Medium Access Control Sublayer

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Introduction

- In broadcast networks, several stations share a single communication channel.
- The major issue in these networks is, which station should transmit data at a given time.
- This process of deciding the turn of different stations is known as **Channel Allocation**.
- To coordinate the access to the channel, **multiple access** protocols are required.
- All these protocols belong to the MAC sublayer.

Introduction

Network Layer	
Logical Link Control (LLC)	Data Link Layer
Medium Access Control (MAC)	
Physical Layer	

- Data Link layer is divided into two sublayers:
  - Logical Link Control (LLC)
  - Medium Access Control (MAC)
- **LCC** is responsible for error control & flow control.
- **MAC** is responsible for multiple access resolutions.

Channel Allocation Problem

- In broadcast networks, single channel is shared by several stations.
- This channel can be allocated to only one transmitting user at a time.
- There are two different methods of channel allocations:
  - Static Channel Allocation
  - Dynamic Channel Allocation

Static Channel Allocations

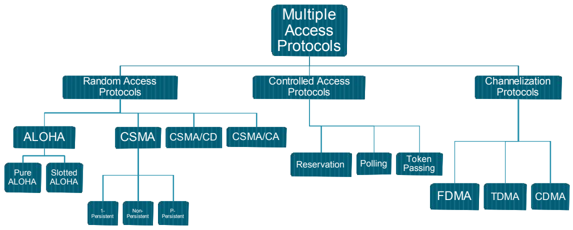
- In this method, a single channel is divided among various users either on the basis of frequency or on the basis of time.
- It either uses FDM (Frequency Division Multiplexing) or TDM (Time Division Multiplexing).
- In FDM, fixed frequency is assigned to each user, whereas, in TDM, fixed time slot is assigned to each user.

Dynamic Channel Allocation

- In this method, no user is assigned fixed frequency or fixed time slot.
- All users are dynamically assigned frequency or time slot, depending upon the requirements of the user.

Multiple Access Protocols

- Many protocols have been defined to handle the access to shared link.
- These protocols are organized in three different groups.:
  - Random Access Protocols
  - Controlled Access Protocols
  - Channelization Protocols



Random Access Protocols

- It is also called **Contention Method**.
- In this method, there is no control station.
- Any station can send the data.
- The station can make a decision on whether or not to send data. This decision depends on the state of the channel, i.e. channel is busy or idle.
- There is no scheduled time for a stations to transmit. They can transmit in random order.

Random Access Protocols

- There is no rule that decides which station should send next.
- If two stations transmit at the same time, there is collision and the frames are lost.
- The various random access methods are:
  - ALOHA
  - CSMA (Carrier Sense Multiple Access)
  - CSMA/CD (Carrier Sense Multiple Access with Collision Detection)
  - CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)

ALOHA

- ALOHA was developed at University of Hawaii in early 1970s by Norman Abramson.
- It was used for ground based radio broadcasting.
- In this method, stations share a common channel.
- When two stations transmit simultaneously, collision occurs and frames are lost.
- There are two different versions of ALOHA:
  - Pure ALOHA
  - Slotted ALOHA

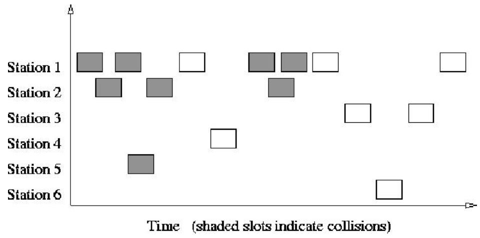
Pure ALOHA

- In pure ALOHA, stations transmit frames whenever they have data to send.
- When two stations transmit simultaneously, there is collision and frames are lost.
- In pure ALOHA, whenever any station transmits a frame, it expects an acknowledgement from the receiver.
- If acknowledgement is not received within specified time, the station assumes that the frame has been lost.

Pure ALOHA

- If the frame is lost, station waits for a random amount of time and sends it again.
- This waiting time must be random, otherwise, same frames will collide again and again.
- Whenever two frames try to occupy the channel at the same time, there will be collision and both the frames will be lost.
- If first bit of a new frame overlaps with the last bit of a frame almost finished, both frames will be lost and both will have to be retransmitted.

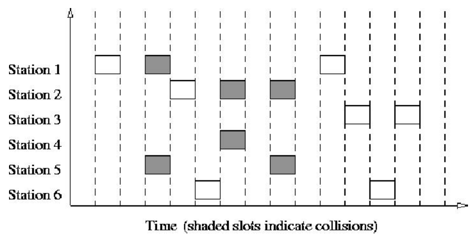
Pure ALOHA



Slotted ALOHA

- Slotted ALOHA was invented to improve the efficiency of pure ALOHA.
- In slotted ALOHA, time of the channel is divided into intervals called slots.
- The station can send a frame only at the beginning of the slot and only one frame is sent in each slot.
- If any station is not able to place the frame onto the channel at the beginning of the slot, it has to wait until the next time slot.
- There is still a possibility of collision if two stations try to send at the beginning of the same time slot.

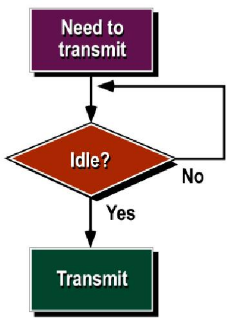
Slotted ALOHA



Carrier Sense Multiple Access (CSMA)

- CSMA was developed to overcome the problems of ALOHA i.e. to minimize the chances of collision.
- CSMA is based on the principle of "carrier sense".
- The station sense the carrier or channel before transmitting a frame.
- It means the station checks whether the channel is idle or busy.
- The chances of collision reduces to a great extent if a station checks the channel before trying to use it.

Carrier Sense Multiple Access (CSMA)



Carrier Sense Multiple Access (CSMA)

- The chances of collision still exists because of propagation delay.
- The frame transmitted by one station takes some time to reach the other station.
- In the meantime, other station may sense the channel to be idle and transmit its frames.
- This results in the collision.

Carrier Sense Multiple Access (CSMA)

- There are three different types of CSMA protocols:
  - 1-Persistent CSMA
  - Non-Persistent CSMA
  - P-Persistent CSMA

1-Persistent CSMA

- In this method, station that wants to transmit data, continuously senses the channel to check whether he channel is idle or busy.
- If the channel is busy, station waits until it becomes idle.
- When the station detects an idle channel, it immediately transmits the frame.
- This method has the highest chance of collision because two or more stations may find channel to be idle at the same time and transmit their frames.

Non-Persistent CSMA

- A station that has a frame to send, senses the channel.
- If the channel is idle, it sends immediately.
- If the channel is busy, it waits a random amount of time and then senses the channel again.
- It reduces the chance of collision because the stations wait for a random amount of time .
- It is unlikely that two or more stations will wait for the same amount of time and will retransmit at the same time.

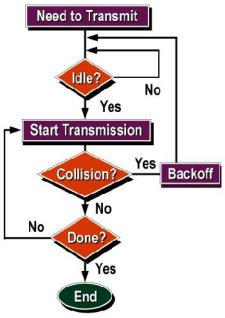
P-Persistent CSMA

- In this method, the channel has time slots such that the time slot duration is equal to or greater than the maximum propagation delay time.
- When a station is ready to send, it senses the channel.
- If the channel is busy, station waits until next slot.
- If the channel is idle, it transmits the frame.
- It reduces the chance of collision and improves the efficiency of the network.

CSMA with Collision Detection (CSMA/CD)

- In this protocol, the station senses the channel before transmitting the frame. If the channel is busy, the station waits.
- Additional feature in CSMA/CD is that the stations can detect collisions.
- The stations abort their transmission as soon as they detect collision.
- This feature is not present in CSMA.
- The stations continue to transmit even though they find that collision has occurred.

CSMA with Collision Detection (CSMA/CD)



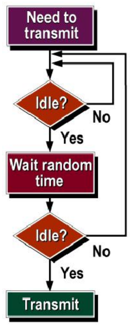
CSMA with Collision Detection (CSMA/CD)

- In CSMA/CD, the station that sends its data on the channel, continues to sense the channel even after data transmission.
- If collision is detected, the station aborts its transmission and waits for a random amount of time & sends its data again.
- As soon as a collision is detected, the transmitting station release a ***jam*** signal.
- Jam signal alerts other stations. Stations are not supposed to transmit immediately after the collision has occurred.

CSMA with Collision Avoidance (CSMA/CA)

- This protocol is used in wireless networks because they cannot detect the collision.
- So, the only solution is collision avoidance.
- It avoids the collision by using three basic techniques:
  - Interframe Space
  - Contention Window
  - Acknowledgements

CSMA with Collision Avoidance (CSMA/CA)



Interframe Space

- 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 idle, it may be possible that some distant station may have already started transmitting.
- Therefore, the purpose of IFS time is to allow this transmitted signal to reach its destination.
- If after this IFS time, channel is still idle, the station can send the frames.

Contention Window

- Contention window is the amount of time divided into slots.
- Station that is ready to send chooses a random number of slots as its waiting time.
- The number of slots in the window changes with time.
- It means that it is set of one slot for the first time, and then doubles each time the station cannot detect an idle channel after the IFS time.
- In contention window, the station needs to sense the channel after each time slot.

Acknowledgment

- Despite all the precautions, collisions may occur and destroy the data.
- Positive acknowledgement and the time-out timer helps guarantee that the receiver has received the frame.

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Controlled Access Protocol

- In this method, the stations consult each other to find which station has a right to send.
- A station cannot send unless it has been authorized by other station.
- The different controlled access methods are:
  - Reservation
  - Polling
  - Token Passing

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Reservation

- In this method, a station needs to make a reservation before sending data.
- The time is divided into intervals. In each interval, a reservation frame precedes the data frames sent in that interval.
- If there are N stations, then there are exactly N reservation slots in the reservation frame.
- Each slot belongs to a station.
- When a station needs to send a frame, it makes a reservation in its own slot.
- The stations that have made reservations can send their frames after the reservation frame.

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Polling

- Polling method works in those networks where primary and secondary stations exist.
- All data exchanges are made through primary device even when the final destination is a secondary device.
- Primary device controls the link and secondary device follow the instructions.

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Token Passing

- Token passing method is used in those networks where the stations are organized in a logical ring.
- In such networks, a special packet called token is circulated through the ring.
- Station that possesses the token has the right to access the channel.
- Whenever any station has some data to send, it waits for the token. It transmits data only after it gets the possession of token.
- After transmitting the data, the station releases the token and passes it to the next station in th ring.
- If any station that receives the token has no data to send, it simply passes the token to the next station in the ring.

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Channelization Protocol

- Channelization is a multiple access method in which the available bandwidth of a link is shared in ***time***, ***frequency*** or ***code*** between different stations.
- There are three basic channelization protocols:
  - Frequency Division Multiple Access (FDMA)
  - Time Division Multiple Access (TDMA)
  - Code Division Multiple Access (CDMA)

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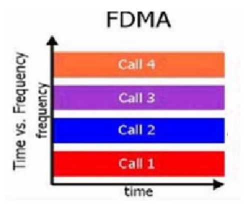
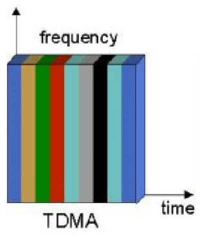
FDMA

- In FDMA, the available bandwidth is divided into frequency bands.
- Each station is allocated a band to send its data.
- This band is reserved for that station for all the time.
- The frequency bands of different stations are separated by small bands of unused frequency.
- These unused bands are called ***guard bands*** that prevent station interferences.
- FDMA is different from FDM (Frequency Division Multiplexing).
- FDM is a physical layer technique, whereas, FDMA is an access method in the data link layer.



TDMA

- In TDMA, the bandwidth of channel is divided among various stations on the basis of time.
- Each station is allocated a time slot during which it can send its data.
- Each station must know the beginning of its time slot.
- TDMA requires synchronization between different stations.
- Synchronization is achieved by using some synchronization bits at the beginning of each slot.
- TDMA is also different from TDM. TDM is a physical layer technique, whereas, TDMA is an access method in data link layer.



CDMA

- Unlike TDMA, in CDMA all stations can transmit data simultaneously.
- CDMA allows each station to transmit over the entire frequency spectrum all the time.
- Multiple simultaneous transmissions are separated using coding theory.
- In CDMA, each user is given a unique code sequence.

Working of CDMA

- Let us assume that we have four stations: 1, 2, 3 and 4 that are connected to the same channel.
- The data from station 1 is d_1, from station 2 is d_2 and so on.
- The code assigned to station 1 is c_1, station 2 is c_2 and so on.
- These assigned codes have two properties:
  - If we multiply each code by another, we get 0.
  - If we multiply each code by itself, we get 4, (no. of stations).

Working of CDMA

- When these four stations send data on the same channel, then station 1 multiplies its data by its code i.e. $d_1.c_1$, station 2 multiplies its data by its code i.e. $d_2.c_2$ and so on.
- The data that goes on the channel is the sum of all these terms:

$$\mathbf{d_1.c_1 + d_2.c_2 + d_3.c_3 + d_4.c_4}$$

- Any station that wants to receive data from the channel multiplies the data on the channel by the code of the sender.

Working of CDMA

- For e.g.: suppose station 2 wants to receive data from station1.
- It multiplies the data on the channel by c_1, (code of station 1).
- Because $(c_1.c_1)$ is 4, but $(c_2.c_1)$, $(c_3.c_1)$ and $(c_4.c_1)$ are all 0s, station 2 divides the result by 4 to get the data from station 1.

data $= (d_1.c_1 + d_2.c_2 + d_3.c_3 + d_4.c_4).c1$

$= d_1.c_1.c_1 + d_2.c_2.c_1 + d_3.c_3.c_1 + d_4.c_4.c_1$

$= d_1.4 + 0 + 0 + 0$

$= (d_1.4) / 4 = d_1$

Working of CDMA

- The code assigned to each station is a sequence of numbers called chips.
- These chips are called orthogonal sequences.
- Each sequence is made of N elements, where N is the number of stations.

c_1	c_2	c_3	c_4
[+1 +1 +1 +1]	[+1 -1 +1 -1]	[+1 +1 -1 -1]	[+1 -1 -1 +1]

Working of CDMA

c_1	c_2	c_3	c_4
[+1 +1 +1 +1]	[+1 -1 +1 -1]	[+1 +1 -1 -1]	[+1 -1 -1 +1]

- This sequence has following properties:
  - If we multiply two equal sequences, element by element, and add the result, we get N, where N is the number of elements in the sequence.
  - This is called ***inner product of two equal sequence***.

[+1 +1 -1 -1] . [+1 +1 -1 -1] = 1 + 1 + 1 + 1 = 4

Working of CDMA

c_1	c_2	c_3	c_4
[+1 +1 +1 +1]	[+1 -1 +1 -1]	[+1 +1 -1 -1]	[+1 -1 -1 +1]

- If we multiply two different sequences, element by element, and add the result, we get 0.
- This is called ***inner product of two different sequence***.

[+1 +1 -1 -1] . [+1 +1 +1 +1] = 1 + 1 - 1 - 1 = 0

Thank You

Have a Nice Day