In-building Cellular: Architectures and Options

Broadband suppliers are racing to add mobile services, making in-building reception a service bottleneck. Solutions include using fiber to carry mobile signals indoors.

By John Spindler ■ *LGC Wireless*

Cellular phones have become standard equipment for businesspeople and consumers, so people expect them to work. Facilities owners now face an additional challenge of providing adequate cellular coverage inside their buildings even as bandwidth needs expand. In this article, we'll look at various ways to extend cellular coverage inside offices, stadiums, shopping centers, airports or other types of facilities.

Passive systems are more difficult and expensive to install, because their heavy rigid cabling requires special expertise and often special cable raceways or hangers. Since the cabling is not as flexible, it is also more difficult to deploy in tight spaces. In North America, passive DAS cabling typically costs up to $4.50 per foot to install.

Outdoor sites typically provide cellular coverage, and the coverage signals can be reduced or blocked by metal, concrete, and other building materials. In addition, different carriers often have outdoor sites located in different places, so users inside a building may have great coverage from one carrier and poor coverage from another.

In-building wireless systems bring cellular coverage indoors. The wireless carrier installs a base station in the building's equipment room and links it via a T1 or other type of wireline connection back to its network. From the base station, the signal is sent via coaxial cabling to a distributed antenna system (DAS), which transmits the signal throughout the building via coaxial, fiber, or Ethernet cabling and ceiling-mounted antennas that look much like fire or smoke detectors. (If the facility's traffic levels are lower, carriers don't go to the expense of installing a new base station, but rather opt to install a rooftop antenna and a repeater that picks up the signal from a nearby external cell tower.)

DAS deployment would be a lot simpler if every carrier used the same cellular system. In Western and Eastern Europe, for example, carriers have standardized on GSM and UMTS. But in North America, different carriers use GSM as well as other technologies such as CDMA and iDEN.

Defining the Need

There are several issues that affect the quality of an in-building solution. Cellular providers in the local area can offer advice about deployment options. Naturally, the project should be worth the effort, so we will assume that the system should be able to deliver any cellular service available, including voice, data, consumer video, text messaging, and e-mail or other data services. Still, there are several questions to consider.

Performance – The performance of a wireless system affects the DAS system's capacity, its ability to effectively support higher-speed data services (such as EV-DO and HSDPA), call quality, and the battery life of user devices. Performance is defined at specific antennas as the coverage and signal strength (for the downlink signal) and the amount of signal noise (for the uplink signal), both measured in dB. The dB level required depends on the data rate needed in the application.

Single- or multi-carrier – The owner may or may not need a DAS that supports multiple wireless carriers. Public venues should support all of the local wireless carriers, but private buildings may need coverage for only one carrier. In fact, private buildings can often gain carrier participation in the cost of deploying a DAS if they sign a multi-year service agreement for a specific number of minutes or wireless devices from one carrier. Even when multi-carrier coverage is required, each carrier may want to deploy its own DAS due to capacity or maintenance concerns.

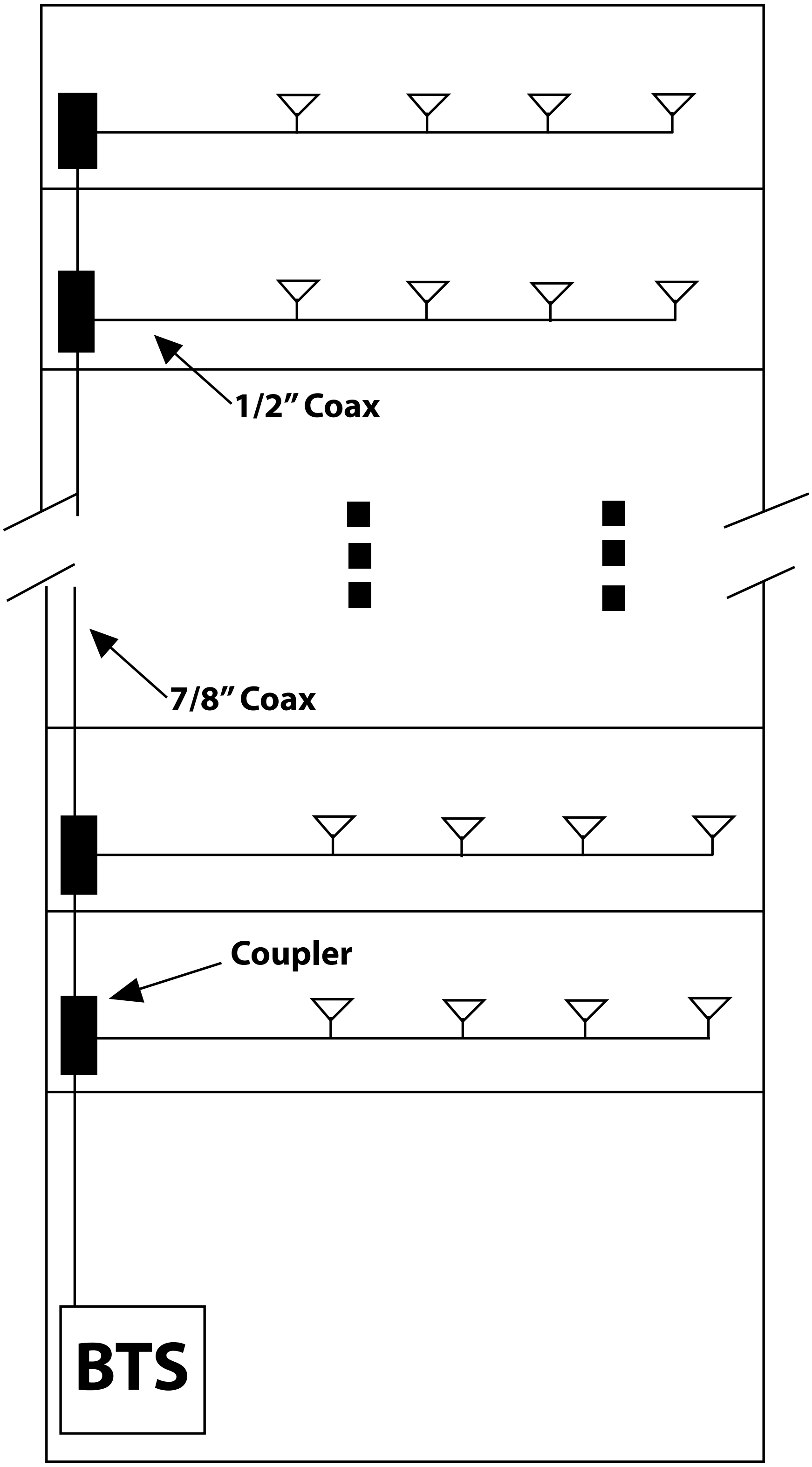

Figure 1: A passive in-building system.

The drawback to active systems is that they don't natively support all carrier frequencies through a single set of hubs and antennas. There are now dual-frequency active systems and antennas, but an active system must be configured to specifically support any frequencies desired.

Manageability – The DAS should be fully manageable, enabling company administrators or carrier personnel to know instantly when an antenna has gone down, for example. In buildings with systems that host several different cellular carriers, individual carriers may want to manage their own services. Extensive management capabilities also reduce the life cycle cost of the system, since any problems can be easily diagnosed and pinpointed without unnecessarily dispatching a technician or spending excessive amounts of time troubleshooting.

Expandability – Deploying a DAS can be expensive and time-consuming, and wireless services are evolving very rapidly. Like electrical or data infrastructure, the project should deliver a system that can be cost-effectively expanded or upgraded to accommodate new carriers or frequencies over time.

Deployment disruption – As with any improvement, building owners want to minimize the disruption to their ongoing operations when the DAS is deployed.

Cost – The overall cost to deploy and maintain an in-building system is always a consideration.

Evaluating Solutions

There are three basic types of DAS on the market today: passive, active, and hybrid. Each type of system has specific strengths and weaknesses when it comes to meeting the foregoing requirements.

Passive Systems use thick coaxial

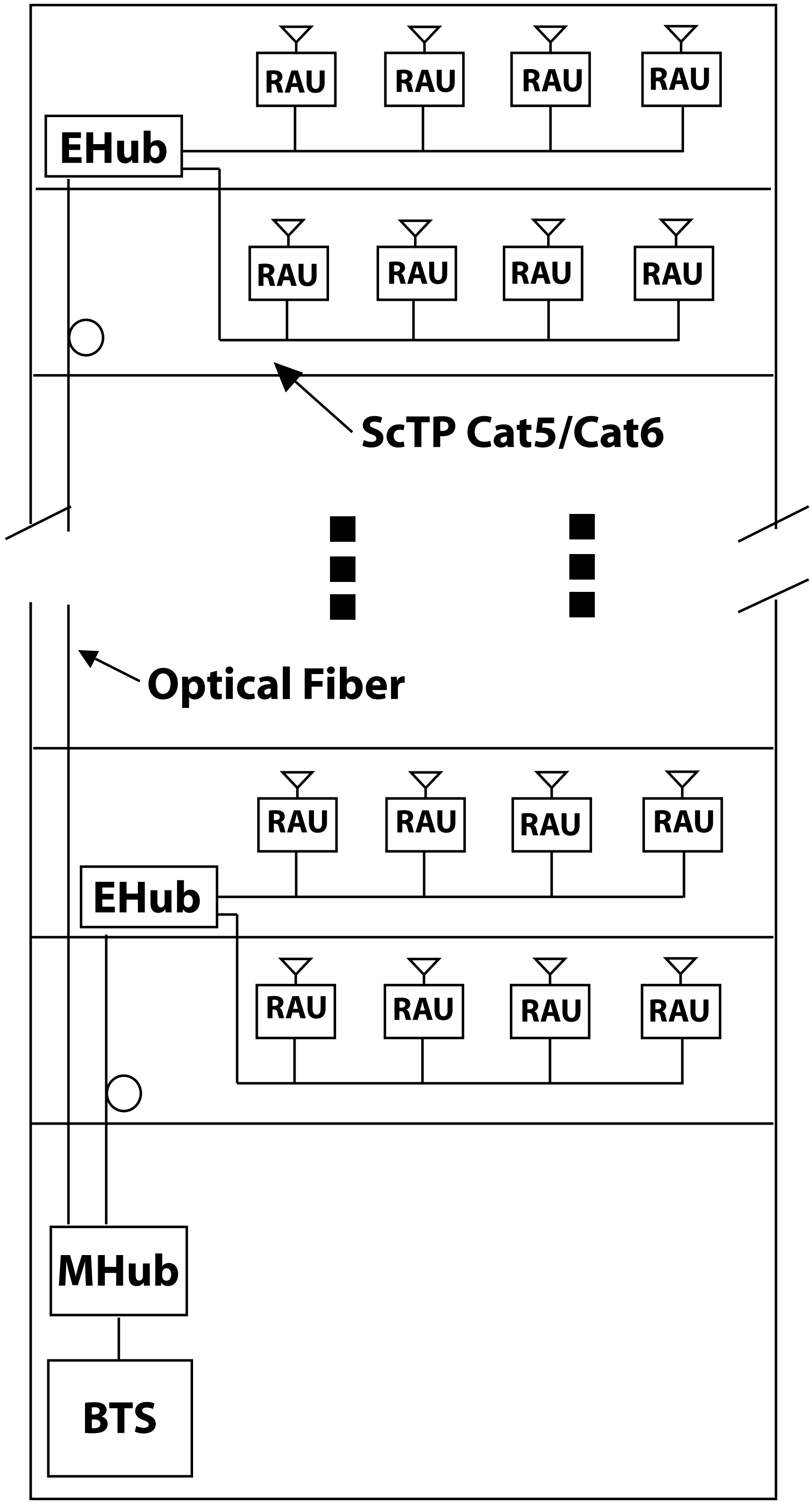

Figure 2: An active in-building system.

cable (1/2" to 1" in diameter) to distribute the wireless signal from a repeater or base station to a set of distributed antennas. The main distribution unit is connected to the repeater or base station and placed adjacent to it, and then the unit drives the signal over the coaxial cable (Figure 1). In larger buildings, these systems may use couplers or splitters to achieve the proper geographic distribution of cabling.

The coaxial cable used to distribute radio signals is inherently capable of supporting multiple carrier frequencies. The cable is essentially a "dumb" pipe and will deliver any frequency supplied to it. Passive systems are thereby viewed as simpler, one-stop solutions for indoor wireless coverage. In fact, you may have seen them along the ceilings in tunnels as a means of providing cellular and broadcast radio coverage.

In a passive system, however, the signal degrades with the length of the cable in any particular run. As a result, passive systems are not well suited to large facilities with long or complex cable runs, or facilities that require high call capacity or high signal strength. Even in a relatively small deployment with as little as 16 antennas, the signal loss at any given antenna can easily exceed 20dB to 30dB, forcing users to stand practically next to the antenna in order to get a good signal.

Because antennas are located at varying distances from the base station in a passive system, their power output and coverage capabilities vary: those located farther away will have more signal loss and thus will provide much less power in the downlink signal and a much higher noise figure in the uplink signal relative to the antennas that are closer to the base station. This makes it difficult to plan the antenna placement. Further, as user traffic expands or new services are added, signal strength variability will present new challenges and may require system redesign with antenna relocations.

Passive systems do not offer end-to-end monitoring and management. The signal is simply being pushed out over copper cabling, so carriers and building owners never know if a particular antenna has failed until users start complaining.

Finally, passive systems are more dif-

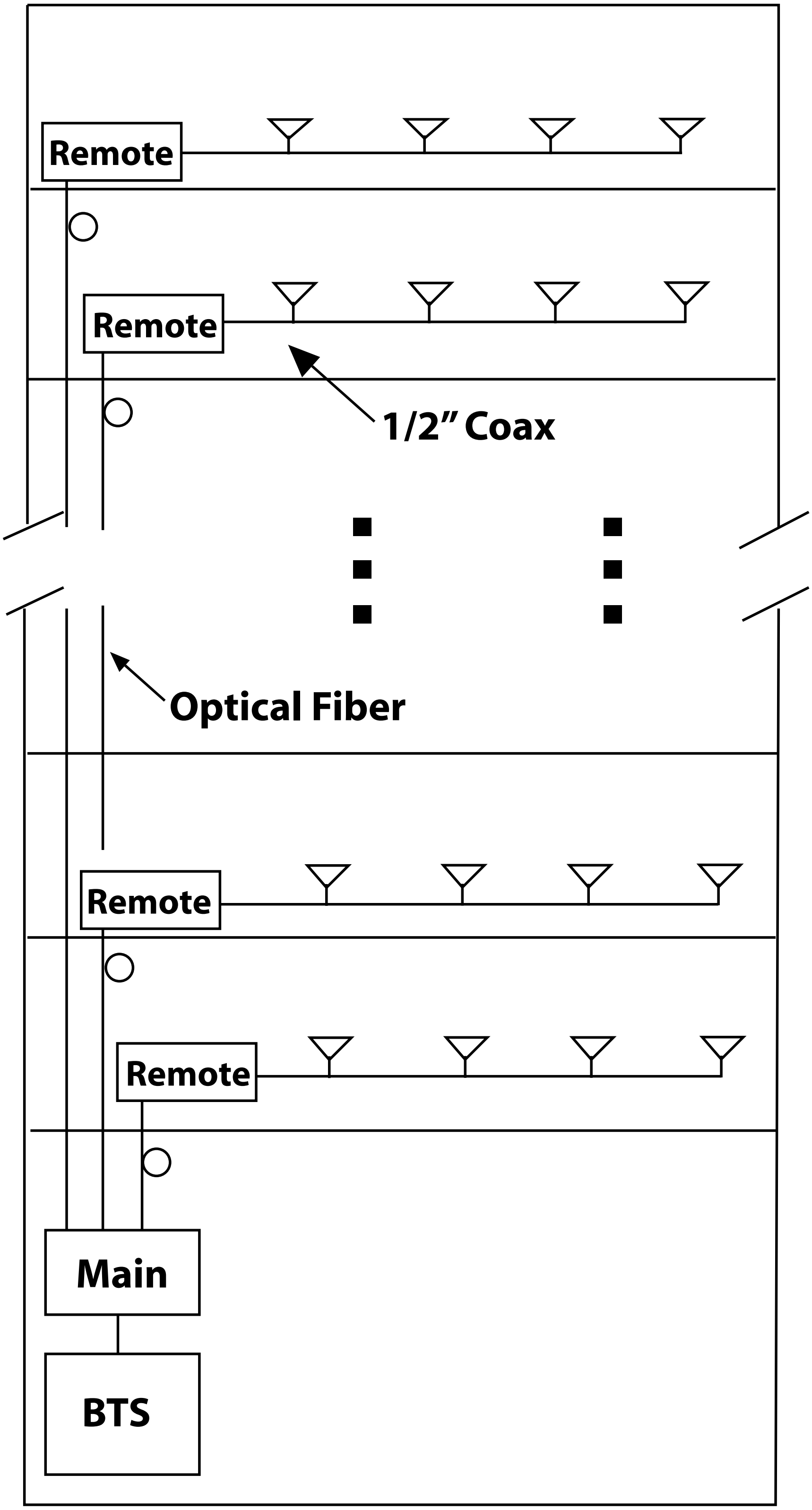

Figure 3: A hybrid in-building system.

ficult and expensive to install, because their heavy rigid cabling requires special expertise and often special cable raceways or hangers. Since the cabling is not as flexible, it is also more difficult to deploy in tight spaces. In North America, passive DAS cabling typically costs up to $4.50 per foot to install.

Active DAS installations use managed hubs and standard building cabling (such as single- or multi-mode fiber and Cat-5), much like an Ethernet LAN. In an active DAS, the Main Hub is deployed next to the base station or repeater in the building's equipment room, and it distributes the wireless signal through a series of managed expansion hubs, remote access units (RAUs), and antennas, as shown in Figure 2. (An RAU can support two antennas if needed.)

The drawback to active systems is that they don't natively support all carrier frequencies through a single set of hubs and antennas. There are now dual-frequency active systems and antennas, but an active system must be configured to specifically support any frequencies desired.

However, active systems are superior in every other way. Because the signal is amplified through expansion hubs and RAUs, active DAS deliver strong and consistent signals at every antenna, no matter how far away it is from the base station and main hub. In the largest airports or multi-facility deployments such as major hotels on the Las Vegas Strip, some active DAS extend for miles. Since every antenna has predictable signal strength and coverage, it is far easier to plan the antenna placement in an active system.

With its double-star architecture, active DAS can be expanded indefinitely through deployment of additional hubs and antennas. The distributed hub architecture of an active system mirrors the design of Ethernet LANs – it scales easily through addition of new antennas and hubs, and the hub electronics can be upgraded to support new services as they come on line. This leaves the most expensive part of the system – the cabling and antenna plant – untouched. Active systems usually support SNMP alarms as well, so a company's IT staff can monitor the status of all remote antennas in the cellular network using the same network management tools used for the LAN.

Active DAS are nearly always less expensive and disruptive to deploy because standard cabling costs about $1 per foot to install, and the job can be handled by standard IT cabling contractors or electricians. Standard cabling can be run across suspended ceilings and in tight spaces just as easily as LAN cabling. In many cases, an active system can use existing, unused fiber that runs up a multi-story building's utility riser to link a main hub with expansion hubs, and then use new CAT-5 cabling to connect each expansion hub to its RAUs and antennas. While multiple sets of electronics may be required to support all carriers, the cost of cable runs is a larger factor in the overall price of a system in all but the smallest facilities.

In many cases, an active system can use existing, unused fiber that runs up a multi-story building's utility riser.

Hybrid DAS combines attributes of both passive and active systems. They use fiber optic cabling to carry the signal from the base station up a building riser, and then use thick coaxial cabling to carry the signal horizontally across each floor of the building (Figure 3).

Hybrid systems partially alleviate the problem with signal loss and variable signal strength at each antenna, because there is far less signal loss in the vertical portion of the system. However, these systems have the same signal loss issues in the horizontal cable runs to individual antennas. Overall, output at any given antenna will be higher, but there will still be wide variability in signal strength and coverage at an antenna, depending on its distance from the fiber optic portion of the system.

In the same way, hybrid systems only partially solve the management and cost challenges of DAS deployment: they offer management between the base station and the hubs at each floor, but not between those hubs and individual antennas. And while building owners save partly on the cost of deployment on the fiber portion of a hybrid DAS, they encounter the same cost and disruption issues when installing cabling and antennas on each floor.

Deploying a DAS

For a better view of DAS in the real world, let's look at a deployment in a specifically difficult environment. Hospitals present unusual challenges for cellular coverage. In addition to their signal-reducing steel and concrete construction, hospitals have a very "dense" design – there are a lot of small rooms with walls that can block a wireless signal, and lots of equipment, which can also cause wireless propagation issues.

At Lima Memorial Hospital (an 8-story, 300-bed facility that serves a 10-county area in western Ohio), doctors and maintenance staff had relied on wireless pagers and an overhead audio paging system for many years. By 2004, the medical staff had begun pushing for cellular phones as a more flexible and inclusive communications device. As they began adopting the phones, however, doctors and staff reported that there was little to no coverage on lower floors or in interior facilities.

As it evaluated various DAS products to eliminate coverage issues, Lima Memorial had another challenge that is common to hospital and scientific environments: interference.

Unless properly implemented, the cellular signals from cell phones or a DAS can interfere with medical telemetry equipment such as wireless EKG monitors on patients. Although the Wi-Fi network that usually carries medical telemetry traffic is at 2.4 GHz compared with cellular's 850 MHz to 1.9 GHz, additional signals injected into the transmissions may interfere.

It is important to ensure that cellular phones and other devices run at the lowest possible power to minimize such interference, and that means that the DAS antennas must have the strongest downlink signals and the lowest uplink interference possible.

Given this requirement, Lima Memorial's technical staff selected an active DAS provided by LGC Wireless based on recommendations from three wireless carriers in the area: Alltel, Verizon, and Sprint Nextel. The InterReach Unison system deployed at the hospital cost roughly $150,000, including deployment.

The deployment occurred in July, 2004. Contractors installed 28 RAUs with individual antennas, each of which delivered approximately 15,000 square feet of coverage. The deployment required seven RAUs for every two floors in the building, and each group of seven RAUs was connected via Cat-5 cabling to an expansion hub located in one of the covered floors' wiring closets.

Each expansion hub in a Unison system can support up to eight RAUs, so there is room for additional RAUs and antennas in the existing system, although it can also be expanded by adding more expansion hubs.

Since the Unison system uses standard cabling to link its electronic hubs with RAUs, Lima Memorial's regular cabling installers could simply pull the required cabling through existing raceways above the hospital ceilings and between floors. Deployment took less than three weeks.

The system's main hub is located in the hospital's telecommunications equipment room, along with repeaters provided by Verizon, Alltel, and Sprint. Rather than deploying base stations inside the hospital, these carriers chose to bring cellular signals into the building via rooftop antennas, which were connected to the repeaters via standard coaxial cabling.

When the system went live in August, 2004, doctors and maintenance staff immediately noticed the difference. They had strong signals throughout the facility. The results have been so positive that many doctors plan to phase out the use of pagers altogether (as does the hospital's maintenance staff), because they can use the cellular phones to receive pages as well.

In addition to providing consistently strong cellular coverage throughout Lima Memorial Hospital, the Unison system also addressed the problem of potential interference with telemetry equipment. The Unison system's ability to deliver uniformly strong signals with low noise through each of its antennas guaranteed that cellular phone handsets used in the hospital could send and receive calls using only minimal power.

As a result, cellular phone users can carry on calls within as little as five feet of any telemetry gear without fear of interference

As mobile services and applications expand, building users from all walks of life will expect continuous access to them. In-building systems are delivering that coverage today for a significant number of public venues, hospitals, and private business facilities worldwide. With continuous improvements in DAS technology, building owners have readily-available solutions for ensuring tenant satisfaction at their properties. **BBP**

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