802.11 TGe – QoS Enhancements (D6.0)

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Summary

- Hybrid Coordination Function (HCF)
  - Enhanced Distributed Channel Access (EDCA)
  - HCF Controlled Channel Access (HCCA)
- Block Acknowledgement (BA)
- Automatic Power-Save Delivery (APSD)
- Direct Link Protocol (DLP)

Background Info

Octets: 2	2	6	6	6	2	6	2	~~0-2312~~n	4
Frame Control	Duration / ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	QoS Control	Frame Body	FCS
MAC Header									

Figure 12 – MAC frame format

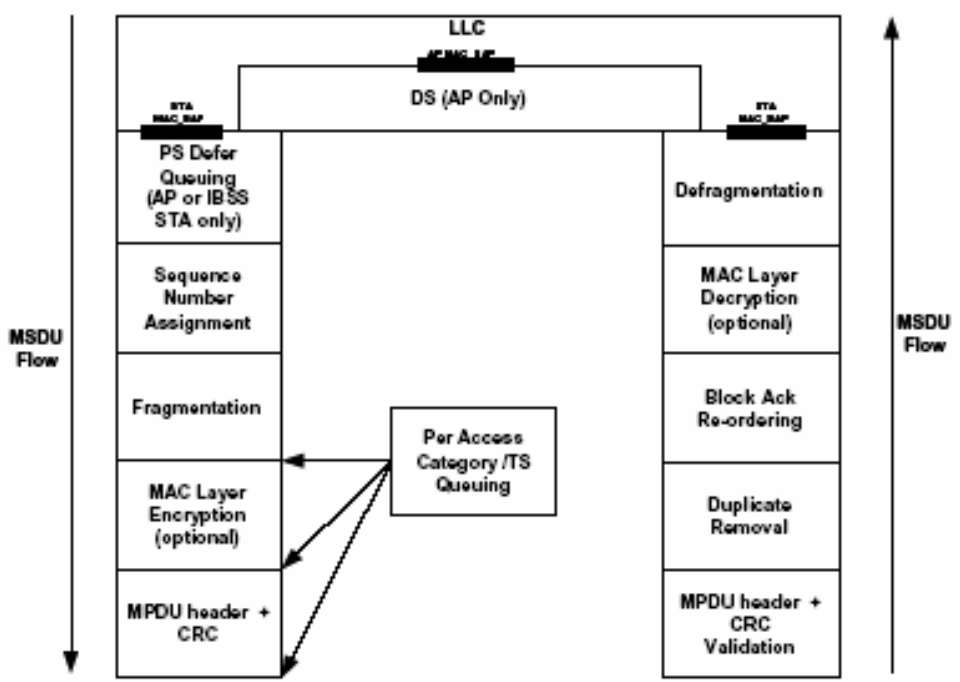
Table 3.1 – QoS Control field

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

	(UP – Same as 802.1D User Priority)	Designation	Category (AC)	(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
	6	VO	AC_VO	Voice
highest	7	NC	AC_VO	Voice

Background Info (cont.)

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.
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.



EDCA Synopsis

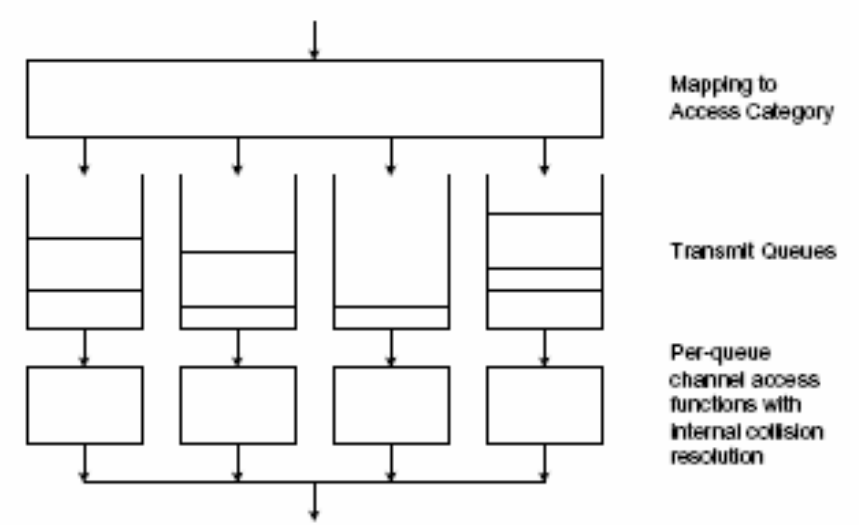
- WME is Wi-Fi's standard for EDCA
- This mechanism delivers traffic based on differentiating user priorities (UPs)
- Differentiation is achieved through varying the amount of time a station senses the channel to be idle BEFORE backoff or transmission
  - And also the length of the contention window to be used for the backoff

EDCA Modes

- EDCA Transmit Opportunity (TXOP) Initiation
  - EDCA rules permit access to the medium
- EDCA TXOP Continuation
  - Channel access function retains the right to access the medium following the completion of a frame exchange sequence

EDCA TXOP Preparation

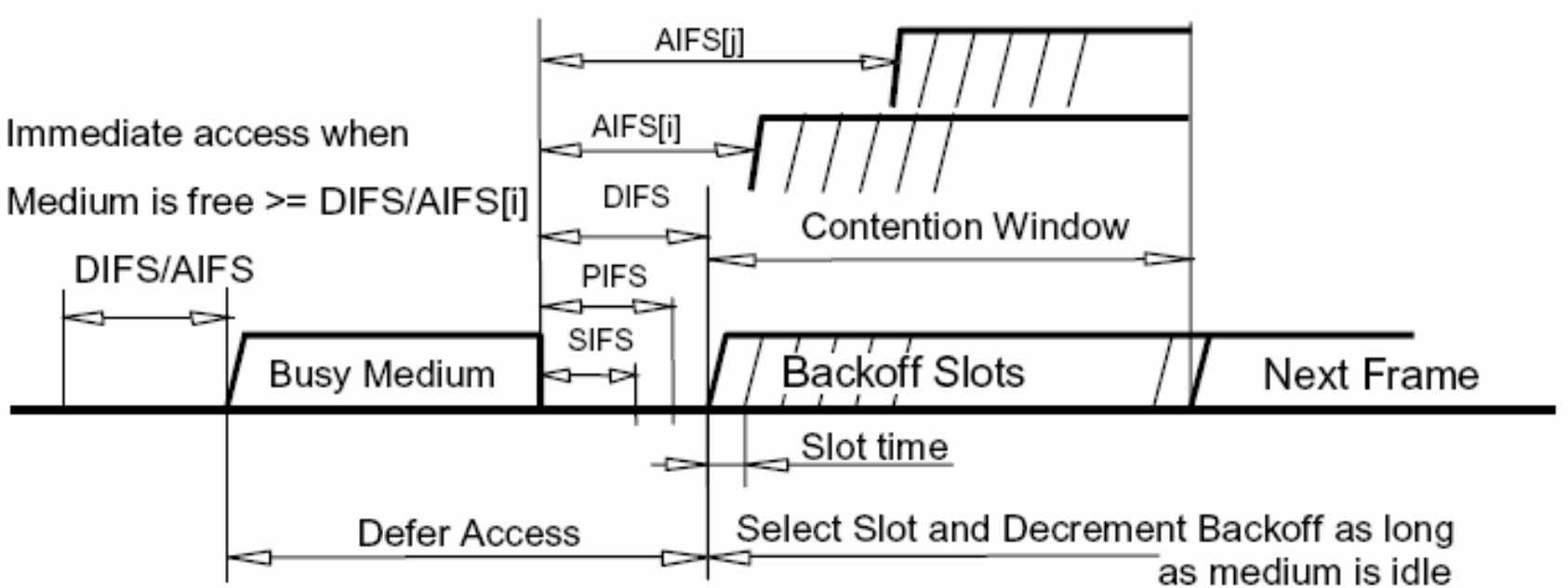
- After MSDUs are potentially fragmented they are sorted by access category
- Each access category has a different channel access function
- Access function properties are specified by the EDCA Parameter Set Information Element



Obtaining EDCA TXOP

- New IFS called Arbitrary InterFrame Space (AIFS)
  - AIFS[AC] = AIFSN[AC] x aSlotTime + aSIFSTime
- Wait for AIFS[AC] (AIFSN[AC] must be greater or equal to 2)
- Then, on specific slot boundary each channel access function does one of the following:
  - Initiates the transmission of a frame exchange sequence for that access function
  - Decrement the backoff timer for that access function
  - Invoke the backoff procedure due to an internal collision
  - Do nothing for that access function

EDCA Timing Relationships



Initiating EDCA TXOP

- At each specific slot boundary after AIFS[AC], each channel access function shall initiate a transmission sequence if:
  - There is a frame available for transmission at that channel access function, and
  - The backoff timer for that channel access function has a value of zero, and
  - No other channel access function of higher UP can initiate a transmission sequence

EDCA Internal Collision

- Each channel access function shall invoke the backoff procedure due to an internal collision if:
  - There is a frame available for transmission at that channel access function, and
  - The backoff time for that channel access function has a value of zero, and
  - Another channel access function of higher UP can initiate transmission sequence
- Retry bit and retry counters are not modified after an internal collision

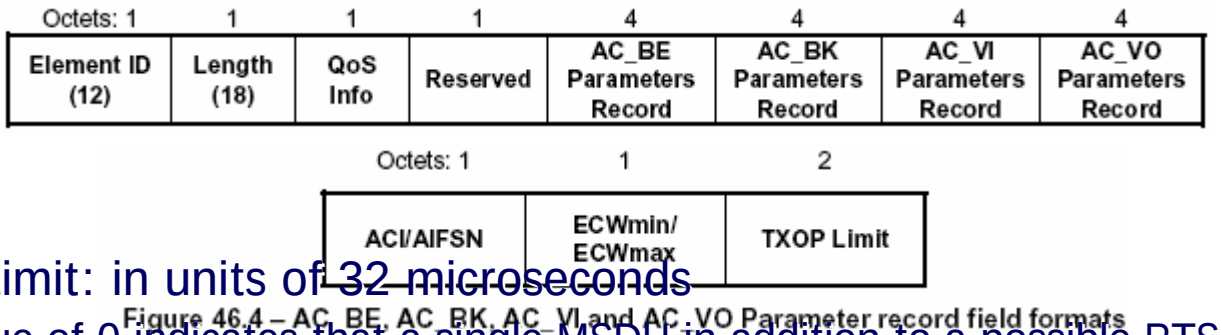
EDCA TXOP Continuation

- For each channel access function there is a TXOP limit value
- Specifies how long a QSTA can transmit after obtaining the TXOP
- Granted to a QSTA's channel access function not to a QSTA
- The QSTA may commence transmission of that frame at SIFS after the completion of the immediately preceding frame exchange sequence if:
  - The QSTA has in its transmit queue of the same AC as the one just transmitted
  - The duration of transmission of that frame plus any expected acknowledgement for that frame is less than the remaining medium occupancy timer value

Duration Field in EDCA

- Intention of using the continuous TXOP shall be indicated by the QSTA through the setting of the duration/ID values in one of the following ways:
  - Long enough to cover the response frame, the next frame and its response frame
  - Long enough to cover the transmission of a burst of MPDUs subject to the limit set by dot11EDCATableTXOPLimit

EDCA Parameter Set



Octets: 1	1	1	1	4	4	4	4
Element ID (12)	Length (18)	QoS Info	Reserved	AC_BE Parameters Record	AC_BK Parameters Record	AC_VI Parameters Record	AC_VO Parameters Record

Octets: 1	1	2
ACI/AIFSN	ECWmin/ ECWmax	TXOP Limit

Figure 46.4 – AC_BE, AC_BK, AC_VI and AC_VO Parameter record field formats

- TXOP Limit: in units of 32 microseconds
  - Value of 0 indicates that a single MSDU in addition to a possible RTS/CTS exchange

Table 20.2 – 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

QoS Info Field

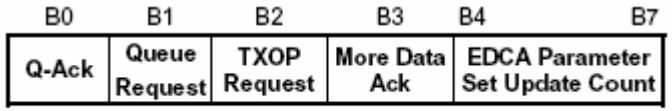


Figure 46.15.1 – QoS Info field

- Q-Ack is set to 1 if a Q -ACK bit
- Queue Request is set to 1 if the QAP can process a non-zero queue size subfield in QoS control field
  - Set to zero by non-AP QSTAs
- TXOP Request is set to 1 if the QAP can process non-zero TXOP duration requested subfield in QoS control in frames
  - Set to zero by non-AP QSTAs
- The More Data Ack bit is set to 1 if a non-AP QSTA can process ACK frames with the more data bit set
  - QAPs always set this subfield to 0
- The EDCA Parameter Set Update Count subfield is incremented every time any of the AC parameters change
  - Set to zero in Association Requests, Re-association Requests

ACI/AIFSN Field

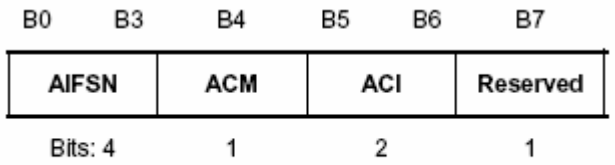


Figure 46.5 – ACI/AIFSN Field

Table 20.1 – ACI to AC coding

ACI	AC	Access Category
00	AC_BE	Best Effort
01	AC_BK	Background
10	AC_VI	Video
11	AC_VO	Voice

- AIFSN: number of slots to backoff before beginning backoff procedure
- ACM: admission control mandatory
  - More details later…
- ACI: see table 20.1

ECWmin/ECWmax field

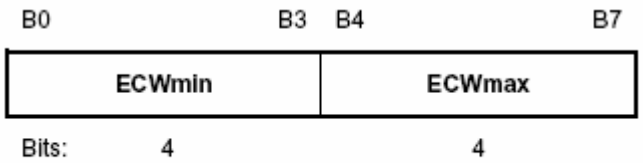


Figure 46.6 – ECWmin/ECWmax field

- The fields ECWmin and ECWmax encode the values of CWmin and CWmax in an exponent form
- $CWmin = (2^{ECWmin}) - 1$
- $CWmax = (2^{ECWmax}) - 1$
- Hence minimum is 0 and the maximum is 32767

EDCA Backoff Procedure

- Each channel access function shall maintain a state variable CW[AC]
  - Initialized to the value of CWmin[AC]
  - Reset to CWmin[AC] after successfully transmitting a frame indicated by:
    - Successful reception of CTS in response to RTS
    - Successful reception of an ACK in response to a unicast MPDU
    - Successful reception of a BlockAck or ACK in response to a BlockAckReq
    - By transmitting a multicast frame or a frame with “no acknowledgement” policy

EDCA Backoff (cont.)

- Backoff procedure should be invoked when either:
  - A frame with that AC is requested to be transmitted and the medium is busy and the backoff timer has a value of zero
    - CW[AC] should be left unchanged
  - The final transmission by the TXOP holder initiated during the TXOP for that AC was successful
    - CW[AC] should be reset to CWmin[AC]
  - The transmission of a frame of that AC fails indicated by:
    - Failure to receive a CTS in response to an RTS
    - Failure to receive an ACK
    - Failure to receive a BlockAck or ACK in response to a BlockAckReq
  - The transmission attempt collides internally with another channel access function of an AC that has higher UP

EDCA Backoff (cont.)

- If backoff procedure is invoked because of transmission failure or internal collision, CW[AC] shall be updated before invoking the backoff procedure:
  - If short or long retry count reached limit, CW[AC] shall be reset to CWmin[AC]
  - Else if CW[AC] is less than CWmax[AC], CW[AC] shall be set to the value (CW[AC]+1)*2-1
  - Else if CW[AC] is equal to CWmax[AC], CW[AC] shall remain unchanged for remainder of any retries
- Following the update of the value of CW[AC], the backoff timer is set to an integer value chosen randomly between (0, CW[AC])

EDCA Retransmit

- QSTAs must maintain short and long retry counters for each AC
  - Defined as QSRC[AC] and QLRC[AC]
- For internal collisions, retry counters are incremented
  - But remember the retry bit is NOT set
- A QSTA shall not initiate the transmission of a data/management frame to a specific RA while the transmission of another frame with the same RA and sequence number assigned from the same sequence counter
  - Sequence numbers are generated by different counters for each traffic identifier (TID)

EDCA AIFS Example

- AIFSN=4, ECWmin=2, ECWmax=10, 802.11a network
  - What is AIFS[AC]?
  - What is range of possible random backoff values if CW[AC] was just reset?
- Give values for AIFSN, ECWmin, and ECWmax to define a DIFS?

HCCA Synopsis

- WSM is Wi-Fi's standard for HCCA
- Allows for the reservation of TXOPs with the Hybrid Coordinator (HC)
  - Called either HCCA TXOP or polled TXOP
- Non-AP QSTAs request the HC for TXOPs
  - Both for its own transmissions and transmissions from the QAP to itself

Hybrid Coordinator

- Hybrid Coordinator Function (HCF) frame exchange sequences may be used during both the CP and CFP
- HC grants a non-AP QSTA a polled TXOP with duration specified in a QoS(+)CF-Poll frame
  - Non-AP QSTAs may transmit multiple frame exchange sequences within given polled TXOPs subject to the limit on TXOP duration
  - Non-AP QSTAs that receive a QoS(+)CF-Poll shall respond within a SIFS period
  - Unused portions of TXOPs are returned back to the HC
- Gains access to the WM as needed by waiting a shorter time between transmissions than the stations using the EDCA procedures

Recovery in Polled TXOP

- The HC MAY initiate recovery by transmitting at a PIFS after the end of the last transmission
- A non-AP QSTA SHALL initiate recovery by transmitting at a PIFS after the end of the last transmission
  - If the polled TXOP limit is greater than 0 and at least one frame (re)transmission can be completed within the remaining duration of a non-zero polled TXOP limit

Creating a Traffic Stream (TS)

- A Traffic Specification (TSPEC) describes the characteristics and the QoS requirements of a TS
  - Reserves resources within the HC
  - Allows other parameters to be specified that are associated with the TS such as traffic classifier and ACK policy
- TSPEC is transmitted by the (Add TS) ADDTS in a QoS Action frame, Reassociation Request or Response
- Following successful negotiation, TS is created and identified with TSID and Direction (uplink or downlink)
  - Identified by HC by TSID, Direction, and non-AP QSTA address
  - TSIDs are TIDs in the range of 8-15

QoS Action Frames

00	Management	1010	Disassociation
00	Management	1011	Authentication
00	Management	1100	Deauthentication
00	Management	1101	Action

- s
- Action frames allow for more management frames to be defined
- If STA receives a unicast Action frame with an unrecognized Category field or some other syntactic error and the most significant bit of the category field set equal to 0 then the STA returns the Action frame to the source without change except the most significant bit of the Category field set to 1

Table 15.1 – Action frame body

Order	Information
1	Action field

	Category	Action Details
Octets:	1	variable

Figure 33.1 – Action Field

Code	Meaning	See subclause
1	QoS	7.4.2
2	DLP	7.4.3
3	Block Ack	7.4.4

Table 20.8 – QoS Action field values

Action field value	Meaning
0	ADDTS request
1	ADDTS response
2	DELTS
3	Schedule
4– 255	Reserved

Block Acknowledgement

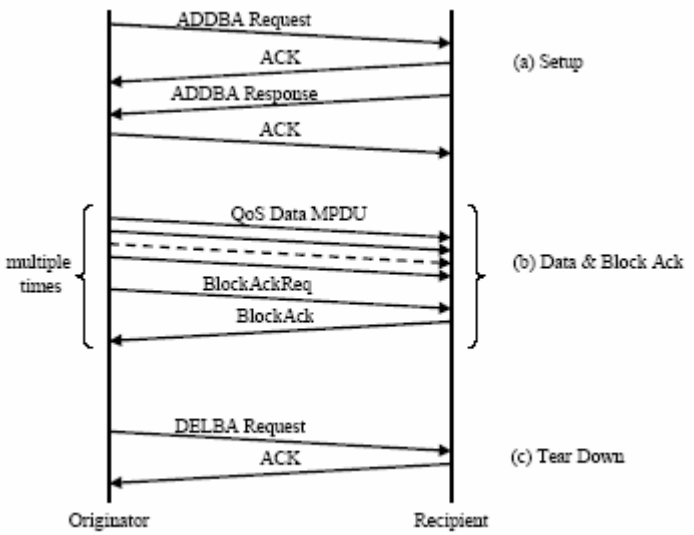
- This mechanism allows a block of QoS Data MPDUs to be transmitted each separated by a SIFS period
- Mechanism is for improving the channel efficiency by aggregating several acknowledgments into one frame
- Immediate Block ACK is suitable for high-bandwidth, low latency traffic
- Delayed Block ACK suitable for applications that tolerate moderate latency
- A block may be started within a TXOP

Block ACK (cont.)

- Each Block ACK block needs to be set up and torn down
- Block ACK capability is advertised in the Capability Information field

Table 20.17 – Block Ack Action field values

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



Automatic Power Save Delivery (APSD)

- Capability is set in the APSD capability bit in the Capability Information field
- Two different types of delivery:
  - An unscheduled service period (SP) begins when the QAP receives any frame from the non-AP QSTA and ends after the QAP has attempted to transmit all frames
  - A scheduled SP starts at fixed intervals of time scheduled between the QSTA and QAP

Direct Link Protocol (DLP)

- QSTAs may transmit frames directly to another QSTA by setting up DLP
  - Not rely on the AP for delivery of frames
- Prohibits QSTAs from going into Power Save

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

DLP Setup

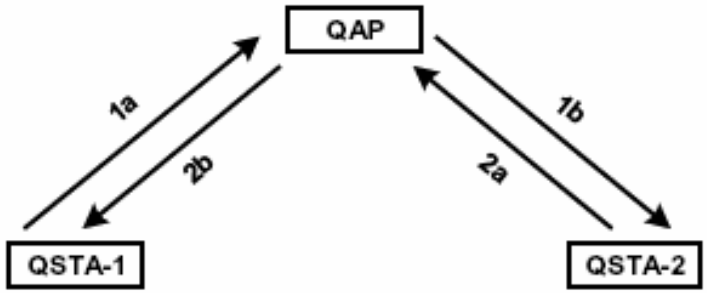


Figure 68.9 – The four steps that are involved in the Direct Link handshake.

a) A station QSTA-1 that has data to send invokes DLP and sends a DLP Request frame to the AP (1a in Figure 68.9). This request contains the rate set, and capabilities of QSTA-1, as well as the MAC addresses of QSTA-1 and QSTA-2.

b) If QSTA-2 is associated in the BSS, direct streams are allowed in the policy of the BSS and QSTA-2 is indeed a QSTA (i.e. compliant to this standard), the AP shall forward the DLP-request to the recipient, QSTA-2 (1b in Figure 68.9).

c) If QSTA-2 accepts the direct stream, it shall send a DLP-response frame to the AP (2a in Figure 68.9), which contains the rate set, (extended) capabilities of QSTA-2 and the MAC addresses of QSTA-1 and QSTA-2.

d) The AP shall forward the DLP-response to QSTA-1 (2b in Figure 68.9), after which the direct link becomes active and frames can be sent from QSTA-1 to QSTA-2 and from QSTA-2 to QSTA-1.