

The Impact of 5G on Location Technologies

Fulfilling the Promise of Positioning
and Location Accuracy

Introduction

5G weaves together many new technologies to make a leap in wireless communications. As 5G devices and networks begin to emerge and expand through the early 2020's, cellular networking is changing the present-day smartphone experience, as well as opening up new use cases for every sector of the economy, such as automotive, smart factories, and telemedicine.

Location and positioning technologies are some of the most interesting areas of advancement in 5G. New use cases, from autonomous vehicles to real-time remote control, are driving the need for significant improvements in the accuracy, speed, and availability of positioning information. 5G is stepping up to the plate with enhancements to current 4G positioning techniques such as A-GNSS and OTDOA, as well as completely new techniques (such as using beamforming information to determine vertical position).

It is critical, of course, to perform testing of these new 5G technologies to ensure the location performance of new 5G devices and services. It is also critical in the near term, though perhaps less obvious, to test 4G positioning performance within 5G devices. There are two factors driving this testing need:

5G devices will use 4G LTE bands and protocols for emergency calling location information, and 5G NR has the proven potential to disrupt the LTE positioning designs that had been serving 4G devices perfectly well.

Before delving into these topics and 5G specifics, we will step back to review positioning technology as it relates to cellular networks.

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Cellular Positioning Technology — It's Not Just GPS Satellites

If you ask most smartphone users about how their iPhone or Android device performs tricks like turn-by-turn navigation, they are likely to say, "it's just GPS." While satellite positioning does form the foundation for cellular location, GPS alone cannot meet the most important cellphone location requirement: rapidly and accurately identifying a caller's location during an emergency call. This is where Assisted GNSS (A-GNSS) comes in.

GNSS is the generic term for a Global Navigation Satellite System. GNSS systems around the world include the North American Global Positioning System (GPS), Russia's GLONASS, China's BeiDou, The European Union's Galileo, and other regional systems from India, France, and Japan.

When an emergency call is placed from a mobile handset, it can take several minutes for the handset to find signals from the appropriate GNSS satellites and to receive a sufficient amount of positioning information (known as ephemeris data) to calculate its position. This startup time, known as Time to First Fix (TTFF), is a critical performance parameter in emergency situations.

To help the handset get a faster TTFF, the cellular network steps in. With **A-GNSS**, the cell network takes what it knows about the location of the user (such as the location of the base station that the user is currently connected to), looks up instantaneous satellite positions in a real-time database, and sends the handset information about which satellites to track. This "assistance data" reduces TTFF down to a handful of seconds, instead of minutes.

Cellular has a couple of other tricks up its sleeve, as well, to determine location even when satellite signals are weak or unavailable.

Beginning in 3GPP Release 9, LTE provided **Enhanced Cell ID (ECID)** and **OTDOA**. In ECID, the mobile device measures how long it takes for signals to get to and from the base station, and the power levels it sees from adjacent base stations. It reports this information to the network, which uses the data to determine the device's location. In OTDOA, the device similarly measures signal timing, but this time from several adjacent base stations. The network uses this timing information to triangulate the device.

Wi-Fi has also been extended to act as a viable indoor position technology, and is already being mandated by some major U.S. carriers (including AT&T) to meet the U.S. Federal Communications Commission (FCC) requirements. The proliferation of public and private Wi-Fi access points (APs) provides an abundance of equipment to control positioning information. Coupled with the fact that almost all new devices are equipped with Wi-Fi, this is an inexpensive and fast-to-market addition to supplement location-based services.

Taken together, A-GNSS, ECID, OTDOA and Wi-Fi form a "hybrid" positioning system that provides location information both indoors and outdoors.

Why the Push for Greater Location Accuracy and Availability?

As cool as they may be, GNSS and LTE-based hybrid technologies are becoming insufficient to meet increasing location demands and regulatory requirements. Coming up, we will look at how 5G and a variety of other technologies are stepping in over the coming years to fill the gap. What, though, are the new requirements?

The Regulatory Driver

The most influential driver for mobile location accuracy may be the regulatory requirements for mobile emergency calls (E911) set by the FCC. Other entities piggy-back on the FCC requirements, such as the European Union for E112 and, for automotive, eCall. Worldwide, the industry as a whole benefits from global handsets that meet these FCC-driven mandates.

The FCC has been driving increasing location accuracy for almost two decades. E911 Phase 1, defined in 1995, required only the caller's phone number and cell tower ID. This progressed in the early 2000's to a requirement of 300-meter accuracy within six minutes. The FCC has continued to evolve its safety requirements as our lifestyles have become so intertwined with and dependent on wireless connectivity. In 2017, the FCC required operators to demonstrate 50-meter accuracy for 40% of mobile E911 calls.

By mid-2021, operators will need to show that they are delivering 50-meter accuracy for 80% of all outdoor and indoor mobile emergency calls.¹

Commercial Drivers

The second mega-driver for location accuracy and anywhere-availability is economic. As wireless technologies have exploded over the past several decades, the opportunities for new applications have dramatically increased. Today's requirements for positioning are coming from a long list of new and envisioned human-to-machine and machine-to-machine use cases. These include augmented reality, fitness wearables, real-time location-based advertising, transportation, package tracking, asset tracking, factory vehicles, shared bikes, and many more.

¹ <https://www.fcc.gov/public-safety-and-homeland-security/policy-and-licensing-division/911-services/general/location-accuracy-indoor-benchmarks>



Figure 1. 3GPP is developing accuracy, latency, and availability requirements across different use cases to help guide 5G wireless development.² While many use cases and requirements are under consideration, it can be useful to think of location requirements within a few rough buckets.

² 3GPP TR 22.872, Study on positioning use cases, <https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3280>

5G, and Other Technologies, Too... Are Expanding the Positioning Toolkit

4G LTE cellular, GNSS, and hybrid positioning techniques are in the ten-to-dozens of meter accuracy range, with TTFF and update latency in the seconds to tens-of-seconds range. These ranges are insufficient for needs such as in-building asset management or unmanned aerial vehicles.

To exceed current-day performance and meet the evolving needs for more stringent accuracy and speed, many innovative technologies are being developed.

- **Advanced Wi-Fi technology** (802.11mc) introduces Fine Time Measurement (FTM) to measure the distance between an access point (AP) and a device within 1–2 meters of accuracy, rather than just using RSSI or Wi-Fi AP physical location. With multiple AP FTM measurements, triangulation (similar to OTDOA) can be performed to get a very accurate location.
- End-devices are able to contribute to location accuracy with **onboard inertial, magnetic, and barometric sensors**.
- GNSS techniques are being improved. The U.S. GPS system has introduced the **L5 band** to improve accuracy and signal robustness. GNSS chipset enhancements such as L5 support the ability to scan multiple GNSS frequencies simultaneously and are now becoming common in cellular handsets.³
- **Terrestrial Beacon Systems** use indoor-penetrating radio deployed on cell towers to create a precision triangulation network. These systems are being explored for emergency calling, public safety,⁴ and other applications.

5G Technology Also Has Many New Assets to Bring to the Table

- 5G is a wideband technology, and **higher bandwidth** enables more positioning information (positioning reference signals, or PRS) to be exchanged between the device and the gNodeB base station.
- 5G brings **massive MIMO** and **beamforming** technologies to the mix. In LTE, the base station may know, at best, the sector that a user is in (typically 120° horizontal range). Beamforming slices base station transmissions into many spatial components just a few degrees apart, providing far greater location accuracy. 5G beamforming antennas are not just horizontal, but are two-dimensional arrays of antenna elements. This allows 5G to step into the arena of vertical z-axis positioning by identifying which vertical beam a user is occupying.
- **Higher frequencies** allow for higher resolution of beamforming. With 5G deployments into mmWave frequencies (28 GHz and higher), the “airspace” will be divided into many beams that are even fewer degrees apart, resulting in yet greater accuracy in both horizontal and vertical dimensions.

³ <https://www.KeysightKeysight.com/Blogs/Positioning/2016/February/How-To-Use-GNSS-Simulators-Test-RTK>, and <https://www.sciencedirect.com/science/article/pii/S0273117718306537>

⁴ <https://firstnet.gov/newsroom/blog/firstnet-evaluating-key-indoor-location-technologies-z-axis>

- **Small cells, picocells and femtocells** (oh my!). Millimeter wave frequency radio has a problem: it does not travel very far, and it is easily blocked by leaves, rain, walls, and even by heads and hands. The industry will overcome these RF propagation issues with densification.⁵ By installing small cells only several hundred meters apart, 5G mobile devices will have better access to line-of-sight radio paths. Similarly, cells (be they pico, femto) and “distributed antennas” (DAS) will be installed throughout public and some private spaces to achieve indoor and underground signal coverage. A happy byproduct of outdoor densification and of indoor coverage is that location accuracy can be greatly improved, initially outdoors, and later indoors and underground as well.
- **Protocol upgrades** are coming, too. To handle all of these new sources of positioning data, the mainstay protocols used in LTE cellular networks will be upgraded in future 3GPP releases.

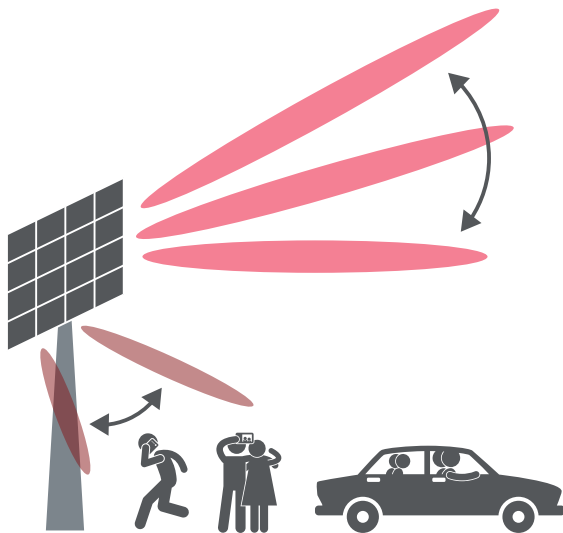


Figure 2. In 3G and 4G, base station signals cover a wide area. With 5G beamforming (shown) a two-dimensional area antenna allows each user to be served by a narrow beam that covers a particular horizontal and vertical space

Timeline for 5G Location Technologies

Moving from today’s positioning technologies to incorporation of 5G enhancements will occur in phases over several years.⁶

In the first phase, 5G handsets and devices will exclusively employ 4G LTE positioning technologies. This may be true for both Non Stand Alone (NSA) mode, where 5G uses the 4G LTE core for call setup, and for Stand Alone (SA) mode, where 5G uses its own 5G core.

Even in 5G SA, devices that provide voice communications will employ dual-mode 4G/5G modems and will fall back to 4G for E911 and other emergency call services.

⁵ <https://www.lightreading.com/mobile/5g/5g-the-density-question-/a/d-id/740634>

⁶ <http://www.3gpp.org/release-15>

In the second phase, location information will be exchanged between the user equipment and base station natively over 5G. Some of the performance improvements that 5G enables may be included.

In the third phase, enhancements to positioning derived from new 5G assets (higher bandwidth, beamforming, higher frequencies, and densification, as described above) will be rolled in.

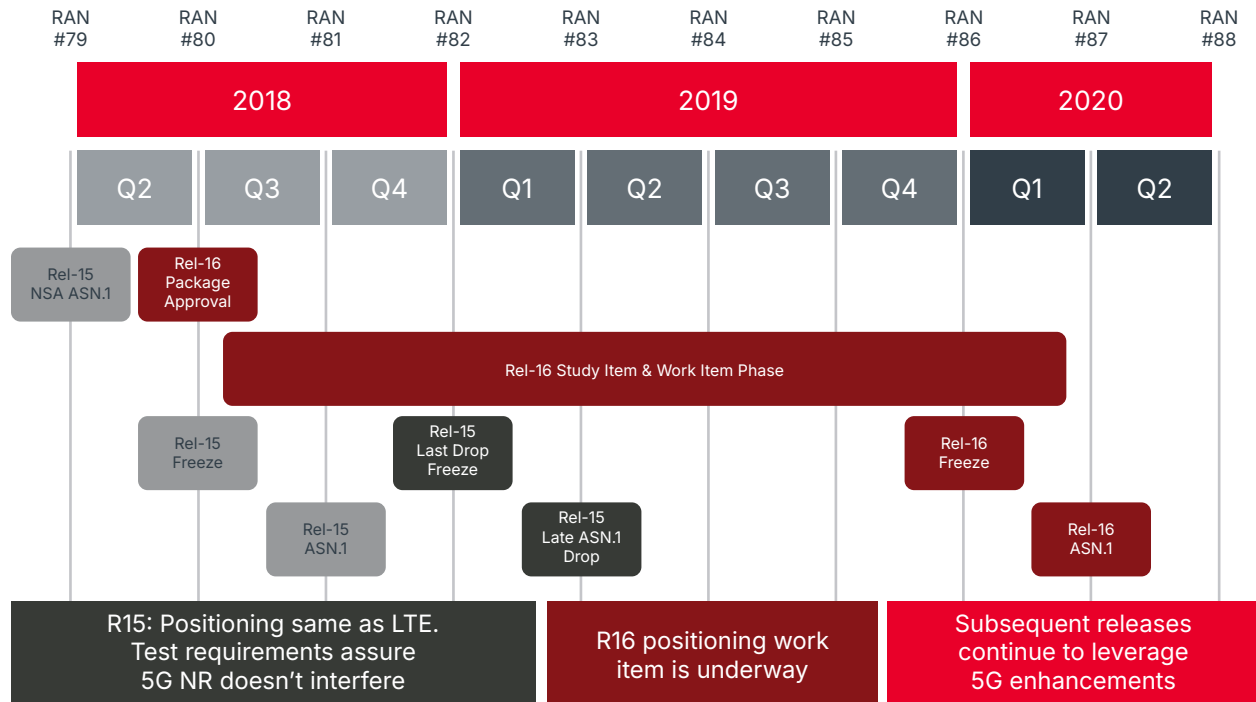


Figure 3. 3GPP's 5G releases 15, 16, and beyond specify the evolution of 5G positioning technology

5G Location Test Challenges

All of these “wonders” of 5G positioning also bring a need for accurate performance testing. Network providers and device manufacturers are already working to understand the potential challenges and design test methodologies to ensure that location-based systems work as intended. In 3GPP, for example, there are several working groups and work items related to 5G positioning technology.⁷

As noted earlier, 5G devices and networks will first be using existing 4G LTE positioning technology in both NSA and SA networks, especially where emergency call services are required.

A similar situation occurred as 4G began to roll out. Handsets were dual mode 3G/4G and used 3G exclusively for E911 emergency calls for several years. (A bit of relevant history: it took seven years after the introduction of nationwide LTE service before Verizon, one of the LTE leaders,

⁷ RAN#80 Study on NR positioning support
<https://portal.3gpp.org/ngppapp/CreateTDoc.aspx?mode=view&contributionUid=RP-181399>

deployed the first phone that did not have any 3G at all.^{8,9)} The initial dual-mode phones that used 3G for E911 suffered a variety of location performance issues that were discovered during testing. As a leader in positioning assurance, Keysight saw quite a few 3G/4G devices where the new LTE bands interfered with the devices' GPS satellite positioning receivers. It was also common to see 3G/4G devices that failed to perform 3G location positioning accurately due to protocol or processing prioritization issues.

Be on the Lookout for Potential Issues

To ensure that history does not repeat itself, test teams will need to be on the lookout for several types of potential issues during early 5G implementations:

- R15 introduces some **protocol changes** to 4G LTE LPP positioning to accommodate dual mode 4G/5G devices, and it is important to ensure these changes do not affect performance.
- Potentially serious new **interference issues** introduced from the interaction between multiple bands will impact the ability to receive GNSS signals. Since 5G devices will be simultaneously connecting on both 5G NR and 4G LTE, intermodulation (IM) and 3rd harmonic distortion can appear at the sum and difference frequencies. For example, 5G NR in both the 3.5 GHz and 5 GHz range combined with LTE band 4 will produce IM RF power directly on top of the main GNSS band (L1). Other common band combinations have similar IM issues with which to contend.
- **Latency** must be tested and measured for 5G to 4G fallback scenarios, such as when a 5G NSA device makes a voice call, to ensure that the device successfully and rapidly enables 4G positioning.
- **Processor lag** also must be assessed to ensure that priorities are properly managed. As devices switch between modes, establish sessions, or juggle background 5G data, they need to maintain positioning algorithms as critical priority during emergency call scenarios.

The net impact of these effects is that 4G technology within 5G devices needs to be verified to ensure that TTFF and location accuracy performance have not been adversely affected. Today's regulatory requirements are far more stringent than they were during the last generational switch. Furthermore, conducted and over-the-air (OTA) conformance tests for emergency calling are required in some regions. Meeting these requirements will necessitate 4G test systems to be upgraded to support 5G NSA and SA connections.

As we move to the next phase of 5G positioning, we will see stringent requirements falling onto 5G device designers. Location test methodologies will need to be adapted to handle more complex OTA cases with array antennas and horizontal and vertical beams. Head and hand and other obstructions will need to be considered for mmWave frequency devices. And indoor testing will become a critical part of location testing.

Test methodologies that span both lab and field testing have the best chances of success.

⁸ Verizon nationwide deployment <https://www.verizon.com/about/news/vzw/2010/12/pr2010-11-30a>

⁹ First VZ non-3G device <https://www.theverge.com/circuitbreaker/2017/6/16/15811502/verizon-lte-flip-phone-lg-exalt>

Keysight's Seamless Path to 5G Location Test

Keysight's 8100 Mobile Device Location Test System has been the industry-leading lab test system for over a decade. It includes the world's first Wi-Fi indoor location emulator and has been the go-to-system for 3G and 4G developers, QA, and conformance test teams.

A high-performance platform is needed to test the high performance that 5G can deliver. Keysight's 8100 Mobile Device Location Test System, a seamless upgrade for existing 8100 customers, features 5G emulation built upon the world-leading National Instruments (NI) PXI platform. Keysight and NI are collaborating to bring together the best in 5G testing performance with the best-in-class user interface, test case environment, conducted and OTA radiated testing, and location expertise in the business.

Finding Your Path Through 5G Location Challenges

5G is rushing towards us, bringing welcome improvements in location and positioning accuracy for our mobile devices. But the transition will be complex, and it brings its own new challenges. Keysight offers proven, cutting-edge testing solutions that can make the transition simpler and smoother, and help assure that device designers and mobile operators fulfill their promise to their customers of high quality, hiccup-free service, even as technologies and networks shift, blend, and evolve in new and possibly unpredictable ways.

Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at www.keysight.com.



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