* Multiplexing process:

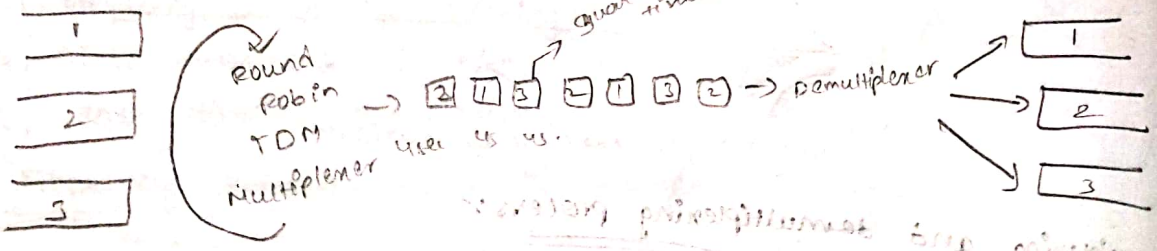
* Multiplexing is done at the sender side.
* In FDM signals generated by each sending device are modulated using different carrier frequencies.
* These modulated signals are combined into a single composite signal.

* Demultiplexing process:-

* Demultiplexing is done at the receiver side.
* In this process a series of filters are used to decompose the multiplexed signal into its component signal.
* The individual signals are passed through a modulator that separates them from carrier signals and transmits them to the output devices.

* Time division Multiplexing:

* TDM total time available is divided among multiple users.
* Each user is alloted a particular time interval called time slot (or) time slice during which the user can transmit the data.
* These time slots are separated by small intervals called as guard time (unused time slot).



* TDM is of two types
  1.) Synchronous TDM
  2.) Asynchronous TDM

1.) Synchronous TDM:- Each device is given same time slot to transmit the data irrespective of the fact that the device has (many) any data to transmit (or) not.

2.) Asynchronous TDM:- In this TDM, the time slots are not fixed slots are flexible (or) variable.

* Code division

* It is widely
* It is a combi
speed spectrum
* It is also k
* In, CDM ea
sequence.
* Transmission
  * If the s
  its chip s
  * If the s
  negation

Ex:- Consider th

* If 'A' needs
'A' → (-
A → '1'

* If 'A' need
'0'

* Properties o

Consider two
pair wise o

$S \cdot \bar{T} =$
$S \cdot T =$
$\bar{S} \cdot T =$
$S \cdot S =$
$S \cdot \bar{S} =$

Consider 4 s

A = (-1
B = (-1
C = (-1
D = (-1

* Code division Multiplexing :-

* It is widely used in 2G and 3G wireless communication.
* It is a combination of analog to digital conversion to and speed spectrum technology.
* It is also known as CDMA (code division multiple access).
* In, CDM each station is given a code called as chip sequence.
* Transmission occurs in the following way.
  * If the station needs to transmit 1 - bit then it sends its chip sequence.
  * If the station is to transmit 0 - bit then it sends of its negation of chip sequence.

Ex:- Consider the station 'A' and chip sequence.

* If 'A' needs to transmit 1- bit then it sends.

'A' → (-1 -1 -1 +1 +1 -1 +1 +1)

A → '1' → (-1 -1 -1 +1 +1 -1 +1 +1).

* If 'A' needs to transmit 0 bit then,

'0' → (+1 +1 +1 -1 -1 +1 -1 -1).

* Properties of chip sequences :-

Consider two distinct chip sequences S and T. If they are pair wise orthogonal then

$S \cdot \bar{T} = 0$

$S \cdot T = 0$

$\bar{S} \cdot T = 0$

$S \cdot S = 1$

$S \cdot \bar{S} = -1$

Consider 4 stations A, B, C, D.

A = (-1 -1 -1 +1 +1 -1 +1 +1)

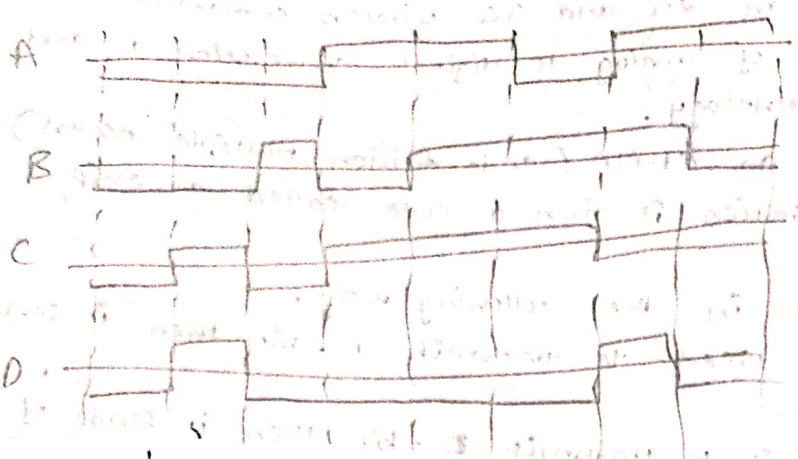
B = (-1 -1 +1 -1 +1 +1 +1 -1)

C = (-1 +1 -1 +1 +1 +1 -1 -1)

D = (-1 +1 -1 -1 -1 -1 +1 -1)

* Signals they represent

-1 - down
0 - Middle
1 - up



$S_1 = \bar{C}$ (-1 +1 -1 +1 +1 +1 -1 -1)

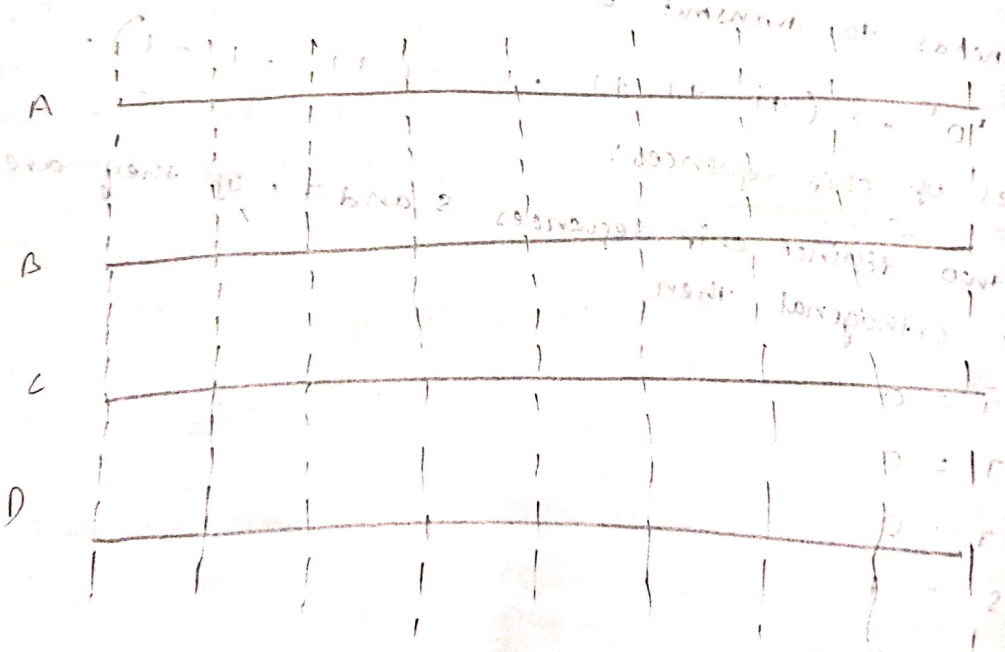
$S_2 = \bar{B} + \bar{C}$ (-1 -1 +1 -1 +1 +1 +1 -1)

$S_3 = \bar{A} + \bar{B}$

$S_4 = \bar{A} + \bar{B} + C$

$S_5 = \bar{A} + \bar{B} + \bar{C} + \bar{D}$

$S_6 = \bar{A} + \bar{B} + C + \bar{D}$



Example:

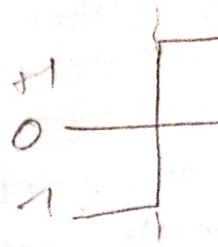
$S = A + \bar{B}$

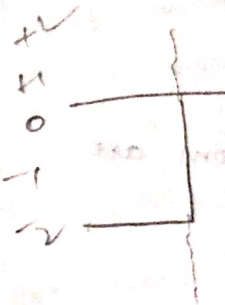
$S \cdot C = CA$

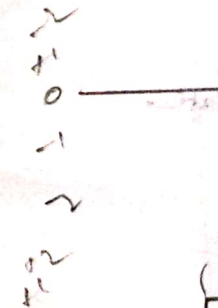
$= A \cdot C$

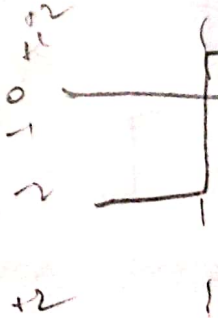
$= 0$

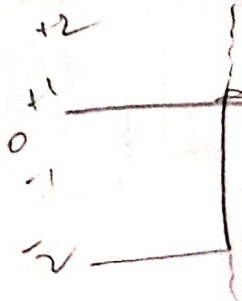
$= 1$











Example:

$S = A + \bar{B} + C$

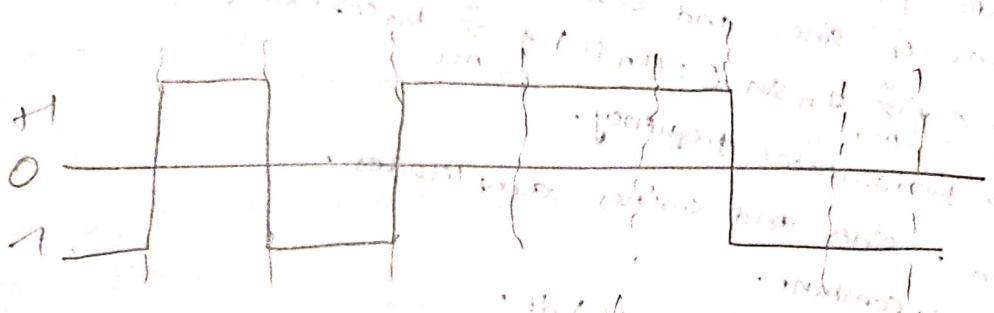
$S \cdot C = (A + \bar{B} + C) \cdot C$

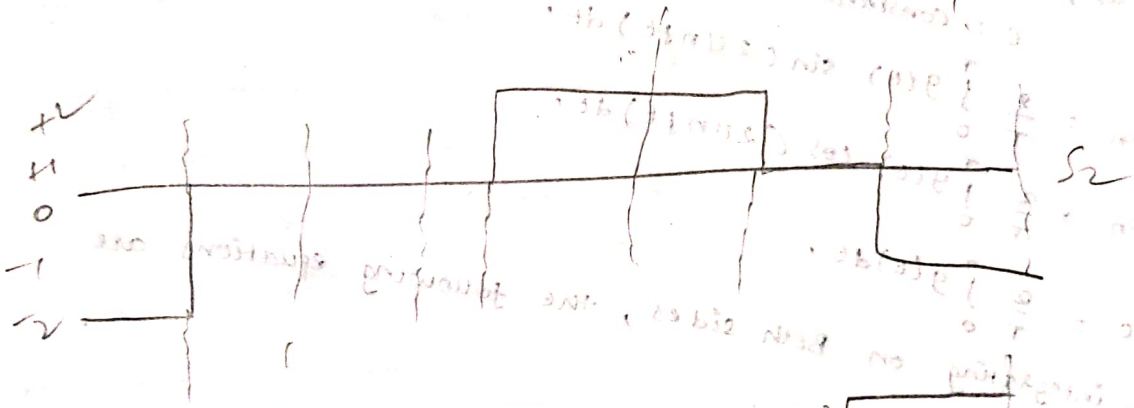
$= A \cdot C + \bar{B} \cdot C + C \cdot C$

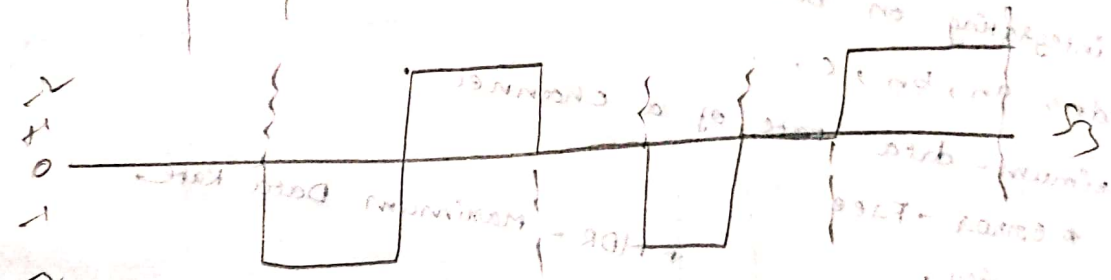
$= 0 + 0 + 1$

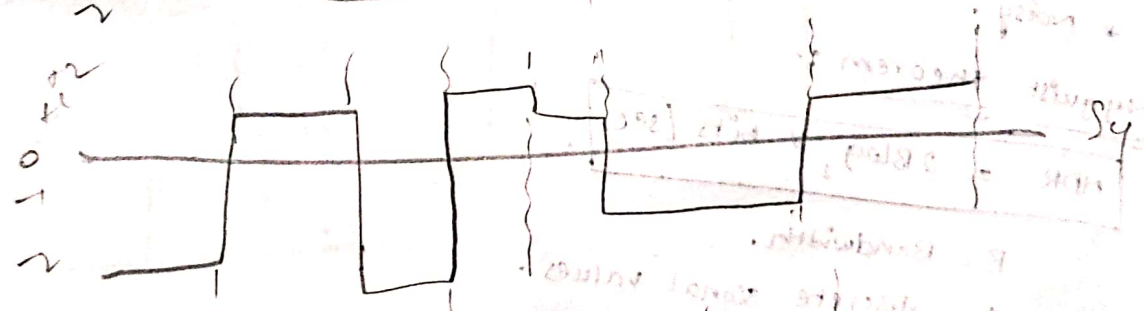
$= 1$.

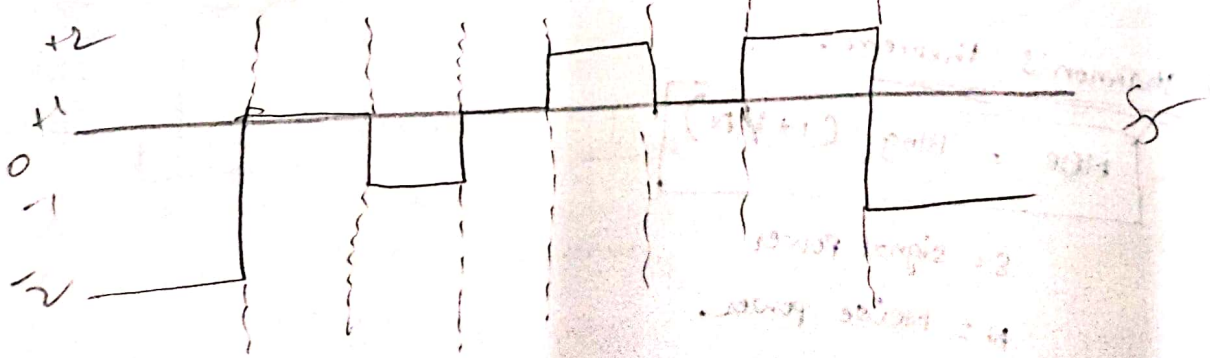
transmitting











28/7/22 * Fourier Analysis :- * To analyze the behaviour of the signal the following concepts are used.

1.) Fourier Analysis

2.) Band-width limited signals.

* A french mathematician Jean-Baptiste Fourier proved that periodic function g(t) with period 'T' can be constructed as the sum of sines and cosines.

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi n f t) + \sum_{n=1}^{\infty} b_n \cos(2\pi n f t).$$

$f = \frac{1}{T}$ is fundamental frequency.

* a_n, b_n = sines and cosines amplitudes.

c = constant.

$$a_n = \frac{2}{T}\int_0^T g(t) \sin(2\pi n f t)\, dt.$$

$$b_n = \frac{2}{T}\int_0^T g(t) \cos(2\pi n f t)\, dt.$$

$$c = \frac{2}{T}\int_0^T g(t)\, dt.$$

* By integrating on Both sides, the following equations are derived as a_n, b_n, c.

* Maximum-data rate of a channel.

* Error-Free

* Noisy.

* MDR - Maximum Data Rate.

* 1.) Nyquist theorem :-

$$MDR = 2B\log_2 V \text{ bits/sec}.$$

B = Bandwidth.

V = discrete signal values.

2.) Shannon's theorem :-

$$MDR = B\log_2(1+S/N)$$

S = signal power

N = Noise power.

* Bandwidth limit

* data → sign

* the range of a signal is cal

B = f_{max}

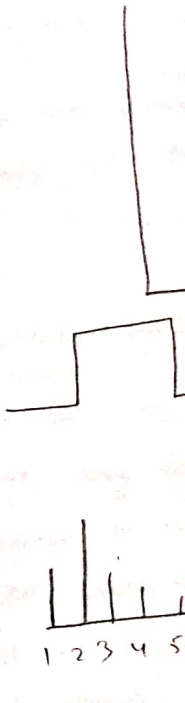
* A signal is amplitude of (cuts) crosses

* Harmonics :- Th frequency for th

Ex :- signal

If Fundam 1st harmo 2nd harm 3rd harm

Ex :- Data =



* **Bandwidth Limited Signals :-**

* data → signals → range of frequency.
* the range of frequencies that are used for transmitting a signal is called as Band width.

$$B = f_{max} - f_{min}$$

* A signal is called Bandwidth limited signal when the amplitude of the signal goes to zero whenever its frequency (causes) crosses allowable limits.

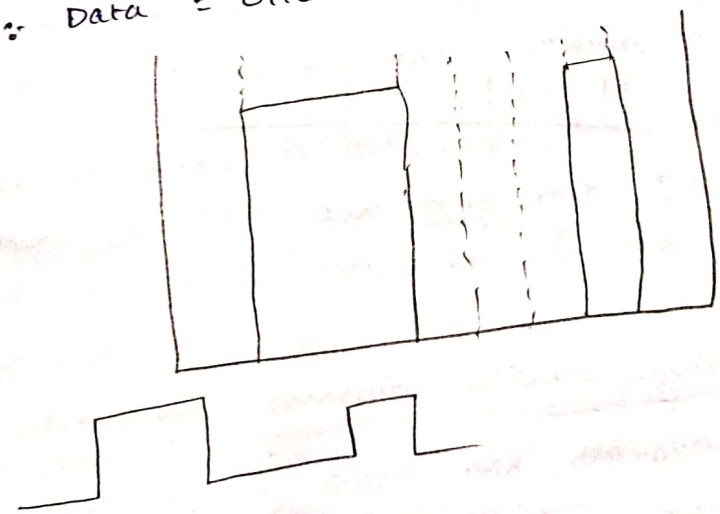
* **Harmonics :-** They are voltages (or) currents that operate at a frequency for the purpose of data transmission.

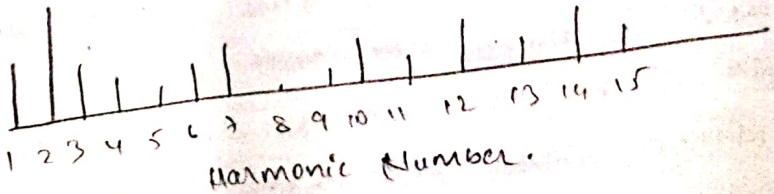
Ex:- signal → voltage
Current.

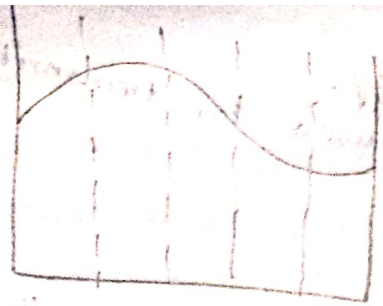
If Fundamental Frequency = 50 Hz.

1st harmonic = 50 → lowest.
2nd harmonic = 2(ff) ⇒ 100
3rd harmonic = 3(ff) = 150

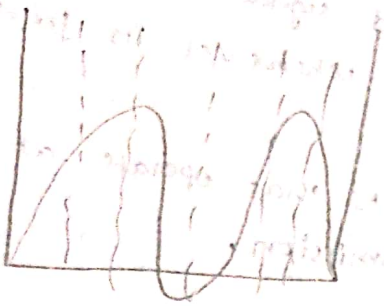
Ex:- Data = 01100010.



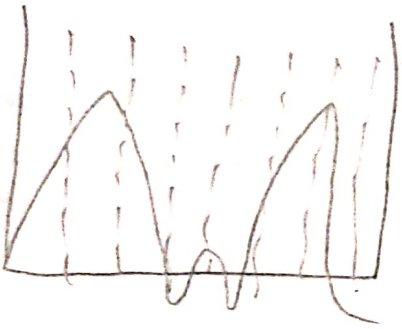




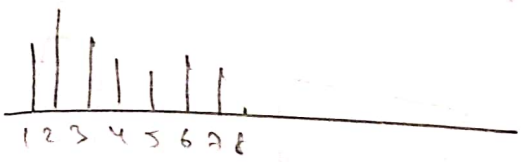
1 Harmonic



2 Harmonics.



4 Harmonics.



8 harmonics.

29/7/23

* Data link
* Services
* Framing
* Error co
* Flow co
* Services pr
1.) UnAcknow
2.) Acknowl
3.) Acknowl
1) UnAcknow
* It consist destination them. E
* This servi
2.) Acknowle
* Each an
* So, the lost.
* If the amount of
* This serv Ex:- wife.
3.) Acknowle
* In this before an
* Each
* It gu and all
* This se

29/7/22

UNIT-2 DATA LINK LAYER.

* Data link layer design issues :-

* Services provided to the Network layer.
* Framing
* Error control
* Flow control.

* Services provided to the Network layer :-

1.) UnAcknowledged, Connectionless service.
2.) Acknowledged Connectionless service.
3.) Acknowledged Connection-Oriented service.

1) UnAcknowledged connectionless service :-

* It consists of source machine, sending independent frames to destination machine without having the destination, acknowledge them. Ex: Ethernet.
* This service is used when error rate is low.

2.) Acknowledged connectionless service :-

* Each and every frame is individually acknowledged.
* So, the sender will know whether a frame is delivered or) lost.
* If the frame is lost, the sender waits for a specified amount of time and retransmits the frame.
* This service is useful in wire-less

Ex:- wifi.

3.) Acknowledged connection-oriented service :-

* In this service, source and destination establish a connection before any data is transfer.
* Each frame send over the connection is numbered.
* It guarentees that each frame is received exactly once, and all the frames are received in right order.
* This service is used over satellite channels or long-distance telephone circuits.

* Error control :-

* To ensure reliable delivery receiver sends special control frames such as positive (or) negative acknowledgment.
* If the sender receives positive acknowledgment it means that frames has transmitted safely.
* If the sender receiver negative acknowledgment it means that frames is lost and sender must retransmit the frame.
* If the (Sender) acknowlegment frame is lost sender indefinetly waits for acknowledgment and may hang over.
* If the timer is set to the timer interval required for the data to reach the destination and the acknowledg -ment to reach the source.
* If the timer expires, it means that either the frame is lost (or) acknowledgment is lost.
* Sequence numbers are used to distingush b/w original frame and retransmit frame.

* Flow control :-

* Flow is controlled in 2 ways,
1.) Feed-back based flow control.
2.) Rate-based flow control.

1.) Feed-back based flow control :-

* In this the receiver sends some feedback to the sender this feed-back includes.
i, when to send the data.
ii, How much data the sender can transmit.
iii, At which date the data can be transmitted.

2.) Rate-based flow control :-

* In this there is built-in mechanism that limits the rate at which senders can transmit the data.

* Framing :-

* Byte count
* flag bytes with byte stuffing.

* Flag bits
* Physical
* Byte count :
* this metho
no. of bytes
* when DLL
count, it wi
hence where
* Problem
only transmi

Ex :-

5	1	2	3

Fra

*If
wi
* Flag
and
* where
data.
* one
called
* The D
before
is called

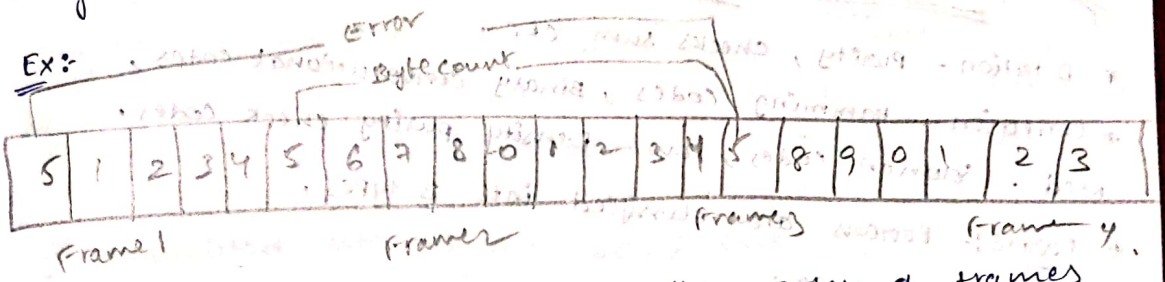
FLAG

* Flag bits with bit stuffing.
* Physical layer coding violations.

* Byte count :-

* this method uses a field in the header to specify the no. of bytes in the frame.
* when DLL at the destination identifies the bytes count, it will understand how many bytes will follow and hence where the end of the frame is
* Problem occurs if the bytecount is changed by only transmission.

Ex:-

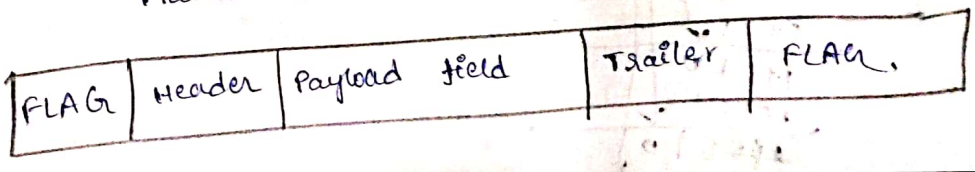


*If 5 is changed to 7 due to error then order of frames will be changed.

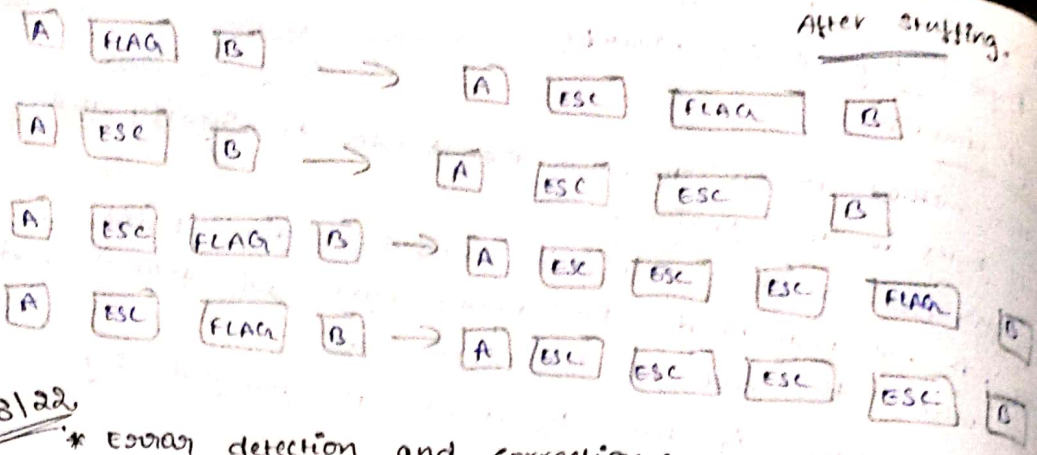
* Flag bytes with byte stuffing :-

* In this method a special type called flag byte is used as both starting and ending delimiter of each frame.
* Two consecutive flag bytes indicates the end of one frame and start of next frame.
* where may be a situation in which flag byte occurs in the data.
* one way to solve this problem is to insert a special byte called SK byte, Just before each flag byte in the data.
* The DLL on the receiving and removes SK bytes before giving the data to network layer. This technique is called byte stuffing.

Frame format using byte stuffing



Original bytes



4/8/22

* Error detection and correction :-

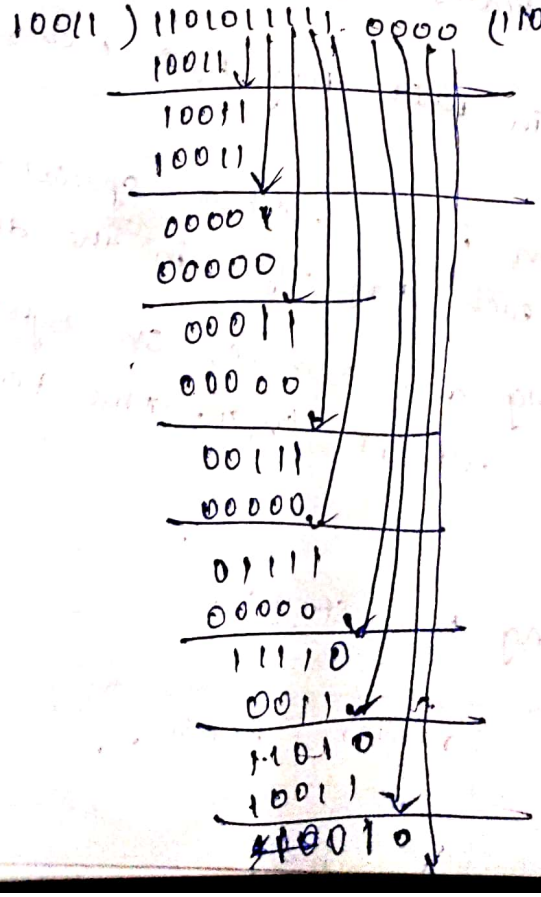
* Detection - Parity, Checks sum CRC.
* Correction - Hamming codes, Binary convolutional codes, Reed - Solomon codes, Low - Density parity check codes.
* Errors :- Errors are classified into 3 types.

1.) Single bit error:
2.) Multiple - bit error
3.) Burst error.

CRC :- Cyclic Redundancy check.

F(x) - Data.

G(x) - Generator polynomial.



Scanned with CamScanner

```
10011 |
-----
00010
00000
-----
00010
```

ii) $M(x) = x^6 + x^5$

$G(x) = x^3 + x + 1$.

$M(x) = x^5 + x^4 + x + 1$

$G(x) = x^4 + x + 1$.

* Parity:-

* Parity is of 2 types.

1.) even parity.

2.) odd parity.

original data	even parity	Transmitted data	odd Priority	Transmitted data
1.) 1011010	0	10110100	1	10110101
2.) 100101	1	1001011	0	10010 10

→ 1.) If transmitted data is 10111100. - even parity '1'.

Error is detected.

```
1 0 0 1 1 0 0 1
1 1 1 0 0 0 1 0
---------------
1 0 1 1 1 0 0 1
```

Ex:-

10011001	11100010	00100100	10000100
1	2	3	4

```
1 0 1 1 0 0 1 1
1 0 1 0 1 0 1 1
---------------
1 0 0 1 1 0 0 1
1 1 1 0 0 0 1 0
---------------
1 1 1 1 1 1 0 1 1
                1
---------------
0 1 1 1 1 1 0 0
0 0 1 0 0 1 0 0
---------------
1 0 1 0 0 0 0 0
1 0 0 0 0 1 0 0
---------------
1 0 0 1 0 0 1 0 0
```

0 0 1 0 0 1 0 1

Check Sum: 1's Compliment

= 11011010.

Receiver side:

```
  0 0 1 0 0 1 0 1
  1 1 0 1 1 0 1 0
-----------------
  1 1 1 1 1 1 1 1
```

Computed 0000 0000

Ex: 10110011 10101011 01011010 11010101

```
  1 0 1 1 0 0 1 1
  1 0 1 0 1 0 1 1
-----------------
1 1 0 1 1 1 1 0
              1
-----------------
  1 0 1 1 1 1 1 1
  0 1 0 1 1 0 1 0
```

```
  1 0 1 1 0 0 1 1 → (1)
  1 0 1 0 1 0 1 1 → (2)
-----------------
1 0 1 0 1 1 1 1 0
            1
-----------------
  0 1 0 1 1 1 1 1
  0 1 0 1 1 0 1 0 → (3)
-----------------
  1 0 1 1 1 0 0 1
```

```
  1 0 1 1 1 0 0 1
  1 1 0 1 0 1 0 1 → (4)
-----------------
1 1 0 0 0 1 1 1 0
              1
-----------------
  1 0 0 0 1 1 1 1
```

1's comp 0 1 1 1 0 0 0 0

At receiver side.

```
  1 0 0 0 1 1 1 1
  0 1 1 1 0 0 0 0
-----------------
  1 1 1 1 1 1 1 1
```

1's comp 0 0 0 0 0 0 0 0

(No error)

M(x) = x^5 + x

G(x) = x^4 +

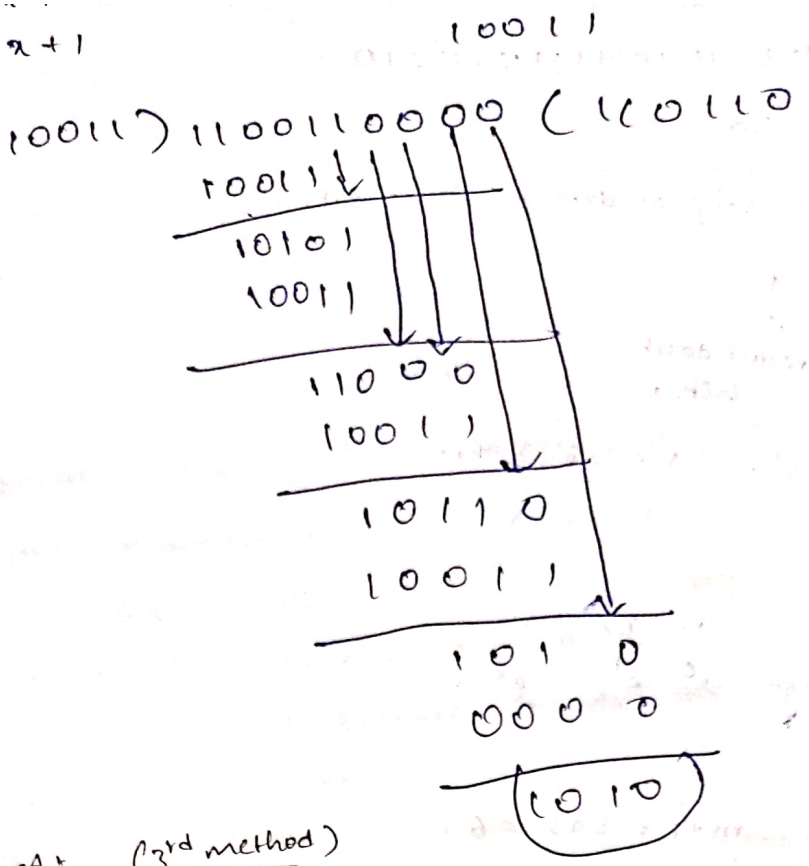
11/8/22

Framing meth

* Flag bits wi
* In this
01111110.
* It is used
frame.
* Two cons
and start
* There
in data.
* one way
5 consecuti
* the D
bits before
* This te
Ex: on

M(x) =

G(x) = $x^4 + x + 1$



11/8/22

Framing method: (3rd method)

* Flag bits with bit stuffing :-

* In this method a special byte called flag byte which is 01111110.

* It is used as both sarting and ending delimiter of each frame.

* Two consecutive 01111110 indicates the end of one frame and start of next frame.

* There may be a situation in which 01111110 occurs in data.

* one way to solve this problem is to insert '0' after 5 consecutive 1's in the data.

* the DLL on the receiving side removes all the zero bits before giving the data.

* This technique is called bit stuffing.

Ex: original data

0110 11111 11111 11111 0010

nsmitted data.

01101111 01111011111001000 .

* Haming code :-

Code word - original data + some bits.

→ m + r

↙ message bits. ↓ redundant bits.

$m+r+1 \leq 2^r$. $r = 1, 2, 3, 4, \ldots$

$4 + r \leq 2^r$

$5 \leq 2^r$

$6 \leq 4^x$

$7 \leq 8$. ✓

$r = 3$

r_1 r_2 r_3

2^0 2^1 2^2

code word = $m+r = 3+3 = 6$.

1 2 3 4 5 6

r_1	r_2	m_1	r_3	m_2	m_3
2^0	2^1	2^1+1	2^2	$1+4$	$2+4$

$r_1 = M_1 \text{ XOR } M_2 = 1 \text{ XOR } 1 = 0$

2^0 $r_1 = 0$.

$r_2 = M_1 \text{ XOR } M_3 = 1 \text{ XOR } 0 = 1$

2^1 $r_2 = 1$.

$r_3 = M_2 \text{ XOR } M_3 = 1 \text{ XOR } 0 = 1$

2^2 $r_3 = 1$.

12/8/22

* Elementary Data Link Control protocols :

1) Unrestricted simplex protocol.
2) Simplex stop-and-wait protocol for error-free channel.
3) Simplex stop-and-wait protocol for Noisy channel.

1.) unrestric
* This pro
1.) Data
2.) Both
always
3.) Proces
4.) Infinit
5.) Comm
6.) No - s
* The o
the data
* This pro
error cont
2.) Simplex
* The com
* Data
* In this
receives
back to
* After
gment
* Protocol
for an
are ca
3.) Simplex
* In thi
* Frame
* For th
following
1.) Error

1.) unrestricted simplex protocol :-

* This protocol used if the following conditions satisfied.

1.) Data is transmitted in one direction only.

2.) Both transmitting and receiving network layers are always ready.

3.) Processing time can be ignored.

4.) Infinite buffer space is available.

5.) Communication channel never damages (or) looses frames.

6.) No-sequence numbers (or) acknowledments are used.

* The only working in this protocol is simply, sender sends the data and receiver receives the data.

* This protocol is unrealistic because it does not handle error control and flow control.

2.) Simplex stop-and-wait protocol for error-free channel :-

* The communication channel is error-free.

* Data traffic is half-duplex

* In this protocol, when the sender sends the data, receiver receives it and sends a dummy frame called acknowledgment back to the sender.

* After sending the frame the sender waits for the acknowledgment from the receiver.

* Protocols in which sender sends one frame and waits for an acknowledgment before proceeding to the next frame are called stop and wait protocols.

3.) Simplex stop-and-wait protocol for noisy channel :-

* In this protocol communication channel is noisy channel.

* Frames may be either damaged (or) lost completely.

* For that purpose, errors should be handled through the following methods.

1.) Error detection techniques.

2.) Error correction methods (Framing boats).

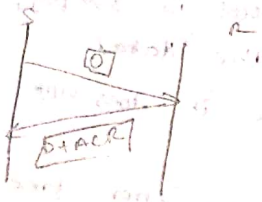
3.) Positive or) negative acknoledgment, timers, sequence numb

4.) Protocols in which sender waits for positive acknowledgment before advancing the next data are called ARQ. (Automa Repeat Request)

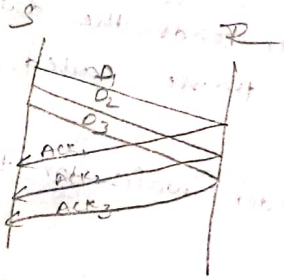
* Sliding windows protocol :-

i)

* Piggy backing :- when a dataframe arrives instead of immedia sending a separate acknowledgment waights until the next frame, then the acknowledgment is attach to the outgoing data frame from the receiver.



ii) Pipelining :- It is a technique in which multiple requests are sent at a time without waiting for the corresponding the individual responses.



* There are 3 types of sliding window protocol.

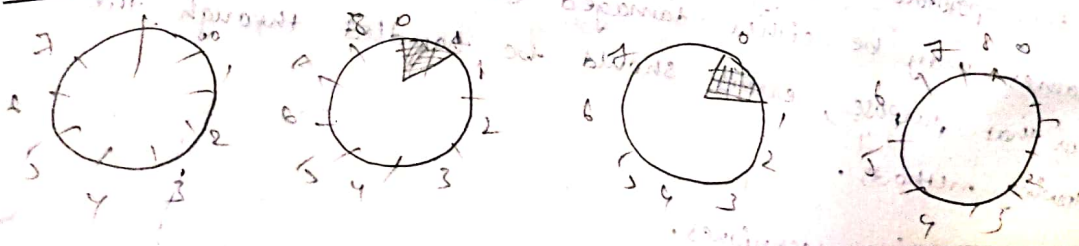
1.) one-bit sliding window protocol.

2.) A protocol using Go-Back-N.

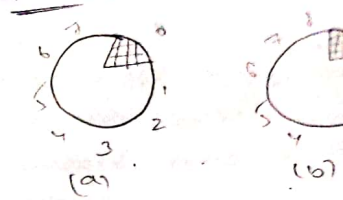
3.) A protocol using selective repeat.

1.) One-bit sliding window protocol :-

Sender :-



Receiver :-



Sending window :- At

a set of sequence

it is allowed to se

Receiving window :- At

a set of frame it

a) Sender : Initially,

Receiver : waiting

b) Sender : It sends

Receiver : waiting

c) Sender : It is

frame

Receiver : Sends

next f

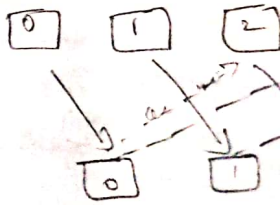
d) Sender : Data

numb

ideal.

Receiver : waiting

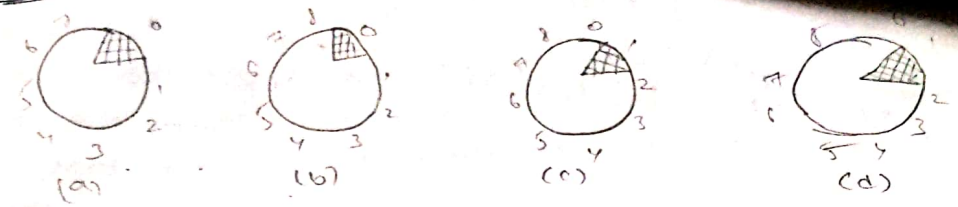
2) A protocol using



receiver

site is

Receiver:-



Sending window :- At any instant of time, sender maintains a set of sequence numbers corresponding to the frames it is allowed to send.

Receiving window:- At any instant of time, receiver maintains a set of frame it is allowed to receive.

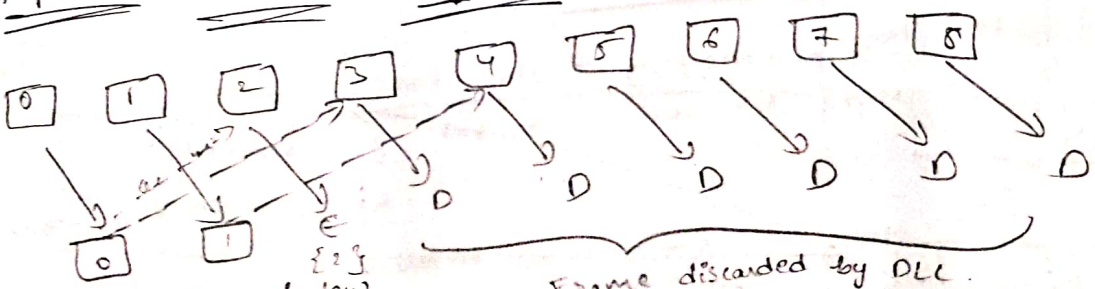
a) Sender: Initially, when data is not yet started,
Receiver: waiting for a frame of sequence number zero.

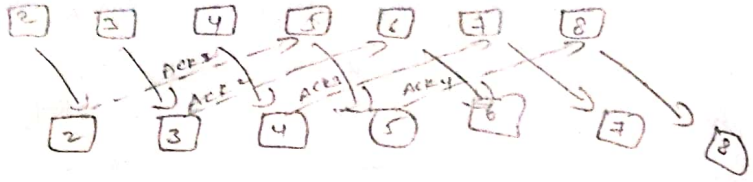
b) Sender: It sends a frame of sequence number zero.
Receiver: waiting for a frame of sequence number zero.

c) Sender: It is waiting for an acknowledgment for the frame of sequence number zero.
Receiver: Sends the acknowledgment and waits for the next frame of sequence number one.

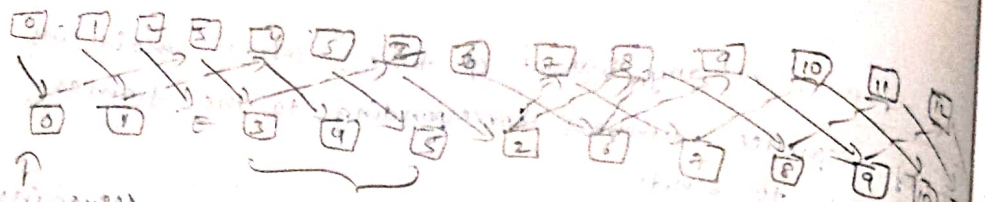
d) Sender: Data transmission of frame with sequence number zero is completed and sender is ideal.
Receiver: waiting for a frame of sequence number one.

2) A protocol using Go-Back-N :-





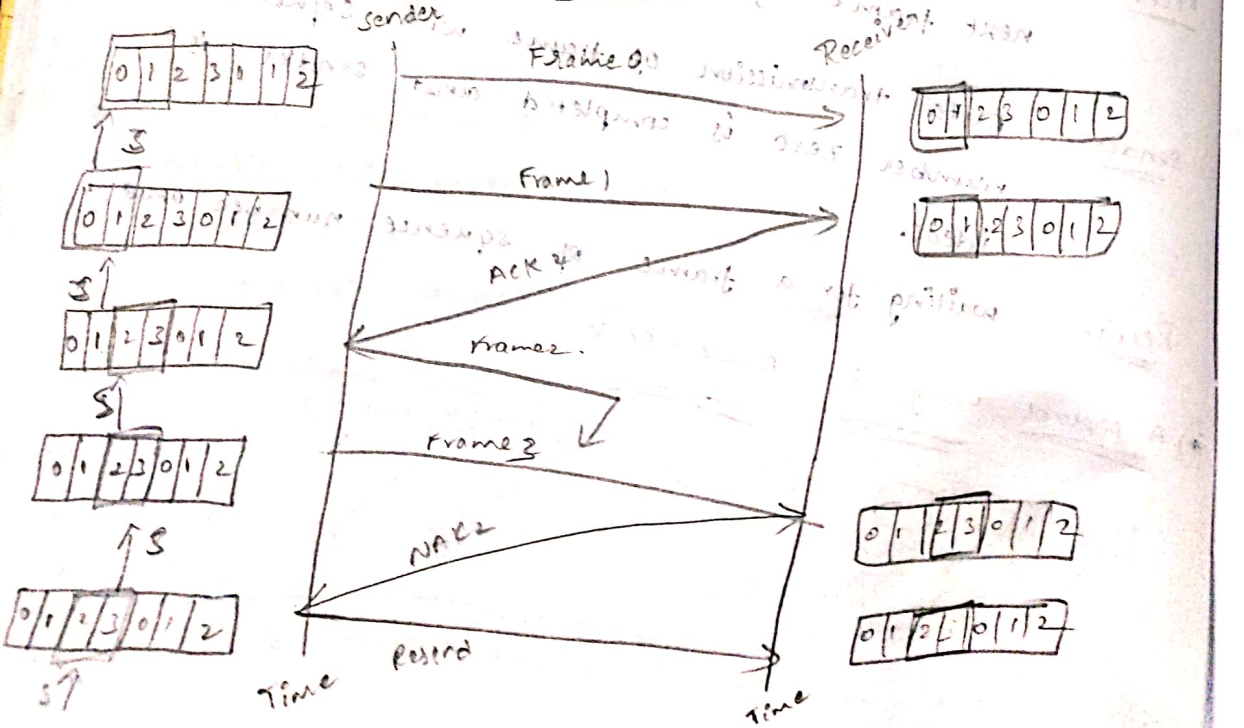
*



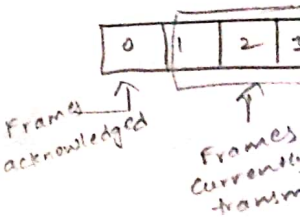
receiver's window size is large

* In this protocol sender re-transmits all the frames that are transmitted after the damage (or) lost frame.
* In this protocol the receiver do not store the frames received after the damage frame until the damaged frame is retransmitted.
* In the above diagram frame 2 is lost. So, all the frames followed by frame 2 are deleted.
* All the frames from frame 2 to 8 are re-transmitted.
* Go-Back-n Protocol peryorms pipe-lining.

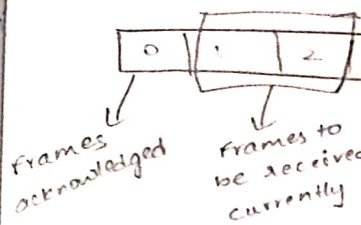
* A protocol using selective repeat :-



* This protocol re-tra
damaged.
* This protocol maintai
* In this protocol rec
damaged frame in
replaced.
* Sender window :-



* Receiver window :-



* Channel Allocation

* Channel allocation
1.) Static channel
2.) Dynamic channe

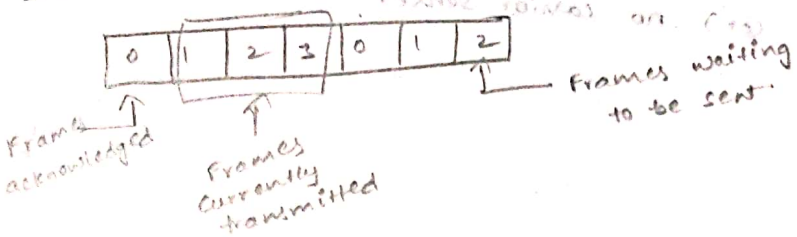
1.) Static channel Al

* If there are
into 'n' equal siz
one portion.
Ex:- FM radio.

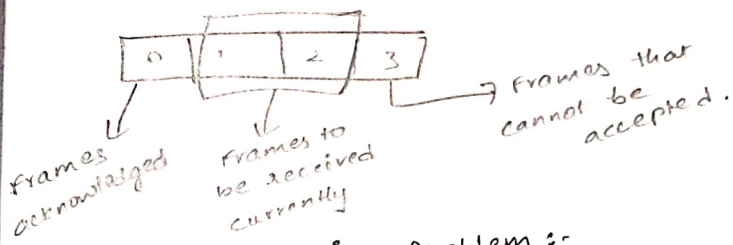
Dis-advantages :-

* If the channel
are currently tra
portions will be
* If more than
some of the us

* This protocol re-transmits only that fra... damaged.
* This protocol maintains a sender window and receiver window.
* In this protocol receiver stores the frames receive after the damaged frame in the buffer until the damaged frame is replaced.
* Sender window :-



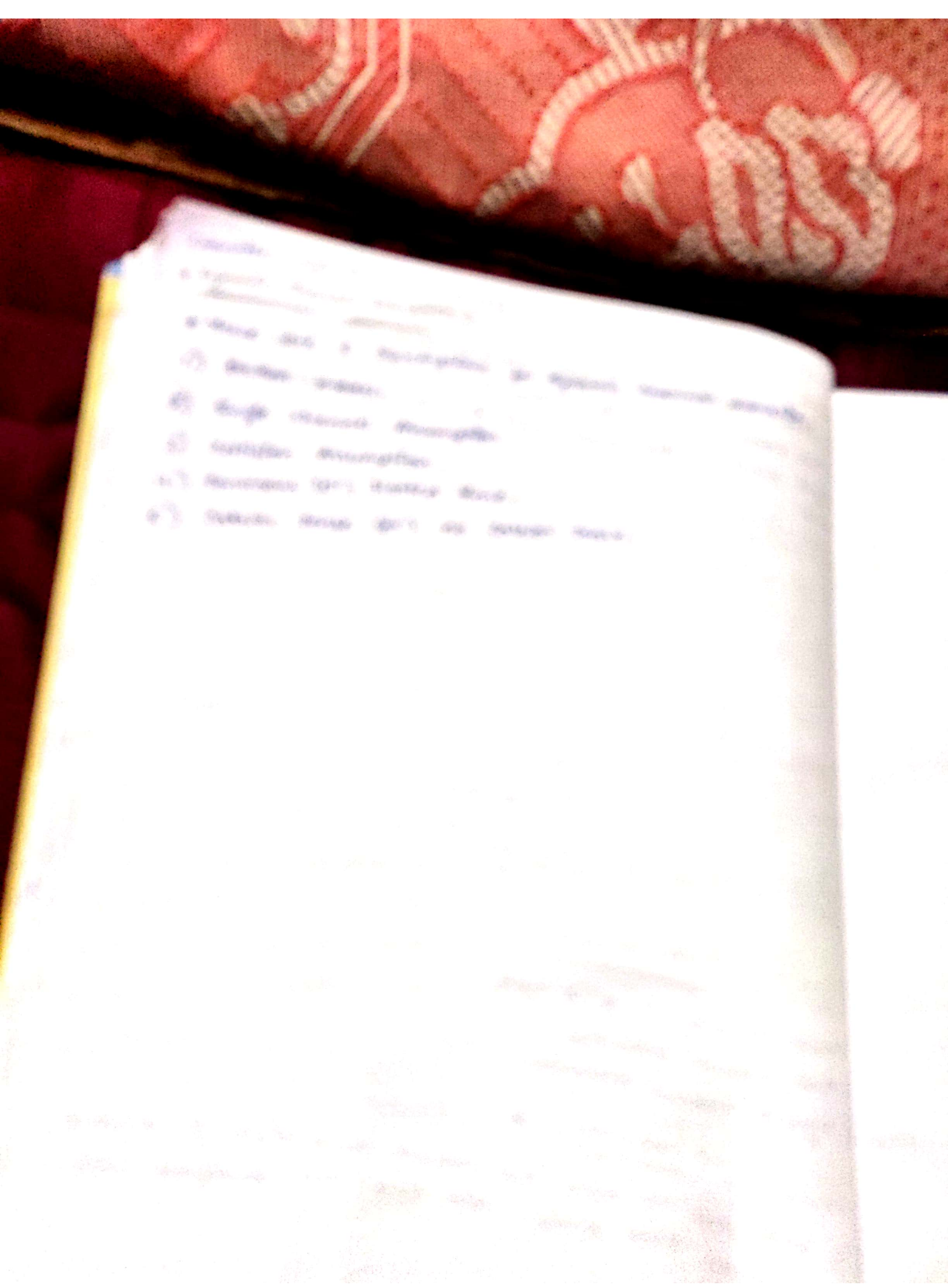
* Receiver window :-



* Channel Allocation Problem :-
* Channel allocation is of 2 types.
1.) Static channel Allocation.
2.) Dynamic channel Allocation.

1.) Static channel Allocation :- *
* If there are 'n' users the channel band-width is divided into 'n' equal sized portions with each user assaigned with one portion.
Ex:- FM radio.

Dis-advantages :-
* If the channel is divided into 5 portions. If only 3 users are currently transmitting the data, Then the other two portions will be wasted.
* If more than 5 users want to transmit the data then some of the users will be denied permition for accessing the



Channel.

* Dynamic channel Allocation :-

* There are 5 assumptions for dynamic channel allocation.

1.) Station model.
2.) single channel Assumption.
3.) collision Assumption.
4.) continous (or) slotted time.
5.) carrier sense (or) no carrior sense.