Shubhangi Khalche.

Chapter 4 Multiple Access

Data Link Layer

Data Link layer:
- LLC sublayer → Flow control, Error control.
- MAC sublayer → Multiple access resolution.

Multiple access protocols
- Random Access
  - → ALOHA
  - → CSMA
  - → CSMA/CD
  - → CSMA/CA
- Controlled access
  - → Reservation
  - → Polling
  - Token passing
- Channelization protocols
  - → FDMA
  - → TDMA
  - → CDMA

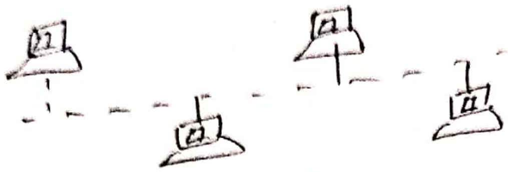
Random Access

- No scheduled time for a station to transmit
- No station is superior to another station.
- No prioritization among the stations, stations compete with one another to access the medium. That is why these methods are also called contention methods.
- If more than one station tries to send, there is an access conflict - collision - & the frames will be either destroyed or modified

ALOHA:

- Developed in 1970's for wireless (radio) LAN.
- W/L medium is shared among stations, So there are chances of collisions.

PURE ALOHA:



If more than one station transmits at a time then there are chances of collision, frames may be lost in medium or corrupted (error occurs).

So Pure ALOHA implements error control Mechanism i.e. every station transmits a frame, set a timer, waits for ack from Rx. If the ack isn't received within the timeout period of the timer, the frame is retransmitted.

- In Pure ALOHA, whenever the timeout period elapses, each station waits a random amount of time before resending its frame.
- This randomness helps to avoid more collisions. (First method)
- This random waiting time is called as the backoff time TB
- Pure ALOHA has a second method to prevent congesting the channel with retransmitted frames.

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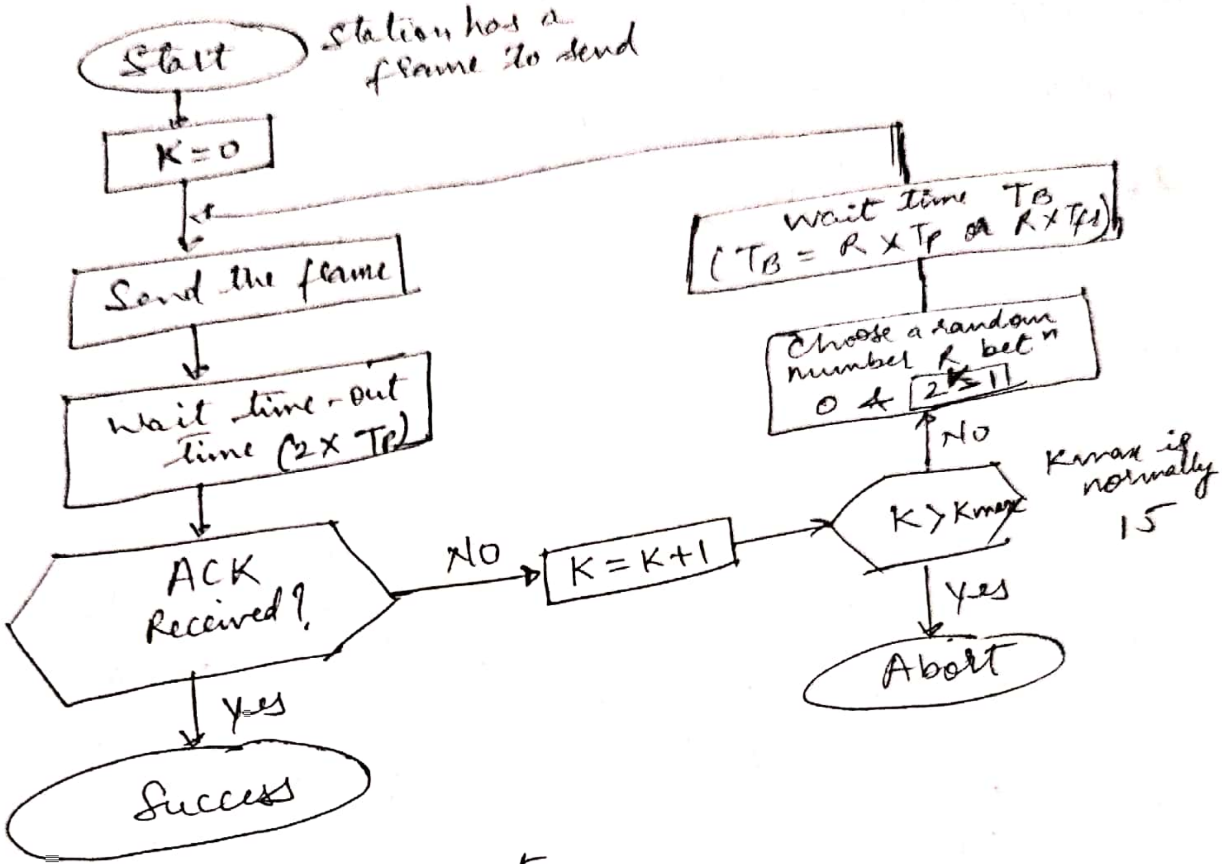
• After a maximum number of retransmission attempts Kmax, a station must give up & try later.



K = Number of attempts
Tp = Maximum propagation time
Tfr : Average transmission time for a frame
TB : Back-Off time.

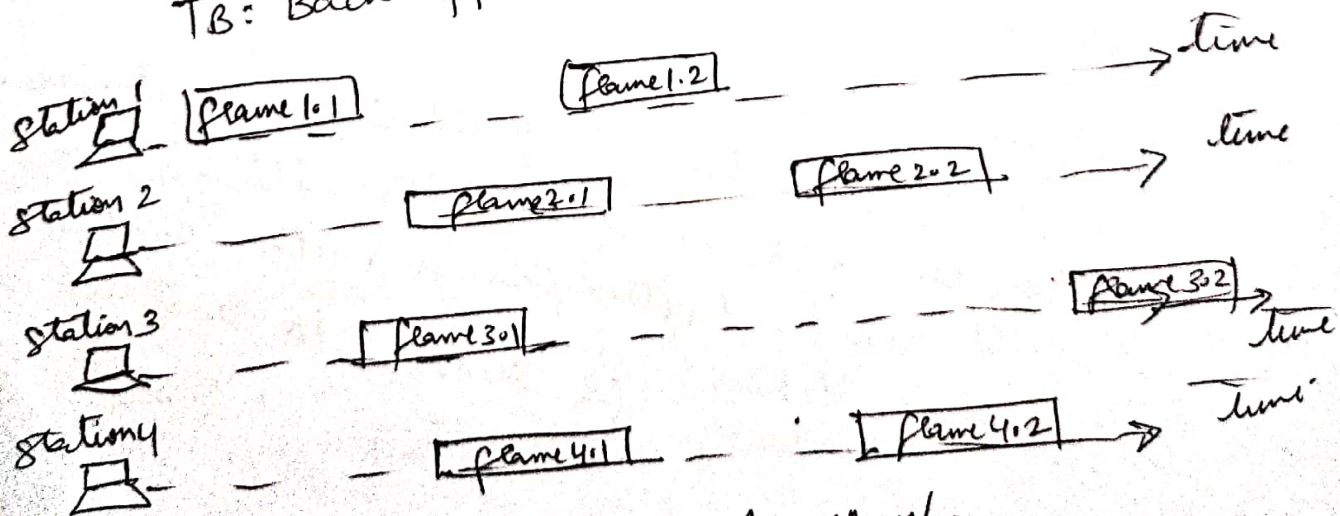


fig: frames in pure ALOHA n/w

- The timeout period is equal to the maximum possible round-trip propagation delay, which is twice the amount of time required to send a frame between the two most widely separated stations ($2 \times T_p$).

- The back-off time T_B is a random value that normally depends on K (the number of attempted unsuccessful transmissions).

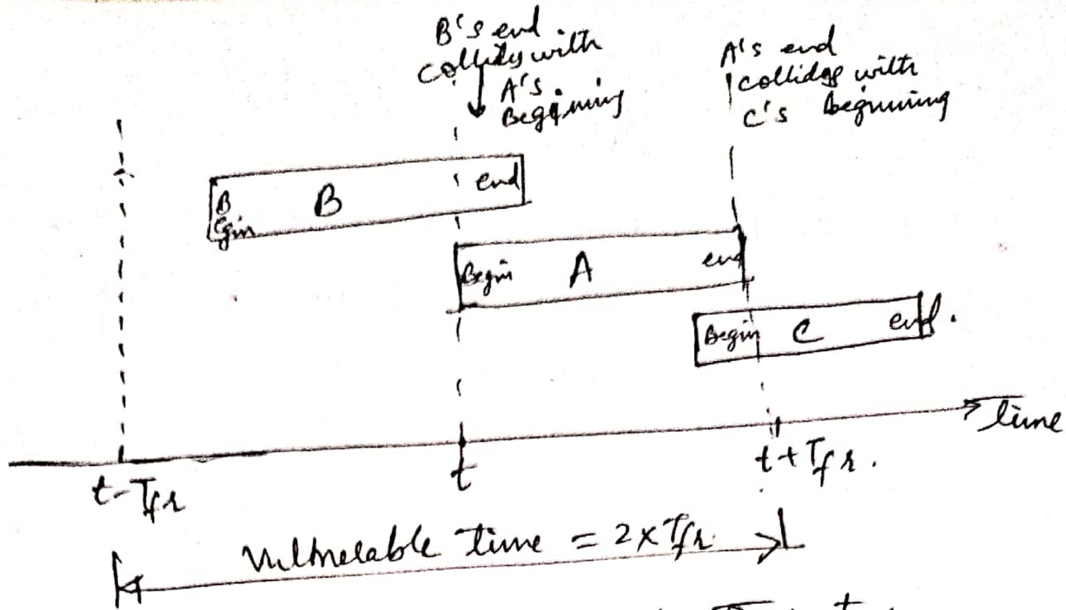
- The formula for T_B depends on the implementation.
- One common formula is the binary exponential back-off.
- In this method, for each transmission, a multiplier in the range 0 to $2^K - 1$ is chosen randomly & multiplied by T_p (max propagation time) or T_{fr} (average frame Tx^n time) to find T_B.

- The range of random number increases after each collision.

- The value of K_{max} is usually chosen as 15.

Vulnerable Time

- It is the time of possibility of collision.
- Let us assume that the stations send fixed-length frames with each frame taking T_{fr} seconds to send.



- Station A sends a frame at time t.
- Now imagine station B has already sent a frame between $t-T_{fr}$ & t.
- This leads to a collision between the frames from station A & station B.
- The end of B's frame collides with the beginning of A's frame.
- On the other hand, suppose that station C sends a frame between t & $t+T_{fr}$. Here, there is collision between frames from Station A & Station C.
- The beginning of C's frame collides with the end of A's frame.
- Thus the vulnerable time, during which a collision may occur in pure ALOHA is 2 times the frame transmission time.

Throughput of Pure ALOHA

- Let G be the average no of frames generated by the system during one frame transmission time
- Then it can be proved that the average no of successful transmissions for pure ALOHA is

$$S = G e^{-2G}$$

- The maximum throughput is

$$S_{max} = \frac{1}{2} e^{-2 \cdot 1/2} \quad \text{at } G = \frac{1}{2}$$

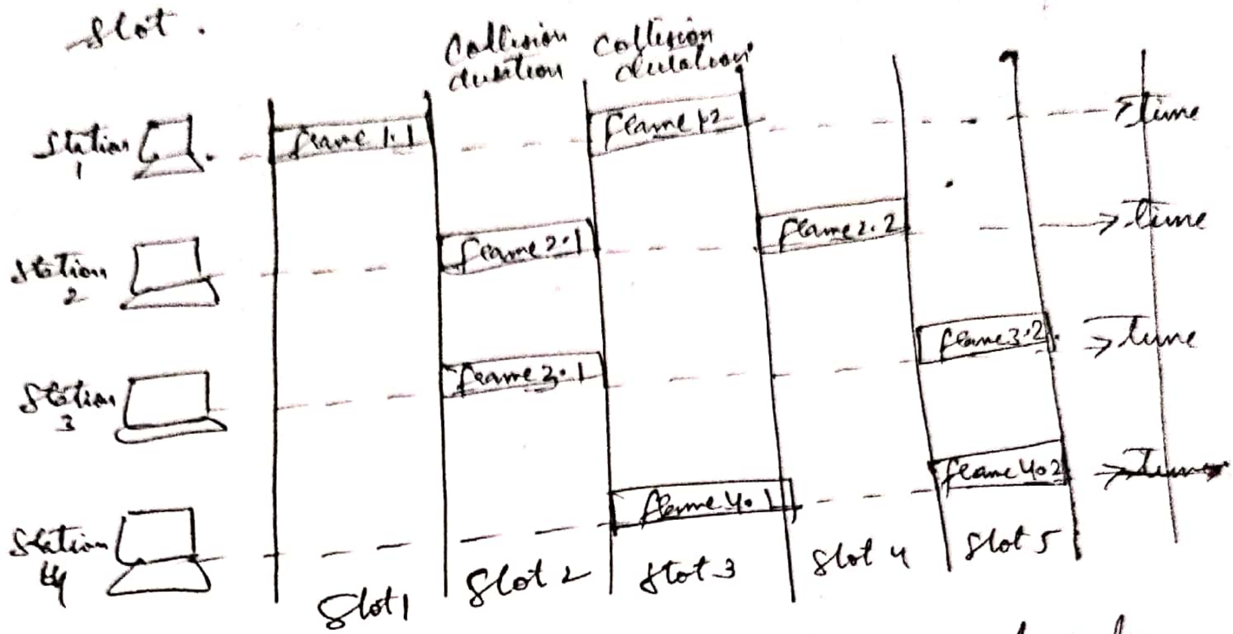
$$\boxed{S_{max} = 0.184} \text{ at } \boxed{G = \frac{1}{2}}$$

or $\boxed{S_{max} = 18.4 \%}$

Slotted ALOHA

- Pure ALOHA has a vulnerable time of $2 \times T_{fr}$.
- This is so because there is no rule that defines when the station can send.
- A station may send soon after another station has started or soon before another station has finished.

In slotted ALOHA we divide the time into slots of Tfr seconds & force the station to send only at the begining of the time slot.



- Because a station is allowed to send only at the begining of the synchronized time slot, if a station misses the moment, it must wait until the beginning of next time slot.
- There is possibilyty of collision if two stations try to send at the beginning of the same time slot.
- The vulnerable time is now reduced to one-half equal to Tfr.

$$\boxed{\text{Slotted ALOHA vulnerable time} = T_{fr}}$$

Throughput of Slotted ALOHA

It can be proved that the average number of successful transmission for slotted ALOHA is $S = G e^{-G}$

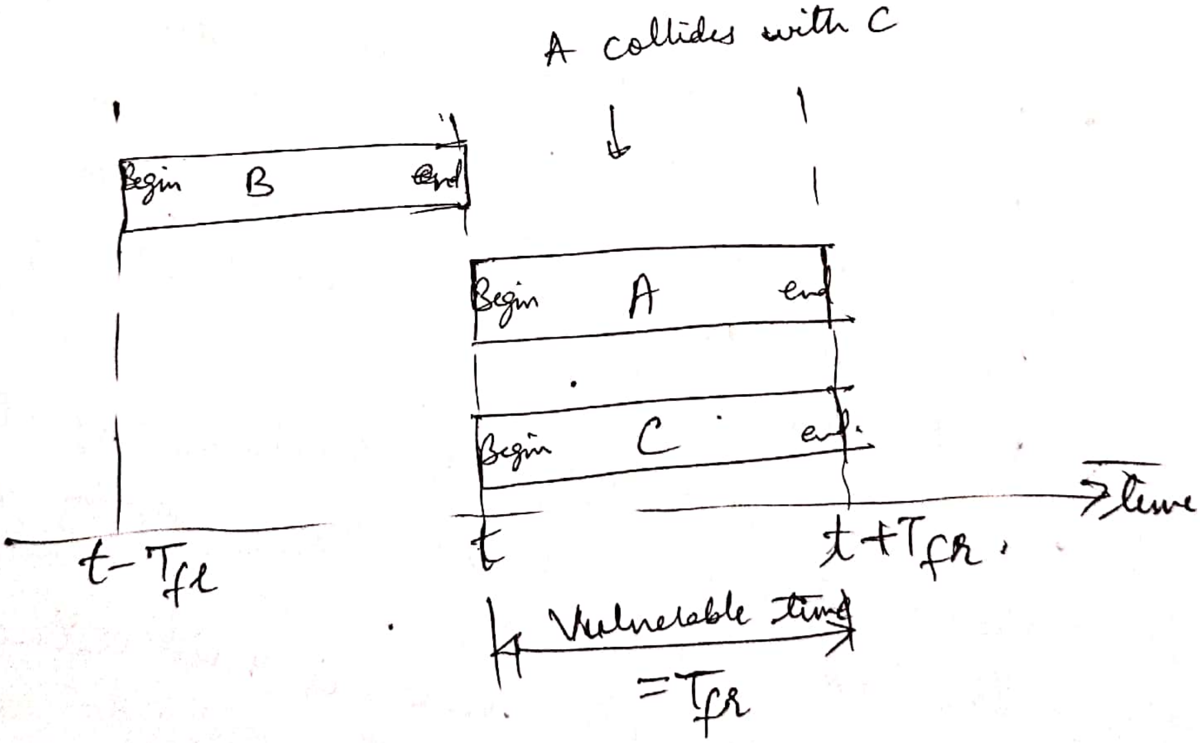
The max throughput is

$$S_{max} = 1 \cdot e^{-1} \text{ at } G = 1$$

$$= 1/e$$

$\boxed{S_{max} = 0.368}$ at $G = 1$.

$\boxed{S_{max} = 36.8\%}$



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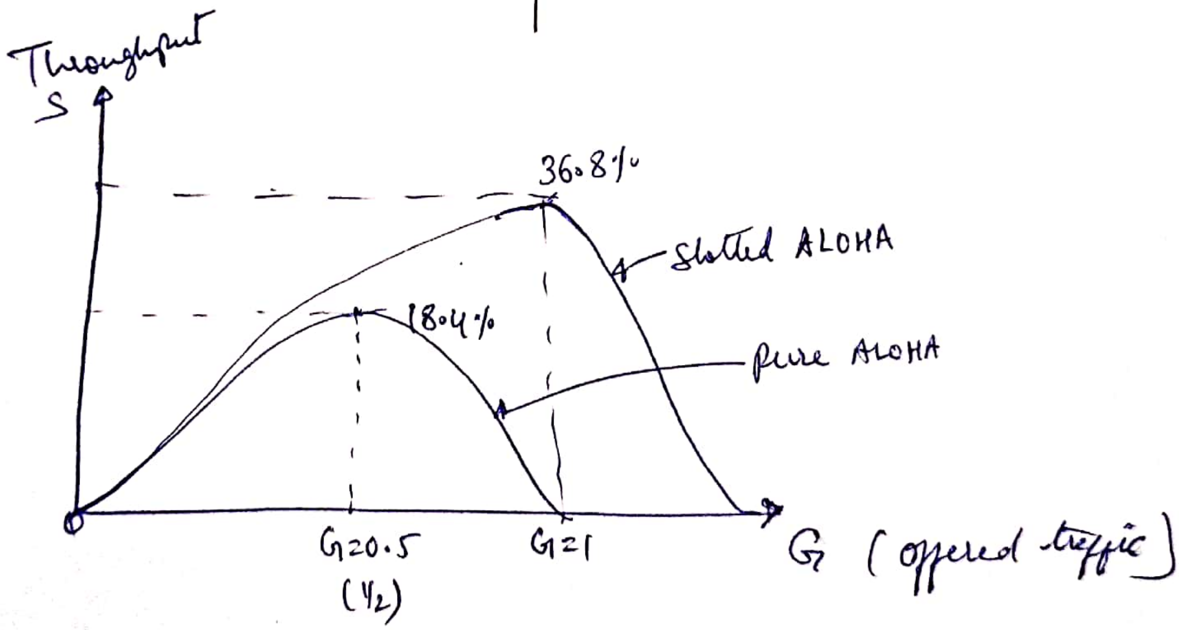
Pure ALOHA	Slotted ALOHA
1) No Synchronized transmission	1) Synchronized transmission (At the beginning of every time slot)
2) Vulnerable period $= 2 \times T_{fr}$	2) Vulnerable period $= T_{fr}$
3) Maximum throughput $S_{max} = 0.184$ $= 18.4\%$ at $G = \frac{1}{2}$	3) Maximum throughput $S_{max} = \cancel{0.368}$ 0.368 $= 36.8\%$ at $G = 1$
throughput $S = G e^{-2G}$	throughput $S = G e^{-G}$



~ $\times$ 1.

Q. A pure ALOHA n/w $x$ts 200-bit frames on a shared ch of 200Kbps. What is the requirement to make this frame collision free?

→ Avg T_{fr} = 200/200kbps = 1 ms. ...

Q. A pure ALOHA n/w transmits 200 bit frames on a shared ch of 200Kbps. What is the throughput if the sys (all stations together) produces

a. 1000 frames per second

b. 500 frames per second

c. 250 frames per second.

→ frame x^n time t_{fr} = 200/200Kbps = 1ms

(a) 1000 frames per second = 1 frame/ms ie $G = 1$

$\therefore S = 1 \cdot e^{-2(1)} = 0.135 = 13.5\%$

In terms of frames S = 1000 × 0.135 = 135 frames, successfully $x$ted out of 1000 f

(b) 500 f/s = 0.5 f/ms, $G = \frac{1}{2}$

$\therefore S = \frac{1}{2} e^{-1} = 0.184 = 18.4\%$.

In terms of frames S = 500 × 0.184 = 92 frames out of 500 f

(c) 250 f/s = $\frac{1}{4}$ f/ms

$G = \frac{1}{4}$

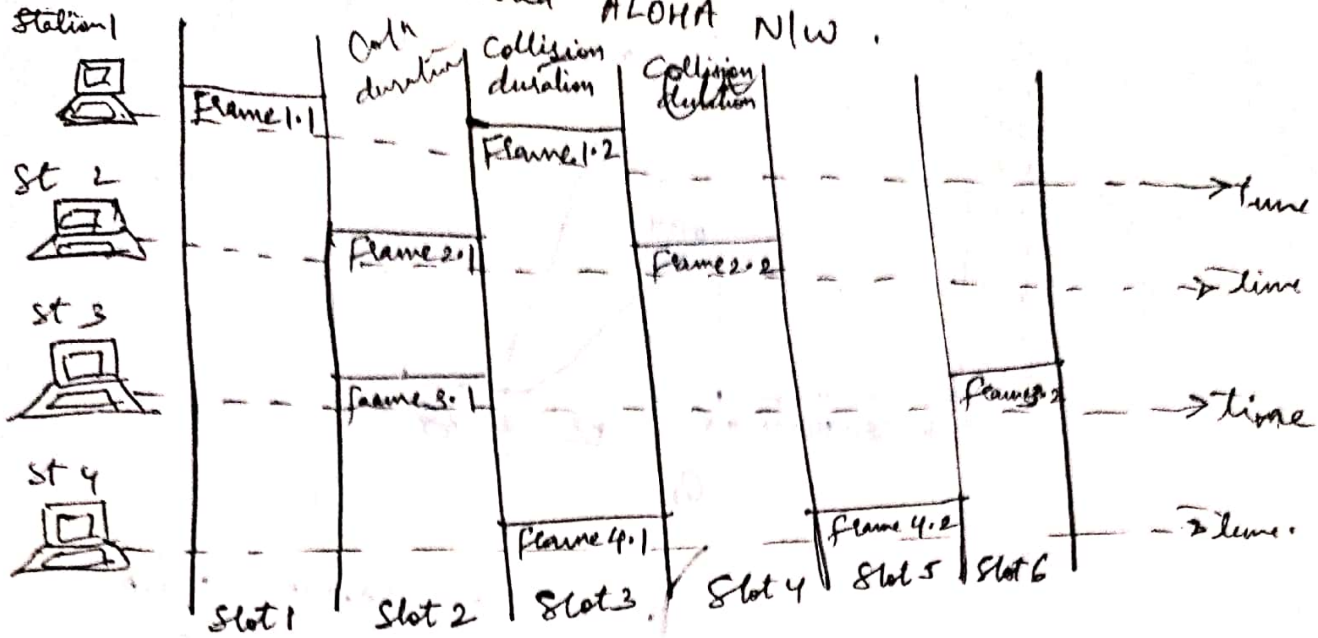
$S = \frac{1}{4} e^{-2(\frac{1}{4})} = 0.152$

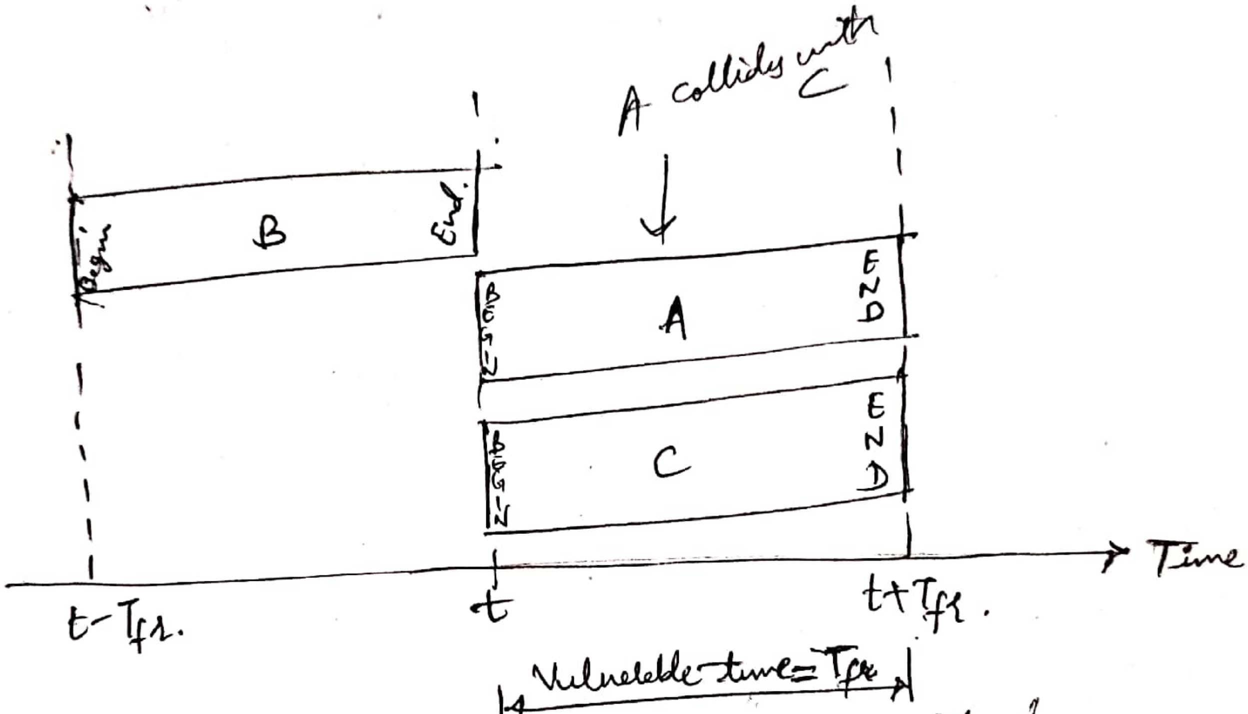
$= 15.2$

0.152 × 25
= 38 frames
out of 2
Succ

184.

Frames in a Slotted ALOHA N/W.





Vulnerable time for Slotted ALOHA protocol.

$$\boxed{\begin{array}{l} S = G \times e^{-G} \\ S_{max} = 0.368 \quad \text{when } G = 1 \end{array}}$$

Q A slotted ALOHA N/W transmits 200 bit frames using a shared ch with a 200 Kbps BW. find the throughput if the System (all stations together) produces

a. 1000 frames per sec

$T_{fr} = 200/200\text{ kb/s} = 1\text{ ms}.$

$G = \frac{1000}{1000} = 1 \text{ frame/ms}.$

$S = 1 \cdot e^{-1} = .368 = 36.8\%.$

$1000 \times 0.368 = 368$ frames out of 1000 frames

b. 500 frames per sec

$G = \frac{500}{1000} = \frac{1}{2} \text{ f/ms}$

$S = \frac{1}{2} e^{-1/2} = 0.303 = 30.3\%$

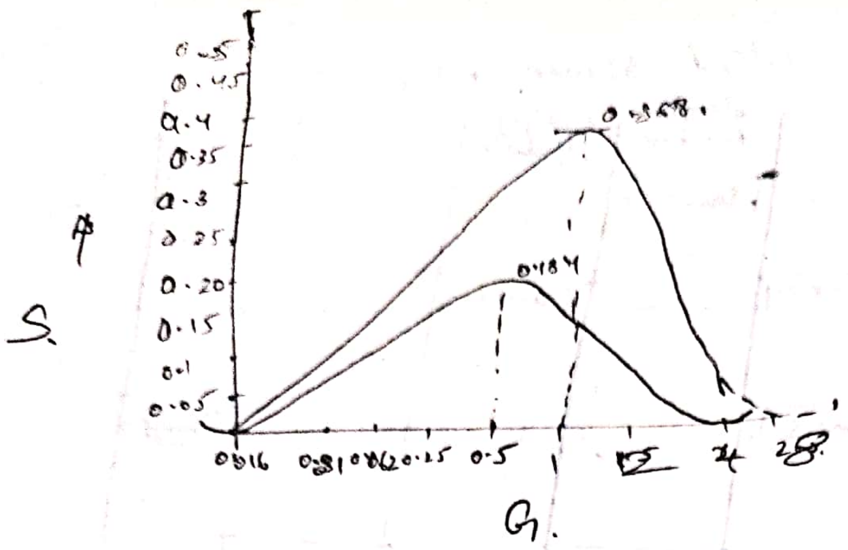
$500 \times 0.303 = 151$ frames out of 500

c. 250 frames per sec.

$G = \frac{250}{1000} = \frac{1}{4} \text{ f/ms}$

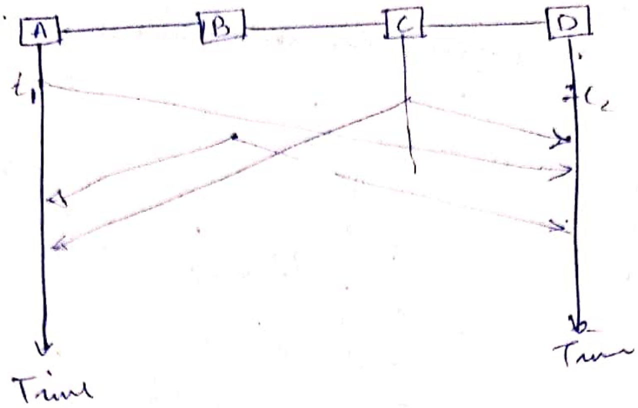
$S = \frac{1}{4} e^{-1/4} = 0.195 = 19.5\%$

$.195 \times 250 = 49$ frames out of 250 success full.

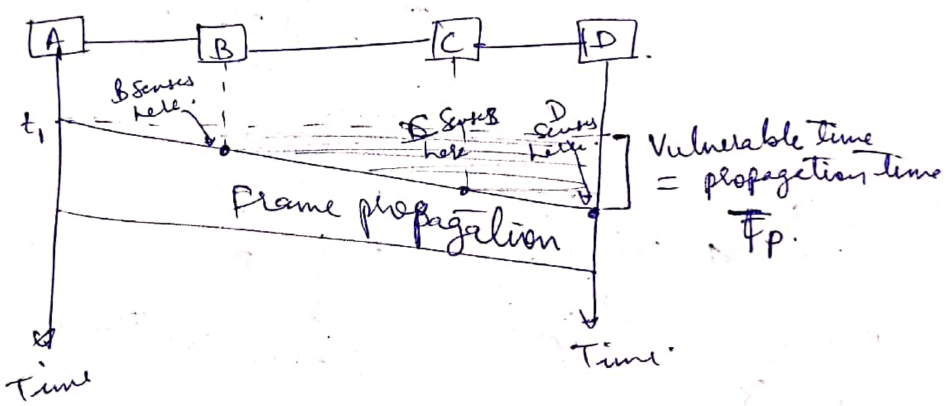


	Pure ALOHA	Slotted ALOHA	CSMA
Vulneration time	$2T_{fr}$	T_{fr}	T_p

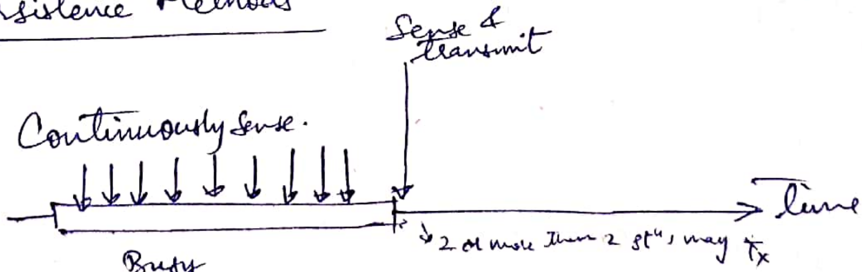
CSMA



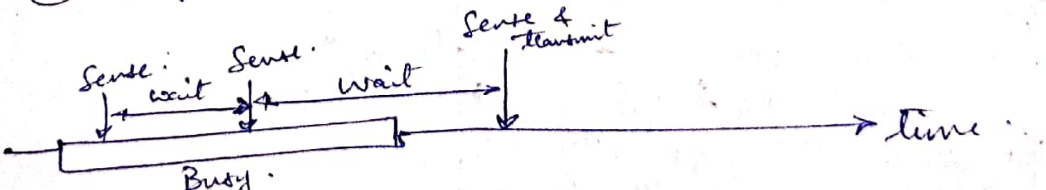
Vulnerable time in CSMA



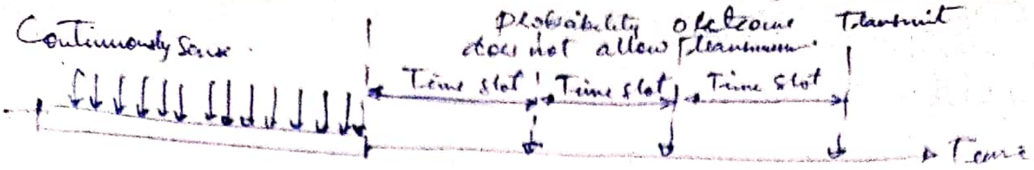
Persistence Methods



(a) 1-persistent (prob 1) (Highest chance of colln).

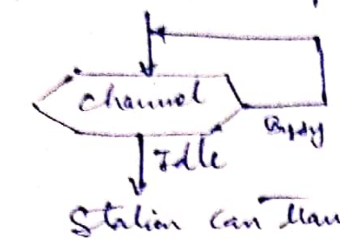


(b) Non persistent (Inefficient, as stations dont send data even if channel is idle).

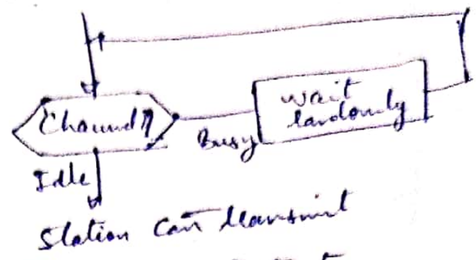


(c) P- persistent (Most efficient, overcomes drawbacks of non-persistent & 1-persistent)

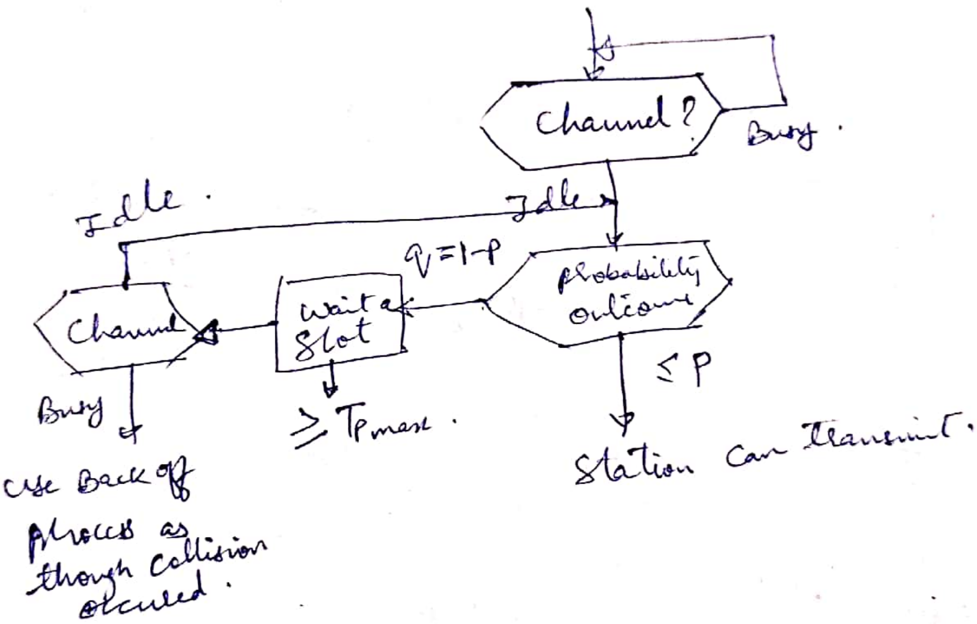
Flow diagram for 3 persistent methods:



(a) 1- persistent.



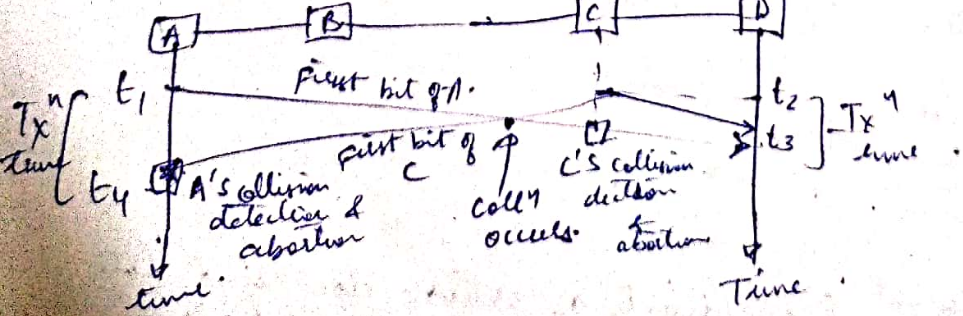
(b) Non persistent.



(c) P- persistent.

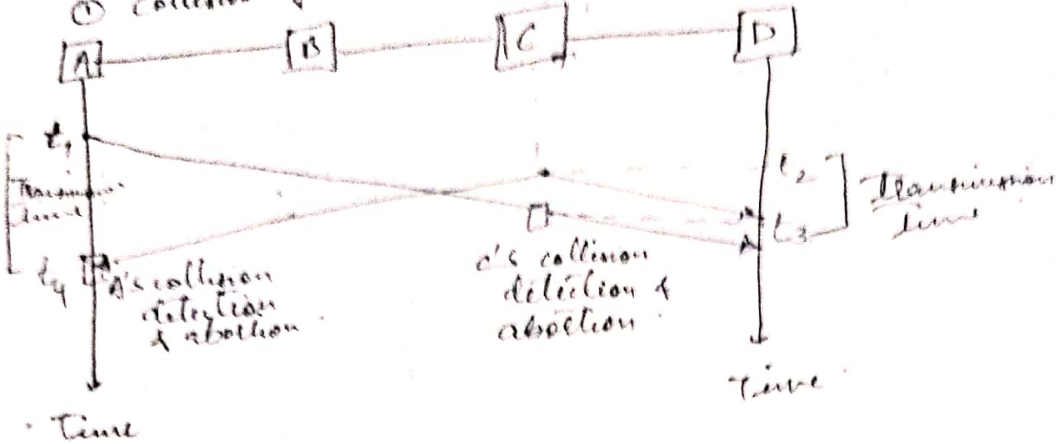
CSMA/CD

Collision of the first bit in CSMA/CD.



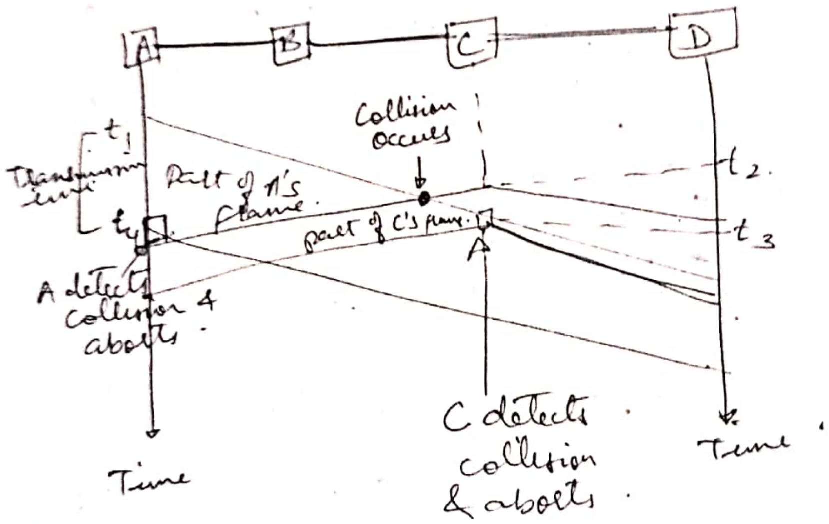
CSMA/CD

① Collision of the r^{th} bit in CSMA/CD.



② Minimum frame size = 2T ; $T_{fr} = 2T_p$

③ Collision & abortion in CSMA/CD.



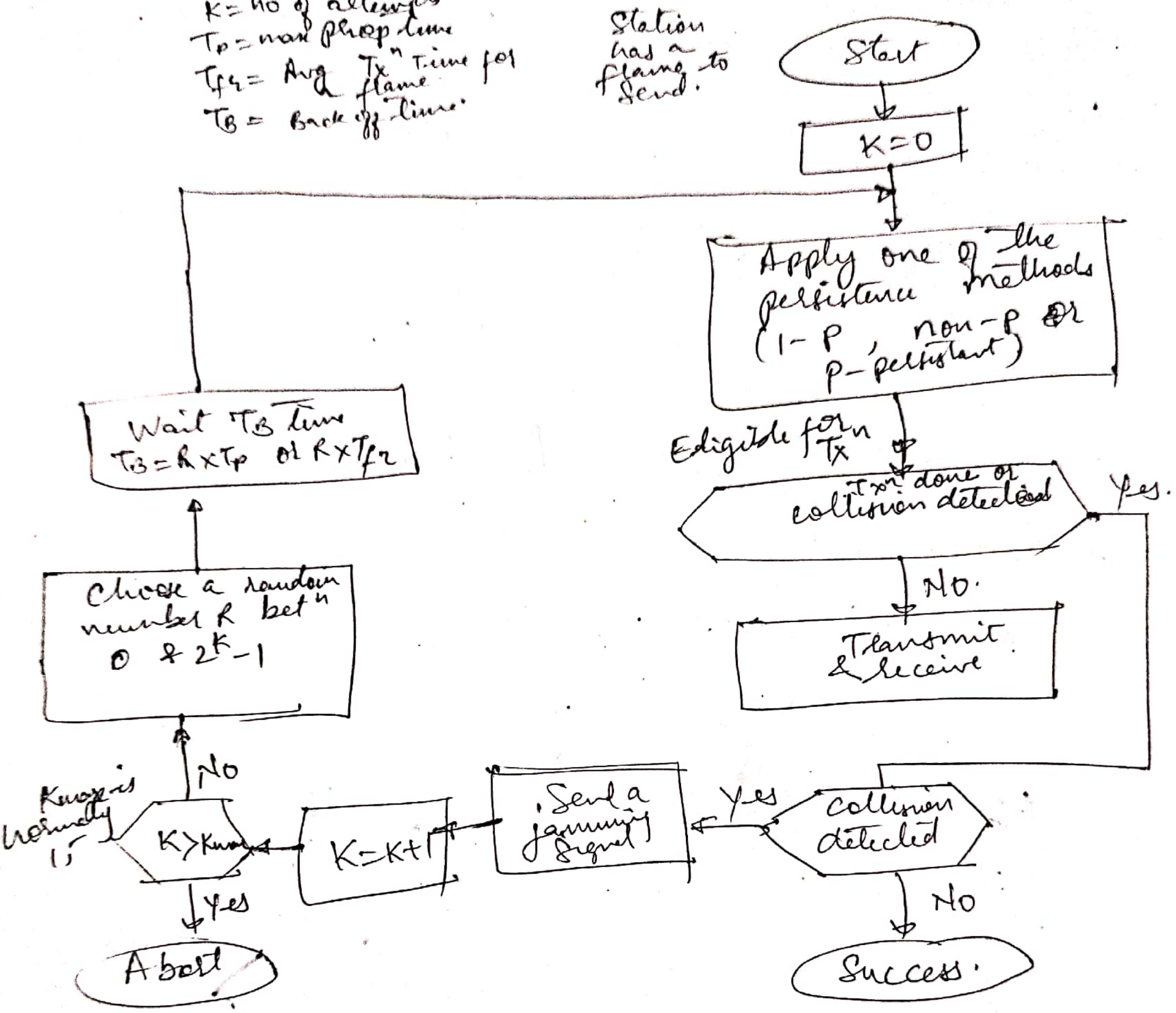
④ CSMA/CD & ALOHA differences:

In CSMA/CD.

1) persistence process is added.
2) T_x^n of a frame & collision detection is a continuous process.
3) Sends A short jamming signal is sent when collision is sensed.

Flow diagram of CSMA/CD

K = no of attempts
T_p = max prop time
T_{fr} = Avg Txn Time for frame
T_B = Back off time.

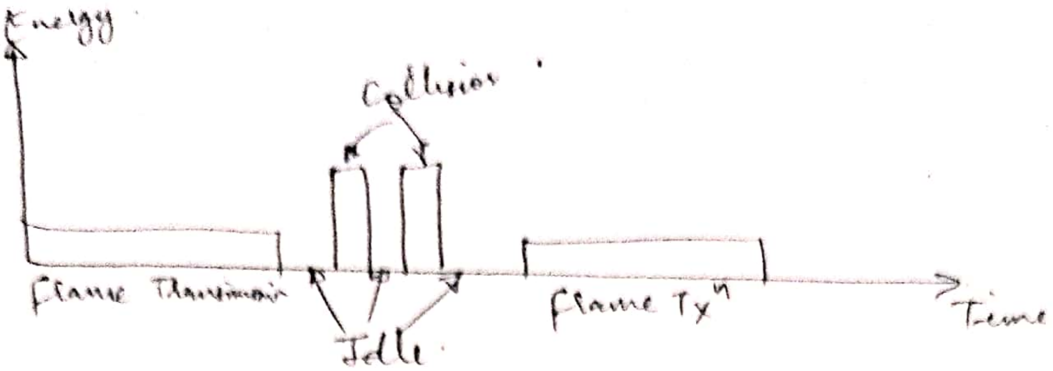


$\boxed{\text{Throughput of CSMA/CD} > \text{pure or slotted aloha.}}$

1-persistent   non persistent

$S_{max} = 50\%$; $G = 1$ $S_{max} = 90\%$; $3 < G < 8$.

CSMA/CA. (for wireless N/w's).



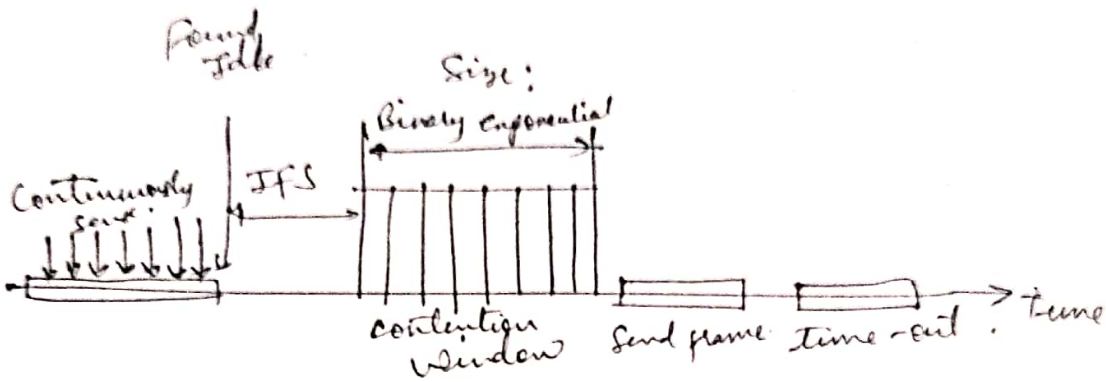
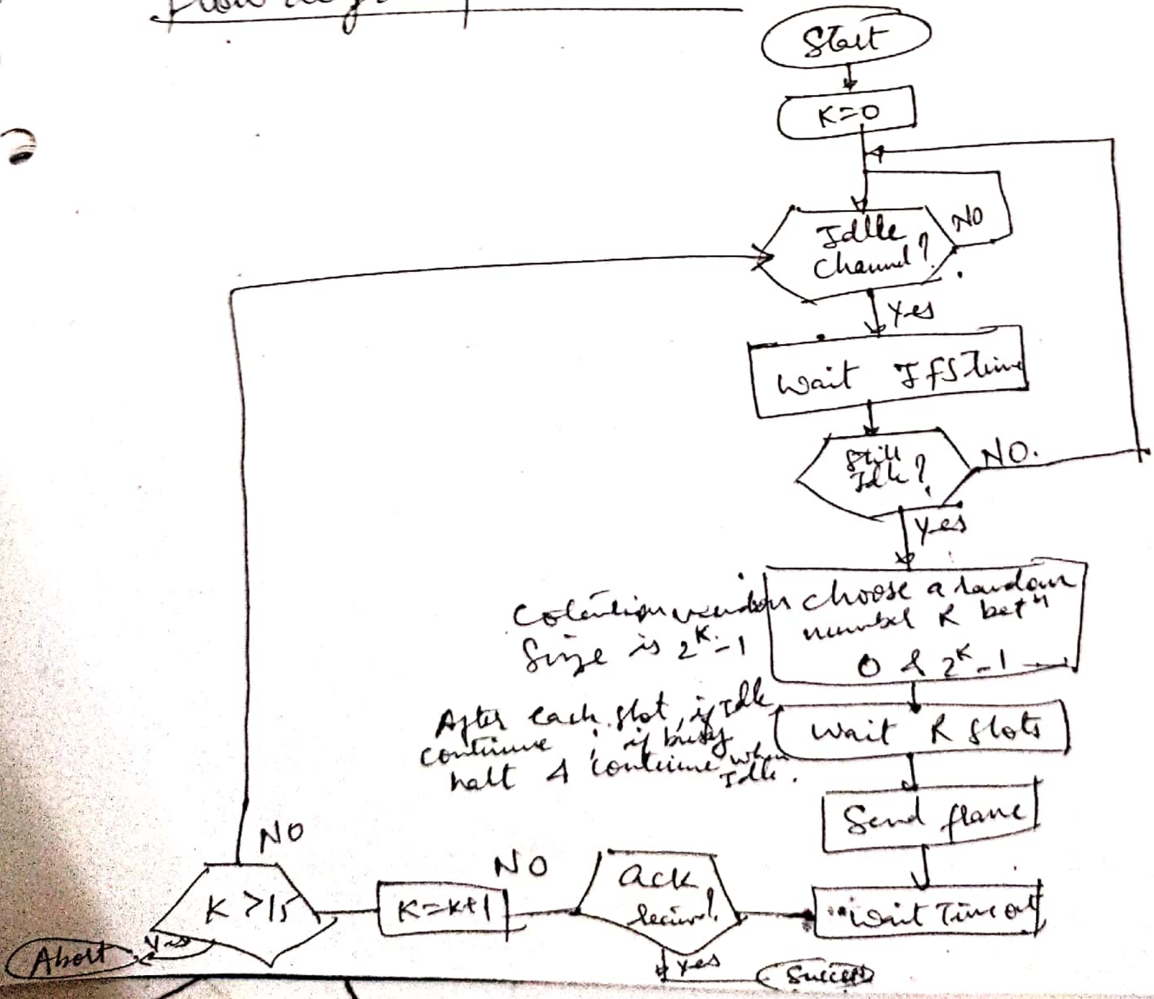


fig: Timing in CSMA/CA.

Flow diagram for CSMA/CA



Q.5. (a) CSMA (Carrier Sense Multiple Access) Protocols.

<u>Carrier Sense</u>: A station can sense the channel to see if anyone is using it. If the channel is being used then the station will not attempt to use the channel.

<u>Types</u>:

(a) 1-Persistent (b) Non-persistent (c) P-persistent.
(d) CSMA/CD.

(a) <u>1- Persistent</u>:

- When a station needs to send data it first listens to the channel.
- If the channel is busy the station waits till the channel becomes free.
- When the channel becomes free a station can transmit a frame.
- A collision occurs when 2 stations detect an idle channel at the same time and simultaneously send frames.
- If a collision occurs the station waits a random amount of time and starts all over again.
- It is called 1-persistent as the station will transmit with a probability of 1 when it finds the channel idle.

Drawbacks:

- **Propagation Delay:** It is possible that just after a station begins transmitting, another station becomes ready to send & it will sense the channel. If the first station's signal has not yet reached the 2nd station, the 2nd station will sense an idle channel & will begin sending its data. This will lead to a collision.

- Assume that station 2 and station 3 are waiting for station 1 to finish its transmission. Immediately after station 1 finishes transmitting both station 2 & station 3 begin transmitting at the same time thus leading to a collision

Advantage: Due to carrier sense property 1-persistent CSMA gives better performance than the ALOHA systems.

(b) **Non-persistent CSMA:**

- A station senses the channel when it wants to send data.
- If the channel is idle the station begins sending.
- However, if the channel is busy, the station does not continually sense the channel like 1-persistant CSMA. Instead, it waits a random period of time & then checks the channel again.

In this the stations abort their transmission as soon as they detect a collision.

Working:

(a) If two stations sense the channel to be idle they begin transmitting simultaneously & cause a collision.

(b) A collision is indicated by a high voltage.

(c) Both the stations monitor the channel for a collision and stop transmitting as soon as a collision is detected.

(d) Now the stations wait for a random amount of time & check if channel is free.

(e) The process continues.

* How long will it take a station to realize that a collision has taken place?

• Let the time for a signal to propagate between the two farthest stations be τ.
• Assume that at time t_0, one station begins transmitting.
• Lets call the most distant station as B.
• At time $\tau - \epsilon$, which is an instant before the signal arrives at B, B itself senses an idle channel and begins transmitting.
• A collision occurs one instant later at time τ.
• B detects the collision almost instantly & stops, but little noise burst caused by the collision does not get back to the original station until time $\tau + \tau = 2\tau$.

Disadvantage: This leads to longer delays than 1-persistent CSMA.

Advantage: This algorithm leads to better channel utilization.

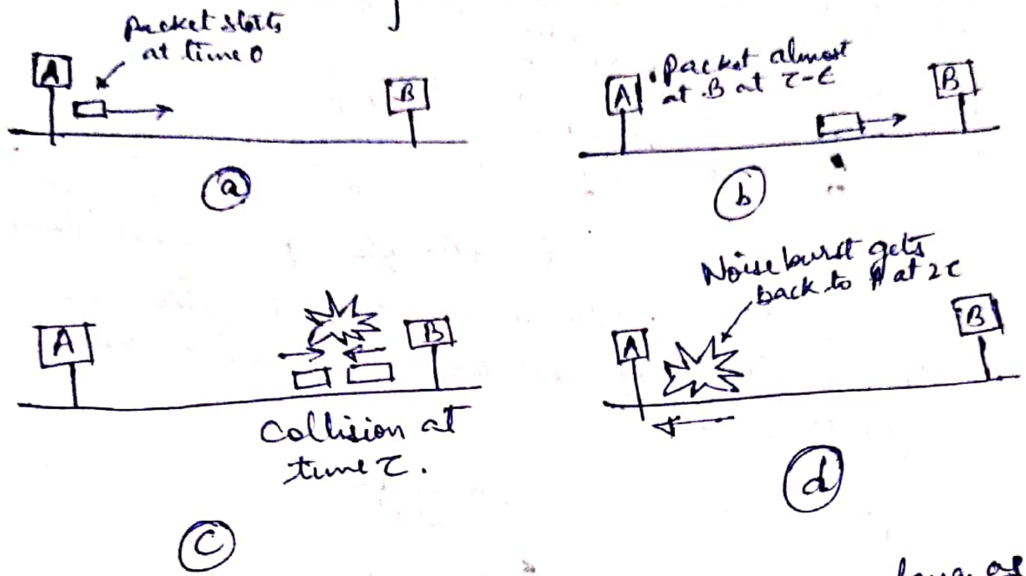
(c) **P-persistent CSMA**

- It is used for slotted channels.
- When a station becomes ready to send, it senses the channel.
- If channel is idle, station transmits within that slot with a probability p and defers from sending with a probability $q = 1 - p$. If $p > q$ then the station transmits else if $p < q$ then the station does not transmit & waits till the next slot and again checks if $p > q$ or $p < q$.
- This process is repeated until either the frame has been transmitted or another station has started transmitting.

(d) **CSMA/CD**:

- Ethernet (IEEE 802.3) sends data using CSMA/CD (CSMA with collision detect).
- CSMA was an improvement over ALOHA as the channel was sensed before transmission begins.
- Now further improvement on CSMA, in the form of CSMA with collision detection has been brought abt.

• In other words, in the worst case a station cannot be sure that it has seized the channel until it has transmitted to 2τ without hearing a collision.



collision detection can take as long as 2τ.

• What happens after a collision takes place?

Binary Exponential Backoff Algorithm

Assume a collision takes place for the first time. Now, each station randomly waits for either 0 or 1 slot times before trying again. If the two stations pick the same waiting time, they will collide again. After the second collision, each station picks either 0, 1, 2 or 3 at random & waits for that number of slot times.

• In general, after i collisions, a random number betn 0 & $2^i - 1$ is chosen, & that no of slots is skipped.

• However, after 10 collisions have taken place, the randomization interval is frozen at a maximum of 1023 slots. • After 16 collisions, the controller reports failure back to the computer.

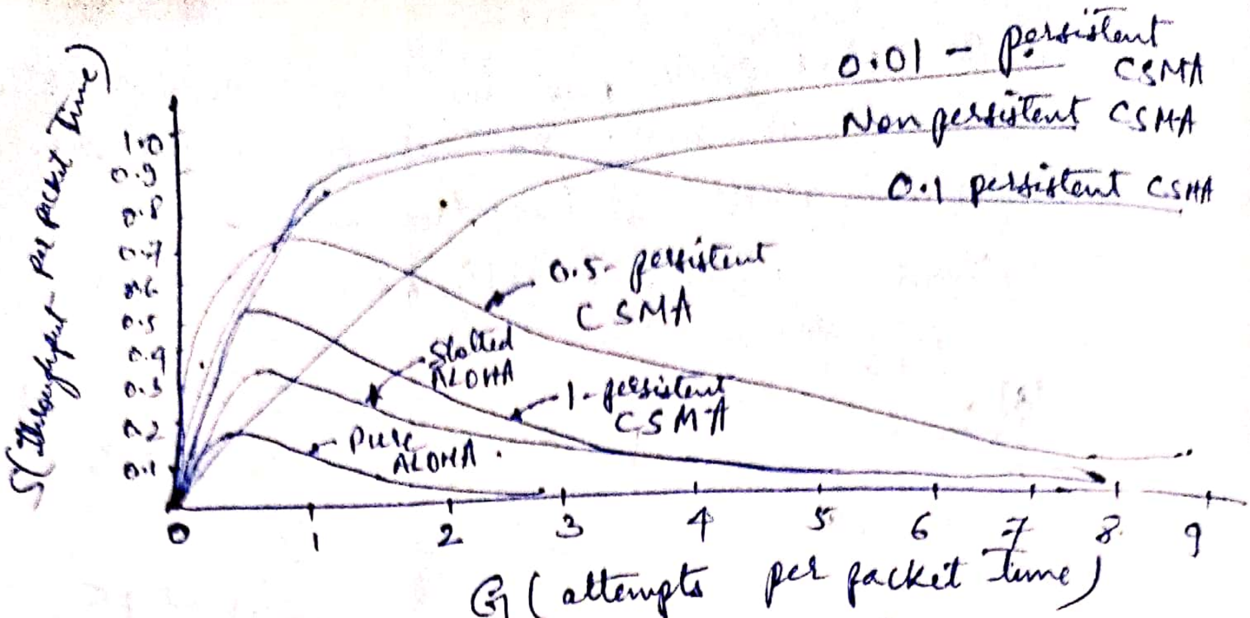


fig- Comparison of the channel utilization versus load for various random access protocols.

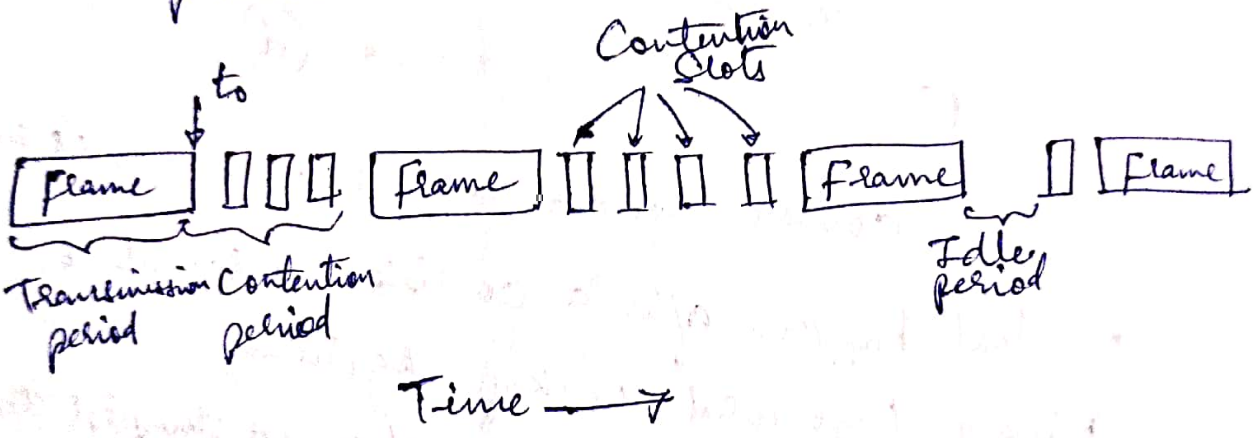
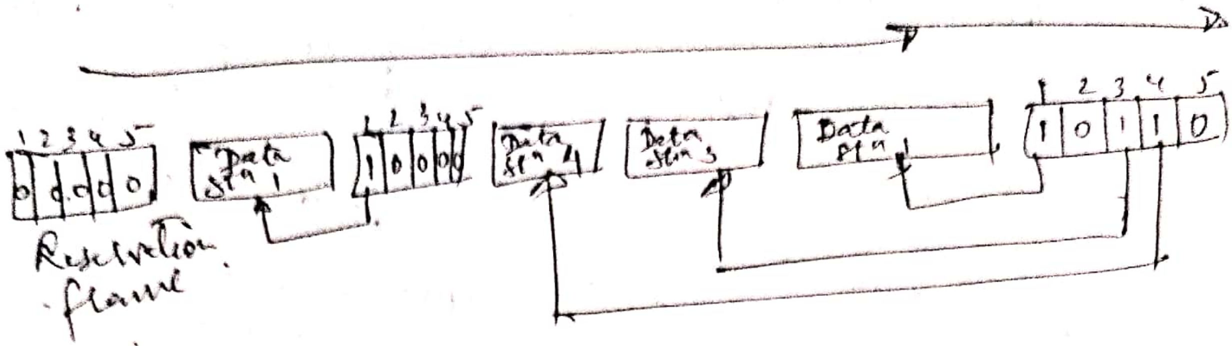


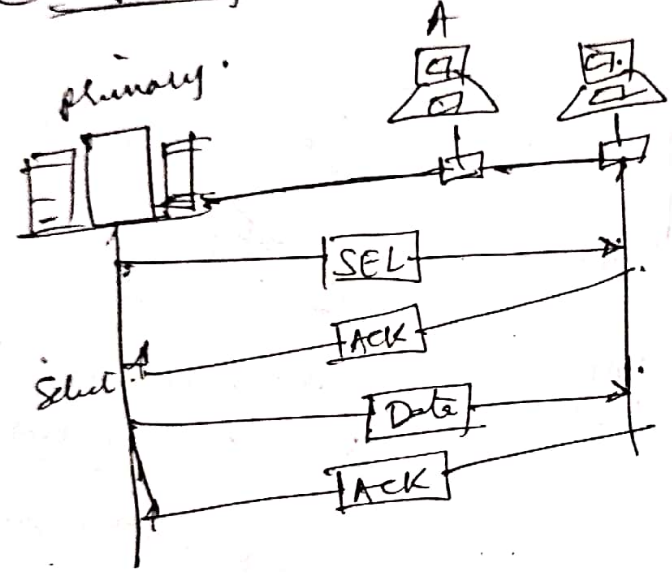
fig: CSMA/CD can be in one of three states: Contention, transmission or idle.

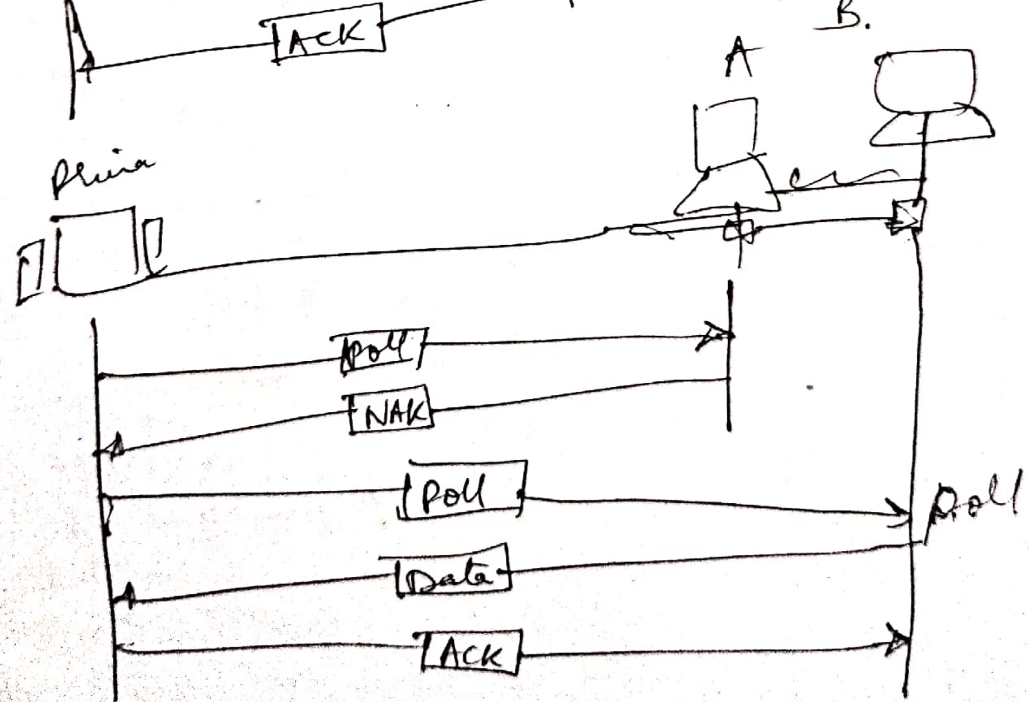
Controlled Access

(1) Reservation Access Method



(2) Polling

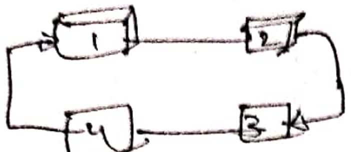




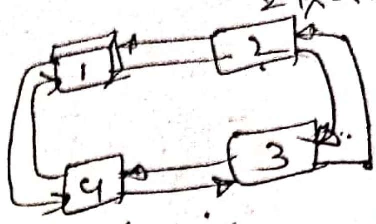
Token passing:

Logical ring & physical topology in token passing access method.

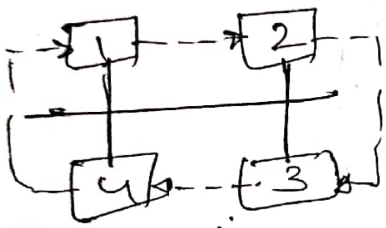
2 Tx & 2 Rx ports



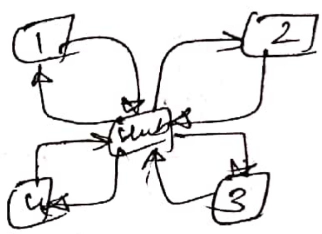
(a) physical ring.



(b) Dual ring
fiber distr Data Inter.
FDDI
CDDI.



(c) Bus ring
Token Bus LAN.
std by IEEE



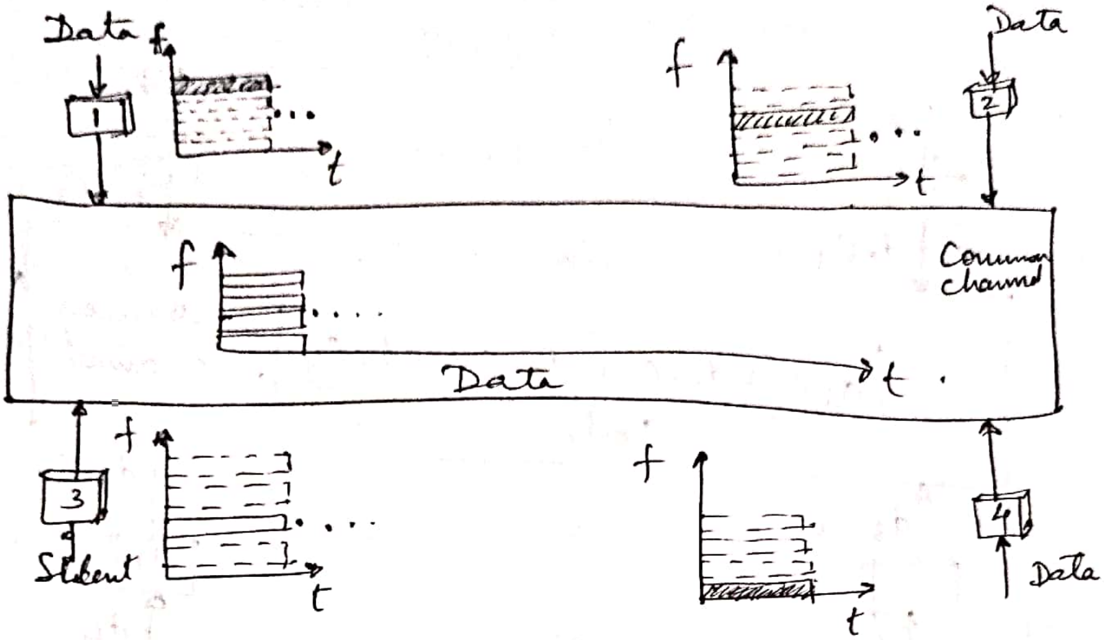
(d) star ring.

(e) Token ring
LAN.
designed by IBM.

Channelization

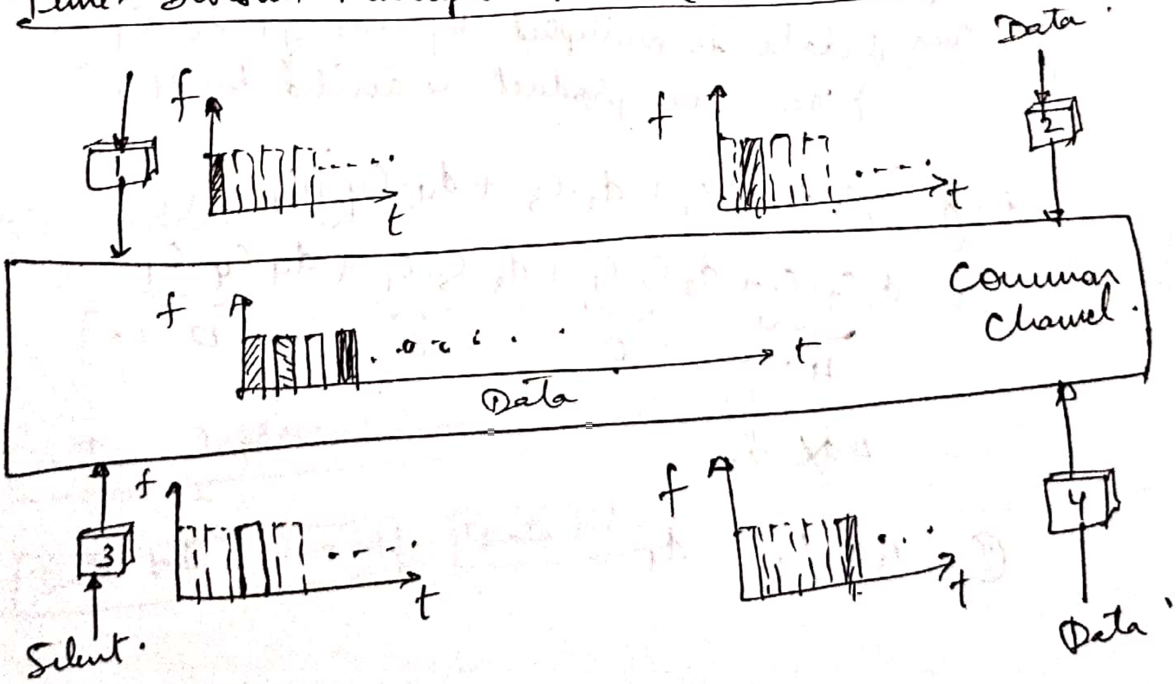
- Multiple Access Method

① Frequency Division Multiple Access (FDMA)



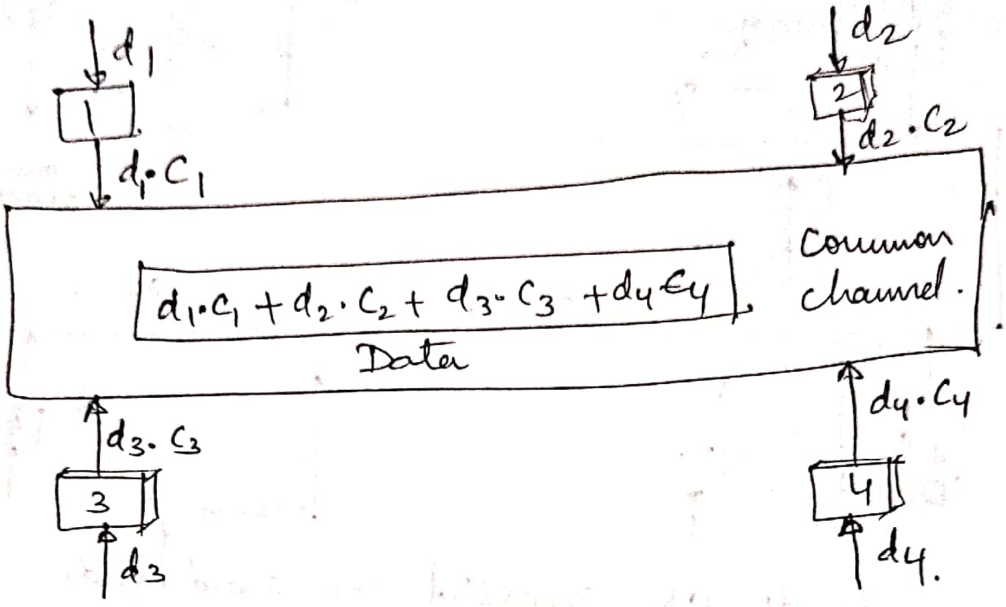
- Bands are separated by guard bands.

② Time-Division Multiple Access (TDMA)



③. Code Division Multiple Access (CDMA)

- → Analogy
- → Idea
- → properties of codes.



e.g. If St^n 2 wants to hear St^n 1

Then 1) data is multiplied by code of 1 ie C_1

2) Then the product is divided by 4.

i.e ① $[d_1 C_1 + d_2 C_2 + d_3 \cdot C_3 + d_4 \cdot C_4] C_1$

$$= d_1 \underbrace{C_1 \cdot C_1}_{4} + d_2 \underbrace{C_2 \cdot C_1}_{0} + d_3 \cdot \underbrace{C_3 \cdot C_1}_{0} + d_4 \underbrace{C_4 \cdot C_1}_{0}$$

$$= 4 \cancel{d} \, d_1$$

② $4d_1/4 = d_1$

Chips

Chip Sequences :

C_1	C_2	C_3	C_4
[+1 +1 +1 +1]	[+1 -1 +1 -1]	[+1 +1 -1 -1]	[+1 -1 -1 +1]

- Chip seq's are orthogonal sequences.

no of bits (elements) = no of stations.

Properties of Orthogonal Sequences

① No of elements in each sequence = No of stations.

② Scalar Multiplication.

e.g. $2[+1\ +1\ -1\ -1] = [+2\ +2\ -2\ -2]$

③ Inner product of 2 equal sequences.

$[+1\ +1\ -1\ -1] \cdot [+1\ +1\ -1\ -1] = 1+1+1+1 = \underline{4}$

④ product of 2 different sequences.

$[+1\ +1\ -1\ -1] \cdot [+1\ -1\ -1\ +1] = 1-1+1-1 = 0$

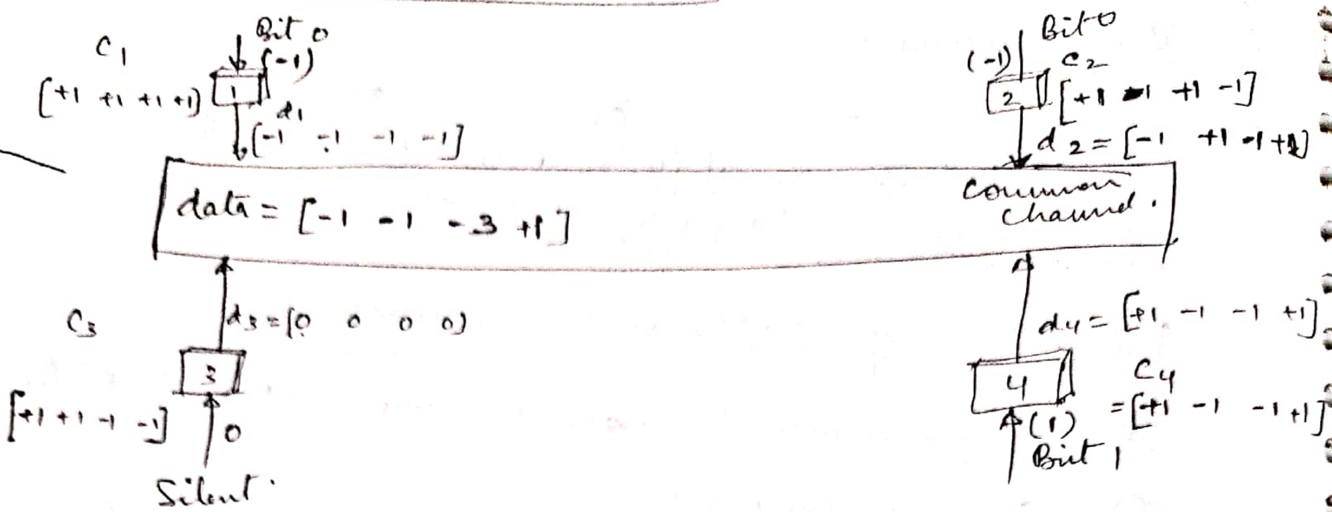
⑤ Addition of two sequences.

$[+1\ +1\ -1\ -1] + [+1\ +1\ +1\ +1] = [+2\ +2\ 0\ 0]$

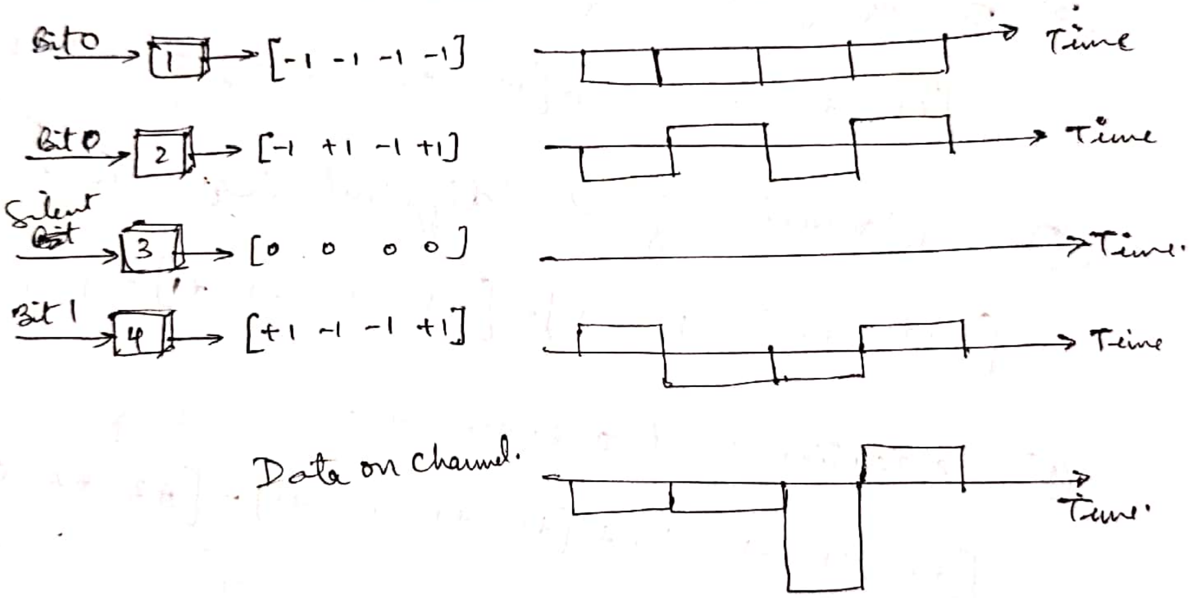
Data representation in CDMA.

$\boxed{\text{Data bit } 0 \rightarrow -1}$ $\boxed{\text{Data bit } 1 \rightarrow +1}$ $\boxed{\text{Silence} \rightarrow 0}$

Sharing channel in CDMA.



Digital signal created by four stations in CDMA.



Decoding of the composite signal for one in CDMA.