IEEE 802.11e Enhanced QoS

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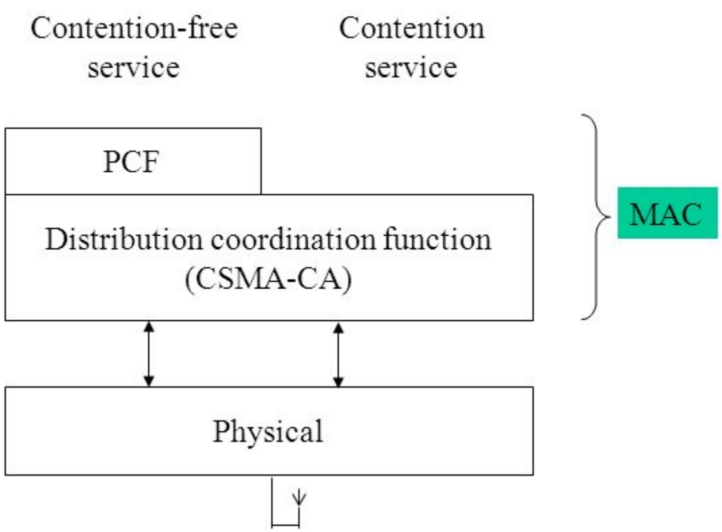
Outlines

- Introduction
- Traffic Differentiation
- Hybrid Coordination Function (HCF)
  - Contention-Based Channel Access – EDCA
  - Controlled Channel Access – HCCA
- Block Acknowledgement
- Direct Link Protocol (DLP)

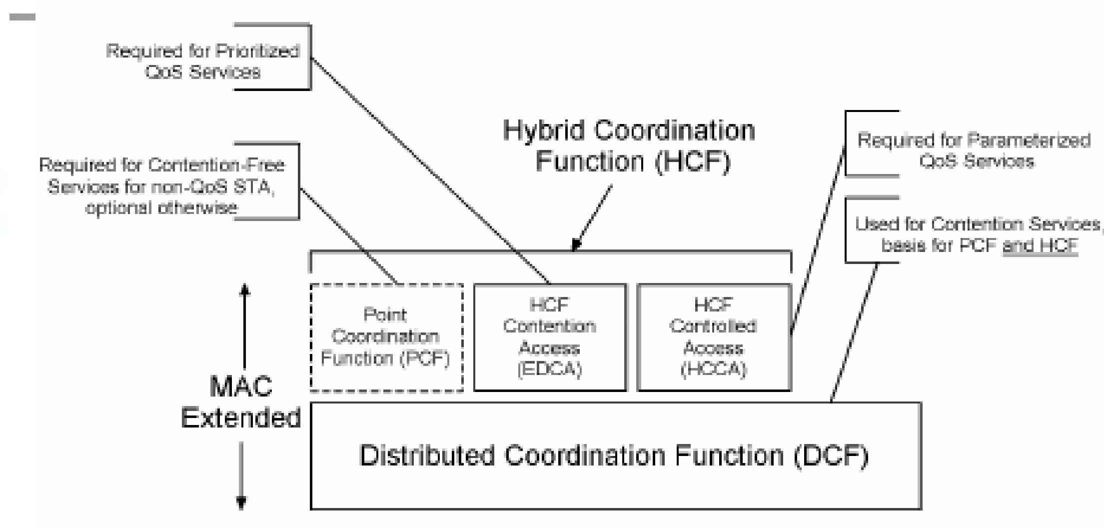
Characteristics of IEEE 802.11e

- The major enhancement of 802.11e
  - Traffic differentiation
  - Concept of Transmission Opportunity (TXOP)
  - Enhanced DCF (contention-based)
  - HCP controlled channel access (contention free)
  - Burst ACK (optional)
  - Direct link protocol (DLP)

MAC Architecture



IEEE 802.11 MAC Architecture



IEEE 802.11e MAC Architecture

- DCF : A contention-base access for 802.11.
- PCF : An option to support contention-free access in 802.11.
- *Hybrid Coordination Function* (HCF): IEEE 802.11 Task Group E (TGe) proposes HCF to provide QoS for real-time applications.

Characteristics of Media Streams

- Media Streams
  - Audio
    - Speech
      - Uncompressed – e.g. 64 kbps Pulse Code Modulation (PCM)
      - Compressed: e.g. ITU-T G.723.1, G.729, …
      - Low bit rate & Constant bit rate
    - Music
      - Uncompressed – e.g. CD: 16bit, 44.1khz
      - Compressed: e.g. MP2, MP3, …
      - Medium bit rate & Variable/Constant bit rate
  - Video
      - Compressed – e.g. Mpeg-1, Mpeg-2, Mpeg-4, …
      - High bit rate & Variable/Constant bit rate

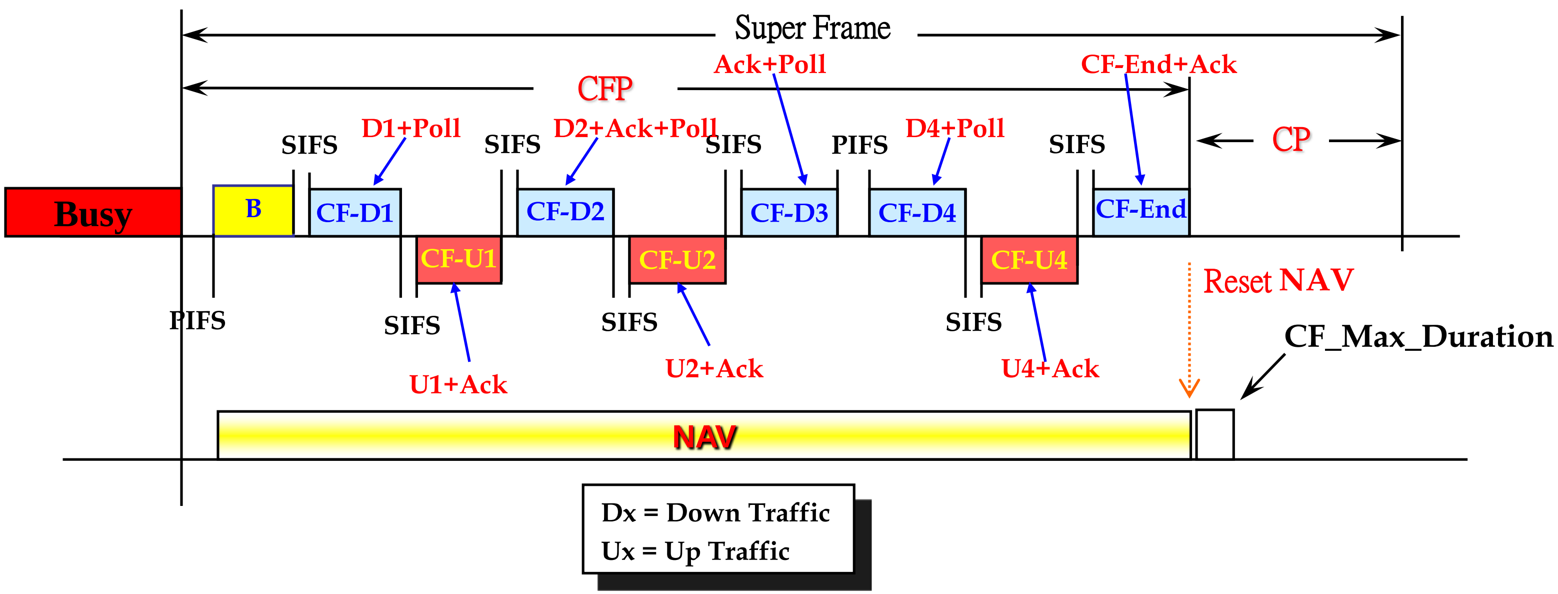
Characteristics of Media Streams (Cont.)

- Requirements of QoS
  - Controlled transmission rate
    - Peak rate & Average rate
  - Controlled Service Interval
    - Minimum & Maximum
  - Burst Size
  - Bounded Delay !
  - Bounded Jitter !
    - Solution in device: Jitter Buffer
    - Solution in network: Prioritized Transmission

Is 802.11 enough for QoS?

- DCF can not provide QoS trivially
- PCF is not enough
  - Only 1 frame can be sent at each polling
  - Point Coordinator (PC) does not know the QoS requirement of traffic
  - Can not guarantee the delay and jitter bound

PCF


Super Frame
CFP
CP
Ack+Poll
CF-End+Ack
SIFS
D1+Poll
SIFS
D2+Ack+Poll
SIFS
PIFS
D4+Poll
SIFS
Busy
B
CF-D1
CF-D2
CF-D3
CF-D4
CF-End
CF-U1
CF-U2
CF-U4
PIFS
SIFS
SIFS
SIFS
Reset NAV
CF_Max_Duration
U1+Ack
U2+Ack
U4+Ack
NAV
Dx = Down Traffic
Ux = Up Traffic

Brief of IEEE 802.11e

- Defined at IEEE 802.11 Task Group E
- Goal: Providing QoS
  - Minimize Latency
    - Jitter
    - Delay variations
  - Maximize throughput
  - Define traffic models for both Ad-hoc and Infrastructure
- Enhance the MAC (802.11)

Brief of IEEE 802.11e (Cont.)

- The major enhancement of 802.11e
  - Traffic Differentiation
  - Concept of Transmission Opportunity (TXOP)
  - Enhanced Distributed Channel Access (EDCA) (*Contention-Based*)
  - HCF Controlled Channel Access (HCCA) (*Contention Free*)
  - Block ACK
  - Direct Link Protocol (DLP)

Terms

- QoS Facility
  - The mechanisms for QoS defined in 802.11e
- QAP
  - Access Point supporting QoS facility
- QSTA
  - Station supporting QoS facility
- QBSS
- Hybrid Coordinator (HC)
- Access Category (AC)
- User Priority (UP)
- Traffic Category (TC)
- Traffic Specification (TSPEC)
- Traffic Stream (TS)
- Traffic Identifier (TID)

Traffic Differentiation

Classification of QoS Data

- New frame subtype: QoS Data
- Each MSDU of QoS Data is classified as one kind of traffic
  - Identified by TID field in frame header
- Two types of traffic classification
  - By User Priority (TC)
    (for prioritized QoS)
  - By Traffic Specification (TSPEC)
    (for parameterized QoS)

User Priority

- 8 User Priorities:
  - Identical to IEEE 802.1D priority tags

Priority	User Priority (same as 802.1D user priority	802.1D Designation	Access category (AC)	(Informative)
Lowest	**1**	BK	**AC_BK**	Background
↓	**2**	-	**AC_BK**	Background
	<u>0</u>	**<u>BE</u>**	**<u>AC_BE</u>**	**<u>Best Effort</u>**
	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

IEEE 802.1p traffic types

Table A.1—IEEE 802.1p traffic types

User priority	Traffic type	Used for:	Comments
0 (default)	Best effort (BE)	Asynchronous data	Default piconet traffic
1	Background (BK)	Asynchronous data	
2	-	A spare	Currently not assigned
3	Excellent effort (EE)	Isochronous	For valued customers
4	Controlled load (CL)	Isochronous	Traffic will have to conform to some higher protocol layer admission control
5	Video (VI)	Isochronous	< 100 ms delay and jitter
6	Voice (VO)	Isochronous	< 10 ms delay and jitter
7	Network control (NC)		

User Priority (cont.)

- Priority Determination of MSDU
  - Directly: provided at MAC SAP
  - Indirectly: defined in TSPEC's

User Priority (Cont.)

- Access Category (AC)
  - In EDCA, media access is based on the AC of MSDU
  - 4 ACs are defined
    - AC_BK (background)
    - AC_BE (best-effort)
    - AC_VI (Video)
    - AC_VO (Voice)
  - The size of Contention-Window (CW) and Inter-frame space (IFS) is dependent on AC

Traffic Specification

- Traffic Specification (TSPEC)
  - Characteristics of traffic streams created by negotiation between QSTA and Hybrid Coordinator (HC)
  - Hybrid Coordinator can schedule the polling within CFP and the data transmission of the traffic stream accordingly
- TSPEC Setup & Delete
  - Use Management Frame with new subtype Action containing TSPEC Element

Frame Formats

MAC frame format:

octets: 2	2	6	6	6	2	6	2	n	4
Frame Control	**Duration / ID**	**Address 1**	**Address 2**	**Address 3**	**Sequence Control**	**Address 4**	**QoS Control**	**Frame Body**	**FCS**

MAC Header

QoS Control Field:

Applicable Frame (sub) Types	Bits 0-3	Bit 4	Bits 5-6	Bit 7	Bits 8-15
QoS (+)CF-Poll frames sent by HC	TID	EOSP	Ack Policy	Reserved	TXOP limit in units of 32 microseconds
QoS Data, QoS Null, QoS CF-Ack and QoS Data+CF-Ack frames sent by HC	TID	EOSP	Ack Policy	Reserved	Reserved
QoS data type frames sent by non-AP QSTAs	TID	0	Ack Policy	Reserved	TXOP duration requested in units of 32 microseconds
	TID	1	Ack Policy	Reserved	Queue size in units of 256 octets

Traffic Identifier (TID)

Frame Formats (cont.)

- QoS control field,
  - TID: Traffic Identifier
  - EOSP: End of Service Period
    - EOSP is used by the HC to indicate the end of the current service period (SP) after the successful transmission of the current frame.
    - The More Data Bit is used to indicate whether there are MSDUs buffered at the AP at the end of the SP.

Traffic Identified (TID)

- Distinguish MSDUs of different traffic types
- Range: 0-15

Bits 0-3	Usage
0-7	UP for prioritized QoS (TC)
8-15	TSID for parameterized QoS (TS)

Traffic Category (TC)
Traffic Stream (TS)

ACK Policy

Bit in QoS Control field:

Bit 5	Bit 6	Meaning
0	0	Normal acknowledgement. The addressed recipient returns an ACK or QoS (+) CF-ACK frame after a SIFS period, according to the procedures defined in 9.2.8, 9.3.3 and 9.9.2.3. The Ack Policy field is set to this value in all directed frames in which the sender requires acknowledgement. For QoS Null (no data) frames, this is the only permissible value for the Ack Policy field.

Bit 5	Bit 6	Meaning
1	0	No Acknowledgement. The addressed recipient takes no action upon receipt of the frame. More details are provided in 9.11. The Ack Policy is set to this value in all directed frames in which the sender does not require acknowledgement. For QoS CF-Ack frames, this is the only permissible value for the Ack Policy field. This combination is also used for broadcast and multicast frames that use the QoS frame format.
0	1	No Explicit Acknowledgement. There may be a response frame to the frame that is received, but it is neither the ACK nor any Data frame of subtype +CF-Ack. For Data frames of subtype QoS CF-Poll and subtype QoS CF-Ack+CF-Poll , this is the only permissible value for the Ack Policy field.
1	1	Block Acknowledgement. The addressed recipient takes no action upon the receipt of the frame except for recording the state. The recipient can expect a BlockAckReq frame in the future to which it responds using the procedure described in 9.10.

Ack Policy

- Normal ACK: An ACK or QoS CF-ACK is required after a SIFS.
- No ACK: No required ACK response.
- No Explicit ACK: There may be a response frame, but it is neither the ACK nor any Data frame of subtype +CF-ACK. (e.g., QoS CF-Poll, or QoS CF-ACK+CF-Poll).
- Block ACK: Instead of transmitting an individual ACK for every MPDU (i.e., frame), multiple MPDUs can be acknowledged together using a single Block ACK frame.

Frame Control Field

B0–B1	B2–B3	B4–B7	B8	B9	B10	B11	B12	B13	B14	B15
Protocol Version	Type	Subtype	To DS	From DS	More Frag	Retry	Pwr Mgt	More Data	WEP	Order
Bits: 2	2	4	1	1	1	1	1	1	1	1

HCF Controlled Access - New Data/Management/Control Frames

Type value b3 b2	Type description	Subtype value b7 b6 b5 b4	Subtype description
10	Data	1000–~~1111~~	QoS Data~~Reserved~~
10	Data	1001	QoS Data + CF-Ack
10	Data	1010	QoS Data + CF-Poll
10	Data	1011	QoS Data + CF-Ack + CF-Poll
10	Data	1100	QoS Null (no data)
10	Data	1101	Reserved
10	Data	1110	QoS CF-Poll (no data)
10	Data	1111	QoS CF-Ack + CF-Poll (no data)
00	Management	1101	Action
01	Control	1000	Group Acknowledgement Request (GroupAckReq)
01	Control	1001	Group Acknowledgement (GroupAck)

Queue size field

- 8-bit field that indicates the amount of buffered traffic for a given TC or TS at the non-AP QSTA sending this frame.
- The queue size value is the total size, rounded up to the nearest multiple of 256 octets and expressed in units of 256 octets.
  - value of 0 indicates the absence of any buffered traffic in the queue used for the specified TID
  - value of 254 is used for all sizes greater than 64768 octets
  - value of 255 is used to indicate an unspecified or unknown size

TXOP

- A TXOP is defined by a starting time and a maximum duration.
- Two types of TXOP: EDCF TXOP and Polled TXOP.
  - An EDCF TXOP begins when the wireless medium is determined to be available under the EDCF 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.

TXOP duration requested

- An 8-bit field that indicates the duration, in units of 32 microseconds, which the sending station desires for its next TXOP.
- The range of time values is 32 to 8160 microseconds.
- TXOP duration requested field values are not cumulative.
- The TXOP duration requested is inclusive of the PHY overhead.

Duration/ID field

- Within all data type frames containing QoS CF-Poll, the Duration/ID value is set to
  - SIFS + TXOP Duration Limit

TSPEC Element Format

Octets: 1	1	3	2	2	4	4	4	4
Element ID (13)	Length (55)	TS Info	Nominal MSDU Size	Maximum MSDU Size	Minimum Service Interval	Maximum Service Interval	Inactivity Interval	Suspension Interval

4	4	4	4	4	4	4	2	2
Service Start Time	Minimum Data Rate	Mean Data Rate	Peak Data Rate	Maximum Burst Size	Delay Bound	Minim um PHY Rate	Surplus Bandwidth Allowance	Medium Time

TS Info:

B0	B1 B4	B5 B6	B7 B8	B9	B10	B11 B13	B14 B15	B16	B17 B23
Traffic Type	TSID	Direction	Access Policy	Aggregation	APSD	User Priority	TSInfo Ack Policy	Schedule	Reserved
Bits: 1	4	2	2	1	1	3	2	1	7

Traffic Classification (TCLAS) Element

- For identifying the Traffic Stream (TS) to which the incoming MSDUs belong

Octets: 1	1	1	L
Element ID (14)	Length (L+1)	User Priority	Frame Classifier

Octets: 1	1	1-253
Classifier Type	Classifier Mask	Classifier Parameters

Traffic Classification (TCLAS) Element

Classifier Type	Classifier Parameters
0	Ethernet parameters
1	TCP/UDP IP parameters
2	IEEE 802.1D/Q Parameters
3 – 255	Reserved

Type 0

Octets: 1	1	6	6	2
Classifier Type (0)	Classifier Mask	Source Address	Destination Address	Type

Type 1 (IPv4)

Octets: 1	1	1	4	4	2	2	1	1	1
Classifier Type (1)	Classifier Mask	Version	Source IP Address	Destination IP Address	Source Port	Destination Port	DSCP	Protocol	Reserved

Type 1 (IPv6)

Octets: 1	1	1	16	16	2	2	3
Classifier Type (1)	Classifier Mask	Version	Source IP Address	Destination IP Address	Source Port	Destination Port	Flow Label

Type 2

Octets: 1	1	2
Classifier Type (2)	Classifier Mask	802.1Q Tag Type

Hybrid Coordination Function (HCF)

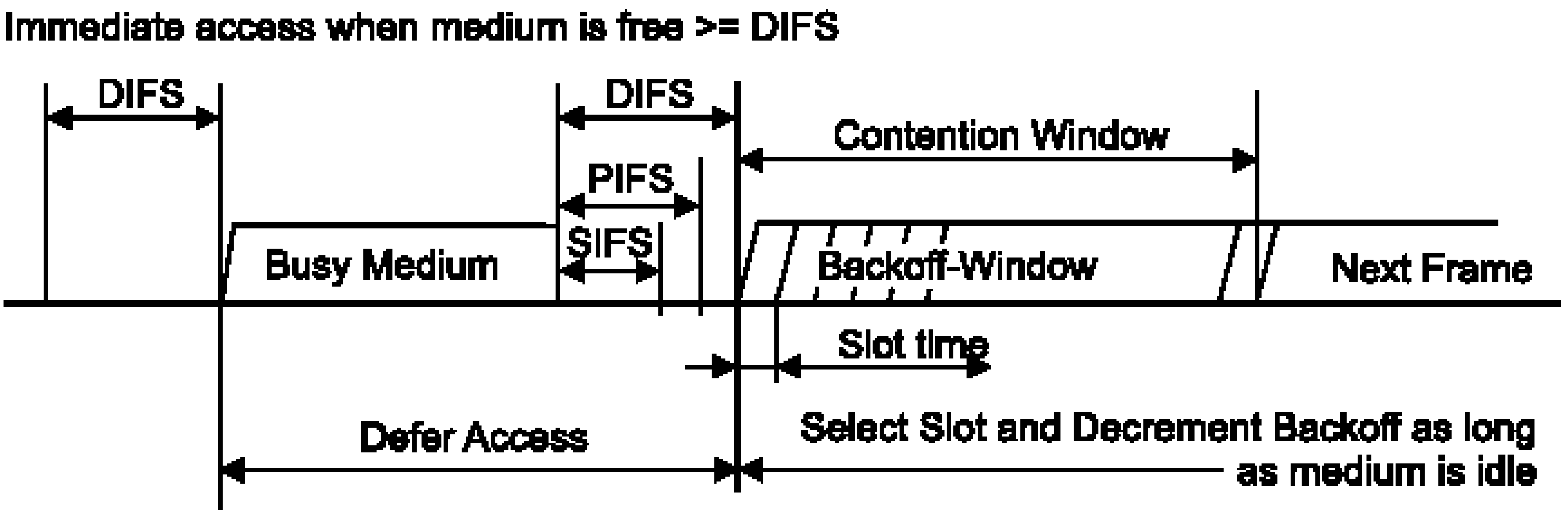
HCF Brief

- In 802.11, two access methods are defined
  - Distributed Coordination Function (DCF)
  - Point Coordination Function (PCF)
- In 802.11e, HCF access method is added, including
  - Contention-Based channel access– EDCA
    - Combined with DCF
  - Controlled channel access – HCCA
    - Similar to PCF but with enhancement

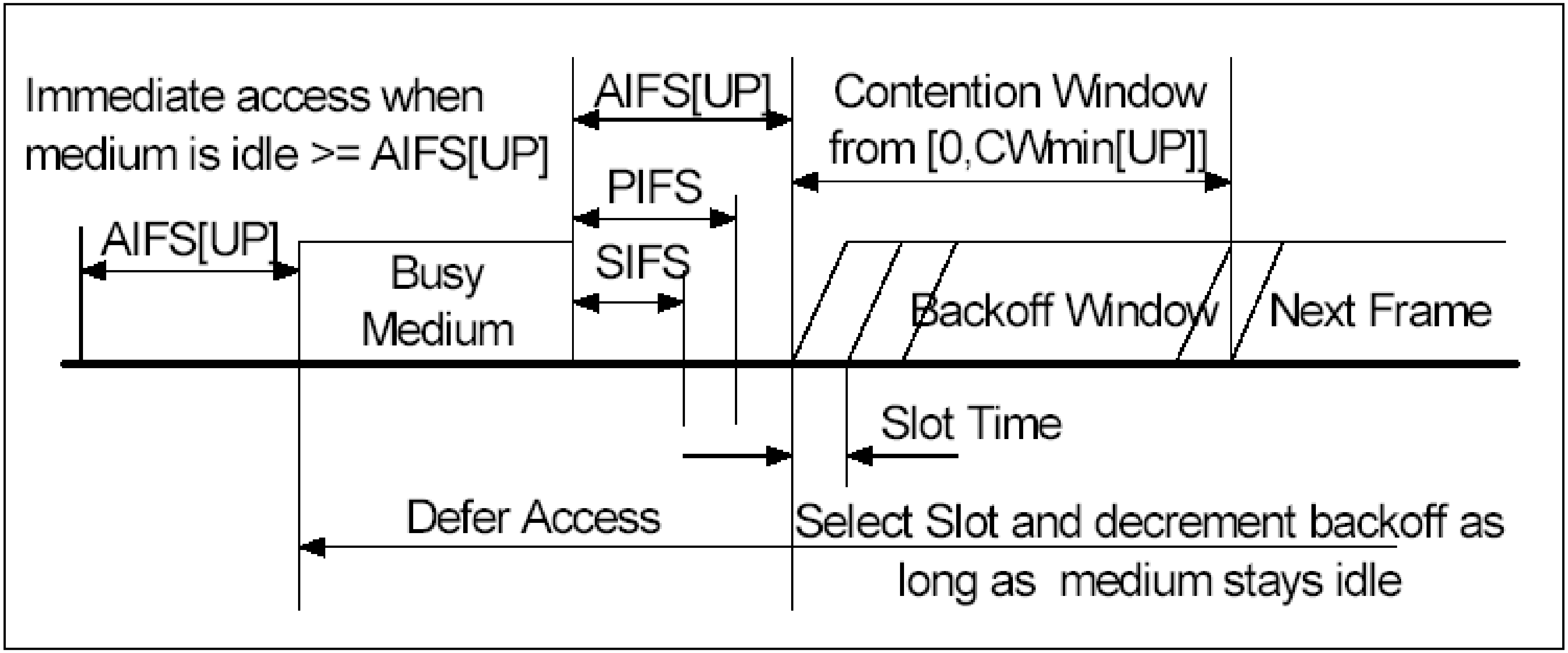
EDCA

- Difference from original DCF
  - Contention between Access Categories (ACs) (Not STAs)
  - AC Contends for Transmission Opportunity (TXOP) in unit of 32 microseconds.
  - New Inter-frame Space (IFS) for each AC: Arbitration Interframe Space (AIFS)

IFS in 802.11 DCF: Contention between STAs

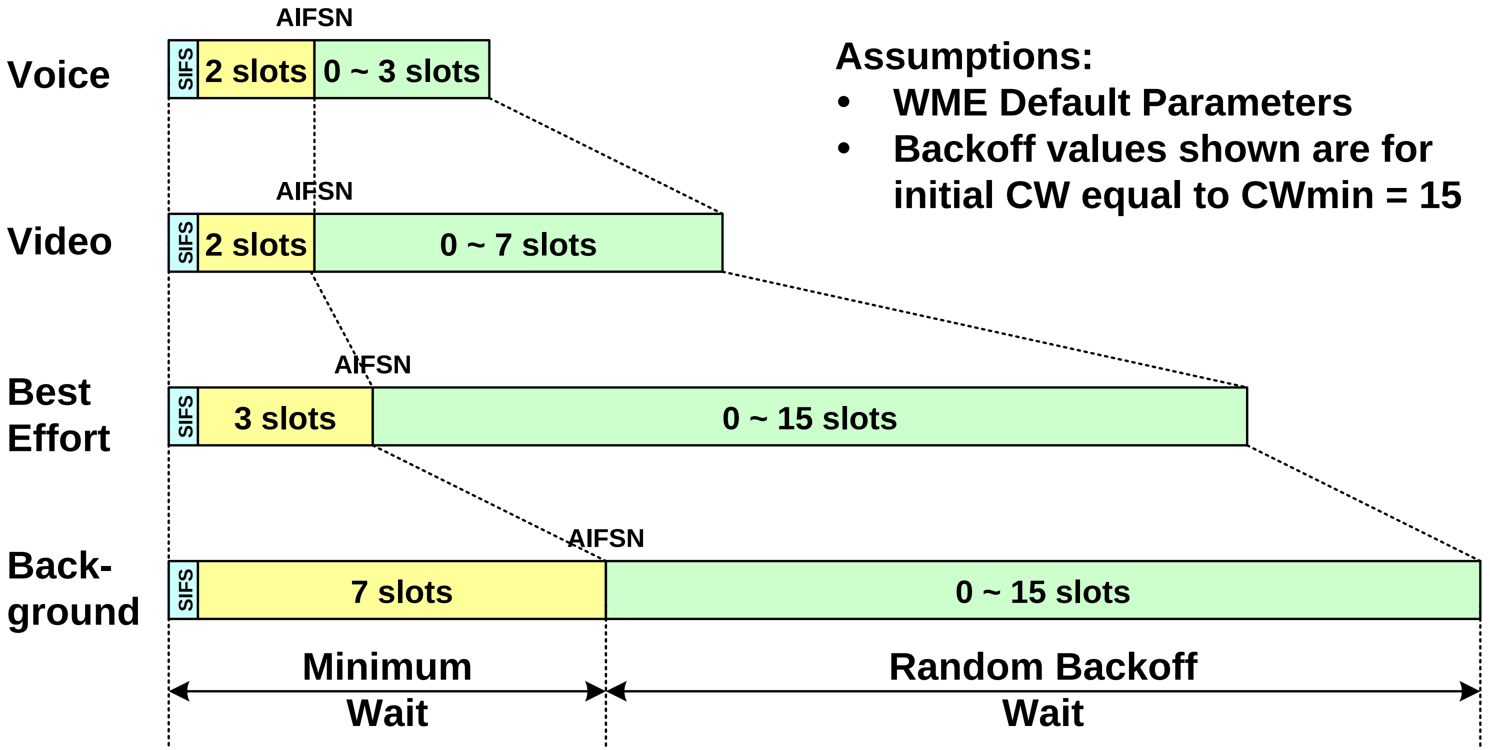


IFS in EDCF: Contention between **ACs**



IFS in EDCF: Contention between **ACs**

- AIFS[UP] > SIFS to protect Acknowledgement (ACK) transmission
- AIFS[UP] and CWmin[UP] announced by AP in beacon frames

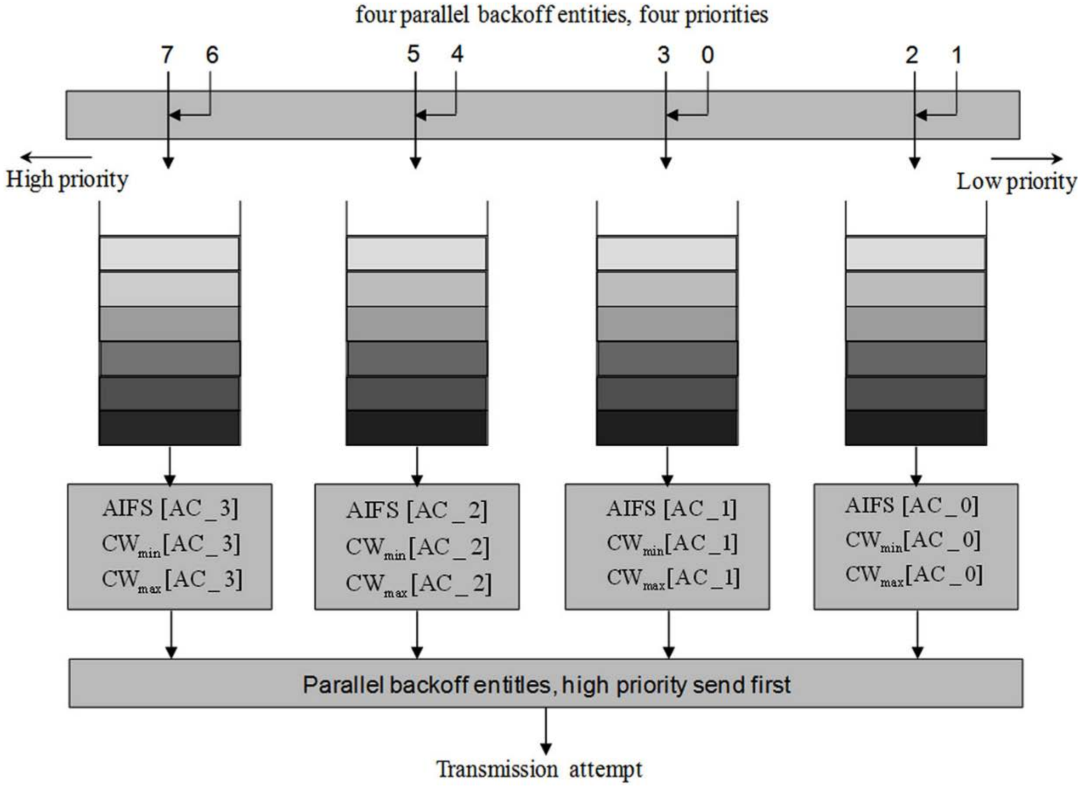


Arbitration Interframe Space (AIFS)

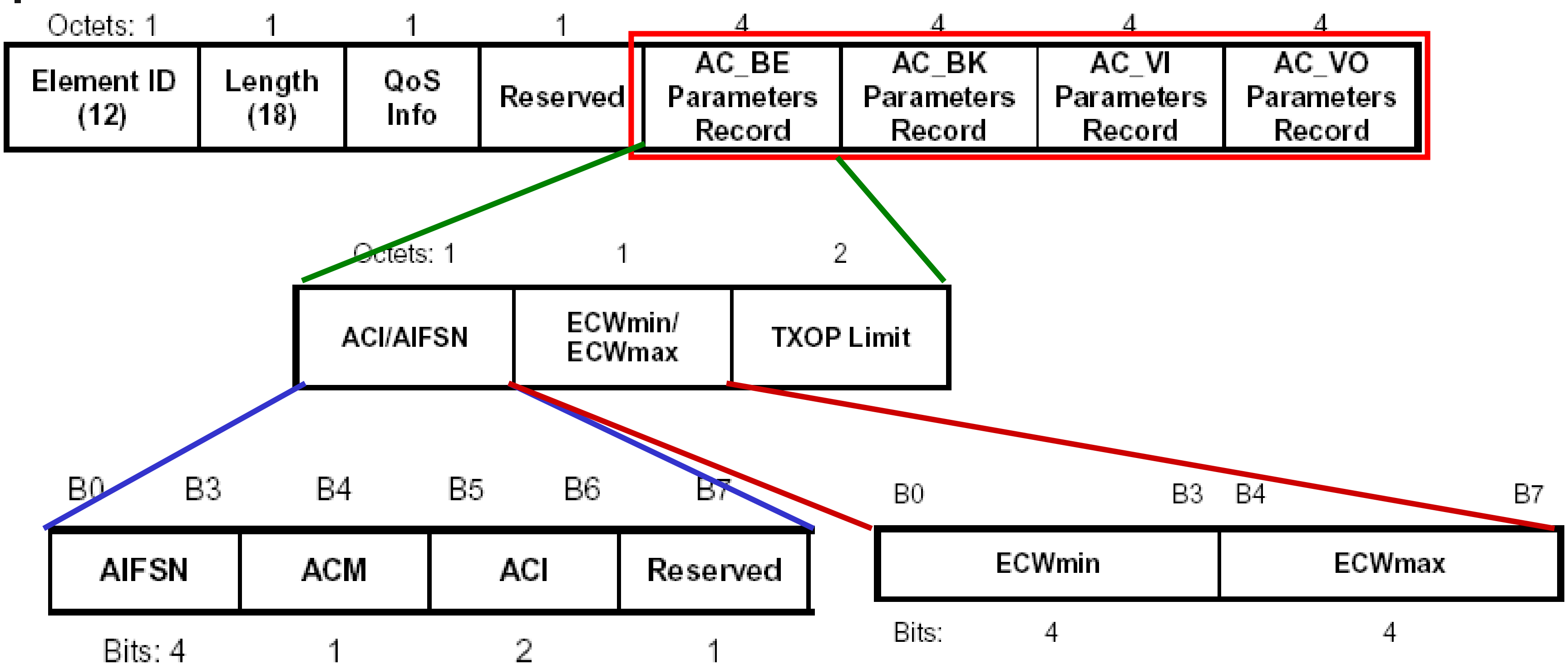
- QSTA use AIFS to defer the contention window or transmission for each AC
- AIFS[AC] = AIFSN[AC] x aSlotTime + aSIFTime
  - *AIFSN* (space number) for each AC is broadcast via beacon frame containing '**EDCA Parameter Set**' element

EDCF Multiple Queues

- Multiple FIFO queues in the MAC: up to 4 queues
- Every queue is an independent contention entity with its own contention parameters



EDCA Parameter Set Element



ACI: AC Index
ACM: Admission Control Mandatory

$CWmin = 2^{ECWmin} - 1$
$CWmax = 2^{ECWmax} - 1$

Default EDCA Parameter Set

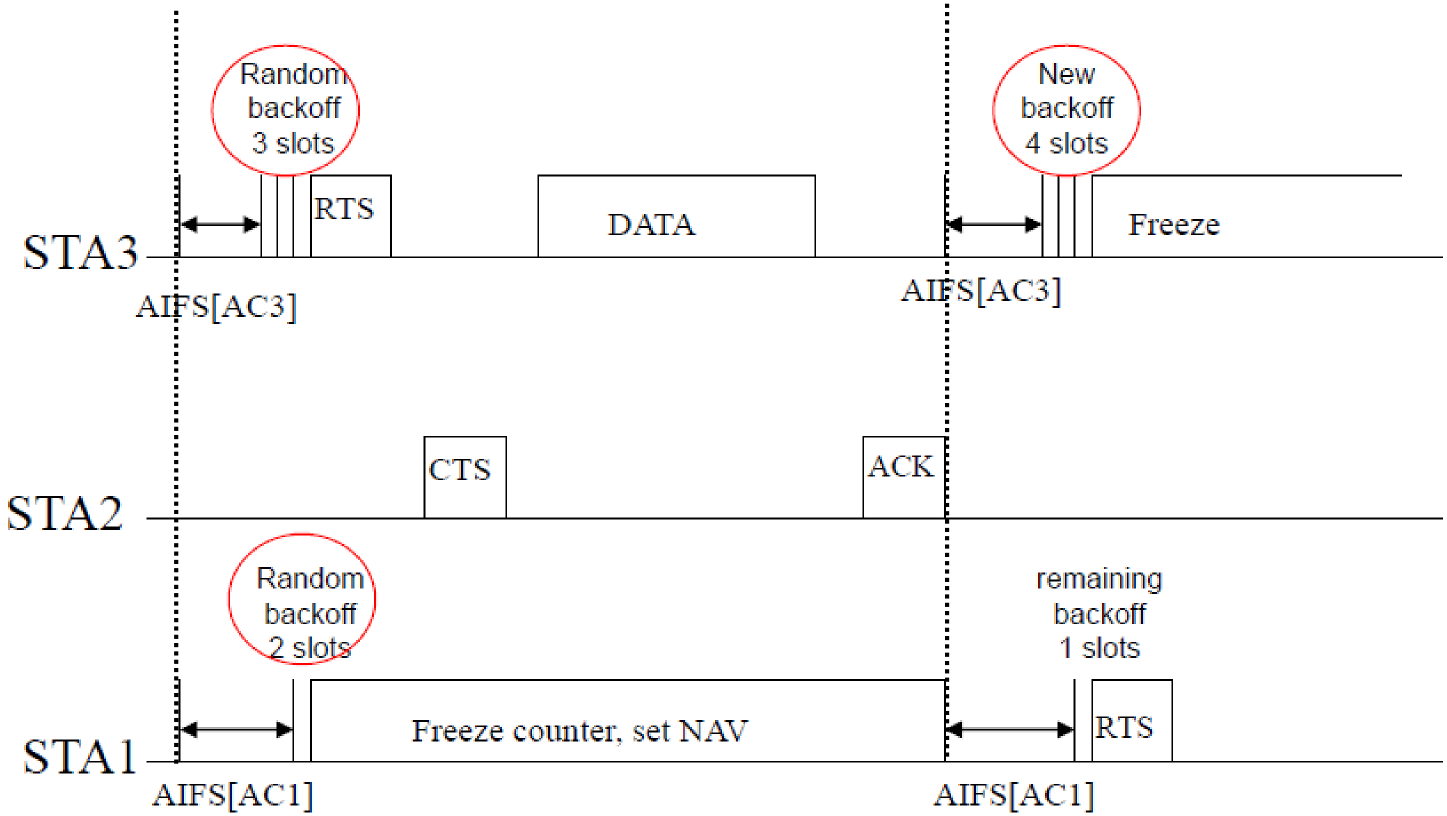
AC	CWmin	CWmax	AIFSN	TXOP Limit		
				DS-CCK[8]	Extended Rate /OFDM[9]	Other PHYs
AC_BK	aCWmin	aCWmax	7	0	0	0
AC_BE	aCWmin	aCWmax	3	0	0	0
AC_VI	(aCWmin+1)/2 – 1	aCWmin	2	6.016ms	3.008ms	0
AC_VO	(aCWmin+1)/4 – 1	(aCWmin+1)/2 - 1	2	3.264ms	1.504ms	0

CW size is smaller than DCF's

AIFS=DIFS

Example

- AIFS[AC1] –AIFS[AC3] = 2

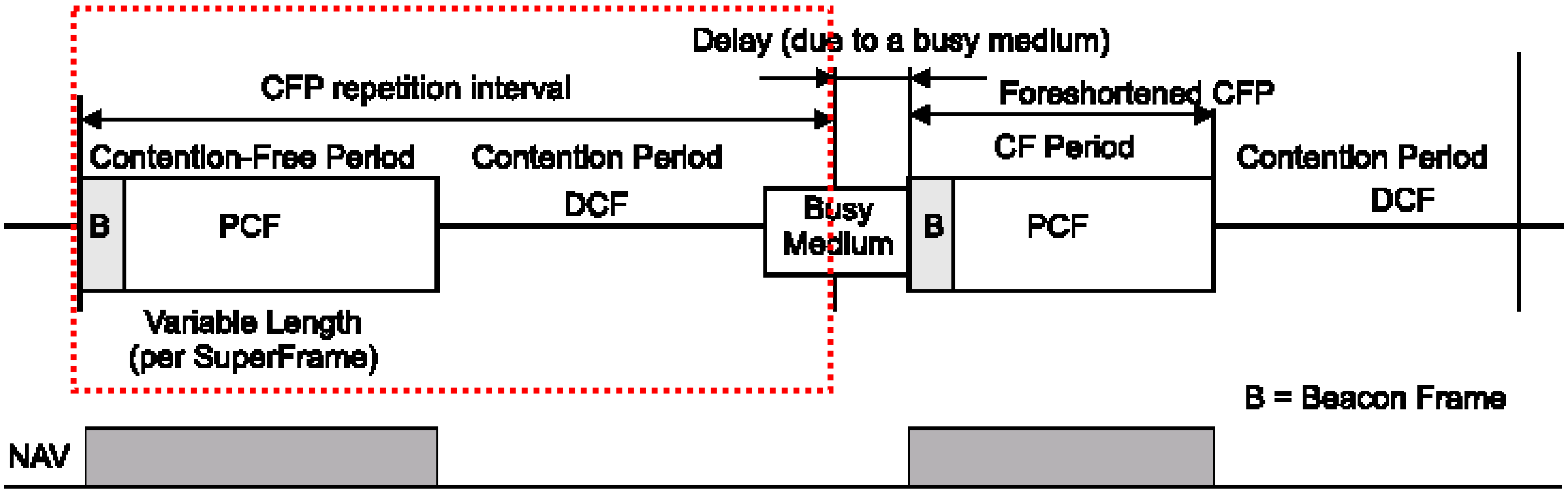


HCF Controlled Channel Access (HCCA)

- The procedure is similar to PCF
- Hybrid Coordinator (HC)
  - Operate at QAP
  - Control the iteration of CFP and CP
    - By using beacon and CF-End frame and NAV Mechanism (Same as PCF)
  - Use polling Scheme to assign TXOP to QSTA
    - Issue **QoS (+) CF-poll** frame to poll QSTA
    - Polling schedule in HC is calculated according to TSPECs (pp. 18)

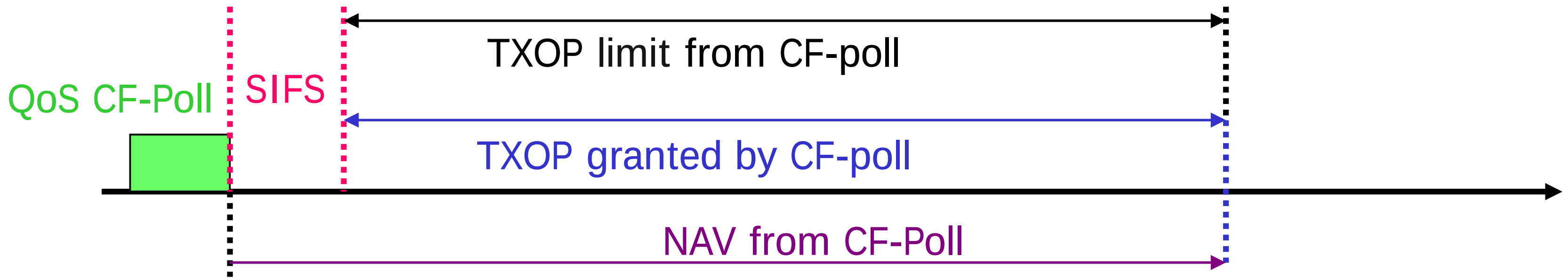
Iteration of CFP and CP

Superframe



Transmission Opportunity (TXOP)

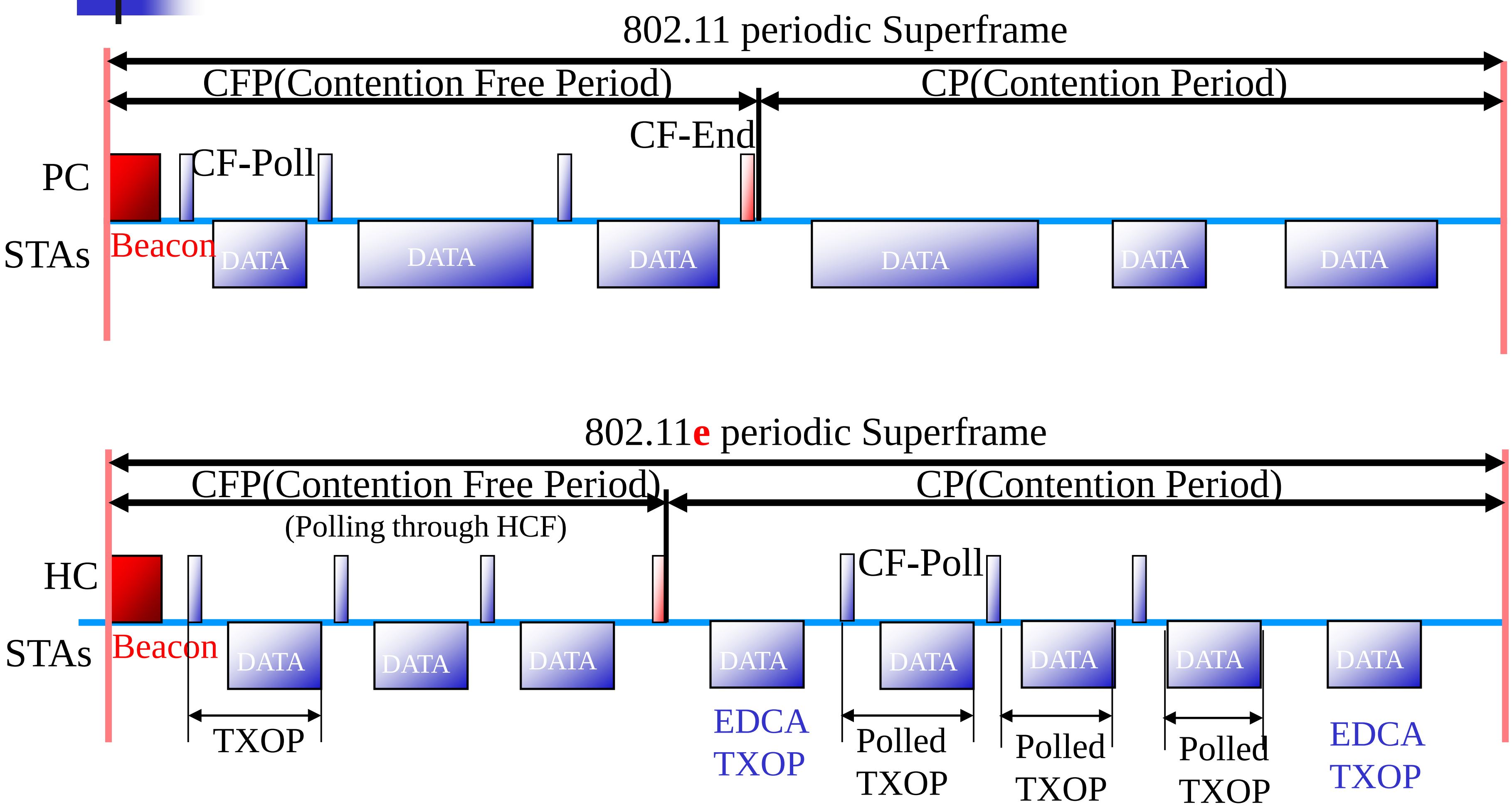
- TXOP: the duration of a QSTA to transmit frame(s)
- When will a QSTA get a TXOP ?
    1. Win a contention in EDCA during CP
    2. Receive a QoS (+)CF-poll (→"polled TXOP")



Transmission Opportunity (TXOP) (cont.)

- In TXOP, frames exchange sequences are separated by SIFS
- How is TXOP limit given
  - For EDCA, TXOP limit is given in Beacon Frame (at EDCA Parameter Set Element in frame body) pp.41
  - For controlled channel access, TXOP limit is given in QoS (+)CF-poll frames (at QoS Control field in MAC header) pp.19

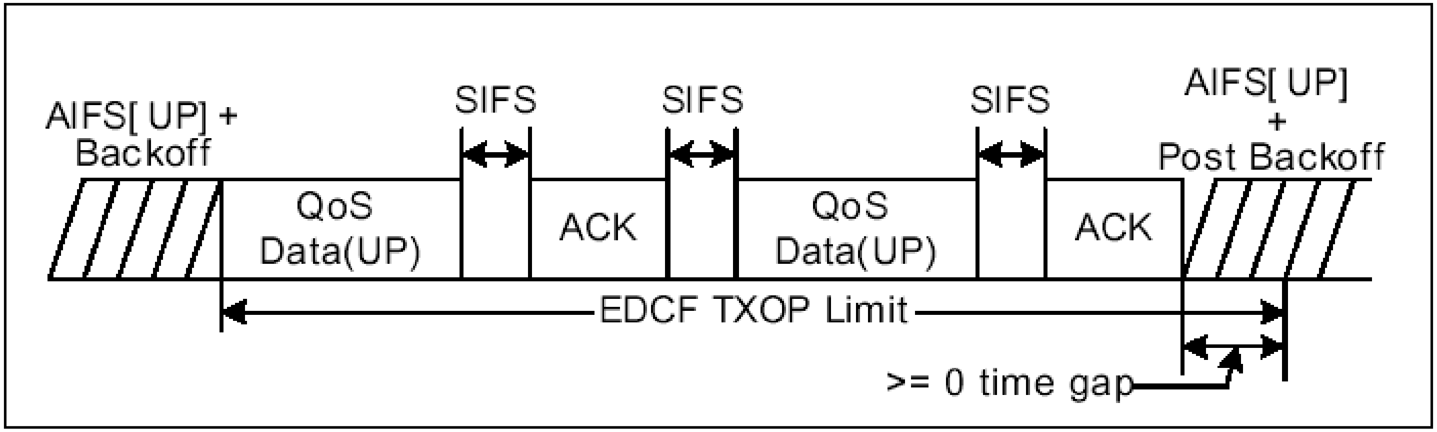
Superframe



802.11 periodic Superframe
CFP(Contention Free Period)
CP(Contention Period)
CF-End
CF-Poll
PC
STAs
Beacon
DATA
DATA
DATA
DATA
DATA
DATA
802.11e periodic Superframe
CFP(Contention Free Period)
CP(Contention Period)
(Polling through HCF)
HC
CF-Poll
STAs
Beacon
DATA
DATA
DATA
DATA
DATA
DATA
DATA
DATA
TXOP
EDCA TXOP
Polled TXOP
Polled TXOP
Polled TXOP
EDCA TXOP

Direct Link Protocol (DLP)

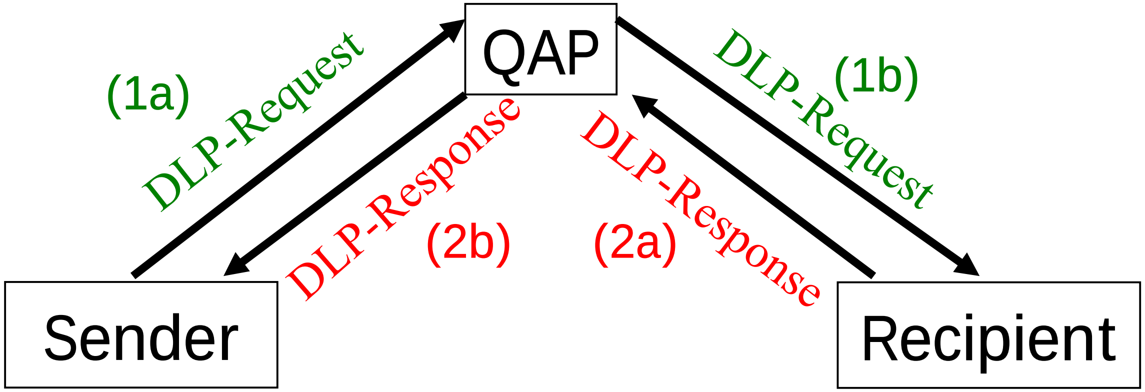
EDCF Bursting



Direct Link Protocol (DLP)

- Motivation
  - Send frames from one QSTA to another in QBSS
  - Wake up the recipient in PS mode via QAP
  - Exchange information between sender and recipient

The handshake procedure



Notes:

1. The direct link will become inactive if no frames have been exchanged for *DLPTimeoutValue duration*.
2. Recipient shall not go into power save for DLPTimeoutValue duration.
3. After timeout, the frames are transmitted via AP again.

DLP

Table 20.13 – DLP Action field values

Action field value	Meaning
0	DLP request
1	DLP response
2	DLP Teardown
3-255	Reserved

Table 20.14 – DLP request frame body

Order	Information
1	Category
2	Action
3	Destination MAC Address
4	Source MAC Address
5	Capability Information
6	DLP Timeout Value
7	Supported rates

Table 20.15 – DLP response frame body

Order	Information
1	Category
2	Action
3	Status Code
4	Destination MAC Address
5	Source MAC Address
6	Capability Information
7	Supported rates

DLP

Table 20.16 – DLP Teardown frame body

Order	Information
1	Category
2	Action
3	Destination MAC Address
4	Source MAC Address

Brief of Block ACK

- Improve channel efficiency
  - By aggregating several ACKs into one frame
- Two types
  - Immediate Block ACK
    - Suitable for High-bandwidth, low latency traffic
  - Delayed Block ACK
    - Suitable for applications tolerating moderate latency

Procedure of Block Ack

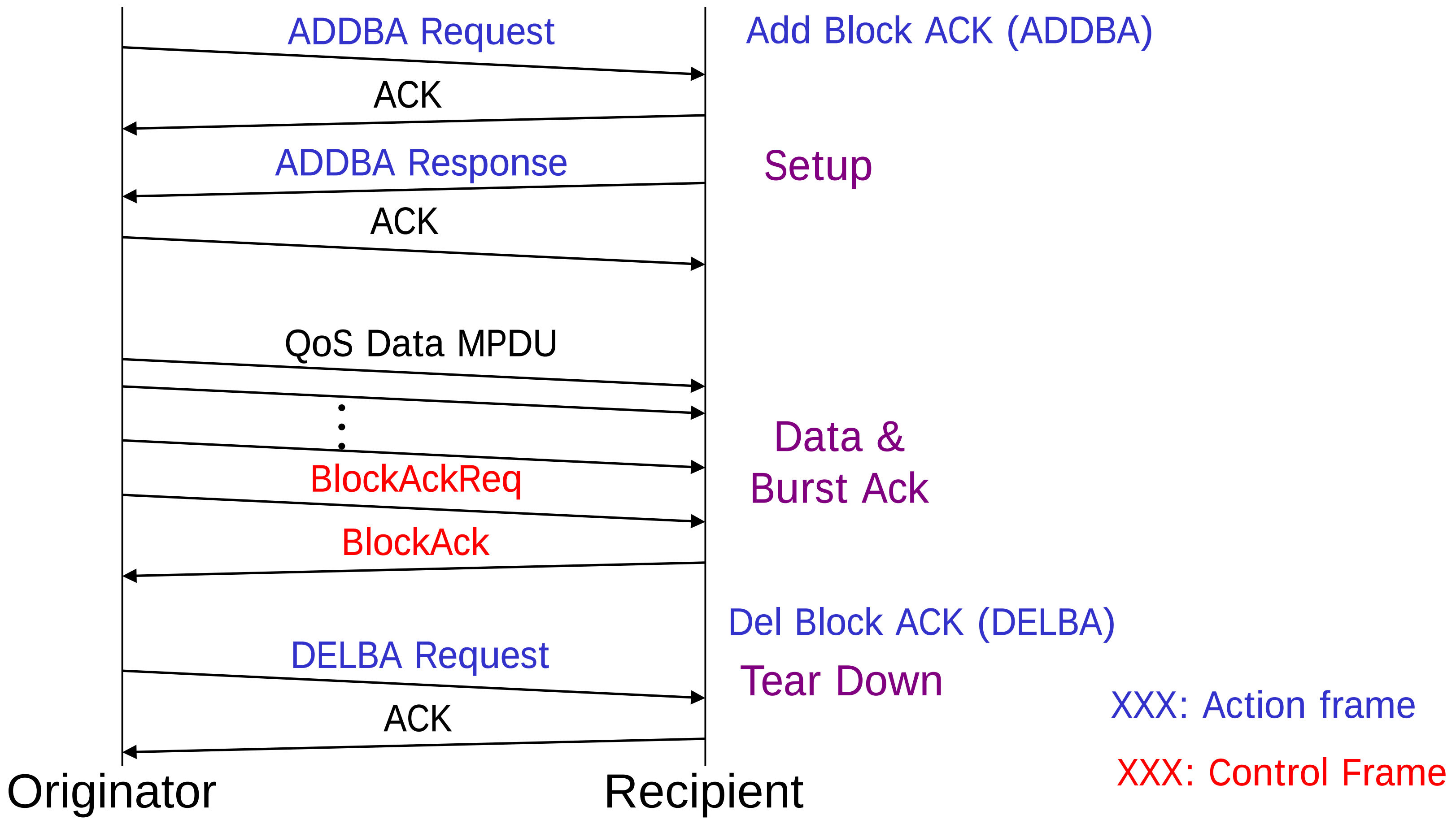


Table 20.17 – Block Ack Action field values

Action field values	Meaning
0	ADDBA request
1	ADDBA response
2	DELBA
3-255	Reserved

Table 20.18 – ADDBA request frame

Order	Information
1	Category
2	Action
3	Dialog Token
4	Block Ack Parameter Set
5	Block Ack Timeout Value

Table 20.19 – ADDBA response frame body

Order	Information
1	Category
2	Action
3	Dialog Token
4	Status code
5	Block Ack Parameter Set
6	Block Ack Timeout Value

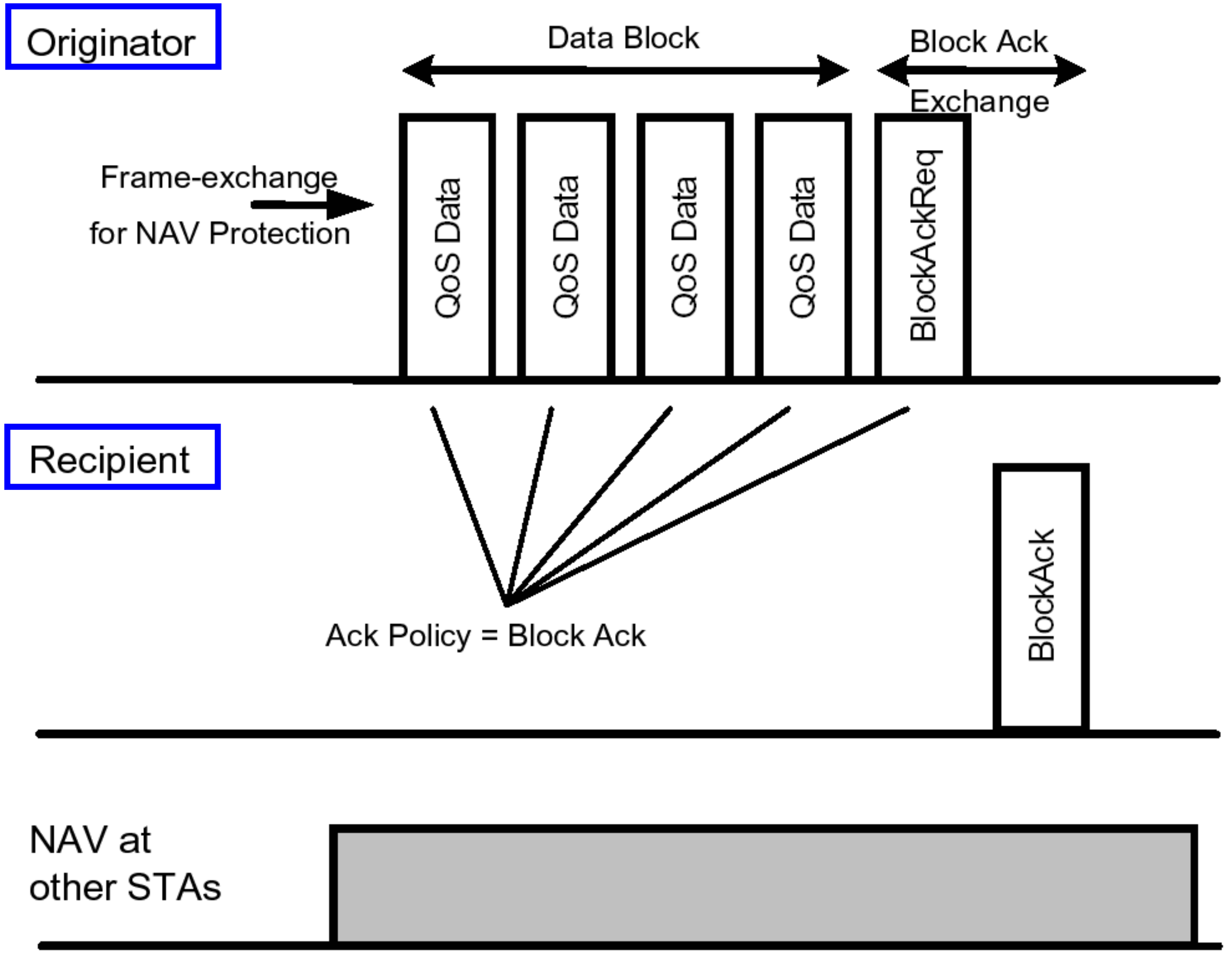
Table 20.20 – DELBA frame body

Order	Information
1	Category
2	Action
3	DELBA Parameter Set

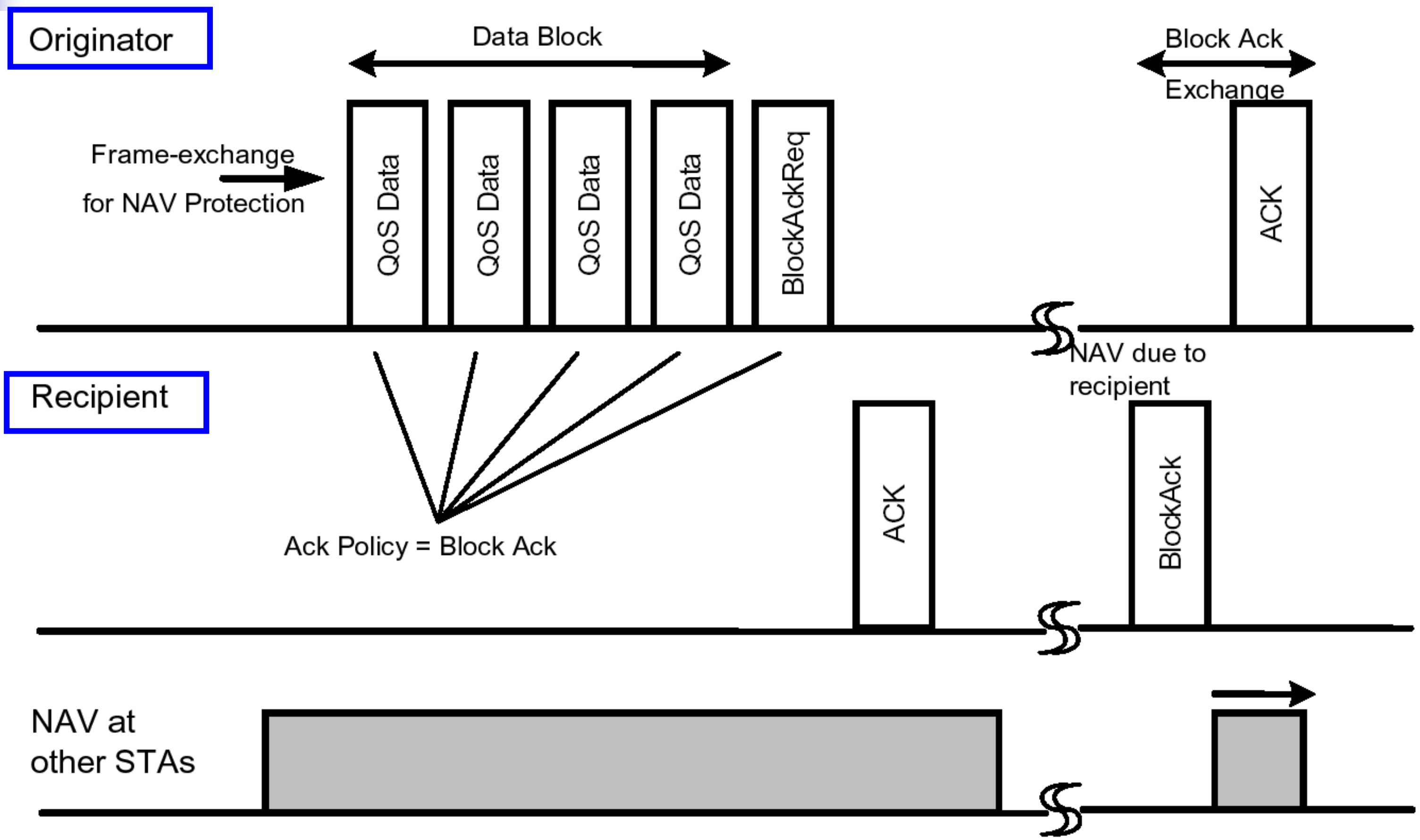
Setup Burst Ack Parameters

- Action Frames (Management frames)
  - *ADDBA Request*, with parameters
    - TID
    - Block Ack Policy (Immediate or delayed)
    - Transmit Buffer Size
    - Timeout Value
  - *ADDBA Response*, with parameters
    - Status Code
    - Burst Ack Policy (1 for Immediate, 0 for Delayed)
    - TID
    - Re-ordering Burst Size (number of buffers)
    - Timeout value

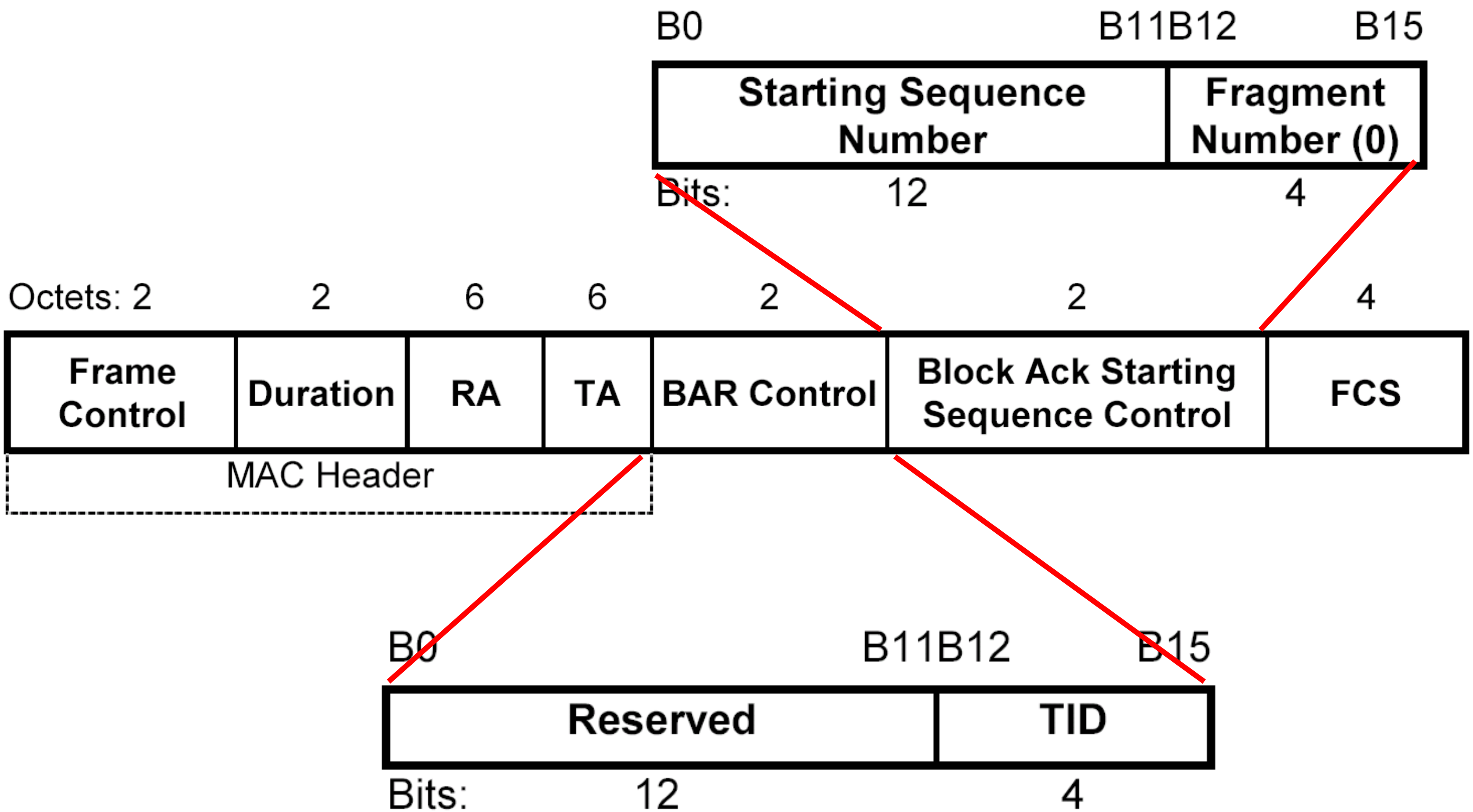
Immediate Block Ack



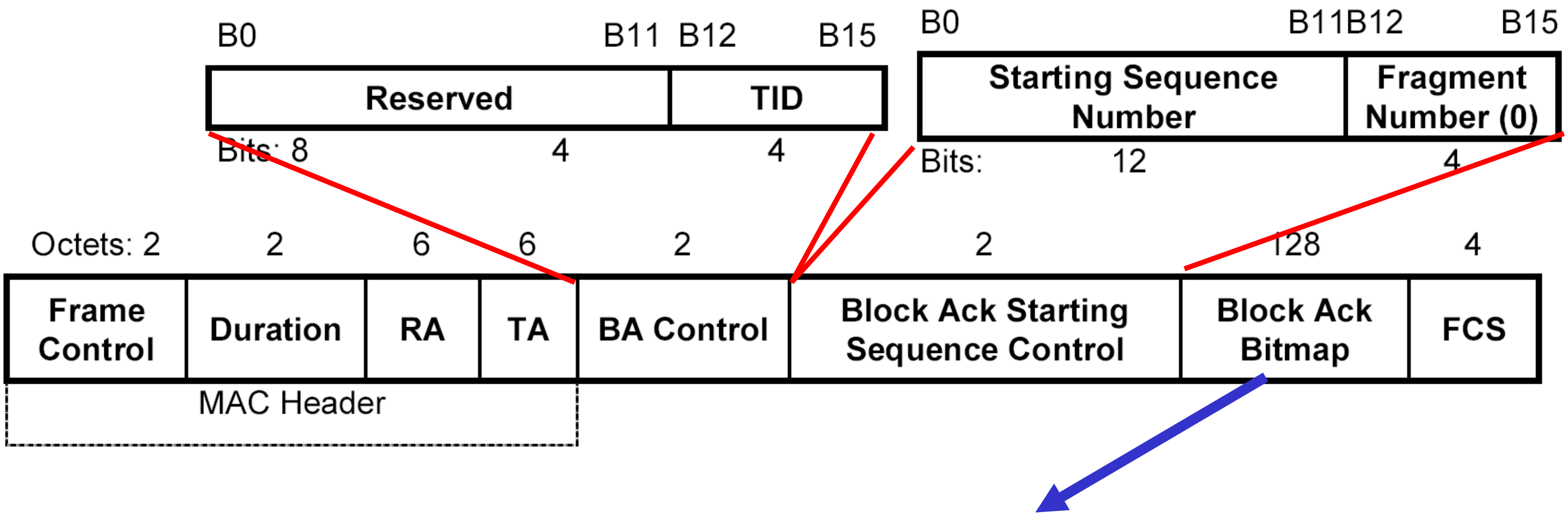
Delayed Block Ack



BlockAckReq Frame Format



BlockAck Frame Format



- Is used to indicate the receiving status of up to 64 MSDUs
- Bit position n acknowledges receipt of an MPDU with Sequence control value (Block Ack Starting Sequence Control + n)

Frame usage

Frame Subtype	IBSS		Infrastructure BSS							
	non-QoS	QoS	non-QoS				QoS			
	CP	CP	CP		CFP		CP		CFP	
	STA	QSTA	STA	AP	STA	AP	QSTA	QAP	QSTA	QAP
(Re) Association Request	- - -	- - -	T	R	- - -	- - -	T	R	- - -	- - -
(Re) Association Response	- - -	- - -	R	T	R	T	R	T	R	T
Probe Request	T, R	T, R	T	R	- - -	- - -	T	R	- - -	- - -
Probe Response	Tbe, R	Tbe, R	R	T	R	T	R	T	R	T
Beacon	Tb, R	Tb, R	R	T	R	T	R	T, R	R	T, R
ATIM	T, R	T, R	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Disassociation	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R
Authentication	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R
Deauthentication	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R
ADDTS Request	- - -	- - -	- - -	- - -	- - -	- - -	T	R	T	R
ADDTS Response	- - -	- - -	- - -	- - -	- - -	- - -	R	T	R	T
DELTS	- - -	- - -	- - -	- - -	- - -	- - -	T, R	T, R	T, R	T, R
Schedule	- - -	- - -	- - -	- - -	- - -	- - -	R	T	R	T
DLP Action frames	- - -	- - -	- - -	- - -	- - -	- - -	T, R	T, R	T, R	T, R
Block Ack Action frames	- - -	T, R	- - -	- - -	- - -	- - -	T, R	T, R	T, R	T, R
BlockAckReq/BlockAck	- - -	T, R	- - -	- - -	- - -	- - -	T, R	T, R	T, R	T, R
PS-Poll	- - -	- - -	T	R	- - -	- - -	T	R	T	R
RTS	T, R	T, R	T, R	T, R	- - -	- - -	T, R	T, R	T, R	T, R
CTS	T, R	T, R	T, R	T, R	- - -	- - -	T, R	T, R	T, R	T, R
ACK	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R
CF-End	(R)	(R)	(R)	(R)	R	T	(R)	(R)	R	T
CF-End+CF-Ack	(R)	(R)	(R)	(R)	R	T	(R)	(R)	R	T
Null	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R
Data	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R	T, R
(Data+)CF-Poll+(CF-Ack)	- - -	- - -	- - -	- - -	R	T	- - -	- - -	- - -	T
(Data+)CF-Ack	- - -	- - -	- - -	- - -	T, R	T, R	- - -	- - -	T, R	T, R
QoS Null	- - -	T, R	- - -	- - -	- - -	- - -	T, R	T, R	T, R	T, R
QoS Data	- - -	T, R	- - -	- - -	- - -	- - -	T, R	T, R	T, R	T, R
QoS (Data+)CF-Poll	- - -	- - -	- - -	- - -	- - -	- - -	R	T	R	T
QoS (Data+)CF-Poll+CF-Ack	- - -	- - -	- - -	- - -	- - -	- - -	Rq, Rda	Tda, Tq	Rq, Rda	Tda, Tq
QoS (Data+)CF-Ack	- - -	- - -	- - -	- - -	- - -	- - -	T, Rq, Rda	Tda, , Tq, R	T, Rq, Rda	Tda, Tq, R

Frame usage

Symbols:

T	frame subtype for row is transmitted by MAC entity for column.
R	frame subtype for row is received by MAC entity for column.
(R)	frame subtype for row is received, but only from other BSSs, by MAC entity for column.
Tb	frame subtype for row is transmitted by station that most recently won beacon arbitration.
Tbe	frame subtype for row is transmitted by a QSTA in an IBSS pursuant to receiving directed request.
Tda	frame subtype for row is transmitted only if recipient of +CF-Ack function is addressee.
Rda	frame subtype for row is received if QSTA is addressee.
Tq	frame subtype for row is transmitted only if recipient of +CF-Ack function has set the Q-Ack subfield in QoS Capability Element to 1.
Rq	frame subtype for row is received if QSTA is not the addressee but has set the Q-Ack subfield in QoS Capability Element to 1.
- - -	frame subtype for row is neither received nor transmitted by MAC entity for column.

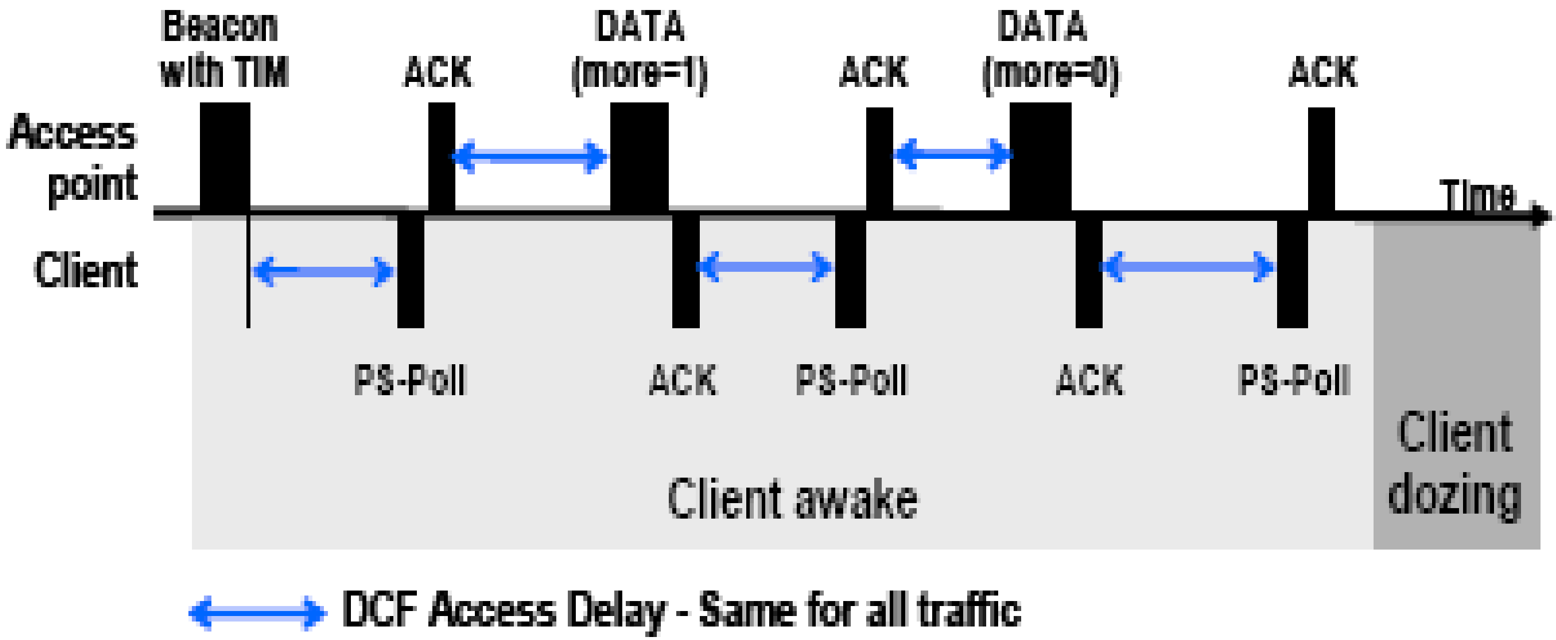
Implementation-Dependent Issues

- HC scheduling
  - Mixture of downlink and polled TXOP scheduling
- QSTA scheduling
  - During a polled TXOP, schedule frame transmissions
- Admission control by HC
  - To decide whether to admit a Traffic Stream (TS) or not

Power Management

- Two Power Management Approaches in 802.11e
- U-ASPD (WMM)
  - Unscheduled Automatic Power Save Delivery
  - Based on EDCA
- S-ASPD
  - Scheduled Automatic Power Save Delivery
  - Based on HCCA

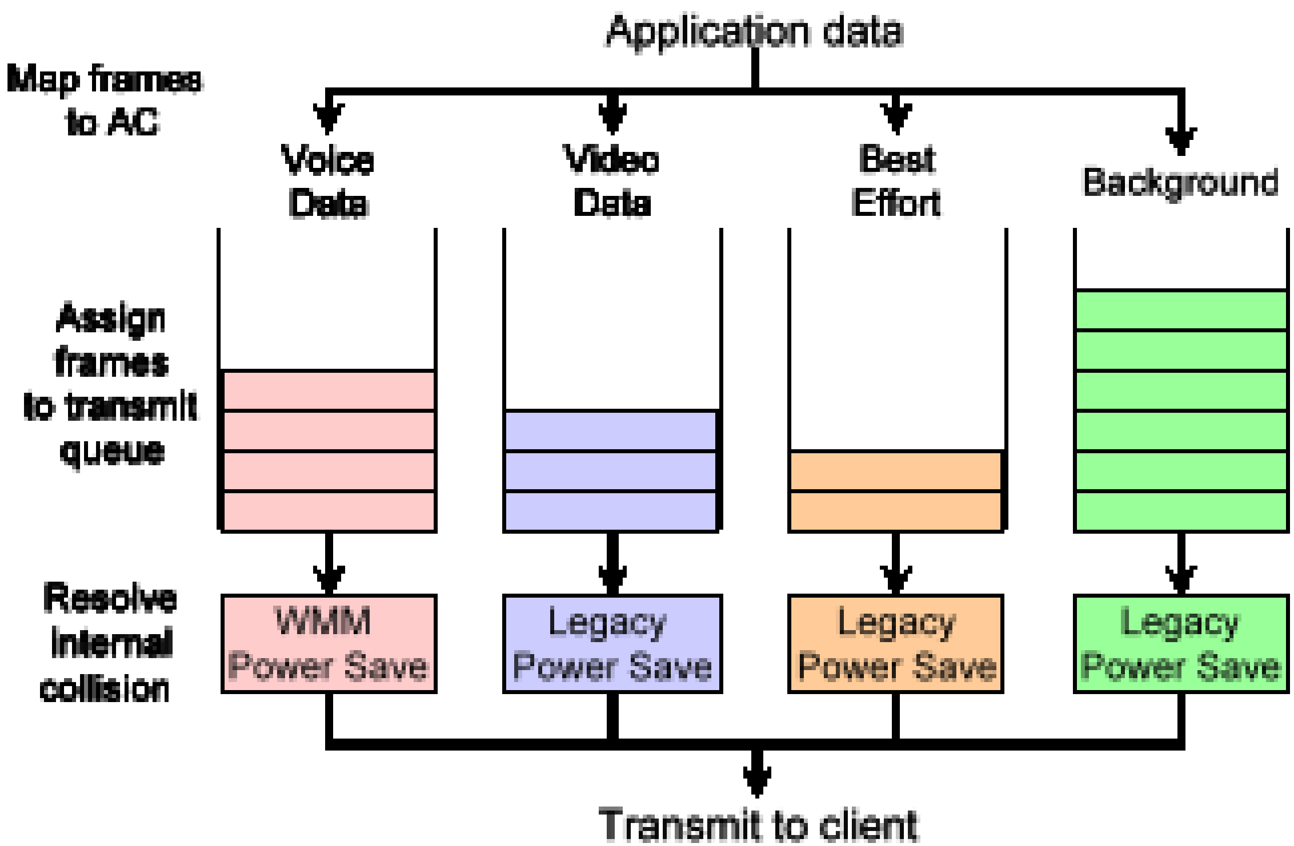
Comparison with Legacy Power Save



- Refer from WMM

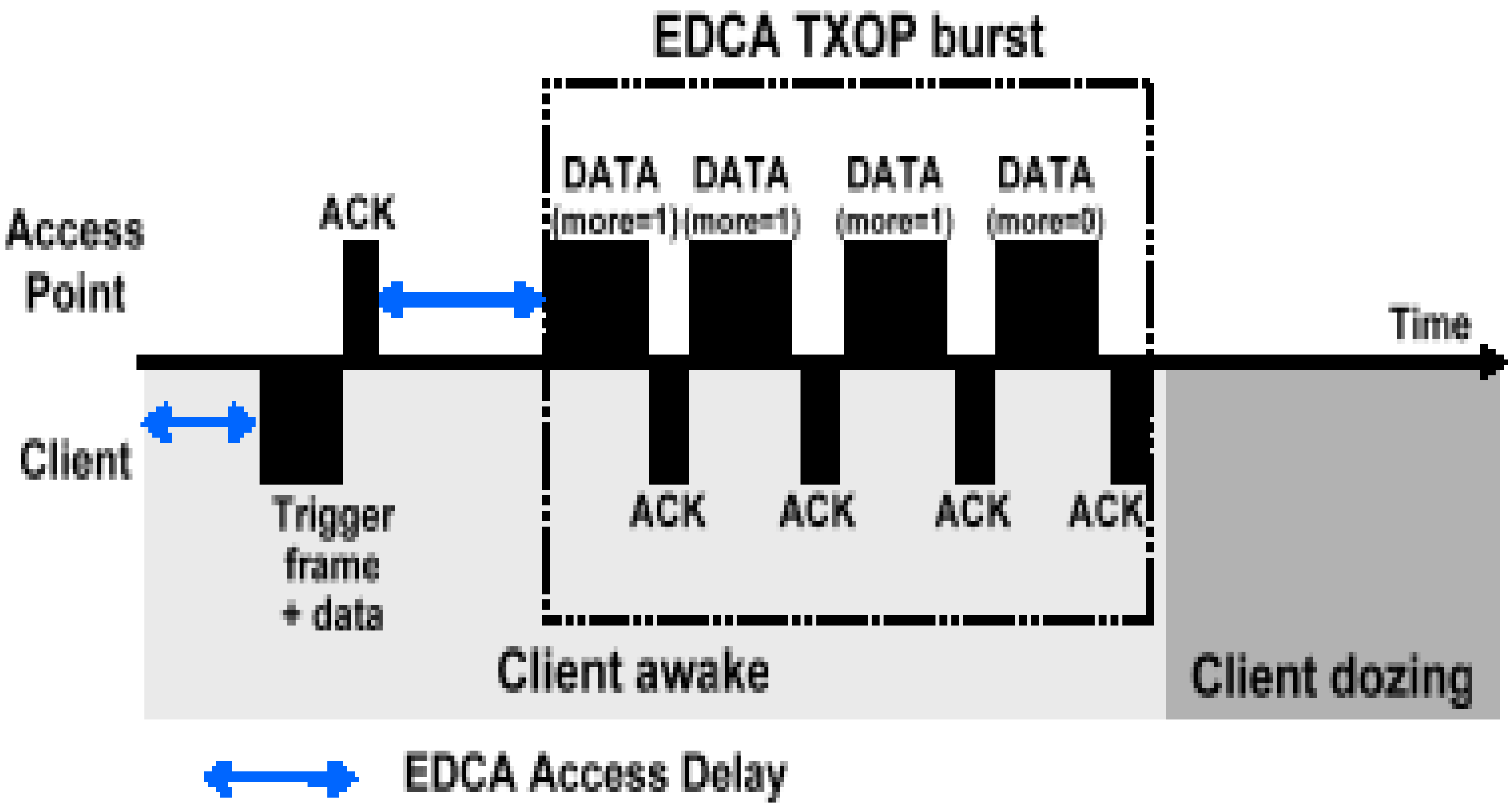
EDCA Priority Access in WMM

- Hybrid mode



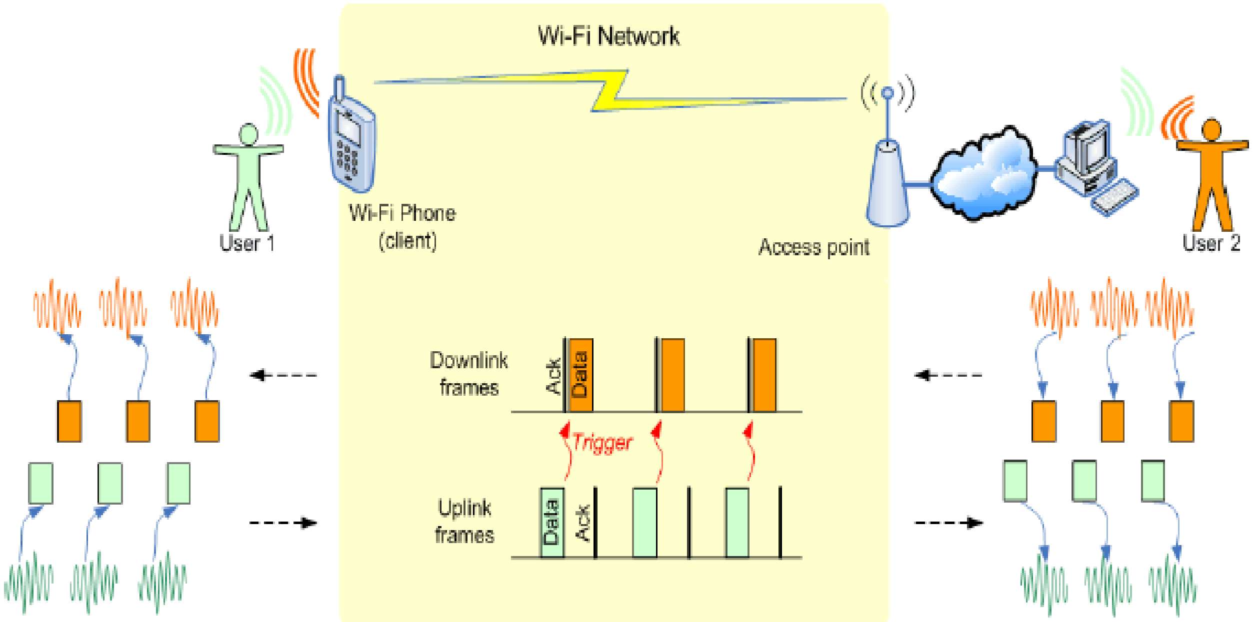
WMM Power Save

- Trigger frame associated with data frame



Study Case: VoIP

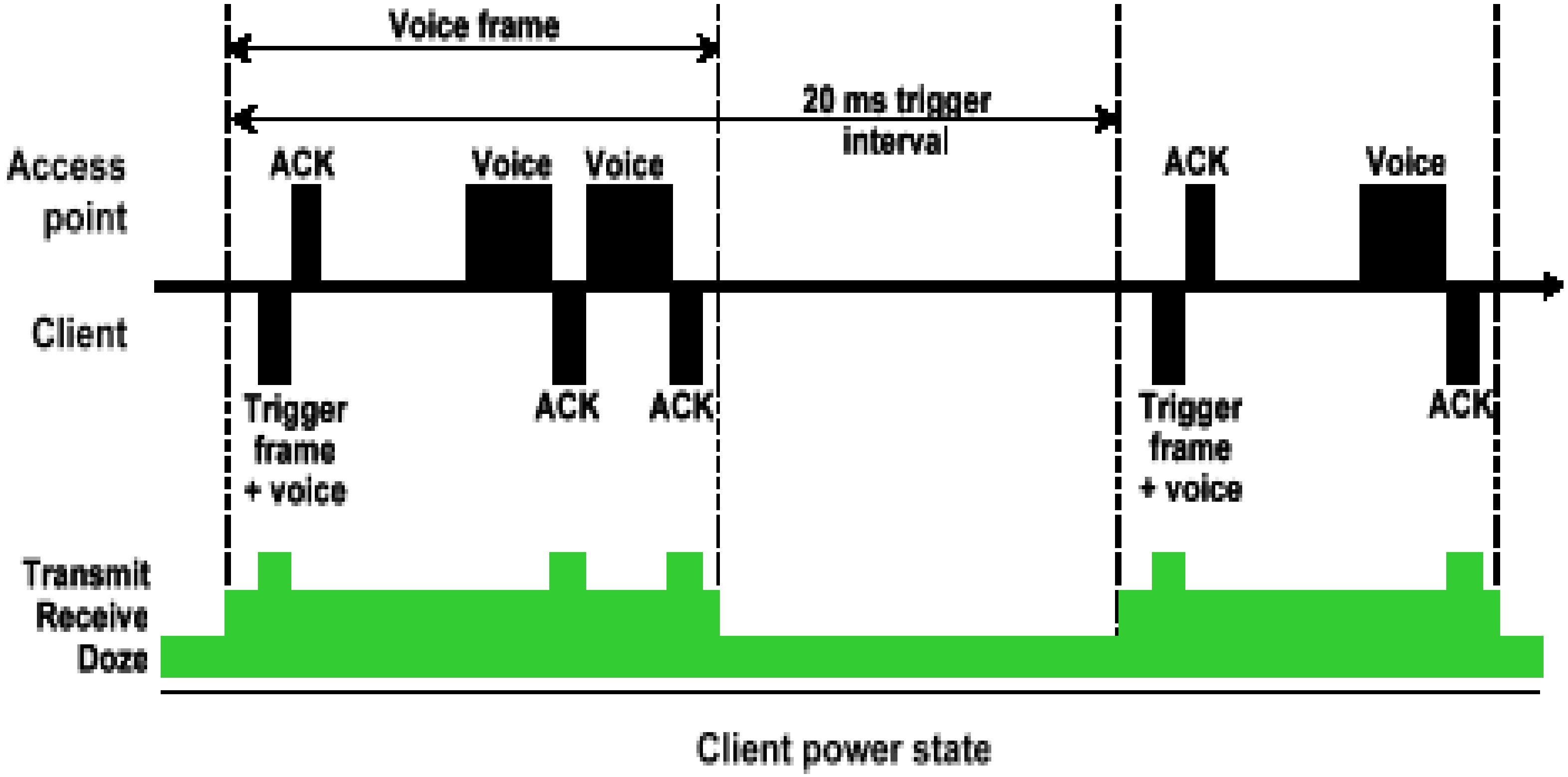
- Less than 20 ms delay is required
- More than 20 ms delay will make voice hard to be understood.
- Beacon Interval is assumed to be 100ms
  - VoIP is not work in legacy power management mode



Comparisons

- In legacy configuration, the client waits for the beacon frame before it initiates the downlink data transmission.
  - It will delay 100 ms to 300 ms.
- In WMM Power save, every 20 ms, The access point buffers all the voice frames to be delivered until it receives a trigger frame from the client.

VoIP in a WMM Power Save network



Thank You!

Q & A