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Cabling for the Wireless Triple Play: Voice, Data and Video

Designing bandwidth capacity and cable drops for radios requires more accuracy than for simple data networking. BY JOE BARDWELL

The term "triple play" refers to the delivery of telephony, television and Internet data across a single network infrastructure. Triple play has quietly been working its way into our daily lives without many of us recognizing its significance. Telephone companies, cellular telephone providers, cable TV operators, and Internet service providers are all offering various forms of converged voice, video and data service. Deploying wireless triple play services often depends upon fixed-mobile convergence (FMC) technologies that allow a telephone call, data connection or streaming video connection to be established in one network (e.g., from a mobile telephone device) and then be seamlessly transferred to another network without loss of connectivity (e.g., to a Wi-Fi network when you enter a building).

To put this in perspective, consider that today there are two main public wired infrastructure systems—the telephone network and the cable TV network. There are also two main public wireless infrastructures—cellular telephone systems and satellite communications. The common denominator for voice, video and data convergence is Internet Protocol (IP), which has been around since the 1960s. It is this protocol that carries voice, video and data across interconnected network systems to facilitate the triple play, and bring previously separate network systems into a single, logical cloud.

In a triple play network, wireless radios, including wireless fidelity (Wi-Fi) access points (APs) and similar equipment, provide connectivity to mobile clients. Knowing where to locate these radios (and running cable drops to them) and knowing the performance and capacity requirements for the system becomes critical for supporting a triple play deployment. Every wireless network that is installed today will be expected to support triple play services during its lifetime.

The Five Fundamental Performance Metrics

It is only a matter of time (months, not years) before you see requirements for triple play services in the networks that you design and install. That applies to both wired and wireless systems. Ultimately, the move from a legacy data network to a triple play environment goes back to five fundamental performance measurements.

1. Bandwidth Capacity—Bandwidth capacity of the network must be sufficient to support the higher requirements of streaming video.
2. Signal-to-Noise Ratio (SNR)—The desired signals from APs and mobile client devices must be stronger than the background noise. Signals must be strong enough to be recognized properly even though the environment has random noise, as might be caused by microwave ovens or electrical disturbances.
3. Signal-to-Interference Ratio (SIR)—This metric may be presented or measured as carrier-to-interference (CIR) or carrier-to-interference and noise (CINR). The implication is that the desired signals have to be stronger than other valid, and potentially useful, signals that are undesired. For example, when two or more APs are visible on the same channel, it is often impossible to completely separate the three-channel (1, 6 and 11) space of an 802.11 network. In a case where two or more APs end up being visible, the "best" one has to be at least four times more powerful (6 dB above) any competitors. Otherwise, client devices will "thrash" back and forth between competing alternatives and the performance of the network will become unsatisfactory.
4. Latency—The interconnection devices in the network, each of which introduces a slight amount of delay in packet transmission, must not introduce too much delay, a metric referred to as latency.
5. Jitter—The delay that is present in the network must be reasonably constant. When delay varies from one moment to the next it degrades voice and video performance. This is a metric referred to as jitter.

The challenge becomes to design and install a network system that meets the five basic requirements of the intended voice, video and data applications. This results in a clear plan for designing a wireless network:

» Find out what applications and hardware devices will be using the network.
» Get the list of bandwidth, SNR, CIR, latency and jitter requirements from the vendors.
» Get the list of these same specifications from the manufacturers of wireless network equipment, Ethernet switches and routers, and other equipment that are used to build the network.
» Make sure the network provides the correct end-to-end levels of each of the fundamental metrics.

Today's wireline networks are quickly spreading out to a mobile user base through the implementation of wireless network systems. While the bandwidth, latency and jitter measurements for a wireline network remain fairly constant from one day to the next, wireless networks are impacted by environmental radio frequency (RF) fluctuations, noise and interference—and by the fact that mobile users move from location to location, where signal coverage may be good or bad.

	802.11a/b/g Conventional Wi-Fi	802.11n High Speed Wi-Fi	802.16d WiMAX Wireless Local Loop	802.16e WiMAX "Mobile WiMAX"	CDMA/GSM High Speed Options
Time Frame	Today	2008	Today	2008 - 2009	2007 - 2008
Specified Bit Rates	11 Mbps (11b) 54 Mbps (11g/a)	Up to 600 Mbps as per the 802.11n standard	75 Mbps	30 Mbps	Some standards specify as high as 20 Mbps
Practical Data Throughput	Typically ½ the specified bit rate	~100 Mbps	45 Mbps	Initially, 2 Mbps to 5 Mbps	Initially less than 1 Mbps to 2 Mbps
Typical Effective Range	100 – 200 ft indoors, 500 – 1000 ft outdoors	Possibly slightly greater than 11a/b/g	Possibly greater than 40 miles	Mobile clients will probably limit range to within 5 miles	Wherever the service is available
Targeted Applications	In-building and metro area	In-building	Fixed, point-to-multipoint outdoors	Outdoor mobile users	Portable devices in-building and outdoors
Things You'll Like	You own it. It's inexpensive	You own it It's the next evolution of Wi-Fi	Replacement for copper/fiber in the ground	Long range for mobile users	Coverage to extend throughout the cell phone networks
Things You Might Not Like	Short range Oversaturation is probable with too many radios	Client device and backhaul support may not be suitable	Expensive (compared to Wi-Fi)	Limited penetration through building walls	Lower data rates compared to WiMAX or Wi-Fi
Biggest Area of Concern	Designing for voice and video is significantly more challenging than simple data Wi-Fi	The standards aren't yet finalized so 11n should not yet be considered for commercial deployment	Make sure that practical data throughput requirements are carefully determined	Until full deployment we won't know how much is "sizzle" and how much is "steak"	Monthly, recurring subscription fees may be cost-prohibitive

Table 1: Wireless standards have trade-offs between data rate, mobility and coverage range.

The Three Families of Wireless Technology—Wi-Fi, WiMax and Cellular

There are several clearly different families of wireless technology in use, and emerging, in the market today. Often, however, the line between these families of standards appears blurred so it is instructive to see what the families are and how they differ. The latency and jitter characteristics for wireless network systems vary from equipment manufacturer to manufacturer, but the bandwidth capacity is very closely tied to the wireless standard being used for RF transmission.

Today, the focus in wireless network deployment is on three different groups of wireless standards.

» In the global view, cell phone technology offers a group of standards that falls into two major camps—code division multiple access (CDMA) and Global System for Mobile Communications (GSM).
» In the local area view, the IEEE 802.11 standards for Wi-Fi provide short-range, high speed connectivity.
» In the middle are the IEEE 802.16 WiMax standards with significantly greater range than Wi-Fi (but at slower speeds) and with significantly greater speed than CDMA or GSM (but with greater power consumption requirements and less ability to penetrate through building walls for indoor coverage from outdoor, pole-mounted antennas).

From the perspective of structured cabling and wireline deployment, the wireless network equipment in a system will always end up being tied back to the wired Internet or to an in-building wired Ethernet. Hence, understanding the wireless component requirements

Reason Why Triple Play Network Design Is Difficult

Prior to triple play requirements, data networks that were used simply for Internet access, e-mail and file transfer had very forgiving standards. A one Mb/s connection is fine for checking e-mail or Web surfing. From the standpoint of specifications, legacy Wi-Fi connections could be assumed down to a weak signal level of close to -95 dBm. In perspective, that translates roughly to a four or five-wall penetration from an AP to a client close to 46 m (150 ft) away in a typical office building. On the other hand, a requirement to support wireless voice-over-IP (VoIP) requires a minimum of -70 dBm and, in some cases, as high as -65 dBm. That is a requirement that is over 1000 times more aggressive than simple data transfer. Remember that an increase of 3 dBm implies the doubling of power. Going up from -95 dBm to -65 dBm is a 30 dB change; hence -65 dBm is 1024 times more powerful than -95 dBm.

This is because power loss over distance is exponential. You may have encountered the inverse square law that states that at twice the distance the power is four times less. This creates havoc on the unsuspecting network designer for triple play services.

Consider the scenario suggested above, where signal strength is -95 dBm at a distance of 46 m (150 ft) from an AP. If you were 23 m (75 ft) from the AP (half the distance) then you would expect signal strength to go up by a factor of four (inverse square). In fact, it would actually go up slightly more than a factor of four since you are not only closer (giving you the factor of four) but you are also several walls closer, eliminating the additional signal loss through these walls. Assume you have gained 6 dB (a factor of four) from the distance and another 6 dB because of two less walls. Signal strength has gone from -95 dBm up to -83 dBm and you've moved 23 m (75 ft). By halving the distance again, from 23 m (75 ft) down to 9.8 m (32.5 ft), there is another 6 dB of increase from the distance and, perhaps, lose another wall; a total gain of 9 dB, bringing the signal level up from -83 dBm to -74 dBm. Doing the math one more time, and moving from 9.75 m (32 ft) to 5 m (16 ft) and assuming a gain of another 9 dB, the power is now 65 dBm.

These distances and signal levels are plausible and within reason. A real-world scenario will have a similar change in signal level over distance. This being the case it should be evident that if a design targets between -83 dBm and -95 dBm you could be off by close to 23 m (75 ft) in your AP placement and still end up hitting your goal. On the other hand, a design targeting -65 dBm to -75 dBm must be accurate to within 5 m (16 ft) to hit its target signal strength objective. Using this reasoning one could suggest that a triple play network design must be four times more accurate than a simple data network design. The logic and the math presented here are open for some discussion, but the basic fact is undisputed: designing for triple play is more challenging, and requires greater accuracy, than designing for simple data networking.

becomes critical even for a designer or installer who is not involved in the wireless component of the overall network.

As shown in Table 1, there is a trade-off between data rate, mobility and coverage range. Today, the IEEE 802.11 Wi-Fi standards remain predominant for in-building, short-range high-speed connectivity. The fixed, point-to-point version of WiMax (IEEE 802.16d) is already an accepted standard for telephone company central office to branch office connectivity. Licensed and unlicensed point-to-point and point-to-multipoint systems that are very similar to WiMax have been deployed for a number of years from vendors including Motorola, RedLine and Orthogon (which is now part of Motorola). Mobile phone companies have mobile broadband services in many markets today and higher-speed standards are expected over the next 12 to 18 months.

Basic Capacity Equation

A customer's bandwidth capacity and performance requirements must be met by the wireless technology selected to provide connectivity.The formula is:

$$\frac{\text{(Bandwidth per User) x (Number of Users)}}{\text{Oversubscription Rate}} = \text{Total Required Bandwidth}$$

Suppose each user needs 768 Kb/s, which would be suitable for most basic voice, video and data applications. You need to support 30 users in the area covered by a single IEEE 802.11b/g AP. In a typical office environment, where wireless is an addition to wired Ethernet to the desktop, you can assume an oversubscription rate of 10:1 (only one person in 10 will be active at any given moment). This means providing a minimum of 2,304 Kb/s (2.3 Mb/s) at the AP. A typical AP will require roughly -90 decibel milliwatt (dBm) to achieve 5.5 Mb/s IEEE 802.11b or 6 Mb/s IEEE 802.11g (the next step up over 2 Mb/s connectivity). Hence, for this network, the design must assure that all desired coverage areas receive -90 dBm signal strength.

Experience and a decision on being conservative or aggressive should be the guide on oversubscription. Still, here are some guidelines for determining oversubscription rate:

- Typical office where wireless is provided in addition to wireline Ethernet – 10:1
- Office where wireless is the primary way of connecting to the network – 2:1
- Public access HotSpot or visitor access network – 20:1 to 40:1

Two Challenges for Wireless and Wireline Integration

There are two core challenges when integrating a wireless network into a wired network system. In fact, any wireless network deployment will always have a wired component, even if there is no other requirement for wireline connectivity. This is because the wireless network equipment is always going to need a cable. Whether that cable is simply for power or whether that cable also carries Ethernet for device data transfer, there is a cable drop in your future for every wireless device.

Challenge number one is to identify the location for the cable drop. Installation locations are determined by the RF design for the wireless network. For this article, the focus is on in-building network systems since these have the most elaborate wiring plans. There might be voice and data cabling to every room in a building and the additional cabling for in-building Wi-Fi APs becomes a natural extension of a project.

The second challenge is that cable drops related to the Wi-Fi network may have to support gigabit Ethernet data rates while the other drops may only require certification for 100 Mb/s Ethernet. There is Wi-Fi equipment on the market today that supports both 100 Mb/s and gigabit Ethernet. It is important to confirm that Ethernet drops for Wi-Fi equipment only need to be certified for 100 Mb/s Ethernet, as opposed to potentially overlooked future requirements for gigabit Ethernet.

If the spec for wireless equipment drops only provides support for 100 Mb/s Ethernet—typical in most specifications—you may want to raise the question as to whether or not the potential requirements for gigabit Ethernet have been considered. Identifying the locations for cable drops is the more difficult of the two challenges.

Three Ways to Identify Access Point Cable Drop Locations

Of the three methods that can be used to identify the right location for AP cable drops, one is ineffective, one is inaccurate and one is available only from a handful of professional design firms.

The first design method—ineffective—is called the poker chip method. Someone takes a floor plan and draws overlapping circles of 40- to 100-foot radius all over the plan. The center of each circle is an AP location, and that is the location of the cable drop. If you see a design based on overlapping circles, be suspicious that it may not actually work once it is installed.

The second design method—inaccurate—is to take a test AP to the site, put it somewhere, and then walk around with a test tool to determine "good" AP locations. This method, often referred to as the legacy on-site survey, cannot consider all possible AP locations. The on-site engineer cannot make measurements over 100 percent of the floor space and the interactions between multiple APs that occur after the network is installed cannot be determined.

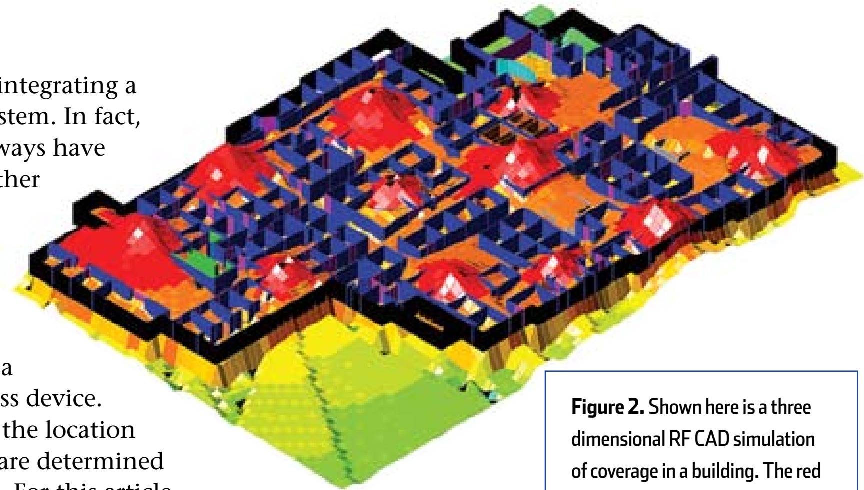


Figure 2. Shown here is a three dimensional RF CAD simulation of coverage in a building. The red (hot) peaks denote strong signal coverage while the green valleys are weak. Notice that some areas inside the building are shown with green (low) coverage. These need attention or they will be weak areas or dead spots after the system is installed. From this type of simulation a set of installation plans can be created.

The common problem that occurs when a legacy on-site survey is used to determine AP locations is that too many APs end up being installed and many of them end up in the wrong place. Manufacturers do produce centrally managed Wi-Fi systems that automatically adjust transmit power and channel settings on their APs. While it is true that these automated systems can reconfigure a poorly designed network to compensate for some types of problems, it is also true that these systems cannot completely eliminate weak areas or dead spots when the design is incorrect.

Automated configuration systems are wonderful for compensating for a failed AP (e.g., by readjusting power settings) and they are excellent post-installation management tools. They cannot, however, fix a problem caused by an RF shadow where an obstruction causes a weak area or dead spot. They also have no way to know what every portable client device sees relative to the coverage in the network. APs can see other APs and they adjust their channel settings based on what other APs are in the environment. When APs are placed improperly the automated systems become confused. In practice, there are some very severe and catastrophic failures that have resulted from dependence on an automated management system in the face of an improperly designed network.

Because an on-site survey typically makes spot measurements based on the movement of a single test AP, there is no way for the on-site engineer to anticipate the overall view that an automated management system will have after the network is installed. Without an automated management system, it is going to be even harder for a post-installation troubleshooter to figure out that a faulty design is causing a problem.

The third design method that is available only from a handful of professional design firms is the use of RF computer-aided design (CAD) modeling and simulation to create a preliminary design using three dimensional predictive computer modeling. Using predictive CAD modeling is the same approach taken by engineers in most engineering disciplines. Automotive engineers build and test car designs in the virtual environment of the computer before mock-ups or prototypes are produced. New airplanes and airplane wings are created as a result of CAD design and virtual testing before anything goes in a wind tunnel. From medicine, to heating and air conditioning, to electronics, every discipline of commercial and professional engineering utilizes CAD modeling for simulation and design.

The Two Benefits of RF CAD Modeling and Simulation

RF CAD modeling to create a network design starts with floor plans. Good AutoCAD plans differentiate between each type of construction material. Whether it is fire-rated drywall, tinted glass, elevators, metal racks, inventory on shelves, or furniture—whatever the material, a good CAD modeling and simulation system will allow an RF engineer to differentiate between every type of building material and interior obstruction. Also, the CAD modeling system will operate in three dimensions, assigning signal reflection characteristics to each obstruction to accurately predict signal coverage.

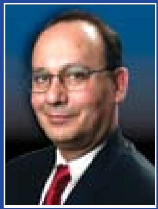
The RF engineer positions APs in the virtual building and can confirm the presence or absence of interference, the expected coverage areas, and the correctness of the design.

This results in two benefits for the installer. First, there is a complete set of accurate installation plans based upon the AutoCAD floor plans or other floor plan formats. This allows identification of cable drop locations for APs even if the building is not yet built. Second, the RF design plan is more accurate than anything that could be created by drawing circles on a floor plan or walking around trying to figure out a plan with a test AP.

Signal strength translates into bandwidth provisioning. When a signal is weak (but usable), Wi-Fi devices will drop to 1 Mb/s operation. When the signal is appropriately strong then IEEE 802.11g and 802.11a devices will operate at their 54 Mb/s spec. In the virtual environment of the three dimensional CAD building model an RF design system can predict signal strength (bandwidth capacity) and calculate predicted SNR and SIR. Calculating SIR cannot be accomplished as part of a pre-installation design by any other means than predictive modeling. Assuring that overlapping channels do not result in thrashing of Wi-Fi devices makes the application of RF CAD modeling a key part of any professional Wi-Fi system design.

Designing for Triple Play Success

When the wireline and wireless standards chosen to provide connectivity meet the bandwidth and performance requirements for a user's applications and devices, and when radio equipment is installed in the right locations, the installation will meet the needs of emerging triple play support. When they don't, you end up with frustrating, time-consuming, and costly retrofitting of an installation. The goal is to do it right the first time by paying attention to the details of AP drop locations. ■



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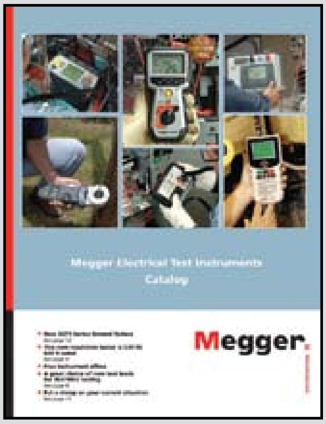

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