BY RICHARD A QUINNELL • CONTRIBUTING TECHNICAL EDITOR

Wireless networking based on the IEEE 802.11 standards is poised for substantial growth in both the numbers of units and the range of their applications. The mobility inherent in wireless networks, however, creates interactions between the physical and the protocol layers that—compared with wired networks—greatly increase the complexity and number of tests necessary to verify a design. Fortunately, tools are becoming available to streamline the process.

The 802.11a/b/g standards, collectively known as WiFi (Wireless Fidelity), have engendered a large and growing market among home users, who are finding wireless a simpler alternative to Ethernet for sharing resources such as printers and broadband connections in their homes. In addition, business users that need mobile-computing capability are adopting the technology in droves. Public WLANs (wireless local-area networks), or "hot spots," are also increasing in popularity with both business and home users. The result: worldwide WiFi-equipment revenues of $737.6 million in the first quarter of 2005 alone, a 15% increase over the first quarter of 2004, according to market-research company In-Stat.

Although the adoption of WiFi in homes and businesses for computer access is still rising, new markets for the technology are poised to emerge. In-Stat is tracking promising applications, such as VOWLAN (voice over WLAN), the use of WiFi as a means of consumer-electronics connectivity, and the combination of VOWLAN with cellular telephones. Each represents a market that could match or exceed that of computer access.

DOUBLE-BARRELED

ADDING "WIRELESS" TO NETWORKING DOES MORE THAN CHANGE PHYSICAL-LAYER-TEST REQUIREMENTS; IT ADDS SYSTEM COMPLEXITY THAT NEEDS SIMULTANEOUS CONTROLLED TESTING OF MANY LAYERS.

The rise of these major markets could result in many designers facing for the first time the challenges of WLAN test. The challenges are significant, and designers' experience with more traditional cabled networking is an insufficient background for meeting them. WLAN is more than traditional networking with a radio-based physical-layer interface.

COMPLEX PROTOCOLS COMPLICATE TESTING

For one thing, the protocols are more complex, says Thomas Alexander, PhD, chief technology officer at VeriWave. He notes that many extra features in WLAN protocols address three aspects of wireless LANs that cabled networks lack: dynamic configuration, a spatial nature, and mobility. These aspects add to the complexity of wireless testing. The dynamic-configuration aspect of WiFi allows endpoint stations to query APs (access points) to gain network access and has APs announce the services they support. Although cabled networking has comparable functions, they are typically present in higher layer protocols. WiFi implements them at the MAC (media-access-control) layer. WiFi stations must also use "association" to determine which AP to use when several are avail-

WiFi TEST

AT A GLANCE

- The WiFi market is large and expanding into new applications, such as entertainment electronics and voice communications.
- WiFi uses more complex protocols and thus requires more extensive testing than cabled networking.
- The mobile, dynamic, and spatial characteristics of a wireless network force testing with combined RF- and data-test tools.
- To ensure repeatability, tests need shielded enclosures or Faraday cages to eliminate outside interference.
- Specialized tools for RF testing and system-environment emulation are becoming available.

able, and the APs must use "authentication" to determine whether the station is a valid user before granting access. Physically secure cabled connections need no authentication. A radio connection could come from someone parked down the block trying to get free Internet access.

The spatial nature of WiFi creates situations, such as "hidden nodes," that you don't find in cabled networks. In such situations, two stations can be in range of an AP yet not in range of each other. As a result, the two can repeatedly clash when trying to send messages to the AP because neither can detect the collision. Similarly, in cabled networks, careful design and installation can control the noise levels in the physical layer, and switches can segment the network into manageable groups. Designers of wireless-network devices, however, cannot assume a controlled environment. WiFi shares its frequency band with Bluetooth, portable phones, and microwave ovens, among other RF sources. Designers also cannot control the number of stations that may be actively attempting to reach an AP. The protocols must allow the network to simply adapt to the environment it finds.

The mobility aspect of WiFi also imposes functions on equipment and protocols that cabled networks don't need. One added function is that battery-operated stations may need power management to optimize power dissipation, such as by turning down transmitting power when close to an AP to save energy. One added protocol function is the ability to dynamically switch a station between APs during a transmission, similar in nature to cell-phone roaming. Another added protocol function is rate adaptation, the ability to adjust the signaling data rate based on the received signal power to optimize the overall channel performance.

Figure 1 Agilent's N4010A consolidates WiFi's RF test needs in a single package that handles all transmitter and receiver measurements.

LAYERS NOT FULLY SEPARABLE

Another complication arises beyond the more complex protocols, however. With cabled networks, engineers can independently test system layers and then simply combine the tested components to assemble a working system. Following the traditional network-testing model, testing of wireless-networking-device designs would have two major tasks. One task would be for digital and software engineers to evaluate the device from the network side by using protocol and logic analyzers. The other component would have RF engineers evaluate the radio section using vector-signal and spectrum analyzers along with signal generators, oscilloscopes, and other RF equipment.

But, the old adage "the whole is greater than the sum of its parts" applies in spades to testing WiFi product designs. The physical and protocol layers need not only independent testing, but also simultaneous testing to verify the proper operation of higher layers. This situation leads to a requirement for many pieces of equipment, both RF and digital, working in concert to create the necessary test conditions and measure the results.

Fortunately, RF-test-equipment vendors have been working to consolidate and automate some of the necessary

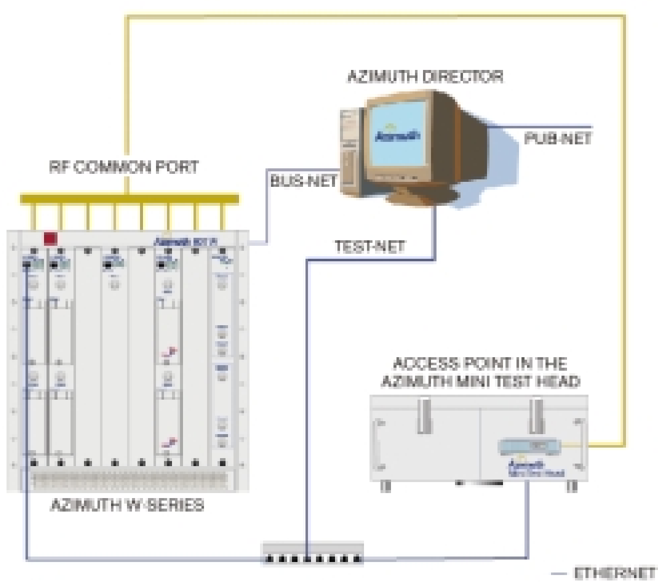

Figure 2 To emulate an entire WiFi network, the Azimuth Systems W-series test equipment provides a mix of WiFi signals under program control to the device under test.

equipment, and many such products emerged in mid-2004 to late 2004. Agilent Technologies created the N4010A wireless-connectivity test set, which uses software modules to implement signal- and vector-analysis functions, as well as signal generation, and to form a more self-contained RF-test package (**Figure 1**). Similarly, Anritsu Corp offers software for its spectrum analyzers to combine several WLAN RF-test abilities in one instrument. LitePoint Corp has IQView for testing WiFi transmitter and receiver functions. The company also offers IQWave software for creating custom signal waveforms with the instruments to test response to impaired waveforms. Most recently, National Instruments has entered the market with a PXI-based instrument package with its LabView development software and a software package from SeaSolve Software that runs physical-layer-compliance tests on WiFi-radio units.

Having covered the testing of the physical-layer components, it would seem that testing the higher layers would simply require digital pattern generators and protocol analyzers. But WiFi's complex protocols must handle the network's dynamic, spatial, and mobile natures, and equipment cannot simulate those parameters with a purely digital pattern. Engineers must test them using the RF link to exercise functions such as rate adaptation, hidden-node detection, and other signal-strength-dependent conditions.

The difficulty of WiFi testing emerges most strongly in this area. To provide repeatable tests, the DUT (device under test) needs a controlled stimulus. This requirement means at least testing the unit in a shielded enclosure to isolate the unit from stray signals. In addition, the stimulus signals must have controllable strengths, which involves the use of programmable attenuation. In addition, to simulate a full network configuration, multiple stimulus signals from independent sources must be present.

Figure 3 VeriWave's TestPoint products simulate WiFi stations and access points with the option of conducting cabled or open-air testing.

PROTOCOL TEST

Unfortunately, most of the RF-test instruments available directly stimulate the DUT with a single signal. Testing the device in a multisignal environment has required the use of many instruments. Coordinating the signals from these multiple instruments to create repeatable test conditions using a home-brewed test setup has been difficult at best. The test setup requires either using a complicated cabling scheme with manual calibration of each source to feed the DUT in a shielded enclosure or placing the entire test configuration in a Faraday cage, a metallic enclosure that prevents the entry or escape of an EM field, to gain repeatability.

Further complicating the test setup, however, is the mobile aspect of WiFi. The tests must somehow replicate the movement of the DUT or the stimulus signals to fully exercise the unit. "The whole idea behind WiFi is mobility," says Ray Cronin, chief executive officer of Azimuth Systems. "You have to have a system that will test the effect of mobility on the quality of service."

Providing the means to generate multiple controlled stimulus signals, along with simulating the effects of mobility by using programmable attenuation, has been the focus of companies such as Azimuth, Ixia, and VeriWave. All of these companies have products that provide protocol analysis as well as allow the coordinated generation of multiple test signals for evaluating WLAN devices under a wide range of conditions.

The companies have different approaches to the testing, however. The Azimuth W-series test platform provides a shielded enclosure for the DUT, feeding it controlled signals through a cable system (**Figure 2**). The test signals come from a bank of generator modules under the common control of a computer system that specifies the function of each module, coordinates signal activity, and manages the combination of the RF outputs using programmable attenuators. This approach allows the system to mimic a variety of traffic patterns and signal conditions, including roaming, in a repeatable configuration without the need for a shielded room.

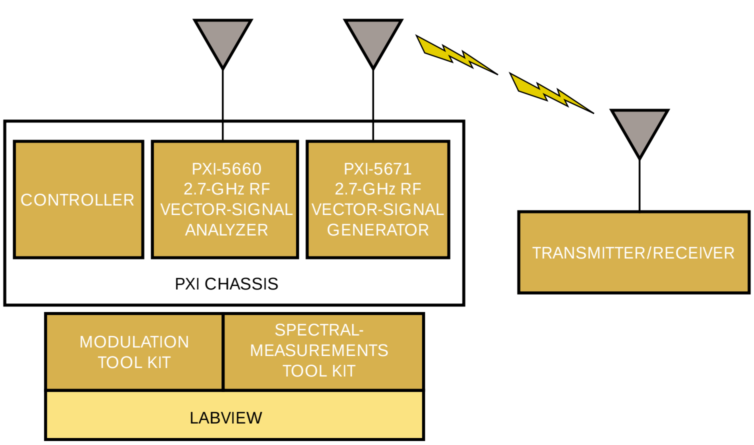

Figure 4 National Instruments has developed a PXI-based WiFi RF-test platform with software-controlled conformance testing.

Testing a WiFi design requires a combination of RF- and data-level test equipment that designers must use together to fully exercise the protocols (courtesy Agilent Technologies).

The Ixia IxWLAN and VeriWave WaveTest systems allow both a cabled and an open-air approach (Figure 3). The systems feature synchronized control of numerous test-stimulus devices to generate the network signals and offer control of both the transmitting power and receiver thresholds of the test-stimulus devices to handle spatial relationships. The systems can work in a cabled configuration, in a Faraday cage, or in an open-air field environment. The VeriWave system can also capture signals in the field for later playback under laboratory conditions.

A key attribute of all three systems is their scalability. They allow the creation of test setups that can mimic dozens of access points with hundreds of stations, all under automated control. This approach allows for testing of designs against the crowded conditions users are likely to find in actual installations as well as the measurement of system performance under such conditions. The tests can thus help system administrators plan their installations to optimize throughput.

Another key attribute of these systems is the level of automation they provide. Development teams can outfit these systems with vendor-provided software that implements a complete compliance-test suite using the system. Running these test suites does not provide design certification but does assure development teams that their designs will achieve certification.

Such protocol test systems help round out the testing of WiFi devices by addressing network issues during the test. They do not, however, provide measurement of the RF parameters, although the WaveTest system can generate triggering signals to RF-test equipment to coordinate such measurements. Test engineers must test the RF portion and the data portions separately. WiFi testing may be consolidating its tools, but some two-step procedures still occur.

TEST SYSTEMS LAG

That two-step dance is likely to continue for some time. As Azimuth's Cronin points out, "A new technology evolves ahead of the test technology to support it." In the case of WiFi, the technology is still evolving. In addition to versions a, b, and g, new versions of the 802.11 standard are in development. The 802.11q standard, for instance, allows the mapping of virtual LANs onto the wireless network. The 802.11i version adds new security protocols to the network to bolster the privacy of wireless connections. Another trend adds voice to the wireless networks, requiring controlled quality of service and timing.

To meet the ever-changing needs of WiFi designs is WiFi testing's ultimate

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challenge. Traditional hard-wired products are too slow to adapt to the rapidly changing technology. Today's wireless test equipment must be adaptable through software if there is to be any hope of keeping pace.

National Instruments is taking the programmability approach in its RF-test system (**Figure 4**), according to modular-instrument product manager Darcy Dement. "As technology evolves, so must the test," says Dement. "When the equipment is software-driven, it lets designers keep their tools in line with the changing standards. Having an open architecture, such as Matlab, also allows designers to get into the test parameters to customize them for their unique needs." Azimuth's Cronin agrees that programmability is key to test's keeping pace with changing standards. "Without the programmability built into tools such as ours, changes in the standards would put the onus on the developers to create their own ad hoc tools," says Cronin.

With complete system-test tools now available, automated RF testing, and tool programmability providing a path for tracking changes in the standards, developers are in a good position to embrace WiFi in their next designs. The test tools to exercise and validate designs are becoming more available—whether for game systems to talk with broadband connections, music players to send data to sound systems, or cell phones to switch from WANs to LANs. The presence of these standardized test tools can mean only more innovation and faster growth in wireless networking with less designer frustration.EDN

AUTHOR'S BIOGRAPHY

Contributing Technical Editor Rich Quinnell has been covering technology for more than 15 years. He has been a practicing engineer in embedded systems and has degrees in engineering and applied physics.

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Agilent Technologies
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