Position Paper

WI-FI IN THE ENTERPRISE

Applications, Environments, Requirements and Solutions

Enterprise WLAN Evolution

As Wi-Fi begins to emerge as a primary network in enterprise environments, administrators must consider both the *applications* that will be delivered and the *environment* in which those applications must be supported. The growth of voice-over-Wi-Fi as a valuable enterprise application brings with it significant requirements that current Wi-Fi products and installations do not address. This includes issues such as more comprehensive RF coverage throughout the enterprise, increased numbers of users with less predictable roaming behavior, and a Wi-Fi network which must support voice and data simultaneously as well as integrate with other telephony systems, such as the enterprise PBX and wide area cellular networks. (Figure 1)

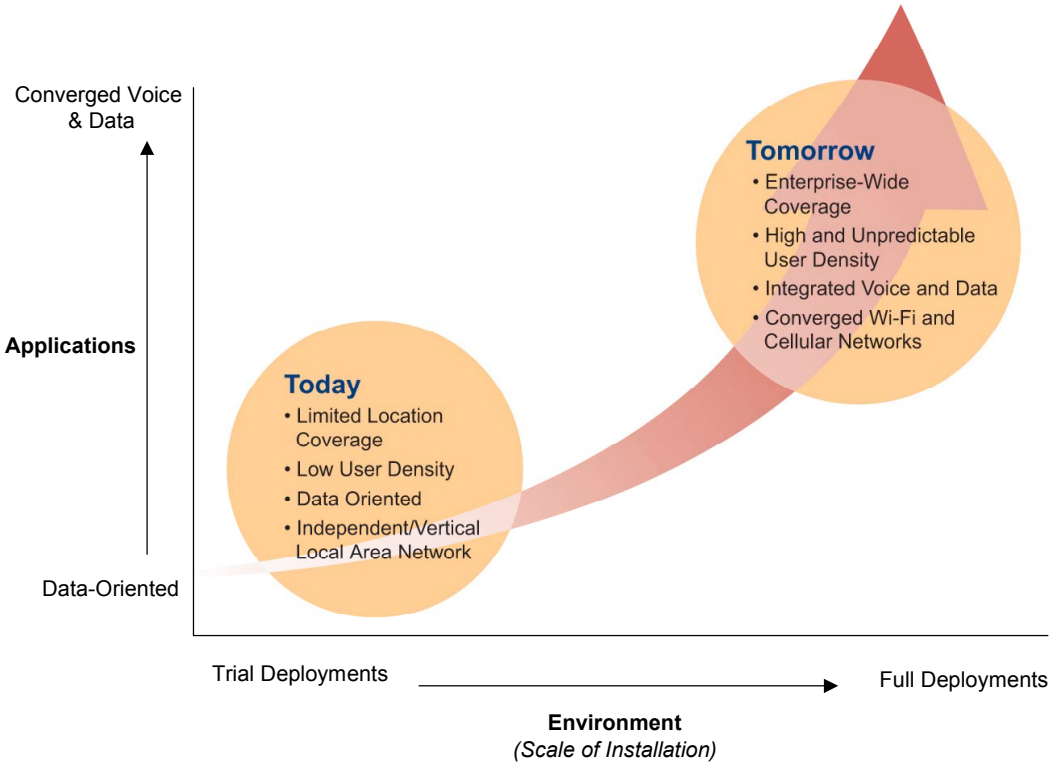

Figure 1: Evolution of Wi-Fi in the Enterprise

The majority of the enterprise WLAN deployments today are relatively small in scale, supporting low user densities, and primarily data oriented from an applications point of view. There are significant differences between the requirements of a small-scale trial wireless network installed in limited areas and providing data access for notebook users, and a large wireless network supporting a high density of highly mobile users on voice handsets. These differences will become evident over the next few years as companies expand their wireless networks and embrace voice applications.

Limited locations vs. enterprise-wide deployment

Most current Wi-Fi installations cover specific areas of the enterprise, such as conference rooms and office areas in a corporate facility, a particular manufacturing floor, a certain wing within a hospital, or specific buildings on a university campus. This type of limited coverage adequately serves the purposes of occasional data access, but is not at all sufficient for the continuous connectivity demanded by voice communications. The usage model associated with voice-oriented handsets is completely different from that of notebook computers. Users expect to be able to stay on their phone call as they roam through hallways, stairways, cafeterias, etc., while they typically only expect to maintain wireless connectivity from their notebook computer while sitting in specific work areas. Because current typical Wi-Fi deployments do not cover large areas, or since they may only cover a number of small non-contiguous areas, there is no expectation that applications and services will be available everywhere, at all times. Users become accustomed to making use of the Wi-Fi network in one location, then shutting down their applications as they move to a new environment. This is the model of *simple portability*. The voice application, however, brings with it a whole new set of user expectations, that service will be available everywhere, even while the user is moving from one location to another. This is the model of *seamless mobility*.

Stationary usage vs. high mobility

In addition to the limited coverage areas provided by today's Wi-Fi networks, the client population is typically stationary. The quantity of computers operating in conference rooms, office areas, classrooms, or the number of hospital staff using PDAs or Wi-Fi-only voice devices, is typically fixed and well characterized. On the other hand, when dual-mode Wi-Fi/cellular handsets emerge in the enterprise, we will find more users roaming in a more random fashion and congregating in a less predictable manner. Further, voice-over-Wi-Fi traffic is more demanding on an access point than data traffic, resulting in limitations on the number of high-quality voice calls that can be handled simultaneously on any access point. These requirements place capacity demands on the Wi-Fi infrastructure, resulting in the need to deploy a higher density of access points; the impact of cost, management, and radio technologies associated with such a high-density installation must be considered.

Data oriented vs. integrated voice and data

Building further on the coverage and capacity issues discussed above, adding voice support to a Wi-Fi network introduces Quality of Service (QoS) and battery life requirements that current data-oriented products and deployments do not address. The Wi-Fi infrastructure must be able to distinguish between voice traffic and data traffic, and manage each appropriately. This requires the ability to not only prioritize voice packets over data packets once received by the access point, but equally important, the system must ensure that voice clients have access to the wireless medium when required. Existing voice over WLAN products can only address the prioritization of voice packets once received at the access point, but there are no standardized mechanisms that address prioritization of access to the wireless channel. An integrated voice/data network must also be able to poll all devices and allow voice handsets to send their packets with higher priority; otherwise a voice handset may not even be able to get its packets sent in the minimal latency time period required. Additionally, the user expectation regarding the battery life of voice-oriented handsets will be significantly different from today's primarily notebook computer-based environment. Given the highly mobile usage models

discussed above, voice handsets will not have frequent access to power, as do notebook computers in fixed locations, and will be expected to maintain battery life similar to current cellular phones.

Independent network vs. converged with cellular network

The vast majority of today's wireless LANs are self-contained local area networks. Even in a data-only environment, there is work to be done to integrate the wireless network with the wired network (for example, consider the challenges associated with moving notebook computers with wireless cards in and out of docking stations) but the voice-over-Wi-Fi application will drive the inevitable user expectation for seamless voice communications across both local and wide area voice networks. This type of seamless voice communications with transparent handover between Wi-Fi and cellular networks requires the Wi-Fi infrastructure to interface with other communications network elements: dual-mode handsets; IP-PBX; "mobility management" servers, etc.

Architectural Solutions

As enterprises consider their Wi-Fi network options, one of the early issues they will face relates to the two types of Wi-Fi infrastructure architectures available today: access point based and switching system based. The industry debate that positions traditional access point architectures ("heavy," "intelligent," "fat") against wireless switch architectures ("lite," "dumb," "thin") is focused in the wrong area. The issue is not whether one architecture is superior to the other, but rather which architecture is best suited to deliver particular applications in the relevant enterprise environment. Choosing which Wi-Fi architecture to invest in should be based on where an enterprise fits along the trajectory demanded by the converged voice/data application in large scale environments. (Figure 2)

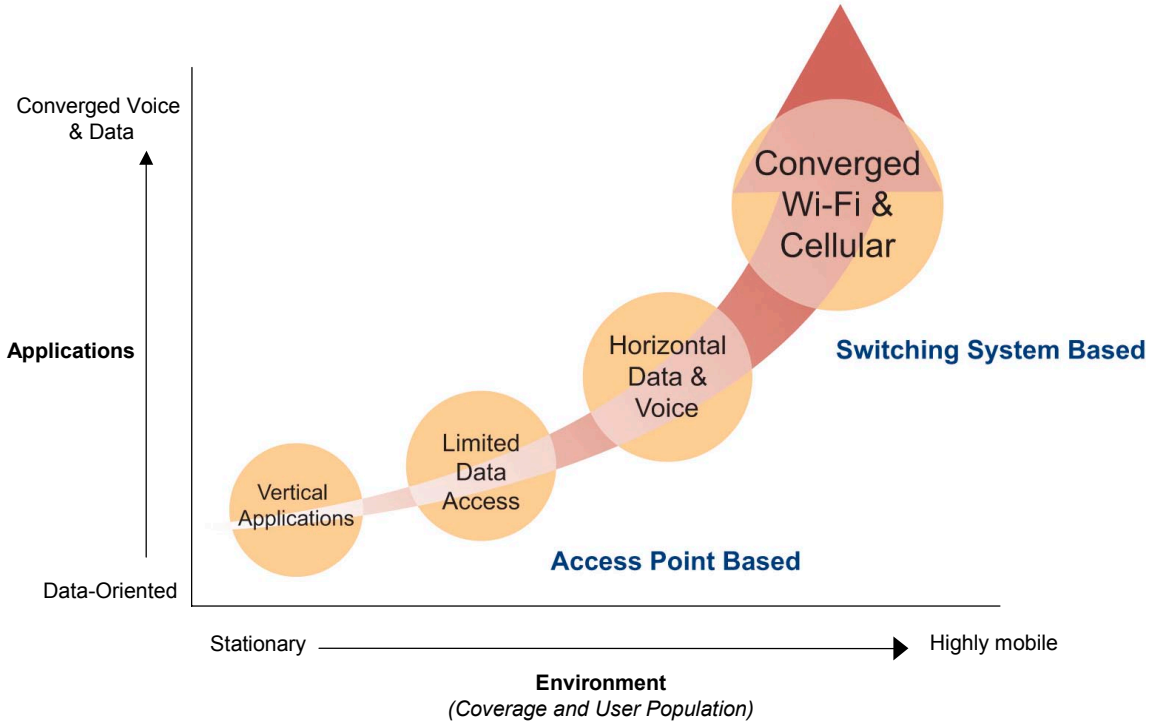

Figure 2: Applications and environment drive architectural choices

Access Point Based Architecture

In the access point based architecture, all of the functionality is delivered by the access points themselves. This architecture is ideal when the areas to be covered are focused on specific locations, and the applications are data oriented and/or voice-over-Wi-Fi services are confined to the primary work areas. For example, in a corporate environment where wireless data access is only required in a conference room, a lobby area, and an office area, the access point architecture may be the best solution. In this case, both the application (data access) and the environment suggest that access point-based architectures can effectively meet these requirements. (Figure 3)

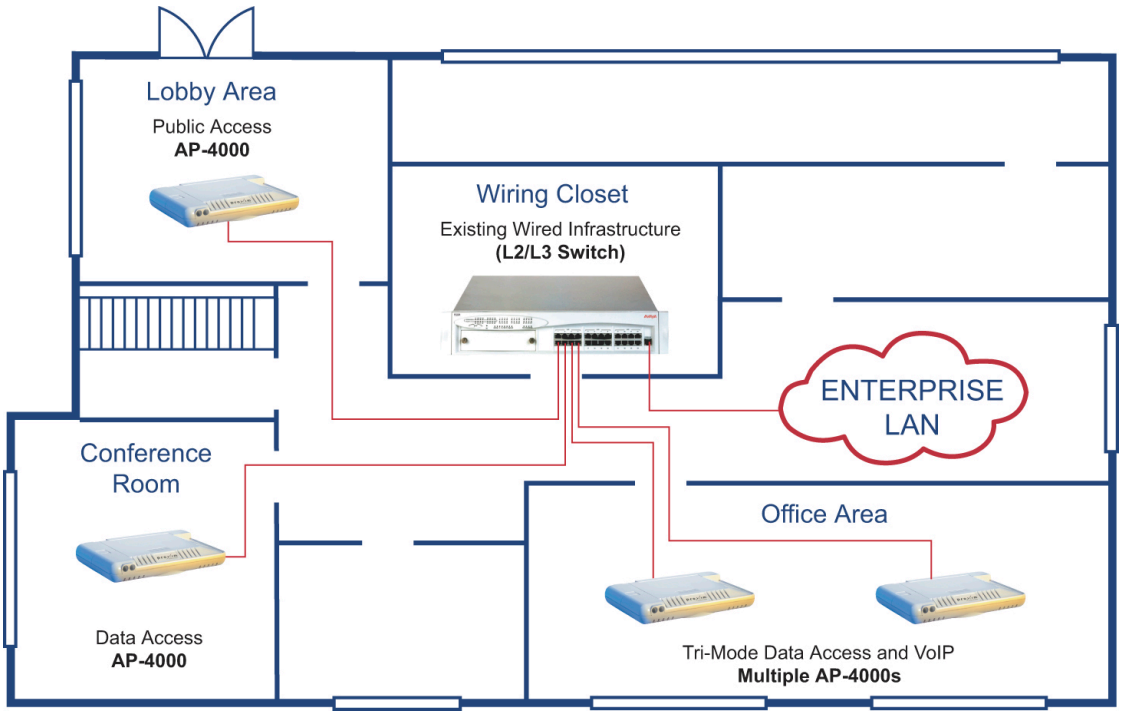

Figure 3: Example localized deployment scenario for access point architecture

Access points can be installed into an existing LAN infrastructure very easily and they provide immediate wireless access to the network. For smaller installations they are often the most cost-effective way to provide wireless access. A disadvantage to this architecture, however, is that in a larger installation, intelligent functionality is being duplicated at every access point, and this functionality is often redundant. In large scale installations this needlessly drives up the cost of the wireless infrastructure as each incremental access point is added to the network. Nonetheless there continues to be a broad application space for traditional access points, and Proxim will continue to enhance its current full-function ORiNOCO Access Points with advanced features and will continue to introduce new models, such as the AP-4000. (Figure 4)

Figure 4: Proxim's new enterprise-class ORiNOCO AP-4000 Access Point

Switching System Architecture

As deployment planning proceeds along the trajectory towards the requirements for converged Wi-Fi/cellular support in a high-density environment, the enterprise should consider transitioning to a switching system architecture. The switching system architecture is best able to meet the increased mobility, QoS, and network integration requirements demanded by the seamless mobility application.

In contrast to the localized access point coverage environment depicted above, continuous, uninterrupted voice communications throughout the enterprise will require a higher density of access points installed in areas not typically covered by traditional access points. (Figure 5) Support for a large population of voice handset users will also require a high density of access points in locations where users might be expected to congregate.

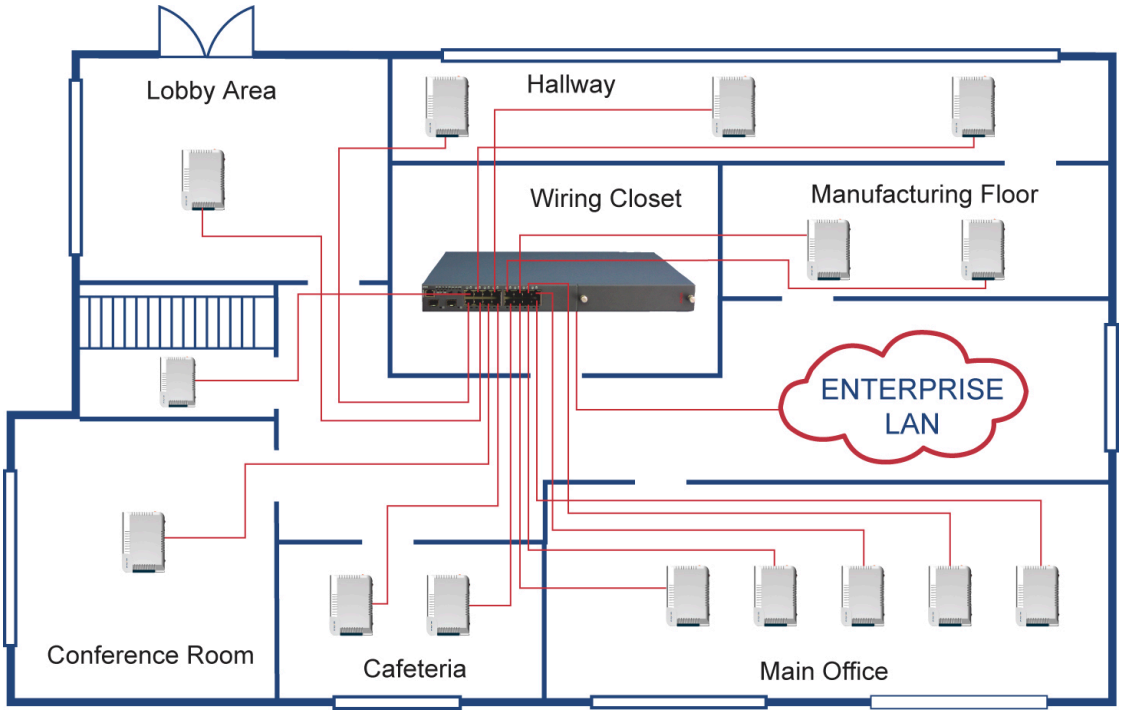

Figure 5: ORiNOCO Switching System facilitates enterprise-wide voice and data services

To meet these requirements, Proxim is developing the ORiNOCO Switching System, which consists of a family of Layer 2 Ethernet switches in a variety of port densities, combined with new performance-

matched, low-cost access points. (Figure 6) The ORiNOCO Switching System facilitates high density deployments by allowing high quantities of low-cost access points to be installed with minimal configuration. The ORiNOCO switch contains all configuration information for each access point and supplies power-over-Ethernet (PoE) to each access point, so installing access points is a simple matter of plugging in its Ethernet cable; all configuration information is automatically downloaded from the switch.

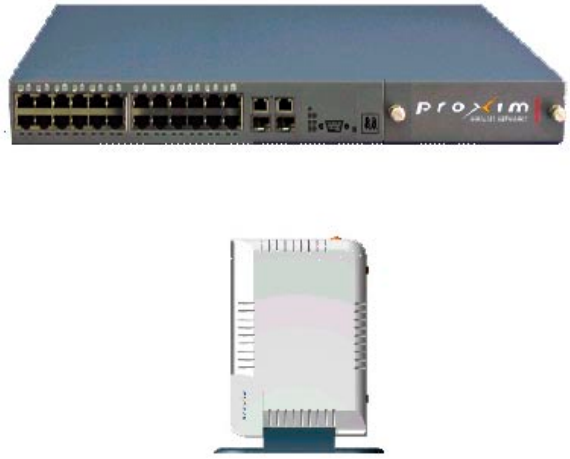

Figure 6: Proxim's ORiNOCO Switching System

Most importantly, the ORiNOCO Switching System is being developed specifically to meet the requirements of integrated voice and data communications. All of the advanced functions described later in this document, such as pre-authentication, subnet roaming, infrastructure-driven roaming, end-to-end QoS, and integration with other network elements, position the switching system as the appropriate solution for an enterprise planning to deliver seamless converged voice and data throughout its facilities.

Voice-Over-Wi-Fi Requirements and Solutions

Numerous technical problems must be solved in order to deliver a solution that will support high quality voice services throughout the enterprise with seamless handover to the cellular network. This includes improvements in mobility (both handoff among the Wi-Fi access points, and roaming from the WLAN to the cellular sysetm), QoS and power management advances, and development of the interfaces to other communication systems. Proxim and its seamless mobility partners, Avaya and Motorola, are developing solutions to these problems. Proxim's ORiNOCO Switching System is being designed from the ground up to incorporate the technologies required to deliver improved Wi-Fi mobility, voice quality, and systems integration.

Each of these developments must be based on industry standards whenever possible in order for the solution to achieve broad industry acceptance. Proxim and its partners are strong supporters of industry standards, and each of the capabilities discussed below are being developed by leveraging existing standards or adopting techniques anticipated to become standardized. Proxim, Avaya, and Motorola are active participants in all wireless LAN industry and standards groups, and contribute significantly to the standards development process. Therefore, all aspects of the seamless mobility solution are expected to become standardized capabilities that other industry participants will eventually adopt.

Mobility Improvements

In order to deliver seamless voice and data communications throughout an enterprise, certain aspects of Wi-Fi mobility must be addressed. Current Wi-Fi implementations have limitations that may not be apparent in a data-oriented network, but are inadequate for a voice-oriented network. The mobility issues that must be addressed include reduced handoff times between access points and transparent mobility across subnets.

Pre-Loading reduces handoff times between access points
"Handoff" refers to the ability of a wireless client to maintain connectivity as it moves from access point to access point throughout a facility. Recent Wi-Fi security implementations have added a significant burden to the client-to-access point association process that must occur each time a client moves from access point to access point. For example, a full 802.1X re-authentication process must be performed each time a client associates with a new access point; this process can take up to two (2) seconds. While a two second interruption is not noticeable to a user downloading a file, a two second gap in a voice conversation is unacceptable; the handoff time must be reduced to less than 250 milliseconds in order to deliver toll-quality voice. Proxim solves this problem through a security context "pre-loading" technique. (Figure 7)

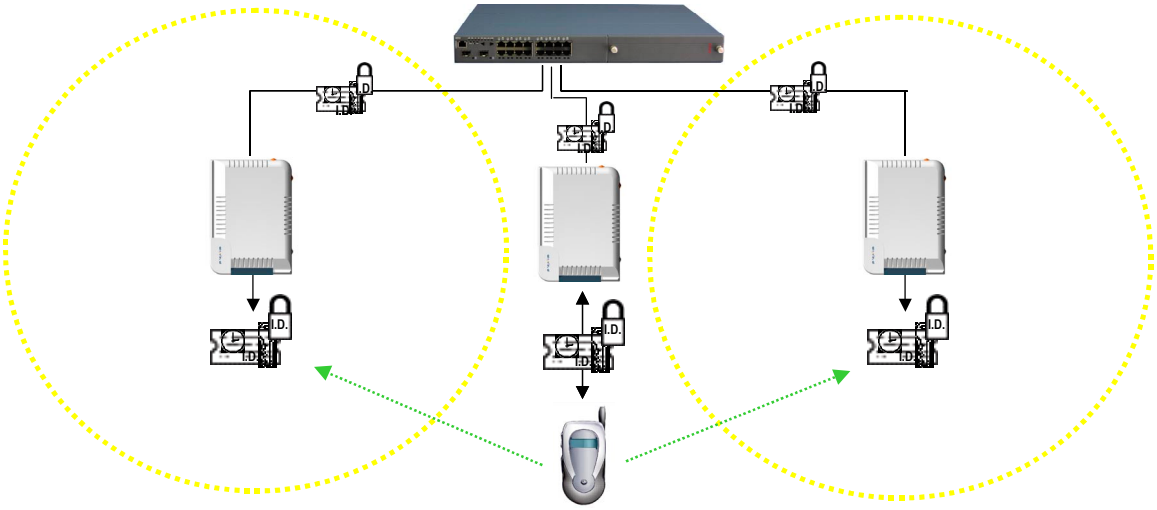

Figure 7: The Switching System pre-loads security context on directed access points

Once a client device decides to attempt a handoff, it must find a new access point with which to associate. The Proxim ORiNOCO Switching System will provide each client with a "neighbor list" of nearby access points in order to speed up that process. Clients will not be required to scan all the channels looking for candidate access points. This list of candidate access points is learned by the wireless enabled switches, and the ORiNOCO Switching System is constantly refining its understanding of the underlying network topology. Through this neighbor list, the switching system can transfer much of the 802.1X-based security context information in advance of the client association process as the client moves from access point to access point. Elements of this technique are expected to be incorporated into the IEEE 802.11 security and fast roaming specifications, and the ORiNOCO Switching System will conform to the standardized pre-authentication methods when ratified. However, the ORiNOCO Switching System will offer certain advantages in terms of widening the choice of access points to which a voice handset has access, and further decreasing the burden on the handset in the handover process.

Subnet mobility allows enterprise-wide connectivity and simplifies deployment

In the ORiNOCO Switching System solution, wireless enabled switches, which may be on different subnets, can act as dynamic home and foreign agents for clients. For example, if a client with an active TCP session roams from an access point on one ORiNOCO Switch to an access point on another ORiNOCO switch in another subnet, the first wireless switch can take on the role of home agent, while the second switch becomes the foreign agent. The ORiNOCO Switching System automatically establishes a tunnel between the second switch and the first switch and the session continues uninterrupted. The client's IP address does not change, even though it is on a different IP subnet, and therefore this process is completely transparent to the user, and is accomplished without any special client software. (Figure 8)

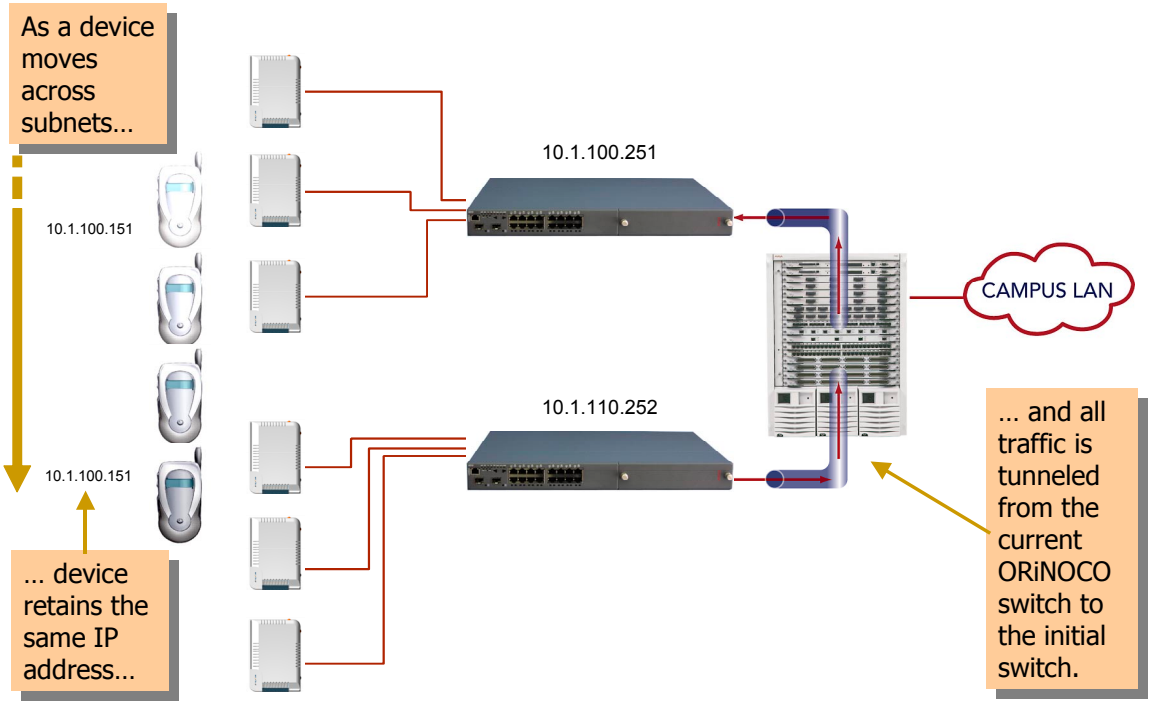

Figure 8: The ORiNOCO Switching System subnet mobility mechanism

The ORiNOCO Switching System's subnet mobility mechanism not only improves client mobility, facilitating the constant connectivity demanded by voice-over-Wi-Fi applications, it also simplifies wireless LAN deployment. IT managers benefit from this capability in two ways. First, given inter-subnet mobility there is no need to design and deploy a wireless LAN so that all access points are on a single subnet, as with an access point based installation. In addition, because the handover from subnet to subnet is managed solely by the infrastructure through the inter-switch tunneling, network administrators do not have to install or configure the software on every client device, as with other mobility solutions. For example, Mobile IP was designed to allow a client device to maintain its IP address across multiple subnets, but requires applications software be installed on each client, and it was not designed to affect a rapid transition between network attachment points.

Traffic Management improves network efficiency

One issue associated with subnet roaming is how to manage traffic flows when large numbers of highly mobile users associate with a particular access point and related "home" switch, and then these users disperse among access points on other switches. An example scenario would be employees entering a facility while on active phone calls and associating with the access point in the lobby. These employees would then spread throughout the facility to their offices and associate with other access points along the way. In this case, the system will maintain a tunnel for each user back to the switch serving the access point in the lobby; this tunnel will follow the user across all of the switches it roams to. While the tunneling mechanism is what allowed the user to roam freely throughout the facility, from a network efficiency point of view it is not optimal to have all traffic being tunneled back to the "lobby" switch.

The ORiNOCO Switching System contains a traffic management function that determines when a session is terminated and automatically updates the client's IP address to the current subnet, removing the tunnel back to the original switch. Again, this process is transparent to the user, and overall network efficiency is improved by reducing the number of tunnels required, thus relieving the burden on any switch that may be experiencing excessive traffic loading, and reducing the backbone traffic associated with those tunneled sessions.

Enhanced Quality of Service (QoS)

The integration of voice traffic into the wireless LAN environment drives the need for quality of service (QoS) mechanisms in the network. These mechanisms can be divided into three categories: over-the-air QoS between clients and access point; capacity-based load balancing; and network-level QoS.

Standards-based over-the-air QoS allows integrated voice and data

The IEEE 802.11 standard committee, within Task Group E (TGe), is creating a specification for the provision of QoS between client devices and access points. This specification provides two different QoS mechanisms. The first provides contention-based channel access for clients by dividing those clients into a set of prioritized access categories. The second is a contention-free, poll-based channel access for clients that request QoS service via a traffic specification made up of detailed QoS parameters, such as latency and jitter.

For over-the-air QoS, these mechanisms are likely to be sufficient, though each has certain drawbacks. The contention-based prioritization offers only statistical QoS, and under high loading conditions significant packet delay can still occur. The polled based QoS mechanism is more predictable, but is more complicated to implement and adds significant channel overhead even for a small number of users. Proxim will support both of these QoS mechanisms when they become available, as well as certain "standards-plus" QoS mechanisms.

Capacity-based load balancing maximized network access and performance

One of the critical capabilities required to ensure a high quality of service for voice traffic on a Wi-Fi network is balancing high traffic loads among multiple access points with overlapping coverage areas. The Wi-Fi infrastructure must have the ability to determine when an access point is reaching its capacity limit, and then direct additional clients to nearby access points that are less heavily loaded in terms of overall capacity (number of associated devices and aggregate throughput).

The ORiNOCO Switching System constantly monitors the capacity of each access point, and will drive excess client traffic to appropriate access points through an infrastructure-driven disassociation/re-association process. Assuming the installation environment has a sufficient number of access points deployed to provide coverage at a minimal data rate, the ORiNOCO Switching System can disassociate an individual client and direct that client to associate to an

access point with excess capacity. This is an example of an advantage offered by a switching system architecture, due to the switch's visibility of multiple access points.

Network-level QoS improves end-to-end voice quality

The true test of QoS mechanisms is the quality that the user perceives at the application level. In order to pass that test, there are many aspects of QoS that 802.11 cannot address at the radio level. The ORiNOCO Switching System integrates with the wired network to provide the following network-level QoS capabilities, such as seamless handoff and admission control.

A user's perception of quality will be influenced by how the network handles the transition between access points. A network-based solution can use its knowledge of the network topology to create timely, fast, seamless handoffs. The improved mobility mechanisms discussed earlier improve overall voice quality by eliminating the "pops" and "cracks" a user would otherwise experience while roaming from access point to access point.

Any QoS mechanism requires, to some extent, admission control to improve its operation. In a prioritized scheme, very high load (especially high load of devices with the same priority) will lead to unacceptably high packet delay. In a poll based access scheme, there will be an amount of traffic beyond which the traffic scheduler cannot provide guaranteed QoS.

The ORiNOCO Switching System has the ability to make admission control decisions based on network-level, not access point-level, considerations. For example, the ORiNOCO Switching System can base its admission decisions not only on the real-time traffic flowing through a single access point, but also on the aggregate traffic flowing through the wireless enabled switch to which a group of access points is connected. In addition, since the ORiNOCO Switching System knows the topology of the access points connected to it, it can make admission control decisions based on predicted traffic movements. That is, the switch can predict to what access point a voice handset connected to a given access point is likely to transition. It can then, in anticipation of this movement, make admission control decisions on the expected future access point so that if the handset does move to the new access point, there are resources available to handle the voice traffic.

Integrated Cellular/Wi-Fi Requirements and Solutions

As mobile professionals experience the convenience and quality offered by voice-over-Wi-Fi, the desire for the ability to continue phone conversations as they roam inside and outside the enterprise will increase. Users will soon realize that Wi-Fi can deliver high-quality voice while inside the building, but they still must switch to a cellular network when outside the building. Thus, the demand for dual-mode cellular/Wi-Fi handsets, and the ability for these handsets to roam seamlessly across local-and wide-area networks, is expected to increase as enterprise Wi-Fi deployments expand.

Further, user expectations concerning the usability of such dual-mode handsets will be much more closely aligned with the cellular phone model than current Wi-Fi phones or other devices such as PDAs. In particular, users will expect the battery life of their dual-mode handset to be similar to that of current cellular phones, since they will use it in the same manner and with the same, or higher, frequency.

In order to achieve seamless voice communications between in-building Wi-Fi and out-of-building cellular networks while meeting users' battery life expectations, the Wi-Fi infrastructure must contain further advances in the way it interfaces to other communications infrastructure elements and voice handsets.

The ability to deliver an enterprise-quality voice communications experience to the mobile professional will depend on how well the Wi-Fi infrastructure will integrate with other enterprise telephony systems. The systems integration functions introduced below are being addressed by the joint development

effort between Proxim, Avaya, and Motorola as these parties work to deliver seamless communications across networks. (Figure 9)

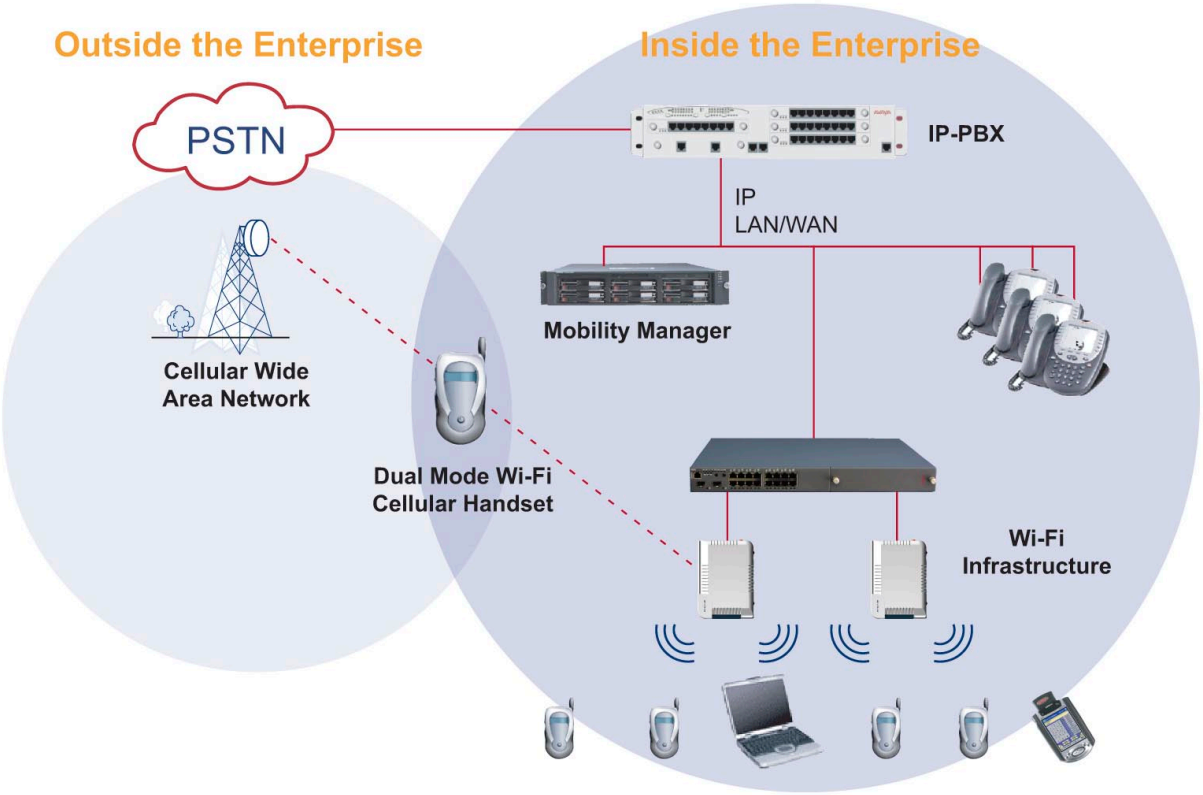

Figure 9: Integrated infrastructure elements deliver high quality voice and seamless roaming

IP-PBX integration allows proper call admission control

By interfacing properly, the Wi-Fi infrastructure and IP-PBX can work together to manage call admission control. Because the access point and switch know their call capacity load limits, if the capacity of an access point is reached and an additional user initiates a call, the Wi-Fi switching system/IP-PBX combination can appropriately manage the new user. Rather than admit the new call and reduce the quality of all calls already established on that access point, or give the new user no indication as to why their call is not going through, the integrated system can deliver a “network busy” message or “busy signal” tone to the new user. When possible, the load balancing techniques described earlier will also drive the new user to another less loaded access point through which the call can be completed.

The situation becomes more complex when E-911 services are taken into consideration. In cases where E-911 services are required to be supported over the Wi-Fi infrastructure, the system must be able to distinguish between a regular (non-emergency) call and an E-911 call. The Wi-Fi infrastructure will not know the calling number, so for each attempted call, it must communicate with the IP-PBX to determining the type of call being placed. In the case of an E-911 call, if the access point is at maximum capacity it must take appropriate action to admit the E-911, which may include any of a number of options, including disassociating an existing user, moving users to another more lightly loaded access point, etc.

Integration with mobility manager facilitates roaming across Wi-Fi and cellular

The seamless roaming process between the Wi-Fi infrastructure and the cellular network requires an interface to a "mobility manager" element within the enterprise. The mobility manager is responsible for keeping track of the location of each user, i.e. whether they are currently logged into the local area (in-building) Wi-Fi network, or whether they are on the wide area cellular network. The mobility manager then determines where to route incoming and outgoing calls. The process of hand-in and hand-out of calls can be facilitated by a Wi-Fi infrastructure that has identified access points at ingress and egress points throughout the facility, and reports to the mobility manager when users are associated with these access points, since the probability of a handover is increased when a user is associated with an access point near an external door. The mobility manager can then pre-configure the roaming condition, allowing the roam to occur quickly and in a manner that is transparent to the user.

Integration with dual-mode handset further improves roaming across Wi-Fi and cellular

Similarly, since the dual-mode handset must make the ultimate determination as to when to switch between Wi-Fi and cellular networks, having a Wi-Fi infrastructure that can inform the handset that it is at an ingress or egress point allows the handset to prepare in advance for the roam. This interface between the Wi-Fi infrastructure and the dual-mode handset helps the handset manage when to activate each radio (place call on cellular network vs. scan for Wi-Fi network), essential for seamless roaming between networks.

Integration with dual-mode handset improves radio management and extends battery life

Another key element of this interaction between the Wi-Fi infrastructure and the dual-mode handset relates directly to battery life. Maximum battery life is essential to an acceptable user experience for the seamless communications capability. If the cellular and Wi-Fi radios in the handset are not managed properly, conditions may exist where a radio is active needlessly or, even worse, both radios are activated at the same time more than is necessary for inter-network roaming. There are two developments related to the handset/access point interface that improve battery life: the roaming management process described above; and advanced "standards-plus" QoS mechanisms which serve to both improve the access and prioritization of voice users and at the same time to minimize the time the Wi-Fi radio is active in the handset. Tight synchronization between the Wi-Fi infrastructure and the handsets allows each handset to access the wireless medium with priority relative to other voice and data devices, while activating its radio to transmit and receive for the shortest interval possible. This mechanism advances the basic 802.11 protocol, which requires client devices to activate their radios more frequently to determine when they can transmit and when there is something to receive. These advanced QoS and power management techniques are being developed in advance of relevant 802.11 standards extensions, but Proxim, Avaya, and Motorola are ensuring that any such developments conform to existing QoS standards, and the companies are actively involved in furthering the standards themselves.

Conclusion

Proxim is unique among wireless LAN equipment providers in recognizing that Wi-Fi is rapidly evolving from a localized data access medium to a critical element of a new seamless communications infrastructure. This seamless connectivity environment converges telephony, data, local area connectivity, and wide area connectivity. Enterprises should base their Wi-Fi infrastructure investment decisions on a thorough understanding of how far down this evolutionary path they intend to progress, how quickly, and how expansively. This assessment of user applications and installation environment will help determine the appropriate Wi-Fi architecture. Given that seamless mobility voice support is an essential capability in an enterprise's communications strategy, Proxim has identified the requirements of this demanding application, and is already developing the technologies necessary to deliver a converged communications solution.