Electro Rent

Into the Future, a 5G Primer

Contents

Introduction to 5G

The Wide-Ranging Impact of 5G on Business, Science, and Society

The potential impact of fifth-generation wireless networks on business, technology, science, and society cannot be underestimated. Just as the semiconductor, the personal computer, the internet, smartphones, and the cloud have improved the way we communicate and collaborate, 5G is set to increase our reach by shrinking perceptions of distance with exponentially faster communication, visualization, and workstream processing. With instantaneous response and imperceptible delay, waiting for downloads, lag, and connection delays will become a thing of the past.

Various world bodies are currently determining global 5G NR (new radio) standards, applications, and use cases. They include the 3GPP (Third Generation Partnership Project), 5GPPP (5G Infrastructure Public Private Partnership, NGMN (Next Generation Mobile Networks Alliance), IEEE 802 LAN/MAN Standards Committee (Local Area Network/Metropolitan Area Network), the IETF (Internet Engineering Task Force), the ITU-R (International Telecommunications Union Radiocommunication sector), and others. The goal is a global system that provides massive bandwidth now and into the future (without the need for network iterations), high availability and reliability, low latency, and superfast speed.

Prominent global consultancies, respected financial institutions, network equipment providers, semiconductor companies, device manufacturers, and telecom service providers are all working to predict, nurture, and bring the 5G future they envision to life. The vision is for 5G to offer massive bandwidth improvements (100 times more devices per unit area compared to 4G LTE), speeds up to 10 Gbps or more, availability and reliability of 99.999%, and ultra-low latency of 1 ms (i.e., the time between the data request and transfer) for mission-critical applications. Based on initial testing, these targets seem within reach.

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The fast-moving stream of potential applications, however, shows no signs of slowing down. Changes in transportation, manufacturing, automation and robotics, energy use, and environmental protection will improve living standards and quality of life for people around the world. Use cases will be driven, in part, by ongoing developments in artificial intelligence, machine learning, neural networks, 3D printing, nanotechnology, quantum computing, biotechnology, and genomics, leading to some of the most important scientific and industrial discoveries the world has ever seen.

In transportation, 5G will enable a variety of self-driving vehicles for personal and commercial use as automated ride hailing, ride-sharing, and public transportation services. With traffic management systems, connected

sensors can collect traffic information to optimize signal timing, smooth traffic flow, and reduce emissions. These changes will increase convenience, productivity, and safety, and reduce costs.

In agriculture, sensors can provide the data needed to analyze soil, crop, water, machinery, and environmental conditions, make better decisions, and increase food production to serve a rapidly-growing global population. In healthcare, connected systems can broaden the reach of patient care by making it more accessible to underserved communities, especially those in rural areas.

In manufacturing, distribution, and logistics, industrial automation can improve productivity and lower costs by allowing machines to communicate and learn from each other. Entire factory systems can be interconnected and managed by a centralized system that will enable products to be tracked across the entire production journey, from manufacturing and distribution to end user.

As legacy companies—and even entire sectors—are transformed, creative destruction will bring new companies and business models, innovative products and services, and numerous inventions and technologies. 5G will be the catalyst that accelerates the pace of change across society, fueling economic growth in the coming decades and beyond.

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In the Internet of Everything (IoE) era, connectivity will be pervasive—always on, accessible anywhere and everywhere. People will interact with billions of connected devices, sensors, machines, and vehicles to share massive amounts of data, high-resolution images, and ultra-HD video. Holographic avatars, 4K and 8K HD images, ultra-HD video, and virtual/augmented/mixed reality can be experienced in real time to enhance education, training, sales, communication, and sales and marketing activities.

Why 5G?

Numerous forthcoming developments—including growing adoption of cellular use in developing markets, billions of additional connected devices via the Internet of Things (IoT), autonomous vehicles, cloud robotics, factory automation, and the seemingly insatiable appetite for HD content—will drive the need for exponential improvements in wireless bandwidth, speed, reliability, and latency.

In 2017, for example, HD images, video, and livestreaming accounted for 55% of all content. By 2023, fully 75% of mobile data traffic worldwide is expected to be in HD and ultra-HD formats such as 4K, 8K, 3D video, and 360-degree video. (Source: Ericsson Mobility Report, November 2017.)

Healthcare

"For patients with serious conditions, remote devices can serve as a proactive early warning system, rather than taking the risk that a severe condition might worsen unexpectedly."

With the advent of 5G, connected healthcare becomes possible, including mass patient monitoring and remote treatment. Wearable sensors and implantable devices can automatically transmit patient status to doctors and hospitals. The so-called Body Area Network (BAN) provides the ability to monitor vital signs, physical activity, medication adherence, and other health parameters in real time. (Source: Center for Technology Innovation at BROOKINGS, How 5G Technology Enables the Health Internet of Things.)

The benefits of connected care include increased access for patients, fewer hospital visits, and lower costs. With 5G, doctors in rural areas can share patient X-rays or CT scans with other doctors and hospitals for additional opinions, input, and discussion. For elderly patients, video or phone conferences based on data from remote sensors and devices can substitute for office visits, reducing the need for frequent travel to and from the physician's office.

For patients with serious conditions, remote devices can serve as a proactive early warning system, rather than taking the risk that a severe condition might worsen unexpectedly between office visits. With 5G, doctors can alter the dosage of medications, monitor pacemaker timing, and adjust implantable cardiac defibrillators (ICDs), drug delivery systems,

and neurostimulators in real time. (Source: springer.com, Remote Patient Monitoring Within a Future 5G Infrastructure.)

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With superfast speed and imperceptible lag, remote robotic telesurgery also becomes practical, allowing for physical distance between surgeon and patient. The surgeon manipulates a console that is remotely connected to a robot that performs the actual surgery. The patient may be in the same building in a clean room to prevent infection, or in a battlefield hospital ten thousand miles away.

High frequency mechanisms can compensate for hand tremors during lengthy or demanding operations. The potential benefits of telesurgery include improved precision, lower invasiveness, reduced trauma, faster recovery times, and ultimately, lower healthcare costs.

Smart Grids

5G holds promise to upgrade and improve our industrial electric grids. Since grid performance is closely tied to latency, 5G will be well suited for such uses. With latencies of 10 to 13 ms seen in testing, 5G can provide quick response across the entire connected grid. Utility providers will be able to predict and adjust to changes in power demand with speed, accuracy, and

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efficiency. Dynamic grids will become more responsive, which is especially important when it comes to the changes that widespread EV charging and smart metering will bring.

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Smart grid management in city centers can be used to streamline service delivery and match resources with demand. Use of water, gas, electricity, and street lighting can be monitored and adjusted in real time. Smart lighting sensors can dim street lights when pedestrians or traffic are not present, smart water sensors can adjust the quality of drinking water, and internet-connected trash cans can signal for waste collection and removal, which can also be automated to improve sanitation and reduce costs.

Real-time availability notifications for parking spaces and electric-vehicle charging stations can be provided as users arrive in the local area. Automation of public transportation can improve user safety, convenience, and on-time reliability. The result is increased efficiency, less environmental impact, less human intervention, and lower cost.

Smart Homes

A multitude of devices will be connected to the internet via home gateways and routers and accessible via smartphone. Self-adjusting HVAC systems and smart sensors will be used to monitor and control environmental conditions. For example, temperature sensors can continually adjust between efficiency and comfort or signal HVAC adjustments when windows or doors are open and lighting sensors can turn off lights or music in unoccupied rooms.

Smart home systems include appliance control (i.e., washers, dryers, refrigerators/freezers, ovens/microwaves), security systems (i.e., motion sensors, cameras, lock control), and entertainment devices (i.e., Bluetooth enabled speakers for music, smart speakers/voice controlled assistants). 5G will also bring improvements in cloud gaming and virtual reality applications for training, education, marketing, sales, and entertainment.

Industrial Automation

The advent of machine learning and machine-to-machine (M2M) communication will enable automated machines to "talk" to each other, share information, and learn how to make improvements, largely on their own. Using connected sensors and cameras to monitor output and adjust in real time, factory machines will be able to share massive streams of data and video with each other to coordinate production—either within a factory or across a global, multi-factory ecosystem.

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Subsequently, data can be analyzed by humans or machine-learning systems to gain additional insight. With automation, less rework is required as error rates are reduced. Efficiency also increases with higher throughput and less human intervention, all of which leads to improvements in quality and satisfaction. (Source: Developers Alliance, Internet of Things, Manufacturing IoT From the Factory Floor.)

As Industrial IoT (IIoT) evolves, multiple systems, factories, and logistics providers will be connected to a centralized IT system that provides total visibility to all manufacturing and supply chain events. Radio Frequency Identification (RFID) tags can be used to track products as they move through the distribution system, informing managers about issues that need resolution.

Today, companies use IIoT largely for predictive maintenance and to improve safety. For example, sensors are used to deactivate a machine if humans inadvertently cross a predetermined safety zone. Although IIoT is in its infancy, it is expected to be the most significant growth category by 2023, when it overtakes consumer IoT. (Source: The Mobile Economy 2018, GSMA Intelligence.)

The Transportation Revolution

In the transportation sector, a revolution is about to occur—although it may take a decade or longer to play out. Automakers are preparing by entering strategic partnerships, making acquisitions, and collaborating with chipmakers, navigation/guidance suppliers, autonomous vehicle producers, and camera, radar, and LIDAR manufacturers. What is driving this change? Economics.

It is estimated that autonomous vehicles could generate $800B per year in 2030 and $7TR annually on a global basis by 2050—$2T of which will be in the Americas. From 2035, when self-driving vehicle production is expected to ramp up globally, to 2050, when autonomous vehicles are expected to account for nearly half of all vehicles sold, the very nature of the industry may change. (Source: Intel and Strategy Analytics, Accelerating the Future: The Economic Impact of the Emerging Passenger Economy.) One-to-one vehicle ownership and new-vehicle sales to consumers are likely to decline as automated transportation services become less expensive and more widespread. This will be driven mainly by economics as the single-largest cost, the driver, will be removed from the equation with automation. As a potential offset, sales of self-driving vehicles to business entities and commercial fleets may increase.

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The components, software, and hardware for self-driving vehicles already exist today. Many companies maintain autonomous test fleets, some of which are in operation on public roads. It has been estimated that the cost of self-driving vehicle components is in the range of $200,000 (excluding the vehicle itself), but this is mainly for low-volume, custom machines in a testing environment. Costs will scale as more vehicles populate our roadways and technology results in more innovative, cost-effective solutions, such as the recent move to solid-state LIDAR.

An Autonomous Future

Based on public information, Waymo (a division of Alphabet, Inc., Google's parent company) appears to have a significant lead in experience with autonomous vehicles. The company began researching such vehicles in 2009 and now has the third-largest self-driving fleet in California. They also have numerous pilot programs in operation around the country, including testing on public roads in Arizona, Texas, Washington, Michigan, and Georgia.

Waymo has accumulated six million miles of pilotless driving experience on public roads. They have also logged five billion computer-simulated miles with 10,000 virtual vehicles that operate 24 hours a day, testing various driving scenarios and strengthening the company's self-learning database. (Source: Forbes.com, Waymo Is Millions of Miles Ahead In Robot Car Tests; Does It Need A Billion More?)

Apple recently registered the second-largest self-driving fleet in California. Up to this point, Apple had maintained a low profile with its autonomous program, so it's hard to discern how far the company has progressed. It has been suggested that Apple may choose to sell its autonomous systems to other automakers rather than creating its own self-driving vehicle. (Source: The Drive, Apple's California Self-Driving Car Test Fleet Continues to Grow).

GM's acquisition of Cruise Automation will hasten their progress in this area with the most self-driving vehicles in California and promises of an automated ride-hailing service in 2018.

A Data Intensive Ecosystem

While an individual autonomous vehicle by itself would not require 5G to operate, the vision is to create an autonomous vehicle ecosystem where vehicles could communicate with each other (V2V); with traffic management systems (V2I) to optimize signal timing and traffic flow; with networks and data centers (V2N) to exchange and analyze information; and with pedestrians (V2P) to provide traffic info and intersection alerts. Collectively known as vehicle-to-everything (V2X), driving will become safer and more efficient with less congestion, lower emissions, and reduced environmental impact.

The volume of data generated by self-driving vehicle sensors, cameras, and processors is massive. Intel estimates that each autonomous vehicle may generate up to four terabytes of information, per-vehicle per-day (assuming 1.5 hours of driving). For reference, the entire collection of printed books in the Library of Congress is estimated to be 10 terabytes (Source: CNN.com politics). This means that each autonomous vehicle would generate enough data to equal to the entire printed volume in the Library of Congress every 3.75 hours of driving.

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Given this, dedicated data centers will be required to receive, store, and analyze information and share it with other vehicles in the network so they can "think, learn, and act without human intervention". (Source: intc.com, Intel Editorial: For Self-Driving Cars, There's Big Meaning Behind One Big Number: 4 Terabytes.)

Transportation as a Service

Other modes of transport, such as ride-hailing and ride-sharing services, robotaxis, and transport pods—collectively known as Transportation as a Service (Taas) or Mobility as a Service (Maas)—will also become more common, especially in urban areas. Because the primary cost of these services (the driver) has been removed, user fees should decline, making

them more popular. As the financial gap between one-to-one vehicle ownership and on-demand transportation services widens, some may forego personal car ownership altogether.

Transport Pods

Time that was previously spent driving can now be used in other ways. Without the need for a steering wheel, pedals, or mirrors, transport pods can prioritize passenger comfort, entertainment, and convenience over interior ergonomics and practicality. Imagine luxurious appointments such as wood floors or big-screen televisions, and an interior more akin to a living room than a traditional car. Hypothetically, pods might even offer mobile business meetings, meals, health screenings, or even hair styling services. (Source: theverge.com.)

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Conclusion

It would not require much of a stretch to say that one day soon, we will look back and acknowledge that 5G was a significant factor in the growth, advancement, and evolution of our society. Such a powerful enabler can serve as a force multiplier to hasten ongoing research and development in

a variety of fields, including artificial intelligence, machine learning, neural networks, nanotechnology, quantum computing, and supercomputing.

The result may be a complete rethink of the way we create, innovate, and manufacture products, conduct business and scientific research, and transfer knowledge between humans and machines. All of which should lead to increased efficiency and productivity in industries ranging from agriculture, healthcare, and manufacturing, to automotive, transportation, and utilities, all for the greater good of the environment and our society.

As a leading global provider of testing and measurement equipment, Electro Rent is committed to advancing 5G testing solutions that help clients reduce costs and accelerate first-to-market 5G solutions and applications.

Why Electro Rent?

Electro Rent is enabling a successful transition to 5G by offering first-to-market solutions at every stage of the test lifecycle. We provide semiconductor, network, equipment, and device manufacturers with efficient solutions that can reduce testing and measurement costs.

- Our large inventory ensures that you get the equipment you need, when you need it.
- We stand behind our products with support and service; our calibration facilities are world class.
- If there's anything you don't like, just let us know and we'll do our best to resolve it to your satisfaction.
- Our advisors recommend a variety of easy-to-start rental and financing programs to fit your situation.

We proudly offer 5G test solutions from Rohde & Schwarz and Keysight, world leaders in RF test and measurement.

Let us help you on your journey to a 5G future.

5G Signal Creation

Rohde & Schwarz SMW200A Vector Signal Generator, 100kHz to 40GHz

Electro Rent Part No. RS-SMW200A-40

The SMW200A is the vector signal generator for the most demanding 5G applications. It offers flexibility, performance, and intuitive operation for generating complex, digitally-modulated signals of high quality for 5G LTE Advanced to 2G applications.

Applications

- Pre-5G NR Signal Generation
- Antenna Array Testing - Conducted and Over-the-Air
- 5G Waveform Candidates

Features

- Single side band phase noise typ. -135dBc @1GHz, 20kHz carrier offset
- High output power up to +18dBm (PEP)
- Analog and digital modulation
- Cellular modulations

Keysight M9383A PXIe Microwave Signal Generator, 1 MHz to 44 GHz

Electro Rent Part No. KT-M9383A-F44

The M9383A is a modular microwave signal generator test solution for design validation. It can be efficiently leveraged into a manufacturing environment with the flexibility to solve today's pre-5G LTE Advanced requirements and can be upgraded to your future test needs.

Applications

- Modular test solution for design validation that can be efficiently leveraged into manufacturing
- Flexibility to solve your immediate test needs, but upgradable for what comes next – whether that's more frequency coverage or a rapid shift to high volume production.
- Pre-5G signal confidence you need with 1% EVM @ 28 GHz, 800 MHz bandwidth

Features

- Single side band phase noise typ. -137dBc @1GHz, 20kHz carrier offset
- High output power @1GHz, -90 to +19dBm
- Analog and digital modulation
- Cellular modulation formats from 2G to Pre-5G LTE Advanced

Keysight E8267D PSG Vector Signal Generator, 100kHz to 44GHz

Electro Rent Part No. KT-E8267D-544

The E8267D vector signal generator is used to test advanced receivers, with realistic wideband radar, EV, Satcom, and 5G applications. It offers up to 4GHz of bandwidth (with external AWG see M8190A), allowing you to simulate complex electromagnetic environments and reduce complex signal creation times.

Applications

- Waveform playback and real-time
- Antenna Array Testing - Conducted and Over-the-Air
- 5G Waveform Creation with signal studio application
- Signal optimizer with K3101A

Features

- Single-side-band phase noise typ. -143dBc @1GHz, 20kHz carrier offset
- High output power @1GHz, -130 to +21dBm
- Analog and digital modulation
- Cellular modulation formats from 2G to Pre-5G LTE Advanced

5G Signal Analysis

Rohde & Schwarz FSW43 Signal and Spectrum Analyzer, 2Hz to 43.5GHz

Electro Rent Part No. RS-FSW43

The FSW43 Signal and spectrum analyzer is designed with 5G measurement analysis in mind. It offers low phase noise, wide analysis bandwidth (2GHz) for complex LTE Advanced applications, with an easy to use GUI.

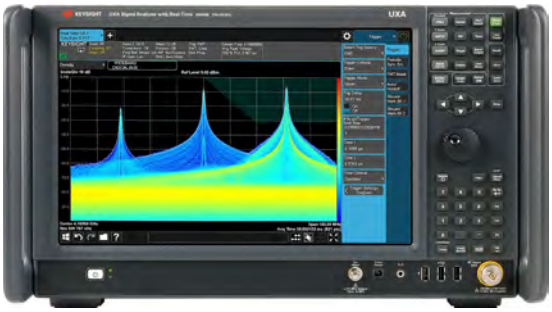
Applications

- Used in aerospace and defense applications (ASD)
- Wideband communication systems for military and commercial use
- 5G Waveform analysis
- Development of oscillators for radar systems and complex LTE Advanced applications

Features

- Analysis bandwidth – 10MHz standard, upgradable to 2GHz
- Displayed average noise level (DANL) +154dBm at 2GHz (1Hz resolution)
- SSB phase noise at 10kHz offset -134dBc
- Cellular modulation analysis from 2G to Pre-5G LTE Advanced

Keysight N9040B UXA Signal Analyzer, Multi-touch, 2 Hz to 50 GHz



Electro Rent Part No. KT-N9040B-550

The N9040B Signal analyzer offers real-time spectrum performance analysis up to 1GHz for deeper views of complex and challenging 5G signals. Clean spectral purity with leading phase noise measurements. Extendable frequency range to 110GHz with external smart mixers.

Applications

- Utilize application measurements that range from parametric to wireless measurements including 5G LTE Advanced, WCDMA, phase noise, noise figure, analog demodulations
- 5G Waveform analysis and vector analysis with VSA software 89601B
- Satellite, radar, EW, fast-hopping signal analysis

Features

- Analysis bandwidth – 25MHz standard, upgradable to 1GHz
- Real-time bandwidth optional to 510MHz
- Displayed average noise level (DANL) +174dBm at 1GHz (1Hz resolution)
- SSB phase noise at 10kHz offset -136dBc
- Cellular modulation analysis from 2G to Pre-5G LTE Advanced
- 5G NR (new radio) with N9085EMOE application software

About Electro Rent

Electro Rent is a leading global provider of test and technology solutions that enable its customers to accelerate innovation and optimize investments. Electro Rent's rental, lease, sales, and asset management solutions serve industry-leading innovators in communications, aerospace and defense, automotive, energy, education, and general electronics and have done so since 1965.

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