Indoor wireless networks: issues and answers

Implementing reliable indoor wireless voice and data networks is difficult at best. To get optimum quality of service, know what you're up against before the system goes in.

By Tom Snyder, John Catlin

A combination of market forces, including the growing number of mobile phone subscribers and the popularity of data applications, are creating a substantial need for capacity within wireless communications networks. Subscribers use their phones everywhere, and so a significant amount of the traffic carried on wireless networks now comes from inside buildings. As 3G services are launched, the maximum data rate of 2 MB/s will be achievable only in low-mobility, mainly indoor situations. With service availability and quality becoming competitive issues, wireless service providers have many reasons to ensure that they are providing adequate coverage and capacity for indoor applications.

Figure 1. An example of a typical test transmitter setup for a site.

Whether an indoor network is cellular, PCS, 3G, or even a wireless LAN, testing plays a crucial role at all stages of network build-out, from determining that some type of indoor system is needed to ensuring that the system meets the service provider's ongoing quality of service requirements.

Initial considerations

The network coverage and capacity needs of a small office building, a busy airport, a subway system, and a metropolitan high rise are all different, and service providers have to evaluate the RF characteristics of each unique indoor setting. This process may begin with a competitive analysis, in which test equipment similar to the receiver- and phone-based systems used for drive testing are carried through the hallways and into the rooms of a building. This is done to actively test how well the macro network performs indoors. A service provider can compare his network's coverage to that of the competition and, based on the test results, decide whether or not it is necessary to invest in indoor wireless infrastructure.

If test results indicate that the outdoor (macro) network cannot provide a strong enough signal to adequately cover the indoor location, the service provider can simply boost power at the outdoor cell site to increase signal penetration inside the building. This solution does not add capacity, however, and it can create greater interference with other outdoor sites and path imbalance. More likely, the service provider will choose to deploy some type of indoor network equipment.

An indoor system of repeaters is a simple and inexpensive way to boost coverage. Similarly, a directional antenna coupled with a bi-directional amplifier can be used to extend the outdoor cell site's coverage into a specific location. To increase network capacity in areas of heavy usage generally requires the addition of one or more micro cells or pico cells inside the building.

All of these solutions can be used to feed a distributed antenna system (DAS), which offers the greatest flexibility in adding coverage and capacity. A DAS also allows for technology expansion and migration. In traffic hot spots, such as airports, distributed antenna systems are popular because multiple service providers can share the same equipment. Technology is developing multiband indoor antennas (at 800, 1900, and 2400 MHz or at 900, 1800, 2200, and 2400 MHz, for example), which support combinations of cellular, personal communications systems (PCS), 3G, Bluetooth and wireless local area networks (W-LAN) applications.

Evaluating the indoor site

Prior to installing network equipment, the service provider must evaluate the indoor site to determine the best placement of equipment and antennas and to identify any hard-to-cover areas. Test transmitters, often provided by the infrastructure vendor, are placed at different points in the building where the desired coverage might be achieved, and a receiver-based indoor test system or a scanner tuned to the transmitter's channel is used to gather data on the characteristics of the in-building signal.

In a process not unlike a drive test, a test engineer walks the hallways with the test system and gathers data, which are later analyzed using standard post-processing software to give a picture of the coverage footprint at each transmitter location.

Testing to determine the effects of indoor antenna placement is important not just to verify that the antennas will provide enough coverage, but also to make sure that they don't provide too much. Controlling the RF inside buildings is crucial in preventing new and unwanted interference from arising

Figure 2. An example of the data collected from test calls and how it relates to location.

inside or outside the building. The channels that the service provider is planning to use for the indoor network may also be scanned to locate any interference arising from pre-existing conditions, either outside or inside — for example, from a wireless alarm system inside the building.

At this stage, a service provider may also want to use predictive modeling (sometimes called propagation modeling) software designed for indoor use. Information such as antenna type, antenna height, antenna location, characteristics of the indoor environment, building plans and building materials with associated losses are entered into the software. The software then models the anticipated indoor signal coverage. Predictive modeling simplifies the creation of an equipment layout, but it does not eliminate the need to visit the site and confirm through testing that coverage objectives have been met.

Once the site evaluation is completed, the creation of a layout plan for the indoor network equipment can begin.

Installation and troubleshooting

Installing the indoor network poses a number of challenges, beginning with the installation team's need to gain access to the building and to identify the locations for equipment. Following the layout plan, the installers must run the fiber optic and category 5 (CAT5) cable, make the AC/DC power connections, and make the necessary connections to T1 lines and the public switched telephone network (PSTN).

They must connect distributed components and maintain optimal antenna locations while working within the building's physical constraints, and they also must consider the effects of heating and cooling systems on temperature in the areas where the cabling and hardware will be located. Once the infrastructure is in place, the installation team performs return-loss measurements on all cabling and wiring to verify performance.

Now the system can be turned on and tests can be run to evaluate coverage under operational conditions. The same indoor test system used for the pre-deployment site survey can be used to make active phone tests, and the test engineer may walk the same hallways placing calls and collecting comparative performance data.

Measurements are taken at different points in the indoor system. For example, antennas must receive a certain amount of power, calculated in the link budget, to operate correctly and achieve the desired reliability objective. Therefore, each antenna port is measured to determine precisely the amount of power being supplied to the antenna and the amount of power leaving the antenna, with all the associated gains and losses. Testing is also performed to ensure path balance. That is, the phone can find the serving antenna, and likewise the antenna can find the phone.

The service provider will also want to test outdoors in the area immediately surrounding the building to make sure that the indoor system is not leaking to the outdoors or causing any new interference problems.

Locating interference that arises inside the building can be problematic because the interference source is not likely to be in the line of sight. In this situation, a directional antenna and spectrum analyzer (or the spectrum analysis capability of the indoor test system) provide the best solution for locating the interferer and resolving the problem.

The maintenance

In maintaining wireless networks, experience shows that the components most likely to fail outdoors are cables and antennas. Indoors, such failures are less likely to occur, so regular maintenance tests can be scheduled less often. However, service providers will want to verify cable integrity by making time-domain reflectometry (TDR) and optical time-domain reflectometry (OTDR) distance-to-fault measurements using dedicated portable or hand-held testers. For power and frequency accuracy tests, the indoor wireless test system has the ability to monitor and measure radiated power and to verify center frequency. If serious problems arise within the micro cell or pico cell equipment, a dedicated base station tester can be brought in to troubleshoot and resolve the issue.

Optimizing the infrastructure

After the indoor infrastructure has been put to work, the service provider will want to optimize system performance. To do this, the test engineer can again walk the indoor site. He can use the test system to fine-tune the input signals and antenna placement or to reroute or re-orient equipment to meet coverage objectives.

The goal of optimization testing is to improve network performance from the end user's point of view. Placing test calls using the phone and receiver-based indoor test system can help uncover problems in the customer service:

• *Is the service available when the customer wants to use it?* – Availability requires adequate coverage. Coverage problems are typically identified by the test system as areas of poor signal strength. Bit error ratio (BER) and frame error ratio (FER) measurements can also help locate coverage problems. To solve coverage problems, the test engineer can adjust power levels and antenna downtilt or even change the type of antenna used. Note that data services, particularly at higher data rates, require more network hardware to achieve coverage than does voice service. Resolving data coverage problems may require adding infrastructure to the indoor network.

• *Do calls get through every time?* – This is a measure of the network's capacity. Capacity problems are identified by blocked calls or longer-than-average call setup and breakdown times. Capacity can be increased by adding micro or pico cells. However, sometimes the problem is the result of handoffs (in code-division multiple access (CDMA) networks) or handovers (in time-division multiple access (TDMA) networks).

For example, a CDMA handset being used on the 20^{th} floor of a high-rise office would likely "see" numerous outdoor cell sites that a handset on the ground floor would not. The handset on the upper floor could attempt a soft handoff with as many as six of those sites at once — not the best use of network capacity. The problem can be controlled using an optimized or "asymmetric" neighbor list, which adds the indoor micro or pico cells to the outside neighbor lists (to control the handoff from the outdoor to the indoor network) but limits the indoor neighbor lists to indoor cell sites only.

• *Do calls last the intended duration?* – Dropped calls are a sign of poor network performance, and troubleshooting tools and techniques such as those used during installation and maintenance can be used to uncover the problem source. Dropped calls can also indicate handoff or handover problems, which require fine-tuning of neighbor lists and handoff or handover parameters. For indoor infrastructure, the handoff/handover parameters typically must be set within tighter tolerances than for outdoor equipment.

• *How do the calls sound, and how responsive are data applications?* – These measures are how customers perceive quality of service. The test system shows voice quality problems as unacceptable EMOS scores. Data problems are shown through poor throughput scores and data errors.

Interference – issue one

Interference is always a major problem in wireless networks. Because users of indoor networks are stationary or moving relatively slowly, they may encounter interference that lasts for longer periods than in a highly mobile environment, such as a moving car. There is a greater chance, therefore, of an indoor call being dropped.

Interference inside a building depends on the relative position and distance of the base station to the user. In addition, the higher up in a building the user is, the more outdoor cell sites will be visible to the handset, increasing the probability of interference.

Controlling handoffs as described above is one way to reduce interference that arises from the outdoor environment. Other methods unique to the wireless technology can be used. For example, in TDMA networks, co-channel and adjacent-channel interference can be reduced by optimizing handover parameter settings to deny call attempts when the timing advance or alignment values are outside the accepted window for outside sites. This action forces the handset to reselect from the indoor network channels for service.

In CDMA networks, pilot number offset interference (co-PN interference) can be reduced by allocating a subset of PNs for indoor use only or by using a second carrier frequency dedicated to the indoor network.

Trends

Although many service providers have been slow to deploy indoor networks, they are starting to look more seriously at the need, particularly in areas where many users congregate and system capacity is strained. If service providers can realize benefits through additional subscriber usage or reduce churn by maintaining quality of service, then they will put in the necessary infrastructure.

In some cases, zoning restrictions on cell sites or excessive interference in the outdoor environment make an indoor RF network preferable. In the long run, data services are going to demand a better RF signal, and indoor systems will undoubtedly be required to deliver guaranteed data rates, particularly in high traffic areas such as airports and shopping malls.

Testing IS required

Testing is an integral part of designing, deploying and ensuring the ongoing operation of wireless networks. It supports all aspects of wireless engineering, from simple verification of data to the complex processes of system design and optimization.

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