Multiple Access Control

- Introduction :

Network layer
Data link layer
Physical layer

Data link layer → LLC (Logic link control) → Error Control, Flow Control
Data link layer → MAC (Multiple Access Control) → Access Control

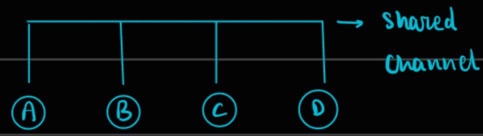
Multiple Access Protocol

Random Access	Control Access	Centralized Access
• ALOHA	• Reservation	• FDMA
• CSMA	• Polling	• TDMA
• CSMA/CD	• Token Passing	• CDMA
• CSMA/CA		

Links

Point to Point link	Broadcast link

Only 1 channel



- Even in full-duplex, there is no problem of collision

- Collisions are a problem. So, medium access control helps here

Random Access Protocols :

- No station is superior to the others and none of them is assigned methods i.e. no station stops or permits other stations to send data
- Any station can send the data whenever it wants
- Each station COMPETES FOR THE CHANNEL hence these are also known as Contention methods
- If more than one station tries to send data, there is an ACCESS CONFLICT COLLISION and the frames will be either DESTROYED OR MODIFIED
- To avoid collision, the station must send data by executing a procedure or condition defined by the protocol
- There is NO FIXED ORDER in which each station sends data (that's why they are called random access protocol)

ALOHA :

- was designed in Hawaii in 1970s. It was designed for wireless LAN but can be used in any shared medium
- Each station sends EQUAL SIZED FRAME
- 2 types : Pure ALOHA and Slotted ALOHA

- Pure ALOHA :
  - It allows the stations to transmit the data at any time whenever they want. So, chances of collisions are high
  - After transmitting the data packet, stations must wait for the Ack.
  - If Ack does not arrive AFTER timeout period, the station assumes the frame (or Ack) has been destroyed
  - Timeout period = 2 * Maximum possible round-trip propagation delay
    = 2 * Pd

Reason why Timeout = 2 * Pd : Consider the stations at 2 extremes :

Data sent from A to D takes 'Pd' time

Ack sent from D to A takes 'Pd' time

$\Rightarrow$ Timeout = Pd + Pd = 2 * Pd

- After timeout, station will again send data but if it immediately tries to send data packet then collision will occur because timeout IS SAME FOR ALL STATIONS. Hence, no station can effectively send data
- So, station MUST NOT send frame immediately after timeout
- It must wait for random amount of time called back-off time.

$\boxed{\text{Backoff time or Waiting time} = K * \text{slot time}}$

NOTE: Collision no. is wrt the data packet NOT wrt Station

$K \rightarrow$ Any random no. in b/w 0 to $2^N - 1$

$N \rightarrow$ Collision number.

Slot time can be either of these : { RTT 2 * Pd , Pd , Td }
(will be given in question)

- Max. no. of attempts for a station = 15

- <u>Binary Exponential Back off Algorithm</u> : Collision prob. decreases exponentially

Eg.

$\longleftarrow$ data pkt 2

data pkt 1 $\longrightarrow$

Collision occurs at time t_0 :

Ⓐ : $N = 1$ and Ⓑ : $N = 1$

$K = \{0, 1\}$ $K = \{0, 1\}$

$P(A) = 25\%$

So, 4 possibilities : $\{ \underbrace{(0,0), (0,1), (1,0), (1,1)}_{\text{Collision } (50\%)} \}$ $P(B) = 25\%$

Say we take $(0, 1)$. This means A does not wait and sends the frame immediately and B waits for (1 * slot time). So, A now sends pkt 2 and B is still trying to send pkt 1.

Say collision occurs now as well (t_1) : $P(A) = \frac{\#\{x > y\}}{\text{Total}}$

Ⓐ : $N = 2$ Ⓑ : $N = 1$ $= 5/8 = 62.5\%$

$K = \{0, 1, 2, 3\}$ $K = \{0, 1\}$ $P(B) = \frac{\#\{y > x\}}{\text{Total}}$

So, 8 possibilities : $\{ \underbrace{(0,0), (1,1)}_{\text{Collision } (25\%)}, \dots \}$ $= 1/8 = 12.5\%$

Now, say we take any non-collision case : $(1,0)$

Ⓐ $N = 3$ and Ⓑ $= 1$, $P(A) = 13/16 = 81.25\%$

$K = \{0, 1, \dots, 7\}$ $K = \{0, 1\}$ $P(B) = 1/16 = 6.25\%$

So, 16 possibilities : $\{ \underbrace{(0,0), (1,1)}_{\text{Collision } (12.5\%)}, \dots \}$

- **Disadvantages**: The algorithm suffers from CAPTURE EFFECT. If any station wins the 1st collision then it has more probability of winning in the next collision. So, here:

$$P(A)_{t0} < P(A)_{t1} < P(A)_{t2} \ldots \qquad CP: \text{Collision Prob.}$$

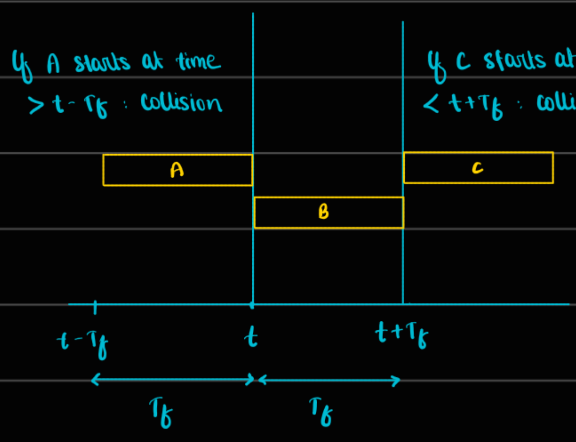
$$P(B)_{t0} > P(B)_{t1} > P(B)_{t3} \ldots$$

$$CP_{t0} > CP_{t1} > CP_{t2} > CP_{t3} \ldots$$

- Throughput of pure ALOHA: $S = Ge^{-2G}$ where G = no. of frames generated by network in one transmission time

For maximum throughput, $dS/dG = 0 \Rightarrow G = 1/2 \Rightarrow$ max. throughput $= 18.4\%$

Also, $G = 1/2$ implies 1 frame should be generated in 2 frames' transmission time meaning, if we do this, collisions WON'T OCCUR. This is called the Vulnerable time:



So, time range at which collisions can occur:

$(t - T_f, t + T_f) \Rightarrow$ Vulnerable time = max. − min. of this range

$V_T = 2T_f$

- Eg. ① Pure ALOHA; 200 bits frames; shared channel of B = 200 kbps, What is the throughput if the system (all stations together) produces 1000 frames generated by network in 1 sec. (Throughput here is defined as average no. of frames successfully transmitted per second)

$L = 200$ bits ; $B = 200 \times 10^3$ bps ; $T_f = L/B = 1ms$

1s $\longrightarrow$ 1000 frames

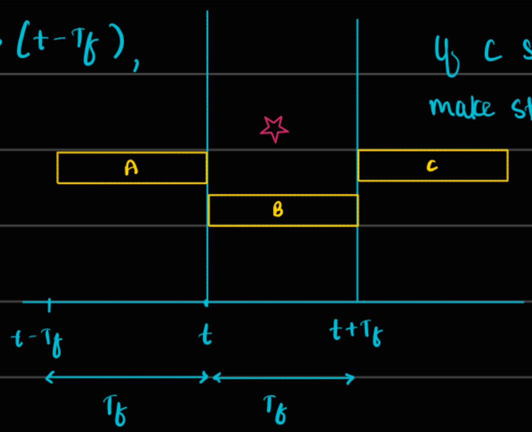
1ms $\longrightarrow$ 1 frame = G

$S = Ge^{-2G} = e^{-2} = 0.135 = 13.5\%$

Throughput (as defined here) = 1000×0.135 = 135 frames per second

- Slotted ALOHA :
  - It divides the time of shared channel in discrete intervals called time slots (time slots = Transmission time for one frame)
  - Any station can transmit its data at any time slots. Only condition is that station must start its transmission from the BEGINNING OF THE TIME SLOT.
  - If the beginning of the slot is missed, then station has to wait until the beginning of the next time slot
  - A collision may occur if 2 or more stations try to transmit data at the beginning of the same time slot

If A starts at time $> (t - T_f)$, make start time as $(t - T_f + T_f) = t$



If C start at time $< (t + T_f)$, make start time as $(t + T_f + T_f) = t + 2T_f$

Vulnerable Time = T_f
(VT)

☆ Collision will occur at cases like this : (say T_f = 2 secs)

A wants to send at $T_f + (T_f/10) \longrightarrow$ A will send at $2T_f$
B wants to send at $T_f + (T_f/20) \longrightarrow$ B " "
C want to send at $T_f + (T_f/3) \longrightarrow$ C " "

$\Rightarrow$ Collision

- Throughput of Slotted ALOHA : $S = Ge^{-G}$ where G = no. of frames generated by network in one transmission time

For max. throughput, $dS/dG = 0 \Rightarrow G = 1$. Meaning, generate 1 frame per transmission time to avoid collision and maximize throughput

Max. Throughput $= e^{-1} = 0.368 = 36.8\%$

CSMA (Carrier Sense Multiple Access)

- was developed to minimize the chance of collision. Chances of collision can be reduced if the station senses the medium or carrier before trying to use it
- CSMA requires each station to sense the carrier before transmitting the data
- Each station can sense the carrier only at its point of contact with carrier
- It is not possible for any station to sense the whole carrier. So, there is huge possibility that the station might sense the carrier free when it is actually not

- Vulnerable time of CSMA :

$$\boxed{\begin{array}{l}\text{So, collision range} = t_0 + P_d - t_0 = P_d \\ \Rightarrow \text{Vulnerable Time (VT)} = P_d\end{array}}$$

So, the possibility of collision exists because of prop. delay as when a frame is sent, it might take a small amount of time for the 1st bit to reach every station (due to which the carrier is sensed as idle by other stations)

$$\boxed{\text{Medium is IDLE TILL the 1st bit of data reaches ALL THE STATIONS}}$$

So, initially B senses as IDLE then as soon as the 1st bit reaches B's point to contact, B senses it as NOT IDLE. Same applies for all stations. ?? Say B sends to D. Since A is not on the path, will it sense the medium as NOT IDLE? If so, Collision occurs ??

- CSMA does not specify what station will do after collision
- In CSMA, if 2 station sense the channel to be idle and begin transmitting simultaneously, then both station's data will collide but still stations will keep on sending data
- Better way to save time and bandwidth is to detect the collision and IMMEDIATELY STOP TRANSMISSION

- <u>CSMA/CD (CSMA - Collision Detection)</u>

  - Frame transmission and collision detection is a CONTINUOUS PROCESS. Sender needs 2 different ports (not the usual ports, obviously) i.e. one for sending the data and another for detecting the collision

  - <u>No Acknowledgement</u> : • There is no need for Ack. If collision is not detected then frame is not detected then frame is definitely received by receiver

  - <u>No Copy</u> : • once frame is transmitted, Sender DOES NOT maintain a copy of that frame because the station is simultaneously sending the frame and detecting collision. So, if collision is not detected, it means receiver has received the data

- How does the station know whether it is its transmitted data that was collided?

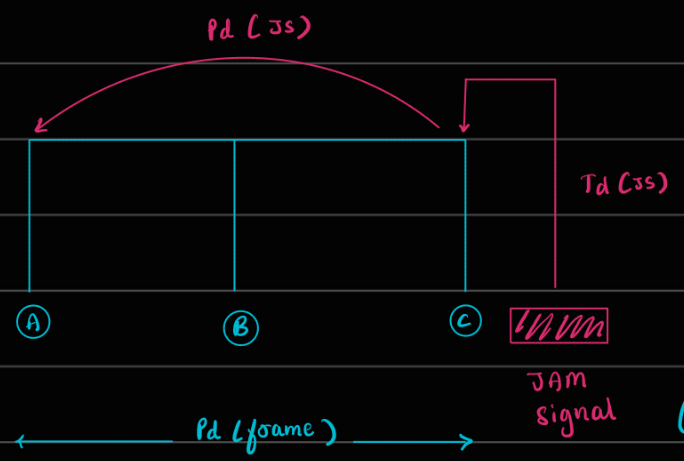
By using JAM signals. Whenever a collision occurs, a JAM signal is sent to all stations. And as soon as a station receives a JAM signal, it IMMEDIATELY STOPS ITS DATA TRANSMISSION. Now, if a station was sending data when it received the JAM signal, it means it was that station's data that was collided.

But there can be a case where the station sends the entire frame BEFORE receiving the JAM signal. In this case, the station won't think the collision is because of its data transmission.

<u>SOLUTION</u>: Station has to be sending frames when a JAM signal is received by it

$\Rightarrow$ <u>There should a minimum frame size</u>

Min. frame size to avoid collision in CSMA/CD (Ethernet)



$$Td\,(frame) \geq Pd\,(frame) + Pd\,(JS) + Td\,(JS)$$
$$\geq 2\,Pd + Td\,(JS)$$
$$\geq RTT + Td\,(JS)$$

(RTT here is different from RTT before)

$$\boxed{\begin{aligned} Td\,(frame) &\geq 2\,Pd + Td\,(JS) \\ &\geq RTT + Td\,(JS) \end{aligned}}$$

Eg. ① CSMA/CD; B = 1Gbps; d = 1km; signal speed = 200,000 km/s; No repeater;

Min. frame size in bits = ?

$$Td\,(frame) = \frac{L_{frame}}{B} \geq 2Pd + \cancel{Td\,(JS)}^{\,0} \quad \text{(not given)}$$

$\Rightarrow L_{frame} \geq B(2d/v) \geq 10^4$ bits

$\Rightarrow$ min. frame size $= 10^4$ bits

② CSMA/CD ; $B = 20 \times 10^6$ bps ; $P_d = 40ms$; min. L_{frame} in Bytes = ?

min. $L_{frame} = B\,(2P_d + T_d(JS)) = 1600$ bits $= 200$ Bytes

③ CSMA/CD ; $B = 10mbps$; $P_d = 46.4\,us$; $L_{JS} = 48$ bits ; min. L_{frame} = ?

$L_{frame} = (2P_d + T_d(JS)) \times B = (2P_d + L_{JS}/B) \times B = (46.4 + 8) \times 10^7 = 512$ bits

- Few Formulae :

- Efficiency in Ethernet (CSMA/CD) $= \dfrac{1}{1 + 6.44\alpha}$ where $\alpha = \dfrac{P_d}{T_d}$

  $= \dfrac{T_d}{\text{Collision time} + T_d + P_d}$ where collision time = slot duration × slot size

- Throughput of host = Prob. of success for a single station

  $= p(1-p)^{N-1}$ where p = prob. that a specific host successfully transmits and N = Total no. of hosts in the network

- Throughput of channel = Prob. of success for ANY station among all stations

  $= Np(1-p)^{N-1}$