BY JAY M. JACOBSMEYER, P.E.

Different strokes

Multiple techniques are used to meet FCC wireless 911 location accuracy requirements

In the U.S. and Canada, 911 is the official national emergency number. When 911 is dialed, the caller is connected to a public-safety answering point, or PSAP, where a dispatcher routes the call to the appropriate emergency personnel. For wireline calls, the PSAP also obtains the telephone number and address of the caller so emergency services personnel can respond to the incident location even if the caller is incapacitated.

Cell phones create an obvious problem for 911 calls because their users are mobile and the phone number does not correspond to a particular location. In 2005, more than one-third of 911 calls in the U.S. were placed by cell phones, and the number is growing: In some places, half of the 911 calls originate from cell phones, according to the National Emergency Number Association.

The FCC understood this problem early on and adopted — in 1996 — its wireless Enhanced 911 (E911) rules. The E911 program is divided into Phase I and Phase II. Under Phase I, wireless carriers are required to provide (when requested by the PSAP) the telephone number of the wireless 911 caller and the location of the antenna (base station sector) that received the call. An urban-area base station can serve up to a ½-mile radius, so this information has limited usefulness. Phase II requires that the wireless carriers provide a position estimate for the 911 caller to within 50 to 150 meters, depending upon the technology used.

Position-location technologies for cellular phones fall into two basic categories: network-based and handset-based. Network-based solutions exploit the fact that the precise coordinates of the cellular base stations are known. Assuming multiple base stations — ideally at least three — can receive the handset signal, time-of-arrival information is used within the network to estimate the location of the caller. This is basically a triangulation technique, which is the favored approach of GSM carriers such as AT&T Mobility and T-Mobile. The FCC requires that network-based systems locate the caller to within 100 meters for 67% of the calls and to within 300 meters for 95% of the calls (one and two standard deviations, respectively, assuming a normal distribution).

In rural areas where the base stations are widely dispersed or perhaps along a straight line, this approach does not work well because typically just one base station receives an acceptable signal. In metropolitan areas where base stations

Table 1

Location technologies	Attributes	Performance
E-CID Enhanced Cell-ID (500–1000 meters depending on cell-site density)	Derives additional timing advance and power measurements from the wireless network.	Works with any phone and provides improved accuracy over Cell-ID in areas of high cell-site density.
A-GPS Assisted Global Positioning System (under 30 meters)	Uses modified handsets that contain a GPS receiver and a special network server to assist in location calculation.	Works well in rural and suburban areas that provide an unobstructed view of the sky.
U-TDOA Uplink Time Difference of Arrival (under 50 meters)	Uses low-cost location measurement units installed in the operators' base stations to precisely calculate location using trilateration.	Works with any wireless phone, existing or future. Works well in urban, suburban and obstructed environments.
AOA Angle of Arrival (100–500 meters)	Uses two or more antennas with multiple element arrays, allowing the exact location of each AOA element to be calculated precisely.	Works with any wireless phone. Supports sparse cell-site density or where cell sites are arranged linearly, such as along a highway.
Hybrid	Any combination of location technologies to achieve optimal performance for any situation.	Highest quality of service for all applications.

are closer together and tend to surround the handset, performance is better. There is always the possibility, however, that only one base station will be in view because efficiently designed networks purposely limit overlapping coverage areas to maximize network capacity.

With handset-based solutions, the handset performs all of the measurements and calculations. If the caller is outdoors, these measurements can be obtained using the Global Positioning System (GPS). The FCC requires that handset-based systems locate the caller to within 50 meters for 67% of the calls and to 150 meters for 95% of the calls.

To improve performance, additional calculations are carried out within the network, resulting in a technique known as Assisted-GPS. A-GPS is useful for 1.25 MHz CDMA signals, which have a chip duration of 814 nanoseconds, (equivalent to a coarse resolution of 244 meters). In contrast, wideband CDMA (WCDMA) signals operate at higher chip rates and can use observed time difference of arrival, which is similar to the network-based technology. But A-GPS also is used on WCDMA networks.

There are five major types of position-location technologies used in cellular radio networks today: A-GPS, Enhanced Cell-ID (E-CID), Uplink Time Difference of Arrival (U-TDOA), Angle of Arrival (AOA), and Hybrid.

A-GPS is the favored technology for CDMA operators such as Verizon Wireless and Sprint. In the U.S., U-TDOA generally is used by the GSM operators, but not by the CDMA operators. AOA works for any wireless phone, but it requires expensive infrastructure that generally is not in place today so it is not widely used. Table 1 summarizes the attributes of the major location technologies. Note that wireless providers are no longer exclusively TDMA (e.g., GSM or iDEN) or CDMA. For example, the major GSM operators — AT&T Mobility and T-Mobile — are implementing WCDMA third-generation systems that will use A-GPS.

Large indoor venues such as airports and convention centers increasingly are turning to distributed antenna systems (DAS) to provide radio coverage. These systems create challenges for the E911 system for several reasons:

- Typically, only one antenna sector receives an adequate signal from the handset
- The particular sector may serve a large area
- GPS does not work indoors

For example, one U.S. airport operates a large DAS used by four wireless providers and the 800 MHz public-safety system. The providers assign sectors — each of which consists of three sets of two antennas pointing in a specific direction (generally due north, 120° and 240° — to areas of the airport in different ways. All assign a sector to the two train tunnels — each of which is 1.5 km long — that connect the main terminal to the three passenger tunnels. Some assign an additional sector to cover the concourse — which is nearly 1.5 km wide — used by a major carrier with a hub in that city to accommodate the additional passenger traffic. Meanwhile, some use still another sector to cover the main terminal and the parking garages, an area of more than 500,000 square meters.

One of the problems with this setup is that using a single sector does not provide the overlapping coverage needed to triangulate the signal to locate the caller. Also, as mentioned previously, GPS is of no use because the signal won't penetrate the buildings. There isn't much airport officials can do about this — at least until the next time the respective leases are negotiated — as the wireless operators own the equipment. And looking to the FCC for help probably would prove fruitless, as it is likely, when the city is taken as a whole, that the wireless operators meet the FCC's aforementioned 95% mandate.

Nevertheless, solutions do exist. One would be to add two additional sectors in each location to create the overlapping coverage necessary for location identification. But that would be an expensive proposition for the wireless operator. Another would be to position GPS antennas on the roof that would pipe the signal into the building. Smaller GPS antennas then could be placed inside the building every few hundred feet to rebroadcast those signals. Of course, this also is a solution that the wireless operators would find cost-prohibitive. Additionally, its value would be limited because not every wireless handset is GPS-enabled; the TDMA operators, for instance, do not use A-GPS.

Cell phones create an obvious problem for 911 calls because their users are mobile.

In the meantime, the 911 call-takers serving that airport are left to ask the caller where they are located — which is very inefficient because callers often become disoriented in such a large expanse, or they become incapacitated after placing the emergency call. There have been many instances where travelers walked into what they thought was the east garage when they were really in the west garage — and vice versa — and then couldn't locate their cars. In such a circumstance, given the current conditions, how is a PSAP supposed to locate them? ■

Jay Jacobsmeyer is president of Pericle Communications, a consulting engineering firm in Colorado Springs, Colo. He holds BS and MS degrees in electrical engineering from Virginia Tech and Cornell University, respectively, and has more than 25 years of experience as a radio frequency engineer.