802.11 QoS Overview

Philippe Klein

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Disclaimer

This presentation is not a highly detailed technical presentation but a crash course aiming to provide - prior to the joint meeting with the 802.11 WG- a basic understanding of the QoS mechanisms currently defined in the IEEE 802.11-2007 specifications

Abbreviations & Acronyms

ADDTS	add traffic stream
AIFS	arbitration interframe space
AIFSN	arbitration interframe space number
AP	access point
APSD	automatic power-save delivery
BSS	basic service set
CSMA/CA	carrier sense multiple access with collision avoidance
CW	contention window
DELTS	delete traffic stream
DIFS	distributed (coordination function) interframe space
DLS	direct-link setup
EDCA	enhanced distributed channel access
EDCAF	enhanced distributed channel access function
EIFS	extended interframe space
HCCA	HCF controlled channel access
HCF	hybrid coordination function
MAC	medium access control
MPDU	MAC protocol data unit
NAV	network allocation vector
PIFS	point (coordination function) interframe space
PS	power save (mode)
QoS	quality of service
S-APSD	scheduled automatic power-save delivery
SIFS	short interframe space
SP	service period
STA	station
TXOP	transmission opportunity
U-APSD	unscheduled automatic power-save delivery
WMM	WiFi Multimedia

802.11 MAC Legacy Access Protocol

802.11 MAC Access Protocol

1. Distributed Coordinated Function (DCF)

   Contention access

   Based on Carrier Sense Media Access /Collision Avoidance (PHY Carrier Sense & Network Allocation Vector)

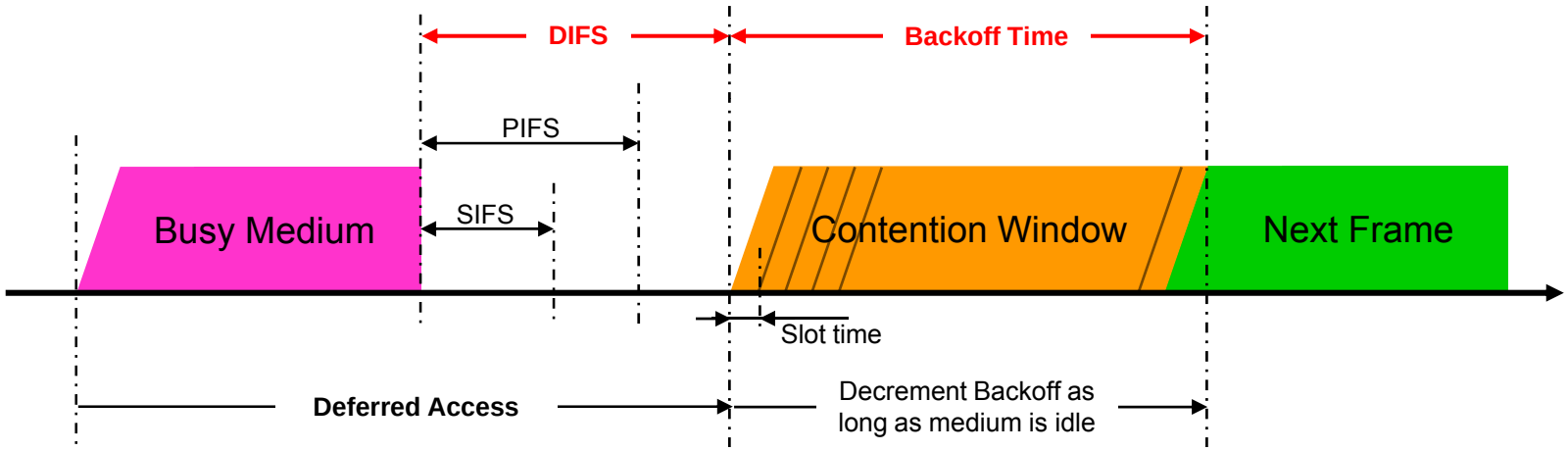
2. Point Coordinated Function (PCF)

   Contention Free access:

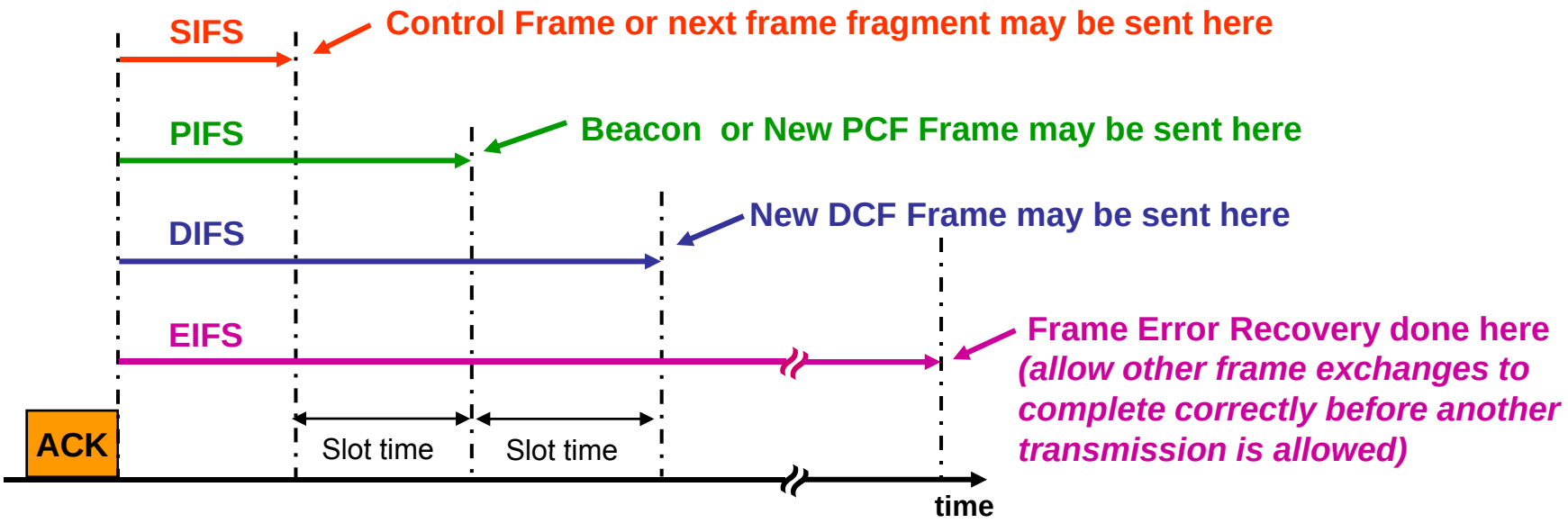
   Access Point (AP) coordinates access for AP and STA transmissions

   Optional !!!

DCF Contention Mechanism

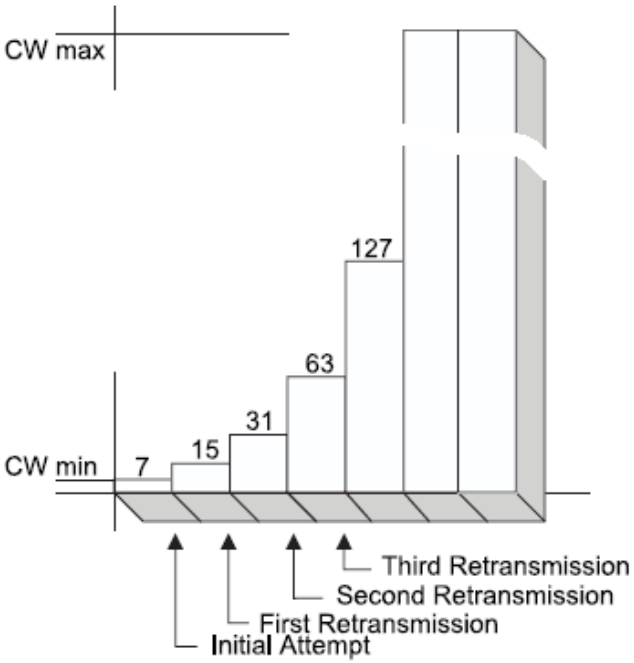


Interframe Spacing in 802.11



	802.11b	802.11a	802.11g
SIFS	10 µs	16 µs	10 µs
Slot time	20 µs	9 µs	9 µs
PIFS (= SIFS + 1 x Slot time)	30 µs	28 µs	19 µs
DIFS (= SIFS + 2 x Slot time)	50 µs	34 µs	28 µs

Random Backoff Time



Backoff Time = Random() * SlotTime

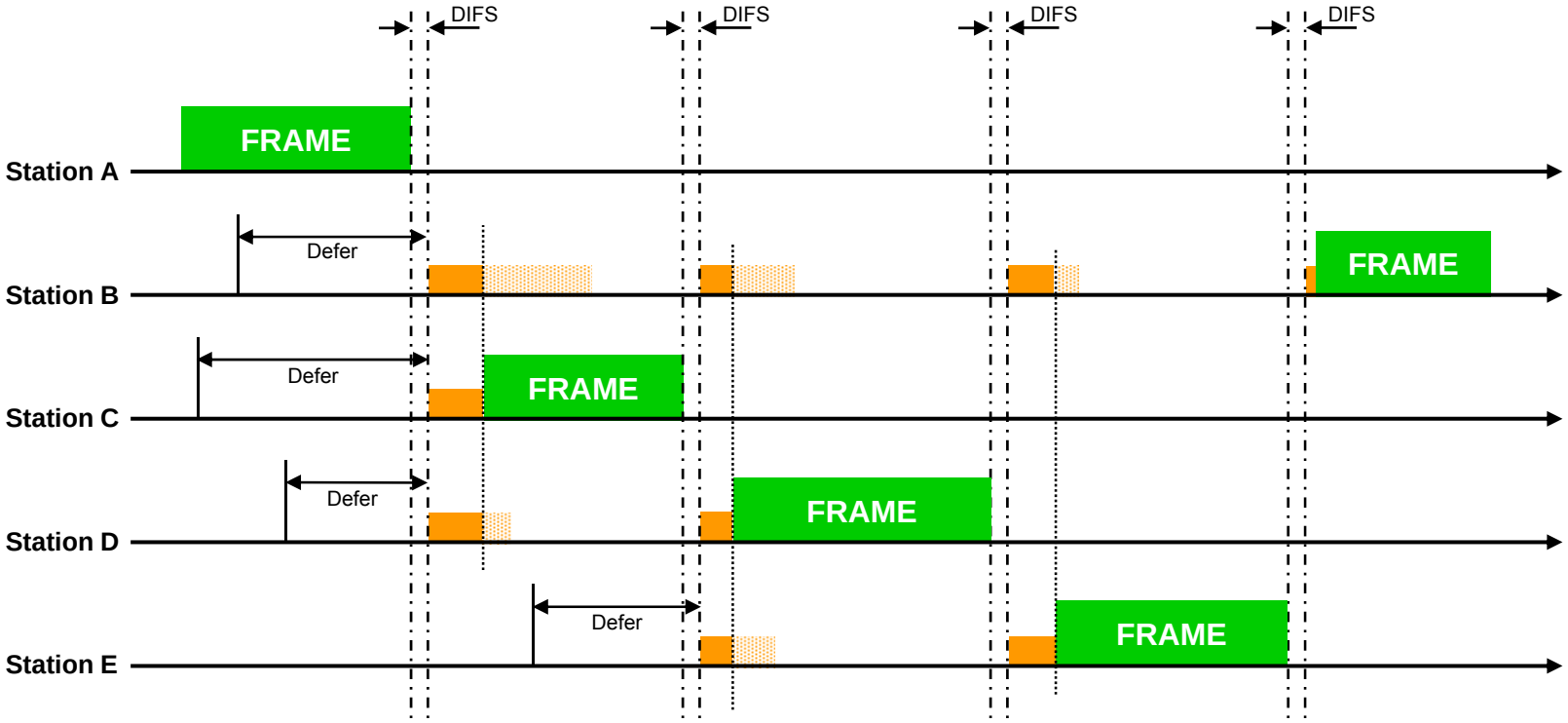
Random() = Pseudo-random [0,CW]

CWmin =< CW <= Cwmax

CW:

- Incremented by 2n-1 on each retransmission
- Reset after successful Txm

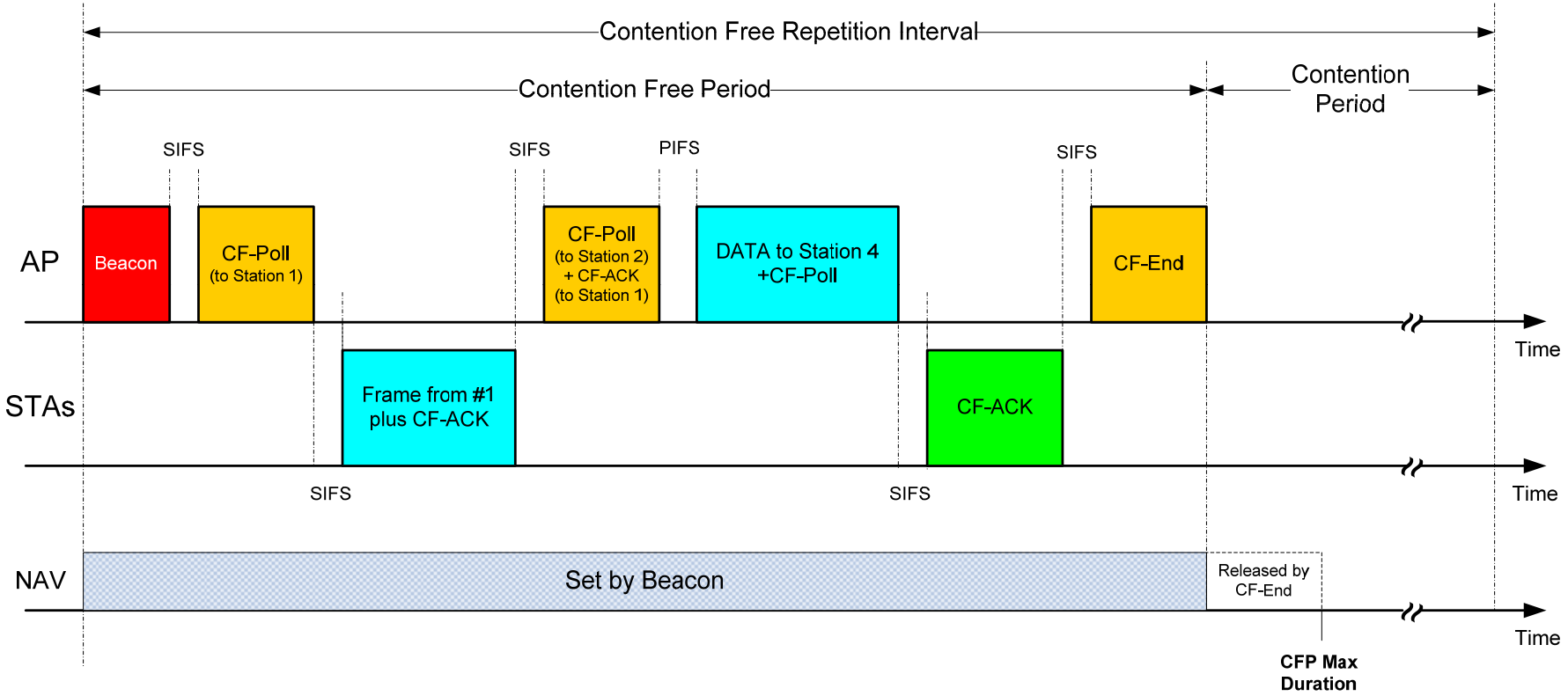
Distributed Coordinated Function



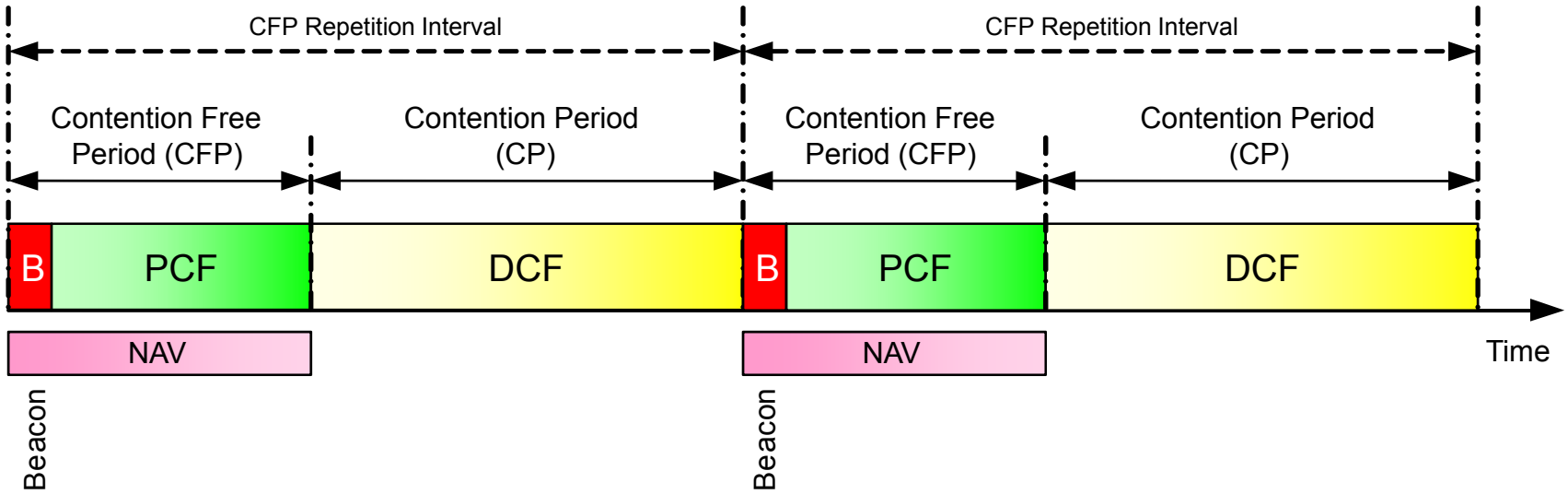
PCF: Point Coordinator Function

- Poll and response protocol to eliminate the possibility of contention for the medium.
- A Point Coordinator (PC) - *always located in an Access Point* - controls the PCF
  - To operate in PCF, stations register to the PC
  - PC regularly polls the registered stations for traffic while delivering traffic to theses stations.

PCF Operation



Co-existence of PCF and DCF



- CFP/C ratio is programmable in the AP
- Beacon marks the beginning of the Contention Free Period (CFP)
- CF-End ends the CFP
- NAV prevent outstanding DCF traffic to interfere with CFP

Quality of Service Limitations

- Both PHY's DCF and PCF methods do not differentiate between traffic types or sources and do not provide QoS
- PCF provides only iso-synchronous services
  - worse latency access only is deterministic
  - access latency is function of the number of registered stations, the CF traffic and the CFP/CP ratio

Medium Access Control Quality of Service Enhancements

(previously 802.11e amendment , now part of 802.11-2007)

Major Enhancements in 802.11e

- Basic Elements for QoS
  - Traffic Differentiation
  - Concept of Transmission Opportunity (TXOP)
- New Contention Channel Access
  - Enhanced Distributed Channel Access (EDCA)
- New Contention Free Channel Access
  - HCF Controlled Channel Access (HCCA)

Major Enhancements in 802.11e

- Automatic Power-Save Delivery (APSD)
- New mechanisms for higher throughput
  - Block Acknowledgement (Block Ack)
  - Direct Link Setup (DLS)

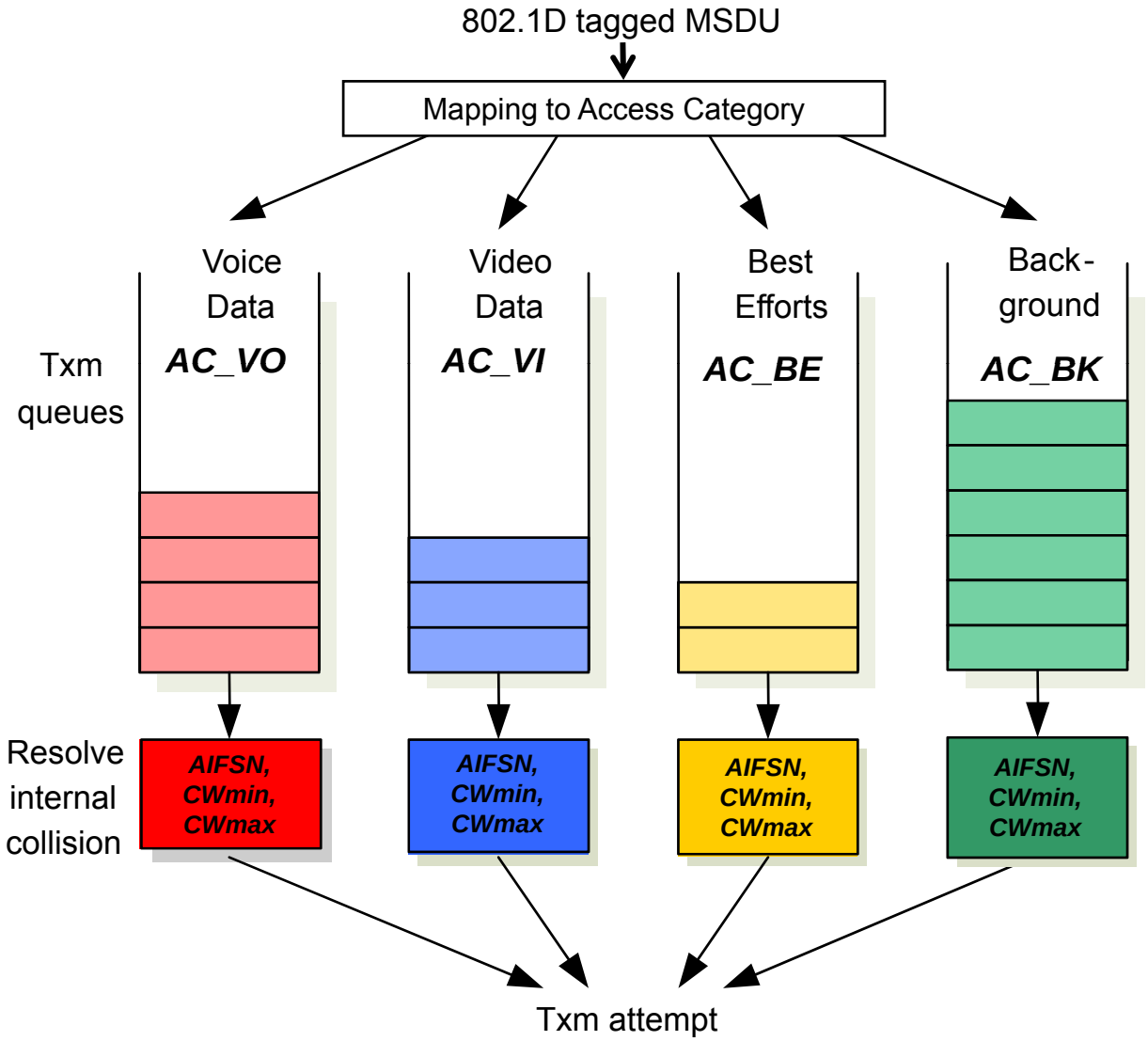
Enhanced Distributed Channel Access (EDCA)

- Same Contention Based that EDC but…
  1. **8 priority levels** per station (identical to IEEE 802.1D priority tags) mapped to 4 access categories (AC)
  2. Different **Arbitration InterFrame Space** (AIFS) per access categories
  3. TxOP Burst Limits

EDCA Frame Priorities

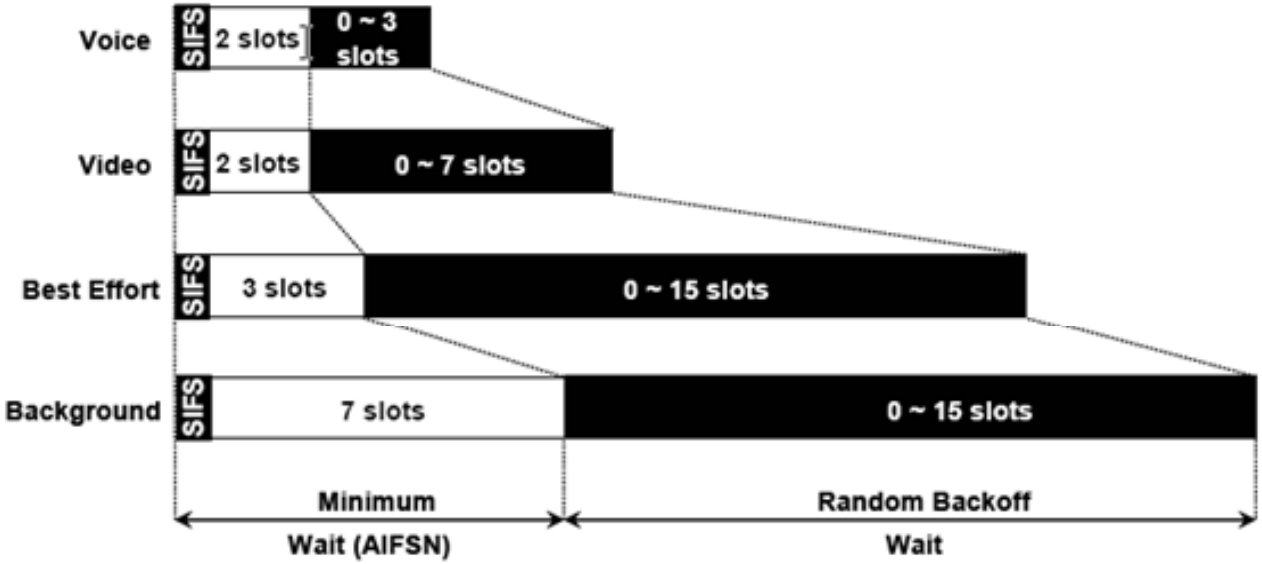
Priority	User Priority (same as 802.1D user priority	802.1D Designation	Access category (AC)	Designation (Informative)
Lowest	1	BK	AC_BK	Background
	2	-	AC_BK	Background
	0	BE	AC_BE	Best Effort
	3	EE	AC_BE	Video
	4	CL	AC_VI	Video
	5	VI	AC_VI	Video
highest	6	VO	AC_VO	Voice
	7	NC	AC_VO	Voice

EDCA Implementation Model

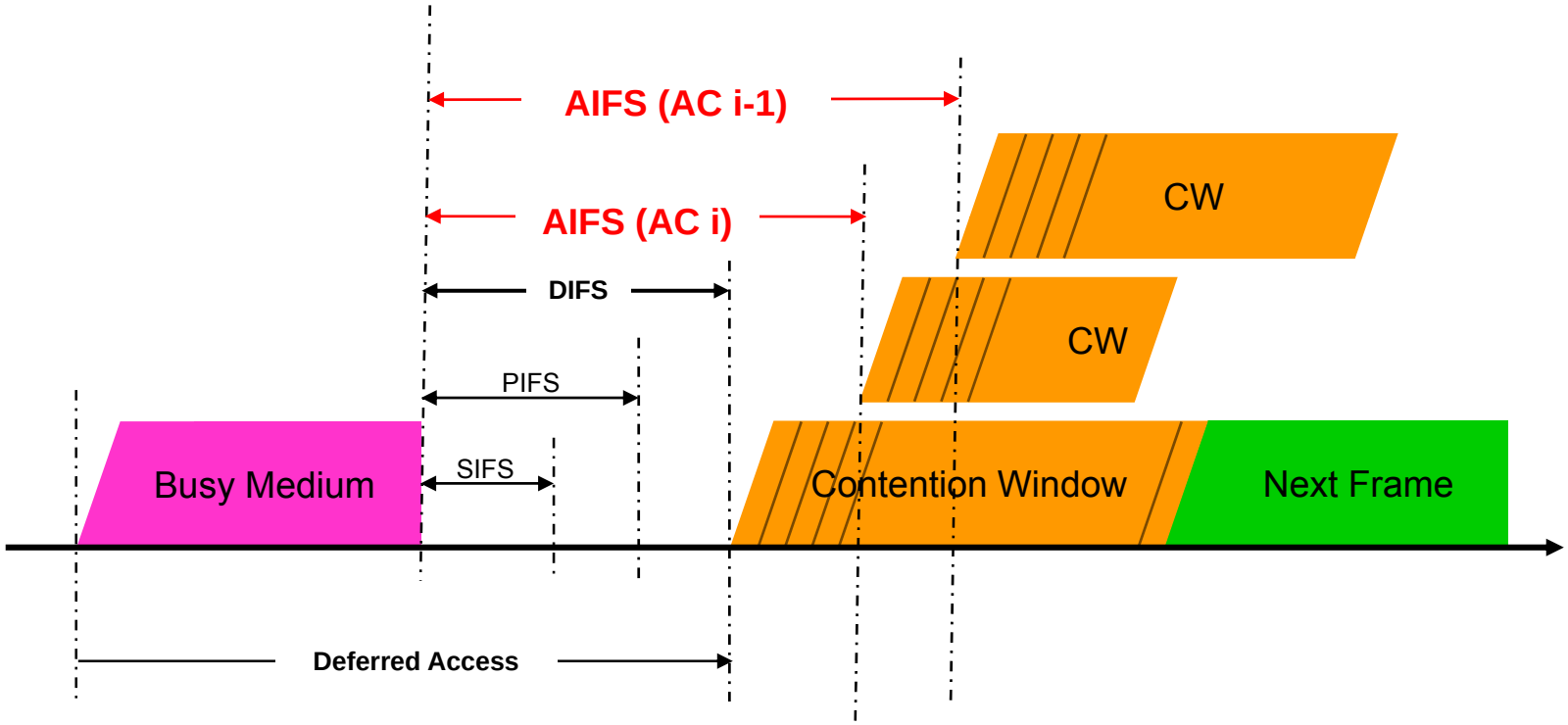


Traffic Prioritization & Collision Resolution

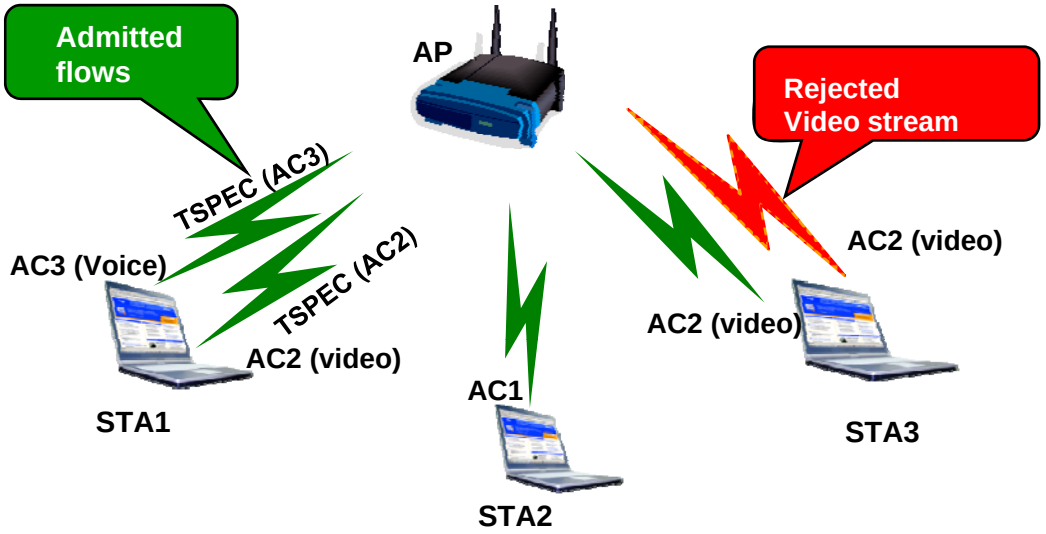
- Depends on 2 timing parameters that vary for each AC:
  1. AIFSN (Arbitrary Inter-Frame Space Number)
  2. CW (Contention Window)
     (and TxOP Limit for AC_VI and AC_VO)



Arbitration InterFrame Space

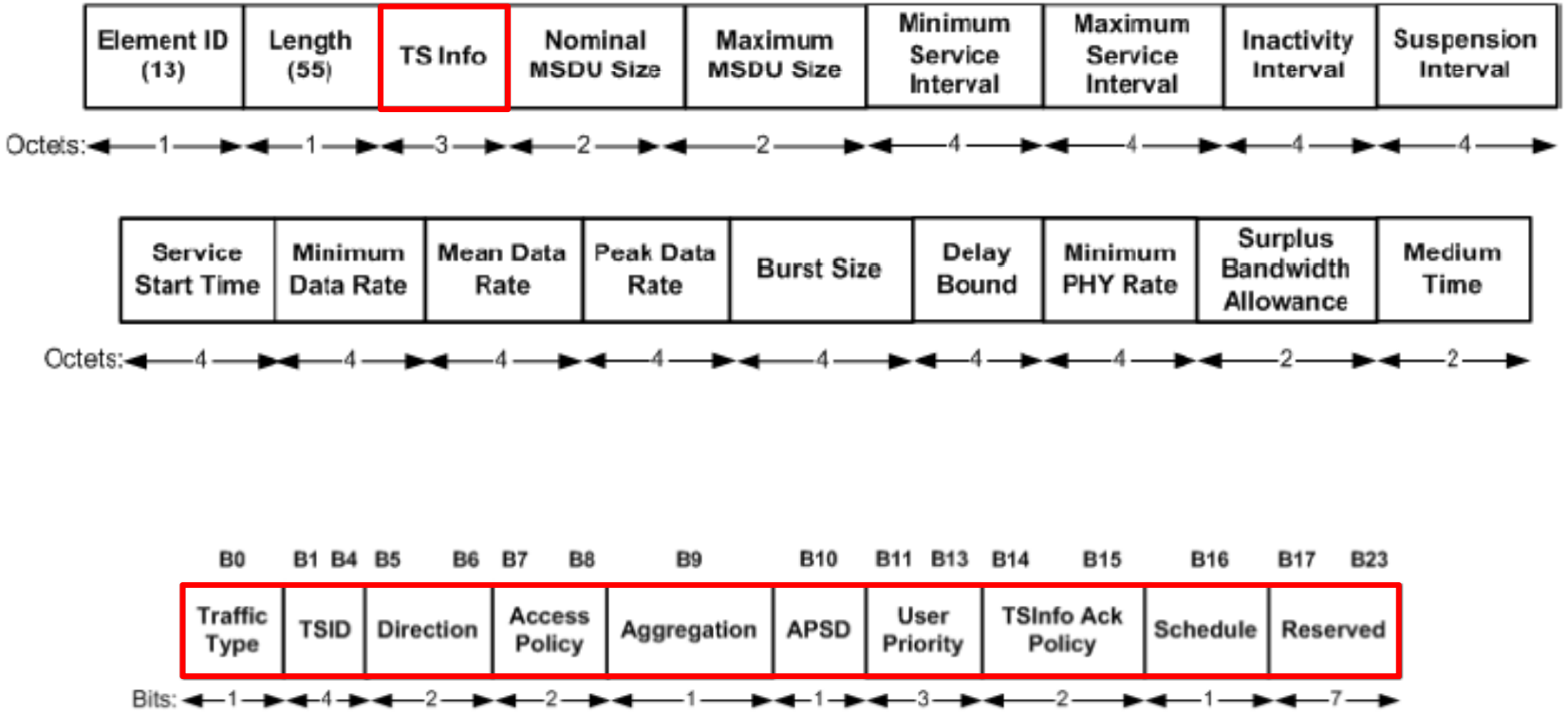


EDCA + Admission Control



- **Capability Negotiation of Admission Control per Access Category (AC) occurs during association:**
  - **STA sends an Add Traffic Stream (ADDTS) request with Txm Specifications (TSPEC) prior to sending packet on a particular AC.**
    - **TSPEC can be for upstream, downstream, or bi-directional traffic.**
    - **AP has proprietary algorithm to accept/deny ADDTS request.**

802.11 TSPEC Element



802.11 TSPEC Main Parameters

User Priority	**0 (lowest) to 7 (highest)**
Maximum MSDU size	**maximum size of the packets (octets)**
Maximum Burst Size	**maximum size of the data burst that can be transmitted at the peak data rate (octets)**
Minimum PHY rate	**physical bit rate assumed by the scheduler for transmit time and admission control calculations (b/s)**
Peak data Rate	**maximum bit rate allowed for transfer of the packets**
Mean data rate	**average bit rate for transfer of the packets (b/s)**
Delay bound	**maximum delay allowed to transport a packet across the wireless interface (including queuing delay, in ms)**
Nominal MSDU size	**nominal size of the packets (octets)**
Maximum Service Interval	**interval required by TS in this TSPEC between the start of two successive TXOPs**

EDCA Limitations

- Still **no** guaranty of service provided but..
- Probabilistic priority mechanism only to allocate bandwidth based on traffic categories

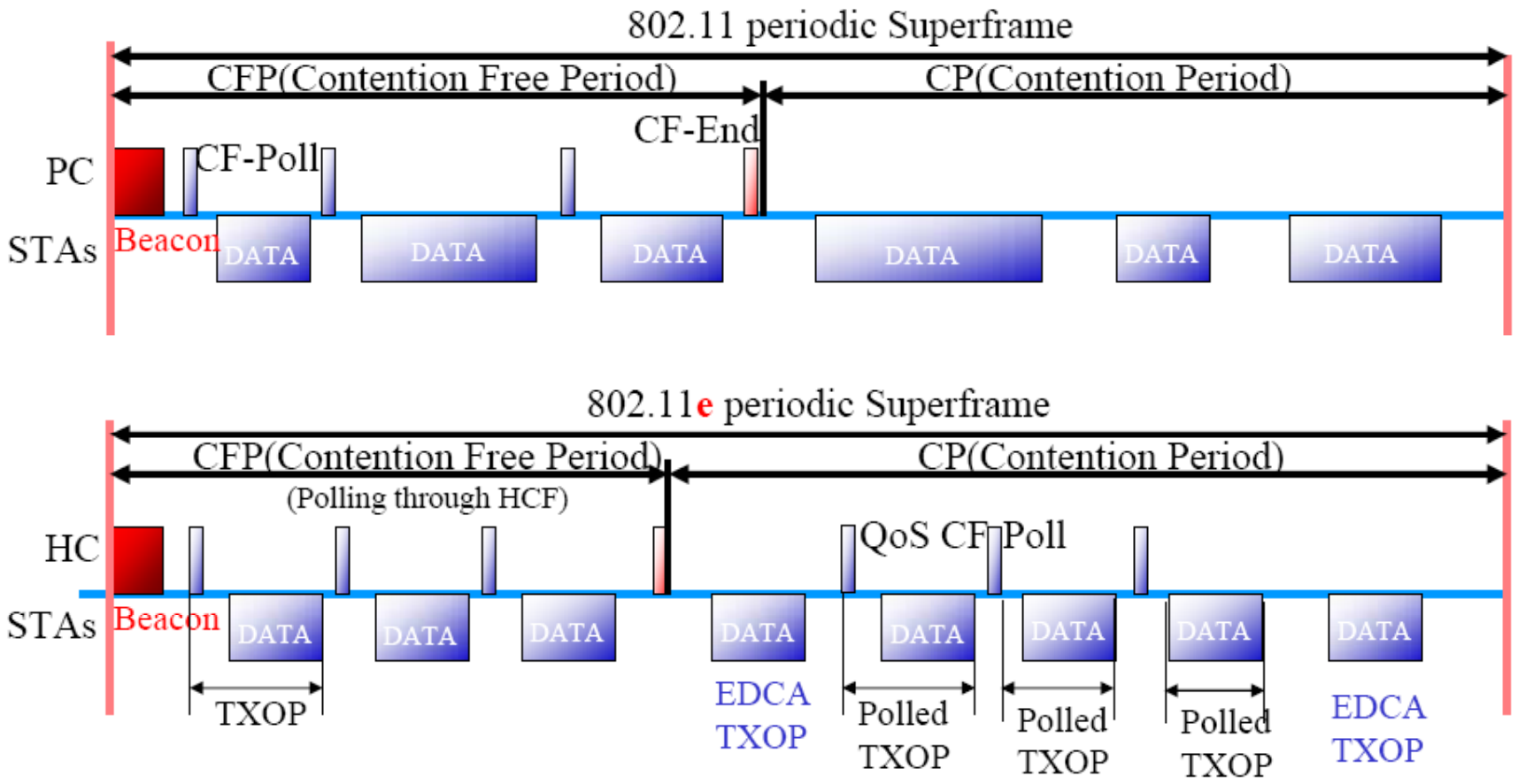
HCF Controlled Channel Access (HCCA)

- HCF = Hybrid Coordination Function
- Hybrid Coordinator (HC) operates at QoS-AP
  - Controls the iteration of Contention Free Period (CFP) and Contention Period (CP)
  - Schedule Transmit Opportunities for contention free accesses

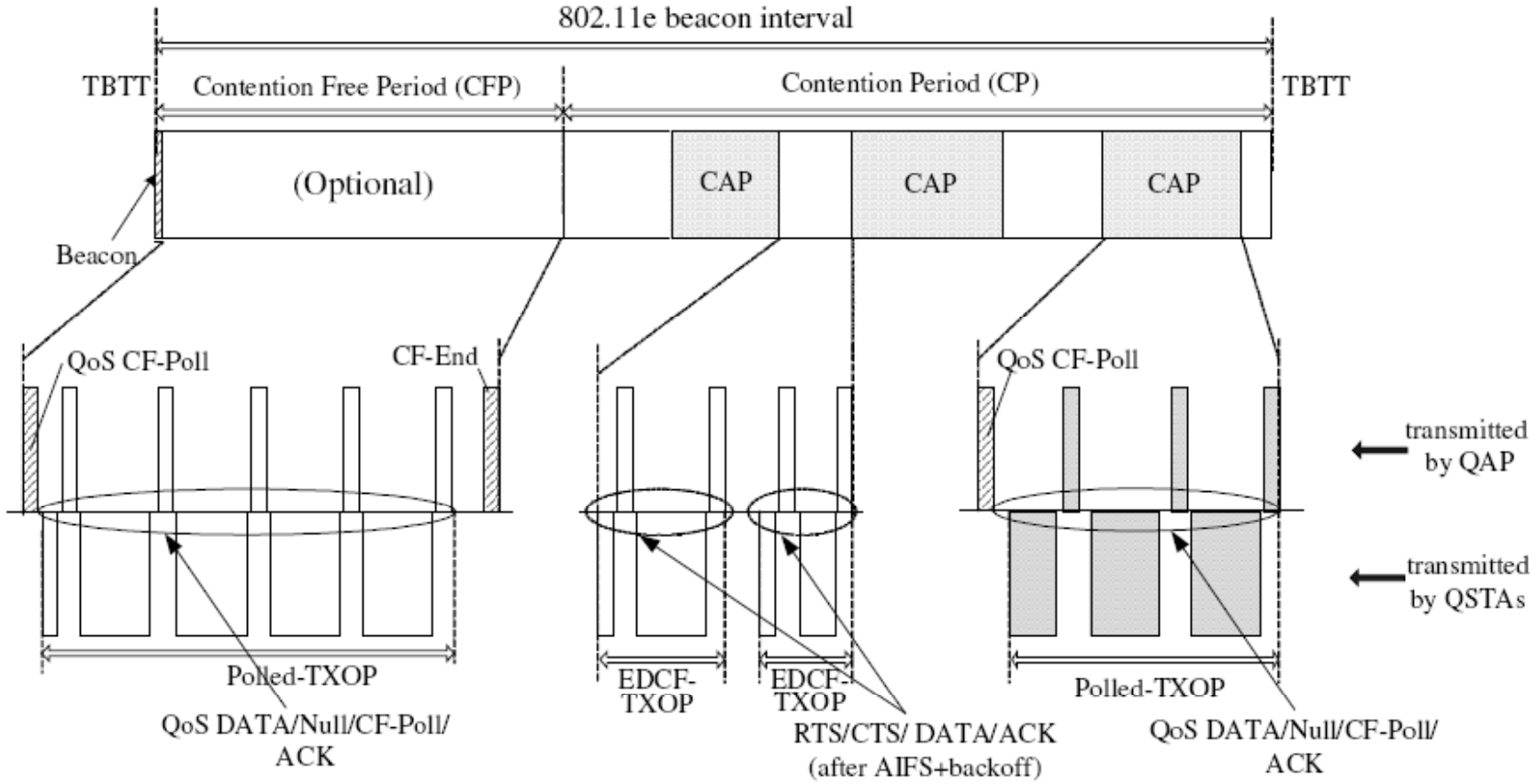
HCF Controlled Channel Access (HCCA)

- Similar to PCF
  - Same polling mechanism to assign Transmission Opportunity (TXOP) to QoS-STA
- but
  - Polling can be issued in both CFP and CP (in Controlled Access Periods)
  - HC Polling is scheduled according to Transmit specifications (TSPECs)

PCF vs HCF Comparison



802.11e Media Access Summary



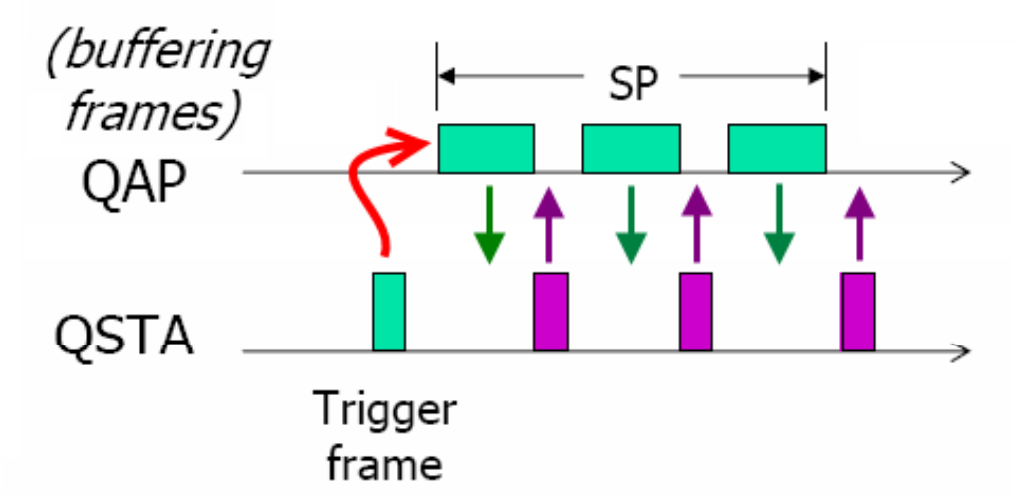
CAP	Controlled Access Period	CP	Contention Period	TBTT	Target Beacon Transmission Time
CFP	Contention Free Period	EDCF	Enhanced Distributed Coord. Function	TXO	Transmission Opportunity
CF-Poll	Contention Free – Poll	QAP	QoS Access Point		
CF-End	Contention Free – End	QSTA	Qos Station		

802.11e
Automatic Power-Save Delivery

Automatic Power-Save Delivery (APSD)

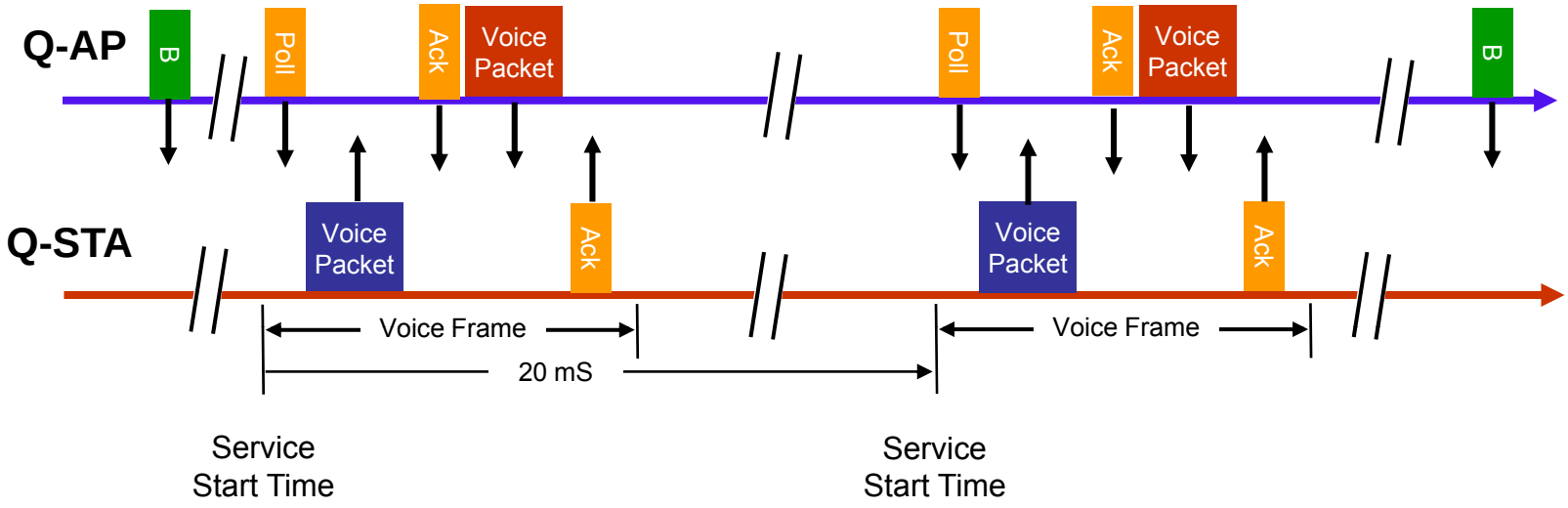
- Enhancing Power Saving mode in QoS Basic Service Set
- QoS-AP automatically delivers downlink frames, which belong to some specified Access Category, to Power-Saving stations
- Two types of delivery mechanism
  - Unscheduled APSD (U-APSD)
  - Scheduled APSD (S-APSD)

Unscheduled APSD (U-APSD)



1. Power-saving QoS-STA wakes up and send a “trigger”data frame belonging to “trigger-enabled” AC to QoS-AP
2. After receiving “trigger” frame, a Service Period (SP) is started
3. QoS-AP send frames belonging to “delivery-enabled” AC to QoS-STA

Scheduled APSD (S-APSD)

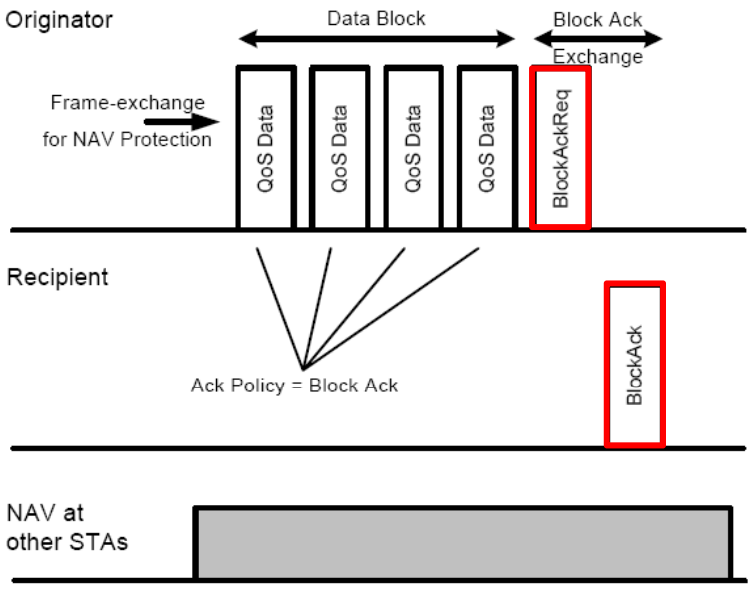


1. QoS-STA negotiates a APSD Schedule with QoS-AP
2. QoS-AP start transmitting the frames of the specified Traffic Stream at Service Start Time and the following periods
3. QoS-STA must wake up at Service Start Time and the following periods to receive frames

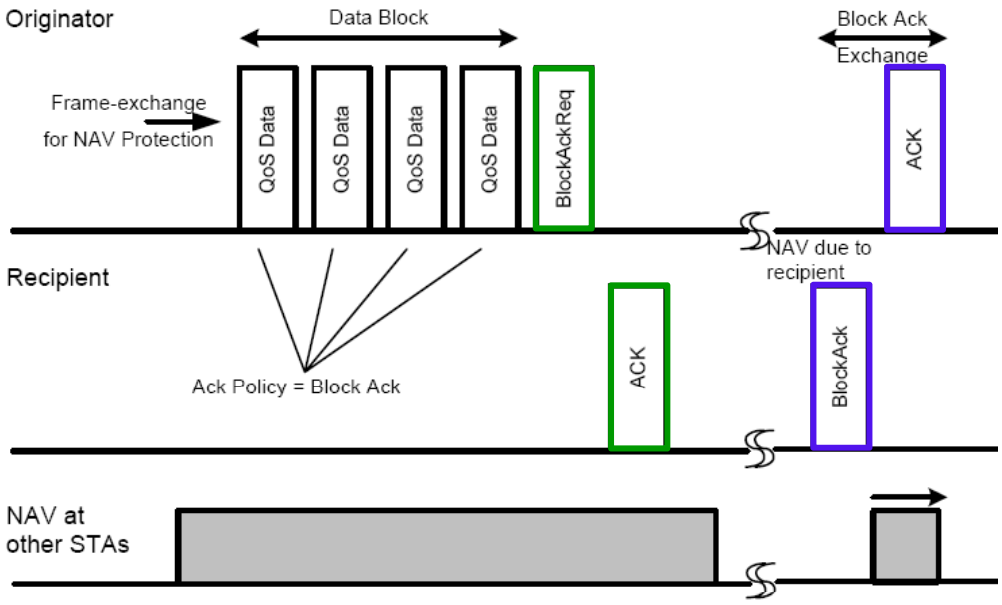
802.11e
Throughput Enhancements

Block ACK

- Improves channel efficiency by aggregating several acknowledgments into one frame.
- 2 types of Block Ack mechanisms:
  - immediate and delayed



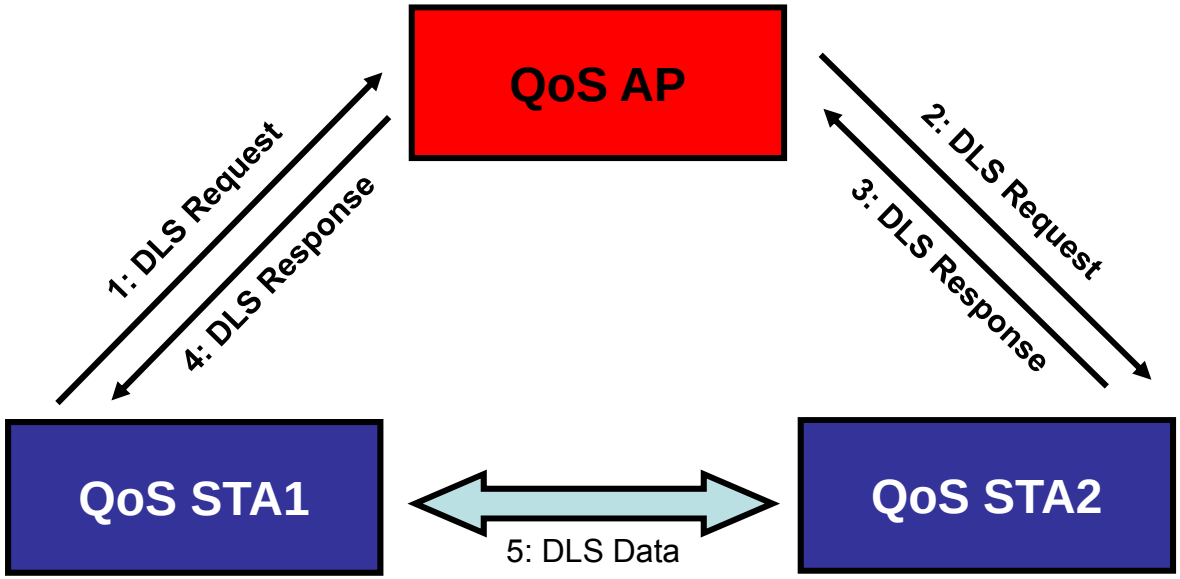
Immediate ACK



Delayed ACK

Direct Link Protocol

- Ability to exchange data directly between two stations in the network, without traversing the AP.



WMM (Wi-Fi Multimedia™)

- Certification program initiated by the Wi-Fi Alliance (www.wi-fi.org)
- Specification document:

  Wi-Fi Alliance Technical Committee Quality of Service (QoS) Task Group, WMM (including WMM™ Power Save) Specification Version 1.1

- Subset of IEEE 802.11e : EDCA & U-APSD only

Thank you