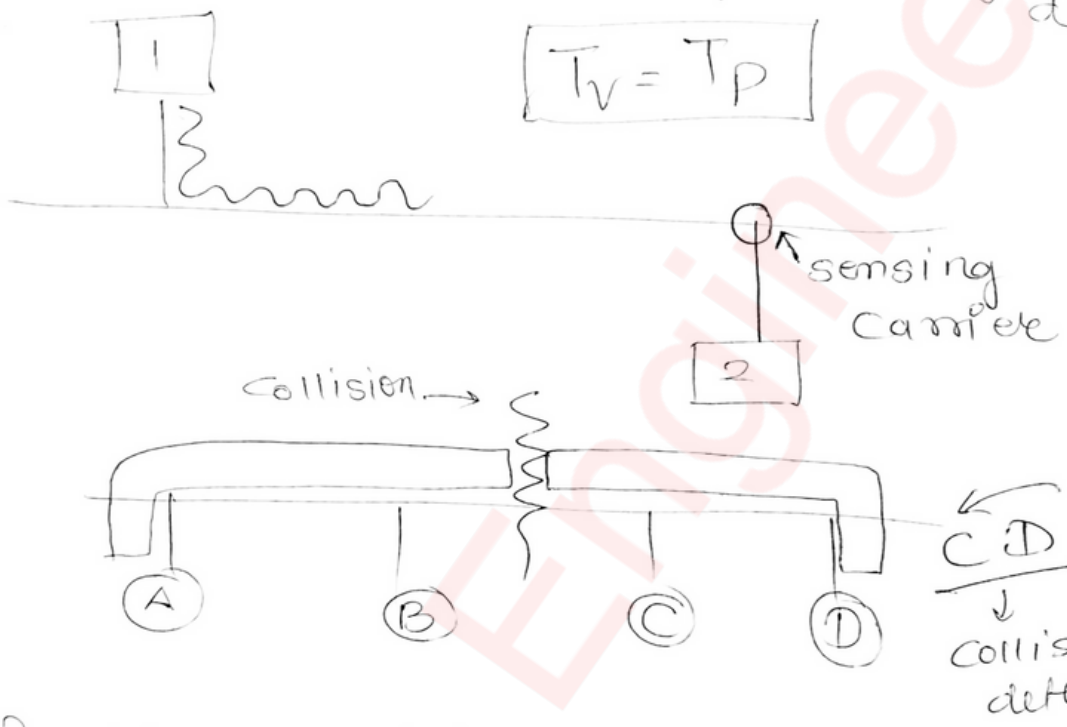
↳ Divide the time `T' into slots. (T_t)

- Station can send only at beginning of slot. (37%) efficiency.

⇒ CSMA

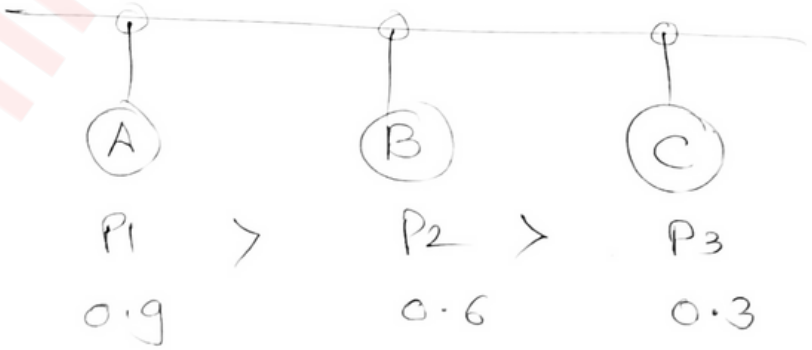
- Carrier Sense Multiple Access
- Collision may happen due to "Tp" propagation delay.

$[T_V = T_P]$



- Persistence Methods
  - 1-persistent (continuosly sensing)
  - Non-persistent (Random time wait) then sense.
  - P-persistent (Probability)

in P-persistent ,it continuously sense and if transmission is idle tb prob. ke According trsmission hoga

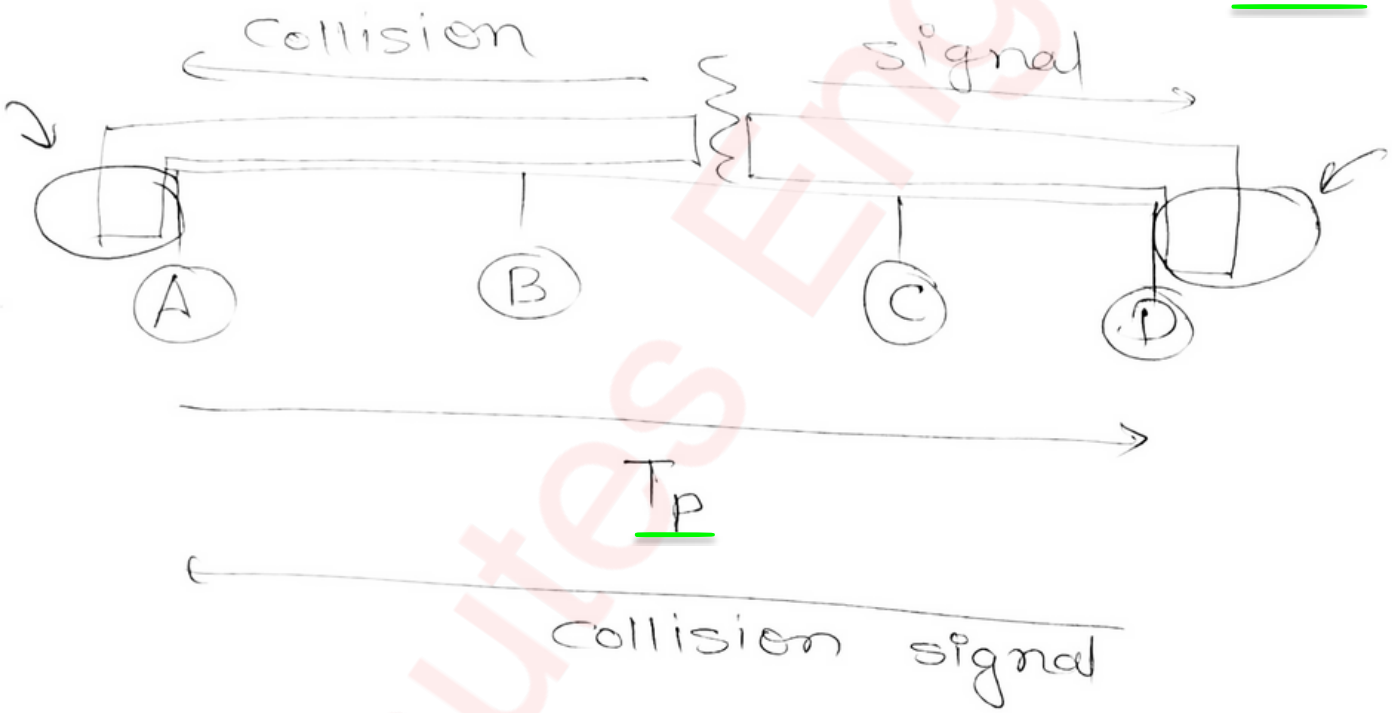


randomly allocated prob

CSMA/CD (wired)

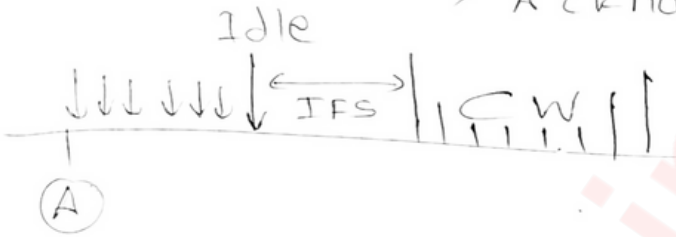
$T_t \geq 2 \times T_p$

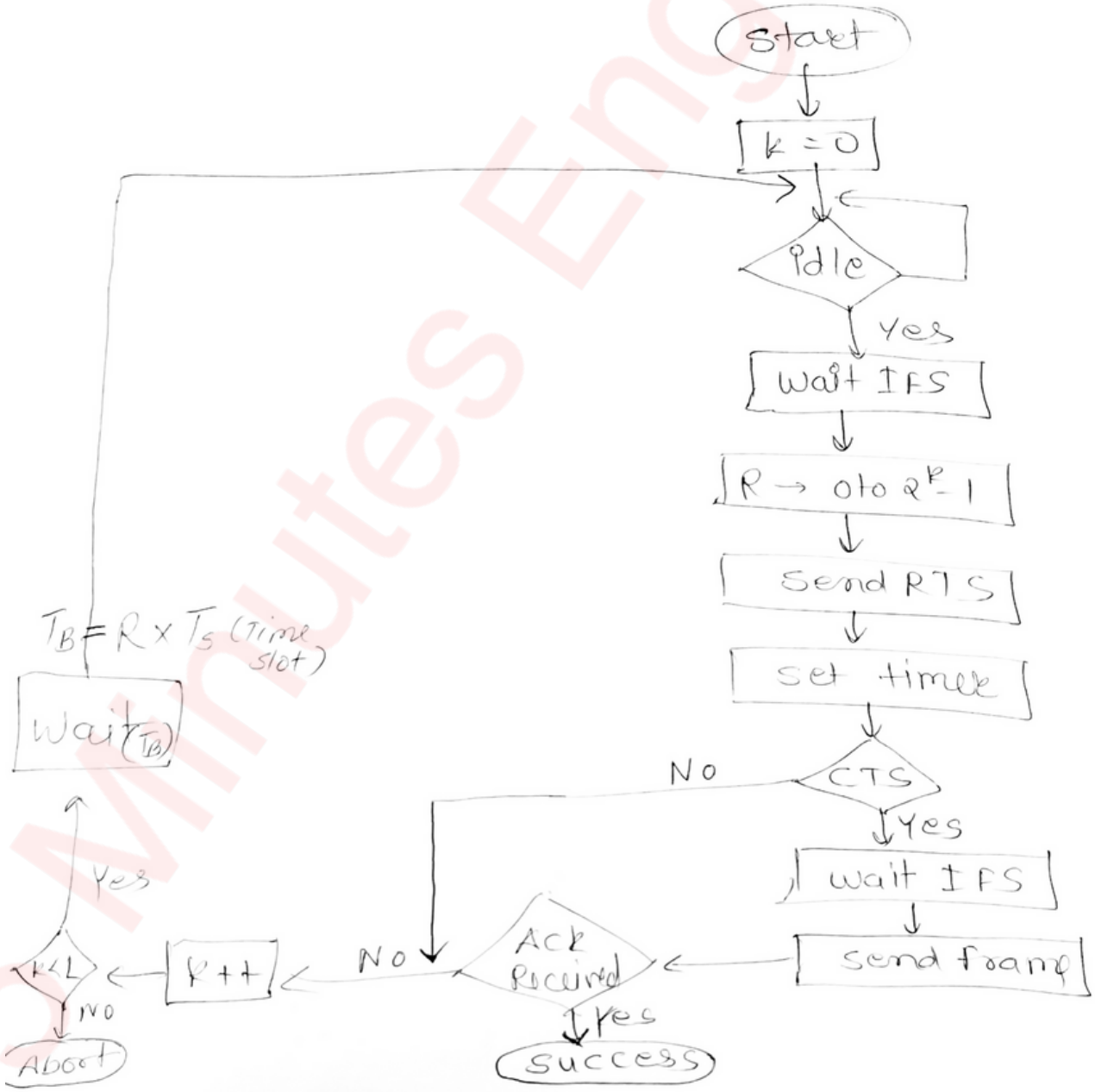
$\frac{L}{B} \geq 2 \times \frac{D}{V}$ } Imp.



$L \geq 2 \times T_p \times B$ Length of packet.

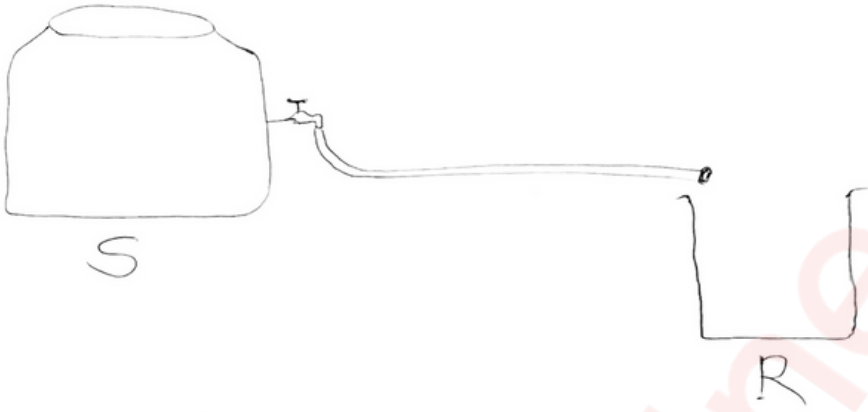
- CSMA/CA (Collision Avoidance) (wireless).
  - Collision May occur.
  - Strategies
    - Interframe space
    - contention window
    - Acknowledgement.





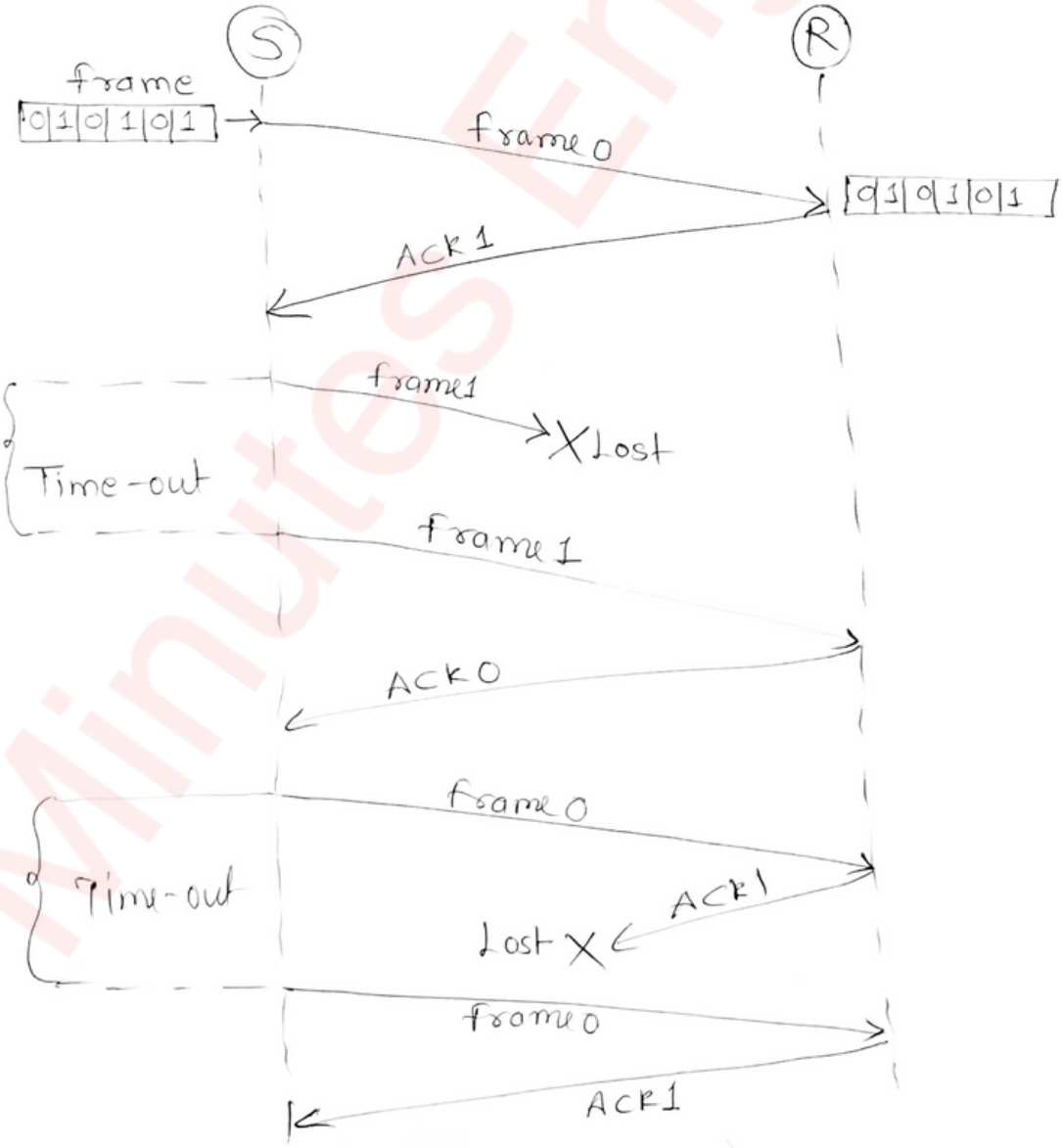
* Flow Control

↳ ① Data Overflow (x)



⇒ Sliding Window Protocol

① Stop & wait



Total time (1 packet) $= T_{t_{data}} + T_p + T_q + T_{pro} + T_{tack} + T_{p_{ack}}$

T_q (Queuing delay)
↳ 0
↳ waiting in I/p or o/p queue of Router

T_{pro} (Processing delay)
↳ 0
↳ Time for processing packet at destination end.

$TT = T_{t_{data}} + 2T_p + T_{tack}$ → negligible

$$\boxed{TT = T_{t_{data}} + 2T_p}$$

In piggy backing $T_{t_{data}} = T_{tack}$

$$TT = 2T_{t_{data}} + 2T_p$$

$\Rightarrow$ $2T_p$ → RTT (Round trip time).

$$\text{Efficiency}(\eta) = \frac{\text{Useful time}}{\text{Total cycle time}} = \frac{T_t}{T_t + 2T_p} = \frac{1}{1 + \frac{2T_p}{T_t}}$$

$$= \frac{1}{1+2a}$$

- Throughput: no. of bits we are actually able to send per second

$$S = \frac{L}{T_t + 2T_p} = \frac{(1/B) \times B}{T_t + 2T_p} = \frac{T_t}{T_t + 2T_p} \times B$$

$$= \frac{1}{1 + \frac{2T_p}{T_t}} \times B$$

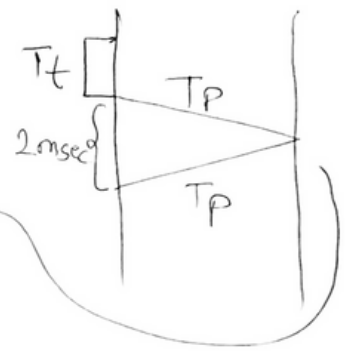
$$S = \frac{1}{1 + 2a} \times B$$

$$\boxed{S = \eta \times B}$$

Q $T_t = 1\,msec$

$T_p = 1\,msec$

$$\eta = \frac{1}{1 + 2\left(\frac{1}{1}\right)} = \frac{1}{3}$$



$$RTT = 2T_p = 2 \times 1\,ms$$

$$= \underline{2\,msec}$$

- If $\eta \geq 0.5$ then $\frac{T_t}{T_t + 2T_p} \geq \frac{1}{2}$

$\rightarrow T_t \geq 2T_p$

$2T_t \geq T_t + 2T_p$

$\boxed{T_t \geq 2T_p}$

$$\frac{L}{B} \geq 2 \times T_p$$

$$\boxed{L \geq 2 \times T_p \times B}$$

If $L = \uparrow$ then 50% 'η'

Q $B = 4\,Mbps$

$T_p = 1\,ms$

$L = ?$ for $\eta = 0.5$

$$L \geq 2 \times T_p \times B$$

$$L \geq 2 \times 10^{-3} \times 4 \times 10^{6}$$

$$L \geq 2 \times 10^{3} \times 4$$

$$L \geq 8 \times 10^{3}\ bits$$

$$S = \eta \times B = 0.5 \times 4 \times 10^{6}$$

$$\boxed{S = 2 \times 10^{6} = 2\,Mbps}$$

- factor affecting 'η'.

$$\eta = \frac{1}{1 + 2\left(\frac{T_p}{T_t}\right)} = \frac{1}{1 + 2\left(\frac{d}{V} \times \frac{B}{L}\right)}$$

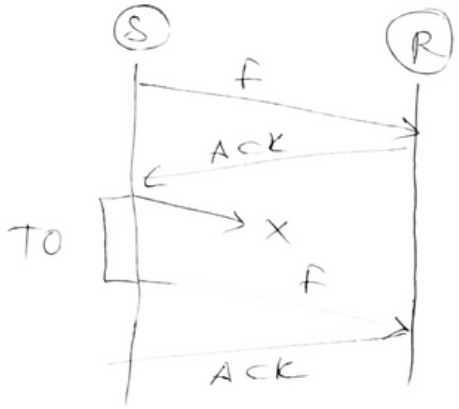
If $d \uparrow$ $\eta \downarrow$

If $L \uparrow$ $\eta \uparrow$

V & B constant as they are property of Link.

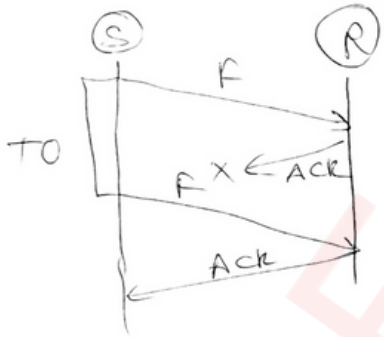
- Problem in stop & wait

1) Data Packet lost



S&W + Time out
= S&W ARQ
↓
(Automatic Repeat Request)

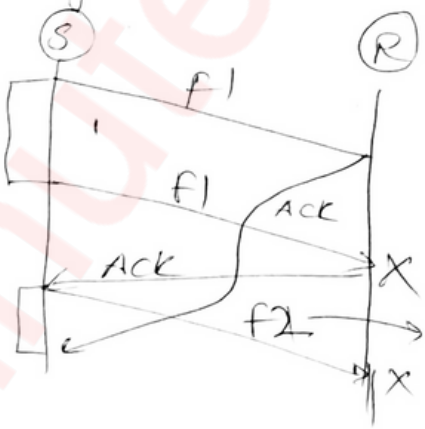
2) Ack lost.



Duplicate packet problem.

Soln: S&W + TO + seq. no.
(sequence of data/frame)

3) Delayed Ack



missed packet

Soln => sequence no. (Ack)

S&W + TO + Seq(Data) + Seq(Ack)

(2) Go Back N (ARQ)

(1) WS: Sender window size. (N)

GB10 → Ws = 10 (N > 1)

If N = 1 then it's simply Stop & wait.

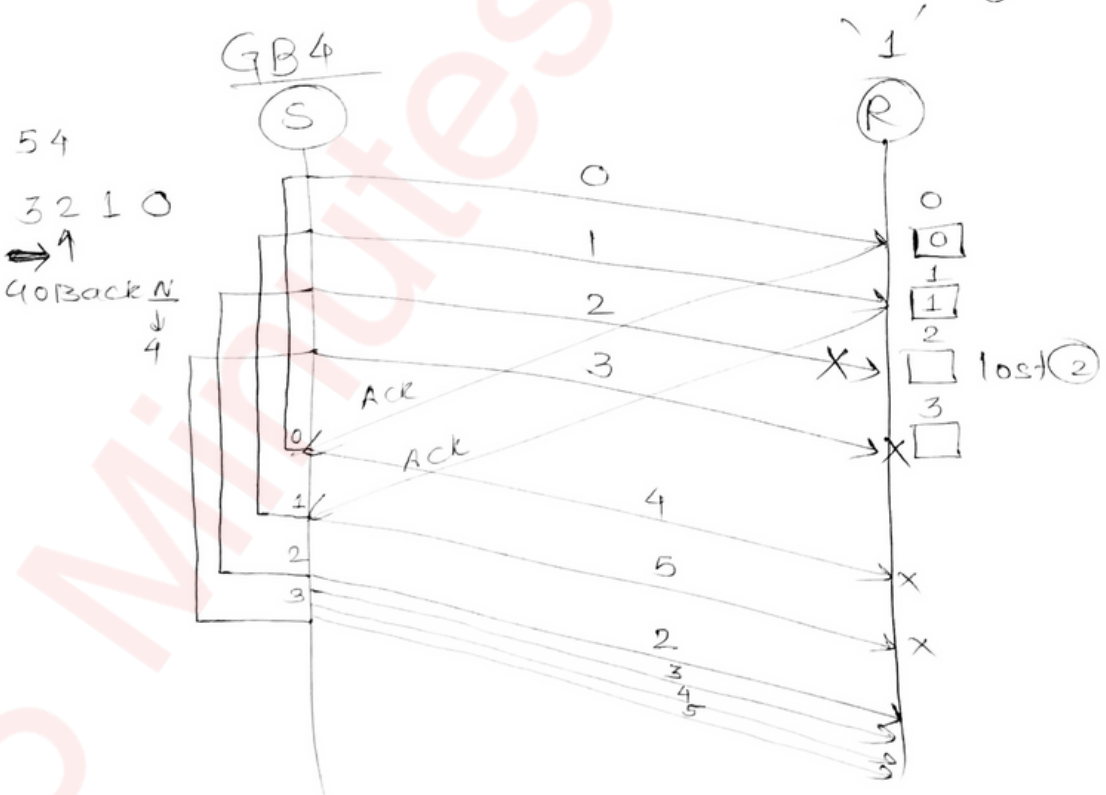
$$\eta = \frac{N}{1+2a} \qquad S\&W = \frac{1}{1+2a}$$

$$a = T_p / T_t$$

$$S = \eta \times B$$

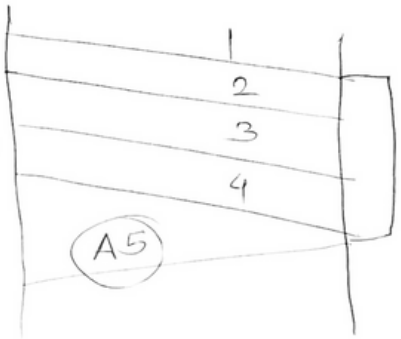
$$S = \frac{N B}{(1+2a)}$$

(2) WR: Receive window size is '1' always



- Acknowledgements types

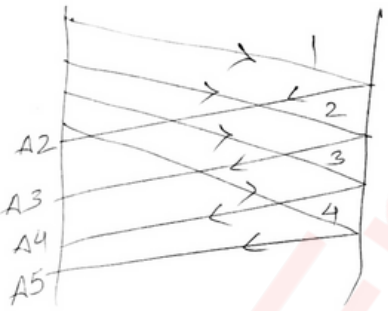
  → Cumulative Ack



Adv : less Traffic

disadv : Reliability is less

→ Independent Ack



more { reliable / Traffic

Timeout (TO) Timer > Ack Time

TO expire

[Not too long nor too small]

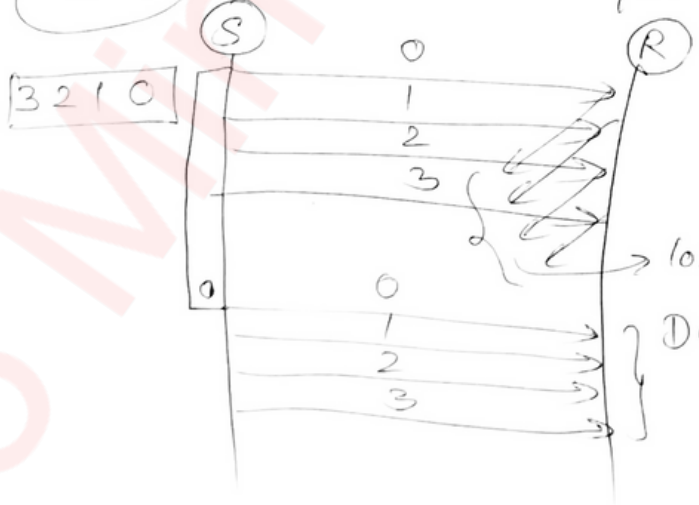
→ Independent Ack

⇒ Sequence Numbers (n)

→ N + 1

→ Bits Required = ceil($[\log_2(N+1)]$)

n = 4



0 1 2 3

But for n = 5 i.e N+1

This problem get eliminated.

$\Rightarrow$ W_S W_R seq. no. required.

N 1 (N + 1)

↑ at least this much is required.

Available sequence no. $\geq (W_S + W_R)$

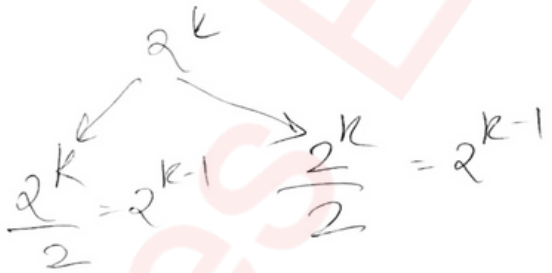
$\Rightarrow$ Bits = k

then seqnos = 2^k

then $W_S = 2^k - 1$

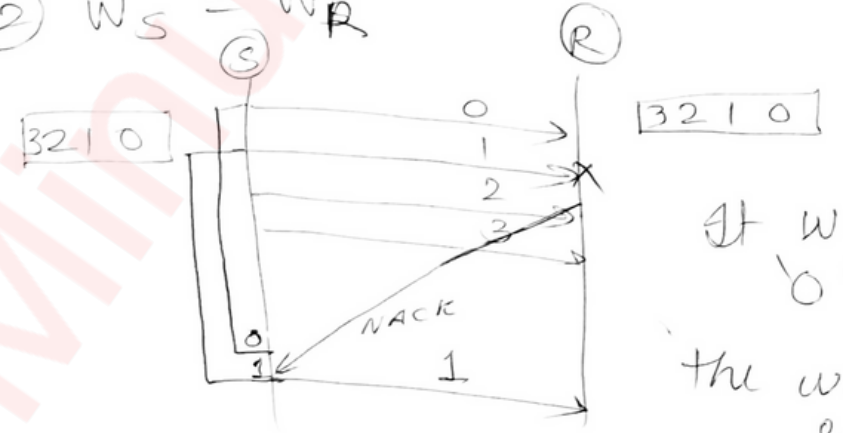
$W_R = 1$

(3) Selective Repeat

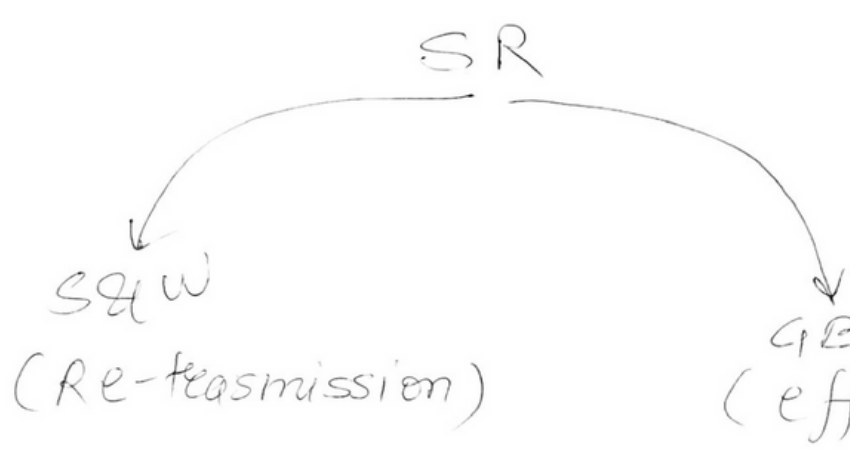


(1) $W_S > 1$

(2) $W_S = W_R$

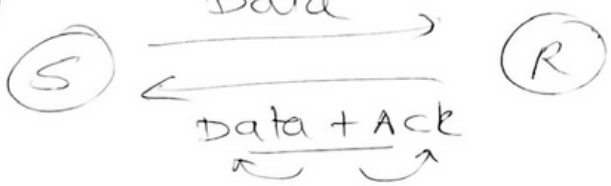


It will only resend '0', & not the whole window as in GBN Approach.



	S&W	GBN	SR
'η'	$1/1+2a$	$N/1+2a$	$N/1+2a$
Buffer	$1+1=2$	$(N+1)$	$(N+N)=2N$
Seq. nos	$1+1$	$(N+1)$	$(N+N)$
Re-teansmission (If 1 Packet lost)	1	N	1
Ack	Independent	Cummulative	Independent
Implementation	Easy	medium/ moderate	Complex/ difficult

- Piggybacking



(3) Error Control

corrupted/
modified/
altered/
changed/
manipulated.

- 1 bit (single bit). [less common]
- Burst error. (2 or more bits) ✓ normal/common.

(1) Hamming Distance

↳ counting the no. of dissimilar bits of given 2 nos.

eg: 1 0 1 0 1
XOR 1 1 0 1 0
0 1 1 1 1

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

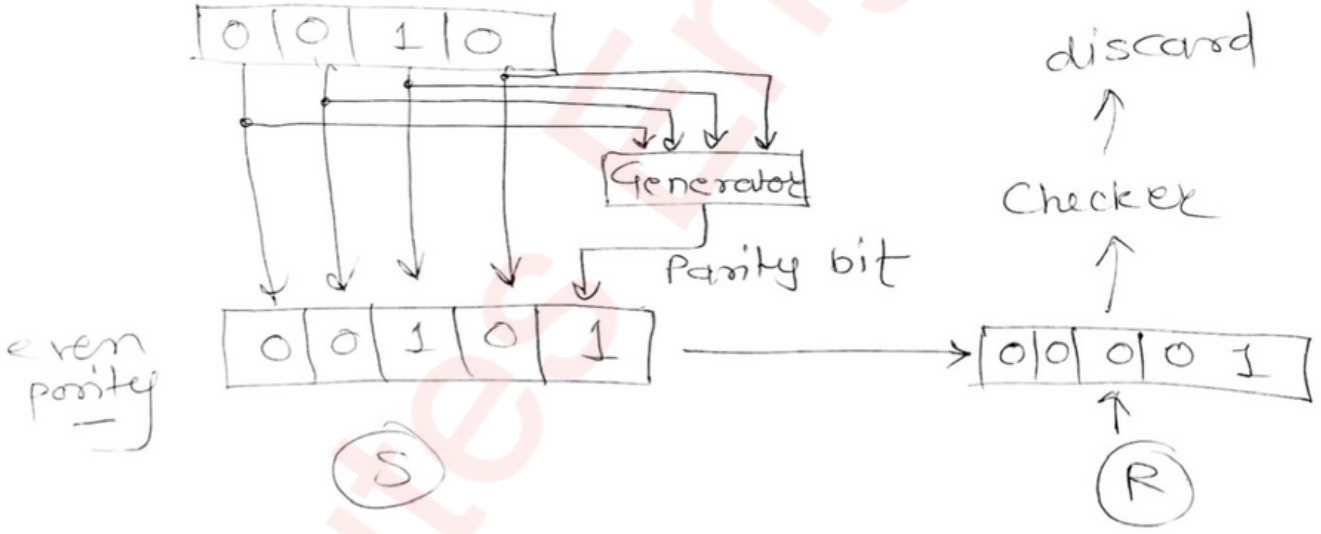
→ (4) ✓

Detection of Error

- simple Parity check
- 2D Parity check
- checksum
- CRC

⇒ simple (single bit Parity).

- odd
- even.

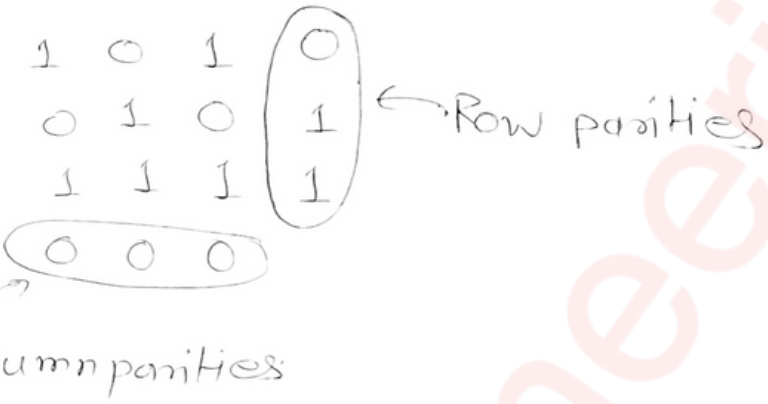


But 0 1 1 1 1

works on single bit update.

⇒ 2D Parity check

⇒ 1 0 1 , 0 1 0 , 1 1 1

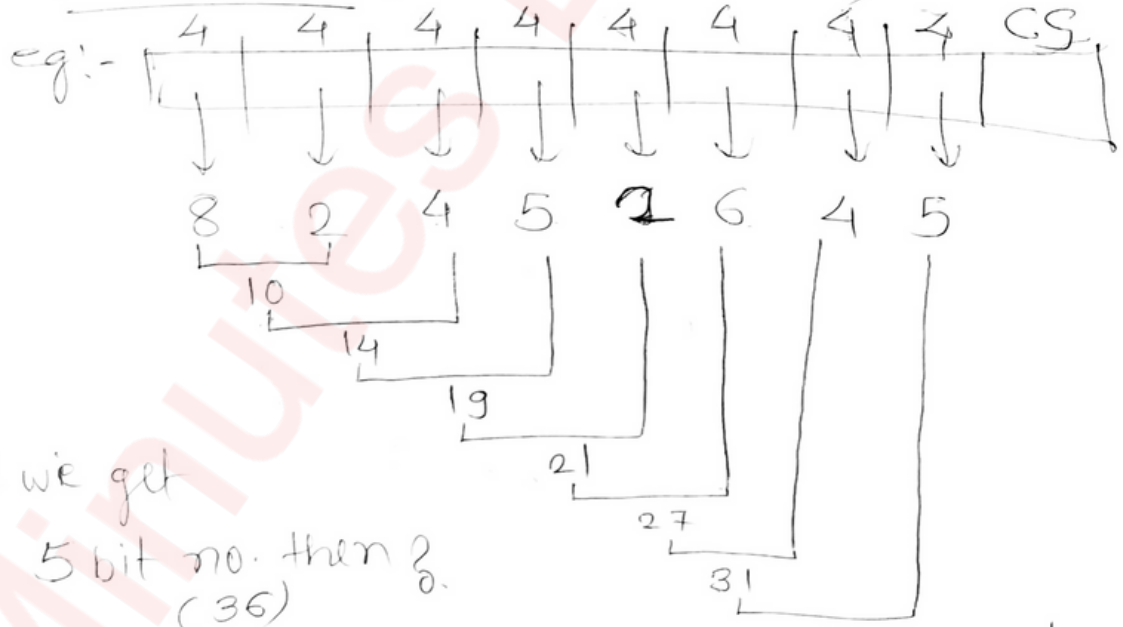


1/single bit error detect & correct.

Error detection till 3bits

>3 bit error → nor detect
→ neither correct.

- Checksum (check the sum)



If we get 5 bit no. then?

(36)

1 0 0 1 0 0

→ 1 0

0 1 1 0 (6)

1 0 0 1 (9)

1's complement

36 → 1's complement → -36

1's complement

(R) end: 36 + 9 = 45

↓

1 0 1 1 0 1

1 0

1 1 1 1 (15)

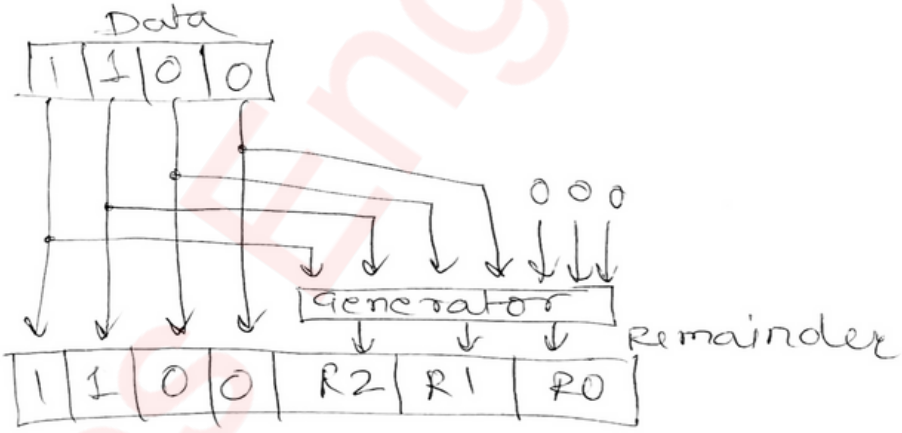
0 0 0 0

1's complement

valid / No error.

=> CRC Cyclic Redundancy Check.

eg:



Divisor : 1 0 1

$x^3 + x + 1$

↓ ↓ ↓ ↓

1 0 1 1

x^2

(4-1)

no. of zeros

1011) 1 1 0 0 0 0 0

XOR 1 0 1 1

0 1 1 1 0 0 0

1 0 1 1

0 1 0 1 0 0

1 0 1 1

0 0 0 0 1 0

↓ ↓ ↓

R_2 R_1 R_0 => 1 1 0 0 0 1 0

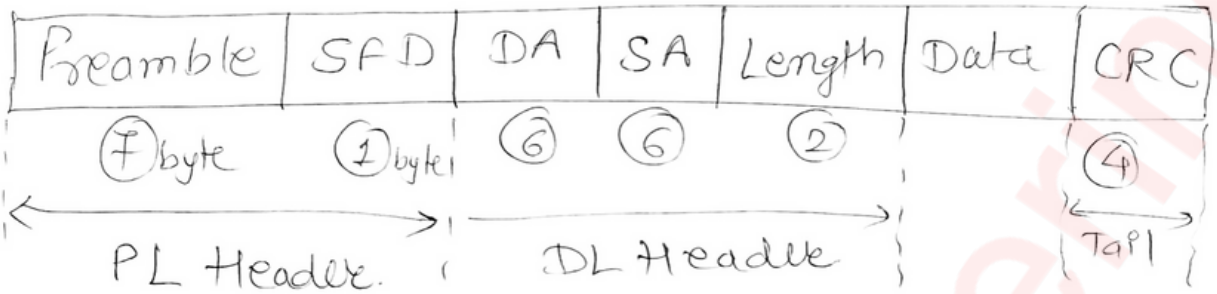
At (R) side checker ↓

```
1011 ) 1100010
       1011
       -----
       0111010
        1011
        ----
        010110
         1011
         ----
         00000   ← all zero.
```

* Ethernet

- → Topology [BUS] ① ② ③
- → Access control Method [CSMA/CD]
- → NO Ack
- → Encoding Technique (Manchester)
- → Data Rates: 10 Mbps — Normal
  100 Mbps — fast
  1 Gbps — Gigabits
- → Real Time Appln (X) } low performance
- → Interactive Appln (X) }

• Ethernet frame format



Preamble : 10101010 - - 10

SFD : 10101011

(start of frame) delimiter

beginning of frame

MAC (DA, SA) addr

only valid Receive Reads Pt

	Min	Max
Data	64 - 18 = 46 B	1500 B
frame	64B	1518 B

* MAC Address :

NIC

↓

ROM (MAC addr hard coded)

A1 : 2B : C4 : D2 : 89 : A5 } Format (: , -)

A1 - 2B - C4 - D2 - 89 - A5

1B 1B 1B 1B 1B 1B = 6B = 48bit

• Types:

→ Unicast (one-to-one)

LS: 1 byte → '0' A2 ← 1 0 1 0 0 0 1 0 ← LSB

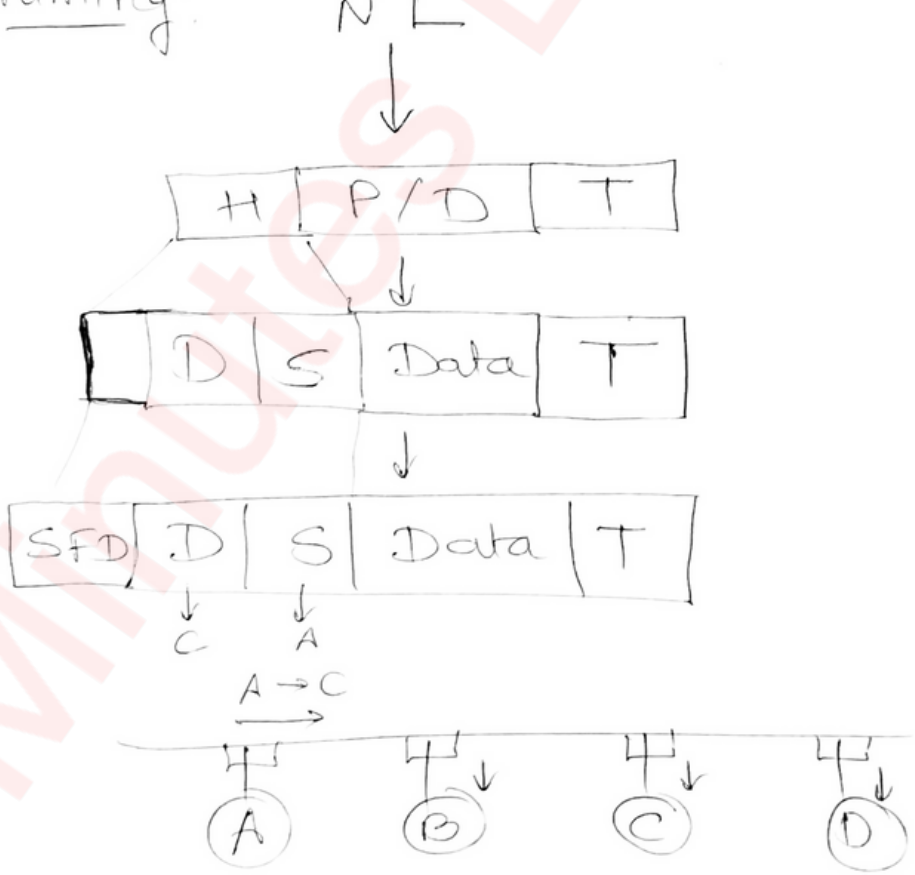
→ Multicast (one-to-many)

LSB 1 byte → '1' ← Group ID [A B C]

→ Broadcast (one-to-all)

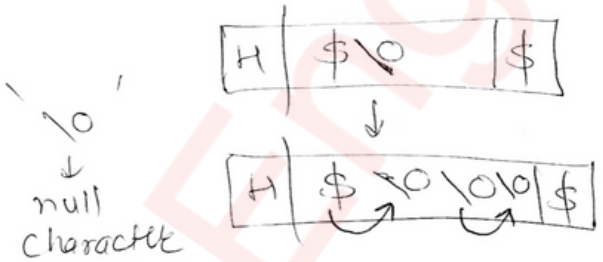
↳ FF:FF:FF:FF:FF:FF

* framing:



Frame length

- **fixed** (100 B)
  - [20B (Data) + 80B (padding)]
- **Variable** (10B, 100B, 1000B)
  - End of frame
    - Length field (Ethernet)
    - (Token Ring) End Delimiter
      - Character stuffing
      - Bit stuffing



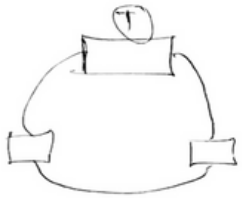
10000
↑↑↑
stuff the bit here.

1 0 0 0 (1) 0
1 0 0 0 (1) 1
(Data)

ED = 10000

* Token Ring

- Topology [Ring]



- Access control method [Token Passing]
- Data flow : Unidirectional.
- Ack - Piggybacking
- Encoding : Differential Manchester
- Data Rates : 4 Mbps, 16 Mbps

Token Ring frame format

SD	AC	FC	DA	SA	Data	CRC	ED	FS
1	1	1	6	6	(0 to max) " ≥ 0 "	4	1	1

Token: | SD | AC | ED |

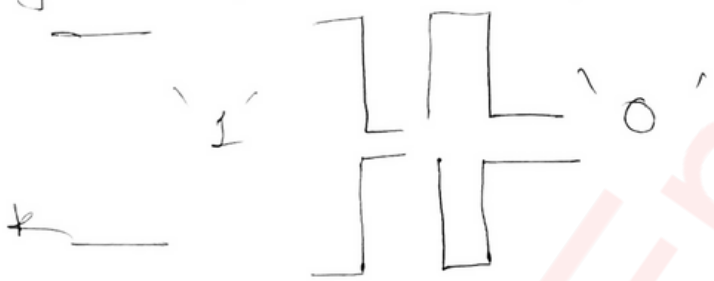
SD → | J | K | 0 | 0 | J | K | 0 | 0 |

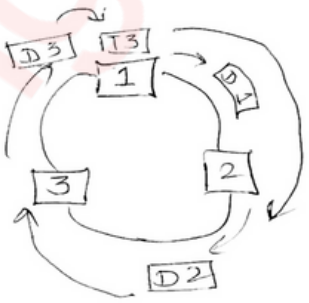
AC → | P | P | P | T | M | R | R | R |

(0-7) Priority bit — Reserved

T: Token (1) & T=0 NOT Token

M: Monitor bit





FC: | | | | | | | |

00 → data frame

11 → control frame

(AMP, Beacon [Alive monitor packet])

ED: | J | K | 1 | 1 | J | K | I | E |

FS: | A | C | 0 | 0 | A | C | 0 | 0 |

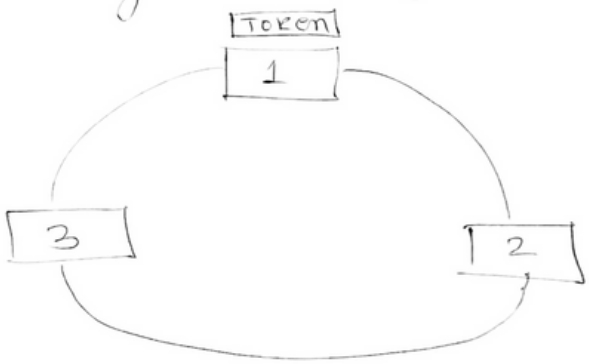
Info bit — Error bit.

I = 1 [more data coming]

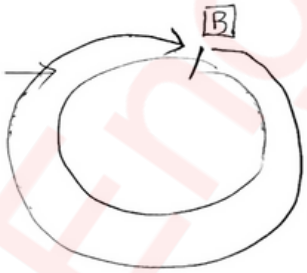
I = 0 [No more data.

frame status — Availability (Destination Available or not) — copy

- Token Passing
  - Ring Topology



⇒ hold the token the transmit the data
⇒ unidirection
⇒ NO collision
⇒ Ring Latency
⇒ LAN



$\Rightarrow \frac{d}{V} + N \times b$

d → length, V → velocity, N → no. of station, b → Time taken by each station to hold the bit before transmitting.

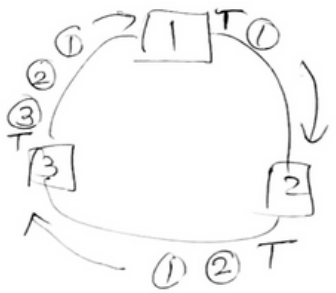
⇒ Token Holding (THT) Time [default 10msec]

⇒ Delayed Token Reinsertion

- $T_t + RL$
- Transmit the data on link, then it takes a Round trip of ring & return to station, then token is released.
- Only one packet at a time in Ring.

Early Token Reinsertion

- T_t
- NO Round trip



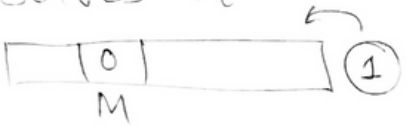
- More than 1 packet at a time in Ring

° Token Ring Problems

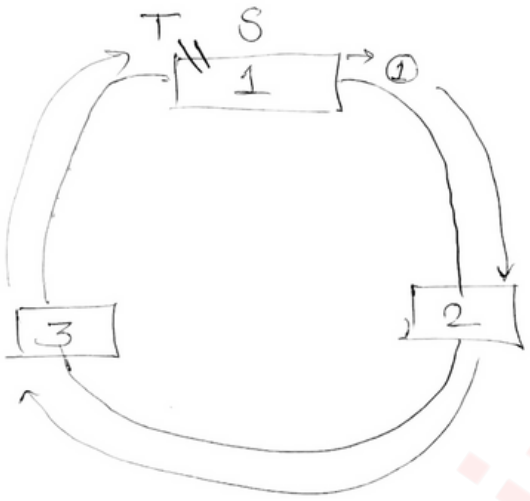
(1) Source Related

"Orphan" Packet as Source is down

- NOW Monitor station solves it.



1st time M = 1
2nd time → monitor discards the packet



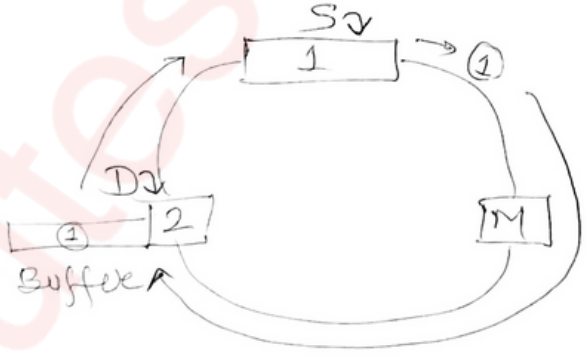
"Stray" Packet gets too much corrupt" so, station 1 doesn't Identify it & doesn't Remove it

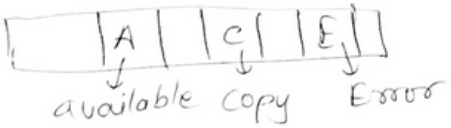
- Monitor station solves it using "CRC"

"CRC mismatch" so packet is discarded.

(2) Destination Related

- Down
- Busy (Buffer full)
- Copied



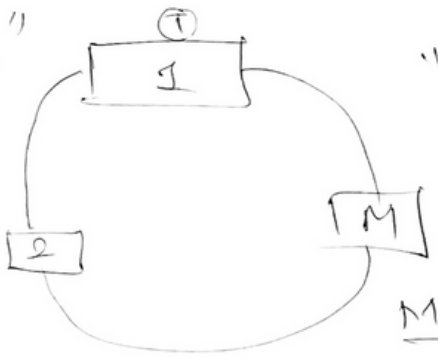


Initially	0	0	0
Down	0	0	0
Busy	1	0	0
Error	1	0	1
Copied	1	1	0

③ Token Related

"Captured Token"
(Monopolisation)
[Injustice]

- Max THT
  - → 10msec



"Token lost"

- station ① holding Token ① gets down

Min TRT : RL

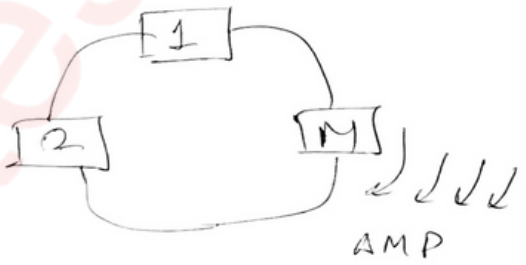
Max TRT : RL + THT × N

- Monitor regenerate Token after MAX TRT

"Token corrupt"
(3 Byte Packet)
Monitor takes care of it
=> Its considered as Disturbance / Noise in Ring.

④ Monitor Related

"Monitor Down"
(Heart beat Signal)
↓
AMP
(Alive Monitor Packet)



Soln: Polling (Make/elect a station as Monitor)

"Monitor Malfunction" (Cracked).

Soln: Human intervention".