Computer Network(CSC 503)

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Lecture 19 and 20

3.2 Medium Access Control sublayer

- Channel Allocation problem, Multiple access Protocol(Aloha, Carrier Sense Multiple Access (CSMA/CD)

Medium Access Control Sublayer

- The Open System Interconnections (OSI) model is a layered networking framework that conceptualizes how communications should be done between heterogeneous systems.
- The data link layer is the second lowest layer. It is divided into two sub layers:
  - **The logical link control (LLC) sublayer**
  - **The medium access control (MAC) sublayer**
- LLC sublayer is responsible for **flow and error control**
- MAC sublayer is responsible for who goes next on a **multiple access channel**.

Contd…

- Shared Channel →Issue--→ How to determine who gets to use the channel?
- The question that underlies the MAC sublayer is "how do we share a single physical medium?"
- The MAC sublayer is especially important in LANs, particularly wireless ones because wireless is naturally a broadcast channel.

Static Channel Allocation

- If there are N users, the bandwidth is divided into N equal-sized portions, with each user being assigned one portion. Since each user has a private frequency band, there is now no interference among users.

Contd…

- **Disadv :**

1. If fewer than N users are communicating a large piece of valuable spectrum will be wasted.
2. More than N users cannot communicate due to lack of bandwidth even if some of the users who have been assigned frequency band hardly ever transmit receive anything.

   Hence inefficient way of channel allocation

Dynamic channel Allocation

- Dynamic channel allocation are schemes for allotting shared network channels to competing users in a dynamic manner as per their requirements.

Assumptions:

1. Station Model:

Model consists of n independent stations and each station generates frame for transmission.

2. Single Channel:

A single channel is available for all communications.

All stations can transmit on it and all can receive from it.

3. Collision Assumption:

If 2 frames are transmitted simultaneously they overlap and the resulting signal is garbled. This event is called as collision.

A collided frame must be transmitted later again

Contd…

4 Time can be either: Continuous or slotted.

a. **Continuous time :**Frame transmission can start at any instant.

b. **Slotted time :**In slotted time, time is divided into discrete slots.

Transmission can begin only at the start of the slot.

If a slot does not contain any frame, it is called an idle slot; if it contains a single frame, then the transmission is successful; if it contains more than one frames, then a collision is said to occur.

Contd…

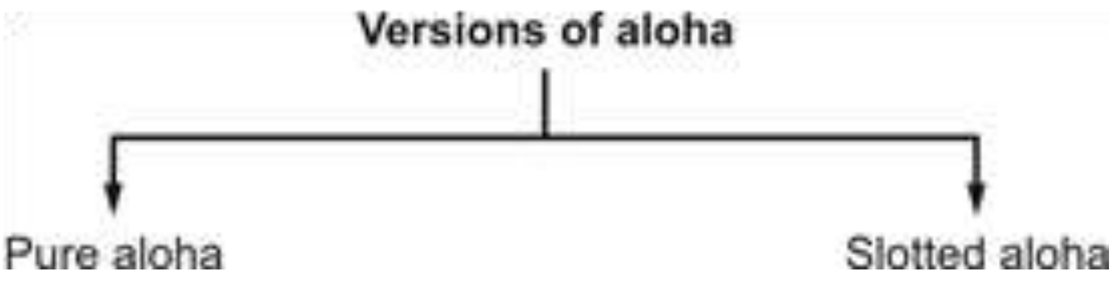
5. Carrier Sense or No Carrier Sense

- The stations may or may not be capable of detecting whether the channel is in use before sending the frames.
- In algorithms which are based upon **carrier sense**, a station sends frame only when it senses that the channel is not busy.
- On the other hand, in algorithms based upon **no carrier sense**, the stations transmit a frame when it is available and later are informed whether successful transmission had occurred or not.

ALOHA

Types of Aloha

- Pure
- Slotted



Pure Aloha

Introduced by Norman Abramson and his associates at the University of Hawaii in **1970**.

Assumptions

1. Continuous time
2. No carrier sense.

- Stations transmit whenever they have data to send.
- There will be collisions and the colliding frames will be destroyed.
- No feedback from receiver, hence the sender just waits for a random amount of time and sends it again.

Note : Waiting time --→Random

(If uniform, then same frames will collide over and over)

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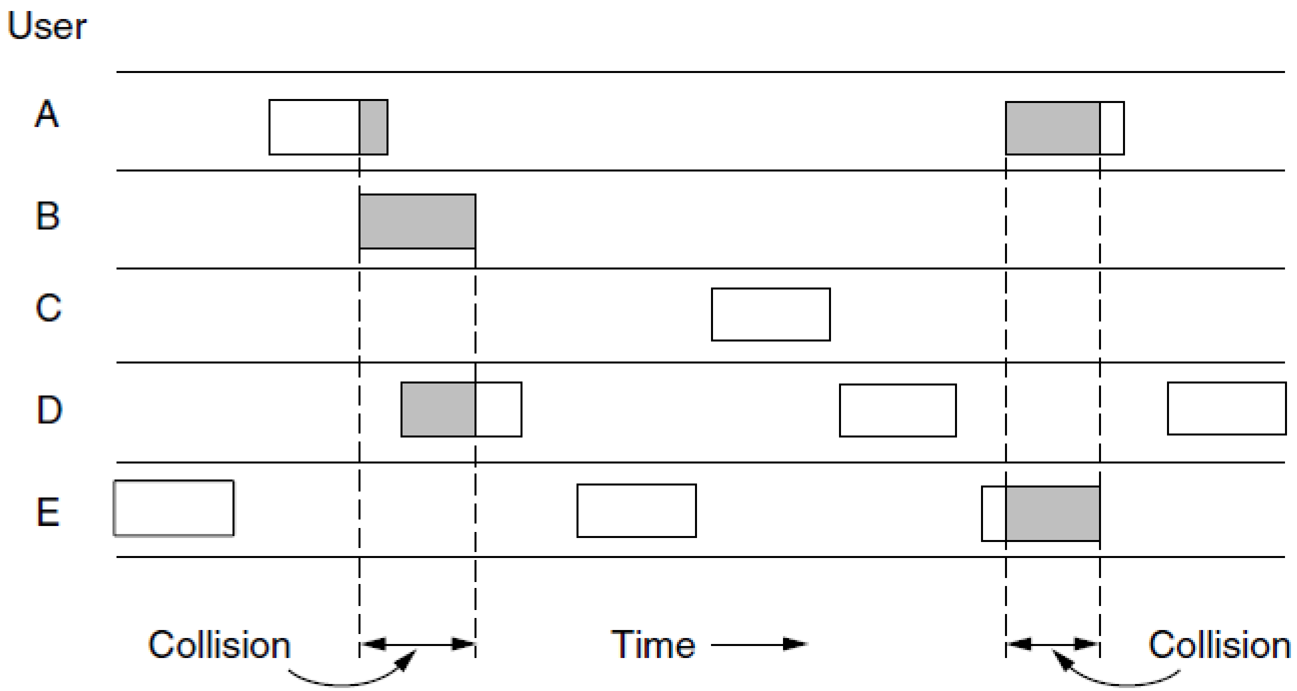

Figure In pure ALOHA, frames are transmitted at completely arbitrary times.

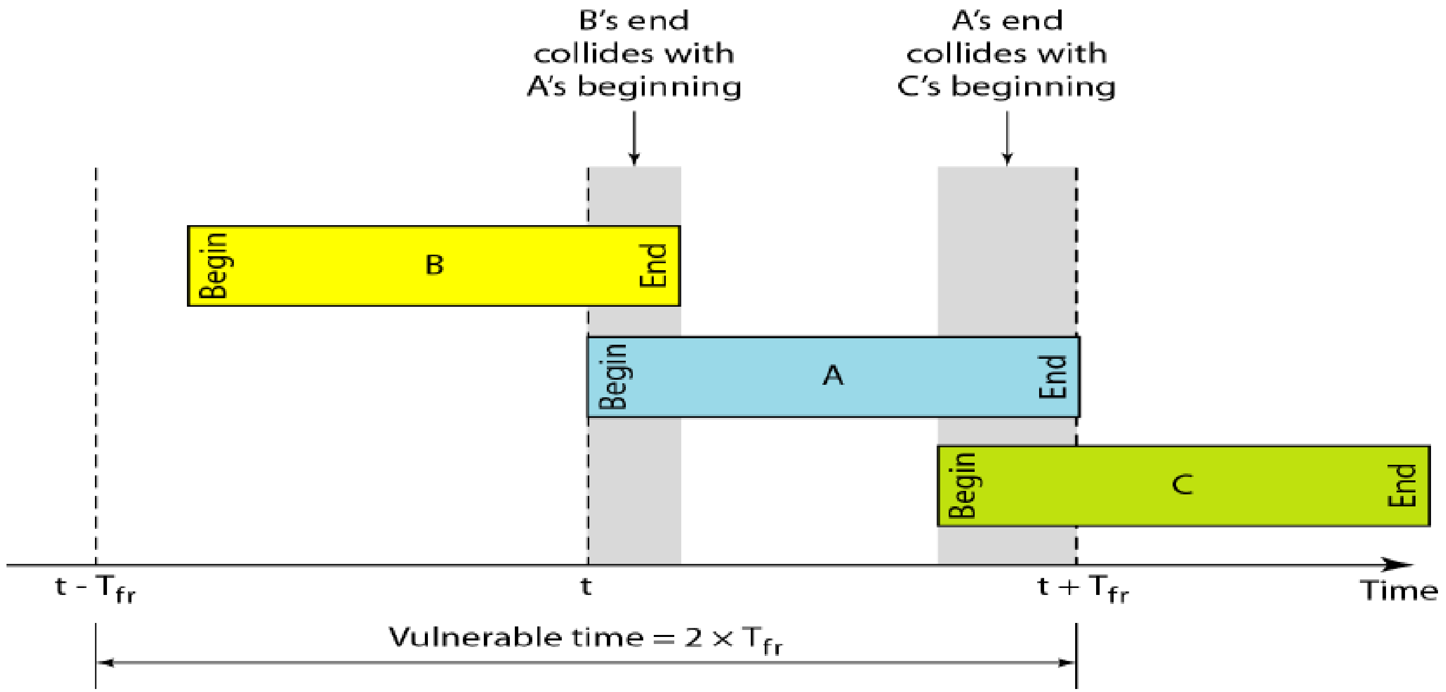

Fig: Vulnerable period for the Blue(middle) frame

Contd…

- The throughput can be calculated as the rate of transmission-attempts multiplied by the probability of success, and it can be concluded that the throughput is :

- S(Throughput$_{pure}$)= Ge^{-2G}

- Vulnerable time = 2*Tr

- The maximum throughput occurs at $G = 0.5$, with $S = 1/2e$, which is about 0.184.

- The channel utilization of 18%.

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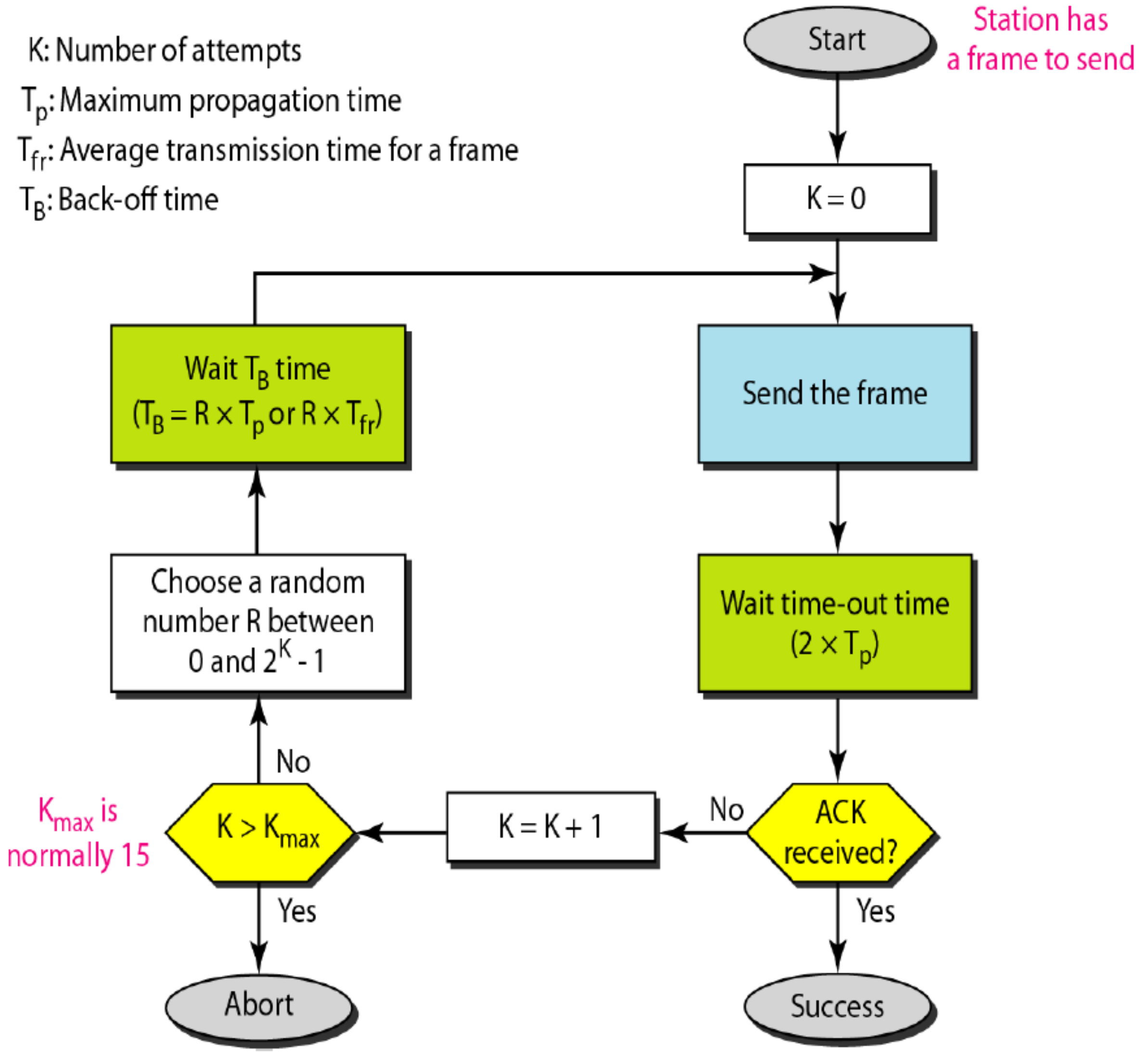

Backoff – a random amount of time that stations must wait after a failed transmission so that both participants don't start sending information at the same time

Slotted Aloha

- Introduced by Roberts in **1972**.
- Assumptions
  - Slotted time
  - No carrier sense
- Time is divided into equal size slots (= frame transmission time)
- Stations transmit only at beginning of a time slot.
- If collision: retransmit frame in future slots.

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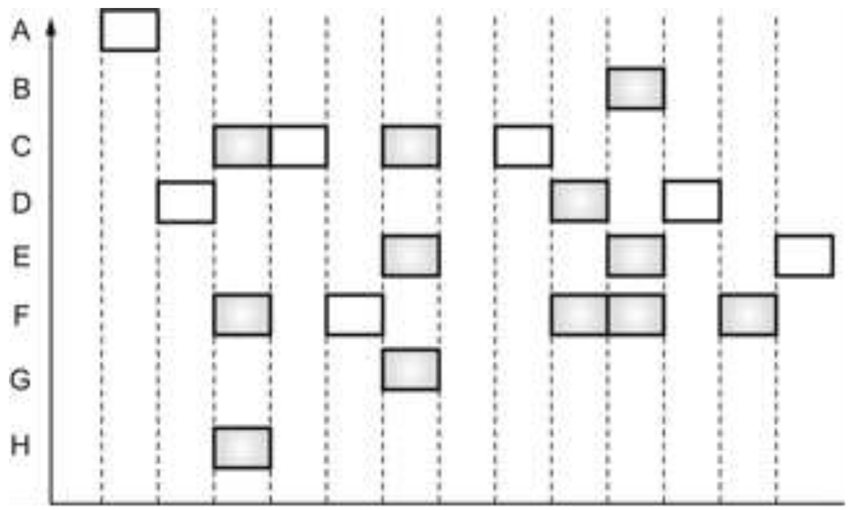

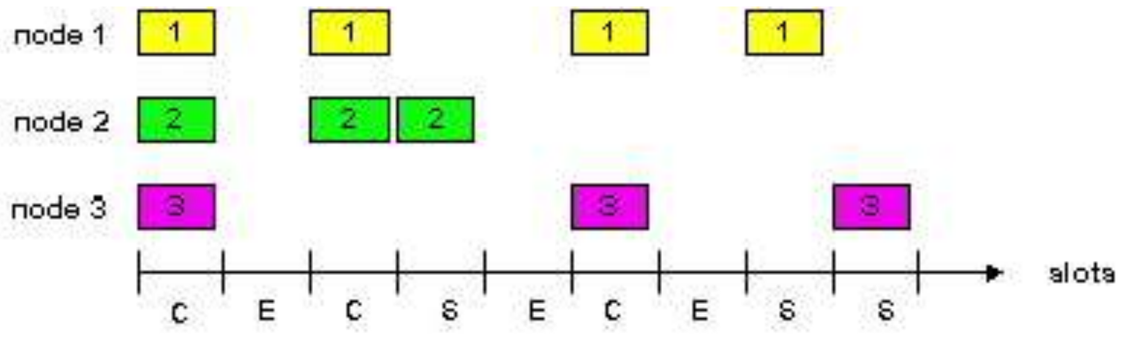

Success (S), Collision (C), Empty (E) slots

Fig: **Slotted ALOHA protocol**(Boxes indicate frames. Shaded boxes indicate frames which are in the same slots)

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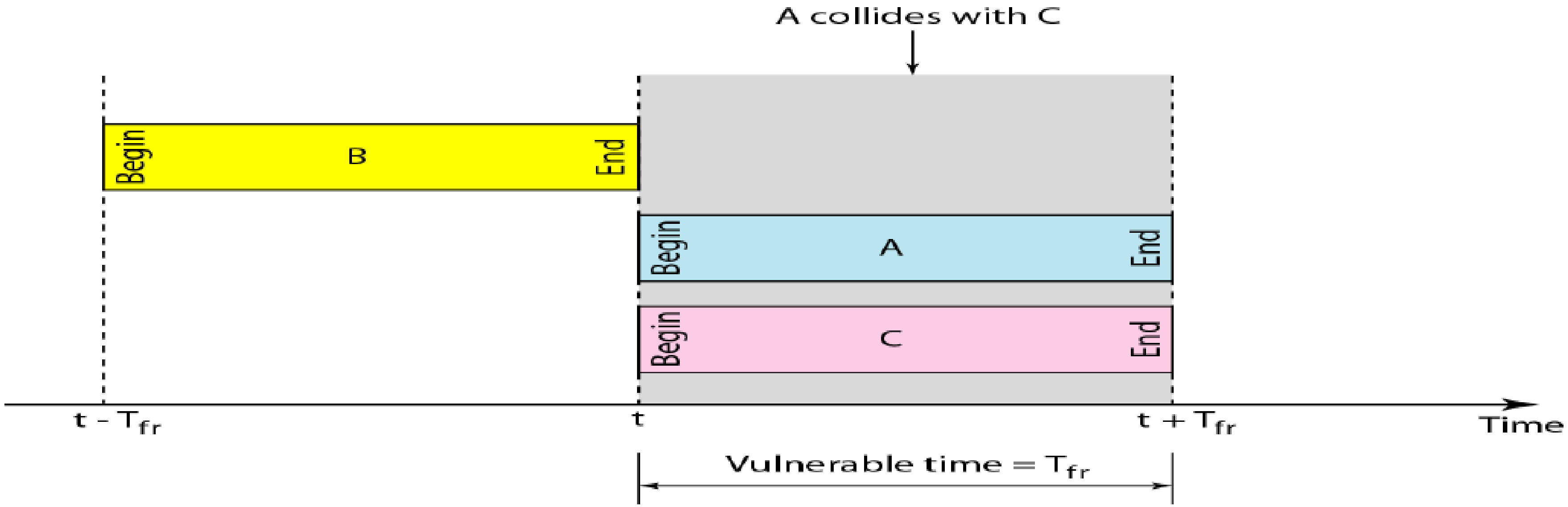
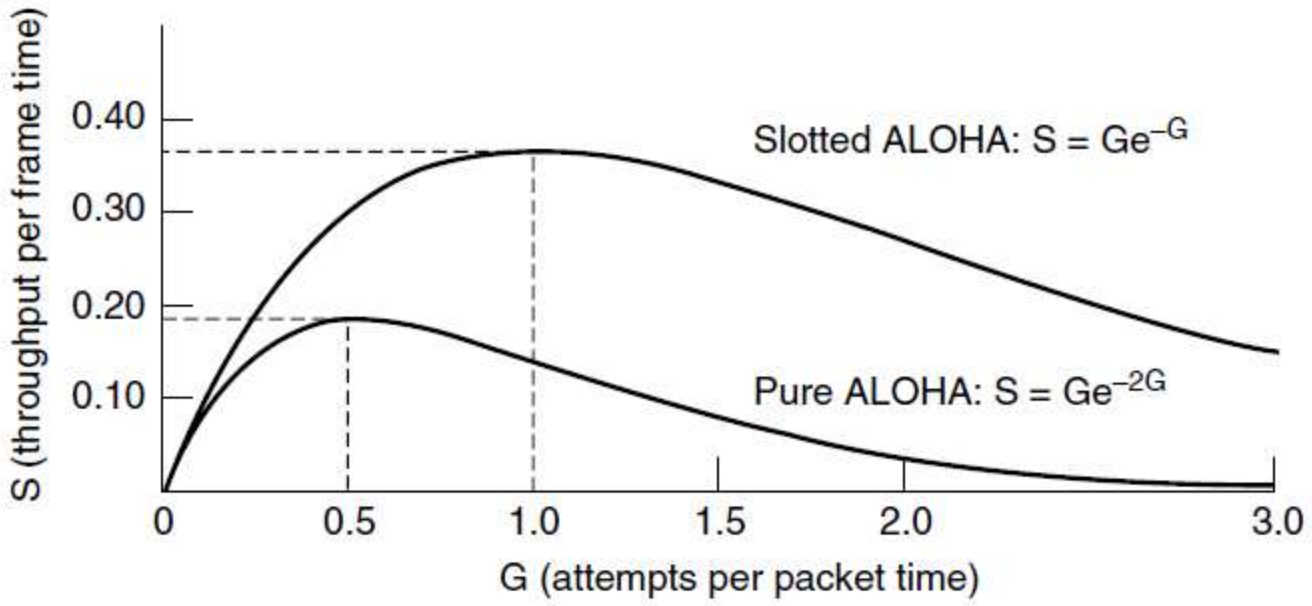


The throughput is : $S_{slotted} = Ge^{-G}$

The maximum throughput is *1/e* frames per frame-time (reached when *G* = 1), which is approximately 0.368 frames per frame-time, or 36.8%.

The throughput for slotted ALOHA is S = G × e−G . The maximum throughput S max = 0.368 when G = 1.

Throughput versus offered traffic for ALOHA systems



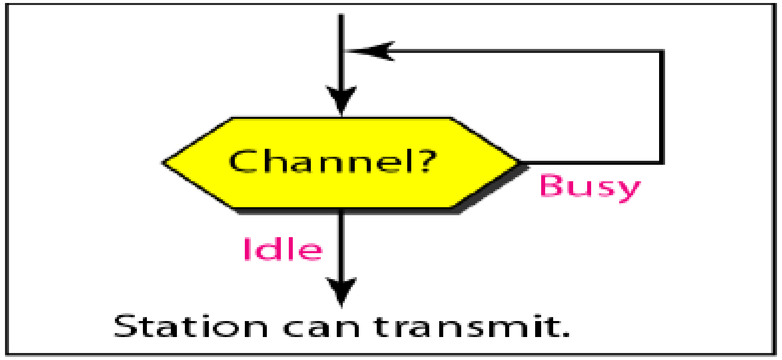
Carrier Sense Multiple Access(CSMA)

- Are protocols in which stations listen for a carrier (i.e. transmission) and act accordingly.

Protocols

- 1 persistent CSMA
- Non persistent CSMA
- p persistent CSMA
- CSMA /CD

1- persistent



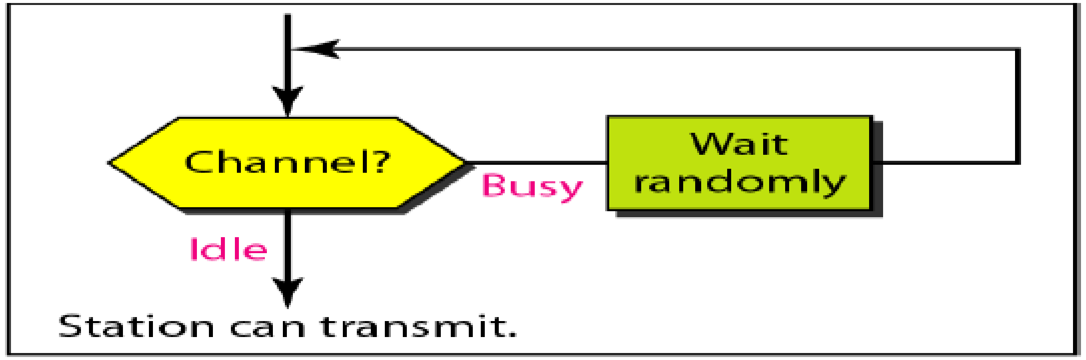
- When a station has data to send, it first listens to the channel.
- If channel is busy, the station waits until the channel is free.
- When it detects an idle channel, it transmits the frame.
- Node waits for an ACK.
- If no ACK received(collision), node waits a random amount of time and resumes listening to the channel.
- When the channel is again sensed idle, frame is immediately retransmitted.
- The protocol is called 1 persistent, because the station sends with probability of 1 when it finds the channel idle, meaning that is continuously listening.

Contd…

Disadvantage

- Propagation delays: Node A might sense idle channel even though node B already began transmitting since the signal hasn't reached A due to propagation delay causing collision.
- If Node A and Node B are sensing a busy channel at the same time, as soon as the channel is free, both A and B will begin transmitting their data.

Non-persistent CSMA



- Less greedy than 1 –persistent.
- Node listens to channel.
- If channel idle, node transmits data.
- If channel busy, node waits a randomly selected interval of time before sensing again.
- Randomized waiting times between channel sensing eliminate most collisions resulting from multiple users transmitting simultaneously upon sensing the transition from busy to idle.

Contd…

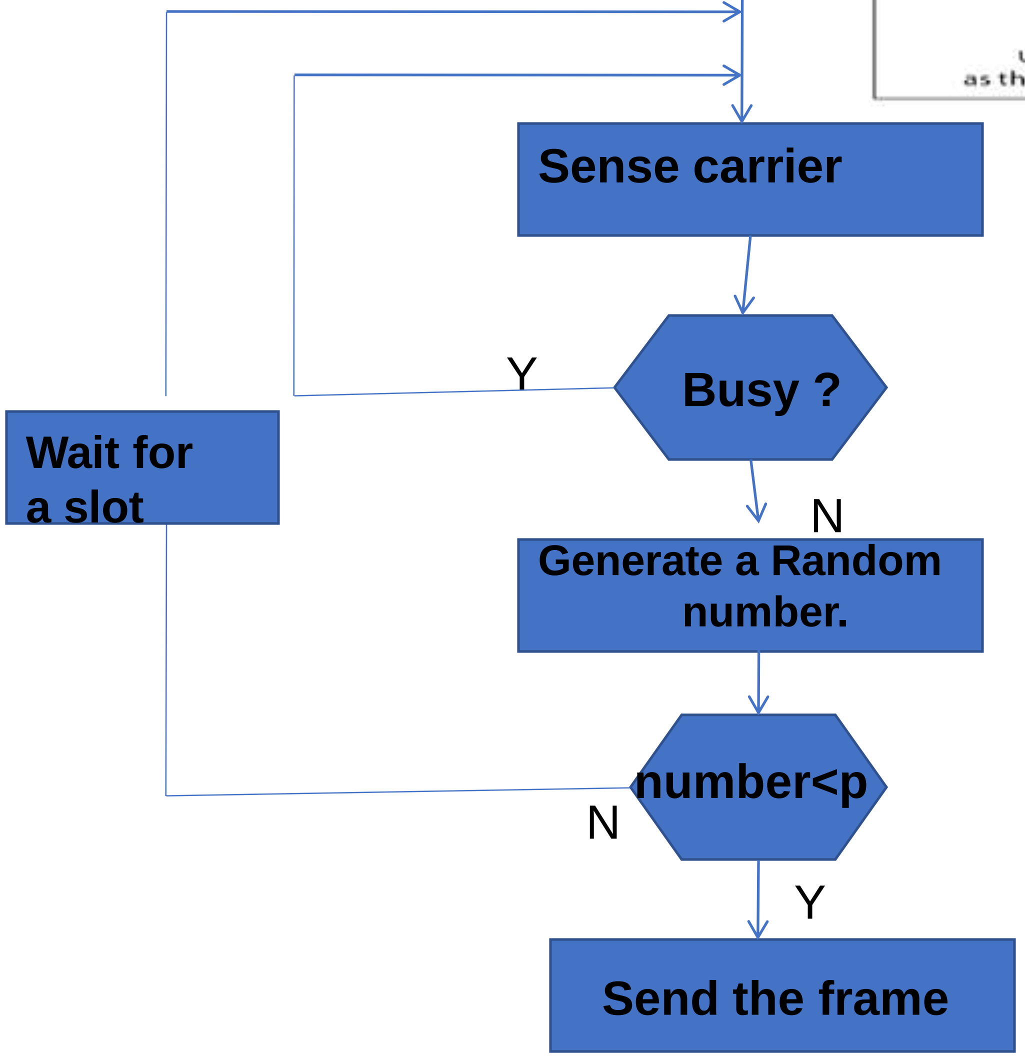
Adv :

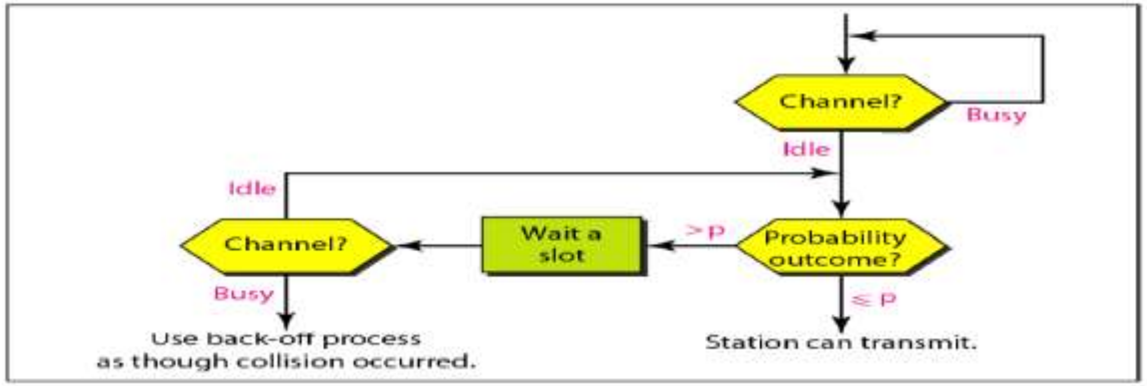
- Collisions are less Channel than 1-persistent.

p-persistent CSMA

- After a station finds the line idle, it may/may not send.
- It sends with a probability p and refrains from sending with a probability (1-p).
- Eg: p=0.3
- Each station generates a random no. between 0 and 1.
- If the random no. is less than 0.3 , then the station will send, otherwise the station refrains from sending.
- In the latter case, the station waits one time slot before sensing the medium again.
- If 2 stations generate no. less than 0.3 . Both will transmit and collision will take place.
- Likelihood of such occurrence can be reduced by reducing the transmission probability p.

- p-persistent





Contd…

- The last protocol is **p-persistent CSMA**. It applies to **slotted channels** and works as follows.
- When a station becomes ready to send, it senses the channel. If it is idle, it transmits with a probability *p*. With a probability $q = 1 - p$, it defers until the next slot.
- If that slot is also idle, it either transmits or defers again, with probabilities *p* and *q*. This process is repeated until either the frame has been transmitted or another station has begun transmitting.
- In the latter case, the unlucky station acts as if there had been a collision (i.e., it waits a random time and starts again).
- If the station initially senses that the channel is busy, it waits until the next slot and applies the above algorithm.

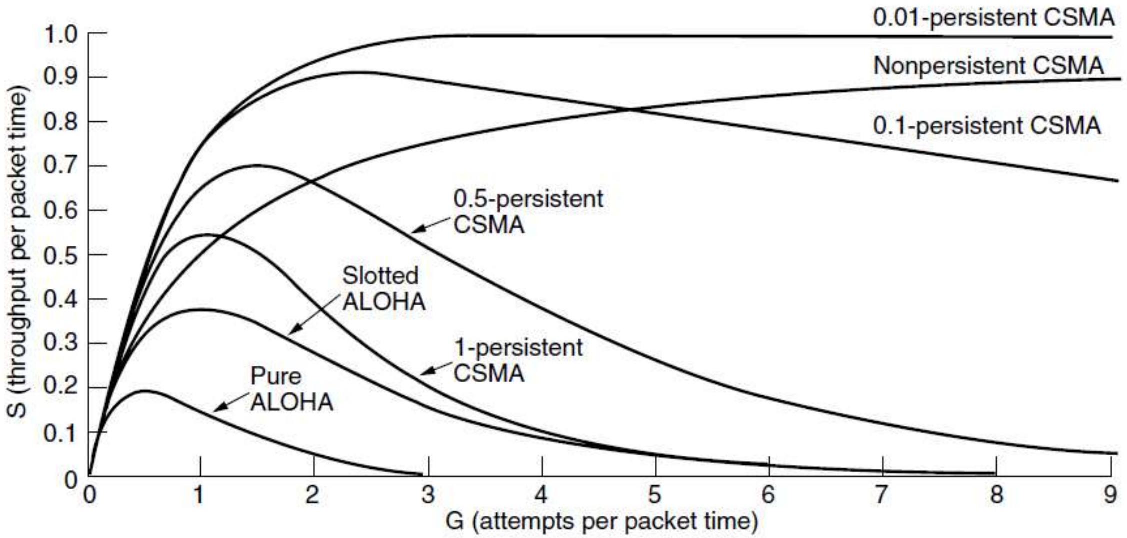


Fig: Comparison of the channel utilization versus load for various random access protocols.

CSMA/CD

Carrier Sense Multiple Access/Collision Detection (CSMA/CD)

- A station wishing to transmit first listens to the medium to determine if another transmission is in progress.
- If the medium is in use, the station must wait.
- If the medium is idle, the station may transmit.
- It may happen that two or more stations attempt to transmit at about the same time. If this happens, therefore will be a collision.

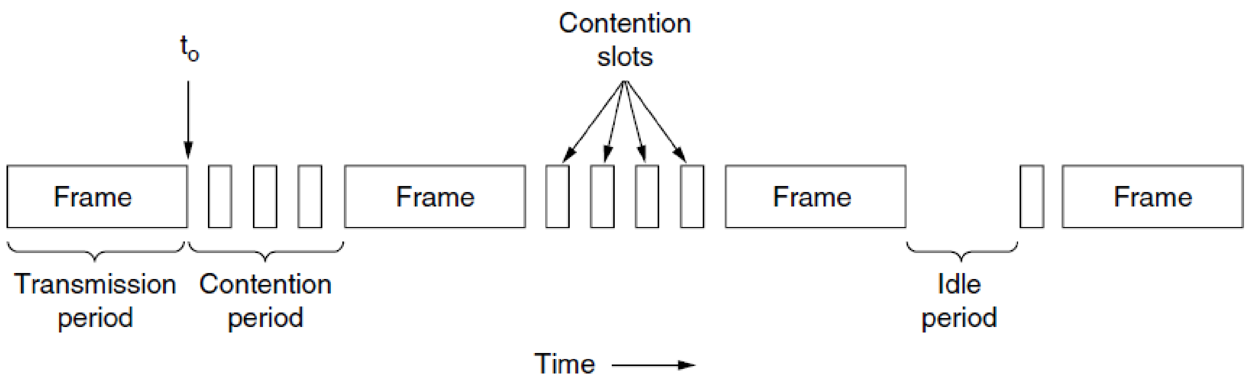


Fig: CSMA/CD can be in contention, transmission, or idle state.

Contd…

- The station waits (round-trip propagation delay) for acknowledgement after transmission.
- With CSMA/CD this time can be reduced.
- In CSMA/CD the station wishing to transmit first listens to make certain that the link is free, then transmits data and listens again.
- The station checks the line for extremely high voltages that indicate a collision.
- After a station detects collision, it aborts it's transmission waits a random period of time and tries again.

CSMA/CD

- How long will it take for a station to realize that it has seized the channel?
- Let the time for a signal to propagate between 2 farthest station be T.
- A station cannot be sure that it has seized the channel until it has transmitted for 2T without hearing a collision.

- A network using CSMA/CD has a bandwidth of 10Mbps. If the maximum propagation time is 25.6 microsec. What is the minimum size of the frame?

In the worst case , a station needs to transmit for a period of

2xTp= 2x25.6 microsec=51.2microsec to detect a collision.

How many bits can be transmitted in 51.2 microsec if the bandwidth is 10Mbps?

512bits or 64 bytes

Ethernet 802.3

- Very popular LAN standard.
- Ethernet and IEEE 802.3 are distinct standards but as they are very similar to one another these words are used interchangeably.
- It covers the physical layer and MAC sublayer protocol.
- IEEE **802.3** is otherwise known as the **Ethernet** standard and defines the physical layer and the media access control (MAC) of the data link layer for wired **Ethernet** networks, generally as a local area network (**LAN**) technology.
- 1-persistent CSMA/CD LAN.
- Before sending data, CSMA/CD stations “listen” to the network to see if it is already in use. If it is, the station wishing to transmit waits. If the network is not in use, the station transmits. A collision occurs when two stations listen for network traffic, “hear” none, and transmit simultaneously.
- In this case, both transmissions are damaged, and the stations must retransmit at some later time.

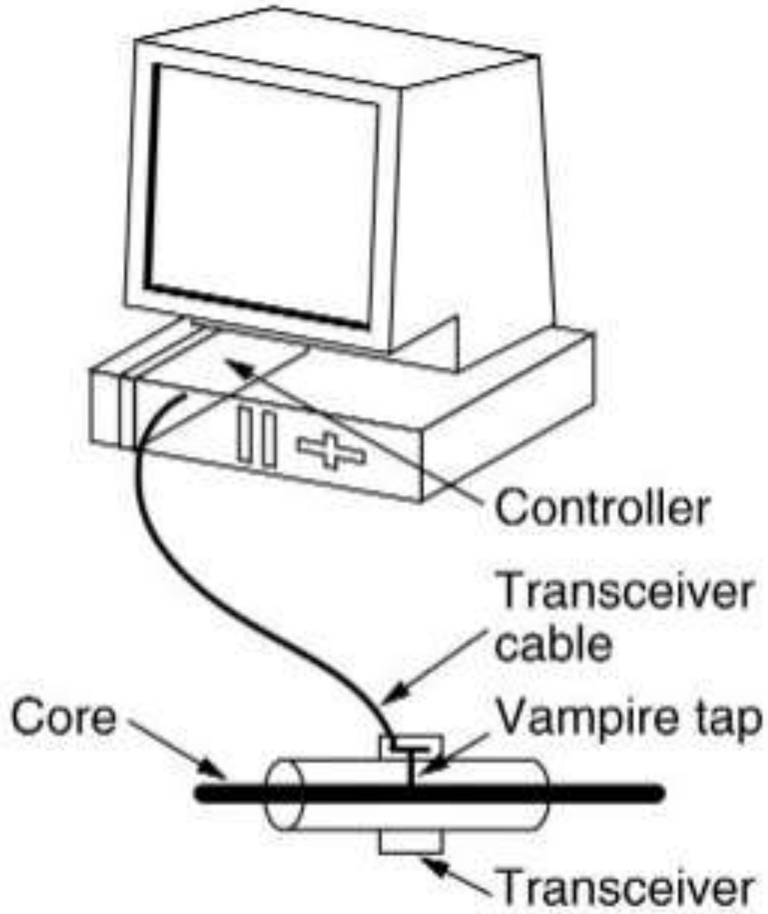
Ethernet 802.3

- Ethernets are broadcast network.
- All stations see all frames, regardless of whether they represent an intended destination.
- Each station must examine received frames to determine if the station is a destination. If so, the frame is passed to a higher protocol layer for appropriate processing.

Ethernet 802.3

Physical properties

- An Ethernet segment is implemented on a coaxial cable.
- This cable is similar to the type used for cable TV.
- Hosts connect to an Ethernet segment by tapping into it;
- Taps(node spacing) must be at least 2.5 m apart.
- A transceiver a small device directly attached to the tap detects when the line is idle and drives the signal when the host is transmitting.
- It also receives incoming signals.
- The transceiver is, in turn, connected to an Ethernet adaptor, which is plugged into the host.



Controller
Transceiver
cable
Core
Vampire tap
Transceiver

Ethernet 802.3

- Ethernet describes a technology for cabled data networks that connect software and/or hardware with each other.
- This mostly takes place via LAN cables, which is why Ethernet is also sometimes referred to as LAN technology.
- In this way, Ethernet enables data exchanges between end devices.
- These could be computers, printers, servers, routers, or others.
- When combined into a local network, these devices establish connections via the Ethernet protocol and can exchange data packages with one another.

Ethernet 802.3

Ethernet frame format

- Ethernet frame starts with Preamble and SFD, both works at the physical layer.
- Ethernet header contains both Source and Destination MAC address, after which the payload of the frame is present.
- The last field is CRC which is used to detect the error.

PREAMBLE	SFD	DESTINATION ADDRESS	SOURCE ADDRESS	LENGTH	DATA	CRC
7 Bytes	1 Byte	6 Bytes	6 Bytes	2 Bytes	46 - 1500 Bytes	4 Bytes

Ethernet 802.3

- **PREAMBLE –** Ethernet frame starts with 7-Bytes Preamble. The preamble tells receiving stations that a frame is coming.This is a pattern of alternative 0's and 1's which indicates starting of the frame and allow sender and receiver to establish bit synchronization.
- (Preamble) indicates the receiver that frame is coming and allow the receiver to lock onto the data stream before the actual frame begins.
- **Start of frame delimiter (SFD) –** This is a 1-Byte field which is always set to 10101011. SFD indicates that upcoming bits are starting of the frame, which is the destination address. Sometimes SFD is considered the part of PRE, this is the reason Preamble is described as 8 Bytes in many places. The SFD warns station or stations that this is the last chance for synchronization.
- **Destination Address –** This is 6-Byte field which contains the MAC address of machine for which data is destined.

- **Source Address –** This is a 6-Byte field which contains the MAC address of source machine.
- **Length** – Length is a 2-Byte field, which indicates the length of entire Ethernet frame. This 16-bit field can hold the length value between 0 to 65534, but length cannot be larger than 1500 because of some own limitations of Ethernet.
- **Data –** This is the place where actual data is inserted, also known as **Payload.** The maximum data present may be as long as 1500 Bytes. In case data length is less than minimum length i.e. 46 bytes, then padding 0's is added to meet the minimum possible length.
- **Cyclic Redundancy Check (CRC) –** CRC is 4 Byte field. This field contains a 32-bits hash code of data, which is generated over the Destination Address, Source Address, Length, and Data field. If the checksum computed by destination is not the same as sent checksum value, data received is corrupted.

Note – Size of frame of Ethernet IEEE 802.3 varies 64 bytes to 1518 bytes including data length (46 to 1500 bytes).

Question) A and B are the only two stations on an Ethernet. Each has a steady queue of frames to send. Both A and B attempt to transmit a frame, collide, and A wins the first backoff race, At the end of this successful transmission by A, both A and B attempt to transmit and collide. The probability that A wins the second backoff race is

A) 0.5

B) 0.625

C) 0.75

D) 1.0

Binary exponential Back off algorithm

- In CSMA/CD the station wishing to transmit first listens to make certain that the link is free, then transmits data and listens again.
- The station checks the line for extremely high voltages that indicate a collision.
- After a station detects collision, it aborts it's transmission waits a **random period of time** and tries again.

- Back-off algorithm is a **collision resolution** mechanism which is used in MAC protocols (CSMA/CD).
- **This algorithm is generally used in Ethernet to schedule re-transmissions after collisions.**

Contd…

- If a collision takes place between 2 stations, they may restart transmission as soon as they can after the collision.
- This will always lead to another collision and form an infinite loop of collisions leading to a deadlock.
- To prevent such scenario back-off algorithm is used.
- Let us consider an scenario of 2 stations A and B transmitting some data:

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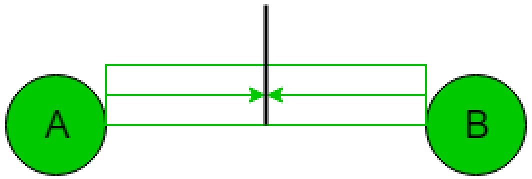
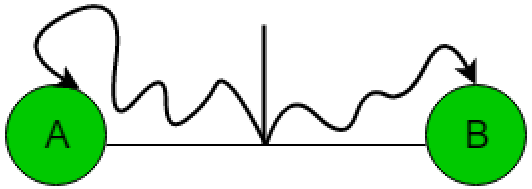
At t = 0 , both A and B start transmission



Packets of both A and B collide



Both stations A and B detect collision

Contd…

- After a collision, time is divided into discrete slots (**T_{slot}**) whose length is equal to 2t, where t is the maximum propagation delay in the network.
- The stations involved in the collision randomly pick an integer from the set K i.e {0, 1}.
- This set is called the contention window.
- If the sources collide again because they picked the same integer, the contention window size is doubled and it becomes {0, 1, 2, 3}.
- Now the sources involved in the second collision randomly pick an integer from the set {0, 1, 2, 3} and wait that number of time slots before trying again.

Contd…

- Before they try to transmit, they listen to the channel and transmit only if the channel is idle. This causes the source which picked the smallest integer in the contention window to succeed in transmitting its frame.
- So, Back-off algorithm defines a *waiting time for the stations involved in collision*, i.e. for how much time the station should wait to re-transmit.

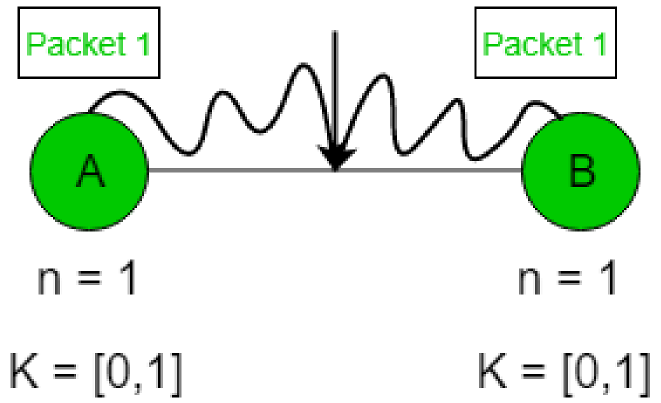
Waiting time = back–off time

Let n = collision number or re-transmission serial number.

Then, Waiting time = $K * T_{slot}$ where $K = [0, 2^n – 1]$

Example –

- **Case-1 :**
  Suppose 2 stations A and B start transmitting data (Packet 1) at the same time then, collision occurs.
- So, the collision number n for both their data (Packet 1) = 1.
- Now, both the station randomly pick an integer from the set K i.e. {0, 1}.



Value of K

A	B
0	0
0	1
1	0
1	1

Contd…

- **When both A and B choose K = 0**
  –> Waiting time for A = $0 * T_{slot} = 0$
  Waiting time for B = $0 * T_{slot} = 0$ Therefore, both stations will transmit at the same time and hence collision occurs.

- **When A chooses K = 0 and B chooses K = 1**
  –> Waiting time for A = $0 * T_{slot} = 0$
  Waiting time for B = $1 * T_{slot} = T_{slot}$ Therefore, A transmits the packet and B waits for time T_{slot} for transmitting and hence A wins.

- **When A chooses K = 1 and B chooses K = 0**
  –> Waiting time for A = $1 * T_{slot} = T_{slot}$
  Waiting time for B = $0 * T_{slot} = 0$ Therefore, B transmits the packet and A waits for time T_{slot} for transmitting and hence B wins.

- **When both A and B choose K = 1**
  –> Waiting time for A = $1 * T_{slot} = T_{slot}$
  Waiting time for B = $1 * T_{slot} = T_{slot}$ Therefore, both will wait for the same time T_{slot} and then transmit. Hence, collision occurs

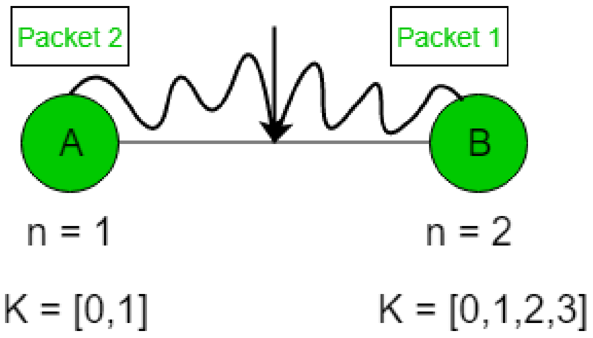
Contd…

- Probability that A wins = 1/4
- Probability that B wins = 1/4
- Probability of collision = 2/4

Case-2 :

- Assume that A wins in Case 1 and transmitted its data(Packet 1).
- Now, as soon as B transmits its packet 1, A transmits its packet 2.
- Hence, collision occurs.
- Now collision no. n becomes 1 for packet 2 of A and becomes 2 for packet 1 of B.
  For packet 2 of A, K = {0, 1}
  For packet 1 of B, K = {0, 1, 2, 3}

Contd…



Value of K

A	B
0	0
0	1
0	2
0	3
1	0
1	1
1	2
1	3

- Probability that A wins = 5/8
- Probability that B wins = 1/8
- Probability of collision = 2/8

So, probability of collision decreases as compared to Case 1.

Contd…

Advantage –

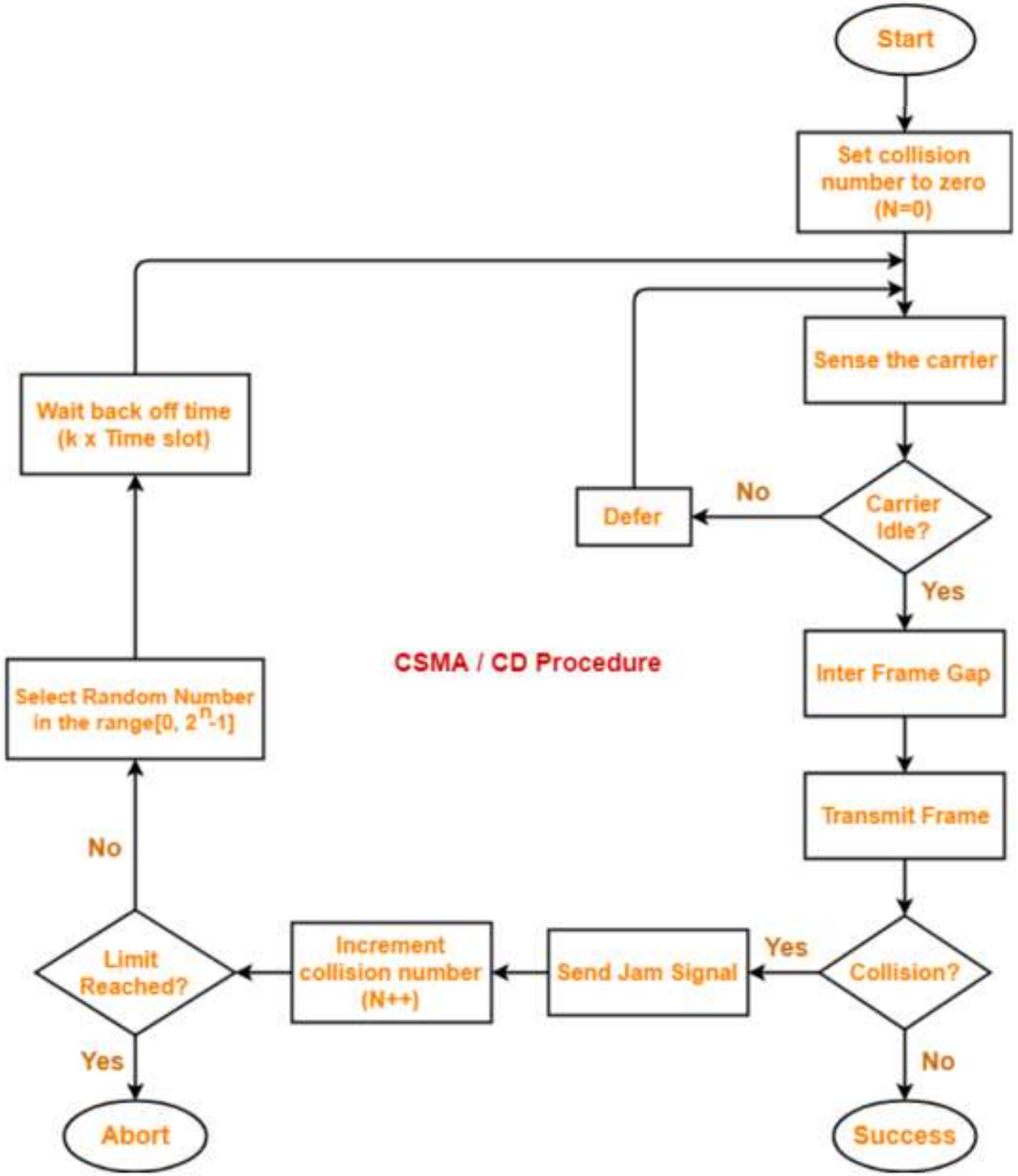
- Collision probability decreases exponentially.

Disadvantages –

- **Capture effect:** Station who wins once keeps on winning.
- Works only for 2 stations or hosts.

Binary exponential Back off algorithm

CSMA/CD flowchart



Jam signal: A **signal** that carries a bit pattern sent by a data station to inform the other stations that they must not transmit. In carrier-sense multiple access with collision detection (**CSMA/CD**) networks, the jam **signal** indicates that a collision has occurred.