Design Principles for Voice over WLAN

Cisco® delivers high-quality voice over WLAN with ease through the Cisco Unified Wireless Network. Proper network design provides the ideal platform for delivering mobile Unified Communications services.

Summary

Wireless LANs (WLANs) are rapidly becoming pervasive among enterprises. The availability of wireless voice clients, the introduction of dual-mode (wireless and cellular) smartphones, and the increased productivity realized by enabling a mobile workforce are moving WLANs from a convenience to a critical element of the enterprise network infrastructure. When deploying a wireless LAN infrastructure to support voice applications, it is useful to understand voice-over-WLAN (VoWLAN) design principles and how they differ from design principles for conventional WLAN networks that support only data applications. This white paper discusses the principles of designing a VoWLAN solution. Even if there is not immediate need for voice services, having a network that is mobility-services-ready from the outset will protect the initial investment in infrastructure.

Scope

This document covers design principles and recommendations for wireless network support for voice over IP (VoIP). It assumes the reader has VLAN, IP telephony, and security architecture design knowledge. This paper assumes that the client is the Cisco Unified Wireless IP Phone 7921G, but any voice device that is Wi-Fi certified will run on the Cisco Unified Wireless Network. In general, the design principles apply to all 802.11a/b/g voice clients, but deployments with third-party phones will have important differences.

Introduction

The Cisco Unified Wireless Network incorporates advanced features that elevate a wireless deployment from a mean of efficient data connectivity to a reliable, converged communications network for voice and data applications. The Cisco Unified Wireless Network is a comprehensive solution encompassing both clients and infrastructure, solving the limitations of traditional WLANs while enabling management capabilities to efficiently deal with problems without overburdening corporate IT resources.

Voice services place stringent performance requirements on the entire network. Because digitized voice is a sampling of an analog signal (verbal communication), its transmission is very sensitive to delays during transit. In fact, in order for voice to work correctly over any infrastructure, the end-to-end transit time (cumulative time encoding the packet, leaving the sending client, traversing the network, and then being decoded at the receiving client) must be less than 150 ms. Issues encountered during transit result in imperfections in the reconstituted signal; also known as jitter. The jitter is basically the variation in delay that the system is experiencing.

Because a WLAN is based on a random access protocol, allows clients to roam freely, is a shared medium among all wireless devices, and has particular security protocols associated with it, adding voice services has implications in several areas, including:

- Coverage requirements and deployment planning
- Network infrastructure and logical subnet design
- Wireless "over-the-air" quality of service (QoS)
- Network security architecture
- Voice client feature requirements

This document provides detailed design principles that are recommended in order to enable high-quality Voice over WLAN service on the Cisco Unified Wireless Network.

The Steps to Success—A Process for Implementation of Voice Services on a Cisco Unified Wireless Network

Voice has been succesfully deployed on wireless networks by thousands of customers over the past four years, and a wide variety of devices and applications are now available to facilitate collaboration.

Successful voice deployments on a wireless network follow the eight-step process in the sequential order shown in Table 1.

Table 1. Steps to a Successful VoWLAN Solution

Step	Description	Purpose
1	Definition	Define what voice applications and clients will be deployed and who the stakeholders are.
2	Coverage areas and project phases	Define what areas within the campus will support voice on the wireless network.
3	Plan approval	Gain buy-in of all key stakeholders.
4	RF audit and site survey	Validate and adjust design.
5	Deploy infrastructure	Implement design.
6	RF test	Test implementation on deployed infrastructure.
7	Final adjustments	Adjust access point settings.
8	Ongoing operation support	Transition to sustaining support with adaptation to usage changes.

The following describes each step in more detail:

Step 1. Definition

It is critical at this stage to identify all key stakeholders to ensure their requirements are incorporated into the design. In this stage, you define what will be accomplished and who the stakeholders are. Be sure to include the facilities department in this step, as they will be critical in supplying power and mounting locations. At the end of this stage, you should be able to answer which group of employees will use voice clients, what type of voice clients are needed, and what voice applications will be utilized. The most common cause of implementation problems is users or applications that are added without upfront identification of their needs.

Note that other mobility services such as location-based services can also influence the design of your wireless network. As a result, you should define and estimate the impact of all the mobile applications upfront and consider them as a whole rather than individually. In this way, you may discover synergies that will save you time and resources.

Step 2. Coverage Areas and Project Phases

In this step, complete the high-level design using the design principles in this document and the requirements defined in step 1. Defining where coverage is provided is critical to setting expectations for end users. In many cases, the implementation will be phased, either to accumulate practical experience or to accommodate budgets. If there are project phases, they should be clearly identified in this stage. Internal and external design reviews should be conducted to help ensure a robust network and application design. A guideline is that at least 10 to 20 percent of the plan should be marked for changes after the deign review. If the design review does not have this kind of impact on the high-level design,, it typically means that the design review was not stringent enough.

Step 3. Plan Approval

Gather all stakeholders and present plan for final approval to secure support and resources from the primary stakeholders.

Step 4. RF Audit and Site Survey

This step should start with an informal site evaluation, which is an in-person inspection of the area targeted for deployment. In a site evaluation, the goal is to look for issues that could affect the network. These issues include:

- The presence of multiple WLANs (owned by your company or overlaps from surrounding businesses).
- Unique building structures such as open floors and atriums.
- High client device usage variances, such as those caused by differences in day or night shift staffing levels or by the presence of meeting rooms that cause recurring increases in the number of users in the meeting room location.
- Extreme thermal changes.
- Presence of other non-Wi-Fi wireless devices such as microwaves or Bluetooth headsets.

After the results of the informal site evaluation are incorporated into the design, actual RF measurements should be taken with the goal of validating the high-level design. This process is commonly called the site survey.

Step 5. Implementation

After adjustments to the design from the RF measurements, it is now time to deploy the access points. It is critical to document the network "as built and configured" at this stage because RF environments tend to change over time, and in most cases a network design will have three to seven years of useful life. Measurements of the background noise upon initial deployment are very useful in performing problem isolation in the future.

Step 6. RF Test

There could be weeks or even months between the RF audit and site survey and the actual deployment of the access points. For this reason, it is always a good idea to test the actual RF characteristics of the deployed equipment to help ensure that they meet the design requirements. In addition, some tests can be done to verify the reliability of the deployment under heavy-traffic conditions.

Step 7. RF Adjustments

In nearly all deployments, the power settings will need to be adjusted once deployed. It is recommended that the initial power be set at 50 mW, or power setting number 4, and then from this point adjusted up or down. The VoWLAN network readiness tool avialble on the Cisco Wireless Control System should help validate that the radio coverage requirements are met post-deployment.

Step 8. Ongoing Support

In step 1, the assembled stakeholders should have included the group that is responsible for ongoing support post-deployment. The transition to this team should be completed in step 8. They will be in charge of the maintenance as well as tuning the network based on the observed usage patterns.

Planning Wireless Coverage For Voice Over WLAN (Steps 1 and 2)

Since steps 1 and 2 are the focus of this document, additional recommendations for planning wireless coverage to support voice are described next.

To deploy a WLAN that is voice-services-ready, it's importaant to anticipate the mobile nature of voice clients and to focus on the minimum expectation that calls will not get dropped as users roam across a building or campus. This means that the network must be deployed with continuous coverage in areas where voice services are planned. The Cisco Unified Wireless Network provides an extensive product line that satisfies the requirements for coverage areas, ranging from just a floor of a building to complete campus coverage, both indoors and outdoors. Areas such as main lobbies, employee entrance areas, parking garages and lots, courtyards, cafeterias and break, copy,supply, storage, and cage rooms will need WLAN coverage when voice clients are deployed on the campus. Additional consideration should be given to providing coverage in stairwells, walkways, and elevators, since these are areas where it is reasonable to conduct a business conversation.

Equally important to the satisfaction of end users is setting proper expectations for voice usage. If the voice network is required in specialized areas, such as customer support or call centers, end users should expect that a given service level is only for those areas. Many customers believe that the coverage expectations have been established by the cellular network service available onsite (i.e. with frequent loss of signal and poor inbuilding coverage) and that the WLAN coverage should be significantly superior as more pervasive than the cellular benchmark.

Creating predictable service quality is important. Users expect that Wi-Fi phones will, at a minimum, operate with the same quality as a cellular handset, and optimally as well as a land-line phone. This means that the WLAN will have to minimize interference in order to optimize call quality.

Voice Services RF Environment

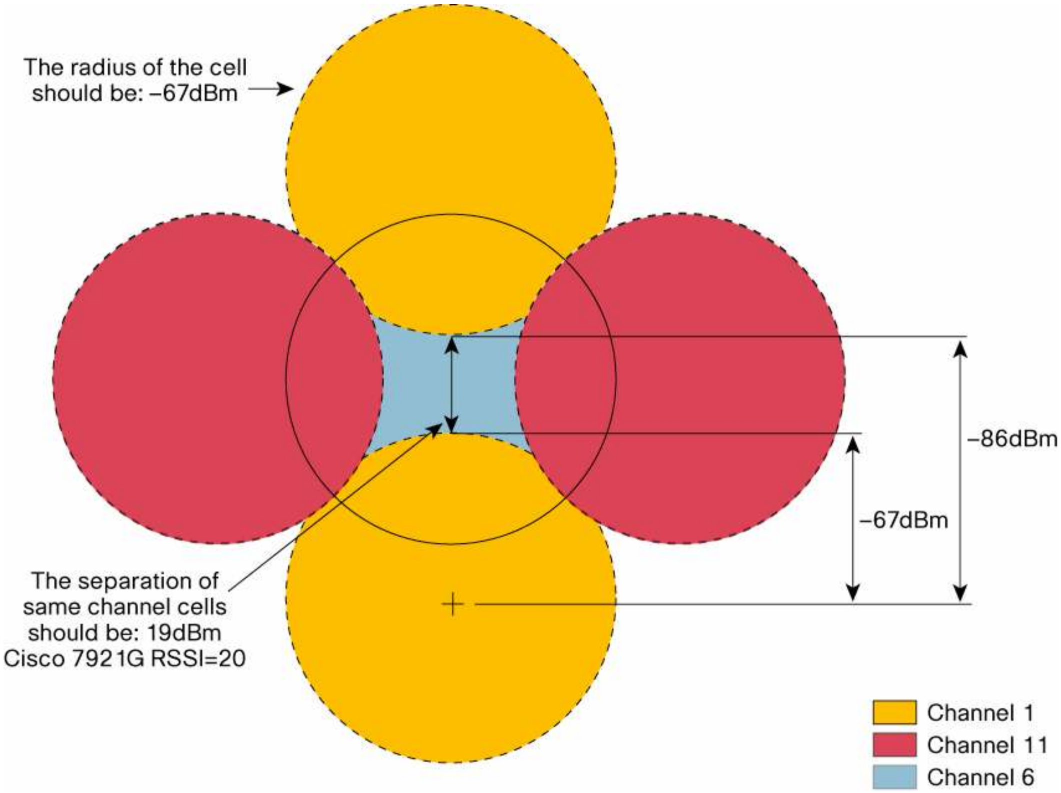
The IEEE 802.11 standards use the 2.4-GHz (802.11b and 802.11g) and the 5-GHz (802.11a) bands. In the 2.4-GHz band, there are up to 11 channels available (14 channels are available in Japan). Each channel offers 11- or 54-Mbps (for 802.11b or 802.11g, respectively) over-the-air data rates. Because the wireless medium is continuous and shared, all clients that are associated with access points on the same channel will share the bandwidth available in that channel, with reception power (and therefore data rates) diminishing with distance.

Adding capacity to the network is accomplished by using more access points on nonoverlapping channels. In the 2.4-GHz band, there are three nonoverlapping channels. However, on the 5-GHz (802.11a) band, all 23 channels (depending on geographic area) are nonoverlapping channels, which results in increased network capacity, improved scalability, and the ability to deploy without interference from adjacent cells. The Cisco Unified Wireless IP Phone 7921G, as well as the Cisco Aironet® family of access points, operate in the 802.11a band.

At the edge of each voice cell, the received signal strength indication (RSSI) measurement should be –67 dBm if you are using a Cisco Unified Wireless IP Phone 7921G. It is recommended that you have RSSI above 35 at the edge of the cell, which is equivalent to –67dBm for optimum preformance on the phone. This concept is illustrated in Figure 1.

Each cell in the network should overlap with the adjacent cells in order to facilitate uninterrupted handoff as a client moves between cells and to provide a minimum service even in case of access point failure. For a typical voice deployment, Cisco recommends a 15 to 20 percent overlap of a given access point's cell from each of the adjoining cells, as shown in Figure 1.

Figure 1. Cell Overlap Guidelines for 802.11 b/g


The radius of the cell should be: –67dBm
–86dBm
–67dBm
The separation of same channel cells should be: 19dBm Cisco 7921G RSSI=20
🟨 Channel 1
🟥 Channel 11
🟦 Channel 6

The RF Audit and Site Survey

The goal of any site survey should be to perform actual measurements of the RF environment where the wireless network will be deployed. Unlicensed frequencies (2.4-GHz and 5-GHz frequencies, especially the 2.4-GHz) can be "noisy" environments, with microwave ovens to radar systems to Bluetooth vying for air time. With the advent of emerging RF technologies such as sensor networks, this trend will continue.

The site survey and a spectrum analysis tool should provide a precise view into what other RF activity is present. A site survey should be conducted using the same frequency plan intended for the actual deployment. This provides a more accurate estimate of how a particular channel at a particular location will react to the interference and to multipath propagation. The site survey should be conducted with the voice client that will be deployed; each client has a unique RF performance, so different clients will yield different results. The same is true for the radios and external or internal antennas in the infrastructure. In summary, access point and client selection should be finalized prior to the site survey. As new client devices are added, a periodic update to the site survey is a proactive step to help ensure that the RF network is optimized. Such updates are part of step 8.

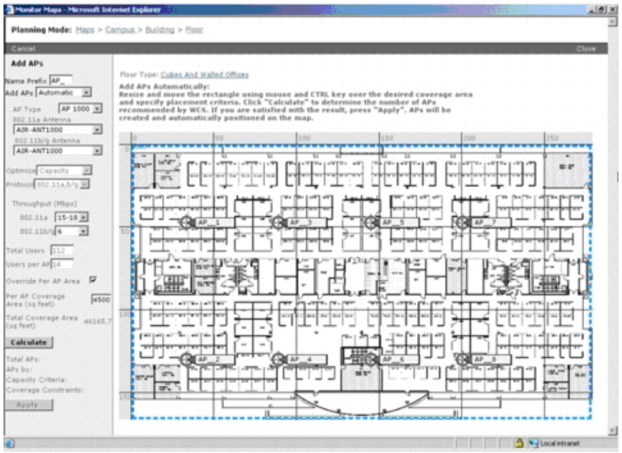
It is also advisable to conduct several site surveys, varying the times and days to ensure that a comprehensive view of the RF domain is obtained. RF activity can be variable and depends on many factors, including employee activity. The site survey should identify sources of RF interference and variability in RF patterns due to physical building changes (for example, the movement of machinery, the presence of elevator shafts) and employee movements (for example, weekly all-hands meetings).

A clear view of the RF domain can help mitigate potential sources of interference. The site survey should also identify areas within the deployment that may require additional capacity due to a concentration of users or likelihood of co-channel interference.

Cisco's Wireless Planning Tools

The Cisco Unified Wireless Network integrates radio resource management software, which works together with the integrated network planning and design features in the Cisco Wireless Control System (WCS). Cisco WCS provides integrated RF prediction tools that can be used to create a detailed wireless LAN design, including access point placement, configuration, and performance and coverage estimates. IT staff can import real floor plans into Cisco WCS and assign RF characteristics to building components to increase design accuracy. Graphical heat maps help IT staff visualize anticipated wireless LAN behavior for easier planning and faster rollout (Figure 2).

Figure 2. The Cisco WCS Deployment Planning Tool



Monitor Maps - Microsoft Internet Explorer

Planning Mode: Maps > Campus > Building > Floor

Add APs

Name Prefix: AP_

Add APs: Automatic

AP Type: AP 1000

802.11a Antenna: AIR-ANT1000

802.11b/g Antenna: AIR-ANT1000

Optimize: Capacity

Protocol: 802.11a,b/g

Throughput (Mbps)

802.11a: 15-18

802.11b/g: 6

Total Users: 112

Users per AP: 14

Override Per AP Area: ☑

Per AP Coverage Area (sq feet): 4500

Total Coverage Area (sq feet): 46165.7

Total APs:

APs by:

Capacity Criteria:

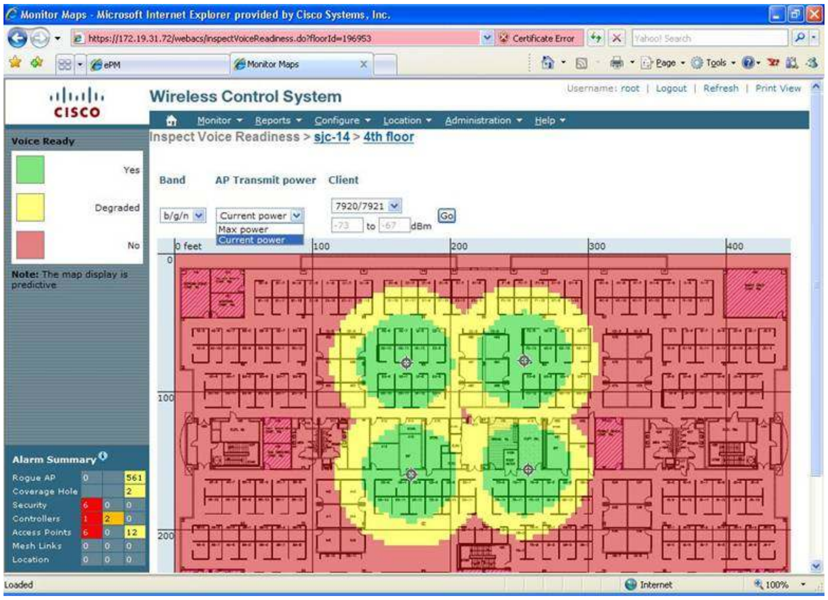
Coverage Constraints:

Floor Type: Cubes And Walled Offices

Add APs Automatically:
Resize and move the rectangle using mouse and CTRL key over the desired coverage area and specify placement criteria. Click "Calculate" to determine the number of APs recommended by WCS. If you are satisfied with the result, press "Apply". APs will be created and automatically positioned on the map.

The WCS deployment planning tool is ideal for general office environments. For challenging RF environments such as those found in hospitals and manufacturing plants, Cisco's Advanced Services or Cisco Certified Partners have extensive experience and expertise in planning and deploying voice over wireless. In addition, for manual verification of the wireless network, the Cisco Unified Wireless IP Phone 7921G integrates site survey tools to enable the IT manager to display a list of access points that are in range. This tool is useful for validating and troubleshooting specific problem areas. In addition, internally stored logs and Web-accessible diagnostics are also available on the phone, and spectrum analysis capabilities, along with a VoWLAN network readiness tool (Figure 3), are available on the Cisco WCS.

Figure 3. VoWLAN Network Readiness Tool



Monitor Maps - Microsoft Internet Explorer provided by Cisco Systems, Inc.

https://172.19.31.72/webacs/inspectVoiceReadiness.do?floorId=196953

Wireless Control System

Username: root | Logout | Refresh | Print View

Inspect Voice Readiness > sjc-14 > 4th floor

Band: b/g/n

AP Transmit power: Current power (Max power / Current power)

Client: 7920/7921, -73 to -67 dBm

Go

Voice Ready

🟩 Yes

🟨 Degraded

🟥 No

Note: The map display is predictive

Alarm Summary

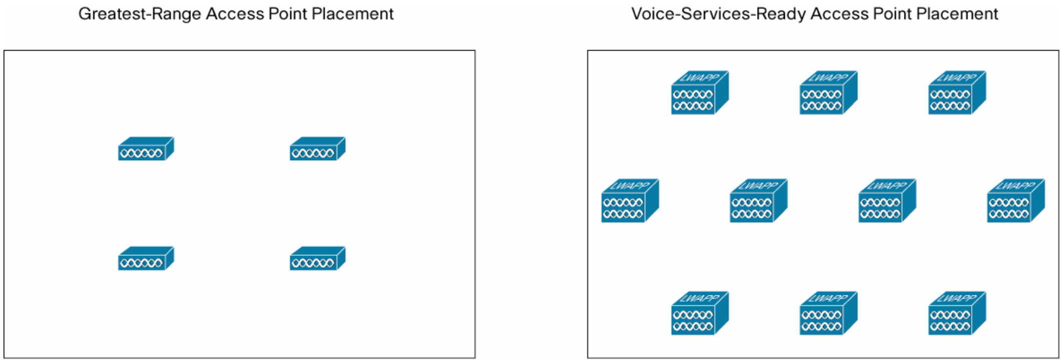
Rogue AP	0		561
Coverage Hole			2
Security	6	0	0
Controllers	1	2	0
Access Points	6	0	12
Mesh Links	0	0	0
Location	0	0	0

Loaded

Access Point Location

The location of access points is an important characteristic in making the network ready for voice services. In contrast to the traditional theory of access point deployment, which recommended deploying for greatest range, the voice-ready approach recommends deploying for density, with as many access points as possible covering a given area without creating excessive interference. The preferred access point placement model places access points around the perimeter of the building as well as in the center, as shown in Figure 4, for more complete coverage and greater redundancy.

Figure 4. Voice-Ready Access Point Placement

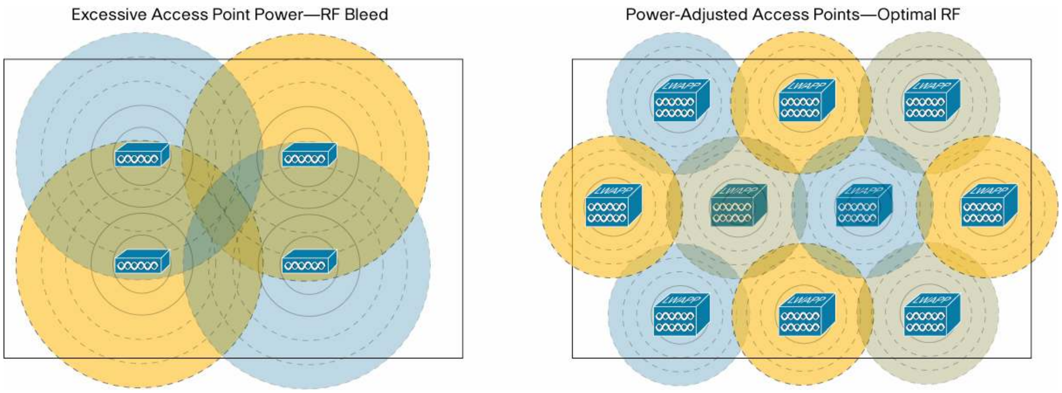


Greatest-Range Access Point Placement
Voice-Services-Ready Access Point Placement
LWAPP

As a guideline and starting point for site surveys, in a voice-ready WLAN, access points should be deployed at a density of approximately one every 3000 square feet, as opposed to one every 5000 square feet used for data-only networks. So to calculate the number of access points required for deployment, divide the total number of square feet to be covered by 3000 and you will have a good starting point in your design. This level of density helps ensure that voice services have the necessary RF coverage redundancy and throughput required to provide optimal service capacity. Ideally, there will still be a site survey to maximize coverage and minimize interference.

Wireless endpoints and access points communicate via radios on particular channels. When communicating on one channel, wireless endpoints are unaware of traffic and communication occurring on other nonoverlapping channels. The Cisco Unified Wireless Network monitors the power output of each access point and will adjust the power according to the topology. In dense deployments (deployments with many access points), each access point’s transmit power will be lowered so as to limit co-channel interference with neighboring access points (Figure 5).

Figure 5. WCS Management of RF Environment


Excessive Access Point Power—RF Bleed
Power-Adjusted Access Points—Optimal RF
LWAPP

However, when you use the Cisco Unified Wireless IP Phone 7921G, Cisco recommends that you keep the transmit power of the access point and the phone at the same level in order to avoid one-way audio occurrences, which are a result of a mismatch between the reach of the signal. This can be configured in one click with the Cisco Wireless Control System.

Voice Capacity Planning

The 802.11 wireless networking protocol uses a contention-based access algorithm. Based on this access methodology, protocol overhead, bandwidth calculations, and wireless voice network testing, Cisco has determined that with the IEEE’s 11-Mbps throughput limitation on 802.11b, a single 802.11b wireless access point can support up approximately to seven active voice streams using the G.711 codec or eight active voice streams using G.729 codec and also handle a reasonable level of data traffic. An active phone session is one carrying on a conversation. A voice client that is associated with an access point and not carrying on a VoIP session (that is, conversation) is not considered active.

Within a cell with active voice traffic, the Cisco Unified Wireless Network is able to help ensure that voice clients have appropriate access and resources. The Cisco Unified Wireless Network ensures access using an advanced QoS standard known as call admission control (CAC). The Cisco Unified Wireless Network controllers enable predictable CAC for the network. In the unified network, the controller has a holistic view of all the clients in the network, along with the total available call capacity between all access points on the same channel. This capability helps to ensure that when a VoWLAN call is admitted into the Cisco Unified Wireless Network, there is enough voice capacity across all access points. The result is more predictable, reliable voice performance.

Another important requirement for wireless networking is the appropriate provisioning of bandwidth. Bandwidth provisioning involves the bandwidth between the wired and wireless networks as well as the number of simultaneous voice calls that an access point can handle. Wireless access points typically connect to the wired network via a 100-Mbps link to an access-layer switch port. While the ingress Ethernet port on the access point can receive traffic at 100 Mbps, the maximum throughput on an 802.11b wireless network (the protocol primarily used by voice devices) is 11 Mbps. After taking into account the half-duplex nature of the wireless medium and the overhead (to learn more about voice bandwidth calculations, please refer to the Cisco Unified Wireless IP Phone 7921G Design and Deployment Guide) of wireless headers, the practical throughput on the 802.11b wireless network is about 7 Mbps. This mismatch in throughput between the wired and wireless network can result in packet drops when traffic bursts occur in the network.

Rather than allowing traffic bursts to send excessive traffic toward the access point only to have it dropped by the access point, it is a good idea to rate-limit or police this traffic to a rate that the wireless network can handle. Forcing the access point to drop excessive traffic causes increased CPU utilization and congestion at the access point. Instead, limiting the traffic rate to 7 Mbps on the link between the wired access-layer switch and the wireless access point helps ensure that traffic is dropped at the access-layer switch, thus removing the burden from the access point. It is important to note that, depending on the wireless network deployment, the practical throughput might be less than 7 Mbps, especially if more than the recommended numbers of devices are associated with a single access point.

Voice-Ready Wireless Infrastructure

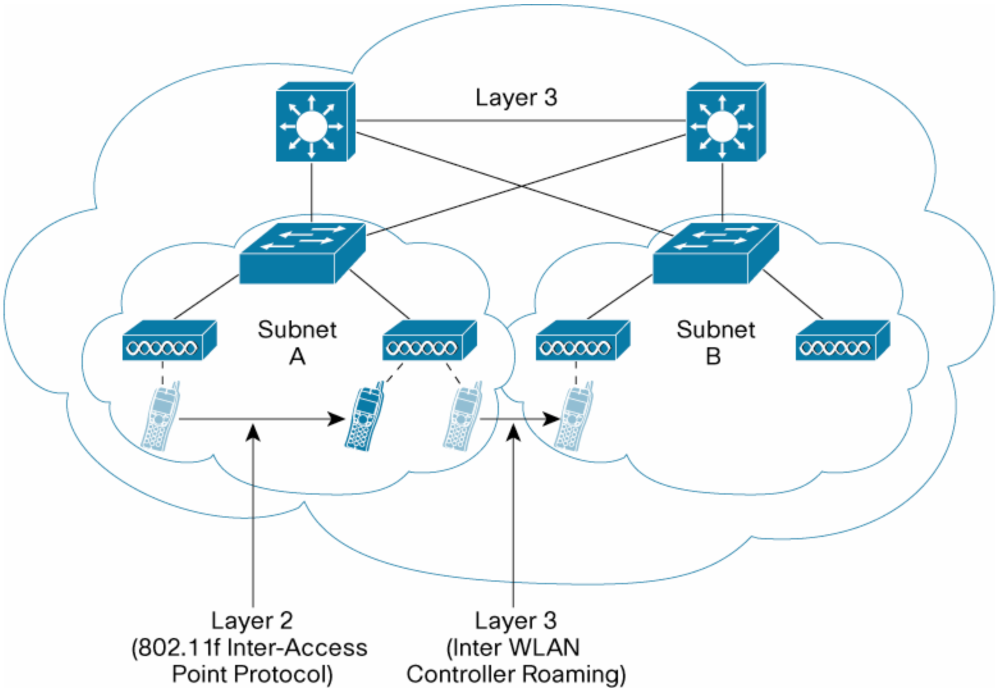
Voice places unique requirements on the WLAN. The Cisco Unified Wireless Network supports these requirements through software capabilities in the infrastructure, in the Cisco Unified Wireless IP Phone 7921G, and in Cisco Compatible Extensions program clients. The following are technological enhancements that you should implement when planning the voice services network.

Roaming

Roaming is integral to voice services on wireless networks. A wireless voice client must be able to maintain its association from one access point to another securely and with as little latency as possible. It is therefore important to understand what roaming is as it relates to infrastructure requirements and how and when it occurs. It's also important to know about the types of roaming and how they differ.

To accommodate roaming, administrators need to carefully consider their IP addressing schemes before deploying wireless voice clients. In particular, they need to consider how WLAN coverage overlays with the Layer 2 and Layer 3 addressing within the IP network. A Layer 2 network is defined as a single IP subnet and broadcast domain, while a Layer 3 network is defined as the combination of multiple IP subnets and broadcast domains (Figure 6).

Figure 6. Layer 2 and Layer 3 Roaming


Layer 3
Subnet A
Subnet B
Layer 2 (802.11f Inter-Access Point Protocol)
Layer 3 (Inter WLAN Controller Roaming)

Layer 2 Roaming—Roaming within the Same IP Subnet

Just as with a wired LAN infrastructure, when deploying VoWLAN, Cisco recommends enabling at least two VLANs at the access layer. In a wireless LAN environment, the access layer includes the access point and the first-hop access switch. Wireless networks should also separate the voice and data service set identifiers (SSIDs) to ensure that voice traffic and its associated security parameters are optimized and customized thanks to segregation from data traffic (for more information, see the Secure Wireless Design Guide 1.0). In addition, as with voice endpoints on wired LANs, wireless voice endpoints should be addressed using RFC 1918 private subnet addresses. More than two VLANs can be used if several types of voice devices are available within the network and have different security capabilities.

With the voice VLAN extended throughout the corporate network, every access point connected to the network should be able to attach to the voice VLAN (as well as a data VLAN). Now, as clients roam across the enterprise, they are able to maintain their connection without noticeable interruption because they never leave the voice subnet and hence always have access to the required network resources (default gateway, IP-private branch exchange [PBX], and so on).

Layer 3 Roaming—Roaming across IP Subnets

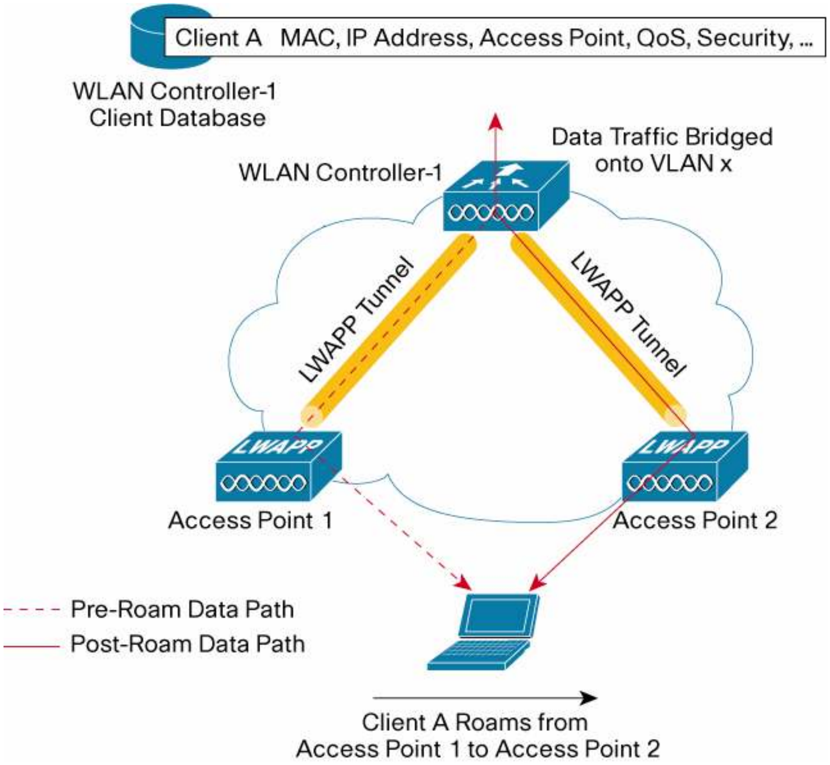
In cases where Layer 2 VLAN configuration is difficult, it is highly recommended that the capability to roam be designed to operate across Layer 3 subnets. This eliminates the need to configure Layer 2 VLANs that extend across the entire enterprise, and reduces the associated operational configuration costs.

Cisco enables Layer 3 mobility through the use of mobility groups, which provide the mechanism for pooling resources to facilitate this desired client behavior. A mobility group does more than just define the RF connectivity of the client. It defines the infrastructure resources and their connectivity to each other. If a client needs to seamlessly roam from one location to another, even across IP subnets, the resources in those locations need to be in the same defined mobility group.

When a wireless client associates and authenticates to an access point, wireless LAN controllers track each client in its client database. In this way, when the client roams to another mobility group, the client’s MAC and IP addresses, security context and associations, QoS contexts, WLAN IDs, and associated access point are transferred to the new WLAN controller.

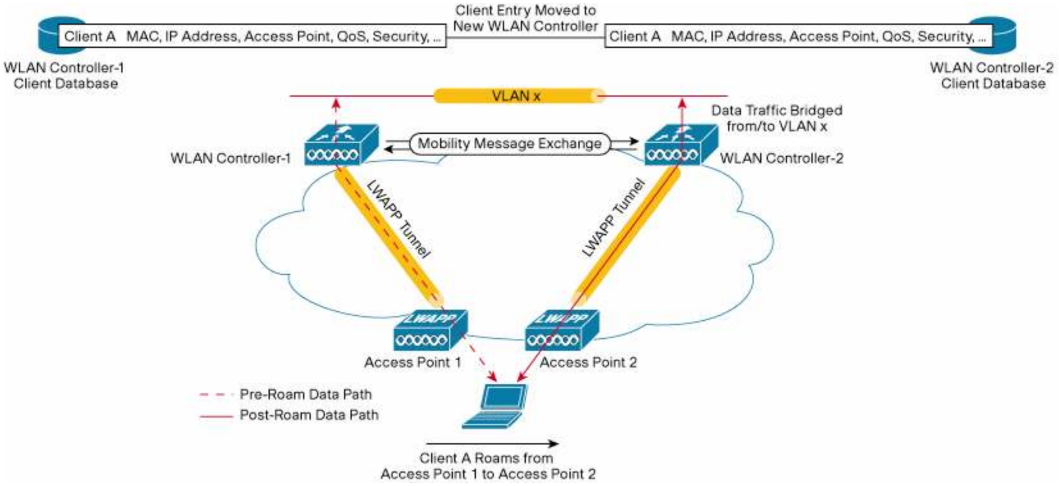
Figure 7 shows a wireless client roaming from one access point to another.

Figure 7. Client Roaming between Access Points


Client A MAC, IP Address, Access Point, QoS, Security, ...
WLAN Controller-1 Client Database
WLAN Controller-1
Data Traffic Bridged onto VLAN x
LWAPP Tunnel
LWAPP Tunnel
LWAPP
LWAPP
Access Point 1
Access Point 2
Pre-Roam Data Path
Post-Roam Data Path
Client A Roams from Access Point 1 to Access Point 2

When the wireless client moves its association from one access point to another, the controllers update the client database with the newly associated access point. If necessary, a new security context and associations are established as well. This capability, coupled with the Cisco Centralized Key Management (CKM) protocol, helps ensure that time-sensitive applications, such as VoIP, can be fully mobile and secure with minimal roaming latency. With the controller-based architecture of the Cisco Unified Wireless Network, it is possible for a client to roam from an access point attached to one controller to an access point attached to a second controller. With intercontroller roaming, the infrastructure can maintain these same roaming characteristics. In addition, the Cisco Unified Wireless Network employs a Mobility Messaging Exchange protocol between the controllers that is used to exchange the client information and maintain the call across IP subnets. When the client associates to an access point joined to a new controller, the new controller exchanges mobility messages with the original controller, and the client database entry is moved to the new controller. New security contexts and associations are established if necessary, and the client database entry is updated for the new access point. This process, as well as the inter-access-point handoff, is transparent to the user (Figure 8).

Figure 8. Layer 3 Inter-Controller Roaming



To enable mobility groups, the administrator simply defines which physical locations should be included. As a general guideline, a single mobility group should encompass an area that covers 80 to 90 percent of user roaming patterns, because clients cannot seamlessly roam across mobility groups. Thus, prior to enabling mobility groups, the deployment team must have a good understanding of how users move throughout the building, and they should incorporate this understanding into the creation of each mobility group.

Quality of Service (QoS) Considerations

QoS on a pervasive WLAN is much more than simply prioritizing one type of packet over another. WLAN traffic is nondeterministic; channel access is based on a binary, backoff algorithm defined by the IEEE 802.11 standard and is by nature variable, because it is based on the number of clients that access the network. Mobility makes this challenge more difficult. The number of active users in any location changes dynamically and cannot be addressed through the capacity management tools used in wired networks. Meeting the WLAN QoS needs of mobile voice users will determine the success or failure of the VoWLAN deployment.

QoS and VLANs

Cisco recommends using VLANs to separate voice traffic from data traffic. This serves two purposes: security (discussed in the next section) and isolation of higher-priority voice traffic so that it can be dealt with using maximum resources.

Separating voice from data requires a minimum of two VLANs, and an assigned SSID on the WLAN for each VLAN. Using separate data and voice VLANs enables specific QoS settings on all traffic on the voice VLAN to give it a higher QoS profile. The Cisco Unified Wireless Network supports four levels of QoS over the air: platinum for voice, gold for video, silver for best effort (the default), and bronze for background. You can configure the voice traffic WLAN to use platinum QoS, assign the low-bandwidth WLAN to use bronze QoS, and assign all other traffic between the remaining QoS levels. Separating traffic by VLAN and using the QoS profiles for VLAN traffic reduces the chance of data clients crowding the voice WLAN and causing unnecessary traffic overhead and delays.

Note that this is in addition to the previous RF recommendation of ensuring nonoverlapping channels to avoid interference. It should not be misconstrued as a replacement for that recommendation.

The Cisco Unified Wireless Network also allows you to maintain a QoS profile for Layer 2 and Layer 3 over wireless and wired network. Indeed, all WLAN traffic that passes between the access point and the wireless LAN controller is encapsulated. However, this encapsulation maintains the Layer 3 marking in the original packet. Once the packet is de-encapsulated at the access point or wireless LAN controller, the original Layer 3 marking is again used by QoS mechanisms in the network infrastructure. With this capability,, the network can achieve end-to-end QoS for voice traffic, over the air and across the wired network.

IEEE 802.11e and Wi-Fi Multimedia

To improve the reliability of voice transmissions in this nondeterministic environment, Cisco recommends the use of Cisco Unified Wireless IP Phone 7921G and any device that supports the industry-standard IEEE 802.11e and is Wi-Fi Multimedia (WMM)-certified. WMM enables differentiated services for voice, video, best-effort data, and other traffic. However, in order for these differentiated services to provide sufficient QoS for voice packets, only a certain amount of voice bandwidth can be serviced or admitted on a channel at any one time. If the network can handle N voice calls with reserved bandwidth, when the amount of voice traffic is increased beyond this limit (that is, to the N+1 call), the quality of all calls suffers.

Call Admission Control

The Cisco Unified Wireless Network supports CAC to police the call capacity on a “per-access-point” basis. Cisco Unified Communications Manager. which performs the call processing functions in a network, provides additional CAC features for the wired network, helping to ensure an end-to-end CAC implementation. Cisco requires the use of Cisco Compatible Extensions clients to enable the use of the traffic specification (TSpec) of the traffic flows for the calculation of call limits and proper WLAN load balancing. The TSpec of each voice flow allows the system to allocate bandwidth to client devices on a first-come, first-served basis and maintains a small reserve so that mobile phone clients can roam into a neighboring access point (even though the access point might otherwise be at “full capacity”). Once the limit for voice bandwidth is reached, the next call will be load-balanced to a neighboring access point ,and the call will be completed without affecting the quality of the existing calls on the channel.

The difficulty of providing a good CAC function is exacerbated the by pervasive-coverage cell design recommended earlier. In a pervasive-coverage design, an RF channel can be shared by several access points. With CAC enabled and the Cisco Unified Wireless IP Phone 7921G clients in use, the Cisco Unified Wireless Network allows the resources to be globally managed by the wireless network controller across all the adjacent access points. Thus, each access point is not permitted to admit the same amount of voice traffic as it could if it were operating in isolation. Access points employ MAC measurements from clients and neighboring access points to aid in determining the amount of traffic on the RF channel and whether a new call should be admitted.

Security Design Considerations

When deploying a WLAN, security should be at the top of the priority list. The strict requirements for voice in terms of packet delivery time and predictability, coupled with the ability for clients to roam across access points and subnets, presents a challenge to security architectures.

Cisco Centralized Key Management and EAP-FAST for Fast Secure Roaming

To minimize the delay introduced by authenticating roaming clients, Cisco recommends using the Extensible Authentication Protocol—Flexible Authentication via Secured Tunnel (EAP-FAST) with Cisco Centralized Key Management. EAP-FAST is an 802.1x EAP framework for authentication that encrypts EAP transactions with a Transport Layer Security (TLS) tunnel. While similar to Protected Extensible Authentication Protocol (PEAP) in this respect, it differs significantly in that EAP-FAST tunnel establishment is based upon strong secrets that are unique to clients. These secrets are called Protected Access Credentials (PACs), which the infrastructure generates using a master key.

During roaming, reauthentication time back to the RADIUS server alone can take 500 ms or more. To remedy this, Cisco recommends using Cisco Centralized Key Management, an innovative solution to achieve access-point-to-access-point roaming latency of less than 100 ms. Cisco Centralized Key Management permits the negotiation of a session key from a cached master key and avoids the need to go back to the authentication, authorization, and accounting (AAA) server during a roam. When the client roams, it informs the infrastructure that it has roamed and the infrastructure forwards the keying material to the new access point. The efficiency of EAP-FAST with Cisco Centralized Key Management helps ensure maximum protection with minimum transaction time. Cisco Centralized Key Management is available with the Cisco Unified Wireless IP Phone 7921G, as well as any client that is compliant with Cisco Compatible Extensions Version 4.

Secure Voice VLAN and SSID Design

Cisco VLAN technology separates the physical network into multiple logical networks. For secure voice calls, Cisco recommends creating separate VLANs and SSIDs for voice. In turn, associating the voice SSID with the voice VLAN creates a single, unified voice network across both the wired and wireless networks with consistent security and QoS profiles. The WLAN controller will bridge the traffic from the voice SSIDs to the voice VLANs. The primary advantage of this physical separation of voice and data traffic is that traffic sent over the voice network is not visible to insiders or outsiders connected to data network. The converse is also true.

Following are some of the ways that VLANs protect the voice system from security threats:

- Preventing toll fraud: Companies can apply different access control policies to their voice VLAN: for example, authorizing employees on the manufacturing floor to access the data segment but not the voice segment. Establishing a separate voice VLAN also prevents employees from using another department’s VLAN for toll calls to avoid increasing their own phone bills.
- Preventing denial-of-service (DoS) attacks: Most DoS attacks originate from a PC; therefore, they cannot affect IP phones and call-processing servers connected to a separate voice VLAN.
- Preventing eavesdropping and interception: Hackers typically eavesdrop on conversations using a PC with special software to connect to the same VLAN as one or more parties in the conversation. If voice participants are logically cordoned off, however, a hacker cannot connect to the voice VLAN with a PC.

Following Best Practices for Wireless Security

With these voice-specific guidelines in place, Cisco has published best practices for general wireless security. The paper “Five Steps to Securing Your Wireless LAN and Preventing Wireless Threats” discusses best practices in a multilayered approach to secure the network—whether wired or wireless—from unauthorized use through a WLAN link. These practices should be validated against an organization’s own risk-management processes and complemented by a strong security implementation.

Together, this combination can protect the organization from inappropriate resource use, theft, and damage to the company's reputation with customers and partners. For a comprehensive evaluation of your organization's network security posture, Cisco Advanced Services consultants and Cisco Certified Partners can analyze your network security in reference to industry best practices, identifying vulnerabilities that could threaten your business. Based on in-depth analysis, Cisco offers recommendations on how to improve your overall network security and prioritizes actions for remediation, which should be complemented by strong access control and security policies.

Voice Over WLAN Client Requirements

A voice-ready WLAN requires the client to be capable of supporting basic 802.11 standards for QoS. In addition, to use the voice-ready Cisco infrastructure for enterprise roaming, management, and security features, Cisco recommends the voice clients be either a Cisco Unified Wireless IP Phone 7921G or any voice-capable Wi-Fi device with, ideally, the advanced voice features available through the Cisco Compatible Extensions program. Table 2 provides a summary of the voice-related features supported by Cisco Compatible clients.

Table 2. Voice Features Supported by Cisco Compatible Clients

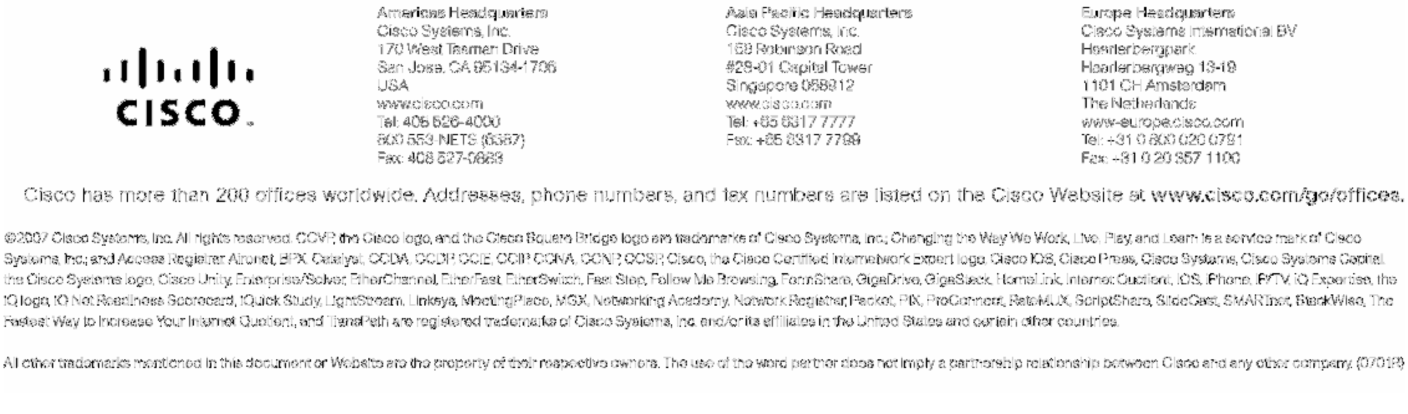
Feature	Function	Benefit	Cisco Compatible Extensions Version
Cisco Centralized Key Management	A device on the network creates a cache of security credentials for Cisco Centralized Key Management-enabled client devices on the subnet. The device forwards the client's security credentials to the access point that the client is destined for, and the process of roaming is reduced to a two-packet exchange between the roaming client and the destination access point rather than being an extended process of re-authenticating all the way back to a RADIUS server in the network.	Eliminates any noticeable delay that is normally introduced by security authentication during roaming.	Version 3
Voice metrics	Defines reporting elements of packet latency, packet jitter, packet loss, and roaming delay.	Allows for proactive management and problem isolation for VoWLAN using quality metrics.	Version 4
Call Admission Control (CAC)	Allocates bandwidth to client devices on a first-come, first-served basis; also maintains a small reserve so that mobile phone clients can roam into a basic service set (BSS) even though the BSS would otherwise be at "full capacity." Access points employ MAC measurements from clients and access points to aid in determining the amount of traffic on the RF channel and whether a new call should be admitted.	Maintains call levels for optimal QoS. If a network exceeds the capacity of a WLAN RF channel by even one call, all calls on the channel will suffer. CAC is a method of preventing channel overload and load-balancing calls that is transparent to the user.	Version 4
Unscheduled Automatic Power Save Delivery (U-APSD)	U-APSD enables the phone to aggregate traffic in order to minimize transitions from active to idle or sleep mode.	QoS feature extends the talk time battery life of mobile clients.	Version 4

Conclusion

A WLAN in an enterprise is no longer a luxury, but a necessary part of the IT infrastructure. With IP telephony growing exponentially as enterprises grow and the wireless LAN being a natural extension of the wired LAN, it is critical to implement wireless technology that enables mobile workforce productivity without handicapping the corporate IT staff. Following some simple design best practices, a successful VoWLAN network is possible with today's network solutions.

The Cisco Unified Wireless Network employs advanced features that help the enterprise establish a voice-ready infrastructure. To deliver a WLAN that provides VoIP service with the quality performance and availability expected from a wired LAN, it is critical to follow some best practices and use the best WLAN technology available for voice deployments. The Cisco Unified Wireless Network lets businesses and other organizations bring the mobility and flexibility of wireless networking to their voice communications systems.

For more information please visit: www.cisco.com/go/wirelessvoice



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Printed in USA

C11-358627-01 9/07