



IEEE 802.11e

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Outline

- **Limitation of 802.11 MAC**
- 802.11e Concept
 - EDCA (Prioritized QoS)
 - HCCA (Parameterized QoS)
- Other 802.11e Specifications



Limitation of 802.11 MAC

- 802.11 baseline MAC does not support QoS Signaling and Admission Control
 - Station sends request to AP
 - AP makes decision
- If BW is not enough, never guarantee QoS
- QoS Specific information is not in the frame



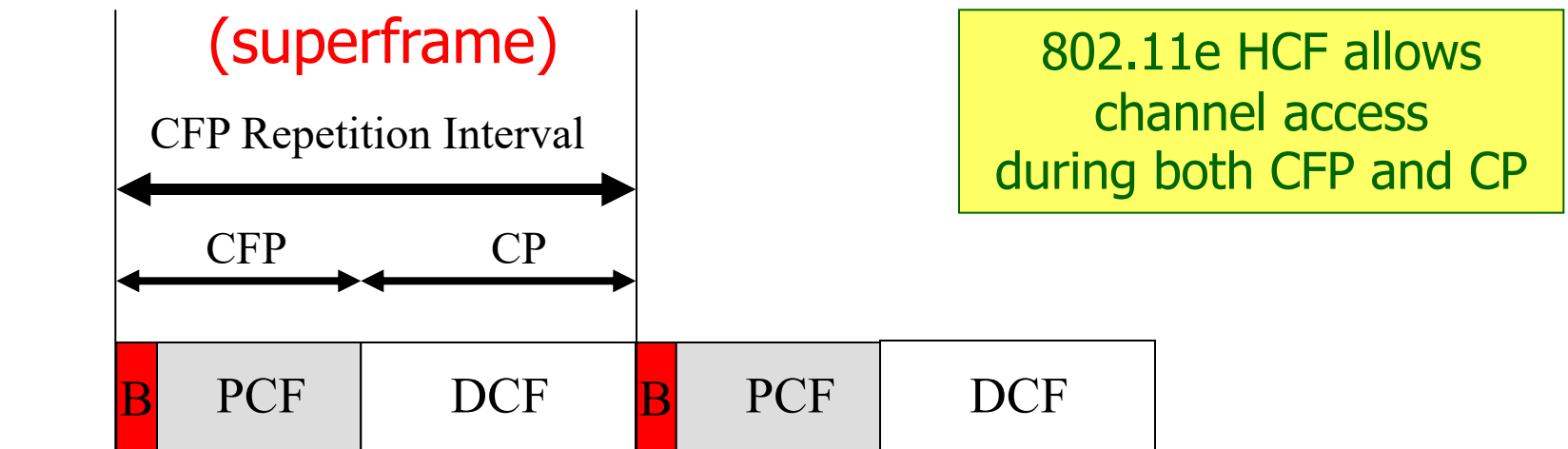
Limitation of Channel Access

- DCF
 - Equal probability for all stations
 - QoS Aware MAC
- PCF
 - For time-bounded services (original for 802.11e)



PCF Problems (1)

- Overhead of CP and CFP
 - Small Frame size, high overhead
 - Short delay (e.g. voice = 10ms) requires small superframe





PCF Problem (2)

- Neighboring AP (BSS)
 - Overlapping BSS
 - Same channel
- CFP cannot be correctly achieved
 - PCF assumes full control → Fail

802.11e HCF polling during CP is performed after channel sensing all the time → not assume full control



PCF Problem (3)

- Beacon transmission can vary
- Station can transmit even if the frame cannot finish before upcoming TBTT (Target beacon transmission time)
- Cause delay of Beacon frame
- Then, cause delay of time-bounded frame in CFP

802.11e QSTA does not transmit a frame if the frame cannot be finished in the upcoming TBTT



PCF Problem (4)

- Transmission time of polled stations is unpredictable with PCF
 - Send a single frame
 - Arbitrary length (up to 2,304 bytes) → more than 20 ms in 802.11b
 - Destroy QoS

802.11e uses Transmission Opportunity (TXOP) to limit the frame size (otherwise fragment)



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Definition

- QAP: QoS Access Point
- QSTA: QoS Station
- EDCA: Enhanced Distributed Channel Access
- HCF: Hybrid Coordination Function
- HCCA: HCF Control Channel Access



Key concepts (1)

- Prioritized VS. Parameterized QoS
 - **Prioritized:** frame from application specifies **User Priority (UP)**
 - **Parameterized:** **Traffic Stream (TS)** specifies the QoS requirements
- Traffic Identifier (TID)
 - MSDU is assigned TID before arriving at MAC Layer (sometimes call TC: Traffic Category)
 - 8 TSs Uplink and 8 TSs Downlink in a QSTA

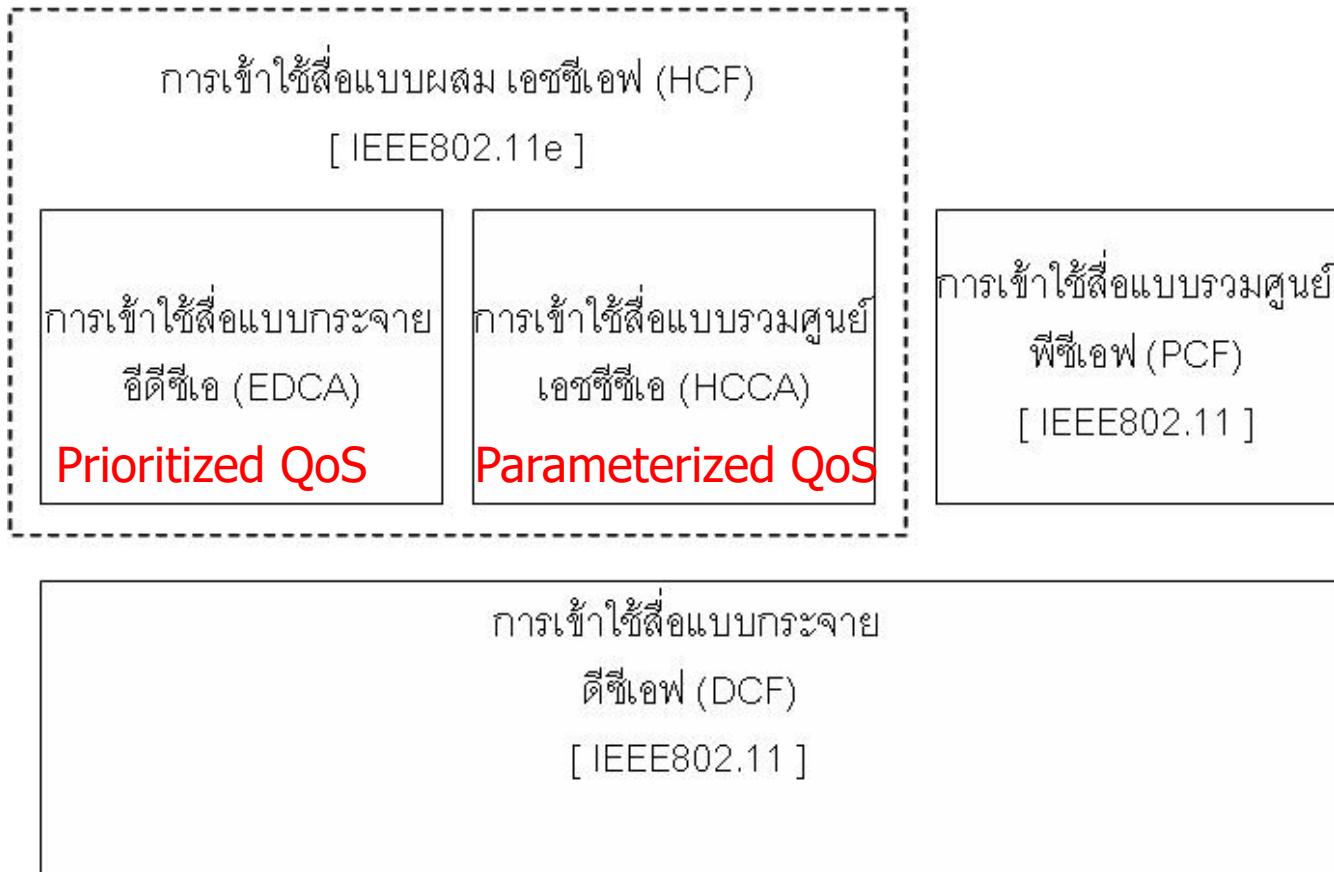


Key concepts (2)

- Transmission Opportunity (TXOP)
 - Multiple frames transmission with SIFS in between
 - Fragmentation for large frame
 - EDCA TXOP
 - HCCA TXOP
 - TXOP limit by QAP, CAP
- QoS control field

HCF:

Hybrid Coordination Function

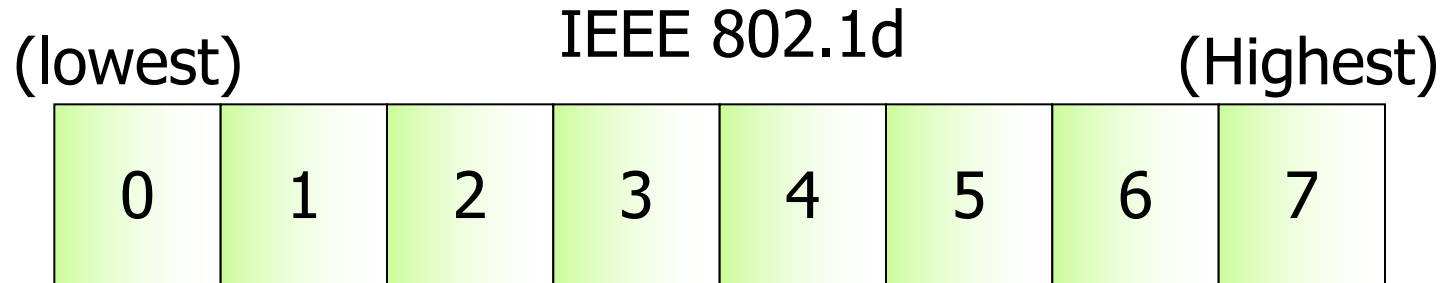






EDCA

- Priority set by Application Layer
- Known as User Priority (UP)





EDCA User-Priority-List

		Net traffic					
		low			high		
		Audio	Video	Data	Audio	Video	Data
User needs	time-critical	7	5	0	6	4	0
	not time-critical	-	-	2	-	-	2

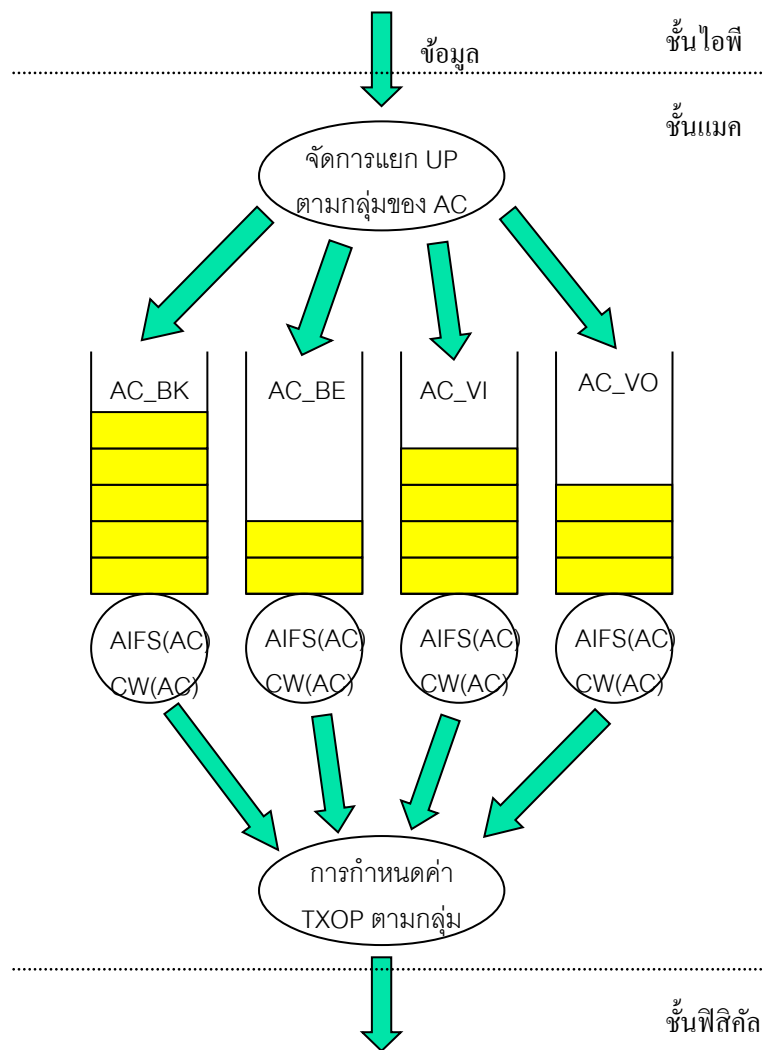


Mapping UP to AC

ลำดับ ความสำคัญ	ค่าความสำคัญ ตามผู้ใช้งาน (UP)	กลุ่มการเข้าใช้ สื่อ (AC)	Access Category
ต่ำที่สุด	1 และ 2	AC_BK	Background
ต่ำ	0	AC_BE	Best Effort
สูง	3, 4 และ 5	AC_VI	Video
สูงที่สุด	6 และ 7	AC_VO	Voice



AC Queues





EDCA Parameters

- AIFS: Arbitrary Interframe Space
- CW: Contention Window
- TXOP Limit: Transmission Opportunity Limitation



AIFS Calculation

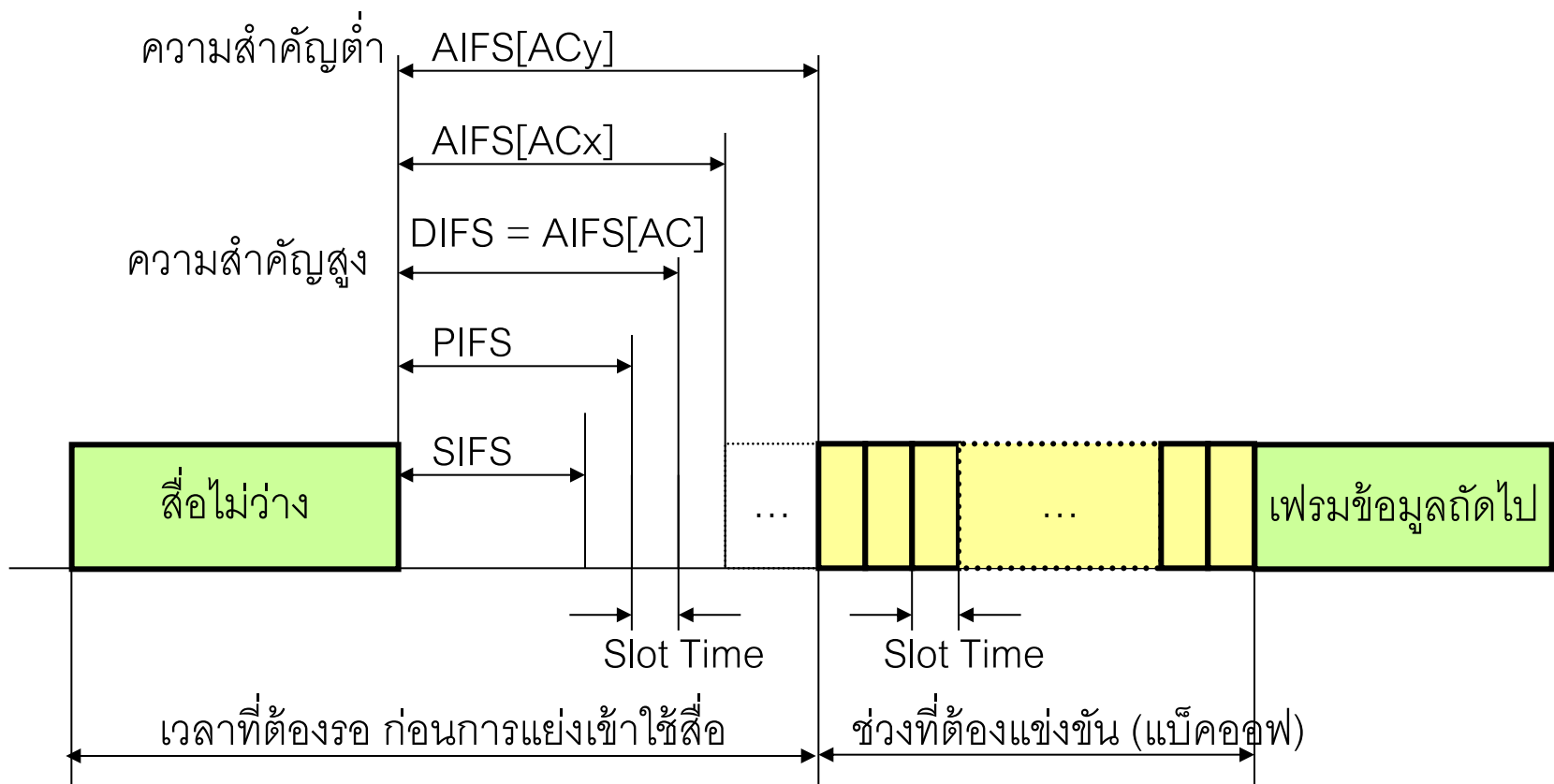
- AIFSN: AIFS Number → Slot Time

$$\text{AIFS[AC]} = \text{SIFS} + \text{AIFSN[AC]} * \text{Slot Time}$$

	Min (AIFSN)	Min (AIFS)
EDCA	2	SIFS + 2*Slot Time = DIFS
HCCA	1	SIFS + 1*Slot Time = PIFS



AIFS



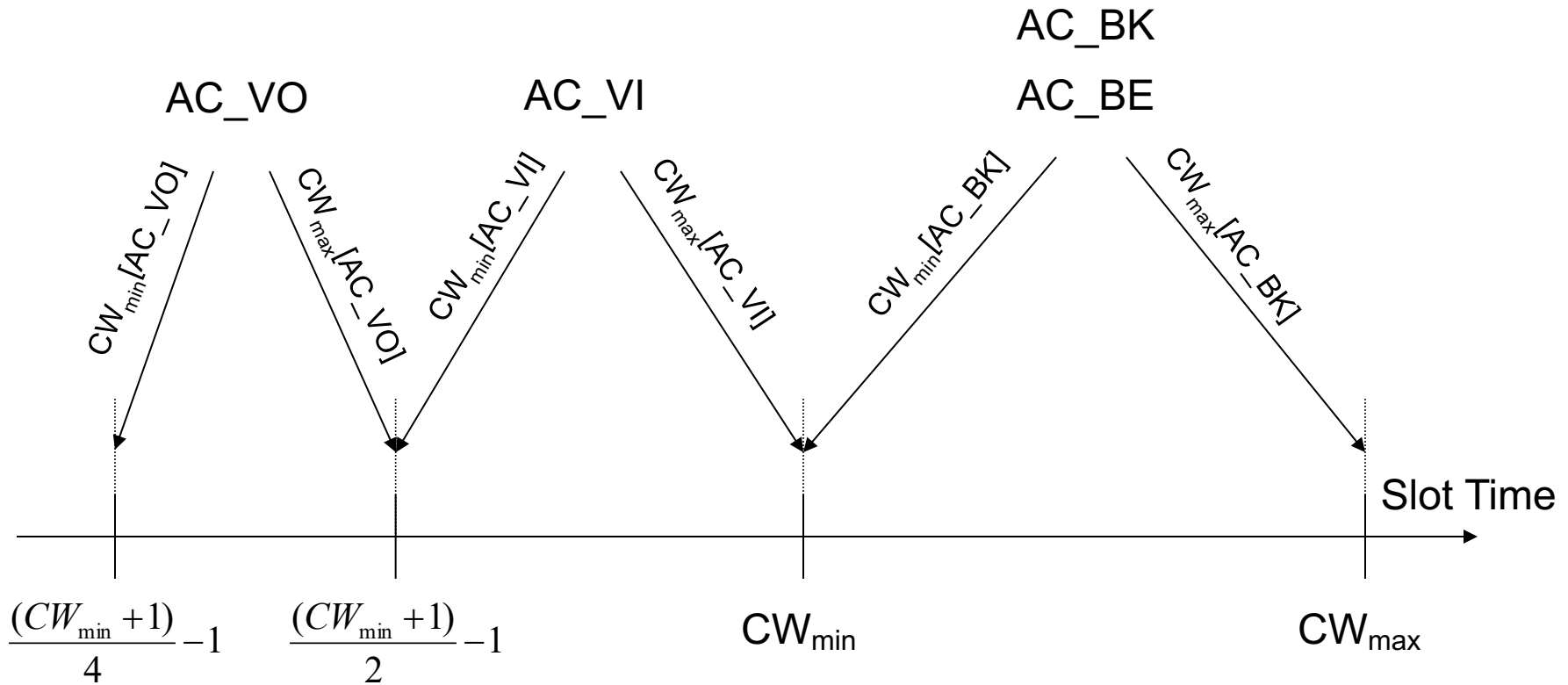


Default EDCA Parameters

กลุ่มการ เข้าใช้สื่อ	ค่า CW_{min}	ค่า CW_{max}	AIFSN	TXOP Limit (802.11b)	TXOP Limit (802.11a/g)
AC_BK	CW_{min}	CW_{max}	7	0	0
AC_BE	CW_{min}	CW_{max}	3	0	0
AC_VI	$\frac{(CW_{min} + 1)}{2} - 1$	CW_{min}	2	6.016 ms	3.008 ms
AC_VO	$\frac{(CW_{min} + 1)}{4} - 1$	$\frac{(CW_{min} + 1)}{2} - 1$	2	3.008 ms	1.504 ms

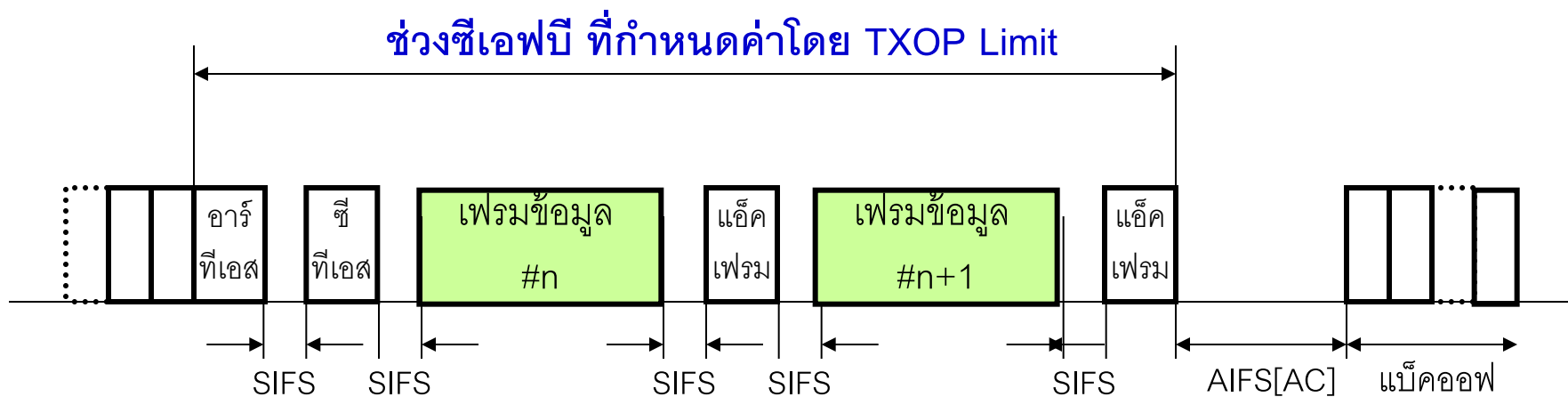


CW for each AC





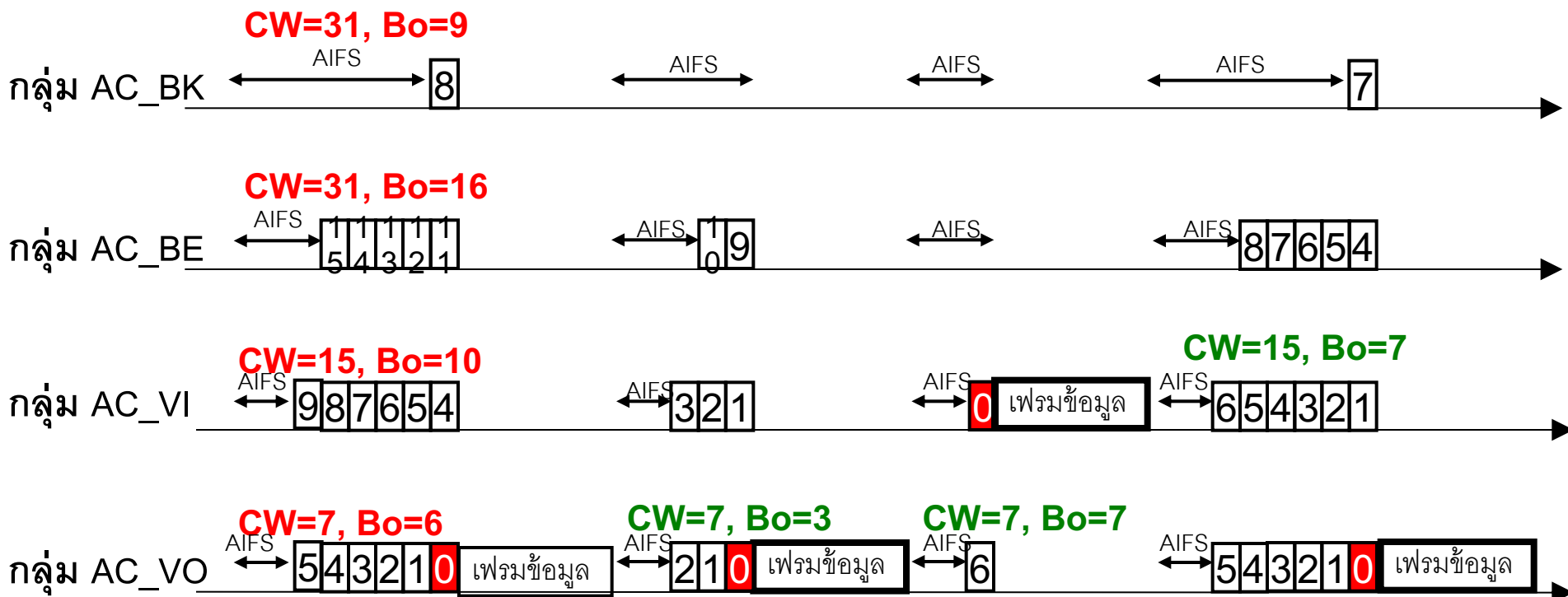
TXOP Limit





EDCA Example

กลุ่ม	CW	Bo	AIFS
AC_BK	31	9	7
AC_BE	31	16	3
AC_VI	15	10	2
AC_VO	7	6	2



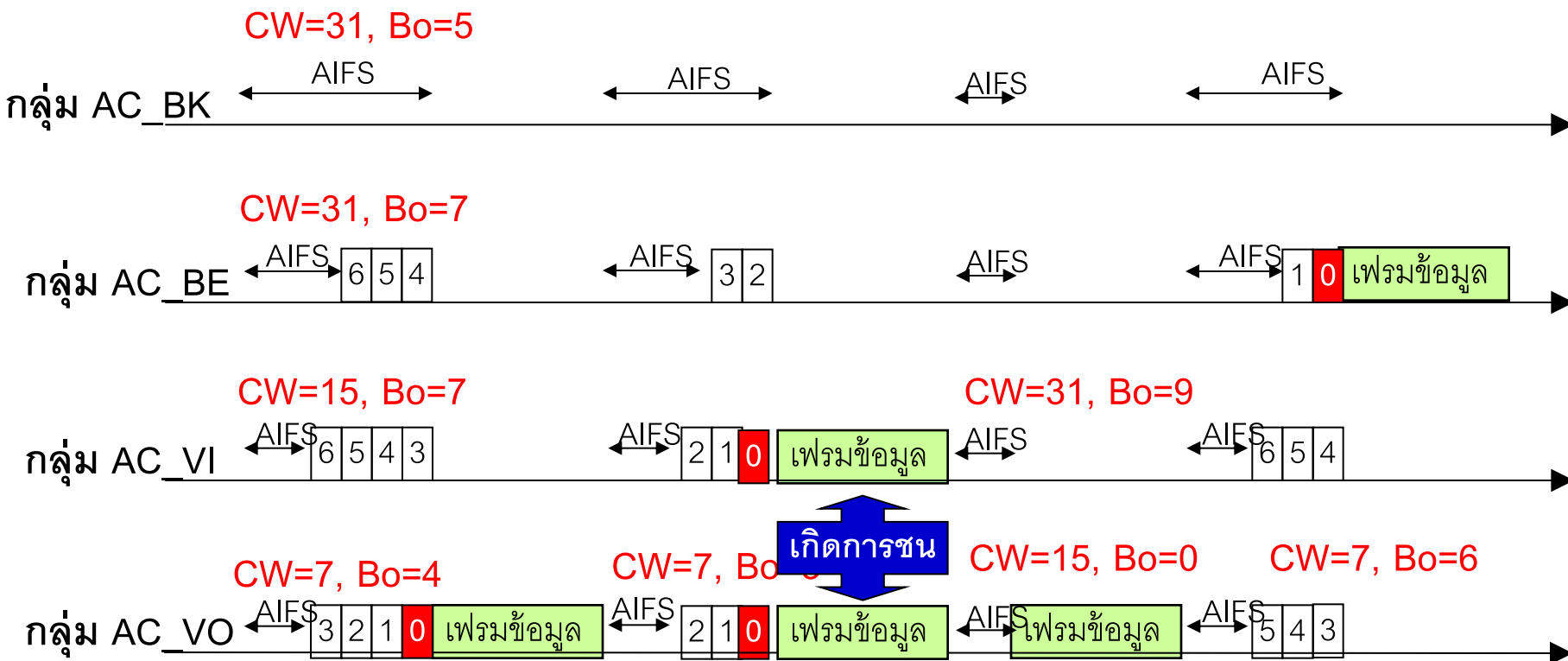


EDCA Collision?

- External Collision
- Internal Collision



Internal Collision



HCCA

(HCF Control Channel Access)

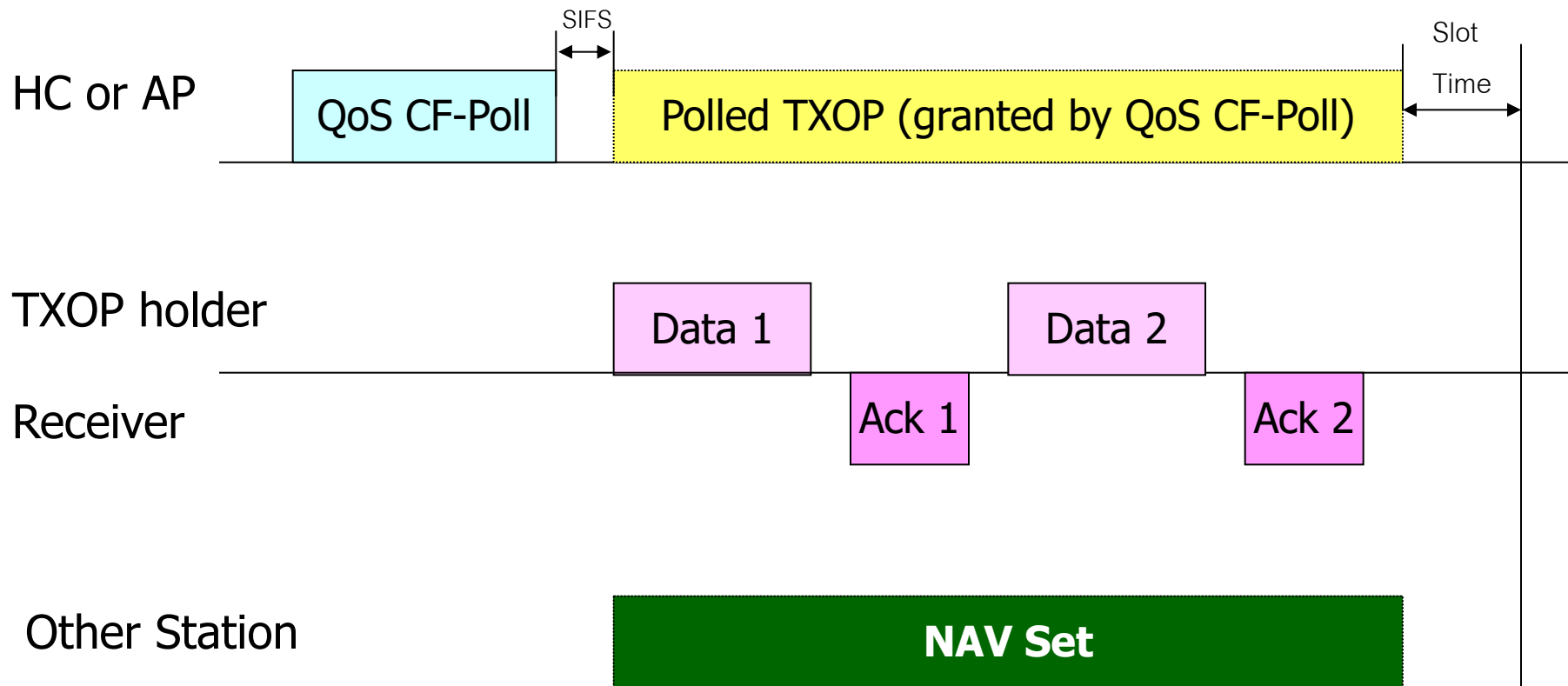




- More flexible than PCF
 - Take control whenever it is needed
- Direct Communication without AP
 - Direct Link Setup (DLS)



Polled TXOP





HCF (HCCA + EDCA)



CAP: Controlled Access Period

SI: Service Interval

CAP Limit is set for starvation protection

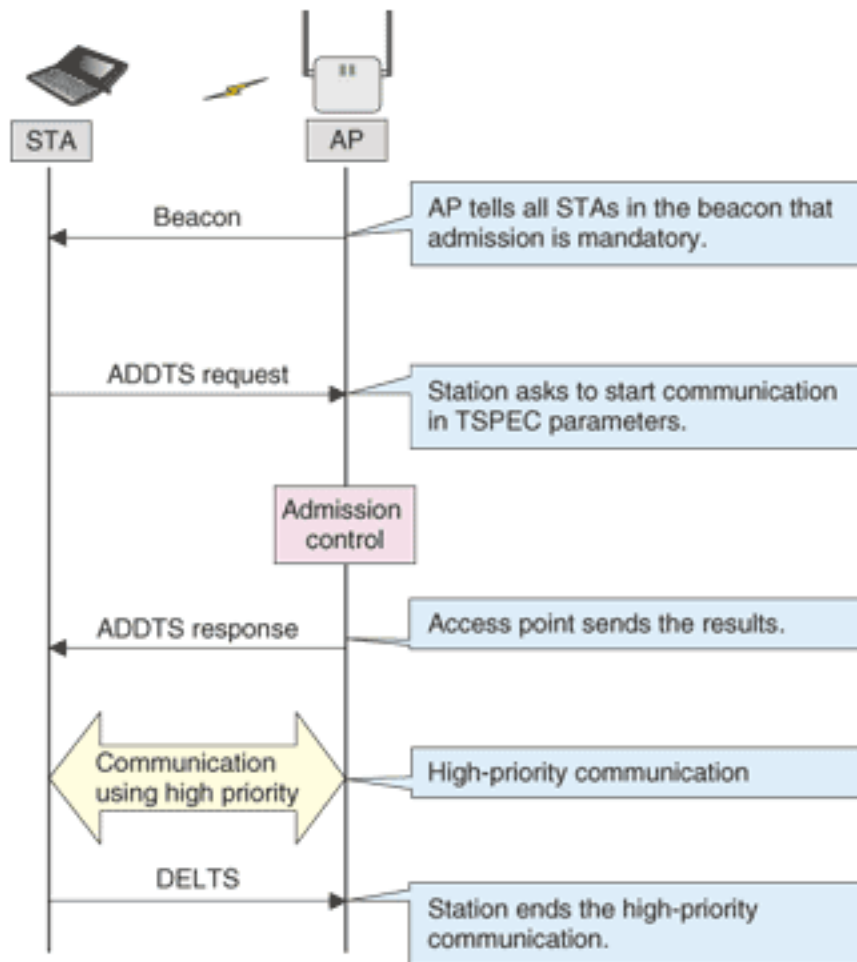


HCCA Operation

- QSTA sends request
 - Identify Traffic Specification (TSPEC)
- Traffic Specification
 - Avg. Throughput
 - MSDU
 - Max Delay
 - RSI: Required Service Interval (Each station)



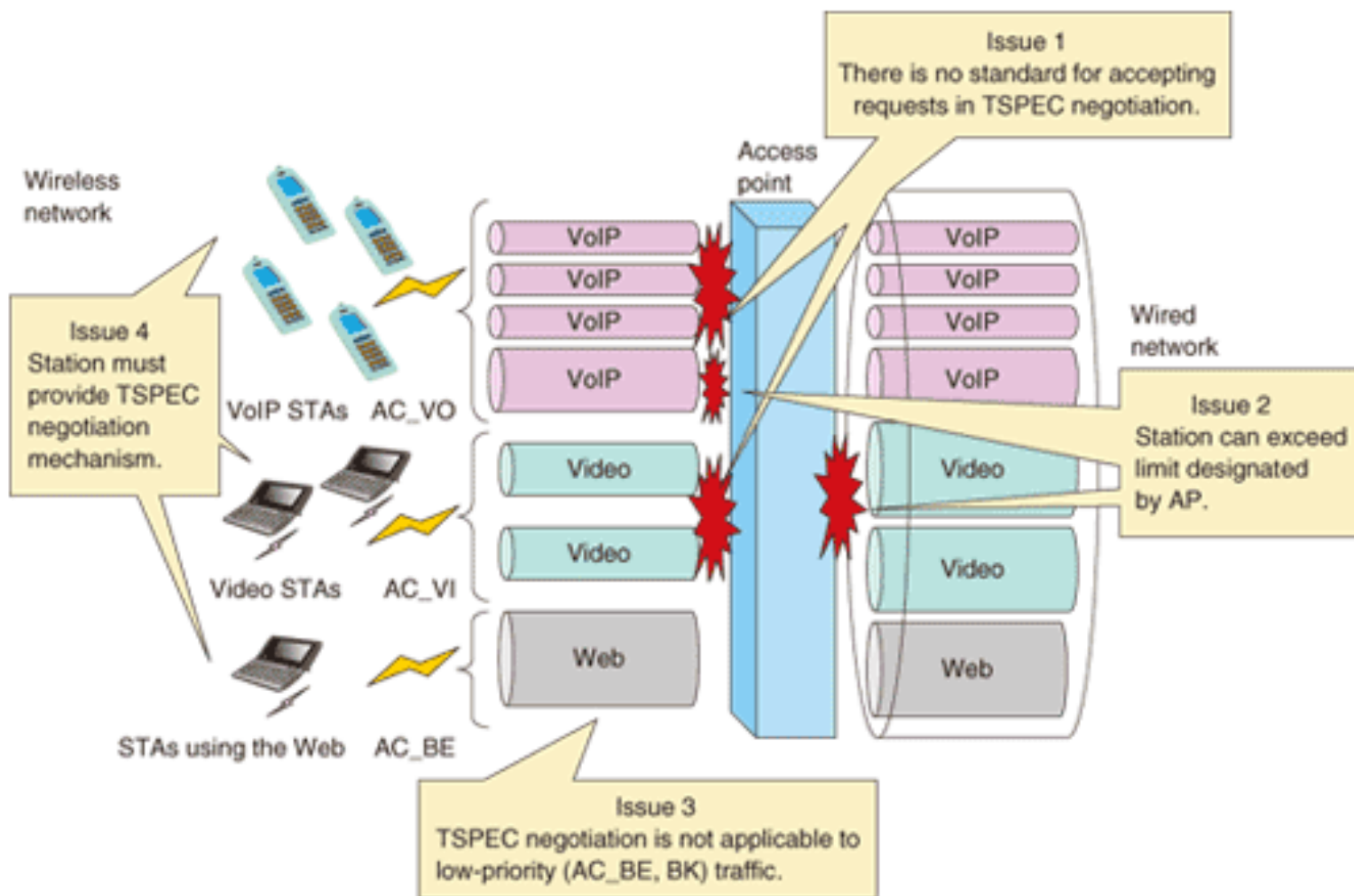
TSPEC negotiation



ADDTS: Add traffic stream request
DELTS: Delete Traffic Stream message



Issues in TSPEC negotiation





SI calculation

- QAP collects info from all requested QSTAs
- Find the **Min. RSI** from QSTAs
- Divide T_{BEACON}
- Find **Max. fraction** T_{BEACON} that $<$ **Min. RSI**





SI Calculation Example

- 3 stations with RSI (Required Service Interval):
 - St#1 = 250 ms
 - St#2 = 140 ms
 - St#3 = 280 ms
- Given $T_{\text{BEACON}} = 600$ ms

← Min. RSI

# Interval	ms
2	$600/2 = 300$
3	$600/3 = 200$
4	$600/4 = 150$
5	$600/5 = 120$
6	$600/6 = 100$

SI = 120 ms

← Min. RSI < 140

TXOP Calculation



$$N_{xy} = \left\lceil \frac{SI * D_{xy}}{F_{xy}} \right\rceil$$

D_{xy} = Avg. Throughput Stream Y in Station X

F_{xy} = Frame Size

N_{xy} = #Frame

F_{max} = Max Frame for each technology

$$TXOP_{xy} = \max\left(\frac{N_{xy} * F_{xy}}{Rate_{Physical}}, \frac{F_{max}}{Rate_{Physical}}\right) + Overhead$$

QAP sums all TXOPs in Station X

$$TXOP_x = \sum_{y=1}^{Y_x} TXOP_{xy}$$

QAP Announces TXOP to Station X

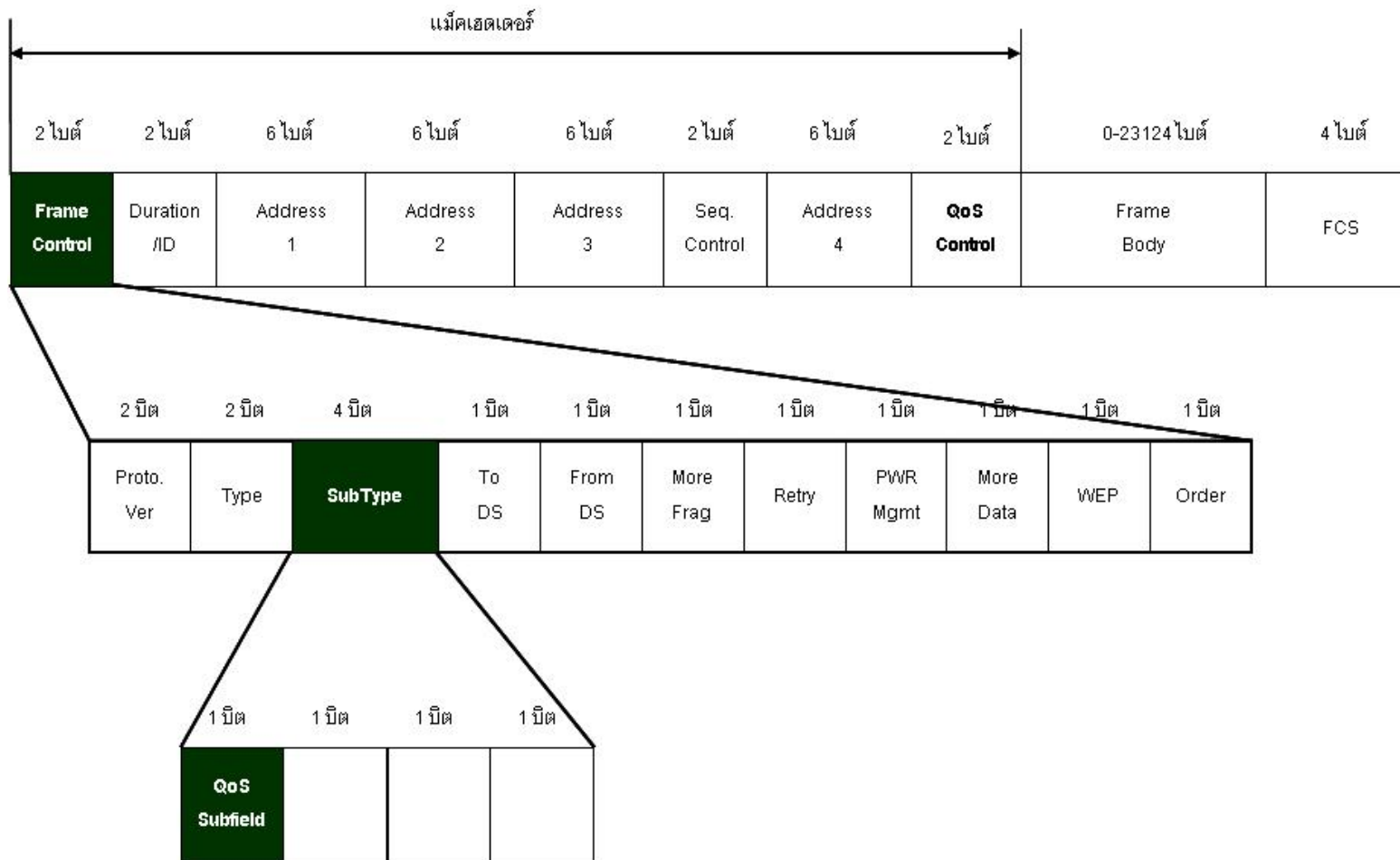


Admission Control

$$\sum_{x=1}^X \frac{TXOP_x}{SI} + \frac{TXOP_{x+1}}{SI} \leq \frac{T_{CAP\ Limit}}{T_{Beacon}}$$



IEEE 802.11e Frame





IEEE 802.11e Frame

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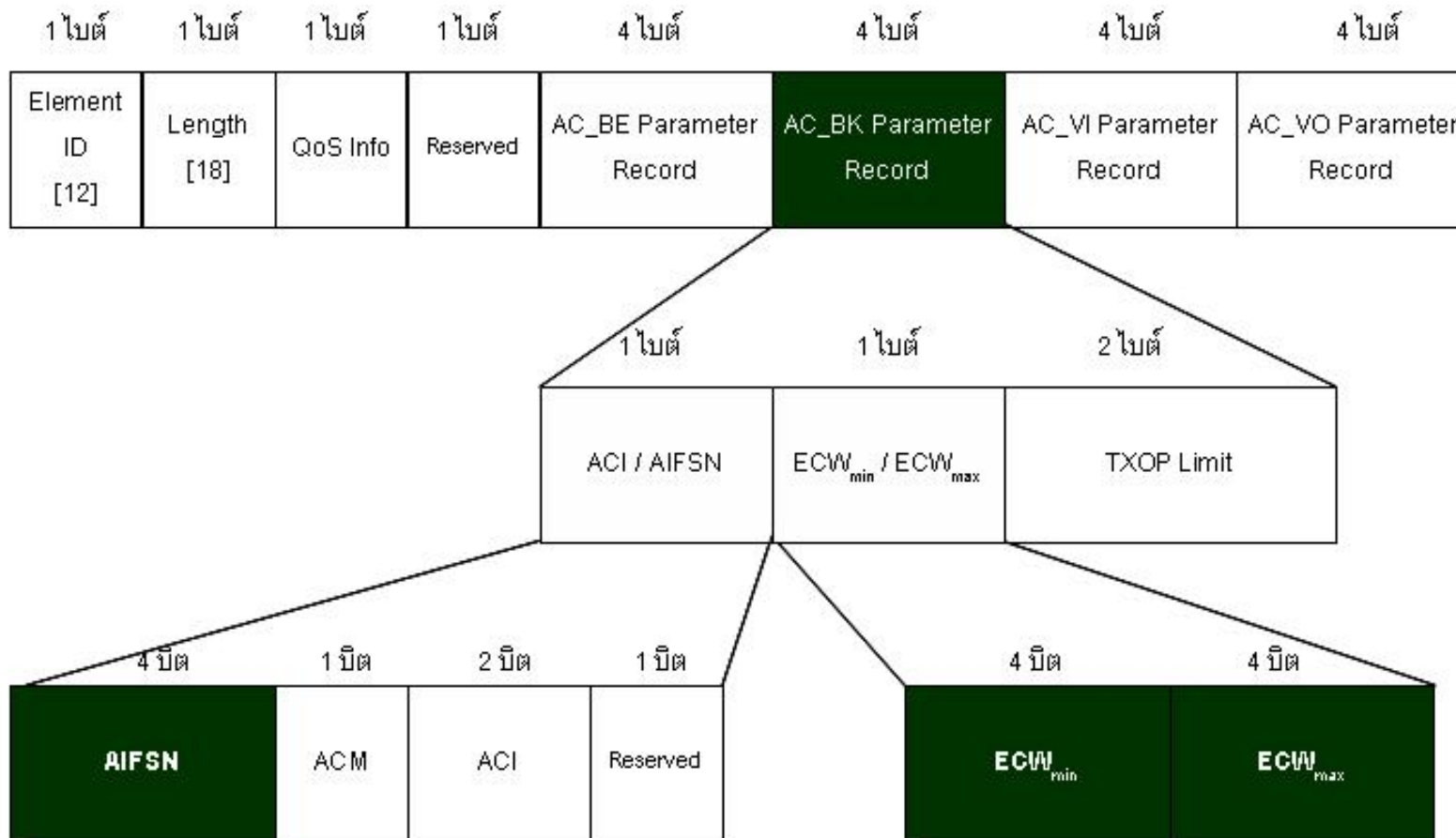


ACK Policy

Bit #5	Bit #6	Meaning
0	0	Normal ACK
1	0	No ACK (Response frame, not ACK)
0	1	No Explicit ACK
1	1	Block ACK (No ACK, record state)



EDCA Parameters



In Beacon Frame



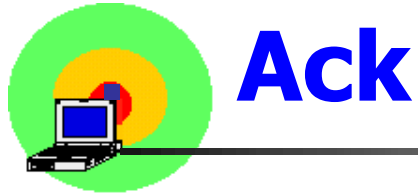
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Automatic Power Save Delivery (APSD)



- For VoIP Phone
- data rates are roughly the same in both directions
- Voice data are sent to the AP
 - AP is triggered to send the buffered Voice data in the other direction
 - Then the VoIP phone enters doze state until next Voice data have to be sent to the AP



- Block Acknowledgments (BA)
 - allow an entire TXOP to be acknowledged in a single frame
 - Lower overhead
- NoAck
 - QosAck and QosNoAck
 - Frames with QosNoAck are not acknowledged
 - Avoids retransmission of highly time-critical data



Wi-Fi Multimedia (WMM)

- Another name: Wireless Multimedia Extensions (WME)
- Based on the IEEE 802.11e
- By Wi-Fi Alliance
- Provides basic QoS features to IEEE 802.11
- WMM prioritizes traffic according to four Access Categories (AC) - voice, video, best effort, and background
- However, not guarantee throughput
- Suitable for simple QoS applications (VoIP on Wi-Fi phones)



References

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