Computer Network

Medium Access Sub-Layer

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Static and dynamic channel allocation

- Channel allocation is a process in which a single channel is divided and allotted to multiple users in order to carry user specific tasks.
- There are user's quantity may vary every time the process takes place.
- If there are N number of users and channel is divided into N equal-sized sub channels, Each user is assigned one portion.
- If the number of users are small and don't vary at times, then Frequency Division Multiplexing can be used as it is a simple and efficient channel bandwidth allocating technique.
- **Channel allocation problem can be solved by two schemes:** Static Channel Allocation in LANs and MANs, and Dynamic Channel Allocation.

Static Channel Allocation:

- The traditional way of allocating a s**ingle channel between multiple users** is called static channel allocation.
- Static channel allocation is also called **fixed channe**l allocation.
- Such as a telephone channel among many users is a real-life example of static channel allocation.

Static and dynamic channel allocation

Dynamic Channel Allocation:

- The technique in which channels are **not permanently** allocated to the users is called dynamic channel allocation.
- In this technique, no fixed frequency or fixed time slot is allotted to the user.
- The allocation depends upon the traffic.
- If the traffic increases, more channels are allocated, otherwise fewer channels are allocated to the users.

Difference Between Static and Dynamic Channel Allocation

Fixed Channel allocation	Dynamic Channel allocation
In this technique, a fixed number of channels are allocated to the cells.	In this technique, channels are not permanently allocated to the cells.
Mobile station centre has fewer responsibilities.	The mobile station centre has more responsibilities.
The allocation is not dependent on traffic.	The allocation depends on the traffic.
Fixed channel allocation is cheaper than dynamic channel allocation.	Dynamic channel allocation is costly as compared to fixed channel allocation.
In this no need of complex algorithms.	Complex algorithms are used in this.

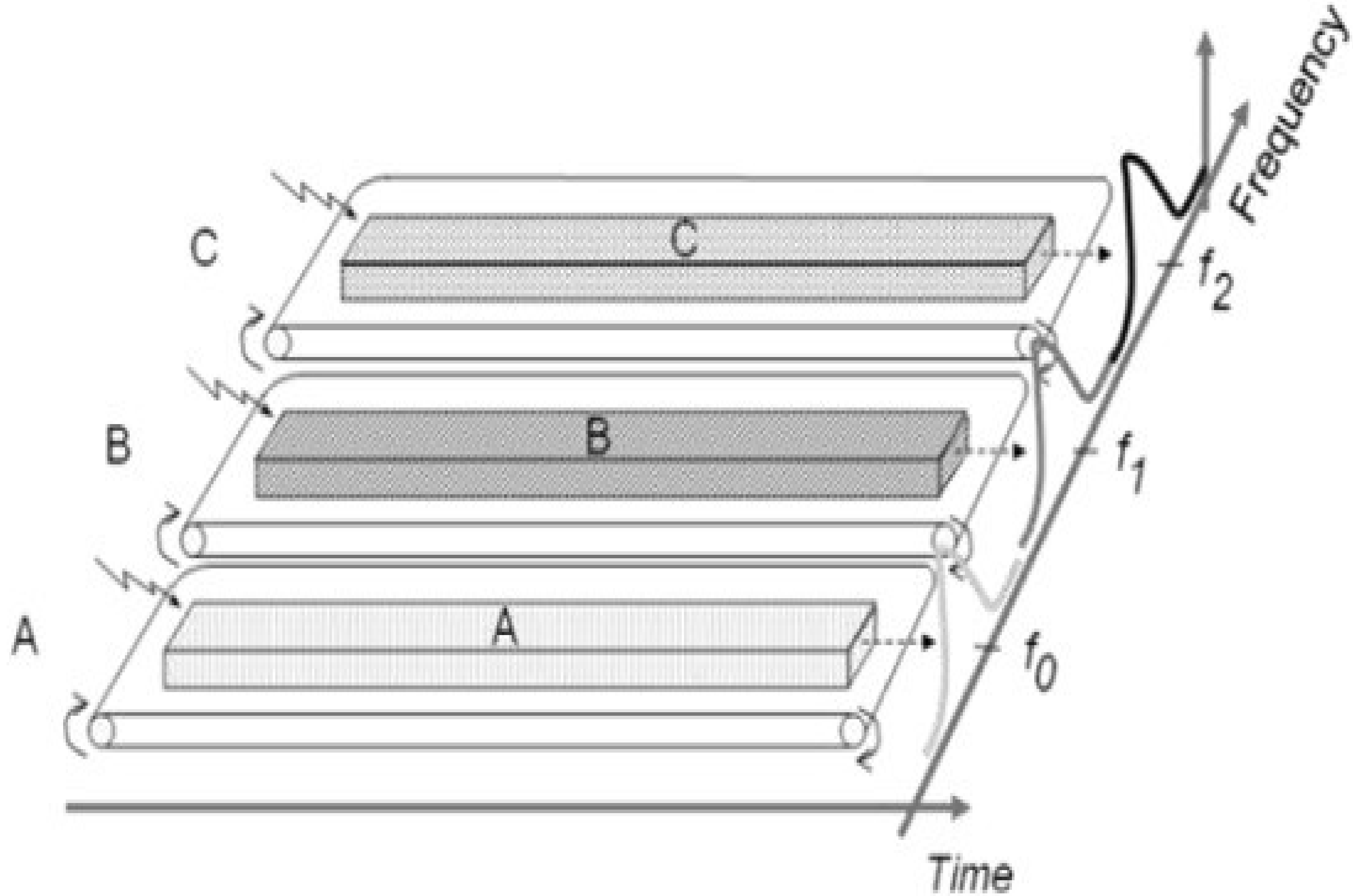
Frequency Division Multiple Access (FDMA)

- Frequency Division Multiple Access (FDMA) is one of the most common analogue multiple access methods.
- The frequency band is divided into channels of equal bandwidth so that each conversation is carried on a different frequency.
- In FDMA method, guard bands are used between the adjacent signal spectra to minimize crosstalk between the channels.
- A specific frequency band is given to one person, and it will received by identifying each of the frequency on the receiving end.
- It is often used in the first generation of analog mobile phone.

Advantages of FDMA:

- It reduces the cost and lowers the inter symbol interference (ISI)
- Since the transmission is continuous, less number of bits are required for synchronization and framing.
- Reduces the bit rate information and the use of efficient numerical codes increases the capacity.
- Equalization is not necessary.

Frequency Division Multiple Access (FDMA)



Frequency Division Multiple Access (FDMA)

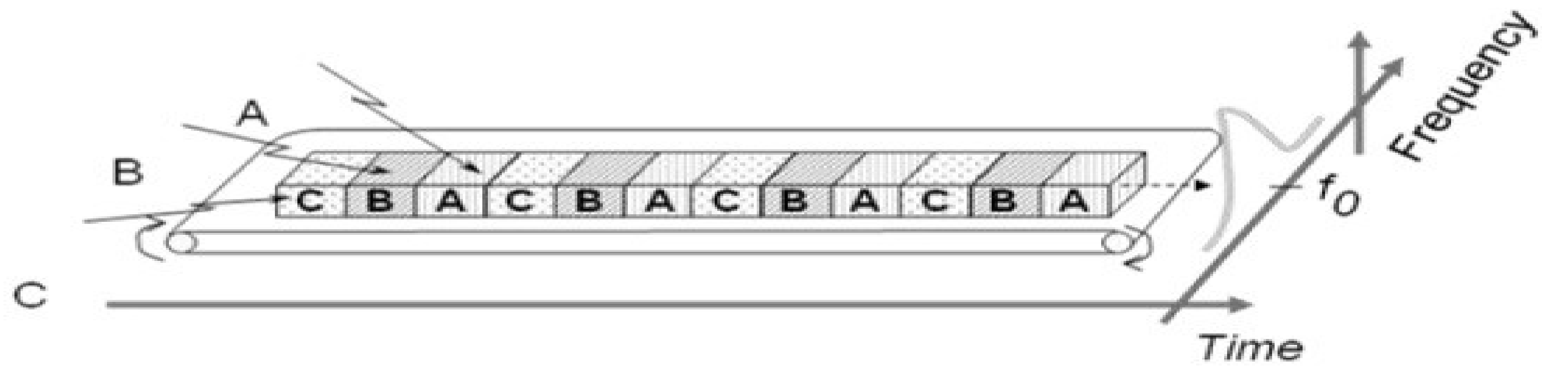
Disadvantages of FDMA:

- The maximum flow rate per channel is fixed and small.
- Guard bands lead to a waste of capacity.
- It does not differ significantly from analog systems; improving the capacity depends on the signal-to-interference reduction, or a signal-to-noise ratio (SNR).

Time Division Multiple Access (TDMA)

- Time Division Multiple Access (TDMA) is a digital cellular telephone communication technology.
- It facilitates many users to share the same frequency without interference.
- Its technology divides a signal into different timeslots, and increases the data carrying capacity.
- Time Division Multiple Access (TDMA) is a complex technology, because it requires an accurate synchronization between the transmitter and the receiver.
- TDMA is used in digital mobile radio systems.
- The individual mobile stations cyclically assign a frequency for the exclusive use of a time interval.
- In most of the cases, the entire system bandwidth for an interval of time is not assigned to a station.
- However, the frequency of the system is divided into sub-bands, and TDMA is used for the multiple access in each sub-band.
- Sub-bands are known as carrier frequencies.
- The mobile system that uses this technique is referred as the multi-carrier systems.

Time Division Multiple Access (TDMA)



Advantages of TDMA:

- No guard band required for the wideband system.
- No narrowband filter required for the wideband system.
- Permits flexible rates (i.e. several slots can be assigned to a user, for example, each time interval translates 32Kbps, a user is assigned two 64 Kbps slots per frame).
- Can withstand gusty or variable bit rate traffic. Number of slots allocated to a user can be changed frame by frame (for example, two slots in the frame 1, three slots in the frame 2, one slot in the frame 3, frame 0 of the notches 4, etc.).

Code Division Multiple Access (CDMA)

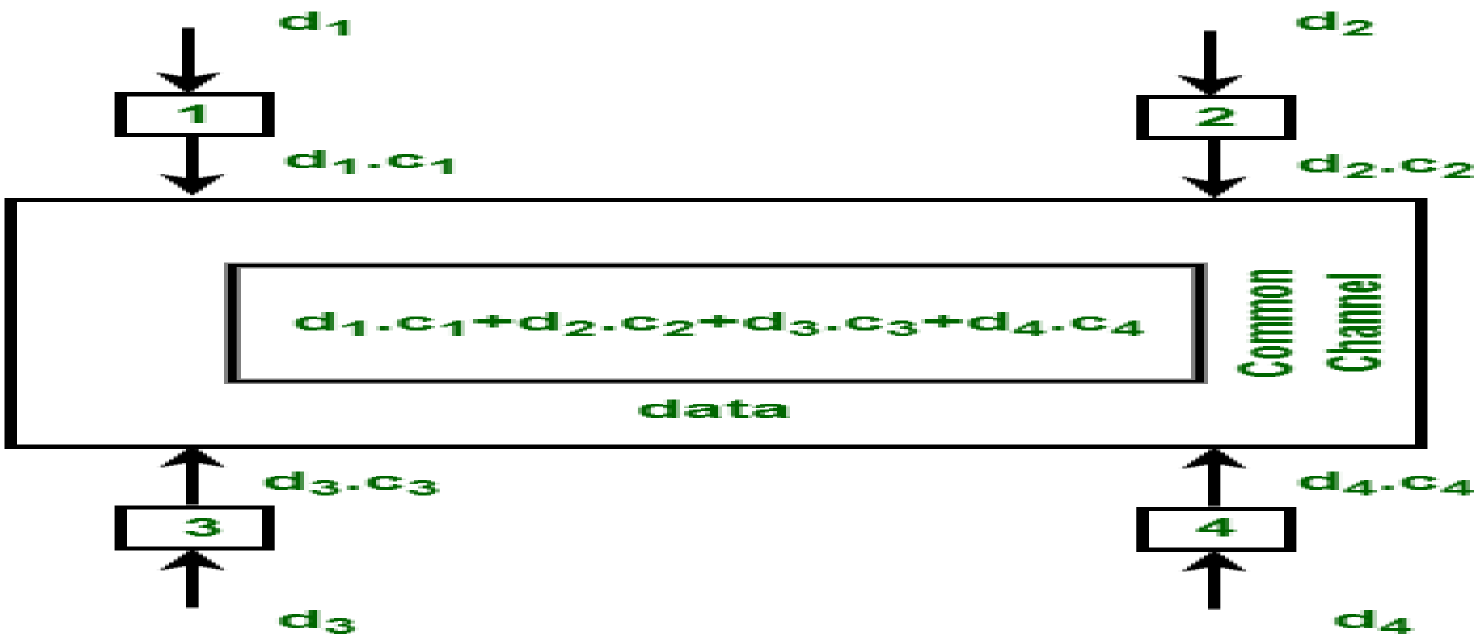
- In CDMA, all the stations can transmit data simultaneously.
- It allows each station to transmit data over the entire frequency all the time.
- Multiple simultaneous transmissions are separated by unique code sequence.
- Each user is assigned with a unique code sequence.
- CDMA differs from FDMA because only one channel occupies the entire bandwidth of the link.
- It differs from TDMA because all stations can send data simultaneously; there is no timesharing.
- Let us assume we have four stations 1, 2, 3, and 4 connected to the same channel.
- The data from station 1 are d l , from station 2 are d 2 , and so on.
- The code assigned to the first station is cI, to the second is c2, and so on.
- **We assume that the assigned codes have two properties:**

1. If we multiply each code by another, we get 0 (Zero).

2. If we multiply each code by itself, we get 4 (the number of stations).

Code Division Multiple Access (CDMA)

- With these two properties in mind, let us see how the above four stations can send data using the same common channel, as shown in Figure
- Station 1 multiplies (a special kind of multiplication, as we will see) its data by its code to get d1.c1, Station 2 multiplies its data by its code to get d2.c2, and so on.



Code Division Multiple Access (CDMA)

- The data that go on the channel are the sum of all these terms, as shown in the box.
- Any station that wants to receive data from one of the other three multiplies the data on the channel by the code of the sender.
- For example, suppose stations 1 and 2 are talking to each other.
- Station 2 wants to hear what station I is saying.
- It multiplies the data on the channel by c1, the code of station 1.
- Because (c1.c1) is 4, but (c2.c1), (c3.c1), and (c4.c1) are all 0s, station 2 divides the result by 4 to get the data from station 1.

$$
\begin{aligned}
\text{data} &= (d1.c1 + d2.c2 + d3.c3 + d4.c4).c1 \\
&= d1 \bullet c1.c1 + d2.c2.c1 + d3.c3.c1 + d4.c4.c1 \\
&= d1 * 4 + 0 = 4d1
\end{aligned}
$$

Medium Access Sub-Layer

- The protocols used to determine who goes next on a multiaccess channel belong to a sublayer of the data link layer called the MAC (Medium Access Control) sublayer.
- The MAC sublayer is especially important in LANs, many of which use a multiaccess channel as the basis for communication.

Medium Access Sub-Layer

RANDOM ACCESS:

- In random access or contention methods, no station is superior to another station and none is assigned the control over another.
- No station permits, or does not permit, another station to send.
- At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.
- This decision depends on the state of the medium (idle or busy).
- In a random access method, each station has the right to the medium without being controlled by any other station.
- However, if more than one station tries to send, there is an access conflict-collision-and the frames will be either destroyed or modified.
- To avoid access conflict or to resolve it when it happens, each station follows a procedure that answers the following questions:
    - When can the station access the medium?
    - What can the station do if the medium is busy?
    - How can the station determine the success or failure of the transmission?
    - What can the station do if there is an access conflict?

ALOHA Random Access Protocol

ALOHA Random Access Protocol:

- It is designed for wireless LAN (Local Area Network) but can also be used in a shared medium to transmit data.
- Using this method, any station can transmit data across a network simultaneously when a data frameset is available for transmission.

Aloha Rules:

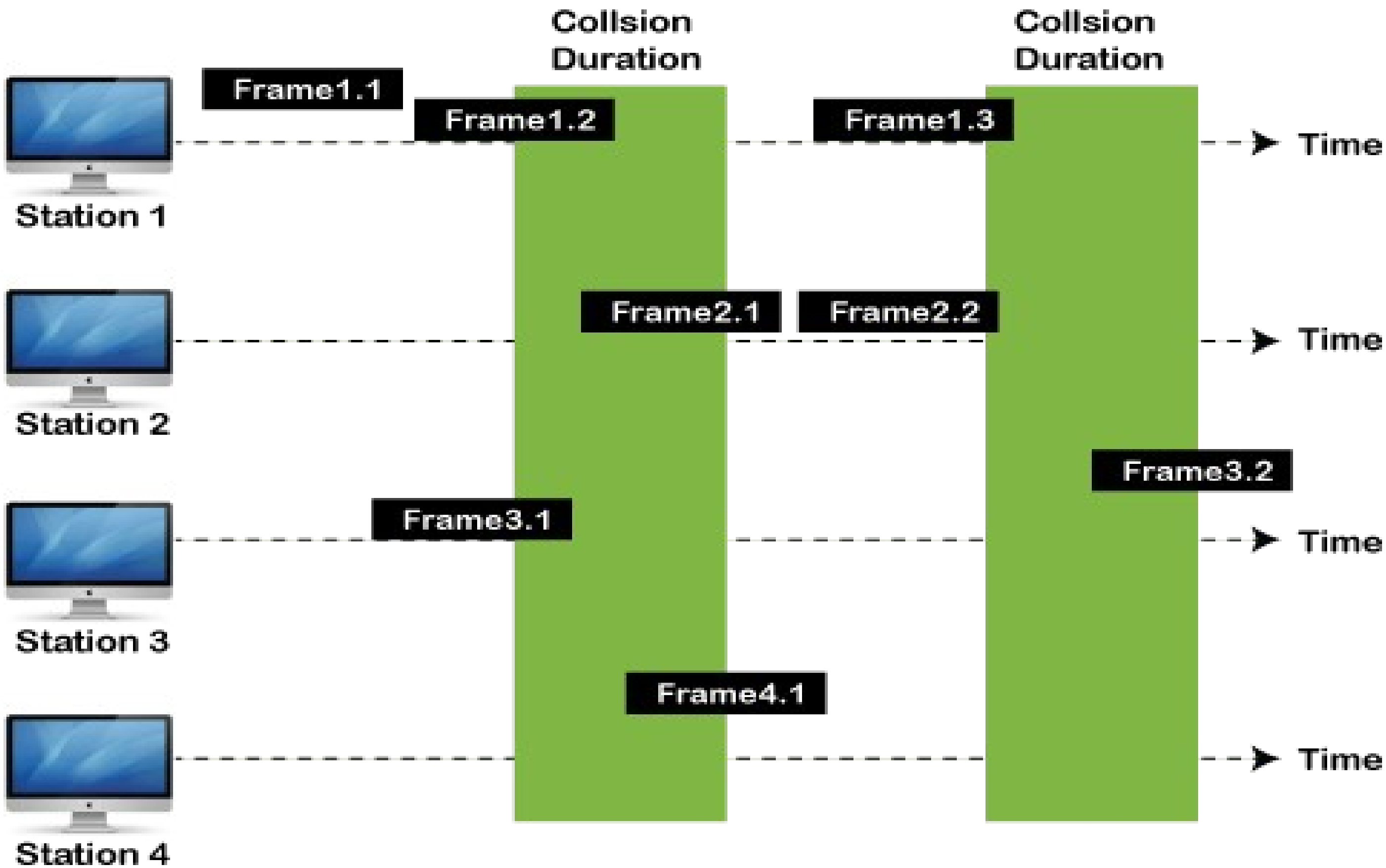
- Any station can transmit data to a channel at any time.
- It does not require any carrier sensing.
- Collision and data frames may be lost during the transmission of data through multiple stations.
- Acknowledgment of the frames exists in Aloha. Hence, there is no collision detection.
- It requires retransmission of data after some random amount of time.

ALOHA Random Access Protocol

Pure Aloha:

- Whenever data is available for sending over a channel at stations, we use Pure Aloha.
- In pure Aloha, when each station transmits data to a channel without checking whether the channel is idle or not, the chances of collision may occur, and the data frame can be lost.
- When any station transmits the data frame to a channel, the pure Aloha waits for the receiver's acknowledgment.
- If it does not acknowledge the receiver end within the specified time, the station waits for a random amount of time, called the backoff time (Tb).
- And the station may assume the frame has been lost or destroyed.
- Therefore, it retransmits the frame until all the data are successfully transmitted to the receiver.
  - The total vulnerable time of pure Aloha is 2 * Tfr.
  - Maximum throughput occurs when G = 1/ 2 that is 18.4%.
  - Successful transmission of data frame is S = G * e ^ - 2 G.

ALOHA Random Access Protocol



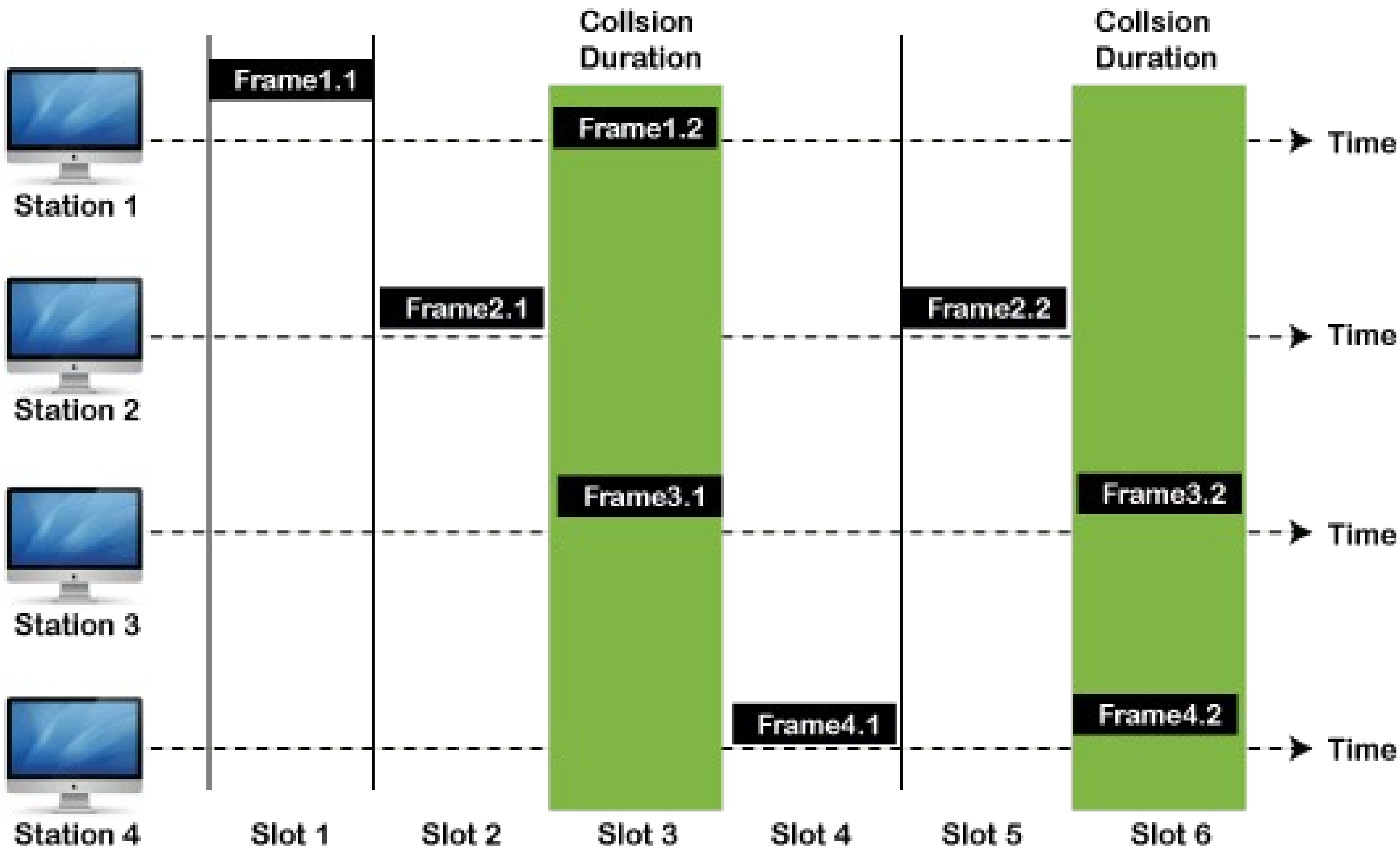
Frames in Pure ALOHA

ALOHA Random Access Protocol:

Slotted Aloha:

- The slotted Aloha is designed to overcome the pure Aloha's efficiency because pure Aloha has a very high possibility of frame hitting.
- In slotted Aloha, the shared channel is divided into a fixed time interval called slots.
- So that, if a station wants to send a frame to a shared channel, the frame can only be sent at the beginning of the slot, and only one frame is allowed to be sent to each slot.
- And if the stations are unable to send data to the beginning of the slot, the station will have to wait until the beginning of the slot for the next time.
- However, the possibility of a collision remains when trying to send a frame at the beginning of two or more station time slot.
  - Maximum throughput occurs in the slotted Aloha when G = 1 that is 37%.
  - The probability of successfully transmitting the data frame in the slotted Aloha is S = G * e ^ - 2 G.
  - The total vulnerable time required in slotted Aloha is Tfr.

ALOHA Random Access Protocol



Frames in Slotted ALOHA

Carrier Sense Multiple Access (CSMA)

CSMA (Carrier Sense Multiple Access):

- It is a carrier sense multiple access based on media access protocol to sense the traffic on a channel (idle or busy) before transmitting the data.
- It means that if the channel is idle, the station can send data to the channel.
- Otherwise, it must wait until the channel becomes idle.
- Hence, it reduces the chances of a collision on a transmission medium.

CSMA Access Modes:

- **1-Persistent:** In the 1-Persistent mode of CSMA that defines each node, first sense the shared channel and if the channel is idle, it immediately sends the data.
- Else it must wait and keep track of the status of the channel to be idle and broadcast the frame unconditionally as soon as the channel is idle.

Carrier Sense Multiple Access (CSMA)

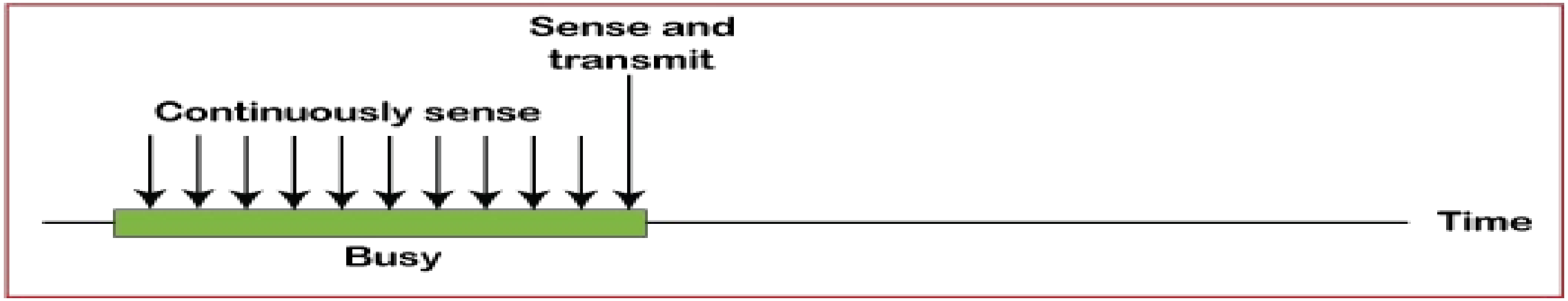
Non-Persistent:

- It is the access mode of CSMA that defines before transmitting the data, each node must sense the channel, and if the channel is inactive, it immediately sends the data.
- Otherwise, the station must wait for a random time (not continuously), and when the channel is found to be idle, it transmits the frames.

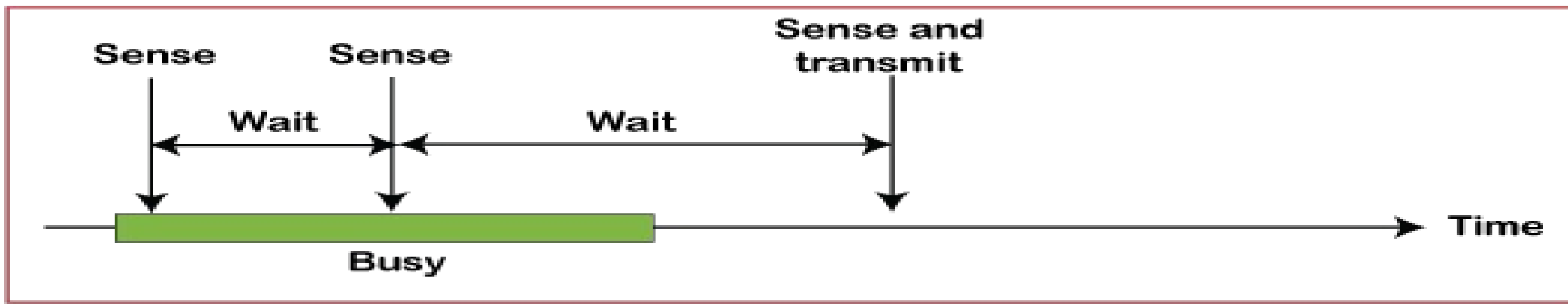
P-Persistent:

- It is the combination of 1-Persistent and Non-persistent modes.
- The P-Persistent mode defines that each node senses the channel, and if the channel is inactive, it sends a frame with a P probability.
- If the data is not transmitted, it waits for a (q = 1-p probability) random time and resumes the frame with the next time slot.

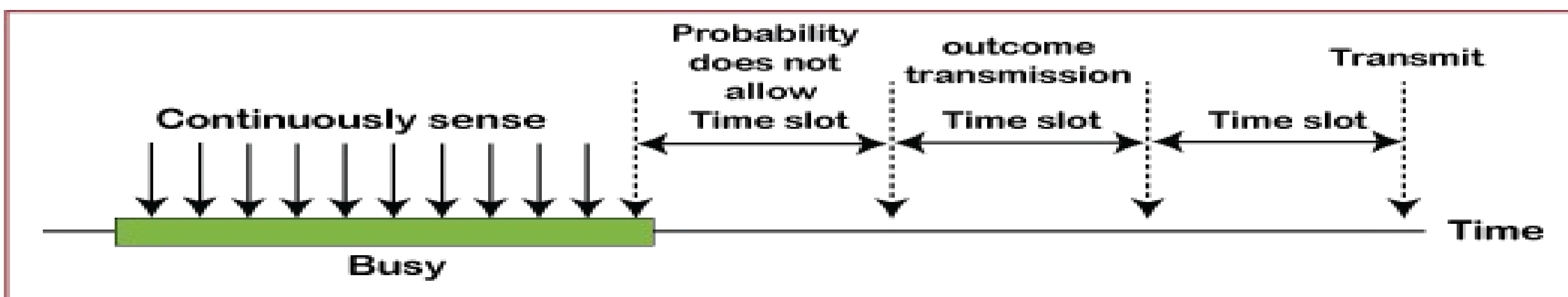
Carrier Sense Multiple Access (CSMA)



a. 1-persistent



b. Nonpersistent



c. p-persistent

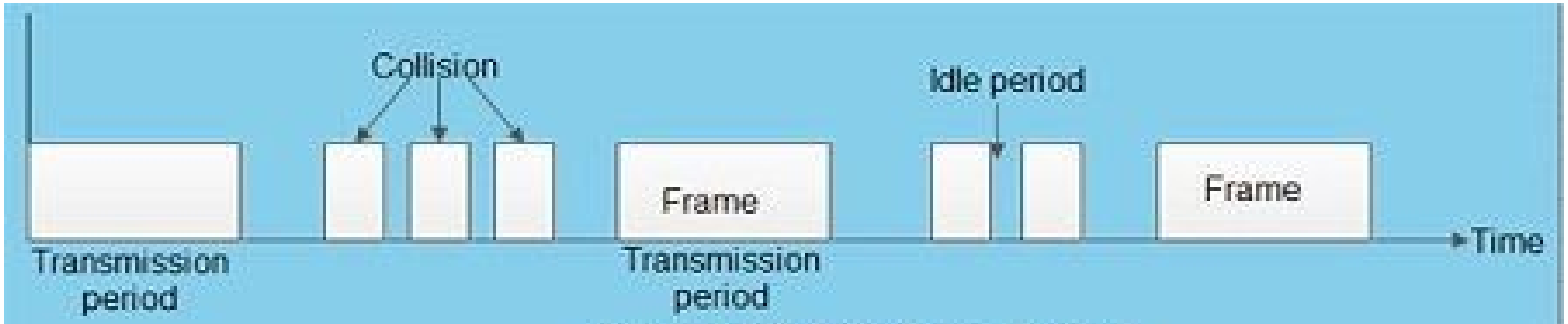
Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

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

- CSMA/CD is a protocol in which the station senses the carrier or channel before transmitting frame just as in persistent and non-persistent CSMA.
- If the channel is busy, the station waits. it listens at the same time on communication media to ensure that there is no collision with a packet sent by another station.
- In a collision, the issuer immediately cancel the sending of the package.
- This allows to limit the duration of collisions: we do not waste time to send a packet complete if it detects a collision.
- After a collision, the transmitter waits again silence and again, he continued his hold for a random number;
- but this time the random number is nearly double the previous one: it is this called back-off (that is to say, the “decline”) exponential.
- In fact, the window collision is simply doubled (unless it has already reached a maximum).
- From a packet is transmitted successfully, the window will return to its original size.

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

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

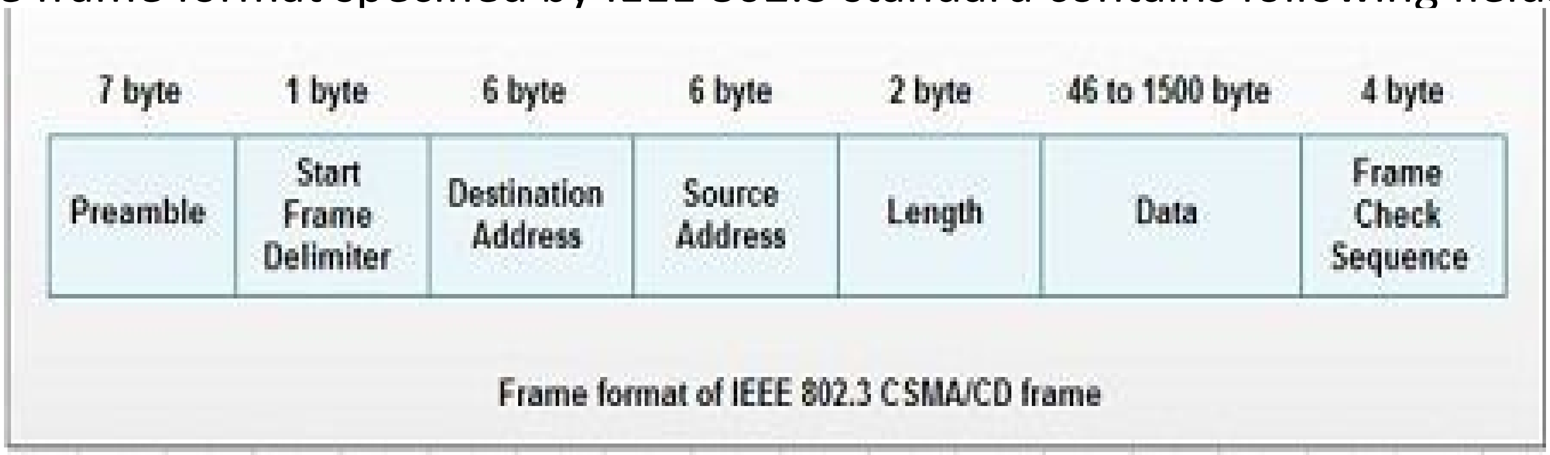


CSMA CD with three states

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

Frame format of CSMA/CD:

•The frame format specified by IEEE 802.3 standard contains following fields.



Frame format of IEEE 802.3 CSMA/CD frame

1.Preamble: It is seven bytes (56 bits) that provides bit synchronization. It consists of alternating Os and 1s. The purpose is to provide alert and timing pulse.

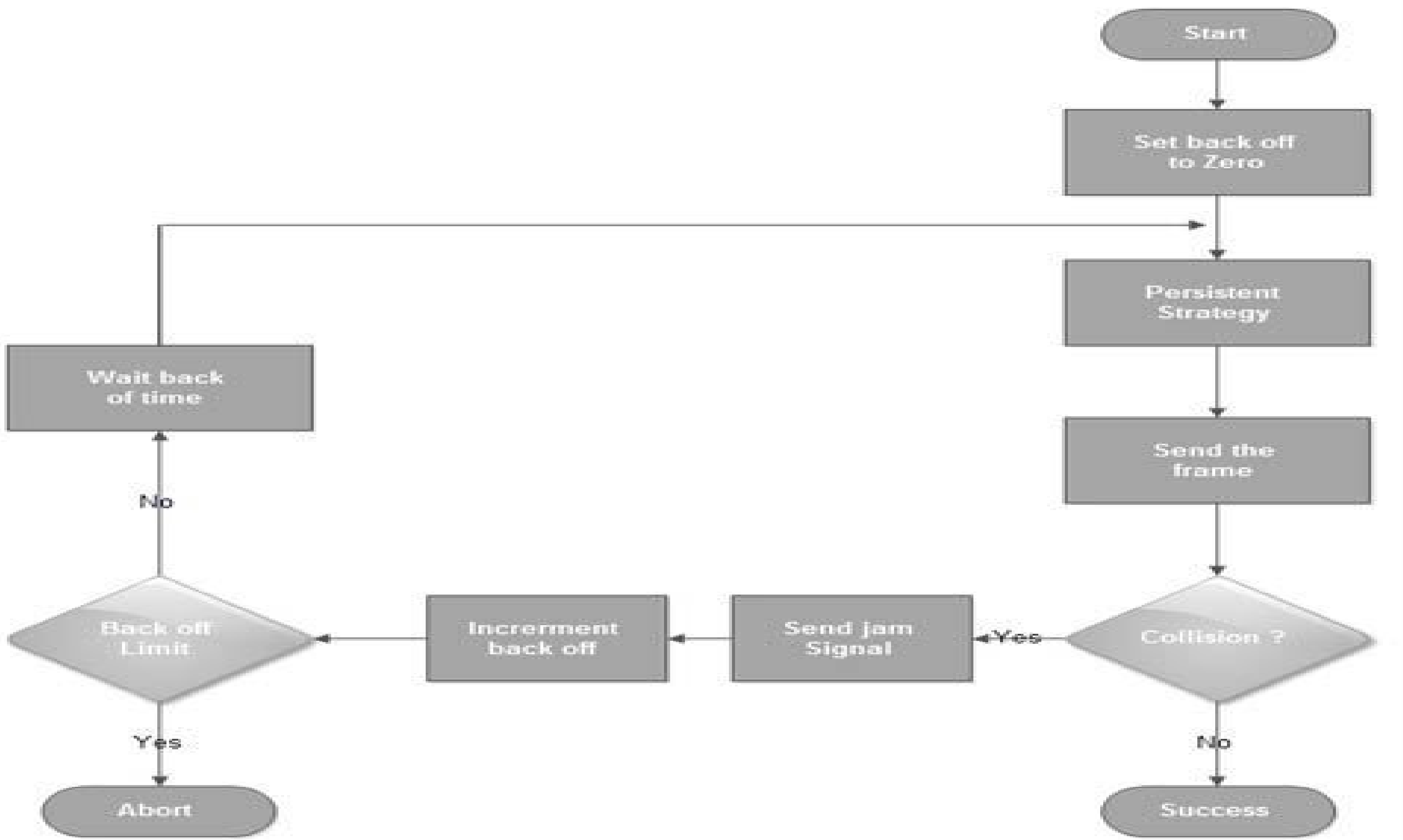
2.Start Frame Delimiter (SFD): It is one byte field with unique pattern: 10 10 1011. It marks the beginning of frame.

3.Destination Address (DA): It is six byte field that contains physical address of packet's destination.

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

4. **Source Address (SA):** It is also a six byte field and contains the physical address of source or last device to forward the packet (most recent router to receiver).
5. **Length:** This two byte field specifies the length or number of bytes in data field.
6. **Data:** It can be of 46 to 1500 bytes, depending upon the type of frame and the length of the information field.
7. **Frame Check Sequence (FCS):** This for byte field contains CRC for error detection

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



CSMA/CD Procedure

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

- The station that has a ready frame sets the back off parameter to zero.
- Then it senses the line using one of the persistent strategies.
- If then sends the frame. If there is no collision for a period corresponding to one complete frame, then the transmission is successful.
- Otherwise the station sends the jam signal to inform the other stations about the collision.
- The station then increments the back off time and waits for a random back off time and sends the frame again.
- If the back off has reached its limit then the station aborts the transmission.
- CSMA/CD is used for the traditional Ethernet.

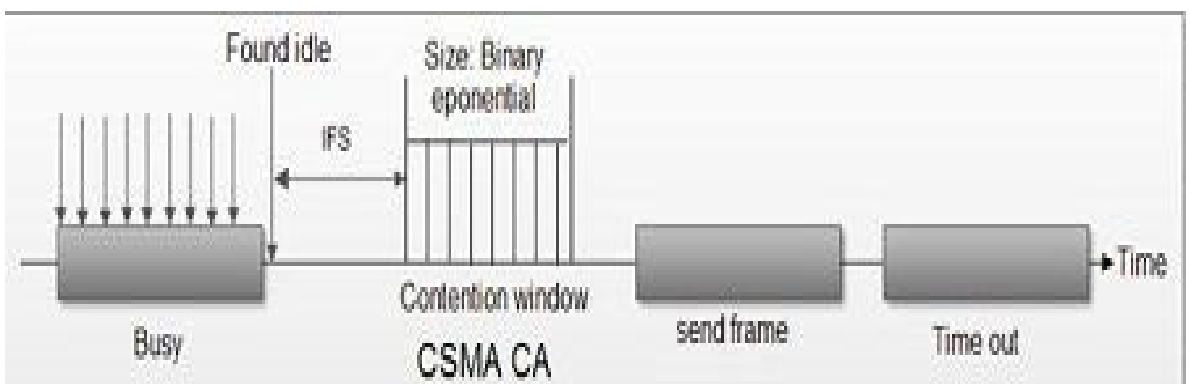
Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

- CSMA/CA protocol is used in wireless networks because they cannot detect the collision so the only solution is collision avoidance.
- CSMA/CA avoids the collisions using three basic techniques.

(i) Interframe space

(ii) Contention window

(iii) Acknowledgements



Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

1. Interframe Space (IFS):

- Whenever the channel is found idle, the station does not transmit immediately. It waits for a period of time called interframe space (IFS).
- When channel is sensed to be idle, it may be possible that same distant station may have already started transmitting and the signal of that distant station has not yet reached other stations.
- Therefore the purpose of IFS time is to allow this transmitted signal to reach other stations.
- If after this IFS time, the channel is still idle, the station can send, but it still needs to wait a time equal to contention time.
- IFS variable can also be used to define the priority of a station or a frame.

2. Contention Window:

- Contention window is an amount of time divided into slots.
- A station that is ready to send chooses a random number of slots as its wait time.

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

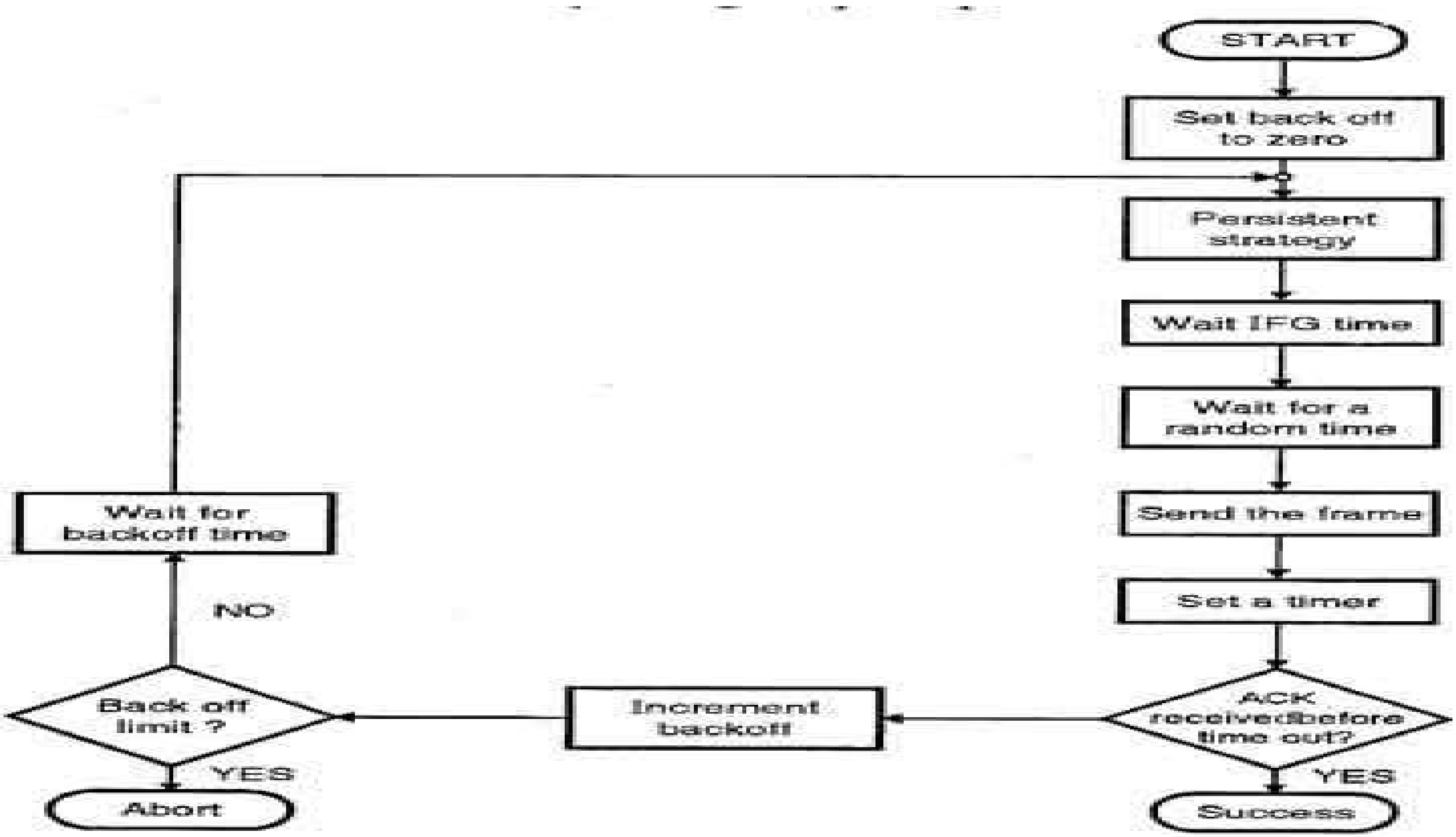
- The number of slots in the window changes according to the binary exponential back-off strategy. It means that it is set of one slot the first time and then doubles each time the station cannot detect an idle channel after the IFS time.
- This is very similar to the p-persistent method except that a random outcome defines the number of slots taken by the waiting station.
- In contention window 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 & restarts it when the channel is sensed as idle.

3. Acknowledgement:

- Despite all the precautions, collisions may occur and destroy the data.
- The positive acknowledgment and the time-out timer can help guarantee that receiver has received the frame.

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

- CSMA/CA Procedure:



CSMA/CA procedure

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

This is the CSMA protocol with collision avoidance:

- The station ready to transmit, senses the line by using one of the persistent strategies.
- As soon as it find the line to be idle, the station waits for an IFG (Interframe gap or Space) amount of time.
- If then waits for some random time and sends the frame.
- After sending the frame, it sets a timer and waits for the acknowledgement from the receiver.
- If the acknowledgement is received before expiry of the timer, then the transmission is successful.
- But if the transmitting station does not receive the expected acknowledgement before the timer expiry then it increments the back off parameter, waits for the back off time and resenses the line.

Controlled Access Protocols

- In controlled access, the stations seek information from one another to find which station has the right to send.
- It allows only one node to send at a time, to avoid collision of messages on shared medium.
- The three controlled-access methods are:

1. **Reservation**
2. **Polling**
3. **Token Passing**

1. Reservation:

- In the reservation method, a station needs to make a reservation before sending data.
- The time line has two kinds of periods:
  - Reservation interval of fixed time length
  - Data transmission period of variable frames
- If there are M stations, the reservation interval is divided into M slots, and each station has one slot.

Controlled Access Protocols

Reservation: Continue...

•Suppose if station 1 has a frame to send, it transmits 1 bit during the slot 1. No other station is allowed to transmit during this slot.

•In general, ith station may announce that it has a frame to send by inserting a 1 bit into i th slot. After all N slots have been checked, each station knows which stations wish to transmit.

•The stations which have reserved their slots transfer their frames in that order.

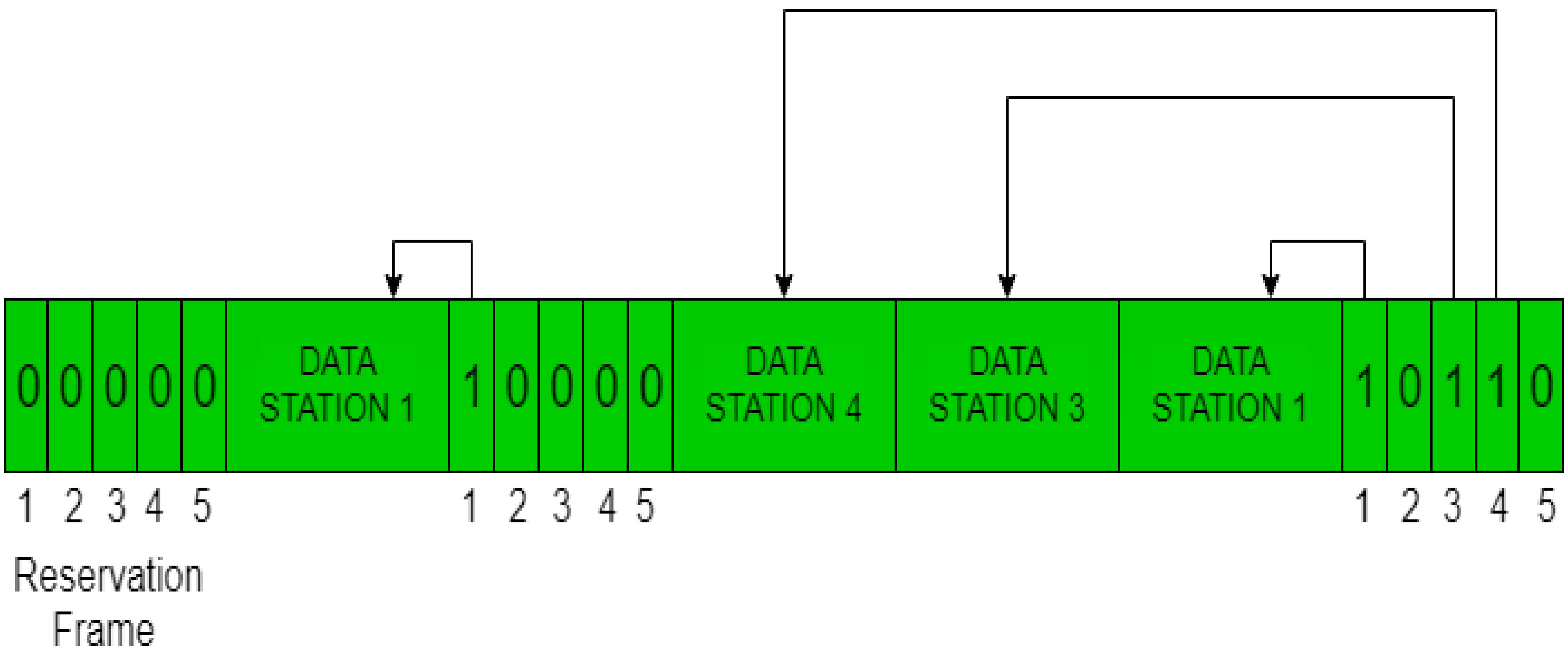
•After data transmission period, next reservation interval begins.

•Since everyone agrees on who goes next, there will never be any collisions.

Controlled Access Protocols

Reservation: Continue...

- The following figure shows a situation with five stations and a five-slot reservation frame.
- In the first interval, only stations 1, 3, and 4 have made reservations. In the second interval, only station 1 has made a reservation.

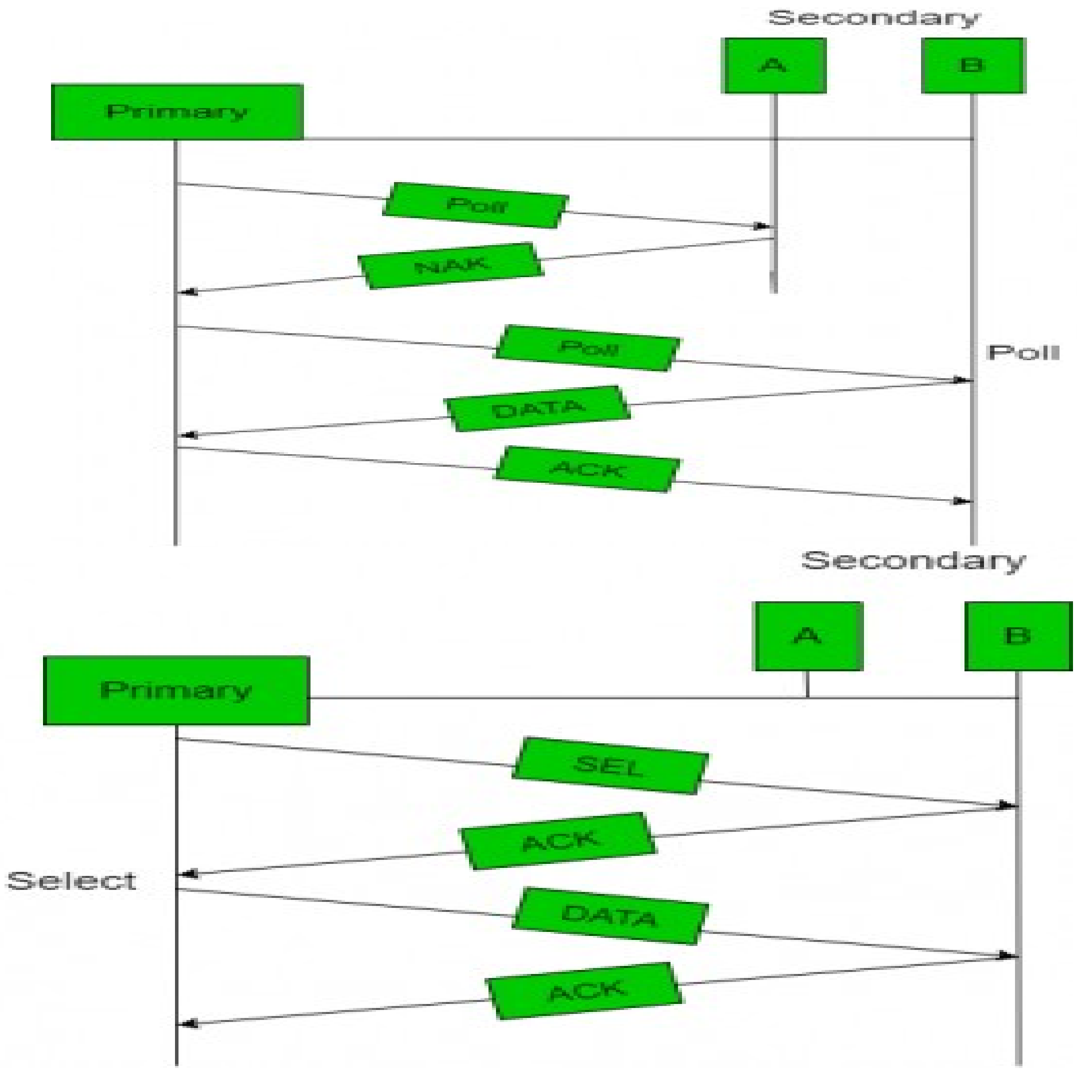


Controlled Access Protocols

2. Polling:

- Polling process is similar to the roll-call performed in class.
    - Just like the teacher, a controller sends a message to each node in turn.
- In this, one acts as a primary station(controller) and the others are secondary stations.
    - All data exchanges must be made through the controller.
- The message sent by the controller contains the address of the node being selected for granting access.
- Although all nodes receive the message but the addressed one responds to it and sends data, if any.
    - If there is no data, usually a “poll reject”(NAK) message is sent back.
- Problems include high overhead of the polling messages and high dependence on the reliability of the controller.

Controlled Access Protocols



Controlled Access Protocols

3. Token Passing:

•In token passing scheme, the stations are connected logically to each other in form of ring and access to stations is governed by tokens.

•A token is a special bit pattern or a small message, which circulate from one station to the next in some predefined order.

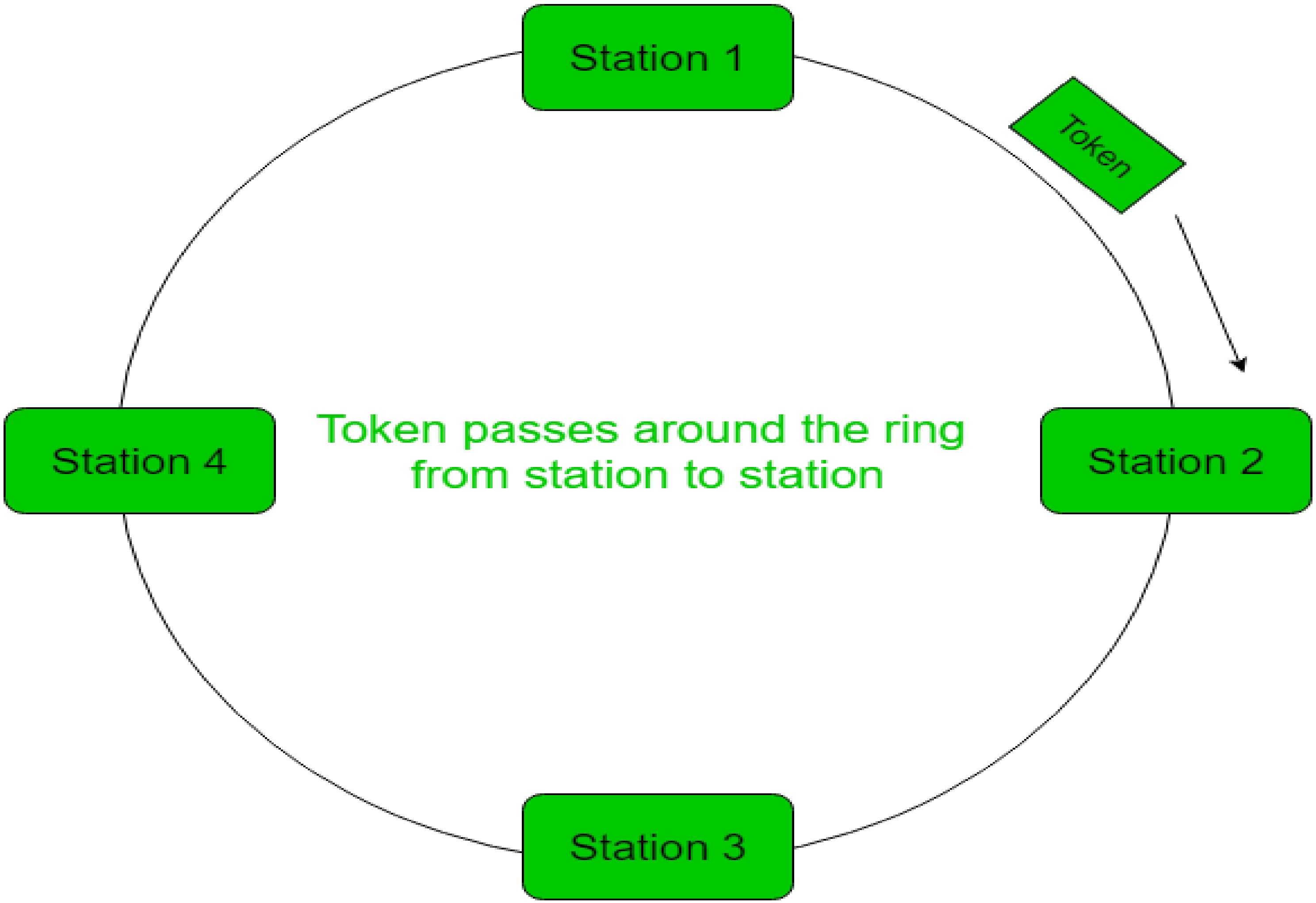
•In Token ring, token is passed from one station to another adjacent station in the ring whereas incase of Token bus, each station uses the bus to send the token to the next station in some predefined order.

•In both cases, token represents permission to send. If a station has a frame queued for transmission when it receives the token, it can send that frame before it passes the token to the next station. If it has no queued frame, it passes the token simply.

•After sending a frame, each station must wait for all N stations (including itself) to send the token to their neighbours and the other N – 1 stations to send a frame, if they have one.

•There exists problems like duplication of token or token is lost or insertion of new station, removal of a station, which need be tackled for correct and reliable operation of this scheme.

Controlled Access Protocols



Controlled Access Protocols

Performance: Performance of token ring can be concluded by 2 parameters

- **Delay:** which is a measure of time between when a packet is ready and when it is delivered. So, the average time (delay) required to send a token to the next station = a/N.
- **Throughput:** which is a measure of the successful traffic.
- Throughput,

$$S = 1/(1 + a/N) \text{ for } a<1 \quad \text{and}$$

$$S = 1/\{a(1 + 1/N)\} \text{ for } a>1.$$

where N = number of station

a = Tp/Tt

(Tp = propagation delay and Tt = transmission delay)

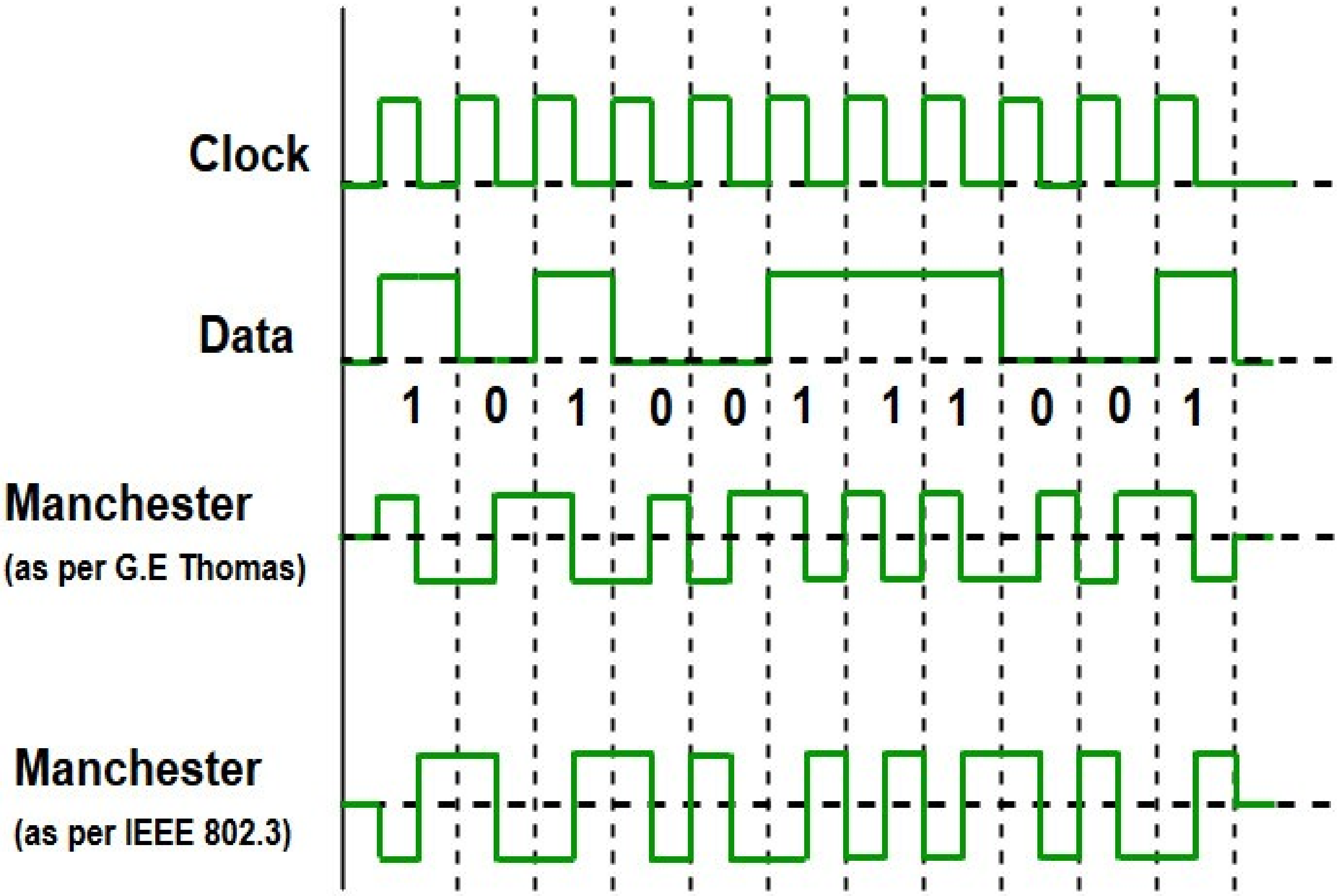
Manchester encoding

- In data transmission, Manchester encoding is a form of digital encoding in which data bits are represented by transitions from one logical state to the other.
- This is different from the more common method of encoding, in which a bit is represented by either a high state such as +5 volts or a low state such as 0 volts.
- Manchester encoding is a synchronous clock encoding technique used by the physical layer of the Open System Interconnection [OSI] to encode the clock and data of a synchronous bit stream.

Characteristics of Manchester Encoding :

- A logic 0 is indicated by a 0 to 1 transition at the centre of the bit and logic 1 by 1 to 0 transition.
- The signal transitions do not always occur at the 'bit boundary' but there is always a transition at the centre of each bit.

Controlled Access Protocols



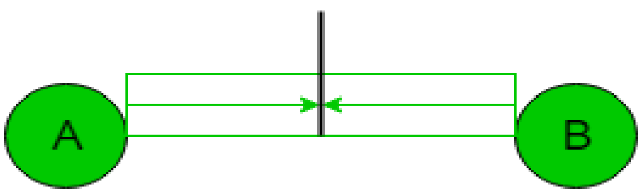
Binary exponential back off algorithm

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

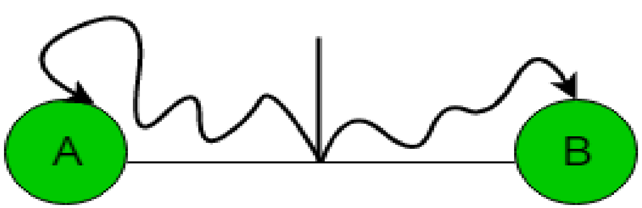
Binary exponential back off algorithm

Let us consider an scenario of 2 stations A and B transmitting some data:

At t = 0 , both A and B start transmission



Packets of both A and B collide



Both stations A and B detect collision

Binary exponential back off algorithm

- After a collision, time is divided into discrete slots (Tslot) 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 for that number of time slots before trying again.
- 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.

Binary exponential back off algorithm

- 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-ransmit.

  Waiting time = back–off time

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

  Then,

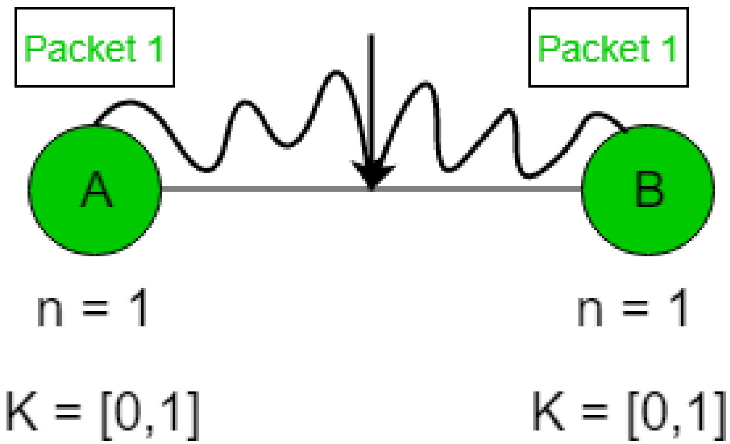
  Waiting time = K * Tslot

  where K = $[0, 2^n - 1]$

Binary exponential back off algorithm

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

Binary exponential back off algorithm

1. When both A and B choose K = 0

–> Waiting time for A = 0 * Tslot = 0

Waiting time for B = 0 * Tslot = 0

- Therefore, both stations will transmit at the same time and hence collision occurs.

2. When A chooses K = 0 and B chooses K = 1

–> Waiting time for A = 0 * Tslot = 0

Waiting time for B = 1 * Tslot = Tslot

- Therefore, A transmits the packet and B waits for time Tslot for transmitting and hence A wins.

3. When A chooses K = 1 and B chooses K = 0

–> Waiting time for A = 1 * Tslot = Tslot

Waiting time for B = 0 * Tslot = 0

- Therefore, B transmits the packet and A waits for time Tslot for transmitting and hence B wins.

Binary exponential back off algorithm

4. When both A and B choose K = 1

–> Waiting time for A = 1 * Tslot = Tslot

Waiting time for B = 1 * Tslot = Tslot

- Therefore, both will wait for the same time Tslot and then transmit. Hence, collision occurs.
- Probability that A wins = 1/4
- Probability that B wins = 1/4
- Probability of collision = 2/4

Question and Answer