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

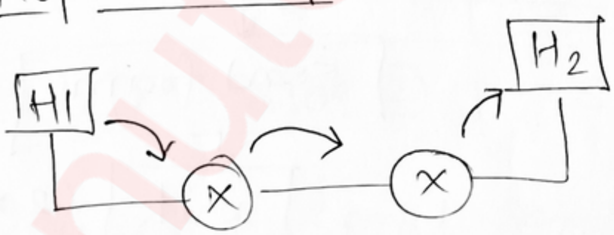
LLC	Logical Link Control
MAC	Media Access Control

Data

↓

Header	Payload	Trailer

- Hop-to-Hop (Node to node)



MAC	LLC
• Access control	• Flow control
• Physical Addressing	• Error control

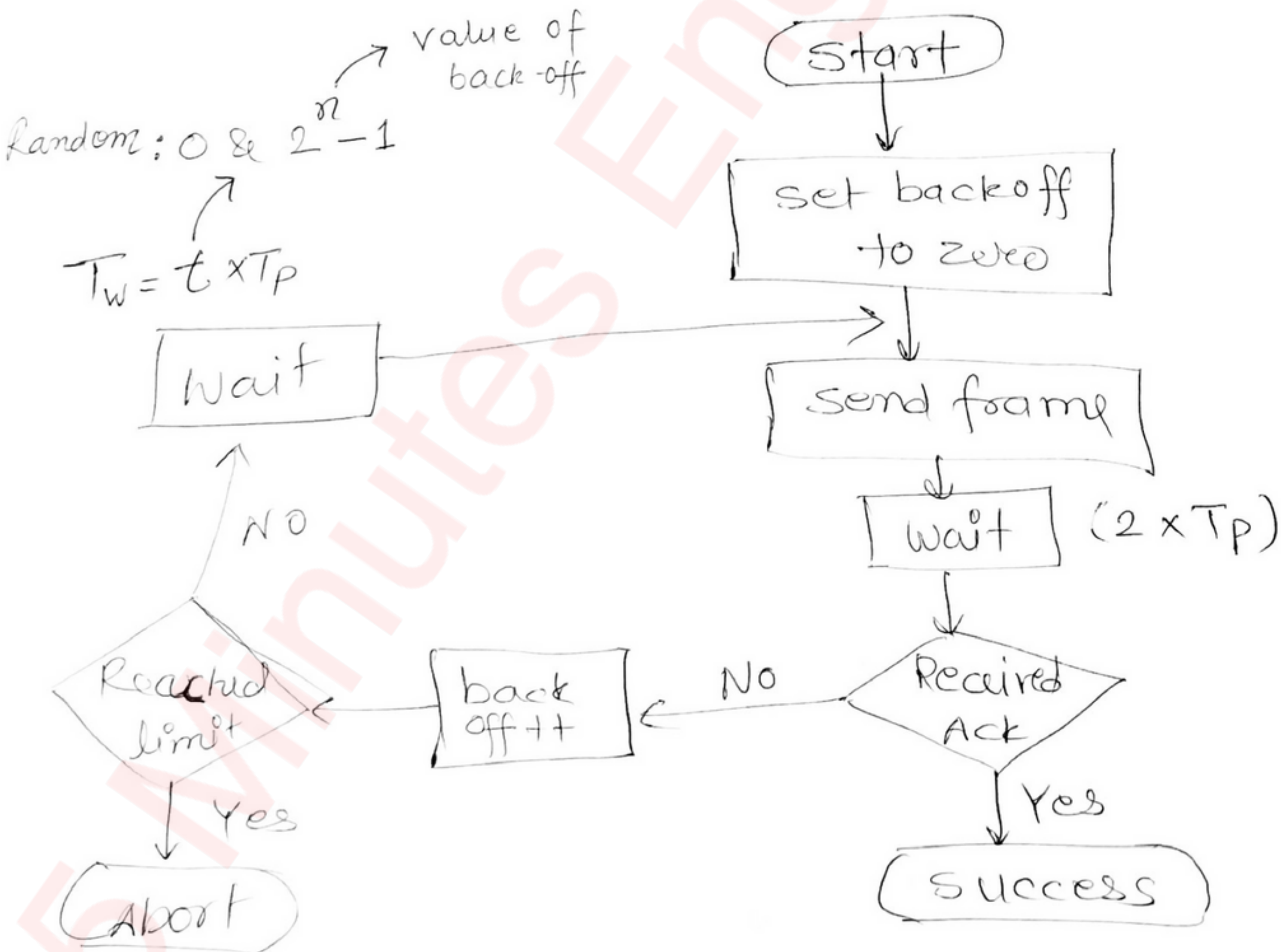
• Framing •

* Access Control

Random Access

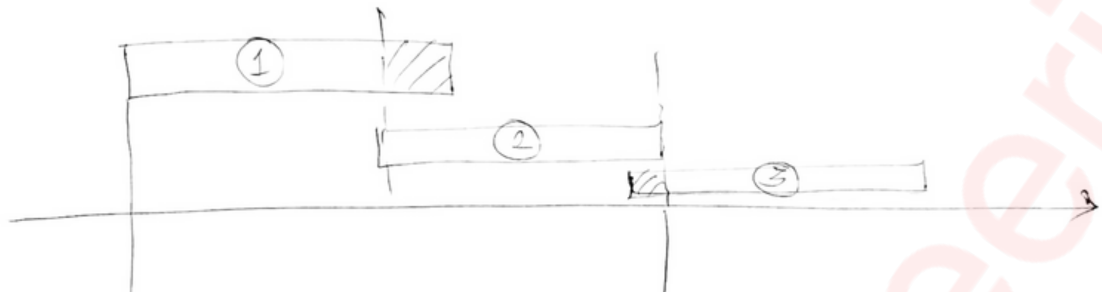
- → ALOHA
  - → Pure
  - → Slotted
- → CSMA
- → CSMA/CD
- → CSMA/CA

⇒ ALOHA



- Vulnerable Time

↳ Possibility of collision



$\leftarrow V_t = 2 \times T_t \rightarrow$

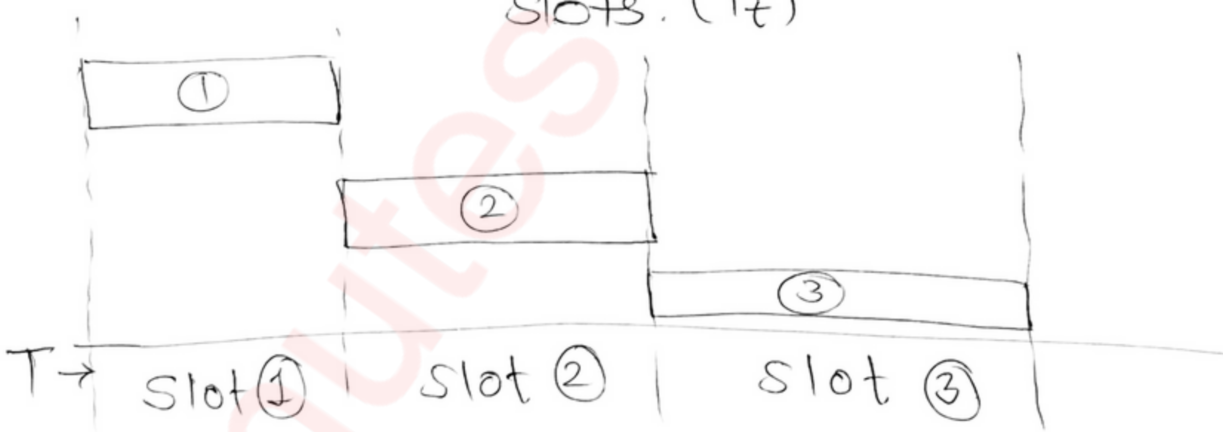
↑

Because of Randomness (18%) efficiency

"But"

→ Slotted ALOHA

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



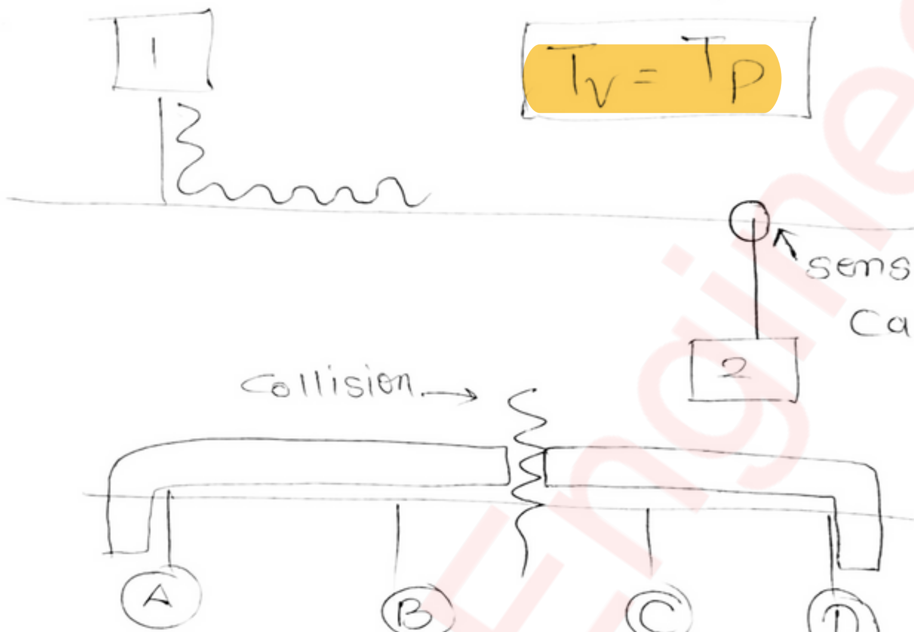
- Station can send only at beginning of slot.

(37%) efficiency.

⇒ CSMA

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

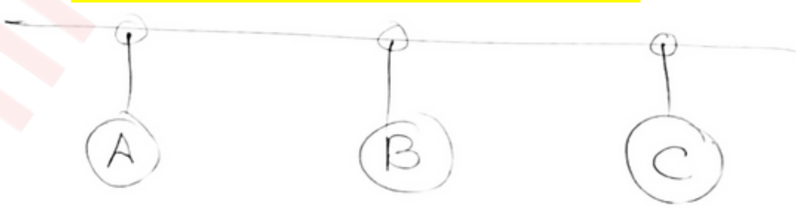
$\boxed{T_v = T_p}$



CD → collision detection

- 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



$P_1 > P_2 > P_3$

0.9   0.6   0.3

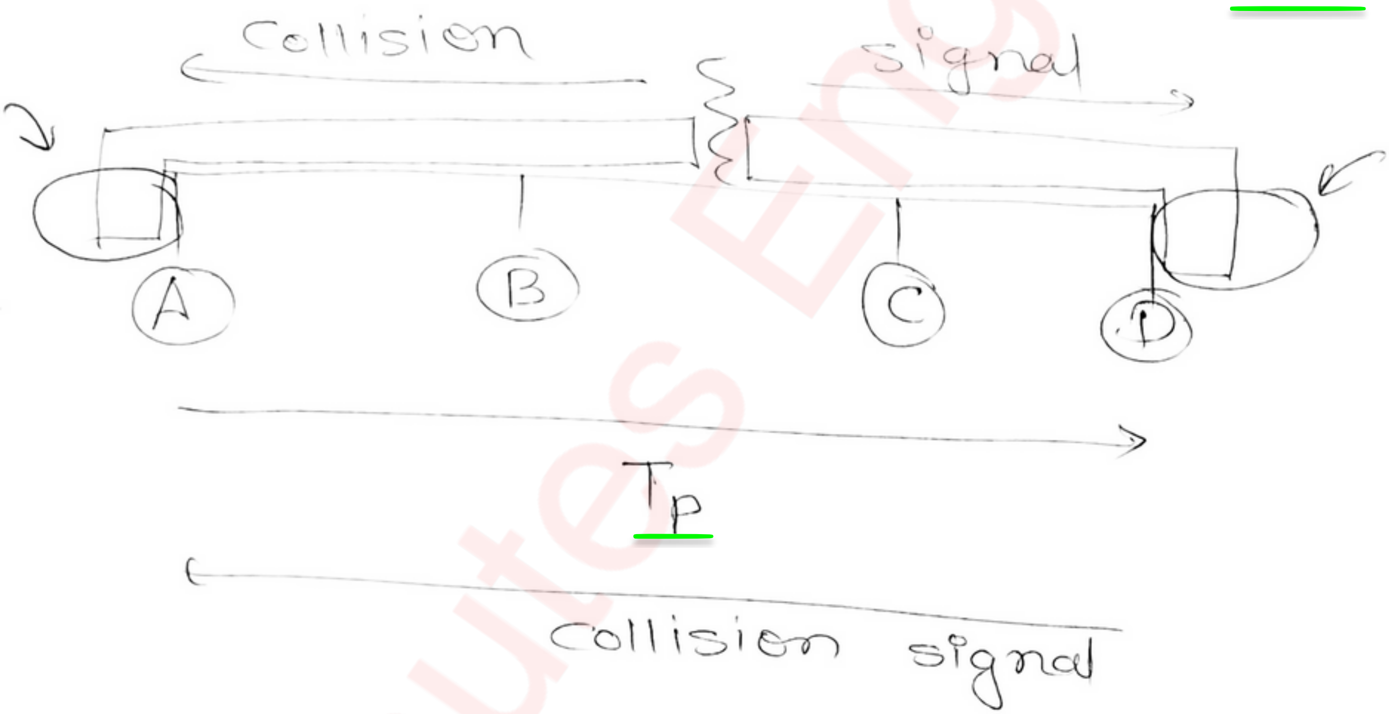
randomly allocated prob

CSMA/CD (wired)

$$\hookrightarrow T_t \geq 2 \times T_p$$

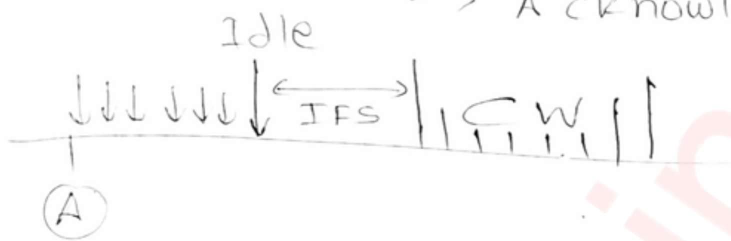
$$\downarrow$$

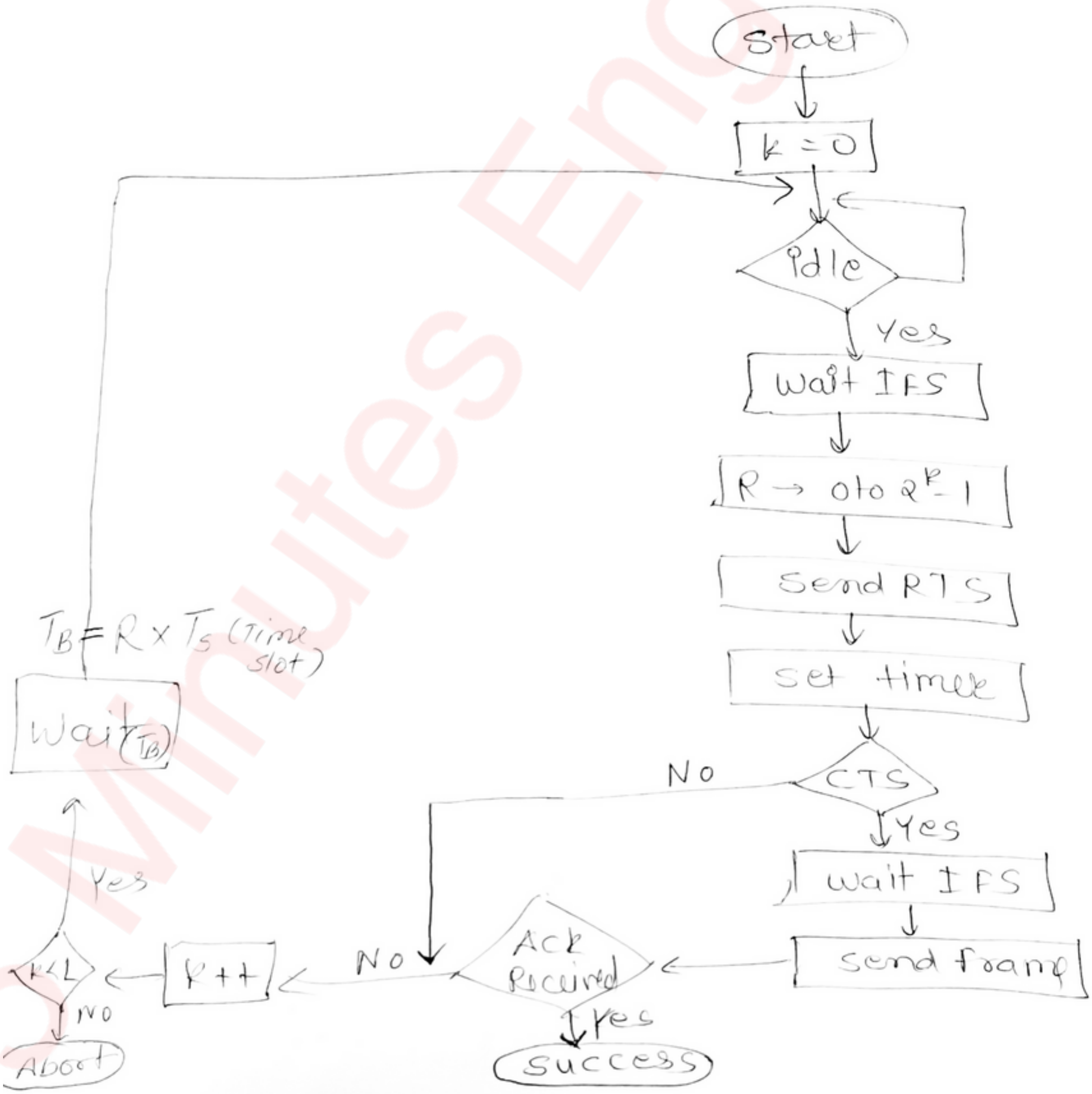
$$\left.\frac{L}{B} \geq 2 \times \frac{D}{V}\right\} \text{Imp.}$$



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

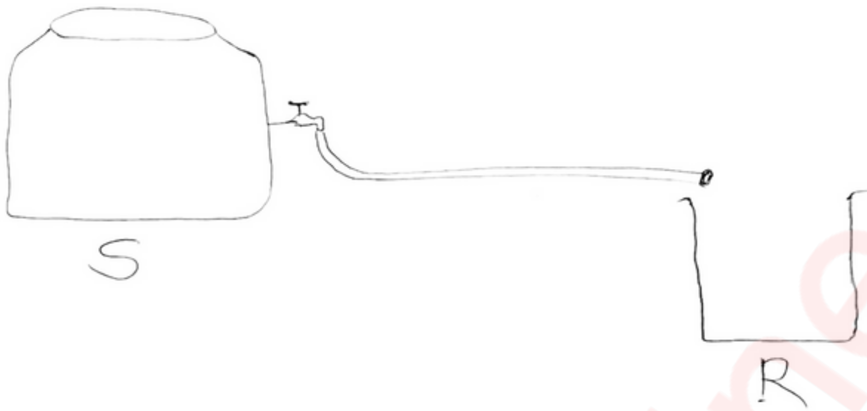
- CSMA/CA (Collision Avoidance) (wireless).
  - → Collision may occur.
  - → strategies
    - → Interframe space
    - → contention window
    - → Acknowledgement.





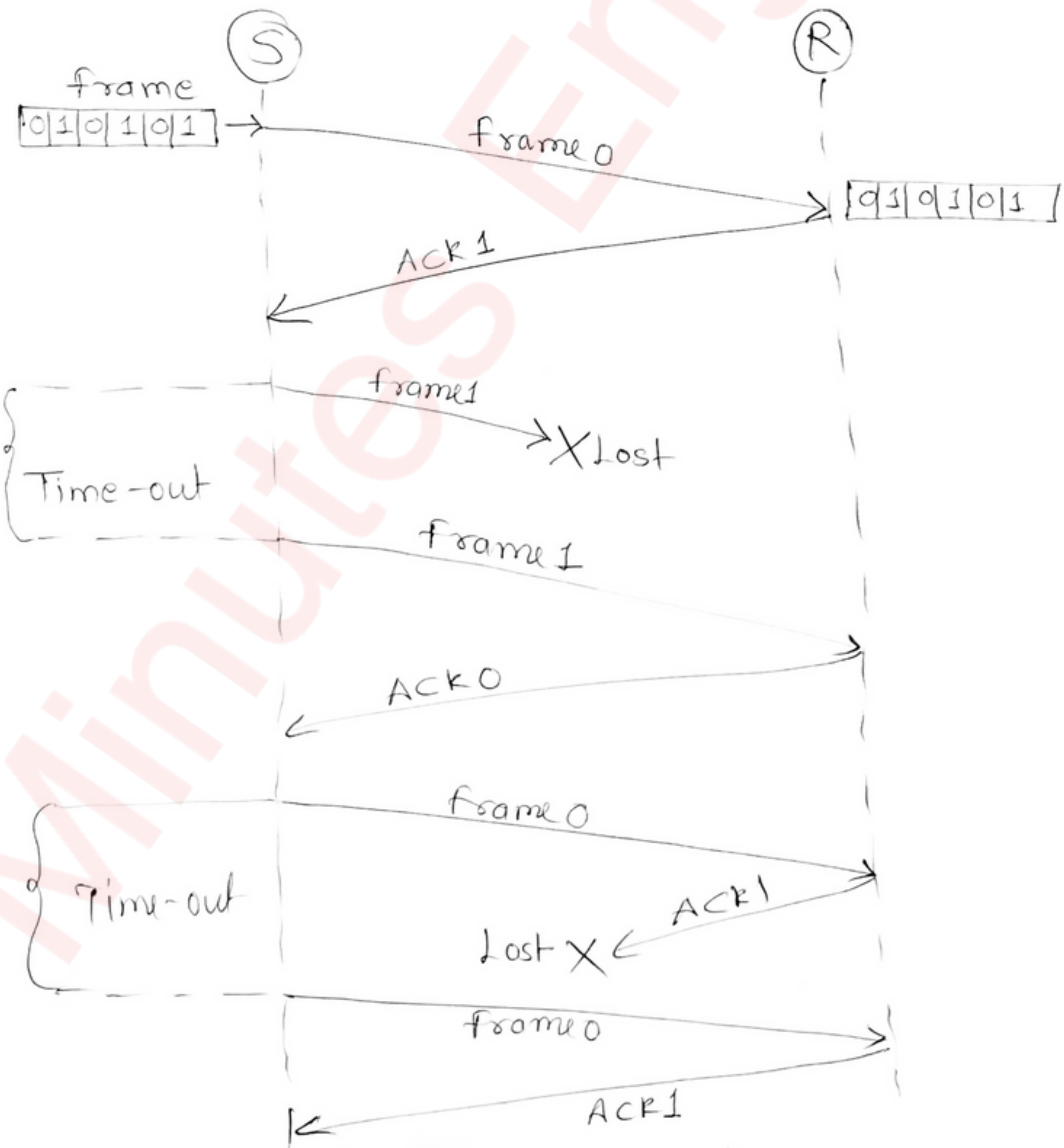
* Flow Control

↳ Data Overflow (x)



⇒ Sliding Window Protocol

① Stop & wait



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

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.

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

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

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

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

⇒ $2T_p$ → RTT (Round trip time).

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

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

• Troughput : no. of bits we are actually able to send per second

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

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

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

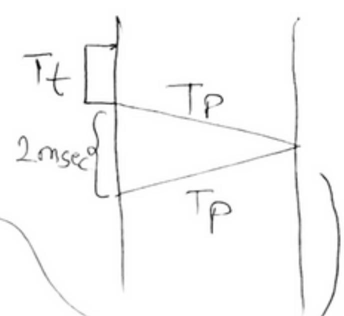
$$\downarrow$$

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

Q $T_t = 1\,msec$

$T_p = 1\,msec$

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



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

• 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 $\eta = 0.5$

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

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

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

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

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

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

- factor affecting 'η'.

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

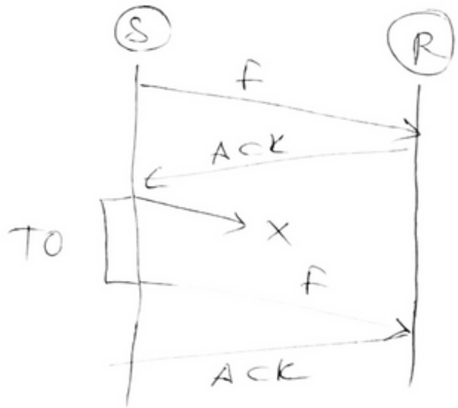
If $d \uparrow$ $\quad \eta \downarrow$

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

v & B constant as they are property of Link.

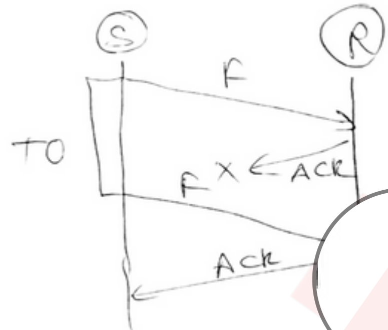
Problem in stop & wait

1) Data Packet lost



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

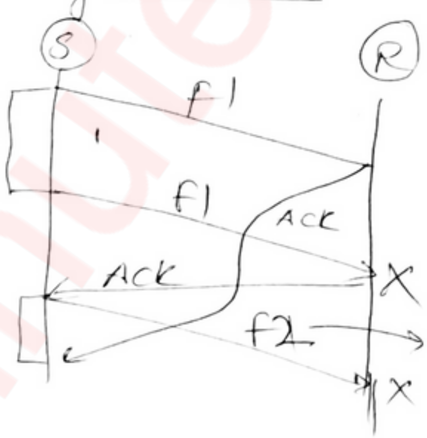
2) Ack lost.



Duplicate packet problem.

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

3) Delayed Ack



missed packet

Solⁿ => sequence no. (Ack)

$\boxed{\text{S\&W + TO + Seq(Data) + Seq(Ack)}}$

(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.

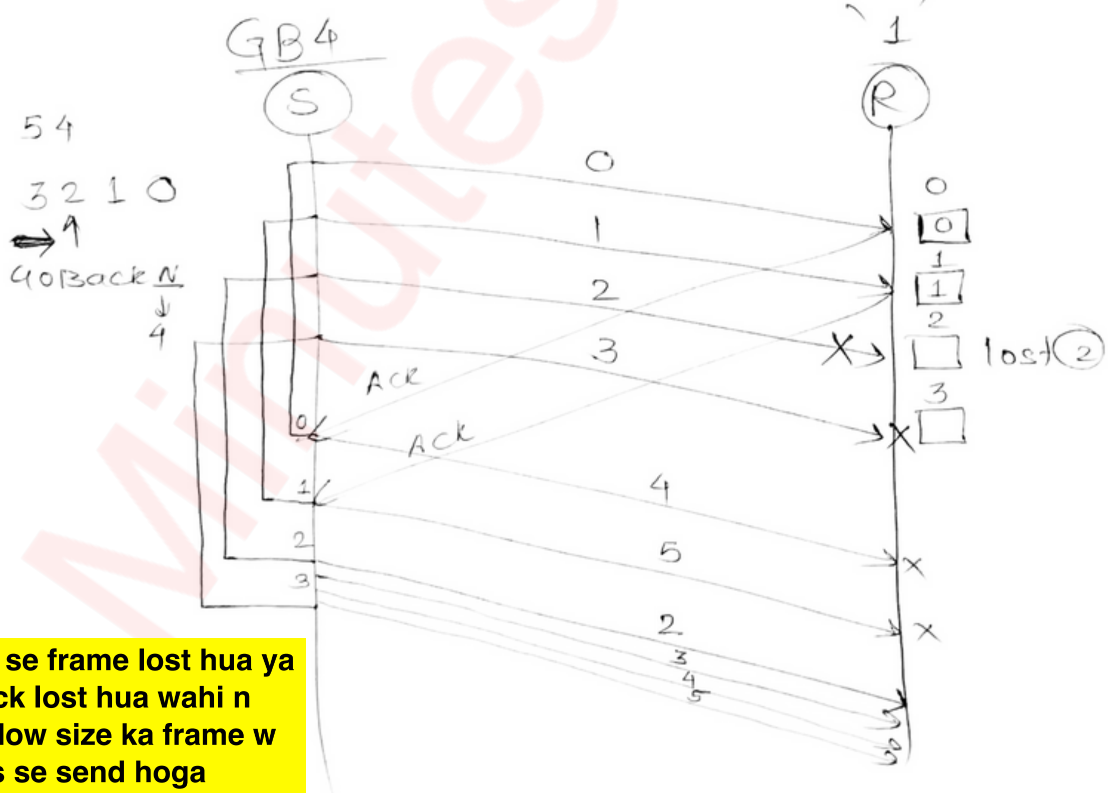
$$\eta = \frac{N}{1+2a} \qquad S\&W = \frac{1}{1+2a}$$

$$a = T_p / T_t$$

$$S = \eta \times B$$

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

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

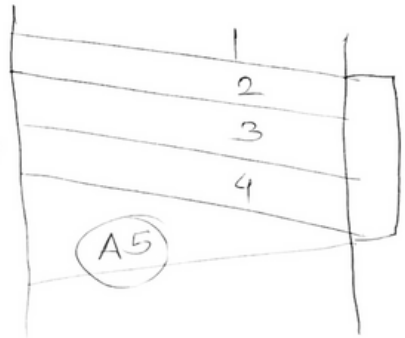


jaha se frame lost hua ya fir ack lost hua wahi n window size ka frame w apas se send hoga

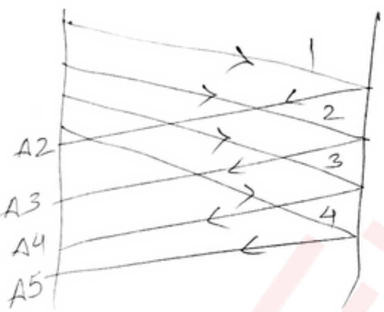
- Acknowledgements types
  - → Cumulative Ack

Adv : less Traffic

disadv : Reliability is less



→ Independent Ack



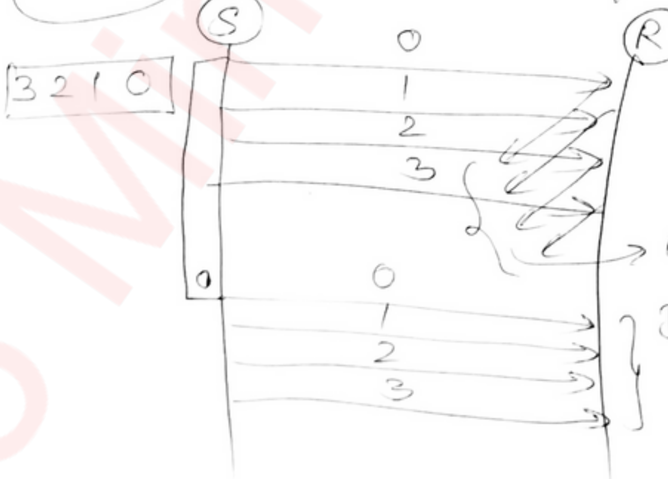
more { → reliable, → Traffic }

Timeout (TO) Timer > Ack Time [Not too long, nor too small] → TO expire; → Independent Ack

⇒ Sequence Numbers (n)

- → N + 1
- → Bits Required = ceil($\lceil \log_2(N+1) \rceil$)

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.

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

$\Rightarrow$ Bits $= k$

then seqnos $= 2^k$

then $W_S = 2^k - 1$

$W_R = 1$

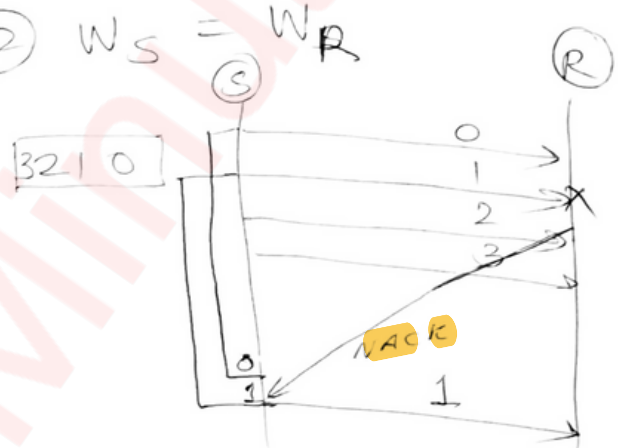
$2^k \rightarrow 2^k - 1,\ 1$

③ Selective Repeat

$2^k \rightarrow \frac{2^k}{2} = 2^{k-1},\ \frac{2^k}{2} = 2^{k-1}$

① $W_S > 1$

② $W_S = W_R$



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

SR

S&W (Re-transmission) ← SR → GBN (efficiency)

	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-transmission (If 1 Packet lost)	1	N	1
Ack	Independent	Cummulative	Independent
Implementation	Easy	medium/ moderate	Complex/ difficult

- Piggybacking

$$S \xrightarrow{\text{Data}} R$$
$$S \xleftarrow[\text{Data + Ack}]{} R$$

③ Error Control

S ⟶ R

| 0 | 1 | 0 | 1 | 0 | → | 0 | 0 | 1 | 0 | 0 |

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:

$$
\begin{array}{rccccc}
 & 1 & 0 & 1 & 0 & 1 \\
\text{XOR} & 1 & 1 & 0 & 1 & 0 \\
\hline
 & 0 & \underbrace{1 \; 1 \; 1 \; 1} & & & \\
\end{array}
\rightarrow 4 \checkmark
$$

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

Detection of Error

- → simple Parity check
- → 2D Parity check
- → check sum
- → CRC

⇒ simple (single bit Parity).

- → odd
- → even.

| 0 | 0 | 1 | 0 |

Generator

Parity bit

even parity

| 0 | 0 | 1 | 0 | 1 |

S

→ | 0 | 0 | 0 | 0 | 1 |

↑ Checker ↑ discard

R

jo bit ka count odd hoga wo parity bit hoga

1 ka count odd h th odd parity ar agar count even h th even parity

But | 0 | 1 | 1 | 1 | 1 |

works on single bit update.

⇒ 2D Parity check

⇒ 101 , 010 , 111

$$
\begin{array}{ccc|c}
1 & 0 & 1 & 0 \\
0 & 1 & 0 & 1 \\
1 & 1 & 1 & 1 \\
\hline
0 & 0 & 0 &
\end{array}
$$

← Row parities

Column parities

1/ single bit error detect & correct.

Error detection till '3bits'

>3 bit error → nor detect, → neither correct.

- **Checksum** (check the sum)

eg:- 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | C.S.

8 2 4 5 2 6 4 5

saree field mae 4 bit number hoga ie ex 8,2,4...

8 + 2 = 10, 10 + 4 = 14, 14 + 5 = 19, 19 + 2 = 21, 21 + 6 = 27, 27 + 4 = 31, 31 + 5 = 36

36 → 1's complement → −36

If we get 5 bit no. then ?.

(36)

↓

1 0 0 1 0 0

these 10 bit are extra ie th hm inne add kr dete h

$$
\begin{array}{r}
0\,1\,0\,0 \\
+\;1\,0 \\
\hline
0\,1\,1\,0 \;(6)
\end{array}
$$

$\boxed{1\,0\,0\,1}$ (9) ← 1's complement

R end : 36 + 9 = 45

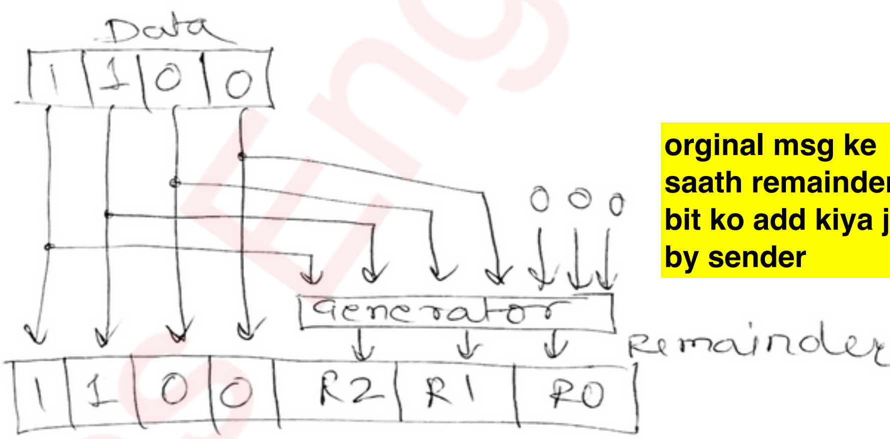
1 0 1 1 0 1
1 0
1 1 1 1 (15) — 1s complement
0 0 0 0

✓ valid / No error.

ie ki if all bit comes zero at the end th no error

⇒ CRC Cyclic Reduncy check.

eg:



orginal msg ke saath remainder bit ko add kiya jata by sender

Divisor : 1 0 1

$x^3 + x + 1$

1 0 1 1

x^2

(4 − 1) no. of zeros

original data mae no. of divisor - 1 utne zero append kr dete h original data mae

divisor phle se hi decider hota h bw sender and receiver

```
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
```

left to right jaenge ar jaise hi 1 dhkega waha tutrant divisor ko rhk denge ar xor opern krenge

jaise yaha 1 dusre bit pe tha 2 bit se divisor rhkha

$R_2 \; R_1 \; R_0 \Rightarrow \boxed{1\,1\,0\,0\,0\,1\,0}$

why stop here ? kyu ki jaise hi 1 mila tb uss 1 ke right mae divisor jitne bits hi nhi h th xor nhi ho paega

At (R) side Checker ↓

```
1011 ) 1 1 0 0 0 1 0
       1 0 1 1
       -------------
       0 1 1 1 0 1 0
         1 0 1 1
         -----------
         0 1 0 1 1 0
           1 0 1 1
           ---------
           0 0 0 0 0   ← all zero.
```

receiver pe bhi same hoga sab ar agar remainder zero hoga th no error

* Ethernet

- → Topology [BUS]

- → Access control Method [CSMA/CD]
- → NO Ack
- → Encoding Technique (Manchester)
- → Data Rates : 10 Mbps — Normal
  - 100 Mbps — fast
  - 1 Gbps — Gigabits
- → Real Time Appl^n (X)
- → Interactive Appl^n (X)

} low performanc

∘ Ethernet frame format

Preamble	SFD	DA	SA	Length	Data	CRC
7 byte	1 byte	6	6	2		4
PL Header		DL Header				Tail

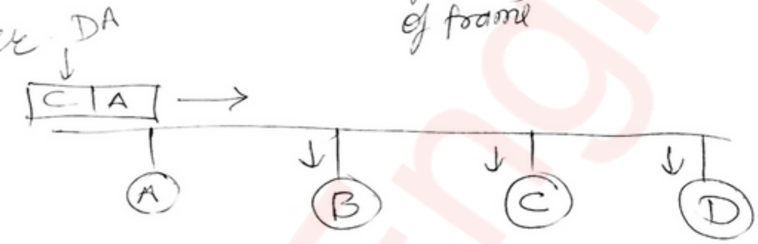
Preamble : 101010 - - 10

SFD : 1010101011

(start of frame) delimiter

beginning of frame

MAC addr (DA, SA)



only valid Receive Reads it

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

$\underbrace{A1}_{1B}$ - $\underbrace{2B}_{1B}$ - $\underbrace{C4}_{1B}$ - $\underbrace{D2}_{1B}$ - $\underbrace{89}_{1B}$ - $\underbrace{A5}_{1B}$ = 6 B = 48bi

· Types:

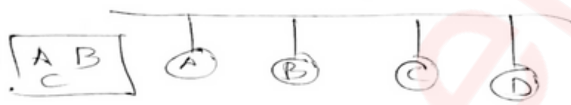
→ Unicast (one-to-one)

LS: 1 byte → '0' A2 1010 0010

LSB

→ Multicast (one-to-many)

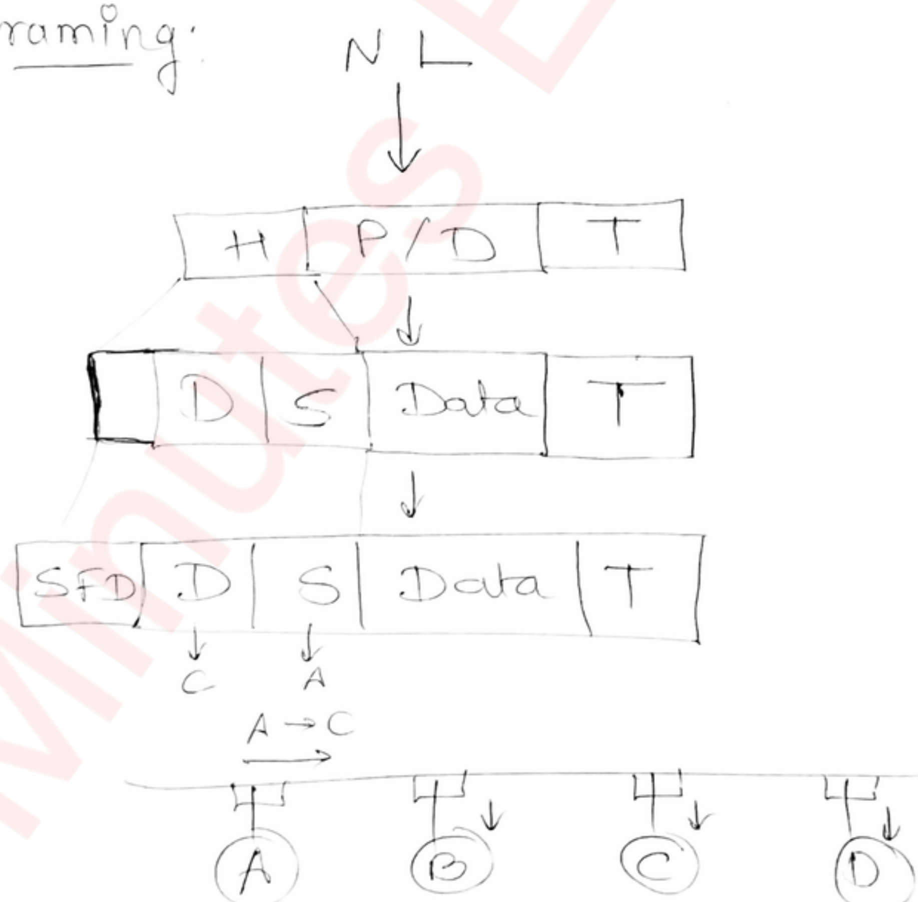
LSB 1 byte → '1' ← Group ID



→ Broadcast (one-to-all)

FF:FF:FF:FF:FF:FF

* framing:



Frame length

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

Character stuffing:

H	\$ \0	\$

↓

H	\$ \0 \0 \0 \0	\$

'\0' → null character

Bit stuffing:

1 0 0 0 0

stuff the bit here.

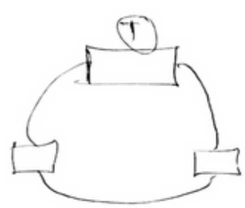
1 0 0 0 1 0

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

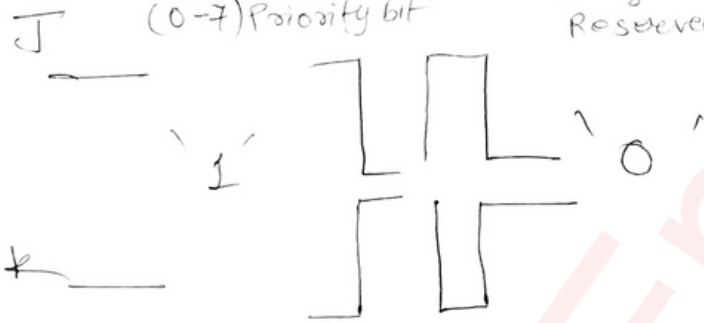
AC →

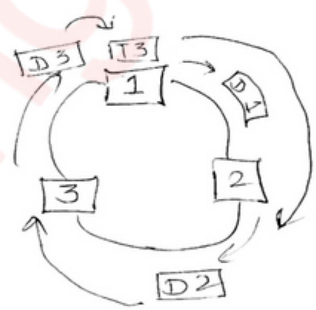
P	P	P	T	M	R	R	R

$\underbrace{P\ P\ P}_{\text{(0-7) Priority bit}}$ $\underbrace{R\ R\ R}_{\text{Reserved.}}$

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

M : Monitor bit





FC :

00 → data frame

11 → control frame

(AMP, Becken

[Alive monitor Packet]

ED :

J	K	1	1	J	K	I	E

Info bit

Error bit.

I = 1 [more data coming]

I = 0 [No more data.

FS :

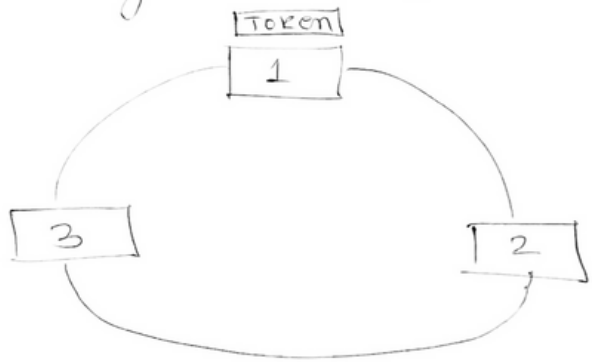
A	C	0	0	A	C	0	0

frame status

Availability (Destination Available or not)

copy

- Token Passing
  - → Ring Topology

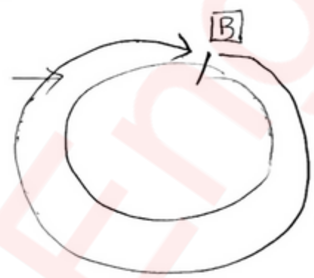


⇒ hold the token the transmit the data

⇒ unidirection.

⇒ NO collision

⇒ Ring Latency →



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

length

no. of station

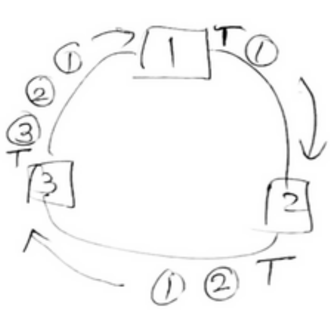
velocity

Time taken by each station to hold the bit before Trasmitting.

⇒ LAN

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

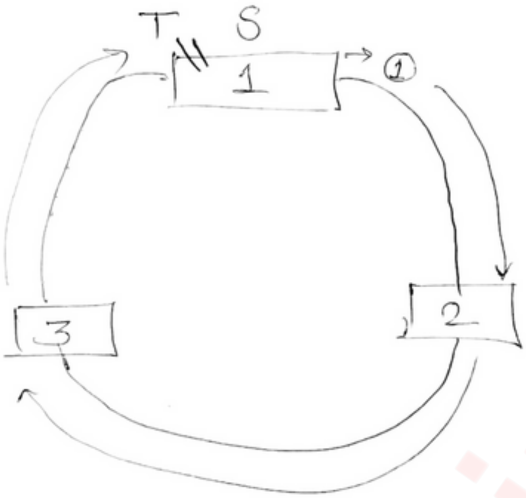
⇒ Delayed Token Reinsertion	Early Token Reinsertion
◦ $T_t + RL$	◦ T_t
◦ Transmit the data on link, then it takes a Round trip of ring & return to station, then token is released.	◦ NO Round trip
◦ Only one packet at a time in Ring.	◦ More than 1 packet at a time in Ring



Token Ring Problems

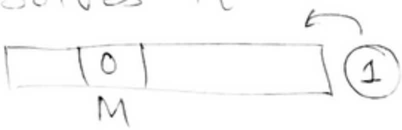
(1) Source Related

"Orphan" packet as source is down



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

- Now Monitor station solves it.

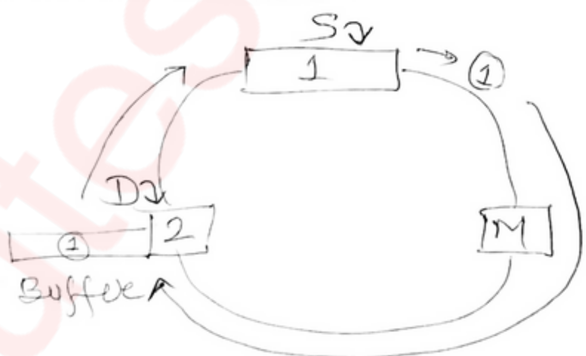


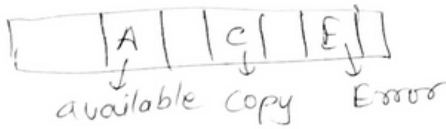
1st time M = 1
2nd time → monitor discards the packet.

- Monitor station solves it using "CRC"
"CRC mismatch" so packet is discarded.

(2) Destination Related

- Down
- Busy (Buffer full)
- Copied



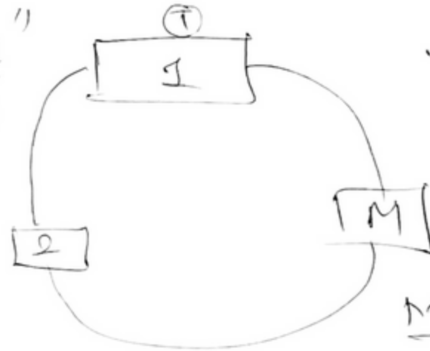


	A	C	E
Initially	0	0	0
Down	0	0	0
Busy	1	0	0
Error	1	0	1
Copied	1	1	0

③ Token Related

"Captured Token"
(Monopolisation)
[Injustice]

- Max THT
  → 10 msec



"Token lost"

- Station ① holding Token ① gets down

Min TRT : RL

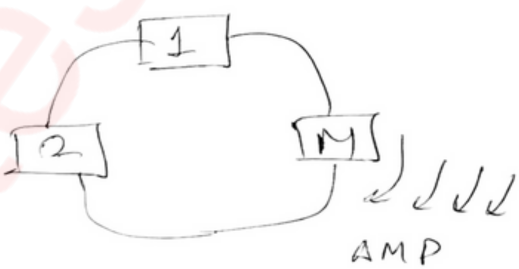
Max TRT : RL + THT × N

- 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)



Sol^n: Polling (Make/elect a station as monitor)

"Monitor Malfunction" (Chacked).

Sol^n: Human intervention".