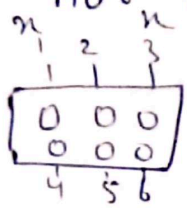
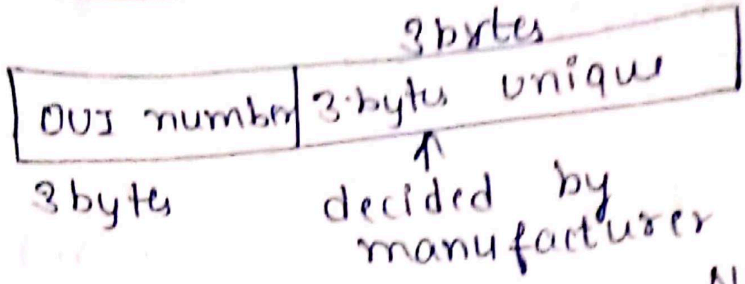
MAC Addressing :

- During the time of manufacturing, unique mac address (48 bits) hardware number embedded into network Interface Card (NIC).
- If a LAN network has two or more NICs configured with same MAC address then that network will not work.

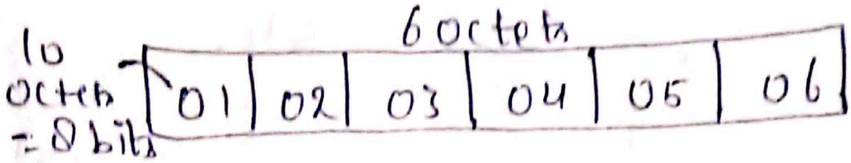


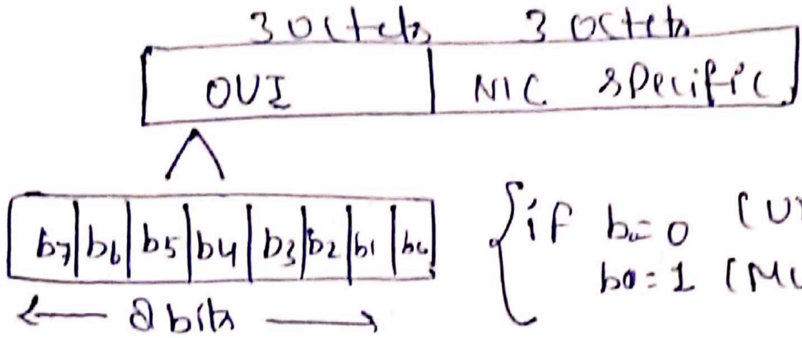
If computer-4 sends a frame to the destination MAC address x, then the switch fails to deliver this frame as it has two recipients of this frame.

- So for proper data transfer in LAN network, a unique MAC address is associated with each device.
- DDL is divided into two sublayers
  1) LLC (Logical Link Control) Sublayer
  2) Media Access Control (MAC) Sublayer
- MAC address is used by MAC sublayer of DDL.
- Every manufacturer obtains a universally unique 3-byte code known as the unique identifier (OUI) from IEEE (regulates and maintains namespace of MAC addresses).
- LAN technologies like Token Ring, ethernet use MAC add. as their Physical addresses.
- If destination MAC add set as FF-FF-FF-FF-FF-FF by DDL then frame will reach to every computer [illegible] that LAN segment.



	OUI	Unique
NIC 1	0000AA	000001
NIC 2	"	000002
NIC 3	"	000003





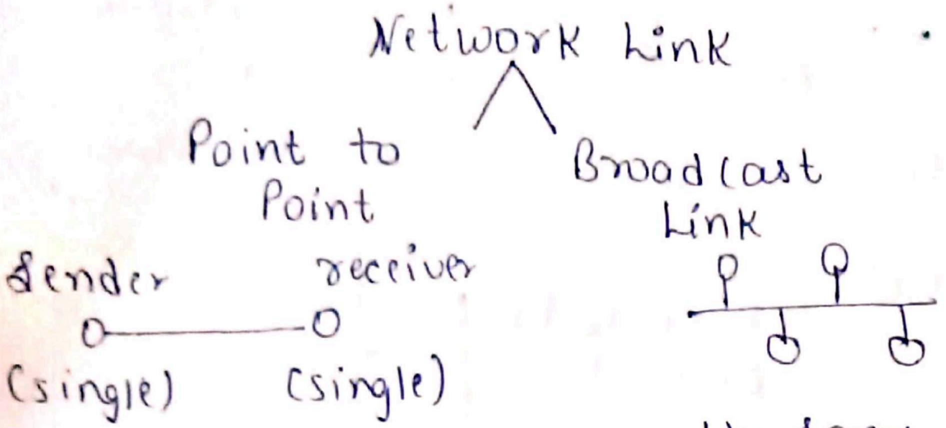
if b0 = 0 (unicast) → frame reach to only one NIC
b0 = 1 (Multicast) → frame reach to multiple NIC

if b1 = 0 {Globally unique}
b1 = 1 {Locally administered}

Distributed Random Access Schemes:
(Contention Schemes for Data Services):

- In random access method, no station is assigned any priority that means no station is superior to another station & none is assigned any control over another.
- Any station can send data depending on medium's state (idle or busy).
- It is called as random access scheme because transmission is random among the stations i.e. no scheduled time for station to transmit.

- It is also called as contention method because there is no specific rule which station should send next, stations compete with each other to access the medium



multiple sender & receiving node connected to the same, single shared broadcast channel.
eg: ethernet, wireless LAN

- To coordinate the access of multiple sending and receiving stations to a shared broadcast channel there is a need of multiple access control protocols.
- These protocols used with wired & wireless LAN & satellite network.
- More than two stations/nodes can transmit frames at the same time, if so then collision will occur & the frame will be either destroyed or modified. For this multiple access control protocols are required to reduce collisions.

Multiple Access Protocols (implemented on the MAC layer/sublayer of DDL)
- Random Access Protocols
  - ALOHA
  - CSMA
  - CSMA/CD
  - CSMA/CA
- Controlled Access Protocols
  - Reservation
  - Polling
  - Token Passing
- Channelization Protocols
  - FDMA
  - TDMA
  - CDMA

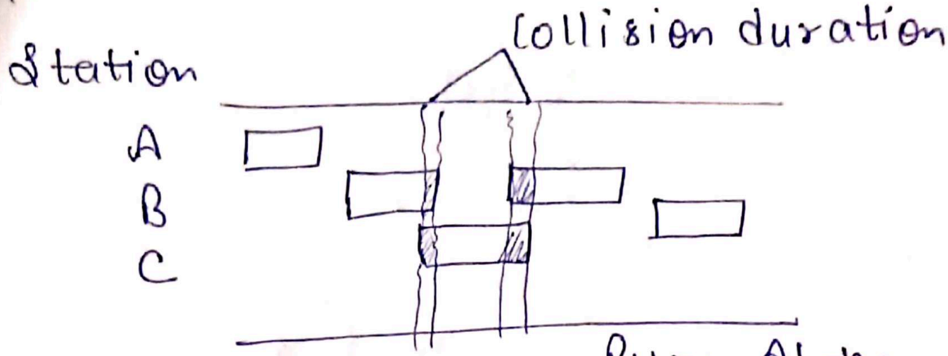
Types of Random Access Protocols:

1) ALOHA :

- It was designed for wireless LAN but also applicable for shared medium.
- Here multiple stations can transmit data at the same time & can hence lead to collision.

ALOHA
- Pure Aloha
- Slotted Aloha

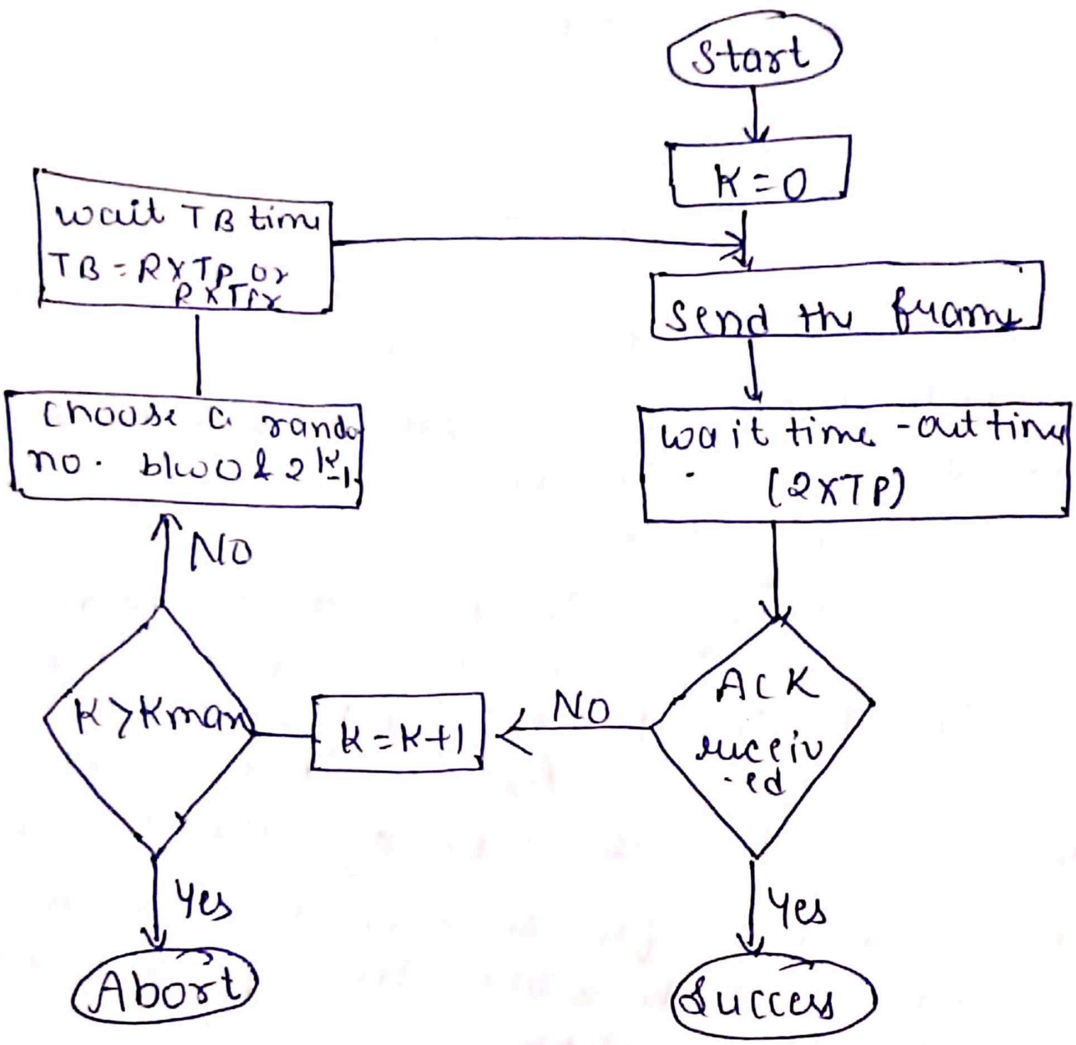
Pure Aloha :-



Pure Aloha

- It is introduced by Norman Abramson and his associates at the university of Hawaii in early 1970.
- It allows every station to transmit the data whenever they have data to be sent without checking whether the channel is free or not. So, there is always the possibility of the collision of data frames.
- In Pure Aloha, after transmitting the data frame, station waits some time for the ack. from the receiving station.
- When transmission station receives an ack. from the receiving station, it assumes that the transmission is successful.
- If transmitting station does not receive any ack within specified time(2×Tp), it assumes that the transmission is unsuccessful
- In Pure aloha, transmitting station uses a Back off strategy & waits for some random amount of time.
- After back off time, transmitting stations transmits the frame again & it keeps trying until the back off limit is reached after which it aborts the transmission.

(6) Flow diagram of Pure Aloha:



- Since diff stations wait for different amount of time, the Probability of further collision decreases.
- Probability of successful transmission of data frame.

Efficiency of Pure Aloha (throughput).

$$\eta = G \times e^{-2G} \quad \text{— (1)}$$

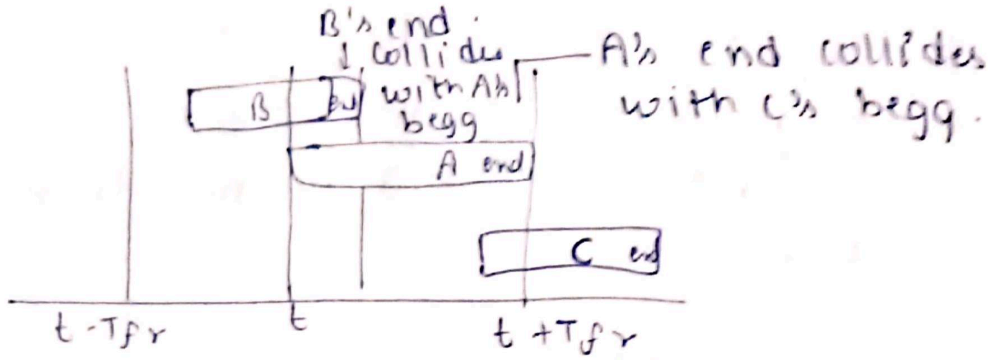
where G is the no. of stations willing to transmit data (avg no. of transmission attempts per sec).

Max value of η occur at $G = \frac{1}{2}$

substitute $G = \frac{1}{2}$ in (1)

$$\eta_{max} = \frac{1}{2} \times e^{-2 \times \frac{1}{2}} = 1 \times e^{-1} = \frac{1}{e}$$

Vulnerable time for Pure Aloha Protocol.



vulnerable time $= 2 \times T_{fr}$ $(t + T_{fr} - (t - T_{fr}))$

- $VT = 2 \times T_t$
- $\eta = G \times e^{-2G}$

$T_t = \frac{M}{BW}$

Max eff.

$$\frac{d\eta}{dG} = 0$$

$$G \times e^{-2G}(-2) + e^{-2G}(1) = 0$$

$$e^{-2G}(1 - 2G) = 0$$

$$1 - 2G = 0$$

$$2G = 1$$

$$G = 1/2$$

- If on half a frame is generated during one frame transmission time then 18.4% of these frames reach their destination successfully

③ $\eta_{max} = \frac{1}{2} \times e^{-2\times\frac{1}{2}}$

$= \frac{1}{2} e^{-1}$

$= 0.184$

$\boxed{\eta_{max} = 18.4\%}$

Throughput, $S = G \times e^{-2G}$

S = avg. no. of successful transmission (through...

G = avg no. of frames generated by the system during one frame transmission time

$\eta_{max} = 18.4\%$

- It is very less due to large no. of collisions
- vulnerable time in which collision may occur = 2 × frame transmission time

Q. St 1 ⟵ wireless Aloha n/w 600 Km ⟶ St 2

signal propagates at 3×10^8 m/s

i) $T_p = \frac{600 \times 10^3}{3 \times 10^8} = 2$ ms $T_p = \frac{\text{distance}}{\text{propagation speed}}$

K<=3

K 0 to $2^K - 1$

	range	TB
K = 1	{0, 1}	0×2 ms : 0, 2 ms
K = 2	{0, 1, 2, 3}	0, 2, 4, 6 ms
K = 3	{0, 1, 2, 3, 4, 5, 6, 7}	0, 2, 4, 6, 8, 10, 12, 14 ms

A Pure Aloha n/w transmits 200 bits frame shared channel of 200KbPs. What is the throughput if the system (all stations together) Produces
i) 1000 frame/sec   ii) 500 frame/sec

→ i) If the system creates 1000 frames Per second.
this is 1 frame per ms ($1000 \times 10^{-3}) = 1$

$\therefore G = 1$

Throughput $S = G \times e^{-2G} = 1 \times e^{-2} = \frac{1}{e^2}$

ii) If the system creates 500 frames Per second.

$G = 500 \times 10^{-3} = \frac{500}{1000} = \frac{1}{2}$

$S = G \times e^{-2G} = \frac{1}{2} \times e^{-2 \times \frac{1}{2}} = \frac{1}{2e}$ (18.4%)

$\therefore$ throughput $= 500 \times 0.184 = 92$

That means only 92 frames out of 500 will probably survive.

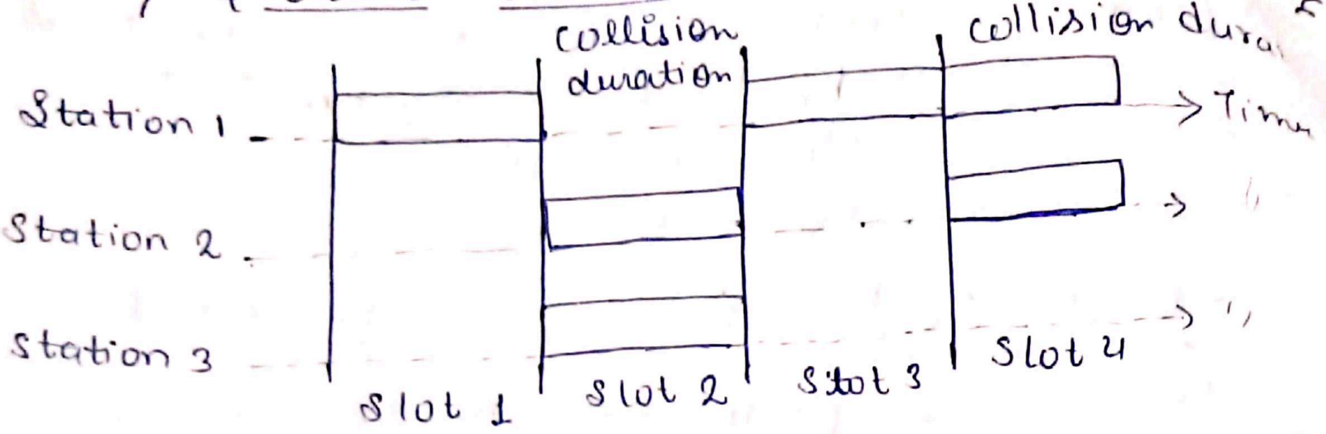
Q A Pure Aloha n/w transmits 200 bit frames on a shared channel of 200KbPs. What is the req. to make this frame collision free.

→ $T_{fr} = \frac{200 \text{ bits}}{200 \text{ KbPs}} = \frac{200}{200 \times 10^3} = 10^{-3} = 1 \text{ ms}$

$V.T = 2 \times T_{fr} = 2 \times 1\text{ms} = 2\text{ms}$

That means no station should send later than 1ms before this station starts trans--mission & no station should start sending during the 1 ms period.

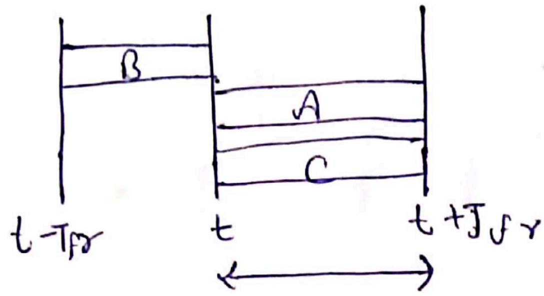
ii) Slotted Aloha :



- In slotted Aloha, time of shared channel is divided into equal size slots (time to transmit 1 frame).
- Here it is assumed that all frames are of same size.
- Any station can transmit its data in any time slot.
- Station starts to transmit frames only at beginning of timer slots. If the begg. of the slot is missed then station has to wait until the begg. of the next time slot.
- If two or more ~~solution~~ station transmit in slot, all nodes detect collision.
- Slotted Aloha does not allow to transmit the data/frame whenever the station has the frame/data to be send.
- It makes the station to wait till the next time slot begins & allow each data data frame to be transmitted in the new time slot.

- The nodes are synchronized so that each node knows when the slots begin.
- If two or more frames collide in a slot, then all the nodes detect the collision event before the slot ends.

Vulnerable time for Slotted Aloha Protocol:



vulnerable time: $t + T_{fr} - t$

$$\boxed{VT = T_{fr}}$$

- $V_T = T_{fr} \ (T_t)$
- $\eta = G \times e^{-G}$

G = avg no of stations want to transfer in given amt of Tt

Max. $\eta - \frac{d\eta}{dG} = 0$

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

$$0 = e^{-G}(1 - G)$$

$$1 - G = 0$$

$$\boxed{G = 1}$$

On an avg only one station can transmit in one slot for max η.

$$\eta_{max} = 1 \times e^{-G}$$
$$= 0.368 = 36.8\%$$

$\eta_{max} = 2 \times$ eff. of Pure aloha

- The maximum efficiency of slotted Aloha is high due to less numbe of collisions.

Q A slotted Aloha network transmits 200 bits frames on a shared channel of 200kbps. what is the throughput if the system (all stations together) produces 500 frames per second.

⇒ If the system creates 500 frames/sec.

$T_{fr} = \frac{200}{200 \times 10^3}$

$T_{fr} = 1 msec$

1sec ——— 500 frames

10^{-3} sec ——— 500×10^{-3} frames

1ms ——— $\frac{500}{1000} = \frac{1}{2}$ frame/ms

$$G = \frac{1}{2}$$

$S = G \times e^{-G} = \frac{1}{2} e^{-1/2}$

∴ $S = 0.303$ (30.3%)

∴ throughput $= 500 \times 0.303 = 151$

only 151 frames out of 500 will probably survive.

Pure Aloha	Slotted Aloha
Any station can transmit the data at any time.	• Any station can transmit the data at the beginning of any time slot
• Time is continuous.	• Time is divided into fixed time slots.
• Vulnerable time = $2T_t$	• $VT = T_t$
• Efficiency = $G \times e^{-2G}$	• $\eta = G \times e^{-G}$
• η_{max} = 18.4% ($G = 1/2$)	• η_{max} = 36.8 ($G=1$)
• Advantage: → Simplicity → Implementation	• Advantage: → It reduces the no of collisions to half & double the efficiency as compared to Pure aloha

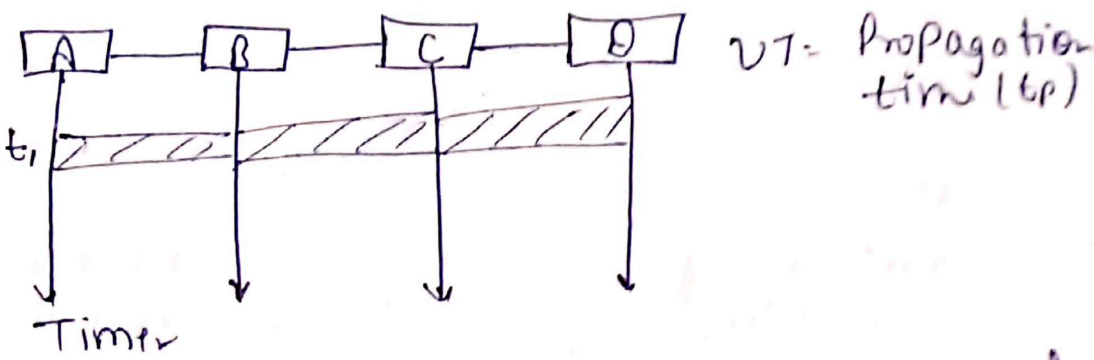
CSMA Protocol

1) CSMA : (Carrier Sense Multiple Access Protocol)

- In CSMA, a node is listens to the channel before transmitting.
- If a frame from another nodes currently being transmitted into the channel, a node then waits a random amt of time & then again senses the channel.
- If the channel is sensed to be idle, the node then begins frame transmission, Otherwise, the node waits another random amt of time & repeats this process.

(14)

- LANs with a broadcast physical medium (like single bus) that permits to a remote station (listening to the physical medium) to recognize whether another transmission begins, then remote station stops from transmitting in order to avoid collisions.

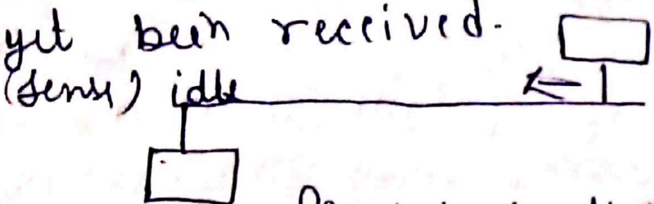


- To minimise the chance of collision & therefore inc. the performance, the CSMA method was developed.

→ CSMA is based on the principle "sense before transmit" or "listen before talk".

→ It can reduce the possibility of collision, but it cannot eliminate it.

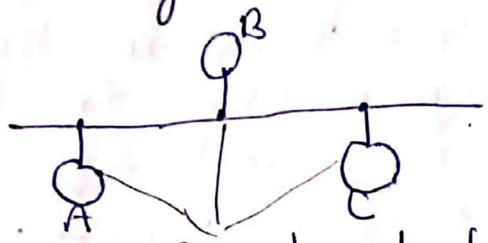
→ The possibility of collision still exists because of propagation delay, a station may sense the medium & find it idle, only because the first bit sent by 1 another station has not yet been received.



Persisting Method in CSMA

CSMA/CD :- [Carrier Sense Multiple Access with collision Detection]:

- Media-access control/method, widely used in ethernet/LANs having shared media. In CSMA/CD method, any station willing to transmit the data senses the carrier.
- If it finds the carrier free, it starts transmitting its data packet otherwise not.

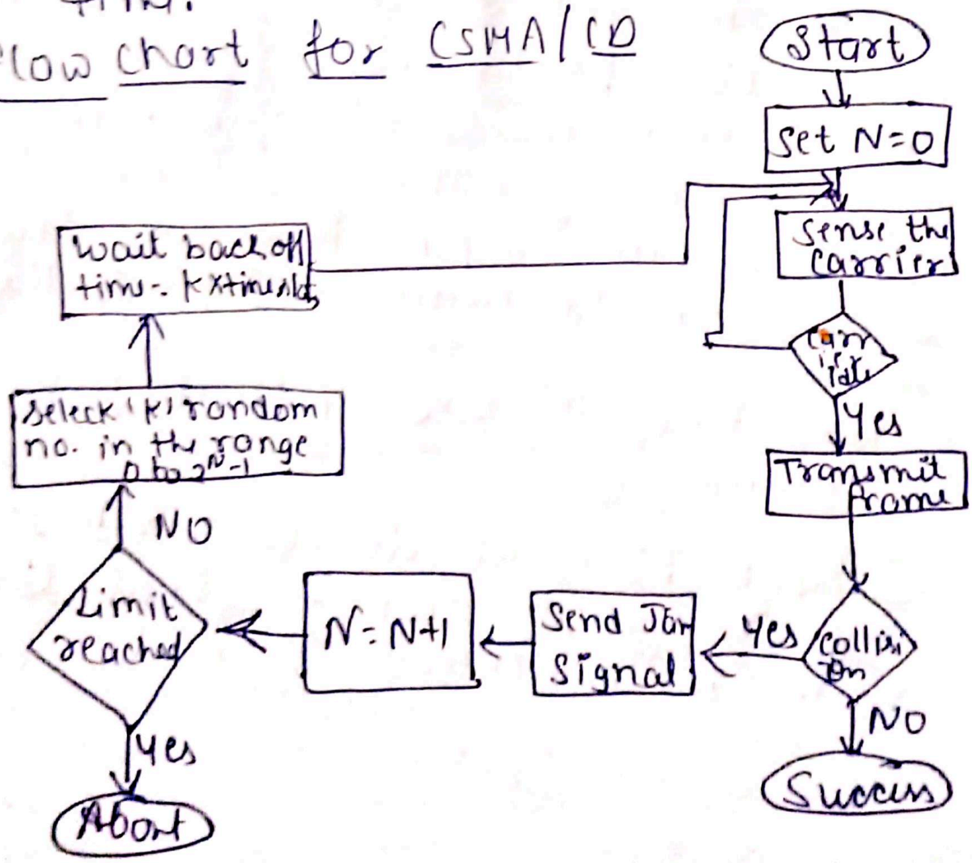


- Each station can sense the carrier only at its point of contact with the carrier (not entire carrier), hence there is a large possibility that a station might sense the carrier free even when it is actually not.
- CSMA/CD rules define how long the device should wait if a collision occurs.
- 1-persistent is used in CSMA/CD systems.
- CSMA/CD protocol decides which station will transmit when so that data reaches the destination without corruption.

⑯. When two or more stations sense the carrier free simultaneously, then they start transmitting their data simultaneously & the collision will occur.

- After the occurrence of collision, station waits for some random amount of time (called as back off time) & then re-transmits the frame. If again collision occurs, then station again waits for some random back off time & then tries again until the back-off time reaches its limit. After the limit is reached, station aborts.
- In CSMA/CD Back off Algorithm is used for calculating the back-off time.

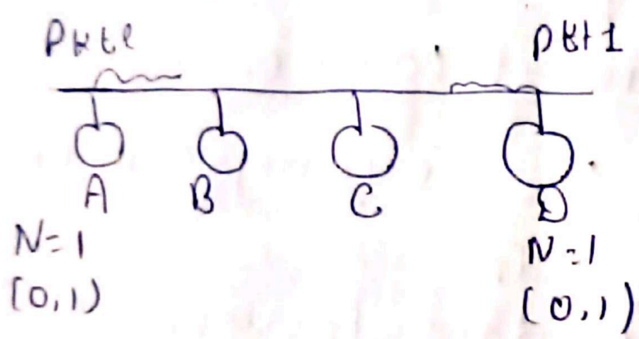
Flow chart for CSMA/CD



Jam signal is a 48 bit signal, it is received by the transmitting stations as soon as they detect a collision.

Jam signal alters the other stations not to transmit their data immedi--ately after the collision.

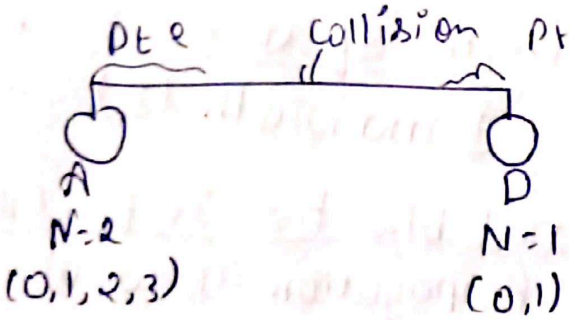
- Ethernet sends the Jam signal at a frequency other than the freq. of data signals. This ensures that Jam signal does not collide with the data signal undergone collision.



	A	D	A	D
(1→	0	0	0	0
	0	1	0	transmit
	1	0	tra	0
c1←	1	1	tr	tra.

P(A) = 1/4
P(D) = 1/4
P(collision) = 2/4

Let A(WT) = 1 D(WT) = 0



A	D	WT
0	0	collision
0	1	D wait
1	0	A wait
1	1	Collision
2	0	A wait
2	1	A wait
3	0	A wait
3	1	A wait

P(A) = 1/8
P(D) = 5/8
P(collision) = 2/8

(18)

Drawbacks of CSMA/CD:

1. Station cannot sense the entire channel is free or not.
2. There is no ack for the collision.

- In CSMA/CD, it is the responsibility of the transmitting station to detect the collision.
- For collision detection, each station must transmit the data pkt of size whose transmission delay is at least twice its propagation delay.

Condition to detect collision:

Transmission delay >= 2 x Propagation delay

$$T_t >= 2T_p$$

- If the size of data packet is smaller, then station cannot detect the collision.

$$\text{Transmission delay } (T_t) = \frac{\text{Length of data pkt } (L)}{\text{Bandwidth } (B)}$$

$$\text{Propagation delay } (T_p) = \frac{\text{Dist. b/w two stations } (D)}{\text{Propagation speed } (v)}$$

$$\therefore \boxed{\frac{L}{B} >= 2 \times \frac{D}{v}}$$

Hence, (min length of data pkt) $\boxed{\text{Length of Data Pkt} >= 2 \times B \times \frac{D}{v}}$

- CSMA/CD is used in wired LANs.
- CSMA/CD does not take any steps to prevent the collision until it has taken place.

Efficiency of CSMA/CD:

$$\eta = \frac{\text{Useful time}}{\text{Total time}}$$

$$\boxed{\eta = \frac{1}{1 + 6.44 \times a}}$$

Where, $a = \frac{T_p}{T_t}$

Q In a CSMA/CD network running at 1Gbps over 1Km cable with no repeater, the signal speed in the cable is 200000 Km/sec. What is the min frame size?

⇒ $B = 1\text{Gbps}$
$D = 1\text{Km}$
$v = 200000 \text{ Km/sec}$

$$T_p = \frac{D}{v} = \frac{1}{200000} = 0.5 \times 10^{-5}\text{sec} = 5 \times 10^{-6}\text{sec}$$

$$\text{Min frame size} = 2 \times T_p \times B$$
$$= 2 \times 5 \times 10^{-6} \times 1 \times 10^{9}$$
$$= 10 \times 10^{3}$$
$$= 10^{4} \text{ bits}$$

$$\boxed{\text{min frame size} = 10000 \text{ bits}}$$

(10) Q A 2 Km long broadcast LAN has 10^7 bps bandwidth & uses CSMA/CD. The signal travels along the wire of 2×10^8 m/sec. what is the min. Packet size that can be used on this network.

⇒ $D = 2$ Km
$B = 10^7$ bps
$v = 2 \times 10^8$ m/sec

$$T_p = \frac{D}{V} = \frac{2 \times 10^3}{2 \times 10^8} = 10^{-5} \text{ sec}$$

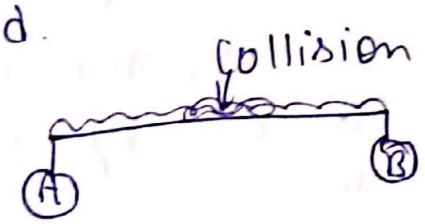
min frame size $= 2 \times T_p \times B$
$= 2 \times 10^{-5} \times 10^7$

min frame size = 200 bits

Binary Exponential Backoff Algo:

- Binary Back-off algo. is a collision resolution mechanism used in CSMA/CD.
- This algo is generally used in Ethernet to schedule re-transmission after collisions.
- If two stations frame collide, then they may restart transmission as soon as after the collision.
- This will lead to another collision & this may happen again & again.
- To prevent this backoff algo is used.

Eg.



Let us assume that A & B start transmitting data at the same time & collision occurs.

- Now A & B knows that there is a collision & they stop transmitting.
- Soon after the collision is detected A & B retransmit the data, if another collision occurs, A & B retransmit again.

So we need an algorithm to check that after collision A & B don't start retransmitting at the same time

- Back off algo. is used for this purpose.
- It uses waiting time (called back off time)
- After the occurence of collision, station waits for some random back-off time & then retransmits.

Back-off time = Waiting time for which the station wait before retransmitting the data.

- It is applicable only for two hosts/station hence it is called as binary back-off algo.
- Probabilities inc/dec exponentially, thus it is also called as binary exponential back off algorithm.
- Drawback of Back off algo is <u>Capture Effect</u> - If a station wins a collision for the first time, it's probability inc winning after next collision increases.

[Collision no-1 for data Pkt 1]

A		B
0	collision	0
0	A retransmit first	1
1	B ,, ,,	0
1	collision	1

Fig! Back off Algo

Probability of A winning after the first collision.

$P(A) = \frac{1}{4}$

$P(B) = \frac{1}{4}$

Probability of collision $= \frac{2}{4} = \frac{1}{2} = 0.5$

Advantage:

- Collision Probability dec exponentially.

Disadvantage:

- Station who wins ones keeps on winning [Capture effect].
- work only for 2 stations/hosts.

CSMA/CA: {Carrier Sense Multiple Access/with Collision Avoidance}

- In contrast to CSMA/CD Protocol, which handles transmissions only after a collision has taken place, CSMA/CA works to avoid collision prior to their occurence.
- It was invented for the wireless networks to avoid collisions
- It inc. network traffic as it requests sending out a signal to the network even before transmitting any real data. This is to listen for any collision scena-rios in the network & to inform other

- devices not to transmit.
- Collision are avoided through the use of CSMA/CA three strategies
  1) The interframe space
  2) The contention window
  3) Acknowledgements

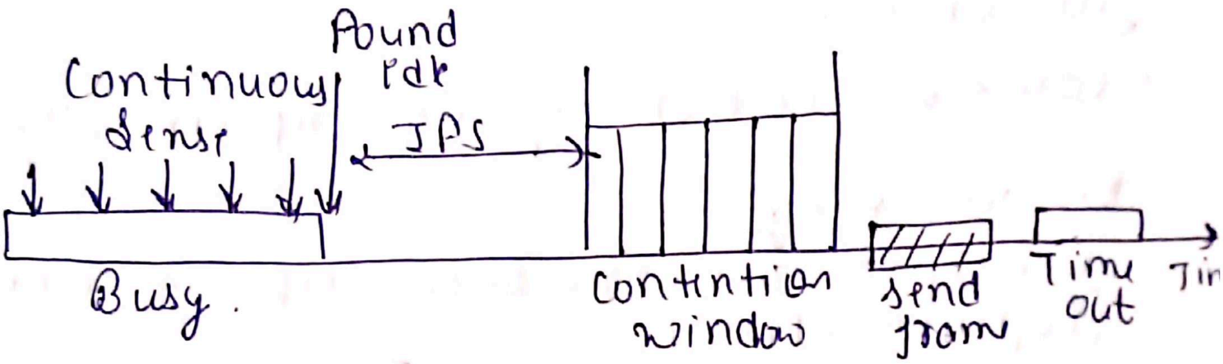


Fig: Timer in CSMA/CA

- P- persistent is used in CSMA/CA system like wifi.
- This mode waits for the medium to be idle, then transmits data with a probability p.
- If the data node does not transmit the data, the sender waits for the medium to be idle again.

Interface Space (IFS):-

Whenever the channel is found idle, the station does not transmit immediately. It wait for a period of time called IFS

- When channel is sensed to be idle, it may be possible that some distant station may have already started transmitting & the signal of that distant station has not yet reached other stations.
- Therefore the purpose of IFS time is to allow the transmitted signal to reach other stations.
- If after the IFS time, the channel is still idle, the station can send, but it still needs to wait a time equal to contention time.

2) Contention Window:

Contention window is an amt of time divided into slots.

- A station that is ready to send, chooses a random no. of slots as its wait time.
- The no. of slots in the window changes according to the binary exponential back-off strategy.

It means that it is set of one slot the first time & then doubles each time the station cannot detect an idle channel after the IFS time.

(26)

- In this, the station needs to sense the channel after each time slot.
- If the station finds the channel busy, it does not restart the process. It just stops the timer & restart it when the channel is sensed as idle.

3) Acknowledgement:

The positive ack & the time-out can help guarantee that receiver has received the frame.

- As despite all the precautions & collisions may occur & destroy the data.

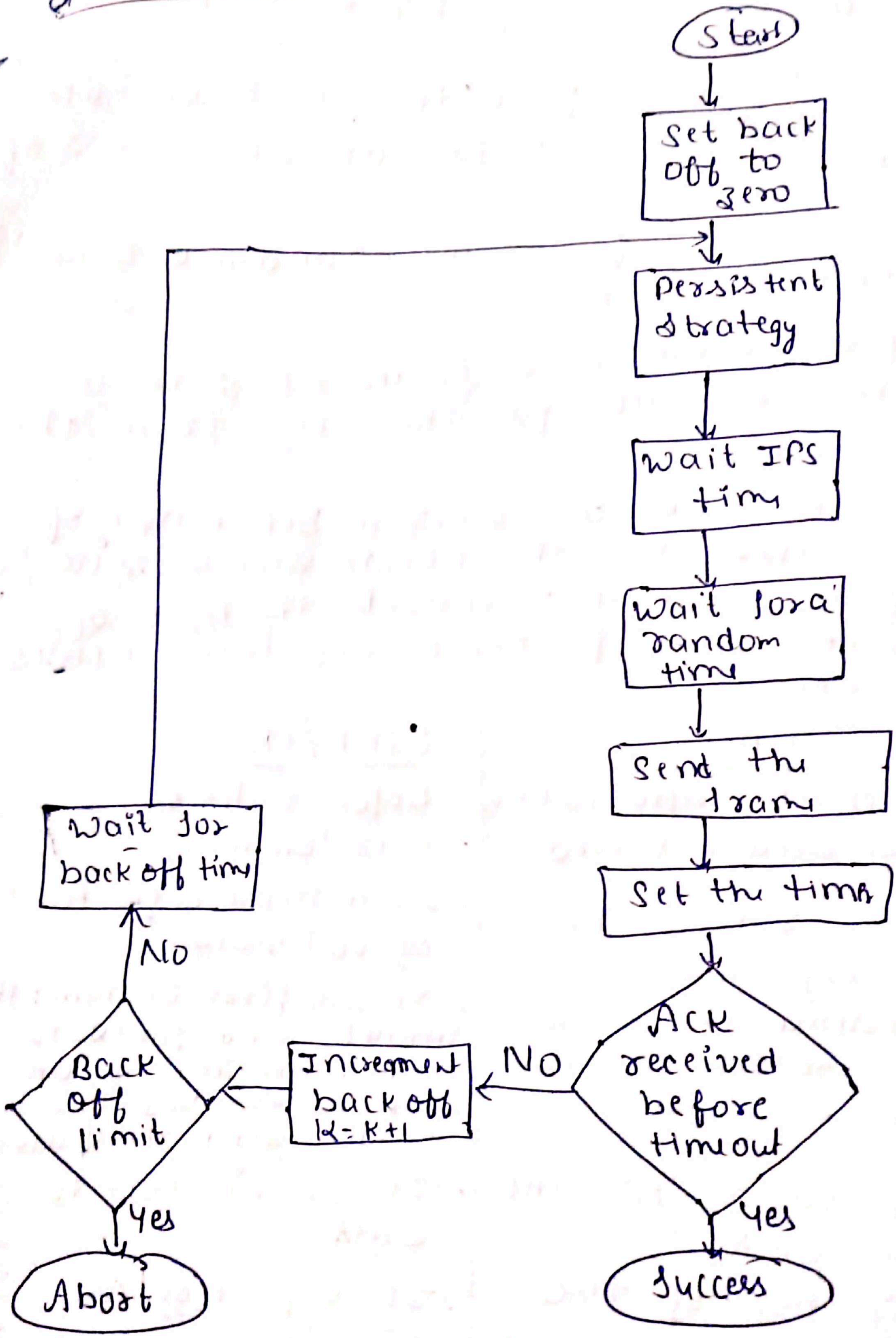
Advantages:

- It prevents collision.
- Data is not lost unnecessarily, due to ack.
- It avoid wasteful transmission.
- It is very much suited for wireless transmission.

Disadvantages:

- Long waiting time.
- High power consumption

Flow Chart of CSMA/CA



(31) • When station is ready to transmit, senses line by using p-persistent strategy.

• As soon as it find the line to be idle, the station waits for an IFS amt of time.

• Then waits for some random time & sends the frame.

• After sending a frame, it sets a timer & waits for the ack from the receiver.

• If the ack is received before expiry of the timer, then the transmission is successful.

• If not, then it increments the back-off parameter, wait for the back off time & resenses the line.

CSMA/CD	CSMA/CA
• It is effective after collision	• Before collision.
• It is used in wired n/w.	• wireless n/w.
• It only reduces the recovery time.	• It minimizes the possibility of collision.
• It resend the data frame ~~without~~ whenever collision occurs.	• It will first transmit the intent to send for data transmission, once an ack is received, the sender send the data
• It is more efficient than CSMA.	• It is similar to CSMA.
• It is part of the IEEE 802.3 standard	• It is part of the IEEE 802.11 standard

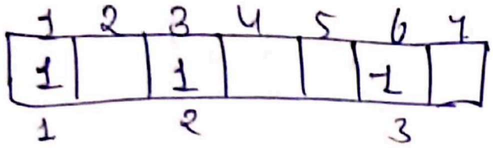
Collision Free Protocol

- Protocols without any collision is called collision free Procols.
- There are two types of CFP:
  1) Bit map Protocol
  2) Binary count down Protocol.

1) Bit Map Protocol:

- Assume there are N stations in a network numbered from 1 to N.
- There is a contention Period of N-slots.
- If a station 1 has a frame to send, it transmits a '1' during the slot 1, no other stations allowed to transmit the frame during this slot.
- Next station 2 will get an opportunity to transmit '1' during slot 2, but only if it has a frame in queue.
- So any station K may transmit '1' in the Kth slot only.
- Every station sees all the bit reservation transmitted during the contention Period, so each station knows which station's want to transmit.

- After the contention period, each station that asserted its desire to transmit send its frame in the order of station number.
- There will never be any collisions because everyone agrees on who goes next.



Bit map

Drawback:

- There is overhead of 1 bit per frame per station.

2) Binary Countdown:

- Binary countdown protocol is used to overcome the drawback of Bit map Protocol.
- It uses binary station addresses.
- A station wants to use the channel, broadcast its address a binary bit string starting with the high order bit.

Eg 4 stations want to transmit

0010 Bit time
0100 0 001 OR winner is 1010
1001 1 00 0
1010 2 01 1
High order bit

Limited Contention Protocols

1) Adaptive Tree Walk:

- Limited contention protocols use a contention method at low loads, but use a collision free method at high loads.
- Limited contention protocols dynamically regulate the no. of competing stations during a contention period.
- If there's not much traffic, the first station will be immediately allowed to transmit a frame & with a lot of traffic, the strategy reduces to the bit-map protocol.

Basic Idea of Limited Contention Protocols

1) Stations are divided into groups.
2) Each group is allocated a slot for transmission.
3) Members of one group compete for one slot only.

$$\text{Channel Efficiency} = \frac{d}{d + \ln N}$$

d = no. of bits in add

- All addresses are assumed of the same length.
- As soon as a station sees that a high order bit position that is '0' in its address has been overwritten by a 1, it gives up. [It means that some high order station wants to transmit].
- The remaining stations keep sending their addresses on the network, until a winner merges.
- The wining station sends out the frame.
- The bidding process repeats.

<u>Collision based Protocols</u>

Contention Methods { Pure Aloha, Slotted ,, , CSMA/CD } good when the n/w load is low

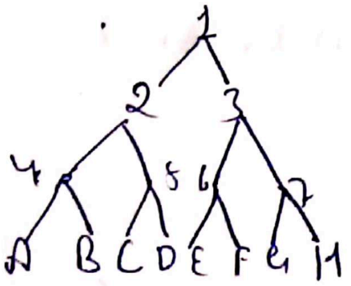
<u>Collision free Protocols</u>

bitmap, binary countdown } good when load is high

Adaptive Tree Walk Protocol:

In this, initially all stations/nodes are allowed to try to acquire the channel.

- If any station is able to acquire the channel, it sends the frame.
- If there is collision, then the nodes are divided into two equal groups & completes for only one of these groups slot 1.
- If one of its members acquire the channel then the next slot is reserved for the other group.
- If there is a collision, then that group is again subdivided & the same process is followed.
- In adaptive tree walk protocol, stations are organized in a binary tree.



Every station is treated as the leaf of binary tree.

- Here each bit slot is associated with a particular node in the tree with the root node corresponding to slot 0 for all stations in one group.

- Under light load, all station can-try for each slot like slotted aloha.
- Under heavy load, only a group can try for each slot.

Eg:

Slot 0: Station A, D, E, H try to transmit & collision occurs.

Slot 1: A & D try to transmit, collision occurs.

Slot 2: A try to transmit, it successful transmits the frame.

Slot 3: E & H try to transmit & collision occurs.

Slot 4: E try to transmit – success

Slot 5: D " " " – success

Slot 6: H " " " – success

order of transmission: A, E, D, H