Notes on Design and Deployment of Wireless Infrastructure Systems

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Most recent news regarding wireless infrastructure has been about deployment of 4G (WiMAX and LTE) systems. Although this upgrade to wireless networks is progressing, it is still limited to the largest markets, with many big cities still not yet developed, despite the messages delivered in the advertising of the major wireless providers.

3G systems are more common, with coverage to all populated areas. However, some of these areas are underserved and unless located along interstate highways, many rural areas have service that is best characterized as "voice only" or "slow 3G data".

Cost of new equipment is certainly a factor in the speed of buildout of 4G wireless systems—for both wireless company investment and consumer purchase of advanced devices and upgraded service plans. However, technical issues are a bog factor, too. The design of base station radios, antenna systems, portable devices, and system routing/switching equipment is very different when an individual connection is expected to pass data at megabit rates instead of kilobits. In addition, higher data rates bring new uses beyond voice, text and the occasional photo. Equipment back end processing must also be upgraded to support these new services and applications.

Higher Data Rate Wireless Requirements

Let's take a look at some of the technical issues involved with the level of service promised for 4G wireless systems:

System support

Backhaul capacity—connecting cell sites to the operators' switching centers is undergoing a major upgrade to support the huge increase in data throughput. This work is underway as fast as crews can plow optical fiber into the ground and/or install high capacity mm-wave point-to-point radio systems. Such work does not happen instantaneously, and is subject to slowdown by weather, supply chain and manpower limitations.

System management—4G wireless provider central office equipment more closely resembles an Internet server farm than a telephone network. New management processes to handle the increased traffic are required, including both data handling and cell site management.

Modulation Bandwidth

Adaptive radios—Making best use of the available bandwidth can mean changing the radio channel between low bandwidth uses such as voice and text, medium rate uses such as web browsing and low resolution video phone, plus the highest data rate services like video download or streaming, online gaming, or video conferencing. PC adapters that use the wireless networks for a high speed connection will add another level of usage beyond that of smartphones and their apps.

Regulatory cooperation—Although out of the headlines, regulatory support and technical standards remain a big part of the behind-the-scenes work in wireless technology. Frequency allocation may be more important in international markets where wireless services are still developing, but even in the U.S., 700 MHz and TV "white space" spectrum is being explored for high speed data services. New policies on "net neutrality" promoted by the U.S Federal Communications Commission (FCC) will affect the business plans of wireless providers in the same way it will affect other broadband Internet portal services.

Signal-to-Noise Margin

High radio performance—Communication theory shows us that higher data rates can be achieved through increased bandwidth and/or higher signal-to-noise ratio (SNR). Achieving the highest possible bandwidth in a given channel bandwidth demands the highest possible SNR performance over the path from transmitter input to the data output of the receiver. Complex modulation schemes that support high data rates require a channel that has maximum transmitter effective radiated power (ERP) and receiver dynamic range, usually determined by the difference between minimum discernible signal (MDS) and the level where intermodulation distortion (IMD) prevents reliable demodulation.

Optimized coverage

The radio channel that carries high data rate signals can be improved in several ways that increase the SNR:

Smart antennas—Steered-beam antennas and multiple input/multiple output (MIMO) technology are part of the solution for achieving high SNR. However, these technologies require additional antenna hardware and control systems to make them work. Steered-beam antennas are implemented only at the cell site, but MIMO requires dual antennas and radio front-ends in portable devices that use the technology. This will affect cost, size and battery lifetime, which is already a design challenge for supporting radio function and data processing required for the new range of high speed applications.

Microcells and picocells—Another means of increasing SNR is a shorter signal path, taking advantage of the $1/r^2$ rolloff of signal level versus distance. Thus, a signal path that is half the distance requires one-fourth the power level to achieve the same SNR. Adding additional small cells to the system accomplishes this improvement, but the tradeoff is significant, since those microcells and picocells require backhaul just like a major cell site. In many cases, the reduced capacity of a small cell may make backhaul easier where a good wired infrastructure exists, but it will be difficult in other areas.

Dynamic system management—Better management of resources will be a major part of all wireless providers' efforts. Some software enhancements will be relatively simple to implement, but it is expected that there will be more reliance on human decision-making by system operating personnel until new traffic and hardware management patterns and control algorithms are developed. Examples of management improvements include better location tracking of users to optimize handoffs between cell sites, and separate operating schemes for inbound and outbound rush hour mobile users.

Increased Reliability

User habits are already changing dramatically where high speed networks are currently deployed, challenging the ability of the network to keep up with traffic in some cases.

Longer connect times—With greater capability, users spend more time using their smartphones, pad computers and other devices over the wireless network. Even at this very early stage of 4G deployment, weaknesses have been revealed that must be addressed before usage increases further.

High-rate apps—Video streaming for television programming, movies and games was not possible before 4G, and this new family of applications represents entirely new challenges for the evolving wireless networks. Combined with longer "on" times, these applications are driving the dramatic order-of-magnitude growth in the amount of data being handled by the networks.

Higher consumer expectations—As implied in the above paragraphs, consumers accustomed to their "always on" home high-speed Internet connections will expect the same level of service when operating wirelessly. This is encouraged by the wireless providers, who are promoting their services as a replacement for the present wired services. In these early months of 4G deployment, service problems have made the news more often than kudos for providing new wireless capabilities.

Summary

Wireless infrastructure to support high speed data services still has technical and operational challenges to meet before achieving the goal of "anywhere, anytime" service. Of course, some of the difficulties are simply a result of trying to get systems operating as quickly as possible—and some lessons must be learned from experience. Despite the significant challenges, there is little debate over the ability of engineers to solve them. The only question is how long it will take.