HOW-TO

In-building cellular: Why it is a Wi-Fi alternative: Part 2

Part 2 of this article compares in-building cellular systems and see how they stand up to the technical challenges of cellular communications
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Part II: In-building systems
Signals from outdoor cell towers may not provide clear and consistent coverage inside buildings, so wireless operators and building owners use distributed antenna systems (DAS) to propagate RF signals throughout their facilities.

As wireless operators roll out 3G data coverage, in-building coverage will become much more important because the higher-frequency 3G data signals experience greater path loss, making in-building penetration even more difficult than for voice calls. In addition, data applications are far less tolerant of dropped or missing bits than are voice calls.

In-building wireless systems can eliminate the problems with signal propagation, coverage, and capacity for voice as well as 3G data applications. As discussed last month, in-building systems work by distributing cellular signals throughout an interior space: the cellular signal is typically brought to the building with a base station (BTS)—each operator that wants to offer coverage through the DAS places a base station in the building's telecommunications equipment room—and this base station is connected to the DAS via coaxial cabling.

There are three types of DAS: passive, active, and hybrid. This article will compare each type of system against the requirements for strong and pervasive cellular coverage.

Passive DAS
In a passive DAS, rigid, large-diameter (7/8 inch or 1 inch) coaxial cable is used to distribute the signals up and down the vertical riser of a building. Couplers are then used to divert a fraction of the RF energy along the horizontal floors of the building via 1/2" coaxial cabling. These systems are called passive because the DAS uses no electronic components (see Figure 1).

The coaxial cable used to distribute radio signals is inherently capable of supporting multiple carrier frequencies. These systems are often touted as "broadband" systems because the DAS itself supports almost any wireless frequency delivered to the coax system.

The biggest problem with the passive system is the large loss of power between the BTS and the antenna points. Even in a relatively small deployment with as few as 16 antennas, the signal loss can easily exceed 20dB to 30dB, which impacts the system's coverage and capacity.

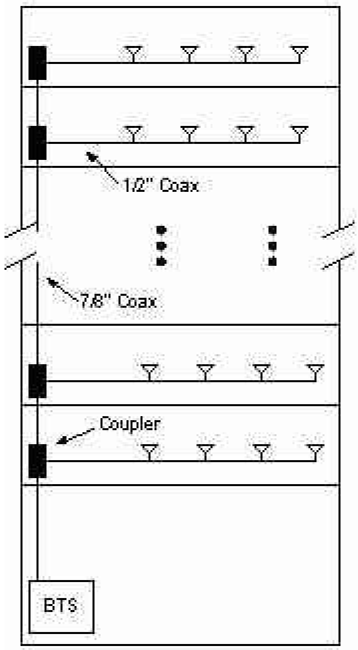

Figure 1: *Passive DAS does not require electronic components.*

Another problem with passive DAS technology is the imbalance of power between antenna points. In a passive DAS, antennas located farther from the BTS will encounter more signal loss, thus exhibiting a much lower output power in the downlink and a much higher noise figure in the uplink compared with antennas that are closer to the BTS. This makes it difficult to plan the network, as each antenna point will have a different coverage area.

In addition, the higher noise figure will result in a need for higher output power from mobile devices on the system, leading to shorter battery life, more "electro-smog," and more interference into the macro cell network.

Active DAS
Active DAS technology uses an approach that more closely resembles standard LAN architecture. Rather than relying on fat but "dumb" transport cabling from the RF source to the antennas, these systems distribute the signal using managed hubs, remote access units (RAUs), and standard building cabling (see Figure 2).

In many cases, an active system uses existing single- or multi-mode fiber running up a building riser to link a main hub with expansion hubs on various floors, and then uses standard twisted pair ScTP category (Cat 5/Cat 6) cabling to connect each expansion hub to its RAUs and antennas. (An RAU can support several antennas if needed).

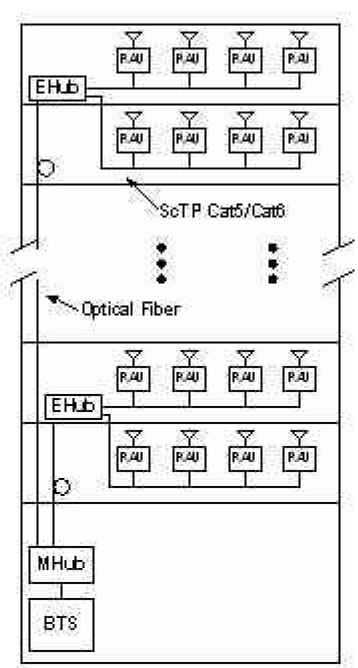

Figure 2: *Active DAS.*

An active DAS uses a double-star network topology, with the first level of the network between the main hub (MHub) and expansion hubs (EHubs) linked via optical fiber. The second level of the network runs between EHubs and RAUs.

The optical link allows the EHubs to be located up to 6km away from the MHub, which is why active systems are favored in larger installations such as major airports. In addition, using ScTP cable allows the RAUs to be remotely powered from the EHub, which removes the requirement for providing a source of power at each remote unit.

The most dramatic advantage of an active DAS system is its performance. By locating small, active units (RAUs) which contain amplifiers at the outer edges of the network, the active DAS provides high, uniform power at each antenna point, thereby providing a uniform coverage area at each antenna point. Since power output is uniformly high at every antenna, it is much easier to enable high-speed data coverage at higher frequencies. This feature also makes antenna placement much easier to plan.

Active DAS are also easier to deploy. Since both ScTP and optical cable are widely used and commonly found in all office, commercial and retail environments, they are much easier to install than rigid coax. The use of optical and ScTP cable also provides a significant advantage in simplifying the total system deployment, which results in fewer network problems and a substantial reduction in installation cost.

Hybrid DAS

Hybrid DAS technology provides better overall performance than pure passive systems, as the hybrid systems incorporate an optical link for distributing signals along the vertical risers of a building. An active remote unit is then used to drive 1/2" coaxial cable along the horizontal floors of the building.

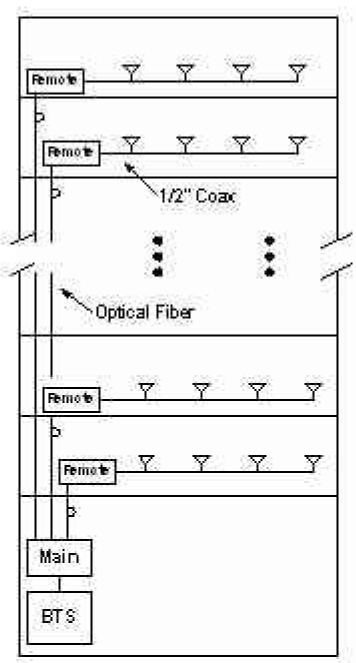

Figure 3: *Hybrid DAS.*

While the hybrid system does not incur as much signal loss as the pure passive system along the vertical sections of the deployment, it does incur the same loss along the horizontal sections since 1/2"coaxial cable is still used for the run between the active remote units and each antenna point along the horizontal layer. This loss results in lower downlink output power and a higher uplink noise figure. And just like a passive system, it also causes discrepancies in output power at the antennas on each floor, depending on their distance from the fiber optic riser.

Performance

Figure 4 provides a comparison of signal losses associated with the major components used in the three types of in-building systems and shows how these losses add to the total system uplink noise figure for a typical 16-antenna installation.

System Component	Passive Coax	Hybrid Optical/Coax	Active DAS
Horizontal Coax Loss	4 dB	4 dB	0 dB
Splitter Loss	6 dB	3 dB	0 dB
Coupler Loss	20 dB	0 dB	0 dB
Vertical Coax Loss	2 dB	0 dB	0 dB
Active Noise Figure	4 dB	32 dB	19 dB
System Noise Figure	36 dB	39 dB	19 dB

Figure 4: *Noise comparison.* The passive system figures incorporate all of the passive components listed for the horizontal and vertical sections of the system. For this example installation, the use of these components results in a +36dB uplink noise figure.

The hybrid optical/coax system replaces the couplers and vertical coax cable runs with an optical link. Thus, there is no loss associated with the vertical sections of the system.

There is also less splitter loss in the horizontal sections of the system as the remote units have multiple output ports, which negate the need for additional splitters. For a deployment of this size, the higher noise figure of hybrid systems on the market today results in a higher overall system uplink noise figure (+39dB) than in passive coax systems.

As with the hybrid system, the active system replaces the couplers and vertical coax cable runs with an optical link, removing the losses associated with the vertical section of the system. However, the active system also replaces the splitters and horizontal coax cable runs with the second layer of the double-star architecture, which removes the losses associated with the horizontal section of the system.

As a result, the only item impacting the overall system uplink noise figure is the system itself, which has an uplink noise figure of +19dB for a 16-antenna deployment.

The lower uplink noise figure of the active system directly impacts the propagation link budget, which means that with the active DAS, the in-building network can tolerate 17dB to 20dB more path loss between the antenna and the mobile device than can a passive or hybrid system. Further improvement of the uplink performance of the active system can be accomplished through the use of diversity techniques.

To put these figures in perspective, Figure 5 presents a sample uplink link budget for a 384kbps service operating on the same 16-antenna deployment example.

Parameter	Passive Coax	Hybrid Optical/Coax	Active
Transmit Power	+21dBm	+21dBm	+21dBm
Thermal Noise (3.84MHz)	-108dBm	-108dBm	-108dBm
Noise Rise (75% loading)	+6dB	+6dB	+6dB
Eb/No	+5dB	+5dB	+5dB
Process Gain	-10dB	-10dB	-10dB
Noise Figure	+36dB	+39dB	+19dB
Receive Sensitivity	-71dBm	-68dBm	-88dBm
Multipath Fading	+10dB	+10dB	+10dB
Log-Normal Shadowing	+10dB	+10dB	+10dB
Body Loss	+3dB	+3dB	+3dB
Margin	+23dB	+23dB	+23dB
Total Antenna Gain	+6dBi	+6dBi	+6dBi
Maximum Path Loss	75dB	72dB	92dB
*Max path loss = Tx power – Rx sensitivity – Margin + Antenna gain			

Figure 5: *Noise comparison.*

Figure 6 shows how the relative amount of dB loss in each type of system affects the coverage at each antenna.

DAS System	Relative Loss	Relative Radius	Relative Area
Active	0 dB	100%	100%
Passive	17 dB	36%	13%
Hybrid	20 dB	30%	8.9%

Figure 6: *Relative dB loss in various DAS.*

Additional considerations
As the figures clearly show, active DAS technology delivers superior performance with respect to noise, signal strength, interference, and path loss. However, there are other considerations involved in the selection of a DAS for in-building coverage.

Applications and upgrades
System designers will want to provide an infrastructure that supports applications today as well as tomorrow. Many passive DAS were deployed to meet 2G cellular system requirements, and now cannot provide enough output for high-speed data applications as EV-DO and HSDPA roll out.

As discussed in Part I of this article, the CINR requirements vary depending on the type of service being provided. For deployment planning, performance requirements are based on the application data rate, while the antenna output power and noise figure will determine the cell radius. A DAS system initially designed for low data rate applications will require up to 16 times as many more antennas to deliver the same coverage and performance for 3G applications.

Frequency support
One virtue of passive DAS is that one set of cables and antennas can support any and all

carrier frequencies. Active and hybrid DAS may require two or more sets of hubs, remote units, and antennas, depending on how many frequencies are required.

Manageability

As with critical computer networking systems, an in-building system should be fully manageable, enabling company administrators or carrier personnel to know instantly when an antenna has gone down, for example. Antenna malfunctions (often due to cut or unplugged cables) are the primary cause of in-building system issues.

Moreover, individual carriers may want to manage their own services in buildings with systems that host several different cellular carriers, and management capabilities make this possible. 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.

Passive DAS are difficult to manage because they provide no end-to-end alarming: if a cable is cut or an antenna fails, building or network managers have no way of knowing this unless users complain. One carrier study showed that up to 20 percent of the antennas in a passive DAS become disconnected over time without the operator being aware of it. Hybrid DAS have the same issue, since the antennas are connected via coaxial cable.

In contract, active DAS offer end-to-end monitoring and management, with SNMP interfaces at every hub and RAU.

Deployment

Most building owners want to minimize the disruption to their ongoing operations when an in-building system is deployed. Passive and hybrid DAS are much more difficult to plan due to the variation in antenna coverage areas, and they are much more difficult to deploy due to the size and weight of the cabling. Active DAS installations are much easier to plan due to uniform antenna coverage; in fact, they are no more disruptive to deploy than wireless LAN systems.

Cost and investment protection

In-building systems are a significant investment, and companies want to minimize capital expenses and operational costs while preserving their investment as much as possible, even if they relocate to a new facility. Costs between passive, active, and hybrid systems are often similar, but the type of facility may well determine which solution is best from an investment protection standpoint.

Since they use rigid cabling, passive systems are far more expensive to install. The cabling requires specialized expertise and cable supports and can run up to $4.50 per foot to install. Hybrid systems are slightly less costly because they use fiber in building risers, but they incur the same installation costs for horizontal runs. Active systems use standard cabling, which can be deployed by any electrical or cabling contractor at a cost of $1 per foot or less.

While passive and hybrid systems cost more for cabling, they compensate for the extra expense with reduced costs for system hubs and electronics. In general, passive DAS are more competitive in parts of the world where installation labor rates are lower. Active DAS are more competitive in larger facilities (where the lower cost of cabling helps outweigh the cost of electronics), and in areas where installation labor is higher.

If the system owner must upgrade or expand a system over time, there are other costs to consider. If a passive DAS must be expanded to cover new areas or to support more traffic, it must be re-engineered for additional antenna placements, new antenna placements, and the addition and rerouting of cabling at considerable expense. Hybrid DAS will require the same re-engineering and redeployment for horizontal runs.

With its double star architecture, however, an active DAS can be expanded through the use of additional hubs, RAUs, and antennas " existing cabling need not be moved. In addition, an active DAS can be upgraded to support new services or higher capacity with additions or changes to the electronics only, rather than to the layout of antennas.

Finally, the coaxial cabling in a passive or hybrid DAS is considered a permanent improvement to a building. This cabling represents about 70 percent of the cost of the system, and this investment must be abandoned if the owner relocates. With an active DAS, however, the owner can relocate hubs and other electronics, thereby preserving approximately 70 percent of the investment in that type of system.

This concludes our examination of the challenges of cellular coverage and the in-building technologies that can address them. With this background, system designers should be able to make more informed choices about how to address the needs of cellular users inside buildings.

About the author
Stefan Scheinert *is the Chief Technical Officer of LGC Wireless. He has more than 25 years' senior management experience in the design, development, and commercialization of innovative mobile communications products, and holds a Masters Degree in Electrical Engineering from Germany's University of Braunschweig. He can be reached at* sscheinert@LGCWireless.com.