Wireless access points are the second most-likely places in the enterprise network to experience congestion (after LAN-to-WAN links). This is because wireless media:
• generally presents a downshift in speed/throughput
• is a half-duplex media
• is a shared media

Furthermore, the nature of wireless media presents additional challenges from a QoS provisioning perspective, including:
• No support for strict priority queuing
• No support for guaranteed bandwidth allocations
• Non-deterministic media access
• A maximum of four levels of service

As such, the case for QoS on the WLAN is to minimize packet drops due to congestion, as well as to minimize jitter due to non-deterministic access to the half-duplex, shared media.

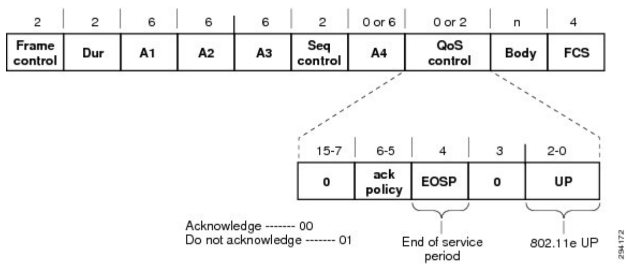
WLAN QoS Design Best Practices
Four QoS design principles that apply to WLAN deployments include:
• Always perform QoS in hardware rather than software when a choice exists.
• Classify and mark applications as close to their sources as technically and administratively feasible.
• Police unwanted traffic flows as close to their sources as possible.
• Enable queuing policies at every node where the potential for congestion exists,

WLAN QoS Design Considerations
There are several considerations unique to WLANs that must be factored into QoS designs:
• The IEEE 802.11e Enhanced Distributed Coordination Function (EDCF), including:
  ▪ User Priorities
  ▪ Access Categories
  ▪ Arbitration Inter-Frame Spaces (AIFS)
  ▪ Contention Windows (CW)
  ▪ EDCF Operation
• UP-to-DSCP and DSCP-to-UP Mapping
• Application Visibility and Control
• Trust Boundaries and Policy Enforcement Points

IEEE 802.11e EDCF
The original 802.11 standard described a Distributed Coordination Function (DCF) to avoid collisions over the WLAN. However, this function had no support for QoS. In 2006, the 802.11e task group provided several enhancements to this function to support QoS, hence the term: Enhanced Distributed Coordination Function (EDCF). These enhancements include:

User Priorities (UP)
802.11e introduced a 3 bit marking value in layer 2 wireless frames referred to as User Priority (UP); UP values range from 0-7. UP fields are showin in Figure 1.

Figure 1 IEEE 802.11e User Priorit y Field



Access Categories (AC)
Pairs of UP values are assigned to 4 access categories, which statistically equate to 4 distinct levels of service over the WLAN. Access categories and their UP pairings are shown in Figure 2.

Figure 2 IEEE 802.11e Access Cat egories

802.11e UP Value	802.11e Access Category	WMM Designation	Cisco AireOS WLC Designation
7	AC_VO	Voice	Platinum
6			
5	AC_VI	Video	Gold
4			
3	AC_BE	Best Effort	Silver
0			
2	AC_BK	Background	Bronze
1			

Arbitration Interframe Spaces (AIFS)
EDCF introduced a variable interframe spacing (IFS) period for wireless frames, called the Arbitration Interframe Spaces (AIFS). The intention of assigning different AIFS values to each AC is that the higher-priority ACs are assigned shorter wait times as compared to the lower-priority ACs. This approach thus gives the high-priority traffic a much better probability of being transmitted first. AIFS by access category are shown in Figure 3.

Figure 3 IEEE 802.11e AIFS by Access Category

Access Category	AIFS (Slot Times)
Voice	2
Video	2
Best Effort	3
Background	7

Contention Windows
If two or more wireless devices began transmitting after waiting only a fixed amount of time after the air was clear (the AIFS) then the probablility of collisions would be high. However, in addition to waiting a fixed amount of time, each station must also wait a variable amount of time, called the Contention Window (CW). The initial, incremental and variable delay is a random number chosen between 0 and the minimum value for the Contention Window (CWmin). The values for CWmin are skewed by access categories, as are the maximum limits for these (CWmax), as shown in Figure 4.

Figure 4 IEEE 802.11e Contention Windows by AC

Access Category	CWmin (Slot Times)	CWmax (Slot Times)
Voice	3	7
Video	7	15
Best-Effort	15	1023
Background	15	1023

EDCF Operation

When the AIFS and CW timers are combined, then the skewing of the probability of transmission of each access categories becomes even more apparent, as shown in Figure 5.

Figure 5 IEEE 802.11e AIFS and CW by AC

shows how AIFS and per-AC CW backoff timers work together to improve the overall handling of the four WMM access categories. In this example, the voice queue waits for five slot times before attempting to send its data onto the channel (2 AIFS slots + a randomly generated CW of 3 slots), thus resulting in a significantly improved probability that the voice traffic is sent over the air before anything else.

For more details, see the AVC/QoS Design chapter of the BYOD CVD at:
http://www.cisco.com/c/en/us/td/docs/solutions/Enterprise/Borderless_Networks/Unified_Access/BYOD_Design_Guide/BYOD_AVC.html
And/or the Cisco Press book: End-to-End QoS Network Design (Second Edition)-Chapter 18