5G Solutions for Mobile Network Operators

Accelerate the Commercialization of 5G Services
5G Solutions for Mobile Network Operators

5G deployments have begun and rollout announcements from mobile network operators are multiplying. Mobile network operators around the world are investing in 5G and launching networks to capture new business models. 5G requires new technologies and performance improvements that challenge the way engineers test the network.

Keysight delivers deep expertise in radio frequency (RF) design and Internet Protocol (IP) networking through an industry-leading integrated portfolio. Keysight can help mobile network operators accelerate the delivery of secure, reliable, and cost-effective 5G networks and innovative services.

"Keysight’s proven expertise in mmWave and 5G test capability in OTA environments enable us to accelerate our 5G commercialization plans and ensure that new 5G mobile devices will operate reliably on our network."

– Toshiyuki Futakata
  Vice President and General Manager, Communication Device Development Department, NTT DOCOMO
Overview: End-to-End 5G Solutions to Connect and Accelerate the Workflow

5G offers significant revenue potential for mobile network operators. Standards are evolving, giving rise to new use cases. The 5G New Radio (5G NR) non-standalone (NSA) standard passed in December 2017, followed by the standalone version (SA) in mid-2018. 5G NR NSA and SA continue to progress in parallel. 5G NR extensions for vehicle-to-everything communication (V2X), ultra-reliable low-latency communications (URLLC), and other applications are on the horizon.

Mobile network operators face new application demands and need to find ways to support the massive increase in future subscribers. Meeting these requirements means that networks need to change to accommodate expanded frequencies in the millimeter-wave (mmWave) spectrum, wider channel bandwidths, denser waveforms, and user behaviors.

Keysight solutions accurately emulate 5G devices, base stations, and massive subscriber behavior scenarios.
Scenario

The complexity of 5G, increasing user demands, and the hypercompetitive nature of the commercial wireless communications industry, make it critical for mobile network operators to validate the performance of networks and user equipment (UE). With Keysight’s solutions, mobile network operators can evaluate device protocol compliance and perform realistic large-scale UE simulation thoroughly and time-efficiently.
5G channel sounding

Keysight’s 5G Channel Sounding Reference Solution consists of multiple hardware and software elements to provide wideband signal generation. This solution helps research engineers to advance 5G channel modeling at mmWave frequencies.

The test platform addresses the challenges posed by mmWave frequencies and wide analysis bandwidths for 5G channel capture and characterization. Researchers can determine the properties of a radio channel by understanding the impact of path loss, Doppler effect, and other issues on signal transmission. The solution easily scales up by adding Keysight up/down converters and digitizers.

Solution highlights

- Comprehensive measurements of frequency response
  - Amplitude and unwrapped phase and group delay
  - Absolute path loss and power delay profile (PDP)
  - Angle of arrival (AoA)
  - Angle of departure (AoD)
  - Angular spread (AS)

- Wideband transmitter and receiver test calibration including vector pre-corrections, IQ frequency response, IQ imbalance, and channel-to-channel skew for complete confidence in your measurements and decisions

- Precise transmit/receive (Tx/Rx) timing and synchronization for high measurement accuracy when capturing and characterizing potential channels

- Configuration and test tools for input/output (I/O) control, system-wide calibration, data storage, and streaming for the efficient characterization of complex 5G channels

- Three standard configurations are available: 40 GHz and four channels, 40 GHz and eight channels, or 44 GHz and four channels. Custom solutions are available for higher frequencies, wider analysis bandwidths, and channel counts (up to 104 channels) to address a wide range of applications
5G network and UE emulation

5G network emulation solutions

Keysight’s 5G network emulation solutions, based on the E7515B UXM Wireless Test Platform, enable mobile network operators to evaluate device compliance against standards and regulations and their own acceptance tests. These solutions comply with the latest 3GPP Rel-15 standard allowing mobile operators, and their 5G mobile device suppliers, to address new technical challenges and accelerate deployment of 5G technology across sub-6 GHz and mmWave frequencies.

Keysight delivers comprehensive OTA test capabilities by combining network emulation and measurement capability with anechoic chambers, such as Keysight’s Compact Antenna Test Range (CATR) solution, which is based on the indirect far field test methodology approved by the 3GPP.

By partnering early with leading chipset and device manufacturers, Keysight introduced 5G network emulation solutions for both protocol testing and RF performance validation. Mobile operators around the world use Keysight’s network emulation solutions as part of their mobile device acceptance plans.

Using a common interface unit (CIU) and remote radio heads (RRH), the platform’s frequency range can extend to high intermediate and mmWave frequencies. Users can validate device-under-test (DUT) performance over the air with chambers designed for different test cases. Early access to a comprehensive set of test cases on a common platform enables mobile ecosystems – consisting of chipset and device manufacturers, mobile operators, and test labs – to quickly and confidently validate the performance of new 5G designs.

5G Protocol R&D Toolset

This toolset addresses diverse spectrum requirements and enables engineers to prototype advanced 5G protocol features, including beamforming at mmWave frequencies for SA and NSA modes. Engineers can emulate all the 5G system elements flexibly, make accurate measurements, and make informed decisions during protocol verification.

5G RF DVT Toolset

This toolset enables the user to validate the RF and radio resource management (RRM) performance of a mobile device on a call using the 5G NR standards. It supports use cases for 5G NR SA and NSA modes, and beamforming technology at mmWave frequencies.
5G Conformance Toolsets

The conformance toolsets provide up-to-date and comprehensive access to 5G conformance test cases to ensure mobile devices perform as expected on a live mobile network.

5G Protocol Conformance Toolset

The 5G Protocol Conformance toolset enables engineers to validate protocol conformance for devices. Protocol conformance test cases are based on the latest TTCN-3 test specification from 3GPP RAN5 and support all Global Certification Forum (GCF) and PTCRB mandated frequency bands in both FR1 and mmWave (FR2) frequencies.

5G RF/RRM Conformance Toolset

This toolset addresses a wide range of RF testing requirements and supports a comprehensive set of 3GPP 5G NR RF and RRM conformance test cases in FR1 and mmWave (FR2) frequencies for both NSA and SA modes.

Solution highlights

- Multiformat stack to support comprehensive testing and increase product quality
- Rich processing power to handle more data faster and accelerate innovation
- Abundant RF resources to address all application needs
- Scalable to support 3GPP Rel-15 and beyond to address new test requirements
- 5G NR SA and NSA modes and frequency range 1 (FR1), frequency range 2 (FR2), and frequency bands support to deal with all aspects of 5G
5G UE emulation RAN and core testing platform

Keysight’s 5G UE emulation solution is the only tool that can perform both radio access network (RAN) and core testing for 5G. With this solution, mobile network operators can perform realistic large-scale simulations. The solution covers legacy and new technologies. Engineers can validate sub-6 GHz and mmWave radio products and new 5G technologies and services at scale and performance.

5G RAN functional and performance testing

Ixia’s 5G RAN Testing Solution performs end-to-end 5G RAN functional and load testing by simulating stateful UEs that model real-world behavior. As a performance tester, it has the capacity to scale up to several thousand UEs.

Solution highlights

- Provides full-featured 5G NR UE emulation for completeness in the testing process
- Offers NSA and SA coverage to address all 5G NR modes
- Addresses 5G use cases, including enhanced mobile broadband (eMBB), URLLC, and massive machine-type communication (mMTC)
- Supports
  - 6 GHz and mmWave frequencies
  - 100, 200, and 400 MHz bandwidths
  - 2x2 and 4x4 multiple input multiple output (MIMO) (8x8 MIMO ready)
  - Four aggregated carriers (eight carriers ready)

5G RAN Testing Solution Benefits

- Validate 5G RAN functionality with full protocol stack testing and perform 5G RAN load testing for both SA and NSA modes
- Validate service quality with subscriber modeling and multiplex voice, video, and data traffic generation
- Equip yourself for the future with scalability to thousands of UEs, 8x8 MIMO, and 8xCC
5G core performance testing

Using the 5G Core Test Engine, Keysight’s 5G Core Testing Solution validates critical 5G requirements to maximize network reliability and performance. The solution scales up to millions of subscribers and performs comprehensive testing of all nodes and interfaces, providing in-depth QoE statistics and metrics.

Solution highlights
- Features topology-based user interface for comprehensive network re-creation in the laboratory
- Includes user plane function (UPF) capability to generate close to line-rate User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) traffic (using the CloudStorm load module)
- Works with Ixia hardware and virtual machines for superior flexibility
- Is public-cloud ready via microservices and containers

User Interface for 5G Core Test Engine

5G Core Testing Solution Benefits
- Ensure carrier-grade quality by characterizing and continuously validating the 5G core network in the laboratory and preproduction
- Prepare for 5G use cases by simulating UE behavior in network slicing and multi-access edge computing (MEC) deployments
- Independently manage control and user planes with network objectives that control test traffic mix and intensity
5G virtual drive testing

Keysight’s Virtual Drive Testing Toolset leverages Keysight’s PROPSIM 5G Channel Emulation Solution, 5G Network Emulation or real network infrastructure, and Nemo field measurement solutions. It enables mobile network operators to thoroughly verify end-user experience by replicating and repeating virtual drive testing scenarios in a controlled environment.

This performance and interoperability testing solution brings real-world multipath propagation conditions into the laboratory, enabling engineers to replicate complex 3D real-world radio channel conditions in drive or indoor test routes. Mobile network operators can benchmark new mobile devices and infrastructure quickly and cost-effectively. With the Keysight Virtual Drive Testing solution, mobile network operators can accelerate product rollouts and QA testing without compromising the quality of experience (QoE).

Solution highlights

- Provides the ability to replicate and repeat the real-world environment with real devices in a laboratory
- Uses data captured in the field; field-to-lab tool with the industry’s most realistic RF conditions
- Includes advanced test automation capability with ready-to-run test case packages and 24/7 automated analysis and reporting capability to accelerate performance and interoperability validation
- Features sub-6 GHz and mmWave frequencies to cover all of the 5G spectrum
- Covers common and supplementary carrier test plans to ensure compliance with any mobile operator
- Supports all wireless technologies for a high return on investment

Virtual Drive Testing Solution Benefits

- Identify and resolve issues earlier in the research and development (R&D) process by benchmarking and testing the interoperability of devices and real networks prior to deployment
- Accelerate root cause identification and resolution of issues found during deployment
- Understand the end-user experience in practice using a toolset that supports your own infrastructure elements and services
5G network propagation model tuning

Early 5G field measurements for path loss and link budget verification

Keysight’s 5G Field Measurement solution is a complete system for early 5G NR radio propagation and coverage verification. These initial measurements give insights into 5G network propagation, creating data for use in more accurate network planning. Measurement data imported into the planning tool enables engineers to calibrate the propagation model, providing more accurate coverage prediction results.

Solution highlights

• Sub-6 GHz and mmWave frequency coverage for measuring and verifying spectrum, reflection, and penetration in indoor and outdoor environments

• Measurement of total channel power over bandwidth to evaluate and verify propagation models for different frequencies and to accelerate time to market for 5G base stations

• Data post-processing; visualization, including spectrum view of the 5G signal, and analysis capabilities to ensure the usability of data and faster time to insight
5G gNB field test

5G operators and network equipment manufacturers (NEMs) will need new OTA test tools for network and UE field test, as well as optimization tools to deploy and verify the performance of these networks. Keysight’s FieldFox handheld analyzer, combined with a phased array antenna, provides a unique, portable solution for measuring and analyzing the 5G air interface in the field.

**5G Phased Array Field Test Solution Benefits**

- Understand gNB beam characteristics by measuring signal power level across azimuth and elevation from base stations.
- Reduce measurement complexity with integrated RF probe and phased array solution to capture energy radiated from gNBs.
- Calibrated-grade mmWave phased array antenna simulates 5G UE antenna performance.
- Phased array performance verification showing boresight, polar antenna pattern with compass, and heat map (azimuth vs. elevation).

Polar antenna pattern with compass

2D scan heat map (azimuth vs. elevation)

Boresight scan
Keysight’s 5G gNodeB (gNB) Field Test solution is based on the FieldFox analyzer. It provides complete tool kits for RF engineers and technicians to install and troubleshoot 5G networks. The solution serves as an all-in-one instrument that can be configured as a spectrum analyzer, real-time spectrum analyzer, cable and antenna tester, and more. FieldFox LTE FDD and 5G TF OTA can measure primary synchronization signal (PSS), secondary synchronization signal (SSS), and decode cell ID, which are key parameters to measure the effective 5G coverage.

Since 5G control channels are based on beamforming and are not always on, this can make it challenging to determine the location of the 5G signal. Switching to real-time spectrum analysis (RTSA) mode on the FieldFox can quickly and reliably detect 5G signals, detect control channels, and provide insights into beamforming performance.

**Solution highlights**

- Features continuous frequency coverage from 5 kHz to 50 GHz
- Serves as an all-in-one instrument: spectrum analyzer, cable and antenna analyzer, real-time spectrum analyzer, LTE and 5G TF over-the-air demodulation, independent signal source for path loss measurement, power meter, GPS
- Records data with GPS information; plays back recorded data on the instrument or offline on a PC

5G TF OTA measures control channels and displays cell ID

Switching into RTSA mode detects various 5G control channels

5G gNB Field Test Solution Benefits

- Supports both FR1 and FR2 5G bands, 5 kHz to 50 GHz
- gNB RF parametric test over-the-air in the field
- mmWave wave beam sweep survey
- Record and playback of data with GPS time stamping and geolocation information
- Equipped with an independent signal source for path loss measurements
- Battery-powered, no fans and no vent, and IP53 design to test 5G gNBs under any condition
Scenario

At the onset of the 5G mobile network rollout, mobile network operators’ top priority is to understand network coverage and identify issues with 5G networks. Keysight’s collaborations across the mobile ecosystem, particularly with NEMs, give mobile network operators a heads-up on the upcoming 5G rollout and network optimization challenges. Keysight’s solutions are available in different form factors and enable mobile network operators to accurately test the network in a variety of use cases and launch 5G services rapidly and successfully.
5G drive test

Keysight’s 5G Drive Test solution, Nemo Outdoor, enables mobile network operators to measure their 5G NR network coverage and quality. Monitoring and improving customer experience can help mobile network operators optimize their network and gain market share in their highly competitive environment. Nemo Outdoor is a powerful solution built on a single laptop-based software platform that gathers QoE metrics for a wide range of services and applications. Operators also use the information to verify, troubleshoot and optimize new services, and accelerate time to market.

Supporting 5G NR field measurements, Nemo Outdoor is 5G ready by combining Qualcomm’s 5G chipsets and third-party scanners. In addition to a variety of metrics such as random-access channel information (RACH), Tx power, and rank (MIMO mode), the solution collects quality-of-service (QoS) metrics such as throughput and latency.

Solution highlights
- Drive test, benchmarking, and voice and video quality measurements for unmatched value from a single platform
- Troubleshooting and verification tools, including distributed antenna system anomaly analysis, real-time RF ingress and missing neighbor detection, pilot pollution, and Global System for Mobile Communications (GSM) interference analysis
- Technology support for 5G NR, NarrowBand IoT (NB-IoT), LTE-M, 5CC carrier aggregation, voice/video over LTE (VoLTE/ViLTE), voice/video over Wi-Fi (VoWiFi/ViWiFi), 4x4 MIMO, and Evolved Multimedia Broadcast Multicast Service (eMBMS)
- Support for 300+ test terminals and scanning receivers for ultimate flexibility
- Optional Nemo Media Router for simple and productive Android-based smartphone deployment in data benchmarking and voice quality measurements

5G Drive Test Solution
Benefits
- Understand the coverage and quality of 5G NR networks
- Get QoE metrics for services and applications customers are using
- Search and display user-defined parameters from signaling messages during measurement and playback
5G OTA Measurements

Modem chipsets, antennas, base stations, and integrated devices require a mix of conducted and over-the-air (OTA) tests. The 3rd Generation Partnership Project (3GPP) defines OTA test methods for frequency range 1 (FR1) and frequency range 2 (FR2) conformance tests. Engineers need to perform OTA tests to characterize radiated beams in research and development (R&D), protocol and RF/radio resource management (RRM) conformance testing, and device acceptance testing.

Keysight offers a portfolio of OTA test solutions for FR1 and mmWave frequencies. A typical solution consists of measurement hardware and software, a network emulator to emulate the 5G gNodeB (gNB), and a channel emulator to imitate the radio conditions. RF enclosures, probe and link antennas, different DUT positioners, and associated control software complete the OTA test setup. Our solutions address the different test approaches and the various requirements across the workflow from R&D to device acceptance test.

The 3GPP has accepted the compact antenna test range (CATR) methodology for RF performance measurements on mmWave devices. Keysight’s OTA test solutions and expertise enable system integrators to provide solutions that meet the requirements set by industry bodies. These include CTIA, 3GPP, and China Communication Standards Association (CCSA). They also address the test plans mandated by major mobile operators.
Scenario

When the pressure is on, costly delays result from waiting on tools, answers, or help with developing or deploying 5G solutions. KeysightCare offers a personalized, cloud-based customer experience. You can access a digital knowledge base 24x7 for answers, training, and expert guidance. Get faster response times, access to experts, and time to resolution through a single point of contact for your instruments, software, and solutions.

Learn more about KeysightCare services here.
**Education Services** 5G creates real-world measurement challenges. With eLearning, you will gain the basic skills necessary to make more accurate, repeatable measurements. Start-Up Assistance complements that skill set with private, customized hands-on instruction specifically designed to help you meet your application measurement objectives.

**Process & Consulting Services** The 5G transformation brings new opportunities for growth, as well as new challenges. Keysight provides expert analysis with quantifiable metrics so you can analyze the current process, offer a quantified evaluation of alternatives, and accelerate time to market.

**Technology Refresh Services** Current test equipment will likely be unable to provide the increased levels of measurement capability required for 5G standards. Technology refresh offers an easy and cost-effective way to upgrade or trade-in existing assets to obtain the test equipment performance for your new requirements.

**Test Asset Optimization Services** Navigating the transition to 5G NR and making the right equipment choices requires access to real-time asset data and effective management of all assets. Keysight Test Asset Optimization services offer an ideal solution to this challenge. Our services offer asset tracking and control capabilities, utilization and health data, and loan pool management tools.

**One-Stop Calibration Services** With increasingly complex multivendor 5G systems and test plans, it is more important than ever to ensure accurate equipment calibration and maintain maximum uptime. Keysight One-Stop Calibration services increase uptime, ensure ongoing accuracy, and reduce logistical complexity with one point of contact for all calibration services — regardless of the manufacturer.

**Financial Services** You need to make the most of your operational and capital budgets to design, produce, and deploy new 5G solutions. Keysight financial options help you get the equipment you need to deliver on time and within budget. Keysight Instant-Buy* gives you the flexibility to make monthly payments at 0% interest over 18 months. With Keysight Rent-to-own*, you can get the instrument that you need now and decide to purchase later. With Keysight Lease* you can access leading technologies while managing your budget.

*Available in select countries.
Accelerating 5G Commercialization and Deployments

The full economic benefit of 5G is greater than $12 billion by 2035\(^1\). 5G’s impact goes far beyond faster speeds. It will generate new experiences through augmented reality and virtual reality, enable connected cars, and give rise to smarter homes. 5G provides significant revenue opportunities for mobile network operators. However, the plethora of use cases, network slicing, and the need for 5G to coexist with legacy technologies pose significant challenges. Engineers need to confirm compliance with standards, regulations, and acceptance tests; perform load testing at scale; and verify and increase end-user experience and network coverage in accelerating timelines.

In the context of regulatory emissions standards, 3GPP standards, and carrier acceptance, network emulation is essential to simulate expected and worst-case scenarios. Functioning network equipment is fundamental to achieve a high QoE for customers. However, diverse global spectrum requirements and the complexity of advanced 5G features are significant challenges. Engineers need to ensure RF and mmWave parametric performance of the radio and its protocol-driven functionality, which requires a high level of parametrization and automation.

Unprecedented traffic on mobile networks is looming with 5G. This traffic increase will have a significant impact on the network core and the RAN, requiring massive UE emulation, with real-world conditions in terms of subscribers and applications. Mobile network operators need to also consider security issues and the dynamic nature, diversity, and complexity of mobility scenarios.

Mobile network operators face intense competition in 5G. Subscriber QoE is a significant competitive differentiator. In the 5G era, maximizing network coverage and uptime will be critical. Mobile network operators should ensure device and network interoperability before deployment, verify 5G radio propagation and coverage, and resolve unforeseen issues during deployment. They should also initiate a virtuous cycle for continuous customer experience improvement. Learn more about Keysight solutions to overcome these challenges here.

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Learn more at: www.keysight.com

For more information on Keysight Technologies’ products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

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\(^1\) IHS Economics & IHS Technology

“4G networks were an amazing improvement over 3G networks. … 5G holds the promise to be that and more, with massive bandwidth, latency in the single milliseconds, (and) scalability to connect billions of devices.”

– Nicki Palmer
Chief Network Officer, Verizon Wireless