Presentation on QoS 802.11e

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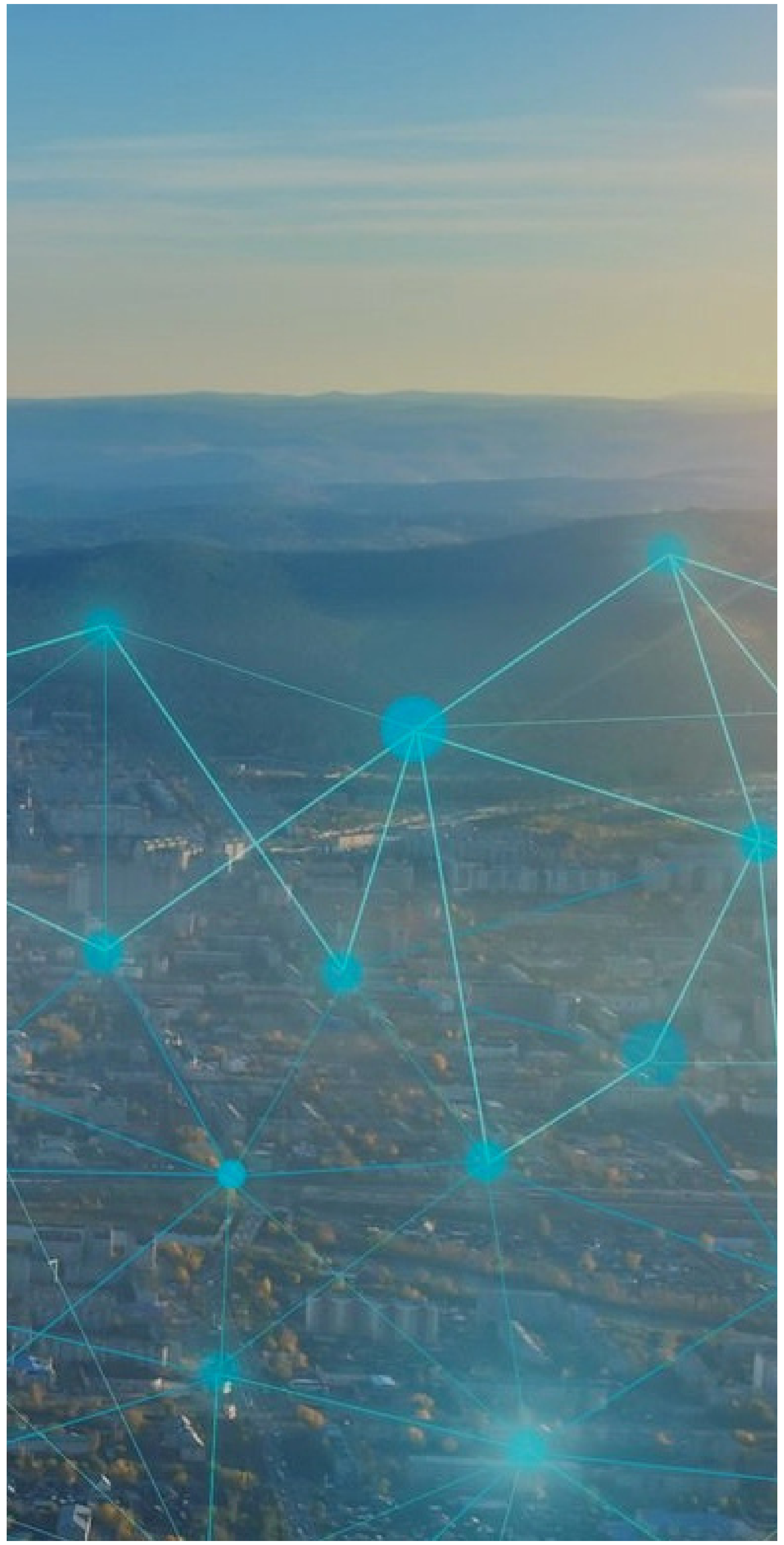


Outline :

1. 802.11 CSMA/CA.
    a. Collision Avoidance (CA).
    b. Network Allocation Vector (NAV).
    c. Contention Window.
2. Inter frame spacing (IFS).
    a. SlotTimes.
    b. Types of IFS's (SIFS,PIFS,DIFS,EIFS,AIFS,RIFS).
3. 802.11e QoS.
    a. Enhanced DCF (EDCF).
    b. Automatic Power Save Delivery (APSD)
    c. Direct Link Protocol (DLP).
    d. Transmit Opportunity (TxOP)
    e. Frame Bursting & Block Acknowledgement.
    f. Types of QoS and WiFi Multimedia (WMM).
4. WireShark session : QoS in Beacon Managment Frames.

Scope of 802.11

- 802.11 standard focuses on the 2 lower layers (1 & 2) of the OSI reference model.
- In the reference model of 802.11, Data Link Control (DLC) layer is divided into:
  - Logical Link Control (LLC).
  - Medium Access Control (MAC).
- 802.11 defines Physical layer (PHY) transmission schemes and the MAC protocol, but no LLC functionality.

Listen Before Talk

- The channel sensing function is called Clear channel Assessment (CCA).
  - It uses a power threshold (-82dBm, possibly implementation dependent).
  - If a station detects a signal with power larger than this threshold, the radio channel is assumed to be busy.
  - Otherwise the channel is idle.
- There are different variants of CCA.
  - Ordinary noise detection.
  - Only signals from other 802.11.

Carrier Sense Multiple Access/Collision Avoidance

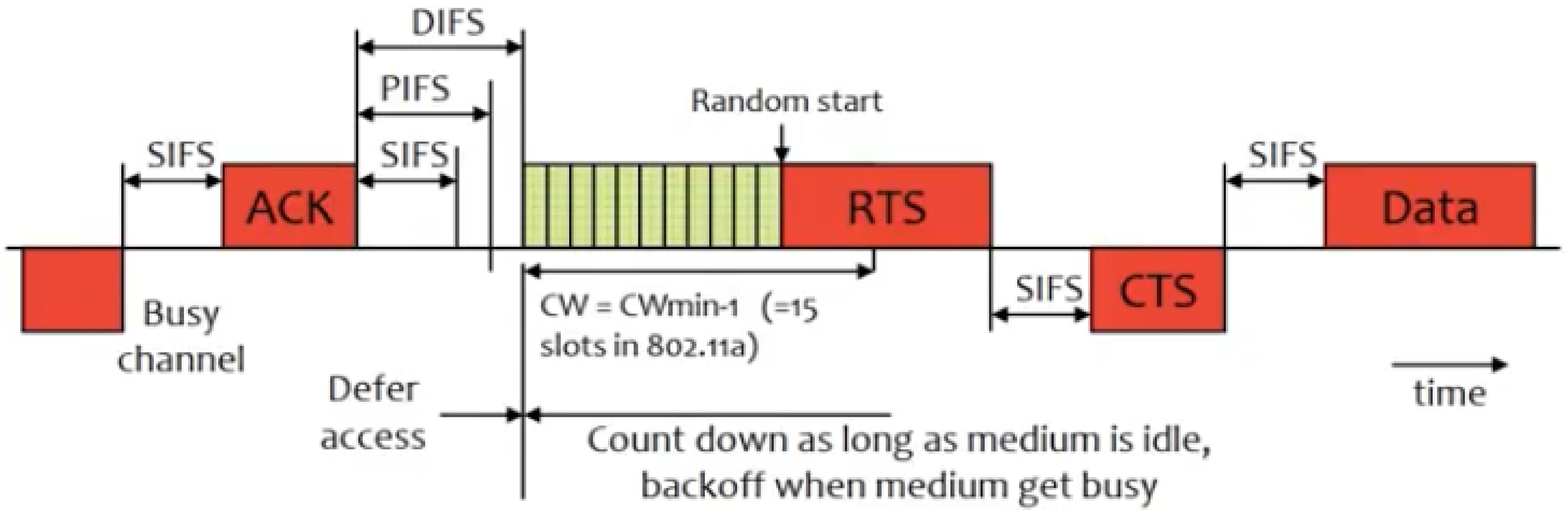
Listen Before Talk **CSMA/CA**

For Wi-Fi we call this:
DCF = Distributed Coordinated Function

Listen Before Talk

- The Network Allocation Vector (NAV) is an addition to the physical sensing of the radio channel.
- It is referred to as Virtual Carrier Sensing and in fact has the function of reserving the channel for some time.
- It is a timer which decrements irrespectively of the status of the medium.
- As long as the NAV is set or the CCA sensed the radio channel as being busy, a station is not allowed to initiate transmissions.

Collision Avoidance



- As part of CA, a station performs the backoff procedure before starting transmission.
- After a successful frame exchange, a station wants to send another data frame, it starts transmitting RTS after sensing the channel is idle for a duration equal to DIFS and its following backoff slots.

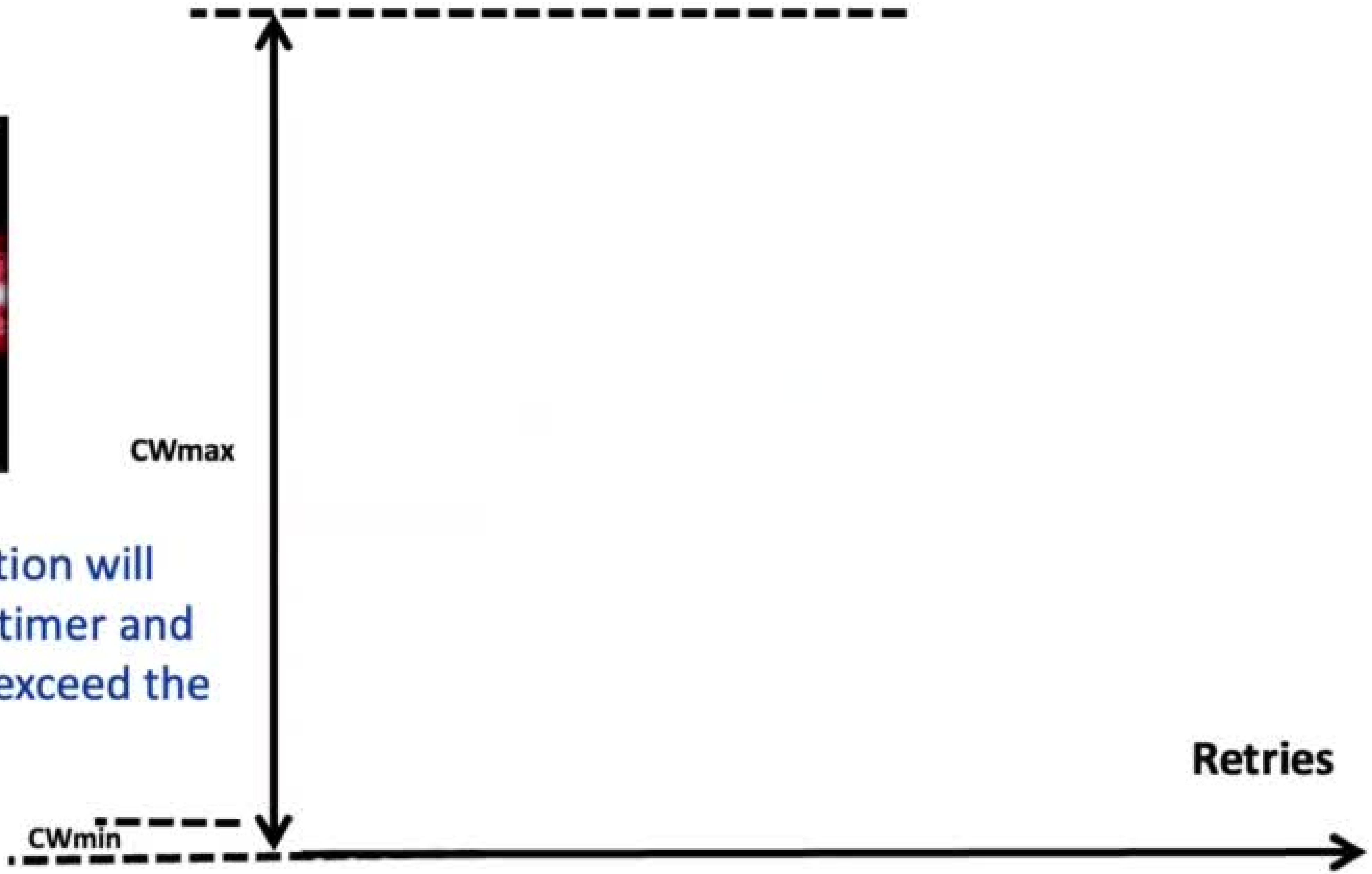
Contention Window (CW)

Total Contention window = Backoff Timer+ all NAVs

Countdown stops when you hear another Network Allocation Vector (NAV). This is the time the medium is going to be held to complete the transmission.

Contention Window (CW)

If there is a collision the station will need to double its back-off timer and try again. The station can't exceed the CWmax value.



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End of Part 1

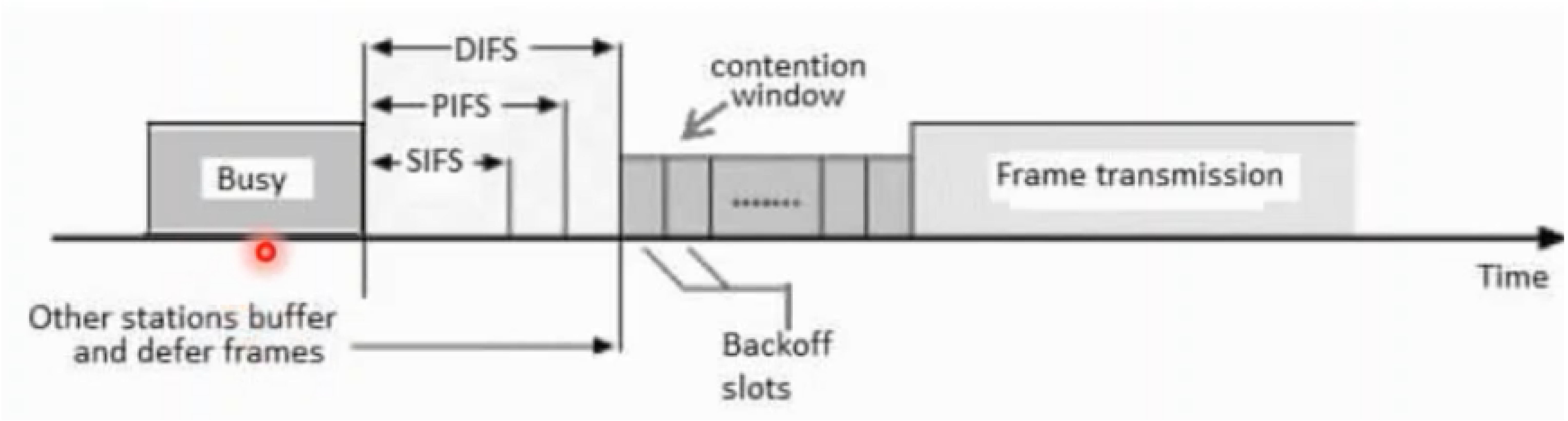
Conclusions :

- All stations are treated the equally in CSMA/CA.
- Stations must get in contention window (CW).
  - They can access the channel only if the backoff timer ends and the channel is clear.
  - If they detect (NAV) they pause the wait until (NAV) ends then they resume the wait.
- CW = Backoff + all NAV's

Why Inter Frame Space

- The main purpose of an IFS is
  - Both to provide a buffer between frames to avoid interference.
  - As well as to add control and to prioritize frame transmissions.
- Interframe spaces are minimum number of microseconds that a channel must remain clear after the previous transmission ends.
- In other words, this is how a station can tell when one frame ends and thus another frame can start. The channel is idle during this interval.
- The interframe spacing timings are defined as time gaps on the medium. Different types of traffic requires different priority levels. This can be achieved by varying spacing between the frames.

Slot Time



- This figure mentions three of the six types used for medium access.
- The idea is to provide less delay for high priority traffic. Hence high priority traffic can use network before low priority one as soon as it is available.

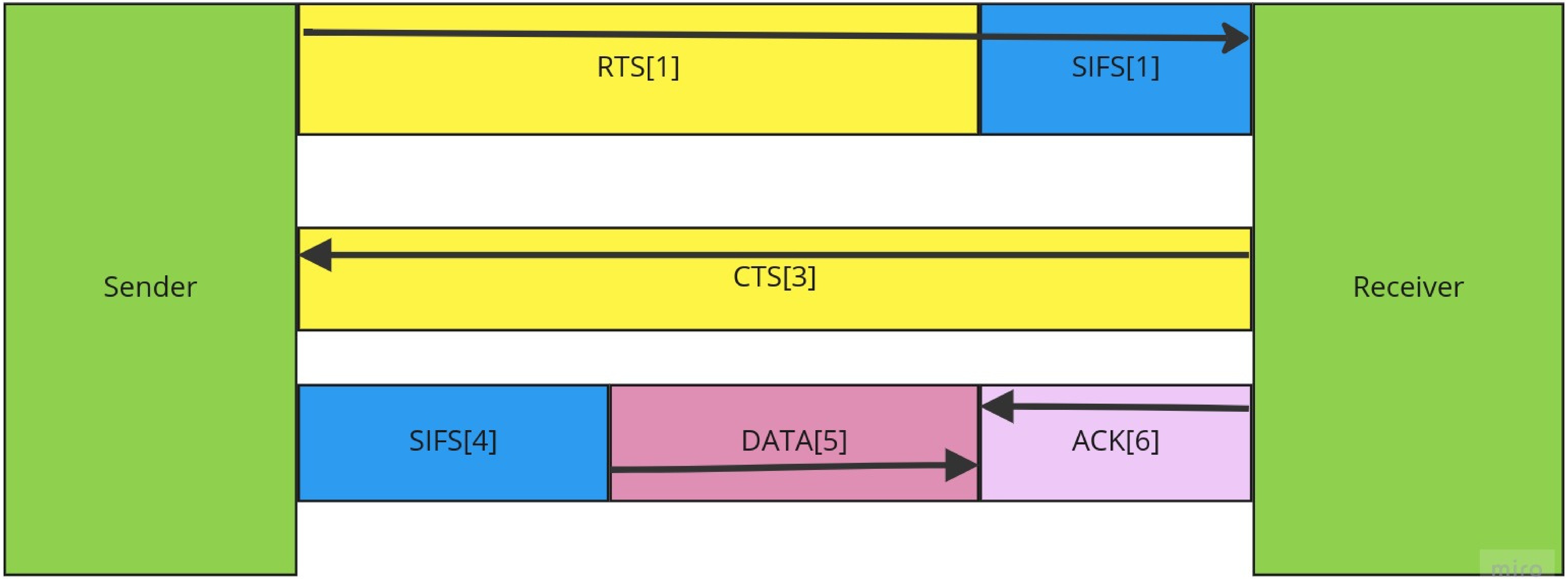
Types of Inter Frame Space

- IEEE 802.11 WLAN standard defines various Inter Frame Spaces (IFS) such as :
  - SIFS (Short Inter Frame Space)
  - PIES (PCF Inter Frame Space)
  - DIFS (DCF Inter Frame Space)
  - EIFS (Extended Inter Frame Space)
  - AIFS (Arbitration Inter Frame Space)
  - RIFS (Reduced Inter Frame Space)
- Out of this six interframe spaces of different maximum durations of time, the order is RIFS < SIFS < PIFS < DIFS < AIFS < EIFS.

SIFS (Short Inter Frame Space)

- SIFS are used for RTS/CTS and positive ack with high priority transmission.
- Once SIFS duration elapses, the transmission can immediately starts.
- The medium will be busy after the SIFS period is over and hence this type of transmission will have higher priority over others.
- SIFS for 802.11 b/g/n (2.4 GHz) = 10μs
- SIFS for 802.11 a/n/ac (5 GHz) = 16μs

SIFS (Short Inter Frame Space)



PIFS (PCF Inter Frame Space)

- PIFS are used by STA (Station) during the contention free period (CFP) in PCF mode.
- Because PCF has not been implemented in 802.11 devices, so there is no use of PIFS.
- PIFS is used (As PIFS is shorter than DIFS) in channel switching announcement (802.11h) scenario to gain access to medium on priority.
- PIFS can be calculated as PIFS = SIFS + SlotTime.

DIFS (Distributed Inter Frame Space)

- DIFS is the minimum medium idle time and is used for contention based services.
- Distributed coordination function (DCF) is a mandatory technique used to prevent collisions in IEEE 802.11-based WLAN standard (Wi-Fi). It is a medium access control (MAC) sublayer technique used in areas where (CSMA/CA) is used.
- DIFS can be calculated as DIFS = SIFS + 2 x SlotTime .

EIFS (Extended Inter Frame Space)

- The EIFS value is used by STAs that have received a frame that contained errors.
- By using this longer IFS, the transmitting station will have enough time to recognize that the frame was not received properly before the receiving station commences transmission.
- If during the EIFS duration, the STA receives a frame correctly it will resume using DIFS or AIFS as appropriate.
- EIFS can be calculated as :
  - EIFS (In DCF) = SIFS + DIFS + ACK_Tx_Time
  - EIFS (In EDCA) = SIFS + AIFS[AC] + ACK_Tx_Time
  - ACK_Tx_Time is the time expressed in microseconds required to transmit an ACK frame.

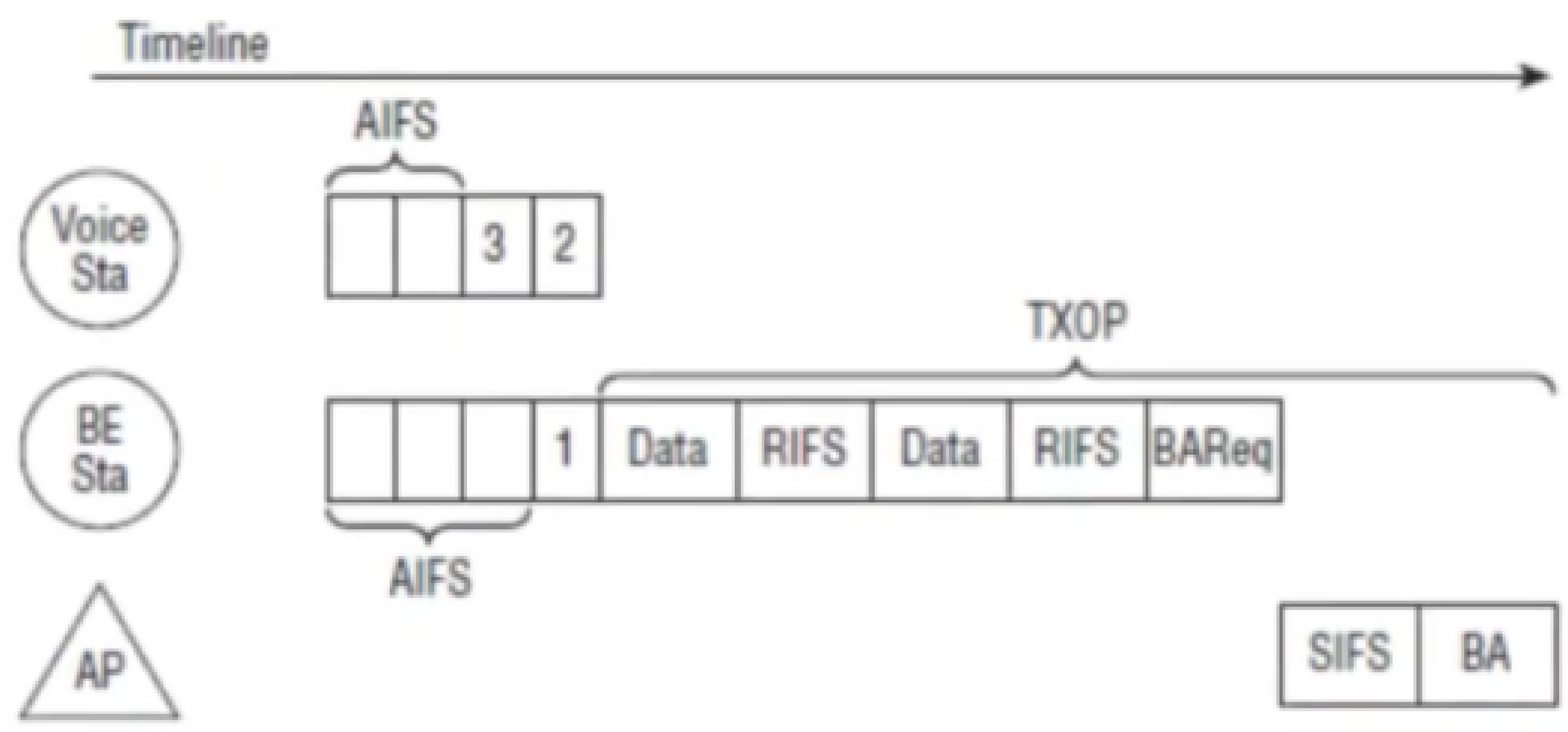
RIFS (Reduced Inter Frame Space)

- The 802.11e QoS amendment introduced the capability for a transmitting radio to send a burst of frames during a transmit opportunity (TXOP).
- During the frame burst, a SIFS was used between each frame to ensure that no other radios transmitted during the frame burst.
- 802.11n standard use RIFS only when Block Acknowledgement (mandatory in 802.11n) is enabled.
- When Block ACK are used, data frames of a CFB (Contention Free Burst) may send consecutively without interruption by ACK.
- At the end of CFB, Tx station will simply send BAR (BA Req) and receiving a single Block Acknowledgement (BA).
- The much shorter RIFS interval is only 2 µS for 802.11n PHY.
- The use of RIFS is obsolete from 802.11ac amendment onwards.

RIFS (Reduced Inter Frame Space)

- Below figure shows the use of RIFS during 802.11n frame transmission. Note that AIFS used initially as of QoS data frames.

FIGURE 7.10 RIFS



Why is RIFS not used in 802.11ac with AMPDU.

2 posts by 2 authors in: Forums > CWDP & CWAP - Enterprise Wi-Fi Design & Analysis
Last Post: March 18, 2015:

By nw80211 March 18, 2015 Reply

Why is RIFS not used in 802.11ac with AMPDU ?

By Howard March 18, 2015 Reply

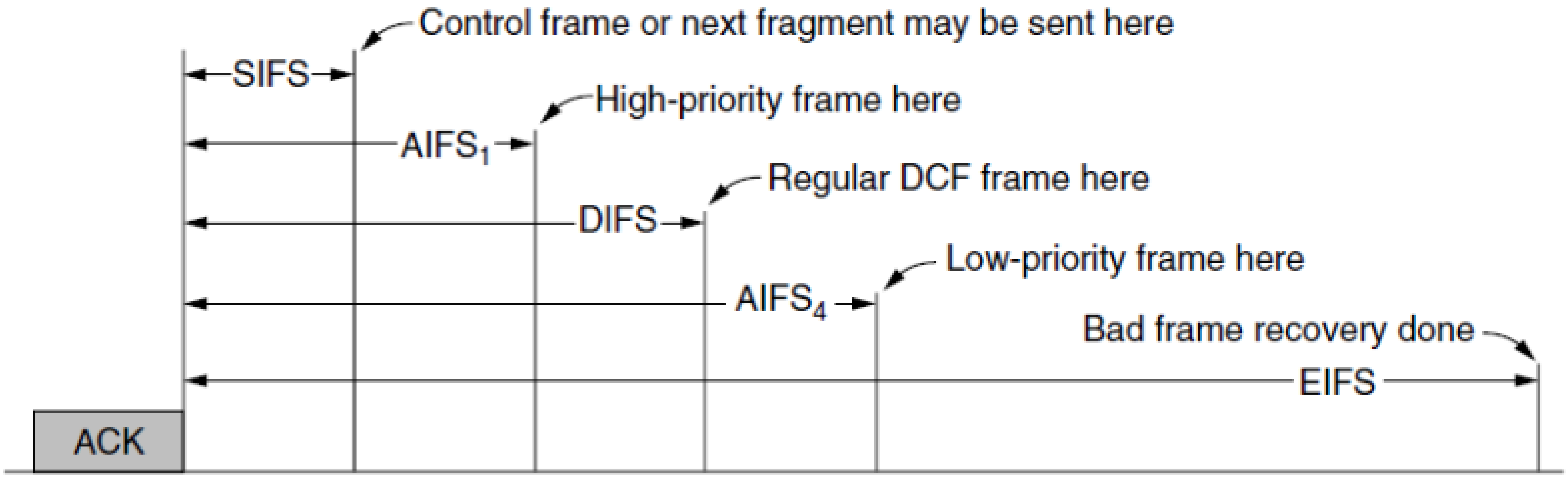
From Cisco:

802.11n introduced reduced interframe spacing (RIFS), which reduces overheads between consecutive transmissions, but experience has shown that A-MDPU solves much the same problem even more efficiently. 802.11ac devices operating in 802.11ac mode are not permitted to transmit RIFS (as of Draft 3.0).

AIFS (Arbitration Inter Frame Space)

- AIFS shall be used by QoS STAs to transmit all data frames (MPDUs), all management frames (MMPDUs) and the following control frames: PS-Poll, RTS, CTS, BlockAckReq and BlockAck.
- The number of slot times used in the AIFS is called the Arbitration Inter Frame Space Number (AIFSN).
- 802.11e specifies 4 access categories.
    - AC_VO : Voice (2 slots by default) .
    - AC_VI : Video (2 slots by default) .
    - AC_BE : Best Effort (3 slots by default).
    - AC_BK : Background (7 slots by default).

AIFS (Arbitration Inter Frame Space)



Summaray of all Inter Frame Space

PHY	Band	Slot Time	SIFS	PIFS	DIFS	RIFS
802.11b	2.4 GHz	20 µS	10 µS	30 µS	50 µS	NA
802.11a	5 GHz	9 µS	16 µS	25 µS	34 µS	NA
802.11g	2.4 GHz	20 µS	10 µS	30 µS	50 µS	NA
802.11n	2.4 GHz	20 µS	10 µS	30 µS	50 µS	2 µS
802.11n	5 GHz	9 µS	16 µS	25 µS	34 µS	2 µS
802.11ac	5 GHz	9 µS	16 µS	25 µS	34 µS	NA

Conclusions :

End of Part 2

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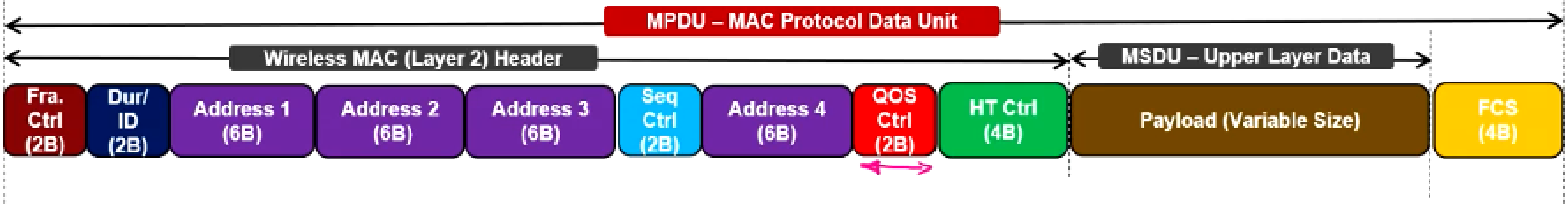
- PIFS = SIFS + Slot Time
- DIFS = SIFS + 2 x Slot Time
- RIFS = 2 µp (Micro Second)

\\ QoS Control in WiFi



- QoS Control Field
  - Only in Data Frames
- 4 different Access Categories
- TXOP Limit
  - AP STA (TXOP limit)
  - non-AP STA ("TXOP duration requested" or "Queue Size")

QoS enhanced Basic Service Set (QBSS)

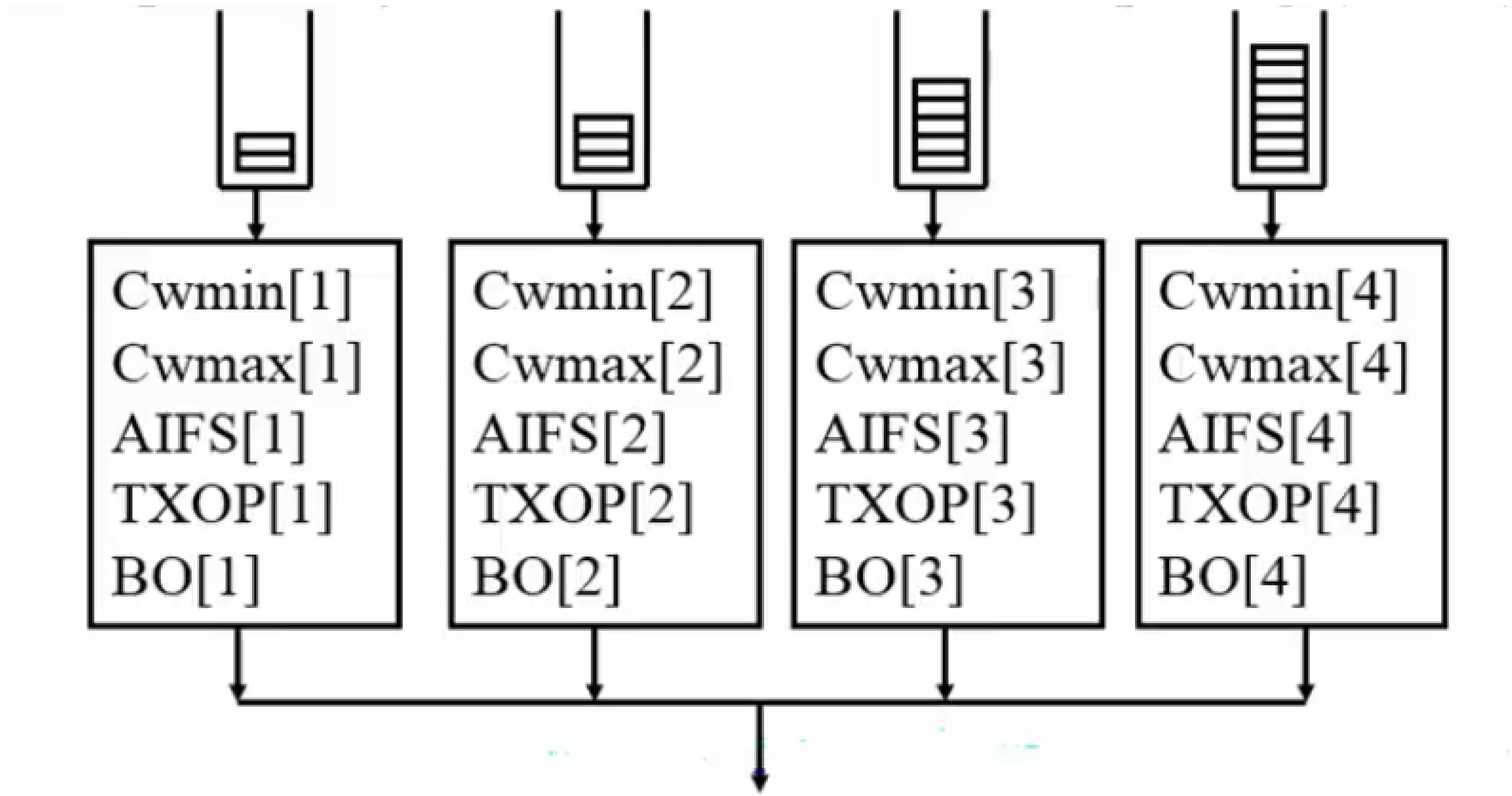
- QBSS is sent as part of the Beacon Frames & Probe Responses
- Station Count : The total number of clients associated.
- Channel Utilization : The percentage of time the AP has sensed the channel busy.
- Available Admission Capacity : Capacity available for new client when associated.

IEEE 802.11e-2005 (Enhanced QoS)

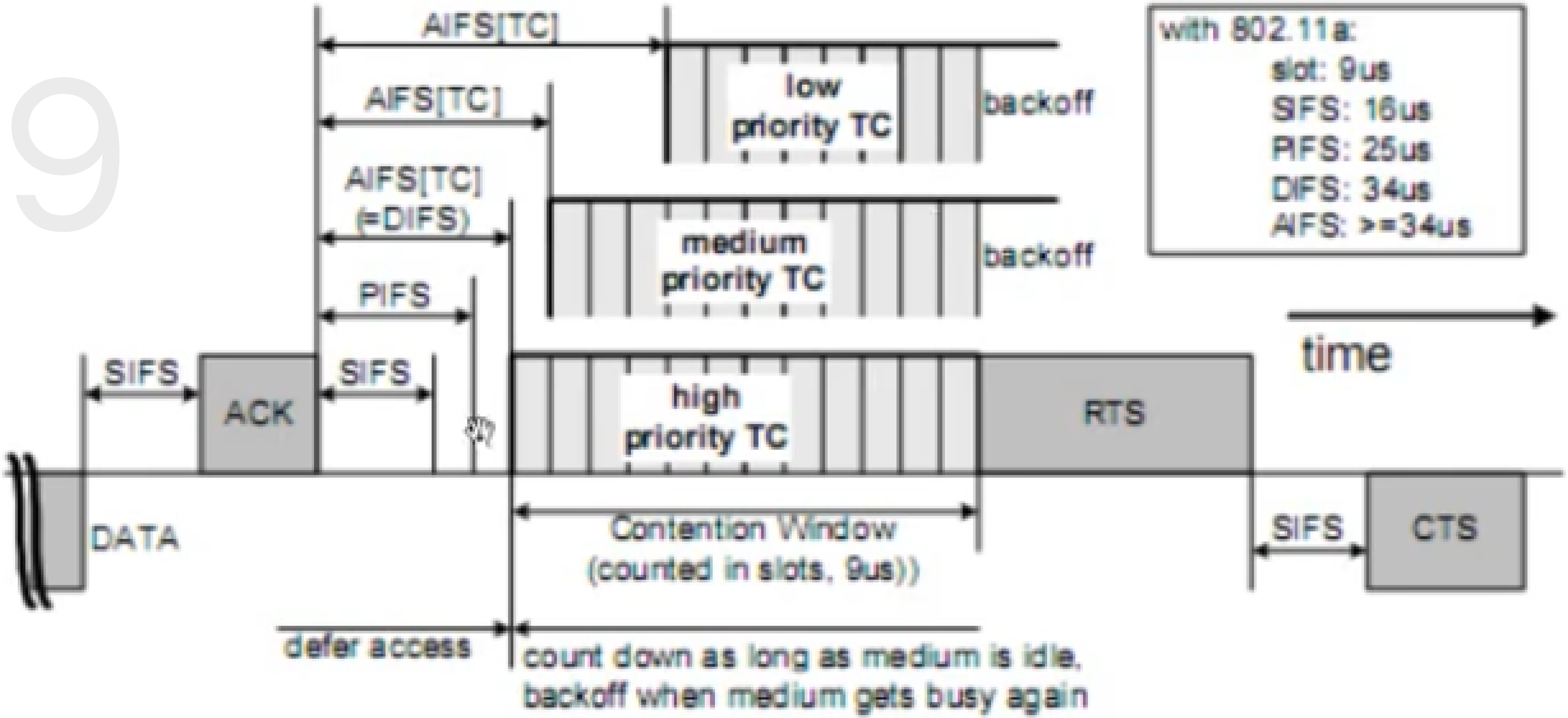
1. Backward compatible : Non-802.11e terminals can receive QoS enabled streams
2. Hybrid Coordination Function (HCF) with two components :
   a. Contention Free Access: Hybrid Polling.
   b. Contention-based Access: Enhanced DCF (EDCF) .
3. Direct Link: Traffic sent directly between two stations.
4. Frame bursting and Group Acknowledge.
5. Multiple Priority levels.
6. Automatic Power Save Delivery.

Enhanced DCF

- Up to 4 queues. Each Queue gets a different set of four Parameter:
  - CWT min / CWT max
  - Arbitrated Inter-Frame Spacing (AIFS) = DIFS
  - transmit Opportunity (TXOP) duration
- DIFS replaced by Arbitrated Inter-frame Spacing (AIFS)

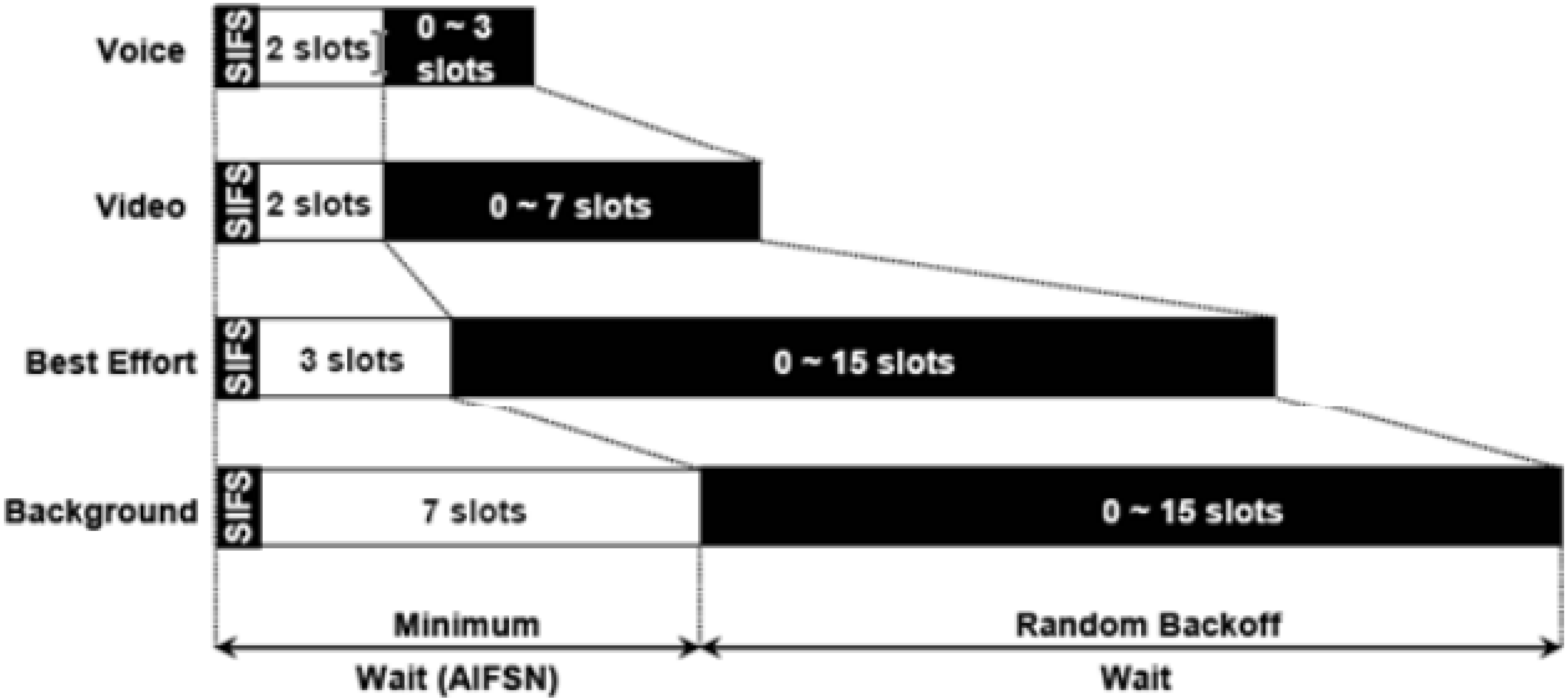


Contention-based Medium Access



- After detecting the medium being idle for a duration of AIFS[AC] (Arbitration Interframe Space), backoff entity start down-counting. AIFS is calculated as follow:
  - AIFS[AC]=SIFS+AIFSN[AC] * (SlotTime >=2)
- Min and Max of the contention window are the other parameters dependent on AC.

Arbitrary Inter-Frame Space Number (AIFSN)



- AIFSN Range: (1-15) Time-Slots.
- CW (Contention Window) Range : (0-15) Time-Slots.

Automatic Power Save Delivery (APSD)

- Unscheduled APSD (U-APSD):
  - AP announces waiting frames in the beacon.

1. When stations wake-up they listen to beacon.
2. Send a polling frame to AP.
3. AP sends frames.

- Scheduled APSD (S-APSD):

1. Station tells AP its wakeup schedule
2. AP sends frame on schedule. No need for polling.

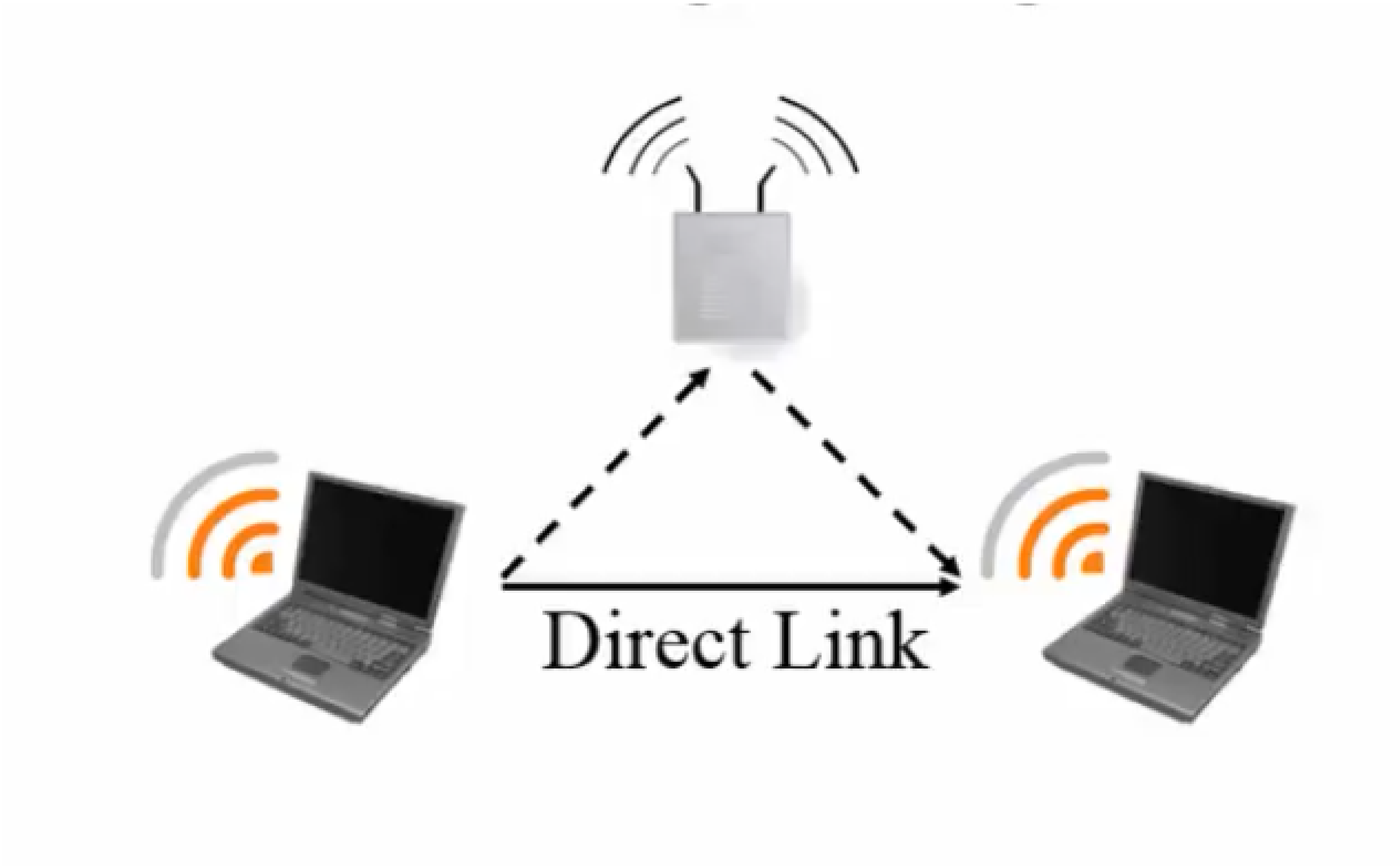
- Pre-802.11e: AP announces in Beacon. STA polls. AP sends one frame with more bit. STA polls. AP sends next frame...

Do it again

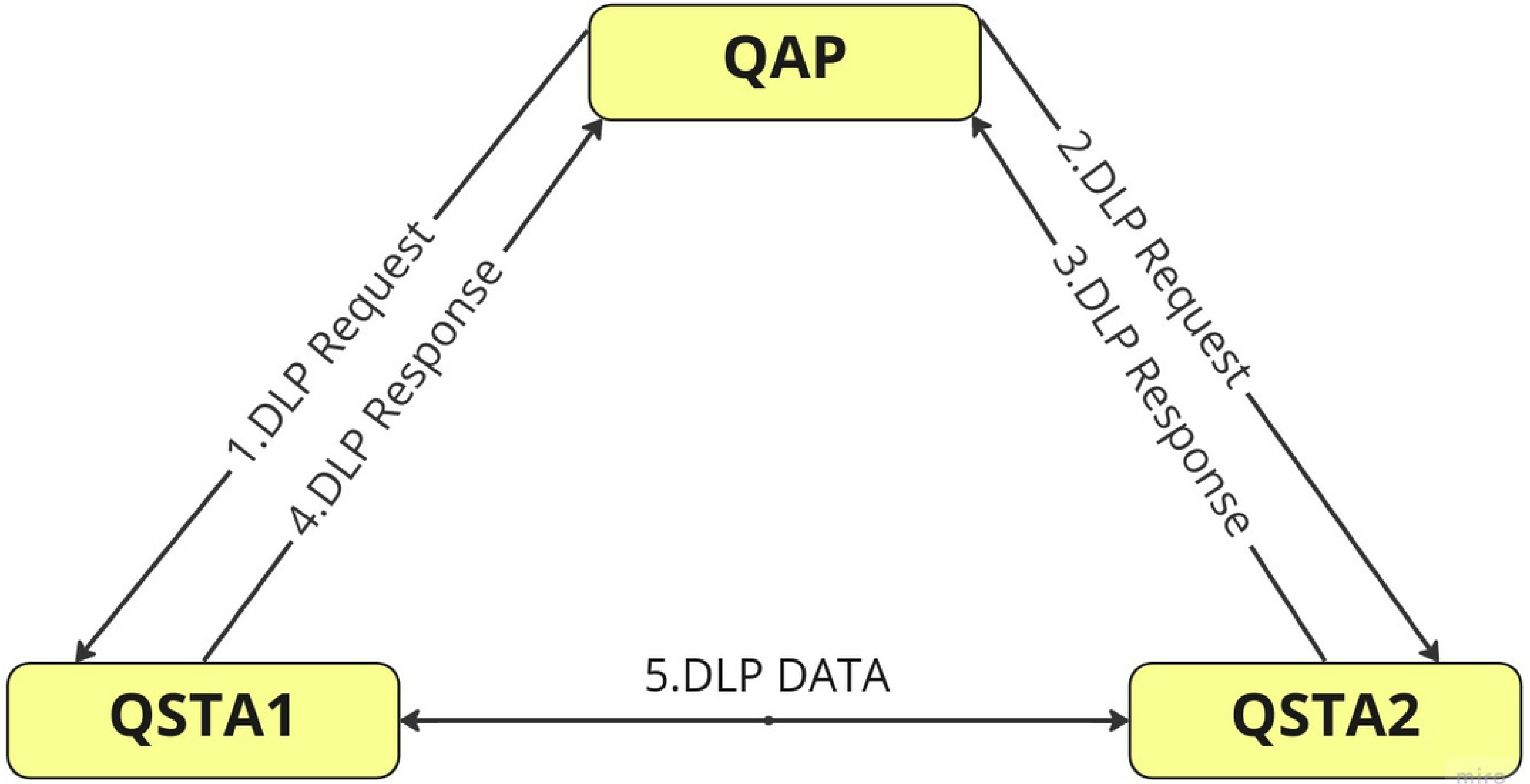
font spacing problem

Direct Link Protocol (DLP)

- Any station can transmit to any other station in the same BSS (No need to go through AP).



Direct Link Protocol (DLP)



- In the legacy 802.11, within an infrastructure-based BSS, AP relays all the frames. This wastes the channel capacity compared to the direct communication.
- The direct communication in 8o2.11e is referred to as Direct Link (DiL).
- A set up procedure, the Direct Link Protocol (DLP) is defined to establish a DiL between 8o2.11e backoff entities.

Transmit Opportunity (TXOP)

- Transmit Opportunity (TXOP) is a MAC layer feature used in 802.11 based wireless local area network (WLAN).
- TXOP defines the time duration for which a station can send frames after it has gained contention for the transmission medium.
- By providing this contention-free time period, TXOP aims to increase the throughput of high priority data such as voice and video.
- TXOP is available in Quality of Service (QoS) as part of Enhanced Distributed Channel Access (EDCA).
- When a station sends QoS data, it must first contend for access to the wireless medium.

How it Works

- TXOP operated in the following sequence of steps:
  - When a station in the WLAN has frames to send, it waits till Network Allocation Vector (NAV) decrements to 0.
  - It determines whether the channel is clear by performing Clear Channel Assessment (CCA).
  - On finding a clear channel, the station waits for a time period equal to Arbitration Inter Frame Spacing (AIFS).
  - Then, it would have to wait for the Contention Window (CW) to complete. the Contention Window has different duration for each of the four Access Categories (AC) :
    - Voice (AC_VO)
    - Video (AC_VI)
    - Background (AC_BK)
    - Best Effort (AC_BE)
  - Each of the four Access Categories has a different TXOP durations.

Working Principle for AC_BK & AC_BE

- Once a station acquires the TXOP, it can send frames depending upon the Access Category in the following manner :
  - The stations of background (AC_BK) and best effort (AC_BE) categories are assigned TXOP value of 0, implying that they can send only one frame during their TXOP.
  - In other words, AC_BK and AC_BE categories needs to contend for the wireless medium for each frame.
  - This is similar to Distributed Coordinated Function (DCF)

Working Principle for AC_VI

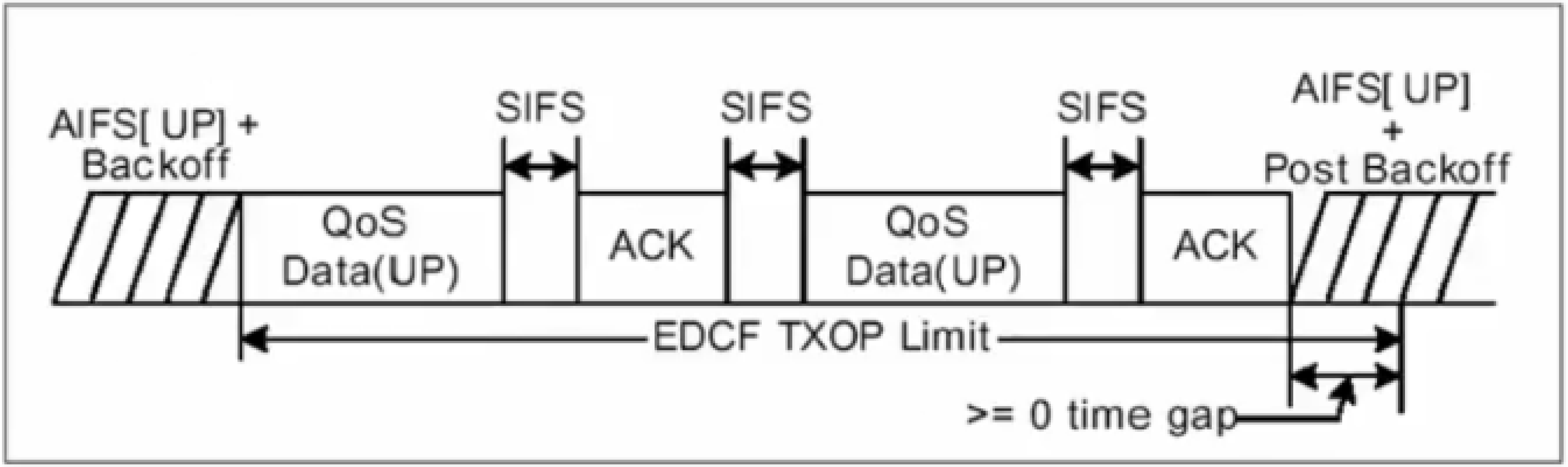
- The Video (AC_VI) has a TXOP of 4.096ms (22.56ms or 16.92ms for 802.11ac devices).
- This means the video category can send as many frames it can within the time it has been granted.
- Once its TXOP is up it must contend for the wireless medium again if it has additional frames to send.

Working Principle for AC_VO

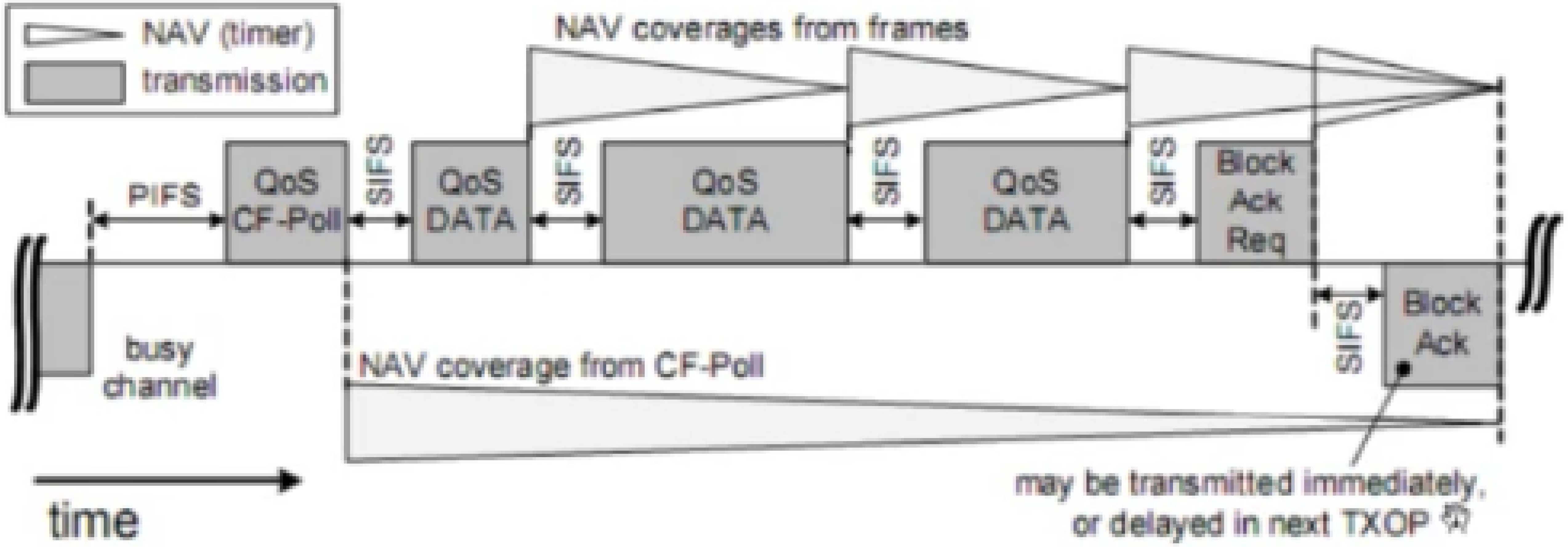
- The Voice (AC_VO) has a TXOP of 2.080ms (11.28ms or 8.46ms for 802.11ac devices).
- This means the voice category can send as many frames it can within the TXOP duration it has been granted.
- Once its TXOP is up, it must contend for the wireless medium again if it has additional frames to send.

Frame Bursting

- EDCF parameters announced by access point in beacon frame.
- EDCF allows multiple frame transmission.
- Max Time = Transmission Opportunity (TxOP).
- Voice has high priority but small burst size.
- Video has lower priority but larger burst size.

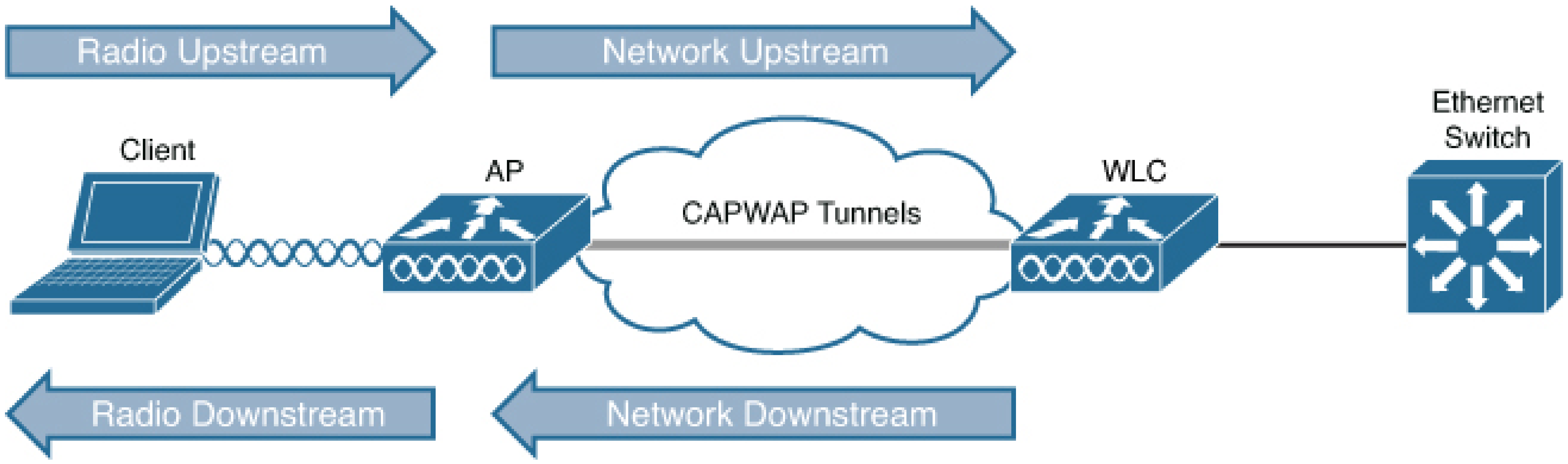


Frame Bursting with Block Acknowledgment



- Block Acknowledgements allow backoff entity to deliver a number of MSDU's being delivered consecutively during one TxOP and transmitted individual ACK. (Throughput efficiency is improved).

TYPES OF WIFI QOS



- Radio downstream QoS (most common deployment)
- Radio upstream QoS
- Network downstream QoS
- Network upstream QoS

802.11e wifi Multimedia(WMM)

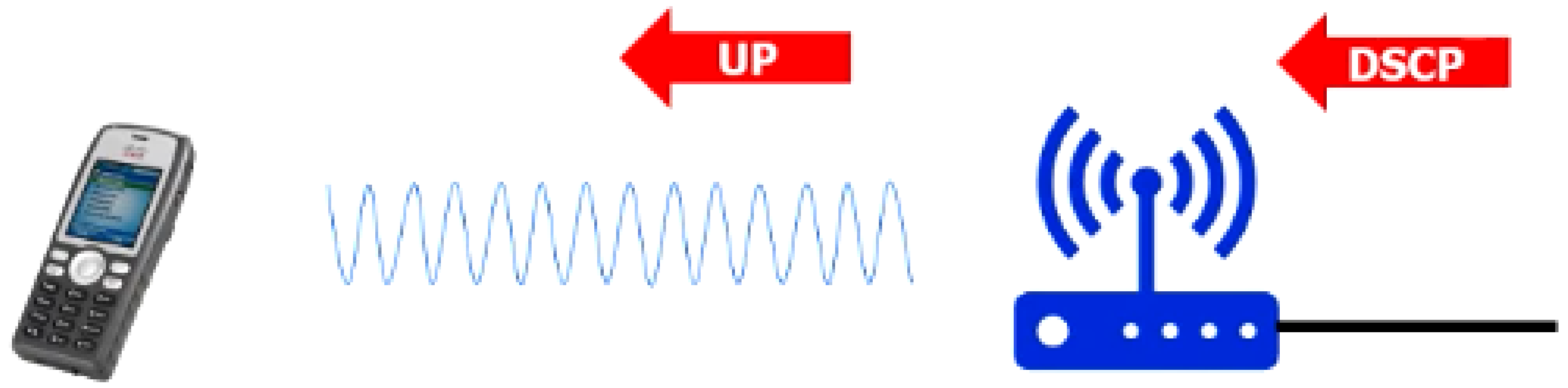
Enhanced distributed channel access (EDCA)

Default EDCA Parameters for each AC				
AC	CWmin	CWmax	AIFSN	Max TxOp
Background (AC_BK)	15	1023	7	0
Best Effort (AC_BE)	15	1023	3	0
Video (AC_VI)	7	15	2	3.008ms
Voice (AC_VO)	3	7	2	1.504ms
Legacy DCF	15 (Non QoS)	1023	2	0

802.11e vs 802.1P

-	802.1P			802.11e	
Priority	Priority Code Point (PCP)	Acronym	Traffic Type	Access Category (AC)	Designation
Lowest	1	BK	Background	AC_BK	Background
	0	BE	Best Effort	AC_BE	Best Effort
	2	EE	Excellent Effort	AC_BE	Best Effort
	3	CA	Critical Applications	AC_VI	Video
	4	VI	Video	AC_VI	Video
	5	VO	Voice	AC_VO	Voice
	6	IC	Internetwork Control	AC_VO	Voice
Highest	7	NC	Network Control	AC_VO	Voice

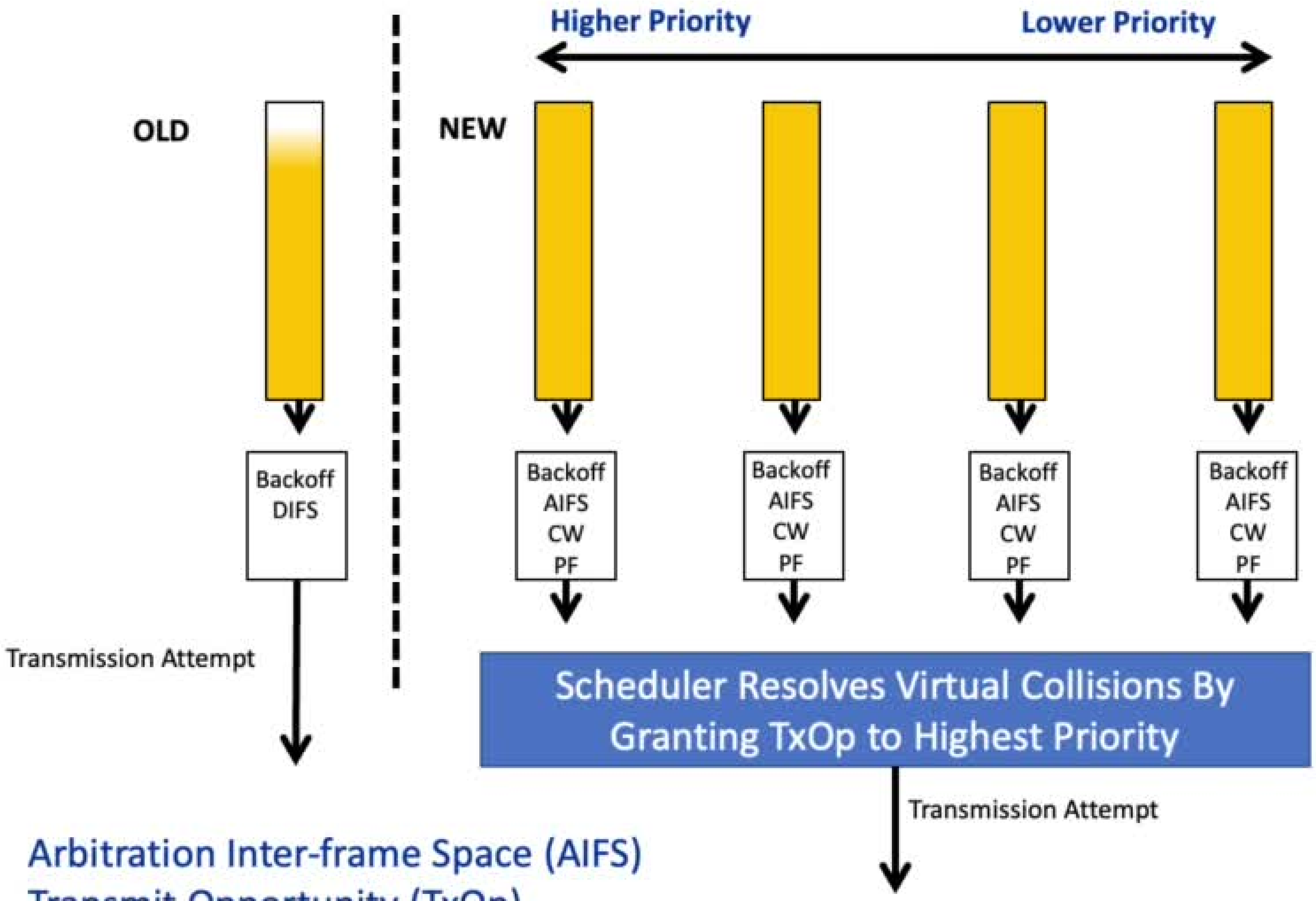
\\ DSCP to UP (Downstream)



IETF Traffic Class	PHB	AC	UP
Network Control	CS6	AC_VO	7
Voice (46), Voice-Admit(44)	EF,VA	AC_VO	6
Signaling	CS5	AC_VI	5
Multimedia Conferencing	AF4x	AC_VI	4
Real-time Interactive	CS4	AC_VI	4
Multimedia Streaming	AF3x	AC_VI	4
Broadcast Video	CS3	AC_VI	4
Low Latency Data	AF2x	AC_BE	3
OAM	CS2	AC_BE	0
High Throughput Data	AF1x	AC_BE	0
Standard (Best Effort)	DF	AC_BE	0
Low Priority Data	CS1	AC_BK	1

Service Class		RFC	User Priority	Access Category
Network Control (reserved for future use)	CS7	RFC 2474	7 OR 0 See Security Considerations-Sec.8	AC_VO (Voice) OR AC_BE (Best Effort)
Network Control	CS6	RFC 2474	7 OR 0 See Security Considerations	AC_VO (Voice) OR AC_BE (Best Effort)
Telephony	EF	RFC 3246	6	AC_VO (Voice)
VOICE-ADMIT	VA	RFC 5865	6	AC_VO (Voice)
Signaling	CS5	RFC 2474	5	AC_VI (Video)
Multimedia Conferencing	AF41 AF42 AF43	RFC 2597	4	AC_VI (Video)
Real-Time Interactive	CS4	RFC 2474	4	AC_VI (Video)
Multimedia Streaming	AF31 AF32 AF33	RFC 2597	4	AC_VI (Video)
Broadcast Video	CS3	RFC 2474	4	AC_VI (Video)
Low-Latency Data	AF21 AF22 AF23	RFC 2597	3	AC_BE (Best Effort)
OAM	CS2	RFC 2474	0	AC_BE (Best Effort)
High-Throughput Data	AF11 AF12 AF13	RFC 2597	0	AC_BE (Best Effort)
Standard	DF	RFC 2474	0	AC_BE (Best Effort)
Low-Priority Data	CS1	RFC 3662	1	AC_BK (Background)

802.11e & Wi-Fi Multimedia (WMM) Queue System



Arbitration Inter-frame Space (AIFS)
Transmit Opportunity (TxOp)
Persistence Factor (PF)


PRACTICAL SESSION
Do it again
fix page number not
clear
Password

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THE END

Q&A SESSION