Data Link Layer →

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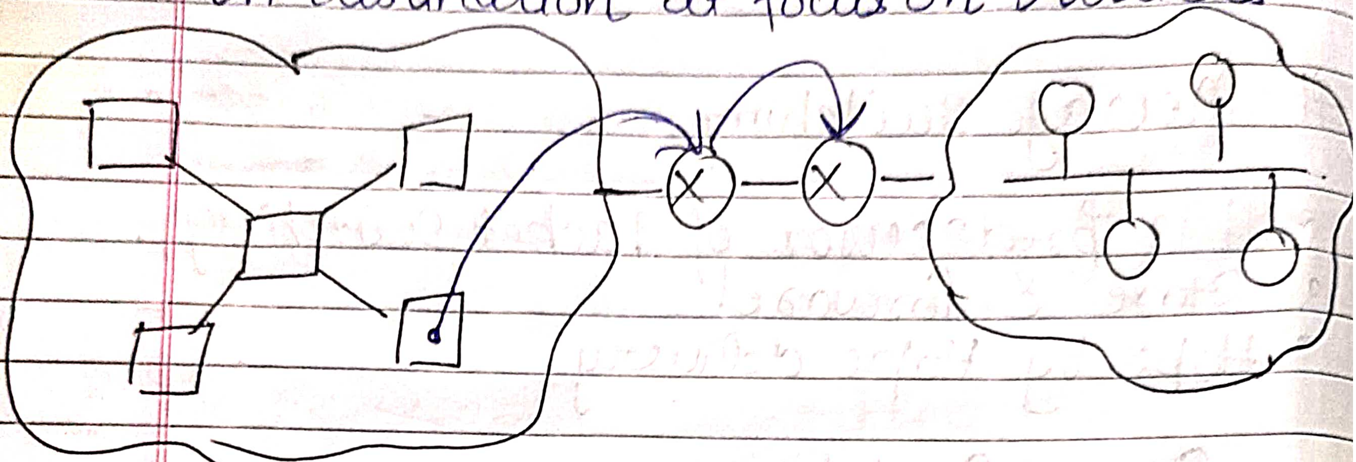
Functionalities →

1→ Hop to Hop delivery:-
datalink layer will work within a network it donnot focus directly on destination it focus on routers.



2. Flow Control:-
when source sends message then flow should be control. suppose ~~the~~ the speed of sender is fast than router than buffer of router will filled and some data may lost so we have to control the flow

→ Stop and wait
→ Go back n
→ Selective repeat

3. Error Control:-
If A send date to ~~a~~ node and if data bit got changed then datalink layer ~~do~~ have to Control the error
Error Control is ~~als~~ done hope to hop not source to destination

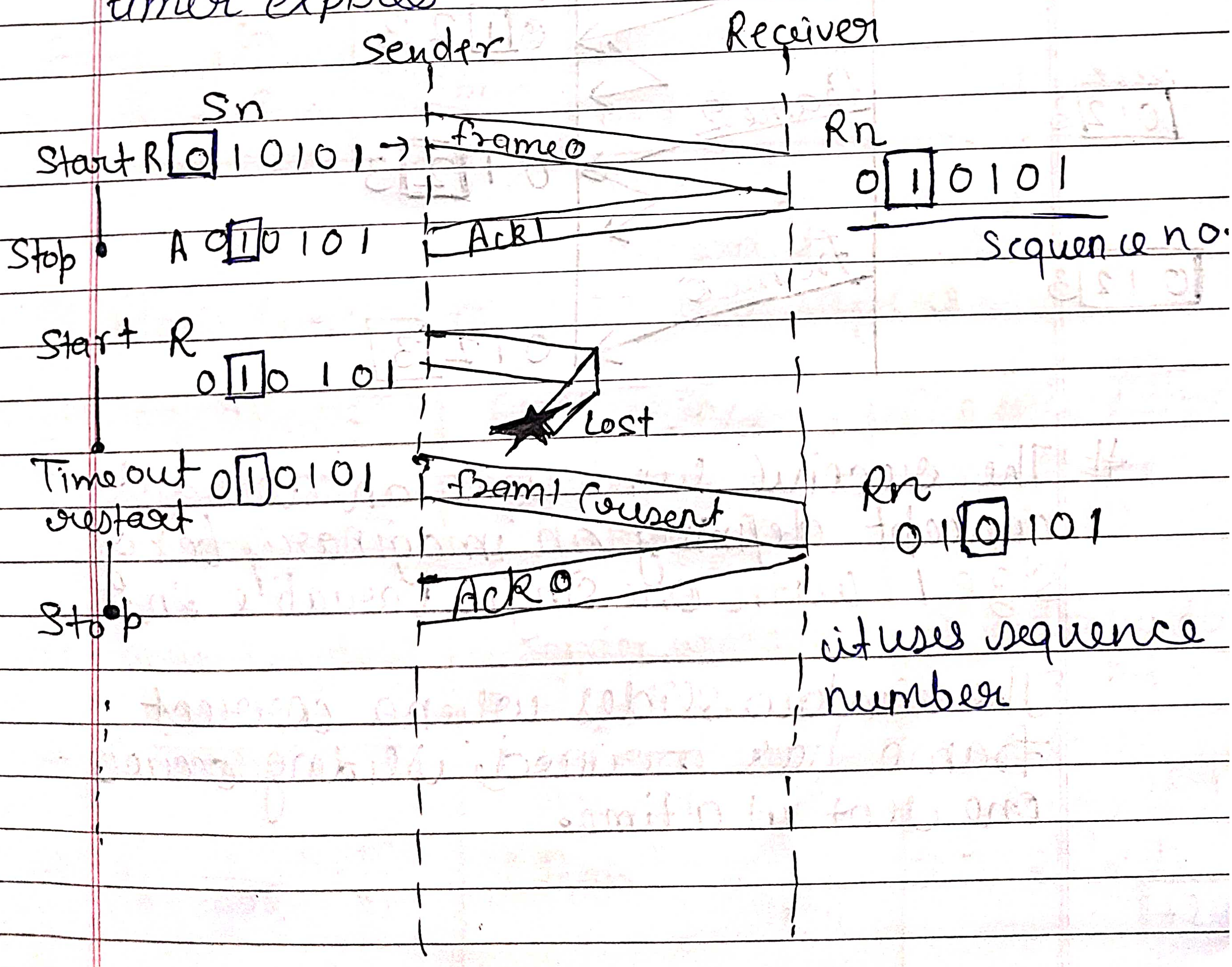
4. Access Control:- datalink layer majorly work within a network. access of nodes should be controlled to avoid the collision.

5. Physical address:- MAC address / it is fixed. within a network MAC address is used to work locally.

6. Frames:- add data in a frame which has a header / trailer.

Stop and wait ARQ

- It is done by keeping a copy of a sent frame and retransmitting of the frame when timer expires.

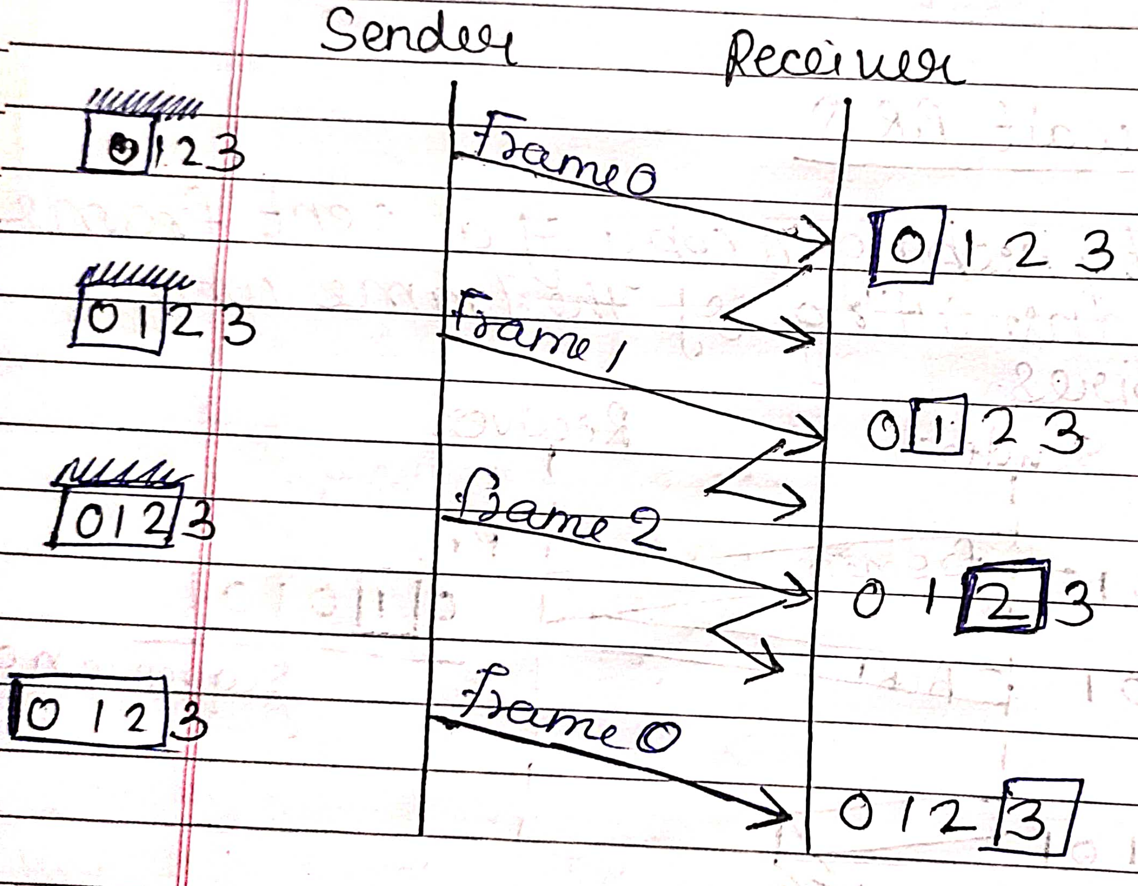


Go Back-N

- The sequence numbers are modulo 2^m, where m is the size of the sequence number field in bits

- The send window is an abstract concept defining an imaginary box of size $2^m - 1$ with three variables: S_f, S_n, S_{size}

- Window size $< 2^m$



The receive window is an abstract concept defining an imaginary box of size 1 with one single variable R_n.

The window slides when a correct frame has arrived; sliding occurs one slot at a time.

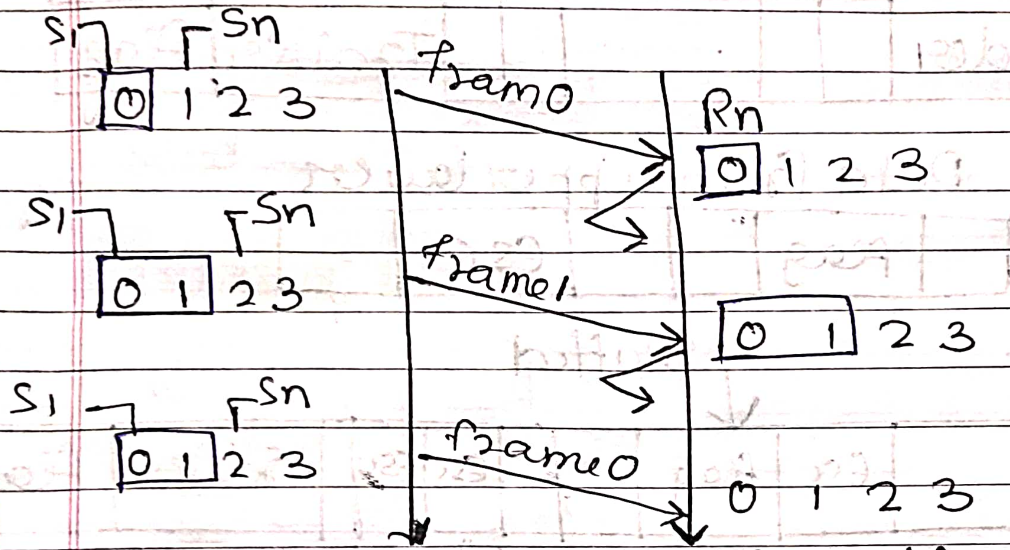
In Go-Back N ARQ the size of the send window must be less than 2^m;
the size of receiver window is always 1.

Selective Repeat ARQ →

Sender's window ⇒ 2^{m-1}

Receiver's window ⇒ 2^{m-1}

a) window-size = 2^{m-1}



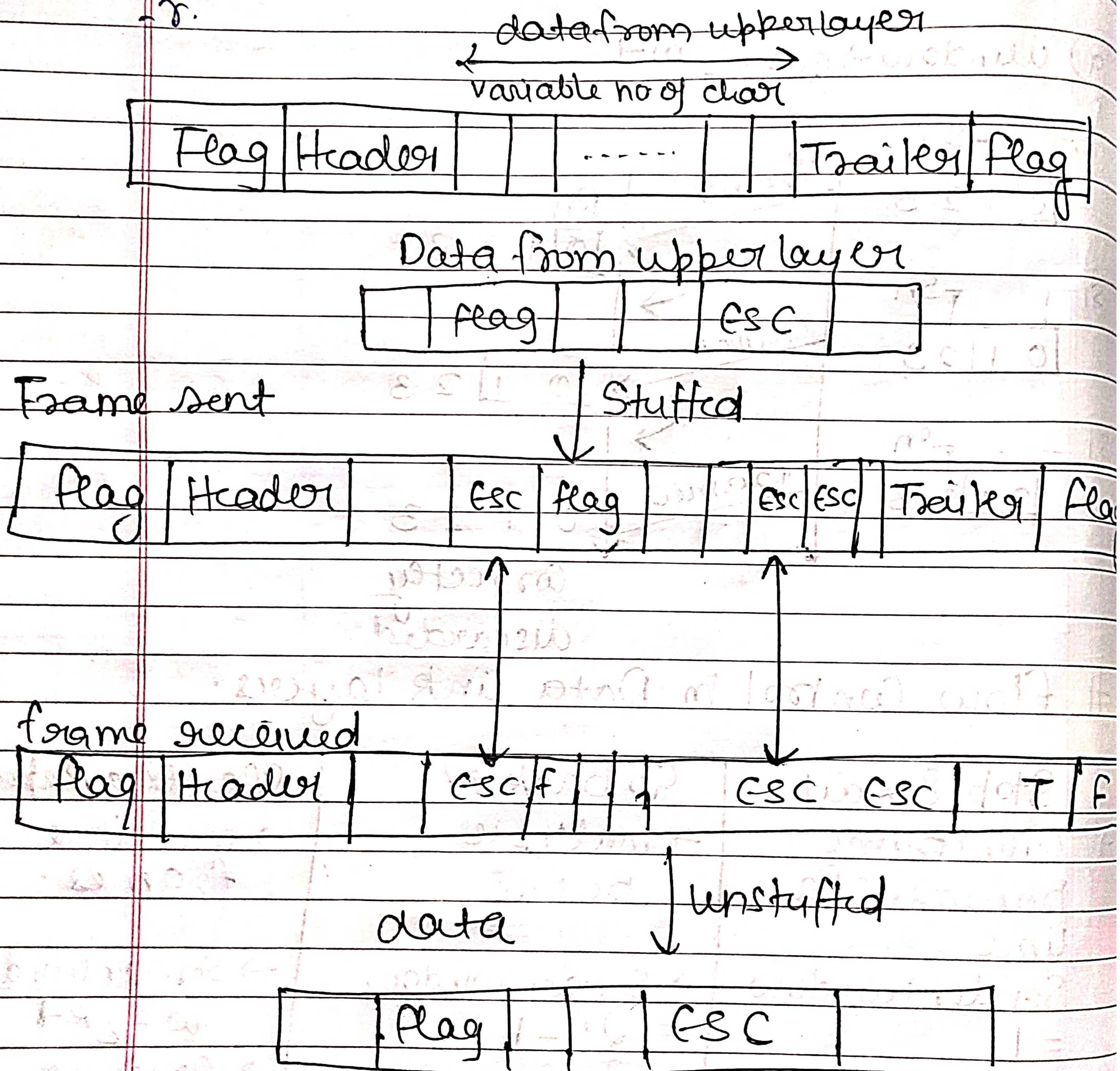
correctly discarded

flow Control in Data link layers.

Stop & wait	Go Back N	Selective Repeat
→ Only 1 frame transmit at a time	→ multiple frames	→ multiple frames.
→ Sender window = 1	→ Sender window = $2^k - 1$	→ Sender window = 2^{k-1}
→ Receiver = 1	→ Receiver window = 1	→ Receiver window = 2^{k-1}
→ $\eta = \frac{1}{1+2a}$, $a = \frac{T_P}{T_t}$	→ $\eta = (2^k - 1) \times \frac{1}{1+2a}$	→ $\eta = 2^{k-1} \times \frac{1}{1+2a}$

Framing in Data link Layer

The datalink layer needs to pack bits into frames, so that each frame is distinguishable from another. Our postal system practices a type of framing. The simple act of inserting a letter into an envelope separates one piece of information from another; the envelope serves as the delimiter.



Byte stuffing is the process of adding 1 extra byte whenever there is a flag or escape character in text

0 followed by 5 1's

when we have 5 consecute 1 then stuff 0

Error Detection and Correction

101 → 100] → Error in data
Sender Receiver

Types of Error

Single bit Error — if only one bit is changed

Burst Error — more than one bit is changed

Detection →

→ Simple parity
→ 2D parity check
→ Checksum
→ CRC (Cyclic Redundancy check)

Correction →

→ Hamming codes

Single parity method

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→ m+1 bits
↳ m is number of message bit.

→ Even parity (no. of 1's should be even)

→ let data = 1010

no. of 1 is already even so redundant extra bit should ~~also be~~ be 0

1010<u>0</u>

→ it can detect all ~~signal~~ single bit error in code.

→ Can detect all odd no of errors also

- Hamming distance
XOR operation between two codes
↓
Same value → 0
diff value → 1

$$\begin{array}{r} 0000 \\ 1111 \\ \hline 1111 \end{array} = 4 \qquad \begin{array}{r} 0101 \\ 1000 \\ \hline 1101 \end{array} = 3$$

CRC (Cyclic Redundancy check)

→ To detect errors.

→ can detect all odd address, single bit.

→ burst error of length equal to polynomial degree.

→ Based on Binary division

→ total bits = $m + r$ → redundant bit
↳ message bit

→ Polynomial Should not be divisible by x

Divisor

$\underbrace{x^4 + x^3 + 1}$

Polynomial.

→ you have to append the largest degree (4) number of bits

$$\overline{)\,1010101010\,}$$

$$\overline{)\,1010101010\underbrace{0000}\,}$$

max degree of polynomial.

→ find coefficients.

$$1x^4 + 1x^3 + 0x^2 + 0 \cdot x^1 + 1 \cdot x^0$$

$\Rightarrow 11001$

if divisior is given in binary form Let say n digit binary divisor so append n+1 0

Encoding

```
11001 ) 1010101010100000 ]— A
        11001
        011000
         11001
        000011010
            11001
            00011000
               11001
               00|0010|
```

replace A by replacing last 4 0's to last 4 digits of remainder. right to left.

$\boxed{1010101010100010}$ Sender will Send this.

Decoding

Receiver will decode this

```
11001 ) 1010101010100010
        11001
        011000
         11001
        000011010
            11001
            00011001
               11001
               000000
```

Remainder is 0 which means that there is no error if any bit change then remainder will never come 0 which means data is changed

$$\eta = \frac{10}{14} \times 100$$

$$\eta \; \frac{m}{m+r} \times 100 \quad \text{Efficiency}$$

Hamming code for Error detection & correction

if I have code of 7 bits.

Position	7	6	5	4	3	2	1
Bit	d_3	d_2	d_1	P_2	d_0	P_1	P_0

In this code there some data bits and some parity bits to check the position of parity bit the formula is 2^n

$2^0 = 1$ (1st position of code is parity bit)
$2^1 = 2$ (2nd " " " " " ")
$2^2 = 4$ (4th " " " " " ")

remaining bits are the data bits.

Q let data = 1010

$P_0 \Rightarrow d_3 \oplus d_1 \oplus d_0$
$P_1 \Rightarrow d_3 \oplus d_2 \oplus d_0$
$P_2 \Rightarrow d_3 \oplus d_2 \oplus d_1$

Position	7	6	5	4	3	2	1
Bit	d_3	d_2	d_1	P_2	d_0	P_1	P_0
value	1	0	1		0		

data = 1010

Now we ~~ca~~ have calculate the parity bit

$\boxed{\text{Suppose we have to calculate } P_0}$

that is on position 1 so take first data that is d_0 now leave 4th position and take d_1 5th position leave 6th pos. take 7th position

P_0 find krna hai to P_0 position 1 pe hai to posi 1 lo 2 choro 3 lo 4 choro 5 lo 6 choro 7 lo

$$\boxed{P_0 \Rightarrow d_0 \oplus d_1 \oplus d_3}$$

$\boxed{\text{Suppose we have to calculate } P_1}$

~~P_1 pos 2 pe hai to Phli data 2 lo 3,4 choro, 5, 6, 7 choro~~

P_1 posi 2 pe to phli data bit lo that is d_0 4, 5, choro 6 posi lo d_2

P_1 2^{nd} posi pe hai to 2 uthao 2 choro

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matlab 2,3 posi utho (d_0)

45 choro

67 uthao d_2, d_3

$$\boxed{P_1 = d_0 \oplus d_2 \oplus d_3}$$

Suppose to find P_2

P_2 apki position 4 pe hai

To 4 uthao 4 choro

4, 5 6 7 uthalo, d_1 d_2 d_3

$$\boxed{P_2 = d_1 \oplus d_2 \oplus d_3}$$

Q data 1001101 Sender's side

1	0	0	1	1	0	1
d_6	d_5	d_4	d_3	d_2	d_1	d_0

11	10	9	8	7	6	5	4	3	2	1
d_6	d_5	d_4	P_3	d_3	d_2	d_1	P_2	d_0	P_1	P_0
1	0	0	P_3	1	1	0	P_2	1	P_1	P_0
			1				0		0	1

$P_0 \Rightarrow d_0 \oplus d_1 \oplus d_3 \oplus d_4 \oplus d_6$

$\Rightarrow 1 \oplus 0 \oplus 1 \oplus 0 \oplus 1$

$\Rightarrow 1$

$P_1 \Rightarrow d_0 \oplus d_2 \oplus d_4$

$\Rightarrow 1 \oplus 1 \oplus 0$

$\Rightarrow 0$

$P_2 \Rightarrow d_1 \oplus d_2 \oplus d_3$

$0 \oplus 1 \oplus 1$

$\Rightarrow 0$

$P_3 \Rightarrow d_4 \oplus d_5 \oplus d_6$

$= 1$

$\boxed{\text{Output data} \Rightarrow 10011100101}$

this code will be send

Receivers side

Supose data received is changed it becomes 10111100101

now to check error take parities again

$P_0 = 1\ 3\ 5\ 7\ 9\ 11$

1 1 0 1 1 1

0

1

0

1

0

$P_1 \Rightarrow 2\ 3\ 6\ 7\ 10\ 11$

$P_2 \Rightarrow 4\ 5\ 6\ 7$

$P_3 \Rightarrow 8\ 9\ 10\ 11$

we are using even parity but here no. of 1's are odd which indicates that there is an error

~~d4~~ P_0 = error 1

P_1 = no error 0

$P_2 \Rightarrow$ no error 0

$P_3 \Rightarrow$ Error 1

$\Rightarrow 1001 = 9$

$r_4 r_3 r_2 r_1$

9^{th} bit is infected so change it here

9^{th} bit is 1 change it to 0

$\boxed{\text{it is how data is corrected.}}$

Multiple Access Protocols (MAC)

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Data link → LLC (Logical link control)
Data link → medium Access control (MAC)

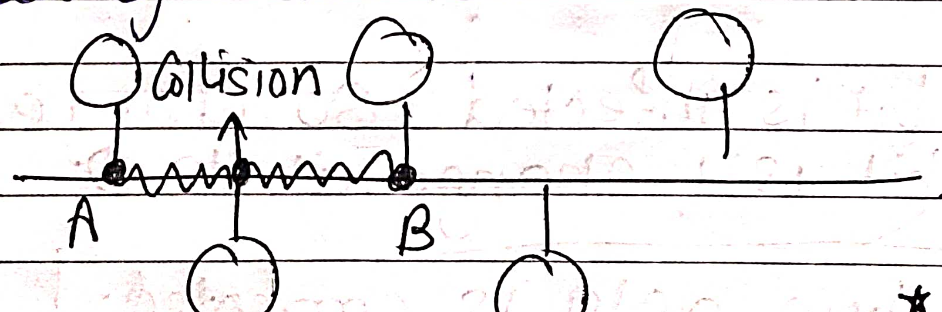
Multiple Access Protocols →

- Random Access
  - Aloha ★
  - CSMA ★★
  - CSMA/CD ★★
  - CSMA/CA
- Control Access
  - Polling
  - Token Passing
- Channelization
  - FDMA
  - TDMA

→ Why do need Multiple Access Protocol

Some topologies which share the same cable to share the data so there are chances of collision. it is possible that multiple systems are accessing a cable at a same time then the collision will occur. ~~at that ti~~

To avoid collision we need multiple Access Protocol to control the ~~protocols~~ Access of resources.



★ = important

★★ = very important

→ Random Access Protocols →

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① There is no priority in systems

② Every system can share / transmit the data at any time.

③ Any amount of data can be transmitted.

→ Control Access →

① There is someone controlling the transmission

Polling :- Like if any system want to transmit the data then controler will take poll wich decides that which system will transmit the data first.

Token Polling / Passing :- There is a token Ring. token revolves continuously. when a system wants to transmit the data, it holds the tocken mean while no other can transmit data.

→ Channelization Protocols :-

• We are using proper channels here.

FDMA → (Frequency division multible Access)
We use concept of multiplexing where frequencies bands are divided and give the station One by One

TDMA → Time division multible Access →

Here time is divided between system

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Pure Aloha →

- Random Access protocol → it can transmit without priority, any no. of data at any time.

Collision is surely possible there.

- Acknowledgement →
when a system received a data they will acknowledge on successful ~~di~~ transmission of data.

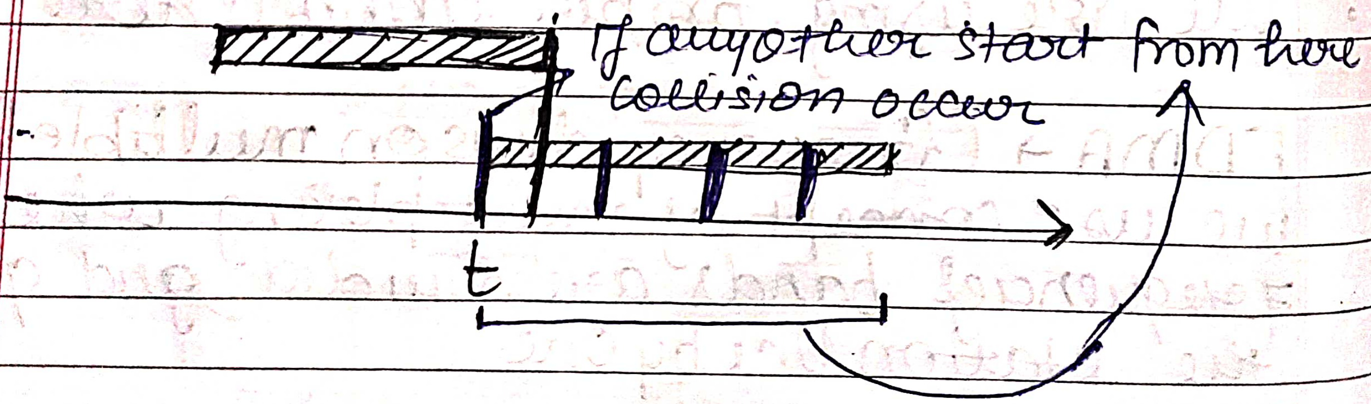
If there is no acknowledgement it means there is collision

retransmission is possible.

- LAN Based →
area is limited.

- Only transmission time no propogation time because it is based on LAN.

- Vulnerable Time → VT = 2 × T_t

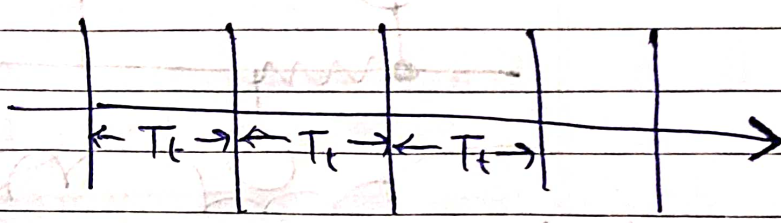
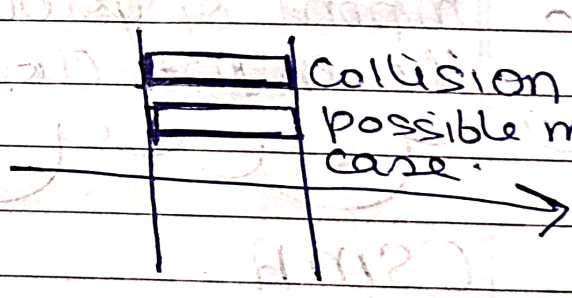


- Efficiency $\eta = G \times e^{--}$

G → no. of stations who want to transmit the data at a particular time

$$\frac{d\eta}{dG} \Rightarrow G \times e^{-2G}(-2) + e^{-2G}(1)$$

Difference between Pure / Slotted Aloha

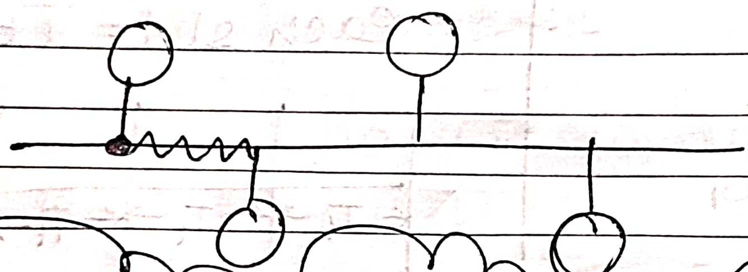
Pure Aloha	Slotted Aloha
• Anytime transmission	• time is divided in slots each slot = T_t
• $V_t = 2 * T_t$	
• $\eta = G \times e^{-2G}$	
• 18.4%	• Each station transmission will start at the start of slot  collision possible in this case. $V_t = T_t$ $\eta = G \times e^{-G}$

Carrier Sensor Multible Access CCSMA

- whenever a system wants to transmit the data so before sending node will sense the channel

- If any ~~the~~ signal is moving in the channel then system will not transmit the data.

- The whole channel will not sense only the node which wants to share data will check at that point only if any signal is here nor not



Leman Example →
Suppose you are at your gate to cross the road you will just the vehical infront of your gate you will not scan the entire channel

CSMA
↳ 1 persistant : it will sense continuously ~~while~~ until it find the empty/available channel.
higher chances of collision suppose in worst case every system find channel empty and sen

data at the same time

↳ 0-persistent : • If medium is ideal, simply transmit the data

• if medium is busy then wait for random amt. of time and at that time it start transmitting

• Collision is comparably less than 1-persistent.

↳ p-persistent : • Hybrid of 0-persistent and 1-persistent.

• If channel is busy system will continuously check wheather the channel is empty or not.

• Once channel is available it will not directly start transmitting it will check the probability. then send accordingly.

Carrier-Sense Multiple Access / Collision Detection (CSMA/CD)

→ There's no acknowledgment System.

→ ~~On~~ while System A is transmitting data and Suppose collision occurred then ~~if to~~ If at the same while A transmitting it gets the collision signal it means there's a system will get to know that there is a collision

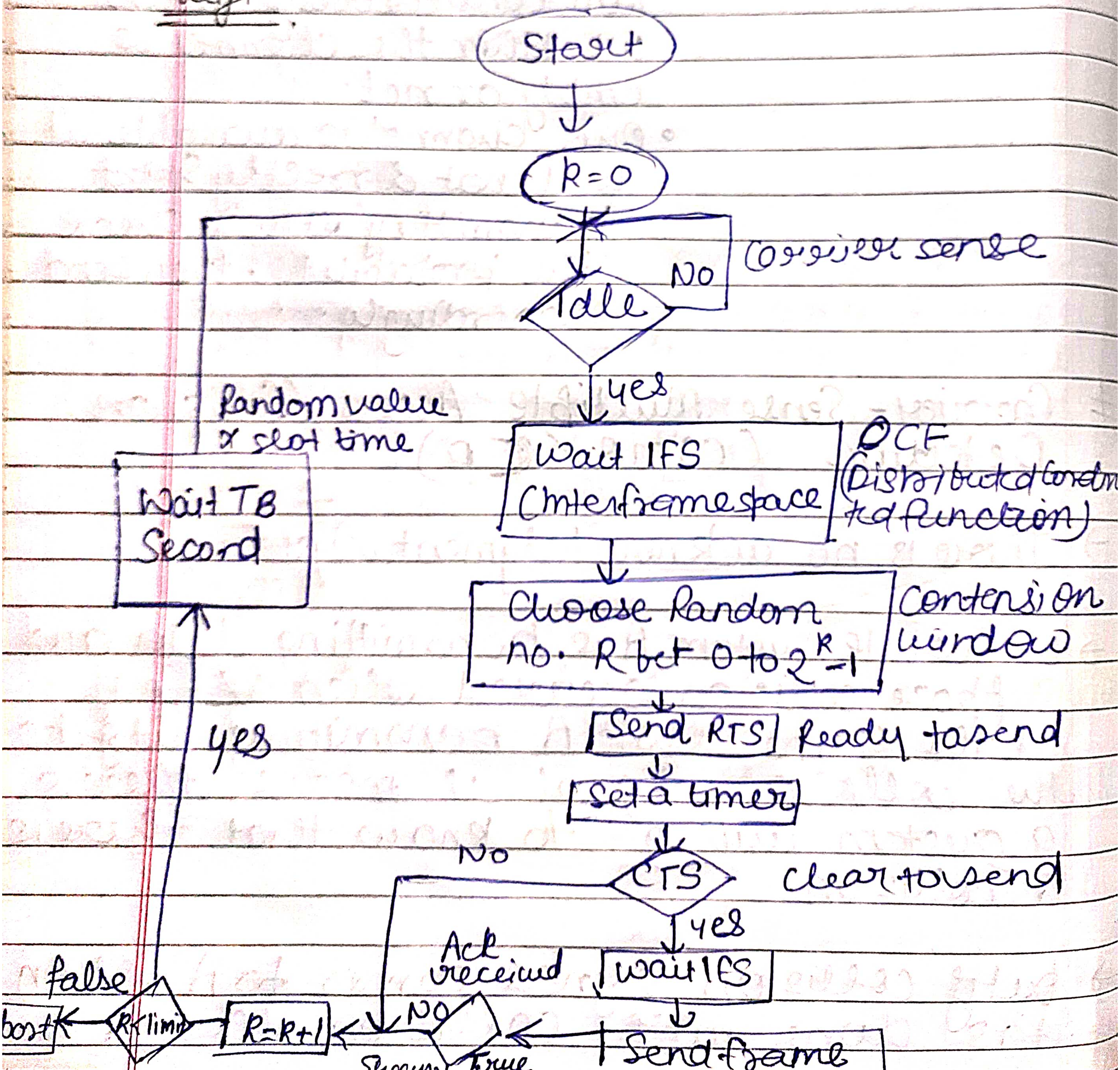
→ but if collision signal comes to A when it is done with collision then A will never get to know that its data is collided

$$\eta = \frac{1}{1+6.44a} \qquad a = \frac{PD}{TT}$$

$$L \geq 2 * PD * PW$$

CSMA/CA (Carrier Sensor multiple Access / Collision avoidance)

(WLAN)
↓
wifi



Ethernet Frame format

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1. Ethernet is a datalink protocol.
2. it is defined on (IEEE 802.3)-1983.

Types of Ethernet

1. 10 Bas 2 - Thin
   10 mbps — if one signal is passing then no other signal can pass — 200m
2. 10 Base 5 Thick
3. 10 Bas T
4. 100 Base fx
5. 10 G Base T Gigabit

★ Topology used is Bus, star can also used but priority is bus.

★ Bit rate = 1mbps/sec - 400 Gbits/sec

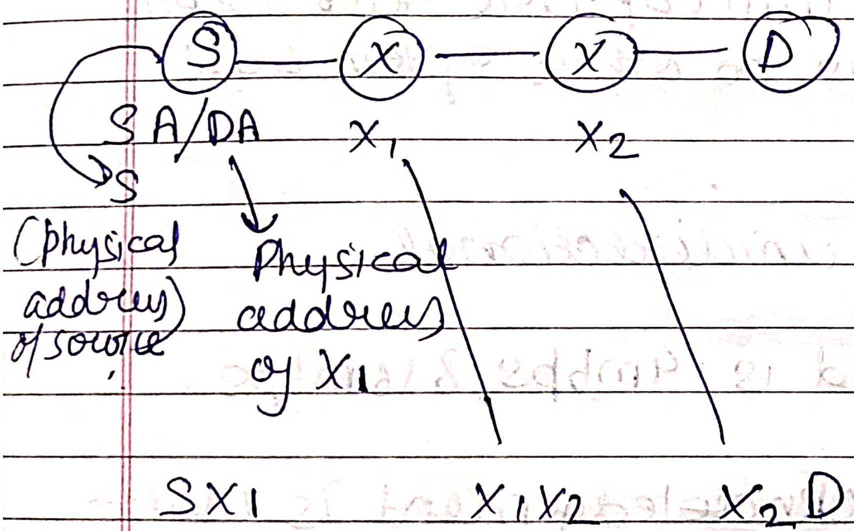
Frame format

PREAMBLE	SFD	DA	SA	Length	Data	CRC
7B	1B	6B	6B	2B	46B – 1500B	4B

add by physical layer just for synchronisation and waking up / alerting the receiver that the message is coming

* Destination Address :- MAC address or destination address

* Source Address :-



* Length → Length of frame 16 bits

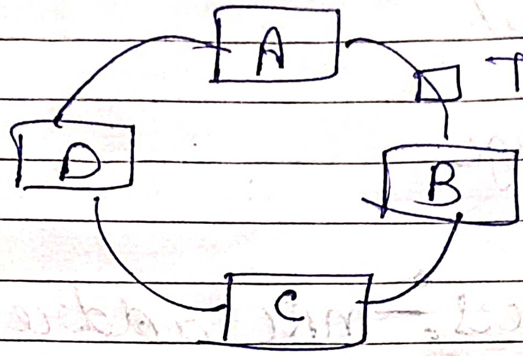
$0 - 2^{16} - 1$

* Data → pure data should be atleast 46B

★ CRC → Cyclic Redundancy check for error detection

Tocken Ring (IEEE 802.5)

- Ring topology is used.
- Access control ~~thod~~ method used is tocken ~~~~ passing.



- Tocken keep revolving around a ring topology, if a node want to send a message so it will capture the tocken and during this no other system will send message
- Tocken ring is unidirectional.
- Data rate used is 4mbps, 8 16 mbps.
- Piggybacking acknowledgement is used:- acknowledgement along data
- Differential manchester encoding is used
- variable size framing
- Monitor station is used

Frame format

SD(1)	AC(1)	FC(1)	DA(6)	SA(6)	Data

CRC(4)	ED(1)	FS(1)

Tocken

SD(1)	AC(1)	ED(1)