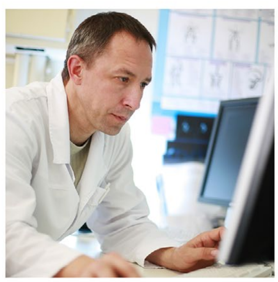
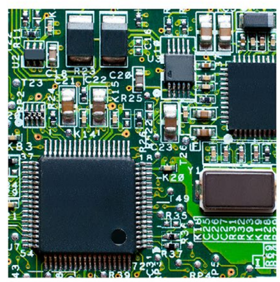
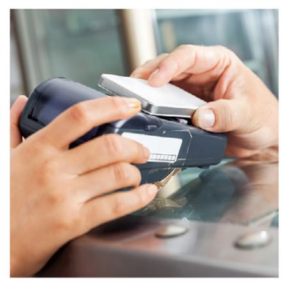
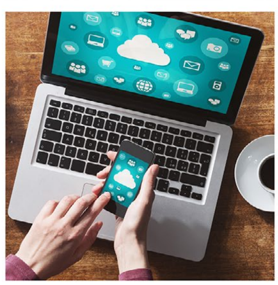
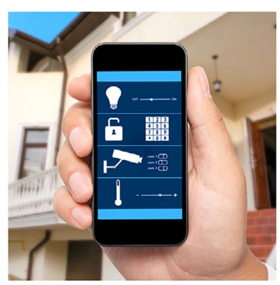
Keysight Technologies

The Internet of Things: Enabling Technologies and Solutions for Design and Test

Application Note




HARDWARE + SOFTWARE + PEOPLE = IOT/M2M INSIGHTS

KEYSIGHT TECHNOLOGIES

Overview

Kevin Ashton of the Massachusetts Institute of Technology (MIT) is crediting with coining the phrase "the Internet of Things" in 1999 as part of a presentation about RFID tags. He described his vision as follows:

"Today, computers—and, therefore, the Internet—are almost wholly dependent on human beings for information... The problem is, people have limited time, attention and accuracy—all of which means they are not very good at capturing data about things in the real world. If we had computers that knew everything there was to know about things—using data they gathered without any help from us—we would be able to track and count everything and greatly reduce waste, loss and cost. We would know when things need replacing, repairing or recalling, and whether they were fresh or past their best."

At that time, a "thing" on the Internet of Things (IoT) was imagined as something that could be counted. These exist in a range of relatively simple applications: RFID tags on shipping containers, parking lot exit-and-entry systems that know when the lot is full, and the hotel minibar that registers your midnight craving for chocolate and automatically adds it to your bill. Initially, the individual counting systems ran as autonomous, unlinked applications.

Current visions for the IoT space have taken on a broader perspective, with more emphasis on post-processing of accumulated data. This has led to the need to connect individual applications to cloud storage and enable remote control via the Internet. The scale of the required network is potentially mind-boggling—and making this scenario a reality depends on absolutely reliable connectivity, designed in from the start and well tested all along the product lifecycle.

Defining the Nature and Scale of "Things"

Since 1999, IoT has expanded into machine-to-machine (M2M) communication and applications such as manufacturing and utilities (e.g., gas and electricity). While automation is already important in manufacturing, IoT and the so-called Industrial Internet are enabling greater automation while also increasing flexibility and efficiency in manufacturing processes. Examples include new tools that support remote and predictive maintenance, thereby reducing costs and otherwise enhancing competitiveness.

These trends are influencing mammoth projections about the scale of IoT implementations: estimates range from 15 billion to 50 billion connected things by 2020, spanning all sectors. Further predictions about new, disruptive IoT-related services suggest potential revenues many times greater than those derived from IoT hardware and network provision.

Another perspective comes from Gartner Group, a research and advisory company that specializes in the world of information technology. In March 2015, it published a range of predictions regarding IoT applications in what it is calling "smart cities." From 2015 to 2017, Gartner expects the fastest growth areas to be smart buildings, both commercial and residential. In these environments, connected things will include temperature controls, LED lighting, healthcare monitors, smart locks, and sensors such as motion detectors and carbon monoxide alarms (Table 1).

Smart city subcategory	2015	2016	2017
Healthcare	9.7	15.0	23.4
Public services	97.8	126.4	159.5
Smart commercial buildings	206.2	354.6	648.1
Smart homes	294.2	586.1	1,067.0
Transportation	237.2	298.9	371.0
Utilities	252.0	304.9	371.1
Other	10.2	18.4	33.9
Total	1,107.3	1,704.2	2,674.0

Table 1. Gartner projects an installed base of more than 2.67 billion connected things within smart cities by 2017.

As a working definition, a thing can be any natural or man-made object, fixed or mobile, that can be given the ability to transfer data over a network. Examples include an intruder alarm in a cellular base station and smart collars that make animal management easier for livestock farmers or pet owners.

The latest areas of focus include personal health and fitness, with the emergence of wearable technology that works in conjunction with a smartphone app. A common healthcare example is remote monitoring of a patient's condition as they go about their daily routine, away from a clinic or hospital. Another is mitigation of injuries suffered during a traffic accident: an involved vehicle not only summons emergency assistance but also reports its location, the number of occupants and the severity of the collision.

Another widely reported application is the connected car and, ultimately, the driverless car. Major vehicle manufacturers are engaged in projects that include either a network provider or major technology company. These include vehicle-to-vehicle (V2V) communication for traffic management and safety applications, and vehicle-to-infrastructure (V2I or V2X) communication for telematics, journey mapping, infotainment, and mobile payment and toll collection.

Enabling Technologies

If recent trends continue, only some devices will use wired connections—USB, Ethernet, fiber—and a majority of IoT things will rely on wireless technology. This will range from near-field communication (NFC) for mobile payments, to geosynchronous satellites for unattended remote weather stations, and everything in between: *Bluetooth*®, wireless LAN (WLAN), ZigBee, point-to-point radio, cellular, and more.

The network will need to cope with all kinds of unique devices with different communication requirements. At one end will be simple wireless devices such as battery-powered sensors and actuators that will transmit very little data while operating unattended for several years. At the other end of the spectrum—literally and figuratively—will be high-bandwidth, mission-critical services and devices such as autonomous cars that require constant, reliable and super-secure connections.

Key to uniquely identifying each device is a vast IP address space. Because the IPv4 addressing space is too limited, currently requiring the use of concentrators (e.g., routers and gateways), the end-to-end use of IPv6 addressing is a key enabler for IoT devices. With its virtually unlimited address space, IPv6 allows unique addressing of billions of devices.

Accessing gateways to the cloud

Server/cloud-based big-data analytics and machine learning are central to the majority of IoT business models. IoT uses M2M communication to harvest data and route control messages between widely distributed things (e.g., sensors or actuators) and cloud-based intelligence. Many topologies include gateway nodes as aggregation points between thing and cloud (Figure 1).

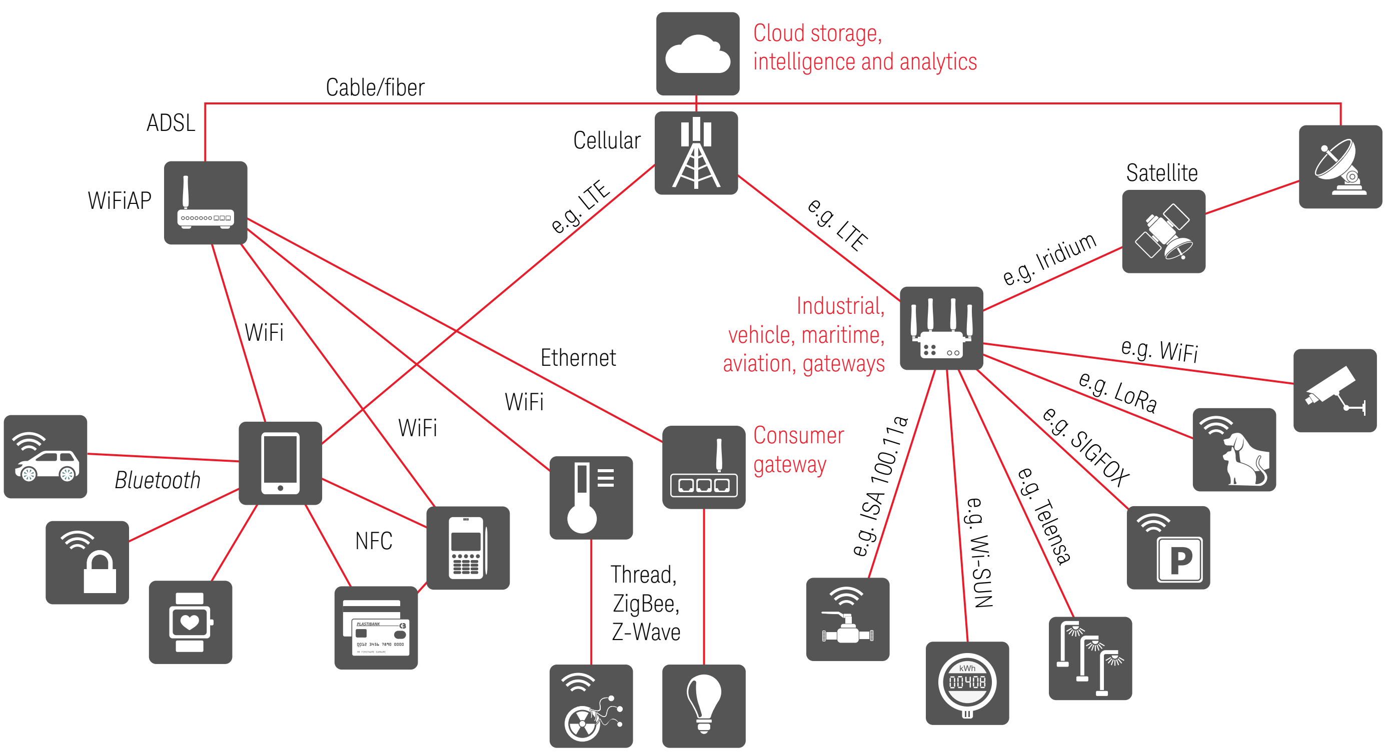


Figure 1. Myriad pathways and gateways can and will be used to provide access to the cloud.

Gateways vary in complexity. For example, a Wi-Fi access point includes an IP router and may also include translation from Ethernet and Wi-Fi to ADSL or another fixed-line protocol. More complex gateways can include significant computing resources programmed with “edge” or “fog” applications capable of local decision making.

Where communication costs are low and latency can be tolerated, IoT implementations tend to use simple gateways and then route most of the data to the cloud for analysis and decision making. In situations that have either high communication costs are demanding latency requirements, complex gateway nodes are often specified. These gateways can be remotely maintained and configured, and they will monitor and control a local constellation of things. Traffic routed to the cloud may include infrequent status updates or alerts when locally monitored thresholds are crossed (e.g., a temperature exceeding a maximum level or an intruder tripping an alarm).

Many wearable applications and some home-automation applications make use of smartphones to provide a user interface or act as a gateway node. The almost ubiquitous availability of Wi-Fi makes it the first choice for many IoT applications. Where fixed-line or Wi-Fi links are unavailable, cellular protocols are frequently used. In wearable applications and for home automation around the smartphone, *Bluetooth* is often used. NFC is the natural choice when security is aided by proximity. ZigBee, Z-Wave and Thread offer robust, low-power mesh networks for home automation and smart energy devices.

ISA100.11a and WirelessHART include frequency hopping for improved resilience in safety critical industrial applications. Emerging low-power wide area (LPWA) technologies such as LoRa and SIGFOX combine the cost, low complexity and low power benefits of technologies such as ZigBee, but with much longer range enabled by narrowband, low data rate protocols.

Mapping technologies versus operating range

Figure 2 shows example IoT technologies grouped by operating range. Terms such as proximity, WPAN, WHAN, WFAN, WLAN, WNAN, LPWA and WWAN are used within the radio-standards community to provide general indications of range.

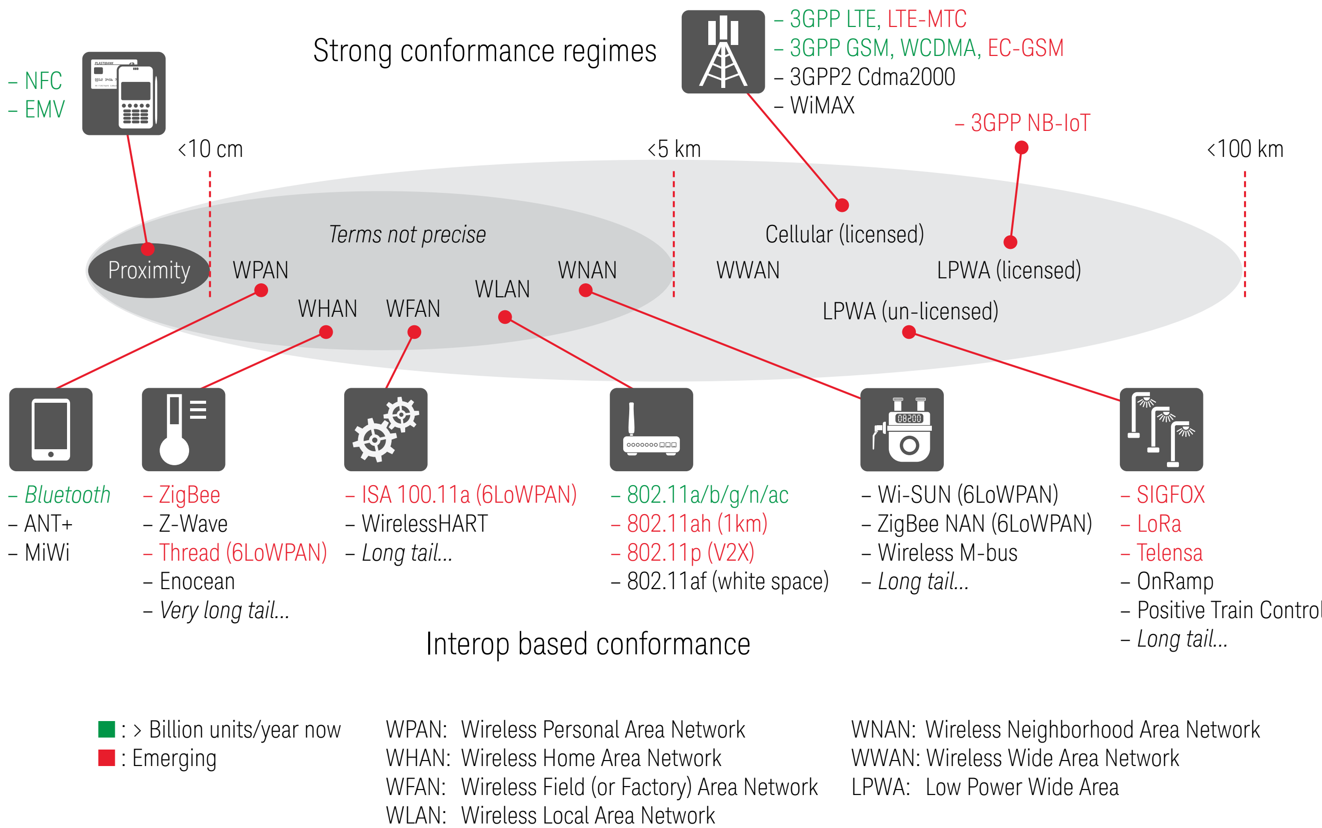


Figure 2. Expected operating range has a direct relation to the available choices of connection technologies.

Many formats are available for short-range connections between devices and gateways. To facilitate future development, standards are quickly forming and evolving as new devices become connected. Currently, there are more than 60 legacy and new RF formats in use for M2M and IoT–related applications. Some, such as *Bluetooth*, WLAN and cellular, are already widely used. Others, such as ZigBee and Thread, are emerging in specific market niches.

To accelerate their products to market, some companies developed proprietary solutions that were relatively easy to create because they had low data rates, low-power transmissions and minimal interoperability requirements. This approach is likely to fall out of favor because the globalization of markets is driving device communication away from proprietary designs and towards standardized solutions.

Scanning the most promising technologies

Figure 2, above, spans several technologies: proximity, WPAN, WHAN, WFAN, WLAN, WNAN and WWAN. Each includes one or more noteworthy connectivity standards. Where available, each overview includes a link to deeper information.

Proximity: Near-field communication (NFC), which is a very short-range system based on ISO 14443 at 13.56 MHz, is used for ticketing, access control, passports and, increasingly, for mobile payment systems. Payment applications are regulated by EMVCo while many other applications are regulated by the NFC Forum. NFC devices can behave as terminals, also called proximity-coupling devices (PCD) or readers. They may also behave as cards, also known as proximity inductive-coupling card (PICC) or tags; cards are often powered by the RF field generated by the terminal. The NFC Forum has added logical link control protocol (LLCP), simple data-exchange format (NDEF) and simple data-exchange protocol (SNEP) to enable peer-to-peer communication (e.g., between two mobile phones). To learn more, please visit www.emvco.org and www.nfcforum.org.

WPAN: In the IoT space, *Bluetooth* low energy (BLE) is of greatest interest. Designed for lower data throughput, it significantly reduces the power consumption of *Bluetooth* devices and enables years of operation using coin-cell batteries. Simplified models for device discovery, service discovery and data exchange result in a radio that needs very little airtime, greatly reducing power consumption. This enables use of BLE in small devices such as watches, health monitors and battery-powered appliances. For more information about BLE, please see the *Bluetooth* Special Interest Group (SIG) website at www.bluetooth.org.

WHAN: To simplify development, a number of short-range wireless technologies use IEEE 802.15.4 as the physical (PHY) and media access control (MAC) layers. For the variants shown in Figure 3, the developer of the higher layers specifies the higher-level protocol that is appropriate for the target application. This low-rate WPAN (LR-WPAN) supports rates that range from 20 to 250 kbps. It is designed for home networking, industrial control and building automation, all of which need low data rates, low complexity and, in many cases, long battery life. To learn more, see standards.ieee.org/about/get/802/802.15.html.

– **ZigBee:** Established in 2002, ZigBee is widely used in commercial applications. These devices are able to connect, exchange information and disconnect quickly before returning to sleep mode. One key attribute is the use of a mesh network topology that can include thousands of nodes. Radios operate with very low duty cycles, enabling sensing and monitoring applications to run for years on inexpensive batteries. Target applications include smart energy, home automation, healthcare, retail, and lighting control, each of which has a specific ZigBee profile and certification. Its transmitter and receiver specifications appear in section 10.3 of the IEEE 802.15.4 specification. More information is available at www.zigbee.org.

– **Thread:** The Thread Group was launched in July 2014 and is growing quickly. This technology is similar to ZigBee in that it is based on the IEEE 802.15.4 PHY and MAC; however, it uses the IPv6 over low-power WPAN (6LoWPAN) protocol. It's a robust, encrypted mesh network designed to connect—securely and reliably—up to hundreds of home-automation products and devices. The network is self-healing and is configured such that there is no single point of failure. Its short messaging conserves bandwidth and power, while a streamlined routing protocol reduces network overhead and latency. To get the details, see www.threadgroup.org.

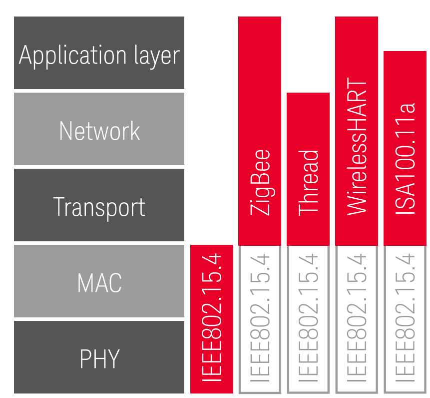


Figure 3. At least four additional short-range technologies are based on 802.15.4.

WLAN: Wi-Fi is the most widely used wireless Internet connectivity technology, with 802.11a/b/g/n being most common today. Figure 4 shows the main amendments to the PHY layer in each version. Two recent amendments address the need for very high throughput data rates: 802.11ac, which operates below 6 GHz and is becoming the standard in mobile phones, tablets and PCs; and 802.11ad, which operates in the 60 GHz band.

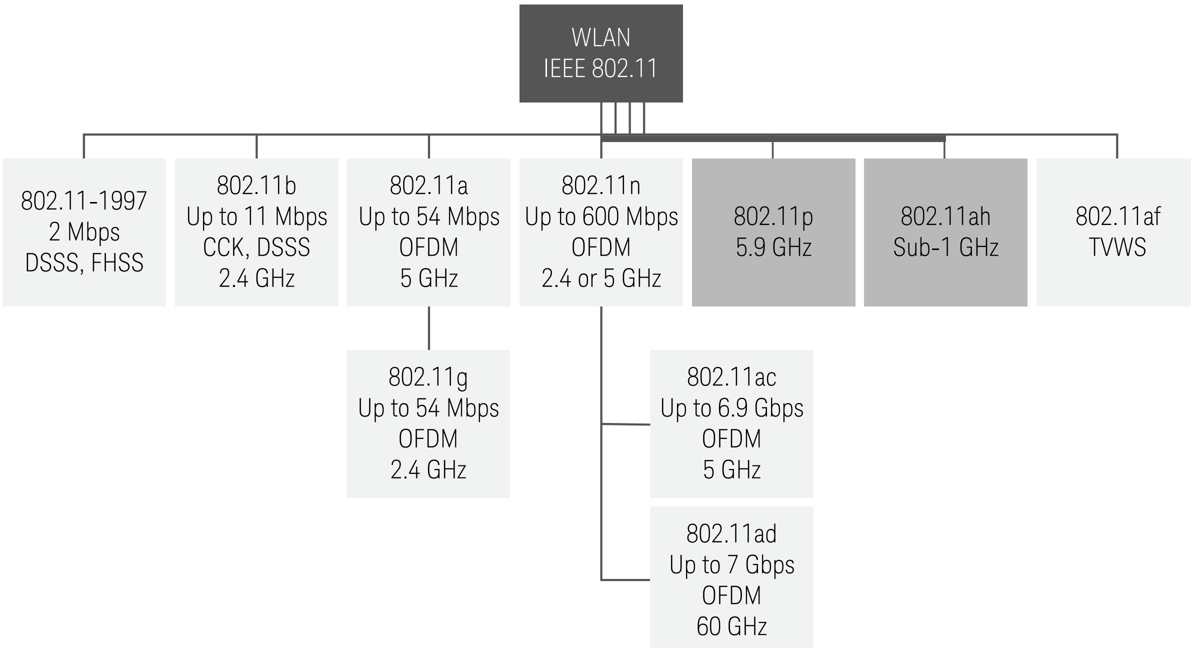


Figure 4. The number of amendments to IEEE 802.11 underscores its ubiquity and usefulness.

- **802.11ah:** The upcoming introduction of 802.11ah is intended to support low energy for IoT applications. It uses low power and low data rates, and because it operates in the sub-gigahertz band, it has a range of up to 1 km.
- **802.11p:** Also called wireless access in vehicular environments (WAVE), 802.11p has been created specifically for wireless access to vehicles. In a connected car, it opens the door to applications such as telematics, roadside assistance, fleet management, and young-driver insurance validation. In the future, 802.11p will also enable V2V and V2I connectivity for enhanced vehicle safety, traffic management and toll collection.

More information about all 802.11 variants is available online at www.ieee802.org/11.

WNAN: The two main technologies are Wi-SUN (IEEE 802.15.4g) and ZigBee-NAN. The IEEE 802.15 Smart Utility Networks (SUN) Task Group 4g created a PHY amendment for local and metropolitan area networks, aiming to provide a global standard that facilitates large-scale process-control applications. Wi-SUN provides a low-rate wireless network capable of supporting large, geographically dispersed smart utility networks with minimal network infrastructure, with potentially millions of fixed endpoints (www.wi-sun.org).

ZigBee-NAN is a recent extension, increasing its operating range to 1,000 m and supporting end-to-end IPv6, thereby broadening its appeal in larger smart-grid networks. The ZigBee Alliance is currently working with the Thread Group on interoperability for home and commercial sensor networks.

WWAN: LPWA systems such as LoRa (www.lora-alliance.org) and SIGFOX (www.sigfox.com/en) are being deployed in lightly licensed regional bands (e.g., 868 and 915 MHz). For applications with low data rates and low duty cycles, LPWA extends battery life, reduces cost and offers improved link budgets compared with current cellular formats. Networks often use a star topology around a gateway node using fixed-line or cellular M2M for backhaul.

Anticipating strong growth in low power M2M applications, 3GPP radio access network (RAN) and the GSM EDGE radio access network (GERAN) are developing cellular protocols to support LPWA in licensed spectrum. 3GPP Rel-12 introduced a new low-complexity device category (Cat-0) for LTE machine-type communication (MTC), offering improved efficiency for low data-rate applications with further optimization planned in Rel-13. Extended coverage GSM (EC-GSM) with improved link budgets for M2M applications is being standardized in GERAN Rel-13.

In September 2015, 3GPP RAN plenary 69 established a work item to define the characteristics of a new clean-sheet proposal for Rel-13 as a stepping-stone to 5G massive machine-type communication. The two competing proposals - narrowband cellular IoT (NB-CIoT), distilled from GERAN's CIoT project, and a new NB-LTE RAN entry – will merge in NB-IoT in the December 2015 3GPP plenary. The goal is a high link budget, long battery life and low data rates technology that can be deployed in some combination of reassigned GSM spectrum, dedicated fragmented spectrum and LTE guard bands. Table 2 shows an overview of the various cellular protocols as of September 2015.

	LTE-MTC (Cat-0)		EC-GSM	NB-CIoT	NB-LTE
	3GPP Rel-12	3GPP Rel-13	3GPP Rel-13 Candidate	3GPP Rel-13 Candidate	3GPP Rel-13 Candidate
Technology	Based on LTE	Based on LTE	GERAN	Clean-slate	Clean-slate
DL peak data rate	1 Mbps	200 kbps		DL 360 kbps, UL 48 kbps	DL 128 kbps, UL 64 kbps
Bandwidth	20 MHz	1.4 MHz	200 kHz	180 kHz DL (48 x 3.75 kHz) UL (36 x 5 kHz)	180 kHz DL (12 x 15 kHz) UL (72 x 2.5 kHz)
Multiple access DL/UL	OFDMA/SC-FDMA	OFDMA/SC-FDMA	TDMA/TDMA	OFDMA/FDMA	OFDMA/SC-FD-MA
Modulation DL	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM	GMSK	BPSK, QPSK, optional 16QAM	BPSK, QPSK, optional 16QAM
Modulation UL	QPSK, 16QAM	QPSK, 16QAM	GMSK	GMSK, optional BPSK, QPSK, 8PSK	BPSK, QPSK, optional 16QAM
Coverage	~141 dB link budget	~156 dB link budget	~164 dB link budget	~164 dB link budget	~164 dB link budget
				Merging in NB-IoT Dec 2015 3GPP plenary	

Table 2. Various 3GPP formats enabling cellular and LPWAN communication in IoT applications.

Frequency Bands of Operation (non-cellular)

Today, with the exception of cellular systems, most IoT systems operate in license-free and lightly licensed frequency bands. The most popular industrial, scientific and medical (ISM) bands include 13.56 MHz, 433 MHz and 2.4 GHz. U-NII bands around 5.8 GHz are often used by WLAN technologies. Lightly licensed regional bands are also widely used at frequencies including 868 MHz, 915 MHz and 920 MHz. Figure 5 shows the most popular frequencies used for IoT communication formats. The map in Figure 6 shows the allocation of popular bands in various regions and countries around the world.

	54-698 MHz (TVWS)														
Usually called	13.56	169	220		315	426	433	470	779	868	915	920	2400	5800	5900 MHz	Aliasses
NFC/EMV	◆															ISO14443
Wireless M-Bus		◆					◆			◆						EN13757
China WMRNET							◆	◆								WMRNET I, II, III. IV
LoRa							◆	◆		◆	◆					
SIGFOX										◆	◆					
Telensa										◆	◆					
OnRamp													◆			802.15 4k
Wi-SUN												◆				802.15.4g/e/GIoWPAN
ZigBee									◆	◆	◆	◆	◆			802.15.4-2003, c d
Thread													◆			802.15.4-2003/GIoWPAN
WirelessHART													◆			802.15.4e
ISA100.11a													◆			802.15.4e/GIoWPAN
Z-Wave										◆	◆	◆				ITU G9959
EnOcean					◆						◆	◆				ISO14543-3-10
ANT+													◆			
Bluetooth													◆			802.15.1
802.11/a/b/g/n/ac													◆	◆		WiFi
802.11ah									◆	◆	◆	◆				
802.11p															◆	V2X
802.11af				◆												White Space
Positive Train Ctrl			◆													802.15.4p

Sub-GHz IC families "802.15.4" family

Figure 5. The red diamonds indicate the intersection of frequency band and IoT technology.

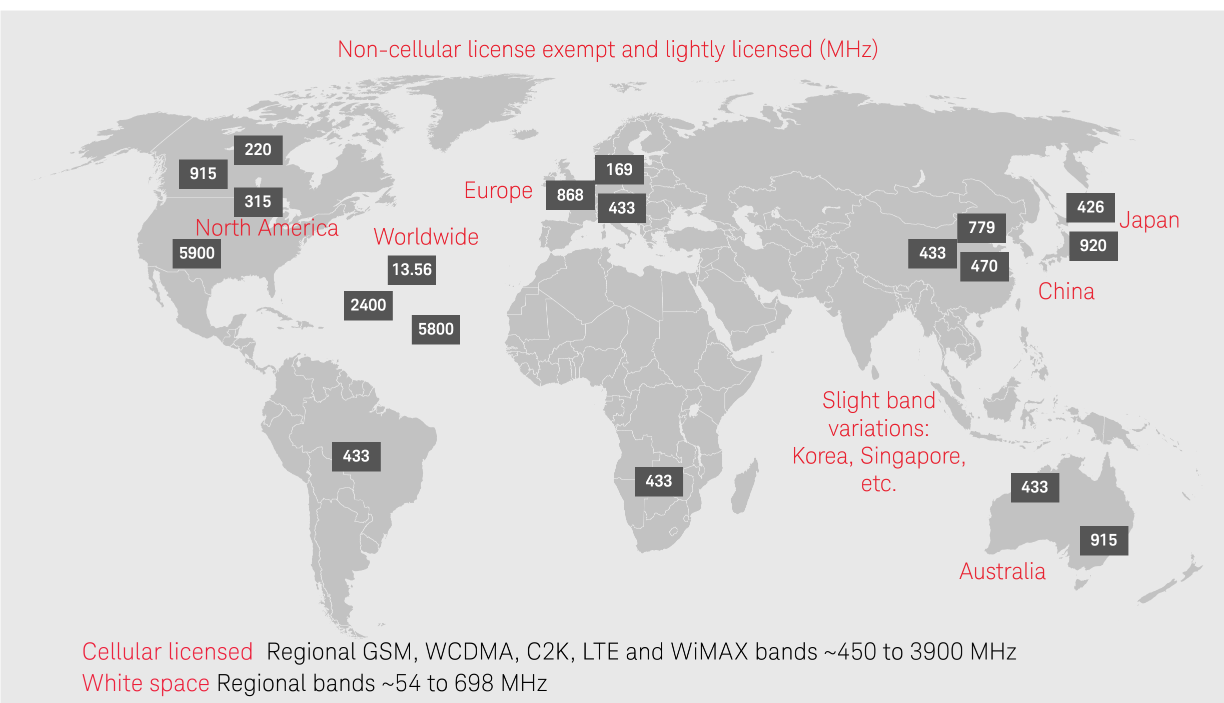


Figure 6. The unlicensed or lightly licensed bands vary slightly from country to country.

Exploring Solutions for Design and Test

Keysight provides a broad range of tools that accelerate a product's progression from the lab to the production floor and, when needed, on to installation and maintenance. Our offering includes design and simulation software as well as standalone instrumentation, wireless test sets and modular instruments—and all carry the common thread of Keysight measurement science. One key benefit of this approach: product feedback across the entire lifecycle is based on a shared understanding of the measurements that determine a product's performance.

Designing and simulating new devices

As IoT becomes more pervasive, design engineers will face important challenges: maximizing power efficiency, managing electro-thermal effects, and dealing with greater electromagnetic coupling as designs become more compact. Additional hurdles include evaluation and selection of the best technology mix (e.g., GaAs, GaN, SiGe/Si/SOI, CMOS) as well as integration of subsystems and verification of performance relative to industry standards.

As design complexity increases, circuit simulation becomes more difficult. Keysight electronic design automation (EDA) software addresses the challenges inherent in communication systems, especially IC and PCB design and simulation for 5G, 802.11xx, BLE, ZigBee, Wi-SUN, and more.

Early in the development process, a new product can be simulated in Keysight SystemVue, a focused EDA environment for electronic system-level (ESL) design. SystemVue enables system architects and algorithm developers to innovate the PHY layer of wireless communications systems, and it provides unique value to RF, DSP and FPGA/ASIC implementers. SystemVue also includes virtual measurement tools that can be attached to nodes in the simulation to provide a view of expected performance.

Additional EDA tools from Keysight include Advanced Design System (ADS), Momentum, Harmonic Balance, Circuit Envelope, Ptolemy, GoldenGate Silicon RFIC simulator, and EMPro 3D EM simulation environment. Leading companies across many industries—mobile communications, wireless networking, aerospace and defense—are using these solutions to design, develop, simulate and manufacture RFICs, MMICs, RF modules, boards and systems (Figure 7).

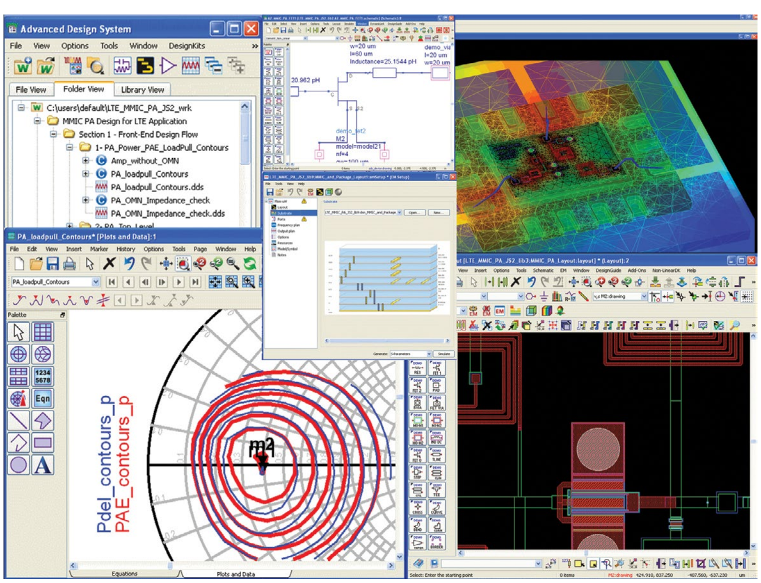


Figure 7. Keysight's Advanced Design System (ADS) software is used by more than two-thirds of the world's RF/microwave design engineers and is helping to solve design challenges for IoT applications

For IoT designs, Keysight EDA solutions such as Momentum simulation software and GoldenGate Silicon RFIC design software support the successful creation of RF transceivers that provide short-distance wireless communication (Figure 8).

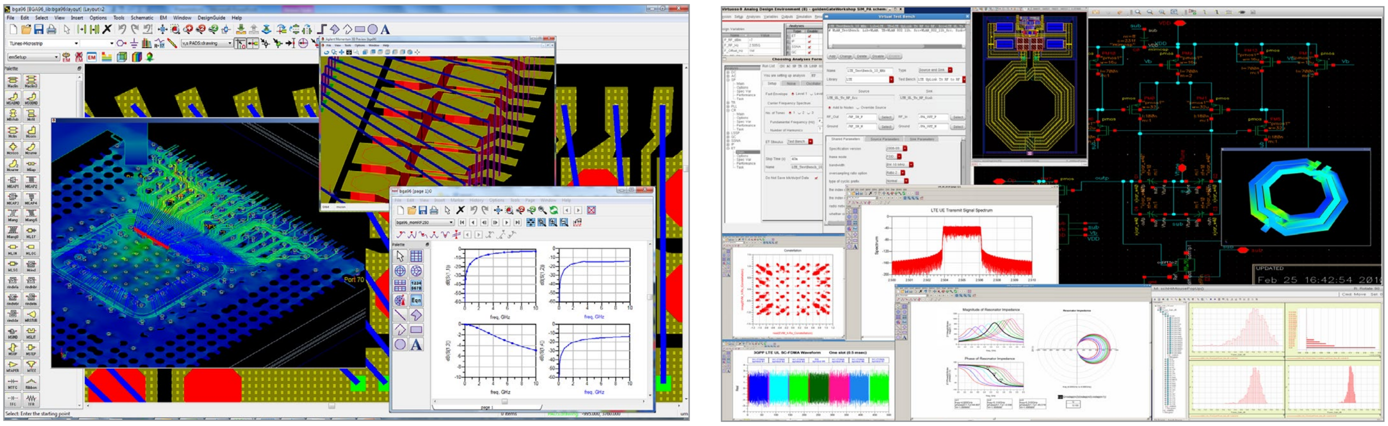


Figure 8. Keysight Momentum (left) is the leading 3D electromagnetic (EM) simulator used for passive circuit modeling and analysis, essential for IoT applications. The Keysight GoldenGate RFIC simulation and analysis software (right) provides links to SystemVue, ADS and Momentum for complete IoT designs.

As the design moves from simulation to reality, completed device modules can be substituted into the simulation: real measurements or hardware-in-the-loop replace virtual tools, enabling developers to compare simulated and actual performance. As designs are completed and prototypes built, Keysight's unparalleled range of lab-grade test equipment—benchtop and modular—ensures measurement continuity.

Measuring and analyzing IoT devices

When choosing a test instrument, typical selection criteria include performance specifications, measurement speed, physical footprint, configuration scalability, and cost (upfront and ongoing). No single solution will be best for all needs. Across benchtop instruments, wireless test sets, and modular solutions, Keysight's advantage is in the common measurement science that ensures consistent and comparable measurement results across the IoT product lifecycle (Figure 9).

Figure 9. Keysight's measurement science ensures consistent measurement results across benchtop signal analyzers and signal generators (top row), wireless test sets (lower left) and modular solutions (lower right), enabling teams to quickly identify the root cause of incorrect results.

In the design phase, benchtop instruments such as the X-Series signal analyzers offer high performance, general-purpose capabilities such as swept-tuned spectrum analysis and comprehensive functionality for signal analysis and troubleshooting. For example, the X-Series measurement applications enable one-button testing of numerous wireless formats, providing standards-compliant measurements of EVM, adjacent channel power (ACPR), spectrum emissions mask (SEM), and more (Figure 10). They also utilize the same algorithms and measurement science on all supported hardware platforms: CXA, EXA, MXA, PXA and UXA benchtop analyzers; PXI instrument modules such as the M9420A VXT; and the EXM wireless test set.

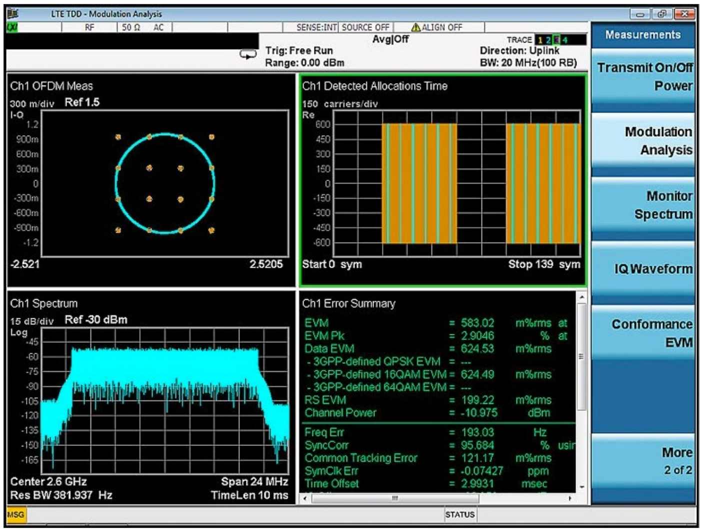


Figure 10. X-Series measurement applications enable one-button characterization of essential performance attributes such as EVM and ACPR for a wide range of wireless formats.

The 89600 VSA software is the industry-leading tool for digital modulation analysis, and it runs on more than 45 Keysight measurement platforms, from basic spectrum analyzers to wide-bandwidth digital oscilloscopes. It can be configured to support most of the wire-less formats used in IoT devices: 2G/3G/4G cellular formats, WLAN, ZigBee, *Bluetooth* and Wi-SUN. The 89600 VSA software also supports general-purpose flexible digital demodulation of more than 75 signal standards and formats, spanning modulation types as simple as BPSK or as complex as 4096 QAM. These tools enable developers to explore virtually every facet of a signal and optimize their most advanced designs (Figure 11).

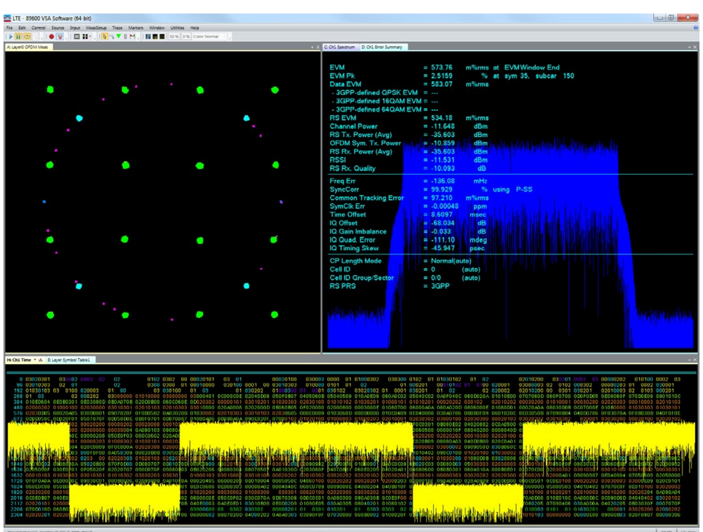


Figure 11. The 89600 VSA software enables designers to see through the complexity of today's most advanced signals.

In R&D, design validation and manufacturing, Signal Studio can be used to create custom and standard-compliant test signals for wireless communications formats including the IEEE 802.11 variants, *Bluetooth*, ZigBee and Wi-SUN (Figure 12). The software is compatible with a number of Keysight vector signal generators—MXG, EXG, and PXI-based modular models—and the EXM wireless test set.

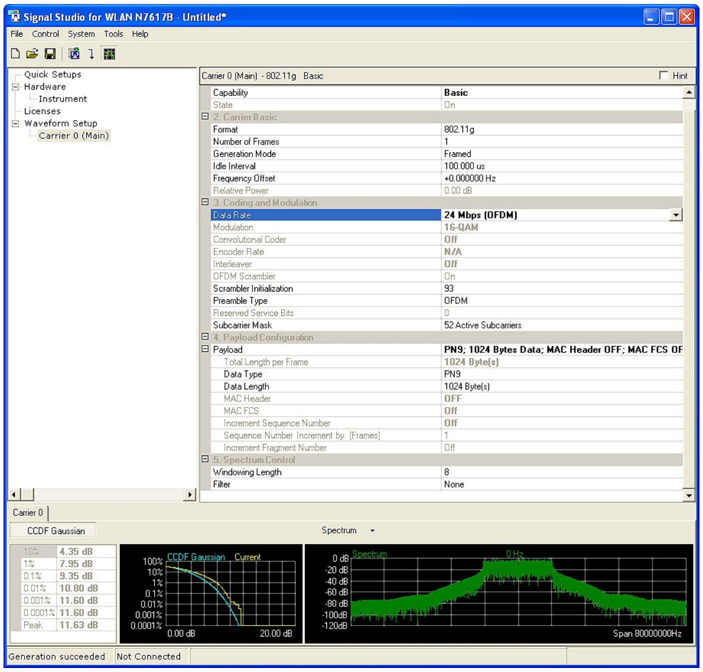


Figure 12. With its flexible suite of signal-creation tools, Signal Studio reduces the time spent on signal simulation.

Scanning Our Latest Solutions

In addition to the X-Series signal analyzers and signal generators, a variety of our most recent solutions and configurations are well suited to the development and manufacturing of IoT devices.

M9420A VXT PXIe vector transceiver: To enable both rapid system development and faster, easier testing of power amplifiers, RF components and front-end modules, the VXT provides an ideal balance of performance and footprint. Half- and full-duplex ports simplify testing; signal creation software and one-button measurement applications streamline standard-compliant testing; and support of the 89600 VSA software makes it easy to debug and refine designs. The modular form factor delivers the measurement speed and flexibility necessary to create custom solutions that incorporate the functionality of an entire test rack into a single PXI chassis. Up to four VXTs can be incorporated into a single chassis, supporting the need to scale up quickly from product development to design validation to manufacturing.

M9420A VXT PXIe vector transceiver

EXM wireless test set: In IoT, the economics of design validation and high-volume manufacturing demand a consistent understanding of device performance from early prototype evaluation to manufacturing. The EXM offers the ultimate in scalability and port density as well as the broadest multi-format coverage for cost-effective testing. Best-in-class measurement performance ensures the highest throughput and yield on the production line. Frequency coverage and bandwidth options, and the addition of new IoT applications, make the EXM a future-proof platform that can adapt to meet new measurement challenges.

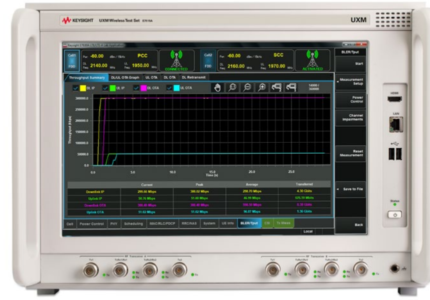
EXM wireless test set

UXM wireless test set: The UXM helps designers develop and optimize cellular devices for the IoT. It integrates flexible multi-format base station emulation and powerful RF measurements with an intuitive touch screen user interface, and multi-layer protocol logging delivers insights to extend battery life. UXM software releases track the evolution of 3GPP standards including those for machine-type communication (MTC). Built around the UXM, the Keysight T4000S series RCT and RRM test systems enable chipset, module and cellphone makers to comply with GCF and PTCRB requirements.

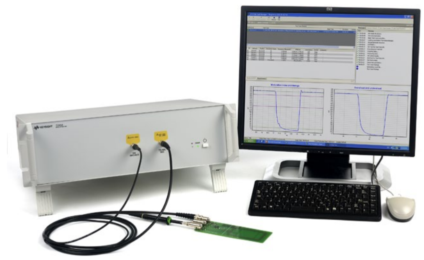
T3111A NFC conformance test system: The T3111S NFC conformance test system, developed in cooperation with FIME, is based on the T1141A test set. It provides a solution for RF analog and digital protocol testing of NFC, EMV™ and ISO devices. The solution includes an automated positioning robot to enable all contactless test specification requirements for NFC and EMV devices.

N6780 Series Source/Measure Units (SMU): The IoT will rely on simple battery-powered sensors and actuators that transmit very little data and are expected to provide years of unattended operation. Designing and developing this type of device requires tools that can measure battery drain during three main conditions: sleep mode, idle mode, and transmit mode. Current consumption is random in nature, ranging from nano-amps in sleep mode to milliamps in idle and amps in transmit, over a very short time with very steep rise and fall times. Only Keysight's N6780 Series SMUs let you visualize current drain from nA to A in one pass and one picture unlocking insights to deliver exceptional battery life.

Cost-effective RF test solutions: Keysight offers a mix of instruments that provide "just enough" performance and functionality for budget-conscious organizations. Examples include the 33522B dual-channel waveform generator and N9310A RF signal generator, and the N9320B/N9322C basic spectrum analyzer (BSA) for spectrum characterization and demodulation of ASK and FSK formats. In addition, the N9000A CXA can be used for complex modulation formats such as O-QPSK, and it can be configured with software for ZigBee and other formats. A close-field probe set, the N9311X-100, can be used with the spectrum analyzers to troubleshoot EMI issues.



UXM wireless test set



T3111A NFC conformance test system

N6780 Series Source/Measure Units (SMU

Cost-effective RF test solutions

Ensuring ongoing accuracy and repeatability

Keysight's legacy of measurement integrity and meteorology is reflected in the intellectual property embedded within our instruments' hardware design, software algorithms and automated calibration procedures (performance verification and adjustments). Our global service network of service centers and mobile labs use consistent automated calibration procedures to ensure our instruments continue to operate to warranted specifications. Among equipment manufacturers, only Keysight stands behind its quality and reliability with a standard three-year warranty on all instruments, worldwide.

Looking to The Future

As the number of deployed IoT devices expands into the billions, the ability to ensure absolutely reliable connectivity will become essential. Creating seamless connectivity across the entire ecosystem—devices, infrastructure, cloud, remote applications, post-processing, services—starts with the ability to create better designs, utilize increasingly realistic simulations, and perform meaningful and cost-effective testing. With its exceptional combination of hardware, software and people, Keysight is uniquely able to help you create the Internet of things—today and into the future.

Related information

- Brochure: *E6640A EXM Wireless Test Set*, publication 5992-0617EN
- Measurement Applications Brochure: *E6640A EXM Wireless Test Set*, publication 5992-0685EN
- Data Sheet: *E6640A EXM Wireless Test Set*, publication 5991-4287EN
- Data Sheet: *M9420A VXT PXIe Vector Transceiver*, publication 5992-1088EN
- Brochure: *Keysight EEsof EDA Advanced Design System*, publication 5988-3326EN
- Brochure: *SystemVue Electronic System-Level (ESL) Design Software*, publication 5992-0106EN
- Brochure: *89600 VSA Software*, publication 5990-6553EN
- Brochure: *Simplify Signal Creation with Signal Studio Software*, publication 5989-6448EN
- Brochure: *X-Series Measurement Applications*, publication 5989-8019EN
- Selection Guide: *Spectrum Analyzer and Signal Analyzer*, publication 5968-3413E
- Technical Overview: *X-Series Signal Generators*, publication 5990-9957EN
- Brochure: *E7515A UXM Wireless Test Set*, publication 5992-0149EN
- Data Sheet: *E7515A UXM Wireless Test Set*, publication 5991-4634EN
- Technical Overview: *T3100S Series NFC Test Systems*, publication 5992-0188EN
- Data Sheet: *N6700 Modular Power System Family*, publication 5989-6319EN
- Data Sheet: *N6780 Series Source/Measure Units (SMUs) for the N6700 Modular Power System*, publication 5990-5829EN
- Data Sheet: *N9320B RF Spectrum Analyzer*, publication 5990-8119EN
- Data Sheet: *N9310A RF Signal Generator*, publication 5990-8116EN

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