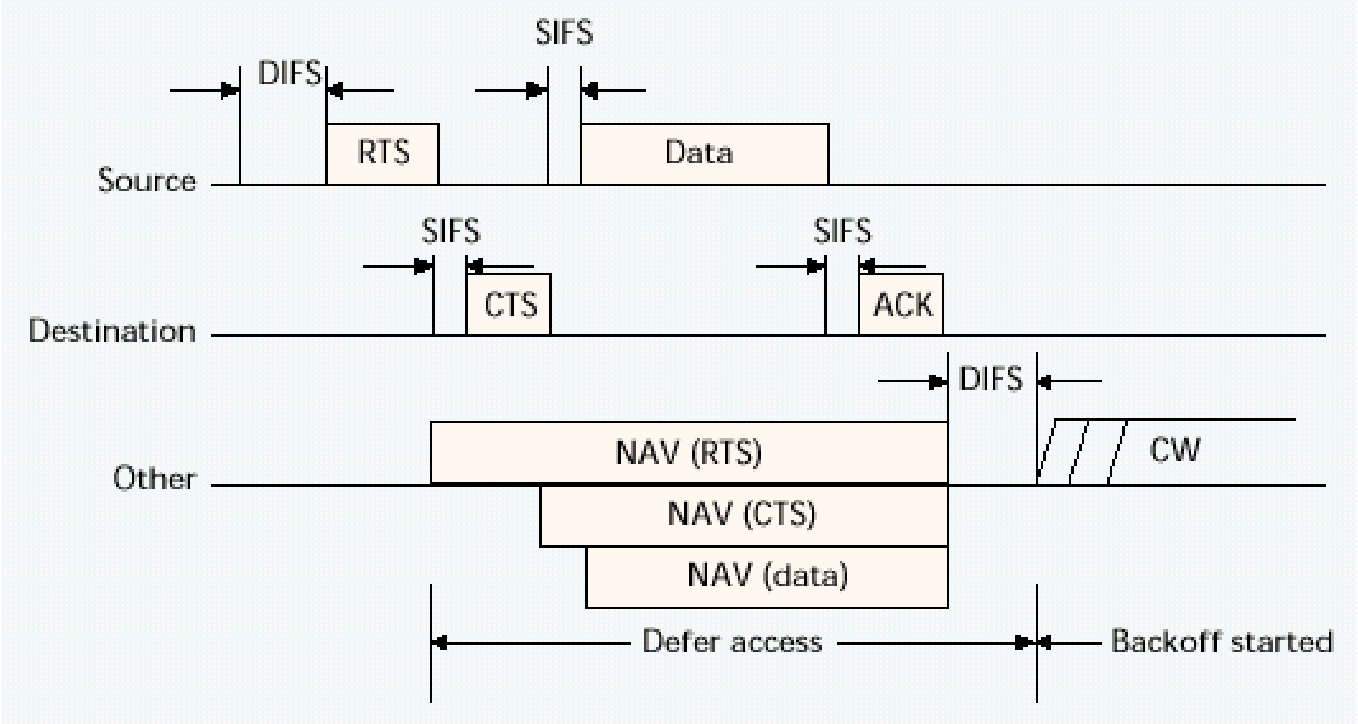
The IEEE 802.11 family of standards

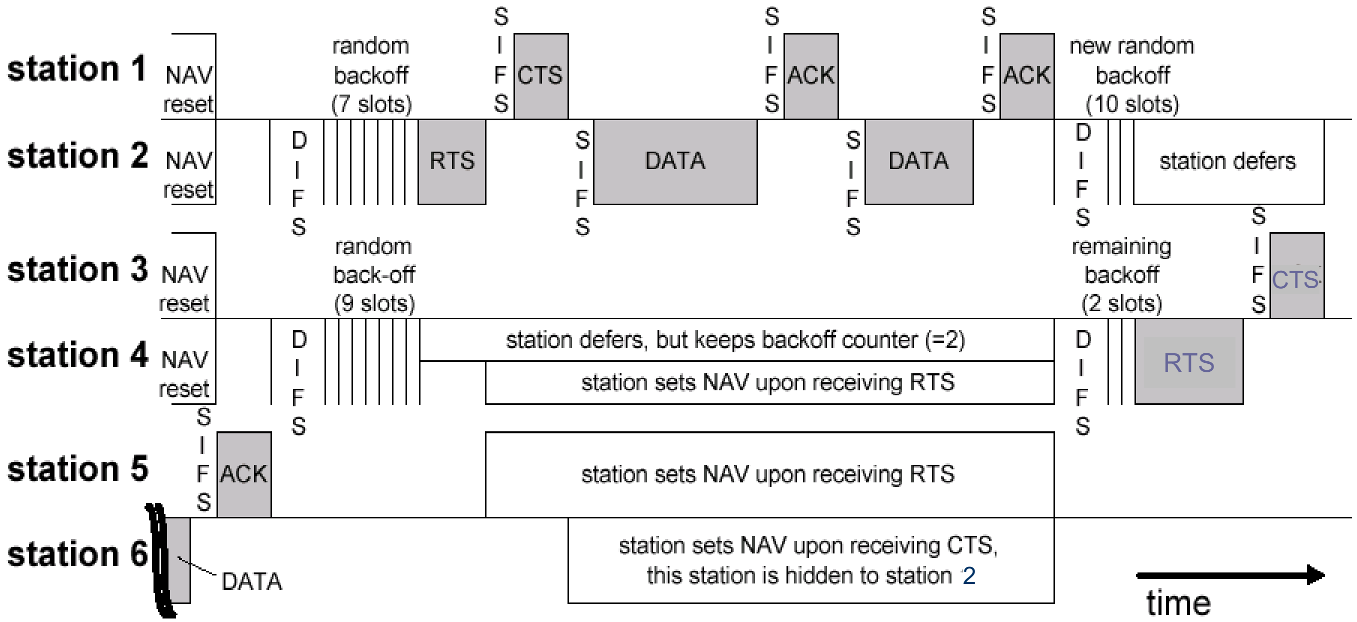
continued



- Always SIFS<DIFS

- Updating of NAVs (Network Allocation Vectors) very important through RTS/CTS/data packets to use power saving

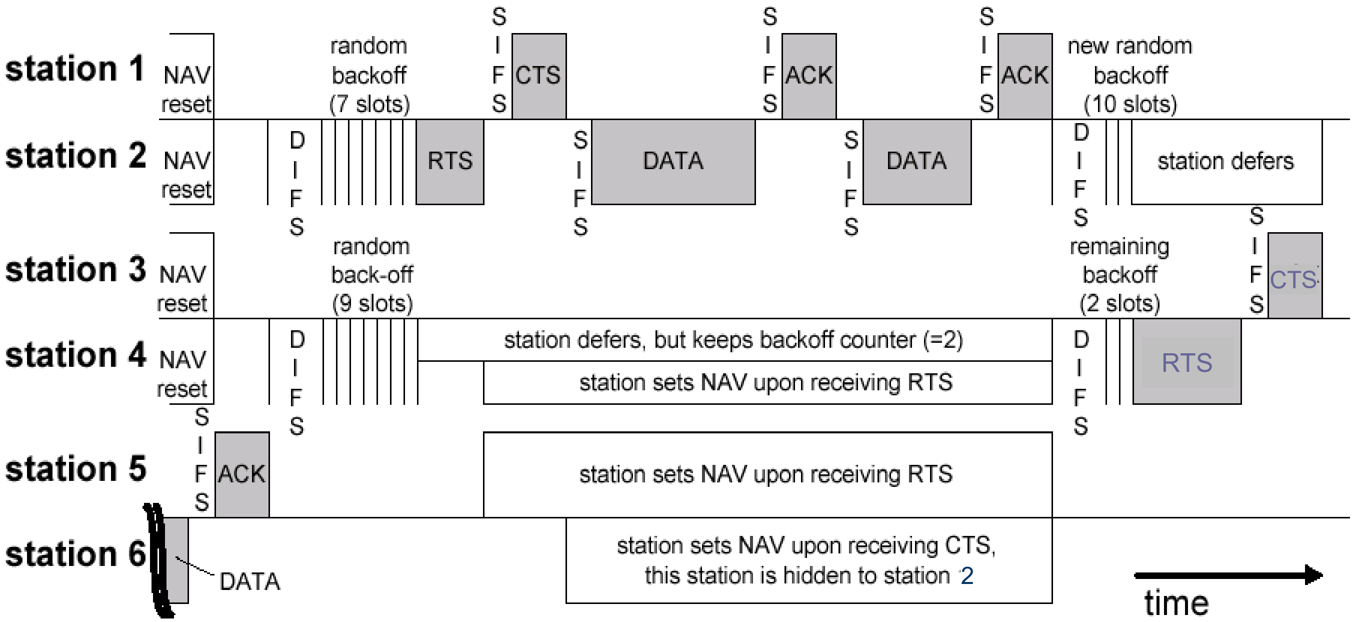
Example of DCF transmission



CW doubles after each collision

- Initial CW -> 3 (backoff 0-3)
- CW after Collision 1 → 7 (backoff 0-7)
- CW after Collision 2 → 15 (backoff 0-15)
- CW after Collision 3 → 31 (backoff 0-31)
- CW after Collision 4 → 63 (backoff 0-63)

Example of DCF transmission



CW doubles after each collision

- Initial CW -> 3 (backoff 0-3)
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- CW after Collision 2 → 15 (backoff 0-15)
- CW after Collision 3 → 31 (backoff 0-31)
- CW after Collision 4 → 63 (backoff 0-63)

How the Contention Window works

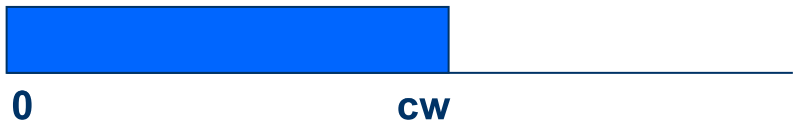
- Whenever a backoff occurs the backoff time is uniformly chosen in the range $[0, W-1]$
- After each unsuccessful transmission the backoff windows size is doubled, up to a maximum value
- Once the backoff window size reaches its maximum value it will stay at that value until it is reset
- The value of W will be reset after every successful transmission of a data or RTS packet, or when a retry counter reaches its limit

Collision Avoidance: Exponential Backoff

- Initial value of CW is CWmin
- For each collision, double the contention window CW
- Maximum value of CW is CWmax
- After successful transmission set contention window to CWmin

Collision Avoidance

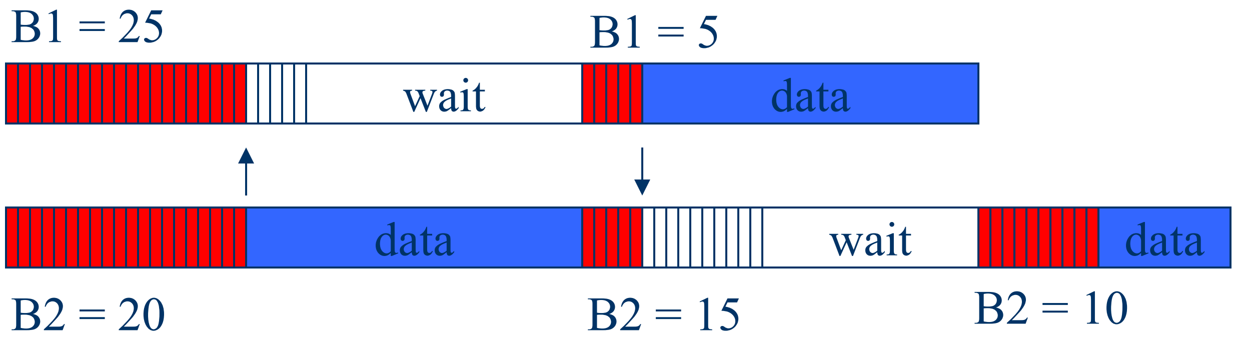
- Collision avoidance mechanism: When transmitting a packet, choose a backoff interval in the range [0,cw]
  - cw is contention window



- Count down the backoff interval when medium is idle
- When backoff interval reaches 0, transmit

Collision Avoidance: Example

Timer decremented only in **RED periods**



cw = 31

B1 and B2 are backoff intervals at nodes 1 and 2

Disadvantages of DCF

- Unpredictable collision number
- Unpredictable delay of successful transmission
- Unpredictable throughput
- Uncontrolled selection of station to transmit

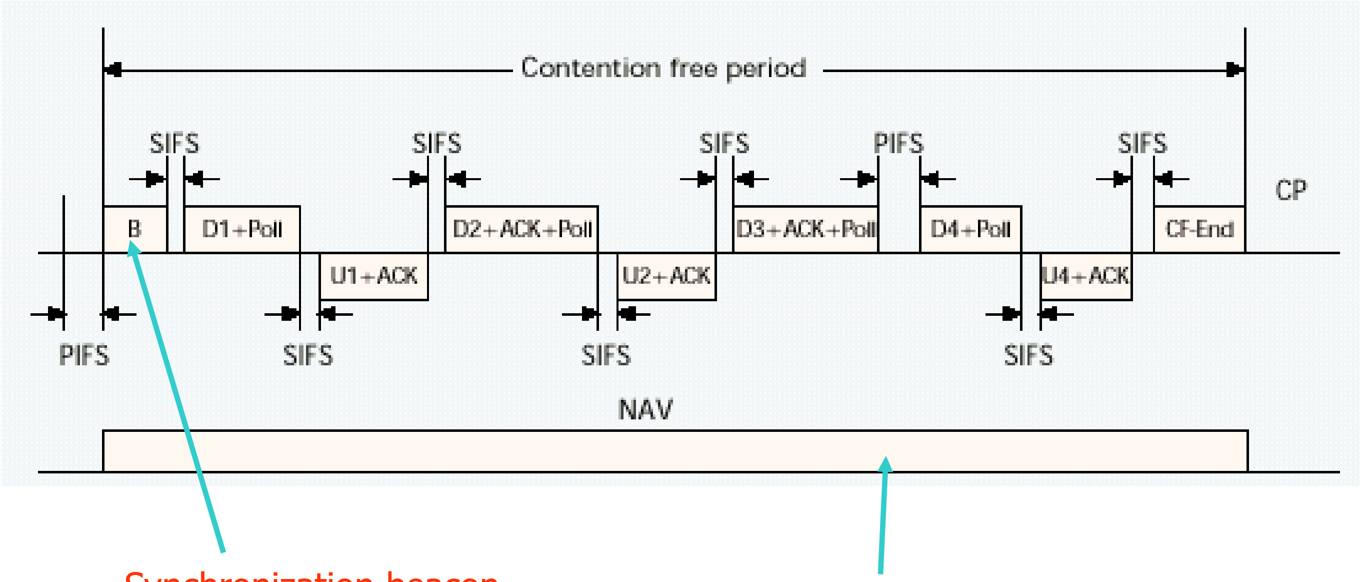
And one advantage:

- Low transmission delay and good performance for low traffic

Point Coordination Function (I)

- ✓ Activated by the AP whenever it decides to switch to contention-free period (e.g. when it observes large number of collisions)
- ✓ As a general rule, DCF for low traffic, PCF for high traffic
- ✓ In this mode the AP is referred to as Point Coordinator
- ✓ It has priority compared to DCF because it is activated for idle period PIFS<DIFS

Point Coordination Function (II)

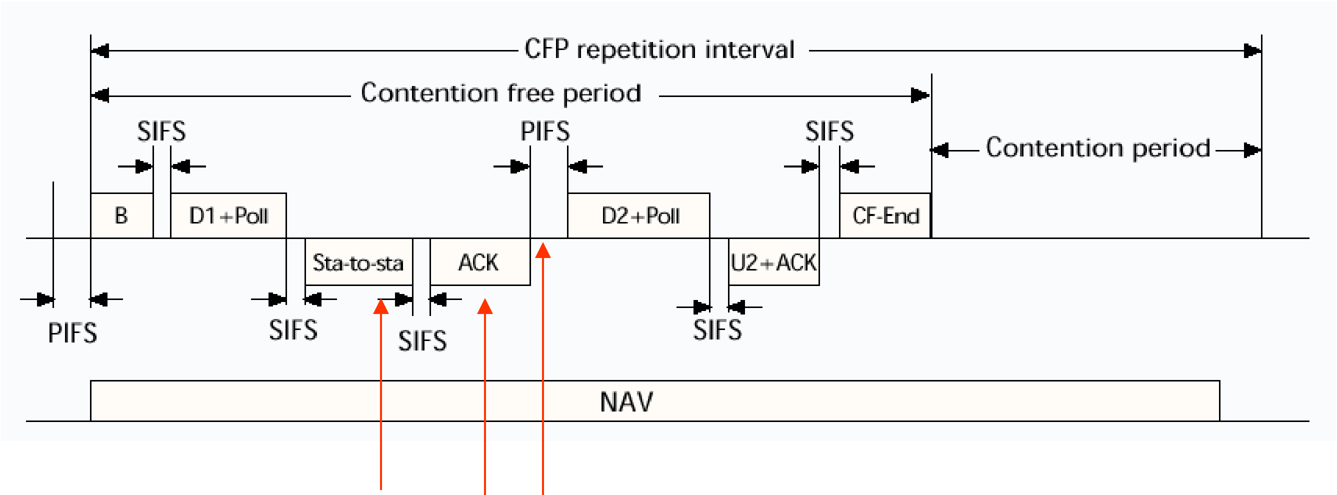


Synchronization beacon

Variable duration of
Contention Free Period

Point Coordination Function (III)

If a Station wants to transmit to another station during a CFP (contention-free period)



- When it is time to transmit, a STA chooses to transmit to aniother STA in the same BSS
- When the other STA receives data, replies with DCF Ack to the first STA
- AP waits for time equal to PIFS before continuing to the next STA (why?)

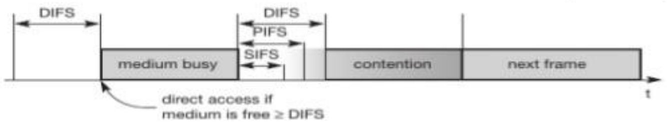
Main restrictions of PCF regarding QoS

- ✓ Terminals cannot send their requirements to AP
- ✓ AP has no way to interrupt an ongoing transmission to send the synchronization beacon* and pass to PCF mode
- ✓ Poll does not set the time the channel is given to a STA, which means that the STA can keep the channel for the maximum allowed time*

* Maximum packet (MPDU) allowed 4095 bytes = 32760 bits = 32,76 msec (for a 1Mbps channel)

Inter-Frame Spaces

Medium Access and Inter-frame Spacing



- **<u>Short inter-frame spacing (SIFS)</u>** – shortest waiting for medium access (highest priority) ex. Control msg.
- **<u>PCF inter-frame spacing (PIFS)</u>** – used for time bounded services.
- **<u>DCF inter-frame spacing (DCF)</u>** – longest waiting time and has the lowest priority for medium access.

[Contention – duration in which several nodes try to access the medium]

DIFS	-	34 μsec
PIFS	-	25 μsec
SIFS	-	16 μsec

- Inter frame spacing required for MAC protocol traffic
  - SIFS = Short interframe space
  - PIFS = PCF interframe space
  - DIFS = DCF interframe space
- Back-off timer expressed in terms of number of time slots

IEEE 802.11e
Quality of Service in 802.11

Best Effort vs. QoS

- Best Effort:
    - You get a link to the Internet with at most B bits/sec.
    - If you don't like it, switch to another provider.
- Quality of Service (QoS)
    - We provide you some kind of guarantees for:
        - Bandwidth
        - Latency
        - Jitter
    - I.e., network is engineered to provide some Quality beyond "Not to exceed B bits/s"

Two Styles of QoS

- Worse-case
  - Provide bandwidth/delay/jitter guarantee to every packet
  - E.g., “hard real time”
- Average-case
  - Provide bandwidth/delay/jitter guarantee over many packets
  - Statistical in nature
  - E.g. “Soft real time”

Worse-case : Guaranteed Services

- Service contract
  - Network to client: guarantee a deterministic upper bound on delay for each packet in a session
  - Client to network: the session does not send more than it specifies
- Algorithm support
  - Admission control based on worst-case analysis
  - Per flow classification/scheduling at routers

Extensions introduced by 802.11e

- AP is called Hybrid Coordinator (HC) implementing Hybrid Coordination Function (HCF) that includes two modes of operation:

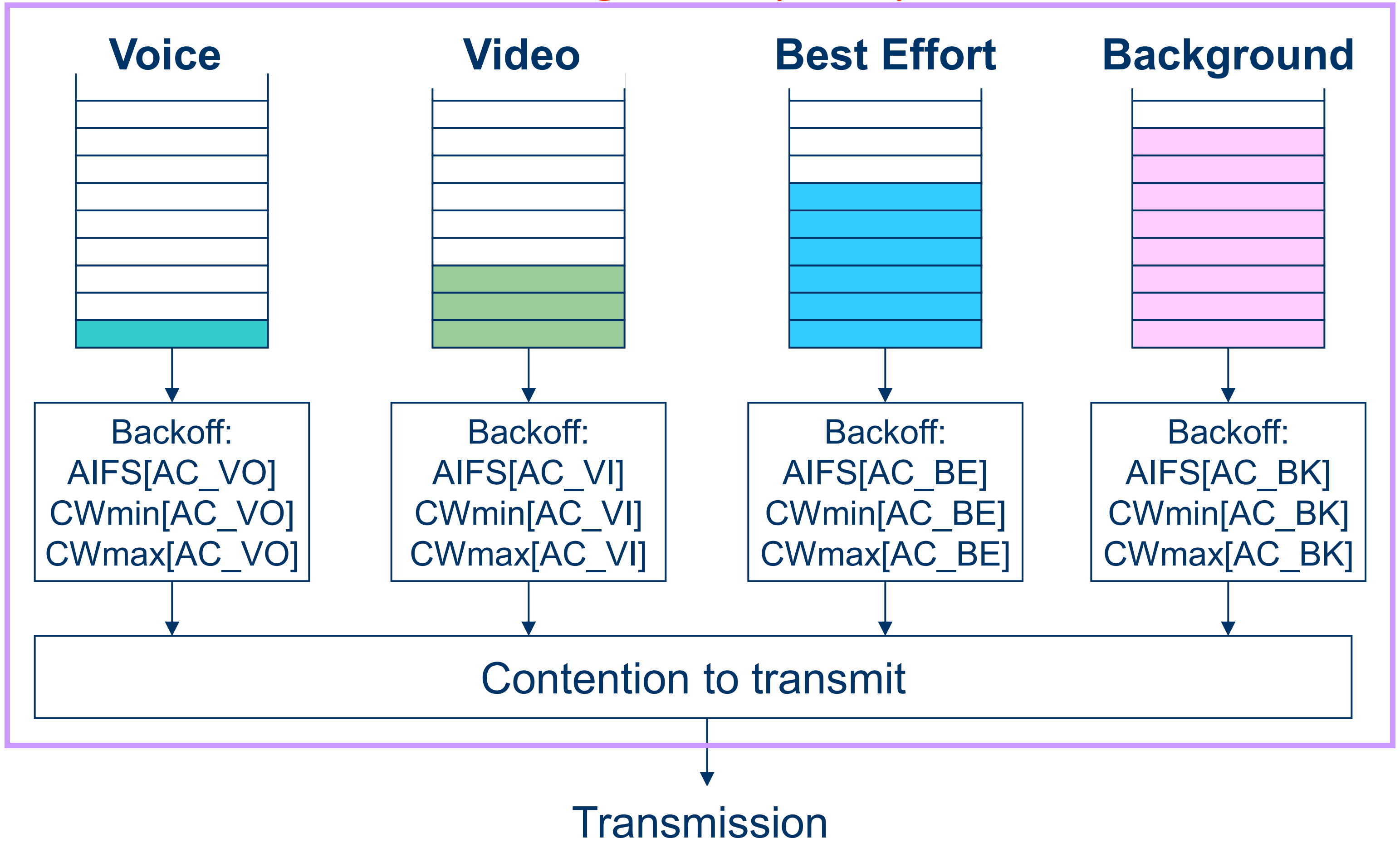
- EDCA (Enhanced Distributed Coordination Access): Different traffic classes in DCF with different behavior and medium access probabilities

- HCCA (HCF Control Channel Access): Improving weaknesses of PCF (beacon transmission, controlled reservation time, queue size information)

EDCA

(Enhanced Distributed Coordination Access)

- CSMA/CA and Exponential Backoff
- Four Access Categories (ACs) within one station



EDCA

(Enhanced Distributed Coordination Access)

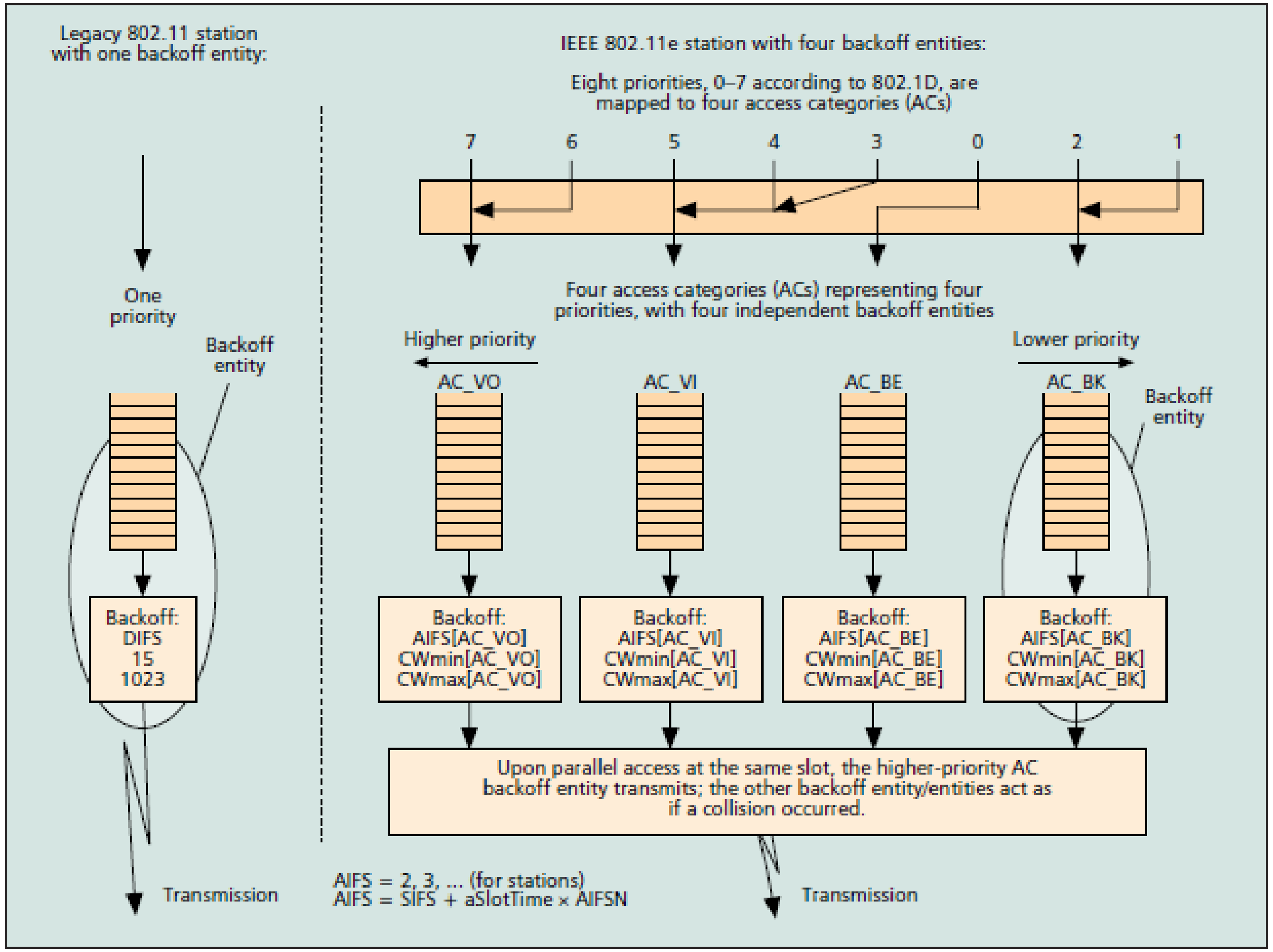
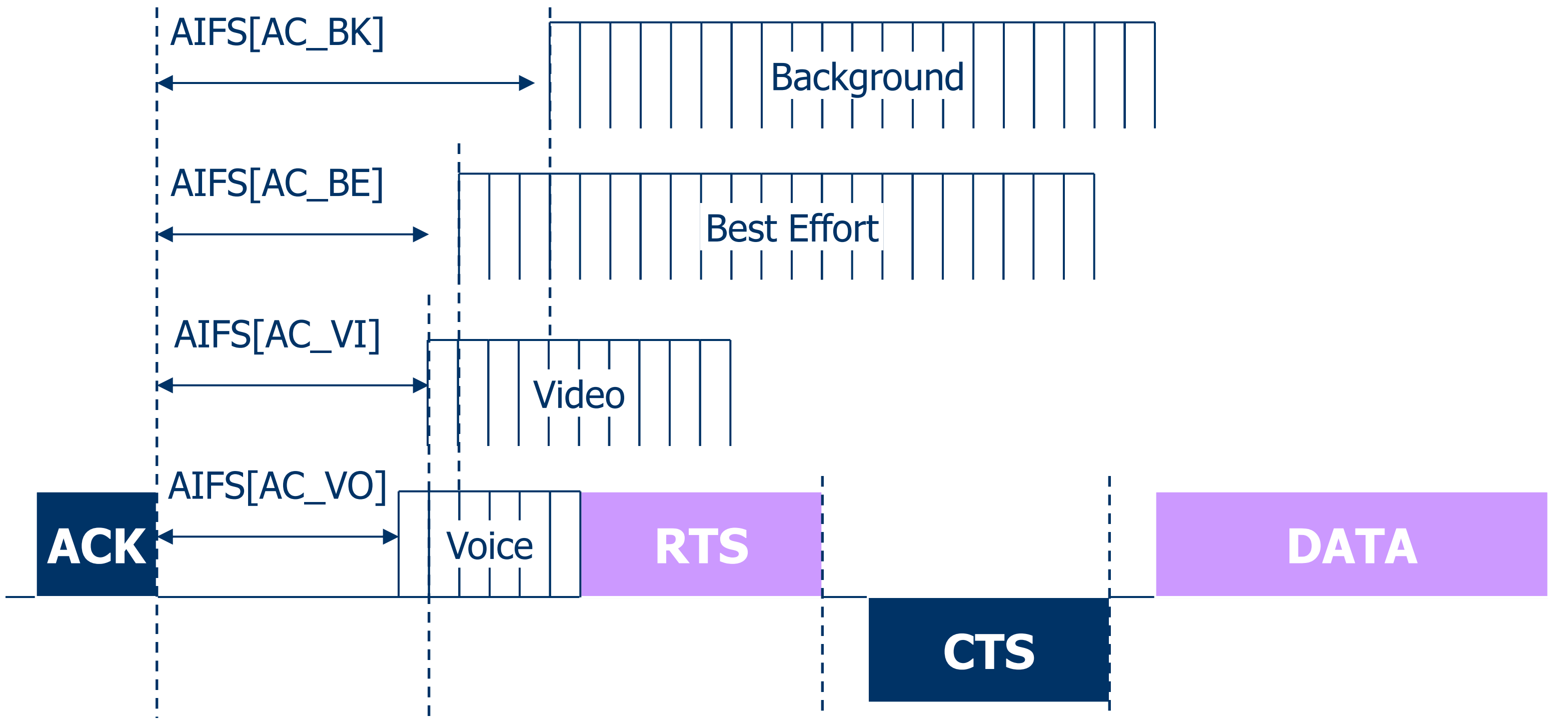
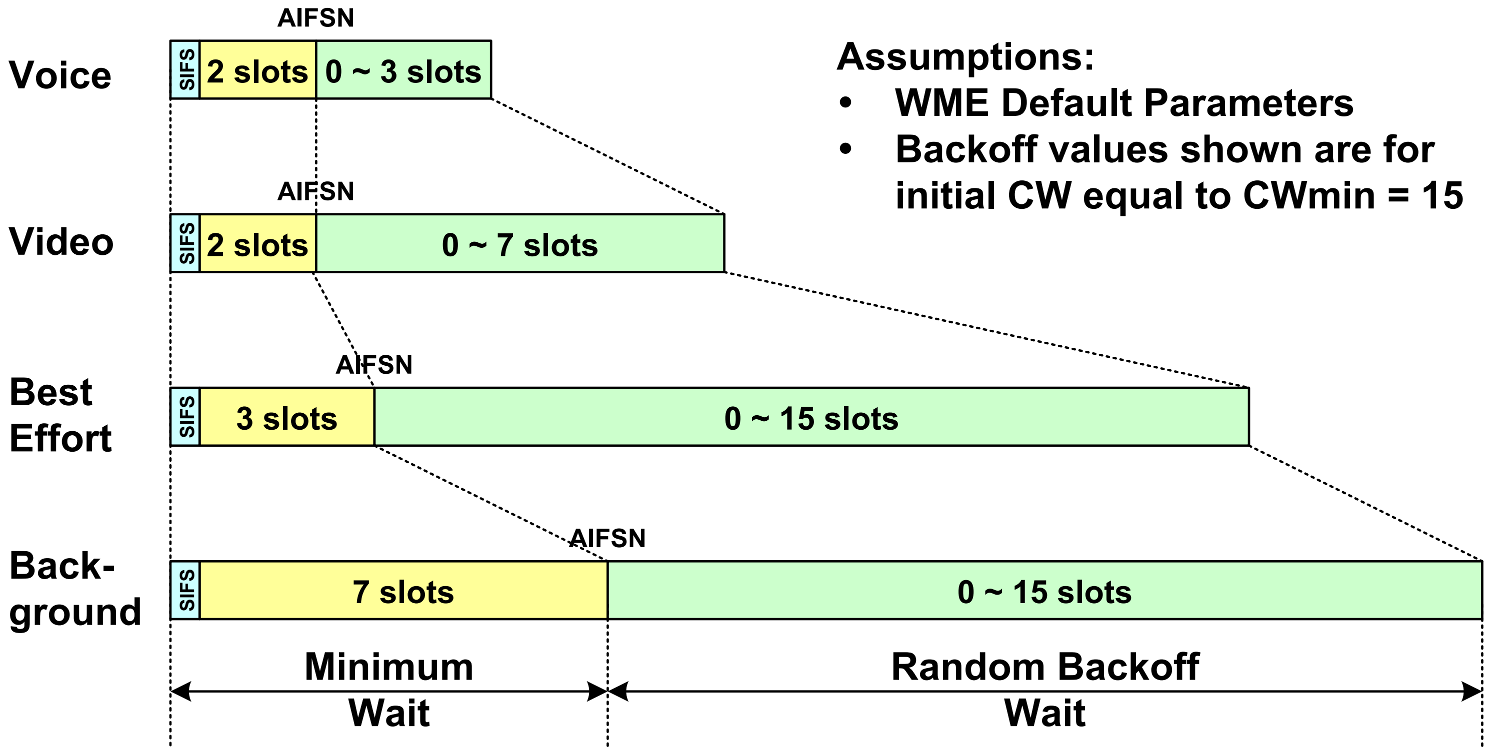


Figure 4. *[3] Legacy 802.11 station and 802.11e station with four ACs within one station.*

Inter Frame Space και Contention Window



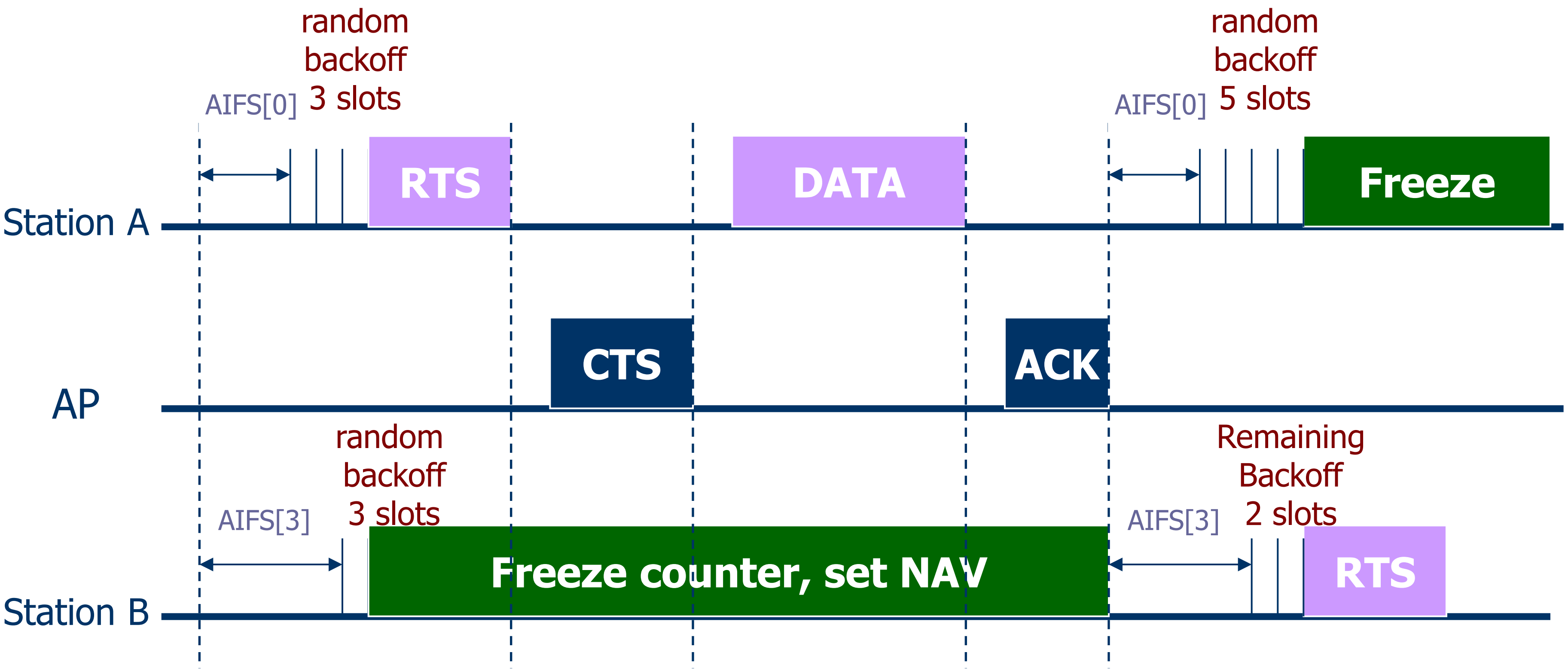
Inter Frame Space και Contention Window



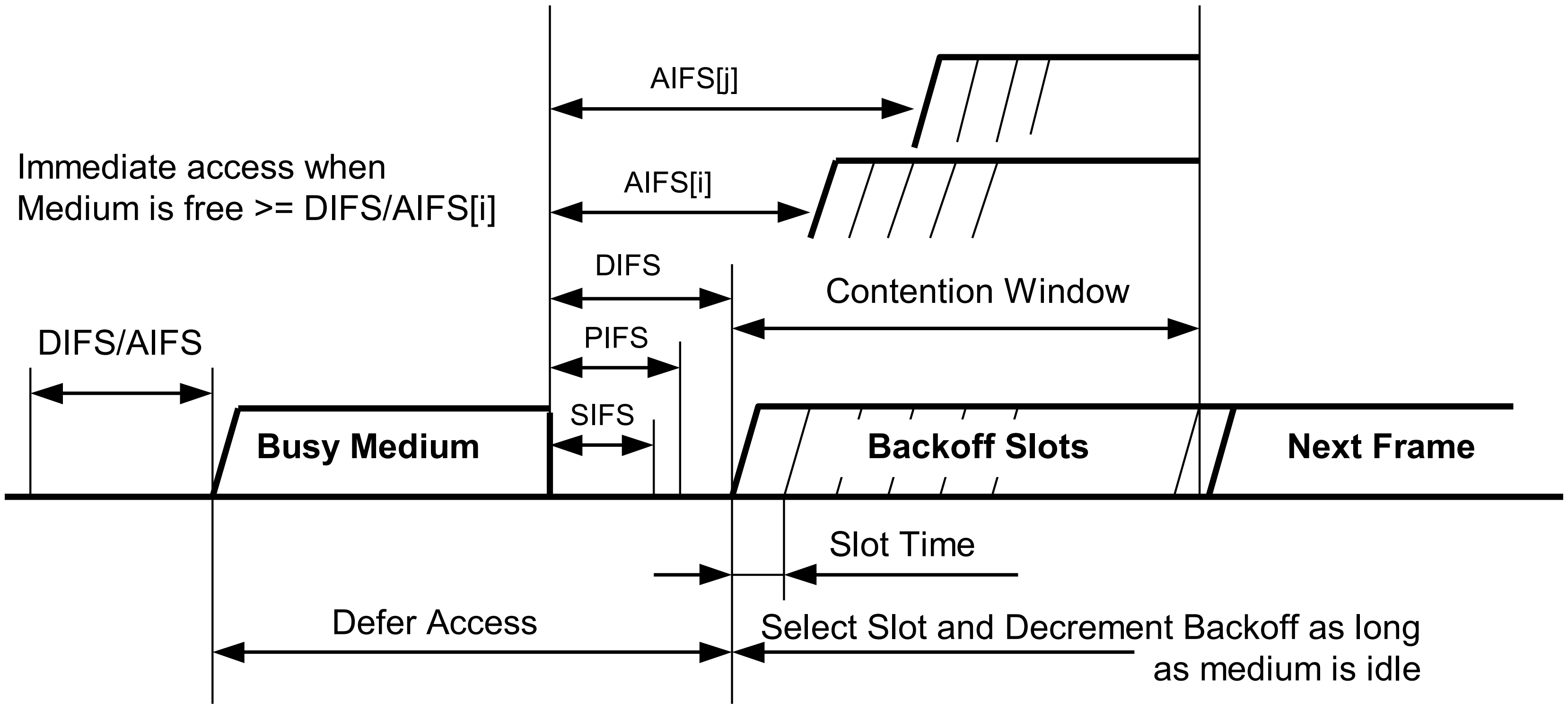
Assumptions:

- WME Default Parameters
- Backoff values shown are for initial CW equal to CWmin = 15

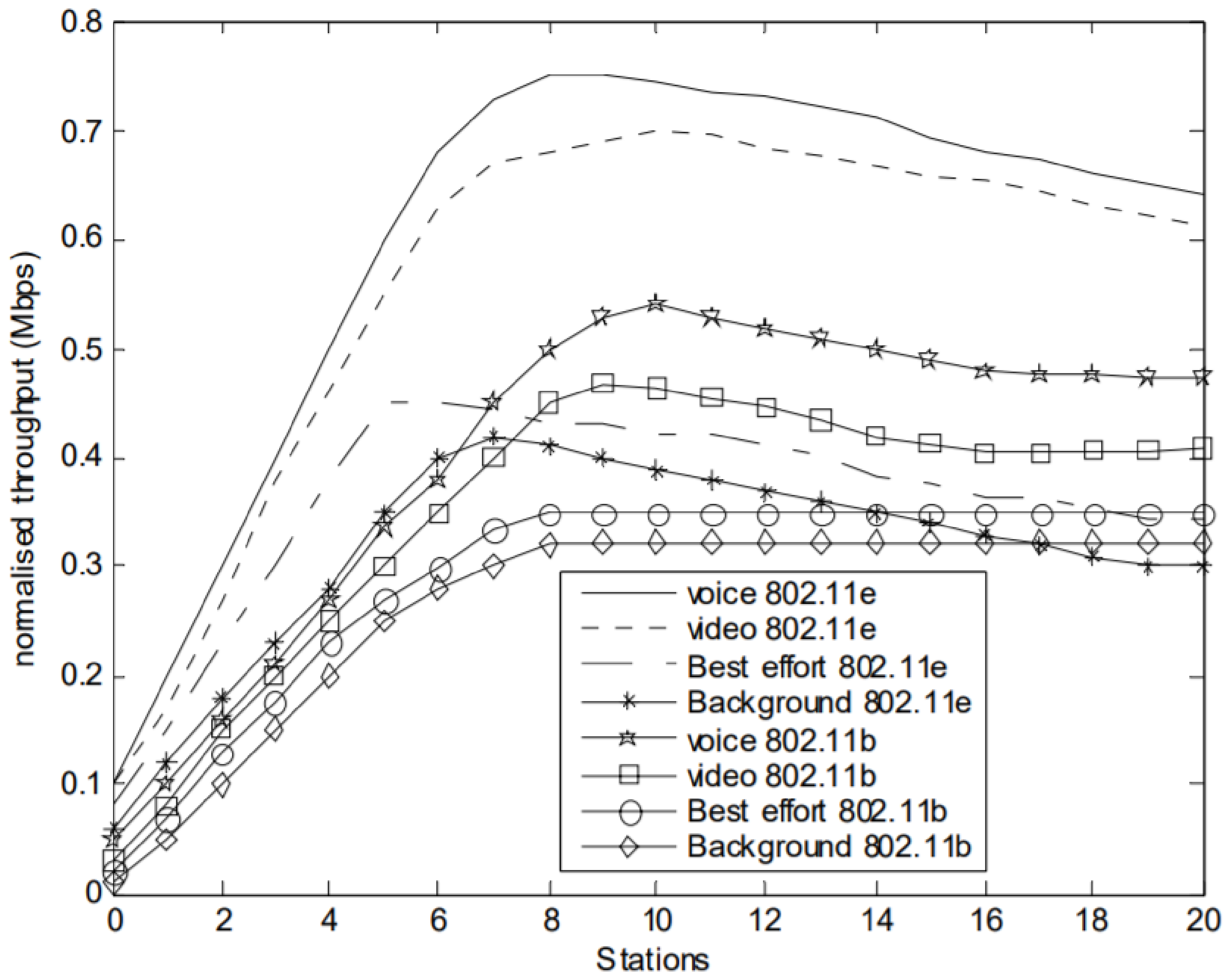
Contention in EDCA



Contention in EDCA



EDCA performance



Transmission Opportunity (TXOP)

- A TXOP is defined by a starting time and a maximum duration.
- Two types of TXOP: *EDCA TXOP* and *Polled TXOP*.
  - An EDCA TXOP begins when the wireless medium is determined to be available under the EDCA rules, and the length of TXOP is specified in beacon frames.
  - An Polled TXOP begins when a QSTA receives a QoS(+)CF-Poll from HC, and the length of TXOP is specified in the QoS(+)CF-Poll.

HCF Controlled Access – Introduction

- Differences between hybrid coordinator (HC) and point coordinator (PC):
  - HC can poll QSTAs in both CP and CFP
  - HC grants a polled TXOP to one QSTA, which restricts the duration of the QSTA's access to the medium.

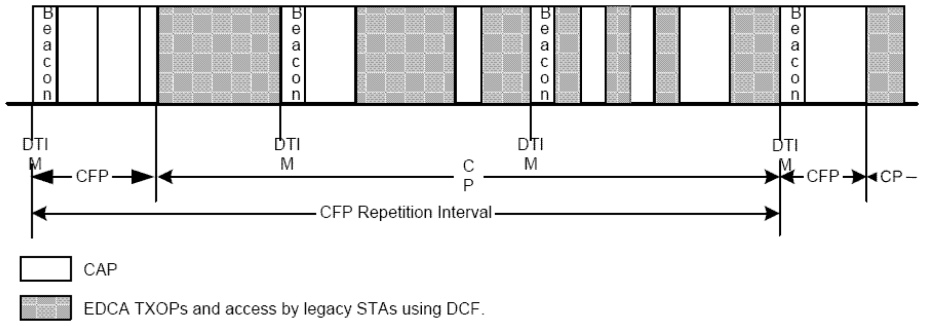
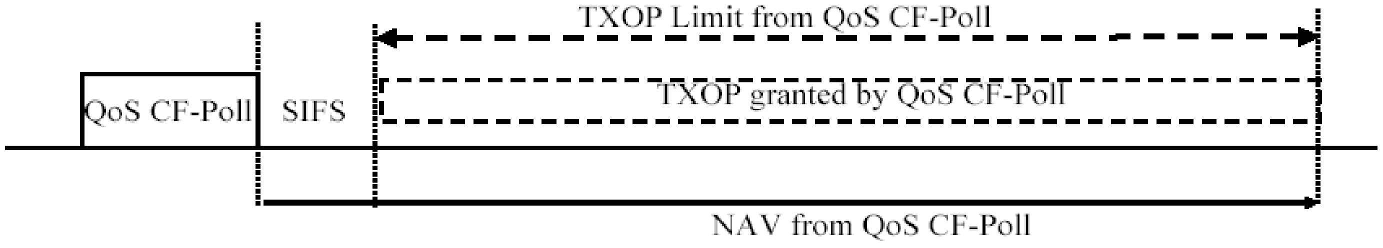
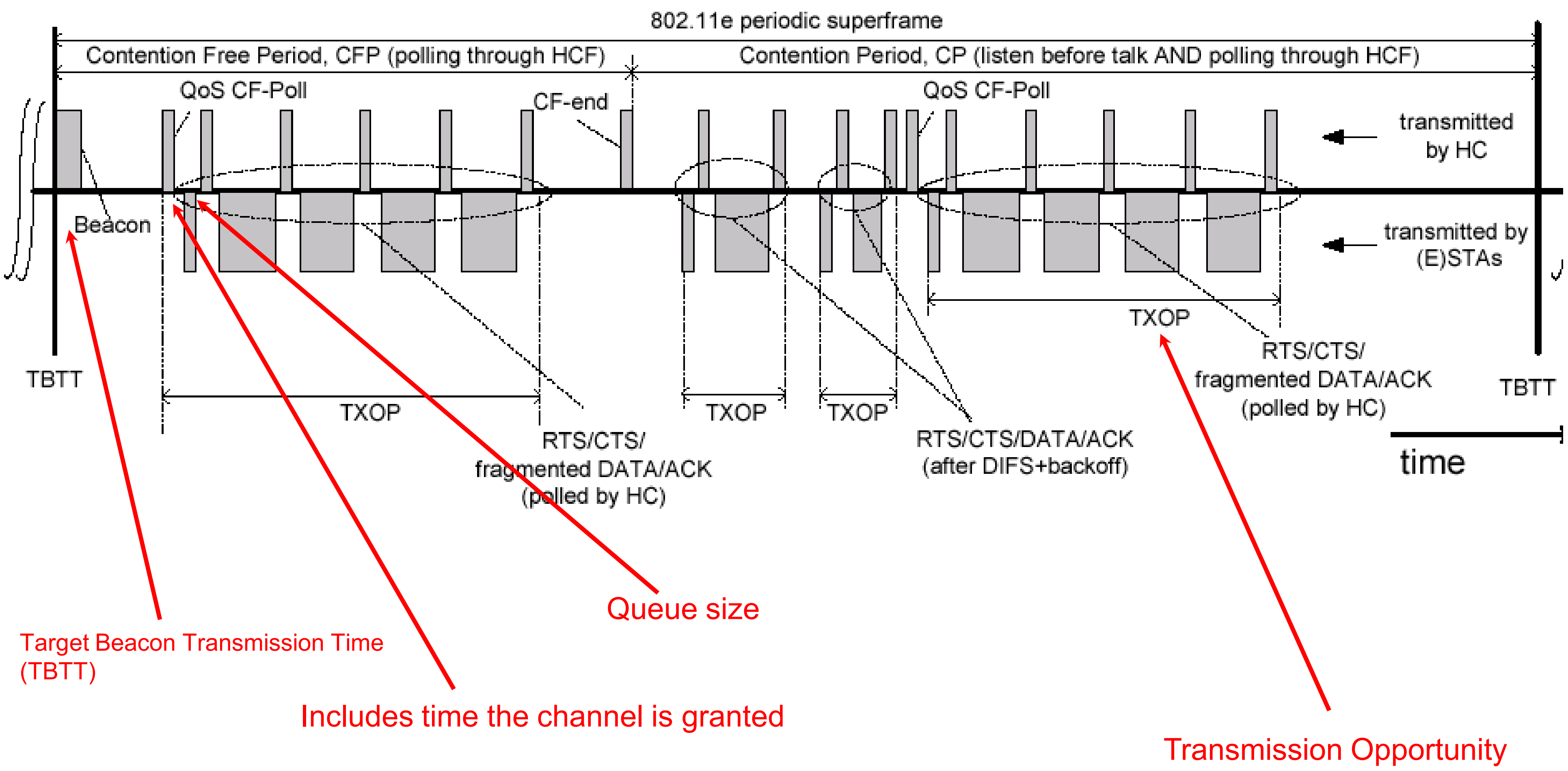


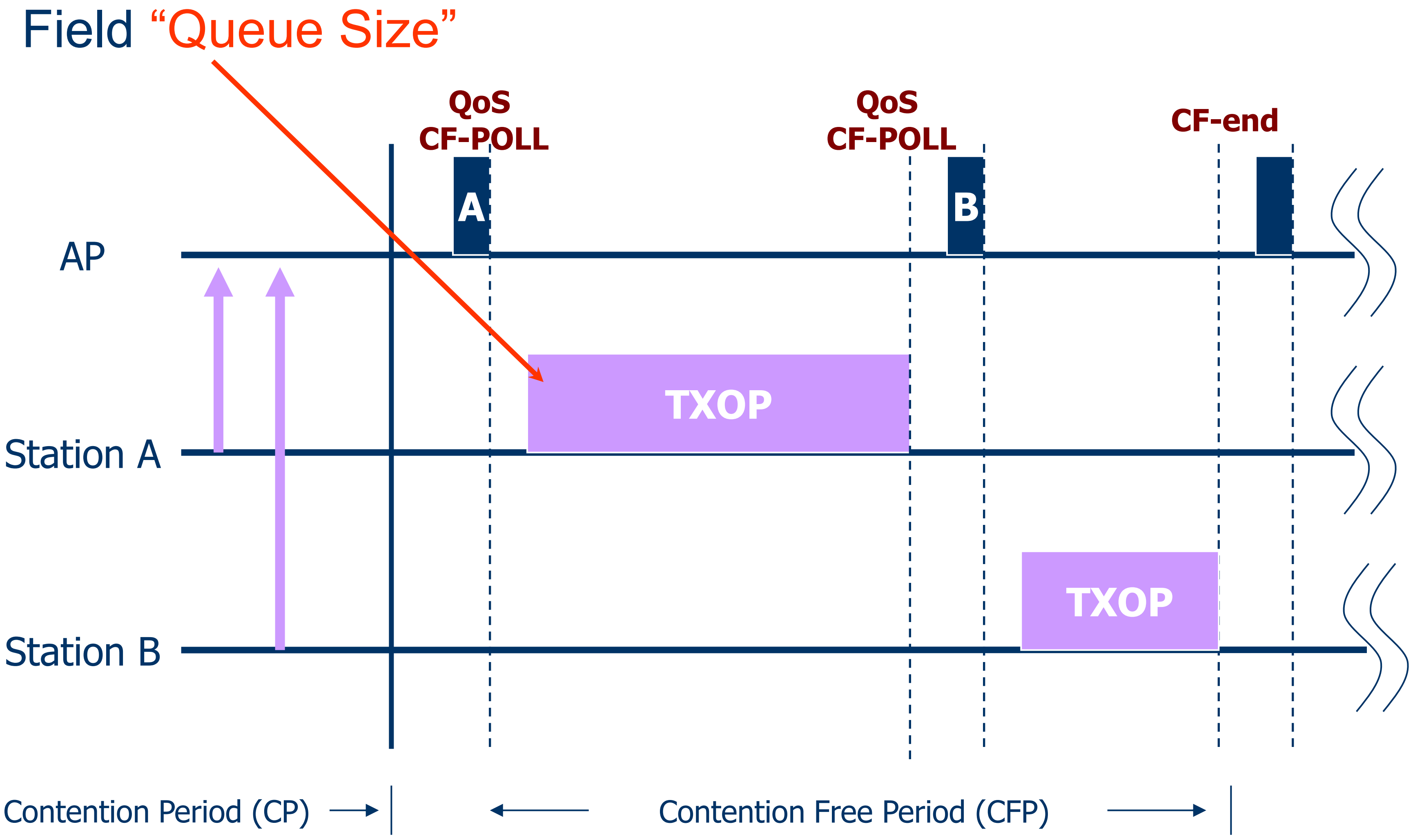
Figure 62c—CAP/CFP/CP periods



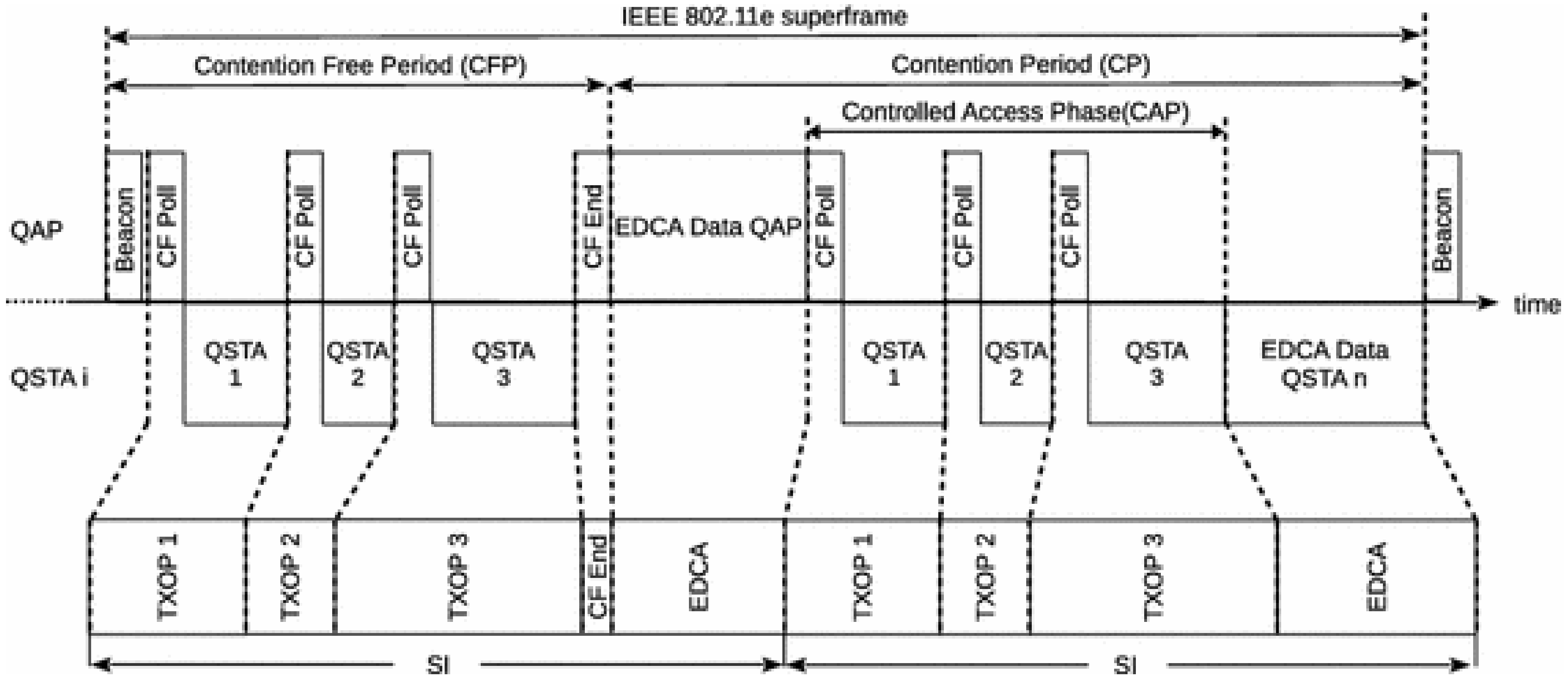
HCCA
(HCF Control Channel Access)



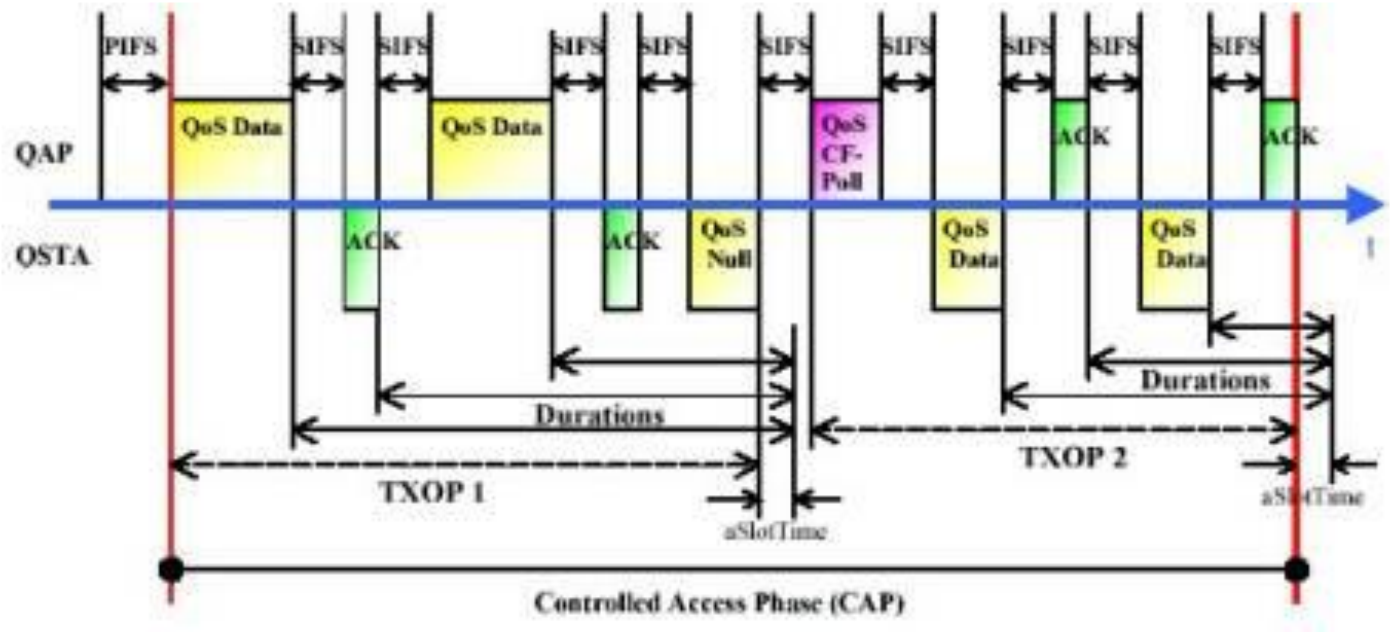
Reservation with HCCA



Reservation with HCCA



Reservation with HCCA



QoS CF-Poll	Transmitted by QAP to grant a HCCA-TXOP, no data.
QoS-Data+CF-Poll	Transmitted by QAP to grant a HCCA-TXOP, with data.
QoS-Null	Transmitted by QSTA when it has no more data, or it is the last frame of the TXOP.
QoS-Data	QoS data transfer between QAP and QSTA. Used by EDCA as well as HCCA.
QoS CF-Ack	Transmitted by QAP in response to QoS-Null requesting a TXOP, no data.
QoS-Data+CF-Ack	Transmitted by QAP in response to QoS-Null requesting a TXOP, with data.
QoS CF-Ack+CF-Poll, QoS-Data+CF-Ack+CF-Poll	Generally not used.

Factors Affecting Wireless QoS

- QoS of wireless network is affected by the following:
  - Attenuation,
  - Multi-path interference,
  - Spectrum interference: for example interferences from neighboring cells,
  - Noise: Noise sources can be natural and man-made such as radio, TV and other radio-frequency transmission,
  - Mobility: affects hand-over and resource utilization, management,
  - Limited capacity: resources are costly.
- Higher error rates are typical

Core Network QoS Components

- **Admission Control**: Limits number of flows admitted into the network so that each individual flow obtains its desired QoS.

- **Scheduling**:
  - Scheduling affects delay, jitter and loss rate.
  - Allows protection against misbehaving flows.
  - Takes into account traffic and channel conditions

Traffic Scheduling in 802.11e