Wi-Fi Technology Fundamentals

WI-FI TECHNOLOGY
FUNDAMENTALS COURSE

Module-3

WLAN MAC Layer

Session-3c

Carrier Sense and Medium Access

Last Session Recap......

Module-3

WLAN MAC Layer

Session-3b

MAC Framing, Headers and Key Functions

- ✔ 802.11 Frame Format
- ✔ Frame Type/Subtype Fields, From DS/To DS
- ✔ Beacon Field Fields
- ✔ Probe, Authentication, Association, Deauth/Disassoc Frames
- ✔ RTS/CTS Frames
- ✔ Data Frames/ACKs

CSMA/CD and CSMA/CA

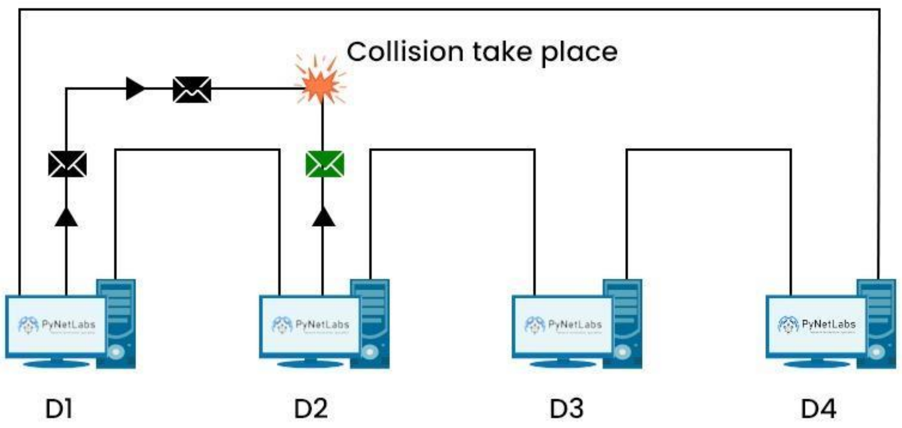
CSMA/CD and CSMA/CA are the media access methods that govern how a device can transmit data to the network.
CSMA/CD stands for Carrier Sense Multiple Access / Collision Detection. CSMA/CA stands for Carrier Sense Multiple Access/Collision Avoidance.

Both methods are used in a single collision domain. A single collision domain is a group of devices that share a collision. Since all devices share a collision, they use a method to avoid and remove the collision. Based on the media type used in the network, this method is known as either CSMA/CD or as CSMA/CA.

If the network uses wired media, this method is known as CSMA/CD. If the network uses wireless media, this method is known as CSMA/CA.

CSMA/CD

- This mechanism is only used in a single collision domain.
- All devices have equal priority.
- In this process, only one device can send data at a time.
- Before a device sends data, it will first sense the wire to ensure that no other device is currently sending data.
- If another device is currently using the media, it will have to wait till that transmission is over.
- If no device is currently using wire it can send the data.
- If two or more devices simultaneously sense wire and see no data in it, they could place their data on the wire at the same time.
- In this situation, a collision will occur.
- When a collision occurs, a special jam signal is created in the wire.
- Jam signal has a waiting time.
- All devices have to wait till the jam signal time is over.
- Once this time is over, devices can sense the wire again.
- If a device's data is lost in the collision, the device sends the same piece of data again.

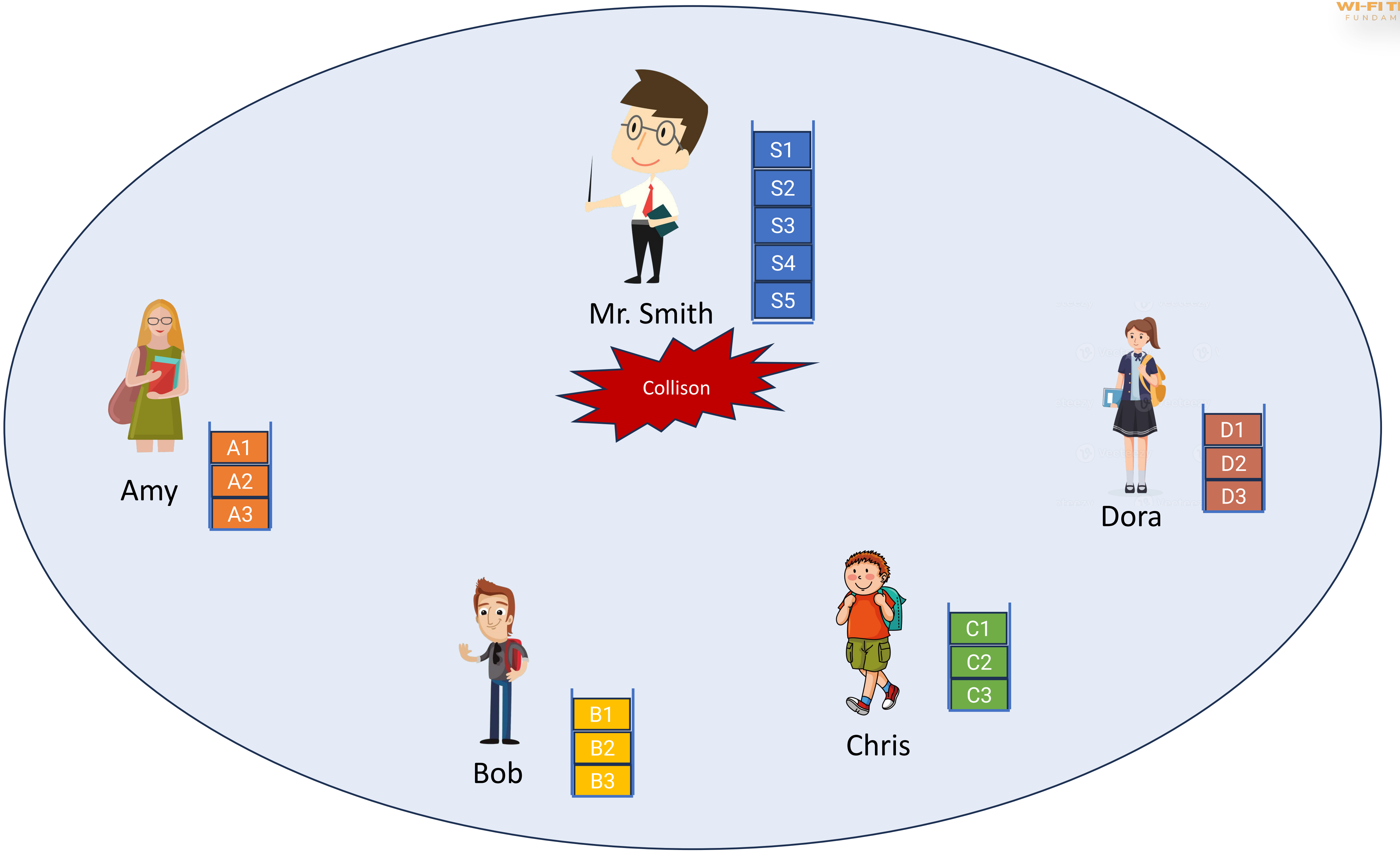


CSMA/CA

- WLANs use a mechanism called Carrier Sense, Multiple Access/Collision Avoidance (CSMA/CA). Unlike Ethernet, it is impossible to detect collisions in a wireless medium. In a WLAN, a device cannot simultaneously send or receive data. It can only do one or the other. Because of this, it cannot detect a collision. To avoid collisions, a device will use virtual carrier sensing and random backoff mechanisms while accessing the medium.

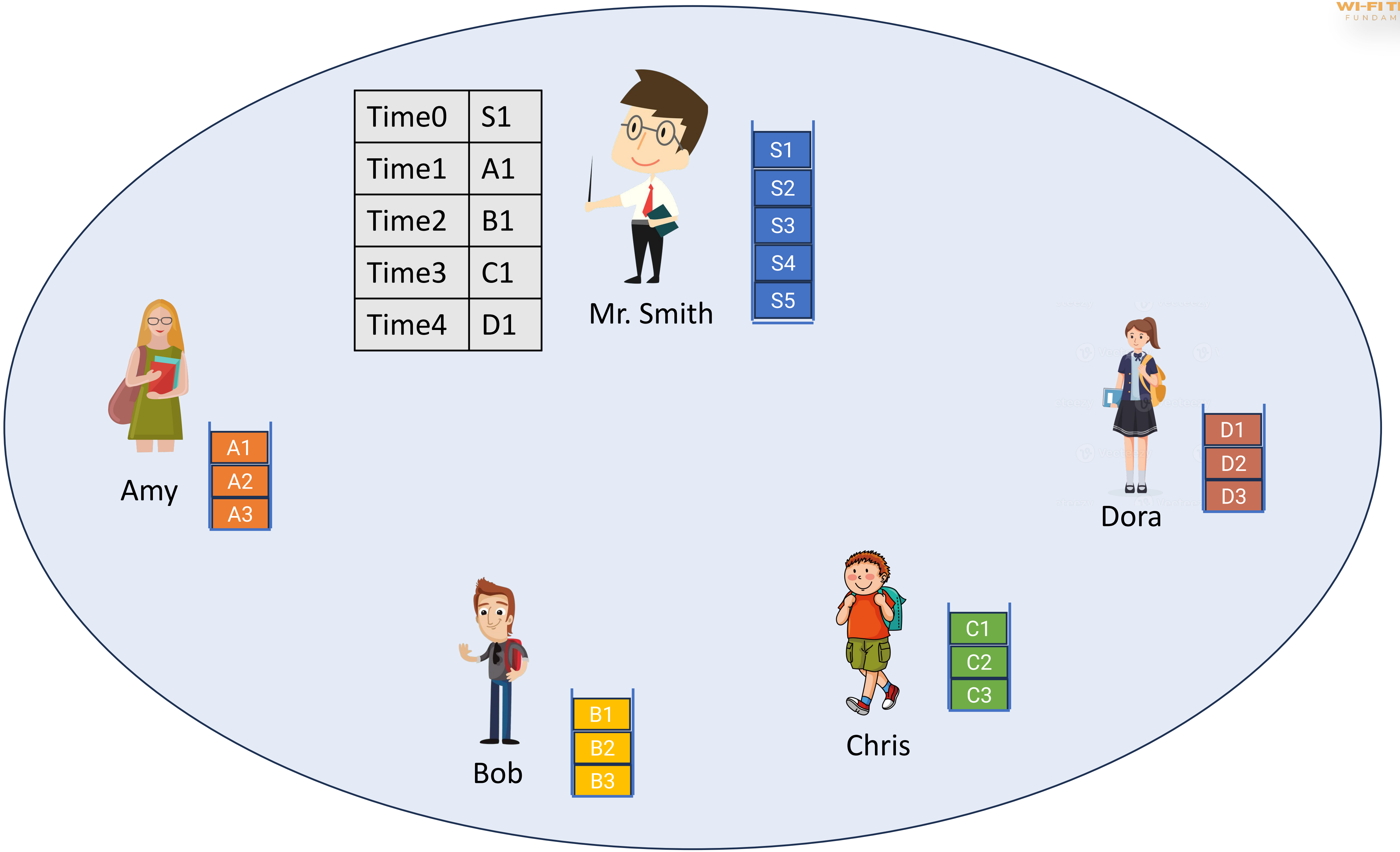
Source: https://www.computernetworkingnotes.com/networking-tutorials/csma-cd-and-csma-ca-explained.html

The Multiple/Medium Access Problem

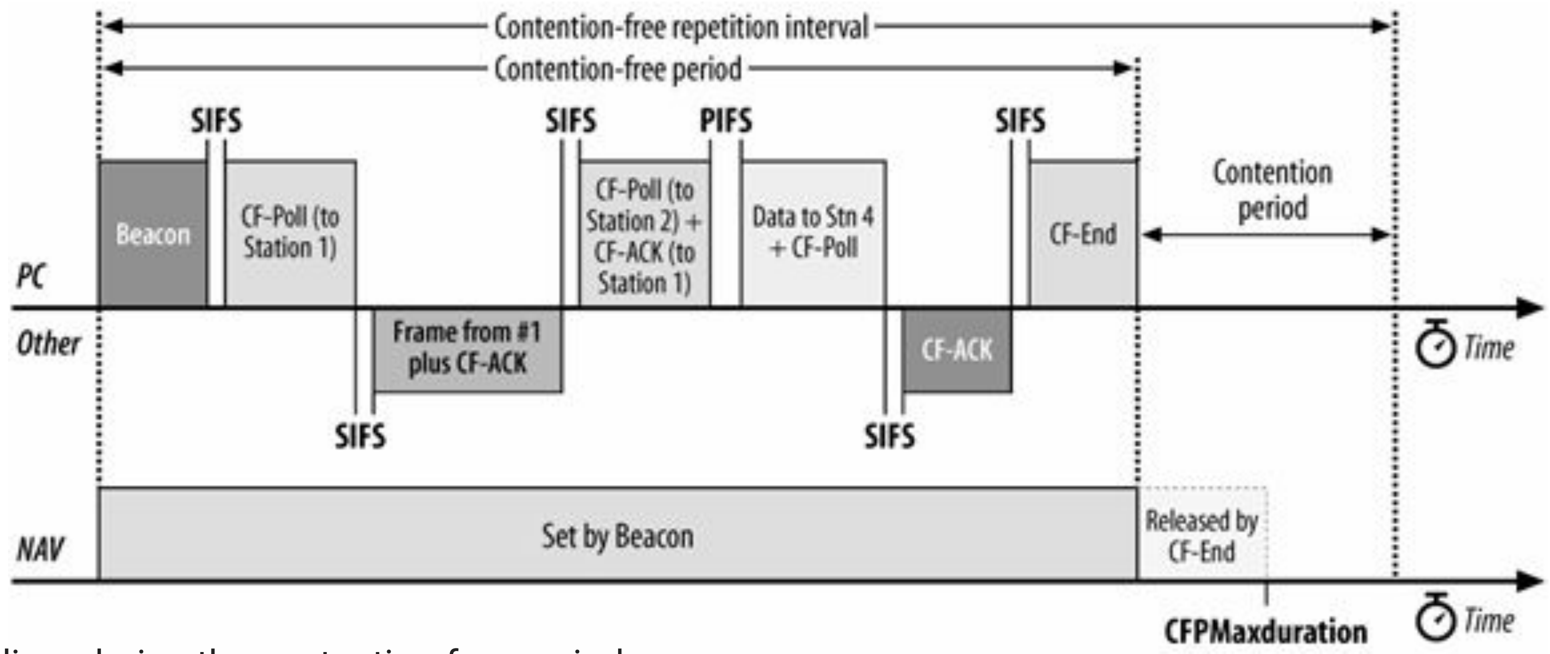


Solution1 – Use Scheduling

Time0	S1
Time1	A1
Time2	B1
Time3	C1
Time4	D1

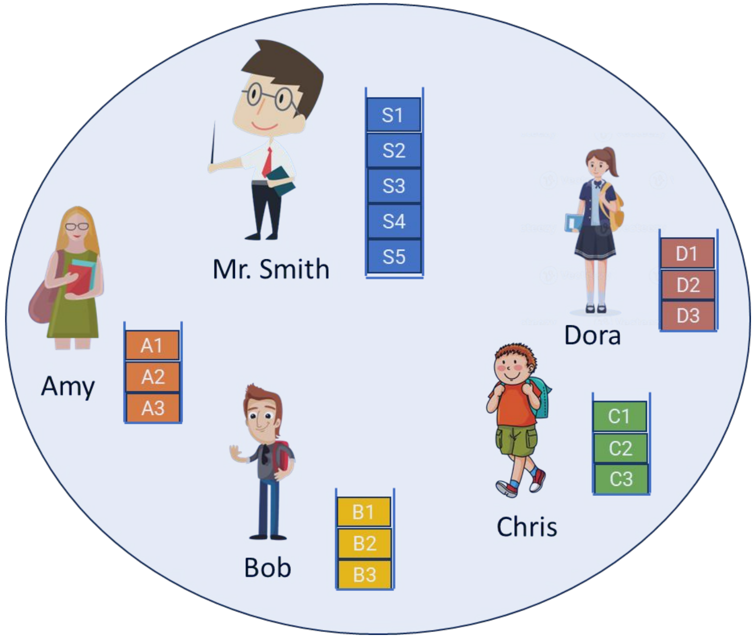


Point Coordination Function (PCF) - AP Scheduling



- Reserving the medium during the contention-free period
- At the beginning of the contention-free period, the access point transmits a Beacon frame.
- One component of the beacon announcement is the maximum duration of the contention-free period, CFPMaxDuration.
- All stations receiving the Beacon set their Network Allocation Vector (NAV).
- After the access point has gained control of the wireless medium, it polls any associated stations on a polling list for data transmissions.
- During the contention-free period, stations may transmit only if the access point solicits the transmission with a polling frame.
- Contention-free polling frames are often abbreviated CF-Poll. Each CF-Poll is a license to transmit one frame.
- Multiple frames can be transmitted only if the access point sends multiple poll requests.
- Stations get on the polling list when they associate with the access point.
- The Association Request includes a field that indicates whether the station is capable of responding to polls during the contention-free period.
- Generally, all transmissions during the contention-free period are separated by only the short interframe space.
- To ensure that the point coordinator retains control of the medium, it may send to the next station on its polling list if no response is received after an elapsed PCF interframe space.

Distributed Coordination Function (DCF) – Random Backoff



- Pick Random number between 0 and 5
- No one should transmit until their number goes to 0
- Every time the medium is free everyone counts down one number.
- First set to go to 0 will transmit if the medium is free at that time.
- Whenever the medium is busy everyone stops counting down.
- Once a person transmit, they will again pick a new random number and repeat the process.
- The only chance of collision is when two people pick same random number at the same time.
- Incase of collision there will be retransmission but this time the students can pick a random number between 0 and 10 to reduce the probability of both picking the same random number.

	Medium Busy	Medium Free	Medium Busy	Medium Free	Medium Busy	Medium Free	Medium Busy
2	2	1	1	0	Tx-S1	5	5
4	4	3	3	2	2	1	1
3	3	2	2	1	1	0	Tx-B1
1	1	0	Tx-C1	4	4	3	3
5	5	4	4	3	3	2	2

Time →

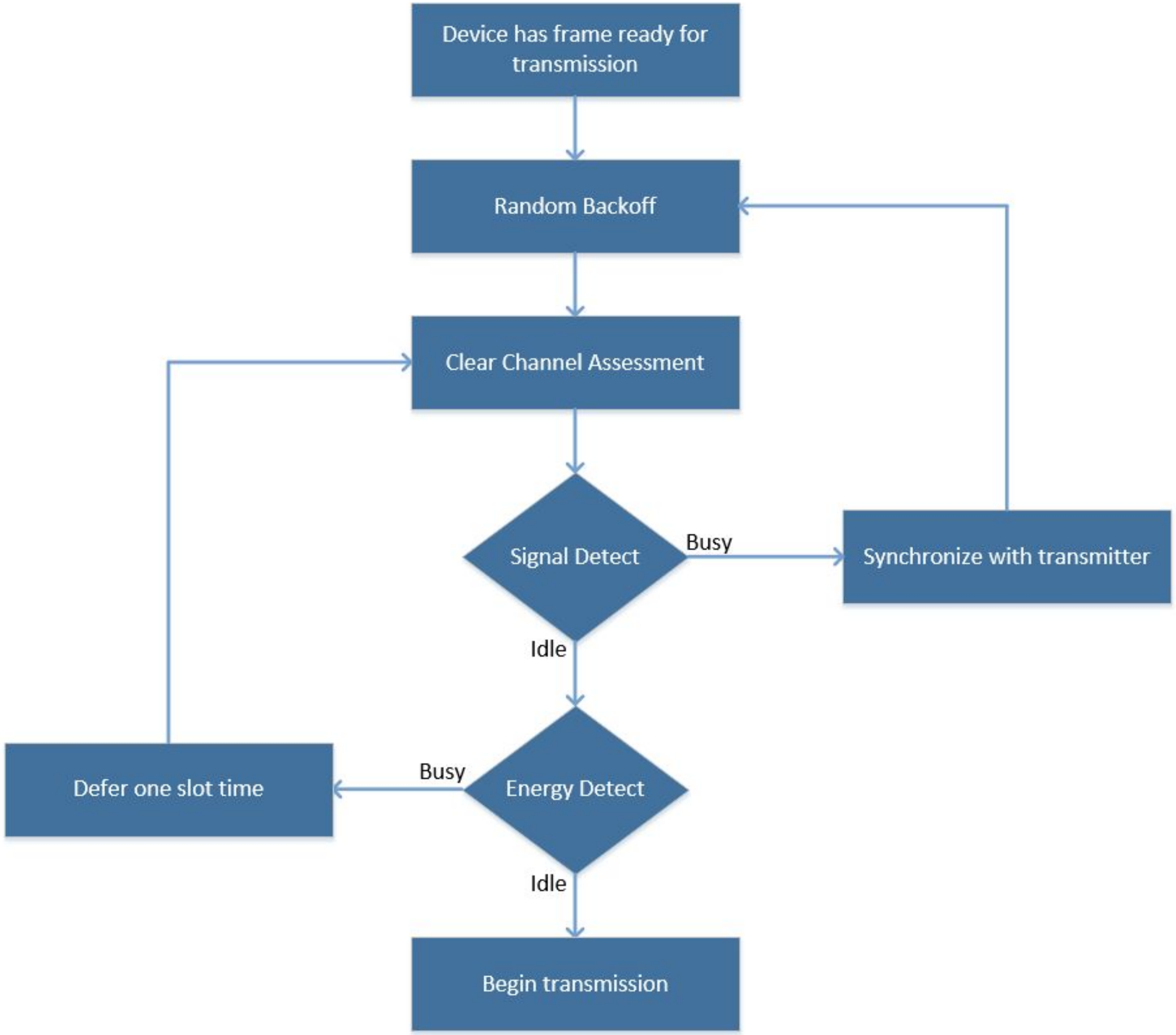
Clear Channel Assessment (CCA)

Devices use two methods to determine whether the channel is clear. One is used to detect other Wi-Fi transmissions, signal detect (SD), and the other is used to detect any sources of interference that are affecting the medium, energy detect (ED).

Signal detect – Device detects an 802.11 preamble in range. The threshold is a signal that is about 4dB above the noise floor. This means that the device will defer transmissions if a nearby device is starting to transmit.

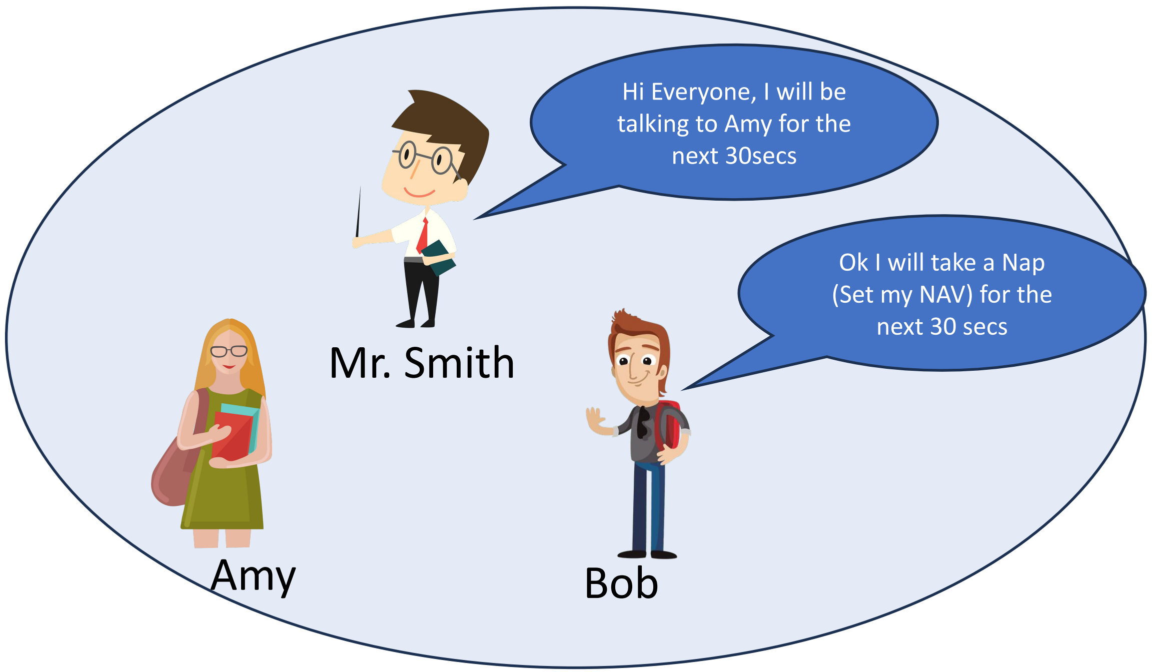
Energy detect – Device listens for any energy in the medium that is 20dB above the signal detect value. These devices could be Bluetooth, microwaves, baby monitors, or any other device that primarily operates in 2.4GHz or causes interference in the 2.4GHz range as a byproduct to its primary function.

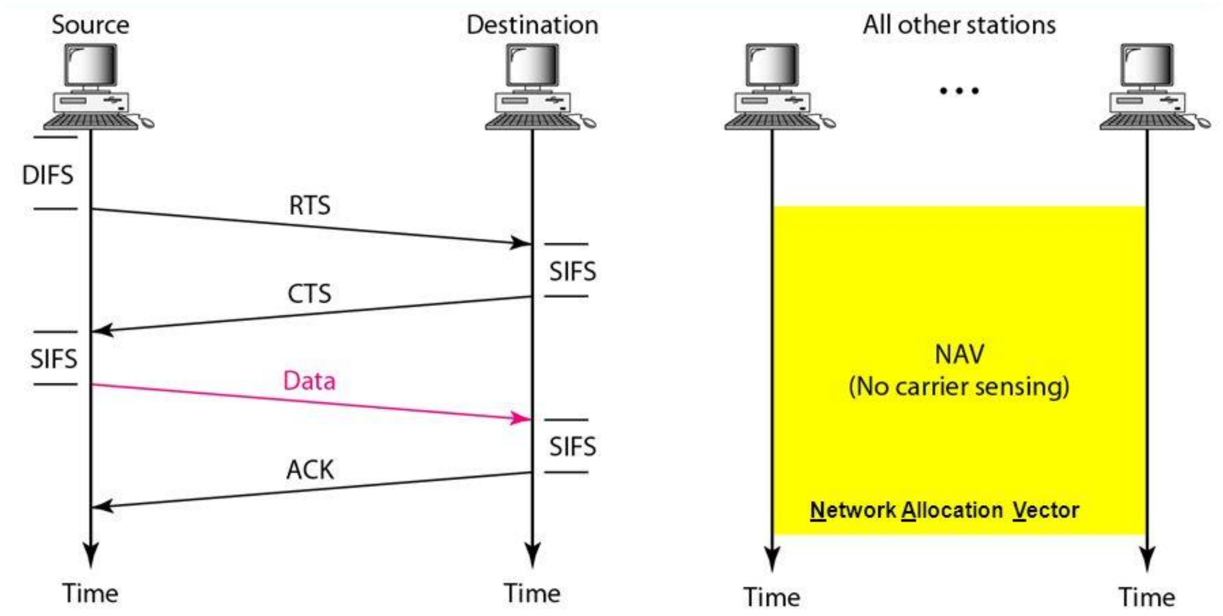
The flowchart represents a simplified version of the CCA process.



Source: https://howiwifi.com/2020/06/30/wireless-contention-mechanisms/

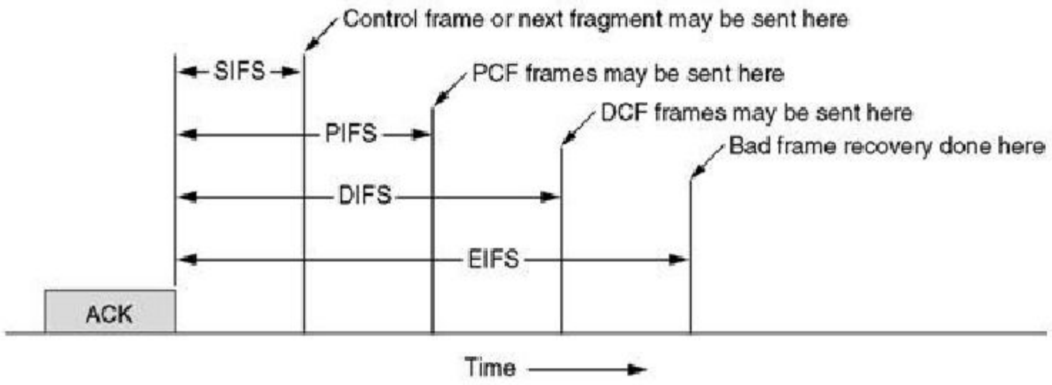
Network Allocation Vector (NAV)





- The network allocation vector (NAV) is a virtual carrier-sensing mechanism.
- The virtual carrier-sensing is a logical abstraction which limits the need for physical carrier-sensing at the air interface in order to save power.
- The MAC layer frame headers contain a duration field that specifies the transmission time required for the frame, in which time the medium will be busy.
- The stations listening on the wireless medium read the Duration field and set their NAV, which is an indicator for a station on how long it must defer from accessing the medium.
- The NAV may be thought of as a counter, which counts down to zero at a uniform rate.
- When the counter is zero, the virtual carrier-sensing indication is that the medium is idle; when nonzero, the indication is busy.
- The medium shall be determined to be busy when the station (STA) is transmitting.
- The NAV represents the number of microseconds the sending STA intends to hold the medium busy (maximum of 32,767 microsecs).

Interframe Spaces

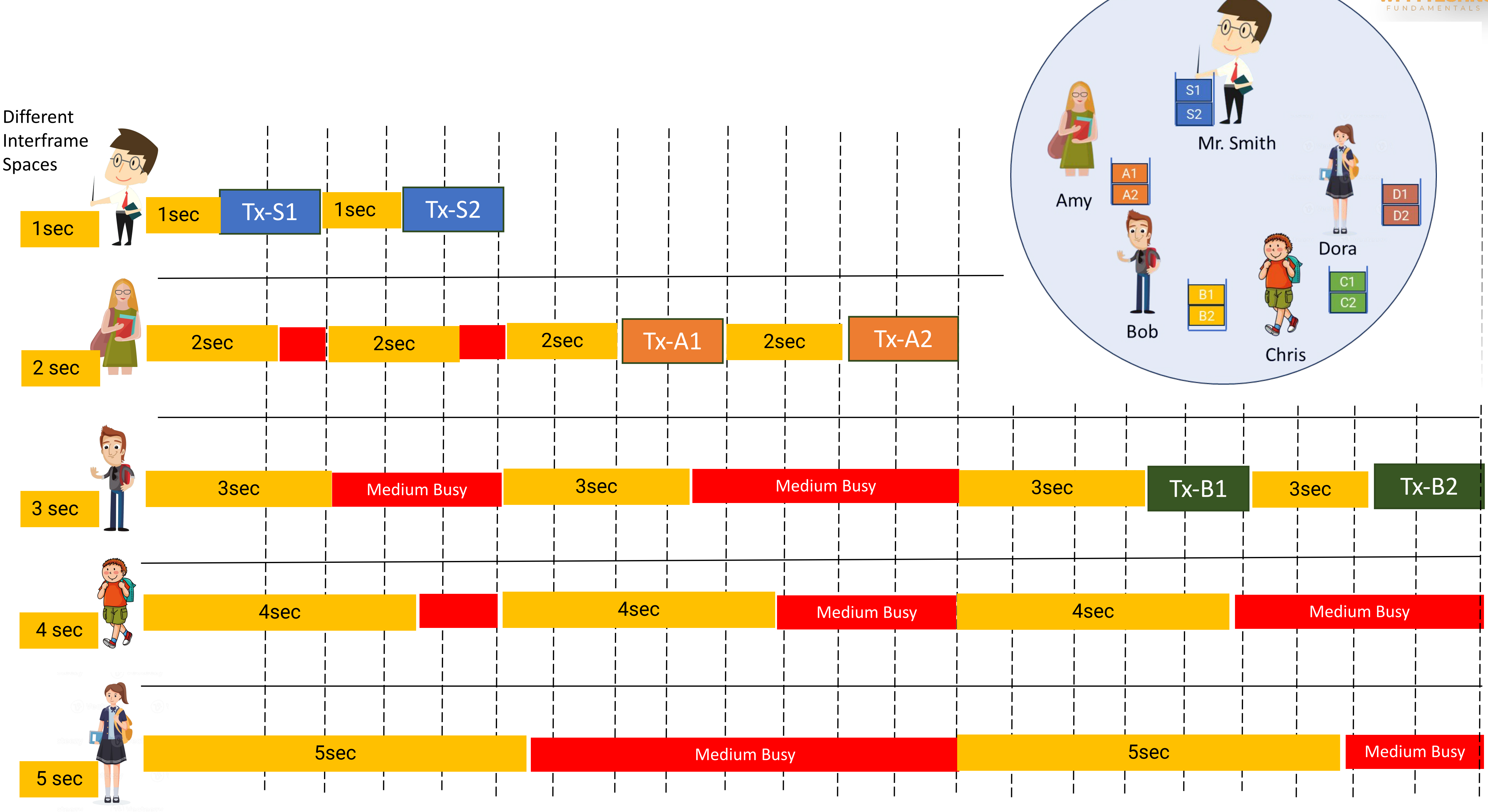


What is an Interframe Space (IFS) : It is a period of time that every Wi-Fi device (station) must wait before it transmits an 802.11 frame. IFS is used to avoid collisions and to prioritize medium access for transmissions.

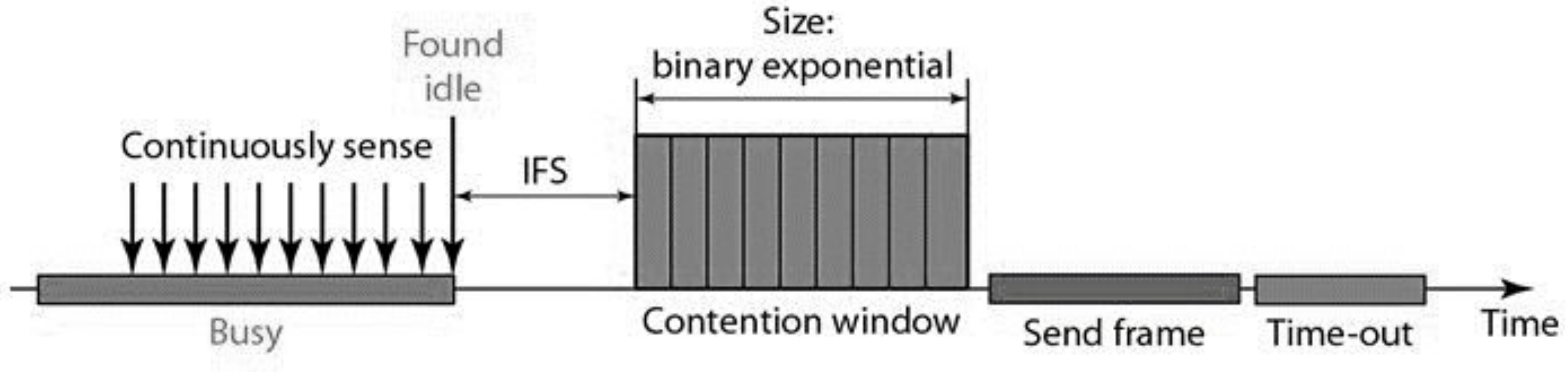
There are 6 types of IFS and each one is used at different times and/or for different purposes.

- SIFS : Once a station has already been given the right to communicate, the SIFS is used between frames of an individual communication stream. SIFS is one of the shortest in length. This means that if a station already has an active communication stream, after having waited a DIFS or an AIFS, then waiting only a SIFS means that it will be able to continue that communication stream until it is through because every other station will have to wait at least a DIFS or AIFS which are both longer than a SIFS.
- PIFS : The Point Coordination Function (PCF) Interframe Space (PIFS) was for use specifically in PCF implementations. According to the 802.11-2016 standard, "The PCF mechanism is obsolete
- DIFS :The Distributed Coordination Function (DCF) Interframe Space (DIFS) is used as part of the process to determine who has the right to transmit. In other words, it is used when contending for the RF medium.
- AIFS : The Arbitration Interframe Space (AIFS) has the same function as the DIFS, except that it is used specifically for Quality-of-Service (QoS) implementations which were introduced as a part of the 802.11e amendment. The length of an AIFS varies based primarily on priority. Compared with a DIFS, an AIFS could be longer or shorter depending on the category of traffic.
- RIFS : The Reduced Interframe Space (RIFS) has a similar function to the SIFS in that it is used after a station has already been given the right to communicate and thus will beat out any other station that must wait a DIFS or AIFS. However, the RIFS is used under very specific circumstances: they are only used following data frames of a Contention-Free Burst (CFB) by 802.11n stations using Multiple Input, Multiple Output (MIMO.
- EIFS : The Extended Interframe Space (EIFS) is used when a station receives a frame which fails the Frame Check Sequence (FCS), in which case it waits an EIFS to give the sending station an opportunity the retransmit. The EIFS is the longest of all IFS and so is called "Extended".

Inter Frame Spaces used for Preferential Access



Contention Window

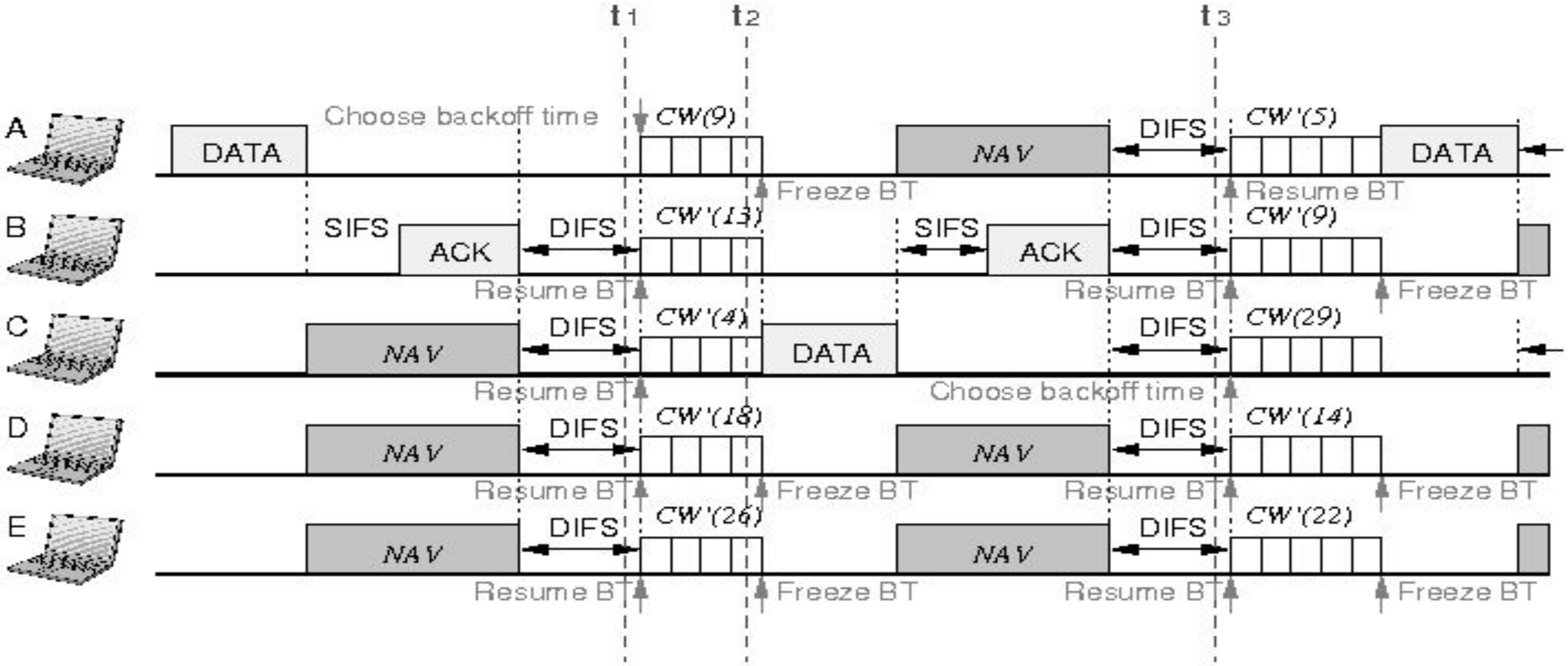


If participants determine that the channel is free, they wait a random amount of time before they start sending. This duration corresponds to the **contention window**. This time window doubles with each collision and corresponds to the binary exponential backoff (BEB) .

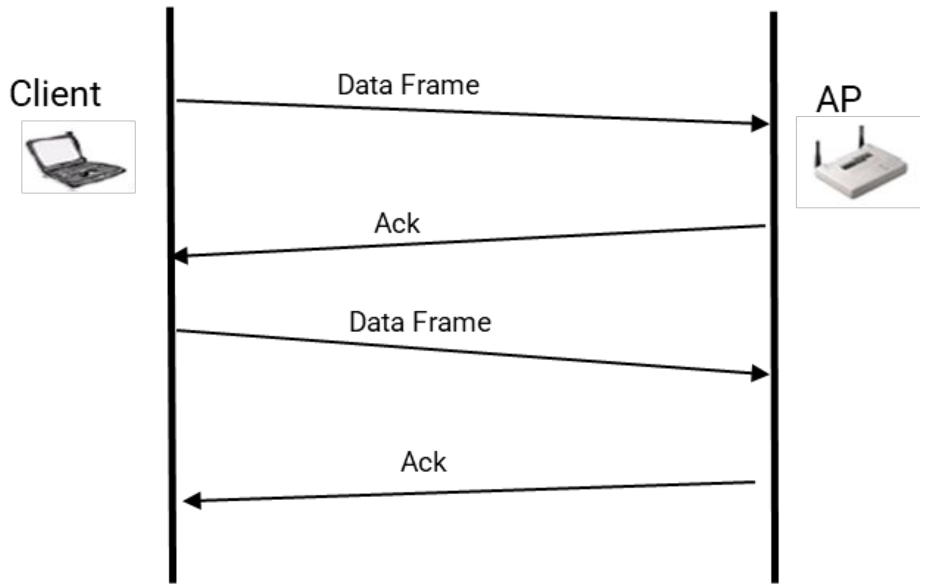
One interesting point about the contention window is that the station needs to sense the channel after each time slot. However, if the station finds the channel busy, it does not restart the process; it just stops the timer and restarts it when the channel is sensed as idle. This gives priority to the station with the longest waiting time.

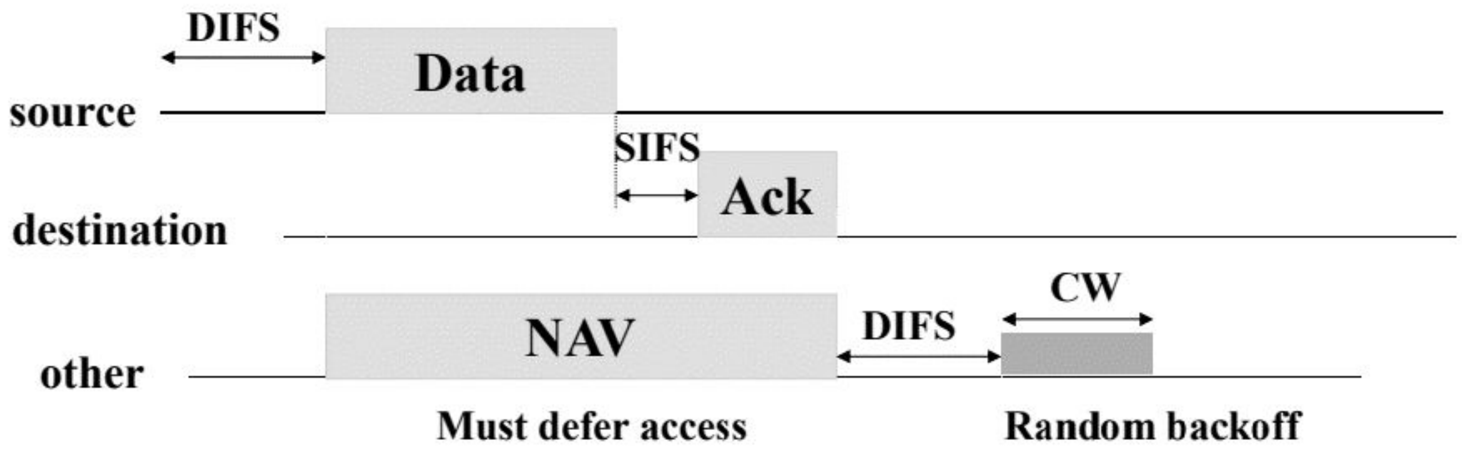
Backoff Algorithm

- Each station senses the channel for an additional random time after detecting the channel as being idle for a minimum duration of DIFS
- Only if the channel remains idle for this additional random time period, the station is allowed to initiate the transmission
- Each station maintains a CW, which is used to determine the number of slot times a station has to wait before transmission
- A backoff counter counts the slots from the random time chosen from zero downwards
- The backoff counter is decreased as long as a slot time is sensed as idle and it is frozen when a transmission is detected
- As soon as the backoff counter reaches the value zero, the station transmits its own frame
- After any unsuccessful transmission attempt, another backoff is performed with a doubled CW size
- This reduces the collision probability in case there are multiple stations attempting to access the channel



Basic Data Transmission





- Every data frames needs to be followed immediately by an Ack frame .
- To make sure this operation is atomic and no other transmission gets in between, for all ACK frame a SIFS is used which is the shortest time needed for any device to find the medium free before transmission.
- Since all other devices need to wait at least for a DIFS period, this ensures that the ACK from the receiver always follows the Data frame from the transmitter.

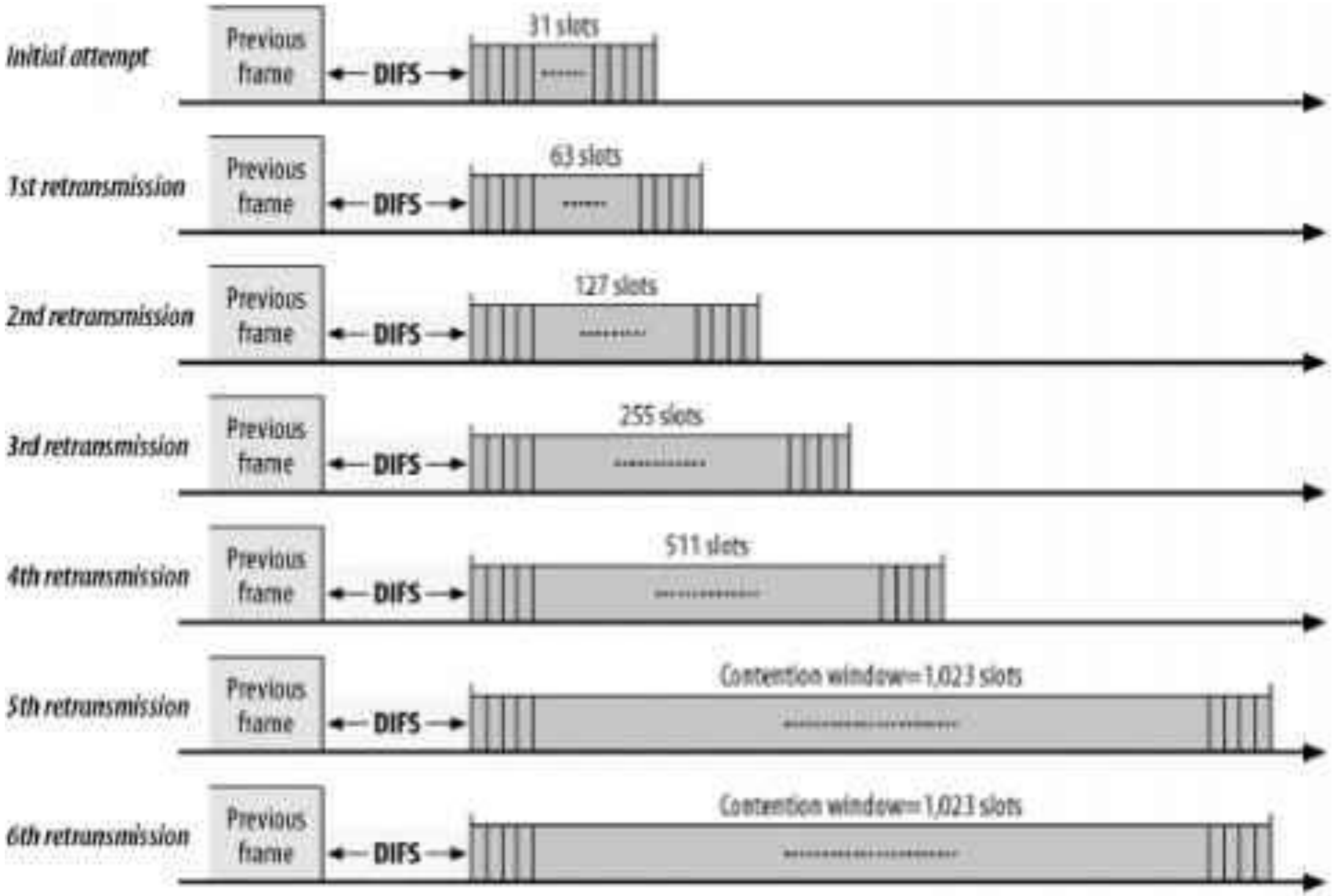
Exponential Backoff

Binary Exponential Backoff (BEB) is an algorithm to determine how long entities should backoff before they retry. With every unsuccessful attempt, the maximum backoff interval is doubled. BEB prevents congestion and reduces the probability of entities requesting access at the same time, thereby improving system efficiency and capacity utilization.

BEB is most useful in distributed systems without centralized control or systems that lack predetermined resource allocation. In such systems, multiple entities attempt to access a shared resource. Because there's no centralized control, whoever manages to grab the resource before anyone else will be allowed to use it. Others have to wait for their turn.

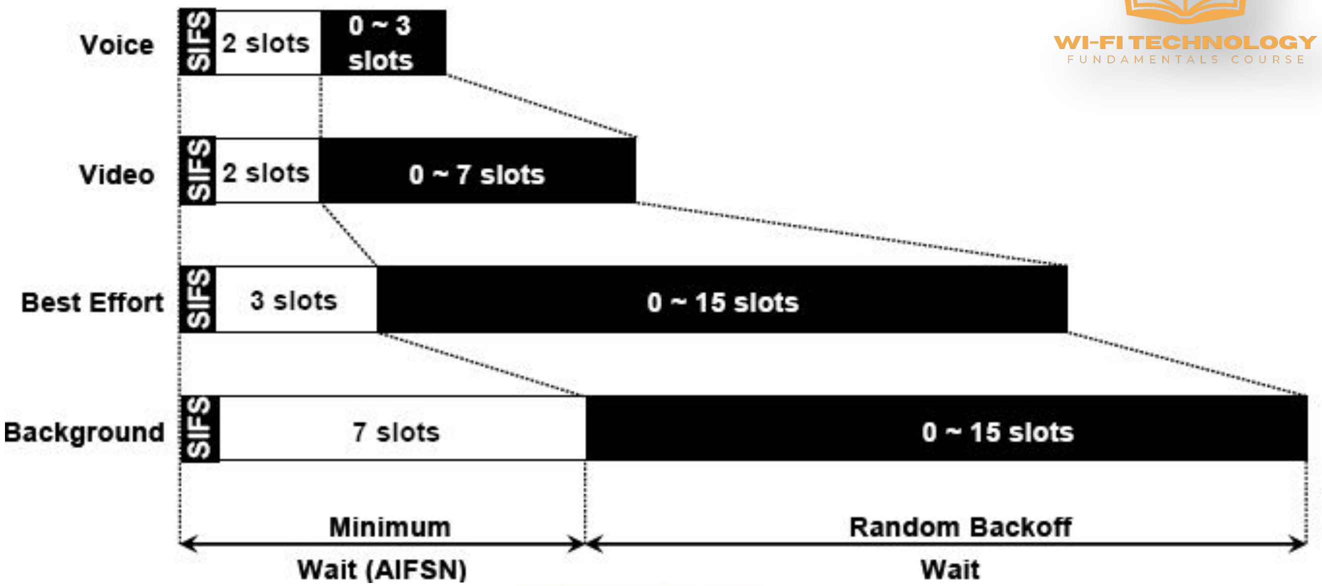
The problem is that when the resource becomes available, everyone else will attempt to grab it. This results in delays. Entities spend time trying to resolve the confusion. Resource utilization is therefore not optimal. The problem gets worse when many entities (dozens or hundreds) are involved.

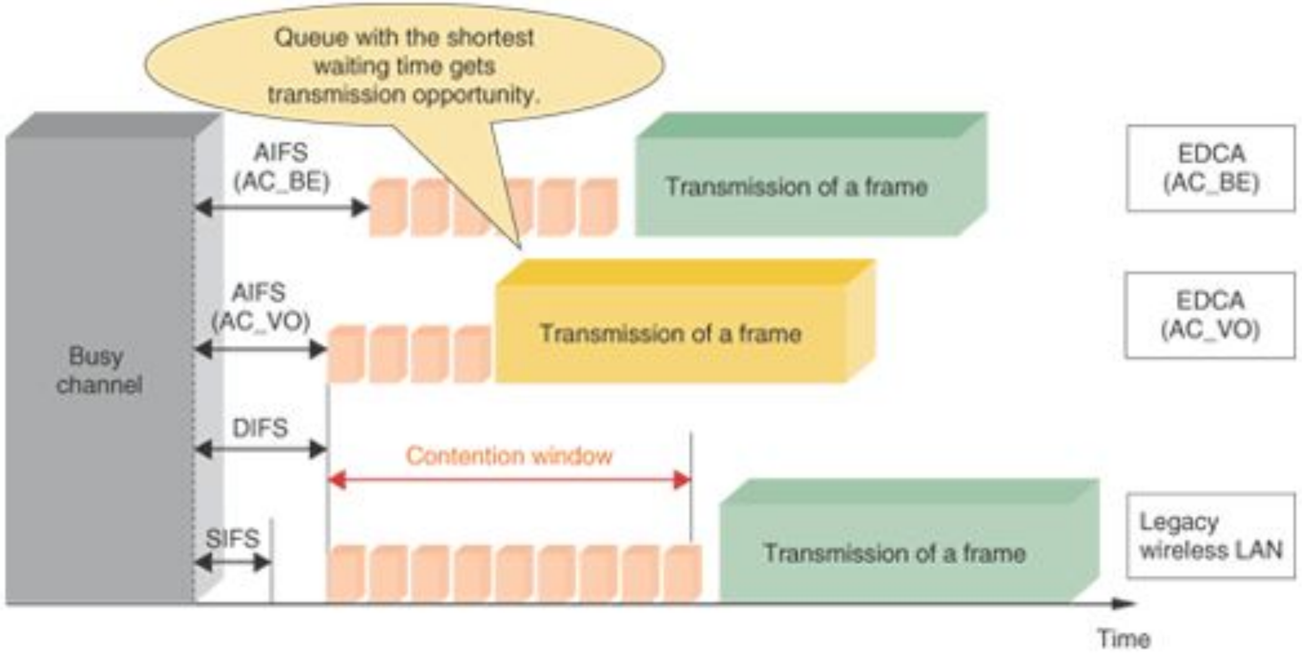
BEB is an algorithm that mitigates this problem. BEB is therefore useful in probabilistic systems. It's not useful in deterministic systems where the resource is allocated by a controller, each entity knows its turn and will use the resource at specific times and durations as allocated.

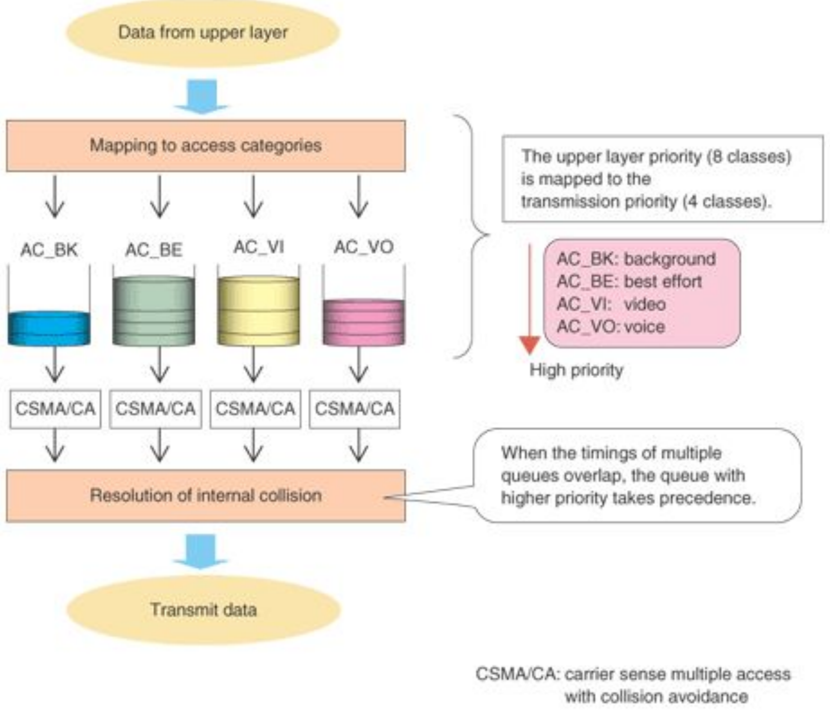


Wi-Fi QoS (WMM) Basics

- Each client station has 4 queues for different traffic types: voice, video, best effort and background
- The higher the AC, the higher the probability to transmit
- The ACs were designed to correspond to 802.1d priorities
- The client has an internal collision resolution mechanism to address collision among different queues, which selects the frames with the highest priority to transmit (opportunity to transmit (TXOP))
- Most AP vendors today implement the WMM spec which is EDCA only



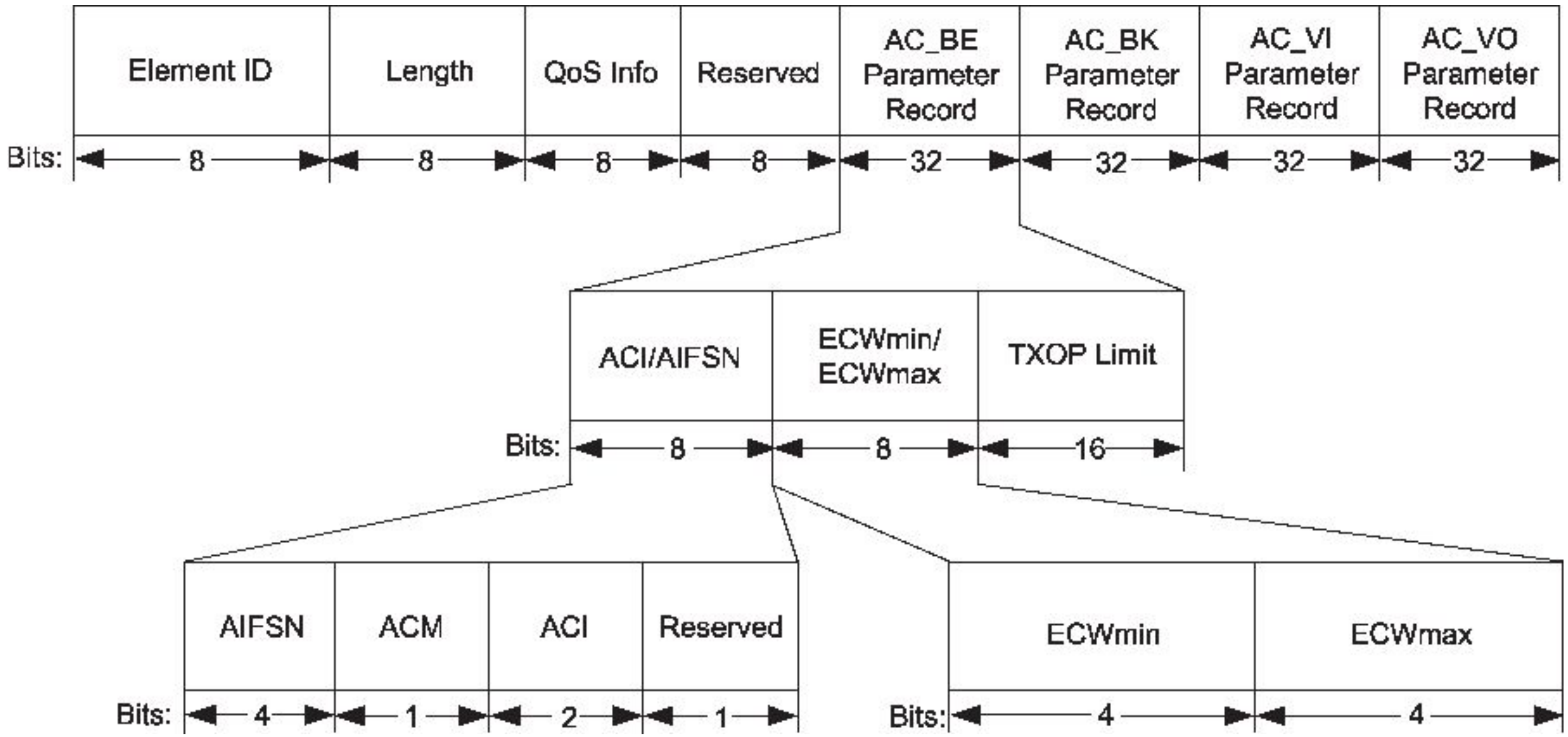




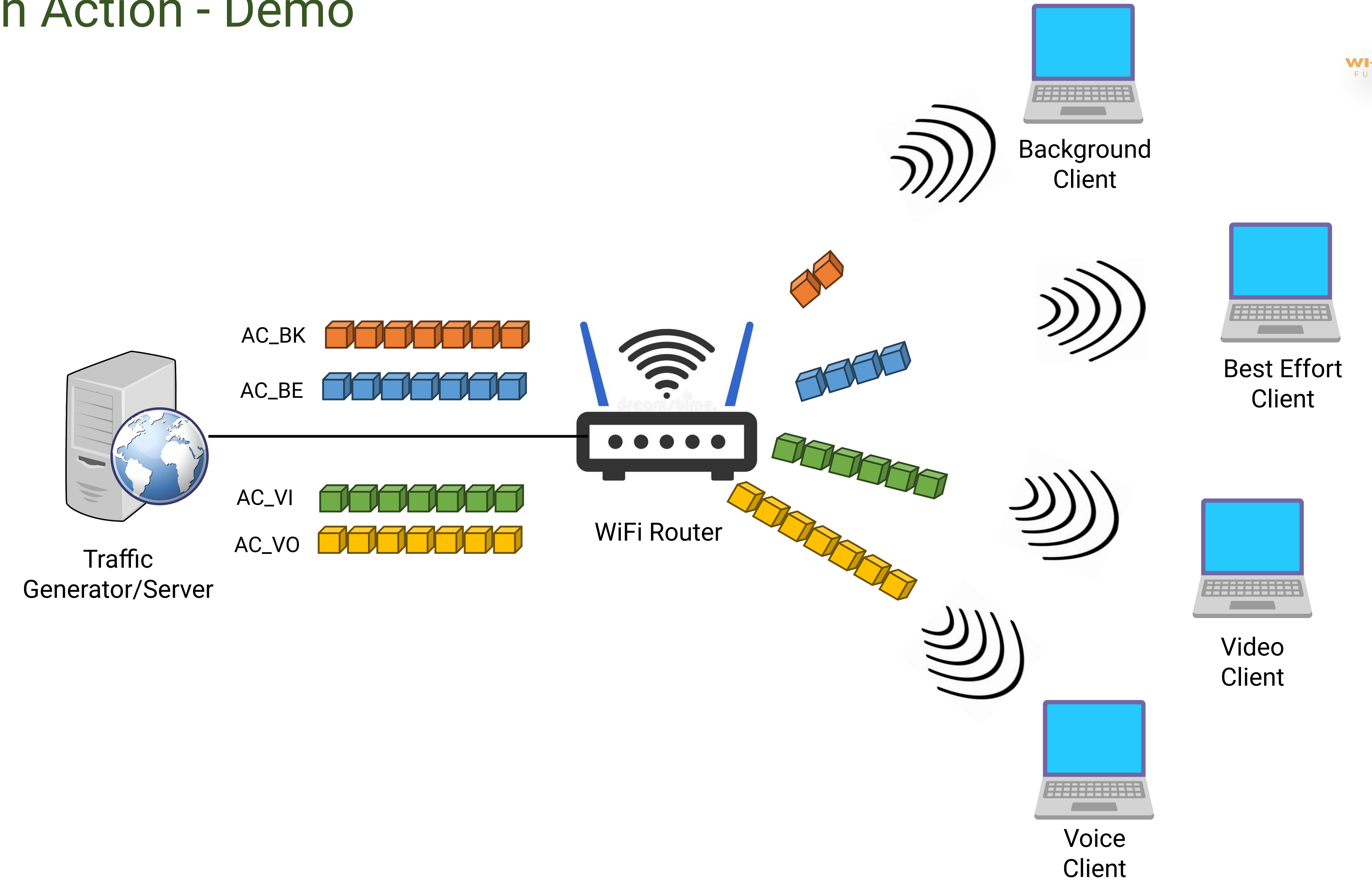
WI-FI TECHNOLOGY
FUNDAMENTALS COURSE

EDCA Parameter Set

- Quality of service (QoS) needed to support multiplay traffic
- The IEEE 802.11e standard defines enhancements to support QoS for the traditional 802.11 MAC protocol
- Introduces enhanced distribution coordination channel access (EDCA)
- QoS is supported with the introduction of traffic categories (TCs)
- In order to introduce priorities, the CW sizes and IFS values are set differently for each TC
- Each traffic queue within the stations contends for a transmission opportunity (TXOP) and independently starts a backoff after detecting that the channel is idle for an arbitration inter frame space (AIFS)



QoS in Action - Demo



References

Interframe Spacing
https://waitbutwifi.com/interframe-space-basics/

CSMA/CD vs CSMA/CA
https://www.pynetlabs.com/csma-cd-vs-csma-ca/

Collision Avoidance and CCA
https://howiwifi.com/2020/06/30/wireless-contention-mechanisms/

Contention based medium access using DCF
https://flylib.com/books/en/2.519.1/contention_based_access_using_the_dcf.html

802.11e QoS Tutorial
https://www.ieee802.org/1/files/public/docs2008/avb-gs-802-11-qos-tutorial-1108.pdf

Q&A


?
QUIZ!
TIME

Quiz 3b Results

Winner

Meena Kumari

INDIA

Number of participants - 131