CISCO

WLAN QoS Design

The Case for QoS in the Wireless LAN

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:
- Classify and mark applications as close to their sources as technically and administratively possible
- 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
  - Transmission Opportunity (TXOP)
  - Transmission Specification (TSpec)
- UP-to-DSCP and DSCP-to-UP Mapping

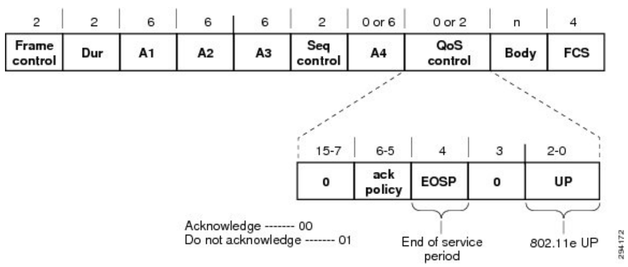
IEEE 802.11e EDCF

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 Priority 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 Categories

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)

Each wireless station was wait a fixed (and a variable) amount of time once the medium is clear prior to attempting to transmit. The fixed amount of time is called the AIFS. EDCF skewed these fixed delays on a per-access category basis, such that higher-priority ACs are assigned shorter wait times as compared to the lower-priority ACs. This approach thus gives the high-priority traffic 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

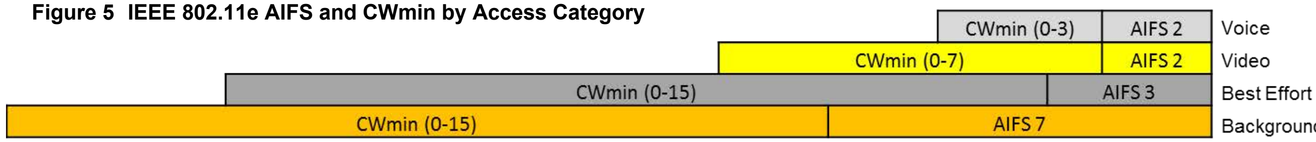
If two or more wireless devices begin transmitting after waiting only a fixed amount of time after the air is clear (the AIFS), then the probability of collisions would be high. However, in addition to waiting a fixed amount of time, each station must also wait a variable amount of time, called a random backoff. The range for these random backoffs is between 0 and the current size of the the Contention Window (CW). The CW can increase over time, but begins at an initial minimum value (CWmin). The values for CWmin are skewed by access categories, as are the maximum values for Contention Windows (the CWmax values), 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 random backoff timers are combined, then the skewing of the probability of transmission of each access categories becomes even more apparent, as shown in Figure 5 (right).

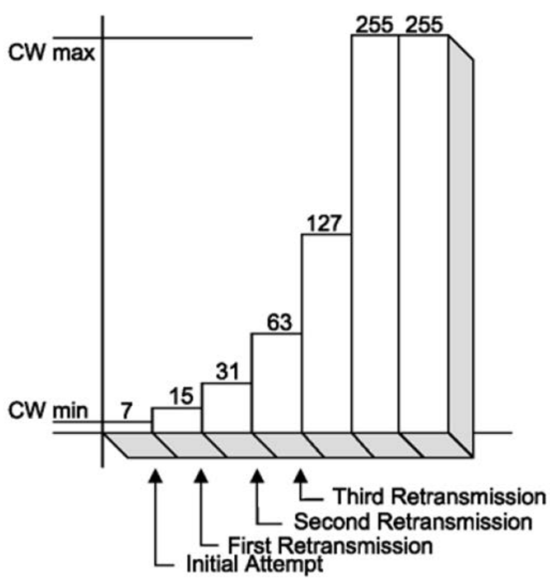
Figure 5 IEEE 802.11e AIFS and CWmin by Access Category



Each wireless station (including the access point, which is competing on equal terms with endpoint devices for airtime) waits until all timers have elapsed before attempting transmission. Statistically, any endpoint transmitting voice traffic will have a better chance at being the next to use the media; however, this is not guaranteed, because of the random value of the CW timers.

If in the event that two (or more) stations still begin transmitting at the same time, then all stations will effectively double their CW sizes and try again. This process repeats (as needed) until the CWmax value for an AC is reached. At this point, Contention Windows remain fixed at the CWmax size until a defined transmission attempt limit is reached (e.g. on Cisco APs this limit is 64 transmission attempts). This operation is shown in Figure 6.

Figure 6 Contention Window Operation



Transmission Opportunity (TXOP)
EDCF provides contention-free period access to the wireless medium, called the Transmission Opportunity (TOXP). The TXOP is a set period of time when a wireless station may send as many frames as possible without having to contend with other stations. With TXOP, each station has a set time limit when it can transmit; once this limt expires, it must give up access to the medium.

Transmission Specification (TSpec)
One last major enhancement introduced by 802.11e is a mechanism for Call Admission Control (CAC) called Transmission Specification (TSpec). TSpec allows real-time applications, such as voice or video calls in-progress, to be prioritized over requests for new calls. To use this feature of EDCF, TSpec must be configured on the AP and optionally on the client stations.

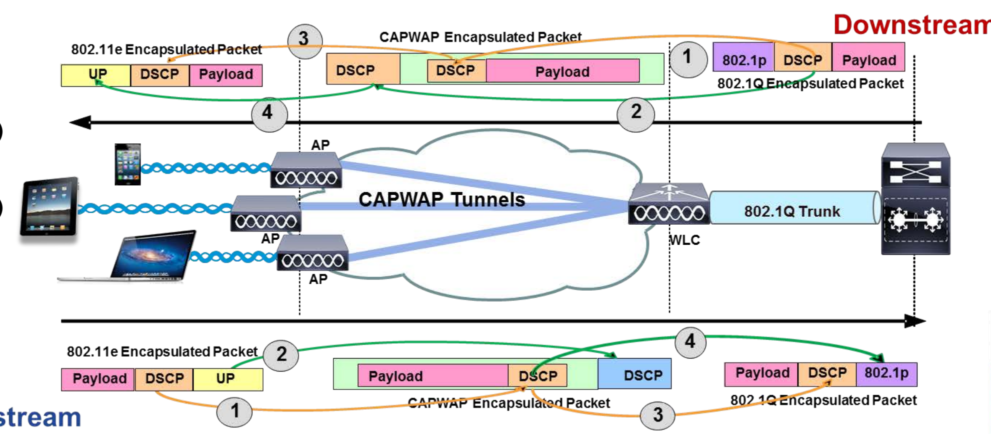
DSCP-to-UP and UP-to-DSCP Mapping
Upstream and downstream DSCP<>UP mapping is shown in Figure 7. By default, 6-bit DSCP values are mapped to 3-bit 802.11e UP values by taking the three Most-Significant Bits (MSB) of the DSCP and copying these as UP values. For example, DSCP EF/46 (binary **101**110) is mapped to CoS or UP 5 (binary **101**), by default.

Conversely, in the reverse direction, the CoS or UP values are simply multiplied by 8 (in order to shift these three binary bits to the left) to generate a DSCP value. Continuing the example, UP 5 (binary **101**) would be mapped (i.e., multiplied by 8) to DSCP 40 (binary **101**000), also referred to as Class Selector 5 (CS5).

As can be seen in the above pair of examples, because information is being truncated from 6-bits to 3-bits, marking details can get lost in translation. In this example, the original voice packet was sent with DSCP EF, but was received as DSCP CS5 (based solely on default Layer 2-to-Layer 3 mapping). This needs to be taken into account when mapping from wired-to-wireless and vice-versa.

Also, it bears explicit mention that (Layer 2) IEEE and (Layer 3) IETF marking recommendations do not always align. For example, DSCP EF/46 is recommended by the IETF for use for voice, which would map by default to UP 5; but the IEEE designates UP 6 for voice. Similarly, the IETF recommends DSCP CS4 or AF4 for real-time or interactive video conferencing, both of which would map by default to UP 4; but the IEEE designates UP 5 for video. Such discrepancies must also be taken into account and reconciled in WLAN QoS designs

Figure 7 Downstream (DSCP-to-UP) Mapping & Upstream (UP-to-DSCP) Mapping



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