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5G REPORT

Industry experts and telecom leaders discuss the most frequently asked questions about 5G and its deployment in Canada.


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To help educate consumers and our business partners on 5G in Canada we have leveraged our network of experts, researchers, analysts, and advisors to create this series of 5G discussion panels. Our panels answer the most popular and emerging questions about 5G in Canada.
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5G Health & Safety

Concerns around 5G center around the biological and environmental effects of electromagnetic radiation.

5G Health & Safety

A revolution in wireless communications is underway. The rollout of 5G wireless technology around the world is triggering excitement and trepidation. As this next-stage infrastructure begins to take shape, users will undoubtedly thrill at the new capabilities available from 5G: faster streaming, quicker uploads, and the ability to communicate across the globe at speeds of up to 100 Gigabits per second. While 4G tops out at a theoretical 100 megabits per second (Mbps). That means 5G is a hundred times faster than the current 4G technology—at its theoretical maximum speed, anyway.

Earlier this year, the country's first 5G network began a rollout in four large cities: Montreal, Ottawa, Toronto and Vancouver. While devices that can use the network won't be available until later in the year, by that time 20 additional markets should also be 5G compatible. The Canadian government has said that the addition of 5G will introduce a revolutionary improvement to the country's communication systems, especially in terms of connectivity, latency and bandwidth. Additionally, the government has assured citizens that safety is its primary concern. As a result, all 5G providers will continue to be held to the country's high SAR standards that establish limits for RF exposure.

As technology evolves, potential benefits always pair with apprehension, and 5G is no exception — the concerns around 5G center around the biological and environmental effects of electromagnetic radiation. Because some 5G networks operate at a higher frequency, the fear is that exposure to 5G will cause cellular damage and increase the risk of cancer.

To gain a clearer picture of the health and safety implications of 5G networks, we reached out to a panel of experts. Comprised of researchers, analysts, and advisors, our respondents provided us with in-depth and insightful information on the potential impacts of 5G on human health and the environment.

Our 5G Health & Safety panel includes: Jonathan MacKenzie, policy and research analyst for CWTA, Tim Singer, Director General, Environmental and Radiation Health Sciences for Health Canada, Marc Bouvrette, President of Gap Wireless, Erika Zeroual, Communications Advisor and Media Relations for Innovation, Science and Economic Development Canada (ISED), Stuart Nicol, Director Product Development at APREL as well as Ernest Cid, CEO of Wavecontrol.

PANEL DISCUSSION

Is it dangerous to live near a 5G cell tower?

The threats posed by electromagnetic waves are related to how close we are to the source, the density and the exposure time," says Marc Bouvrette, President, Gap Wireless.

"The typical safety perimeter for a standard cell site is on the order of 3-5 meters whereas the typical height of a cell tower is 50+ meters," he continues, "so if we are 50 meters away from a transmitter that has been identified by Safety Code 6 regulations to have a safety perimeter of 5 meters… 10 times further away than the minimum recommendable distance."

"Given the antennas are placed at the top of cell towers at distances that are multiples of the safety perimeter, living near a cell site does not pose a specific threat due to electromagnetic radiation," Bouvrette concludes.

"All wireless devices must meet ISED's requirements and be certified before being sold in Canada," adds Jonathan MacKenzie, policy and research analyst, Canadian Wireless Telecommunications Association, CWTA. "Antenna installations must also meet ISED's requirements at all times as a condition of a carrier's license."

"Canada's mobile network operators consistently monitor their networks, and ISED audits wireless devices and antenna installations to ensure compliance with safety standards," Mackenzie continues. "Research by Health Canada and international bodies, including the World Health Organization, has produced no substantiated evidence of harmful effects from RF technologies used within existing safety standards."

"There is consequently no basis for finding that living or working next to cell towers, or other mobile wireless network equipment would pose a health hazard to the Canadian public."

Are there specific health concerns about 5G vs. 4G

"Contrary to misunderstandings about 5G technology and, in some cases, deliberate misinformation, there are no established health risks from the radiofrequency waves used in 5G networks in accordance with applicable safety standards," says Mackenzie.

"The primary difference between any of the technologies over time is mostly related to the modulation or signal type, which should not have any effect on health concerns," says Bouvrette. "While there have not been any conclusive studies on the long term effects of electromagnetic waves used in mobile communications networks on the human body, we do know from other types of radiation such as ultra-violet and X-rays (which are more than 1,000,000 times to 100,000,000 times the frequency of current mobile communications and above the visible light range), that the amount of power, density of power and total exposure time will contribute to the lasting effects of electromagnetic radiation."

"Electromagnetic waves of higher frequencies carry more energy than lower frequency fields," adds Ernest Cid, CEO of Wavecontrol. "(While) 5G uses higher frequencies than earlier generations, allowing more devices to connect and at faster speeds, 5G radio waves are still non-ionizing, like precedent 2G, 3G, and 4G technologies, which means they do not have enough energy to break bonds between molecules."

"At this moment, neither ISED nor any other international body related to RF safety, like ICNIRP or WHO, has raised specific health concerns about 5G, other than not exceeding the currently established limits," he adds.

. "Research by Health Canada and international bodies, including the World Health Organization, has produced no substantiated evidence of harmful effects from RF technologies used within existing safety standards".

Jonathan MacKenzie, policy and research analyst, Canadian Wireless Telecommunications Association, CWTA

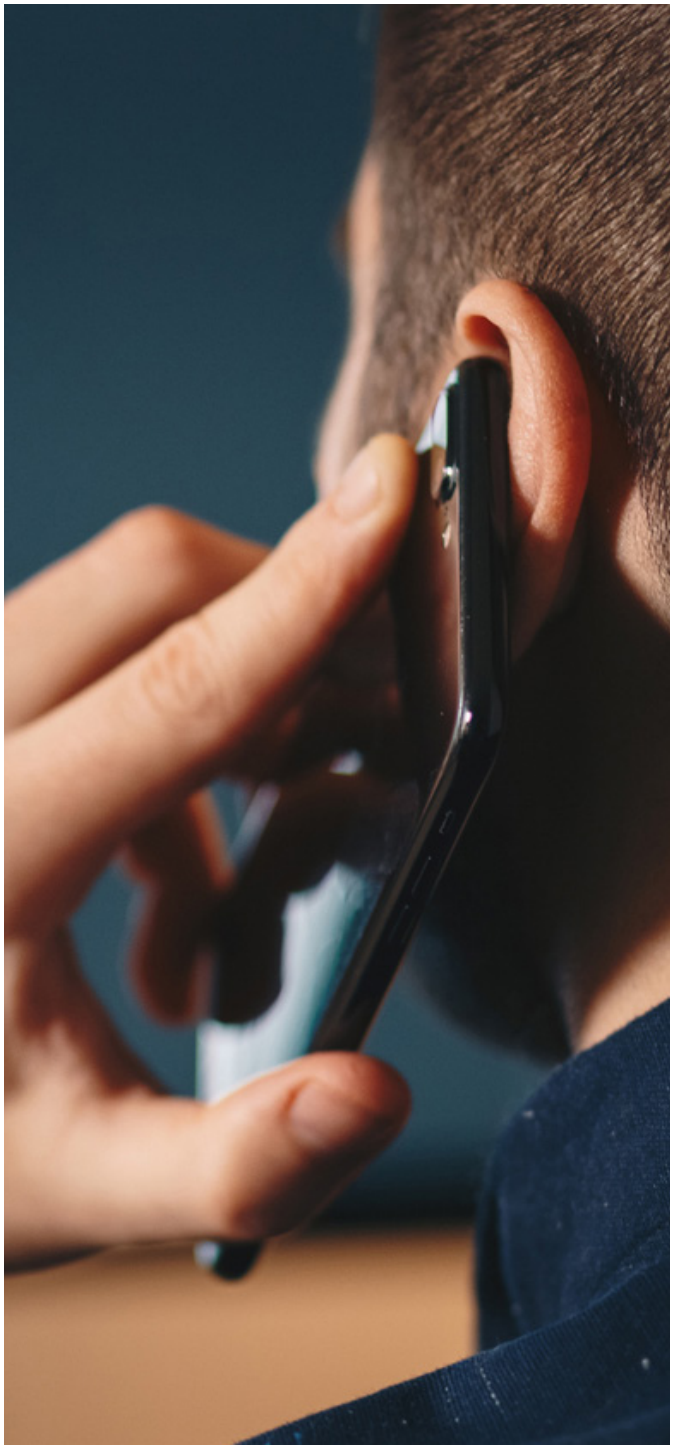
Discussion Panel Profile: CWTA

Canadian Wireless Telecommunications Association is the authority on wireless issues, developments and trends in Canada. It represents companies that provide services and products across the wireless sector. Representing the industry before all levels of government and various regulatory agencies, CWTA actively promotes the industry with the goal of ensuring continued growth of the wireless sector in Canada. CWTA administers a number of initiatives on behalf of its members, including corporate social responsibility programs and the national common short codes program.

Is 5G an issue for the environment?

"5G works with higher frequencies to be able to provide higher communication speeds," explains Ernest. "Higher frequencies mean less coverage, so the 5G network will consist of more antennas that are closer to us. However, they will be smaller and will need less power to operate. It shouldn't be an issue for the environment if they are correctly deployed."

"While 5G does operate on both the lower and higher frequency spectrum, all 5G devices will still be required to comply with current RF safety requirements," says Erika Zeroual Communications Advisor, Media Relations, Innovation, Science & Economic Development Canada, ISED. "Because safety limits are already set well below the threshold for potential adverse health effects, widescale implementation of 5G will not significantly increase RF exposure to the general public."



Is it safer to use a cellphone or a hands-free device near the ear?

"Both devices will transmit and receive electromagnetic signals, so the evaluation of risk from one vs. the other is related once again to power, power density, and time of exposure," says Bouvrette. "In both cases, the total power that can be transmitted is well below the prescribed rates by ISED and Safety Code 6. Like with transmitter sites, a safety perimeter could be calculated for these devices, and we would find that the perimeter would be less than 1mm around the antenna, which means the perimeter is internal to the actual device."

"We have demonstrated above that power, and power density is not a concern, and this is true for any amount of exposure time," Bouvrette adds. "Looking at the way we use each of these devices if one was concerned with accumulated exposure time and considering the hands-free devices often remain attached to our ears even when not in use, total radiation absorption could be considered to be higher with the use of hands-free devices."

"It is important to point out however that while not in use but while powered on, mobile phones like hands-free devices will continue to transmit and receive, but at much lower levels and for short periods of times, essentially "checking in" to ensure communication is available and ready to open a full channel if required," he concludes.

Discussion Panel Profile: ISED Canada

Innovation, Science and Economic Development Canada is the department of the Government of Canada with a mandate of fostering a growing, competitive, and knowledge-based Canadian economy. ISED has three core responsibilities. These responsibilities are to oversee Canadian companies, investment and growth; people, skills and communities; and science, technology, research and commercialization.

Innovation, Science and Economic Development Canada
Innovation, Sciences et Développement économique Canada

What specific safety measures should be adopted around 5G?

"Basically, (safety measures should be) the same as with previous generations," says Ernest Cid. "(that means ensuring) that all antenna systems meet Canadian limits (Safety Code 6) [1], which are consistent with limits used in other parts of the world (USA, EU, Australia, etc.)"

"There are three basic means of assessing human exposure: using portable EMF meters, monitoring EMF exposure 24/7 with fixed units, and wearing RF personal monitors," Cid elaborates. "Portable EMF meters are used for the certification of transmitters or working places, fixed monitoring instruments are used at specific sensitive places, while RF personal monitors are mainly worn by workers that have to be near transmitters, like tower climbers or RF engineers. IEEE Std. C95.7 points out that a good RF Safety Program 'must include RF safety awareness training for all tower workers and use of RF personal monitors.' The same applies to other workers that may find themselves near transmitters, for example, electrical service contractor workers."

"Safety Code 6 should continue to be respected along with recommendations from ISED and Health Canada," adds Bouvrette. "Special considerations should be given to antenna transmission techniques such as "Massive-MIMO" or Beamforming to ensure we understand the dynamic adjustments in power density and power steering."

"Although we will see an increase in power density for 5G sites, the incremental size of the safety perimeters will likely no more than double – we must remember that power density decreases at a rate of the square of the increase in power, meaning a doubling in safety perimeter radius would represent a quadrupling in power density, which is not the case in current beamforming solutions. This means that the biggest impact around 5G will be related to cell site technicians and other workers that may come in close contact with cell site transmitters, specifically on rooftop sites where other workers (like roofers, window washers or HVAC installers) may need to come in relatively close proximity with transmitters," he continues.

"All technologies in use today and prior to 5G for mobile communications operate under 3 GHz. Some 5G will also be deployed in the sub-3GHz spectrum and many studies have been made on health effects at these frequencies. New spectrum being made available for 5G services rises to 28 GHz and 39 GHz, more than 10 times the frequency of current technologies, but still millions of times smaller than the penetrating Ultraviolet, X-Ray or Gamma Rays we know to have effects at higher power densities and exposure times. It is important to understand, however, that power dissipates at much higher rates as frequency increases compared to a lower frequency, physical forces that will contribute to lowering the power density being transmitted by these high-frequency transmitters," he concludes.

"Health Canada does not call for taking specific steps to avoid RF from wireless networks, as exposure levels in Canada are far below the safety limits set by the federal government," explains Mackenzie. "In the United States, the Federal Communications Commission (FCC) has determined that current RF exposure limits are sufficient to ensure the safety of 5G networks, and Canada's science-based safety standards are consistent with those of the United States, as well as other jurisdictions including the EU, Japan, Australia, and New Zealand."

"Although the public is already protected by ISED's and Health Canada's existing RF exposure regulations, individual Canadians may choose to limit their personal exposure to RF energy from mobile wireless equipment - including 5G devices and antennas - by shortening the length of phone calls; substituting calls with text messages; or using accessories such as headsets, speakerphones or earpieces to increase the distance between a user and the device," he concludes.

The WaveMon RF-60 exposimeter can trigger an E-field overexposure alarm according to the international limits, with a new feature: it now includes the limits not only for workers, but also for the general public in the standards ICNIRP, European Directive 2013/35/EU, FCC, Safety Code 6 (2015) and NATO.

The WaveMon RF-60 has the same advantages of the rest of the WaveMon family: GPS and altimeter to map the measurements, lightweight, portable, easily wearable on the arm or in the harness, and a huge battery autonomy.

Discussion Panel Profile: Wavecontrol

Wavecontrol designs and develops professional instruments for measurement, monitoring and evaluation of human exposure to electromagnetic fields. Their calibration laboratory (LabCal Wavecontrol) is ENAC accredited and recognised in most countries around the world through the ILAC network. All devices manufactured by Wavecontrol are delivered standard with ISO 17025 accredited individual calibration at no extra cost.

WAVECONTROL
Safety, Quality, Service

What is SAR or Specific Absorption Rates and how are they measured?

"The emergence of 5G has led to a need for changes in the methodologies in how manufacturers will certify their radios for safety, specifically human exposure or Specific Absorption Rate (SAR)," begins Stuart Nicol, Director Product Development at APREL. "As it currently stands in Canada, there won't be any real change to the dynamics of how we will see 5G for frequencies above 3GHz in the next 12 months, considering the previous Spectrum Auction only sold off the 600MHz band with the next slice being 3500MHz," adds Nicol.

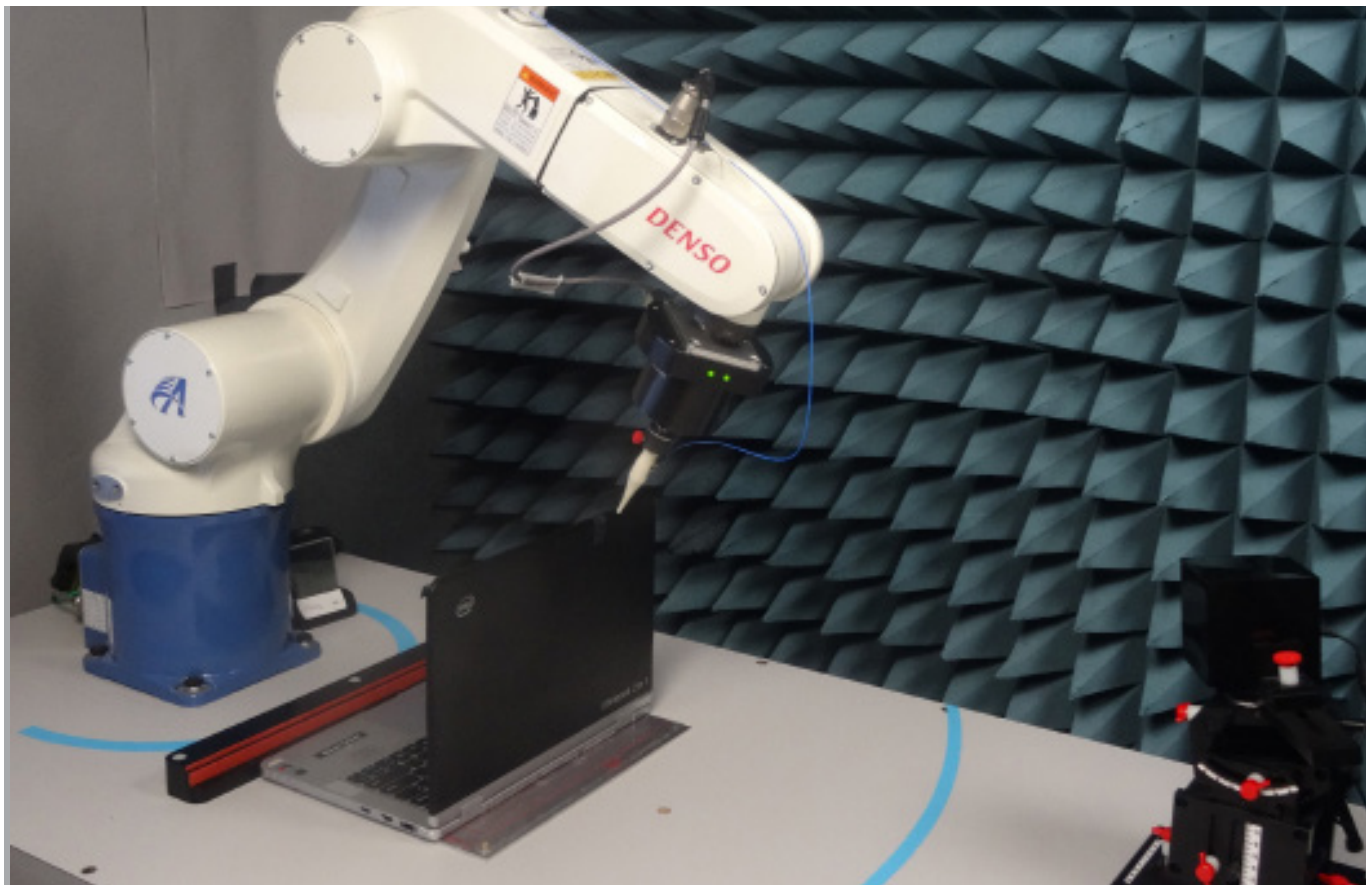
"Traditional SAR measurement techniques that use E-Field probes which demodulate the complex radio frequency signal have concerns where higher bandwidths and complex modulation schemes may not be properly addressed when measuring for exposure following the current experimental SAR methodology," says Nicol. "Studies conducted by APREL where 200/400/800MHz bandwidths using 2/4/8 carriers have revealed significant issues in regard to how much exposure has been measured when applying existing standards [2]

IEC tasked the committee JWG12 with the job of creating methodologies for the assessment of 5G technologies operating in the mm-wave frequency range."

"The working group had to investigate appropriate methods for the assessment of exposure-based in science and applicable to an experimental process," he continues. "Consideration of antenna types (MIMO, Phase Array), modulation schemes, and bandwidth all had to be investigated, and appropriate methods for assessment understood and described."

"The result of this research was the publication of a technical report IEC-TR63170 [3], which will be the basis for experimental assessment in regard to human exposure for mm-wave technologies," he adds.

"By employing a system that can be utilized as a design tool that can also perform compliance measurements, the effectiveness of the development process can be improved on significantly."



Discussion Panel Profile: APREL

APREL is an independent research-driven engineering company specialized in automated near-field test solutions for a wide range of existing and new technologies. Our approach through working directly with world leading manufacturers provides a unique opportunity and insight into emerging technologies where our solutions ensure they get to the market quicker.

The R&D team at APREL is forging a new path in system development within near-field evaluations for SAR, HAC and EMI.

Which Government body is responsible for ensuring the public is not exposed to unsafe exposures of Radio Frequencies? What is Safety Code 6?

"Health Canada administers the Radiation Emitting Devices Act, which governs the sale, lease, and importation of radiation-emitting devices in Canada," explains Tim Singer, Director General, Environmental and Radiation Health Sciences for Health Canada.

The Department's mandate regarding human exposure to radiofrequency (RF) electromagnetic energy from wireless devices includes carrying out research into possible health effects, monitoring the scientific literature related to such effects on an ongoing basis, and developing RF exposure guidelines, commonly referred to as Safety Code 6.

"Safety Code 6 sets recommended limits for safe human exposure to electromagnetic fields (EMF) in federally regulated industries and workplaces and covers all frequencies (and combinations thereof) in the range from 3 kHz to 300 GHz," says Singer. "This range covers both the frequencies used by existing communications devices (including those using 4G technology) and those that may be used by devices employing 5G technology (i.e., above 6 GHz."

"Health Canada's Safety Code 6 takes into account recent scientific data from studies carried out worldwide," he continues. "When developing the exposure limits in Safety Code 6, departmental scientists consider all peer-reviewed scientific studies and employ a weight-of-evidence approach when evaluating possible health risks from exposure to RF energy. Safety Code 6 limits are among the most stringent science-based limits in the world."

"Compliance with Health Canada's Safety Code 6 is an ongoing obligation, regardless of the technology used," adds Zeroual.

"The radiofrequency exposure limits set by Safety Code 6 cover the frequency ranges that will be used by 5G devices and antenna installations, which are set far below the threshold (at least 50-fold safety margin) for all known established adverse health effects. These limits protect all age groups, including children, on a continuous basis (24 hours a day, seven days a week)," Zeroual elaborates.

"This means that if anyone, including a small child, were exposed to radiofrequency energy from multiple sources within the Safety Code 6 limits for 24 hours a day, 365 days a year, their exposure would still be well below the threshold for adverse health effects," says Zeroual. "Similar to current wireless devices and associated infrastructure, 5G devices and antenna installations must meet radiofrequency exposure requirements before they can be sold or operated in Canada.

"ISED maintains a market surveillance program and routinely audits antenna installations and devices to verify compliance with SC6," she concludes. "As the responsibility for developing Safety Code 6 lies with Health Canada, questions regarding its development should be directed to that Department."

Does 5G cause cancer?

"To date, thousands of scientific studies have been carried out globally to evaluate the safety of RF energy," says Singer.

For over 20 years, Health Canada has conducted its own research on the biological effects of RF energy. As Singer explains, this research has increased scientific knowledge regarding the intensity of RF energy in the environment. It has also helped to establish the human exposure threshold where potentially adverse health effects can occur.

"This important information, along with all other Canadian and international peer-reviewed scientific studies, forms the basis for establishing safety standards for RF energy that protect the health of Canadians," says Singer.

"It is Health Canada's position that the health of Canadians is protected from RF energy when the human exposure limits recommended by Safety Code 6 are respected," emphasizes Singer. "This applies to devices using 4G and 5G technologies. Safety Code 6 has always established and maintained a human exposure limit that is far below the threshold for potential adverse health effects. Health Canada continues to monitor scientific research.

"If new scientific evidence were to demonstrate that exposure to RF energy below levels found in Safety Code 6 from wireless technologies is a concern, Health Canada would take appropriate action to help protect the health and safety of Canadians," he adds.

Nine years ago, in 2011, a cadre of international scientists working as part of the International Agency for Research on Cancer (IARC), assessed the cancer risk of RF-EMF exposure. They concluded that although the risk of developing some cancers – like glioma (cancer of the central nervous system) and acoustic neuroma – they felt evidence of a connection between exposure to RF-EMF and cancer was "not conclusive." (4)

"The language used by researchers can seem vague," says Bouvrette, "but their caution is indicative of the broader cancer research community, where cause-and-effect is scrutinized and continually tested."

"Perhaps it makes more sense to look to organizations that operate under a less stringent mandate, like the World Health Organization (WHO)," Bouvrette continues. "According to WHO, there are no adverse health effects from long-term, low-level exposure to radiofrequency or power frequency fields, like RF-EMF." (5)

"In the US, WHO's conclusions are substantiated," says Bouvrette. "The Federal Communications Commission recently stated that harmful biological effects associated with low levels of RF radiation exposure were "ambiguous and unproven." (6)

"Generally speaking, many international studies on the health effects of RF energy have been conducted over the last several decades," says Bouvrette, "and the conclusion reached is that the impact of RF exposure depends on frequency range and duration. Higher ranges could result in tissue heating, while prolonged exposure to lower frequency ranges can produce nerve stimulation and a tingling sensation." (7)

"In the US, the FDA is responsible for the collection and analysis of scientific information that may relate to the safety of cellphones and other electronic products. In an April 24th, 2019, letter from the FDA to the FCC addressed to Julius Knapp, Chief of the Office of Engineering and Technology publicly stated that as part of their ongoing monitoring activities, the FDA had reviewed the results and conclusions of the recently published rodent study from the National Toxicology Program (8). The review was conducted in the context of all available scientific information, including epidemiological studies. The letter also states that they concluded that no changes to the current standards are warranted at this time. As we have stated publicly, NTP's experimental findings should not be applied to human cell phone usage. The available scientific evidence to date does not support adverse health effects in humans due to exposures at or under the current limits, and that the FDA is committed to protecting public health and continues its review of the many sources of scientific literature on this topic. (9)

In other words, while studies continue to assess the impact of exposure to RF, at this time, 5G falls well within the safety parameters for human exposure. It is also worth noting that while 5G transmitters will require the creation of a large number of new base stations with a large number of transmitters, each transmitter will operate on lower power levels than 4G technology, resulting in a net reduction of RF exposure.

The electromagnetic spectrum is ever-present. It includes radar, satellites, Bluetooth, WiFi, and, of course, 5G. While invisible to the human eye, humans interact with high-frequency radio waves every day. While there's no doubt higher-energy signals, like X-rays, can pose a danger to humans and the environment, it is essential to understand that technologies like 5G operate in a completely different spectrum, where the risk of harm is significantly lower.

For Canadians, the introduction of 5G will create a completely new method of communication. This fast, flexible network will not only enhance existing systems, but will adapt to evolving generations of wireless technology. The government is also establishing a set of protocols to ensure the safety and security of all Canadians. This includes adherence to Safety Code, as well as continued monitoring of 5G systems. With the rollout of 5G, the Canadian government has set the stage for smarter, more innovative use of wireless technologies and set the country up to be a world in leader in 5G.

The truth is, the advantages made possible by 5G are extraordinary. The accelerated speeds made possible by 5G infrastructure will enable us to achieve new heights in terms of connectivity and communication, not to mention the Internet of Things and its potential to transform society. Even more importantly, the evidence clearly demonstrates that 5G is not only safe, but continues to be highly regulated and monitored. And that's good news because we can all safely reap the benefits of a better, faster, more Connected world.

References

(1) Health Canada, (June 2015). Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz. Retrieved from https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/limits-human-exposure-radiofrequency-electromagnetic-energy-range-3-300.html

(2) IEC 62209-2:2010. Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)

(3) IEC TR 63170:2018. Measurement procedure for the evaluation of power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 100 GHz

(4) Carcinogenicity of radiofrequency electromagnetic, The Lancet, Vol. 12, Issue 7, P624-626, July 01, 2011 (https://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(11)70147-4/fulltext)

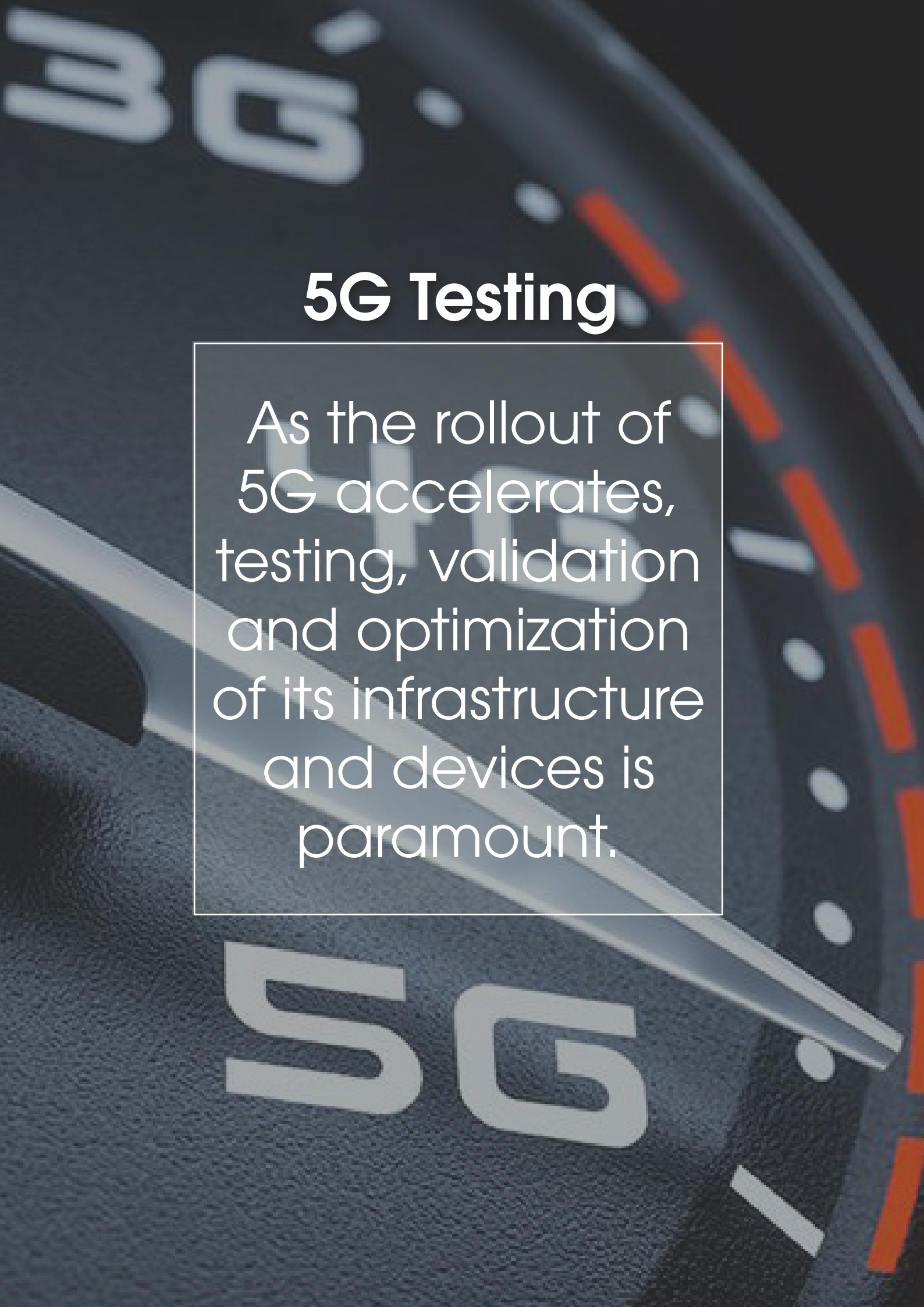
(5) World Health Organization, (August, 2016), What are electromagnetic fields?, Retrieved from https://www.who.int/peh-emf/about/WhatisEMF/en/index1.html

(6) RF Safety FAQ, FCC, (Nov 2015), RF Safety FAQ, Retrieved from https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#Q5

(7) Industry Canada, (February 2019), Radiofrequency Energy and Safety, Retrieved from https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11467.html

(8) Shuren, Jeffrey. "Re: FDA to the FCC on Radiofrequency Exposure", Received by Knapp, Julius, April 24, 2019, Retrieved from https://www.fda.gov/media/135022/download

(9) National Toxicology Program, (November 2018), Cell Phone Radio Frequency Radiation, Retrieved from https://ntp.niehs.nih.gov/whatwestudy/topics/cellphones/index.html



5G Testing

As the rollout of 5G accelerates, testing, validation and optimization of its infrastructure and devices is paramount.

5G Testing

With enhanced mobile broadband (eMBB), ultra-reliable and low-latency communications (URLLC), and massive Machine-Type Communications (mMTC) 5G mobile networks will revolutionize communications. The ability to transmit and receive large amounts of data while also connecting millions of devices at once is nothing short of a revolution. Fast, seamless mobile interactions will connect consumers, enhance business operations, and fundamentally alter the mobile broadband landscape.

As the rollout of 5G accelerates, testing, validation and optimization of its infrastructure and devices is paramount. According to a recent report from Global Industry Analysts entitled "Global OTA Testing Industry", the Over the Air (OTA) testing market for 5G is poised to hit almost US$1.4 billion within the next five years. That growth is due primarily to shifting dynamics and "the changing pulse of the market.

To gain a clearer picture of the testing protocols and challenges associated with 5G networks, we reached out to a panel of experts. Comprised of researchers, analysts, and advisors, our respondents provided us with in-depth and insightful information on the how 5G is tested, and what solutions and new strategies are emerging.

Our 5G Testing panel includes: Adam Hostetter, Director of Sales, Test & Measurement for SAF North America, Kevin Ramdas, Professor of Wireless Telecommunications at Humber College and Director of Training at TelecomTRAIN.ca Dr. Nikhil Adnani, CTO at ThinkRF and Keysight Technologies representatives: Roger Nichols, Keysight 5G Program Manager, Rolland Zhang, FieldFox Product Manager, and Peter Schweiger, Southern Ontario Telco Account Manager.

PANEL DISCUSSION

What are over-the-air (OTA) test solutions, and why are they important?

Mobile communications performance and functionality are characterized by a foundational set of standardized test cases for both base stations and user equipment (UE). For LTE and previous generations, cabled tests were used to measure performance in virtually all of these test cases. Such is also the case for Frequency Range 1 (FR1) for NR. FR1 includes sub-6GHz frequency bands, some of which are bands traditionally used by previous standards but has been extended to cover potential new spectrum offerings from 410 MHz to 7125 MHz. The other frequency range is FR2 which includes frequency bands from 24.25 GHz to 52.6 GHz. Bands in this millimeter wave range have shorter range but higher available bandwidth than bands in the FR1. With the advent of these higher frequency 5G bands above 24.25 GHz, it is not practical to make cabled or conducted measurements because antennae are integrated with the semiconductor amplifiers and there is no practical spot for an RF connector. As a result, Over the Air (OTA) testing is needed to test performance and functionality.

"3GPP, and other standards bodies (e.g. CTIA), have stipulated that 100% of the FR2 test cases must be performed OTA," explains Roger Nichols, Keysight 5G Program Manager. "Most of this is due to the necessity of complete integration of antennas into radio-systems—there is no place to put a connector for a cable. The RF transmission and receive parameters as well as radio functionality KPIs (Key Performance Indicators) need to be tested over-the-air."

OTA involves taking measurements with no galvanic connection between the test equipment and the device under test (DUT). With OTA testing, these entities are connected to antennas, and measurements are made with a true "wireless" link between the equipment and DUT. These OTA measurements can be accomplished in any number of ways, from outdoor ranges to using chambers to contain the electromagnetic fields and prevent external signals from interfering with the analysis.

"Not only is OTA test the only standardized way to qualify the FR2 air interface performance of 5G devices and base stations," adds Rolland Zhang, Keysight FieldFox Product Manager, "it will also help RF designers, system engineers, and network optimization engineers to optimize designs, tweak site locations, adjust antenna orientation and tilts to meet system parameter settings as well as to achieve targeted performance and capacity at reasonable engineering cost."

OTA testing includes verification of beamforming and MIMO—both implemented through electrically steerable antenna arrays. Beamforming implementations involve multi-element antenna arrays. Steering the beam requires tight control of the phase of the signal entering each element. Access to the radio and the internal signal paths is limited.

"The larger the array of antenna elements, the tighter the beams that can be produced," explains Kevin Ramdas, Professor of Wireless Telecommunications at Humber College in Toronto and Director of Training at TelecomTRAIN.ca. "Currently, we are moving to a set of phase-matched cables to connect radios to the antennas. However, as we increase our frequencies, especially the FR2 frequencies, there will need to be direct, manufactured control of the interconnections between the radios and antenna elements. This means that the radio and antenna will have to be part of the same physical unit."

5G radio channel performance will also be heavily dependent upon control of the MIMO link. For MIMO to work correctly, the multiple streams from the transmit antennas to receive antennas require a low level of correlation. The level of variation in the air interface plays a fundamental role in the performance of the link, pushing our testing methodology further toward OTA testing.

"The MIMO link performance will highly depend on how the UE internally processes the MIMO conditions of the radio link," says Ramdas. "The UE will, in a way, send a recipe to the gNb to tell the gNb how best to precode the MIMO streams of data to decrease the level of correlation between the MIMO streams."

What frequency spectrum will 5G technology use? What will be the frequency spectrum in Canada?

"Two frequency ranges are used for 5G NR (5G New Radio), FR1 and FR2. FR1 (Frequency Range 1) refers to spectrum from 410 MHz to 7.125 GHz, and FR2 (Frequency Range 2) refers to spectrum from 24.25 GHz to 52.6 GHz. In Canada, 5G is also being launched at 600 MHz, along with the eventual inclusion of 3.5 GHz bands. Industry Canada is actively working to reallocate frequencies in 1.5, 1.6, 3.5, 26, 28, 39 and 65 GHz bands, with some of that spectrum to be auctioned in 2021," explains Zhang.

As of mid-March 2020, 3GPP has defined forty-five (45) bands in FR1 and four (4) bands in FR2 These band definitions are designed and set to integrate national frequency spectrum policy decisions from around the globe with state-of-the-art radio development and testing technology.

The Canada spectrum situation for spectrum that is new to mobile wireless is as follows (from "GSA Spectrum for Terrestrial 5G Networks: Licensing Developments Worldwide" updated August 2019). Figure 1.

"Performance is defined, specific, and tested depending upon the frequency and the duplex method," says Nichols.

Many operators will have to make a transition over time to 5G in their existing spectrum. Since this is now dedicated to LTE, as UEs come on the market with 5G capability, the best way to utilize the new technology is a gradual transition. This is enabled by a standardized approach to allowing NR in the same channel as LTE with Dyanamic Spectrum Sharing. "Dynamic Spectrum Sharing (DSS) will allow coexistence of 5G sharing existing LTE bands as well," adds Peter Schweiger, Southern Ontario Telco Account Manager, Keysight. "Spectrum Outlook 2018 to 2022 includes more relevant details related to this rollout."

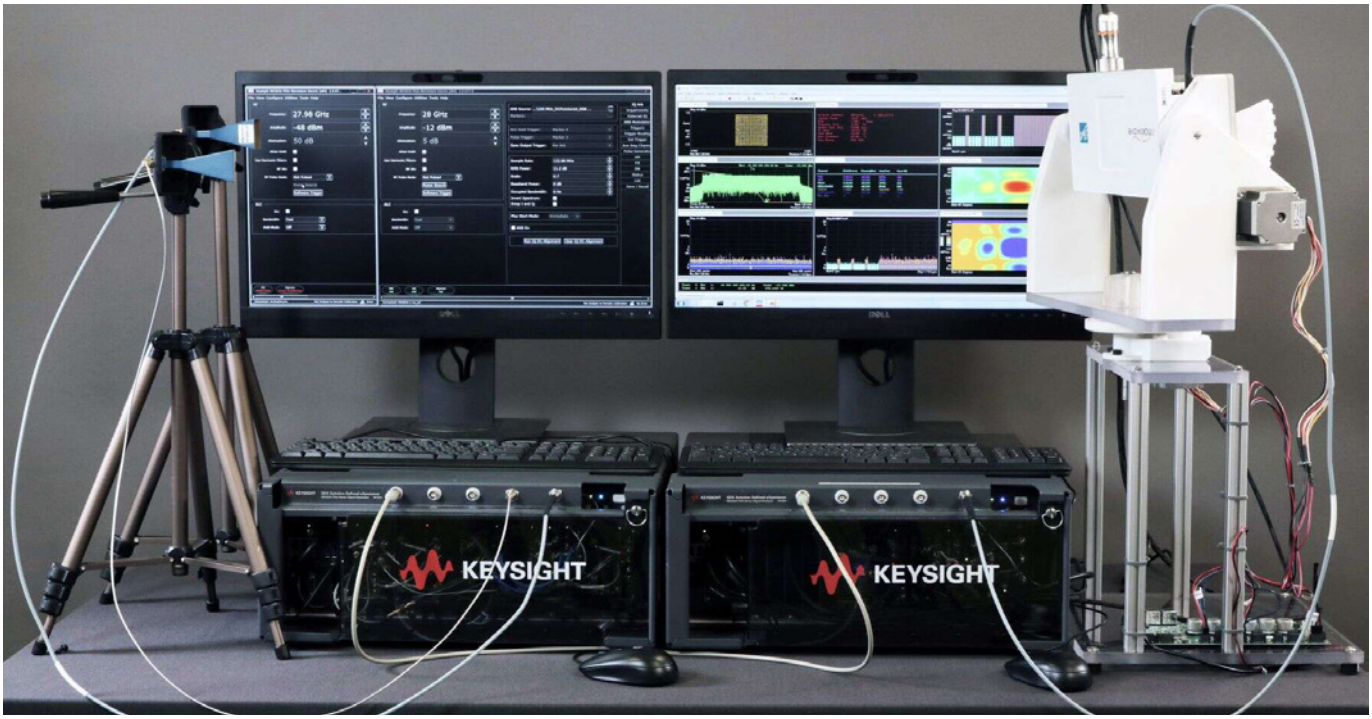
Figure 1.

Frequency Range	Status	Comments
614-698MHz	Auction Complete	Technology-Neutral: Some operators will use this for NR
3540-3650 MHz	Auction/Licensing Planned or Complete	Considered "C-band" as part of ITU definition. TDD only.
3650-4200MHz	Taking consultation from national stakeholders.	No immediate plans for license and auction but doing consultation to take appropriate next steps for policy.
26.5GHz-28.4GHz	Auction/Licensing Planned or Complete	
25.25GHz-26.5GHz	Under consideration	
Other FR2 Bands	Likely to be made available late 2021	Includes 37-40GHz and 64-71GHZ (this latter already added as unlicensed in the USA)

What are the challenges that test instrument companies face while delivering solutions to the 5G ecosystem?

5G systems operate in mm-wave frequencies up to 470 GHz. Historically, a vast majority of commercial wireless networks have operated at frequencies no higher than 3 GHz. This has been the case since the first generation of wireless technologies were introduced.

"The Wireless Industry has a limited amount of experience in the areas of real-world performance of mmWave-wave wireless systems and this necessitates over-the-air experiments and trials," says Dr. Nikhil Adnani - CTO - ThinkRF. "Legacy field test equipment only operates up to 3 or 6 GHz. At the very least such equipment needs to be frequency extended to address the mm-wave bands – 40 GHz being the most necessary. For deeper testing of 5G demodulation, the bandwidth of such equipment needs to be extended to 100 MHz."



In the context of field testing 5G solutions, testing can involve both static beamforming and dynamic beamforming. Static beamforming uses multiple beams produced by one antenna array, and the UE moves from one narrow beam to another. Dynamic beamforming operates though the coordination of both transmit and receive antennas beam following the user's changes in physical location and in orientation of the UE.

"Dynamic beamforming requires test equipment manufacturers to re-examine how testing is done," says Ramdas. "That makes it the more costly of the two test options, especially dynamic beamforming might require a more distributed test probes (possibly built into the UEs) where test data from the probes are aggregated to analyze 5G system performance."

"While the low and mid-band spectrum (3-7.125 GHz) propagation characteristics for cellular are well known, mmWave is a whole new beast," adds Adam Hostetter, SAF North America. "For carriers to deliver on, and monetize the promised data rates of 5G, extensive testing of the signal quality of mmWave deployments will be essential."

That's because, according to Hostetter, early in the 5G development cycle, the established T&M players developed sophisticated OTA test solutions for highly controlled environments, such as anechoic chambers. While there will undoubtedly be a need to perform throughput and QoS testing, characterizing and optimizing the physical layer will be prioritized. As a result, low-cost, ultra-compact, and easy to use solutions for field teams performing these measurements will be needed.

"As 5G is rolled out at mmWave, SAF believes there will be significant demand for an extensive walk and drive testing in the real world," explains Hostetter.

Discussion Panel Expert: Keysight

Keysight Technologies is a leading provider of RF test and measurement equipment. From parametric test of semiconductor wafers to functional and production test of PCBs to the final test of computer systems, Keysight products help engineers achieve the best performance possible. Keysight can also help designers of high-speed digital devices achieve cutting-edge performance while verifying compliance and interoperability with industry standards.

KEYSIGHT TECHNOLOGIES

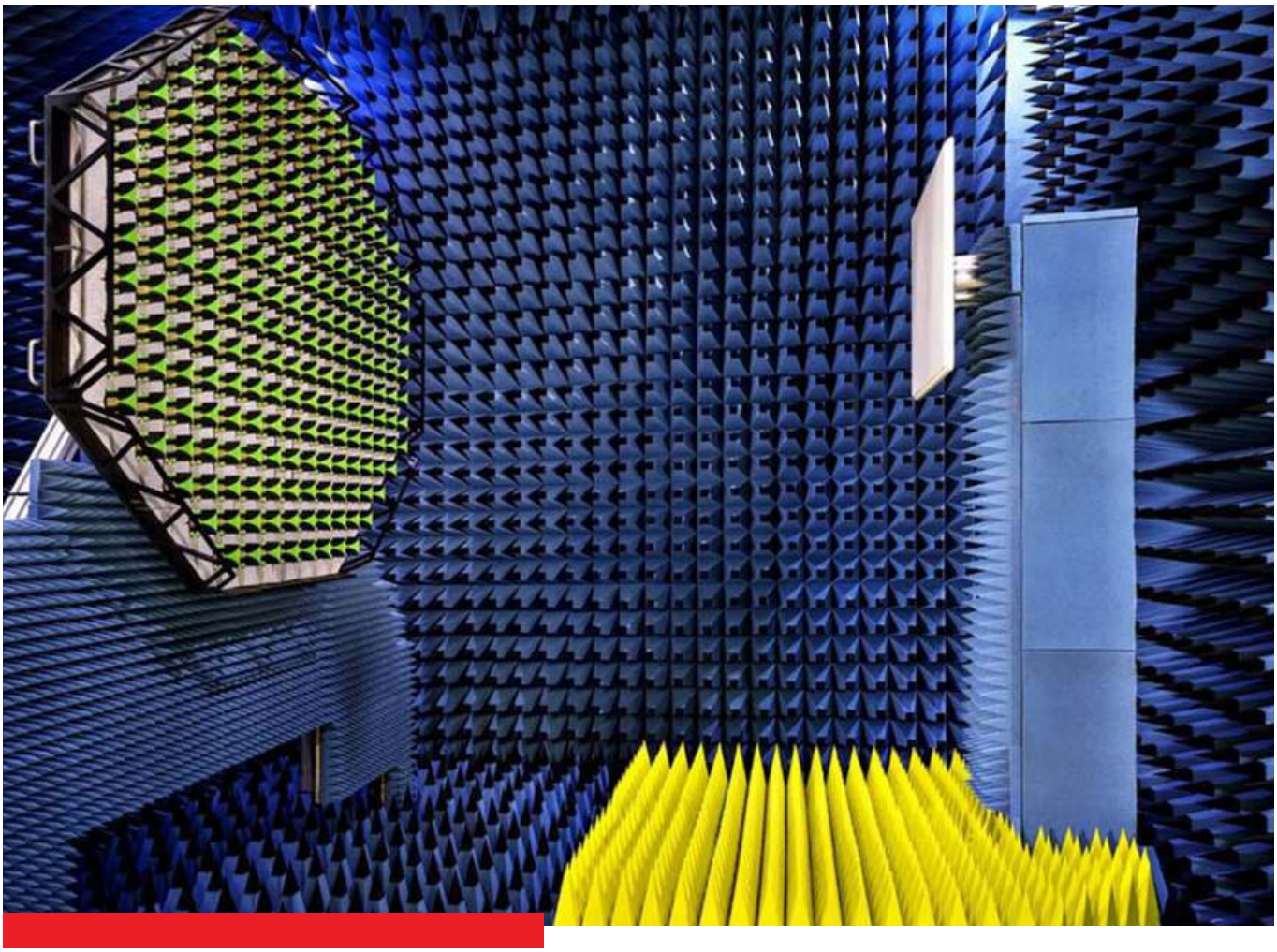
What technology developments are needed for testing millimetre-wave 5G?

The test solutions available for wireless development and deployment workflow are designed to take into account many of the testing challenges that must be overcome. That is why many test solutions include component modeling and design, circuit modeling and design, mmWave circuit, and system testing for both UE's and base stations, as well as mmWave measurements once systems are deployed in the field. Of course, the constant change in testing protocols triggered by new products, standards, and test cases are developed can be challenging, especially when those changes occur monthly rather than quarterly or annually.

As Nichols elaborates, Devices (UE's) and Base Stations have added new challenges, including some of the following examples:

Antenna technologies: most mmWave antennas require gain (and thus directivity) and be electrically steerable. Hence measurements need to be made on these systems which include measuring the semiconductors that make up these active antennas and also making antenna performance measurements in OTA situations. Most of this is done in anechoic chambers and the challenges include making accurate measurements with reduced dynamic range, spherical measurements with multi-dimensional positioners, and ensuring everything is calibrated and well-understood by customers.

UE tests: the FR2 test cases mean that everything is done in an anechoic chamber—these can be protocol and functional tests, they can be parametric tests, and they can be a combination of the two (Radio Resource Management for example). The challenges abound but mostly are related to accuracy, repeatability, dynamic range, and test time. Spherical/3D performance of these systems is crucial, and these measurements are complex and take a long time. The commercial communications industry is not used to these challenges and it is up to us to simplify the process, make it economical, and ensure that the results are indicative of actual performance in a live system.



We have spent significant engineering time on these measurements and include:

• Development of complex mathematics and control software for device manipulation to ensure spherical performance is measured

• Development of improved probe antenna systems for accuracy, speed, etc.

• Development of high-speed techniques for the sake of manufacturing test

When it comes to In-field Network testing, millimeter wave presents unique challenges compared to conventional workflow embedded with RF engineering teams. Steerable phased-array antennas are prevalent in the state of the art. For in-system field testing, there are different approaches to the antennas we use on our measurement equipment. An omni antenna may work for CW path loss model tuning in a controlled environment because it measures all energy from all directions. But power levels are such that these antennas are not very practical for mmwave. A fixed horn antenna is a popular choice because they cover reasonable frequency ranges and are easy to use and inexpensive. For example, a WR28 gain horn antenna covering 26 to 40 GHz is suitable for most of 5G mmWave frequency bands. It also has a narrower beamwidth, not precisely like a mobile device, but the designer could interpolate the data to match with any device measurement. The drawback, according to Nichols, is that the designer must manually align antenna direction for each measurement sample and perform a complex walkaround test. This type of analysis is not possible for any drive-test or automated test processes.

"The preferred solution is to use a phased array antenna with the FieldFox spectrum analyzer or channel scanner mode," concludes Zhang. "If connected with a transmitter or signal generator, it can emulate gNB beams to provide precise and realistic operation scenarios. This phased array antenna is very powerful tool and versions exist for the different FR2 bands."

"For customers seeking a complete millimetre-wave 5G testing solution, end-to-end performance guarantees and support are important," adds Schweiger. "Because mmWave testing is much tougher than sub 6 GHz testing, and the need to provide the entire solution including chambers, test equipment, calibration routines and application engineers backed by experts ratified by 3GPP standards should be a priority."

Discussion Panel Expert: ThinkRF

ThinkRF is the leader in software-defined spectrum analyzers that monitor, detect and analyze complex waveforms in today's rapidly evolving wireless landscape. Built on patented technology and quality by design principles, the ThinkRF solution offers greater versatility, better performance and additional capabilities for 5G, signals intelligence (SIGINT), spectrum monitoring, technical surveillance countermeasures (TSCM) and test and measurement applications.

thinkRF
monitor. detect. analyze

Why do mmWave channel measurement campaigns continue to be a focus for the entire industry?

The channel measurement work for the favored NR bands started about eight years ago in academia and in commercial research teams in the wireless industry. The measurements include an assessment of many parameters: Path Loss, Power Delay Profiles, number of reflected paths to be expected depending upon environment, Line-of-Sight and Non-Line-of-Sight (reflected) characteristics, Polarization Impact, and Scattering and Diffraction. For a full understanding of the channel, these measurements have to be made in multiple types of channels, both indoor and outdoor. Various environments (urban, rural, roads, trains, stadium, office, etc.) have to be considered under both static and dynamic conditions.

"The measurement campaigns take several weeks to plan multiple weeks to execute and months of post-processing to analyze the results and build channel models," explains Nichols. "They also require a variety of test approaches, all of which are complex, expensive, and generate large resulting data-sets. The industry is still learning how to make all of these measurements and refine our initial models to reflect what happens in the real world."

One of the promises of 5G technology is fast download speeds. Using mmWave frequencies provides the bandwidth needed to deliver that promise. But mmWave measurements are new to the commercial wireless handset ecosystem from chipset providers all the way to service providers and they require Over the Air Measurements which is also new in this ecosystem's labs.

"The ecosystem is eager for good partners with experience with these measurements," advises Schweiger.

"The Wireless Industry has very limited experience in how mm-wave communication systems that are to deliver large amounts of data will perform in the real world," cautions Dr. Adnani. "How will they perform with the added complexity of mobility and under a variety of propagation conditions in an urban landscape? To answer these questions, channel measurement campaigns are a necessity."

How is Massive MIMO technology being considered as one of technologies for inclusion in the 5G specifications?

At its most basic, Massive MIMO involves increasing the number of base station antennas, and associated independent transceiver chains for each antenna element, to provide improved coverage (spatial diversity) and capacity (reuse time/frequency resource blocks in the same cell). One big benefit of Massive MIMO is to resolve the large difference in link-budget demand between uplink and downlink in the mid-band frequency ranges. Because of practicalities of antenna design and radio systems, the uplink budget is required to be from 15-19dB more demanding than that of the downlink.

According to Nichols, one way to address a large part of this discrepancy is with massive MIMO. Most entities implementing systems in these bands expect to use this technology (or are already doing so) to ensure appropriate uplink performance.

"There is early research for massive MIMO at FR2 in only one universities of which I am aware, so that technology will take time to mature," says Nichols. "For FR1, however, Massive MIMO is seen as a necessary technology especially for the increasing demands of capacity and for link-budget management in the mid-band spectrum (2.5 - 4.9 GHz)."

While massive MIMO does not have to be unique to 5G, the large arrays of antennas combined with formable signal processing, allows better beamforming, spatial reuse of spectrum, and multiple streams—all of which are required to realize the 5G vision.

The result, according to Schweiger, is "higher data rates, more efficient spectrum use, and higher subscriber density. All things 5G is also trying to achieve."

Discussion Panel Expert: TelecomTRAIN

Telecomtrain are national leaders in providing hands-on training courses to help your technical and business employees succeed in implementing communication systems. They design a custom learning solution that revolve around your requirements, or you can select from their pre-designed courses.

Telecomtrain's training delivers a strong practical approach using the latest industry equipment.

TelecomTRAIN
5G ready

F-OFDM vs. FBMC ? Which one is a better match in 5G frequency range and why?

"F-OFDM and FBMC are only two examples of many alternate modulation approaches for 5G that were proposed in early 5G applied research. The intent of most of these is to reduce the out-of-band spectral "splatter" of OFDM-type modulations to either insert other modulations inside of an OFDM channel, or to reduce the guard-bands required between adjacent channels. To date, none of these have been adopted by 3GPP for NR.

The primary reason is that while these approaches yield excellent performance gains in simulation, those gains are neutralized in practical applications. The primary drivers are the state of the art of phase noise in transmitter local oscillators and non-linearities in real-world power amplifiers," explains Nichols.

"The combination of these two non-ideal facets render all of these novel ideas to be equivalent of OFDM given today's semiconductor and radio system technology," adds Zhang.

"OFDM will continue to be used with 5G networks with more flexible subcarrier spacings to take advantage of bandwidths and frequencies," adds Schweiger.

How will new use cases for 5G, like autonomous driving and IoT, affect how we test mobile networks?

As we look forward to additional 5G use cases, such as autonomous driving, critical infrastructure, and even applications such as remote surgery, fail-proof networks are going to be essential. Currently, if downloading via a 5G networks takes longer than the promised length of time – 30 seconds vs. 10 seconds, for example – most consumers may not notice the difference, but as use-case demands increase, speed will become a priority.

"In these future use cases, such as autonomous driving and critical infrastructure, fast, reliable, ultra-low latency communication is going to be a matter of life and death," says Hostetter. "While these applications are likely 5-10 years away, we believe there will be a requirement for extensive physical layer testing to ensure the RF coverage is solid."

"In addition, throughput and QoS testing at the network and cell edge are going to be critical to ensure 99.999% or better reliability for these critical networks. Lastly, the test routines will need to be continuous and proactive," adds Hostetter.

Schweiger agrees. "Different applications will need different frequencies (IOT mostly the lowest, Autonomous driving will likely be sub 6 GHz using C-V2x) requiring test equipment at different frequency ranges," he says. "Different applications also have different key performance indicators (KPI's). IoT sensors working ten years off a button cell will need to test battery drain and signal to noise ratio, where remote control will want to test latency and packet error rates (reliability) requiring different test cases and equipment."

Business and governments that use mobile wireless for services in which safety, finances, and fundamental business continuity are at stake will pushing demands of a different sort. Mission-critical use of wireless will prioritize performance related to reliability, latency, and security. As a result, businesses selling mission-critical services will be required to verify their performance in ways that are not fully specified and standardized today (e.g. there are multiple definitions for latency, reliability, and security and not significant standards set—especially for end-to-end performance).

"The change of mobile wireless to be used for industries beyond typical smartphone access will have a significant long-term impact on how we test networks," adds Nichols. "While the demands of today's users are significant and testing and optimizing are a large part of what we work on, the approach to new industries will change this picture."

How will crowdsourcing play a role in testing 5G networks?

It remains to be seen how crowdsourcing will impact testing of 5G networks. Peter Schweiger points to test automation platforms like OpenTap as one avenue that could be explored.

"Companies and individuals can contribute test code based on Standard Commands for programmable instruments (SCPI) in an open, scalable platform and build a library for useful 5G device tests," Schweiger says.

Roger Nichols believes crowdsourcing of information about the network has the advantage of reducing the need for implementing dedicated monitoring transducers and routing their data to the proper analytics engines, but he sees some limitations

"Crowdsourcing information provides only information from 'where the crowds are' and is limited to what the devices and base stations can derive from their normal functionality," he explains, "Such information also has to be 1) tested for validity and reliability; 2) protected from a privacy and security standpoint; 3) efficiently processed by analytics and perhaps even AI engines in the network."

"All of these latter steps are far more complex and expensive than the industry hype would suggest. But we do see this as one necessary part of understanding and optimizing system performance—much like the crowdsourced information of today's most popular mapping systems. It will take dedicated development and computing resources to be put to use for the overall improvement of the networks," he concludes.

Discussion Panel Expert: SAF Tehnika

SAF Tehnika is a designer, producer and distributor of digital Microwave Data transmission equipment. SAF Tehnika products provide wireless backhaul solutions for digital voice and data transmission to mobile and fixed network operators, data service providers, governments and private companies. SAF sells microwave point-to-point radios for licensed and license free frequency bands as well as unique spectrum analyzer Spectrum Compact. SAF Tehnika also provides customized microwave solutions for various applications, such as Broadcasting and Low latency networks.

Who is the governing body for 5G standards globally? Are the variations in the standard in Canada versus other countries/regions such as the USA or Europe?

The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations and provides a stable environment to produce the Reports and Specifications that define 3GPP technologies. Created to establish 3G networks initially, they have successfully continued their work to help provide 5G standards being used today.

In Canada the ministry for Innovation Science and Economic Development (ISED) controls and governs the use of the electromagnetic spectrum in Canada.

As Nichols explains, "5G NR is the first mobile wireless standard that has no concurrent competitor from a similar industry consortium, so it is considered global and universal."

"There are not variations in the standard between countries and regions," he says. "The variations that do drive differences in behavior are driven by national policy differences—most of these are how spectrum is governed, which varies by country despite international work to build some degree of harmonization."

It's clear that when it comes to 5G, business-as-usual is not applicable, and that's even more clear when it comes to testing. Because DUT integration will increase significantly, physical testing of equipment will become ever-more challenging, if not impossible. As a result, OTA testing will become essential.

Many 5G providers are already strategizing and preparing for this shift in testing protocols, and will be well-placed for a smooth transition to OTA testing.

Specifically Keysight Technologies, SAF Tehnika and ThinkRF have designed and brought to the market the following 5G testing solutions available at Gap Wireless.

Keysight FieldFox
SUPER 5G NR Next Generation Microwave Analyzers

Over-the-air (OTA) 5G NR measurements (Option 378) – Supported on N991xB/ N993xB models only.

Support for 5G NR FR1 and FR2 over-the-air measurements. The FieldFox B-Series N991xB/N993xB with 100 MHz of bandwidth are perfectly suited to capture and demodulate over-the-air transmissions of 5G NR FR1 and FR2 control channels. Provides key performance indicators including physical cell ID, received power levels and beam index information. Conducted EVM measurement is also included with Option 378.

SAF Spectrum Compact
The world's first handheld microwave spectrum analyzer

0.3 GHz – 3 GHz and 24 GHz – 40 GHz test and measurement solutions are a great fit for 5G network deployment. Thanks to its size, usability and sensitivity, the Spectrum Compact can be used for high precision detection of existing interference on installed paths or available radio channels in microwave, millimeter wave and other frequency ranges. Data logging of all spectrum scans is available with the Spectrum Compact device, and enhanced data processing and analysis are provided by SAF Tehnika PC software for your laptop.

ThinkRF D4000 5G 40 GHz Downconverter/Tuner
Small, powerful and cost-effective downconverter / tuner for the Next Generation RF Environment

Downconverters are one of the most economical and cost-effective methods for increasing the frequency performance of RF signal analysis systems. In the new world of 5G networks, a downconverter can reduce time to market and costs for mobile operators and system integrators.

The ThinkRF series of RF downconverters / tuners are designed for maximum performance and interoperability. The D4000 RF Downconverter / Tuner enables translation of RF signals in the frequency range of 24-40 GHz with up to 500 MHz of real-time bandwidth (RTBW), to capture mm-wave 5G signals.

5G Coverage

5G operators are facing two significant optimization challenges: bandwidth and propagation.

5G Coverage

5G operators are facing two significant optimization challenges: bandwidth and propagation. If these challenges are looked at separately, the preferences for 5G frequencies can vary. Additionally, while 5G is an evolution of the cellular technology from 4G, 3.5 GHz is a new and additional frequency band upon which the 5G systems can operate.

To gain a clearer picture of 5G Network coverage and the importance of MIMO (Multiple-Input and Multiple-Output) and the 3.5 GHz frequency, we reached out to a panel of experts. Our respondents provided us with in-depth and insightful information on how frequencies and frameworks will impact 5G propagation and bandwidth, and what solutions and new strategies are emerging.

Our 5G Coverage panel includes:
Chuck Powell, Product Director for Base Station Antennas, North America at Radio Frequency Systems (RFS), Amr Elgazzar, CEO of Consultix, Greg Dial, Senior Vice President for Product and Marketing Strategy at JMA Wireless, and Roger Nichols, 5G Program Manager at Keysight Technologies.

PANEL DISCUSSION

How do new 5G bands differ from traditional bands in terms of propagation?

It is well known that 5G and frequency bands are independent. That means that for 5G providers, the first priority is providing enough dedicated bandwidth to achieve optimal speeds for as many users as possible. One solution is to use large blocks of millimeter wave spectrum, which is ideal for supporting huge bandwidths and fast data-streams. Of course, choosing this option comes at the expense of propagation because millimeter-wave networks will likely be set up with a typical cell size of 200m.

As Chuck Powell, Product Director for Base Stations Antennas North American at RFS explains, "In dense urban environments it is feasible to have enough users in a 200m cell to justify the number of antennas necessary to provide consistent coverage across the city, but the usefulness of millimeter waves drops as the population density falls."

Another challenge involves rural areas, although they don't have as many users. As Powell points out, the lower frequencies, like 600 MHz, have a cell radius of 20 miles to but not enough bandwidth to support many users at high data rates.

"600 MHz ideal for coverage in rural areas," he says, "but a middle option is still needed for capacity outside of highly populated cities."

The solution? A mid-band frequency can balance the two priorities by having sufficient bandwidth for multiple users while still having a reasonably large cell size to keep deployments costs economically viable. "The other advantage of the mid-band is that it is greenfield-spectrum. New to cellular and thus does not require operators to refarm existing 4G spectrum to get a 5G system up and running," adds Roger Nichols.

Greg Dial, Senior Vice President Product Marketing at JMA Wireless, adds that some of the newly available bands available for 5G already offer unique bandwidth sizes and propagation characteristics not seen in the bands available during the 4G LTE evolution over the past decade. Additionally, these new bands provide better penetration in most FR1 frequencies and pass through objects such as foliage, while FR2 frequencies tend to be more affected by these materials which can make coverage prediction more difficult.

"Bands are categorized into two segments, FR1 at lower than 6 GHz and FR2, which covers today's mmWave frequencies," he explains. "Low frequencies at high power can coverage multiple miles and penetrate structures very well. The higher those frequencies go, the less that travel and the less they penetrate. The flipside is of course that they carry much more bandwidth in the process. We generally think of mid band as less than one mile and mmWaves in terms of 100s of feet." Mid band options are ideal for centralized areas that might be a little more spread out but need significant capacity. They are also ideal for supporting indoor capacity.

"Ultimately networks will entirely migrate from 4G to 5G in all available frequency bands and will use tools like dynamic spectrum sharing, or DSS, as ways to bridge the migration," he concludes.

Discussion Panel Expert: JMA Wireless

JMA Wireless is a global leader in mobile wireless connectivity solutions including outdoor and indoor distributed antenna systems. Wireless solutions from JMA Wireless ensure reliable infrastructure that maximizes wireless performance and streamlines service operations. With a broad portfolio of powerful and patented innovations, JMA Wireless solutions are proven to lower operation cost and ensure unparalleled performance and quality for coverage and high-speed mobile data.

Why is 3.5 GHz a core candidate for 5G?

While 5G is an evolution of the cellular technology standard that offers some critical additional features over 4G, 3.5 GHz is newly added for 5G and is common across many countries. Additionally, frequencies can vary from country to country, depending on regional restrictions. As stated above, within this challenging landscape, 5G network providers are looking for a balance between capacity and coverage. For Powell, 3.5 GHz is one frequency that can be described as a Goldilocks solution because it has "just right, the balance between capacity and coverage."

For Amr Elgazzar, CEO of Consultix, another reason 3.5 GHz is a core-candidate is reasonable propagation. "The reasonable propagation characteristics of 2.5 GHz implies reliable coverage," he says. "This capability is important to provide connectivity for IoT devices and critical communications (that require 99.999% reliability) and applications such as remote control, automotive or smart manufacturing."

Other benefits of 3.5 GHz, according to Elgazzar, are higher band capacity and excellent penetration characteristics.

"The band capacity can be considerably higher than those of low GHz bands as it allows using massive MIMO antennas at a practical size," he says. "While the fairly good penetration characteristics of this band in buildings make it excellent for broadband communication for both worlds, 4G and 5G."

"Network deployment can be considerably fast due to its propagation characteristics which open the door to reuse the installed base of macro sites that serve sub-3 GHz bands," he concludes.

"Frequencies will ultimately be selected for various 5G applications based on availability, bandwidth size, and propagation characteristics," says Dial. " The 3.5 GHz spectrum's relatively wide continuous bandwidth, mid-range propagation distance, and reasonable building penetration make it a good candidate for 5G urban and sub-urban small cell type applications that require high speed, high throughput, high density, and low latency."

"3.5 GHz is the frequency closest to the majority of recent "mid-band" allocations for mobile wireless around the world," adds Roger Nichols,5G Program Manager, Keysight Technologies. "This band has enough harmonization in major countries around the world to allow for the economy of scale for radio technology investment."

"While this is not the only new band set aside for 5G, it is one of the most pervasive worldwide—being common to many large modern nations," he says. "The addition of NR (New Radio) services to existing LTE bands comes with many challenges that impact spectral efficiency and thus the capacity for the mobile network operators. Given the value of these bands and their LTE-based revenues, transitions are challenging, and opening new 5G services in a spectrum that is unencumbered with legacy technology means an opportunity for a more graceful transition."

Discussion Panel Expert: Keysight

Keysight Technologies is a leading provider of RF test and measurement equipment. From parametric test of semiconductor wafers to functional and production test of PCBs to the final test of computer systems, Keysight products help engineers achieve the best performance possible. Keysight can also help designers of high-speed digital devices achieve cutting-edge performance while verifying compliance and interoperability with industry standards.

How is Massive MIMO different than current 2x2 or 4x4 MIMO, and why will it aid in 5G coverage?

Massive MIMO uses constructive and destructive interference in the channel and many more antennas at the base station to isolate user-specific radio signals to the physical location of the user. According to Nichols, because of propagation and physical antenna-design and transmitter-design constraints, the uplink performance (mobile-to-base station) at 3.5GHz is far worse than the downlink performance. This is a problem because many new use-models for 5G mean higher demand for data rates in uplink than in the downlink. As a result, massive MIMO was initially conceived as a way to improve capacity by allowing for spatial multiplexing—even to the extent of using the same time/frequency resource blocks for different users in the same cell.

"Massive MIMO is seen as being essential not just for better spectral efficiency, but also to making 3.5 GHz systems work in practical production networks," says Nichols.

Dial agrees, saying, "Massive MIMO improves spectral efficiency and provides a significant capacity benefit over 2X2 or 4X4 MIMO, not a coverage benefit."

"While massive MIMO is technically possible at all frequencies, the antenna array size required at lower frequency bands makes deployment of this technology impractical in the lower spectrum of a portion of FR1," he continues. "Generally, as we increase to higher-order MIMO, we get many times more throughput than a 2X2 or 4X4 MIMO system."

"Experimental results showed more than 10 dB difference in overall losses between 3.5 GHz and 1.8 GHz," says Elgazzar. "This difference is almost equally caused by penetration loss & propagation losses, which is even worse in buildings equipped with a thermally-efficient glass window.

"Due to high propagation losses, mmwave bands are candidates for LOS scenarios & confined hotspots while 3.5 GHz is prime for dense urban coverage," he concludes.

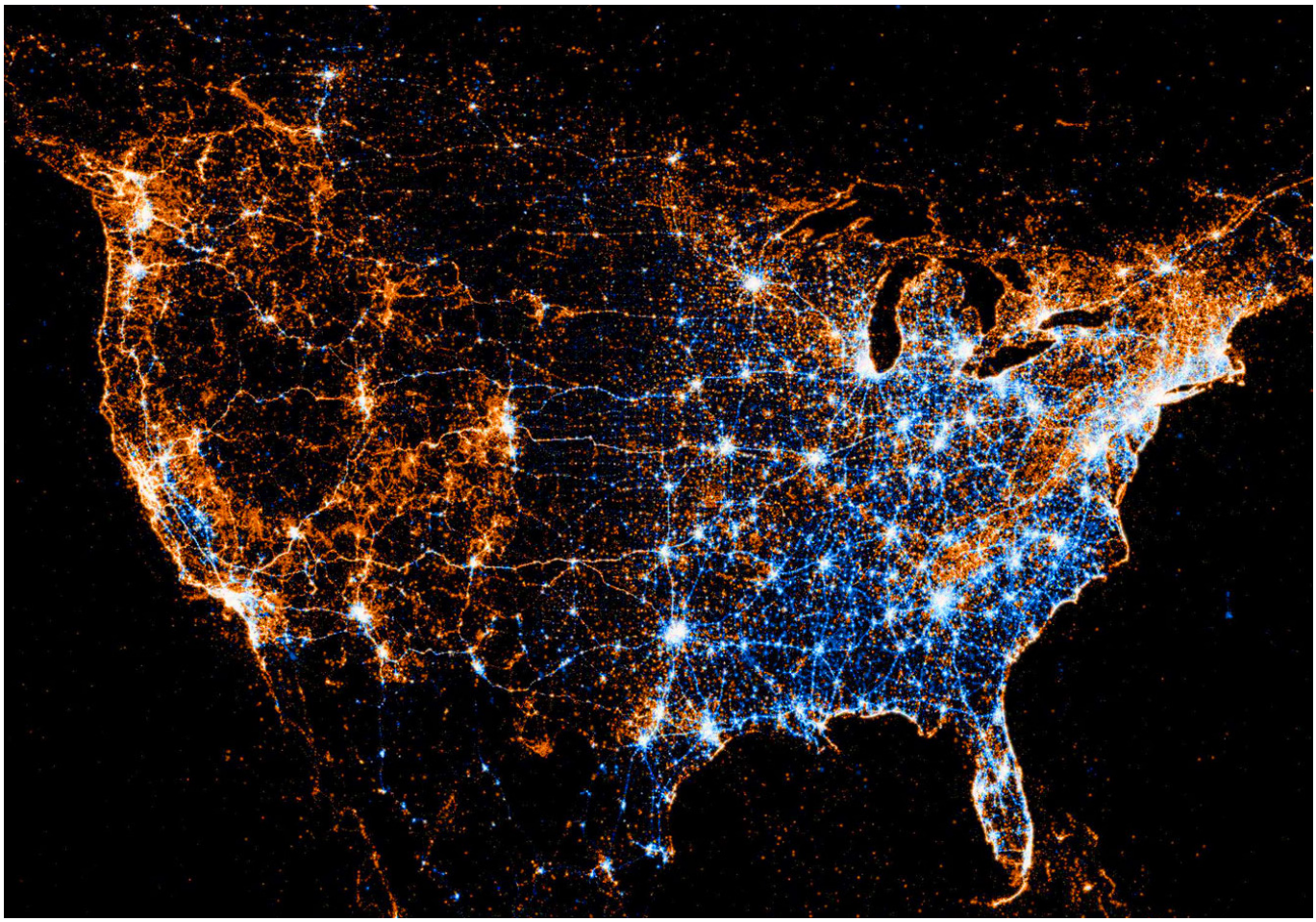
Nichols delves deeper into the practicalities of 2X2 and 4X4 multi-User MIMO systems, noting the opportunities provided by "taking advantage of multiple radio paths between transmit and receive (the simplest examples being two paths: a direct path and a reflected path)."

"MIMO systems determine that the channel has two (or more) uncorrelated signal paths through channel-state determination (deterministic signals transmitted, and channel-impact analyzed at the other end)," he says. "They then precode the data transmissions to multiple independent antennas such that they arrive at independent antennas at the receiver in two independent data-streams—thus increasing the effective number of channels for communication."

According to Powell, Self-Optimizing Networks have been used where the system responds to various KPI's on a more regular basis to change the tilt, but the tilt would be the same for every frequency. Nevertheless, as Powell explains, 2x2 or 4x4 MIMO scenarios were limited to typical base station antennas that could not steer their beams in the azimuth plane. "Normally, the azimuth beamwidth was 65°, with some sites having a narrower 32 or 45° beamwidth," he says. "The elevation pattern was capable of some optimization using Remote Electrical Tilt, but that optimization often only happened during the initial site installation."

"Massive MIMO takes advantage of the multiple radio-to-antenna connections to allow dynamic beamforming in both the azimuth and elevation plane for each user. That means whether the user is close to the tower or at the cell edge, to the left or to the right, the antenna will be able to direct a narrow 12° beam right at the user. Combined with the ability to steer a null at any interferers, this creates a C/I ratio capable of supporting 5G speeds for many users simultaneously."

"This has the potential of decreasing the amount of total RF transmission power for a given number of users," says Nichols. "By getting higher spectral efficiency by using the same time/frequency resource blocks for different users in the same cell—this latter is possible because a resource block effectively becomes time-frequency-space."



Why do we hear 5G will require more transmitter sites?

When talking about transmitter sites, it is essential to first understand that "transmitter sites" include base stations, receivers, and transceivers. As Powell explains, the number of transmitter sites used is primarily applicable to dense urban areas where millimeter-wave antennas are used.

Nichols also adds that generally speaking, new FR1 bands are higher than the traditional cellular applications typically below 2.6 GHz and that Radio propagation loss is higher at these frequencies. Therefore, "ensuring appropriate link-budgets with these bands means smaller cells (shorter distance over which the signal travels), far more acute in the FR2 space, for FR2, where even for fixed wireless systems, we cannot expect cells to be larger than perhaps a 300-meter radius. Hence, more cells will be needed," he concludes.

"The propagation losses will require smaller cells and thus many more cell-sites. And the capacity advantage by adding these sites will benefit the areas with higher population density." he says. "Regardless of whether the area is supported by 600 MHz or up to 3.5 GHz, the number of cell sites is likely to increase."

Dial adds that new hardware needs to be deployed anytime new frequency bands are used. "The newer bands that become available tend to be higher in frequency than those currently deployed, he says, "and as a result, they don't propagate as far. Therefore, more sites need to be constructed to cover a given geography than were needed to deploy the current network at lower frequencies."

"Spectral efficiency is critical in mobile communications," says Nichols, who explains that spectral efficiency is measured in bits/second/Hz/square-meter, where "Hz" is the bandwidth available. So far, spectral efficiency improvements have been significant, based on technology investments in new radio waveforms, modulation, and encoding techniques in addition to new MIMO technologies.

"But improvements in spectral efficiency driven by making the cell-size smaller are thousands if not tens of thousands of times larger than improvements made using any other technique," declares Nichols. "This has been the case ever since radio communication was invented."

"Decreasing the cell-size allows for more frequency reuse, but also means more base stations," he adds.

"To realize the vision of 5G, more cell-sites, in most cases, much smaller and lower-power is necessary."

Will I be able to use a booster/repeater to increase 5G coverage in my home or office?

According to Powell, in areas supported by millimeter-wave 5G radios, a booster will be needed since, "the frequencies are too high for sufficient in-building penetration."

"This makes in-building solutions more important than ever before," he says. "A 5G transmitter will send a very clean signal to the booster's external antenna, which is then passed through the building's wall via cable, before being amplified and re-transmitted inside.

Elgazzar adds that repeaters will be used in some use cases at 5G "only for very small office/shop."

"Repeaters can counteract the problems associated with in-building penetration specifically in FR2, he says, "but this is an outdoor to indoor view of the market. For 5G and densification, an in-building / high-density strategy is required to support both ultrawideband throughput and low latency use cases."

Nichols agrees about the importance of taking indoor-to-outdoor performance in cellular systems into account. "This has been a technological challenge ever since 1G," he explains. "Many different approaches have been implemented including boosters, distributed antenna systems, 3-dimensional MIMO schemes, and even small-cells mounted indoors (or in multi-story car parks, or stadiums, etc.)."

"The trend for this will continue since the same physics apply in getting signals to and from where they need to be," Nichols concludes. "The FR2 situation is more acute with propagation through walls and windows and around corners being far less reliable than the traditional cellular and WiFi bands."

"To maximize the performance of FR2 systems, we can expect to see FR2 relays and boosters on the market. Some early versions of these are already getting lots of attention on the technical speaking circuits in 5G."

Discussion Panel Expert: Consultix

Consultix has the most comprehensive portfolio in the industry for IBS / DAS testing and design tools. Consultix unique solutions cover the entire IBS/DAS project life cycle end to end; From design and verification, installation testing & commissioning all the way to long-term maintenance, optimization and monitoring solutions.

Consultix is the market and technology leader in the fast-growing IBS/DAS Testing field.

What type of venue will most benefit from 5G coverage?

Dial predicts "in-building venues will need extremely high throughput, low latency networks to support applications like virtual reality and machine learning. But there will be other applications that haven't been thought of yet, enabled by the new feature-set of 5G. While for Chuck Powell, the ideal 5G venue would be "a line-sight-environment with an extremely high level of user density."

"This would allow the high-capacity millimeter-wave antennas to be used without any of the normal limitations caused by their smaller propagation range," says, pointing to football stadiums and parking lots as some good examples.

"These are the types of venues that already benefit from highly specialized multi-beam antennas such as Luneburg Lenses," he explains. "The 5G Massive MIMO arrays will replace the Luneburg Lens with the capability to steer more beams in many more different directions."

How are coverage patterns changing for 5G vs. previous technologies?

Previously, the "middle ground for the middle frequency" involved 8T8R technology widely deployed in the 2.5 GHz band in North America and other parts of Asia. As Powell explains, the 8T8R beamformers allowed for azimuth steering for each user, but the elevation tilt was controlled by a mechanical phase shifting mechanism that requires all frequencies to tilt to the same angle.

"This type of antenna may be better for the moderately dense areas that need for capacity than a typical x4 MIMO system," he says, "but it does not have enough users in the cell radius to justify a massive MIMO system."

Because 600 MHz 5G will continue to rely on 4x4 MIMO. That's because, according to Powell, the wavelengths needed for a massive MIMO version are "far too large to put on a tower. Their coverage pattern will not be very different from previous technologies."

"In dense urban areas, where millimeter waves are used, many people refer to the "tower" being taken out of the network," he continues. "They are correct, the 200m cell size does not necessitate a large tower," he says. "The antennas themselves are relatively small and will be closer to the ground to reduce propagation losses.

"The 3.5 GHz band will be an interesting mix between the two extremes," he says. "Some 3.5 GHz arrays will simply be embedded within traditional macro antennas to provide 4xMIMO, others will be massive MIMO, while yet others may choose a technology that lies between x4 MIMO and Massive MIMO."

Scavenger Keywords: are

What about 5G Coverage in tunnels?

As Tom Kuklo, Global Product Manager In-Building Solutions at RFS, explains, "When we look at delivering 5G in tunnel environments, operators face even greater signal penetration and signal density challenges if they are to achieve the download speeds needed."

"Tunnels will require a MIMO distributed antenna to form the backbone of the infrastructure to deliver 5G signal," he continues. "There are several ways to approach this, but we have found that using vertically polarized and horizontally polarized cables offers the optimum way to deliver 5G in such a challenging environment."

"Because tunnel environments make for particularly tricky installations, those making product decisions need to think about how the equipment they invest in today will serve future coverage needs to avoid the need to rip and replace further down the line," he concludes.

"When selecting the radiating cable that will help create that backbone for 5G delivery, procurement officers should look to future-proof by selecting equipment with no stop bands. This gives maximum flexibility and allows today's infrastructure to meet tomorrow's requirements."

5G Coverage

The potential of 5G to expand the uses and capabilities of mobile technology is enormous, which is why it is so crucial that 5G spectrum plans consider bandwidth and propagation. Because 5G needs to operate across three spectrums – low, medium, and high – to deliver adequate coverage and support for all use cases, the mobile bands chosen need to take these demands into account. In general, the 3.5GHz spectrum is the true "Goldilocks" option because of it can suite both high-density urban environments and satisfy the macrocells needed for coverage in wider areas, including fixed wireless access. Because of its versatility and adaptability, many network providers believe 3.5GHz is the best option for most 5G networks.

RFS, JMA Wireless, Keysight Technologies, and Consultix all have several 5G solutions available at Gap Wireless.

RFS C-Band 5G Small Cell Antennas

Broadband panel and omnidirectional antennas that support spectrum from 694 MHz to 5.9 GHz including the soon to be available C-Band.

Broadband spectrum support. Simplifies antenna siting in neutral-host environments and reduces costs by enabling use by multiple operators.

CBRS and LAA spectrum capabilities. Enables smooth evolution to new technologies as they are deployed in network densification plans.

JMA Private Wireless

JMA provides the only 100% U.S. designed, developed, and manufactured 4G and 5G solutions on the market today. JMA's Private Wireless platform offers industrial grade capacity, including 150 MHz of CBRS in a single radio, as well as best in class software based flexibility, allowing customers to maximize utility on deployed private networks.

JMA's private wireless solution is powered by XRAN™, a 100% software-defined radio access network platform and CellHub radio system. All JMA systems are fully software upgradable and future ready without the limitations of hardware based systems.

Keysight FieldFox SUPER 5G NR Next Generation Microwave Analyzers

Over-the-air (OTA) 5G NR measurements (Option 378) – Supported on N991xB/ N993xB models only.

Support for 5G NR FR1 and FR2 over-the-air measurements. The FieldFox B-Series N991xB/N993xB with 100 MHz of bandwidth are perfectly suited to capture and demodulate over-the-air transmissions of 5G NR FR1 and FR2 control channels. Provides key performance indicators including physical cell ID, received power levels and beam index information. Conducted EVM measurement is also included with Option 37

Consultix 5G CW Transmitter

Consultix 5G CW Transmitter
Consultix 5G test transmitter is a portable RF signal generator that brings simplicity and affordability to mmWave test scenarios pertinent to 5G applications.

The fast growing 28 GHz band has generated a prominent demand for a handheld mmWave test transmitter to characterize its channels and calibrate its propagation models.

The ultra-compact size and RF performance of this 28 GHz CW transmitter makes it ideal for such field applications as well as several laboratory use cases.

5G & IoT

Within three years, the number of IoT devices worldwide will be somewhere in the region of 40 billion.

5G & IoT

It is predicted that within three years, the number of IoT devices worldwide will be somewhere in the region of 40 billion. Each of those devices will need a network to connect and communicate, and hopes are high that 5G will meet the challenge and expand the capabilities of IoT. With the addition of LoRa and SigFox networks, the breadth and reach of IoT will be significant, ranging from small, precise data readings to complex interactions between devices and the cloud.

To gain a clearer picture of how 5G Network coverage will impact IoT, we reached out to a panel of experts. Comprised of researchers, analysts, and advisors, our respondents provided us with in-depth and insightful information on how frequencies and frameworks will impact 5G propagation and bandwidth, and what solutions and new strategies are emerging.

Our 5G and IoT panel includes Nader Famili, MTS leader at Radio Frequency Systems (RFS), Scott Terry, VP of Engineering at SureCall, Dr. Nikhil Adnani, CTO at ThinkRF, Brad Jolly, Sr. Application Engineer, Barry Scott, IoT Program Manager, and Roger Nichols, 5G Program Manager from Keysight Technologies, and Dr. Esteve Hassan, Ph.D., PEng, Industrial Research Chair for IIOT Applications, Mohawk College.

PANEL DISCUSSION

What are the differences between the 5G IoT layer and the LoRa and Sigfox networks?

Along with enhanced mobile broadband and ultra-reliable low latency communication, massive connectivity has been one of the essential requirements for enabling technologies of 5G. While 5G IoT, LoRa, and Sigfox are often portrayed as competing technologies, the truth is that each plays an important role when it comes to IoT.

Ultimately, the difference is one of scale. While both LoRA and Sigfox are primarily based on unlicensed frequencies, which may limit their use to small and medium enterprises, 5G IoT is based on licensed frequencies and can be used wherever 5G coverage is available. Nevertheless, as Dr. Esteve Hassan, Ph.D., PEng, Industrial Research Chair for IIOT Applications, Mohawk College points out, "for IoT, low power consumption and wide area coverage for end devices (ED) are important figures of merit, which make LoRa and SigFox are dominant technologies."

Dr. Nikhil Adnani, CTO at ThinkRF adds another layer, explaining that because of its broader coverage capabilities, 5G IoT is "more suited for more ubiquitous applications, anytime, anywhere."

"The ecosystem for 5G IoT is considerably larger," Nader Famili, MTS leader at RFS explains. "In the longer term, that means a lot more frequent upgrades, cheaper devices, and ever-evolving technology and applications."

"Broadly speaking, the three technologies are appropriate for different application sizes," summarizes Brad Jolly, Sr. Application Engineer, Barry Scott, IoT Program Manager, and Roger Nichols, 5G Program Manager at Keysight.
LoRa also operates in unlicensed bands, with data rates from 300 bps to 50 kbps, allowing it to be used in applications where the data volumes are simply too much for Sigfox. LoRa is also supported by a prominent alliance comprised of some 500 members.

At 0G, Sigfox is the lightest network that Brad Jolly describes as "the polar opposite of 5g."

"It operates in unlicensed spectrum, has very low data rates between 100 and 600 bps, and has a long battery life in applications with small amounts of data, such as environmental sensors that measure something once or twice a day and sleep the rest of the time," Jolly adds.

Unlike Sigfox and LoRa, 3GPP standards for IoT were designed for primary operation in a licensed spectrum. The 3GPP IoT standards support higher data rates and a larger device-connection scale, with 1 Mbps for LTE Cat M1 and 250 kbps for NB-IoT (as of 2016). As a result, much denser applications are supported, as Keysight puts it, "tens of thousands of IoT devices per cell."

"The 5G standards, especially starting with 3GPP Rel-16, will take the next step in terms of capacity and flexibility," concludes Keysight. "(Enabling) large range of data-rates, much higher connection density and quantity, and compatibility with existing cellular infrastructure."

Discussion Panel Expert: RFS

RFS positions itself as the telecommunications partner of the transportation industry featuring field-proven innovations spanning in-tunnel, in-building, and outdoor wireless coverage solutions for the transportation market, including turnkey solutions for optimized communications. Radio Frequency Systems provides the most advanced active, passive and hybrid RF distribution systems for in-tunnel coverage, railway station coverage, and outdoor track-side rail coverage.

What does 5G mean for IoT?

IoT in the 5G system will be a game-changer in the future generation. It will open a door for new wireless architecture and smart services. Existing cellular networks, like LTE (4G), will not be sufficient and efficient to meet the demands of multiple device connectivity, which will require higher data rates, more bandwidth, low-latency quality of service (QoS), and low interference.

"To address these challenges, we consider 5G as the most promising technology," says Dr. Hassan. "In the context of wireless technology, fifth-generation (5G) technology has become the most challenging and interesting topic in wireless research."

5G is built around considerably higher throughput (x10), much shorter latency (<1 ms), and the use of a lot higher concentration of devices.

As Nader Famili explains, the high concertation of devices is, "specifically targeted toward IoT applications."

"A 5G gNodeB will be capable of maintaining connections with 100s of thousand devices and, as such, can accommodate any type of IoT application," he says.

5G will also allow for an expansion of IoT use-cases, including both the kinds of things for which SigFox or LoRA were designed (low data-rate, large-area, low power), as well as applications that require higher speeds (e.g., automotive and industrial), low latency, and very high reliability. 5G will also "increase the infrastructure footprint available for IoT applications, especially those requiring real-time handoffs for mobile devices," says Jolly. "The limiting factor is, however, that 5G IoT systems will be available only where 5G networks are deployed."

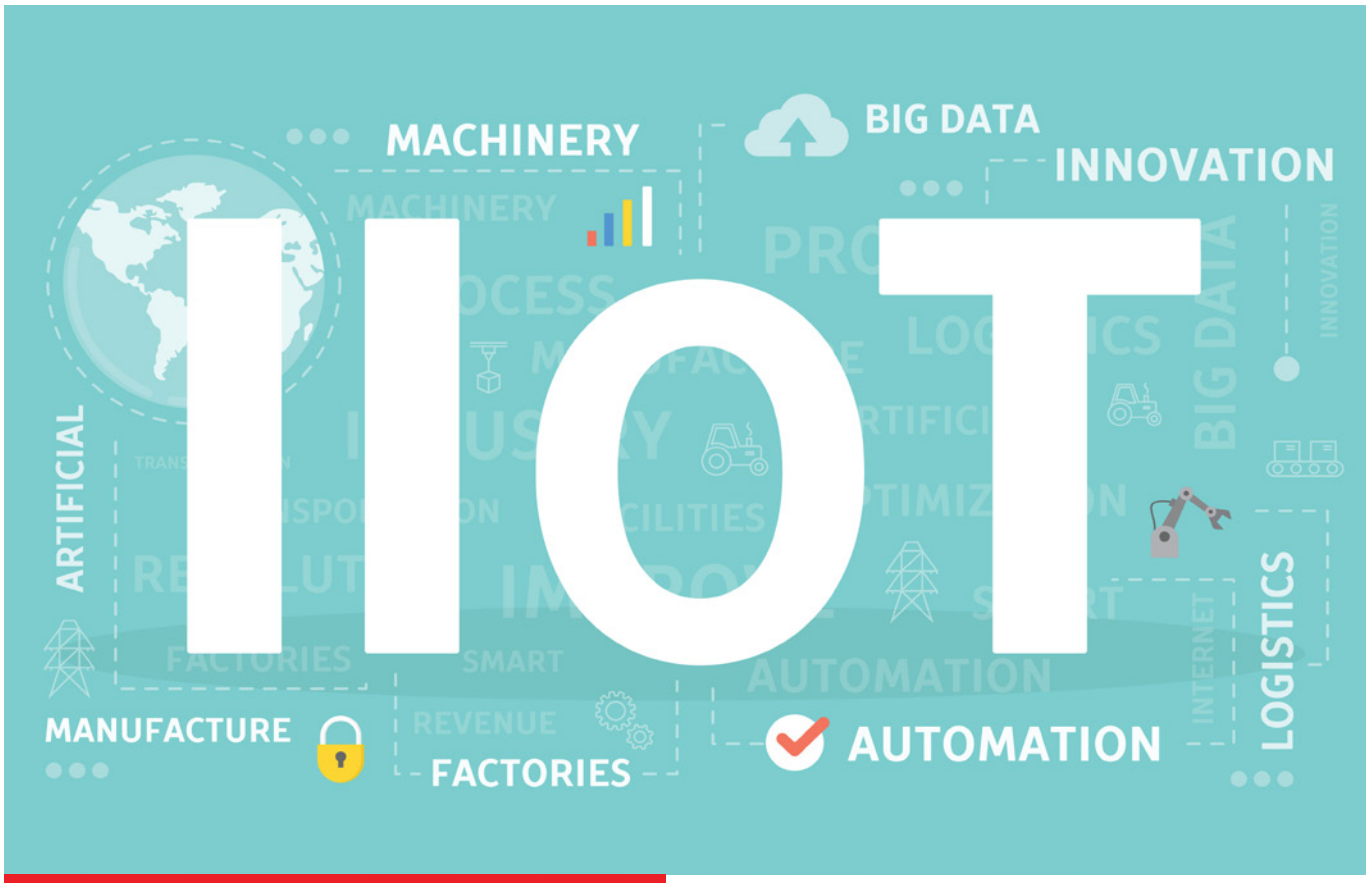
For Adnani, the key improvements and differentiators for 5G are low latency and faster throughput.

"Within the context of IoT, low latency is key to real-time processing required in smart factories, robotics, and automation," he says. "As data flows across network IoT sensors, for instance, 5G means higher throughput with the capacity to process data from a larger number of sensors than previously possible."

"Furthermore, low latency results in faster response times where required."

"When you combine this with the 5G technology, those devices can take advantage of what5G offers," adds Scott Terry, VP of Engineering at SureCall. "Where this will mostly be seen is in devices that can take advantage of very high speed and/or very low latency, which are the two main benefits of 5G."

"This will be very big for industries like factory automation, construction sites, and automotive transportation. But in the end, every industry will get benefits from what 5G does for IoT."



What is the Internet of Things (IoT), and how is it different from IIoT (Industrial Internet of Things)?

"When you think of "the Internet," you think of people exchanging information via social media, videos, web sites, e-mail, etc. The IoT is similar, except it is electronic devices exchanging information (on behalf of people). If all people suddenly disappeared, traffic on the traditional internet would quickly plummet, while the IoT would tick along as usual until batteries started to run out. IoT allows for the connection of "smart" objects to the internet. These smart objects are devices that receive, transmit, and possibly analyze data," says Brad Jolly.

"Industrial IoT is just that subset of the IoT used for industrial purposes, such as manufacturing and process control and industrial applications in areas such as automotive manufacturing and the Oil and Gas Industry. These objects could be sensors, home appliances, city furniture, or anything else for that matter. IIoT also has the characteristics of connectivity and intelligence. However, IIoT refers to applications used for industrial purposes such as manufacturing and transportation. The goals of an IIOT deployment broadly speaking are enhancements in productivity and reduction in cost.

The IIoT requires a lower latency than many other IoT segments, which is significant for activities like machine monitoring and control, where fractions of a second matter," says Dr. Adnani

"There are two other primary challenges in IIoT," says Jolly. "The first is a reliability requirement given that IIoT will likely involve some mission-critical functions for the industry in question. The second is that IIoT will have a majority of installations indoors where connection densities are high, and radio interference issues become more significant."

"Important considerations for IIOT are security, reliability, accuracy, and precision," adds Dr. Adnani. "IoT also includes wearables and other products for consumer applications where the impact of lower reliability or accuracy, for instance, isn't as high."

"Industrial Internet of Things (IIoT) plays an indispensable role in Industry 4.0, where people are committed to implementing a general, scalable, and secure IoT system to be adopted across various industries," concludes Dr. Hassan.

How will 5G latency be lower if the processing is being done in the cloud?

According to the team at Keysight, there are two major technical contributors to lower latency in 5G systems. The first is a redesign of the air-interface protocol, which allows for, among other things, connectionless data-exchange (data is sent without the complexities complex handshakes), and self-contained sub-frames which will enable for successful packet communication to be acknowledged in much less time. The second area is in establishing more computing in the network—on the "edge" so that information travels through much less of the network before being addressed by the application in question.

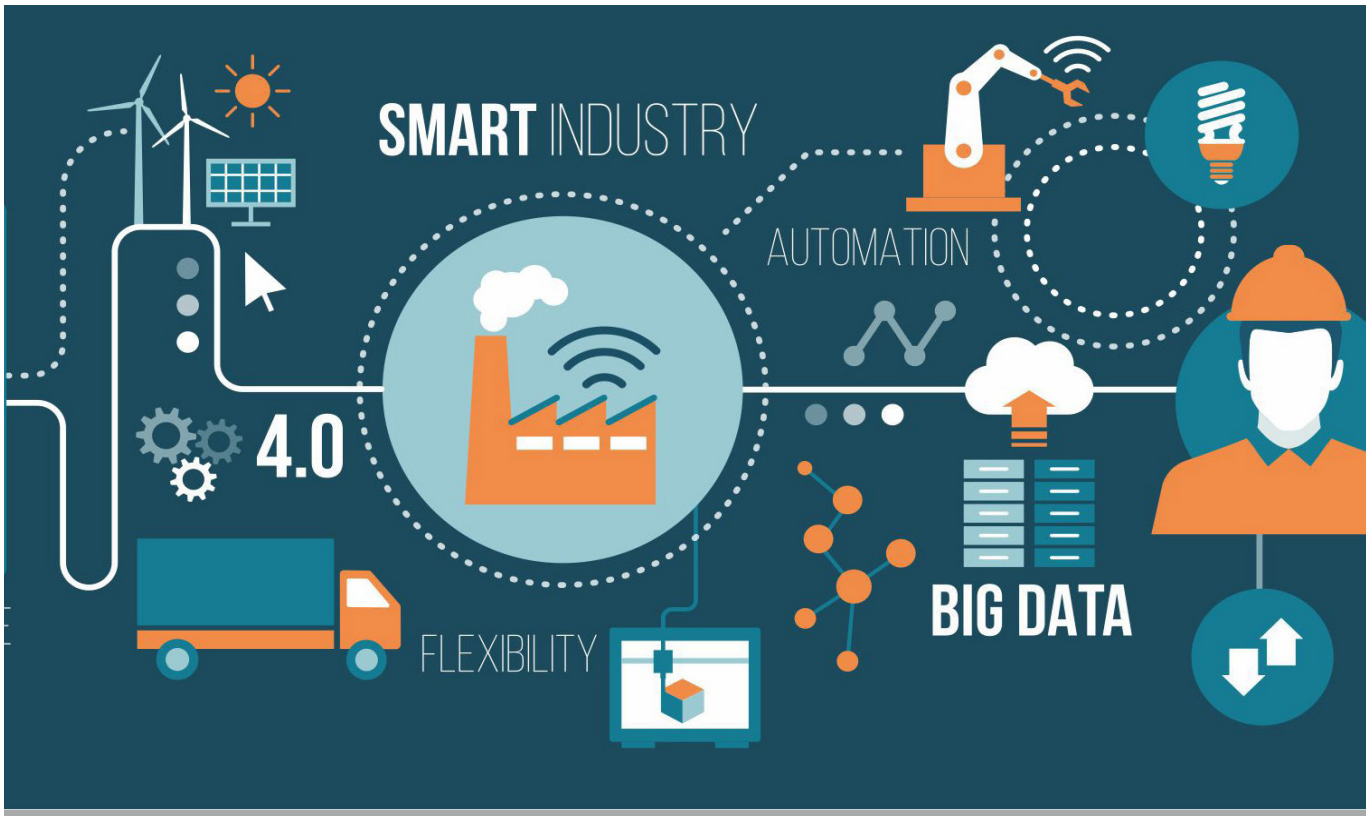
Part of the latency is core processing. Clearly, the core processing will have more delay if done in the cloud, which is why an important aspect of 5G is edge services.

"By using the concept of CUPS (control and user plane separation), 5G networks will try to process as much of the data at the edge (close to the user) and process the control data on the cloud," says Nader Famili. "This will reduce the latency for user plane data tremendously. In addition, other techniques in 5G air interface and IP flatness also contribute to the reduction of the latency."

"Not all processing will be done in the cloud," adds Jolly. "Some processing will take within single edge devices, some will be done in the "fog" of edge devices, and some data will be locally cached."

"Cloud computing is great for applications with huge amounts of data and processing power, but getting data to and from the cloud can be problematic," he adds. "The 5G networks will have large bandwidth to transfer data from towers to the cloud, but will also take full advantage of mobile-edge computing to process information quicker."

"Through adopting a hierarchical edge cloud-based traffic networking, low latency is expected to be much lowered in 5G," adds Hassan.



Will 5G technology have important implications for the logistics industry?

The logistics industry has long relied on wireless technology for tracking and delivery time estimation. Nader believes the expansion of 5G will allow for an expanded ability to track accounts with exact time and location.

"5G technology, given its low latency and high throughput capabilities, will also allow the logistics industry to develop much more sophisticated applications that suit their needs," he says. "The addition of drones relying on 5G for control and guidance, will also further expand logistics industry capabilities."

Terry disagrees. "It is erroneously thought that 5G will help the logistics industry due to more coverage of 5G signals; however, 4G will continue to have better coverage going forward for logistics services that use IoT devices for tracking," he says. "Where 5G can help is in certain logistics applications that can take advantage of the much higher data rates. This can be applications that benefit from high-resolution video to remote locations for providing assistance or navigation, or to logistics that can benefit from virtual reality (VR) or augmented reality (AR) to allow intelligent remote assistance."

"Low latency is a key one, especially for vehicle safety," adds Jolly. "The amount of data that can be shared is much greater, which opens up real-time video applications inside of vehicles and warehouses, (and) real-time tracking creates opportunities for optimizing vehicle routing, improves delivery estimation, and reduces the need for incoming inspection since the data trail is so much more complete."

"The on-going digital transformation is key to progress towards a new generation of more efficient, sustainable, and connected industrial systems," concludes Hassan. "This new generation, commonly referred to as industry 4.0, will be accompanied by a new wave of use cases that will allow companies from logistics and manufacturing sectors to increase flexibility, productivity, and usability in the industrial processes executed within their factory premises."

"Unlike typical use cases from other vertical sectors (e.g., energy, media, smart cities), industry 4.0 use cases will bring very stringent requirements in terms of latency, reliability, and high-accuracy positioning. The combination of 5G technology with enterprise network solutions becomes crucial to satisfy these requirements in indoor, and private environments."

Are testing standards in place for IoT devices and networks?

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Discussion Panel Expert: Surecall

SureCall develops industry-leading cellular signal boosters that provide people and businesses with enhanced connectivity using superior technologies that improve their ability to stay connected at home, in the office or on the go. SureCall leads by innovation. Since 2001, SureCall has been the first-to-market leader in new signal booster technology. Premium parts and innovative design result in the longevity and reliability of SureCall boosters.

Will large numbers of connected objects increase exposure to radio signals?

Large numbers of connected objects will indeed increase exposure to radio signals. In fact, Ericsson has predicted that there will be over 5 Billion cellular IoT devices in 2025. However, in total, including unlicensed band technologies, Dr. Adnani predicts that the total number of IoT devices will probably be closer to 40 billion.

"Many of these devices are wideband, and systems that utilize cellular and Wi-Fi technologies are relatively high power as well," he says. "The rapid proliferation of communicating devices will increase exposure to radio signals across the electromagnetic spectrum."

Hassan concedes that expanding IoT means "radiofrequency electromagnetic field (RF-EMF) exposure limits have become a critical concern for fifth-generation (5G) mobile network deployment."

Increased exposure is a given, says Jolly, "due to the increased number of transmitters."

"There are some IoT applications, especially indoors in industrial settings, where radio interference mitigation will become a significant challenge. But there are also countervailing trends, such as increased edge and "fog" computing, limiting the need to transmit data. In addition, we see improvements in collision avoidance schemes that limit retransmissions."

"The RF density from connected devices is extremely low," Nader Famili counters. "Exposure to radio signal will continue to be dominated by personal smartphones which are close to the person's organs."

Are 5G smart devices safe?

It has been established that RF density from connected devices is extremely low.

"Exposure to radio signal will continue to be dominated by the personal smartphones which are close to the person's organs," says Nader "The Rf emanating from smart devices is very low and very infrequent. Almost all smart devices will be on the sleep mode for the great majority oftime, and when they emanate RF, it is at extremely low power."

"5G smart devices are definitely safe," states Terry. "They are basically the same as a cell phone, except they are transmitting for MUCH shorter durations, and they are not located right next to a person. There should be no concern with safety regarding 5G devices."

"I am neither a doctor nor a biologist, so I would refer you to two scientific authorities," says Jolly, who suggests those with concerns review information provided by the World Health Organization (https://www.who.int/news-room/q-a-detail/5g-mobile-networks-and-health) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

"I also consider safety in terms of what 5G enables in terms of telemedicine and emergency response," he adds. "Is there a safety benefit in having 5G for emergency responders? Is there a safety benefit in having video access to a medical specialist I could not otherwise consult?"

Can RFID and IoT work together?

"Passive RFIDs can be viewed as indirect IoT, and active RFIDs are simply IoT devices," says Nader. "As such, they are complementary and in the great scheme of things the same thing."

How this works is based on radio technology and device requirements. RFID is the use of radio technology to automatically identify and track tags that are attached to objects. RFID is used in asset tracking and inventory management. Connecting the RFID reader, a computing device, to the internet as an IOT device enables access to this data, opens up a number of possibilities by way of applications, and where and how it can be utilized.

"(RFID and IoT) can work very well together," says Jolly. "For example, RFID can be an authentication mechanism to help secure an IoT application. Also, RFID can help in inventory, smart security, smart agriculture, and smart logistics applications."

Are IoT deployments on track with projections?

"There are so many projections out there, and they range from billions to trillions of devices," says Jolly. "Based on my reading, I would make two observations:

1) IoT deployments have slowed in some areas due to the global economic situation. This is especially true where the initial costs of the IoT application were to be funded by governments or by increased product sales.

2) The trend towards increasing "things" operating in places where human beings used to interact face-to-face will accelerate in some areas, particularly in medical applications and routine check-in/check-out applications (ticket-takers, cashiers, hotel front desks, and so on).

"It depends on many factors such as the size of the IoT deployment, type of used communication protocols, and data connectivity," adds Dr. Hassan.

Unquestionably, 5G technology will expand the uses and capabilities of IoT, especially when combined with other technologies like LoRa and SigFox networks.

"The main vision of the Internet-of-Things (IoT) is to create an intelligent world where the real, the digital and the virtual are converging to create smart environments that provide more intelligence to energy, health, transport, cities, industry, buildings and many other areas of our daily life," says Hassan. "RFID is a key part of this version representing an efficient sensor communication technology that enables a ubiquitous computing network."

RFS, Surecall, Keysight Technologies, and ThinkRF all have several 5G solutions available at Gap Wireless.

RFS DragonSkin Coax Cable

The formidable, tenacious, fire-eating dragon doesn't need to carry an extraneous shield or bulk up with armor. It's built in.

A number of jurisdictions in the United States require NFPA 72 Survivability. DragonSkin is the only standalone RF communications cable that has been proven to successfully transmit radio frequency signals through a minimum of a 2-hour burn, continuing to operate after severe heat conditions and when suddenly cooled down with water.

SureCall Fusion Professional Signal Booster

The Fusion Professional is a powerful cell phone signal booster for mid-size buildings that provides strong, reliable connections in areas up to 8,000 sq. ft.

The Fusion Professional significantly improves voice, text, 4G, and LTE data speeds for all North American cell carriers for 4G & 5G phones with built-in 2XP technology which doubles uplink transmission power to maintain the cellular connection to the tower in the weakest signal environments. It also features SureIQ technology to prevent shut down and provides continuous performance in urban and rural environments.

Keysight FieldFox SUPER 5G NR Next Generation Microwave Analyzers

Makes 5G test a reality with a wide analysis bandwidth — up to 100 MHz — over-the-air (OTA) measurement options, and much more.

Captures the smallest interfering signals with wide-band, real-time analysis (RTSA). Measures from 4 to 50 GHz with precision comparable to benchtop results. Withstands your toughest working environments — meets MIL-specs.
Weighs less than alternative solutions — 30% lighter than other handheld analyzers. Performs as a cable and antenna analyzer (CAT), a VNA, a spectrum analyzer, or as an all-in-one combination analyzer.

ThinkRF D4000 5G 40 GHz RF Downconverter/Tuner

A practical approach to extend existing RF equipment's performance to 5G frequencies

As new and innovative technologies for wireless communications continue to emerge and push into mmWave 5G bands, companies must be able to adapt and enhance the lifetime of their existing RF systems to meet these new bands in an agile manner, while managing ever-tighter resources and budgets.

The ThinkRF series of RF downconverters / tuners are designed for maximum performance and interoperability. The D4000 RF Downconverter / Tuner enables translation of RF signals in the frequency range of 24-40 GHz with up to 500 MHz of real-time bandwidth (RTBW), to capture mm-wave 5G signals.

5G Public Safety Applications

Our responders provided us with in-depth and insightful information on how 5G will impact future public safety.

5G Public Safety Applications

It is reasonably certain that the opportunities and challenges of the connection between IoT and 5G implementation within the public safety realm will be driven by the initiatives of connected "smart cities".

As more information is collected and shared within municipalities, situational awareness also increases, and public safety agencies will make more informed decisions in how they respond.

To gain a clearer picture of how 5G Network coverage will impact the public safety sector and expand the capabilities, we reached out to a panel of experts. Comprised of public safety sector professionals, analysts, and advisors, our respondents provided us with in-depth and insightful information on how 5G will impact future public safety efforts.

Our 5G Public Safety panel includes Carlos Tobar, Manager of Emergency Systems, City of Edmonton Fire Rescue Services, Wayne Black, Chief Technical Officer at Freedom Products at Astronics Test Systems, and Tim O'Brien, Director of Strategic Development, Public Safety at Bird RF.

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How will IOT and 5G Public Safety play together?

While many believe 5g will accelerate some of the changes triggered by 4G implementation, Carlos Tobar, Manager for the City of Edmonton Fire Rescue Services, believes 5G will go even further, including an expansion of IoT functionality and improved public sector operations.

"I believe 5G will enable faster adoption of IoT, due to the reduced infrastructure costs (and challenges) with fibre and other physical networks," says Tobar. "The ability to have a camera in more locations and with the continuous improvement of AI, the ability to detect crime, traffic collision, or other events that require public safety response will be possible."

Tim O'Brien, Director of Strategic Development, Public Safety Bird RF, also sees an expansion of public safety services made possible through the interlay of IoT and 5G. He says this will include devices capable of tracking public safety personnel and sensors to detect officer down scenarios automatically. O'Brien says that 5G will also allow for the creation of more "smart buildings" outfitted with sensors for smoke, fire, and carbon monoxide location identification.

"While LTE provided IoT capabilities," he says, "5G greatly expands on these capabilities by supporting more than an order of magnitude more devices per square mile, providing much more efficient spectrum usage, as well as using up to 90% less energy."

"The promise of high speed and low latency offered by 5G will spark the creation of innovative IoT devices that can drastically change the way public safety officials operate and respond to emergencies," anticipates Wayne Black, Chief Technical Officer for Freedom Products at Astronics Test Systems.

Of course, in addition to the many improvements 5G will enable regarding the interplay between IoT and public safety, there are still risks and challenges to ponder. Tobar points to cybersecurity, privacy, information storage, and governance as areas that will require oversight and scrutiny. Tobar is also cautious about the speed at which these public safety enhancements will be implemented.

"The challenge right now is that the public safety sector is small compared to the consumer market," he says. "There has not been as much focus on public safety, and thus the evolution of tools and applications has not always been seen."

How will 5G affect the way public safety communicates in the future?

The hope is that 5G networks will provide a data movement system that will enable innovation "in ways that have yet to be imagined," says Black.

"More than just mission-critical, push-to-talk, 5G opens the path to collecting, integrating, processing, and distributing information from hundreds to thousands of sensors in real-time."

Black uses a situation awareness room as an example of what he foresees. "The command and control team in a situation awareness room will be able to 'see' everything that every responder on the ground can see via high-definition, body-worn cameras," he explains. "Responders on the ground will be able to 'see' through buildings or walls or in the dark via augmented reality, heads up displays, where the augmented views come from a merge of data from all the IoT sensors in the area. 'Virtual' responders will be joining the response team on the ground via robots or drones, resulting in improved response coordination in every situation.

For Tobar, these advancements face some challenges, mainly because there has not been as much focus on public safety, which has sometimes stifled the evolution of tools and applications. For example, Tobar points to PSAPs across the country that are currently preparing to transition to next-generation infrastructure (NG9-1-1), facilitating the transmission of multimedia (i.e., video, text, etc.…) from the public to public safety dispatch centers.

"5G won't accelerate this transition, but rather facilitate the collection and analysis of information by PSAPs (both through IoT devices and public shared) to develop better-informed decisions and responses," he explains.

"With respect to the front line, there currently is a lack of 5G PTT devices that are rated for use in fire environments," he continues. "5G devices and MCPTT (along with other advancements) will first be developed for and adopted by medical and law enforcement. Until that time, fire departments will need to continue to rely on older legacy radio systems (e.g., P25, DMR, Tetra, …) for communications.

"That said, there are various manufacturer initiatives that have combined legacy systems and cellular within their devices to improve functionality and tools."

Bird remains optimistic about the promise of 5G in the public safety sector. "While public safety will continue to rely primarily on LMR systems for voice communications for years to come, 5G gives promise to greatly augment public safety communications by enabling low latency – real-time high bandwidth applications," he says.

"While LTE enabled high-resolution mobile video, the high latencies of the networks typically prevented true real-time performance," he continues. "However, 5G NR brings with it the possibility for low network latencies (<10ms) that can enable public safety communications applications such as bi-directional real-time heads up displays to aid collaboration between front line first responders and other public safety personnel, keeping everyone up-to-date with the latest pertinent information including live video feeds and venue floor plans for navigation. Additionally, in the next release of 5G NR (Rel 17), there will be expanded support for sidelink (SL) communication allowing communication between first responders without connection to a base station by each individual first responder."

Tobar agrees that from a high-level view, the capabilities of 5G and the potential impact it could have on public safety communities are excellent.

"That said, it is up to the vendors and manufacturers to really understand the need of the various public safety entities," he counters. "With that comes the education of both public and users alike."

"5G comes with a lot of misconceptions and misinformation being fed by the internet and other media," says Tobar. "Education needs to start now to help ease the adoption of additional sensors and other connected devices as well as the use of mm-wave for 5G devices."

"Also, additional thought needs to be given to the impacts (including unintended impacts) from the increased sensors and sharing of data. This will help with the current struggle of 5G hype versus reality."

Discussion Panel Expert: Freedom

Freedom is a developer and manufacturer of communication test equipment for the land-based mobile radio test market providing innovative solutions to Long-Term Evolution (LTE) high-speed wireless communications customers globally. Freedom also provides an extensive range of capabilities, including automated radio testing and alignment, coverage mapping, and interference analysis.

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Communication Technologies

How can 5G improve 911 and first responders?

The capabilities of 5G when applied to public safety are impressive. Ultimately, the result will be real-time situational awareness, first responders. This will allow first responders to be better prepared to handle the emergency as it unfolds. 5G can throttle up or throttle down bandwidth as needed, so first responders only pay for what is used. Black even anticipates the use of remote-controlled drones to assess outdoor situations or deliver emergency support equipment to a remote site.

As Black explains, with higher frequency operational bands and many more access points, 5G user-devices will quickly provide an accurate 3D position of a caller. The caller will be able to send a live video directly to 911 to describe the issue. "If the caller is in a public area, the 911 operator will be able to access IoT devices near the caller's location to obtain quick access of security footage, temperature data, and floor plans of a building where an emergency is taking place," says Black. "This gives the ability to identify potential threats and victims before responders enter, as well as the ability to open, close, or lock doors."

While 5G will expand the capabilities of existing 911 call centers, that expansion won't be easy. "There will need to be a technology overhaul and training to handle and coordinate the new streams of information that 5G can support," warns Black.

How can 5G help surveillance to prevent acts of terrorism?

"Preventing acts of terrorism is a very challenging problem," admits Black. "Terrorism can happen in an almost infinite number of ways, and public safety can only watch a limited number of paths."

"To truly prevent an act of terrorism, you must know who, when, and where it is going to happen before it happens. 5G can be a part of the toolset used in the collection of information needed to identify and locate potential terrorists."

O'Brien believes one way to do this is by expanding mobile video bandwidth and support for real-time monitoring both through IoT devices such as fixed cameras and mobile body and dash cameras. "Situational awareness and ability to act with the most up to date information can be a game-changer," he says.

"With increased sensors, there will be increased data available for sharing among public safety agencies," adds Tobar. "Although this is a scary thought in terms of 'big brother' watching, it can significantly improve public safety and security."

"For example, for facial recognition to be truly useful at finding a suspected terrorist, the technology must be deployed not only at airports but at every available entry location," elaborates Black. "This can only become possible with a high number of low-cost IoT surveillance devices deployed to collect identification information. These devices would then feed the data to a cloud facial recognition system that determines possible matches and alerts the local port authorities before the identified individual has left the location."

Of course, using advanced technologies like facial recognition triggers additional concerns about privacy and government overreach, says Tobar.

"The unintended impact is the availability of big data becomes a target for cyber-crime (much greater than it is now). Governance of the shared data will be necessary. All levels of government will need to be involved in managing this future better," he says.

Discussion Panel Expert: City of Edmonton

Edmonton Fire Rescue Services (EFRS) serves a population of over 980,000 citizens through both uniformed and civilian personnel. EFRS is committed to protecting life, property, and the environment and is recognized as one of nine internationally accredited fire departments in Canada through CFAI (Commission of Fire Accreditation International). Services include Fire Suppression, Public Safety, Training & Logistics and Technical Services.

How can 5G help improve fire prevention and firefighting?

For O'Brien, it's the ability for real-time access that is key when it comes to the impact 5G will have on fire prevention and firefighting. He points to enhanced IoT fire sensors accurately pinpoint a fire's location as a way to minimize property damage and loss of life. Also, enabling commanders and other public health authorities to see what the firefighters are seeing "can dramatically improve firefighting capabilities, keep first responders safer, and minimize lives lost in fires," he says.

Black agrees that the combination of 5G coverage with IoT devices will provide firefighters with the ability to coordinate their actions and react in ways that are faster and more efficient.

"With good 5G coverage at a low cost, all building sensors used to help identify a fire (smoke, temperature, video, etc.) can be IoT devices that report to not only a local monitoring system, but also a local fire department," he explains.

"As firefighting personnel prepares to deploy, proximity video sensors could be accessed to verify if an emergency event is occurring," Black continues. "While on the route, 5G could allow the team commander to access temperature data and floor plans of a building where an emergency is taking place."

Black also believes "sensor- and video-enabled robots or drones" will help firefighters identify hot spots and plan the most effective response to the fire or a rescue operation.

"Once on site, the commander sitting outside the fire scene can see exactly what all his firefighters can see at the same time from all the sensors from each firefighter stitched together," Black explains, "the commander in charge of the operation can make critical decisions in real-time with live data.

"The firefighters themselves will be able to utilize augmented reality in their helmets for situational awareness or even the ability to 'see in the dark' or 'through the smoke.' Data sent from the firefighter's protective equipment will provide monitoring of health and welfare of each firefighter."

Tobar remains skeptical. "I don't think that 5G will have a major impact on fire prevention or firefighting that 4G doesn't already provide," he counters. "The impact will result from the development of public safety applications. 5G does have the capability to encourage the industry to develop these tools to assist in the services fire departments provide."

"The major improvement will be the speed at which this data is shared and the increased capacity to share large amounts of data."

How can 5G improve public transit safety?

The current widespread development of self-driving vehicles was instigated by the desire to create safer ways of traveling. Public transit systems are also being pushed to improve safety for customers and prevent accidents. Black believes 5G can play a role in these improvements.

"On the road, smart vehicles will be able to communicate to provide situational awareness such as location, velocity, and changes in effect," he says. "On-vehicle sensors will be able to 'see' road hazards ahead and make real-time decisions to stop if the driver does not."

"Roadside sensors can provide information about traffic conditions that are fed back to public transit vehicles," he adds, also point to video or IR sensors that could be utilized on tracks to identify hazards day or night.

"Providing faster data back to cloud systems means faster analysis of data and return of warning or action to take."

"Public transit systems can cover huge geographic areas many times with limited points of access for public safety personnel and the potential for public safety emergencies to move throughout the system, for example when a fire or police situation takes place on a subway car" adds O'Brien.

"The ability for IoT sensors to detect and provide the exact (dynamic) location of an incident is key, as is the ability for first responders to have robust, real-time communication and information, including real-time video."

The potential of 5G to expand the uses and capabilities of IoT for public safety is enormous. Of course, there remain issues regarding the development of public sector devices and the ubiquity of those IoT devices across different sectors, including law enforcement, firefighting, EMT, and more.

As advanced wireless technologies continue to impact how public safety agencies operate, 5G will inevitably facilitate the tools and applications that will be developed and significantly enhance how those tools and applications are used to maintain and improve public safety.

Freedom and Bird featured solutions available at Gap Wireless.

Bird Fiber Fed Signal Booster II+

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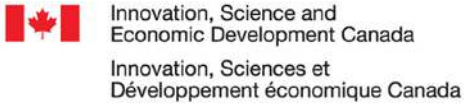
Freedom R8200

The Freedom R8200 from Astronics Test Systems represents a major step in the evolution of the Land Mobile Radio service monitor. The R8200 is the first and only test instrument that combines comprehensive digital and analog LMR testing with the ability to measure important RF network characteristics such as Return Loss, VSWR and Phase. The R8200 is also the only service monitor with the ability to display RF parameters in a Smith Chart for more complicated network analysis.

A special thank you to all our 5G panel participants



5G Report

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