Technology Trends

5G Networks

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Shared Services Canada
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Table of Contents

Business Brief

With today's 4G network, internet infrastructure providers are quickly realizing that 4G is not equipped to handle the increase in mobile data traffic. By 2020, the projected mobile traffic will be too great for 4G networks to support. To resolve this issue, providers and consumers will need to make the shift to 5G networks.

5G, also known as 5G NR ("new radio"), stands for *5th-Generation* cellular wireless technology.[i] In the mobile universe, a generation (a 'G') usually indicates a compatibility break – meaning that users will need new equipment.[ii] Although wireless generations have technically been defined by their data transmission speeds, each has also been marked by a break in encoding methods, or "air interfaces," that make it incompatible with the previous generation.[iii]

1G – Analog Voice: introduced in the late 1970s, the first cellphones provided voice-only calls. Years later, some 1G cellphones occasionally provided wireless data service to a laptop by connecting them to the laptop's dial-up modem, but hookups were precarious, and when it worked, the data transfer rate was minuscule.[iv]

2G – Digital Networks: introduction of a new digital technology for wireless transmission also known as Global System for Mobile communication (GSM). GSM technology became the base standard for further development in wireless standards. This standard was capable of supporting a data rate from 14.4kbps up to 64kbps (maximum), which is sufficient for SMS and email services. Data networks (GPRS, EDGE, IS-95B) were added and commonly called 2.5G and 2.75G technologies.[v]

3G – High speed IP Data Networks: the third generation, features faster access to the Internet with downstream speeds up to 1 Mbps and more, depending on the 3G version.[vi] Third generation mobile communication started with the introduction of UMTS – Universal Mobile Terrestrial / Telecommunication Systems. After the introduction of 3G mobile communication systems, smart phones became popular across the globe. Specific applications were developed for smartphones, which handle multimedia chat, email, video calling, games, social media and healthcare.[vii]

In order to enhance data rate in existing 3G networks, another two technology improvements were introduced to the network. HSDPA – High Speed Downlink Packet access and HSUPA – High Speed Uplink Packet Access, developed and deployed to the 3G networks, known as 3.5G. The next 3G development, known as the 3.75 system, is an improved version of 3G networking with HSPA+ – High Speed Packet Access Plus. Later, this system would evolve into the more powerful 3.9G system known as LTE (Long Term Evolution).

4G – Growth of Mobile Broadband: 4G systems are enhanced versions of 3G networks developed by IEEE, offerings higher data rate and capable to of handle handling more advanced multimedia services. LTE and LTE advanced wireless technology are used in

4th generation systems. Furthermore, it has compatibility with previous versions thus easier deployment and upgrade of LTE and LTE advanced networks are possible.[viii] It is basically the extension in the 3G technology with more bandwidth and services. One of the main ways in which 4G differed technologically from 3G was in its elimination of circuit switching, instead employing an all-IP network. Thus, 4G ushered in a treatment of voice calls just like any other type of streaming audio media, utilizing packet switching over internet, LAN or WAN networks via VoIP.[ix]

5G – Unlicensed Spectrum: a 5G network has three main advantages over its predecessor:

- It is set to offer between 10 and 20Gbps data download speed;
- It offers low latency, of less than a millisecond, which is crucial for applications that need to be updated in real-time; and
- Because the technology makes use of millimeter radio waves (mmWave) for transmission, it can provide higher bandwidth over current LTE networks, as well as much higher data rates.

In practical terms, this means that 5G networks will be able to provide access to cloud storage, the ability to run enterprise applications, and the power to run more complex tasks virtually. A 5G network also offers the possibility of 100x more device connections than 4G LTE. It may also offer a 90% reduction in energy consumption compared to 4G, while providing internet speeds currently only capable of being achieved through a direct network connection via fiber optic cable.

5G is also poised to transform the world of IoT devices. The use of mmWave and 5G core network not only allow for faster data transmission but also greater connection reliability. This means greater connectivity for new kinds of mobile applications, factory automation, autonomous vehicles and so forth. Essentially any IoT application currently using Low Power Wide Area (LPWA) will see incremental improvements. Many cellular vendors are set to release smartphones and other devices capable of connecting to 5G networks by the end of 2019. Currently, organizations such as AT&T have released 5G Evolution, which is a step up from 4G LTE but does not provide the full range of capabilities that 5G will.

Technical Brief

Much like current cellular networks, 5G divides a territory into small sectors in which devices connect to cell sites. These cell sites are then able to transmit encrypted data through the use of radio waves. Where 5G differs from its predecessor is in its ability to transmit these radio waves at much higher frequencies – which translates into faster data speeds, even faster than current fibre network speeds, which are 1Gbps. This minimal disruption has already seen real world application when Sprint released a similar feature with its LAA technology. In the millimeter wave (mmWave) spectrum, these frequencies are between 30 and 300 GHz.

There are two sets of frequencies being approved by the United States' Federal Communications Commission (FCC). "Low-band 5G" and "Mid-band 5G" use frequencies from 600 MHz to 6 GHz, especially 3.5-4.2 GHz. Mid-Band waves will likely not affect existing wireless support hardware very much. Although there will be a need for boosters to avoid a lot of signal attenuation, mmWave will completely disrupt wireless technologies – requiring a whole new system of antennas, cabling, and amplifiers.

5G networks will be used with much smaller cell sites. Higher frequency radio waves are only capable of travelling short distances as compared to the lower frequency 4G LTE waves. Since the 5G signal can only be transmitted about the distance of a city block and cannot permeate buildings, there will be less need for large network towers and more need for small cell towers approximately every city block as well as within buildings. This also means that the speed on the individual networks will be greater than before.

An article written by professors from the University of Waterloo, Carleton and Ozyegin Universities explains that 5G networks could completely transform the current cellular architecture. They explain that for 5G to function with such a high demand for network bandwidth from IoT devices, the traditional cellular architecture may be divided into a two-tier architecture: 1) a macrocell layer, for base station-to-device communication, and 2) a device layer, for device-to-device (D2D) communication. However, this poses risks for security. D2D communication requires more complex network security than what is currently available. Communication is possible through the use of device relaying; connected devices use one another to retransmit data, creating an ad hoc mesh network. In this way, the devices can communicate with one another in a licensed cellular bandwidth without the use of a base station (BS). This capability is a dramatic shift from conventional cellular architecture where cell phones connect to a cell tower.

Previously, D2D communication has only been used minimally. Recently, demand for this capability has grown as more context-aware applications come to market. These applications generally require both location services and the ability to communicate with other devices. Providing this capability through D2D would offer cost savings since not all devices on the network would need to be connected through the BS. D2D could also play a role in mobile cloud computing and enable more effective sharing of resources. If a device is at the edge of a cell site or in a crowded area, D2D could eliminate a significant resource burden on the BS.

Industry Use

Several telecom vendors in the U.S. have begun developing and testing 5G networks. Telecom providers like Verizon, AT&T and Sprint have all made strides in this field, with individual research projects underway to test the networks. Verizon, AT&T, Sprint, and T-Mobile have all begun to deploy 5G in various markets and will continue to do so throughout 2019. Verizon has fixed and mobile 5G in a few areas. AT&T has mobile 5G for select businesses in select cities, as Sprint is deploying 5G to select areas. T-Mobile will launch commercial 5G in the second half of 2019 and is expecting to have nationwide coverage in 2020.

Sprint and T-Mobile have invested in lower-frequency 5G, which provides slower speeds in exchange for more range. This will allow them to provide 5G to less-dense areas more economically. Sprint has invested in mid-band, 2.5 GHz 5G, while T-Mobile is planning to use "low-band" 600 MHz 4G in addition to higher-frequency 5G in denser areas. In comparison, Verizon and AT&T will mostly be using much higher-frequency bands, such as the 28-GHz range.

In Canada, widespread availability of 5G won't be until sometime in 2020. Although 5G has a potential of reaching speeds of 20Gbps, it will likely be around 6Gbps when it is first deployed. As with similar technologies, it will take up to 10 years for this new technology to reach full maturity.

One of the uses of 5G is to help manage solar, wind, and other renewable energy sources by balancing out power consumption. Since 5G will enable the collection of data, this information can be collected and analyzed to determine power consumption peaks and valleys. This information can then be used to plan a more consistent and dependable power grid.

The fast speed of 5G networks and its inherent low latency will also enable remote surgery. This gives people in smaller communities' access to surgeons and specialists that are normally only available in larger cities. The first successful remote surgery has already been completed in China. A 5G network adds the missing piece to the remote surgery puzzle. A remote surgery needs a patient, surgeon, robot, and a super-fast, stable internet connection.

What if self-driving cars could signal their intentions or broadcast their route to other self-driving cars? 5G could enable this to happen and it would help make the roads safer. It could also be possible for the rest of us to broadcast to nearby drivers where we are going. This could be done when we are using our phones to give us directions to our destination. The phone could also broadcast this info via 5G to nearby phones and self-driving cars.

Canadian Government Use

5G (or 5th Generation) mobile networks are not yet available in Canada or most of the world for that matter. Despite this, the Government of Canada (GC) has been preparing for its arrival. Canada is on par in preparation for 5G compared to other developed countries.

Innovation, Science and Economic Development Canada (ISED) & the Management of Mobile Spectrum

The demand for digital applications and content continues to rise, both in Canada and around the world, which is the main driving force for the ushering in of 5G technology. Smartphones and other cellular devices, along with tablets, personal computing devices (i.e. Internet of Things, or IoT) and machine-to-machine connectivity, are increasingly pivotal in the daily lives of Canadians and Canadian business. As use of such devices grows, the compound growth rate of mobile data traffic has been calculated at 54% annually. As such, the creation of new or conversion of existing spectrum (or radio frequencies upon which mobile data travels) by national regulators is crucial in order to meet demand to prevent any negative economic consequences.

All global radio spectrum is allocated by The International Telecommunication Union (ITU). In Canada, cell phones and radio frequencies are regulated by Innovation, Science, and Economic Development (ISED), which forms part of the ITU. This department also oversees licensing and placement of cell phone towers, conducts environmental impact and land use assessments regarding the installation of cell phone towers or other cell phone infrastructure, and ensures that this equipment meets all regulatory requirements. It is also responsible for the provision and licensing of spectrum to wireless carriers in Canada. In 2015, after consultations with telecommunications carriers and television broadcasters, it was decided that Canada will repurpose the 600 MHz portion of the TV spectrum band for mobile use. The auctioning of this spectrum to mobile carriers was completed in April 2019 and demonstrates the Government of Canada's (GC) awareness of the constantly increasing importance of mobile technology and the need for greater frequency bands.

However, with 5G looming on the 2023 horizon, the year that most carriers in North American intend to have 5G launched on a large scale, even more spectrum will be required:

> *"New spectrum is critical for the success of fifth-generation (5G) terrestrial mobile service. Globally, there are significant on-going activities to identify suitable spectrum, including bands that can be used in as many countries as possible to enable global roaming and economies of scale. Various efforts around the world are underway to find harmonization around [the] spectrum to be used for 5G. The 5G services are expected to cover a wide range of applications." 5G Americas*

In June 2017, ISED launched consultations regarding the future release of additional spectrum, beyond the current used 648 MHz. ISED wanted to consider the quantities most likely required, as well as the need for possible policy and regulatory considerations, as new business models and network applications emerge. Various stakeholders took part in the consultations and showed support for the GC's proposal for the release of 28GHz, 37 to 40GHz and 64 to 71GHz frequency bands. The Minister of ISED, the Honourable Navdeep Bains, has said that more conclusive decisions will not take place before the World Radiocommunication Conference in the Fall of 2019 and that consultations around such issues generally take two years. However, some major stakeholders would like to see the speed of this process increased. A representative from Telus has said, "Immediate and decisive regulatory action is required to allow Canada to reap early mover advantages in the new global digital economy."

Public Safety & Concerns Regarding Espionage

As of May 2019, the GC is conducting a cybersecurity review of 5G technology and potential equipment suppliers. Currently, the main suppliers globally include Nokia, Ericsson, Samsung, Qualcomm, and Huawei, with the greatest concerns involving the latter company. In 2018, Australia, New Zealand, and the United States all banned the use of Huawei telecom equipment in its 5G networks after concerns that the company had ties to the Chinese government, which could potentially use Huawei to help it perform espionage or to attack vital public infrastructure by the deployment of malicious code. Huawei has vehemently denied these allegations to date. The United Kingdom has ordered a partial ban of Huawei in the core of its 5G network. Other European countries have so far refrained from doing so.

While it is normally the responsibility of Canadian carriers, like Bell, Rogers, and Telus, to ensure the security of their networks, the GC has an obligation towards public safety, of which cybersecurity is a part. As of May 1, 2019, according to Public Safety Minister Ralph Goodale, the minister responsible for national security and Canada's National Cyber Security Strategy, the security review over 5G including Huawei's potential role is ongoing and a final decision is expected by Fall 2019. Regardless of this decision, ongoing efforts will be needed by both carriers as well as the GC in terms of network security, similar to how it is with current 4G LTE.

Other Investments & Initiatives

On March 19, 2018 the GC announced its investment in the 5G test corridor between Quebec and Ontario. The investment in ENCQOR represents a step in the adoption of the next generation of wireless technology. The GC is partnering with several private industry partners and demonstrates an important example of collaboration among all stakeholders. 5G will demand a huge infrastructure overhaul that must be accounted for.

CWTA has launched the 5G Canada Council to promote supportive collaboration as Canada establishes this new 5G ecosystem. The technology is still set to release by 2020. The GC will still need to address how it will support radio frequencies between 600 and 3500 MHz, which are required for 5G networks. This range of frequencies is crucial as 600 MHz is one of the highest frequencies still able to reach individuals in more rural and remote regions of the country.

The Canadian Government has announced the investment of up to $40 million to support Nokia's research on 5G technology in Canada. Nokia has launched multiple projects regarding data routing in optical networks, as well as the development of cybersecurity tools that will protect telecommunication networks as they move toward 5G.

Implications for Shared Services Canada (SSC)

SSC will have an important role to play in ensuring that the GC departments have the tools, infrastructure, and architecture available when 5G launches on a large scale in the next few years. Thus, the rollout of 5G will have major implications for SSC.

Value Proposition

As mentioned in the Business Brief, 5G offers three main advantages over the current 4G network: greater speed, lower latency, and the ability to connect many more devices at once. In practical terms, this means that 5G networks will be able to provide better access to cloud storage (and edge computing), the ability to run enterprise applications with greater "real-time" response, and the power to run more complex tasks virtually. These advantages couple well with the GC's ongoing commitment to open-government and greater data sharing and collaboration from any device (including mobile) as elaborated in the Digital Operations Strategic Plan 2018-2022.

SSC has made considerable shifts in the modernization of the GC data centres, as well as the brokerage of cloud services in terms of data processing and storage. However, as technology evolves, edge computing will provide a complement to these two models. "By 2022, more than 50% of enterprise-generated data will be created and processed outside of the data centre or cloud" according to Gartner research. Edge computing is advancing as a solution to latency issues from one machine to another. 5G will help to improve bandwidth, and therefore latency issues in its own right, thus being able to support a greater density of edge and other devices. 5G will also help enable data to get to their end points (whether cloud or data center) faster for processing and storage.

Challenges

First, compatible devices will need to be re-issued to all GC employees throughout Canada. Current devices will not be compatible with 5G networks nor will automatic updates be available. Only 5G compatible devices can be used on 5G networks (they can also be used on 4G networks). However, an immediate update will probably not be required. Initially, 5G launches will use 4G networks and equipment and not standalone. Regardless, a complete renewal of all GC devices over roughly the same time period will be a massive logistical and financial undertaking. Nonetheless, to maintain itself as a digitally-enabled government that can best serve Canadians, one of the main strategic themes outlined in the Digital Operations Strategic Plan 2018-2022 and also outlined in Blueprint 2020, this investment will be critical.

Second, 5G will in part be broadcast using millimeter waves, which have frequencies between 30 and 300 GHz. The problem with mmWaves is that they typically have poor range and are susceptible to interference and blockage by objects, such as buildings, trees, even rain and clouds. This presents an obstacle in terms of ensuring adequate device coverage. Moreover, interference and range problems can prevent certain vital systems from working at all, such as weather forecasting, SmartCities initiatives, medical procedures, and military and policing operations. To get around this, "small cells", the term devised to describe the use of many small antennas, towers, and transmitters in a dense area, will need to be deployed. This will significantly alter the current network structures that we have now and may prove difficult in some remote or rural areas.

Lastly, the arrival of 5G may bring about occupational health & safety concerns from employees and citizens in general regarding radiation exposure from the increased number of antennas and towers in closer proximity to where people live and work. Even with current 4G technology and existing telecommunications equipment, there are some who believe that devices and their equipment pose a threat to human health. However, no research has currently shown a definitive risk. Health Canada has developed guidelines for safe human exposure to radiofrequency (RF) energy. 5G RF is well-below the high end safety range of 300 GHz.

Considerations

The largest impact 5G networks will have on SSC is in its datacenters. 5G promises to support higher network traffic at greater speeds with lower latency. It also means that applications will begin to be designed to use 5G networks. The shift to 5G will still require data centers to perform many of the same tasks except on a much larger scale. Datacenters will need to become decentralized and follow a two and/or three tier model to provide low latency processing at the edge of the network while maintaining a central data aggregation and coordination role. Datacenters will also require an increase in bandwidth, processing power and storage.

5G will also transform the traditional cellular architecture. Having a two-tier architecture as explained in the technological brief requires heightened security. This is because using devices to connect to each other to establish a network connection means there isn't only one central base station to protect. Now, the provider will have to also focus on protecting against the devices that establish the connections themselves. Security will be a vital concern for SSC moving into the 5G era as IoT devices will all be connected. This increased number of IoT devices brings forth a high amount of network traffic.

Companies like Cisco and Ericsson have begun using software-defined-networks (SDNs) and network functions virtualization (NFV) because they are more flexible and can dynamically support a growing number of devices. SDNs decouples the hardware from the software, meaning tasks can be performed in the cloud or in clusters of servers. NFVs, which are usually used in combination with SDNs, shift network functions from being hardware-specific to being able to run in virtual machines. These are viable options for SSC moving forward as the department migrates to the cloud while entering the 5G era.

5G networks are considered not simply an evolution in technology, but a revolution. It has the potential to significantly alter the way data is transmitted, processed, and by whom (or what). It may be necessary for SSC to investigate the potential of enterprise 5G networks, as many large business enterprises have begun. Due to certain "mission critical" operations performed by various government departments, such as National Defence and the Royal Canadian Mounted Police (RCMP) amongst others, the development of private 5G networks may be necessary for the sharing of sensitive information or when public infrastructure and networks may not be reliable or deemed secure.

Despite the advantages of 5G, there will be initial upfront financial and human resources costs. Not only will updating and deployment of current infrastructure and devices be required, but densification of infrastructure will also be an inevitable result of 5G technology. Due to the challenges in transmission distances and interference, small cell deployments of radio towers and antennas, possibly on each government building throughout the country, may be necessary. This has impacts on budgets and manpower.

Finally, lessons can be learned from the early 5G adopters. At present, 5G technology is still very much immature and not deployed on a wide scale globally. However, in April 2019, South Korea became the first country to fully adopt 5G and expect close to 1 million users by the end of June 2019. Within these early months of its launch, complaints arose from users regarding coverage issues and speed, mostly as a result of a lack of base stations (towers and antennas) outside of densely populated urban areas. Carriers have responded by installing 3,000-4,000 new stations weekly in order to meet the demand and resolve issues. This highlights the importance of needing key infrastructure in place prior to launch in order to prevent the alienation and frustration of clients.

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