Next Generation Voice Testing

Glossary of Acronyms

WiMAX — World Interoperability for Microwave Access Standard
3GPP — Third Generation Partnership Project
AP — Access Points
ITU-T — International Telecommunications Union Standardization Sector
MOS — Mean Opinion Score
PESQ — Perceptual Evaluation of Speech Quality
QoS — Quality of Service
R — Rating, as in R-Factor, a transmission rating from 0 (worst) to 100 (best) involving noise, delay, loss and distortion.
SOHO — Small Office, Home Office
UMA — Unlicensed Mobile Access
VoIP — Voice over Internet Protocol
VoWi-Fi — Voice over Wi-Fi
WCC — Wi-Fi/Cellular Convergence
Wi-Fi — short for Wireless Fidelity, a name applied by the Wi-Fi Alliance and usually taken to mean any type of 802.11 network.

WLAN — Wireless Local Area Network

As cellular and Wi-Fi technologies converge, platforms such as VoIP and VoWi-Fi, along with Wi-Fi enabled handsets, will call for a new paradigm for voice testing in the unlicensed spectrum.

By Graham Celine

If you doubt that Wi-Fi and cellular technology are on the brink of convergence, look at the proliferation of new products and industry groups during the past 18 months. WLAN and enterprise voice vendors such as Cisco, Spectralink and Symbol offer voice-optimized Wi-Fi equipment, and SOHO VoIP players such as Vonage and Net2phone deliver residential-optimized Wi-Fi handsets to users. Cell phone vendors, including Motorola, Samsung and Nokia, have followed suit, releasing Wi-Fi-enabled mobile handsets.

In addition, mobile vendors and operators have spearheaded the formation of the WCC task group within the Wi-Fi Alliance to address the cellular industry's certification requirements for Wi-Fi-capable equipment. The industry also initiated UMA, an effort to specify expansion of the cellular network to Wi-Fi networks, enabling wireless devices to automatically select the best available network. UMA has been adopted by 3GPP, a group of standards bodies collaborating on 3G data capabilities.

While 20 year-old cellular technology — ancient by high-tech standards — is mature enough to interface with Wi-Fi, the real question is whether Wi-Fi is ready for cellular. Can the WLAN infrastructure, originally designed to transport best-effort data, support the 400 million Wi-Fi-enabled handsets[1] expected to be roaming among the world's Wi-Fi hotspots by 2009? And are these new handsets themselves ready for the complexities of the unlicensed spectrum and the array of Wi-Fi protocols?

Voice over Wi-Fi Requirements

First, a quick review of the technical requirements for WLANs carrying voice. When voice packets travel over a WLAN, they must arrive at their destination at regular time intervals (typically every 20 ms) to minimize distortion in the received voice signal. Packet loss, delay and jitter must be kept to a minimum, or the reduced quality of the voice signal will be interrupted or distorted, especially when the network is congested with traffic.

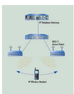

Figure 1. Wi-Fi protocols are designed to optimize packet loss, delay and jitter performance as the data signal travels through the handsets and the infrastructure. Roaming time between APs must be below 50 ms to minimize the bursts of packet loss that affect voice quality. Click here [1] to enlarge.

ITU-T[2] developed the G.107 standard to provide overall guidance for measuring voice quality on the Internet infrastructure, including the WLAN infrastructure of APs, switches and routers. Typically, to get acceptable quality voice, network delay should not exceed 500 ms, and packet loss should be less than 20%. However for a single AP wireless network, the guidelines translate into low latency (< 50 ms), jitter (< 5 ms) and packet loss (< 1%). Another significant parameter is roaming time from AP to AP, which must be low to avoid call disturbance or drop (< 50 ms — see Figure 1)

VoWi-Fi handset requirements for voice delivery are as important as network requirements. In addition to the identical performance requirements, the usability of a Wi-Fi handset is determined in part by the power consumption profile of the WLAN subsystem, which must be optimized for low power consumption in all operating modes to guarantee acceptable handset battery life. Voice traffic is sporadic, yet to receive incoming voice calls, the handset needs to maintain association with the WLAN network at all times. This requires rapid transition between multiple power saving modes, making the power optimization of WLAN handsets particularly challenging.

Protocols and Issues

For every Wi-Fi challenge, there’s a corresponding 802.11 protocol. To optimize VoWi-Fi, protocols must be designed to minimize packet loss, delay and jitter as the voice signal travels through the Wi-Fi infrastructure, consisting of APs, Ethernet switches, routers and gateways — both wired and wireless.

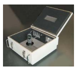
Figure 2.Click here [2] to enlarge.

IEEE has developed multiple 802.11 protocols for optimum VoWi-Fi quality. For example, 802.11e includes the QoS and Admission Control protocols. The 802.11e standard prioritizes voice over data traffic, providing higher priority access to specific traffic in the network and facilitating the provision of constant delay and low jitter. It also maintains a manageable number of simultaneous active calls. By managing the number of high priority users, 802.11e holds the system within the physical limitations of 802.11 and ensures that there is no oversubscription.

Roaming can cause performance problems. Bursts of packet loss may occur as the user moves around a site and the handset switches between APs. The fast roaming protocol, or 802.11r, provides a standard and efficient roam mechanism to the handset to guarantee smooth, fast roams in any network.

Security is critical to Wi-Fi networks, and intelligent security protocols such as 802.11i enhance the capabilities of Wi-Fi systems. To support faster roaming, 802.11i offers pre-authentication, which minimizes roaming time by authenticating the handset with neighboring APs before roaming. Finally, the radio resource measurement protocol (802.11k), an expected new addition to the standard, allows the handset to make fast roaming decisions by pre-discovering neighboring APs, their distances and call capacity.

This abundance of new and developing capabilities advances Wi-Fi to become a more robust protocol. Wi-Fi now theoretically has the functionality to deliver constant streams of traffic required today by VoIP and tomorrow by multimedia streaming. But as these changes are introduced to the system, the validation of the theory is critical to vendors and users alike. Is Wi-Fi able to efficiently and reliably deliver voice quality?

Controlled Test Networks

Measuring VoWi-Fi is about testing performance. The classic data performance measurement of b/s is replaced with a more complex measure of the reliability of the data stream and then calculated to the voice industry's standard quality measurement — MOS, as defined in the ITU-P.800 Telephone Transmission Quality specification. Proper testing of Wi-Fi-compatible handsets and voice-enabled WLAN infrastructure should verify adherence to appropriate protocols and measure performance, including packet loss, delay and jitter, in a controlled and repeatable manner.

Traditional open-air testing of Wi-Fi infrastructure, handsets and systems is difficult because it's expensive, time-consuming and physically challenging to perform tests on handsets in motion. But most important, the results are neither error-proof nor repeatable.

Many product developers, service providers and test labs circumvent open-air testing with a different approach that guarantees a consistently repeatable test scenario and therefore, more useful results. Handsets, APs and other wireless devices are placed in specialized mini-isolation chambers and cabled to a network of programmable RF attenuators, combiners and switches that provide accurate, automated emulation of device motion relative to other clients and APs installed in the system (see Figure 2).

With a cabled test network, devices under test can be accurately controlled. Single or multiple devices can be introduced to the test, and the behavior of each device can be programmatically controlled to create both typical network conditions and worst-case scenarios. The devices can be "moved" and "positioned" by software, which can also simulate situations such as different amounts and types of network traffic and varying channel conditions. Test scripts to simplify the testing of compliance to voice-enabling protocols such as fast roaming (802.11r), radio resource measurements (802.11k), pre-authentication (802.11i), QoS (802.11e) and others replace ad-hoc walk around testing.

Testing One, Two, Three…

To the user, measuring compliance or packet jitter is important, but difficult to correlate to the end need: reliable VoWi-Fi. Testing the VoWi-Fi system — with tests and measurements that analyze and interpret critical parameters and put them into application context — is invaluable. Testing VoWi-Fi devices can be segmented into three categories: infrastructure tests, handset tests and system tests.

Infrastructure tests— The objective of testing infrastructure is to characterize its ability to support VoIP in the wireless network. Testing must be conducted on the specific components of the WLAN infrastructure, including APs, switches and routers. The infrastructure tests should measure the ability of the devices to forward and prioritize voice traffic in the presence of background data traffic.

Figure 3a. Click here [3] to enlarge.

Figures 3a and 3b illustrate an infrastructure test that measures voice quality as a function of call load and background traffic. The test includes two Wi-Fi client emulators for simulation of traffic from multiple Wi-Fi handsets or other devices. To prioritize calls over the background traffic, the client emulators must support the 802.11e QoS protocol. While sending traffic, the client emulators can measure forwarding rate, packet loss, delay and jitter on the packet streams going through the infrastructure under test.

Call capacity is measured by having Emulator 1 deliver multiple voice calls, each generating a voice packet stream, while Emulator 2 simulates typical background traffic expected from conventional PC clients and wireless users.

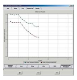

Figure 3b. Click here [6] to enlarge.

In addition, WLAN infrastructure components should be tested for conformance to 802.11 protocols and compliance with the Wi-Fi Alliance certification process.

Handset tests— In Wi-Fi networks, handset capabilities have a significant effect on network capabilities. Because the handset is an active participant in the protocol and the voice call, it is vital to evaluate handset performance. Wi-Fi enabled handsets must be tested for roaming performance, voice quality and power consumption. As with individual infrastructure components, handsets should also be tested for conformance to 802.11 protocols and the Wi-Fi Alliance certification process. The most important handset tests measure roaming time and the effects of the roaming on call integrity.

Handset Roaming Test

For WLANs carrying voice traffic, performance while roaming is critical — because in busy WLANs with high densities of APs, roaming can occur every few seconds for a moving user. A roaming Wi-Fi handset stops communicating through the source AP and begins communicating through the destination AP, a process causing bursts of lost packets that can have a negative impact on voice quality. IEEE and the Wi-Fi Alliance are discussing a 50 ms limit on roaming time.

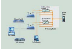

Figure 4. Click here [5] to enlarge.

Roaming time and roaming behavior of the handset must be measured and analyzed. As shown in Figures 4, 5 and 6, the handset is connected between two APs via programmable attenuators. As the attenuators are varied, the handset is forced to roam in a controlled way from one AP to another. Data collection is performed on the source and destination channel simultaneously.

System tests— When the handset and AP are linked and multiple APs and handsets are joined, the performance of the system begins to take shape. Clarifying the capabilities of the individual components ensures that they "play well together" in the system. Multi-AP systems must be tested to ensure their robustness as well as the interoperability of equipment from multiple vendors. Complex systems must be verified to ensure proper behavior and performance in heavy use conditions, including multiple roaming handsets and controlled background traffic.

One important test for the system is range. This test examines the ability of the handset and AP to coordinate traffic upstream and downstream and to rate adapt and range while maintaining best-performance voice quality.

VoWi-Fi Range vs. Voice Quality

To qualify a Wi-Fi handset or the voice quality of a pair of access points, the operating range must be measured under controlled conditions while attenuation is varied between the handset and the AP. Shown in Figure 7, the range test configuration is a subset of the roaming test configuration.

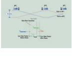

Figure 5. Click here [6] to enlarge.

The test results can be highly granular, examining packet loss, delay and jitter of the traffic, which can be used to compute the R-factor and MOS score. In addition, detailed analysis of the handset and AP rate adaptation behavior validates that both are behaving as expected as signal strength decreases and packet errors increase.

Using a controlled, cabled test environment, system tests are performed in an environment that allows for motion and roaming to be simulated without RF interference. Device behavior under heavy traffic load is easier to monitor and analyze. In this type of environment, a system under test can be pushed to its limits by simulating multiple active clients — actual devices in the test bed can be supplemented by call and data client emulation.

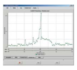

Figure 6.Click here [7] to enlarge.

Summary

Cellular and Wi-Fi technologies are on track to converge, but success depends on how well data-oriented WLANs carry voice — not on how well cell networks transmit data. QoS, roaming, power optimization and other demanding requirements of the Wi-Fi voice application have resulted in a number of 802.11 protocols from the IEEE. But the complications of the protocols suggest that the only way to ensure the success of converged cell/Wi-Fi technologies is by thorough, accurate and repeatable testing in a controlled environment.

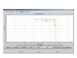

Figure 7.Click here [8] to enlarge.

About the Author

Graham Celine is Senior Director of Marketing for Azimuth Systems, a vendor of wireless LAN test equipment in Acton, MA.

Footnotes

1. ON World, April 2004

2. ITU-T is the United Nations telecommunications standards organization publishing standards for voice quality.

3. The MOS (mean opinion score) is based on the ITU R-factor and conversion from R-factor to MOS, based on the ITU-T G.107 standard.

Links:
[1] http://www.wirelessdesignmag.com/sites/wirelessdesignmag.com/files/legacyimages/0509/wd59f2_1_lrg.jpg
[2] http://www.wirelessdesignmag.com/sites/wirelessdesignmag.com/files/legacyimages/0509/wd59f2_2_lrg.jpg
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