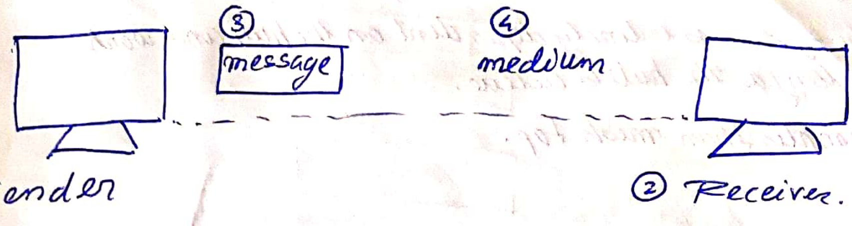
26/7/19

* Components of data communication



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.

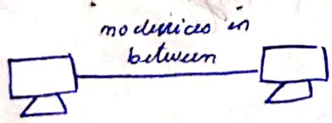
Full duplex - comm. can take place in both dir.

Criteria for communication

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

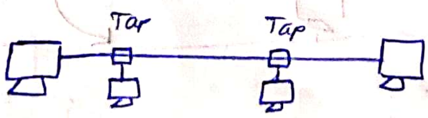
Attributes of physical structure of network.

1. Type of connection



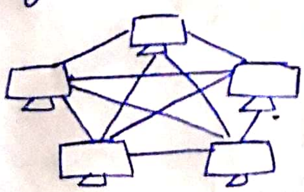
a) Point to point connection

(data will be visible to all nodes)



b> Multi point connection

2. Physical Topology

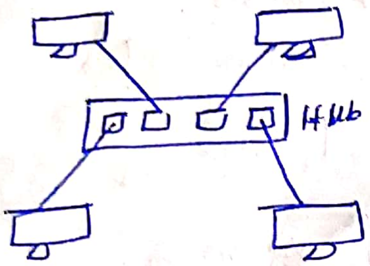


i> Mesh topology

- 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

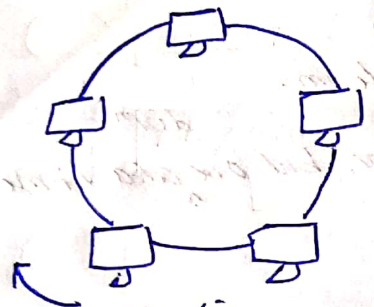
Cons:-
- Inaubility of physical space
- cost ineffective

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.

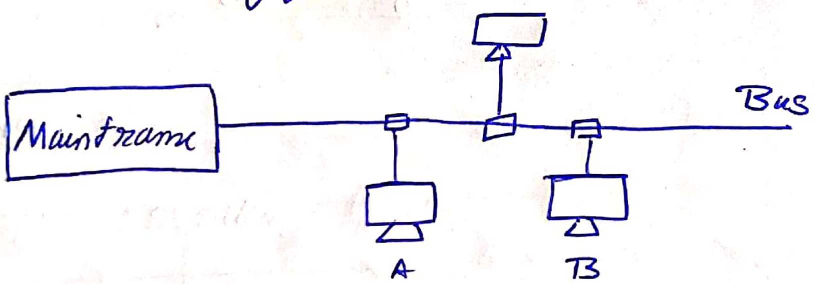
iii> Ring topology.



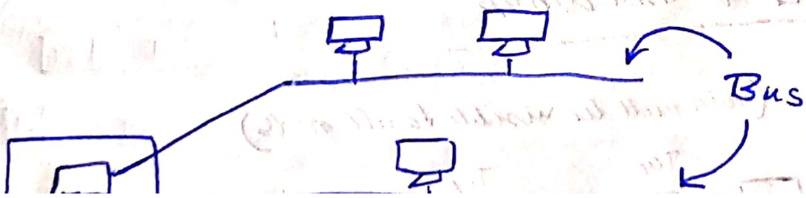
comm. can take place only in one direction

considering this dir.

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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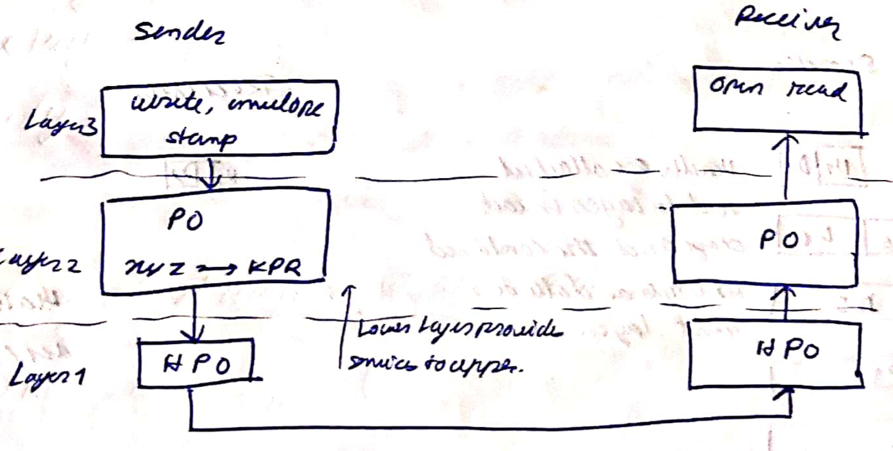
* Network Models

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

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

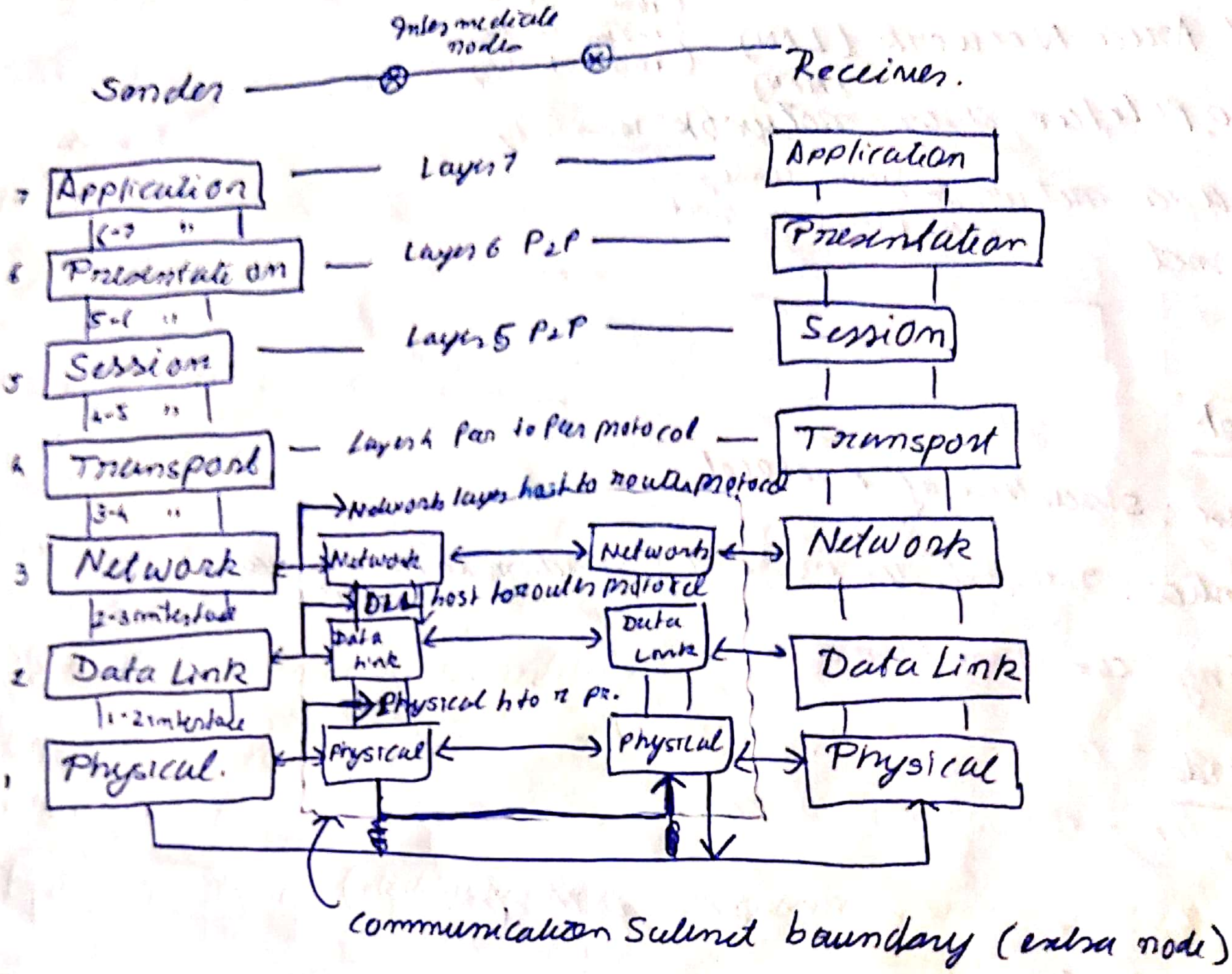
How we are going to access service from lower layer. By calling some fn.
It is a connection b/w 2 layers.



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 a suitable path from source to destⁿ)



OSI reference model

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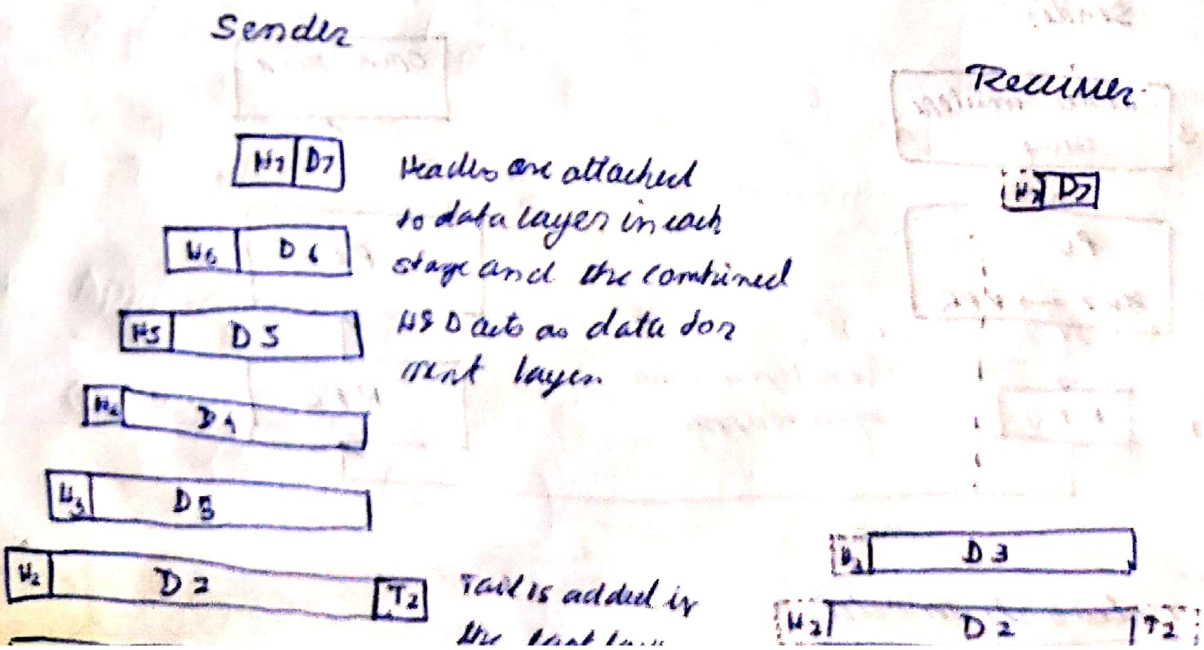


Headers are attached to data layer in each stage and the combined H & Data as data for next layer.

Headers are removed accordingly.

Tail is added in the last layer

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, halfduplex, fullduplex)
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 being a raw transmission of bits to a reliable link.

② Framing (converting the data to bits)

③ Physical Addressing

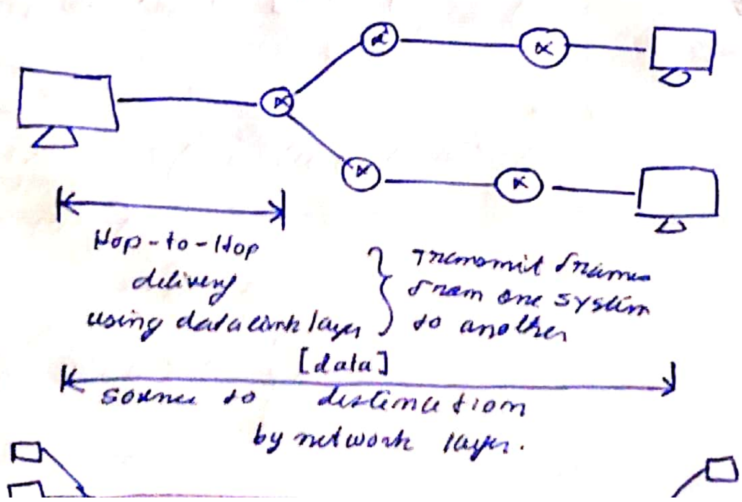
i> within the network → add sender + receiver address

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 ~~packets~~ packets 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. Provides services to user.
   (topmost layer)

Scanned by CamScanner

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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	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.

$$\boxed{\text{Bit length} = \text{Propagation speed} \times \text{bit duration}}$$

To transmit signals through communication medium

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

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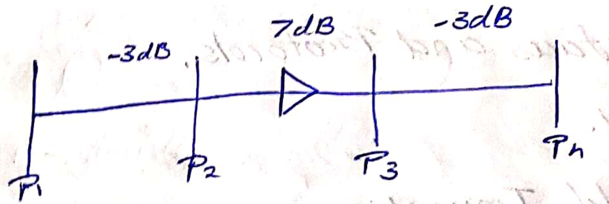
* Transmission Impairments

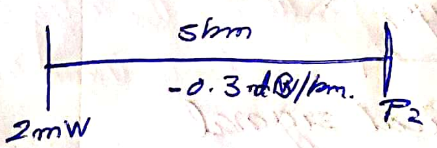
1. Attenuation (Loss in signal strength across the medium)
2. Distortion (change in signal shape)
3. Noise (in wired or wireless)

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



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

Q. Suppose the loss in a cable at beginning is -0.3dB/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

Max bit rate = $2B \log_2 L$

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

② Noisy → Shanon

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.

Solⁿ- ~~Max bit rate = B log₂~~

$SNR_{dB} = 36 dB$

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

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

$S/N = 10^{3.6}$

$S/N = 3981.07$

MBR = ~~Bx~~ $2 \times 10^6 \log_2 (1 + 3981.07)$

$= 23.918 \times 10^6$

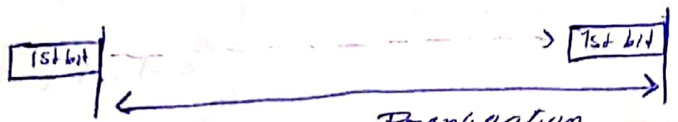
$= 23.918$ MB/sec

* 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 :-

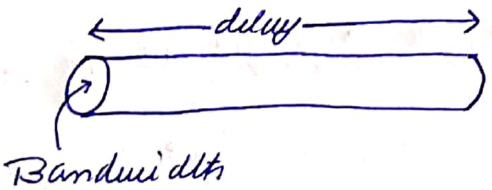
1. Propagation time (measures the time reqd. for a bit to travel from source to destination)
2. Transmission time (measures the time reqd. for entire message to leave from the source node)
3. Queuing time (The time needed for each intermediate or end device to hold the message before it can be processed)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

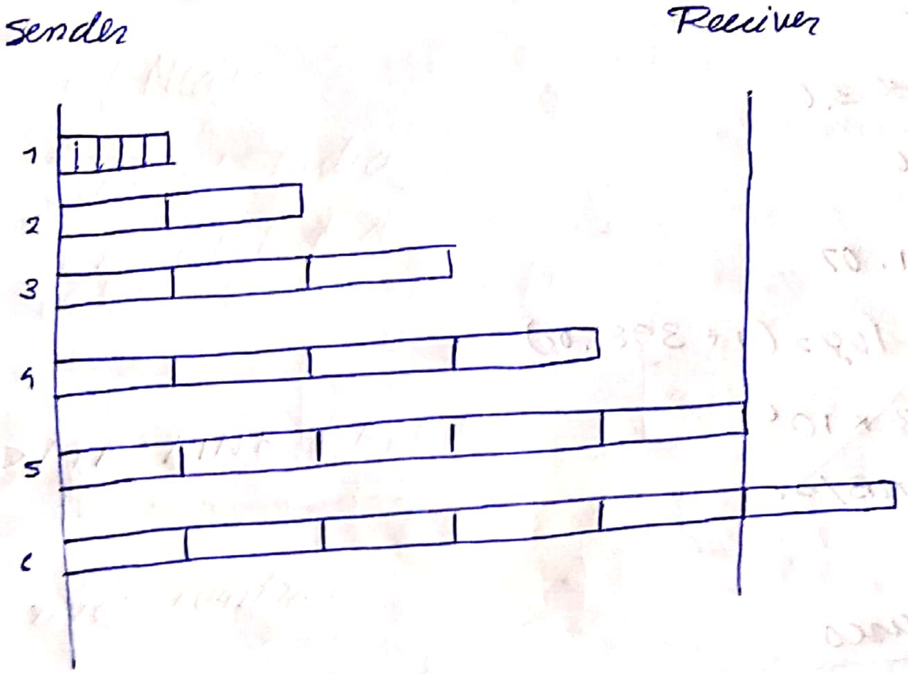


Propagation time = distance / Propagation speed.

Latency = ① + ② + ③ + ④

4. Bandwidth delay product.





B = 5 bits/sec

delay = 5

Max = 25 bits.

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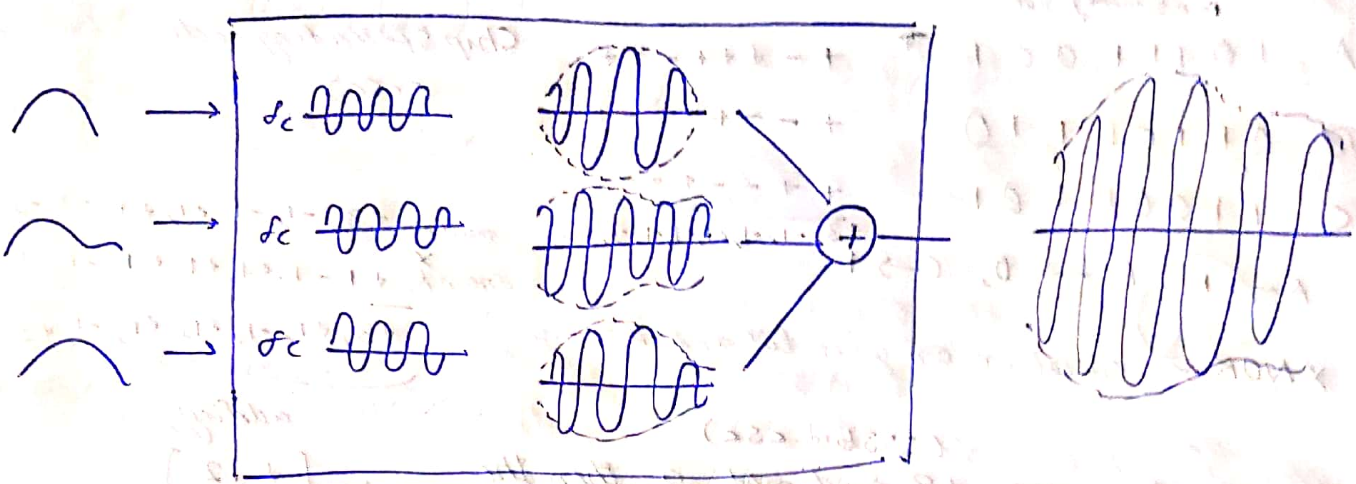
* Bandwidth utilization

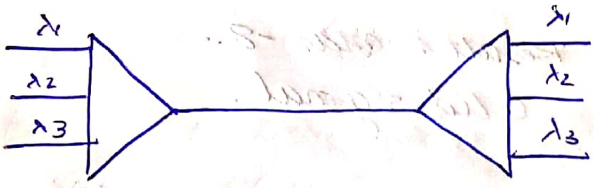
- Analog
- Digital
  - TDM

Frequency Division Multiplexing (FDM)

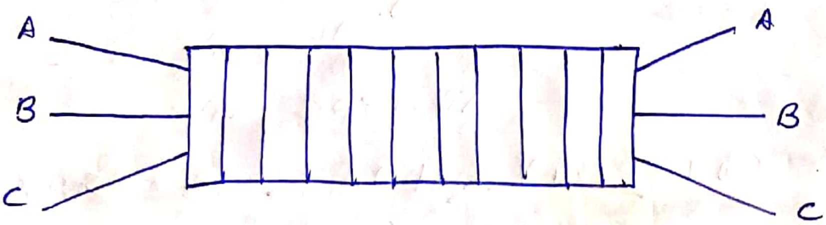


Wavelength division Multiplexing (WDM)

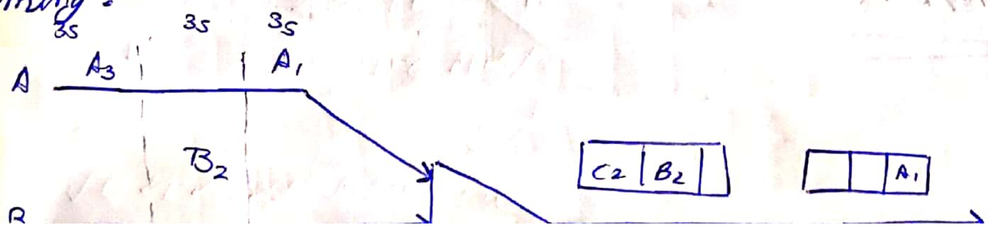
Used in optical fibre cables.



Time division Multiplexing (TDM)



Framing :-



* Code Division Multiplexing (CDM)

chip spreading code

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 → + + - - + + - +

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

Chip spreading code 64 bit.
(CSC)

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

$\underbrace{+3, +1, -1, +1, +1, +1, +3, +3}_{\text{adding, } [+12]}$

A → 1, B → 0, C → 1

XNOR ✓ operation on given bit and sequence.

(∵ 8 bit CSC)

∵ The result is near +8 and not -8, then the result has arrived from A → 1. (it is a 1 Bit signal)

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

$\underbrace{-3, -1, -1, -1, +1, -1, -3, -3}_{-12}$

Result is near -8..
0 bit signal.

* Types of Media

- Guided Media
- Unguided Media.

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* DATA LINK LAYER

Error control

Sender: | 0 | 1 | 1 | 0 | 1 | → Receiver: | 0 | 1 | 1 | 1 | 1 |

↓ single bit error.

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

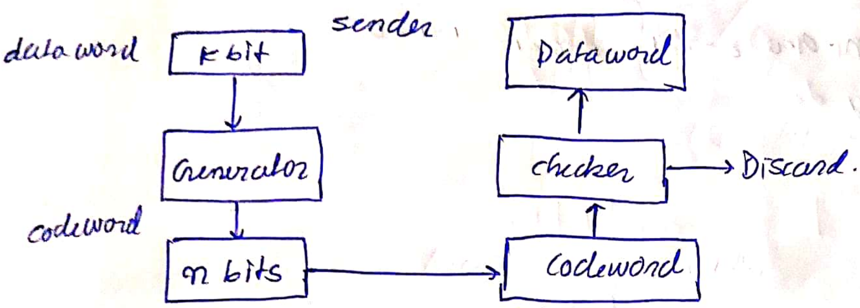
⟵ Burst error length ⟶

burst error

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

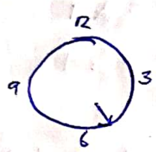
$$
\begin{array}{r}
00000 \\
10101 \\
\hline
1\ 1\ 1
\end{array}
$$

Hamming dist^n = 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 ⟶ no. of error it can detect.

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

★ **Parity checking**

↓

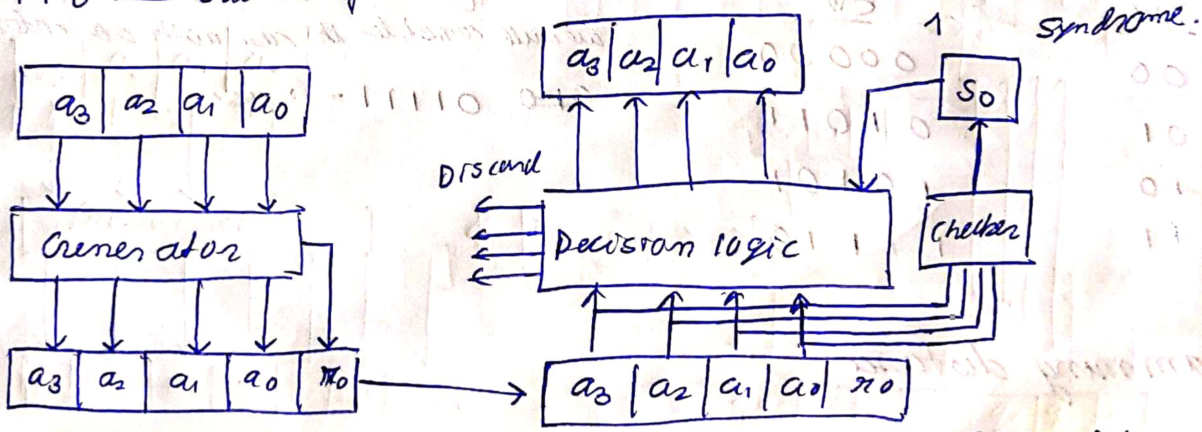
checking if the no. of bits are even or odd.

1010 ⟶ even no. of 1's

1110 ⟶ odd no. of 1's.

$a_3\ a_2\ a_1\ a_0$

0 1 0 1



0 1 0 1 0

0 1 1 1 0 → here S_0 → 1 because it has odd parity.

0 0 1 1 1 → here S_0 → 1

we can detect error.

★ Two dimension parity checking

1101 1100 1001 0101

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

arrange in rows & columns

calculate parity row wise first and then columnwise.

~~disadv~~: For 16 bit data we need 9 extra bits.

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★ Hamming code

$2^r > k + r + 1$

$r \rightarrow$ 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.

$(2^0 \; 2^1 \; 2^2 \; 2^3 \ldots\ldots)$

10011010

code word →

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

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

$P_8 = 0$

※

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

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

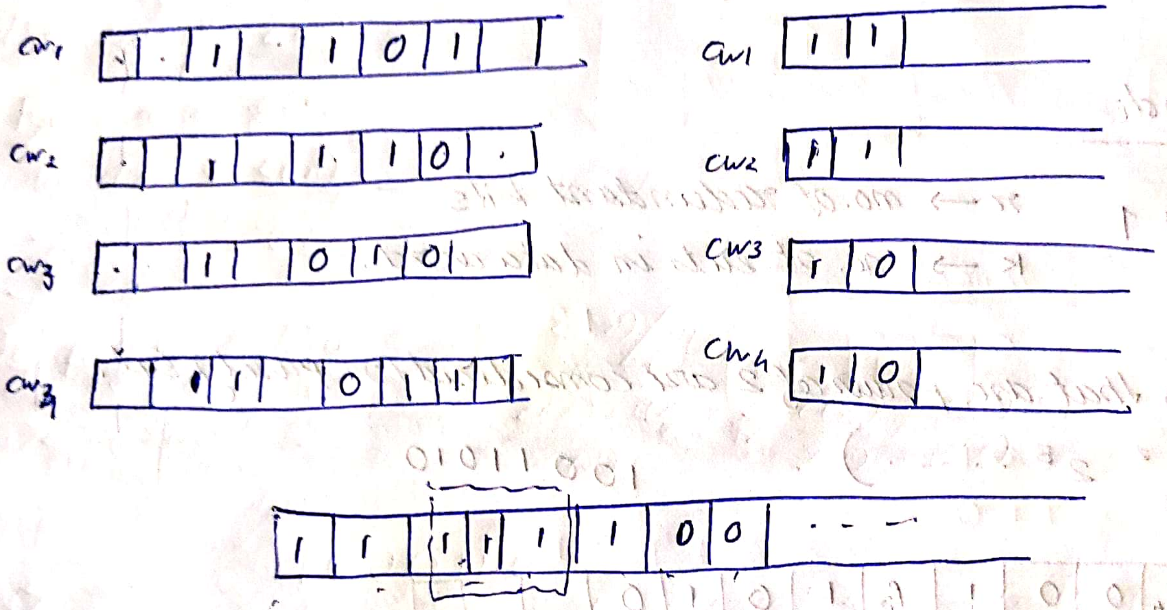
Error in position 5

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

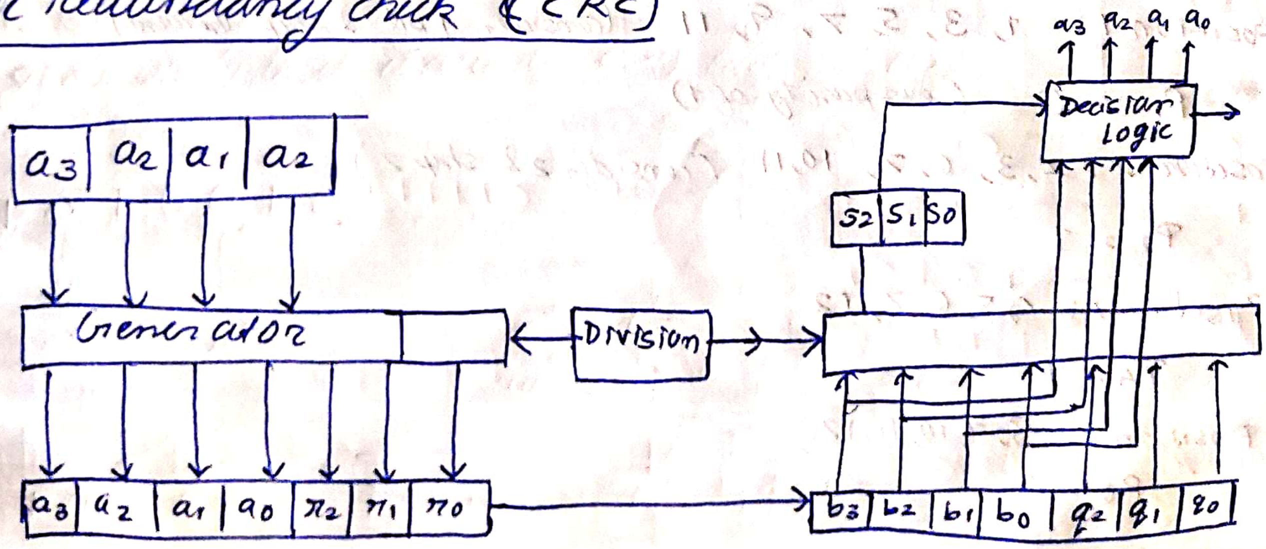
Now, $P_1 = 1$
$P_2 = 1$
$P_4 = 0$
$P_8 = 0$

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

1101 (d_1) 1110 (d_2) 1010 (d_3) 1011 (d_4)



* Cyclic redundancy check (CRC)



DW 1001

Divisor → 1011 (There are 4 bits in dw & hence we add 3 bits after that)

~~1001~~

$$
\begin{array}{r}
1011 \overline{)\,1001000\,}(1010 \\
1011 \\
\hline
0100 \\
0000 \\
\hline
1000 \\
1011 \\
\hline
110 \\
0000 \\
\hline
110
\end{array}
$$

we will add the remainder bits behind the dw

$$
\begin{array}{r}
1001000 \\
110 \\
\hline
1001110
\end{array} \longrightarrow CW
$$

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✱ Receiver side CRC checking

Divisor 1011

$$
\begin{array}{r}
1011 \overline{)\,1001110\,}(1010 \\
1011 \\
\hline
0101 \\
0000 \\
\hline
1011 \\
1011 \\
\hline
0 \\
0
\end{array}
$$

Rem → 0

hence, no error.

★ $x^3 + x^3 = 0$ $x^3 - x^3 = 0$ $x^3/x^2 = x$ $x^3 . x^2 = x^5$

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

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

1011 $\rightarrow$ x^3+x+1

1001000 $\rightarrow$ $x^3(x^3+1)$

$$x^3+x+1 \overline{)\, x^6+x^3} \quad (x^3+x$$

$$\frac{x^6+x^4+x^3}{x^4}$$

$$\frac{x^4+x^2+x}{x^2+x} \longrightarrow 0110$$

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 $\frac{c(x)+e(x)}{g(x)} \Rightarrow \frac{c(x)}{g(x)} + \frac{e(x)}{g(x)}$

★ 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 $e(x)$.

1 0 1 0 0 1 0 1

x^j $\quad$ x^i

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

If 1 0 1 0 0 1 0 1 $\quad$ x^3+x+1

x^3+x+1 $\quad$ 1ex, 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, 12, 0, 6, 9)

★ 1's complement arithmetic

wrapping

10101 ⟶ represent it as ~~one~~ 4 bit no.

$$
\begin{array}{r|l}
1 & 0101 \longrightarrow 21 \\
 & 1 \\
\hline
 & 0110 \longrightarrow 6
\end{array}
$$

~~...~~ 1's complement of 6 ⟶ 9

0110	6
1001	9

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

Sender

7	
11	
12	
0	
6	
0	
0100	36 sum
10	
0110	6 – complement
1001	9 → complement

CW (7, 11, 12, 0, 6, 9)

Receiver

7
11
12
0
6
9
———
45

```
10 | 1101
     10
---------
   1111  → wrapping
   0000  → complement.
```

Q. 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 and 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

A | Flag | B → bytes

After (stuffing)

A | Esc | Flag | B

Esc → escape byte

b> Bit Stuffing

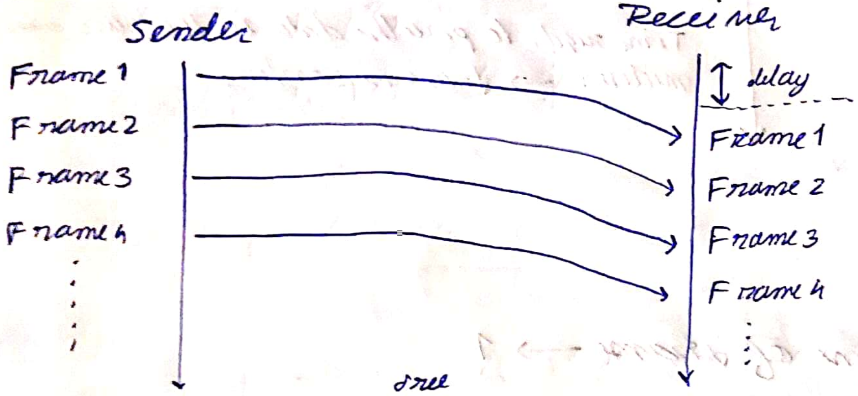
Flag 01111110

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

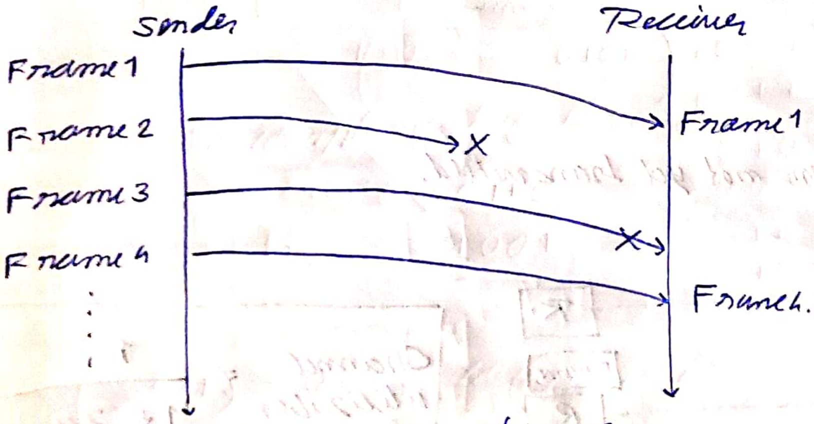
1 0 1 0 1 1 1 1 1 ↓ 1 1 1 1 1 ↓ 1 0 1 1
(0 inserted at each ↓)

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

iv> Flow Control



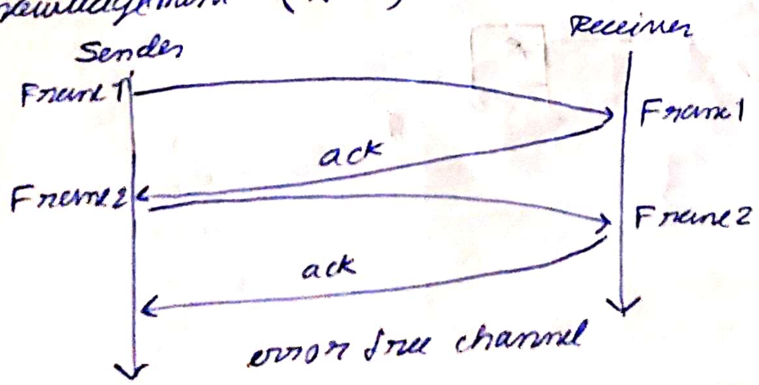
error free channel.



noisy channel

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

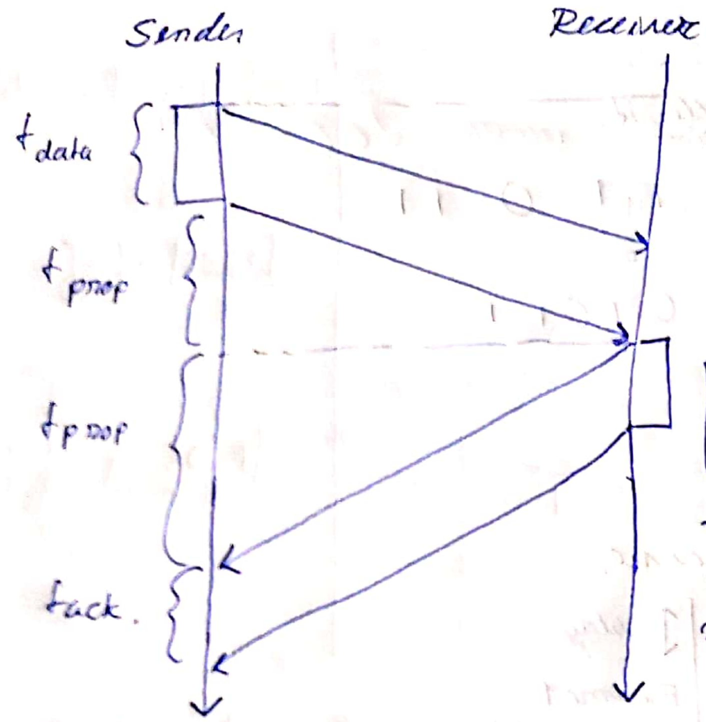
→ Acknowledgement (ACK)



error free channel

* receiver will send an acknowledgement
* sender will wait for ack

Stop and wait flow control



1 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

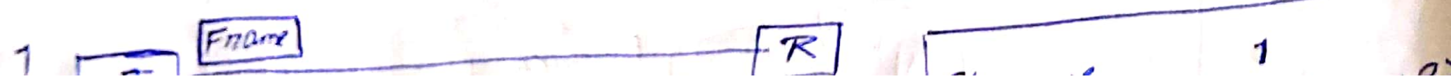
i> Transmission time of frame → 1

ii> Transmission time of ack → 0

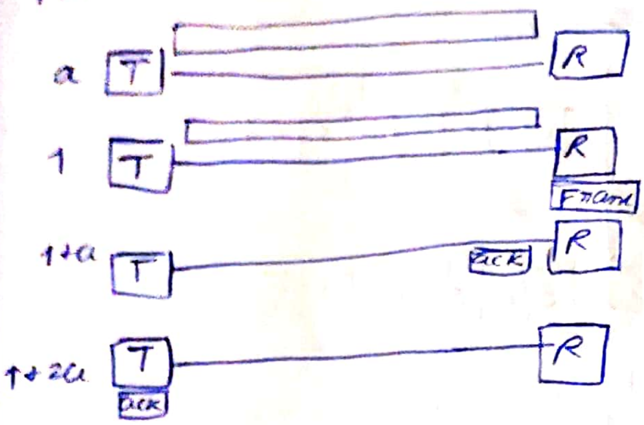
iii> Propagation time → a

iv> noise free channel

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



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



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

It is always < 1.

Sliding Window Flow Control

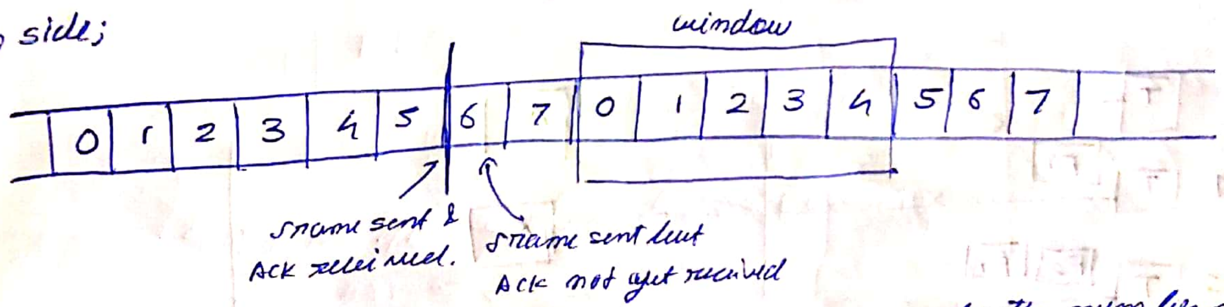
1. Window of size W
2. Sender can transmit W frames without receiving "ack".
3. Receiver sends cumulative ~~ack~~ Ack.
4. Frame sequence numbers to identify frames

K-bit seq

seq. no. will be modulo 2^K.

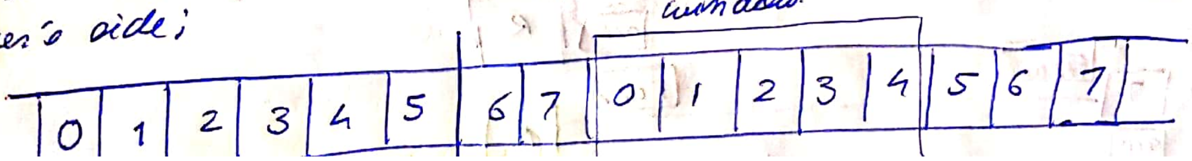
Window size = $2^K - 1$

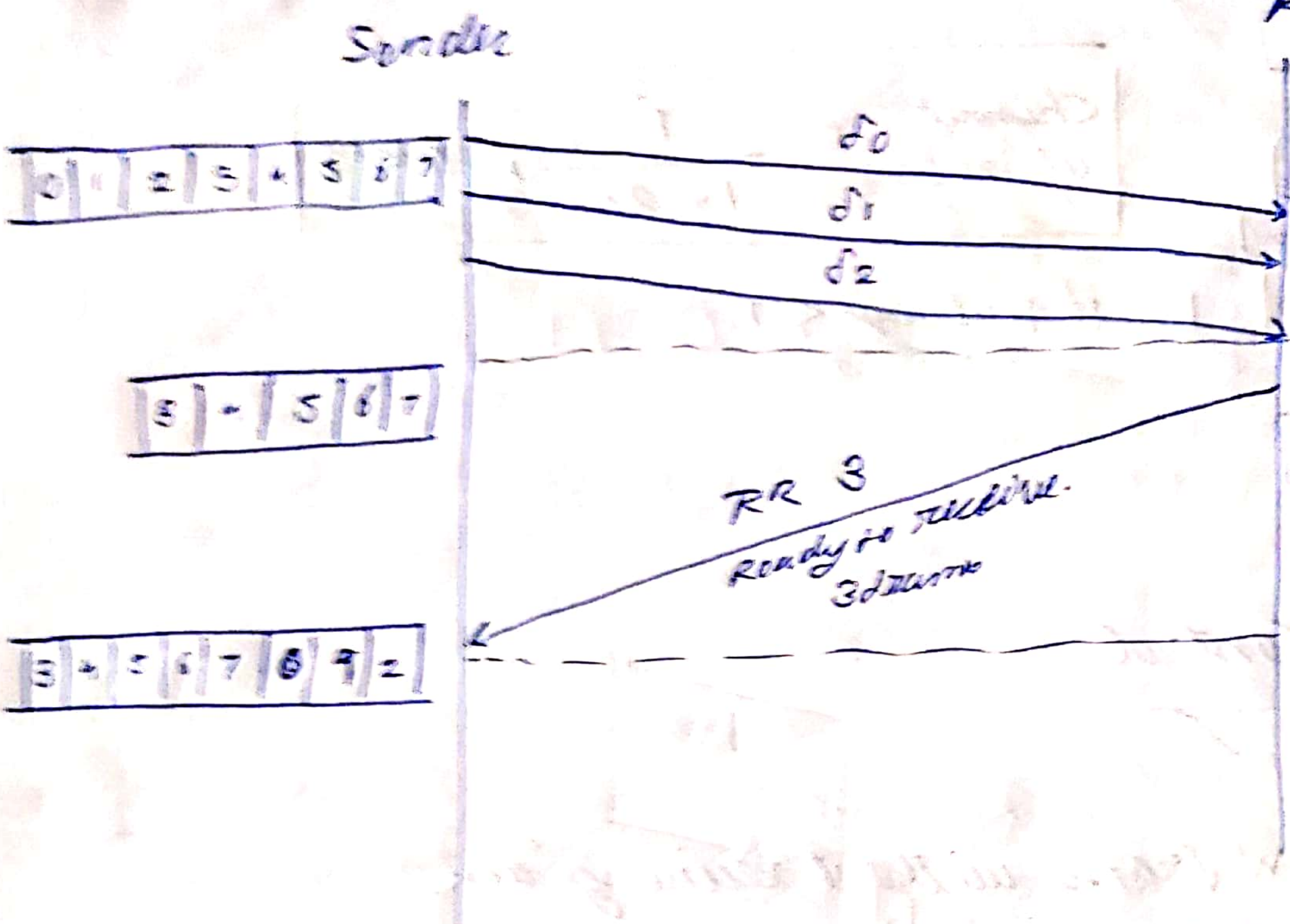
Sender side;



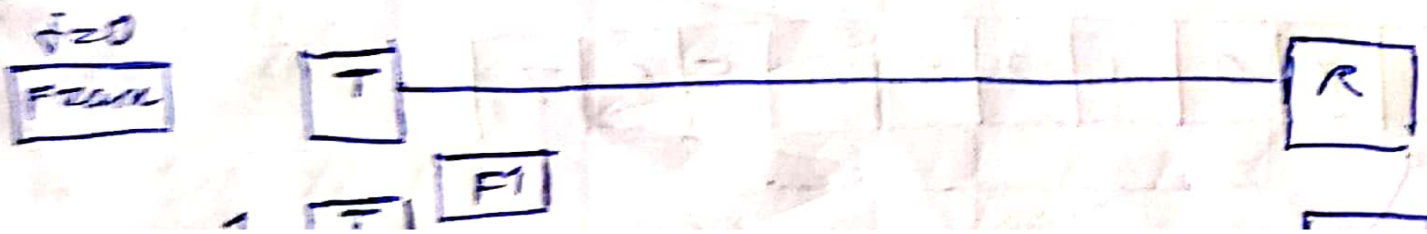
when we receive ack, the size of the window increases by the number of frames for which ack received.
Here, when ack for 6 received, window (5) ⟶ (6)
when frame sent, decrement window size by 1.

Receiver's side;

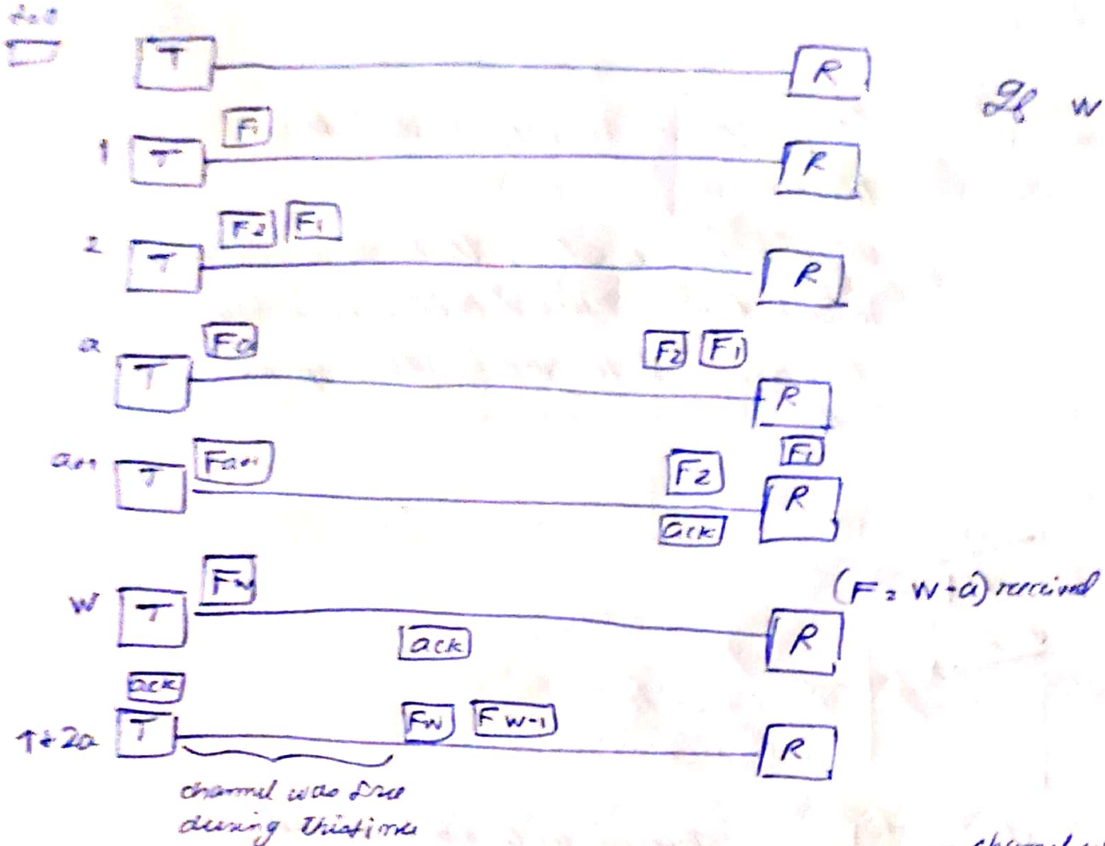




1. window size → W
2. Transmission time → 1
3. Propagation time → a
4. Transmission of ack → 0
5. Noise free channel.



If $W < 2a+1$



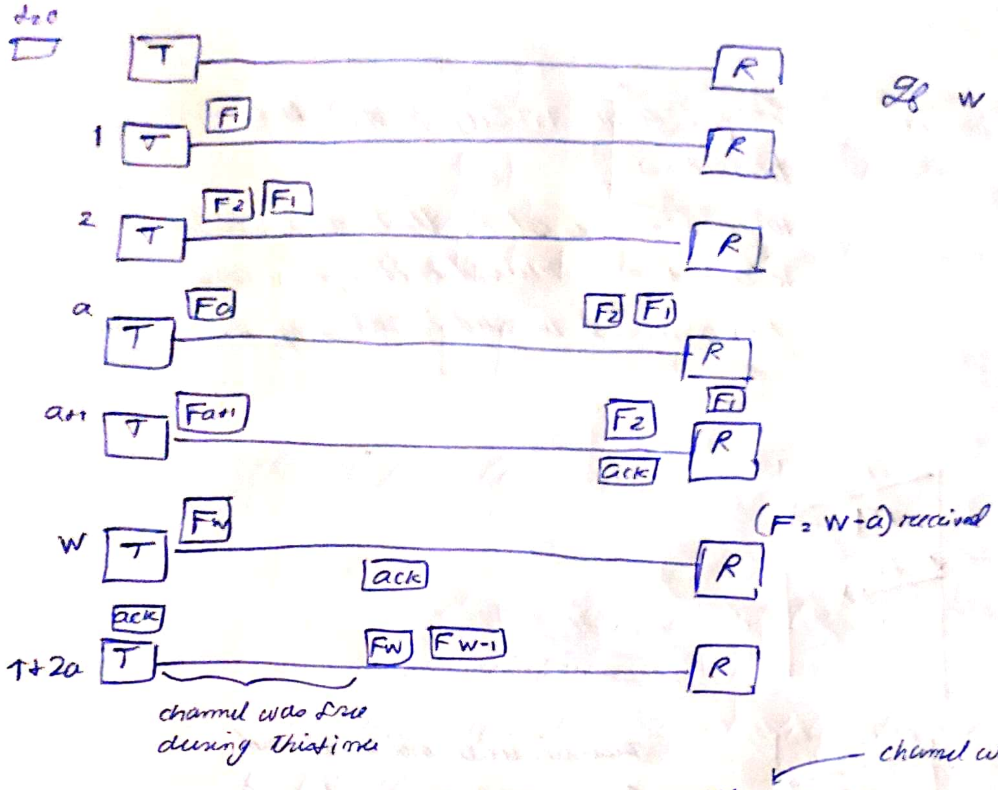
channel was busy during W time

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

29/8/19

* Error control in Noisy channel

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

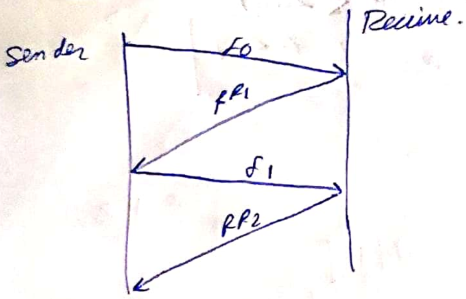
1. Frame Damaged $\xrightarrow{\quad}$ Frame error correction
   measures → Retransmission
2. Frame Lost $\xrightarrow{\text{measures.}}$ ↑

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

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

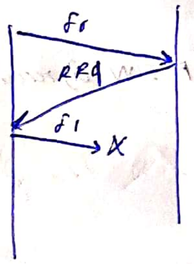
Automatic Repeat Request (ARQ)
- → Stop and wait (ARQ)
- → Go Back - N ARQ
- → Selective Reject ARQ

Stop and Wait.

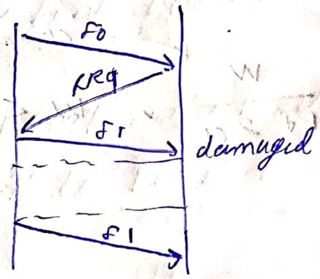


Every frame in stop & wait ARQ has a timer.
When frame is sent, the timer is started,
If ack is not received in time, time out happens and we need to retransmit.

i) Frame lost

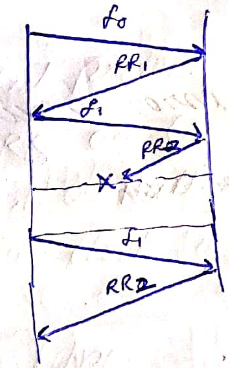


ii) Frame Damaged



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

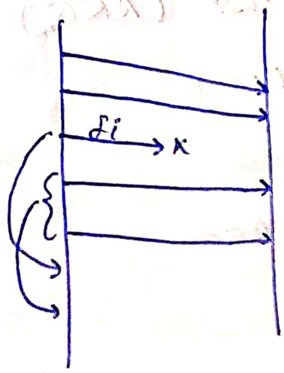
iii) Ack lost



retransmission.

iv) Ack damaged. → retransmission.

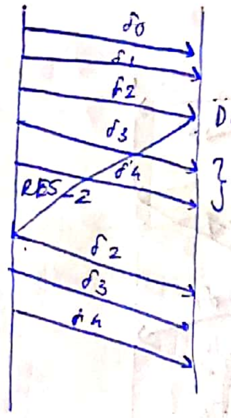
Go Back N ARQ



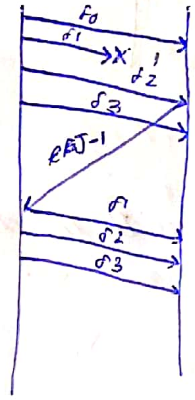
REJ - i

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

a> Frame damaged.

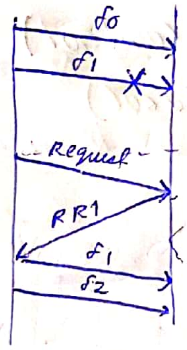


b> Frame lost



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

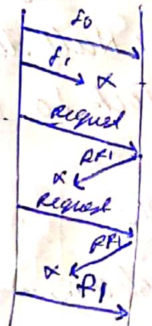
when no additional frames have not been transmitted



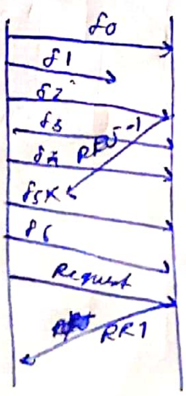
sender send request on the basis of timer.

c> Positive ACK (RR) lost

~~d> Negative ACK REJ lost.~~



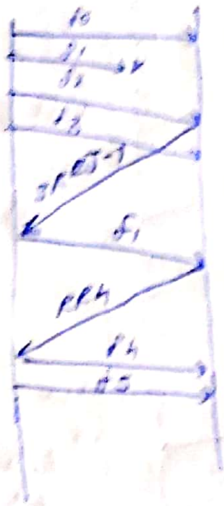
d> Negative ACK REJ lost



Scanned by CamScanner

Selective Reject ARQ

SREJ - 1



* Piggybacking

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.

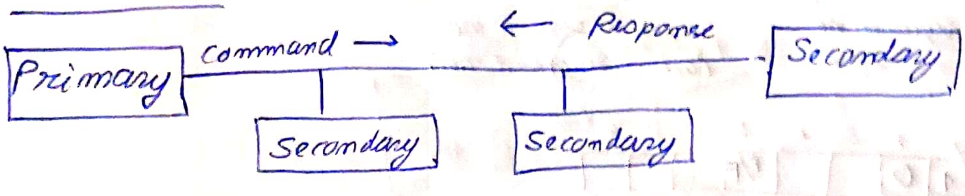
HDLC station types

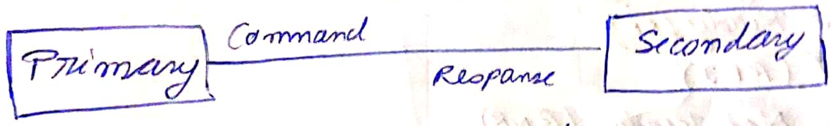
1. Primary stations → initiate the communication means
2. Secondary stations – act in response to primary station
3. Combined station.

Scanned by CamScanner

HDLC Link configuration:

Unbalanced.

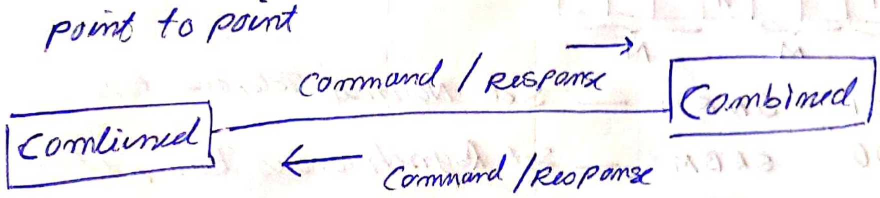




point to point.

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
8 bit	8 bit extendable	8 bit.		CRC	8 bit

I Frame:

1	2	3	4	5	6	7	8
0				P/F			

$\underbrace{2\ 3\ 4}_{N(S)}$ $\underbrace{6\ 7\ 8}_{N(R)}$

P → Poll 1
F → Final 0

N(S) Send sequence no:
N(R) Receive sequence no: (acknowledgement no.)

S Frame.

1	2	3	4	5	6	7	8
1	0			P/F			

$\underbrace{6\ 7\ 8}_{N(R)}$

00 → Receive Ready (RR)
01 → Reject (REJ)
10 → Receive Not Ready (RNR)
11 → Selective Reject (SREJ)

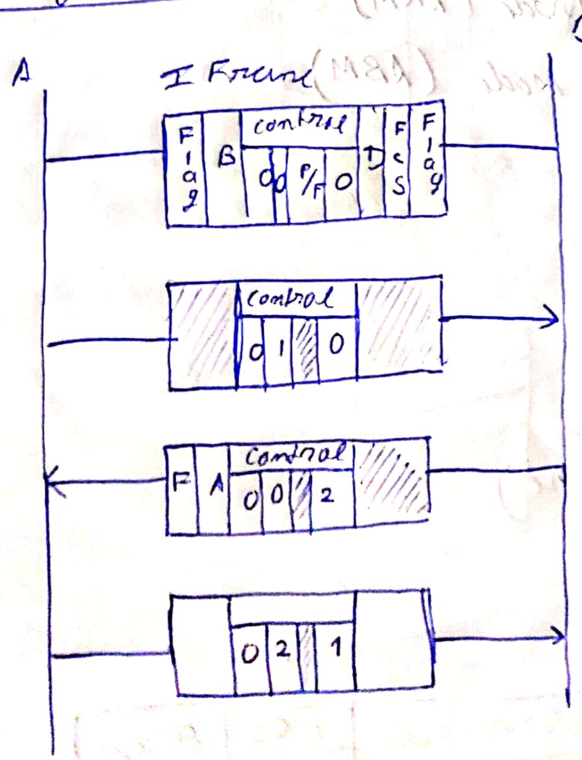
U Frame

1	2	3	4	5	6	7	8
1	1			P/F			

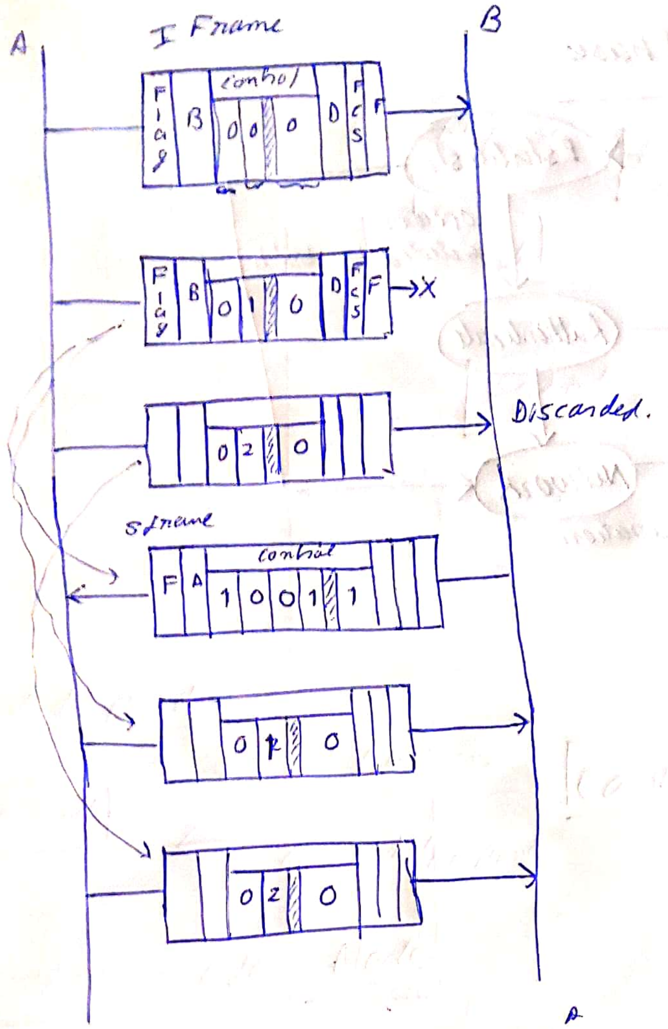
$\underbrace{3\ 4}_{M}$ $\underbrace{6\ 7\ 8}_{M}$

00 001 SNRM — Set Normal Response Mode
11 100 SABM — Set Asynchronous Balanced Mode.
00 110 UA → Unnumbered Ack
00 010 DISC → Disconnect.

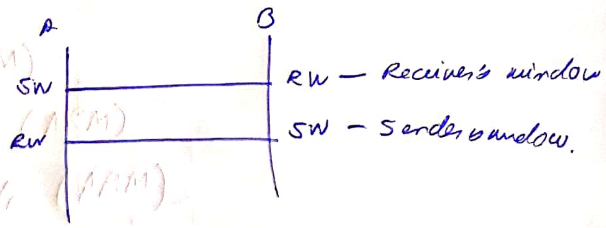
Piggybacking of HDLC Frame without error



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
	11111111	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 Phases