A typical radio site

LTE and LMR Coverage Comparisons

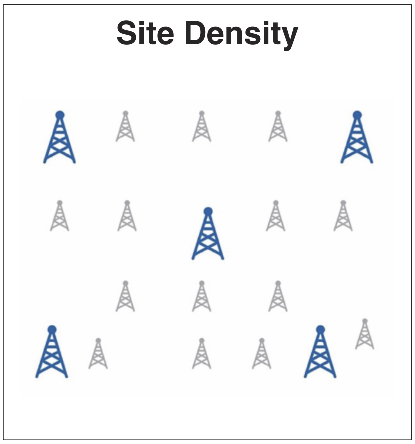
Many variables affect the coverage of an LTE network.

By Ryan Poltermann

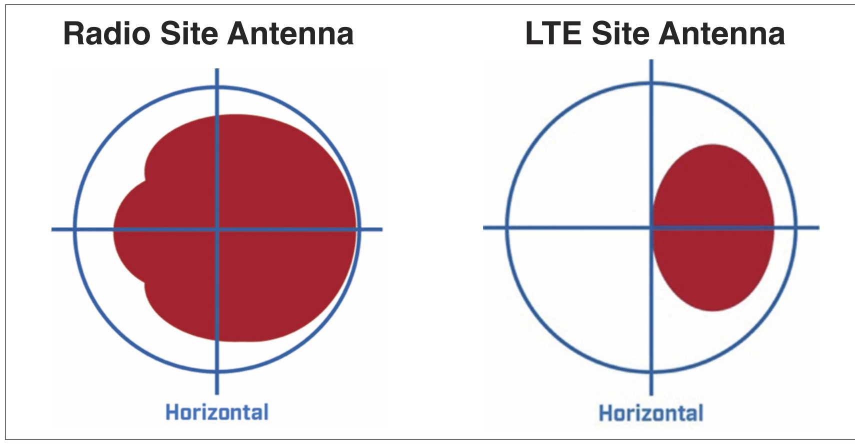
A typical LTE site

Images courtesy Ryan Poltermann

There has been a lot of discussion involving the potential transition from an LMR network to a cellular push-to-talk (PTT) system, but there hasn't been much information about the significant differences in technology. "The Blue Book: Wireless Communications for Public Agencies" will be published soon, and a selection of content based on the draft book follows. The free digital book covers many topics, including LMR, cellular, the First Responder Network Authority (FirstNet), cybersecurity,



The site density required for LTE (light gray) is higher for the same coverage.



A typical omnidirectional antenna pattern on the left and a highly directional cellular antenna pattern on the right (both viewed from above)

unmanned aerial systems (UAS) and satellite communications.

Cellphone Coverage Variables

Radio trunking can be used as the point of comparison. As a summary, the following are aspects that will change the performance of a cellphone:

Number of cell sites. As the power output of a cell site is typically lower and the transfer speed is higher, a cellphone requires more sites to provide the same amount of coverage expected from radio systems.

Frequency bands. Cell sites don't use just one frequency band; they can use a number of frequency bands such as 700 MHz and 1.7, 1.9 and 2.3 GHz. Band 14 isn't exclusive to public-safety use, even going back to the initial FirstNet request for proposals (RFP). FirstNet uses more than just band 14, as well. 5G frequencies, such as 24 and 39 GHz, can be even higher than LTE and have significant coverage limitations. Each cellular frequency performs differently, and which frequency band you're using can change even at the same location. However, radio systems use one frequency band for each site, and therefore, the site's entire coverage is consistent.

Cell site backhaul. How much total bandwidth does the site itself have to communicate with the main cellular infrastructure? Think of it as similar to your home internet — how much faster your Wi-Fi is versus the lower speed your internet provider typically offers. In cellular, however, you don't have a guaranteed speed, and the maximum speed available to you is being shared among all of the cellular users at the site. This will almost always be the limiting factor when it comes to cellular speeds, and it will be much lower than the advertised speed. The maximum speed at the site may also be further limited if multiple cellular sites use the same backhaul/transport.

How busy is the cell site? Because multiple antennas are used at the cell site, performance can be dramatically different depending on which antenna you're on.

Cellphone power output. The power output of the cellphone is lower than a radio push to talk (PTT), and the power can be reduced even further if the cellphone is close to a user's body. Be careful about comparing power directly because the rated power output for a cellphone is from the antenna, whereas the rated power output for the radio is before the antenna. There is also a significant focus on high-power user equipment (HPUE) for band 14, although band 14 HPUE was never meant for smartphones.

Modulation. As the speeds increase, there is less room for error either from the devices themselves or interference from the environment. This means the range will inherently be less.

LTE Needs More Sites

At a high level, the architecture can be considered somewhat similar to LMR, but the site density, or how many RF sites there are, is much higher and should be factored into disaster situations. When a cell site is isolated from the network, it's down completely. This will change when isolated operations for public safety (IOPS) technology is available. Don't forget to ask the provider about how long the cell sites can run on backup power.

The number of sites required is both a property of LTE's higher frequencies — 600 MHz and above — along with the power output LTE uses and how it transmits.

Multiple Frequency Bands

While trunked radio systems use one frequency band per site (700/800 MHz being an exception), cell sites can use many frequency bands. This can cause issues with older cellphones or phones from another carrier, which may not support all of the frequency bands at the site. Using many bands can also cause inconsistent performance from a user's perspective.

Here's an example. The cell site assigns frequency A to a user who walks into a building without issue. The next day, the cell site assigns frequency B to the user and momentarily drops the user's coverage when the user walks into the exact same building with the cellphone switching back to frequency A upon entering. This performance inconsistency can frustrate users and administrators as well. How does a system administrator find out what happened and why there's an issue? Is there even a way for a system administrator to correct it?

Besides the RF impacts, each frequency band may have different bandwidths available to it. Band 14, as an example, has 10 megahertz for talking to the cellphone and 10 megahertz for talking to the cell site. Assuming some standard things, such as 2-by-2 multiple input multiple output (MIMO) at 64 quadrature amplitude modulation (QAM) for the technical, the absolute maximum speed (throughput) you would theoretically see is about 100 Megabits per second (Mbps). Higher frequencies tend to have more bandwidth available, and because the signals don't go as far, they can be reused more often.

Antennas

For most radio sites, you'll have one or two transmit antennas and one or two receive antennas. An omnidirectional antenna is used at most radio sites. An omnidirectional antenna pattern is mostly circular because the antenna is meant to transmit in all horizontal directions.

Cellular coverage breathes based on the number of users on a particular antenna and site, the relative distance of the users and the capabilities of the devices.

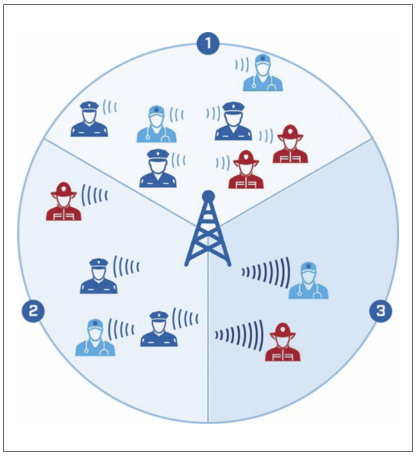
LTE sites have more antennas arranged horizontally, three or more per side. This is because the antennas are directional. This directional LTE antenna is called a sector antenna, and it provides coverage to only part of an area. Each antenna essentially acts as its own site and works with the other antennas at the site to provide more complete coverage. Antennas on the same side may also work together to improve bandwidth to the cellular device, known as MIMO, but the site's total throughput to the cellular infrastructure still has to be divided between all of the antennas and users on the system.

Changes with Loading

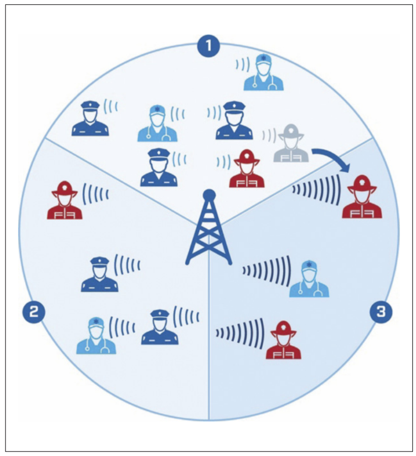
Project 25 (P25) uses two potential methods to transmit: FDMA or TDMA. Within each modulation type, the coverage map is always the same regardless of the number of users.

Cellular coverage, however, is more dynamic. Cellular coverage breathes based on the number of users on a particular antenna and site, the relative distance of the users and the capabilities of the devices. As a simplification, the performance can't be looked at from a site perspective but which side of the site you're on.

In the first circle on Page 24, Sector 1 has a lot of users, and the performance of the site isn't going to be



Antennas play a major role in performance. Numbers indicate the sector, and waves indicate cellular performance.



Moving just a little bit could make a huge performance difference as shown in Sectors 1 and 3 above.

Coverage breathes, and some users might get left out. Users with exclamation marks no longer have coverage.

high. Sector 2 has a moderate number of users, so the performance is okay but not great. Sector 3 has only a few users, so it will have the highest performance.

If users know where the site is, they might be able to improve performance by moving, as shown by the middle circle above. This would just be moving to a different antenna on the same site instead of a different cellular site. When a sector starts to get overloaded, the site will reduce the coverage in that sector to accommodate the users it has closer to the site as shown in the third image.

As mentioned, this is a simplification. Real cell sites will have more than three antennas (sectors), and many additional factors impact coverage and performance. Two examples are MIMO and beamforming. All of these factors make understanding coverage and troubleshooting difficult, as it won't be consistent and could change in a moment.

You may wonder what happens to a public-safety user who is in the fringes of coverage. How does that affect the coverage breathing and handoff between sites? The short answer is that it's not clear and will come down to the carrier's implementation. Be sure to ask your carrier how your users are handled in these situations.

What Device and How's It Worn?

In reality, cellular coverage maps don't mean much. Radio coverage maps are modeled with a specific device worn in a particular way (receive on hip belt clip and transmit at head level, receive/transmit in belt swivel case) or installed in a vehicle with a certain antenna. This isn't the case for cellular coverage maps, which only show where "coverage" is or isn't, and don't reflect actual usage.

To complicate matters further, the power output of a cellphone is reduced if it's close to the user's body. In contrast, radios use a constant power output. Cellphone performance is also dependent on how the cell site and cellphone are sending the information (frequency and modulation), and the user can't control this. Faster transmission speeds offer less range and less consistent performance in movement and changing environments. In contrast, radio systems use a consistent method every time for the RF site and the radio.

If you get detailed cellular coverage maps, you'll notice that the speed advertised on the map is extremely low, especially when compared with the speeds you may be expecting or what the carrier might even be advertising. Smaller numbers make the coverage look bigger, so check if the bandwidth on the coverage maps is realistic for your operations.

Regardless of which carriers you're testing, test at the same time and with the same type of devices. This will keep the playing field as level as possible and demonstrate where actual issues are instead of theoretical ones. Always compare your results with crowdsourced coverage maps such as Opensignal and RootMetrics.

This won't be enough to provide an informed decision, but it acts as a starting point. The Blue Book has additional information available for free, and it can help guide your agency. Test as much as possible, ask questions and share information with other agencies. By working together, you can get the best possible solution. ■

Ryan Poltermann is the principal investigator of National Cooperative Highway Research Programs Project 03-129: Essential Communications: A Guide to Land Mobile Radio (LMR) and the author of the "Blue Book: Wireless Communications for Public Agencies." With publication pending by the National Academies Press, the book covers all facets of wireless communications and will be free to download. Poltermann is an innovation architect at Commdex and responsible for public-safety innovation within the company. He has been involved in public-safety communications design and consulting for more than a decade and has contributed to more than half the U.S. states and six countrywide systems. He also participated in the Public Safety Communications Research (PSCR) public-safety haptic and augmented reality challenges. Email feedback to editor@RRMediaGroup.com.