Extricom

White Paper

Voice over WLAN

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I. Introduction

Voice over IP (VoIP) is maturing and achieving increasing corporate acceptance as device costs decrease and VoIP phones improve. Employing VoIP over wireless LAN (VoWLAN), freeing the telephone from the cord, is an obvious next step. It is expected that the enterprise VoWLAN market will initially be driven by specific corporate needs, such as warehouse and retail sales tracking and control, ubiquitous mobile telephony in medical campuses and hospitals, and mobile security applications. The convergence of voice and data networks enables new applications and cost reductions. VoWLAN phones are already being offered to enterprises by leading vendors. Integration of WLAN and cellular technology is underway.

Unfortunately, there are still a number of factors that inhibit wide spread adoption of VoWLAN in the enterprise. Extricom introduces a completely new WLAN architecture that overcomes the challenges that inhibit VoWLAN adoption in the enterprise. Extricom's WLAN is specifically designed to provide seamless and secure mobility as well as high-performance WLAN for the enterprise, at a very low cost of ownership. Providing low latency and jitter, as well as supporting very low transmission power, Extricom's unique WLAN solution is built from the ground up for voice. This document describes today's main VoWLAN challenges in the enterprise environment.

II. Voice over WLAN Challenges

VoWLAN introduces a number of challenges that must be addressed for successful deployment:

"A latency of tens of milliseconds is intolerable"

- Excessive latency and jitter, degraded voice quality
- Poor coverage, interrupted voice service
- Roaming latency
- Security problems
- Retransmissions and dropped packets
- Low capacity, reduced number of calls
- Quality of service, required for voice and data convergence
- Power consumption requirements

Excessive Latency and Jitter, Degraded Voice Quality

One of the major differences between VoIP applications and data applications is the sensitivity to latency (transmission delays). Data applications (e.g., web, e-mail, file transfers) are much less sensitive to latency than to reduced throughput. A delay of seconds in receiving a data file is normally acceptable; however, a latency of tens of milliseconds in a voice call is very noticeable, annoying, and typically intolerable. TCP/IP has a maximum latency of 120 seconds, while the ITU G.114[1] recommends a maximum latency of 150 milliseconds for voice calls.

Another difference between VoIP applications and data applications is the sensitivity to jitter. Jitter is random variations in latency. Jitter in a voice call is readily audible as clicks, pauses, or unintelligible speech. Jitter buffers are used to overcome the effects of jitter. A jitter buffer turns jitter (variable latency) into a longer constant latency, by buffering received voice packets and delaying the decoding of the packets. The jitter buffer adds delay according to the slowest packet (largest latency), creating substantial additional latency.

Every transmitting and receiving node in the network (such as the Access Point in a WLAN network) typically buffers incoming and outgoing packets. This causes latency and jitter. The overhead of roaming, security mechanisms, retransmissions, as well as data and voice convergence add latency and jitter in WLAN networks. These challenges are discussed below.

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"Interference and obstructions make it difficult to provide uninterrupted voice service "

"As mobile users move from cell to cell, inter-Access Point handoffs are required"

"Currently VoWLAN deployments resort to no security at which is unacceptable "

Poor Coverage, Interrupted Voice Service

One of the great advantages of VoWLAN over standard VoIP is that no cord is required, thereby providing the freedom of mobility. To enable callers to move around the enterprise freely, however, their connections must be maintained without interruption; that is, in order to have true mobility, coverage must be ubiquitous and continuous throughout the enterprise. Traditional topologies based on cell planning cannot provide continuous coverage at the maximum data rate. The limited number of channels result in limited overlap between cells, creating shadows, or "black holes" (areas of poor or no coverage). In addition, interference and obstructions result in a continuously changing RF environment. This makes it difficult to provide uninterrupted voice service even in a single cell.

Roaming Latency

Traditional WLAN topology uses cell planning to achieve coverage. As mobile users move from cell to cell, inter-Access Point handoffs are required. As the cell size decreases to provide higher capacity, inter-Access Point handoffs occur more frequently. A handoff requires several steps, including Access Point discovery, reassociation, security measures, and higher-level protocol exchanges. Access Point discovery typically takes 150–400 milliseconds, and introduces 40–100 milliseconds of jitter in 802.11b and 802.11g,[2] well in excess of acceptable voice latency. Access Point discovery latency and jitter in 802.11a or in multimode networks may be two times greater or more.

Reassociation consists of several steps: station-to-Access Point handshake, inter-Access Point protocol (IAPP) exchanges, and bridge notification. Each step introduces additional latency and jitter. Furthermore, IAPP solutions were standardized in the 802.11f standard, which was only recently ratified. Until 802.11f is universally supported, IAPP solutions will be proprietary and not interoperable. Security measures, which introduce even greater latencies and jitter, are described in the next section. Although higher-level protocol exchanges are beyond the scope of this document, they can introduce several seconds of latency, and result in temporary disruption of service. The exact amount of latency depends on network configuration.

Traditional topologies place the burden of inter-Access Point handoffs on the client. Clients, unaware of network topology, frequently make wrong choices. Clients require a long time to select an Access Point, and tend to remain with an Access Point, even if it is far away. Since the handoff is controlled by the client, newer solutions, which provide Access Point topology awareness, only marginally improve the described latency and jitter. Not handing off quickly enough or handing off to a less than optimal Access Point causes rate adaptation, which introduces more latency and jitter, reduces capacity, and increases power consumption. Since the client controls the handoff, packets buffered in the previous Access Point may be dropped, degrading voice quality.

Security Problems

WEP (Wired Equivalence Privacy), the original security protocol for 802.11 wireless networks, is now considered flawed by the industry. In response, the IEEE 802.11i task group is writing a new security standard for WLAN. The interim Wi-Fi Protected Access (WPA) includes temporal-key encryption (TKIP), message integrity checks (MIC) and strong authentication (EAP), thus resolving several of the security problems of WEP.

While WPA is necessary to provide adequate security, it introduces an additional overhead at each inter-Access Point handoff. WPA requires strong authentication mechanisms, and exchange of pairwise (Access Point to Station) keys. These processes typically introduce a latency of 500–1500 milliseconds,[3] effectively disrupting service. While attempts are being made to achieve fast handoffs, these will not be completed before 2005. In the interim, VoWLAN deployments resort to the insecure WEP, or no security at all. Voice without security is unacceptable for an enterprise deployment.

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"The wireless medium is notoriously unreliable; voice applications require timely arrival of packets, while retransmissions take up precious time"

Retransmissions and Dropped Packets

Data applications do not tolerate dropped packets. TCP/IP retransmits erroneous or missing packets to avoid data corruption. However, due to TCP/IP's slow start mechanisms, a drop rate of 1% or above will result in a severe degradation of throughput .

Unlike data, voice can tolerate some packet dropping, typically around 4–5%,[4] as long as the dropped packets are not consecutive. The wireless medium is notoriously unreliable, and therefore the WLAN MAC includes a retransmission mechanism to avoid dropped packets. Unfortunately, while this is a good solution for data, it results in a significant amount of jitter and latency for voice applications. Voice applications require timely arrival of packets, while retransmissions take up precious time.

However, to abandon retransmissions in voice applications, a low drop rate is required. This is impossible in traditional topologies. In traditional topologies, large distances from the Access Point, temporary and random interference and obstructions, as well as co-channel interference caused by neighboring cells all cause poor reception of packets. RF technologies at neighboring organizations or sites may add another source of interference. Whether the neighbor site is using WLAN, or another RF technology, it is another source of interference that can lead to poor packet reception. Unlike other causes of poor packet reception, neighboring sites cannot be controlled or overcome by a more careful deployment. Without retransmissions, a large drop rate and consecutive dropped packets occur. With retransmissions, significant latency and jitter is experienced, and the capacity is greatly reduced. In either case, voice quality is severely degraded.

Low Capacity, Reduced Number of Calls

Although the major requirement for voice is low latency and jitter, the need for adequate capacity cannot be ignored. Capacity determines the number of concurrent calls that can be supported. Because of VoIP's small packets and large overhead, the usual methods of measuring network capacity do not apply to voice. The more relevant measure of capacity for voice applications is the number of packets per second (PPS) that can be transmitted. Several factors limit the PPS of a WLAN network, the most important of which are contention windows, ACK packets, retransmissions, and rate adaptation.

"The restrictions are so severe that current recommendations suggest a maximum of 5–7 voice calls per network"

The recently proposed Wireless Scheduled Multimedia (WSM) standard reintroduces contention-free access, based on 802.11e's Hybrid Coordination Function (HCF). Similar to the original 802.11 Point Coordination Function (PCF), HCF replaces client competition for airtime with centralized client polling. By avoiding contention, contention-free access methods typically utilize 75% of the maximum bandwidth (compared with 37% for contention-based access methods). Contention-free access provides a higher PPS, resulting in double the number of available voice calls.[5] Unfortunately, PCF is not supported by mobile clients, and WSM is not yet available. Even if WSM will be supported (which is not certain yet), multiple co-channel Access Points are bound to cause interference, making it difficult to use WSM in cell-planning–based topologies.

ACK packets are one the most significant cause of PPS reduction for VoWLAN applications, and can account for 30–40% of the airtime used in a single VoIP packet transfer. If retransmissions can be avoided altogether, while maintaining a low drop rate, the need for ACK packets is eliminated.

Unfortunately, in traditional topologies, retransmissions, and the resulting lower network PPS, are unavoidable (see "Retransmissions and Dropped Packets"3). Furthermore, retransmissions trigger rate adaptation at the client. As a result, more airtime is required to transmit the same packet, resulting in a reduced PPS.[6] This, in turn, necessitates ACK transmissions, reducing the network PPS even further. In addition, for a user to be able to move from cell to cell, some slack is necessary in each cell to allow a user to roam in. This means that even the already low capacity cannot be fully utilized. The restrictions described above are so severe that current recommendations suggest a maximum of 5–7 voice calls per 802.11b network.

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Quality of Service, Required for Voice and Data Convergence

Converged voice and data networks pose additional difficulties for VoWLAN deployment. Although voice applications do not require much bandwidth per call, they do require very low latency and jitter. When network load is high, data packets, which are large compared to voice packets, might use up a disproportionately high amount of airtime, causing latency and jitter for the voice packets. Typical deployments will prefer good voice quality even if it means lower bandwidth for data. The 802.11e task group has proposed Quality of Service (QoS) extensions to the 802.11 MAC, providing a mechanism for giving higher priority to voice packets over the shared wireless medium. Until the standard is ratified, a subset of the standard, Wireless Multimedia Extensions (WME), has been proposed. The mechanisms proposed are required in converged voice and data networks to provide acceptable voice quality; but they will only be effective if the above challenges are overcome.

Power Consumption Requirements

Mobile telephones must be light and easily portable, which limits the size, power, and lifetime of the battery. To extend battery life-time, mobile phones take advantage of 802.11 power save mode when the phone is inactive. Power save mode increases the latency of setting up a call, but normally does not affect the call itself.

"To extend the battery life of mobile phones in an active call, the mobile user should be as close as possible to the Access Point"

To extend the battery life of mobile phones in an active call, the mobile user should be as close as possible to the Access Point. Mobile users that are close to an Access Point are able to transmit at the highest data rate. Transmitting at the highest data rate reduces the time the transmitter is on, thus decreasing the client's power consumption.[7] In addition, if the mobile unit is close enough to the Access Point, it can successfully transmit a packet with greatly reduced transmission power.

The choice of transmission standard, OFDM (Orthogonal Frequency Division Multiplexing) or CCK (Complementary Code Keying), also affects power consumption. On the one hand, OFDM provides higher data rates, reducing transmission time. On the other hand, OFDM's high data rates require extremely short distances from the Access Point and consume more power during packet reception. Compared with OFDM, CCK uses less power during reception of packets, is more power efficient, and provides greater distances. On the other hand, CCK supports lower data rates than OFDM.

Since the distances required for OFDM VoWLAN telephones cannot be achieved by traditional topologies, and the power consumption of OFDM chips is currently too high, VoWLAN devices currently use CCK. This results in a mixed 802.11g and 802.11b network, which significantly reduces network capacity.[8]

Conclusions

WLAN provides an excellent opportunity to enable VoIP, since it combines the cost effectiveness of VoIP solutions with cordless mobility. However, VoWLAN deployments have special needs in order to be effective. VoWLAN requires a very strong uplink to reduce latency and jitter. It requires complete coverage and seamless mobility that allow strong security, without interrupting service with constant handoffs. In addition, increased capacity is needed to provide a sufficient number of simultaneous voice calls. Users must always be close to an Access Point to cope with power constraints of VoWLAN devices, allowing them to transmit at the highest data rate and avoid retransmissions, dropped packets, or using lower transmission powers.

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III. The Extricom Solution

"Extricom's unique WLAN architecture is built from the ground up for voice applications. No modifications are required either in Category 5 cabling or on the client side"

WLAN Built for VoIP

Extricom's unique WLAN architecture is built from the ground up for voice applications. The unique centralized MAC solution overcomes the challenges of VoWLAN by providing an enhanced infrastructure. Extricom's solution consists of ultra-thin Access Points™ containing a radio (PHY device), and a single wireless switch, which implements the central MAC. No modifications are required either in Category 5 cabling or on the client side, which may use any off-the-shelf wireless Network Interface Card.

Extricom's WLAN covers the entire enterprise with continuous single-channel blankets, each providing the maximum data rate. There are no black holes or areas of poor coverage, and the latencies of inter-Access Point handoffs are eliminated. Extricom's central MAC allows low-latency packet-by-packet decisions, eliminating downlink contention. Access Points can be added at will without limitation, eliminating the high costs of RF site surveying and maintenance, and providing a highly scalable WLAN deployment.

Extricom's new approach to eliminating co-channel interference allows reuse with high spatial density. Blanket coverage allows all stations to support the highest data rate. Since multiple radios can be placed in each ultrathin Access Point™, multiple blankets of high data rate coverage are provided. With 8 channels operating at 54 Mb/s, Extricom can provide more than 1 Gb/s of aggregate bandwidth.

Result: Extricom provides an infrastructure that is much more suited for voice, and can easily overcome or avoid the problems of traditional WLANs described above.

Reduced Latency and Jitter

Extricom's WLAN greatly reduces latency and jitter. Extricom's ultra-thin Access Points™ contain no buffers, reducing the latency and jitter in the network. Incorporating the latest QoS extensions enables transmitting data and voice over one converged WLAN. Extricom currently supports the Wireless Multimedia Extensions (WME) and will support the Wireless Scheduled Multimedia (WSM) and 802.11e standards once ratified. This allows voice and data to coexist, while still providing low latency and jitter for voice packets.

Result: Extricom's WLAN provides low latency and jitter, making it perfect for VoWLAN deployments.

"Extricom's WLAN covers the entire enterprise with continuous single-channel blankets, each providing the maximum data rate"

Complete Coverage, Uninterrupted Voice Service

Extricom's ubiquitous blanket coverage provides perfect and complete coverage throughout the enterprise. Closely spaced Access Points can be placed throughout the enterprise, providing multiple overlapping coverage cells, thereby eliminating black holes and areas of poor coverage.

On a packet-by-packet basis, Extricom centrally selects the Access Point to handle the packet and acknowledge its receipt. This allows multiple Access Points on the same channel, avoiding contention and co-channel interference. Extricom's packet-by-packet uplink Access Point diversity is able to overcome RF interference and obstructions, delivering complete coverage for uninterrupted voice calls.

Result: Extricom provides complete and ubiquitous coverage, avoiding black holes and overcoming interference and obstructions, providing an uninterrupted voice service.

Zero Latency Roaming, Secure Mobility

Extricom's central MAC and uplink Access Point diversity enable client mobility with zero latency roaming. This eliminates the latencies and jitter associated with inter-Access Point handoffs. The station associates once to the entire network, and seamlessly roams throughout the enterprise without having to reassociate. Extricom's packet-by-packet decisions allow per packet lossless inter-Access Point handoff. The difficult decisions are made by the infrastructure, allowing the station to roam unaware of the inter-Access Point handoff.

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By providing zero latency roaming, Extricom avoids the latencies associated with security measures. This enables the use of WPA, AES, and 802.11i (once ratified), the most advanced security mechanisms available, providing secure and seamless mobility without additional latency and jitter.

Result: Extricom provides zero latency roaming throughout the enterprise, eliminating inter-Access Point handoff latencies and jitter allowing secure VoWLAN.

Access Point Diversity Reduces Retransmissions and Dropped Packets

Extricom's complete coverage at the highest data rate, combined with packet-by-packet uplink Access Point diversity, greatly reduces the number of incorrectly received packets. Mobile stations are always close to an Access Point. Since multiple Access Points receive each packet, random RF interference and obstructions can be overcome. Moreover, neighboring sites are less likely to interfere when mobile stations are much closer to the Access Points and uplink Access Point diversity is used. Uplink Access Point diversity and avoiding co-channel interference overcome nearly all sources of poor packet reception.

The combination of these improvements reduces the number of poorly received packets. This allows a reduction in the number of retransmissions for data packets, and abandoning retransmissions altogether for voice packets. Since the number of poorly received packets is small, abandoning retransmissions improves voice quality by reducing jitter and latency, while maintaining a low drop rate.

"The station associates once to the entire network, and seamlessly roams throughout the enterprise without having to reassociate"

Result: Uplink Access Point diversity allows for abandoning retransmissions, providing higher quality voice

Increased Capacity, More Calls Supported

By eliminating retransmissions, Extricom greatly increases the maximum number of concurrent calls. With a reduced drop rate providing high-quality voice, ACK packets are not needed for voice. Abandoning retransmissions and blocking the transmission of ACK packets can nearly double the maximum number of calls in a given network. Extricom's single-channel blanket and centralized MAC are perfectly suited to support contention-free access (e.g., WSM). Since Extricom avoids downlink contention and co-channel interference altogether, WSM can be used throughout the network, doubling the number of calls.

Extricom further increases the maximum number of calls by allowing all stations to operate at the highest data rate. With TrueReuse™, optimum frequency reuse is possible, multiplying the number of calls per channel. Since each ultra-thin Access Point™ supports several channels, the number of calls is multiplied further. In addition, since Extricom provides blanket coverage with zero roaming, slack capacity is not required, allowing the full utilization of the greatly increased capacity.

Result: Extricom's unique technology allows a significant increase in the number of calls, while maintaining low latency and jitter.

Reduced Power Consumption

Extricom's blanket coverage and multiple Access Points on the same channel greatly reduce the distance between the mobile stations and the Access Points. This, in turn, allows a significant reduction in power consumption. VoWLAN telephones are able to reduce the transmission power of each packet. Furthermore, VoWLAN can always transmit at the highest data rate, even in OFDM, reducing transmission time and power consumption of mobile phones. In addition, Extricom's single-channel blanket coverage enables the use of dynamic and static load balancing. By deploying several blankets throughout the enterprise, slower VoWLAN devices are placed on a separate channel, freeing other channels for high-rate data applications.

Result: Extricom's blanket coverage significantly reduces power consumption.

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IV. Summary

Extricom's unique WLAN is built from the ground up to provide quality voice over WLAN. Extricom's central MAC, providing uplink Access Point diversity, complete blanket coverage, and zero latency roaming overcome the technological barriers that inhibit widespread adoption of VoWLAN. With Extricom, VoWLAN delivers flexibility and mobility throughout the enterprise, in a converged data and voice network.

Voice over Extricom WLAN provides:

- Reduced latency and jitter, allowing toll-quality voice
- Complete coverage, providing uninterrupted voice service
- Zero latency roaming
- Highest available security
- Greatly increased capacity, allowing a significantly large number of calls
- Quality of service, enabling voice and data convergence
- Reduced power consumption

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