How Cell Towers Work

BY MICHAEL HARRIS

As a cell tower site leaseholder, you are familiar with the income and expenses of the business. But how about the technologies involved and their role in the delivery of wireless communications services that we rely on every day?

To understand how cell towers and base stations work, start by taking a look in your own home.

If you are like 80% of your American neighbors, you own a cordless phone system that plugs into your home telephone line. As the name implies, a cordless handset connects wirelessly to a small "base station," allowing you to walk and talk untethered while maintaining a link to the wires of the public switched telephone network (PSTN).

In principle, a cellular tower and base station that enable voice and data services for a Blackberry or iPhone aren't much different. Except, of course, that they are built to withstand the elements, cover a far greater geographic area than your home, simultaneously support hundreds of handsets, operate in different radio frequencies, and allow users to maintain their connections while traveling from one base station to another, even while driving at highway speeds.

Towers, Cells and Hexes

We're not launching into a discussion about life in medieval Europe. Rather, towers, cells and hexes are key building blocks for the design and operation of wireless communications networks.

In the wireless world, a cell is the geographic coverage area enabled by a tower. Locations are carefully selected to ensure that individual cells form a tightly knit mesh without coverage holes or unnecessary overlap, as shown in Figure 1. Engineers use hex schemes to design cellular networks and pinpoint tower locations to meet service demand.

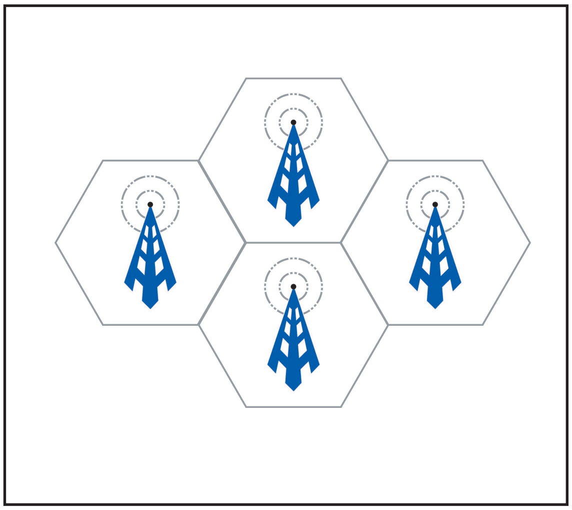

FIGURE 1: Towers and Cells in a Hex Pattern

The What, Where and How

The primary job of a cell tower is to elevate antennas that transmit and receive radio-frequency (RF) signals from mobile phones and devices. Wires run from the tower antennas to base station equipment, typically located at ground level in sealed telecom equipment cabinets. Components of the base station include transceivers, which enable the transmission and reception of radio signals through the antennas, plus signal amplifiers, combiners, and a system controller.

To ensure antennas are tall enough to cover a targeted cell area, cell towers are typically 50 to 200 feet in height. Towers can be standalone structures, such as steel poles or lattice frame, or affixed to other structures. In the latter category, cell towers are attached to buildings, water towers, bridges, tunnels, street lights, traffic lights, stadium lights, and billboards, among other things. To accommodate community aesthetic concerns, towers are increasingly camouflaged to resemble trees or flagpoles, or concealed in purpose-built structures, such as church bell towers or steeples.

The factors affecting cell tower site selection are complex and plentiful. At a basic level, the site must be adjacent to a road for physical access, with availability of electrical power and telecommunications network connectivity. Local zoning ordinances must accommodate tower height requirements to ensure signal coverage across the terrain. Sources of electromagnetic interference need to be avoided to ensure radio signal integrity. Environmental and wildlife impacts must be considered, in addition to architectural historic preservation and aviation requirements.

“The primary driver for cell tower locations is the service delivery needs of wireless carriers. Simply put, they want to be sure they are investing in infrastructure where it is needed most. When considering a tower placement, they will evaluate population and demographic data, plus the profiles of nearby businesses, pedestrian traffic, and the proximity of roads and highways.”

- Michael Harris

This mix helps carriers understand how many potential wireless users live or work in the area each day, plus those that will be passing through on the way to another destination.

Additionally, wireless carries carefully study the voice and data traffic traversing their networks in each cell area. If utilization begins to near the capacity limits of the antennas on a given tower, they need to evaluate options to increase capacity. Likewise, if local population and demographic data is favorable, before a carrier begins aggressively marketing wireless service in a given geographic area, they want to be sure they have enough capacity in place to serve the new subscribers that will be added to the network.

Like beverages, cell towers come in small, medium and large sizes (see Table 1). On the super-size side of the scale are macrocell towers. These standalone or structure-attached cell sites literally tower over the target area, offering a range of 10 miles or more in rural settings. Microcells are the mid-sized option, frequently employed in urban and suburban areas, covering cell areas less than a mile in diameter. Tiny picocells typically cover less than 250 yards and are used in office buildings, airports and business centers. The newest arrival, femtocells, are personal devices intended for home or office use and offer a coverage range similar to a cordless phone base station.

TABLE 1: Cell Tower Types

TOWER TYPE	MEANING	DESCRIPTION
Macrocells	10 miles	Standalone or structure attached
Microcells	1 mile in diameter	Urban and suburban
Picocells	250 yards	Office buildings, airports, campuses
Femtocells	Limited in building	Personal devices for home/office

Running the RAN

Together, the radio frequency spectrum, tower, base station equipment and user mobile devices create a Radio Access Network (RAN), illustrated in Figure 2. It is the foundation for the delivery of all mobile services and applications, just like physical networks constructed of fiber-optic and copper wiring enable telephone, data and TV services to homes and businesses. The RAN creates a reliable and robust communications network infrastructure, just without the wires.

In the U.S., wireless carriers typically use one of two standard technology platforms to offer digital mobile services – Code Division Multiple Access (CDMA) or Global System for Mobile Communications (GSM) – in a range of radio frequencies allocated by the Federal Communications Commission (FCC). CDMA and GSM are considered digital second-generation (2G) technologies, as they supplanted the first-generation of analog cellular technologies.

“Third-generation (3G) and fourth-generation (4G) extensions of both CDMA and GSM are designed to offer faster data access speeds and network efficiencies for mobile Internet and multimedia applications.”

- Michael Harris

CDMA is a general term for technical standards known as cdmaOne (IS-95), a 2G technology, and CDMA2000 (IMT-MC), a 3G platform. CDMA2000 includes protocols for accelerated data

services, including 1xEV-DO (Evolution-Data Optimized) protocols. The successor to CDMA2000, a 4G technology, is called 3GPP Long Term Evolution (LTE).

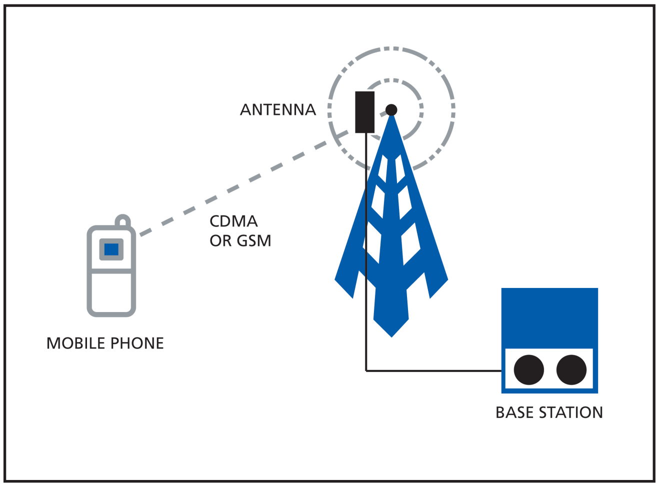

FIGURE 2: Wireless Radio Access Network

Worldwide, GSM is the most widely used 2G wireless communications technology. For 3G GSM, there are two favored technical approaches –Enhanced Data rates for GSM Evolution (EDGE) and Universal Mobile Telecommunications System (UMTS). UMTS requires that carriers completely replace their existing base station equipment to offer 3G services, while EDGE does not. However, UMTS is also a foundation for LTE 4G technology. Mobile WiMAX (also known as 802.16e) is separate 4G technology now being deployed in the U.S.

Wireless Tech Alphabet Soup

ACRONYM	MEANING
1xEV-DO	Evolution-Data Optimized, a 3G CDMA technology for boosting data speeds and network capacity
2G, 3G, 4G	The second-generation, third-generation and fourth-generation of digital wireless technologies
3GPP	3rd Generation Partnership Project, a GSM wireless technology standards consortium
CDMA	Code Division Multiple Access, a foundational digital wireless technology
cdmaOne	The 2G version of CDMA, also called IS-95
CDMA2000	The 3G version of CDMA, which includes 1xEV-DO
EDGE	Enhanced Data rates for GSM Evolution, a 3G GSM technology
GSM	Global System for Mobile Communications, the world’s most widely deployed 2G wireless technology
LTE	Long Term Evolution, a 4G technology platform
UMTS	Universal Mobile Telecommunications System, a 3G GSM technology
WiMAX	Worldwide Interoperability for Microwave Access; the Mobile version is a 4G technology and is also called 802.16e

What's the Frequency?

In the U.S., today's 2G and 3G wireless communication services are commonly delivered in two radio-frequency spectrum bands – the Cellular band and the PCS (Personal Communications Services) band. Cell towers are configured with antennas to support services in these frequencies.

The Cellular band, also called "800 MegaHertz" (MHz), includes two blocks of frequencies of 25 MHz each, one from 824-849 MHz and the other from 869-894 MHz. The PCS Band, also known as 1.9 GigaHertz (which equates to 1900 MHz), includes six frequency blocks of 10 to 30 MHz each.

When auctioning these Cellular and PCS frequency blocks to carriers, the FCC placed strict limits on the amount of spectrum an individual carrier could purchase in a given geographic area. The intent was to create a competitive market with multiple wireless carriers in every major metropolitan service area (MSA). As a result, limited wireless spectrum was available to each carrier to offer services. As more customers were added to their networks, carriers needed to find ways to stretch the finite RF spectrum they had available.

In 2006, the FCC auctioned additional spectrum for Advanced Wireless Services (AWS) operating in the 1710-1755 MHz and 2110-2155 MHz bands. The forced transition from analog to digital broadcast television services freed up a swath of additional spectrum in the 700 MHz band, which the FCC auctioned to wireless carriers in 2008. Verizon Wireless and AT&T Mobility were the biggest buyers and are eyeing the frequencies for 3G and 4G services.

Reduce and Reuse

Two technical approaches – frequency reuse and sectorization – have helped wireless carriers get the most of their Cellular and PCS spectrum.

Carriers typically configure adjacent cells to use different frequencies, preventing "confusion" among handsets about which tower antenna to connect (see Figure 3). A limited number of simultaneous mobile calls can be carried within a given frequency. Thus, in a highly-populated area, were a single cell to be used, the available capacity would be quickly saturated, resulting in wireless busy signals and unhappy customers. To prevent this, wireless carriers would deploy additional towers to split a large cell into several smaller ones, each using a different frequency band (see Figure 4). As the cell segmentation pattern is repeated, it allows the carrier to reuse

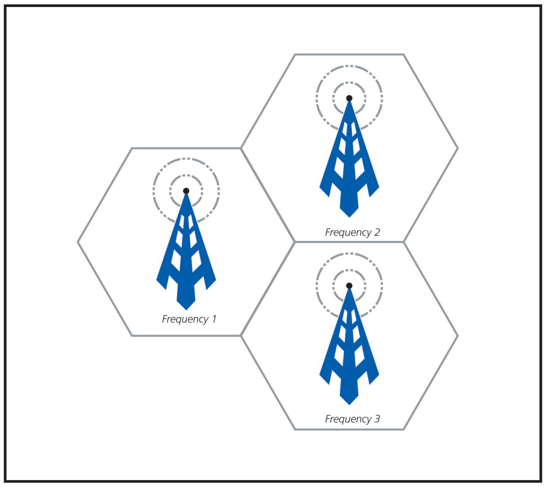

FIGURE 3: Large Cells with Omnidirectional Antennas

frequencies, and squeeze far more customers in the same spectrum.

Wireless carriers have taken the reduce and reuse approach a step further with the use of directional antennas, illustrated in Figure 5. Rather than using a single omni-directional antenna that covers a circular radius around a tower, carriers introduced directional antennas, to further segment cell sizes and enable the reuse of additional frequencies. For example, placing three antennas operating in separate frequencies on a tower allows sectors to be created within a cell, essentially tripling capacity per cell.

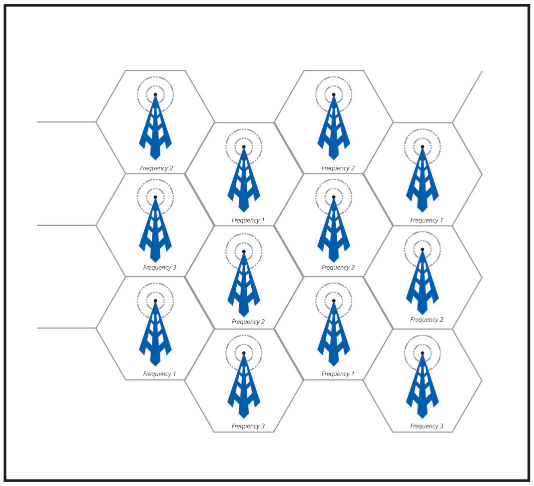

FIGURE 4: Reduced Cell Sizewith Frequency Reuse

Besides squeezing every last drop of available capacity from their available spectrum, major wireless carriers have leapt at opportunities to increase their spectrum holdings each time the FCC has offered new frequency blocks for sale.

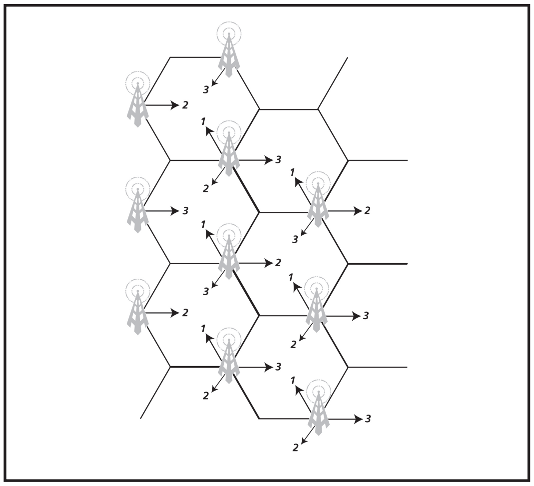

FIGURE 5: Reduced Cells with Directional Antennas

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New Technologies Could Mean Fewer Towers

Interestingly, with the additional spectrum available from auctions and carrier consolidation, plus the introduction of more efficient digital protocols associated with 3G and 4G technologies, some wireless providers are now actually looking to recombine cells. This would allow them to reduce the number of towers in use and the operating expenses associated with each. For example, in September 2010, Sprint unveiled plans to eliminate as many as one-third of its cell sites – some 20,000 towers – in the coming years.

The Whole Enchilada

So, now that you're familiar with how cell towers and base stations work, why not pick up that cordless phone at home and call your friend Bob on his cell phone? Follow the call signal past the telephone poles and through the public switched telephone network (PSTN), across the wireless carrier's network, to the base station, up to the antenna on the cell tower and over the air via radio frequencies to Bob's mobile phone on the go (see Figure 6). Bob is so excited you shared the intricacies of wireless network technology, that after hanging up with you, he calls Sally on her mobile phone across town to share what he learned. She then calls you at home to say "Thanks for the information!"

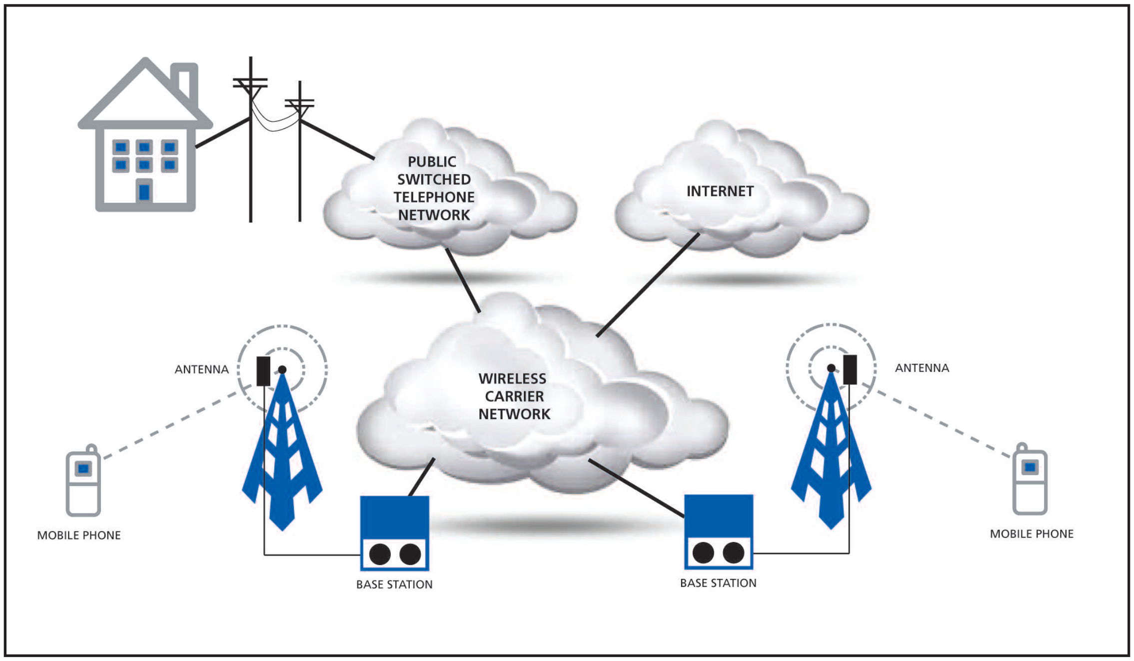

FIGURE 6: Wireless Communications Network

After reading this brief primer, you'll be ready the next time someone asks you to explain how that cell tower that you lease actually works. "Well, to start with it's not that different from that cordless phone base station in your house. Except for the cells, hexes, frequencies, and alphabet soup of technology protocols, of course…"

About the Author

Michael Harris is principal consultant at Phoenix, Ariz.-based Kinetic Strategies, Inc. Applying more than 15 years of experience as a strategist, research analyst, journalist, public speaker and entrepreneur, Michael consults with select clients in the networking, Internet and telecommunications industries.

About Unison Site Management

Unison Site Management is the largest independently owned cell site management company in the United States, managing thousands of wireless leases. As wireless lease consultants, Unison helps cell site owners protect against uncertainty, maximize return and provide peace of mind.

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