Metrics And Methods Bring VoWLAN Success
Emerging standards, suitable metrics, and appropriate testing methods smooth the way for the deployment of voice over WLAN.

Fanny Mlinarsky
March 2005

Mobile phones have been a runaway success for two decades. Over the years, however, the cellular market has stabilized. Can Wi-Fi give the cell-phone industry a boost? The IEEE 802.11-based Wi-Fi data-networking technology has penetrated the small-office/home-office (SOHO) market. Now, it is expanding rapidly into the enterprise and public-access markets. Wi-Fi is well suited to carry packetized voice, such as Voice over IP. It also can offer cellular users better indoor coverage at a lower cost.

Dedicated voice-over-WLAN (VoWLAN) solutions have been available since the late '90s from Cisco, Symbol, and Spectralink. Recently, Motorola, Proxim, Avaya, NEC, Nokia, Senao, and others have started to introduce products and services for next-generation, converged Wi-Fi/cellular networks.

But are the enterprise and public-access Wi-Fi networks ready to support the 400 million Wi-Fi enabled handsets that are forecasted to exist by 2009? Are the new handsets themselves ready to support the complex 802.11 protocol? As IT managers in enterprises and public-access networks evaluate the possibility of bringing voice applications to their WLANs, they'll want accurate performance measurements. Such measurements must validate the networks' ability to manage real-time applications like voice. To achieve acceptable voice quality, WLANs must meet strict performance requirements.

A Wi-Fi handset digitizes and sends an audio signal over a Wi-Fi network in the form of data packets. After these packets travel through a network of access points (APs), Ethernet switches, and routers, they must enter the receiver at regular intervals—every 20 or 30 ms depending on the codec (coder-decoder for digitized voice). Packet loss, delay, and jitter on the network interfere with the regular arrival of packets in a voice stream. They therefore contribute to the distortion of the received audio signal (FIG. 1). Jitter is defined as a delay variation from packet to packet. It causes distortion in the reconstructed signal.

When the network is congested with traffic, packet loss, delay, and jitter get worse. To keep these parameters within acceptable bounds, the IEEE and the Wi-Fi Alliance are developing a number of new standards. For example, several new IEEE standards are required to control the interference that's caused...
by these parameters while obtaining optimum VoWLAN quality:

- **802.11e**: Quality of Service (QoS) protocol to prioritize the forwarding of voice traffic and Admission Control protocol to keep the number of simultaneous active calls manageable
- **802.11r**: Fast roaming protocol to minimize bursty packet loss as the moving handset switches from AP to AP
- **802.11i**: Intelligent security protocols, such as pre-authentication, to reduce roaming time by enabling the handset to authenticate with neighboring APs before roaming
- **802.11k**: Radio Resource Management protocol to enable the handset to make fast roaming decisions through pre-discovering all neighboring APs, their distances, and call capacity

The most important of these emerging IEEE standards for optimizing voice quality is 802.11e—the QoS specification. 802.11e specifies two methods of prioritizing voice traffic over data traffic—Wireless MultiMedia (WMM) and WMM scheduled access (WMM-SA). The use of these priority protocols minimizes the packet loss, delay, and jitter that impact voice quality by giving voice traffic the right of way through the Wi-Fi infrastructure.

The WMM-SA QoS method relies on the polling-based optimization of the airlink bandwidth. It is not yet commercially available. Yet WMM implementations are already on the market. In fact, they are being certified by the Wi-Fi Alliance. WMM describes four relative priorities for the Wi-Fi traffic: voice (highest), video, background, and best effort (lowest). It also specifies the Admission Control protocol that lets APs reject calls when the call load exceeds capacity. Prioritization of voice traffic together with Admission Control optimizes VoWLAN performance by minimizing packet loss, delay, and jitter.

The Wi-Fi Alliance is now performing the certification testing of new WMM implementations. In addition, the Wi-Fi Alliance certification of WMM-SA is scheduled for late this summer.

The IEEE also is addressing mobility and roaming, which have a significant impact on voice quality. As a caller walks around a Wi-Fi site, the phone roams from AP to AP. Each time the phone roams, the caller experiences a burst of lost packets. Bursty packet loss impacts voice quality more significantly than uniform packet loss.

In modern Wi-Fi networks, the AP densities are high. Roaming can occur every few seconds at normal walking velocity. The AP densities can be as high as one AP per 6 ft. in networks based on switched architectures (such as Airespace). To reduce the impact of bursty packet loss caused by roaming, roaming time must be minimized. The IEEE and the Wi-Fi Alliance are discussing a 50-ms limit on roaming time.

To meet that 50-ms roaming-time requirement, the IEEE is developing a new standard. 802.11r will define the fast-roaming algorithm. In turn, 802.11r relies on another new standard, 802.11k. 802.11k helps the phone discover the neighboring APs and query their status in preparation for a fast roam.

The fast-roaming 802.11r protocol also relies on the security standard, 802.11i, to support pre-authentication. The lengthy authentication process can therefore be avoided during a fast roam. Clearly, roaming is a complex process that relies on a number of emerging 802.11 protocols.

Organizations like ITU-T, TIA, and ETCI have standardized voice-quality measurements. ITU-T is the United Nations agency that is setting global telecommunications standards. TIA sets the U.S. telecom standards, while ETCI sets the European telecom standards. Several generally recognized metrics are mean opinion score (MOS), perceptual speech quality (PESQ), and the rating factor (R-factor). MOS is specified in the ITU-T P.800 document. PESQ is specified in the ITU-T P.862 document. Lastly, the R-factor is specified in the ITU-T G.107 document. The MOS method uses people to provide a subjective quality score of 1 to 5. 3.6 represents the toll voice quality.

The PESQ method measures the voice quality of the infrastructure and handsets. Essentially, it compares a reference signal at the transmit end to a distorted signal at the receive end. By employing sophisticated signal processing, the PESQ algorithm aligns the reference and receive signals. It then estimates the differences between these two signals. The PESQ score corresponds to the MOS score of 1 to 5 (FIG. 2).
R-factor—a widely used voice-quality metric for VoIP networks—is computed as a function of delay, packet loss, and other parameters like noise, echo, and path loss. The R-factor quality indicator ranges from 1 to 100. Yet it is convertible to the MOS score of 1 to 5. The ITU-T G.107 document specifies how the R-factor can be converted to MOS (FIG. 3).

VoWLAN testing verifies conformance to the new voice-related IEEE protocols. It also measures the voice-quality performance of phones and infrastructure systems in a controlled and repeatable manner. The test metrics focus on voice quality as a function of call capacity, background traffic load, range, and roaming. Voice quality can be determined from the basic measurements of delay, jitter, and packet loss.

The ITU-T G.107 standard specifies the following limits on delay and packet loss through the Internet infrastructure: delay of 500 ms and a packet-loss rate of 20%. For a single-AP network, the desired limits are latency that's less than 50 ms, jitter under 5 ms, and roaming time under 50 ms. The packet-loss rate should be less than 1%.

Qualifying Wi-Fi handsets and infrastructure requires a special approach that overcomes the challenges of open-air measurements. After all, performing open-air measurements while Wi-Fi handsets are in motion is time-consuming and unreliable. Repeatable test results can only be obtained when interference is eliminated or controlled. But shielded EMI chambers are traditionally used to control interference and impede mobility. As a result, they cannot be used for the many measurements that involve roaming and rate adaptation.

The new Wi-Fi test techniques feature specialized isolated test enclosures for devices like handsets and APs. The Wi-Fi devices that are placed in these enclosures connect to a network of programmable RF attenuators, combiners, and switches. Those components allow for the accurate emulation of device motion relative to the other clients and APs installed in the system. Devices can be "moved" and precisely "positioned" under software control in order to exercise the new voice protocols like fast roaming (802.11r), radio resource measurements (802.11k), pre-authentication (802.11i), and QoS (802.11e) (FIG. 4).

The test methodology for VoWLAN metrics follows the work that's being done at the IEEE 802.11t task group. The 802.11t committee is working to define test methods and metrics for 802.11 devices and systems. It also is looking into classifying tests by device under test (DUT). Each test is designed with a specific DUT in mind.

VoWLAN tests are classified as infrastructure tests, client tests, and system tests. The infrastructure tests measure the ability of APs, switches, and other infrastructure devices to forward and prioritize voice traffic in the presence of background data traffic. The important metrics for infrastructure are call capacity and call quality as a function of traffic congestion and the number of active stations.

To measure voice quality as a function of call and background traffic, Wi-Fi calls and low-priority background traffic are generated through the DUT. The low-priority background traffic comes from multiple clients. The test configuration shown in Figure 4 includes two Wi-Fi client emulators. They can emulate call traffic and background data traffic from multiple Wi-Fi devices (PCs, handsets, and so on). To test the AP's ability to prioritize voice packets and manage the number of active calls, the client emulators must support WMM and Admission Control.

While sending traffic, the test system measures the forwarding rate, packet loss, delay, and jitter on the voice-packet streams. Those streams are passing through the infrastructure under test. Call capacity is measured by having Emulator 1 generate multiple voice calls at a high voice priority. Meanwhile, Emulator 2 is generating background traffic from conventional PC clients (FIG. 5).

Client tests, or handset tests, also must be performed. Among the important handset tests are roaming performance and operating range versus voice quality. The roaming test measures the roaming time and analyzes the roaming behavior of the handset. As shown in Figure 5, the handset is connected between two APs via programmable attenuators. The attenuators are varied so as to force the handset to roam from one AP to another.

The velocity of the motion and the overlap between two basic service sets (BSSs) significantly impact the
roaming time. (A BSS is a system of an AP and the stations that are associated with it.) These velocity and overlap parameters can be programmatically controlled during the test. Data captures are performed on the source and destination channels simultaneously (FIG. 6 AND FIG. 7).

The second important handset test is operating range versus voice quality. The operating range of a Wi-Fi handset must be measured under controlled conditions while attenuation is varied between the handset and the AP (FIG. 8).

Finally, system tests qualify the behavior and performance of multi-AP systems. These tests use a number of roaming handsets in conjunction with controlled background traffic. The tests aim to quality the robustness of complex systems. They also strive to test the interoperability of equipment from different vendors. In addition, it's possible to push the limits of the system under test in terms of how many active clients it can support. To check these limits, use call and data client emulation to supplement real devices in the testbed. Such a system test should be performed in a conducted interference-free environment. In that environment, it's ideal if controlled motion and roaming can occur while device behavior under heavy traffic load is monitored and analyzed.

There is considerable complexity to the IEEE 802.11 protocols that are required to support voice-over-WLAN networks. Good engineers know that complex systems don't always work as expected—especially in the early phases of deployment. Good marketers know that the successful deployment of complex technologies hinges on the customers' initial experience. If early VoWLAN deployments fail to offer satisfactory performance or resilience to stressful and adverse traffic conditions, this fledgling new technology might never enjoy widespread success. Thorough and controlled VoWLAN testing is the key to its future.

Figure 1

1. As voice packets travel through a Wi-Fi network, they are subject to loss, delay, and jitter that deteroriate voice quality at the receiver. As the phone in motion roams from AP to AP during an active call, the voice-packet stream is subject to a bursty packet loss. This packet loss has a more detrimental impact on voice quality than uniform packet loss. To minimize the impact of bursty packet loss, roaming time should be below 50 ms.

Figure 2
2. The PESQ method of determining signal quality relies on comparing the distorted voice signal at the listening device to the clean reference signal at the sending device. The PESQ score of 1 to 5 is the same as the MOS score.

Figure 3

MOS vs. R-factor

3. The R-factor quality indicator ranges from 1 to 100. It is convertible to the MOS score of 1 to 5. The ITU-T G.107 document specifies how an R-factor can be converted to a MOS score.

Figure 4
4. A cabled Wi-Fi test methodology involves placing devices under test into shielded and filtered enclosures. Through these enclosures, they connect to a test network composed of RF combiners, programmable attenuators, and switches. To exercise the full dynamic range of 802.11 radios, the cabled RF environment must have isolation of at least 110 dB among devices in the test setup. To achieve these levels of isolation, test heads must filter Ethernet, serial, and RF connections to the devices.

Figure 5
5. The call-capacity test increases the number of calls going through the infrastructure in a controlled way. At the same time, it varies the background traffic load. The test measures and plots delay, jitter, and packet loss on each active call. It then computes the MOS voice-quality metric for each call. In this example, the MOS voice-quality score of an AP under test starts to drop off with more than 10 active calls.

6. In this handset-roaming test configuration, one set of attenuators is initially programmed to minimum while the other is set to maximum. As a result, the handset receives a strong signal from AP1 but does not see AP2. The handset associates with AP1. Then, the attenuators between AP1 and the handset are gradually increased, eventually moving AP1 out of range of the handset. At the same time, the attenuators between the handset and AP2 are gradually decreased. AP2 is moved within range, forcing a roam.
Figure 7

7. The data collected during the test shows each phase of the roaming process. As AP1 is moved out of the handset’s range, the data rate of the handset transitions down (t_{trans}). When AP1 is completely out of range, the handset starts to scan for another AP (t_{scan}). We then measure the time that it takes to associate with AP2 (t_{roam}) and the time that it takes to resume data transitions (t_{data}). The roaming time (t_{roam}) is defined as the time between the last data packet before roam and the first data packet following the roam.

Figure 8

8. Handset range testing involves varying attenuation between the handset and the AP while measuring voice quality as a function of path loss. The MOS score can be obtained either using the PESQ method or by measuring packet loss, delay, and jitter statistics and then computing the R-factor. That factor can then be converted to MOS.
Marketplace

**CDNLive! Silicon Valley September 12-14, 2006**
Explore Cadence solutions while networking with your peers at the premiere Cadence Designer Network event of the year. For a limited time, the price of 1. Register today!

**Register for Expert Training at UL University**
Need help navigating safety standards or new regulations? UL University’s 1,500+ course list includes seminars on hazard-based safety and short-circuit current ratings. Visit UL University and sign up now for a workshop in your area.

**Feel like the microcontrollers you’re using are limiting?**
Need more performance and flexibility for your next application? Our AVR microcontrollers are here to help! Click here to receive the guide.

**Free Electronic Design Whitepapers for Design Engineers**
Get up to speed on the major issues facing Design Engineers today. These free, in-depth reports offer valuable insights on specific topics -- all in one concise and convenient PDF.

**Electronic Design Ebooks from National Semiconductor, Arrow, Keithley and more!**
Download a free Ebook from our library and stay up-to-date on current trends and technologies. Technical resources are compiled by Design and available for immediate download to your PC.

Sponsored Links

**Allen Bradley Super Mart**
New And Pre-Owned Huge Inventory 1 Year Warranty Free
[www.Tek-Supply.com](http://www.Tek-Supply.com)

**Embedded Industrial PCs**
Reliability leader, cost-effective unlimited support, stock & custom
[www.octagonsystems.com](http://www.octagonsystems.com)

**Microprocessors**
AMD vs. Intel - Get More Info About AMD's Proposed Dual-Core Duel
[www.amd.com/duel](http://www.amd.com/duel)

**PC/104 & PC/104+**
ET offers the broadest selection of PC/104 and PC/104+ connectors
[www.emulation.com/173](http://www.emulation.com/173)

*Planet EE Network Home | Contact Us | Editorial Calendar | Media Kit | Headlines | Site Feedback & Bugs*
*Copyright © 2006 Penton Media, Inc., All rights reserved. Legal | Privacy*