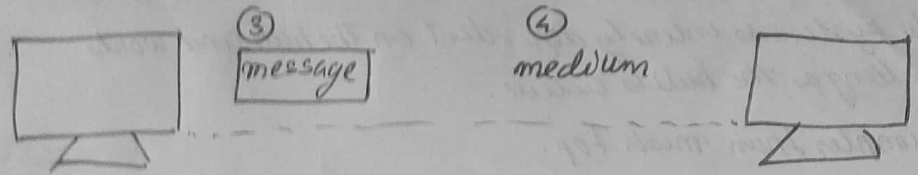
* Components of data communication



① Sender

② Receiver.

⑤ Protocol.

#

Simplex - communication can take place in one direction.

Half duplex - communication can take place in both dir. but one dirⁿ at a time.

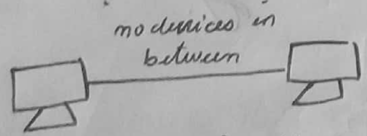
Full duplex - comm. can take place in both dir.

Criteria for communication

1. Performance
   - i> Throughput
   - ii> Delay
2. Reliability
3. Security

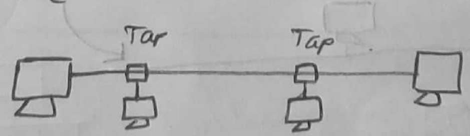
Attributes of physical structure of network.

1. Type of connection



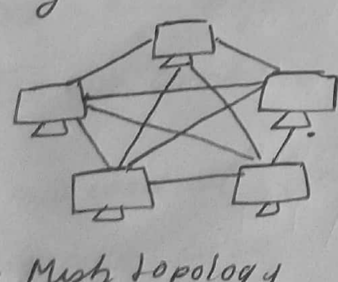
a> Point to point connection

(data will be visible to all nodes)



b> Multi point connection

2. Physical Topology

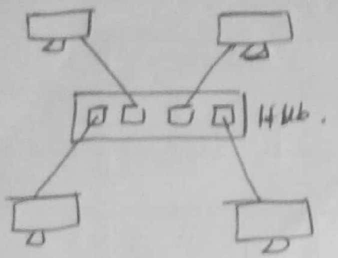


- data directly transferred to concerned device.
- data transfer is fast.
- It is reliable because of the redundant connections available.
- No intermediate nodes involved in sharing which provides more security

i> Mesh topology

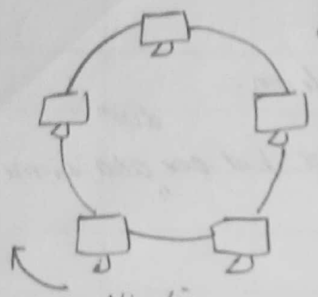
Cons:-
- Inavability of physical space
- cost ineffective

ii> Star topology



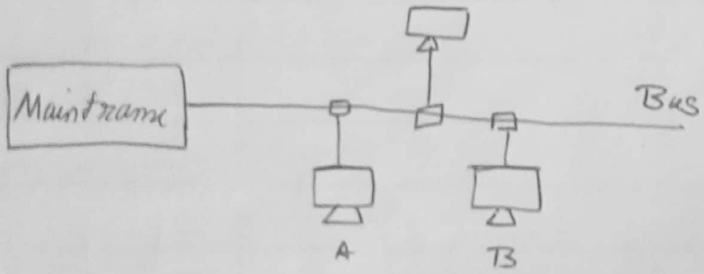
- We can have a central control over the network as the hub governs the systems in the network.
- The system is entirely dependent on the hub and works as long as the hub is active.
- Simpler than mesh top.

iii> Ring topology.

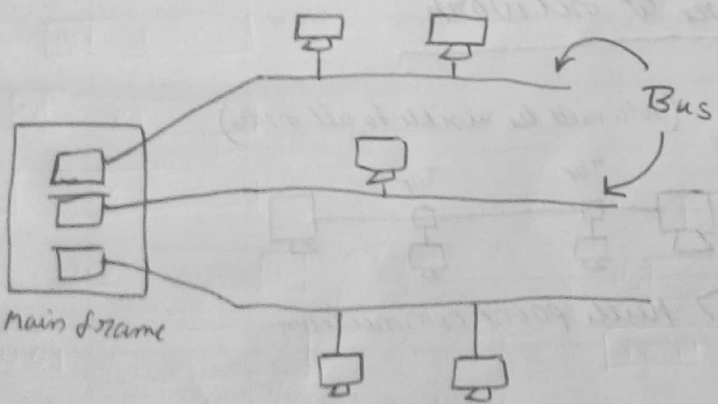


comm. can take place only in one direction

iv> Bus topology



* Hybrid topology



Carries same adv. & disadv. as star & bus topology.

#

1. Local Area Network (LAN) { 10m room; 1-2km campus; 100m building
2. Metropolitan area network (MAN) 10km city
3. Wide area network (WAN) { 100km country; 1000km continent
4. Internet

Protocol

1. Syntax : structure of protocol
2. Semantics : interprets the info and instruction in the signal.
3. Timing : condition defined.

Standards

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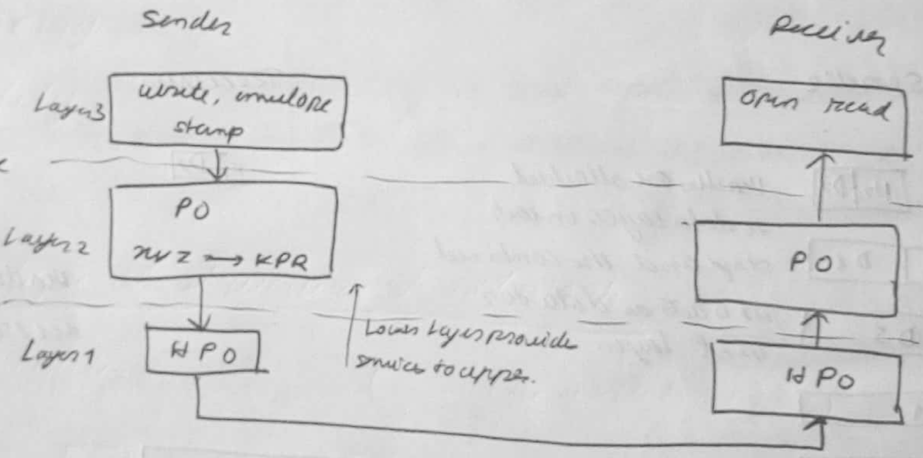
* Network Models

1. Open systems Interconnection (OSI) Model
2. TCP / IP Model

* i) Layers
ii) Services
iii) Interface
iv) Protocol

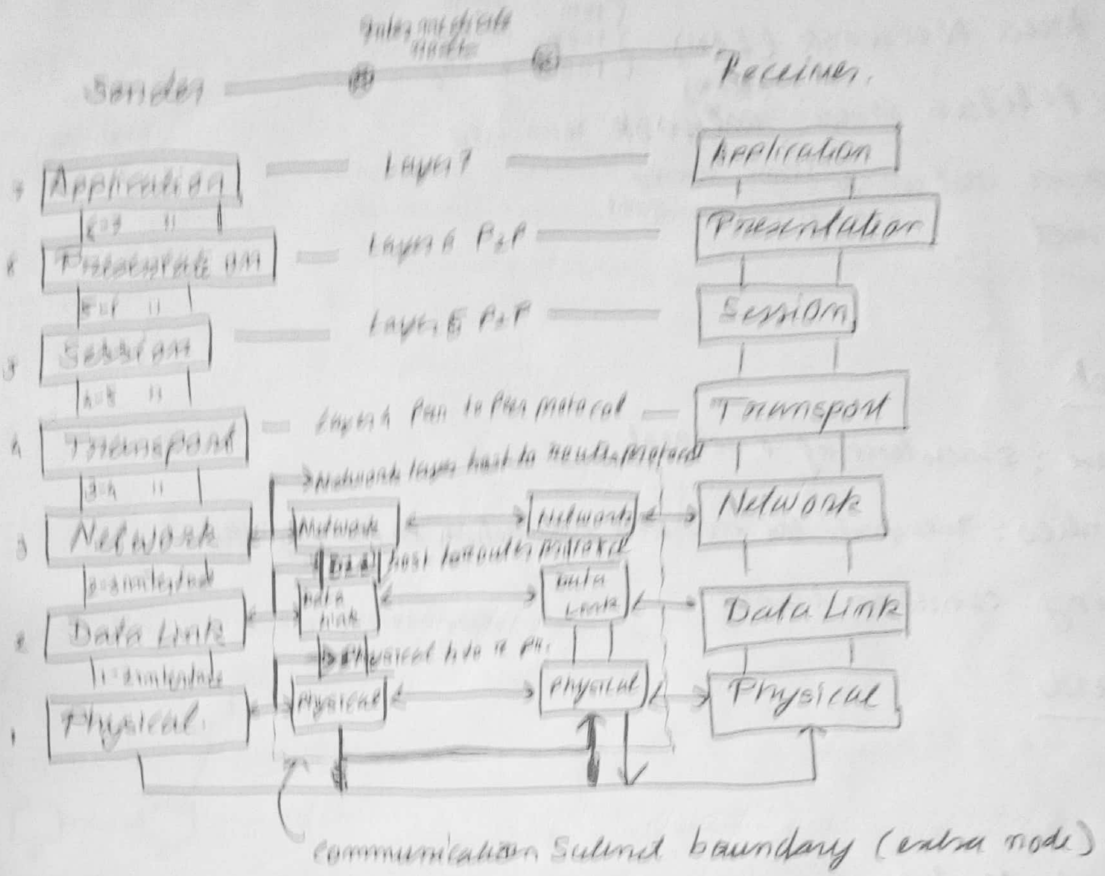
How we are going to access service from lower layer. By calling some fn. It is a connection b/w 2 layers.



Design issues of network model

1. Process identification.
2. Data transfer { simplex; Duplex (Half or full)
3. Error control { • detect; • try to fix or retransmit
4. Flow control { System may get overflowed with data. }
5. Message size

6. Routing (Find available path from sender to dest^n)



OSI Reference model

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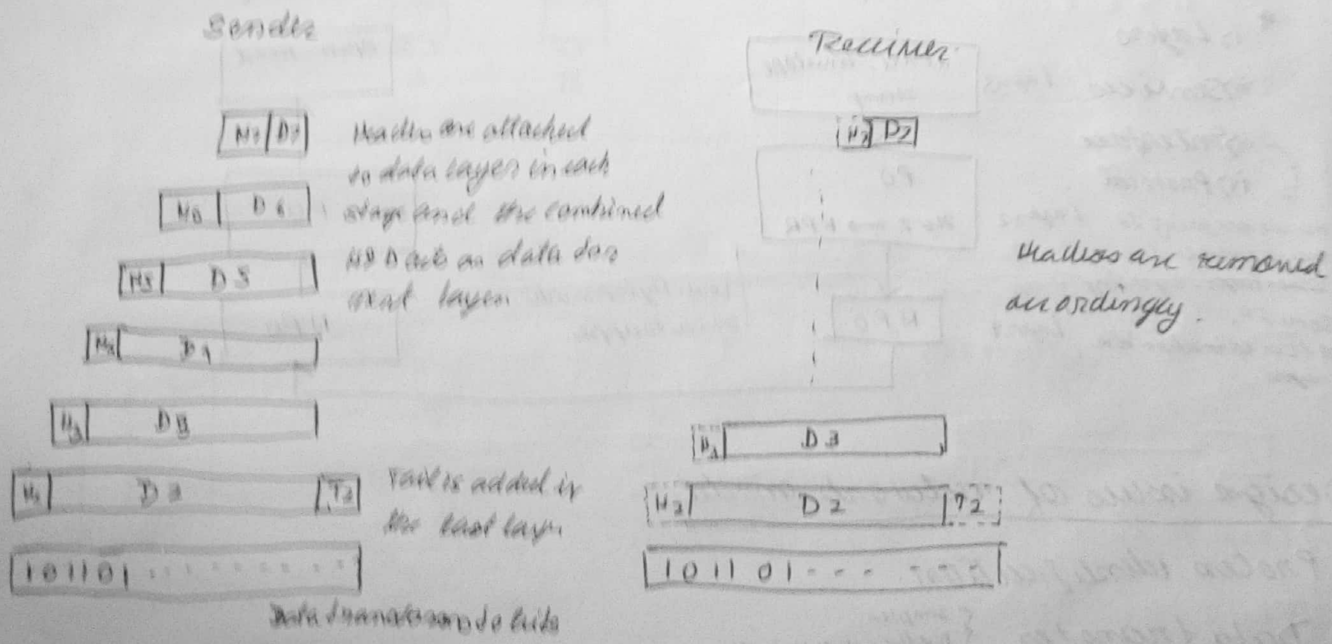


PHYSICAL LAYER

[Transmission of data through electrical signals]

Main:
1. Transmission of raw bits.
2. Physical characteristics of interface and medium.
3. Synchronization of bits.
4. Line configuration
5. Physical topology
6. Transmission Mode (simplex, half duplex, full duplex)
7. Representation of bits.
8. Data rate

NOTE: Revise representation of bits like NRZ-I, NRZ, Manchester, etc.

* Data Link layer

Main responsibility :-

① It transforms physical layer from ~~a~~ being a raw transmission of bits to a reliable link.

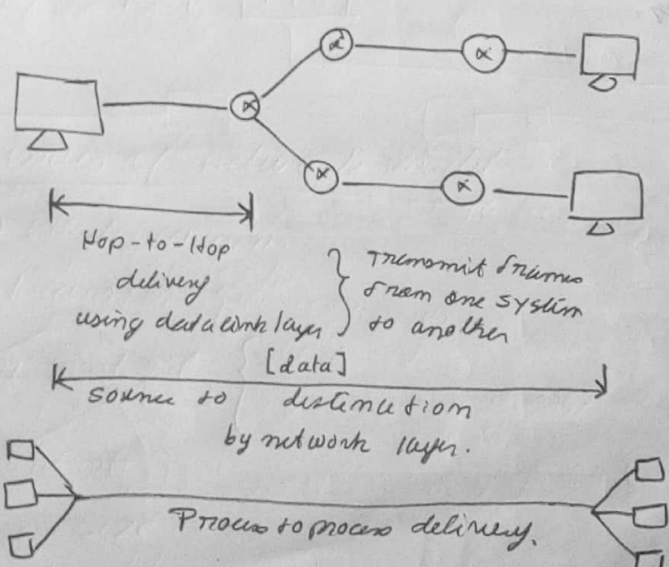
② Framing (converting the data to bits)

③ Physical Addressing
- i> within the network → add sender + receiver address
- ii> outside the network → address of next node.

④ Flow control (at frame level)

⑤ Error control

⑥ Access control.



* **Network layer**

Main responsibility:-

① Transmit the packet from source to destination

② Routing

③ Logical Addressing

* **Transport layer**

Main responsibility:-

① Process to process delivering of data segments

② Service point addressing (port)

③ Segmentation and reassembly (frames combine to form packets at the destination and hence reassembly is necessary)

④ Connection control

⑤ Flow control

⑥ Error control (deals with errors during transmission of packets)

* **Session Layer**

Main responsibility:-

① Dialog control and synchronization

* **Presentation layer**

Main responsibility:-

① Translation, Encryption, Compression

* **Application layer**

① Providing services to user. (top most layer)

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* TCP/IP Protocol Suite

Layers in OSI	Layers in TCP/IP
7 Application	Application
6 Presentation	
5 Session	
4 Transport	Transport
3 Network	~~Network~~ Internet
2 Data Link	~~Data Link~~
1 Physical	1 Host to network

TCP/IP vs OSI

1. Distinction of Services, Interfaces and Protocols.
2. Flexibility to New Technology.
3. Order of Protocol and Model Invention.
4. Number of Layers.
5. Way of communication.

Physical layer

Electrical signal → Analog, Digital.

Bit rate → No. of bits per second

Bit ~~Frequency~~ length → is the distance one bit occupies on transmission medium.

$$\left[\text{Bit length} = \text{Propagation speed} \times \text{bit duration} \right]$$

To transmit signals through communication medium

1. Baseband → Low pass
2. Broadband $\xrightarrow[\text{via}]{\text{transmitted}}$ band pass.

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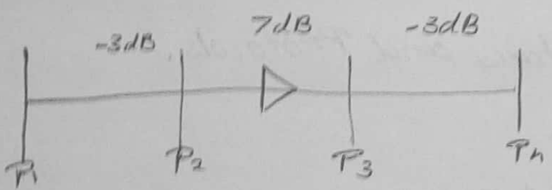
* Transmission Impairments

1. Attenuation (Loss in signal strength across the medium
2. Distortion (change in signal shape)
3. Noise (in wired or wireless)

$$10 \log_{10}\left(\frac{P_2}{P_1}\right) \quad \underline{\underline{dB}}$$

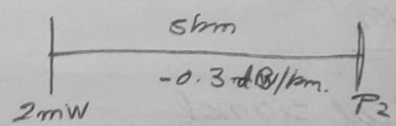


Power ~~gain~~ gain/loss $= -3+7-3$

Q. Suppose the loss in a cable at beginning is $-0.3\,dB/km$ and a signal having power 2 mW. What is the power of the signal at 5km?

Soln. $P_1 = 2\,mW$

Power loss $= -0.3\,mW/km$



$$10 \log_{10}\left(\frac{P_2}{2\times10^{-3}}\right) = -0.3 \times 5$$

$$\Rightarrow \log_{10}\left(\frac{P_2}{2\times10^{-3}}\right) = -0.15$$

$$\Rightarrow \log_{10}(500P_2) = -0.15$$

$$\Rightarrow P_2 = 0.001415$$

$$= 1.415\,mW$$

* SNR (Signal to noise ratio)

$$SNR_{dB} = 10 \log_{10}\left(\frac{S}{N}\right) dB$$

① Noiseless → Nyquist

$$\text{Max bit rate} = 2B \log_2 L$$

B → bandwidth
L → No. of levels of signal representation

② Noisy → Shanon

$$\text{Max bit rate} = B \log_2 (1 + SNR)$$

If SNR = 0, then max bit rate = 0

Q. ~~The SNR~~ Assume that SNR = 36dB and the channel bandwidth is 2MHz. Compute the channel capacity.

Sol^n. ~~Max bit rate = $B \log_2$~~

$$SNR_{dB} = 36 dB$$

$$10 \log_{10}\left(\frac{S}{N}\right) = 36$$

$$\log_{10}(S/N) = \cancel{10^{36}}\ 3.6$$

$$S/N = 10^{3.6}$$

$$S/N = 3981.07$$

$$MBR = \cancel{8x}\ 2 \times 10^6 \log_2 (1 + 3981.07)$$

$$= 23.918 \times 10^6$$

$$= 23.918\ MB/sec$$

* Performance Measures

1. Bandwidth (Max. capacity of the channel)
2. Thoughput (Actual capacity)
   It is a measure of how fast we can actually send data through a network.
3. Latency (delay)

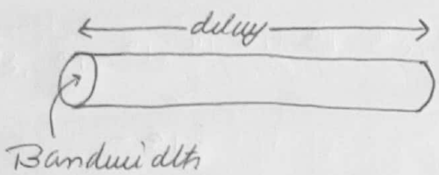
Latency:-

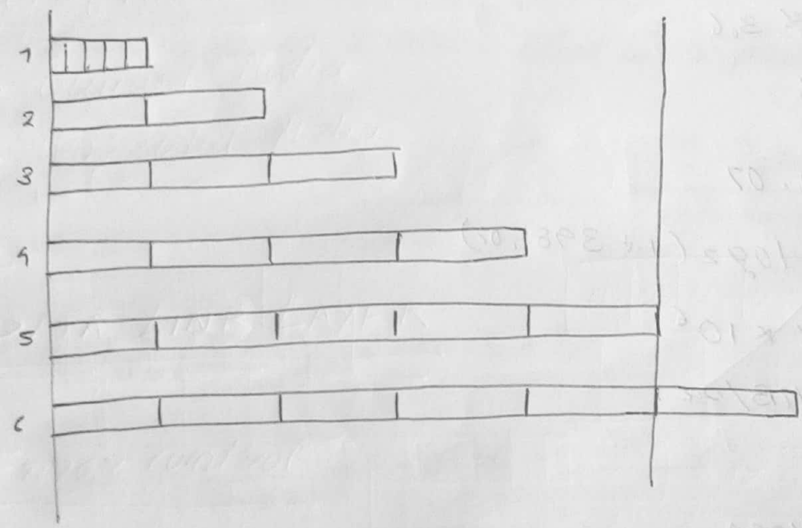
1. Propagation time (measures the time reqd. for a bit to travel from source to destination)
2. Transmission time (measures the time reqd. for entire message to leave from the source node)
3. Queuing time (The time needed for each intermediate or end device to hold the message before it can be processed)
4. Processing time.

Propagation time = distance / Propagation speed

Latency = ① + ② + ③ + ④

4. Bandwidth delay product.





B = 5 bits/sec

delay = 5

Max = 25 bits.

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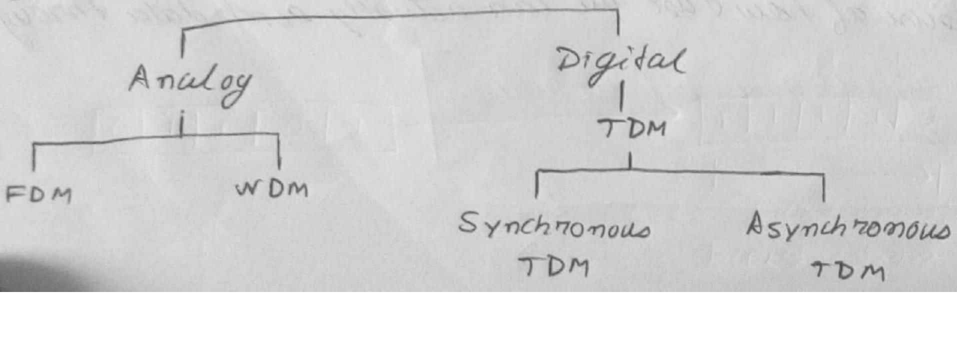
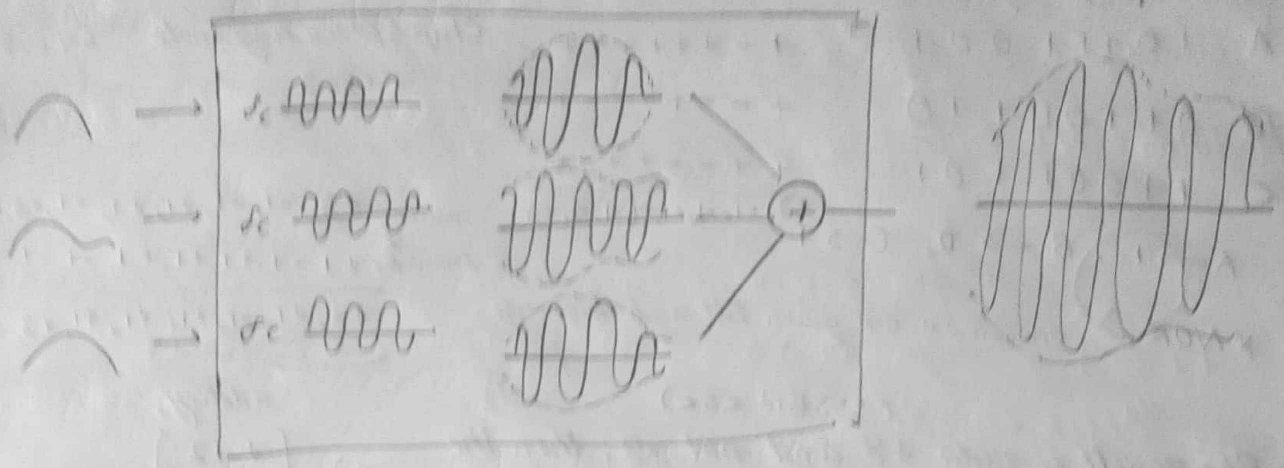
* Bandwidth utilization

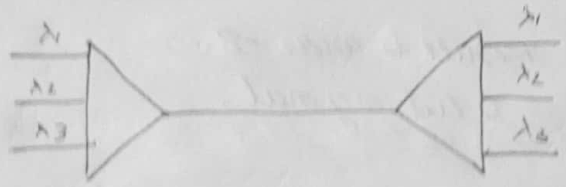


Frequency Division Multiplexing (FDM)

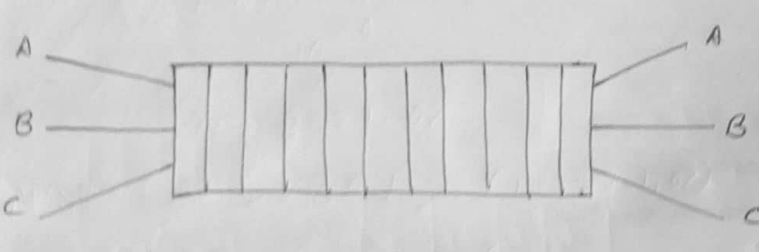


Wavelength division Multiplexing (WDM)

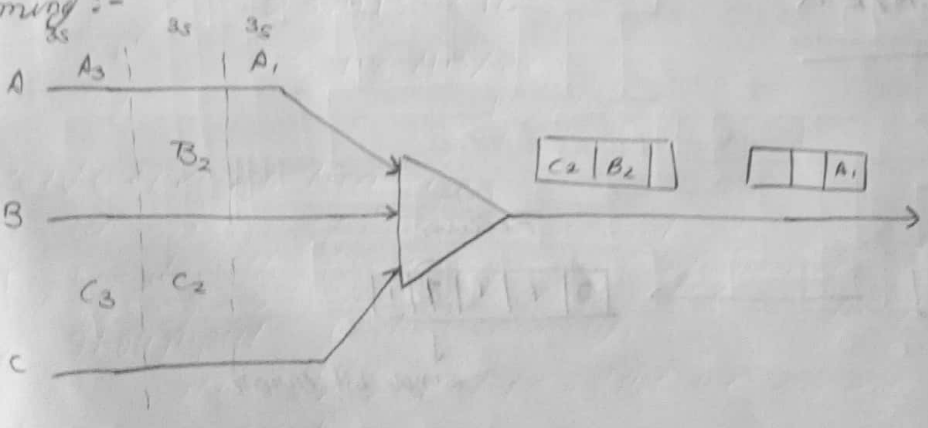
Used in optical fibre cable.



Time division Multiplexing (TDM)



Framing :-



Interleaving

* Code Division Multiplexing (CDM)

chip spreading code

Chip spreading code 64 bit.
(CSC)

A 1 0 1 1 1 0 0 1 → + − + + + − − +

B 0 1 1 0 1 1 1 0 → + − − + − − − +

C 1 1 0 0 1 1 0 1 → + + − − + + − +

$\overline{+3, -1, -1, +1, +1, -1, -3, +3}$

A → 1, B → 0, C → 1

XNOR ✓ [illegible] on given bit and sequence.

(∵ 8 bit CSC)

∴ The result is [illegible] +8 and not −8, then the result [illegible] from A → 1 (at [illegible] 1 bit signal)

multiply +3, −1, −1, +1, +1, −1, −3, +3
× from A, +1 −1, +1, +1, +1, −1, −1, +1

$\underbrace{+3, +1, +1, +1, +1, +1, +3, +3}_{\text{adding}}$

[+12]

+3, −1, −1, +1, +1, −1, −3, +3
× −1, +1, +1, −1, +1, +1, +1, −1 (B)

$\underbrace{-3, -1, -1, -1, +1, -1, -3, -3}$

= −12

Result is [illegible] −8.
0 bit signal.

* Types of Media

- Guided Media
- Unguided Media

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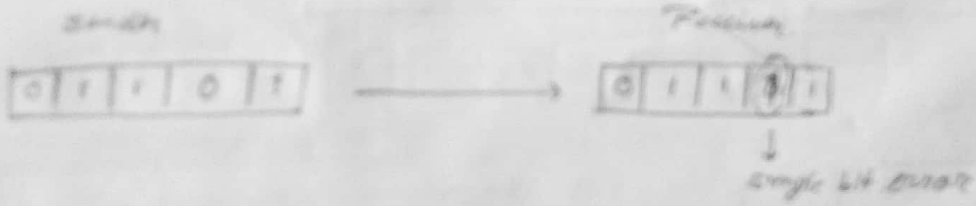
* DATA LINK LAYER

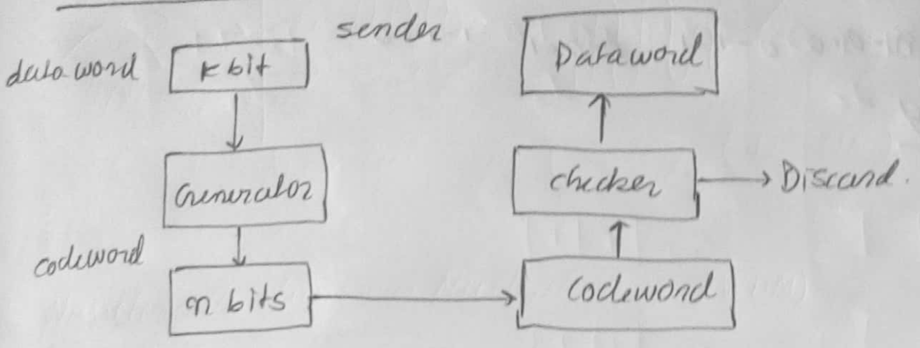
Error control



i> Error detection

ii> Error correction
- → Forward error correction.
- → Retransmission

i> Error detection :-



2B/3B

dataword	codeword
00	000
01	011
10	101
11	110

010
This codeword isn't available
→ here, only 1 bit is changed, so we can detect the error.

101
→ here, 2 bits have been changed. so we cannot detect the error.

2B/5B

DW	CW
00	00000
01	01011
10	10101
11	11110

Assuming that here is only 1 bit error, we will consider the case with all codeword.

~~010~~ 01111 → case

* Hamming distance

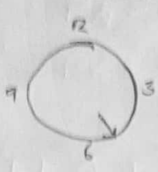
```
 00000
 10101
-------
 1 1 1
```

Hamming distⁿ = 3

★ Minimum hamming distance

- consider all possible pairs of codewords.
- calculated on the basis of codewords & not dataword.

★ Modulo N - Arithmetic



9:00 + 5 = 14 ⟶ 2

ADD: 0+0 = 0   0+1 = 1   1+0 = 1   1+1 = 0

SUB: 0-0 = 0   0-1 = 1   1-0 = 1   1-1 = 0

★ Linear block encoding

2B/3B

00	000
01	011
10	101
11	111

$d_{min} = S+1$, $S \to$ no. of error it can detect.

$d_{min} = 2t+1$ $t \to$ no. of error it can correct.

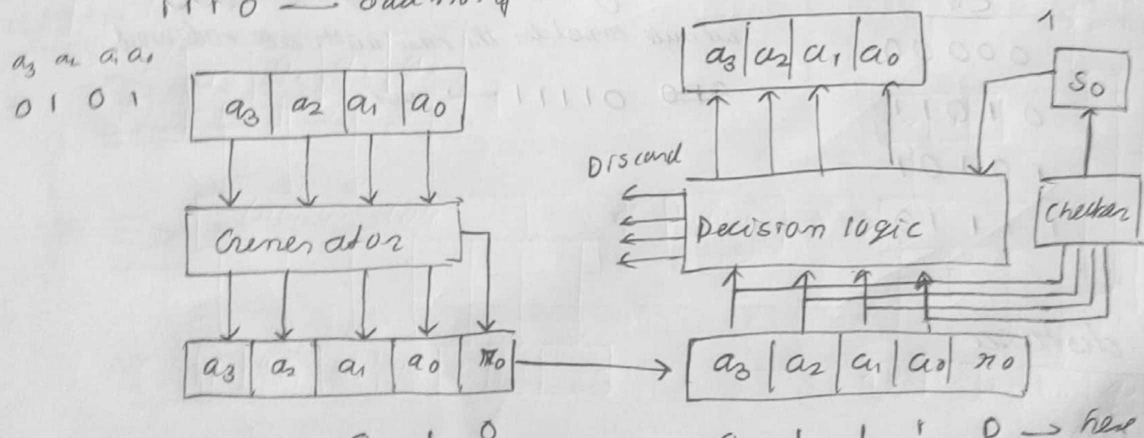
★ Parity checking

↓

checking if the no. of bits are even or odd.

1010 ⟶ even no. of 1s

1110 ⟶ odd no. of 1's.



0 1 0 1 0

0 1 $\frac{1}{0?}$ 1 0 → here $s_0 \to 1$ because it has odd parity

0 0 1 1 1 → here $s_0 \to 1$ we can detect error.

* Two dimension parity checking

1101 1100 1001 0101

Arrange in rows & columns
calculate parity row wise first and then column wise.

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

Note: For 16 bit data we need 9 extra bits.

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* Hamming code

$2^r \geq k + r + 1$

$r \rightarrow$ no. of redundant bits
$k \rightarrow$ no. of bits in data word.

i> The positions that are power of 2 are considered for parity bit.
(2^0 2^1 2^2 2^3 ......)

10011010

code word →

P_1	P_2	1	P_4	0	0	1	P_8	1	0	1	0			
2^0	2^1	2^2	2^3	2^4										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Position 1: 1, 3, 5, 7, 9, 11 (consider 1 bit & skip the next)

$P_1 = 0$ (even parity of 1)

Position 2: 2, 3, 6, 7, 10, 11 (consider 2 & skip 2.)

$P_2 = 1$

Position 4: 4, 5, 6, 7, 12

$P_4 = 1$

Position 8: 8, 9, 10, 11, 12

$P_8 = 0$

*

0	1	1	1	1	0	1	0	1	0	1	0		
1	2	3	4	5	6	7	8	9	10	11	12	13	14

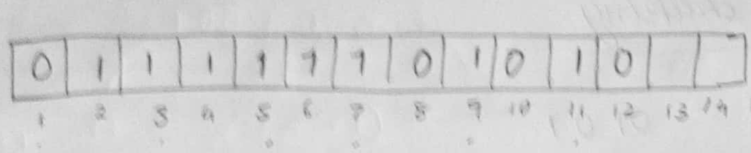
Now, for position 1

$P_1 = 1$

$P_2 = 0$

$P_4 = 1$ $P_8 = 0$

Here we are getting P_1 & P_4 as 1 which should have been 0.
Error = 1 + 4 = 5
Error in position 5



NOW, $P_1 = 1$

$P_2 = 1$

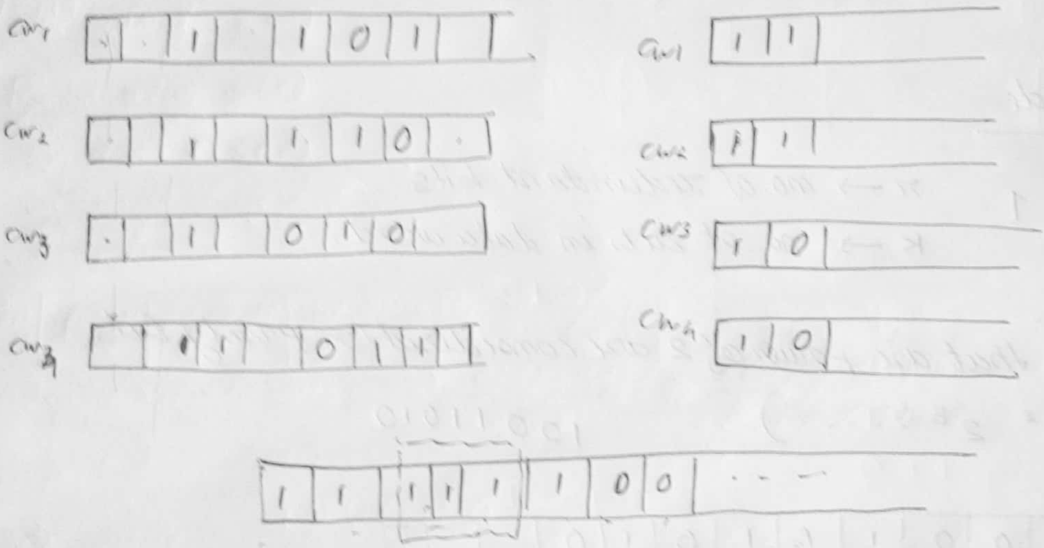
$P_4 = 0$

$P_8 = 0$

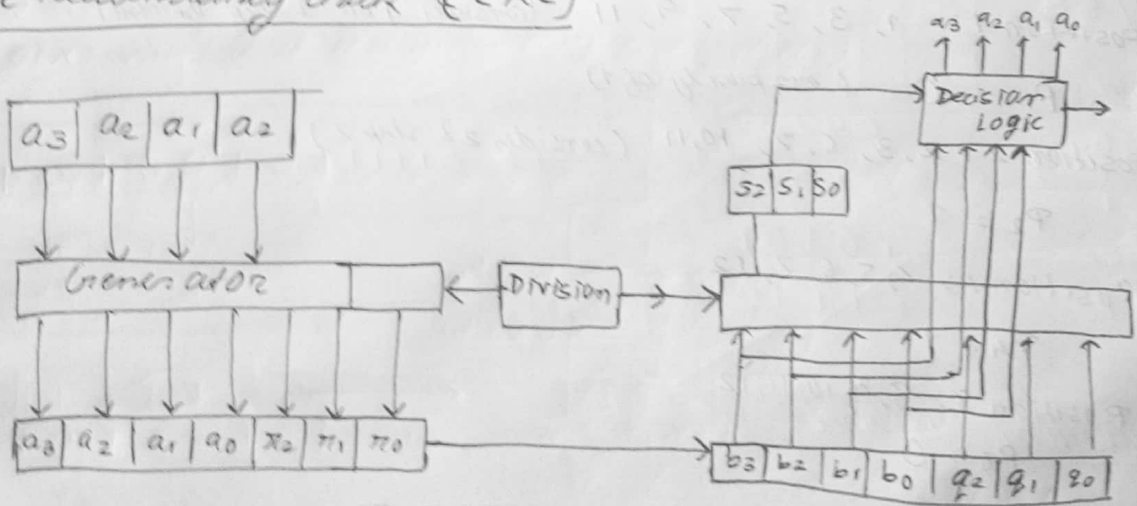
Here there is no way of correcting it. All can only correct 1 bit error.

1101 1110 1010 1011

d_1 d_2 d_3 d_4



* Cyclic redundancy check (CRC)



DW 1001

(There are 4 bits in dw & hence we add 3 bits after that)

Divisor → 1011

~~1001~~

```
1011 ) 1001000 ( 1010
       1011
       ----
        0100
        0000
        ----
         1000
         1011
         ----
          110
          000
          ---
          110
```

we will add the remainder bits behind the dw

```
1001000
    110
-------
1001110 → CW
```

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* Receiver side CRC checking

Divisor 1011

```
1011 ) 1001110 ( 10
       1011
       ----
        01110
        00000
        -----
         1110
```

```
1011 ) 1001110 ( 1010
       1011
       ----
        0101
        0000
        ----
         1011
         1011
         ----
            0
            0
```

Rem → 0

hence, no error.

* $x^3 + x^3 = 0$ $x^3 - x^3 = 0$ $x^3/x^2 = x$ $x^3 \cdot x^2 = x^5$

Eg: $(x^3 + x^2 + x)(x^2 + x + 1) = x^5 + \cancel{x^4} + \cancel{x^3} + \cancel{x^4} + \cancel{x^3} + \cancel{x^2} + x^3 + \cancel{x^2} + x$

$= x^5 + x^3 + x$

1011 $\quad\quad$ 1001000

$\downarrow \quad\quad \downarrow$

$x^3+x+1 \quad\quad x^3(x^3+1)$

$$x^3+x+1 \,\big)\, x^6+x^3 \,\big(\, x^3+x$$
$$\underline{x^6+x^4+x^3}$$
$$x^4$$
$$\underline{x^4+x^2+x}$$
$$x^2+x \longrightarrow 0110$$

dataword $d(x)$

codeword $c(x)$

generator $g(x)$

syndrome $s(x) \longrightarrow$ remainder

error $e(x)$

In receiver's side we divide $c(x)/g(x)$

If there is an error $\dfrac{c(x)+e(x)}{g(x)} \Rightarrow \dfrac{c(x)}{g(x)} + \dfrac{e(x)}{g(x)}$

★ 1000110

$c(x) = x^6+x^3+x^2+x+\cancel{x^4}$

$e(x) = x^3$

Find $g(x)$ such that it divides $c(x)$ but not $e(x)$. 11

1 0 1 0 0 1 0 1

$\downarrow \quad \downarrow$

$x^j \quad x^i$

$x^j+x^i \longrightarrow$ error

where $j>i$

If 1 0 1 0 0 1 0 1   i.e., x^3+x+1

$\downarrow$

x^3+x+1

will detect all double bit errors.

i> It ~~should~~ should have ~~at~~ least 2 terms.

ii> The coefficient of x^0 should be 1

iii> It should not divide ~~by~~ x^t+1, where $t \in (2, n-1)$

iv> It should have factors of $x+1$

~~(7, 11, 12, 0, 6, 36)~~

* checksum (4 bit)

Dataword (7, 11, 12, 6, 36

codeword (7, 11, 17, 0, 6, 36)

* 1's complement arithmetic

wrapping

10101 ⟶ represent it as 4 bit no.

1 | 0101 ⟶ 21
1
0110 ⟶ 6

~~orig~~ 1's complement of 6 ⟶ 7

~~0110~~ 0110 6
1001 9

$(2^n-1) - no = complement$

Sender

7
11
12
0
6
0

0100 2C sum
10
0110 6 - complement
1001 9 ⟶ complement

CW (7, 11, 12, 0, 59)

Receiver

7
11
12
0
6
9
———
45

10 | 1101
      10
———
1111 ⟶ wrapping

0000 ⟶ complement.

If 46,

10 | 1110
      10
———
1 | 0000 (complement it)
   1
———
0001 ⟶ wrapping
1110 ⟶ complement.

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iii) Framing

Structure and Frame

Flag	Address	Control	Information	FCS	Flag
8 bit	8 bits extendable	8 or 16 bits	variable size	16 or 32 bits	8 bits

i) Identify a frame from where it starts ⟵ indicated by flag byte

It is a bit pattern but same bit pattern may appear elsewhere.

a) Byte stuffing
b) Bit stuffing

a) Byte stuffing

If flag byte is appearing somewhere in between, we add ESC Flag.

Before		After (stuffing)
$\underbrace{\boxed{A}\ \boxed{Flag}\ \boxed{B}}_{\text{bytes}}$	⟶	$\boxed{A}\ \underbrace{\boxed{Esc}}_{\text{Escape byte}}\ \boxed{Flag}\ \boxed{B}$
$\boxed{A}\ \boxed{Esc}\ \boxed{B}$	⟶	$\boxed{A}\ \boxed{Esc}\ \boxed{Esc}\ \boxed{B}$
$\boxed{A}\ \boxed{ESC}\ \boxed{Flag}\ \boxed{B}$	⟶	$\boxed{A}\ \boxed{Esc}\ \boxed{ESC}\ \boxed{ESC}\ \boxed{Flag}\ \boxed{B}$

If multiple flag & esc bytes are available, we add additional esc byte for each of them.

b) Bit Stuffing

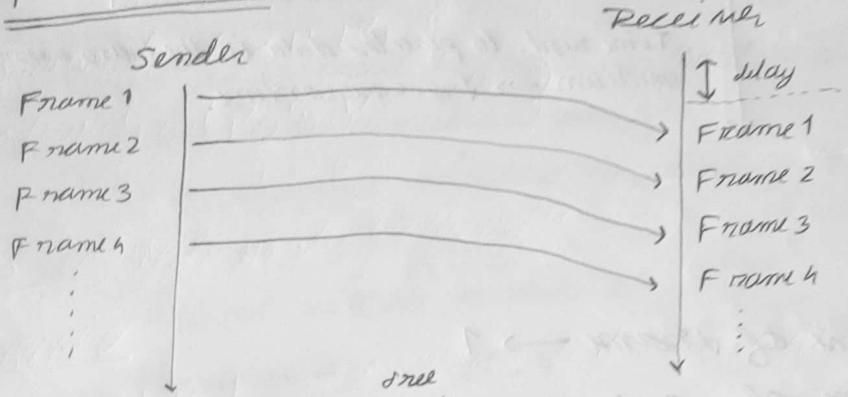
Flag 01111110

5 consecutive 1s and 0s before & after it.

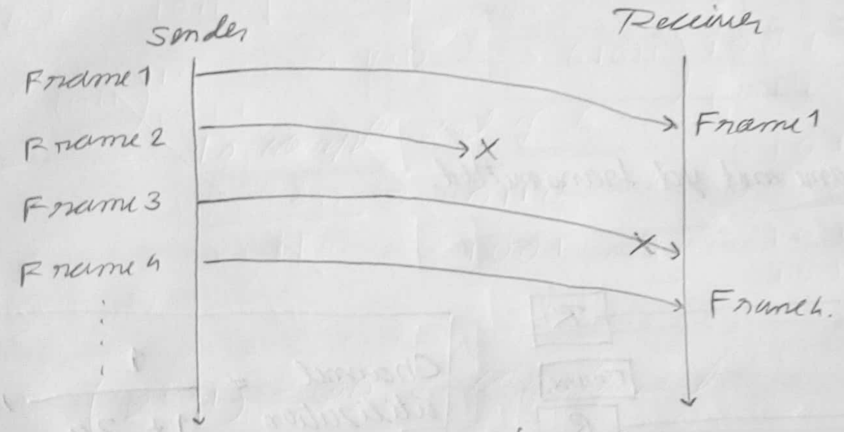
1010 1111111 11111 1 0 11

1010 11111 0 111111 0 1011

iv) Flow Control



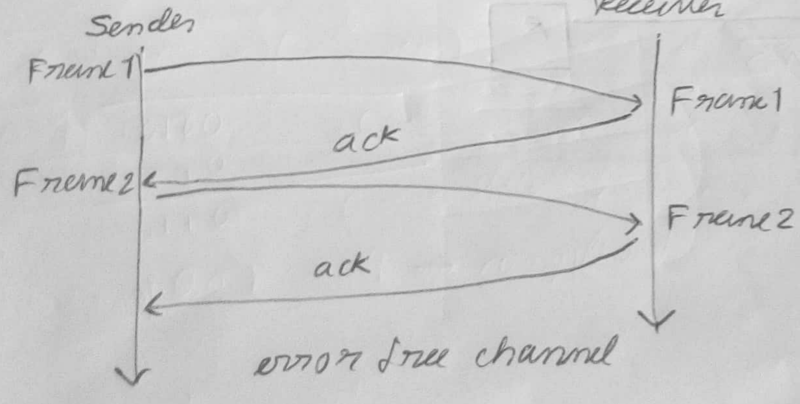
error free channel.



noisy channel

There should be same instruction by which sender gives info to the receiver.

→ Acknowledgement (ACK)

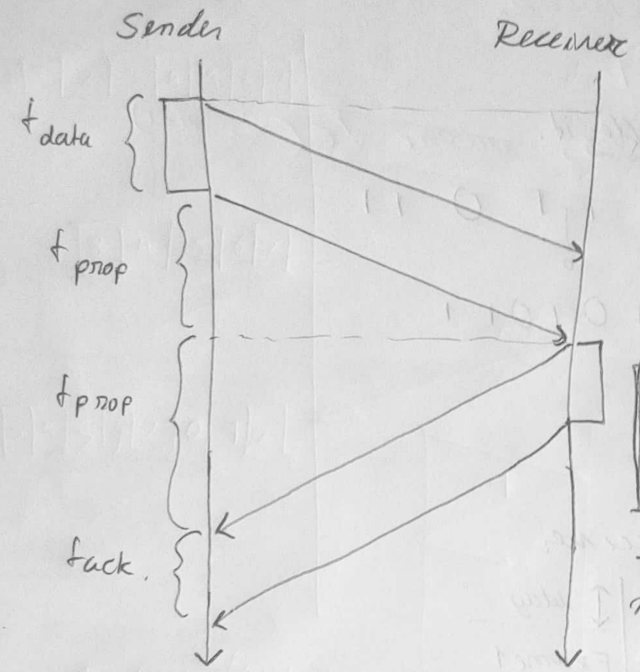


* receiver will send an acknowledgement

* sender will wait for ack

error free channel

Stop and wait flow control



$1 \text{ cycle} = t_{data} + 2t_{prop} + t_{ack}$

Sender was busy during 1 cycle (for transmitting frames)

$= t_{data}$

$$\boxed{\text{channel utilization} = \frac{t_{data}}{t_{data} + 2t_{prop} + t_{ack}}}$$

Time reqd. to place the data in the transmission medium → transmission time

Assumptions

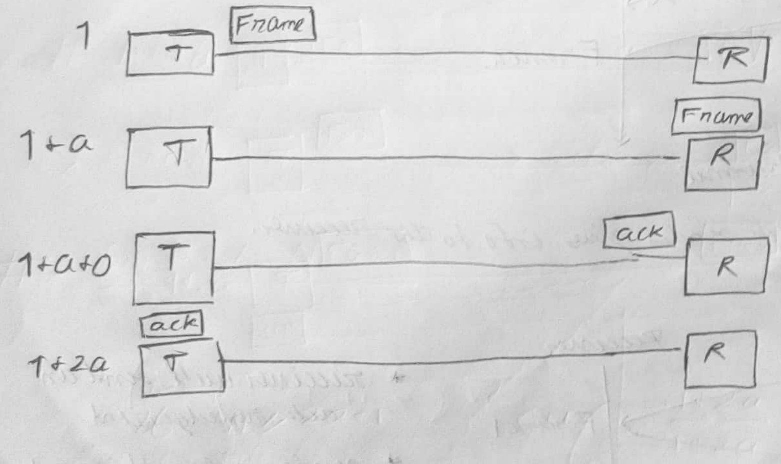
i> Transmission time of frame ⟶ 1

ii> Transmission time of ack ⟶ 0

iii> Propagation time ⟶ a

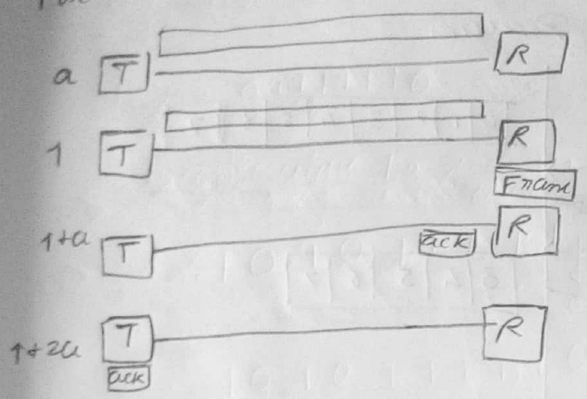
iv> noise free channel

For $a > 1$ $t = 0$. frame not yet transmitted.



$$\boxed{\text{Channel utilization} = \frac{1}{1 + 2a}, \quad a \geq 1}$$

For $a < 1$, $t = 0$, frame not yet transmitted.



$$\boxed{\text{Channel utilization} = \frac{1}{1+2a}, \quad a<1}$$

It is always < 1.

Sliding Window Flow Control

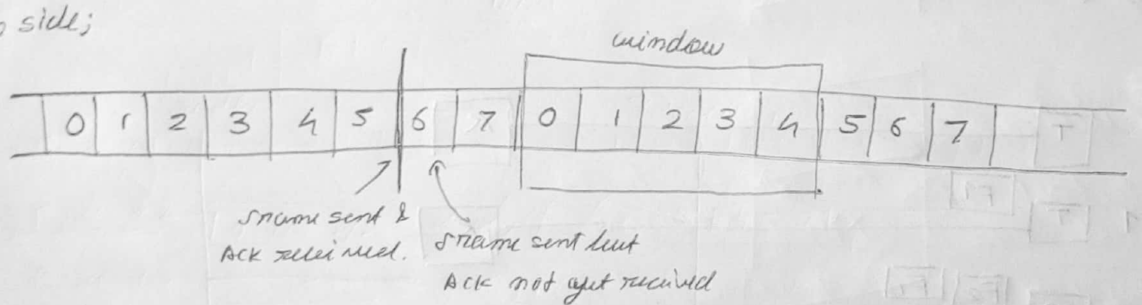
1. Window of size W
2. Sender can transmit W frames without receiving "ack".
3. Receiver sends cumulative ~~ack~~ Ack.
4. Frame sequence numbers to identify frames

   k-bit seq

   seq. no. will be modulo 2^k.

   Window size = $2^k - 1$

Sender side;

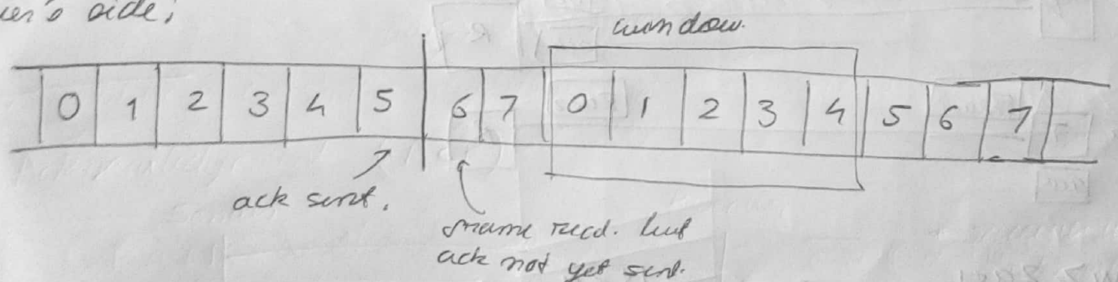


when we receive ack, the size of the window increases by the number of frames for which ack received.

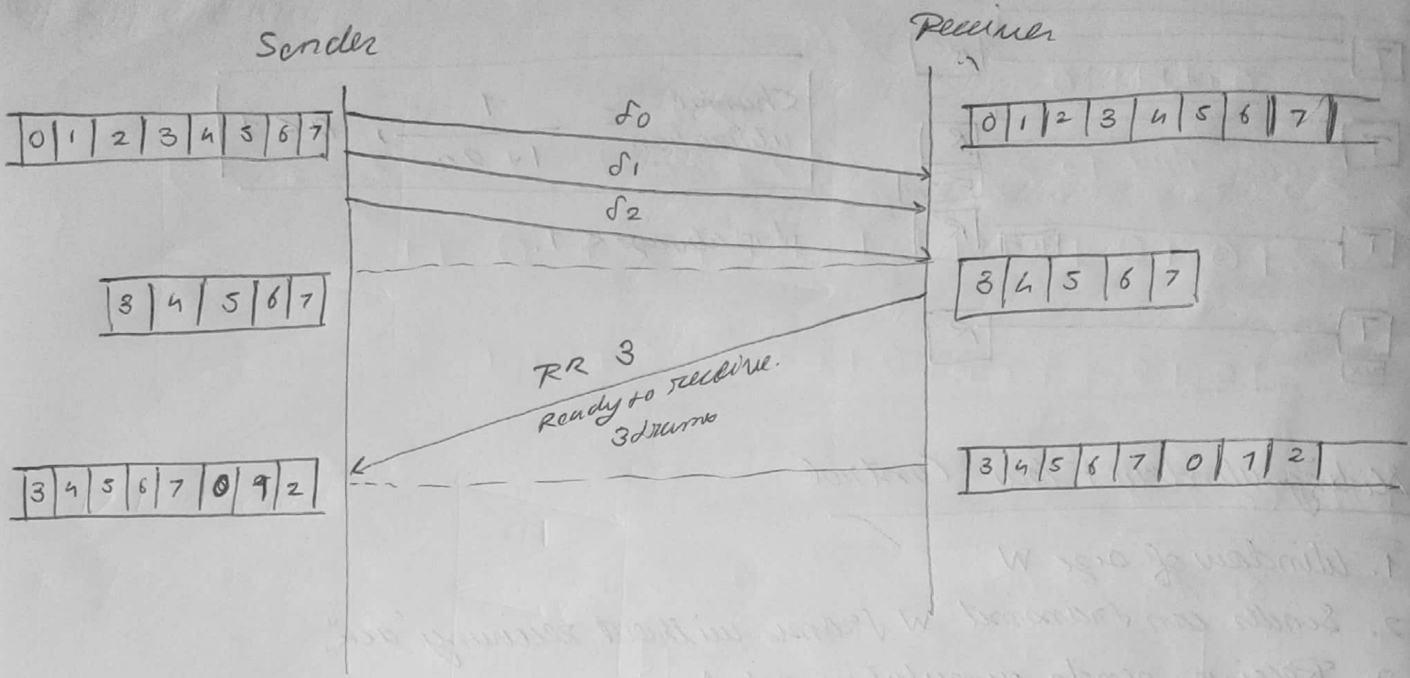
Here, when ack for 6 received, window (5) ⟶ (6)

when frame sent, decrement window size by 1.

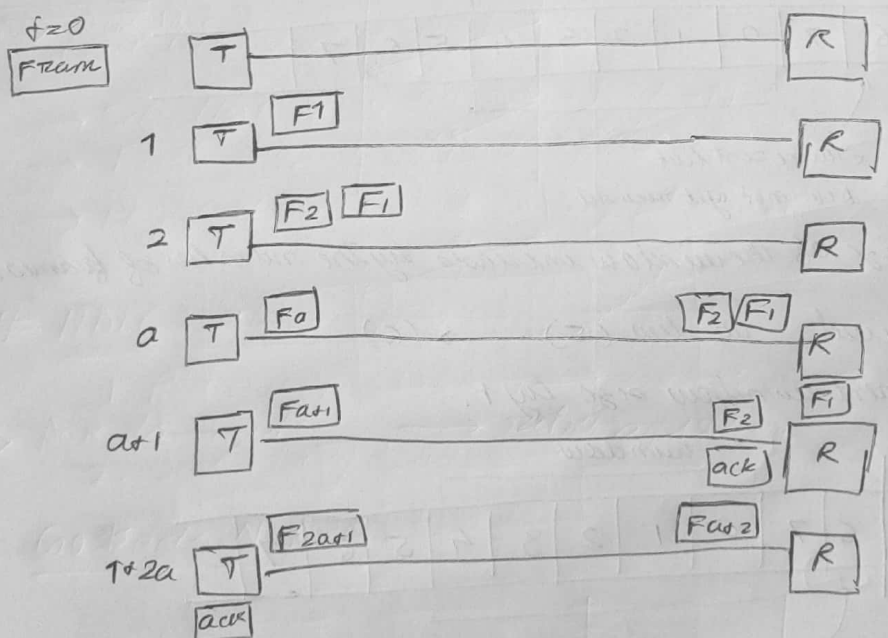
Receiver's side;



when Ack is send, window size is incremented by 1.

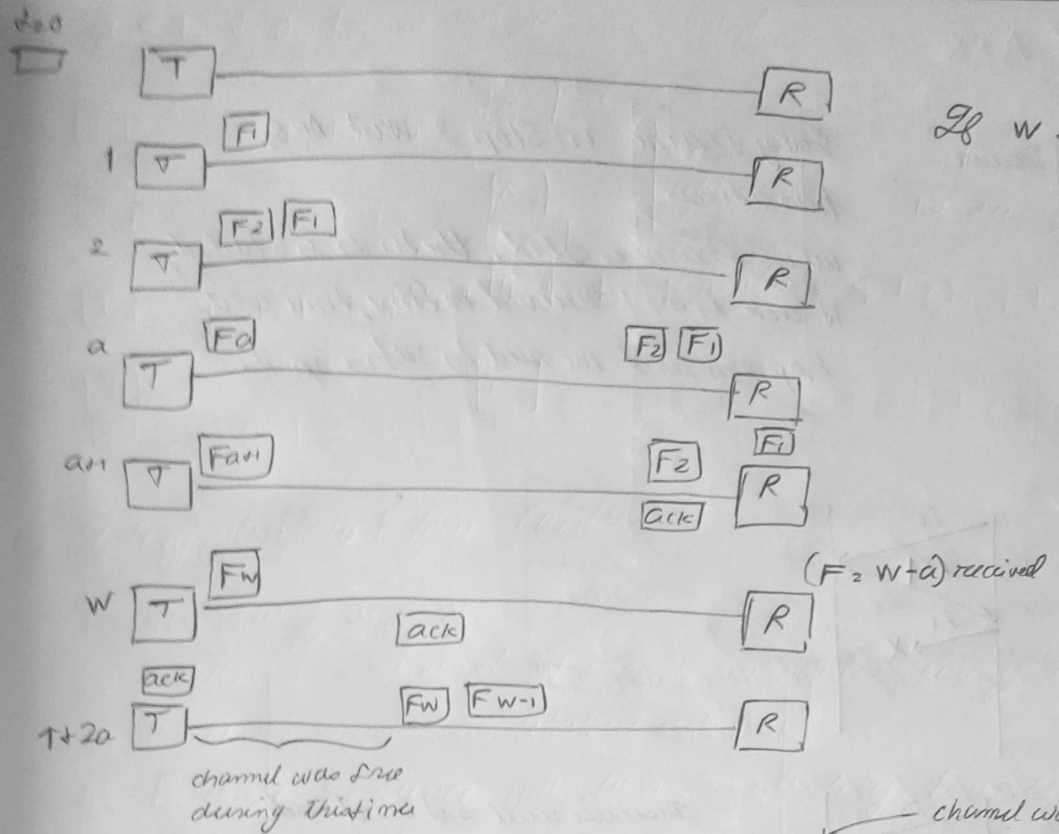


1. window size $\longrightarrow W$
2. Transmission time $\longrightarrow 1$
3. Propagation time $\longrightarrow a$
4. Transmission of ack $\longrightarrow 0$
5. Noise free channel.



If $W \geq 2a+1$ $\quad CU = \dfrac{1+2a}{1+2a} = 1$

If $W < 2a+1$.



channel was busy during w time

$$CU = \frac{W}{1+2a}, \quad W < 2a+1$$

29/8/19

* Error control in Noisy channel

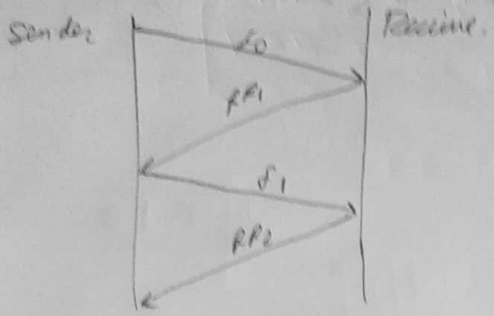
1. Frame Damaged ⟶ Frame error correction
   measures ⟶ Retransmission
2. Frame Lost ⟶ measures ⟶ Retransmission

i> Positive ack (Ready to receive frame i) RR - i

ii> Negative ack (NAK)
- REJ - i (Particular frame i has been lost)
- SREJ - i

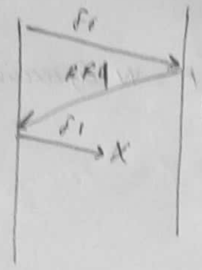
Automatic Repeat Request (ARQ)
- ⟶ Stop and wait (ARQ)
- ⟶ Go Back - N ARQ
- ⟶ Selective Reject ARQ

Stop and Wait.

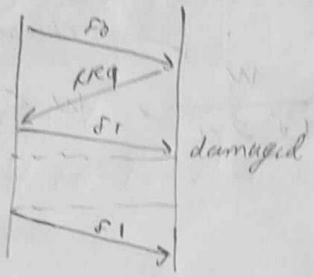


Every frame in Stop & Wait ARQ has a timer.
when frame is sent, the timer is started,
If ack is not received in time, time out happens and we need to retransmit.

i> Frame lost

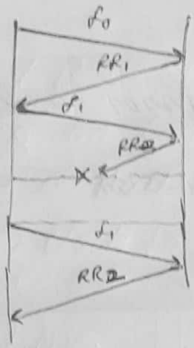


ii> Frame Damaged



Receiver will not send ack.
there will be time out.
↓
retransmission.

iii> Ack lost



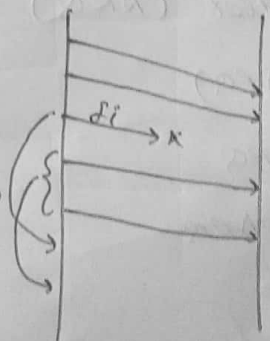
retransmission.

iv> Ack damaged. ⟶ retransmission.

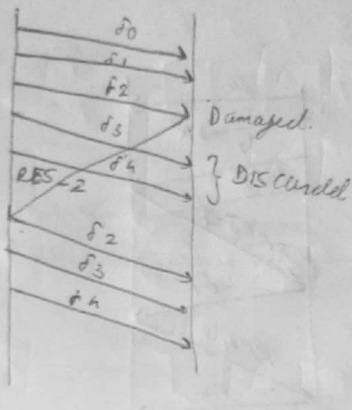
Go Back N ARQ

REJ - i

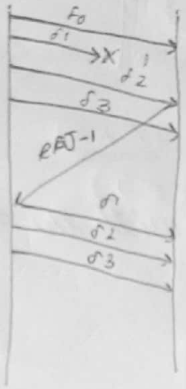
frame i will be retransmitted along with the frames transmitted afterwards.



a) Frame damaged.

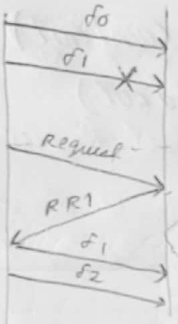


b) Frame lost



when further frames are transmitted after a particular frame is sent, we can identify the lost frame on the basis of the subsequent frames.

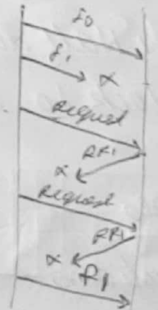
when no additional frames have not been transmitted



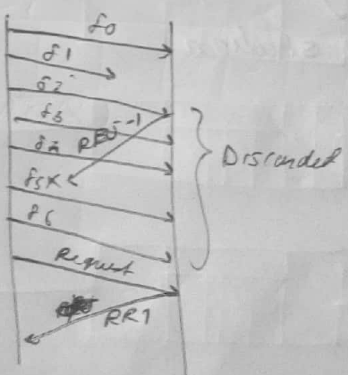
sender send request on the basis of timer.

c) Positive ACK (RR) lost

~~d) Negative ACK REJ~~ lost.

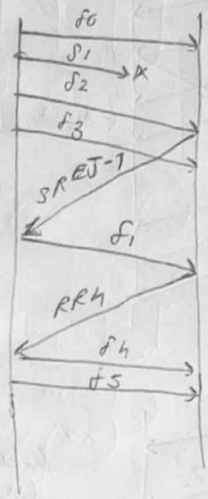


d) Negative ACK REJ lost



Selective Reject ARQ

SREJ - i



* Piggy backing

It we send the acknowledgement along with the data.

* Protocols in Data Link Layer

1. HDLC (High Level Data Link control)
2. PPP (Point to Point Protocol)

1. HDLC

It is a bit oriented protocol.

→ Selective ARQ or Go-back-N ARQ.

→ Full duplex or Half duplex

→ Physical layer clock to Synchronize.

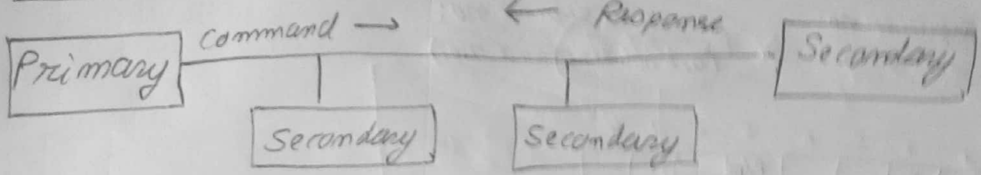
HDLC station types

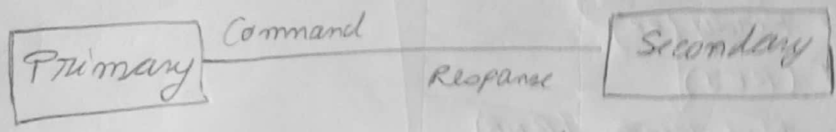
1. Primary stations ⟶ initiate the communication process
2. Secondary stations — act in response to primary station
3. Combined station

Scanned by CamScanner

HDLC Link configuration:

Unbalanced

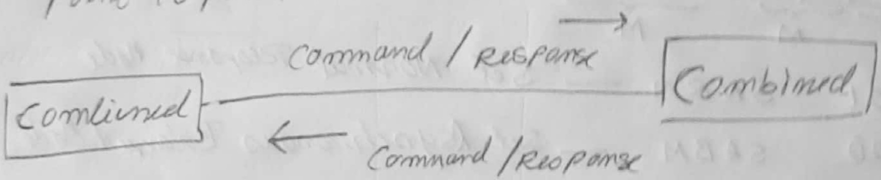




point to point

Balanced

point to point



HDLC Data Transfer Modes

1. Normal Response Mode (NRM)
2. Asynchronous Response Mode (ARM)
3. Asynchronous Balanced Mode (ABM)

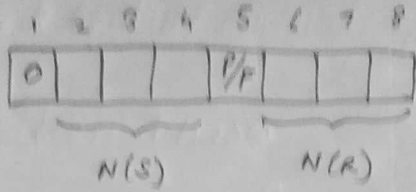
HDLC Frame Types.

1. Unnumbered (U Frame)
2. Information (I Frame)
3. Supervisory (S Frame)

HDLC Frame structure:-

Flag	Address	Control	Information	FCS	Flag
8bit	8bit extendable	8bit.		CRC	8bit

I Frame:

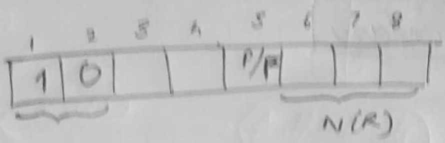


P → Poll 1

F → Final 0

Send sequence no: Receive sequence no: (acknowledgement no.)

S F Frame.



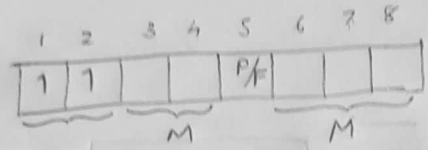
00 → Receive Ready (RR)

01 → Reject (REJ)

10 → Receive Not Ready (RNR)

11 → Selective Reject (SREJ)

U Frame



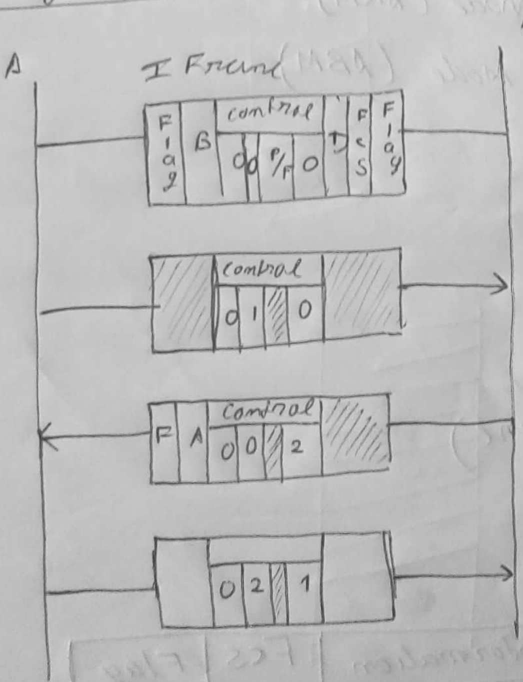
00 001 SNRM — Set Normal Response Mode

11 100 SABM — Set Asynchronous Balanced Mode.

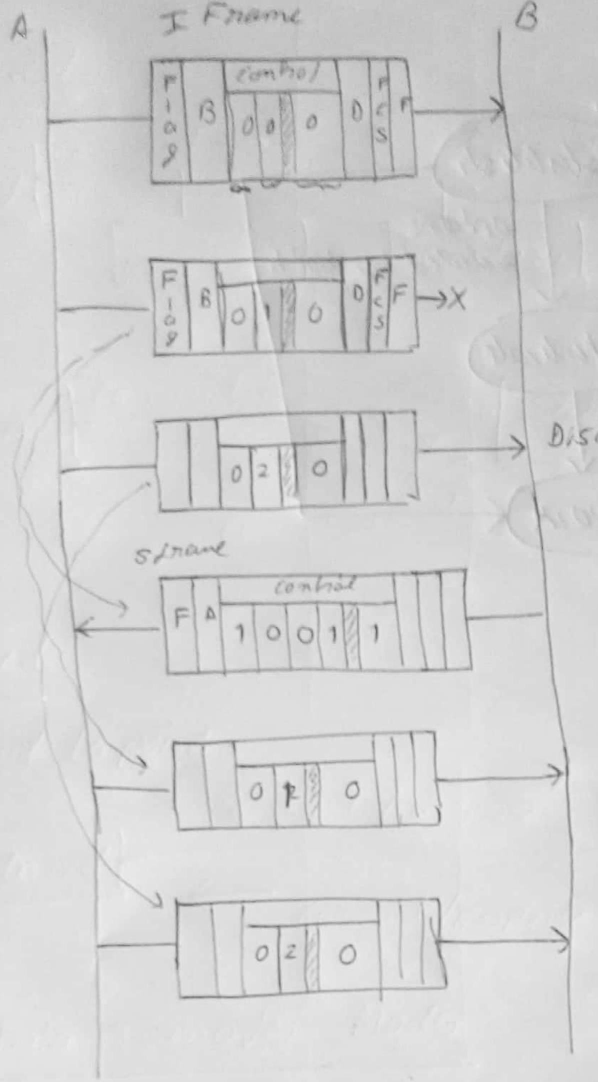
00 110 UA → Unnumbered ACK

00 010 DISC → Disconnect.

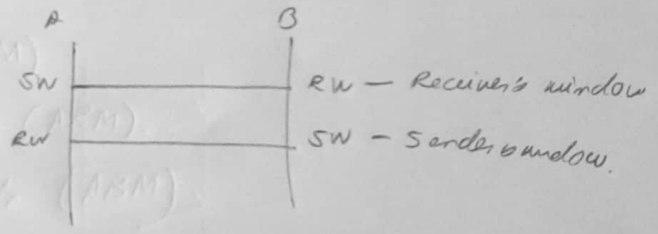
Piggybacking of HDLC Frame without error



Piggy backing of HDLC Frame with error



* when data comm. occurs both sides, then there are 2 windows on each side



* PPP

- → Byte oriented
- → Point to point

Flag	Address	Control	Protocol	Payload	FCS	Flag
	1111111	11000000	↑			

i) Link Control Protocol (LCP)

ii) Authentication Protocol

a) Password authentication Protocol (PAP)

b) Challenge Handshake Authentication Protocol (CHAP) iii> Network control Protocol.

PPP Transition Phase