IEEE 802.11e

รศ. ดร. อนันต์ ผลเพิ่ม

Assoc. Prof. Anan Phonphoem, Ph.D.

anan.p@ku.ac.th

Intelligent Wireless Network Group (IWING Lab)

http://iwing.cpe.ku.ac.th

Computer Engineering Department

Kasetsart University, Bangkok, Thailand

Outline

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

Limitation of 802.11 MAC

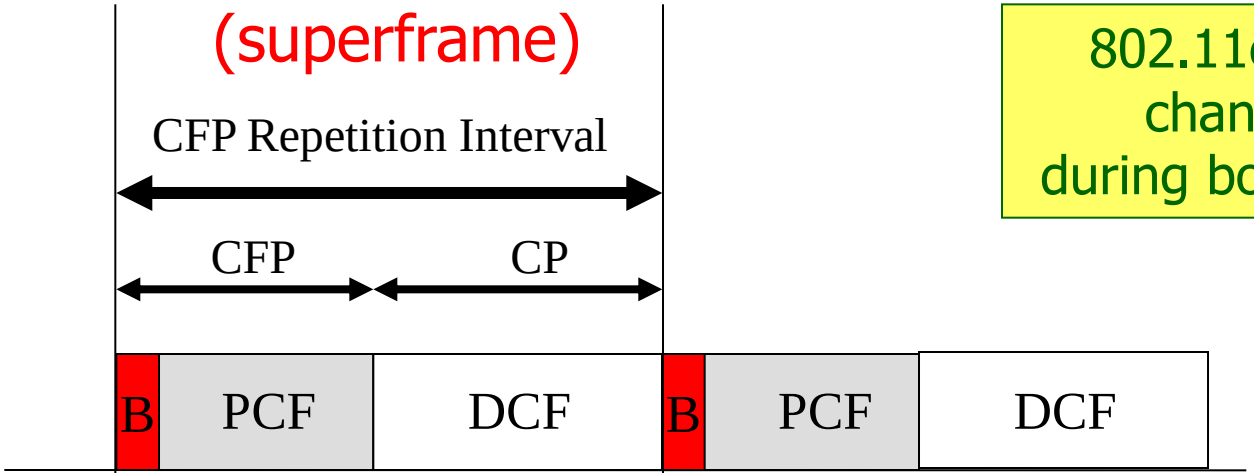
- 802.11 baseline MAC does not support QoS Signaling and Admission Control
  - Station sends request to AP
  - AP makes decision
- If BW is not enough, never guarantee QoS
- QoS Specific information is not in the frame

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



802.11e HCF allows channel access during both CFP and CP

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

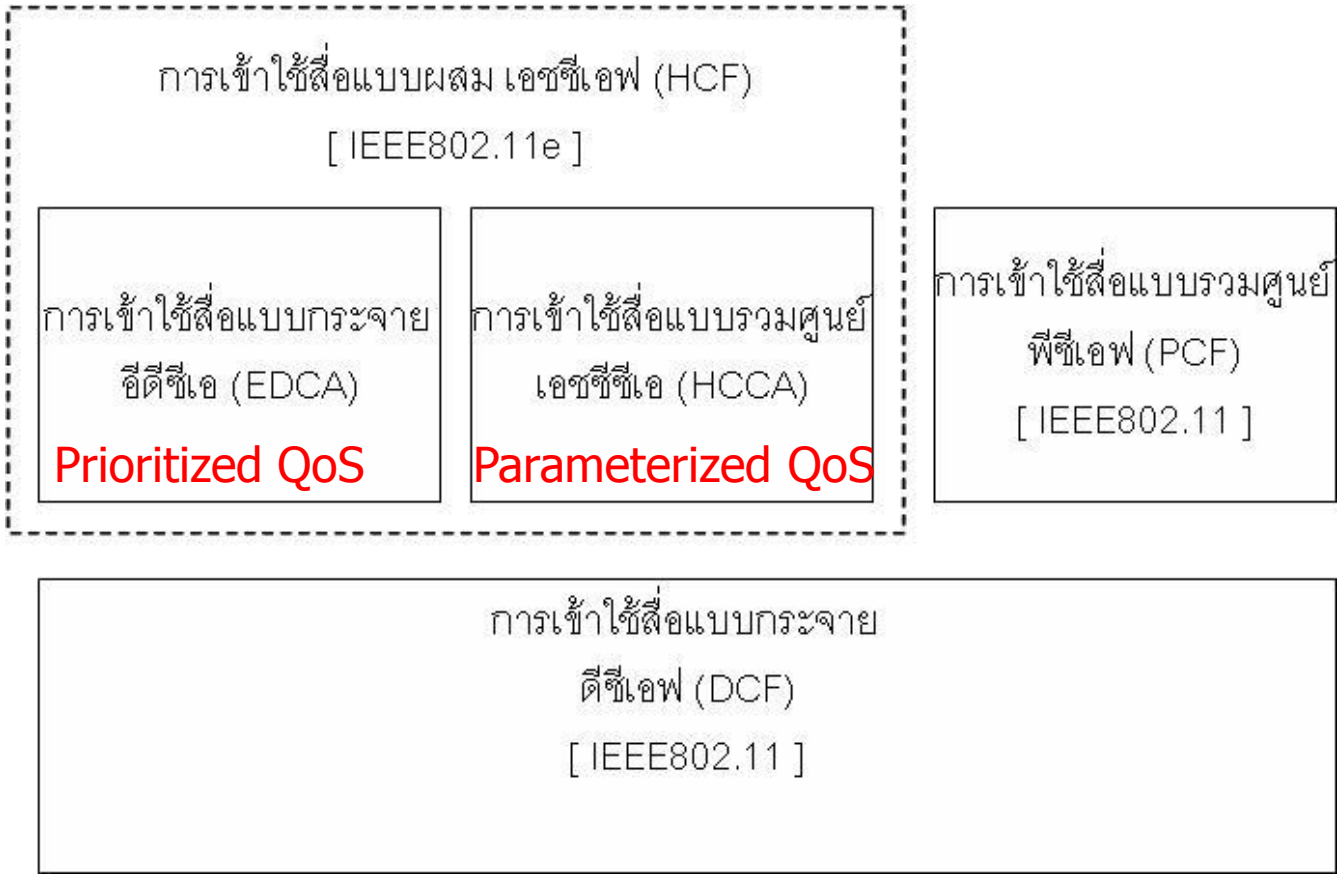
Key concepts (1)

- 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

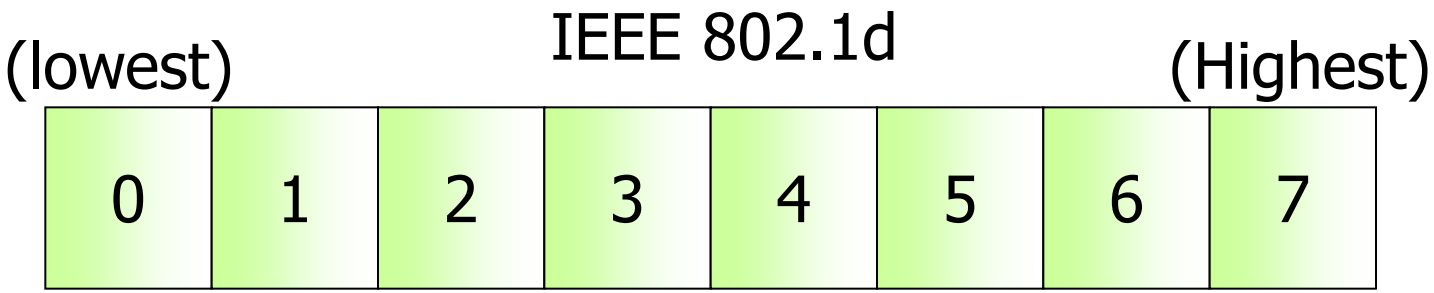
HCF:
Hybrid Coordination Function



EDCA

EDCA

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



EDCA User-Priority-List

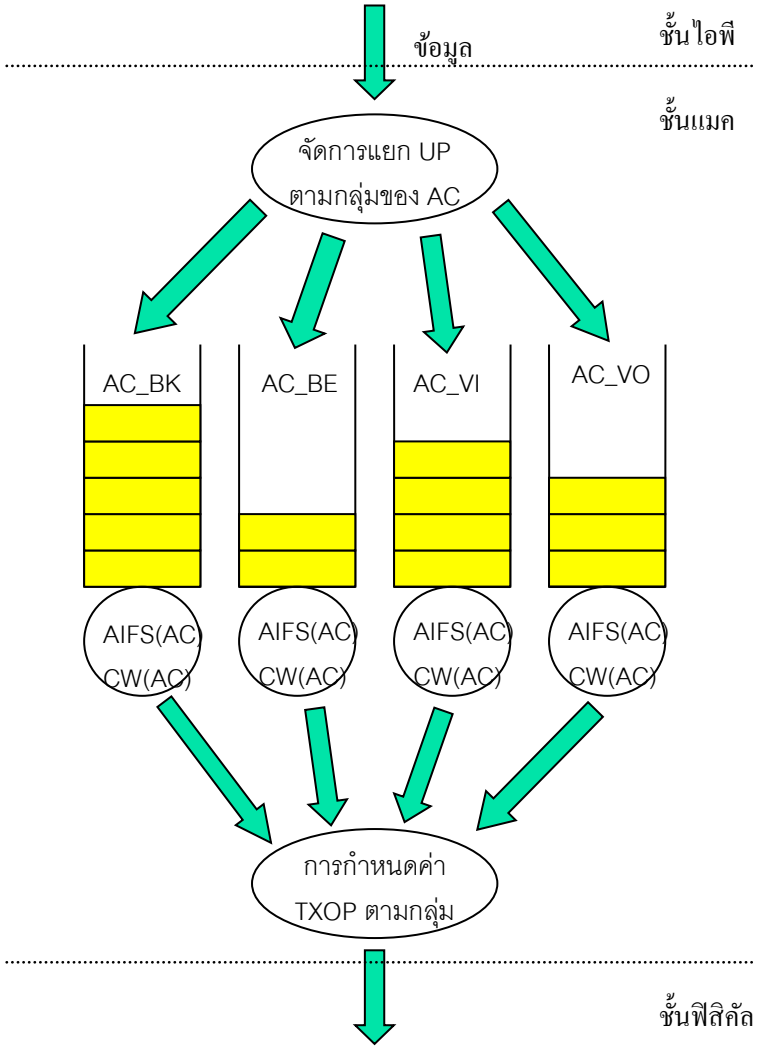
		Net traffic					
		low			high		
		Audio	Video	Data	Audio	Video	Data
User needs	time-critical	7	5	0	6	4	0
	not time-critical	-	-	2	-	-	2

Pommer, p.116ff

Mapping UP to AC

ลำดับความสำคัญ	ค่าความสำคัญตามผู้ใช้งาน (UP)	กลุ่มการเข้าใช้สื่อ (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


ข้อมูล
ชั้นไอพี
ชั้นแมค
จัดการแยก UP
ตามกลุ่มของ AC
AC_BK
AC_BE
AC_VI
AC_VO
AIFS(AC)
CW(AC)
AIFS(AC)
CW(AC)
AIFS(AC)
CW(AC)
AIFS(AC)
CW(AC)
การกำหนดค่า
TXOP ตามกลุ่ม
ชั้นฟิสิคัล

EDCA Parameters

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

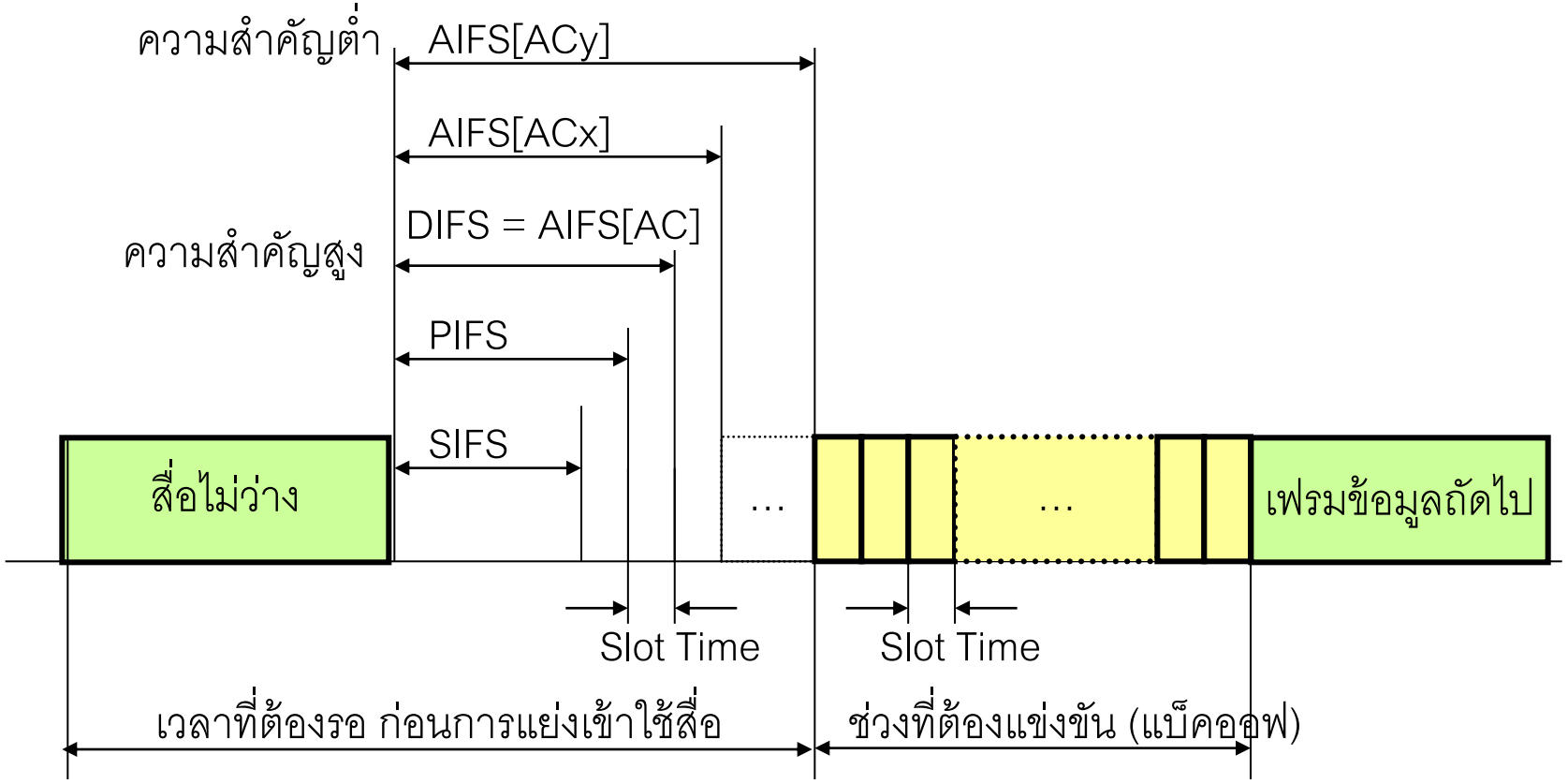
AIFS Calculation

- AIFSN: AIFS Number → Slot Time

AIFS[AC] = SIFS + AIFSN[AC] * Slot Time

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

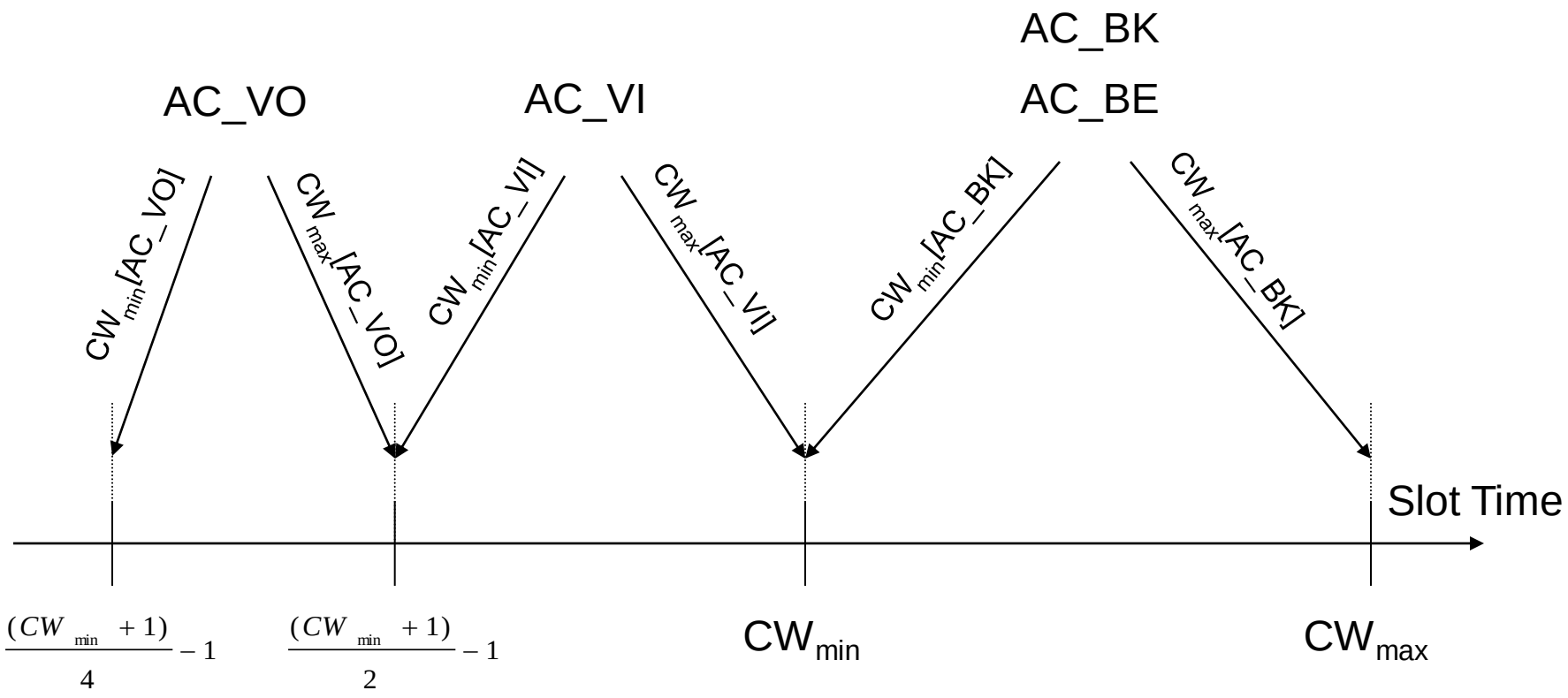
AIFS


ความสำคัญต่ำ
AIFS[ACy]
AIFS[ACx]
ความสำคัญสูง
DIFS = AIFS[AC]
PIFS
SIFS
สื่อไม่ว่าง
...
...
เฟรมข้อมูลถัดไป
Slot Time
Slot Time
เวลาที่ต้องรอ ก่อนการแย่งเข้าใช้สื่อ
ช่วงที่ต้องแข่งขัน (แบ็คออฟ)

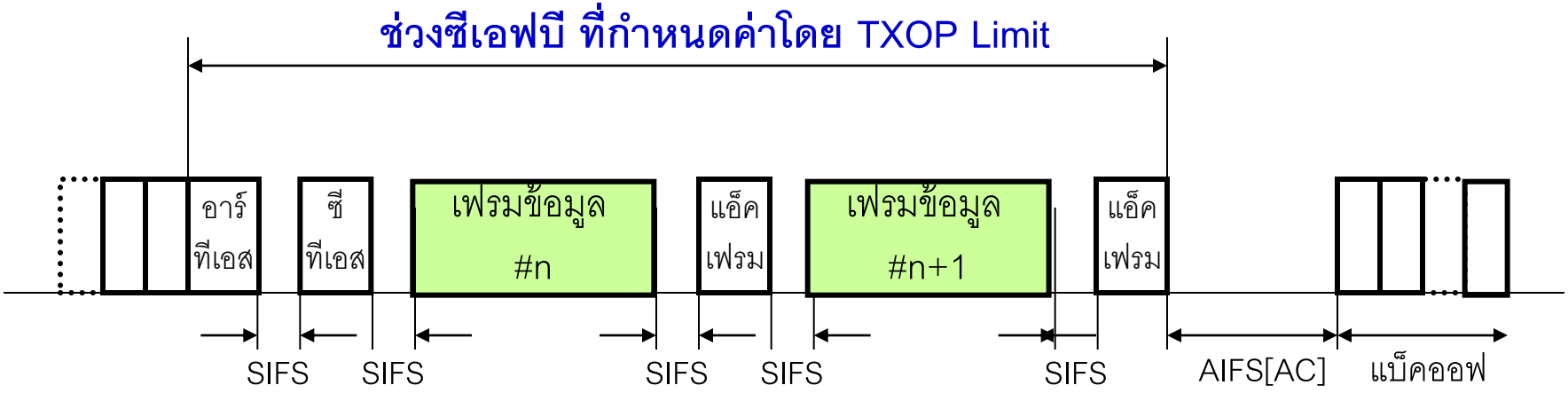
Default EDCA Parameters

กลุ่มการเข้าใช้สื่อ	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

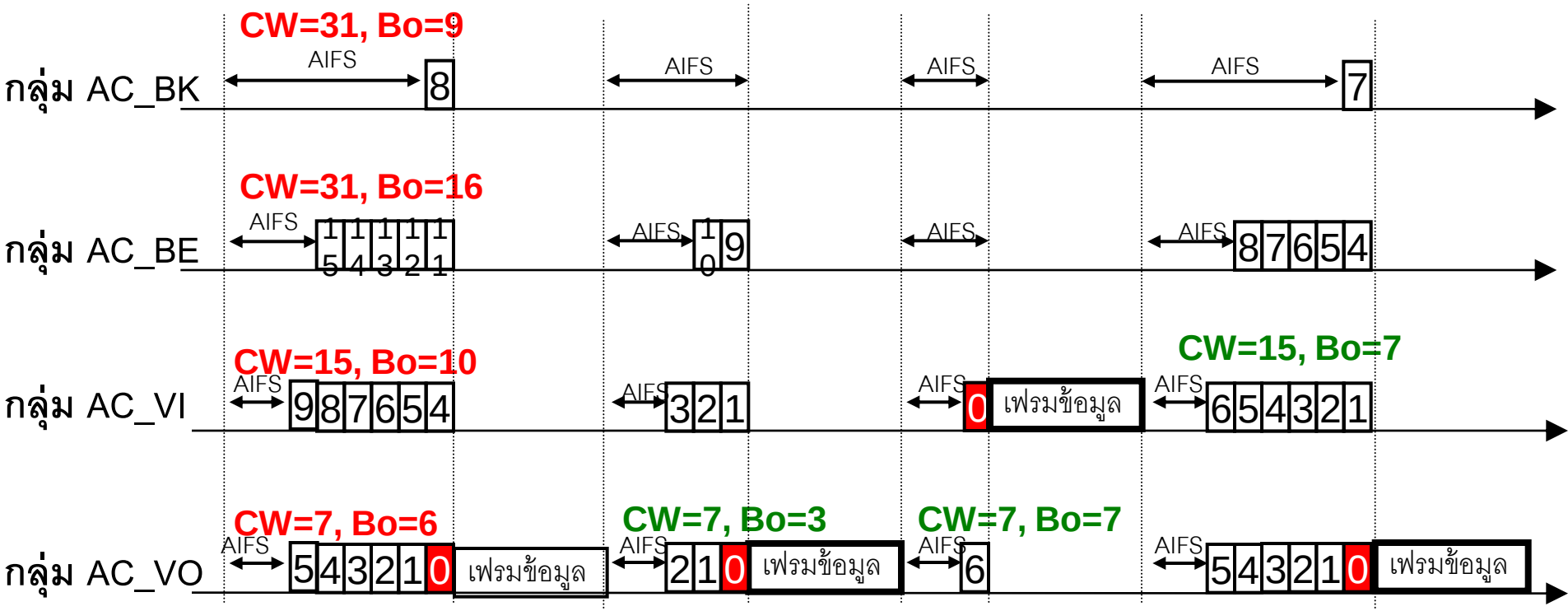


TXOP Limit


ช่วงซีเอฟบี ที่กำหนดค่าโดย TXOP Limit
อาร์ทีเอส
ซีทีเอส
เฟรมข้อมูล #n
แอ็คเฟรม
เฟรมข้อมูล #n+1
แอ็คเฟรม
SIFS
SIFS
SIFS
SIFS
SIFS
AIFS[AC]
แบ็คออฟ

EDCA Example

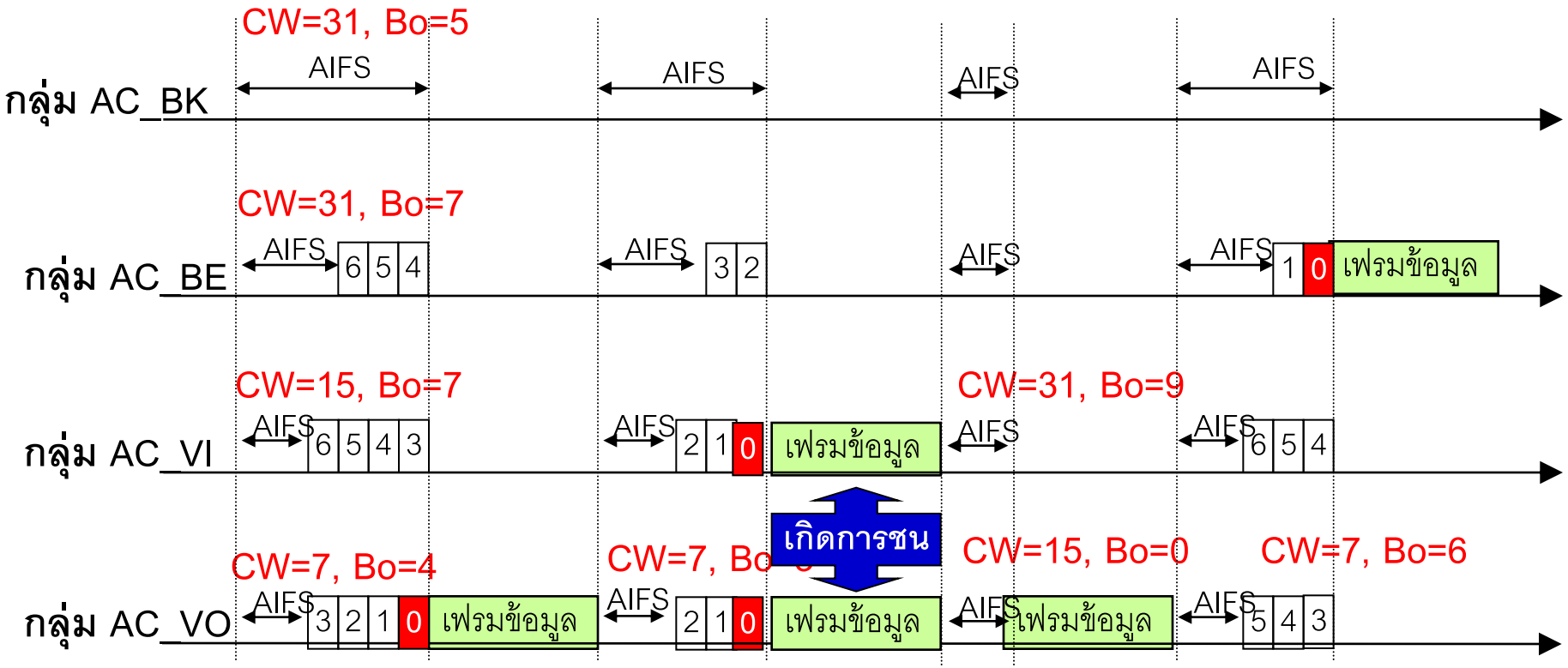
กลุ่ม	CW	Bo	AIFS
AC_BK	31	9	7
AC_BE	31	16	3
AC_VI	15	10	2
AC_VO	7	6	2



EDCA Collision?

- External Collision
- Internal Collision

Internal Collision

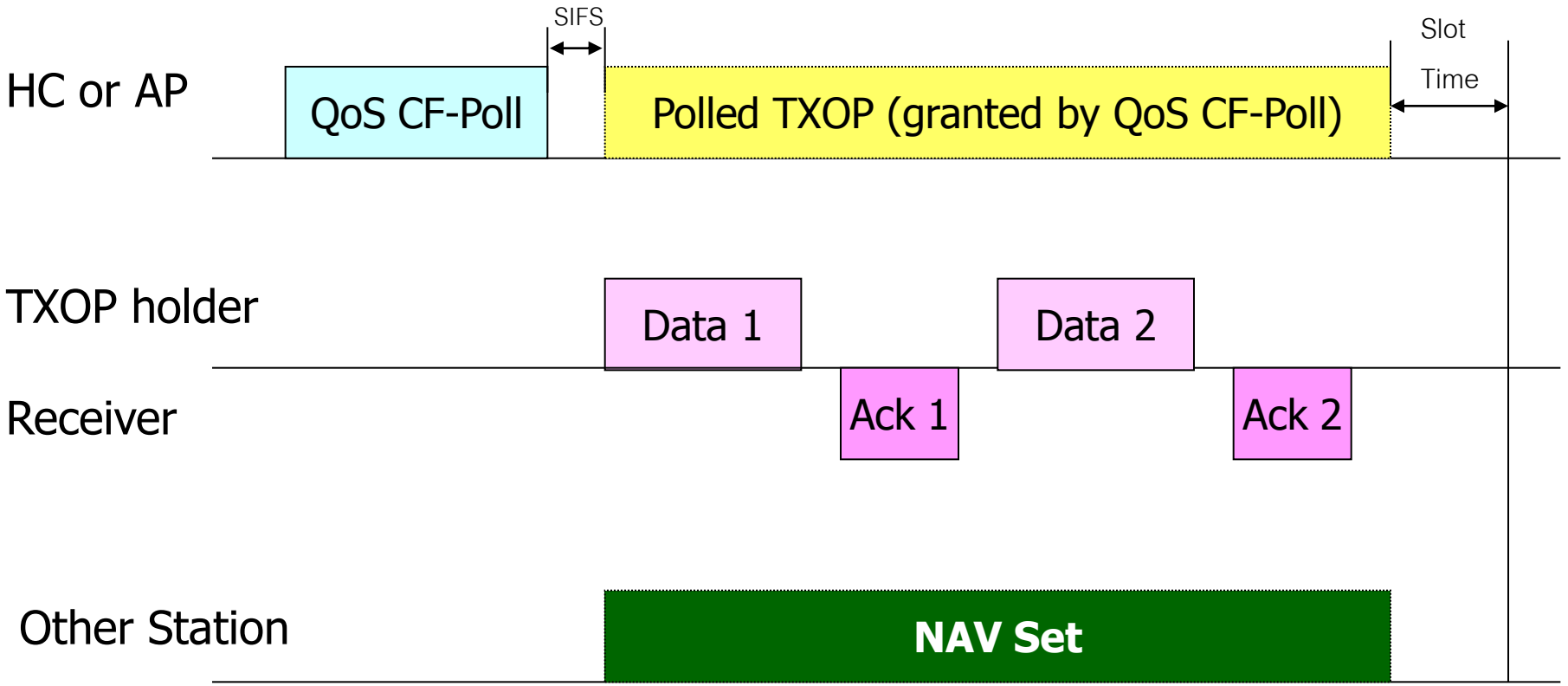


HCCA
(HCF Control Channel Access)

HCCA

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

Polled TXOP


SIFS
Slot
Time
HC or AP
QoS CF-Poll
Polled TXOP (granted by QoS CF-Poll)
TXOP holder
Data 1
Data 2
Receiver
Ack 1
Ack 2
Other Station
NAV Set

HCF (HCCA + EDCA)

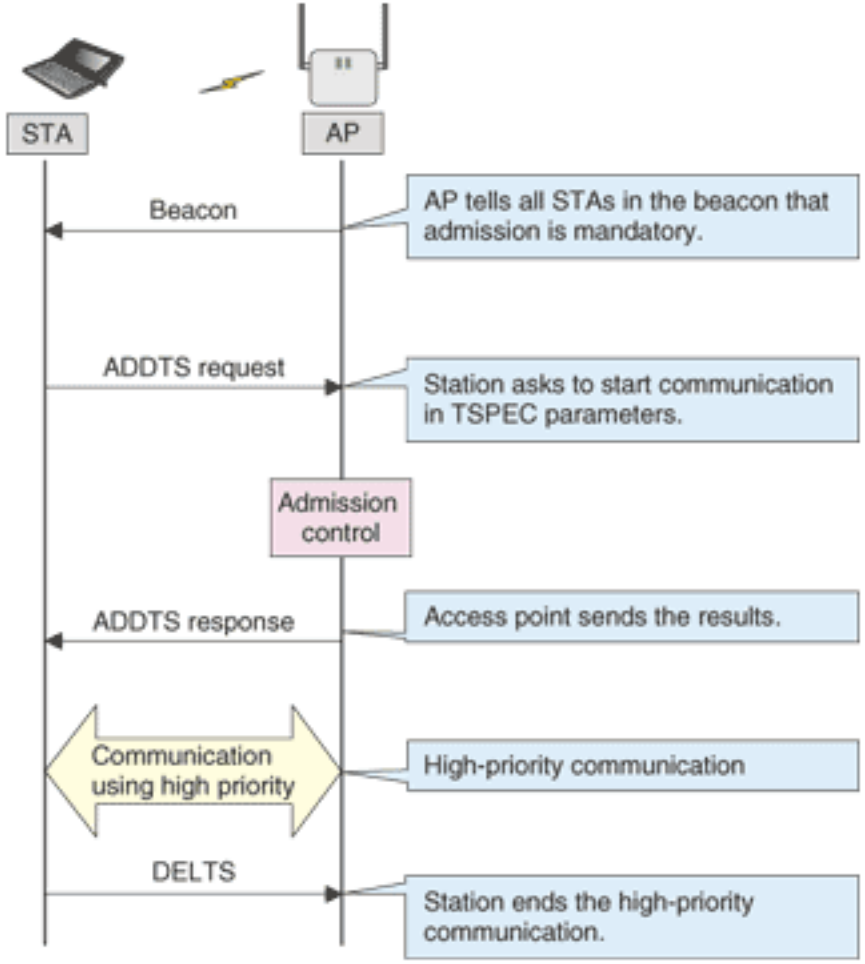
CAP: Controlled Access Period
SI: Service Interval

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)

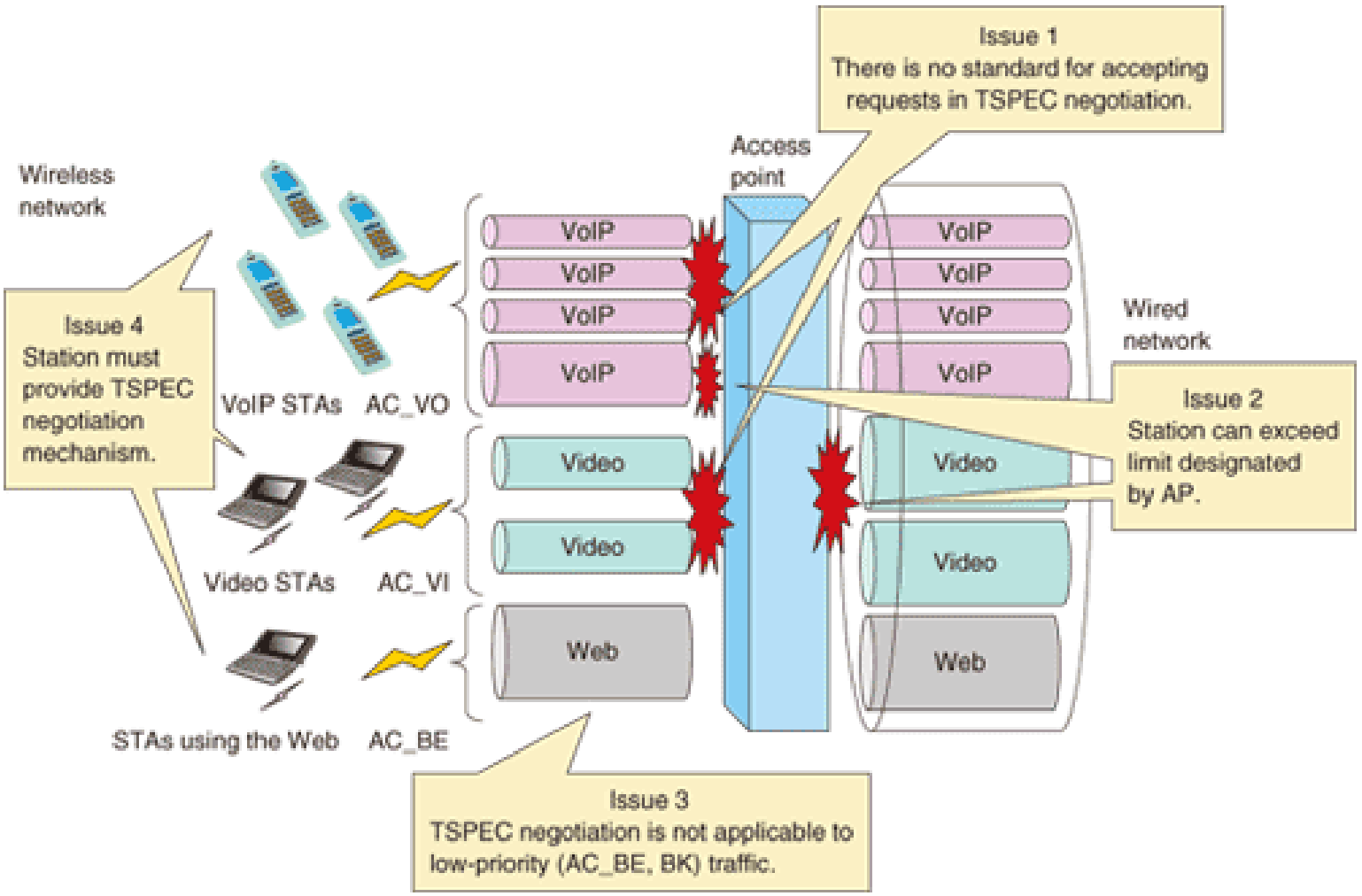
TSPEC negotiation



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

https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr200711sf7.html

Issues in TSPEC negotiation



https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr200711sf7.html

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

RSI: Required Service Interval

SI Calculation Example

- 3 stations with RSI (Required Service Interval):
  - St#1 = 250 ms
  - St#2 = 140 ms
  - St#3 = 280 ms

Min. RSI

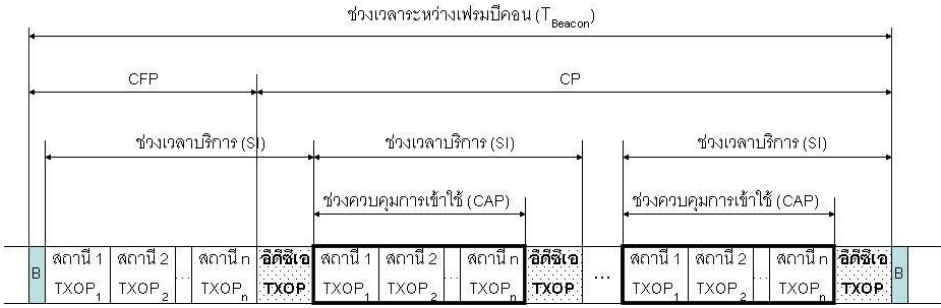
- Given T_{BEACON} = 600 ms

# 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



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

Dxy = Avg. Throughput Stream Y in Station X
Fxy = Frame Size
Nxy = #Frame
Fmax = 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

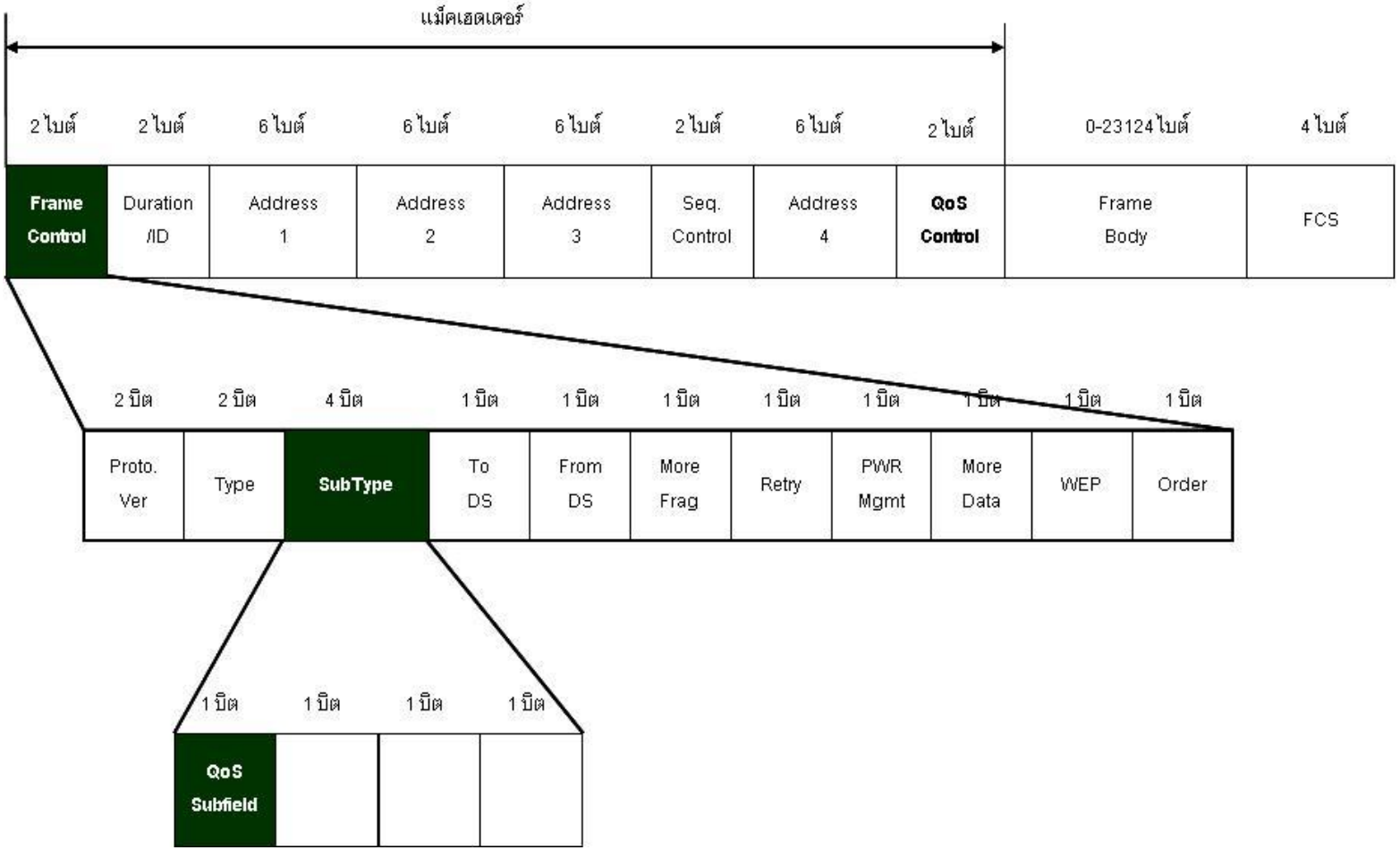
$$TXOP_{x} = \sum_{y=1}^{Y_x} TXOP_{xy}$$

QAP Announces TXOP to Station X

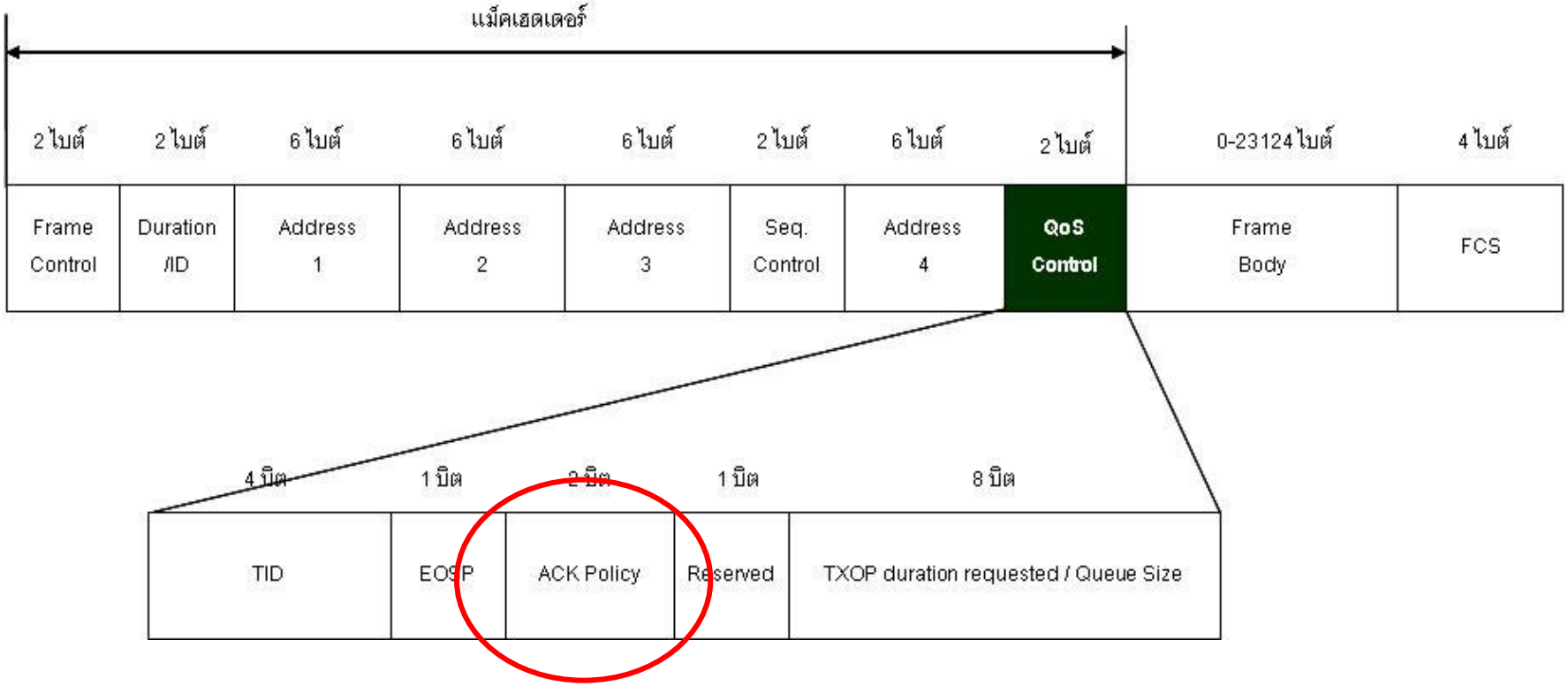
Admission Control

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

IEEE 802.11e Frame



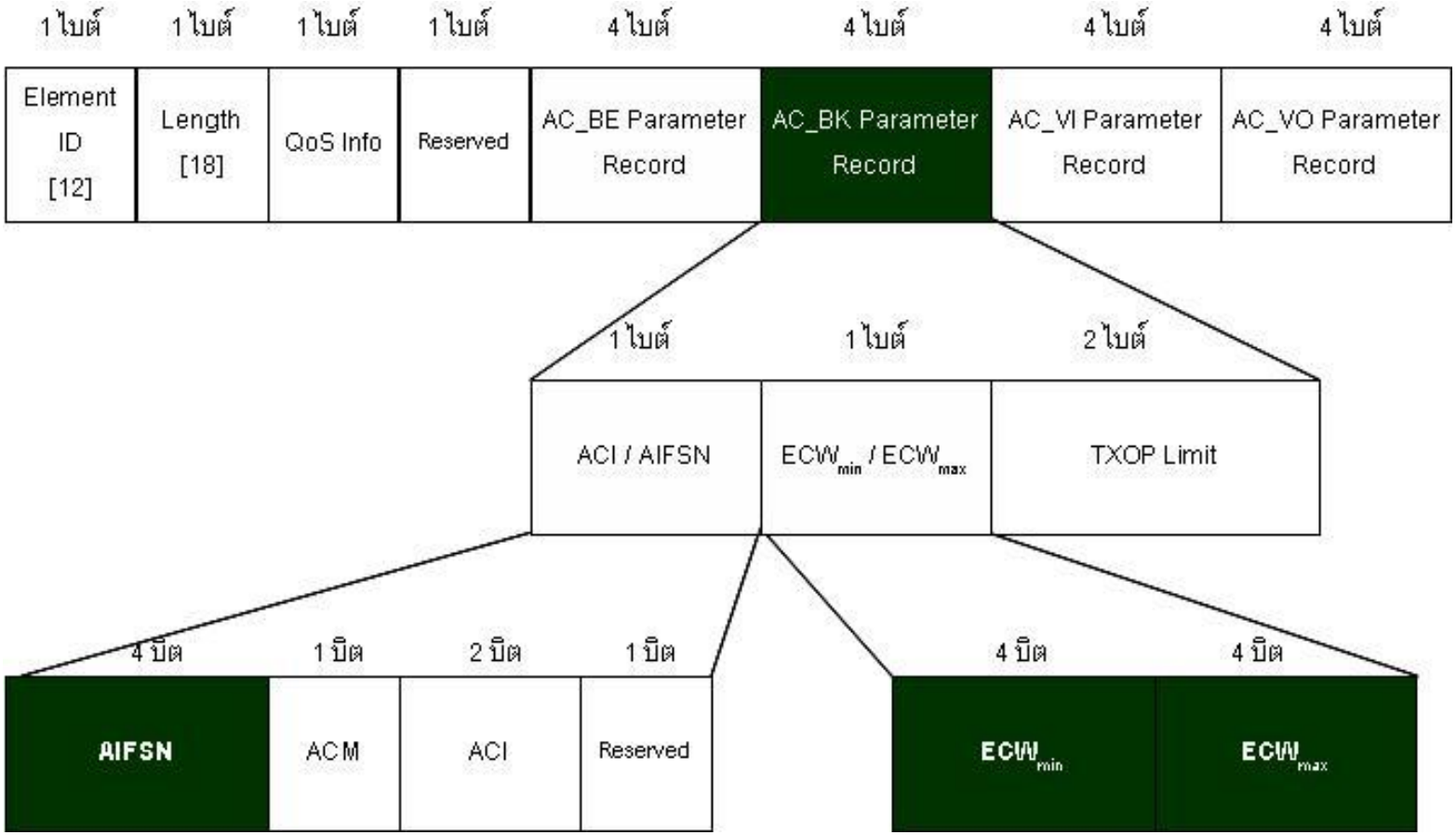
IEEE 802.11e Frame



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

Ack

- 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 guarante throughput
- Suitable for simple QoS applications (VoIP on Wi-Fi phones)

References

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- Broadband wireless access and Local network: Mobile WiMax and WiFi, *Byeong Gi Lee and Sunghyun Choi*, Artech house, 2008, ISNB -13: 978-1-59693-293-7
- Wiki, http://en.wikipedia.org/wiki/802.11e