WHITE PAPER

Extricom

Voice over Wireless LAN (VoWLAN)

System Design and Performance Considerations

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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, while integration of WLAN and cellular technology (dual mode handsets) is also being pursued by numerous vendors and carriers in several countries.

Unfortunately, there are still a number of factors that inhibit widespread adoption of VoWLAN in the enterprise. Traditional WLAN infrastructure approaches manifest the following inhibitors:

- Excessive latency and jitter, leading to degraded voice quality
- Poor coverage
- Roaming latency between Access Points (APs), leading to interrupted voice service
- Security issues
- Retransmissions and dropped packets
- Low capacity, reduced number of calls
- Quality of service, required for voice and data convergence
- Power consumption requirements

Extricom introduces the patented Interference-Free™ architecture, a completely new wireless LAN architecture that overcomes the challenges that inhibit VoWLAN adoption in the enterprise. Extricom's technology eliminates the coverage and capacity limitations of traditional WLAN architectures, as well as the need for cell planning and site surveys, the most expensive aspect of owning a WLAN. This solution provides seamless, secure mobility and high-performance traits, all at a very low cost of ownership. The Extricom WLAN is ideally suited for real-time applications such as VoIP, thanks to the architecture’s zero-latency and jitter, as well as its ability to support very low transmission power.

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Voice over WLAN Challenges

In enterprise-scale deployments, traditional wireless LAN solutions utilize a cell-planning topology. Cell planning means taking an available 802.11 channel and assigning it to a specific wireless access point. This process is repeated for every access point. Each access point then operates as a "cell" in the system. While this topology can serve the needs of transactional data users, it presents a set of inherent challenges for real-time applications such as voice.

Excessive Latency and Jitter, Degraded Voice Quality

"A latency of tens of milliseconds is intolerable for voice applications."

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. As a comparison, 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 AP in a WLAN, 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. These challenges are discussed below.

Poor Coverage

"Interference and obstructions make it difficult to provide uninterrupted 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; Interrupted Voice Service

"As mobile users move from cell to cell, inter-AP handoffs are required."

Traditional WLAN topology uses cell planning to achieve coverage. As mobile users move from cell to cell, inter-AP handoffs are required. As the cell size decreases to provide higher capacity, inter-AP handoffs occur more frequently. A handoff requires several steps, including AP discovery, re-association, security measures, and higher-level protocol exchanges. AP 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. AP discovery latency and jitter in 802.11a or in multi-mode networks may be two times greater or more.

Re-association consists of several steps: station-to-AP handshake, inter-AP protocol (IAPP) exchanges, and bridge notification. Each step introduces additional latency and jitter. 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 of service. The exact amount of latency depends on network configuration.

Traditional topologies place the burden of inter-AP handoffs on the client. Clients, unaware of network topology, frequently make the wrong choices. Clients require a long time to select an AP, and tend to remain with an AP, even if it is far away. Since the handoff is controlled by the client, newer solutions, which provide AP topology awareness, only marginally improve the described latency and jitter. Not handing off quickly enough or handing off to a less than optimal AP 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 AP may be dropped, degrading voice quality.

Security Issues

"Currently, VoWLAN deployments resort to no security which is unacceptable."

Wired Equivalence Privacy (WEP), the original security protocol for 802.11 wireless networks, is now considered flawed by the industry. The IEEE 802.11i standard introduced newer security standards 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-AP handoff. WPA requires strong authentication mechanisms, and exchange of pair-wise (AP to Station) keys. These processes typically introduce a latency of 500–1500 milliseconds[3], effectively disrupting service. Until better solutions will be introduced, VoWLAN deployments resort to the insecure WEP, or no security at all. Voice without security is unacceptable for an enterprise deployment.

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 standard 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.

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However, to abandon retransmissions in voice applications, a low drop rate is required. This is impossible with traditional topologies. In traditional topologies, large distances from the AP, temporary and random interference and obstructions, as well as co-channel interference caused by neighboring cells all cause poor reception of packets.

Radio Frequency (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, the most important of which are contention windows, acknowledgment (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 proposed IEEE 802.11e standard re-introduces contention-free access (scheduled access), termed the 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 was never supported by mobile clients, and client support for HCF is not yet available. Even if scheduled access will be supported (which is not certain yet), multiple co-channel APs are bound to cause interference, making it difficult to use scheduled access in cell-planning–based topologies.

ACK packets are one the most significant causes 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"). 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.

Furthermore, 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.

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 standard, 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 (WMM), is being tested. The mechanisms proposed are required in converged voice and data networks to provide acceptable voice quality; but they will only be effective when all the clients in the network support these extensions.

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 AP. Mobile users that are close to an AP 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 AP, 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 AP 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 AP to cope with power constraints of VoWLAN devices, allowing them to use lower transmission powers, and to transmit at the highest data rate.

The Extricom Solution

WLAN Built for VoIP

"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."

Extricom's patented Interference-Free WLAN architecture is built from the ground up for voice applications. This unique solution solves the problems of VoWLAN by providing an enhanced infrastructure. Extricom's solution consists of UltraThin™ APs containing little more than WLAN radios, and a central WLAN switch which controls the entire network. 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 (NIC).

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-AP handoffs are eliminated. Extricom's technology enables low-latency, packet-by-packet decisions, eliminating downlink contention. APs 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 patented TrueReuse™ technology allows frequency reuse with high spatial density, while avoiding co-channel interference. Blanket coverage allows all stations to support the highest data rate. Since multiple radios can be placed in each UltraThin AP, multiple blankets of high data rate coverage are provided

Reduced Latency and Jitter

"Multiple channel blankets allow Extricom to separate voice from data on different channels, enabling guaranteed voice quality even today."

Extricom's WLAN greatly reduces latency and jitter. Extricom's UltraThin APs contain no buffers, reducing the latency and jitter in the network. Multiple channel blankets allow Extricom to separate voice from data on different channels, enabling Extricom to guarantee voice quality even today, while most clients do not yet support advanced QoS mechanisms. Extricom is further dedicated to support WMM, 802.11e, and any future extensions to enhance QoS mechanisms. This allows voice and data to co-exist in an Extricom WLAN, while providing the low latency and jitter that is required for voice applications.

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

Complete Coverage, Uninterrupted Voice Service

"Extricom's patented packet-by-packet uplink AP diversity is able to overcome RF interference and obstructions, delivering complete coverage for uninterrupted voice calls."

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

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

Zero-Latency Roaming, Secure Mobility

"By providing zero-latency roaming, Extricom delivers secure and seamless mobility without additional latency and jitter."

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

Furthermore, by providing zero-latency roaming, Extricom avoids the latencies associated with security measures. This allows Extricom to use WPA, AES, and 802.11i, 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-AP handoff latencies and jitter, and allowing secure VoWLAN.*

AP Diversity Reduces Retransmissions and Dropped Packets

Extricom's complete coverage at the highest data-rate, combined with packet-by-packet uplink AP diversity, greatly reduces the number of incorrectly received packets. Mobile stations are always close to an AP. Since multiple APs 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 APs and uplink AP diversity is used. Uplink AP diversity and avoiding co-channel interference overcomes 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.

Result: *Uplink AP diversity allows for abandoning retransmissions, providing higher quality voice.*

Increased Capacity, More Calls Supported

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

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. In addition, Extricom's Interference-Free architecture is perfectly suited to support scheduled access (e.g., HCF in 802.11e). Since Extricom avoids downlink contention and co-channel interference altogether, scheduled access 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 is possible, multiplying the number of calls per channel. Since each UltraThin AP can support several channels, the number of calls is multiplied further. In addition, since Extricom provides blanket coverage with zero-latency 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 – several times the number of any other system, while maintaining low latency and jitter.***

Reduced Power Consumption

"Extricom's blanket coverage allows handsets to reduce the transmission power of each packet and reduce transmission time by using higher data rates."

Extricom's blanket coverage and multiple APs on the same channel greatly reduce the distance between the mobile stations and the APs. This, in turn, allows a significant reduction in power consumption. VoWLAN handsets are able to reduce the transmission power of each packet. Furthermore VoWLAN handsets 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.***

Summary

Extricom's Interference-Free WLAN architecture is built from the ground up to provide quality voice over WLAN. Extricom's technology, providing uplink AP diversity, complete blanket coverage, and zero-latency roaming overcomes 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 roaming latencies
- 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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