

Distributed Antenna Systems for Healthcare

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Just as the use of wireless local area networks (LANs) is exploding in healthcare, so is the use of mobile phones, broadband adapters for laptops, and handhelds such as Blackberries and iPhones. A new era has arrived whereby physicians, patients, and their families are demanding to use these devices in the hospital. Hospitals often require coverage for other services as well, such as in-house mobile radios, paging and emergency responders. Typically the healthcare customer wants in-building wireless coverage from all carriers and frequencies. A distributed antenna system (DAS) is one option for providing such coverage.

Many forces are driving this trend toward wireless communication. New ordinances are being enacted in the United States that require pervasive first responder coverage for new building construction. The City of Burbank, CA was the first jurisdiction to require such public safety coverage, and in that city a Certificate of Occupancy will not be issued to any structure if the building fails to offer adequate coverage. Physicians increasingly need to stay in constant communication via either their cell phone, Blackberry, or a similar converged device like the iPhone. Patients and their families also demand that their devices work. Wireless medical device applications are also coming online in such areas as telemetry, transport, and infusion pumps.

Hospitals notoriously are some of the worst environments for radiofrequency (RF) coverage. Due to the age of buildings and the use of lead-lined rooms, tile

walls, fluids and lots of metal, they are challenged with multi-path—an RF signal propagation phenomenon that results in signals reaching the receiving antenna by two or more paths, causing interference with and fading of signals. Poured concrete pan construction of new hospitals also tends to keep signals out, and the reflective glass that is designed to increase energy efficiency by keeping heat and cooling from leaving the building also tends to keep cellular signals from penetrating into the building environment.

Distributed antenna systems are proving effective at meeting the need for multi-carrier, multi-frequency coverage in the hospital environment. DAS systems were intended for broadband coverage, that is, in-building cellular, public safety, and Personal Communications Service (PCS) coverage. (PCS is the name for the 1900 MHz radio band used for digital mobile phone services in Canada, Mexico and the United States.) That has been their intended use model.

Today there is a movement to expand this use model to include other medical applications. Yet, this technology is relatively new in the hospital environment. A team of healthcare professionals—including representation from information technology, clinical engineering, facilities, and executive management—needs to carefully evaluate the risks and benefits of this technology in a particular healthcare environment prior to implementation. This article will offer an overview of DAS systems and a discussion of the risks and benefits of such systems in the healthcare environment.



ABOUT THE AUTHOR

David H. Hoglund is the principal and founder of Integra Systems, Inc. His core business practice revolves around improvements in mobility communications, work flow, and automation process, coupled to productivity through all the aspects of wireless technologies. He has worked extensively with distributed antenna systems with a variety of

clients. Integra Systems, Inc. provides strategic planning for these technologies.

What is a Distributed Antenna System?

A distributed antenna system (DAS) is a network of spatially separated antenna nodes connected to a common source via a transport medium that provides wireless service within a geographic area or structure (see Figure 1). A DAS uses fiber optic cable, coaxial cable, and antennas to enhance public safety, cellular, and other signals within a building environment. Hospitals find them valuable because the construction of many hospitals impedes the

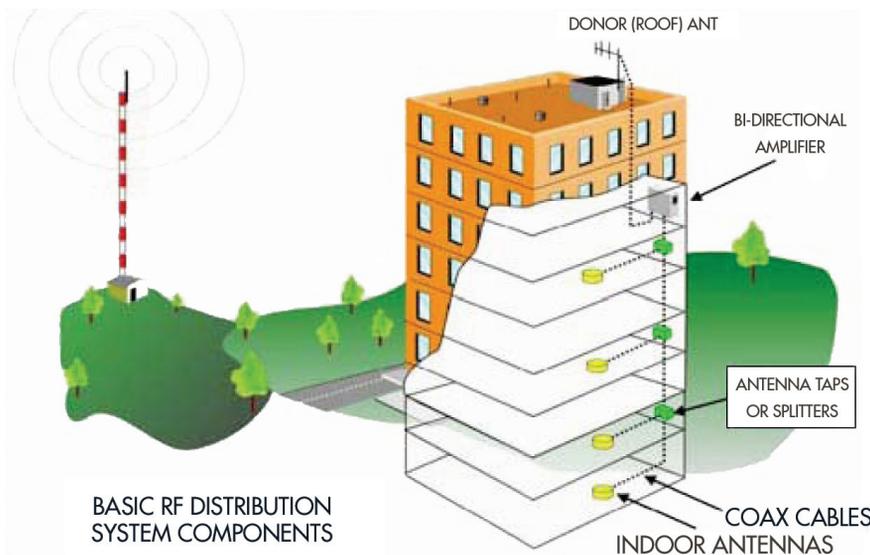


Figure 1. A typical distributed antenna system shown from a high level.

ability for public safety and cellular signals to penetrate the building. For example, a DAS will enable the public safety signal to be enhanced to a signal strength of -85 dBm, while providing up to 90% coverage in any building environment, which is now often a requirement in new building construction.

A DAS uses a repeater on top of a building to retrieve the multiple carrier, PCS and/or public safety signals. A repeater is an electronic device that receives a signal and retransmits it at a higher level and/or higher power, or onto the other side of an obstruction, so that the signal can cover longer distances. A DAS system then distributes the signals throughout the building through one of two designs: passive or active. Passive DAS systems use a coaxial cable with antennas as end points to distribute the signals. Alternatively, in an active design, the signals can be converted to optical light and carried vertically via fiber optic cable through the building floor plate. In this design the signals are then converted back to RF signals and distributed on each respective floor via a coaxial cable and antenna design.

Depending upon the size of the implementation, most DAS systems use either a Bi-Directional Amplifier (BDA) or a Base Transceiver Station (BTS). A BDA is a device used to boost the cell phone reception to the local area by the using a reception antenna, a signal amplifier and an internal rebroadcast antenna. These are similar to the cellular broadcast towers that network providers use to broadcast signals, but are much smaller, usually intended for use by one building. A BTS is more typically used in areas like an airport or stadium where huge numbers of

users might overwhelm a cell site. In most hospital environments a typical BDA is sufficient.

Passive Versus Active DAS Design

The size of the desired coverage area is the key factor in deciding whether a passive or active DAS design is needed. Generally speaking, in smaller coverage areas (under 200,000 sq. ft.), passive designs are adequate, but in larger areas over 200,000 sq. ft., from a coverage, link budget, and cost standpoint, it makes more sense to use an active system.

A passive DAS, which is less expensive and easier to install, uses no amplification (see Figure 2). With no power to amplify the signals, the 200,000 sq. ft. range is the limit at which you can achieve the required -85 dBm (five bars) on the mobile device. An active system uses power to amplify signals and is, of course, more expensive and more complicated to install (see Figure 3).

When designing a DAS, the existing and potential construction model and also building materials will dictate the actual design and signal propagation. Thus a site survey combined with a signal propagation model will need to be completed. The leading manufacturer of an in-building propagation modeling tool is iBwave Solutions, Inc. (Quebec, Canada, www.ibwave.com). An image of the building layout in computer-aided design (CAD) or PDF format can be imported into this tool, which has a library of building materials such as walls, lead-lined, reflective windows, etc. Once these are noted on the design, the software can actually model the signal strength and create a BOM (Bill of Materials), along with the actual design for the specific building environment.

Financing the Indoor DAS

In some business models with dedicated carrier contracts, carriers will sometimes fund the installation of DAS systems to support their frequencies. Carriers simply make a financial decision, calculating the number of units times the average revenue per unit times the term of the contract, to offset the cost of the DAS. The carriers should always be approached to see what role they will play. They will sometimes fund some or part of

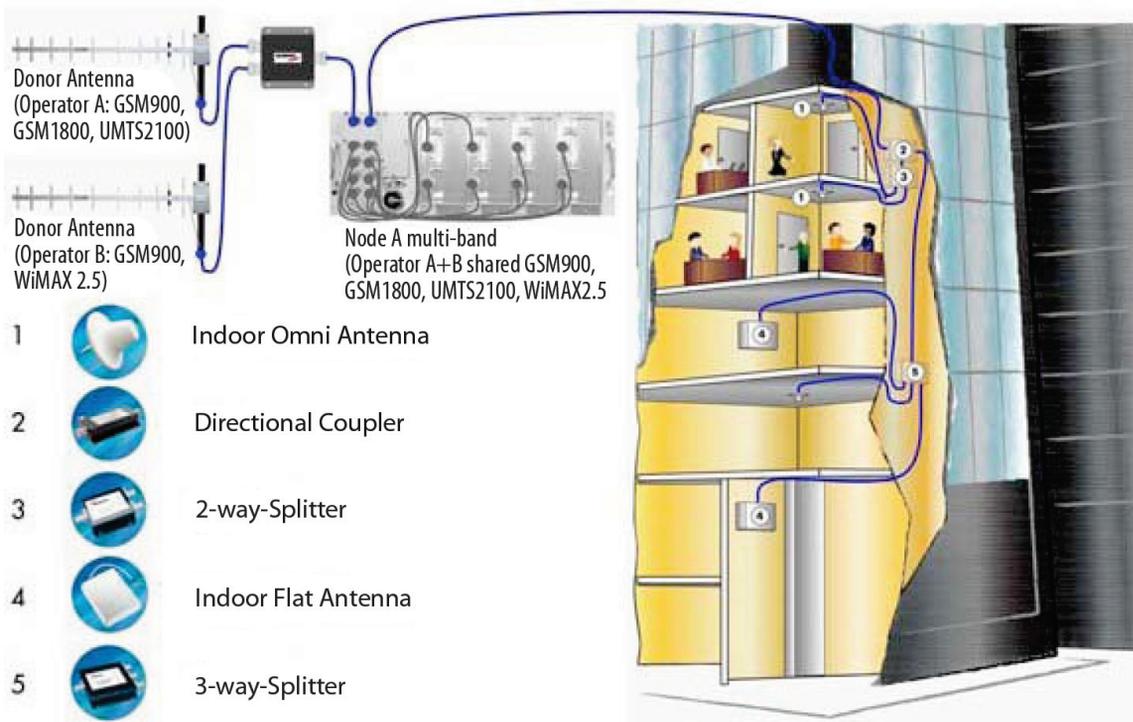


Figure 2. A typical passive design for a distributed antenna system.

Bi-Directional Amplifiers with Antennas that obtain Cell, PCS, Public Safety Sources. Located on the top of the building.

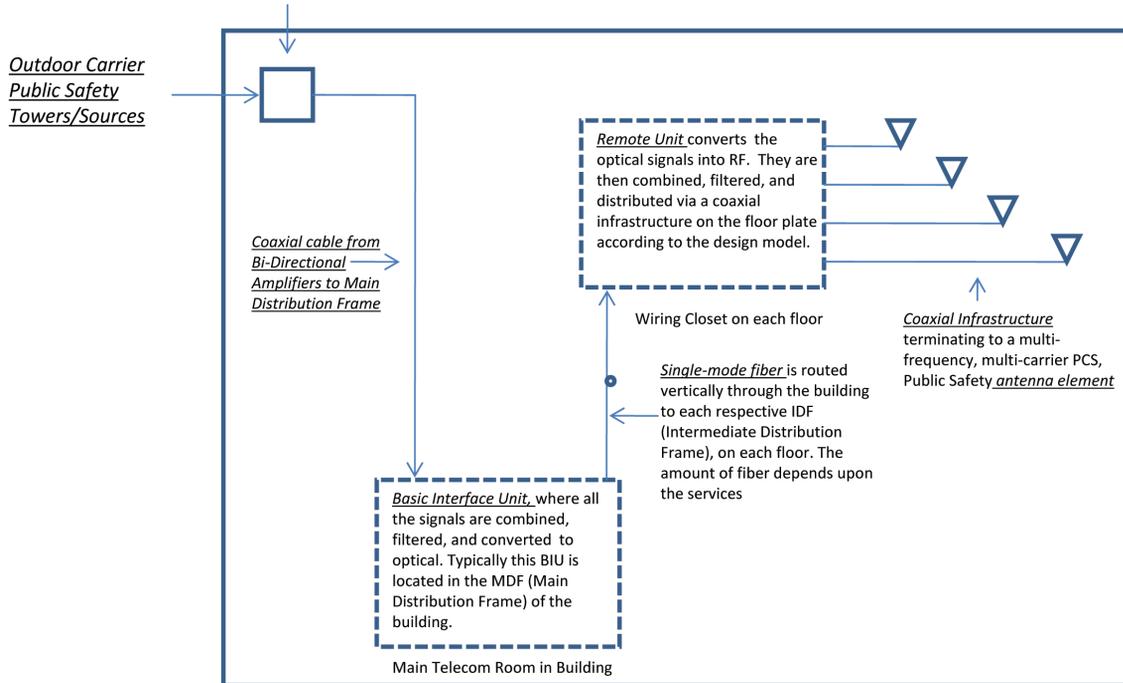


Figure 3. This diagram shows in a simplified format how the signals from the carriers are received by an antenna and amplified in an active DAS. The signals are first filtered and converted to an optical transport, then distributed throughout the building. On each floor the signals are converted back to RF and transmitted via a coaxial cable infrastructure. At the end of this coaxial cable infrastructure, one antenna acts to provide uniform and consistent coverage in a general area of 20,000 square feet.

the DAS, simply because they want to ensure quality of their service. Sometimes hospitals may simply fund the entire DAS themselves and then approach the carrier and charge them for access. Healthcare systems should explore different models by discussing these issues up front with specific carriers.

The carriers will of course only fund those systems on which they can actually make money. For this reason, the carrier-funded model generally does not work in healthcare, since the hospital does not represent a central purchasing point for a large number of mobile devices. Hospitals do not control patients, visitors, and sometimes not even physicians or employees. The problems with signal propagation in hospital environments discussed earlier also make it more expensive to provide coverage than in, for example, hospitality, higher education and commercial applications.

Therefore, healthcare facilities typically have to fund the cost of DAS systems without help from carriers. The costs to implement DAS solutions include planning, propagation modeling, design, project management, carrier negotiations, materials, installation, and commissioning (meaning turning on and testing) and ongoing support and maintenance. Generally speaking it makes good business sense today to implement a DAS where needed, with careful evaluation of several key considerations outlined below.

Why should hospitals invest in this technology? It is the author's opinion that multi-carrier communication will be a requirement in healthcare, not an option. Since healthcare is one of the most intense communication environments, it will become mandatory for pervasive public safety, first responder, and overall cellular voice and data coverage.

System Design Considerations

When designing the system, many calculations need to be taken into account, including the forward link budget (downlink) and the reverse link budget (uplink). The downlink is the signal coming from the tower to the mobile devices inside the building. The uplink is the signal from the mobile device back to the cellular site (outside).

A link budget (see Figure 4) is the accounting of all of

What is Wi-Fi and 802.11?

IEEE 802.11 is a set of standards carrying out wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. They are implemented by the IEEE Local Area Network (LAN)/Metropolitan Area Network (MAN) Standards Committee (IEEE 802). The Wi-Fi Alliance is a nonprofit international association formed in 1999 to certify interoperability of wireless Local Area Network products based on the IEEE standards. Although the terms 802.11 and Wi-Fi are often used interchangeably, the term Wi-Fi is trademarked by the Wi-Fi Alliance.

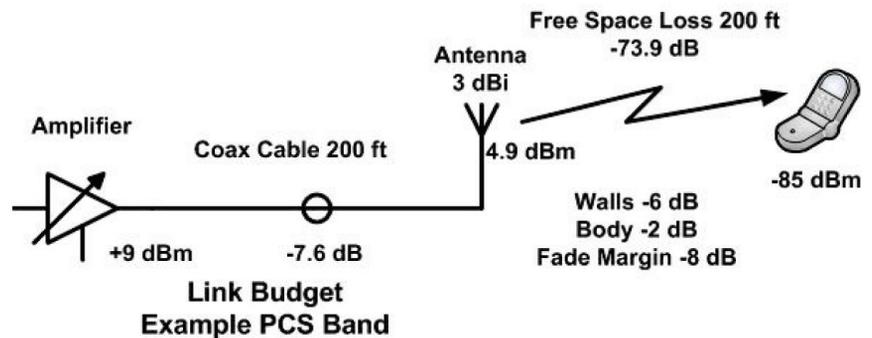


Figure 4. Diagram of a typical link budget.

the gains and losses from the transmitter, through a medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunications system. It accounts for the attenuation of the transmitted signal due to propagation, as well as the antenna gains, feedline, and miscellaneous losses. A simple link budget equation looks like this:

$$\text{Received Power(dBm)} = \text{Transmitted Power(dBm)} + \text{Gains(dB)} - \text{Losses(dB)}$$

Note that decibels are logarithmic measurements, so adding decibels is equivalent to multiplying the actual numeric ratios.

Challenges of Multiple Service Offerings on a DAS

Originally, distributed antenna systems were designed to propagate signals up to the frequency of 1900 MHz. Their purpose was to distribute cellular, PCS, and public safety signals. However, in the past five years, DAS developers have tried to broaden the market for their systems by converging additional wireless services onto their systems, including cellular, PCS, two-way radios,

paging, Wi-Fi (data on an 802.11 system, see sidebar on page 35), and wireless medical telemetry systems (WMTS).

Adding services such as Wi-Fi and WMTS to a DAS system creates several challenges that must be factored into system design, including the laws of physics and the pesky link budget. Traditionally, DAS systems were designed for in-building cellular and PCS distribution to a signal strength of -85 dBm, in lay terms five bars on the mobile device. Connecting Wi-Fi access points on a DAS may have some merit but comes with technical and cost considerations; for example, signals may need to be amplified to ensure the proper signal strength.

On the surface, combining all these services sounds attractive: One infrastructure and one installation, with all access points back into the same wiring closet. However, each of these added requirements affects system capacity, throughput, and output power, and must be factored into site design, installation plans and output power calculations. The simple tradeoffs in design point back to the frequencies used, the application model, and the link budget. Understand that the higher frequencies reduce the actual ability of a DAS to cover the intended area, and thus increase total system costs.

DAS and Rapidly-Changing Technologies

Healthcare users considering purchasing a DAS need to carefully consider emerging networking technologies to evaluate how these systems will be evolving in the future. For example, IEEE 802.11n-2009 is an emerging wireless networking standard that seeks to improve network throughput over previous standards. IEEE 802.11n builds on previous 802.11 standards by adding multiple-input multiple-output (MIMO) technology. MIMO uses multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology.

With the pending approval of 802.11n, one questions how a DAS will support MIMO requirements, and at what price point? A DAS system uses a single antenna element, while MIMO technology requires the use of up to four antenna elements. It is likely that a whole

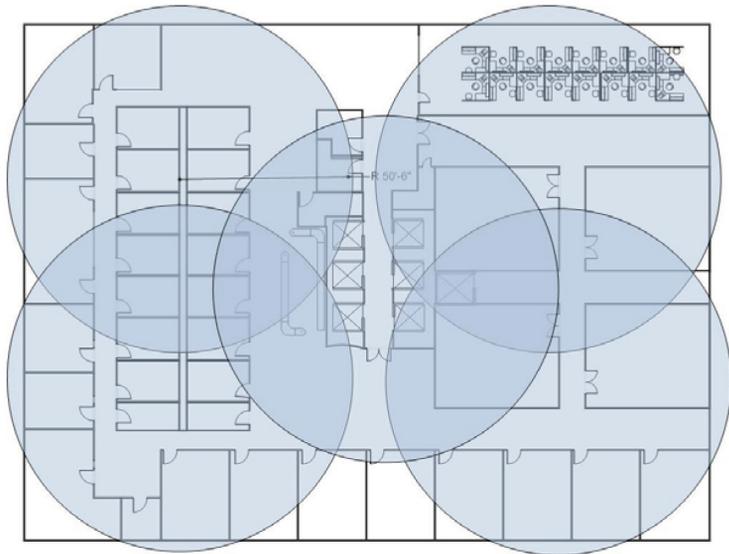


Figure 5. A DAS antenna radiation pattern with typical 12,000 square feet of coverage per antenna element.

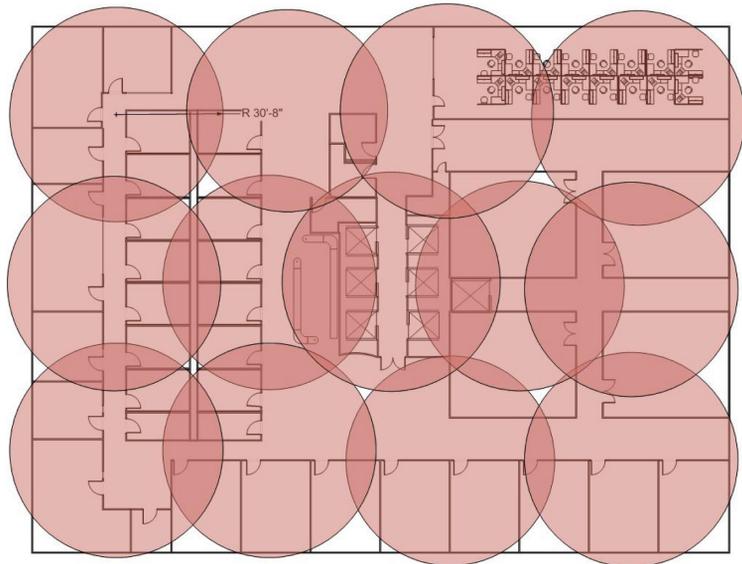


Figure 6. Hospital VoIP coverage, with DAS antenna radiation pattern. Notice antenna radiation coverage now around 3,500 sq. feet with increased density to meet the link budget and signal strength of -65 dBm.

new design of redundant cabling infrastructures may be required to support MIMO. Hospitals considering purchasing a DAS should consider this new technology in their contract offering.

Other technologies to watch, and questions to ask when negotiating contracts, are:

- How will the DAS support any new public safety requirements in 700MHz?
- How will the DAS support other new technologies like single input, multiple output (SIMO) smart an-

tennas or next-generation mobile wireless broadband technologies like 4G or Long Term Evolution (LTE)?

- What about WiMAX, meaning *Worldwide Interoperability for Microwave Access*, a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL?

DAS v. WLAN for Medical Applications

A wireless local area network (WLAN) links two or more devices using some wireless distribution method and usually provides a connection through an access point to the wider Internet. This gives users the mobility to move around within a local coverage area and still be connected to the network. WLAN designs are proven in every vertical market including healthcare, and can ensure the proper security and quality of service needed for medical applications. The majority of medical devices have received U.S. Food and Drug Administration (FDA) approval based upon discrete WLAN designs.

Shifting wireless medical devices or telemetry from a WLAN environment to a DAS environment introduces a different antenna distribution model and adds a level of non-conformance to the industry best practices. The question is then, who will assume the risk for the performance of the medical device application once this third element of design is introduced?

While some DAS providers promote the value of moving Wi-Fi-based medical devices to a DAS, there are very significant caveats. Will the DAS solution provider guarantee performance and quality of service if a medical application solution is used on a DAS, and assume the cost and risk of performance? The medical device company will have to test all their respective devices both with the WLAN provider and DAS provider if they follow in line with best practices and any previous FDA approval submission based on a Wi-Fi WLAN.

In addition, integrating WLAN medical devices—or any other Wi-Fi type of data or voice application—on a DAS will change the economics of a DAS installation. Integrating Wi-Fi voice or data applications will decrease an antenna element's coverage area from around 10,000 square feet to 3,800 sq. ft of coverage due to coaxial cable loss and higher frequencies. For example, see the antenna distribution patterns in Figures 5 and 6. As can be seen, more coverage requires more access points and increases costs.

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Wireless medical telemetry systems will require dual coaxial infrastructures and major increase of antenna elements to provide diversity and to ensure that the link budget (signal strength) is assured. These factors will significantly increase the cost of the DAS, as compared to a separate discrete WLAN or a stand-alone DAS used only for broadband coverage.

Key Recommendations for DAS Systems

Healthcare customers should carefully define their technical requirements and then obtain multiple quotes on different system configurations for a combined services offering on a DAS. For instance, obtain one quote for a DAS with Wi-Fi coverage, and another for a DAS with both Wi-Fi and WMTS coverage. Then, obtain a quote for each system separately: Wi-Fi, WMTS, and DAS. All quotes should be for the same coverage area. Then, compare costs of separate or combined systems.

The following recommendations will touch on some key technical variables:

- For Wi-Fi (802.11b/g), the requirement will be a signal strength of -85 dBm. If voice over Internet protocol (VoIP) service is needed, it will require an improved signal strength of -65 dBm. Roaming and latency requirements must be met (180 msec) if effective voice calls are to be ensured. Signal strength requirements are defined by devices and by application requirements, but these requirements are only a starting point. The actual overall signal strength requirements are unique in each environment as they will be dictated by the construction of the building. This fact highlights the importance of defining basic requirements that are predicated on a real building signal propagation model.
- If 802.11a coverage is needed, the signal will have to be amplified either at the antenna or in the wiring closet to meet the link budget.
- WMTS will require dual coaxial infrastructures to ensure diversity support.
- In general, single-mode fiber fed systems are better for healthcare because they support the link budget better. Single mode optical fiber can transmit

multiple RF signals with minimum loss of signal strength up to 20 km. Multiple mode fiber, which is generally used for IT installations, reaches its limitation to lose signal strength and quality around 300 meters. Passive coaxial antenna designs for DAS experience loss of signal strength due to continued splitting and combining the signals for the design; coaxial cable is not very efficient at carrying RF signals throughout a building environment without a lot of amplification of the signal. All in all, single mode fiber is not only the technically efficient way to go, but also much more cost effective for typical healthcare enterprise implementations.

- Factors to negotiate include a support contract in which DAS providers will provide all design changes on a no-charge basis, to include project management on a no-charge basis, and accept the liability of any application performance to include data, voice, and medical applications for 802.11n. Further, they should guarantee on a no-charge basis complete forward design changes to support both either WIMAX or LTE.
- Finally, the healthcare customer should consult with their WLAN provider to ensure all the features and functionality of the WLAN enterprise solution are truly supported by a DAS.

Conclusion

Distributed antenna systems offer great benefits to healthcare today for providing pervasive cellular, PCS, and public safety communications coverage. However, these systems are not as well suited for medical device-specific applications for the reasons cited above. In addition, DAS systems as currently designed are not likely to support emerging networking technologies like MIMO for 802.11n in a cost-effective manner.

These DAS systems are complex and require healthcare professionals to work effectively with a systems integrator and the carriers to ensure the proper engineering design. DAS systems require a lot of planning. There will be a need for coordination with the carriers on design and modeling, installation, system commissioning, and ongoing support and maintenance.

When thinking about combining other services such as wireless data coverage (802.11a/b/g/n) or WMTS on a DAS system, there are significant caveats on the technical side as well as cost considerations. These considerations should be evaluated carefully to understand the value

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proposition of a converged DAS solution versus separate discrete infrastructures. A reasonable strategy for healthcare facilities moving forward is to provide a DAS system for all broadband offerings and to separately provide a different system for all WLAN offerings, including all life critical medical applications.

It is important to note that individuals with expertise in medical device technologies must be involved in the purchasing and installation of wireless systems. Their expertise is necessary to help information technology professionals evaluate competing marketing claims for new technologies and decide which are best suited to an individual facility's environment. ■

References

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Interference Concerns

Much has been written about cellular devices interfering with medical equipment. Generally, the use of a DAS will greatly lower the power output of the mobile device, reducing the risk of interference.

Poor coverage inside a building means that a mobile device has to transmit at a higher power setting to ensure that a connection with the cell site is made. Cellular devices can transmit at relatively high power levels (perhaps 1 W) for short periods of time such as during the ring cycle. However, if the cellular device is in a reasonably good coverage location, it will transmit at much lower levels (potentially under 5 mW), which is not a real concern. In addition if you have good coverage, the battery life of the device will be greatly enhanced. Essentially a DAS provides 5 bars all the time, thus less power is required to enable the up-link from the mobile devices. The use of DAS in healthcare will actually decrease electromagnetic interference and improve battery life of these devices.