CHAPTER 24

# Mobile Traffic Engineering with Application Visibility and Control (AVC)

**Revised: August 7, 2013**

## Executive Summary

Mobile wireless traffic is soon about to exceed wired traffic on a global basis and is comprised mainly of mobile video applications. Furthermore, the devices generating wireless traffic are shifting away from traditional laptops towards smartphones and tablets. As such, the volume, composition, and device-shift of mobile application traffic can pose a challenge to network administrators tasked with ensuring their quality.

Business use cases for managing mobile applications include:

- Improving the quality of wireless voice from cellular-quality to toll-quality
- Enhancing the quality of experience for wireless video applications
- Expediting the response times for business critical data applications over wireless devices
- Managing background application traffic by preventing bulky traffic flows from monopolizing bandwidth away from more transaction-oriented flows, thus further improving user productivity
- Controlling non-business applications on wireless networks, including social networking applications, video and media-downloading applications, peer-to-peer sharing applications, gaming applications, etc.

This document presents design considerations relating to wireless (and wired) network quality management by overviewing the underlying technologies involved and showing how these interact to create an end-to-end solution.

However, the main theme of this document is detailed design guidance on best-practice Quality of Service (QoS) configurations for Cisco Wireless LAN Controllers (highlighting the new Cisco Application Visibility and Control feature) as well as for network switches to achieve the business use cases for mobile application management.

# Macro Trends and Business Requirements

Mobile application traffic is continuing to explode. According to Cisco's Visual Networking Index Forecast, global mobile data traffic will grow 13-fold from 2012 to 2017.[1]

Additional key trends relating to mobile devices, applications, and traffic include:

- By 2014, wireless IP traffic will exceed wired (and will exceed 60% by 2016).[2]
- By 2016, the number of mobile-connected devices will exceed three-times the world's population.[3]
- By 2016, non-PC devices (such as smartphones and tablets) will generate 30% of all IP traffic.[4]
- By 2017, tablets will account for more than 12% of global mobile data traffic.[5]
- By 2017, mobile video will represent two-thirds of all mobile data traffic.[6]
- By 2017, 45% of global mobile data traffic will be offloaded to fixed networks via WiFi or femtocell.[7]

Therefore (non-PC) mobile devices will generate exponentially more traffic in the coming years, with the bulk of this traffic traversing wireless networks and with the traffic itself being primarily composed of video applications.

Since QoS is critical to the overall Quality of Experience (QoE) of video-based applications, network administrators need to concern themselves with ensuring that the applications traversing their networks—especially their wireless LANs (where the majority of traffic will be sourced from)—is being adequately provisioned.

1. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf
2. Cisco Visual Networking Index: Forecast and Methodology, 2011-2016 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf
3. Cisco Visual Networking Index: Forecast and Methodology, 2011-2016 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf
4. Cisco Visual Networking Index: Forecast and Methodology, 2011-2016 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf
5. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf
6. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf
7. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf

Business use-cases for wireless application quality include:

- Guaranteeing voice quality from wireless applications meets enterprise VoIP requirements. For example, independent third-party testing has shown that wireless VoIP quality over congested wireless networks can be improved from a Mean Opinion Score (MOS) of 3.92 (which is considered cellular quality) to 4.2 (which is considered toll quality) by applying the recommendations detailed later in this document.[1]
- Ensuring video applications—both interactive and streaming—are delivered to/from wireless devices with a high Quality of Experience, so that users can communicate and collaborate more efficiently and effectively—regardless of their location or device. As another example, the same testing has shown video quality to improve from Good (9 fps) to Excellent (14 fps) after respective policies were deployed.[2]
- Provisioning preferred services for business-critical applications running on wireless devices, such as Virtual Desktop applications, sales applications, customer relationship management (CRM) applications, and enterprise resource planning (ERP) applications, etc. Yet another example has shown Citrix traffic latency to decrease by a factor or 7 (from 14 ms to 2 ms) when properly provisioned over the wireless network.[3]
- De-prioritizing "background" application traffic (i.e., applications that send data to/from servers, rather than directly to other users and which do not directly impact user-productivity), such as email, file-transfers, content distribution, backup operations, software updates, etc.
- Identifying, de-prioritizing (or dropping) non-business applications, which can include social networking applications, peer-to-peer file-sharing applications and type of entertainment and/or gaming applications so that network resources are always available for business-oriented applications.

A key facilitating technology for identifying and managing application traffic over wireless networks to meet these business use case requirements is the Cisco Application Visibility and Control (AVC) feature for Cisco Wireless LAN Controllers, which is discussed next.

# Cisco Application Visibility and Control (AVC) for Wireless LAN Controllers

Beginning with Cisco WLC software release 7.4, the Application Visibility and Control set of features—already supported on Cisco routing platforms, like ASR 1000s and ISR G2s—became available on WLC platforms, including the Cisco 2500, 5500, 7500, 8500 WLCs, and WiSM2 controllers on Local and Flex Modes (for WLANs configured for central switching only in 7.4 release).

The AVC feature set increases the efficiency, productivity, and manageability of the wireless network. Additionally, the support of AVC embedded within the WLAN infrastructure extends Cisco's application-based QoS solutions end-to-end.

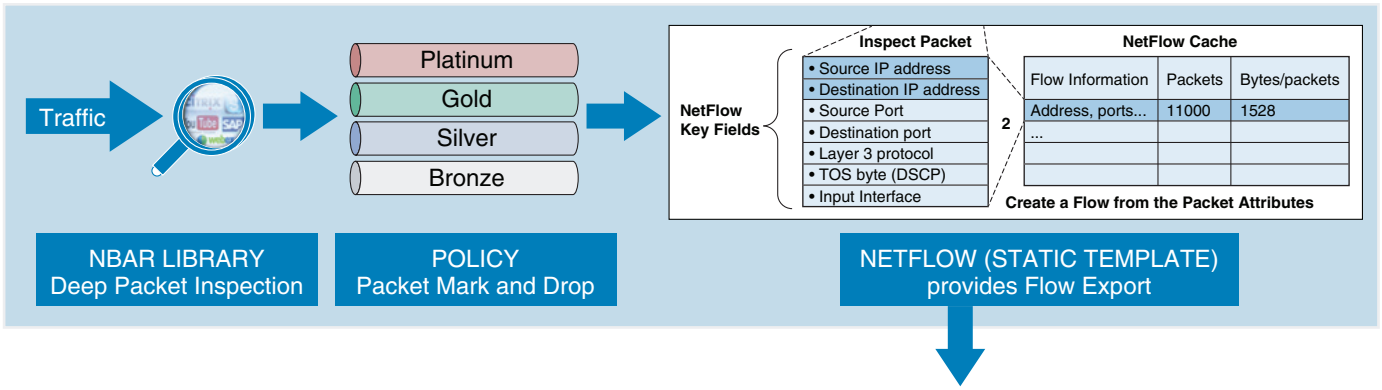
1. Syracuse University: Network Technology Performance Evaluation Cisco Application Visibility and Control (AVC) (February 1, 2013)
http://www.cisco.com/en/US/prod/collateral/wireless/cisco_avc_application_improvement.pdf
2. Syracuse University: Network Technology Performance Evaluation Cisco Application Visibility and Control (AVC) (February 1, 2013)
http://www.cisco.com/en/US/prod/collateral/wireless/cisco_avc_application_improvement.pdf
3. Syracuse University: Network Technology Performance Evaluation Cisco Application Visibility and Control (AVC) (February 1, 2013)
http://www.cisco.com/en/US/prod/collateral/wireless/cisco_avc_application_improvement.pdf

AVC includes these components:

- Next-generation Deep Packet Inspection (DPI) technology called Network Based Application Recognition (NBAR2), which allows for identification and classification of applications. NBAR is a deep-packet inspection technology available on Cisco IOS based platforms, which includes support of stateful L4-L7 classification.
- QoS—Ability to remark applications using DiffServ, which can then be leveraged to prioritize or de-prioritize applications over both the wired and wireless networks.
- A template for Cisco NetFlow v9 to select and export data of interest to Cisco Prime or a third-party NetFlow collector to collect, analyze, and save reports for troubleshooting, capacity planning, and compliance purposes.

These AVC components are shown in Figure 24-1.

***Figure 24-1 Cisco AVC Components***




AVC on the WLC inherits NBAR2 from Cisco IOS that provides deep packet inspection technology to classify stateful L4-L7 application classification. This is critical technology for application management, as it is no longer a straightforward matter of configuring an access list based on the TCP or UDP port number(s) to positively identify an application. In fact, as applications have matured—particularly over the past decade—an ever increasing number of applications have become opaque to such identification. For example, HTTP protocol (TCP port 80) can carry thousands of potential applications within it and in today's networks seems to function more as a transport protocol, rather than as the OSI application-layer protocol that it was originally designed as. Therefore, to identify applications accurately, Deep Packet Inspection technologies—such as NBAR2—are critical.

Once applications are recognized by the NBAR engine by their discrete protocol signatures, it registers this information in a Common Flow Table so that other WLC features can leverage this classification result. Features include QoS, NetFlow, and Firewall features, all of which can take action based on this detailed classification.

Thus AVC provides:

- Application Visibility on the Cisco WLC by enabling Application Visibility for any WLAN configured. Once Application Visibility is turned on, the NBAR engine classifies Applications on that particular WLAN. Application Visibility on the WLC can be viewed at an overall network level, per WLAN or per client.
- Application Control on the Cisco WLC by creating a AVC profile (or policy) and attaching it to a WLAN. The AVC Profile supports QoS rules per application and provides the following actions to be taken on each classified application: Mark (with DSCP), Permit (and transmit unchanged) or Drop.

Key business use cases for AVC include:

- Classifying and marking wireless mobile device applications—Identifying and differentiating realtime voice, video, or business-critical applications from less important, but potentially bandwidth-hungry-applications so as to prioritize, de-prioritize, or drop specific application traffic.
- Capacity planning and trending—Baselining the network to gain a clearer understanding of what applications are consuming bandwidth and trending application usage to help network administrators plan for infrastructure upgrades.

To better understand how AVC works in WLAN scenarios, an overview of the challenges and tools for managing quality of service over wireless media may be helpful (and is discussed next, along with a summary of the overall strategic recommendations for deploying quality of service policies across an enterprise). Network administrators already familiar with these concepts may find it more efficient to skip the following sections and to proceed directly to Configuring Downstream QoS Policies for Mobile Applications and Configuring Upstream QoS Policies for Mobile Applications.

# Challenges and Solutions for Managing Application Quality over Wireless Media

To better understand design recommendations available for managing application quality over wireless media, it is beneficial to lay some context as to the challenges and solutions available for managing traffic over this media. To begin with, it should be noted that the very nature of wireless as a transmission media makes it less predictable and controllable from a quality perspective, as compared to wired networks.

For example, wired campus networks operate at full-duplex mode, with endpoints being able to transmit data at any time at maximum capacity. For example, a server connected to a switch by a 1 Gbps full-duplex link can theoretically both send and receive at 1 Gbps of data simultaneously, without having to contend with other stations for access to the medium.

Wireless networks, on the other hand, operate in half-duplex mode, with endpoints contending among themselves as well (as with the wireless access point) for the opportunity to transmit data. This is because in WLANs, every station associated to a particular access point (AP) must share the radio frequency (RF) with all the other stations; however, only one station—including the AP itself—may transmit at a given time. The result of this is that each station must contend with all the other stations for airtime. WLANs are-by definition-a multiple-access, broadcast medium, meaning that if more than one station transmits at any one time, no other station is able to understand what has been transmitted. Put another way, if two (or more) stations began transmitting data simultaneously over a WLAN, this would result in a collision. This limitation means that to avoid RF interference, full-duplex is simply not possible in WLANs (if both transmitting and receiving are performed on the same channel, as is the case in most WLAN deployments). Before quality can even be addressed over WLANs, the first requirement is finding a solution to avoiding collisions over wireless media.

## IEEE 802.11 Distributed Coordination Function (DCF)

A baseline understanding of the Distributed Coordination Function (DCF)—operating at the 802.11 MAC layer (which is responsible for scheduling and transmitting Ethernet frames onto the wireless medium)—is essential to understanding the subsequent enhancements that allow for wireless quality of service.

DCF has the following key components, which are briefly described below:

## Collision Sense Multiple Access/Collision Avoidance (CSMA/CA)

Wi-Fi wireless networks are completely egalitarian, meaning that all wireless stations have equal access to the medium. In fact, even the AP has no more priority to access the medium than the client stations do. For example, a wireless IP phone has to abide by exactly the same principles as a wireless laptop, regardless of the fact that one of them might be transmitting real-time VoIP traffic and the other might be transmitting peer-to-peer (P2P) traffic. Since each client, and thus each application, has an equal opportunity to transmit frames at any given time, there must be an orderly system to coordinate the transmission of packets onto the medium. If no control were implemented, there would be a high probability of a collision. Additionally, the more clients associated to the AP, the higher the likelihood of collisions occurring. Furthermore, each time a collision occurs, stations would reattempt their transmissions, likely causing additional collisions in the process.

A similar problem existed in the early days of wired Ethernet, when half-duplex links and hubs were common. In half-duplex wired Ethernet environments collisions were a common outcome of multiple end-stations trying to transmit frames onto the wire at the same time. To address this situation, a system called Carrier Sense Multiple Access/Collision Detection (CSMA/CD) was developed. CSMA/CD is a set of rules that all end stations are required to follow when trying to transmit a frame onto the medium. For example, if a collision occurred, the stations involved in the collision would follow a strict set of backoff rules, involving random timers that help to reduce the probability of a future collision next time round. CSMA/CD thus proved a relatively effective mechanism to reduce collisions on half-duplex Ethernet networks.

**Note** While CSMA/CD worked well enough, the problem of collisions was to be obviated altogether in wired networks by introducing switching technology, which provided dedicated collision domains to each network segment. In this manner, no endpoint contended for media access with any other endpoint, as each had a dedicated collision domain between itself and the switch and as such could then operate at full-duplex capacity.

However while it may seem that CSMA/CD might likewise be applicable to wireless networks, there is a key difference: wireless stations have no way to detect a collision.

In a wired network, transmissions are sent as bursts of energy on the wire that can be reflected back to the end stations, thus allowing accurate detection of collisions. In a wireless medium, the RF energy is shared over the air, meaning reflections of the energy wave do not come back to the sending station, thus making collision detection impossible; hence CSMA/CD is an impractical approach for WLANs.

Notwithstanding this, the IEEE modified the CSMA/CD mechanism to accommodate wireless networks, as Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA). The techniques differ in that CSMA/CD deals with what to do after a collision occurs, whereas CSMA/CA works to prevent a collision in the first place.

To understand this better, consider a person participating in an audio conference call. If many people are on the call together, there is a good chance that one person may begin talking at the same time as another, making both of them unintelligible to everyone else (effectively, a “collision”). If the parties used a CSMA/CD approach, they would pause for a few seconds and then try talking again in the hopes that they would not again talk at the same time, so that at least one of them could be understood. On the other

hand, if the parties were following a more polite CSMA/CA approach, then instead of simply starting to talk on the conference call (while hoping that no one else would at the same time), each party would wait patiently for a quiet period. Then, when they were certain that no one else was talking, they would begin. Additionally, the other parties would recognize and respect that one party was talking and would remain silent until they had completed speaking (without interruption).

Thus CSMA/CA opts to listen to the channel first to see if any transmissions are in progress and only when the channel is free does it attempt to send its frame. If a collision does occur even after listening and waiting, the wireless station deals with it in a similar way to CSMA/CD, by waiting for a random backoff period before it tries to resend the frame.

However it is important to note that CSMA/CA can never fully guarantee that a collision won't occur; rather, it reduces the probability that a collision will occur by trying to "avoid" a future collision. CSMA/CA is a bit like arriving in your car at a four-way stop at the same time as three other drivers. Although you might try very hard to avoid a collision by looking both ways very carefully before driving into the intersection, you can never fully guarantee what the other driver will do. If you make a decision to proceed, there is always a slight possibility that the other driver might do the same thing at the same time and thus there is always the possibility of a collision. The same goes for WLAN stations that operate using CSMA/CA.

## Short Interframe Space (SIFS)

So how does a sending station know that its transmission succeeded? Since, due to the broadcast nature of the wireless medium, collisions cannot be detected (they can only be avoided with a measure of probability), there is an obvious need to confirm whether a transmission was successful. To solve this problem, DCF ensures that each frame is acknowledged once the transmission is successfully received. Specifically, there is a provision in DCF where all clients keep silent after a transmission finishes so the receiving station has a chance to send the acknowledgement. This is period is called the Short Interframe Space (SIFS). This ensures that the transmitting station knows that it does not need to retransmit and it can move on to its next frame.

## DCF Interframe Space (DIFS)

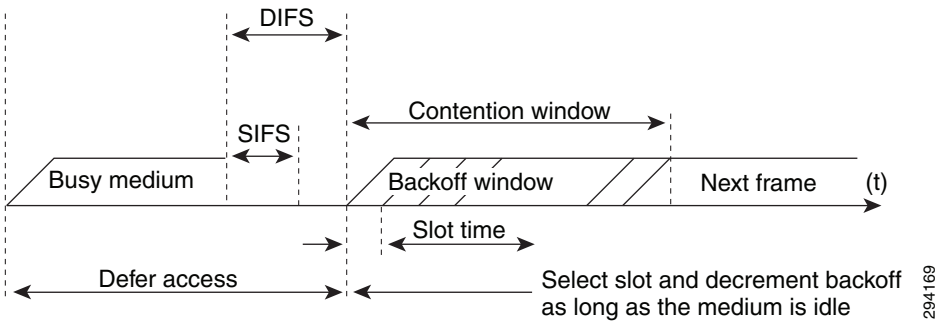
To help control and organize the transmission of frames on the wireless medium, DCF uses some clever rules whereby the contending stations wait for different periods of time before they can transmit their frames onto the channel. A central and key concept to how DCF operates is the DCF Interframe Space (DIFS). DIFS is a pre-established, fixed wait timer observed by all stations before they attempt transmission of a frame onto the channel.

**Note** There are actually several Interframe Space (IFS) types used in 802.11 networks; however, for the purposes of this discussion attention is focused only on SIFS and DIFS.

As mentioned, CSMA/CA provides a framework of "listen before you talk" for wireless stations. When a wireless station wants to transmit a frame, the first thing it does is to wait the appropriate DIFS time. Once this DIFS countdown has finished, if the medium is still clear, it transmits. DIFS is like a level set for all stations that want to transmit. If they all just started transmitting as soon as they had a frame in the queue, collisions would be plentiful. By waiting the DIFS period it gives a chance for the station to confirm that the channel is indeed clear for transmission.

Figure 24-2 shows the operation of Interframe Spaces (SIFS and DIFS) within DCF.

*Figure 24-2 Interframe Spaces Operation*




## Contention Window (CW)

However, it may be the case that after waiting for the DIFS period to expire, the DCF process detects the medium is not idle. If this is the case, the station waits (technically speaking the station will "defer") for a random period of time, called the contention window (CW). The first time a station needs to defer, the CW random backoff period is set from 0 to a maximum value known as CWmin. There is an obvious advantage to waiting a random period of time, for if multiple stations are all trying to transmit at the exact same time because a collision occurred and they all backed off for the same length of time, collisions would continually occur. After the CW timer expires the station again looks to see if the medium is free and if it is, it begins transmission.

However, if after the CW timer expires the sending station detects that the medium is still not clear, then it will:

- Defer again until the wireless medium is finally clear.
- Wait again for the DIFS period.

  Then:

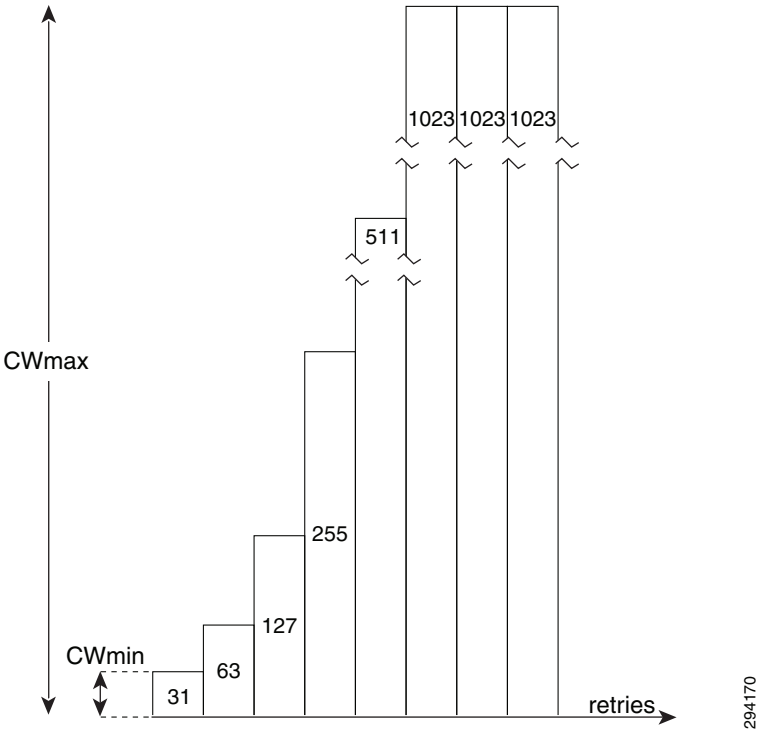
- Wait for another (longer) backoff period.

At first, the station doubles the CW value it used previously. However, if the station continually finds that the medium is not clear, then the station will continue to double the backoff window each time it tries to send the frame. It keeps on doing this up to a maximum amount of time, known as the CWmax value. This continues until it either it transmits the frame or the Time to Live (TTL) expires.

The amount of time that the station counts down is not actually measured in seconds, but rather in slot times. The slot time is a time value derived from the RF characteristics of the radio network and so it is unique for each network (but the actual length of these times is in microseconds, with 802.11 specifying about 20 microseconds for a slot time). As an example, in the case of IEEE 802.11n, the CWmin default is 15 slot times (~300 µs or 0.3 ms) and CWmax is 1023 slot times (~20,460 µs or 20.46 ms).

Due to the variable nature of contention windows, it is easy to see how significant amounts of delay variation (jitter) can be introduced into the packet flows. Figure 24-3 illustrates Contention Window Operation.

*Figure 24-3 Contention Window Operation*

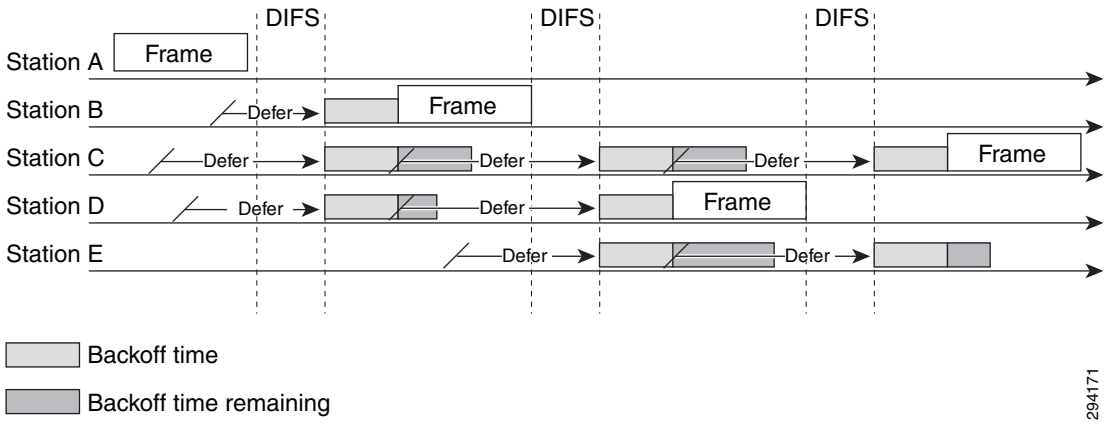



To illustrate how this works, if the random backoff for a station was initially set to 10 slot times, the second backoff would be 20. If the channel is still busy, the CW backoff is increased to 40, then 80, then 160, then 320, and finally 640 (as 640 doubled would exceed the CWmax value of 1023 slot times). At this point, if the frame has not been sent, the process begins again. These retries continue until the packet TTL is reached. This process of doubling the backoff window is referred to as binary exponential backoff.

## DCF Operation

Consider an example of the DCF process might apply to a real world contention scenario. As illustrated in Figure 24-4, five stations associated to the same AP and all are trying to send data at approximately the same time.

*Figure 24-4 DCF Operation*




The DCF operation steps illustrated in Figure 24-4 are as follows:

**Step 1** Station A successfully sends a frame; three other stations also want to send frames, but must defer to Station A traffic.

**Step 2** After Station A completes the transmission, all the stations must still defer to the DIFS. When the DIFS is complete, stations waiting to send a frame can begin to decrement the backoff counter, once every slot time, and can send their frame.

**Step 3** The backoff counter of Station B reaches zero before Stations C and D, and therefore Station B begins transmitting its frame.

**Step 4** When Station C and D detect that Station B is transmitting, they must stop decrementing the backoff counters and defer until the frame is transmitted and a DIFS has passed.

**Step 5** During the time that Station B is transmitting a frame, Station E receives a frame to transmit, but because Station B is sending a frame, it must defer in the same manner as Stations C and D.

**Step 6** When Station B completes transmission and the DIFS has passed, stations with frames to send begin to decrement the backoff counters. In this case, the Station D backoff counter reaches zero first and it begins transmission of its frame.

**Step 7** The process continues as traffic arrives on different stations.

# IEEE 802.11e/WMM

As can be seen from the previous section's analysis of the DCF model, there is no provision to differentiate service levels by traffic types, thus quality assurance is not possible using legacy DCF. To address this (and other limitations) the IEEE 802.11e task group provided enhancements to the original 802.11 specification that recommended several modifications to the way DCF operates that would facilitate a differentiated services model. These 802.11e modifications to the DCF model have been rolled into the wider 802.11-2007 standard (which is essentially a retrofit of the original 802.11 specification). The IEEE 802.11e model was also certified by the Wi-Fi Alliance as the Wireless Multimedia (WMM) model; as such these terms generally refer to the same mechanisms and are used interchangeably in this paper.

The 802.11e task group has provided many enhancements to the overall 802.11 specification, but the key goal was to introduce an intelligent system of application traffic differentiation on wireless radio interfaces. Two of the most significant changes proposed by this task group were:

- To support marking within wireless frames by supporting a 3 bit marking value known as 802.11e User Priority (UP); 802.11e UP is essentially the same as 802.1p CoS marking, but for wireless frames (as opposed to wired Ethernet tagged frames).
- To replace DCF with a new MAC layer protocol known as Enhanced Distributed Channel Access (EDCA), which introduces the concept of relative prioritization by giving different application traffic varied access levels to the wireless media.

However, a critical point to understand about wireless QoS tools is that—unlike wired QoS tools—these can only offer a greater probability of one traffic type being differentiated from another, not an absolute guarantee of it.

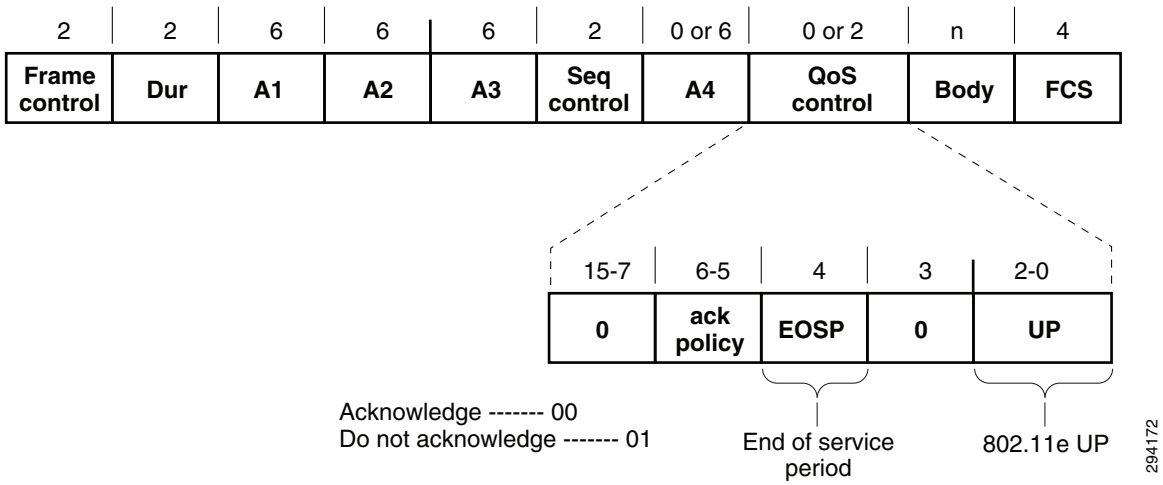
IEEE 802.11e/WMM introduced major enhancements over DCF, which in turn enables a QoS toolset over Wi-Fi networks. Each of these enhancements is briefly described:

- 802.11e User Priorities
- Access Categories (AC)
- Enhanced Distributed Coordination Function (EDCF)
- Arbitration Interframe Spacing (AIFS)
- Contention Window Enhancements
- Transmission Opportunity (TXOP)
- Call Admission Control (TSpec)

## 802.11e User Priorities

IEEE 802.11e/WMM introduced a new frame format, shown in Figure 24-5, which includes support for a 3 bit marking field—compatible with 802.1D priority and 802.1p CoS—that is referred to as 802.11e User Priority (UP).

*Figure 24-5 WMM Frame Format and 802.11e UP*



## Access Categories (AC)

IEEE 802.11e/WMM specifies four different access categories, which are:

- Voice (AC_VO)
- Video (AC_VI)
- Best-Effort (AC_BE)
- Background (AC_BK)

IEEE 802.11e also supports a default mapping of User Priority markings to these access categories; these mappings are shown in Table 24-1.

*Table 24-1 IEEE 802.11e/WMM Access Categories, Mappings and Designations*

| Relative Priority | 802.11e UP | 802.11e Access Category (AC) | WMM Designation | Cisco WLC Designation |
|---|---|---|---|---|
| Highest | 7 | AC_VO | Voice | Platinum |
| | 6 | | | |
| | 5 | AC_VI | Video | Gold |
| | 4 | | | |
| | 3 | AC_BE | Best Effort | Silver |
| Default | 0 | | | |
| | 2 | AC_BK | Background | Bronze |
| Lowest | 1 | | | |

**Note** An important item to note regarding the 802.11e/WMM AC model shown in Table 24-1 is that several CoS values in this WMM model do not line up with their IETF DSCP counterparts. For example, voice is mapped to a 802.11e UP value of 6. However, in wired networks, voice is typically marked 802.1p CoS value of 5, as this corresponds to the three Most Significant Bits (MSB) of the IETF recommended (six-bit) DSCP marking value for voice traffic of EF/46 (based on RFCs 3246[1] and 4594[2]). The root cause of this marking incompatibility is that the IETF defines Layer 3 marking standards (i.e., DSCP), while the IEEE defines Layer 2 standards (like 802.1p CoS and 802.11e UP). Unfortunately, this sometimes leads to confusion and inconsistencies with the marking schemes that must be dealt with by the network engineer. These mapping considerations are discussed in greater detail later.

**Note** There is no relative priority between UP or CoS markings assigned to a single access category over the WLAN; for example, flows marked with either UP or CoS values of 4 and 5 are assigned to the video/gold WMM access category, but there is no difference in treatment between these flows.

**Note** While the WMM uses specific application designations for these access categories (Voice, Video, Best Effort, and Background), Cisco WLC software uses a more generic designation based on precious metals: platinum, gold, silver and bronze. Nonetheless each set of names refers to the same underlying

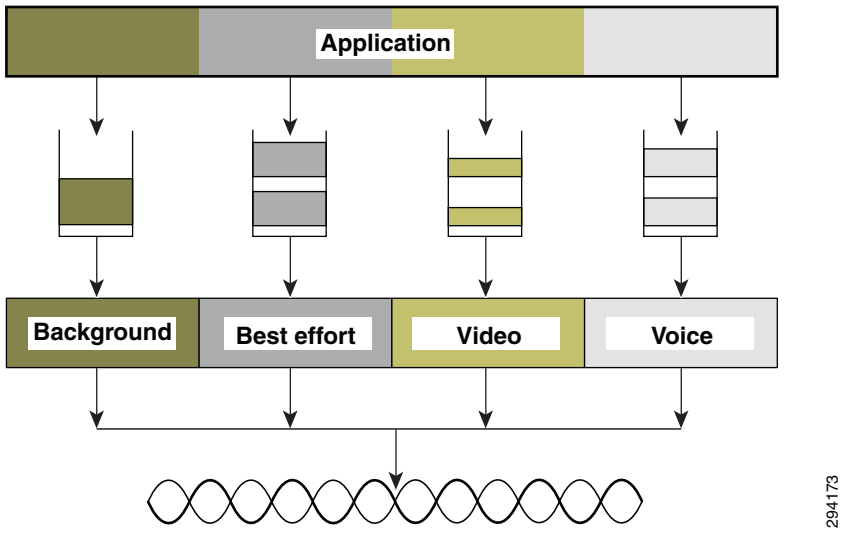
1. An Expedited Forwarding PHB (Per-Hop Behavior) http://www.ietf.org/rfc/rfc3246
2. Configuration Guidelines for DiffServ Service Classes http://www.ietf.org/rfc/rfc4594

access categories. In this paper, the latter (precious-metal-based) designations are used to simplify mapping examples and reduce confusion when describing RFC 4594-based application classes versus WMM access categories.

## Enhanced Distributed Coordination Function (EDCF)

Figure 24-6 shows the queuing performed on a WMM client or AP. There are four separate queues, one for each of the access categories. Each of these queues contends for the wireless channel in a similar manner to the DCF mechanism described previously, but with each of the queues using different interframe spaces and with different CWmin and CWmax values. If frames from different access categories collide internally, the frame with the higher priority is sent and the lower priority frame adjusts its backoff parameters as though it had collided with a frame external to the queuing mechanism. This system is called the Enhanced Distributed Coordination Function (EDCF).

***Figure 24-6 WMM Queues***




## Arbitration Interframe Spacing (AIFS)

One of the key limitations of DCF is that the DIFS value is the same for all traffic types. The rule to remember here is that once the channel is declared available, all stations wanting to transmit must wait the DIFS time period following the end of the current station's transmission. The problem is that if there are multiple stations waiting to transmit, they all have to wait the exact same DIFS gap, regardless of how latency-sensitive their data is, thus giving no preferential treatment to either high or low priority traffic.

To address this, EDCA introduces a variable interframe spacing (IFS) period for data and management frames, called the Arbitration Interframe Spacing (AIFS) number. The intention of assigning different IFS 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.

While AIFS numbers are configurable, the default values defined in EDCF (as measured in slot times) are shown in Table 24-2.

*Table 24-2 EDCA Default AIFS Numbers*

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

## Contention Window Enhancements

DCF gives no preferential treatment to high-priority traffic during the CW, meaning that all traffic types have the same statistical probability of being the next one to transmit. Therefore an additional enhancement EDCA introduced is to give preferential CW random backoff ranges for higher priority traffic, thus making it much more likely for a voice or video frame to be transmitted before a best-effort or background frame. This is particularly important for latency sensitive traffic, such as voice and video, which suffers greatly if they have to wait up to the CWmax interval. Similar to the different AIFSN values assigned to the different priority queues, different contention window values serve to give higher priority traffic a better probability of having to wait a shorter period of time before having a chance to transmit and also limit the impact of long CW wait times. The default EDCA CW values for 801.11a/g/n are shown in Table 24-3.

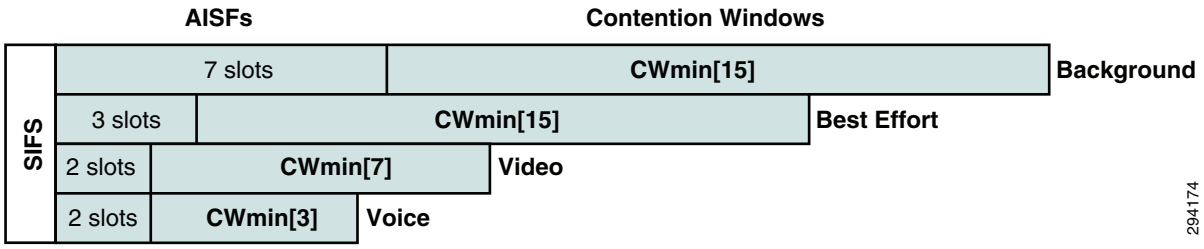
*Table 24-3 EDCA/WMM Default Contention Window Values*

| Access Category | CWmin (Slot Times) | CWmax (Slot Times) |
|---|---|---|
| Legacy DCF (for comparison) | 15 | 1023 |
| Voice | 3 | 7 |
| Video | 7 | 15 |
| Best-Effort | 15 | 1023 |
| Background | 15 | 1023 |

Table 24-3 shows that voice only backs off between 3-7 slot times compared to background traffic (which is still the same as the legacy DCF CW backoff period). Of course, since the CW is randomly generated, there is still a small probability that the lower priority queues might backoff for a shorter period than a higher priority queue; however, over time the higher-priority queues are statistically serviced much more often.

Figure 24-7 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.

*Figure 24-7 AIFS and CW Operation for Access Category Priority*




## 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. In the legacy DCF model once a station has access to the medium, it is able to keep sending frames as long as it wants. When a low data-rate station gains access to the medium, it forces all other stations to wait until it is finished its transmission.

With EDCA's TXOP enhancement, each station has a set TXOP time limit where it can transmit. Once the TXOP limit expires, it must give up access to the medium.

## Call Admission Control (TSpec)

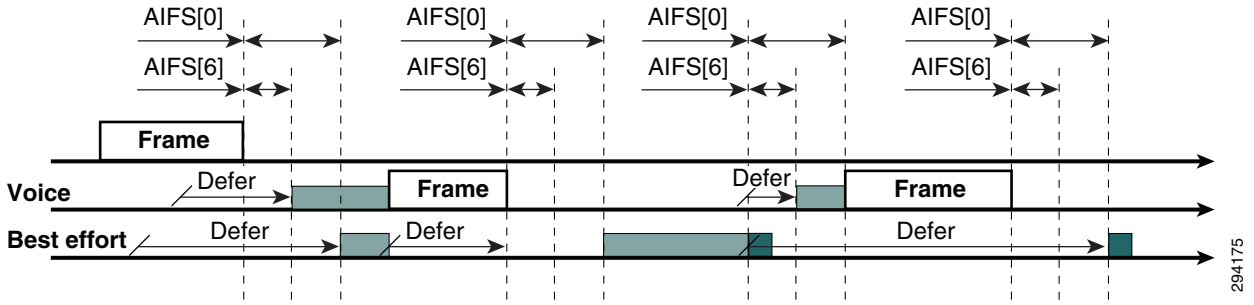
One last major enhancement introduced by 802.11e is a mechanism for Call Admission Control (CAC) called Transmission Specification (TSpec). TSpec allows real-time applications, such as voice calls or video calls in-progress, to be prioritized over requests for new calls. To use this feature of EDCF,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

When running TSPec, a client station signals its traffic requirements (mean data rate, power save mode, frame size, etc.) to the AP. In this way, before a client sends traffic of a certain priority type (AC), it must first request permission via the TSpec mechanism. For example, a WLAN client device wanting to use the voice AC must first make a request for use of that AC to see if there is sufficient space on the network to do so. If the AP decides there is insufficient availability on the network, it denies access for that client station, thus protecting the currently transmitting stations.

## EDCF Operation

With all the elements combined, EDCF operation highlighting application-level QoS over wireless media, is presented in Figure 24-8. In this example voice traffic is contending with best effort.

*Figure 24-8 EDCF Operation*




The EDCF process follows this sequence:

**Step 1** While Station X is transmitting its frame, other stations determine that they must also send a frame. Each station defers because a frame was already being transmitted, and each station generates a random backoff.

**Step 2** Because the Voice station has a traffic classification of voice, it has an Arbitrated Interframe Space (AIFS) of 2, and uses an initial CWmin of 3, and therefore must defer 5 slot times total before attempting to transmit.

**Step 3** Best-effort has an AIFS of 3 and a longer random backoff time, because its CWmin value is 15.

**Step 4** Voice has the shortest random backoff time, and therefore starts transmitting first. When Voice starts transmitting, all other stations defer.

**Step 5** After the Voice station finishes transmitting, all stations wait their AIFS, then begin to decrement the random backoff counters again.

**Step 6** Best-effort then completes decrementing its random backoff counter and begins transmission. All other stations defer. This can happen even though there might be a voice station waiting to transmit. This shows that best-effort traffic is not starved by voice traffic because the random backoff decrementing process eventually brings the best-effort backoff down to similar sizes as high priority traffic, and that the random process might, on occasion, generate a small random backoff number for best-effort traffic.

**Step 7** The process continues as other traffic enters the system.

# Cisco's Strategic Approach to Application Quality Management

Having reviewed the QoS tools and mechanisms available for managing application quality over WLANs, the administrator is faced with having to make the decisions as to which applications to assign to each of the four WMM access categories available, as well as how to interconnect the QoS policies for the WLAN with the rest of the network so as to create an end-to-end solution.

When making these decisions, it is best to take a step back from the tools and technical elements of the equation and examine the business or organization needs. Focusing on the tools exclusively can be compared to going to a hardware store, coming across a handy tool, and then going home and trying to decide what to build with it. Conversely, a better approach is to understand what needs to be built and then finding the right tool(s) to achieve that objective.

Therefore a network administrator needs to first define the business and organizational objectives to be addressed with QoS policies across their end-to-end network, which includes defining:

- Which applications are viewed as critical for achieving business/organizational objectives?
- What are the respective service-level requirements of these critical applications?
- What applications are present over the network that consume resources away from critical applications and which could be deprioritized?
- How many unique classes of service need to be provisioned in order to meet these per-application service level requirements and thus the business objectives?

Cisco recommends a strategic approach to application quality management in an end-to-end manner that encompasses all Places-in-the-Network (PINs), including the WLAN. This approach is based on IETF RFC 4594.

# Cisco's Strategic Application-Class QoS Recommendations

Cisco's strategic approach to application QoS (which is based on IETF RFC 4594) is summarized in Figure 24-9.[1]

***Figure 24-9 Cisco's (RFC4594-based) Strategic Application-Class QoS Recommendations***

| Application Class | Per-Hop Behavior | Admission Control | Queuing and Dropping | Application Examples |
|---|---|---|---|---|
| Voice | EF | Required | Priority Queue (PQ) | Cisco IP Phones (G.711, G.729 |
| Broadcast Video | CS5 | Required | (Optional) PQ | Cisco IP Video Surveillance/Cisco Enterprise TV |
| Realtime Interactive | CS4 | Required | (Optional) PQ | Cisco TelePresence |
| Multimedia Conferencing | AF4 | Required | BW Queue + DSCP WRED | Cisco Jabber, Cisco WebEx |
| Multimedia Streaming | AF3 | Recommended | BW Queue + DSCP WRED | Cisco Digital Media System (VoDs) |
| Network Control | CS6 | | BW Queue | EIGRP, OSPF, BGP, HSRP, IKE |
| Signaling | CS3 | | BW Queue | SCCP, SIP, H.323 |
| Ops/Admin/Mgmt (OAM) | CS2 | | BW Queue | SNMP, SSH, Syslog |
| Transactional Data | AF2 | | BW Queue + DSCP WRED | VDI Apps, ERP Apps, CRM Apps, Database Apps |
| Bulk Data | AF1 | | BW Queue + DSCP WRED | E-mail, FTP, Backup Apps, Content Distribution |
| Best Effort | DF | | Default Queue + RED | Default Class |
| Scavenger | CS1 | | Min BW Queue (Deferential) | YouTube, iTunes, BitTorrent, Xbox Love |

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1. Enterprise Medianet Quality of Service Design 4.0-Overview http://www.cisco.com/en/US/docs/solutions/Enterprise/WAN_and_MAN/QoS_SRND_40/QoSIntro_40.html#wp61104

**Note** Cisco has adopted RFC 4594 as its general DiffServ QoS strategy with the following exception: Cisco has swapped the marking recommendations of the RFC 4594 Broadcast Video class (of CS3) with the Signaling class (of CS5). Therefore Cisco has decided to mark Broadcast Video traffic as CS5 and Signaling traffic as CS3. This is primarily because Cisco has been marking Signaling to CS3 for over a decade (well before RFC 4594 was even drafted) and lacking a compelling business case to change the defaults on all its voice and video-telephony products, has decided to continue doing so. Furthermore, such a marking change would correspondingly force their customer base to change all their network QoS policies relating to the Signaling class as well. Therefore, Cisco has swapped these marking recommendations. It is important to remember that RFC 4594 is an informational RFC and not a standard and, as such, compliance-in full or in part-is not mandatory.

As shown in Figure 24-9, an enterprise may be required to support up to twelve application classes of that have unique service level requirements:

- Voice—This service class is intended for VoIP telephony (audio media only traffic-VoIP signaling traffic is assigned to the "Signaling" class). Traffic assigned to this class should be marked EF. This class is provisioned with an Expedited Forwarding (EF) Per-Hop Behavior (PHB). The EF PHB-defined in RFC 3246-is a strict-priority queuing service and, as such, admission to this class should be controlled (admission control is discussed in the following section). Example traffic includes G.711 and G.729a.
- Broadcast Video—This service class is intended for broadcast TV, live events, video surveillance flows, and similar "inelastic" streaming video flows ("inelastic" refers to flows that are highly drop sensitive and have no retransmission and/or flow control capabilities). Traffic in this class should be marked Class Selector 5 (CS5) and may be provisioned with an EF PHB; as such, admission to this class should be controlled. Example traffic includes live Cisco Digital Media System (DMS) streams to desktops or to Cisco Digital Media Players (DMPs), live Cisco Enterprise TV (ETV) streams, and Cisco IP Video Surveillance.
- Real-Time Interactive—This service class is intended for (inelastic) room-based, high-definition interactive video applications and is intended primarily for voice and video components of these applications. Whenever technically possible and administratively feasible, data sub-components of this class can be separated out and assigned to the "Transactional Data" traffic class. Traffic in this class should be marked CS4 and may be provisioned with an EF PHB; as such, admission to this class should be controlled. An example application is Cisco TelePresence.
- Multimedia Conferencing—This service class is intended for desktop software multimedia collaboration applications and is intended primarily for voice and video components of these applications. Whenever technically possible and administratively feasible, data sub-components of this class can be separated out and assigned to the "Transactional Data" traffic class. Traffic in this class should be marked Assured Forwarding (AF) Class 4 (AF41) and should be provisioned with a guaranteed bandwidth queue with DSCP-based Weighted-Random Early Detect (DSCP-WRED) enabled. Admission to this class should be controlled; additionally, traffic in this class may be subject to policing and re-marking. Example applications include Cisco Jabber and Cisco WebEx.
- Multimedia Streaming—This service class is intended for Video-on-Demand (VoD) streaming video flows which, in general, are more elastic than broadcast/live streaming flows. Traffic in this class should be marked AF Class 3 (AF31) and should be provisioned with a guaranteed bandwidth queue with DSCP-based WRED enabled. Admission control is recommended on this traffic class (though not strictly required) and this class may be subject to policing and re-marking. Example applications include Cisco Digital Media System Video-on-Demand (VoD) streams.
- Network Control—This service class is intended for network control plane traffic, which is required for reliable operation of the enterprise network. Traffic in this class should be marked CS6 and provisioned with a (moderate, but dedicated) guaranteed bandwidth queue. WRED should not be

enabled on this class, as network control traffic should not be dropped (if this class is experiencing drops, then the bandwidth allocated to it should be re-provisioned). Example traffic includes EIGRP, OSPF, BGP, HSRP, IKE, etc.

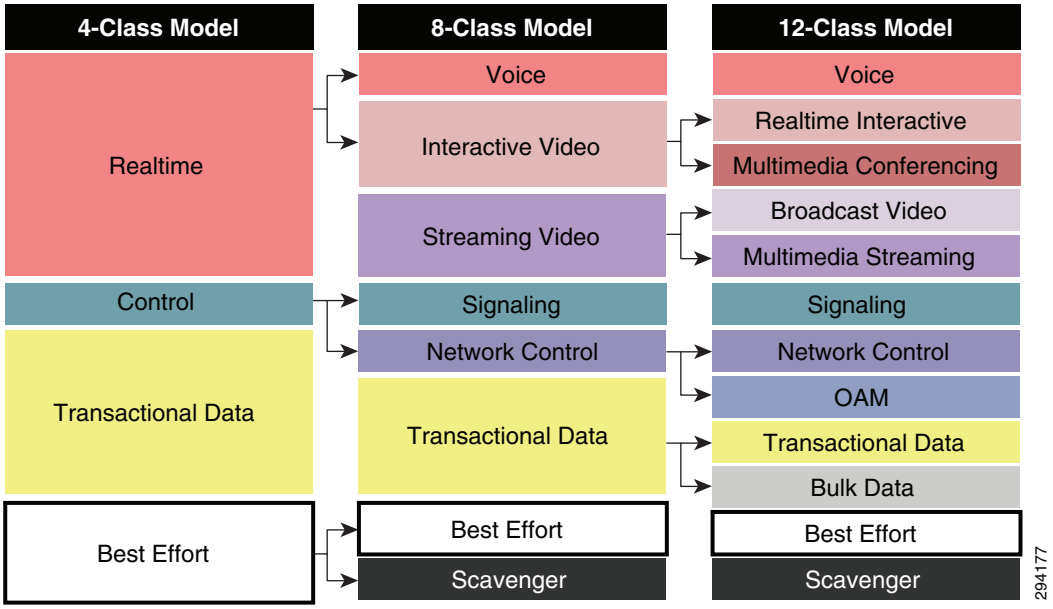
- Signaling—This service class is intended for signaling traffic that supports IP voice and video telephony. Traffic in this class should be marked CS3 and provisioned with a (moderate, but dedicated) guaranteed bandwidth queue. WRED should not be enabled on this class, as signaling traffic should not be dropped (if this class is experiencing drops, then the bandwidth allocated to it should be re-provisioned). Example traffic includes SCCP, SIP, H.323, etc.
- Operations/Administration/Management (OAM)—As the name implies, this service class is intended for network operations, administration, and management traffic. This class is critical to the ongoing maintenance and support of the network. Traffic in this class should be marked CS2 and provisioned with a (moderate, but dedicated) guaranteed bandwidth queue. WRED should not be enabled on this class, as OAM traffic should not be dropped (if this class is experiencing drops, then the bandwidth allocated to it should be re-provisioned). Example traffic includes SSH, SNMP, Syslog, etc.
- Transactional Data (or Low-Latency Data)—This service class is intended for interactive, "foreground" data applications ("foreground" refers to applications from which users are expecting a response—via the network—in order to continue with their tasks; excessive latency directly impacts user productivity). Traffic in this class should be marked AF Class 2 (AF21) and should be provisioned with a dedicated bandwidth queue with DSCP-WRED enabled. This traffic class may be subject to policing and re-marking. Example applications include data components of multimedia collaboration applications, Virtual Desktop Infrastructure (VDI) applications, Enterprise Resource Planning (ERP) applications, Customer Relationship Management (CRM) applications, database applications, etc.
- Bulk Data (or High-Throughput Data)—This service class is intended for non-interactive "background" data applications ("background" refers to applications from which users are not awaiting a response—via the network—in order to continue with their tasks; excessive latency in response times of background applications does not directly impact user productivity). Traffic in this class should be marked AF Class 1 (AF11) and should be provisioned with a dedicated bandwidth queue with DSCP-WRED enabled. This traffic class may be subject to policing and re-marking. Example applications include: email, backup operations, FTP/SFTP transfers, video and content distribution, etc.
- Best Effort (the default class)—This service class is the default class. The vast majority of applications will continue to default to this Best-Effort service class; as such, this default class should be adequately provisioned. Traffic in this class is marked Default Forwarding (DF or DSCP 0) and should be provisioned with a dedicated queue. WRED is recommended to be enabled on this class.
- Scavenger (or Low-Priority Data)—This service class is intended for non-business related traffic flows, such as data or video applications that are entertainment and/or gaming-oriented. The approach of a "less-than Best-Effort" service class for non-business applications (as opposed to shutting these down entirely) has proven to be a popular, political compromise. These applications are permitted on enterprise networks, as long as resources are always available for business-critical voice, video, and data applications. However, as soon as the network experiences congestion, this class is the first to be penalized and aggressively dropped. Traffic in this class should be marked CS1 and should be provisioned with a minimal bandwidth queue that is the first to starve should network congestion occur. Example traffic includes YouTube, Facebook, Xbox Live/360 Movies, iTunes, BitTorrent, etc.

# Application-Class Expansion

While there are merits to adopting a 12-class model, Cisco recognizes that not all enterprises are ready to do so, whether this be due to business reasons, technical constraints, or other reasons. In fact, most businesses deploying QoS are typically somewhere between a 4 and 8 class model today.

Therefore, rather than considering these QoS recommendations as an all-or-nothing approach, Cisco recommends considering a phased approach to application class expansion, as illustrated in Figure 24-10.

***Figure 24-10 Application-Class Expansion Models***




By considering such a phased approach to application class expansion network administrators can incrementally implement QoS policies across their infrastructures in a progressive manner, in line with their evolving business needs. Nonetheless, at each phase of QoS deployment, the enterprise needs to clearly define their business objectives to determine how many traffic classes will be required at each phase.

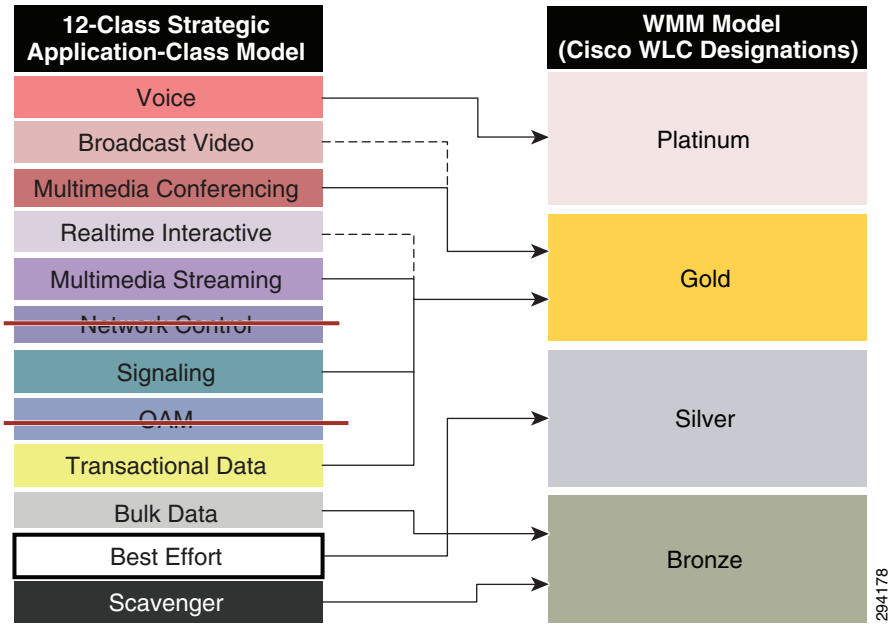
# Application-Class Mapping to WMM

As previously mentioned, it is important to base the overall network QoS strategy on business or organizational requirements—first and foremost—and not by the number of classes of service supported on a platform, place-in-the-network, or service provider. This is because platforms, technologies, and service provider models all change over time, yet the QoS strategy should only change as the business evolves. Furthermore, any strategic class-of-service model can be mapped to a reduced number of service classes, as required.

For example, it has already been shown that in the IEEE802.11e/WMM model there are four access categories supported on the WLAN. This should not be taken to mean that an enterprise should never deploy more than four application classes. Rather, they should define their overall end-to-end strategy based on their organizational requirements and then map into these four access categories at the WLAN.

Even highly complex models—such as an RFC 4594-based 12-class model—can be mapped into the four WMM access categories, as illustrated in Figure 24-11.

*Figure 24-11 Example Twelve-Class Application-Class Model Mapped into WMM*




**Note** Figure 24-11 serves only to illustrate the concept of application class mapping into a reduced set of traffic classes; additional details are provided later in this document to show best-practice recommendations in mapping a 4-Class model, an 8-Class model and this same 12-Class enterprise model into WMM.

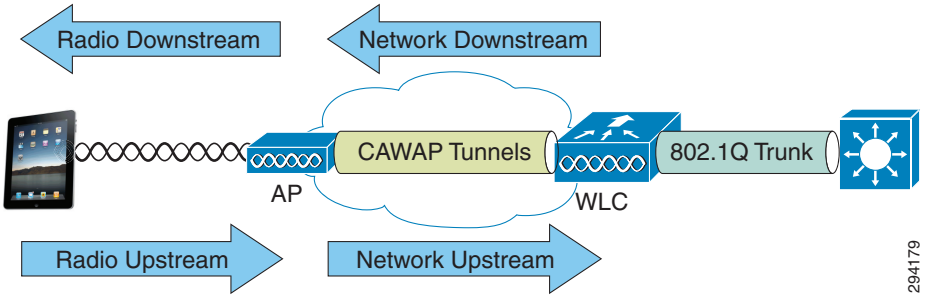
# Cisco 802.11e/802.1p/DSCP Mappings

At this point, it may be helpful to clarify some terms that will be used extensively throughout the rest of this paper:

- Downstream—Used to refer to the flow of packets from the wired network infrastructure to the wireless devices, including:
  - Network Downstream—Refers to traffic leaving the WLC traveling to the AP; this traffic is encapsulated within LWAPP. Wired campus QoS policies provision downstream QoS.
  - Radio Downstream—Refers to traffic leaving the AP and traveling to the WLAN clients. WMM provides downstream QoS for WLAN clients.
- Upstream—Used to indicate the flow of packets from the mobile wireless device to the wired network infrastructure, including:
  - Radio Upstream—Refers to traffic transmitted by the WLAN clients and traveling to the AP. WMM provides upstream QoS for WLAN clients.
  - Network upstream—Refers to traffic leaving the AP, traveling to the WLC; this traffic is encapsulated within LWAPP. Wired campus QoS policies provision upstream QoS.

These terms are illustrated in Figure 24-12.

*Figure 24-12 Downstream and Upstream QoS*




In order for campus wired networks to interoperate with WLAN networks, their respective markings need to be translated or mapped in either direction of flow (upstream and downstream).

# Default DSCP-to-CoS/UP Mappings

By default, 6-bit DSCP values are mapped to 3-bit 802.1p CoS and 802.11e UP values by taking the three Most-Significant Bits (MSB) of the DSCP and copying these as the CoS and/or UP values. For example, DSCP EF/46 (binary 101110) is mapped to CoS or UP 5 (binary 101), by default. For example, by default, the network switch that connects to the Cisco WLC will generate 802.1p CoS values (for the 802.1Q trunked traffic) by setting these to match the three MSB of the DSCP values.

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, CoS or UP 5 (binary 101) would be mapped (i.e., multiplied by 8) to DSCP 40 (binary 101000), also known as 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 3/Layer 2 mapping). This needs to be taken into account when mapping from wired-to-wireless and vice-versa.

# Cisco WLC/AP QoS Translation Table

As has already been pointed out in the consideration of Table 24-1, IEEE 802.11e and 802.1p application marking values do not always align with IETF-based DSCP-to-CoS mappings. For example, DSCP EF/46 is recommended by the IETF for use for voice, which would map by default to CoS/UP 5; but the IEEE designates CoS/UP 6 for voice. Similarly, the IETF recommends DSCP CS4 or AF4 for realtime or interactive video conferencing, both of which would map by default to CoS 4; but the IEEE designates CoS/UP 5 for video.

In an effort to reconcile the markings recommendations between these independent and disagreeing standards bodies, Cisco has implemented an automatic mapping function within WLC software to automatically convert special marking values to the respective IETF or IEEE marking recommendations, as shown in Table 24-4.

*Table 24-4 Cisco WLC/AP DSCP-to-UP Translation Table*[1]

| Application Class | IETF DSCP | IEEE 802.11e UP | WLC QoS Profile |
|---|---|---|---|
| Network control | 56 (CS7) | 7 | Platinum |
| Internetwork control | 48 (CS6) | 7 | Platinum |
| Voice | 46 (EF) | 6 | Platinum |
| Multimedia Conferencing | 34 (AF41) | 5 | Gold |
| Multimedia Streaming | 26 (AF31) | 4 | Gold |
| Transactional Data | 18 (AF21) | 3 | Silver |
| Bulk Data | 10 (AF11) | 2 | Bronze |
| Best Effort | 0 (BE) | 0 | Silver |

1. Cisco Wireless LAN Controller WLAN Configuration Guide, Release 7.4 - Working with WLANs - Assigning QoS Profiles http://www.cisco.com/en/US/partner/docs/wireless/controller/7.4/configuration/guides/consolidated/b_cg74_CONSOLIDATED_chapter_01010111.html

# Residual DSCP-to-WMM Mappings

The IEEE 802.11e UP value for DSCP values that are not mentioned in the Table 5 are calculated by considering 3 MSB bits of DSCP. Thus with the exceptions noted in Table 5, DSCP values will map to the WMM/WLC Access Categories shown in Table 24-5.

*Table 24-5 Default DSCP, UP and WLC Access Category Mappings (Excluding the Exceptions Listed in Table 24-4)*

| DSCP Range | IEEE 802.11e UP | WLC QoS Profile |
|---|---|---|
| DSCPs 56-63 | 7 | Platinum |
| DSCPs 48-55 | 6 | |
| DSCPs 40-47 | 5 | Gold |
| DSCPs 32-39 | 4 | |
| DSCPs 24-31 | 3 | Silver |
| DSCPs 0-7 | 0 | |
| DSCPs 16-23 | 2 | Bronze |
| DSCPs 8-15 | 1 | |

# WLC AVC/QoS Profile-to-DSCP Mappings

If QoS or AVC Profiles are created on a Cisco WLC and applied to WLANs, then the packets assigned to the access-categories within these profiles will be marked to the DSCP values shown in Table 24-6. For example, if an application is assigned to the Gold profile, then all application traffic will be marked to DSCP 34.

*Table 24-6 Default WLC Profile to DSCP Mappings*

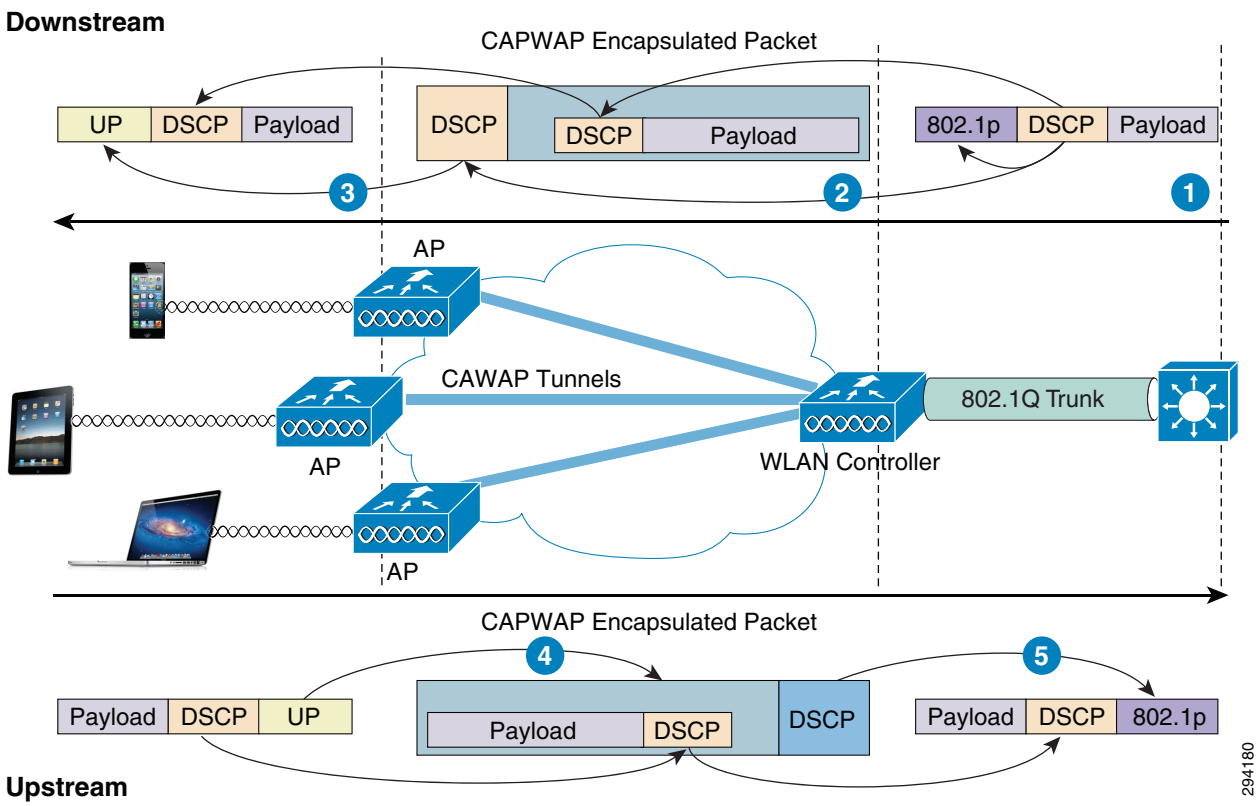
| WLC QoS Profile | DSCP |
|---|---|
| Platinum | EF (DSCP 46) |
| Gold | AF41 (DSCP 34) |
| Silver | DF (DSCP 0) |
| Bronze | AF11 (DSCP 10) |

# Cisco Wired-Wireless Mapping Points

With the translation-mapping table and default mapping methods in place, the questions that remain are: where is mapping done between wired and wireless networks? And how?

Figure 24-13 is a very important diagram that identifies the various places where wired-and-wireless mapping takes place-in both the downstream direction (top of Figure 24-13) and the upstream direction (bottom of Figure 24-13).

*Figure 24-13 Downstream and Upstream Layer 2/Layer 3 Mapping*




In Figure 24-13, the following mappings occur in the downstream direction:

**Step 1** The network switch maps the DSCP value of an incoming packet (destined to a WLAN via the WLC) to an 802.1p CoS value as it transits the 802.1Q trunks connecting to the WLC (by default this mapping is done by taking the three MSBs of the DSCP and copying these to the 802.1p CoS value).

**Step 2** An 802.1Q frame/packet with an 802.1p marking and a DSCP marking arrive at the WLC. The DSCP of the packet is copied to the inner and outer DSCP fields of the CAPWAP packet on egress as it transits toward the destination APs and WLANs.

**Note** An exception will occur if the DSCP exceeds the Maximum Priority (i.e., the maximum DSCP marking value) defined in the QoS Profile associated with the destination WLAN, in which case both the inner and outer DSCP values will be marked down to this Maximum Priority value.

**Step 3** The outer DSCP of the CAPWAP packet arriving at the AP will be mapped to an 802.11e UP marking based on the QoS Translation Table (Table 24-4) or a default mapping (if no explicit mapping is found for the specific DSCP value in the QoS Translation Table). The inner DSCP value is copied to the DSCP-field of the 802.11e frame/packet.

Conversely, in Figure 24-13, the following mappings occur in the upstream direction:

**Step 1** The 802.11e UP values and DSCP values of a mobile application are marked in the software of the device as it is transmitted. When the frame/packet arrives at the AP, the UP value will be mapped to the outer DSCP value of the CAPWAP packet; this mapping is based on the QoS Translation Table (Table 24-4) or a default mapping (if no explicit mapping is found for the specific DSCP value in the QoS Translation Table). Additionally, the DSCP value set on the mobile device will be copied to the inner DSCP value of the CAPWAP packet.

**Note** As previously, the DSCP value assigned to the CAPWAP packet is subject to any Maximum Priority value capping that may be configured within the QoS Profile associated with the WLAN.

**Step 2** The outer DSCP of the CAPWAP packet will be mapped to an 802.1p CoS value as the frame/packet leaves the WLC towards the wired network (by default this mapping is done by taking the three MSBs of the DSCP and copying these to the 802.1p CoS value). Additionally, the inner DSCP of the CAPWAP packet will be copied to the DSCP value of the 802.1Q trunked IP packet.

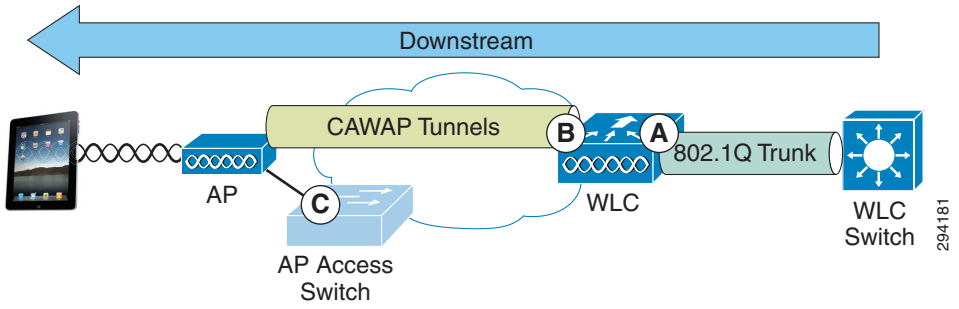
# Configuring Downstream QoS Policies for Mobile Applications

Provisioning end-to-end mobile application QoS requires policy configuration at the following points in the wired and wireless networks for downstream flows:

- WLC AVC Profiles—Are configured and assigned to WLANs to identify applications and mark (with DSCP) or drop these packets. Additionally AVC Profiles assign applications to WMM access categories in the radio-downstream direction. AVC Profiles are applied on WLC ingress and are shown as point A in Figure 24-14.
- WLC QoS Profiles—Are assigned to each WLAN and define the (unicast and multicast) Default Priority (i.e., default/Best Effort DSCP value and access category) and the Maximum Priority value for the WLAN. QoS Profiles are applied on WLC egress and are shown as point B in Figure 24-14.

- AP Access Switch QoS Policies—The entire underlying wired-network infrastructure should be configured with QoS policies in line with the strategic application-class model in use for the given enterprise. Additionally, the access-switch to which a given wireless access-point connects to may be used to work-around non-configurable upstream/downstream mapping operations (as is discussed in detail later); these policies are typically applied on access switch egress and are shown as point C in Figure 24-14.

*Figure 24-14 Downstream QoS Policy Configuration Points in Wired/Wireless Networks*




# Wireless Controller QoS Profile GUI Configuration

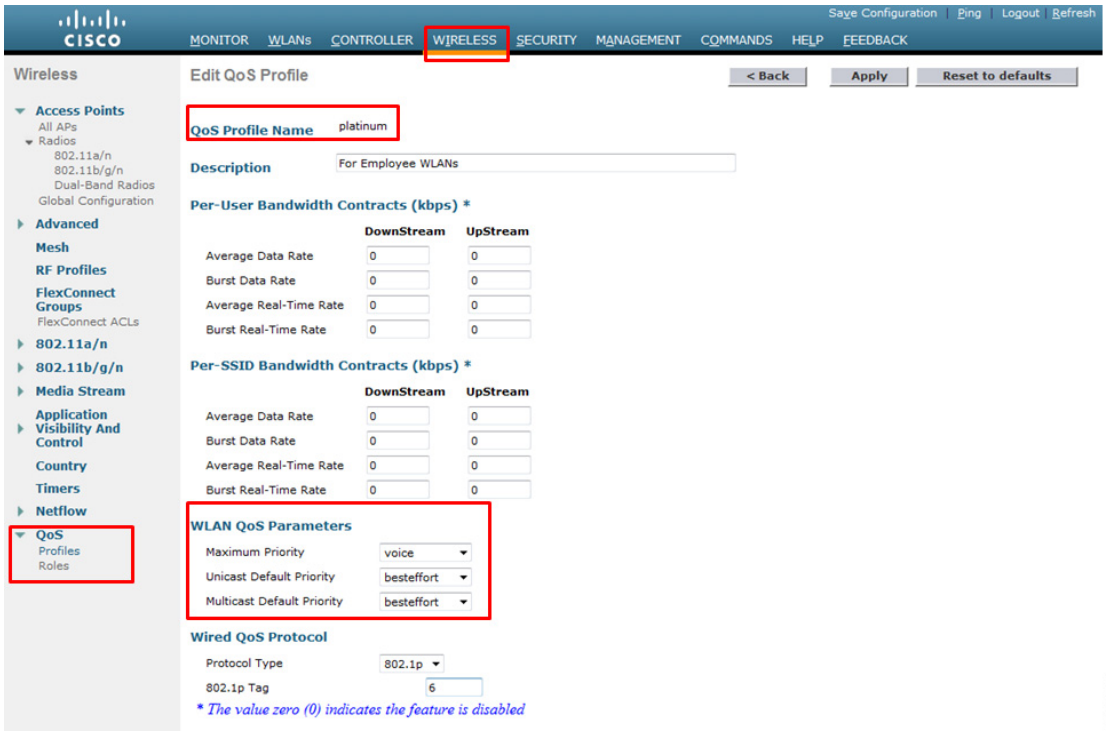
QoS Profiles—like AVC Profiles—are applied to both upstream and downstream flows on WLC egress. It is recommended to complete these steps to define an appropriate QoS Profile for a given WLAN. Among many other parameters, the WLAN QoS Profile defines:

- Per-User Bandwidth Contracts—(Optional) per-user limits for average and peak data and realtime traffic rates.
- Per-SSID Bandwidth Contracts—(Optional) per-SSID limits for average and peak data and realtime traffic rates.
- WLAN Maximum Priority—The highest DSCP marking value that may be used on the WLAN; this value can override AVC policies as well DSCP-values received from the wired network. As such, in multiservice WLANs, it is generally recommended to ensure that the Maximum Priority value be set to voice (i.e., platinum).
- Unicast and Multicast Default Priority—The default DSCP marking value to be used on the WLAN for all traffic not explicitly classified by an overriding AVC Profile. Typically these values are set as best effort (i.e., silver), however there may be cases where this default value may be set to background (i.e., bronze), which is discussed later in the Four-Class Model Mapping Configuration.
- Wired QoS Protocol—Can be set to 802.1p and the maximum CoS value can be defined per WLAN.

Details of a given QoS Profile can be viewed and modified by performing the following steps:

1. Open a web browser to the WLC IP address via HTTPS and login.
2. Click the **WIRELESS** heading bar and expand the **QoS** link on the lower left and click **Profiles**.
3. Click the profile to be viewed/modified (these are listed in alphabetical order: bronze/gold/platinum/silver). Details of the Platinum QoS profile are shown in Figure 24-15.

*Figure 24-15 Viewing/Editing the Platinum WLC QoS Profile*

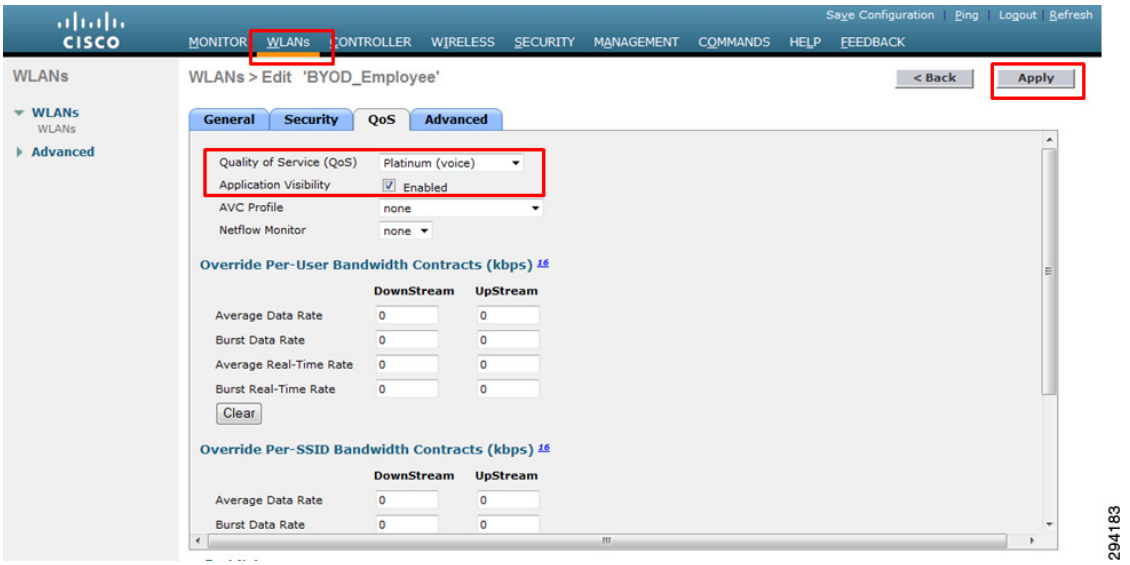



To apply a QoS profile to a WLAN, complete the following steps.

1. Click the **WLANs** heading and select an existing WLAN (or click the **CREATE NEW** button to create a new one).
2. Click the **QoS** tab of the selected WLAN and ensure that:
   a. **Quality of Service (QoS)** is set to **PLATINUM (VOICE)**; this allows for the highest DSCP markings values to be used for AVC policies that are to be attached to the WLAN (in the following section).
   b. **Application Visibility** checkbox is **ENABLED**, as shown in Figure 24-16.
3. Click **Apply**.

**Note** Applying a QoS policy to a WLAN will momentarily interrupt service.

*Figure 24-16 Assigning a QoS Profile to a WLAN and Enabling AVC*




## WLC QoS Profile CLI Configuration

The following CLI commands will apply the Platinum QoS Profile configuration to WLAN as well as enable AVC Visibility for the WLAN:

*Example 24-1 Configuring QoS Profiles for WLANs and Enabling Application Visibility*

```
(Cisco WLC) > config wlan disable 1
 ! Disables the WLAN so that the QoS profile may be changed

(Cisco WLC) > config wlan qos 1 platinum
 ! Applies the Platinum QoS profile to the WLAN

(Cisco WLC) > config wlan avc 1 visibility enable
 ! Enables AVC Visibility on WLAn 1

(Cisco WLC) > config wlan enable 1
 ! Re-enables WLAN 1

(Cisco WLC) >
```

This configuration can be verified with:

- **show wlan** (as shown in Example 24-2)

*Example 24-2 QoS Profile Verification: show wlan*

```
(Cisco WLC) >show wlan 1

WLAN Identifier.................................. 1
Profile Name..................................... BYOD_Employee
Network Name (SSID).............................. BYOD-Employee
Status........................................... Enabled

<snip>
```

```
Quality of Service.............................. Platinum

<snip>

AVC Visibilty.................................. Enabled

(Cisco WLC) >
```

# Wireless Controller AVC QoS Profile Configuration

AVC Profiles are applied to both upstream and downstream flows on WLC ingress. While this may simplify the QoS policy configuration on the WLC, it has design implications in upstream/downstream mapping, as has been previously discussed (and which is expanded on in the following sections).

Additionally, each WLAN can have only one AVC profile attached to it to control applications, however an AVC Profile can be attached to multiple WLANs. Also, an AVC Profile can contain a maximum of 32 application rules and a maximum of 16 AVC profiles can be created on a WLC.

Limitations of AVC on the WLC are as noted below and should be kept in mind while deploying AVC on WLC:

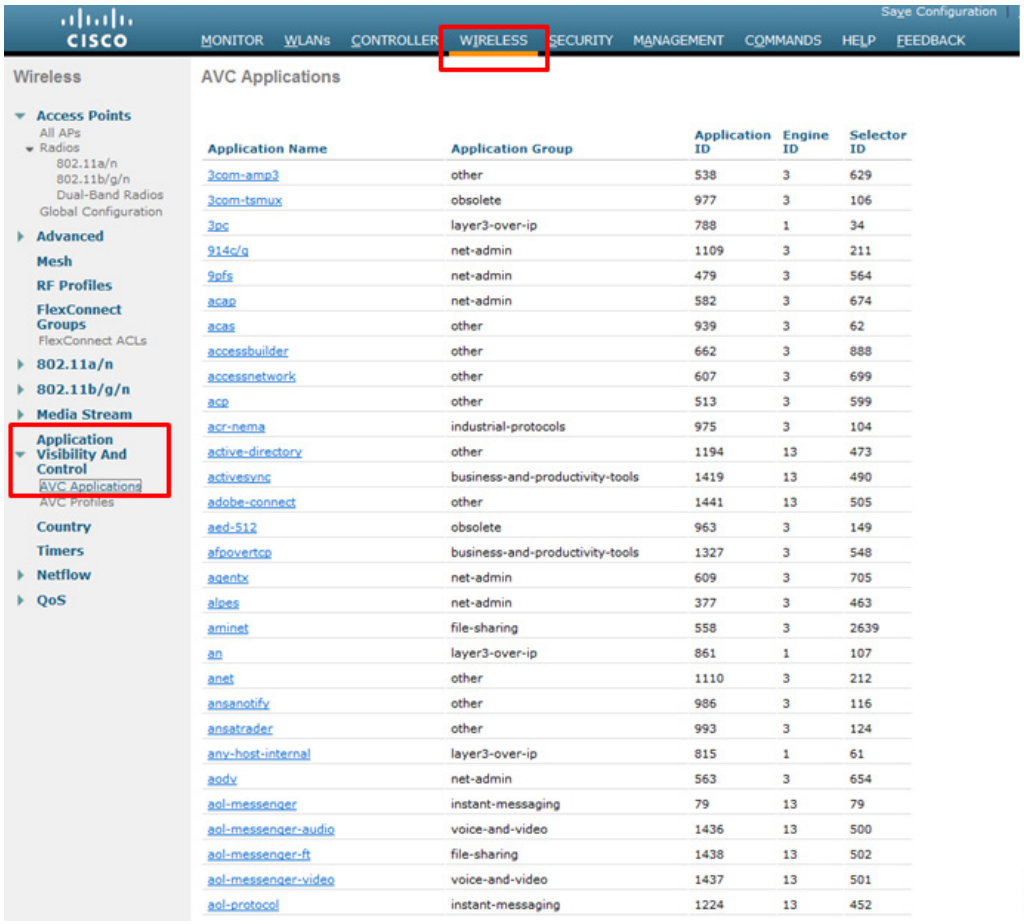
- IPv6 traffic or Multicast traffic cannot be classified.
- AVC is not supported on virtual WLC models.
- AVC is not supported on WLAN configured for Local Switching.
- AVC Profiles cannot be applied on a per controller, VLAN, or client basis (only WLAN).
- The AVC profiles do not support AAA override.
- NBAR based Rate Limiting per Application is not supported, however AVC will work with wireless Bi-Directional Rate Limiting (BDRL) per controller/interface/WLAN/user.
- Any application which is not classified/supported/recognized by the NBAR2 engine is captured as UNCLASSIFIED traffic.

As has been previously discussed, it also is important to note that each WLAN can have both a QoS Profile and an AVC Profile attached to it. The AVC Profile is applied when the packet enters the WLC and the QoS policy is applied when packet exits the WLC. If an AVC profile is mapped to WLAN with an explicit rule for a MARK action, that MARK action will override any default QoS Profile marking configured on the WLAN. However, QoS Profiles may define a Maximum Priority DSCP value for packet marking, which will override any AVC Profile marking policy. Thus care should be taken that QoS and AVC Profiles are correctly configured to complement-and not contradict-one another.

It may be helpful to begin by viewing the list of the over 1000 AVC supported applications by performing the following:

1. Select the **Wireless** heading and then expand the **Application Visibility and Control** link on the lower left.
2. Click the **AVC Applications** link and scroll through the alphabetical application list, as shown in Figure 24-17.

*Figure 24-17 AVC Application List*




The 1039 AVC applications supported in WLC software version 7.4 are grouped into 16 Application Groups:

- Browsing
- Business-and-productivity-tools
- Email
- File-sharing
- Gaming
- Industrial-protocols
- Instant-messaging
- Internet-privacy
- Layer3-over-ip
- Location-based-services
- Net-admin
- Newsgroup
- Obsolete
- Other

- Trojan
- Voice-and-video

Example 24-3 shows how to display a list of these applications via the WLC CLI.

***Example 24-3 WLC CLI-Show AVC Applications***

```
(Cisco WLC) > show avc applications

 Application-Name            App-ID  Engine-ID  Selector-ID   Application-Group-Name
 ================            ======  =========  ===========   ======================
 3com-amp3                    538        3       629        other
 3com-tsmux                   977        3       106        obsolete
 3pc                          788        1        34        layer3-over-ip
 914c/g                      1109        3       211        net-admin
 9pfs                         479        3       564        net-admin
 acap                         582        3       674        net-admin
 acas                         939        3        62        other
 accessbuilder                662        3       888        other
 accessnetwork                607        3       699        other
 acp                          513        3       599        other
 acr-nema                      975        3       104         industrial-protocols
…
```

## AVC Applications By Business Use Case

Sample AVC applications that relate to the business use cases mentioned at the outset of this document—of provisioning preferential services to protect voice, video, and data applications over wireless networks—are listed below. Additionally applications that might be given a deferential level of service are also listed. However, it is important to note that these are only example applications and do not represent an exhaustive list of applications by class. With over a thousand applications to choose from, these lists are simplified for the sake of brevity and serve only to illustrate the AVC policy concepts.

To ensure voice quality for wireless devices, the cisco-phone application would typically be assigned to the Platinum (Voice) access category via AVC. However, additional VoIP applications may include:

- aol-messenger-audio
- audio-over-http
- fring-voip
- gtalk-voip
- yahoo-voip-messenger
- yahoo-voip-over-sip

Similarly, to protect video and multimedia applications, the following applications might be assigned to the Gold (Video) access-category via AVC:

- cisco-ip-camera
- telepresence-media
- webex-meeting
- ms-lync-media
- aol-messenger-video
- fring-video

- gtalk-video
- livemeeting
- msn-messenger-video
- rhapsody
- skype
- video-over-http

**Note** It may be that some of these video conferencing applications may be considered non-business in nature (such as Skype and gtalk-video), in which case these may be provisioned into the Bronze (Background) access category.

To deploy AVC policies to protect the signaling protocols relating to these voice and video applications, the following applications might be marked to the Call-Signaling marking of CS3 (DSCP 24) via AVC:

- sip
- sip-tls
- skinny
- telepresence-control
- h323
- rtcp

To deploy policies to protect business-critical applications, the following applications might be marked AF21 (DSCP 18) via AVC:

- citrix
- ms-lync
- ms-dynamics-crm-online
- salesforce
- sap
- oraclenames
- perforce
- phonebook
- semantix
- synergy

On the other hand, some business applications would be best serviced in the background by assigning these to the Bronze (Background) access category via AVC:

- ftp / ftp-data / ftps-data
- cifs
- exchange
- notes
- smtp
- imap/secure imap

- pop3 / secure pop3
- gmail
- hotmail
- yahoo-mail

And finally, many non-business applications can be controlled by either being assigned to the Bronze (Background) access category or dropped via AVC policies:

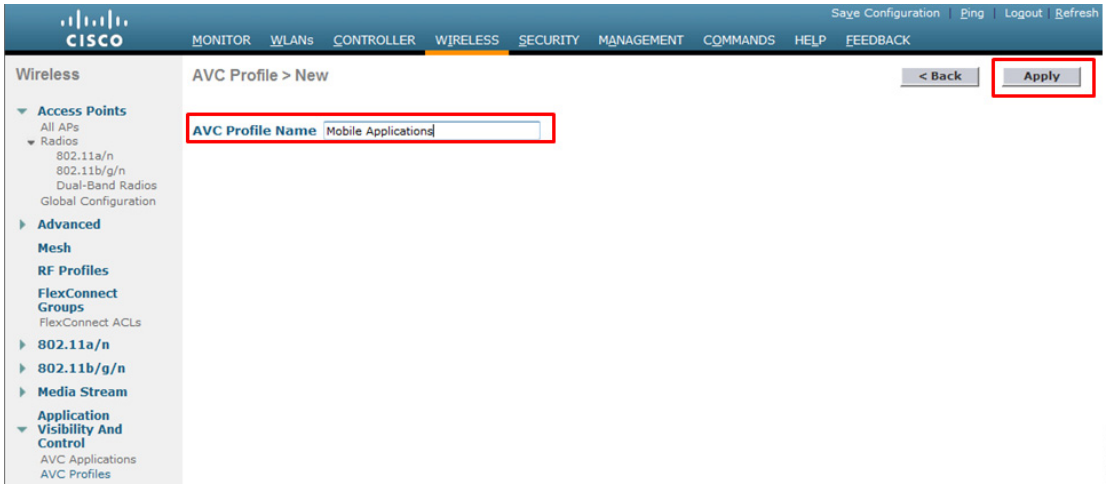
- youtube
- netflix
- facebook
- twitter
- bittorrent
- hulu
- itunes
- picasa
- call-of-duty
- doom
- directplay8

## WLC AVC Profile GUI Configuration

To configure an AVC Profile (a set of AVC policies to be applied on a per-WLAN basis), perform the following steps:

1. Click the **AVC Profiles** link on the lower right.
2. Click the **NEW** button on the upper right to create a new AVC profile.
3. Name the new AVC profile and click the **APPLY** button, as shown in Figure 24-18.

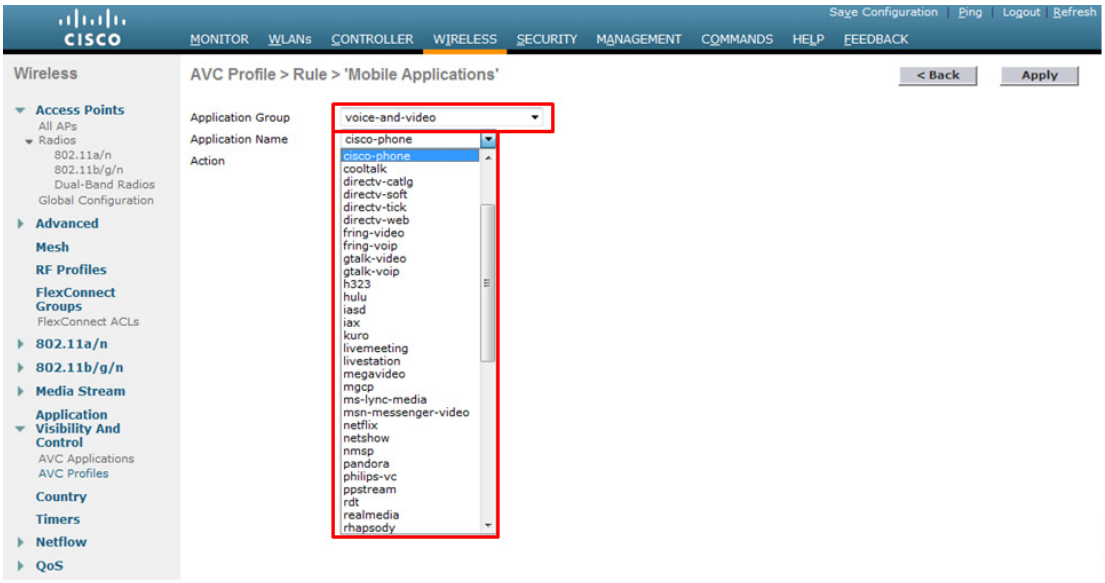
***Figure 24-18 Creating an AVC Profile—Part 1***




4. Click the name of the new AVC profile (which has become a link).

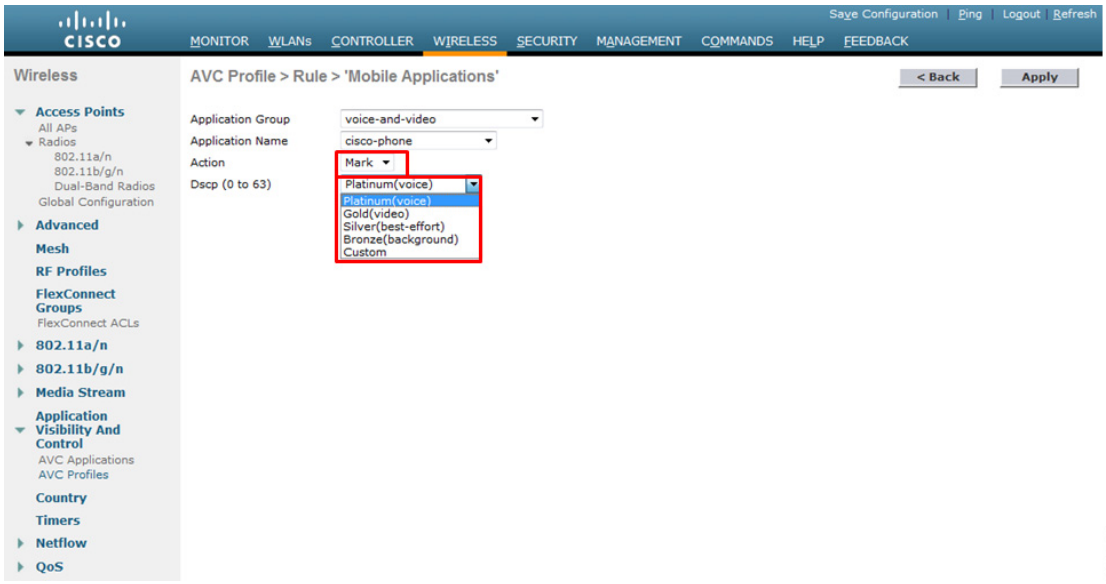
5. Click the **ADD NEW RULE** button on the upper right.
6. Select an **Application Group** to which the application to be controlled belongs.
7. Scroll down the **Application List** to specifically select the application to be controlled, as shown in Figure 24-19.

***Figure 24-19 Creating an AVC Profile—Part 2***




8. From the **Action** drop-down box select either **DROP** or **MARK**.
9. From the **DSCP** drop-down box select the WMM access category or a **Custom** DSCP marking for the application (as shown in Figure 24-20):
   - Platinum (Voice)—Marks packets to DSCP EF/46.
   - Gold (Video)—Marks packets to DSCP AF41/34.
   - Silver (Best Effort)—Marks packets to the default DSCP DF/0.
   - Bronze (Background)—Marks packets to DSCP AF11/10.
   - Custom [DSCP]—Allows for custom DSCP packet marking between 0 and 63.

*Figure 24-20 Creating an AVC Profile—Part 3*




10. Click the **Apply** button.

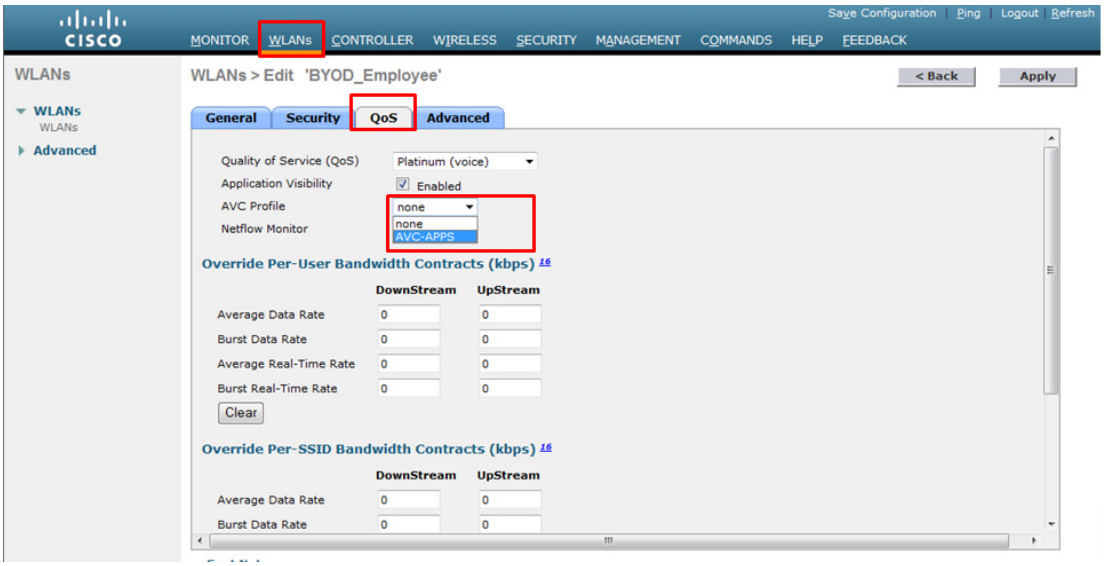
**Note** Applying a QoS policy to a WLAN will momentarily interrupt service.

Steps 4 through 10 can be repeated to add other applications to the AVC profile; up to 32 rules can be configured within an AVC profile.

Care should be taken to align DSCP marking policies with the enterprise strategic QoS model in use (4/8/12 class models).

Figure 24-21 shows an extended AVC profile that matches a 12-class model's marking scheme and includes temporary markings for the Signaling class and the Transactional Data class.

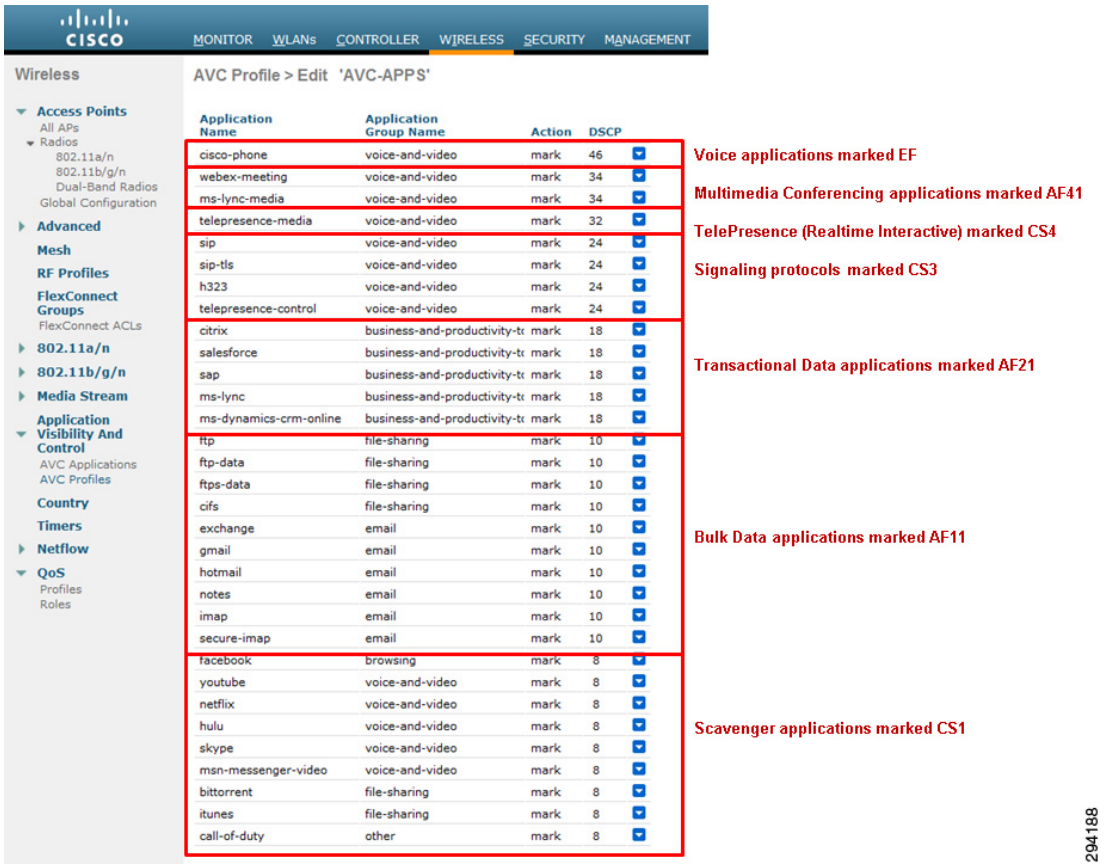
*Figure 24-21 Creating an AVC Profile—Part 4*




Once the AVC profile has been completed with all the applications to be classified (or the maximum of 32 applications has been reached), then complete the following steps to apply the profile to the WLAN.

1. Click the **WLANS** heading again.
2. Select the WLAN the AVC profile is to be applied to by clicking its WLAN ID link.
3. Click the **QoS** tab.
4. Select the AVC profile to be applied to the WLAN from the AVC Profile drop-down list, as shown in Figure 24-22.

*Figure 24-22 Attaching an AVC Profile to a WLAN*




A WLAN can only have a single AVC profile applied to it, however AVC profiles may be applied to multiple WLANs.

## WLC AVC Profile CLI Configuration

AVC profiles can also be created via the WLC CLI, as shown in Example 24-4.

*Example 24-4 WLC CLI—AVC Profile Creation and Definition Example*

```
 ! This section creates the "AVC-APPS" AVC profile
(Cisco WLC) > config avc profile AVC-APPS create


 ! This section configures AVC for Voice
 ! Marking Cisco Phone Voice as DSCP EF and assigning it to the Platinum WMM AC
(Cisco WLC) > config avc profile AVC-AVC-APPS rule add application cisco-phone mark 46


 ! This section configures AVC for Multimedia Conferencing applications
 ! Marking these as DSCP AF41 and assigning them to the Gold WMM AC
(Cisco WLC) > config avc profile AVC-APPS rule add application webex-meeting mark 34
(Cisco WLC) > config avc profile AVC-APPS rule add application ms-lync-media mark 34


 ! This section configures AVC for Realtime Interactive applications
 ! Marking these as DSCP CS4 and assigning them to the Gold WMM AC
```

```
(Cisco WLC) > config avc profile AVC-AVC-APPS rule add application telepresence-media mark
32

 ! This section configures AVC for Signaling protocols
 ! Marking these to DSCP 24 and assigning them to the Gold WMM AC
(Cisco WLC) > config avc profile AVC-APPS rule add application sip mark 24
(Cisco WLC) > config avc profile AVC-APPS rule add application sip-tls mark 24
(Cisco WLC) > config avc profile AVC-APPS rule add application h323 mark 24
(Cisco WLC) > config avc profile AVC-APPS rule add application telepresence-control mark
24

 ! This section configures AVC for Transactional Data applications
 ! Marking these to DSCP 18 and assigning them to the Gold WMM AC
(Cisco WLC) > config avc profile AVC-APPS rule add application citrix mark 18
(Cisco WLC) > config avc profile AVC-APPS rule add application salesforce mark 18
(Cisco WLC) > config avc profile AVC-APPS rule add application sap mark 18
(Cisco WLC) > config avc profile AVC-APPS rule add application ms-lync mark 18
(Cisco WLC) > config avc profile AVC-APPS rule add application ms-dynamics-crm-online mark
18

 ! This section configures AVC for Bulk Data applications
 ! Marking these to DSCP AF11 and assigning them to the Bronze WMM AC
(Cisco WLC) > config avc profile AVC-APPS rule add application ftp mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application ftp-data mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application ftps-data mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application cifs mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application exchange mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application gmail mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application hotmail mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application notes mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application imap mark 10
(Cisco WLC) > config avc profile AVC-APPS rule add application secure-imap mark 10

 ! This section configures AVC for Scavenger applications
 ! Marking these to DSCP CS8 and assigning them to the Bronze WMM AC
(Cisco WLC) > config avc profile AVC-APPS rule add application facebook mark 8
(Cisco WLC) > config avc profile AVC-APPS rule add application youtube mark 8
(Cisco WLC) > config avc profile AVC-APPS rule add application netflix mark 8
(Cisco WLC) > config avc profile AVC-APPS rule add application hulu mark 8
(Cisco WLC) > config avc profile AVC-APPS rule add application skype mark 8
(Cisco WLC) > config avc profile AVC-APPS rule add application msn-messenger-video mark 8
(Cisco WLC) > config avc profile AVC-APPS rule add application bittorrent mark 8
(Cisco WLC) > config avc profile AVC-APPS rule add application itunes mark 8
(Cisco WLC) > config avc profile AVC-APPS rule add application call-of-duty mark 8
```

This configuration can be verified with:

- **show avc profile summary** (as shown in Example 24-5)
- **show avc profile detailed** (as shown in Example 24-6)

***Example 24-5 AVC Profile Verification: show avc profile summary***

```
(Cisco WLC) > show avc profile summary
  Profile-Name                    Number of Rules
  ============                    ===============
  AVC-APPS                               32
(Cisco WLC) >
```

### Example 24-6 AVC Profile Verification: show avc profile detailed

```
(Cisco WLC) > show avc profile detailed AVC-APPS

  Application-Name          Application-Group-Name            Action  DSCP
  ================          ======================            ======  ====
  cisco-phone               voice-and-video                    Mark     46
  webex-meeting             voice-and-video                    Mark     34
  ms-lync-media             voice-and-video                    Mark     34
  telepresence-media        voice-and-video                    Mark     32
  sip                       voice-and-video                    Mark     24
  sip-tls                   voice-and-video                    Mark     24
  h323                      voice-and-video                    Mark     24
  telepresence-control      voice-and-video                    Mark     24
  citrix                    business-and-productivity-tools    Mark     18
  salesforce                business-and-productivity-tools    Mark     18
  sap                       business-and-productivity-tools    Mark     18
  ms-lync                   business-and-productivity-tools    Mark     18
  ms-dynamics-crm-online    business-and-productivity-tools    Mark     18
  ftp                       file-sharing                       Mark     10
  ftp-data                  file-sharing                       Mark     10
  ftps-data                 file-sharing                       Mark     10
  cifs                      file-sharing                       Mark     10
  exchange                  email                              Mark     10
  gmail                     email                              Mark     10
  hotmail                   email                              Mark     10
  notes                     email                              Mark     10
  imap                      email                              Mark     10
  secure-imap               email                              Mark     10
  facebook                  browsing                           Mark      8
  youtube                   voice-and-video                    Mark      8
  netflix                   voice-and-video                    Mark      8
  hulu                      voice-and-video                    Mark      8
  skype                     voice-and-video                    Mark      8
  msn-messenger-video       voice-and-video                    Mark      8
  bittorrent                file-sharing                       Mark      8
  itunes                    file-sharing                       Mark      8
  call-of-duty              other                              Mark      8

  Associated WLAN IDs       :
  Associated Remote LAN IDs :
  Associated Guest LAN IDs  :

(Cisco WLC) >
```

AVC profiles can also be attached to the WLAN via the WLC CLI, as shown in Example 24-7.

### Example 24-7 WLC CLI-Attaching AVC Profiles to WLANs Example

```
(Cisco WLC) > config wlan avc 1 profile AVC-APPS enable
 ! This command applies the AVC profile "AVC-APPS" to WLAN ID 1
```

This configuration can be verified with:

- **show avc profile detailed** (as shown in Example 24-8)
- **show wlan** (as shown in Example 24-9)

### Example 24-8 AVC Profile Verification: show avc profile detailed

```
(Cisco WLC) > show avc profile detailed AVC-APPS

  Application-Name          Application-Group-Name            Action  DSCP
```

```
  ================          ======================          ======  ====
  cisco-phone               voice-and-video                  Mark     46

<snip>

  Associated WLAN IDs        : 1
  Associated Remote LAN IDs  :
  Associated Guest LAN IDs   :

(Cisco WLC) >
```

***Example 24-9 AVC Profile Verification: show wlan***

```
(Cisco WLC) >show wlan 1

WLAN Identifier.................................. 1
Profile Name..................................... BYOD_Employee
Network Name (SSID).............................. BYOD-Employee
Status........................................... Enabled

<snip>

Quality of Service.............................. Platinum

<snip>

AVC Visibilty.................................... Enabled
AVC Profile Name................................. AVC-APPS

(Cisco WLC) >
```

# AP Access Switch Downstream QoS Policies

The purpose of network QoS policies is to ensure that enterprise application classes will map into the correct WMM access categories (and vice versa). Since the admission to the WMM access categories is based on 802.11e UP values, which in turn are based on DSCP-to-UP translations (as covered in Step 3 of Figure 24-13), the packets need to enter the AP with the necessary (outer) DSCP values (of the CAPWAP packet) to achieve the desired mappings. This requirement is underscored by the fact that the WLC/AP QoS Translation Table (Table 24-4) is not modifiable and neither is the default DSCP-to-CoS/UP mapping (Table 24-5). Therefore the final point that an administrator could correctly set (or reset) DSCP values in packets before handing these off to the AP to ensure the traffic is placed in the desired WMM access category is at the egress interface of the network access switch to which the AP is connected (shown as point C in Figure 24-14).

**Note** Granted, it would be possible to perform DSCP remarking within the Cisco WLC via an AVC policy. Such an AVC policy would match on an application type(s) and then set this to a differing DSCP value as used in the enterprise campus network. However AVC policies apply in both directions simultaneously (and there is no option to apply these in the downstream or upstream direction only). Therefore such an AVC policy—intended for downstream remarking—would include the undesired effect of marking these application types incompatibly with the enterprise models for traffic in the upstream direction towards the wired network.

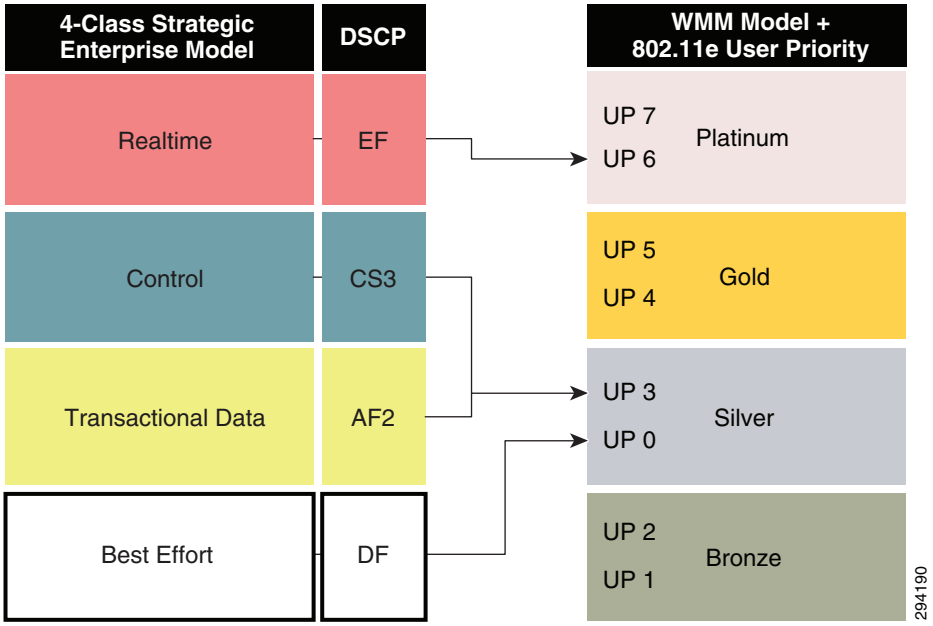
The details of the network downstream DSCP remarking policy will vary according to the enterprise application-class models in use. To illustrate a cross-section of marking-model variations—as well as Catalyst switching platform variations—the following mappings examples will be considered in detail:

- Four-class enterprise model mapped to WMM on a Catalyst 3750-X series switch (Four-Class Enterprise to WMM Mapping Model)
- Eight-class enterprise model mapped to WMM on a Catalyst 4500E series switch with Supervisor 7-E (Eight-Class Enterprise to WMM Mapping Model)
- Twelve-class enterprise model mapped to WMM on a Catalyst 6500 series switch with Supervisor 2T (Twelve-Class Enterprise to WMM Mapping Model)

## Four-Class Enterprise to WMM Mapping Model

If the enterprise has deployed a four-class strategic model, then this allows for a 1:1 mapping into the four WMM access categories. The default mapping for a four-class enterprise model to WMM is shown in Figure 24-23.

***Figure 24-23 Default Downstream Four-Class Enterprise Model Mapping to WMM***




As can be seen in Figure 24-23, if the QoS Translation Table (Table 24-4) and default mappings (Table 24-5) were applied on these four enterprise QoS classes, these would map to only two access categories: Platinum (Voice) and Silver (Best Effort). The remaining two access categories would not even be used. While this default mapping will ensure voice quality, no other application will benefit from wireless QoS.

An alternative approach would be to perform remarking at the network access switch (connecting to the wireless AP) at the egress interface in the outbound direction such that the Control/Signaling application class is remarked to a DSCP value that will map to an UP value (on the AP) that will, in turn, be assigned to the Gold WMM AC. Similarly, Best Effort traffic may be mapped to a DSCP value that will map to an UP value that will, in turn, be assigned to the Bronze WMM AC. This re-mapping approach would

then leave the Silver WMM AC to exclusively service Transactional Data applications and thereby reflect the same overall relative priority of servicing as the original model. The modified four-class mapping model is shown in Figure 24-25.

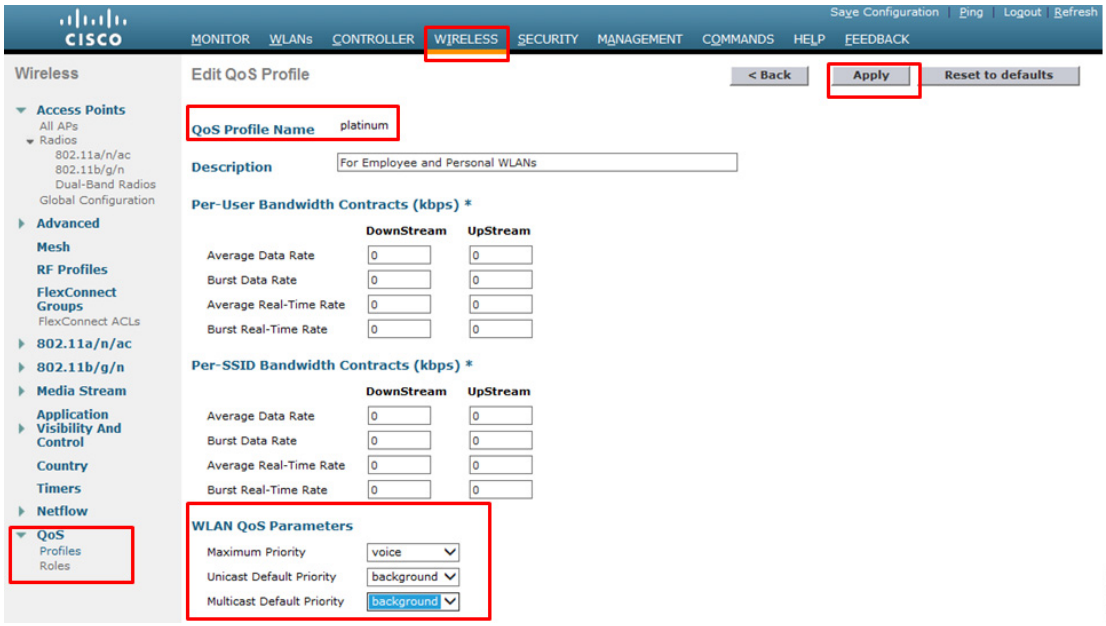
Perhaps the question may arise: why not just configure an AVC policy on the WLC to match signaling traffic and remark it to a DSCP value that will map to the Gold WMM AC—like say CS4/DSCP 32—rather than configuring mapping policies on the access switch? To answer this, it should be kept in mind that such an AVC marking policy on the WLC—which operates both in the upstream and downstream direction—will interfere with QoS policies on the rest of the wired network (which includes both the upstream network as well as the transit network between the WLC and the APs). Specifically, while such a policy may achieve the intended result in the downstream direction, it will include the unintended effect of marking signaling to CS4 (rather than CS3) in the upstream direction also, which would be incompatible with the rest of the enterprise strategic policy and would have to be remapped at the WLC upstream switch. Furthermore, Signaling traffic marked on the WLC to CS4 by AVC and transiting in the downstream direction would have no QoS applied over the wired network between the WLC and the APs unless the administrator modified all the policies in the path to accommodate. Therefore, a much simpler approach to achieve the same end result is to include a simple remarking policy on the final access switch connecting to the AP.

However, rather than remapping signaling traffic to a code-point that may be used for another application, it may be better to remark signaling to a non-standard codepoint for this one-time operation, such as DSCP 33. DSCP 33 would map (by default) to the Gold WMM AC and would uniquely identify this remapped signaling traffic.

Similarly the default Best Effort class could be remapped on the network access switch to a non-standard codepoint that would be assigned to the Bronze WMM AC-such as DSCP 9. However, some platforms, such as the Catalyst 3750, do not support egress marking policies and only support marking/remarking/DSCP-mutation policies on ingress. In such a case, remarking Best Effort traffic on access switch ingress will affect BE marking on all interfaces and not just the interface connecting to the access point.

In such a case, a more elegant method would be to modify the QoS Profile for the WLAN so that the Unicast/Multicast Default Priority for the WLAN is set to Background instead of Best Effort, as shown in Figure 24-24.

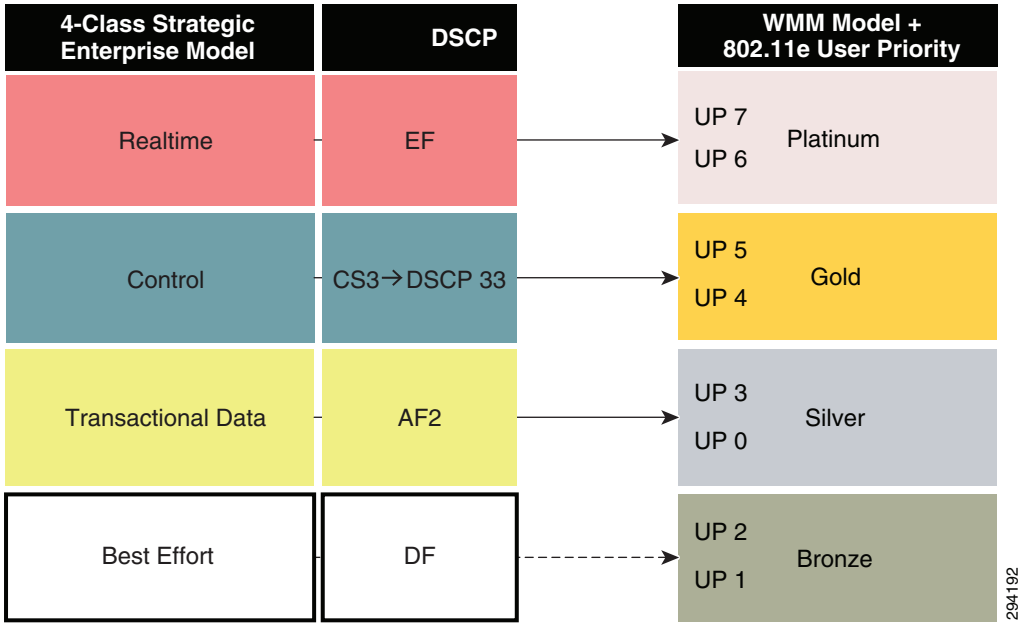
*Figure 24-24 Modifying the Platinum WLC QoS Profile-Best Effort 'Background*




It bears noting that assigning the default class to the Background WMM category will marginally delay best effort traffic, however this is the nature of QoS as there is always a tradeoff. In this scenario, this is the necessary cost of providing superior levels of service to the signaling and transactional data application classes, thus providing the four levels of service required to meet their strategic business objectives of QoS.

The modified mapping of a four-class enterprise model to WMM is shown in Figure 24-25.

*Figure 24-25 Modified Downstream Four-Class Enterprise Model Mapping to WMM*

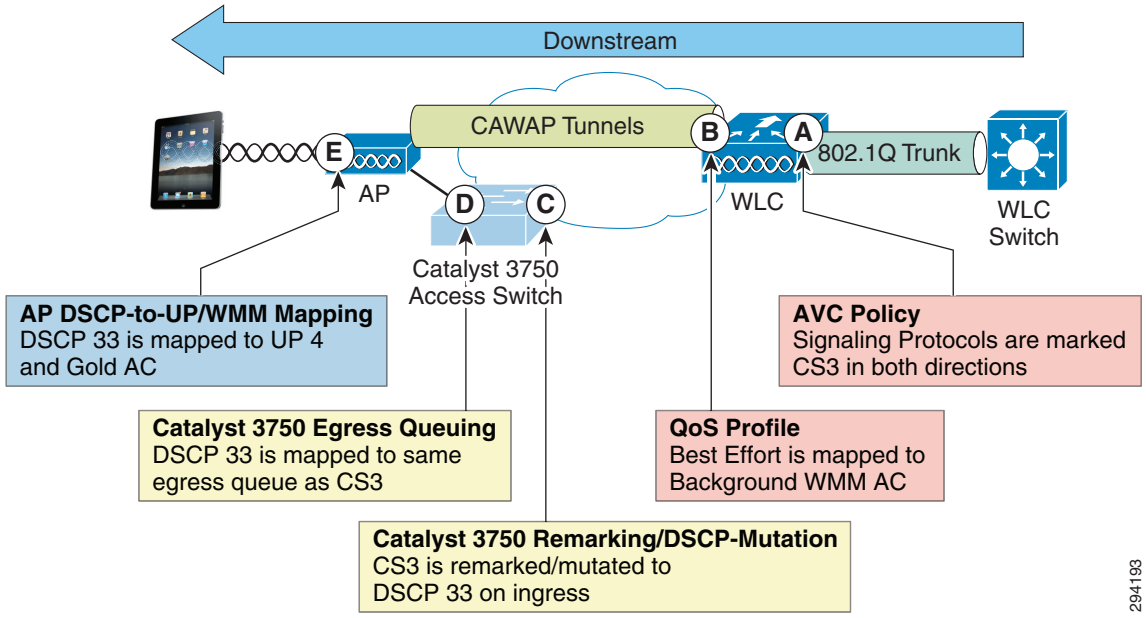


## Catalyst 3750 Configuration Example

To highlight platform-specific syntax, features, and limitations, each mapping model is presented on a different Catalyst switching platform. This four-class enterprise mapping to WMM AC is presented on the Catalyst 3750 (which will be identical to configuration for the Catalyst 2960 and 3560 switches also).

As noted, the Catalyst 3750 does not support egress remarking; only ingress marking or ingress DSCP-mutation are supported, as shown in Figure 24-26.

***Figure 24-26 Catalyst 3750 Four-Class Enterprise to WMM Marking and Mapping Policies***




The Catalyst 3750 employs Multilayer Switch QoS (MLS QoS), and as such DSCP-remarking policies can be configured in one of two ways:

- Class-based marking policy (as shown in Example 24-10)
- DSCP-Mutation (as shown in Example 24-11)

***Example 24-10 Catalyst 3750 Downstream Four-Class Enterprise Model Mapping Policy to WMM via Class-Based Marking***

```
 ! This section configures the class-map
C3750-X(config-cmap)# class-map match-all SIGNALING
C3750-X(config-cmap)#  match ip dscp cs3
 ! Signaling traffic is matched on DSCP CS3


 ! This section configures the Network Downstream Remarking policy-map
C3750-X(config-cmap)# policy-map DOWNSTREAM-WMM-REMARKING
C3750-X(config-pmap-c)# class SIGNALING
C3750-X(config-pmap-c)#  set dscp 33
 ! Signaling is remarked DSCP 33 to map into WMM Gold downstream


 ! This section attaches the Downstream policy to the campus-side interface
C3750-X(config)# interface TenGigabitEthernet2/1/1
C3750-X(config-if)# mls qos trust dscp
```

```
 ! Configures the port to statically trust DSCP on ingress
C3750-X(config-if)# service-policy input DOWNSTREAM-WMM-REMARKING
 ! Attaches the Downstream DSCP remarking policy to the interface on ingress
```

This configuration can be verified with the commands:

- **show mls qos interface**
- **show class-map**
- **show policy-map**
- **show policy-map interface**

### *Example 24-11 Downstream Four-Class Enterprise Model Mapping Policy to WMM via DSCP-Mutation*

```
 ! This section configures the Downstream DSCP Mutation map
C3750-X(config)# mls qos map dscp-mutation DOWNSTREAM-WMM-MUTATION 24 to 33


 ! This section attaches the Downstream policy to the campus-side interface
C3750-X(config)# interface TenGigabitEthernet2/1/1
C3750-X(config-if)# mls qos trust dscp
 ! Configures the port to statically trust DSCP on ingress
C3750-X(config-if)# mls qos dscp-mutation DOWNSTREAM-WMM-MUTATION
 ! Attaches the Downstream DSCP mutation map to the interface on ingress
```

This configuration can be verified with the commands:

- **show mls qos interface**
- **show mls qos maps dscp-mutation**

Additionally, this non-standard DSCP representing signaling traffic should be mapped to the same egress queue as regular signaling traffic (marked CS3), as shown in Example 24-12.

### *Example 24-12 Catalyst 3750 Egress Queuing Configuration*

```
! This section configures buffers and thresholds on Q1 through Q4
C3750(config)# mls qos queue-set output 1 buffers 15 30 35 20
 ! Queue buffers are allocated
C3750(config)# mls qos queue-set output 1 threshold 1 100 100 100 100
 ! All Q1 (PQ) Thresholds are set to 100%
C3750(config)# mls qos queue-set output 1 threshold 2 80 90 100 400
 ! Q2T1 is set to 80%; Q2T2 is set to 90%;
 ! Q2 Reserve Threshold is set to 100%;
 ! Q2 Maximum (Overflow) Threshold is set to 400%
C3750(config)# mls qos queue-set output 1 threshold 3 100 100 100 400
 ! Q3T1 is set to 100%, as all packets are marked the same weight in Q3
 ! Q3 Reserve Threshold is set to 100%;
 ! Q3 Maximum (Overflow) Threshold is set to 400%
C3750(config)# mls qos queue-set output 1 threshold 4 60 100 100 400
 ! Q4T1 is set to 60%; Q4T2 is set to 100%
 ! Q4 Reserve Threshold is set to 100%;
 ! Q4 Maximum (Overflow) Threshold is set to 400%
 ! This section configures egress CoS-to-Queue mappings (if required)
C3750(config)# mls qos srr-queue output cos-map queue 1 threshold 3 4 5
 ! CoS 4 and 5 are mapped to egress Q1T3 (the tail of the PQ)
C3750(config)# mls qos srr-queue output cos-map queue 2 threshold 1 2
 ! CoS 2 is mapped to egress Q2T1
C3750(config)#mls qos srr-queue output cos-map queue 2 threshold 2 3
 ! CoS 3 is mapped to egress Q2T2
C3750(config)# mls qos srr-queue output cos-map queue 2 threshold 3 6 7
 ! CoS 6 and 7 are mapped to Q2T3
```

```
C3750(config)# mls qos srr-queue output cos-map queue 3 threshold 3 0
 ! CoS 0 is mapped to Q3T3 (the tail of the default queue)
C3750(config)# mls qos srr-queue output cos-map queue 4 threshold 3 1
 ! CoS 1 is mapped to Q4T3 (tail of the less-than-best-effort queue)


 ! This section configures egress DSCP-to-Queue mappings
C3750(config)# mls qos srr-queue output dscp-map queue 1 threshold 3 32 40 46
 ! DSCP CS4, CS5 and EF are mapped to egress Q1T3 (tail of the PQ)
C3750(config)# mls qos srr-queue output dscp-map queue 2 threshold 1 16 18 20 22
 ! DSCP CS2 and AF2 are mapped to egress Q2T1
C3750(config)# mls qos srr-queue output dscp-map queue 2 threshold 1 26 28 30 34 36 38
 ! DSCP AF3 and AF4 are mapped to egress Q2T1
C3750(config)# mls qos srr-queue output dscp-map queue 2 threshold 2 24 33
 ! DSCP CS3 and DSCP 33 is mapped to egress Q2T2
C3750(config)# mls qos srr-queue output dscp-map queue 2 threshold 3 48 56
 ! DSCP CS6 and CS7 are mapped to egress Q2T3
C3750(config)# mls qos srr-queue output dscp-map queue 3 threshold 3 0
 ! DSCP DF is mapped to egress Q3T3 (tail of the best effort queue)
C3750(config)# mls qos srr-queue output dscp-map queue 4 threshold 1 8
 ! DSCP CS1 is mapped to egress Q4T1
C3750(config)# mls qos srr-queue output dscp-map queue 4 threshold 2 10 12 14
 ! DSCP AF1 is mapped to Q4T3 (tail of the less-than-best-effort queue)


 ! This section configures interface egress queuing parameters
C3750(config)# interface range GigabitEthernet1/0/1-48
C3750(config-if-range)# queue-set 1
 ! The interface(s) is assigned to queue-set 1
C3750(config-if-range)# srr-queue bandwidth share 1 30 35 5
 ! The SRR sharing weights are set to allocate 30% BW to Q2
 ! 35% BW to Q3 and 5% BW to Q4
 ! Q1 SRR sharing weight is ignored, as it will be configured as a PQ
C3750(config-if-range)# priority-queue out
 ! Q1 is enabled as a strict priority queue
```

This configuration can be verified with the commands:

- **show mls qos queue-set**
- **show mls qos maps cos-output-q**
- **show mls qos maps dscp-output-q**
- **show mls qos interface interface x/y queueing**
- **show mls qos interface interface x/y statistics**

**Note** Additional design recommendations for the Catalyst 3750 can be found in the Medianet Campus QoS Design 4.0 design chapter at: http://www.cisco.com/en/US/docs/solutions/Enterprise/WAN_and_MAN/QoS_SRND_40/QoSCampus_40.html#wp1099462.

## Eight-Class Enterprise to WMM Mapping Model

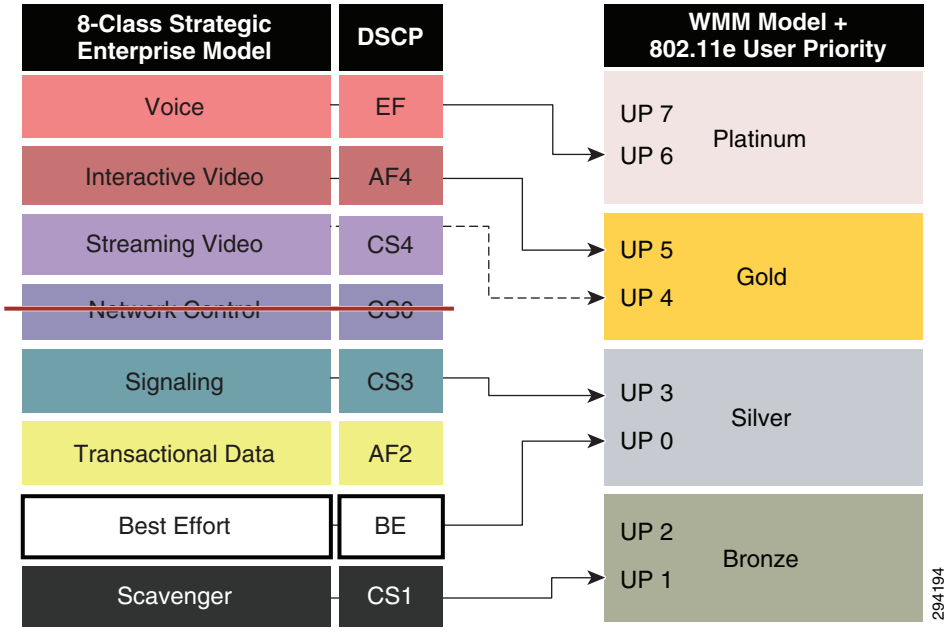
If the enterprise has deployed an eight-class strategic model, then a simple 1:1 mapping is no longer possible and some additional considerations need to be taken into account.

One such consideration is whether all eight traffic classes will have application traffic generated to and/or from wireless mobile devices. For example, no mobile clients or devices should be transmitting or receiving Network Control traffic (as this application class is intended for servicing the control plane requirements of the network infrastructure).

**Note** It also can be argued that no Streaming Video traffic should be sourced from mobile devices (although these devices might be receivers of such streams). Nonetheless, since traffic for this class may be present—primarily in the downstream direction—and as such will be included in the mapping model (albeit with a dashed line to indicate that this application traffic is typically unidirectional in the downstream direction only).

The default mapping for a four-class enterprise model to WMM is shown in Figure 24-27.

***Figure 24-27 Default Downstream Eight-Class Enterprise Model Mapping to WMM***



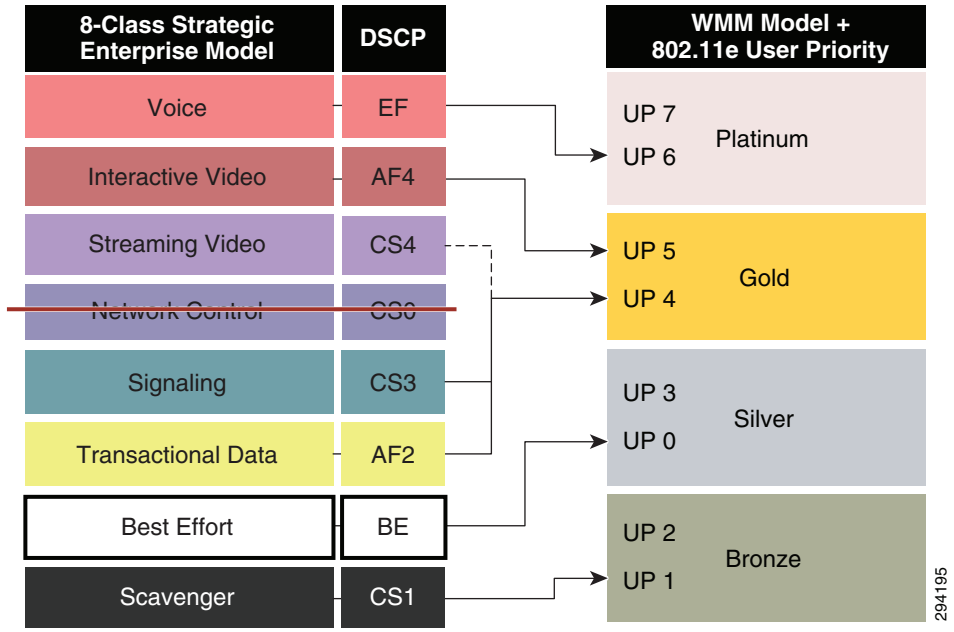

While this default Eight-Class mapping may be adequate for some environments, it should be noted that there is no QoS provisioned for Transactional Data traffic (that may include VDI applications like Citrix XenDesktop or VMware View) nor for Signaling traffic (which is control plane traffic for IP telephone and/or IP video telephony applications)—other than merely protecting these application classes from Scavenger traffic.

Therefore, it may be desirable to remap these applications to the Gold access-category, using non-standard codepoints (as in the previous example). In this case, Signaling traffic can again be mapped to DSCP 33 and Transactional Data can be mapped to DSCP 35 at the AP access switch in the egress direction,

**Note** As both DSCP 33 and 35 map to the same UP value of 4, there is no advantage/disadvantage to marking these applications to a higher/lower DSCP value, provided these maps to the desired WMM AC. The key is keeping these values unique and distinct for traffic management purposes.

The modified eight-class mapping model is shown in Figure 24-28.

*Figure 24-28 Modified Downstream Eight-Class Enterprise Model Mapping to WMM*



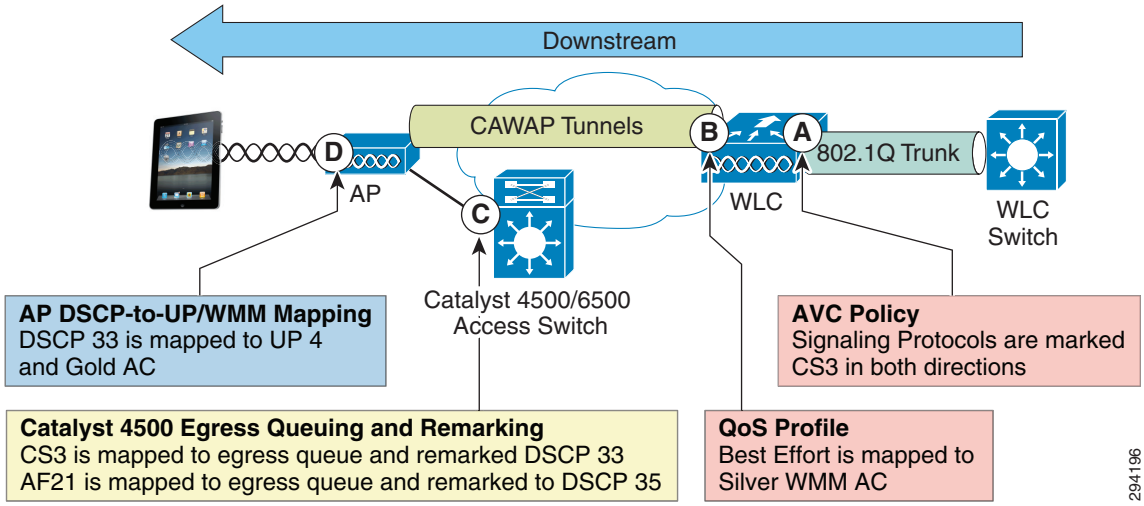

**Note** Best Effort traffic is assigned to the default Silver (Best Effort) WMM Access Category in the WLC WLAN QoS Profile for this mapping model.

### Catalyst 4500E Supervisor 7-E Example

This DSCP remarking tactical design adapted for the Catalyst 4500 is illustrated in Figure 24-29. Since the Catalyst 4500 uses MQC QoS, it supports egress remarking. As such, only a single policy is required on this switch: namely adapting the final egress queuing policy to remark the Signaling and Transactional Data application classes to DSCP 33 and 35, respectively.

**Note** Incidentally, the remarking policies and enforcement points for an Eight-Class Enterprise to WMM Mapping Model on a Catalyst 4500 are the same as a Twelve-Class Enterprise to WMM Mapping Model on a Catalyst 6500. As such, both are shown in a single diagram (Figure 24-29).

*Figure 24-29 Catalyst 4500/6500 Eight-Class/Twelve-Class Enterprise to WMM Marking and Mapping Policies*




This modified eight-class mapping configuration example is presented on the Catalyst 4500-E series switch (with Supervisor 7-E), as shown in Example 24-13. Since MQC only supports one service-policy statement attached to a given interface in a single direction, the egress remarking policy must be combined with the (eight-class) egress queuing policy as a single MQC service-policy in the output direction, as shown in Example 24-13.

***Example 24-13 Catalyst 4500 Downstream Eight-Class Enterprise Model Queuing and Mapping Policy to WMM***

```
 ! This section configures the class-maps for the egress queuing policy
C4500(config)# class-map match-any PRIORITY-QUEUE
C4500(config-cmap)# match dscp ef
 ! VoIP (EF) is mapped to the PQ
C4500(config)# class-map match-all INTERACTIVE-VIDEO-QUEUE
C4500(config-cmap)# match dscp af41 af42 af43
 ! Interactive-Video (AF4) is assigned a dedicated queue
C4500(config)# class-map match-all STREAMING-VIDEO-QUEUE
C4500(config-cmap)# match dscp af31 af32 af33
 ! Streaming-Video (AF3) is assigned a dedicated queue
C4500(config)# class-map match-any CONTROL-QUEUE
C4500(config-cmap)# match dscp cs6
 ! Network Control (CS6) is mapped to a dedicated queue
C4500(config)# class-map match-any SIGNALING-QUEUE
C4500(config-cmap)# match dscp cs3
 ! Signaling (CS3) is mapped to a dedicated queue
C4500(config)# class-map match-all TRANSACTIONAL-DATA-QUEUE
C4500(config-cmap)# match dscp af21 af22 af23
 ! Transactional Data (AF2) is assigned a dedicated queue
C4500(config)# class-map match-all SCAVENGER-QUEUE
C4500(config-cmap)# match dscp cs1
 ! Scavenger (CS1) is assigned a dedicated queue


 ! This section configures the 1P7Q1T+DBL egress queuing policy-map
C4500(config)# policy-map 1P7Q1T+DBL+DOWNSTREAM-MAPPING
C4500(config-pmap-c)# class PRIORITY-QUEUE
C4500(config-pmap-c)#  priority
```

```
 ! Defines a priority queue
C4500(config-pmap-c)# class INTERACTIVE-VIDEO-QUEUE
C4500(config-pmap-c)#  bandwidth remaining percent 23
C4500(config-pmap-c)#  dbl
 ! Defines a interactive-video queue with 23% BW remaining + DBL
C4500(config-pmap-c)# class STREAMING-VIDEO-QUEUE
C4500(config-pmap-c)# bandwidth remaining percent 10
C4500(config-pmap-c)#  dbl
 ! Defines a streaming-video queue with 10% BW remaining + DBL
C4500(config-pmap-c)# class CONTROL-QUEUE
C4500(config-pmap-c)#  bandwidth remaining percent 5
 ! Defines a control/management queue with 5% BW remaining
C4500(config-pmap-c)# class SIGNALING-QUEUE
C4500(config-pmap-c)#  bandwidth remaining percent 2
 ! Defines a signaling queue with 2% BW remaining
C4500(config-pmap-c)#  set dscp 33
 ! Remarks signaling traffic to DSCP 33 for WMM Gold downstream mapping
C4500(config-pmap-c)# class TRANSACTIONAL-DATA-QUEUE
C4500(config-pmap-c)#  bandwidth remaining percent 24
C4500(config-pmap-c)#  dbl
 ! Defines a transactional data queue with 24% BW remaining + DBL
C4500(config-pmap-c)#  set dscp 35
 ! Remarks transactional data to DSCP 35 for WMM Gold downstream mapping
C4500(config-pmap-c)# class SCAVENGER-QUEUE
C4500(config-pmap-c)#  bandwidth remaining percent 1
 ! Defines a (minimal) scavenger queue with 1% BW remaining/limit
C4500(config-pmap-c)# class class-default
C4500(config-pmap-c)#  bandwidth remaining percent 25
C4500(config-pmap-c)#  dbl
 ! Provisions the default/Best Effort queue with 25% BW remaining + DBL


 ! This section attaches the egress queuing & mapping policy to AP interface
C4500(config)# interface GigabitEthernet 3/1
C4500(config-if)# service-policy output 1P7Q1T+DBL+DOWNSTREAM-MAPPING
 ! Attaches the combined egress queuing and egress remarking policy to the int
```

**Note** Additional detail on Catalyst 4500 queuing policy recommendations can be found in Medianet Campus QoS Design 4.0 design chapter at: http://www.cisco.com/en/US/docs/solutions/Enterprise/WAN_and_MAN/QoS_SRND_40/QoSCampus_40.html#wp1100873.

**Note** Class-maps defined for egress-queuing policies require unique names from any ingress-policy class-maps; otherwise classification errors may occur due to overlapping classification-logic. Therefore the class-maps names in this example have "-QUEUE" appended to them.

**Note** It is recommended to use **match dscp** and **set dscp**—as opposed to **match ip dscp** and **set ip dscp**—as the former will match on both IPv4 and IPv6 packets, whereas the latter will match only on IPv4 packets. Although AVC does not yet classify IPv6 traffic, these packets can still be properly mapped at this node to the correct downstream WMM access category.

This configuration can be verified with the commands:

- **show class-map**
- **show policy-map**

- **show policy-map interface**

## Twelve-Class Enterprise to WMM Mapping Model

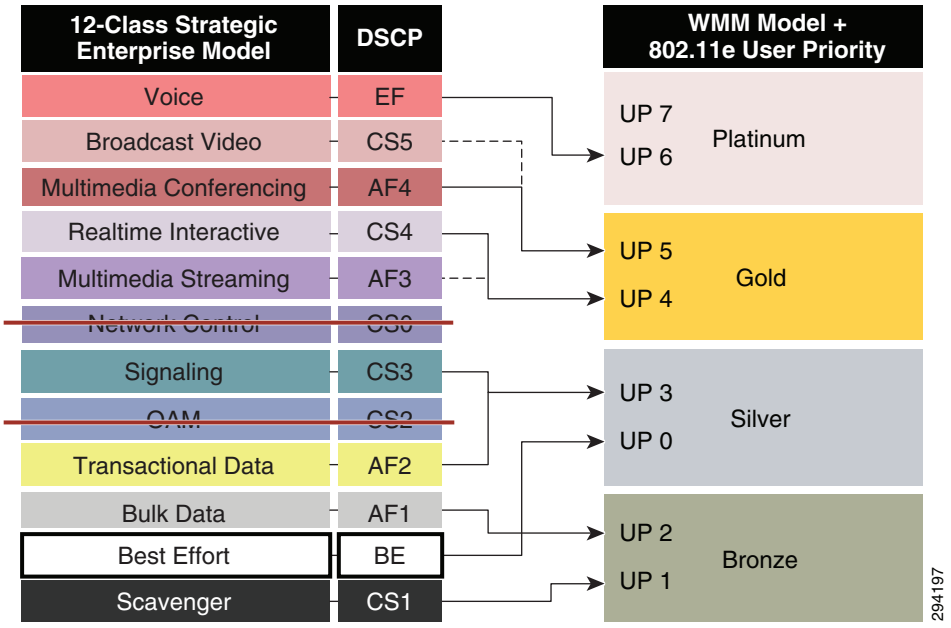
If the enterprise has deployed a twelve-class strategic model, then further class-pruning and application-class collapsing needs to take place.

To this end, both the Network Control and the Operations/Administration/Management application traffic classes can be pruned out of the mapping model, as wireless endpoint devices should not be generating nor receiving traffic from these classes (as these classes are intended as control plane classes for the network infrastructure).

**Note** It can be argued that neither Broadcast Video nor Streaming Video traffic should be sourced from mobile devices (although these devices might be receivers of such streams). Nonetheless, since traffic for this class may be present, it is included in the mapping model (albeit with a dashed line to indicate that this application traffic is typically unidirectional in the downstream direction).

The default mapping for a twelve-class enterprise model to WMM is shown in Figure 24-30.

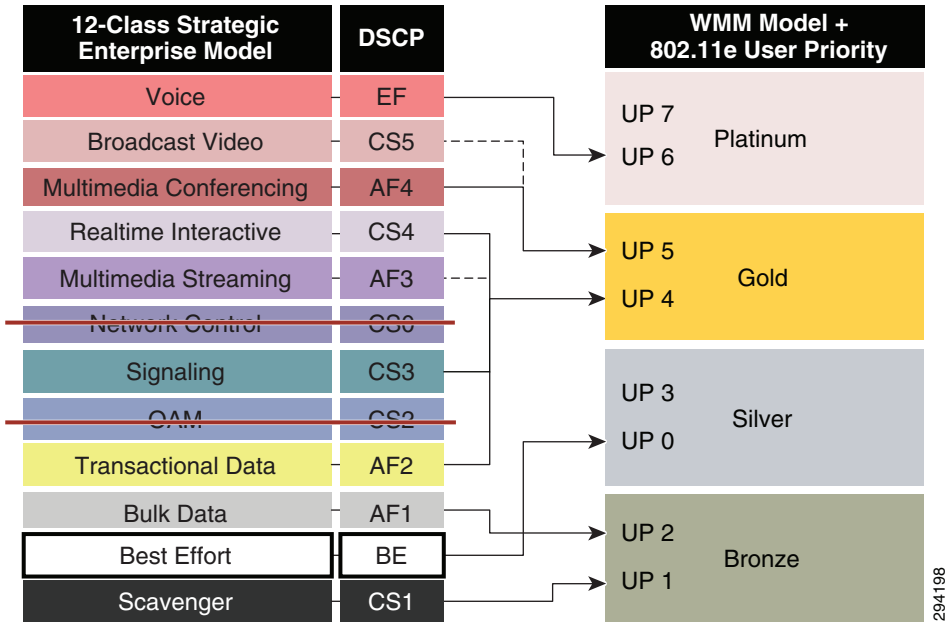
*Figure 24-30 Default Downstream Twelve-Class Enterprise Model Mapping to WMM*




As with the previous Eight-Class Model, the default Twelve-Class model provisions no QoS for Transactional Data traffic (that may include VDI applications like Citrix XenDesktop or VMware View) nor for Signaling traffic (which is control plane traffic for IP telephone and/or IP video telephony applications)—other than merely protecting these from Scavenger traffic.

Therefore it may be desirable to remap these applications to the Gold WMM access-category, as shown in Figure 24-31.

*Figure 24-31 Modified Downstream Twelve-Class Enterprise Model Mapping to WMM*




## Catalyst 6500 Supervisor 2T Example

This modified twelve-class mapping example is presented on the Catalyst 6500 series switch (with Supervisor 2T). The Catalyst 6500 employs Cisco Common Classification Policy Language (C3PL) QoS and, as such, supports egress class-based marking. Therefore class-based marking policies are only applied on the AP-side network interface, as with the Catalyst 4500, and are shown in Figure 24-30.

Unlike IOS MQC, C3PL does not allow for the combining of class-based marking policies with queuing policies. However both may be simultaneously applied to an interface in a given direction because queuing policies require the additional keywords **type lan-queuing** in their respective class-maps and policy-maps (and class-based marking policies do not).

The Catalyst 6500 supports ingress queuing, but such a policy would technically not be required on an interface connecting to an AP as this interface would not be oversubscribed (due to the AP's capacity being less than 1 Gbps).

Furthermore, the egress queuing policy applied to the interface would remain unchanged, as queuing policies on Catalyst 6500 10/100/1000 interfaces are CoS-based and as such remarked Signaling and Transactional-Data traffic cannot be assigned to the same queues as Signaling. This is because remarked Signaling (DSCP 33) and remarked Transactional Data (DSCP 35) would map to CoS 4, whereas Signaling traffic (DSCP CS3/24) maps to CoS 3. These remarked flows will receive a preferential QoS treatment, but it will be the one ordinarily intended for the video application classes that traditionally align to CoS 4, rather than the Data and Signaling classes that map to CoS 3.

Thus two policies will be present on the AP interface on the Catalyst 6500:

- A class-based marking policy to remap and to restore temporary DSCP values for Signaling and Transactional Data traffic (as shown in Example 24-14).
- An egress C3PL queuing policies to map 12-application classes into a 4 hardware queue (1P3Q8T) model and provide intra-queue QoS via DSCP-based WRED.

**Note** Since the egress queuing policy remains unchanged, it is not included here for the sake of brevity, but can be referenced from the Medianet Campus QoS Design Guide at http://www.cisco.com/en/US/docs/solutions/Enterprise/WAN_and_MAN/QoS_SRND_40/QoSCampus_40.html.

Therefore, altogether two separate service-policy statements will be applied to a Catalyst 6500 10/100/1000 interface connecting to an AP, as shown in Example 24-14.

- **service-policy output** DOWNSTREAM-WMM-REMARKING
- **service-policy type lan-queuing output** EGRESS-1P3Q8T

***Example 24-14 Catalyst 6500 Downstream Class-Based Marking Mapping Policies for WMM***

```
 ! This section configures the class-maps
C6500(config-cmap)# class-map match-any SIGNALING
C6500(config-cmap)#  match dscp cs3
 ! Signaling from campus is matched on CS3
C6500(config-cmap)# class-map match-all TRANSACTIONAL-DATA
C6500(config-cmap)#  match dscp af21 af22 af23
 ! Transactional Data from campus is matched on AF2


 ! This section configures the Downstream DSCP-Restoration Policy
C6500(config)# policy-map DOWNSTREAM-WMM-REMARKING
C6500(config-pmap)# class SIGNALING
C6500(config-pmap-c)#  set dscp 33
 ! Signaling is mapped to DSCP 33 for Downstream WMM Gold AC
C6500(config-pmap-c)# class TRANSACTIONAL-DATA
C6500(config-pmap-c)#  set dscp 35
 ! Transactional-Data is mapped to DSCP 35 for Downstream WMM Gold AC


 ! This section applies the downstream remarking policies to AP interface
C6500(config-pmap-c)# interface GigabitEthernet1/10
C6500(config-if)# service-policy output DOWNSTREAM-WMM-REMARKING
 ! Attaches the DOWNSTREAM-WMM-REMARKING policy to the AP interface
C6500(config-if)# service-policy type lan-queuing output EGRESS-1P7Q4T
 ! Attaches the EGRESS-1P3Q8T queuing policy to the interface
```

**Note** It is recommended to use **match dscp** and **set dscp**—as opposed to **match ip dscp** and **set ip dscp**—as the former will match on both IPv4 and IPv6 packets, whereas the latter will match only on IPv4 packets. Although AVC does not yet classify IPv6 traffic, these packets can still be properly mapped at this node to the correct downstream WMM access category.

This configuration can be verified with the commands:

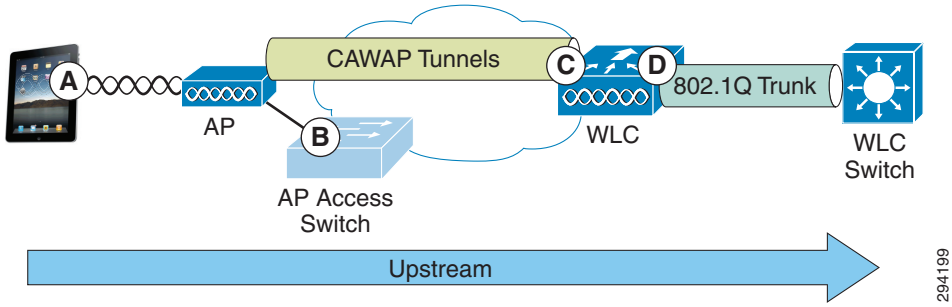
- **show class-map**
- **show policy-map**
- **show policy-map interface**

# Configuring Upstream QoS Policies for Mobile Applications

The following policies are required for upstream flows:

- Wireless Device Marking and WMM Policies—QoS policies are embedded within mobile application software and operating systems which can mark UP and DSCP values as well as assign application traffic into the respective WMM access categories in the radio-upstream direction. These policies are shown as point A in Figure 24-32.
- AP Access-Switch QoS Policies—These policies are typically applied on access switch ingress and are shown as point B in Figure 24-32.
- WLC AVC Profiles—Applied on WLC ingress and are shown as point C in Figure 24-15; when configured, these policies apply in both directions-therefore no additional configuration is required to configure AVC QoS in the upstream direction.
- WLC QoS Profiles—Applied on WLC egress and are shown as point D in Figure 24-15; when configured, these policies apply in both directions-therefore no additional configuration is required to configure QoS in the upstream direction.

*Figure 24-32 Upstream QoS Policy Configuration Points in Wired/Wireless Networks*




Each of these sets of policies will be covered in detail in the respective following sections.

# Wireless Device Marking and WMM Policies

The initial upstream over-the-air WMM policies are up to the mobile application vendor to include within their application software and the network administrator has no control over these policies. However, they really only have effect in the upstream “first-hop” to the AP (whereas the majority of traffic to wireless devices flows in the downstream direction, which administrators can control via WLC AVC and QoS profiles).

Nonetheless, it is not a matter of every application on every BYOD device behaving in the same manner. Consider Figure 24-33, which shows various Cisco, Apple, and Samsung phones and their corresponding voice and signaling IP and DSCP marking values.

*Figure 24-33 Mobile Wireless IP Phone/Smartphone 802.11 UP and DSCP Marking Values by Hardware Vendor[1]*

| Device Model | Application | Traffic Type | QoS marking done by Client | | DSCP in CAPWAP | DSCP in Wired Packet |
|---|---|---|---|---|---|---|
| | | | 802.11 UP | IP DSCP | | |
| Cisco 7921 | N/A | RTP-Vocie | UP-6 (Voice) | EF | EF | EF - VOICE |
| Cisco 7921 | N/A | SCCP-Vocie signalling | UP-4 (Cont Load) | CS3 | AF31 | N/A |
| Cisco7925G | N/A | RTP-Vocie | UP-6 (Voice) | EF | EF | EF - VOICE |
| Cisco7925G | N/A | SCCP-Vocie signalling | UP-4 (Cont Load) | CS3 | AF31 | N/A |
| iPhone4 | Jabber | RTP-Vocie | UP-5 (Video) | EF | AF41 | EF - VOICE |
| iPhone4 | Jabber | SCCP-Vocie signalling | UP-0 (Best Effort) | CS3 | 00 | N/A |
| iPhone5 | Jabber | RTP-Vocie /Video | UP-5 (Video) | EF | AF41 | EF - VOICE |
| iPhone5 | Jabber | SIP-Vocie signalling | UP-0 (Best Effort) | CS3 | 00 | N/A |
| Galaxy SII | Jabber | RTP-Vocie | UP-4 (Cont Load) | EF | AF31 | EF - VOICE |
| Galaxy SII | Jabber | SIP-Vocie signalling | UP-3 (Excelent Effort) | CS3 | AF21 | N/A |
| HTC Desire C | Jabber | RTP-Vocie | | | | |
| HTC Desire C | Jabber | SIP-Vocie signalling | | | | |

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Additionally, 802.11 UP and DSCP markings are virtually non-existent on tablet devices, as shown by Figure 24-34.

*Figure 24-34 Mobile Wireless Tablet 802.11 UP and DSCP Marking Values by Hardware Vendor[2]*

| Device Model | Application | Traffic Type | QoS marking done by Client | | DSCP in CAPWAP | DSCP in Wired Packet |
|---|---|---|---|---|---|---|
| | | | 802.11 UP | IP DSCP | | |
| iPad2 | Jabber | RTP-Vocie/Video | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| iPad2 | Jabber | SIP-Vocie signalling | UP-0 (Best Effort) | CS3 | 00 | N/A |
| iPad2 | Policom RealPresence | RTP-Vocie/Video | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| iPad2 | Policom RealPresence | H.245-Signalling | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| iPad3 | Jabber | RTP-Voice/Video | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| iPad3 | Jabber | SIP-Vocie signalling | UP-0 (Best Effort) | CS3 | 00 | N/A |
| iPad3 | Policom RealPresence | RTP-Vocie/Video | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| iPad3 | Policom RealPresence | H.245-Signalling | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| iPad mini | Jabber | RTP-Vocie/Video | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| iPad mini | Jabber | SIP-Vocie signalling | UP-0 (Best Effort) | CS3 | 00 | N/A |
| iPad mini | Policom RealPresence | RTP-Vocie/Video | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| iPad mini | Policom RealPresence | H.245-Signalling | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| Nexus 7 | | | | | | |
| Nexus 7 | | | | | | |
| Samsung Galaxy | Policom RealPresence | RTP-Vocie/Video | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| Samsung Galaxy | Policom RealPresence | H.245-Signalling | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |

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And finally UP and DSCP markings for laptop applications are shown in Figure 24-35, which are similarly absent.

*Figure 24-35 Mobile Laptop 802.11 UP and DSCP Marking Values by Hardware Vendor[3]*

| Device Model | Application | Traffic Type | QoS marking done by Client | | DSCP in CAPWAP | DSCP in Wired Packet |
|---|---|---|---|---|---|---|
| | | | 802.11 UP | IP DSCP | | |
| Dell 6420 | Jabber (9.1.0) | RTP-Vocie | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| Dell 6420 | Jabber (9.1.0) | SCCP-Vocie signalling | UP-0 (Best Effort) | 00 | 00 | 00 - Best Effort |
| MacBook Pro | Jabber (8.6.5) | RTP-Vocie/Video | UP-5 (Video) | EF | AF41 | EF - VOICE |
| MacBook Pro | Jabber (8.6.5) | SIP-Vocie signalling | UP-0 (Best Effort) | CS3 | 00 | N/A |

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1. BYOD with QoS http://mrncciew.com/2013/01/08/byod-with-qos/
2. BYOD with QoS http://mrncciew.com/2013/01/08/byod-with-qos/
3. BYOD with QoS http://mrncciew.com/2013/01/08/byod-with-qos/

Without WMM markings on these wireless client devices, these multimedia applications have reduced quality on their radio upstream connections.

# AP Access Switch Upstream QoS Policies

As shown in the above tables, most applications do not yet mark media and signaling flows. However those that do typically mark signaling flows to UP 4 and DSCP CS3. This presents a slight misalignment in QoS policies, as UP 4 will be mapped to (an outer CAPWAP DSCP value of) AF31 (as shown in Figure 24-13) as it is received by the access point (refer to Table 24-4). As such, signaling traffic will not have the proper QoS applied to it in the upstream direction in transit over the wired network between the AP and the WLC. Only when it exits the WLC in the upstream direction is the original inner DSCP value (of CS3) going to be used.

Therefore, to correct this, administrators can configure an ingress marking policy on the access switch interface(s) connecting to wireless access points that receives traffic marked AF31 (which is derived by the AP mapping for UP 4) and remarking these to DSCP CS3. Such remarking policies will now be presented for the same access switches as before, specifically, the:

- Catalyst 3750
- Catalyst 4500
- Catalyst 6500

## Catalyst 3750 Configuration Example

The upstream ingress configuration required on a Catalyst 3750 switch to remap Signaling traffic from (the AP UP 4 mapped marking of) AF31 to the enterprise marking of CS3 is shown in Example 24-15.

***Example 24-15 Catalyst 3750 Upstream Signaling-Marking Restoration***

```
 ! This section configures the class-map
C3750-X(config-cmap)# class-map match-all AP-SIGNALING
C3750-X(config-cmap)#  match ip dscp af31
 ! Signaling traffic from the AP is matched on DSCP AF31


 ! This section configures the Network Upstream Remarking policy-map
C3750-X(config-cmap)# policy-map UPSTREAM-WMM-REMARKING
C3750-X(config-pmap-c)# class AP-SIGNALING
C3750-X(config-pmap-c)#  set dscp cs3
 ! Signaling is remarked to DSCP 24 to align to enterprise QoS model


! This section attaches the upstream policy to the AP-connected interface
C3750-X(config)# interface GigabitEthernet1/0/10
C3750-X(config-if)# mls qos trust dscp
 ! Configures the port to statically trust DSCP on ingress
C3750-X(config-if)# service-policy input UPSTREAM-WMM-REMARKING
 ! Attaches the upstream DSCP remarking policy to the AP interface on ingress
```

This configuration can be verified with the commands:

- **show mls qos interface**
- **show class-map**
- **show policy-map**
- **show policy-map interface**

## Catalyst 4500 Configuration Example

The upstream ingress configuration required on a Catalyst 4500 switch to remap Signaling traffic from (the AP UP 4 mapped marking of) AF31 to the enterprise marking of CS3 is shown in Example 24-16.

***Example 24-16 Catalyst 4500 Upstream Signaling-Marking Restoration***

```
 ! This section configures the class-map
C4500(config-cmap)# class-map match-all AP-SIGNALING
C4500(config-cmap)#  match dscp af31
 ! Signaling traffic from the AP is matched on DSCP AF31


 ! This section configures the Network Downstream Remarking policy-map
C4500(config-cmap)# policy-map UPSTREAM-MAPPING
C4500(config-pmap-c)# class AP-SIGNALING
C4500(config-pmap-c)#  set dscp cs3
 ! Signaling is remarked to DSCP 24 to align to enterprise QoS model


 ! This section attaches the upstream and downstream policies to AP interface
C4500(config)# interface GigabitEthernet 3/1
C4500(config-if)# service-policy input UPSTREAM-MAPPING
 ! Attaches the upstream DSCP remarking policy to the AP interface on ingress
C4500(config-if)# service-policy output 1P7Q1T+DBL+DOWNSTREAM-MAPPING
 ! Attaches the combined egress queuing and remarking policy to the AP interface
```

This configuration can be verified with the commands:

- **show class-map**
- **show policy-map**
- **show policy-map interface**

## Catalyst 6500 Configuration Example

The upstream ingress configuration required on a Catalyst 6500 switch to remap Signaling traffic from (the AP UP 4 mapped marking of) AF31 to the enterprise marking of CS3 is shown in Example 24-17.

***Example 24-17 Catalyst 6500 Upstream Signaling-Marking Restoration***

```
 ! This section configures the class-map
C6500(config-cmap)# class-map match-all AP-SIGNALING
C6500(config-cmap)#  match dscp af31
 ! Signaling traffic from the AP is matched on DSCP AF31


 ! This section configures the Network Downstream Remarking policy-map
C6500(config-cmap)# policy-map UPSTREAM-WMM-REMARKING
C6500(config-pmap-c)# class AP-SIGNALING
C6500(config-pmap-c)#  set dscp cs3
 ! Signaling is remarked to DSCP 24 to align to enterprise QoS model


 ! This section applies the upstream & downstream remarking policies to AP interface
C6500(config-pmap-c)# interface GigabitEthernet1/10
C6500(config-if)# service-policy input UPSTREAM-WMM-REMARKING
 ! Attaches the UPSTREAM-WMM-REMARKING policy to the AP interface on ingress
C6500(config-if)# service-policy output DOWNSTREAM-WMM-REMARKING
 ! Attaches the DOWNSTREAM-WMM-REMARKING policy to the AP interface on egress
C6500(config-if)# service-policy type lan-queuing output EGRESS-1P7Q4T
```

```
! Attaches the EGRESS-1P3Q8T queuing policy to the interface on egress
```

This configuration can be verified with the commands:

- **show class-map**
- **show policy-map**
- **show policy-map interface**

# Application Visibility and Management

Cisco AVC for wireless LAN controllers provides application visibility:

- Globally
- On an WLAN basis
- On an individual client basis

Additionally, AVC supports the export of application statistics via Netflow.

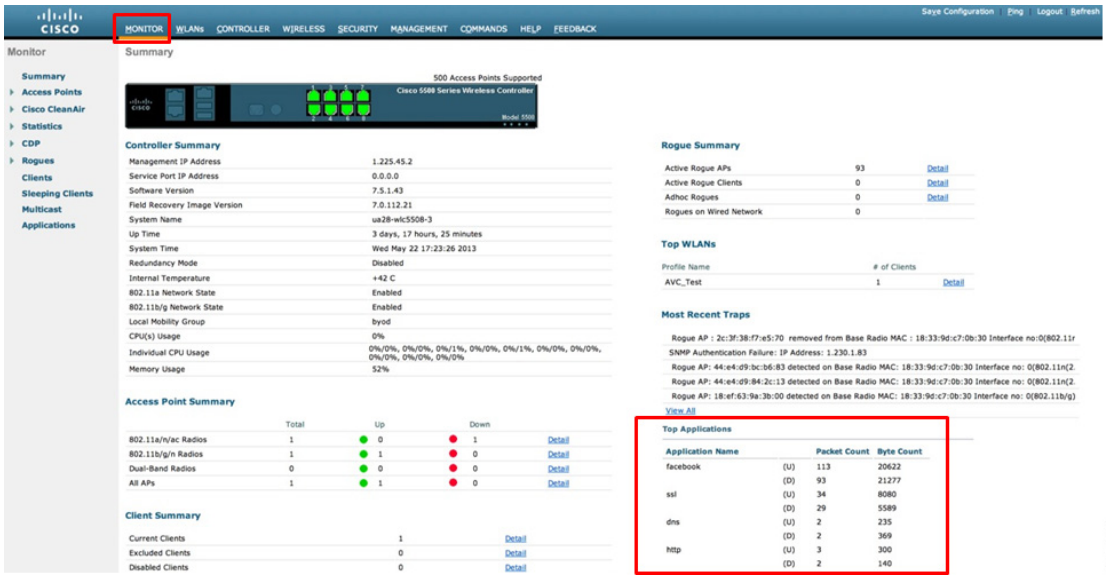
Each of these options is presented in turn.

**Note** It should be noted that in order to see any application visibility statistics on either a global, WLAN, or client level, the Application Visibility feature must be enabled on at least one WLAN, as shown in Figure 24-17.

## Global Application Visibility

To see application traffic at a global level for all traffic traversing the WLC, click the **MONITOR** heading bar and from the main **Summary** screen (in the bottom right corner) the Top 10 applications are summarized by name, as well as by Packet and Byte Count, as shown in Figure 24-36.

*Figure 24-36 Global Application Visibility Monitoring*




This information can also be collected via CLI by issuing the command:

- **show avc statistics top-apps { upstream | downstream}**

# Per-WLAN Application Visibility

To see application traffic at a WLAN-level, perform the following steps.

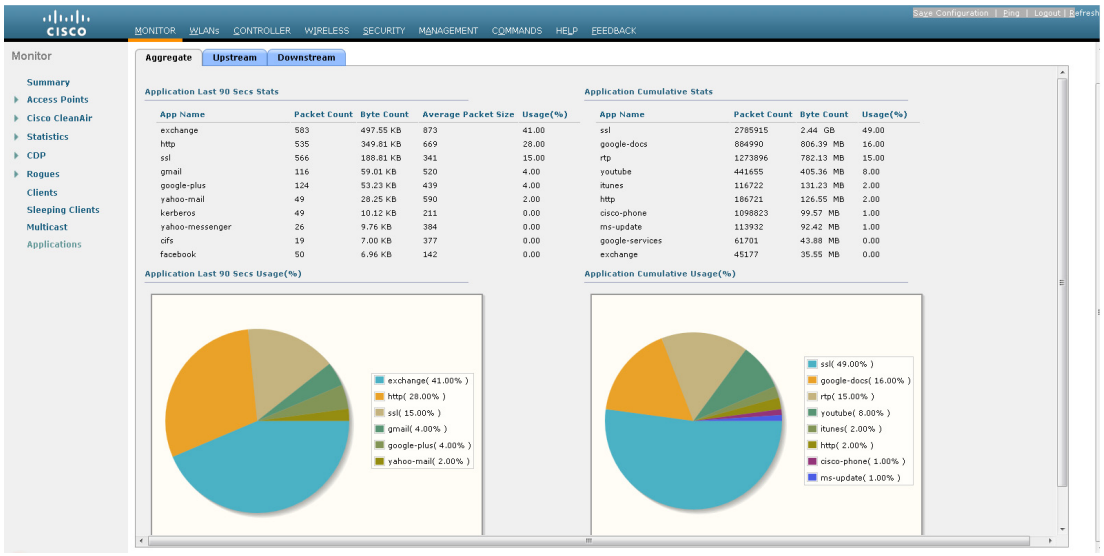
1. Click the **Monitor** heading bar.
2. Select the **Applications** link on the lower-left.
3. Select the **WLAN ID** to be monitored.

Application traffic for the WLAN is summarized in the following tabs:

- **Aggregate**—Includes both upstream and downstream application traffic.
- **Upstream**—Upstream-only application traffic.
- **Downstream**—Downstream-only application traffic.

Per-WLAN application visibility monitoring is shown in Figure 24-37.

*Figure 24-37 Per-WLAN Application Visibility Monitoring*




This information can also be collected via CLI by issuing the commands:

- **show avc statistics wlan** [*WLAN_Number*] **top-apps { upstream | downstream}**
- **show avc statistics wlan** [*WLAN_Number*] **top-app-groups { upstream | downstream}**
- **show avc statistics wlan** [*WLAN_Number*] **application** [*application_name*]

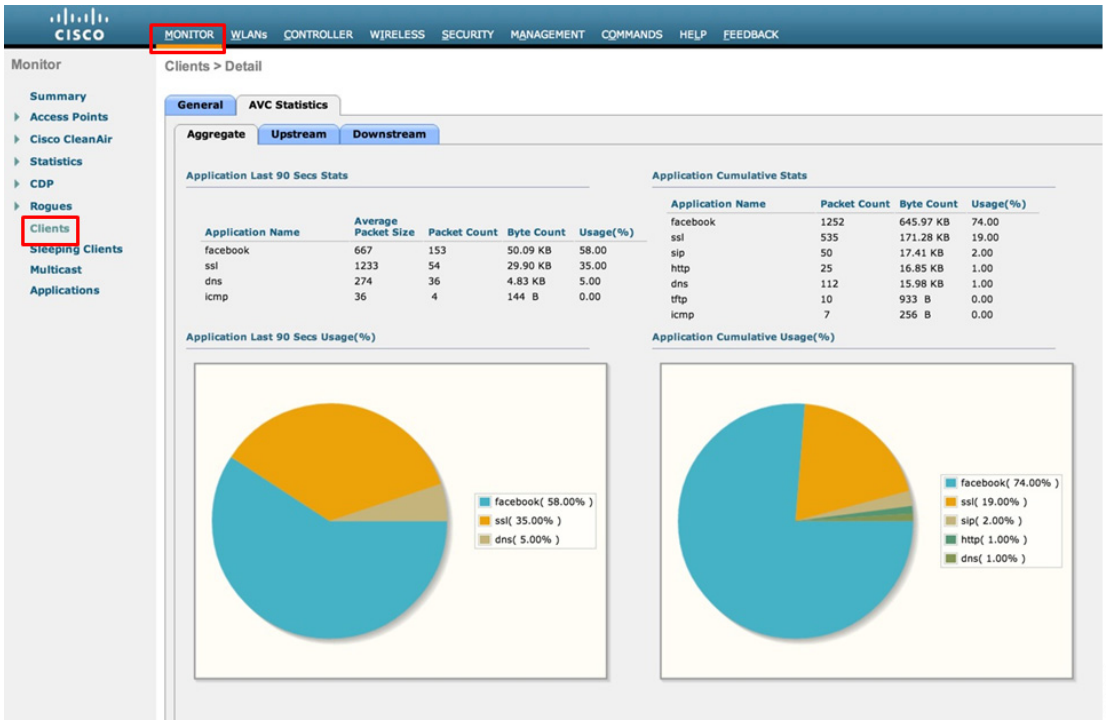
# Per-Client Application Visibility

To see application traffic at a client-level, perform the following steps.

1. Click the **Monitor** heading bar.
2. Select the **Clients** link on the left.
3. Select the **Client MAC Addr** of the client to be monitored.

Per-Client application visibility monitoring is shown in Figure 24-38.

*Figure 24-38 Per-Client Application Visibility Monitoring*




This information can also be collected via CLI by issuing the commands:

- **show avc statistics client** [*client_mac*]
- **show avc statistics client** [*client_mac*] **application** [*application_name*]

# NetFlow

NetFlow is a protocol that provides information about network users and applications, peak usage times, and traffic routing. The NetFlow protocol collects IP traffic information from network devices to monitor traffic. The NetFlow architecture consists of the following components:

- Collector—Entity that collects all the IP traffic information from various network elements.
- Exporter—Network entity that exports the template with the IP traffic information. The WLC can be configured to act as an exporter.

## NetFlow Configuration-GUI

Netflow Export can be configured on the WLC via the GUI by performing the following steps:

1. Click the **Wireless** heading bar and expand the **Netflow** link and click **Exporter**.
2. Click **New**.
3. Enter the *Exporter name*, *IP address*, and the *port number*.
4. Click **Apply**.
5. Click **Save Configuration**.

NetFlow Monitoring can be configured by following these steps:

1. Click the **Wireless** heading bar and expand the **Netflow** link and click **Monitor**.
2. Click **New** and enter the *Monitor name*.
3. On the Monitor List page, click the Monitor name to open the Netflow Monitor > Edit page.
4. Choose the Exporter name and the Record name from the respective drop-down lists.
5. Click **Apply**.
6. Click **Save Configuration**.

A NetFlow Monitor can be associated with a WLAN by following these steps:

1. Click the **WLANs** heading bar and click the WLAN ID to open the WLANs > Edit page.
2. In the QoS tab, choose the **NetFlow Monitor** from the Netflow Monitor drop-down list.
3. Click **Apply**.
4. Click **Save Configuration**.

## NetFlow Configuration-CLI

Create an Exporter by entering this command:

**config flow create exporter** *exporter-name ip-addr port-number*

Create a NetFlow Monitor by entering this command:

**config flow create monitor** *monitor-name*

Associate a NetFlow Monitor with an Exporter by entering this command:

**config flow add monitor** *monitor-name* **exporter** *exporter-name*

Associate a NetFlow Monitor with a Record by entering this command:

**config flow add monitor** *monitor-name* **record** *ipv4_client_app_flow_record*

Associate a NetFlow Monitor with a WLAN by entering this command:

**config wlan flow** *wlan-id* **monitor** *monitor-name* **enable**

NetFlow configurations can be verified with the following show commands:

- **show flow monitor summary**
- **show flow exporter {summary | statistics}**

# Summary

This design document presented the business case for managing applications over wireless networks, highlighting the macro trends in wireless traffic volume growth and application trends. Benefits of applying policies to manage application quality were presented, including increasing voice and video quality, business-critical application responsiveness, as well as controlling background applications and non-business applications over wireless networks.

Next, to set design context, wireless QoS tools were overviewed to show how these evolved and operate, highlighting both their capabilities as well as their limitations. Following this, a discussion of how Layer 2 and Layer 3 mapping works over Cisco wired and wireless networks was presented, including a QoS Translation Table that performs non-default mappings to reconcile IEEE Layer 2 markings with IETF Layer 3 markings in Cisco WLCs and APs.

Subsequently, the various policies required to ensure QoS in both the downstream and upstream directions were summarized, including:

- QoS Profiles
- AVC Profiles
- Network switch DSCP-mapping
- Mobile Device WMM marking

Each of these main policy elements were then discussed in detail to show how these could be configured. WLC policies configuration—namely QoS and AVC Profiles—were presented both in GUI format and in CLI commands.

Wired network switch policies for the access switches connecting to Cisco wireless access points were presented for a Four-Class, Eight-Class, and Twelve-Class enterprise strategic application-class models mapped to WMM. Additionally, these policies configurations were shown for Catalyst 3750, 4500, and 6500 series switches, highlighting the platform-specific idiosyncrasies in function and CLI relating to the policy configurations.

Finally, administrators were shown how to monitor application visibility on a global level, WLAN level, and a client level, as well as how to configure NetFlow Export and Monitoring for network management purposes.

# Additional Reading

- Cisco Wireless LAN Controller Configuration Guide, Release 7.4
  http://www.cisco.com/en/US/docs/wireless/controller/7.4/configuration/guides/consolidated/b_cg74_CONSOLIDATED.html
  - Configuring QoS
    http://www.cisco.com/en/US/docs/wireless/controller/7.4/configuration/guides/consolidated/b_cg74_CONSOLIDATED_chapter_01110.html
  - Configuring Application Visibility and Control
    http://www.cisco.com/en/US/docs/wireless/controller/7.4/configuration/guides/consolidated/b_cg74_CONSOLIDATED_chapter_01111.html
  - Working With WLANS-Assigning QoS Profiles
    http://www.cisco.com/en/US/docs/wireless/controller/7.4/configuration/guides/consolidated/b_cg74_CONSOLIDATED_chapter_01010111.html
- Medianet QoS 4.0 Design:
  - Strategic QoS Design Overview 4.0
    http://www.cisco.com/en/US/docs/solutions/Enterprise/WAN_and_MAN/QoS_SRND_40/QoSIntro_40.html
  - Campus QoS Design 4.0
    http://www.cisco.com/en/US/docs/solutions/Enterprise/WAN_and_MAN/QoS_SRND_40/QoSCampus_40.html#wp1099462