Wireless and Broadband Management for the Integrated Healthcare Network

David H. Hoglund

As the wireless mobility continuum continues to unfold in healthcare, it is becoming critical that disparate medical devices from all device companies share the overarching wireless local area network (WLAN) infrastructure. In addition, the voice and data requirements of new applications are demanding a neutral host environment; since the healthcare environment cannot always control the end user, a multi-carrier environment is needed.

The radiofrequency (RF) environment is a dynamic environment and spectral changes do occur due to electromagnetic interference (EMI) and other factors. Years ago, the main options were very high frequency (VHF) and ultra high frequency (UHF) medical telemetry. Now the wireless medical telemetry (WMTS) bands and 802.11a/b/g/n options are available. Other wireless frequency options include Zigbee for building automation, Bluetooth headsets, RF identification (RFID) and RF location systems (RFLS), and the proliferation of cellular/personal communication service (PCS) and public safety devices all converging onto the healthcare scene today.

This paper will explore two areas vital to healthcare facilities: 1) the correct test environment and design models for a WLAN infrastructure to support the quality of service requirements needed for a life critical wireless network; and 2) design considerations that will ensure the broadband requirements are met for the in-building wireless space.

Drivers of Change

Many forces are converging in today's wireless healthcare environment. Medical device companies are increasingly embedding 802.11a/b/g client adapters in devices like infusion care systems and patient monitors, giving them built-in wireless capabilities. A myriad of wireless medical devices like bar code medication administration systems and workstations on wheels are being deployed. How can these systems be deployed consistently in the healthcare environment to ensure application integrity? Healthcare network managers must accurately monitor

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this airspace to ensure consistency of signal strength and that the intended applications all work correctly.

Cellular use within the healthcare environment is now common, but concerns about electromagnetic interference remain. The standard ANSI/AAMI/ES60601-1-2, *Medical electrical equipment—Part 1-2: General requirements for basic safety and essential performance—Collateral standard: Electromagnetic compatibility—Requirements and tests* specifically addresses radiofrequency (RF) susceptibility. This standard offers a clear starting point to determine medical equipment susceptibility to interference. Some recent studies have shown that the potential for EMI from cellular voice and data devices is low, but that the value proposition of these devices for improvements in productivity are high. In its proceedings published in March 2007, the Mayo Clinic[1] concluded "… EMI is unlikely to occur in a hospital setting and … internal regulations in health care facilities should reflect that fact. Recommendations should also reiterate that the risk is not zero and that medical personnel should remain vigilant in order to detect and mitigate the uncommon occurrence of clinically relevant EMI of medical devices."

Quality of service expectations have been set by improving mobile communications experiences outside of buildings. Healthcare users are now demanding this same mobile experience whether in the operating room, hallways, or basement of the building. Options for expanding wireless cellular, PCS, and public safety coverage technologies into healthcare buildings must be carefully explored for benefits and potential problems. There is an expanding need to provide in-building distributed antenna system (DAS) coverage to enable mobility improvements. However, combining 802.11a/b/g onto a DAS is not always straightforward, and there is often a case for multi-carrier coverage as well as public safety coverage in such an in-building system. Healthcare network managers must proactively manage the wireless environment and all its different modalities—including 802.11a/b/g/n, WMTS, public safety coverage, cellular, and PCS—and be alert to any problems that are occurring in the network or with new technology deployments.

Ensuring Quality of Service: The Test Environment

Meeting quality of service requirements for medical devices on a wireless network is essential for success. To ensure this quality of service, application testing must be conducted. Quality of service simply means the expectation is that the communications link for a medical device on a wireless network should take precedence over any other data and voice traffic. But how do you actually ensure that the medical device within this network has priority, and who is going to take responsibility for ensuring the needed quality of service?

Network managers who want to use medical devices with embedded 802.11a/b/g/n radios on an enterprise WLAN face several challenges. For instance, how can they demonstrate that the actual device and application will be able to establish and maintain the connection under various circumstances to include perhaps poor coverage and different roaming situations? How can they evaluate the impact of numerous application traffic patterns and loads expected to run on the hospital's Wi-Fi network? Can they be confident that the medical device application is reliable in a real-world deployment?

Performance validation should include evaluation of the distance at which the medical device application will maintain a reliable connection. How will this application act in the presence of other traffic using the same access point? There should be a way to determine and analyze the application performance while roaming in a repeatable environment. Finally, there should be a way to generate service level agreement (SLA) reports providing detailed client results. SLAs can contain numerous service performance metrics with corresponding service level objectives.

Traditionally, accomplishing these goals required a lab environment. The traffic generating client devices such as Voice over Internet Protocol (VoIP) phones, client laptops, etc. had to be reproduced—no small task. In addition, scaling the number of devices to emulate a realistic hospital WLAN environment is challenging and difficult.

A potential solution that provides scaling and device emulation is now available from a company called VeriWave, based in Beaverton, OR (www.veriwave.com).[2] Another solution from Ixia, based in Calabasa, CA (www.ixiacom.com) has been used by enterprise customers to test VoIP performance. These test tools allow a virtual test environment to be developed and used in an isolated lab environment. They allow a consistent methodology and reproducible results that can ensure consistent deployments of medical device applications across the enterprise healthcare environment. The testing systems may create inconsistent traffic patterns to test realistic conditions, like traffic spikes. But the methods used are controlled and the results are reproducible and reflective of future performance in a live environment.

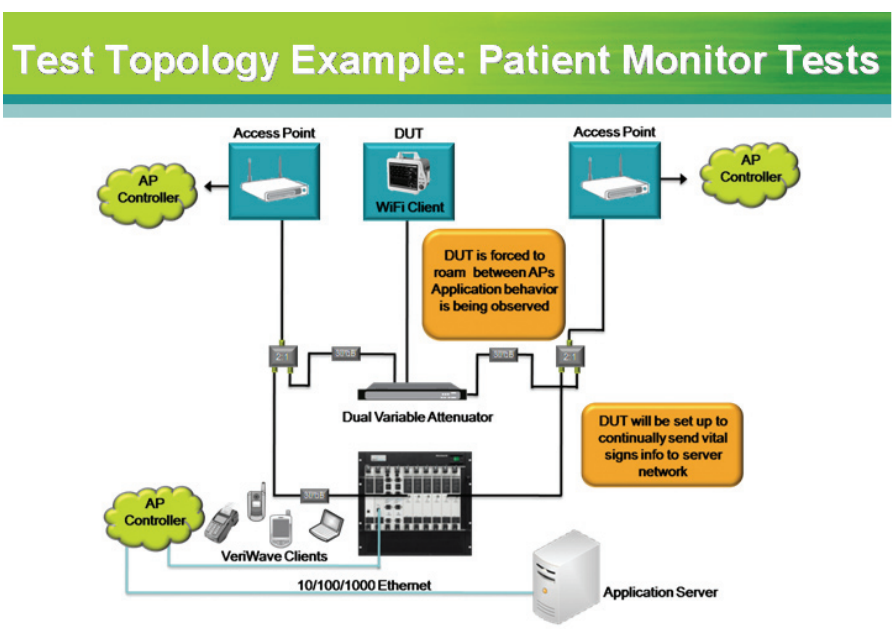

Figure 1. This image from VeriWave describes a device under testing (DUT), in this case a patient monitor set up in a virtual test environment to test roaming between wireless access points and performance and/or bandwidth loading scenarios.

At a minimum, testing criteria as per VeriWave guidelines should include the ability to provide up to 500 fully independent 802.11 client state machines per port to enable precise measurement of critical performance metrics. Complete client control should be provided over median access times to identify aggressive non-compliant clients and study the effects on the wireless access point and centralized wireless LAN controller for the management of the wireless access points (APs) as well as medical devices. Built-in transmit power attenuation and per packet frame error should be allowed that will emulate real-world distance between the AP and the client.

Test environments should allow the introduction of real-world effects such as hidden node issues that cause client collisions resulting in malformed packets to the AP. Finally, user customizable client behavior and traffic types ranging from raw 802.11 frames to a variety of IP-based higher level protocols should be provided.

Ensuring Quality of Service: Real-Time Spectrum Analysis

How do you ensure that the radiofrequency (RF) environment and wireless devices operate consistently and with a low propensity for drop-outs? Real time spectrum analysis is the key to success. Such spectrum analysis for wireless devices should include 2.4GHz and 5GHz, and why not WMTS bands?

It should be considered that the proverbial site survey is not a tool that can provide ongoing spectral analysis in real time, and only is focused on the 802.11a/b/g/n use models. The ability to spectrally monitor the WMTS bands is not provided today in off-the-shelf tools. The healthcare environment is probably the most RF challenged environment today, partly due to the structural characteristics, such as lead lined walls, old construction, fluids, a myriad of movable metal equipment, and just the mobility requirements to take care of patients. All of this significantly increases the propensity of "multipath" or drop out of the RF signal. Multipath is the propagation phenomenon that results in radio signals' reaching the receiving antenna by two or more paths. Having "real time" spectrum analysis would be a huge benefit for the wireless healthcare environment of today.

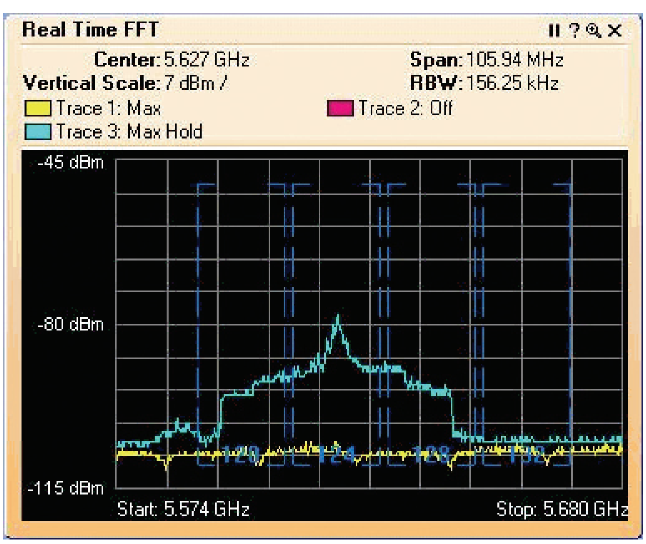

Figure 2. Cisco Spectrum Intelligence Solution showing real time FFT (Fast Fourier Transform).

Electromagnetic interference is an undesirable disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source. EMI may be broadly categorized into two types: narrowband and broadband. Narrowband interference usually arises from intentional transmissions, such as by radio and TV stations, pager transmitters, and cell phones; broadband interference usually comes from incidental radio frequency emitters, including electric power transmission lines, electric motors, thermostats, microwave ovens, bug zappers, and other devices. Anywhere electrical power is being turned off and on rapidly is a potential source of EMI.

The spectra of these sources generally resemble that of synchrotron sources, stronger at low frequencies and diminishing at higher frequencies. EMI noise is often modulated, or varied, by the creating device in some way. Examples include computers and other digital equipment, as well as televisions. The rich harmonic content of these devices means that they interfere over a very broad spectrum. One characteristic of broadband radiofrequency interference (RFI) is an inability to easily filter it effectively once it has entered a medical device's electronics. I have seen tremendous drop out of a VHF telemetry signal caused by a bad ballast in a fluorescent light and by an electric motor in a heating, ventilation, and air conditioning system.

To solve such problems, the RF engineer can bring out the Anritsu[3] (www.anritusu.com) or Tektronix (www.tektronix.com) spectrum analyzer to troubleshoot a potential RF issue, but these analyses are only as good as the time they are done.

Over the past year a company called Cognio[4], recently purchased by Cisco (www.cisco.com), has provided the first real-time 802.11a/b/g spectrum analyzer that can provide this pervasive 24x7x365 analysis in a small form that actually can be used in a laptop, making it a very cost effective solution. They also have provided a unique RFID analyzer as well. The ultimate goal would be to provide a spectrum analyzer real-time to cover all frequencies in the healthcare setting to include all the WMTS bands of 608–614MHz, 1395–1400MHz and 1429–1432MHz.

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Some of the best practices to follow include but are not limited to performing an initial full RF survey. The RF survey for WMTS should occur before the WMTS is installed. This is usually performed by the vendor so they can correctly install any needed filters for digital television (DTV). This should be done once before deployment or as a part of a post-deployment coverage sweep. The purpose would be to proactively discover any pre-existing problems, enable planning around known sources of interference, and establish an RF baseline. Periodic RF update surveys should be done once a year that will discover any new devices that have been added into the spectrum and compare to see any deviations from the RF baseline. Finally, it is important to establish, publish, and enforce a spectrum policy to define what is not allowed on the hospital premises.

Policies and procedures on the use of all wireless devices should be written and posted within the common patient care areas, public areas, and/or critical care areas. Policies that exist only in a policy manual are easily overlooked or ignored. Action items should be written at a user level, not a technical level. This will set the correct tone and use model for the clinical staff, the public, and patients/families. It is also the first step to mitigate any risks and to establish benchmarking for all new technologies entering the healthcare RF ecosystem thereafter. If you want any policy to work, teach medical staff how to gracefully enforce it.

Ensuring Signal Strength

What are the needs and requirements for consistent in-building cellular and public safety signal coverage in hospitals today? Ideally, digital signal processing and narrow band filtering should be used for obtaining quality cellular and PCS signals.

The selection of the overall macro in-building design is important, together with the correct selection of the individual components. Together these choices will provide secure mission critical or life critical communications for cellular, PCS, and public safety communications. There have traditionally been two ways to bring the cellular and PCS signals inside a building environment: a dedicated micro-cell base transmitter station (BTS) or a repeater.

Most healthcare environments can get by with a traditional repeater due to capacity requirements. It is important to go to the technology that can take the signal or multiple signals from the macro (outside environment), to repeat and amplify this signal inside the building environment. It is this critical piece at the front end that determines the value of the interplay of signals throughout. Carriers in some instances mandate digital repeaters, especially as far as the PCS band is concerned. They only want to be re-radiating their own spectrum. Many traditional in-building systems used broadband repeaters, which essentially amplified all carrier signals to include harmonics. The advantage of using digital repeaters is that they allow you to precisely control which frequencies you amplify and repeat. This actually provides better quality of signals without the risk of voice or data signal quality going down.

Figure 3. Pictured is a digital repeater designed for use within enclosed structures where sufficient signal strength from local cell sites to operate cell phone or data cards is limited or unavailable. Digital signal processing (DSP) is utilized to achieve the highest level of performance and spectrum agility. DSP filtering provides unmatched selectivity, which helps to overcome difficult RF problems such as adjacent channel interference.

Some broadband signal repeaters automatically take a broad range of frequencies and amplify all of them, including the undesired frequencies, such as harmonics and interfering frequencies. During a major emergency, often many first responders—ambulances, police, fire, and emergency medical technicians—could arrive at the healthcare facility at once and all could be trying to communicate at the same time. In this case the signal strength from a broadband signal repeater may decrease when it is most required. There have also been instances when broadband signal repeaters interfered with mission critical environments.

These situations should be mitigated as many public safety and P25 networks move to the new National Public Safety Planning Advisor Committee (NPSPAC) band 806-809/851-854MHz. How these changes affect you depends on which part of the country and which wave of re-banding you are located in.

Frequency agility is the key here. Frequency agility includes the ability to change filter configurations to support virtually any passband combination within a specific set of wireless frequencies. This agility solves the problem of rebanding or augmenting of existing channels requiring forklift repeater upgrades. Mitigation of adjacent channel interference should be provided by allowing the fine tuning of band edges to eliminate or mitigate adjacent band interferers. There should be the ability to provide custom filter sets and filter plots prior to implementations of distributed antenna systems.

Distributed Antenna Systems

Healthcare is actively looking to deploy distributed antenna systems to satisfy the mobility of this environment. There are many considerations involved in this process. Digital signal processing (DSP) provides the highest level of performance and spectrum agility. DSP filtering provides unmatched selectivity and allows for fine tuning to help overcome difficult RF problems such as adjacent channel interference. Some complain that DSP filters add delay, which can create problems as opposed to traditional analog amplifiers. Class A versus Class B repeaters provide ways to design around this. The digital repeater should permit re-tuning of multiple passband configurations, locally or remotely, with virtually no downtime. The repeater should support the Simple Network Management Protocol (SNMP), used in network management systems to monitor network-attached devices for conditions that warrant administrative attention.

What is important for the enterprise integrated delivery network management of the WLAN model as well as the broadband (cellular) and public safety wireless coverage model?

Many WLAN hardware vendors offer proprietary element management systems (EMS). An EMS is usually designed to enable network engineers to configure settings on the vendor's devices and to distribute software

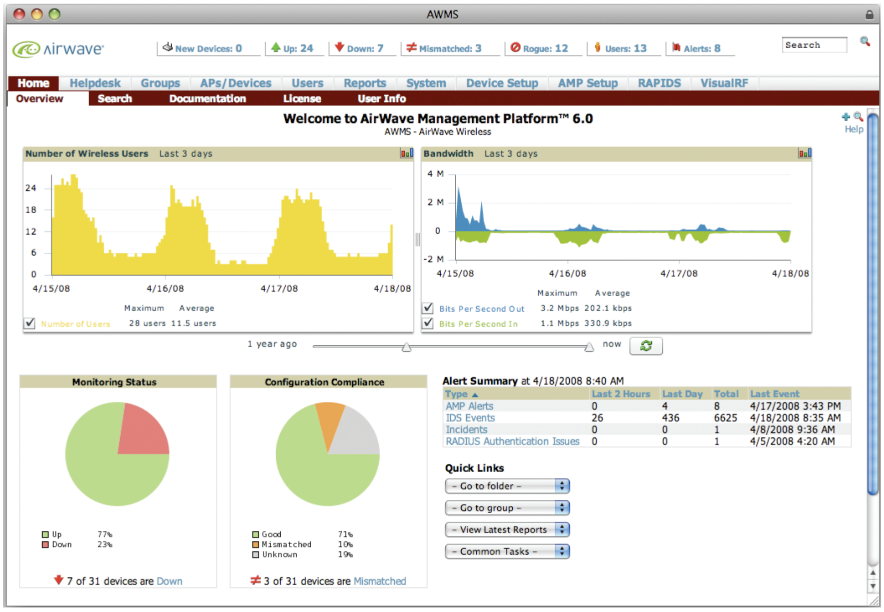

Figure 4. Airwave AMP™ (Airwave Management Platform). The AirWave Wireless Management Suite software offers you a single console from which to monitor, configure, and control your entire wireless network—whether you have 50 WiFi access points from a single vendor or 50,000 WiFi, mesh, and WiMax devices from a variety of different providers. The AirWave software enables intelligent lifecycle management for your wireless infrastructure, helping you extend the useful life of your legacy infrastructure even as you migrate to 802.11n and other critical new technologies.

updates. In contrast, an Operations Management Solution helps the whole IT organization (or network operations center [NOC] staff) control the entire wireless infrastructure to ensure reliable performance and deliver efficient support to wireless users.

When your wireless LAN was a small "best-effort" network, a proprietary EMS may have met your most basic needs. As your wireless network transforms into a mission critical network with thousands of users supported by multiple groups within the hospital, you will need an Operations Management Solution like the one from AirWave Wireless, based in San Mateo, CA (www.airwave.com), to deliver the secure and reliable performance your users require. In addition, any network management system for a distributed antenna system (DAS) should provide a common network management platform.

A Look Ahead

The "all-wireless enterprise" will not be implemented overnight using a single wireless technology, or even a single generation of products. Instead, wireless access will gradually penetrate all locations over a number of years, and in most cases will require use of multiple wireless technologies to provide cost-effective coverage. Few organizations have the budget or need to implement wall-to-wall wireless in all locations simultaneously. Instead, they deploy first in the locations where the benefits of mobility and the wireless return on investment are the most clear cut. Additional coverage is then added according to user demand and business need.

In large organizations, this organic process may take many years, spanning multiple generations of wireless technology, from thick APs to thin, from 802.11b,g to 802.11a and finally to 802.11n. The wireless infrastructure used in the initial phases of the rollout may no longer even be supported or sold by the hardware vendor by the time the project is complete. An IT organization must have the flexibility to take advantage of the best new technologies as they are introduced, but cannot afford to "rip and replace" existing infrastructure with every new innovation. Similarly, in a rapidly changing market, IT cannot risk tying itself exclusively to any single hardware vendor or product line. Yet, neither can IT afford the time and expense of training all staff members to use separate management consoles for each vendor and for each generation of technology. Instead, organizations need a multi-layered management strategy that enables them to control complex, heterogeneous networks across their entire lifecycle—driving down support costs while extending the useful life of the network infrastructure.

> "Proactively managing the wireless spectrum, following industry best practices, and keeping up with the latest technologies are keys to success in this rapidly-changing environment.

Conclusion

Consistently deploying the myriad wireless medical devices being introduced into today's healthcare environment to ensure application integrity requires that the healthcare network manager must accurately monitor the airspace to ensure consistency of signal strength. The correct test environment and design models for both the WLAN infrastructure and broadband system are essential. Proactively managing the wireless spectrum, following industry best practices, and keeping up with the latest technologies are keys to success in this rapidly-changing environment. ■

References

1. "Safety While Swimming in a Sea of Energy," Mayo Clinic Proceedings. March 2007;82(3):276-278. www.mayoclinicproceedings.com.
2. Evaluating Patient Vital Signs Monitor System (PVMS) using Veriwave's Test System, available online at http://www.veriwave.com/products/WaveClient.asp
3. Guide to Spectrum Analyzers, available on online at http://www.us.anritsu.com/sitesearch/default.aspx?site=us_www_downloads_whitepaper&psite=us_www_downloads&q=MS2687B&filter=p.
4. Cisco prepares to go deep with Cognio, available at http://www.wi-fiplanet.com/news/article.php/3701791.

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What is 802.11?

IEEE 802.11 is a set of standards for wireless local area network (WLAN) computer communication, developed by the IEEE LAN/MAN Standards Committee (IEEE 802) in the 5 GHz and 2.4 GHz public spectrum bands. Although the terms *802.11* and *WIFI* are often used interchangeably, the WIFI Alliance uses the term WIFI to define a slightly different set of overlapping standards. In some cases, market demand has led the WIFI Alliance to begin certifying products before amendments to the 802.11 standard are complete.

Source: "Wireless Technology Infrastructure: A Business Strategy" by David Hoglund, BI&T Nov/Dec 2007, page 458.

A Guide to Networking Terms

EMI
Electromagnetic interference (or EMI, also called radio frequency interference or RFI) is a (usually undesirable) disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit.

PCS
Personal Communications Service or PCS is the name for the 1900 MHz radio band used for digital mobile phone services in Canada, Mexico and the United States.

BTS
The Base Transceiver Station, or BTS, contains the equipment for transmitting and receiving of radio signals (transceivers), antennas, and equipment for encrypting and decrypting communications with the Base Station Controller (BSC).

Repeater
A cellular repeater, cell phone repeater, or wireless cellular signal booster, a type of bi-directional amplifier (BDA) as commonly named in the wireless telecommunications industry, is a device used to boost the cell phone reception to the local area by the usage of a reception antenna, a signal amplifier and an internal rebroadcast antenna.

P25
Project 25 (P25) or APCO-25 refers to a suite of standards for digital radio communications for use by federal, state/province and local public safety agencies in North America to enable them to communicate with other agencies and mutual aid response teams in emergencies.

GSM
GSM (Global System for Mobile communications: originally from Groupe Spécial Mobile) is the most popular standard for mobile phones in the world. GSM is used by over 3 billion people across more than 212 countries and territories. Its ubiquity makes international roaming very common between mobile phone operators, enabling subscribers to use their phones in many parts of the world.

UMTS
Universal Mobile Telecommunications System (UMTS) is one of the third-generation (3G) cell phone technologies, which is also being developed into a 4G technology.

WMTS
Wireless Medical Telemetry Service (WMTS) refers to certain frequencies set aside by the FCC for wireless medical telemetry.