

# 5G

## THE LAST BEACHFRONT PROPERTY



### **INFORMATION AND COMMUNICATIONS TECHNOLOGY COUNCIL**

300-116 Lisgar Street, Ottawa

Phone: 613-237-8551

Fax: 613-230-3490

Email: [info@ictc-ctic.ca](mailto:info@ictc-ctic.ca)

Web: [www.ictc-ctic.ca](http://www.ictc-ctic.ca)

## About ICTC:

ICTC is the trusted source for evidence-based policy advice, forward looking research, and creative capacity building programs for the digital economy.

## To cite this report:

MacEachern, A. (2018). 5th-generation mobile: the last beachfront property (ICTC). Ottawa, Canada

Researched and written by Alexandra MacEachern (Director of Policy and Outreach) with generous support from Namir Anani (CEO and President) and Jeremy Depow (Vice President of Research).

## 5th-generation mobile: the last beachfront property

The Information and Communications Technology Council (ICTC) is undertaking the first comprehensive study of fifth-generation (5G) wireless mobile and its impacts on the Canadian labour market and economy.

This initial white paper is based on secondary research. In the course of its analysis, ICTC also compiled a number of relevant policy questions to stimulate a national discourse on potential approaches and measures for fast-tracking Canada's entry in this space. A follow-up, in-depth publication based on primary data for Canada is also planned for release at the end of 2018.

5G is heralded as the last crucial frontier of network communication, attaining download speeds of up to 20Gbps and a sub-1 millisecond latency. Such attributes are destined to drive the true promise of smart cities, autonomous vehicles, advanced manufacturing, intelligent retail, and connected healthcare among many others.

5G is also expected to address a wide range of applications that enable massive Machine Type Communications (mMTC), enhanced Mobile Broadband (eMBB), and most importantly Ultra-Reliable & Low-Latency Communication (URLLC). All these applications will fuel the world of artificial intelligence (AI) decisions and actions, micro-payments and transactions, as well critical health applications.

Economists estimate the global economic impact of 5G in new goods and services could reach up to \$12.3 trillion in 2035, representing 4.6% of all global real output in 2035.<sup>1</sup> For the period of 2020 to 2035, forecasts indicate that global Real Gross Domestic Product (GDP) will grow at an average annual rate of 2.9%, with 5G predicted to contribute 0.2% of that growth.<sup>2</sup> This means that global Real GDP would expand at a slower pace of 2.7%, without the deployment of 5G.<sup>3</sup>

5G is also expected to create a substantial number of jobs, with estimates indicating that the global 5G value chain will support 22 million jobs by 2025.<sup>4</sup> In the United States, it is estimated that 5G will help to create 3 million jobs and approximately \$500 billion in GDP over the next seven years.<sup>5</sup> Moreover, if municipalities embrace 5G to become smart cities, it is estimated that this could add an additional \$90 billion in GDP and 870,000 new jobs across the United States.<sup>6</sup> Ericsson has also estimated that 5G will create \$27 billion in business opportunities for India by 2026.<sup>7</sup>

With the potential to create jobs, increase GDP, and power industries across Canada, the time for a national discourse on 5G has never been timelier.

### What is 5G?

Every 10 to 15 years, the telecommunications industry deploys a new generation of mobile technology. For instance, first-generation mobile (or 1G) was voice-only but proved that mass market mobile phones were feasible. Second generation (2G), which spanned most of the 1990s, brought interoperability and text messaging. Third generation (3G) arrived in the early 2000s and delivered mobile internet—and with it, the rise of online platforms—and was also the first to enable global roaming, WiFi, Bluetooth, picture sharing, and low-definition streaming.<sup>8</sup> Fourth generation (4G) emerged in the 2010s and built upon this to provide high-speed internet, with more sophisticated applications including high-definition video stream-

ing and numerous IoT (Internet of Things) operations for cars and home.<sup>9</sup>

5G has some unique spectrum capabilities, including the ability to utilize both licensed and unlicensed bands, as well as to share spectrum. This allows it to make better use of high frequency bands (above 24 GHz/gigahertz), the mid-bands (1-6 GHz), and the low or sub-GHz bands.<sup>10</sup> Of particular interest in the lower 5G bands are bands in the ranges of 3300-4200 megahertz (MHz) and 4400-4990 MHz, which are already being used in 5G trials in China. Higher bands include 26, 28, 38 and 42 GHz, which are being considered for rapid 5G deployment by the United States, China and Europe.<sup>11</sup> Other bands of interest include the 600 MHz, 700 MHz, 800 MHz, 900 MHz, 1.5 GHz, 2.1 GHz, 2.3 GHz and 2.6 GHz.<sup>12</sup>

Fifth-generation mobile is emerging now and expected to be widely available beginning in 2020. The actual definition of what constitutes “5G” is still being debated by the International Telecommunications Union (ITU) and is not expected to be finalized until 2019. Despite this, there is general agreement among nations and industry that 5G will have several distinct features including low latency, better speeds, lower power consumption, and massive connectivity of devices.

Latency is the amount of time it takes for data to move from one point to another over a network. 5G will bring URLLC and a minimum of 1 millisecond of latency. By comparison, the current 4G benchmark is 50 milliseconds. This decrease in latency will be particularly useful in the deployment of autonomous vehicles<sup>1</sup> and remote surgeries, where every millisecond of latency increases the risk to users and could be fatal.

Under ideal conditions, 5G is expected to have a download speed of 20 gigabits (GB) per second. This is 20 times faster than the current 4G download speed of 1 GB per second. Ideal conditions depend on a variety of factors and to meet the definition of 5G, the minimum reliable speed achieved must be 100 megabits (MB) per second. This is still an impressive benchmark, as it is 10 times faster than the reliable speed threshold for 4G.

Lower power consumption and the ability to use energy more efficiently while sending and receiving data and while in sleep mode are also key components to the definition of 5G. Fifth generation will enable less complex receivers, which are believed to have a battery life of up to 10 years.<sup>13</sup>

Today’s telecommunications networks are limited in the number of devices that can be connected to them. This is why it is often difficult to use your cellphone while attending a crowded sporting event or concert. The 5G benchmark will markedly increase the number of devices that are able to connect to the network: from 4G’s 2,000 devices per square kilometre, to 1 million devices per square kilometre.

These features make fifth-generation mobile uniquely qualified for disruption of industry verticals across Canada. Its ability to facilitate machine-to-machine (M2M) connectivity and to enable the proliferation of massive IoT applications yields extraordinary economic potential. While business use cases are still being identified, it is believed the industry verticals most likely to utilize 5G are automotive, manufacturing, media, logistics, agriculture, energy, and healthcare.<sup>14</sup> Many of these industries are already using 4G and LTE (Long-Term Evolution) technology but are exploring the benefits of 5G. For example, the increased network reliability of 5G makes it well suited to power mining drones, which could be operated remotely from kilometres away to carry out measurements or dig in dangerous terrain.<sup>15</sup> 5G’s low battery life and connection density also make it well suited for precision agriculture—such as the real-time monitoring of livestock for location and health information; or soil and crop monitor-

i For more information of Autonomous Vehicles, see ICTC’s Autonomous Vehicles and the Future of Work Report, [https://www.ictc-ctic.ca/wp-content/uploads/2018/01/ICTC\\_-\\_Autonomous-Vehicles-and-The-Future-of-Work-in-Canada-I-I.pdf](https://www.ictc-ctic.ca/wp-content/uploads/2018/01/ICTC_-_Autonomous-Vehicles-and-The-Future-of-Work-in-Canada-I-I.pdf)

ing, which uses sensors to identify issues with pests, humidity, or diseases.<sup>16</sup>

However, while 5G millimeter wave (mmWave) frequencies have the advantage of carrying higher bandwidth throughput with low latency, the trade-off is that such high frequencies have a shorter range and signal penetration capability through structures and buildings. To overcome the propagation challenges, advanced multi-antennae technology and networks will need to be deployed at potentially sizable investments. This may result in 5G's initial roll-out being limited to core urban areas, where dense connectivity and higher economic rent are expected.

## State of play in Canada

5G generated headlines when it was first tested at the PyeongChang 2018 Olympic Winter Games in South Korea. The recent merger of Sprint and T-Mobile has also attracted attention to the state of 5G in the United States. Despite not garnering the same international attention, Canada's public and private sectors have made notable investments in 5G technology.

In January of this year, the Government of Ontario announced it would invest \$63 million into a project with CENGN and the Ontario Centres of Excellence, to launch a "next-generation network" testbed in Ontario.<sup>17</sup> This testbed will be open for SMEs (small and medium-sized enterprises) to conduct proof-of-concept models for a variety of industry applications including autonomous vehicles and smart mining.<sup>18</sup> CENGN is comprised of academia, industry and researchers including Bell Canada, Huawei, EXFO, Cisco, Invest Ottawa, Juniper Networks, Mitel, Nokia, Ribbon Communications, Rogers, Telus, and Wind River.<sup>19</sup>

In March of this year, the Governments of Ontario, Quebec, and Canada also each invested \$67 million in the ENCCOR project, which will create a 5G corridor between the two provinces.<sup>20</sup> Five private-sector partners—Ericsson, Ciena Canada, Thales Canada, IBM and CGI—have invested an additional \$200 million toward the project. ENCCOR is designed to spur research and innovation within the 5G technology space and will be open to approximately 1,000 SMEs. The testbed technology is expected to be deployed this year and should be operational in 2019.<sup>21</sup>

In April 2018, Rogers announced its partnership with Ericsson to bring 5G trials to Toronto, Ottawa, and other select cities over the next year.<sup>22</sup> Rogers has already outfitted the Rogers Centre with dozens of 5G antennae and demonstrated live examples of 5G—such as wearing virtual reality glasses while tossing a baseball back and forth, and shopping in a virtual store.<sup>23</sup>

Telus and Huawei partnered in 2015 for their 5G Living Lab project in downtown Vancouver, which began testing next-generation technologies inside the homes of Telus employees. The pilot successfully achieved speeds of 30 Gbps (gigabits per second) and is helping to develop new technologies, which will make the transition from indoor to outdoor communications more seamless.

Bell and Huawei's "Wireless to the Home" project uses the 3.5 GHz and 28 GHz spectrum bands to run high-speed trials in Ontario towns including Orangeville, Feversham, and Bethany.<sup>24</sup> They plan to soon expand the number of trials and upgrade them to 5G specifications.

Despite these investments, Canadian service providers have not named a specific date when 5G will become commercially available. Telus has stated that "5G technology is expect-

ed to become commercially available beginning in 2020.” Bell and Rogers have also suggested they will not be deploying until 2020.<sup>25</sup>

This is similar to the European Union’s (EU) self-imposed deadline of making 5G available for consumer use in at least one major city per member state by 2020. European national governments agreed in 2017 that they would aim to have faster internet networks available everywhere in the bloc by 2025.<sup>26</sup>

By contrast, American service provider Verizon has stated that it will have residential internet access in three to five markets by the end of the year. AT&T has promised to deploy 5G in a dozen cities within a year, with a focus on hotspot devices. The recent merger of Sprint and T-Mobile has been branded as a way for them to accelerate deployment, which they had originally planned for 2019.

One of the main reasons why some Canadian service providers are hesitant to provide a more exact timeframe of when 5G will become available is that the federal government has not yet allocated the 600 and 3,500 megahertz (MHz) spectrum bands, which are important for 5G deployment.

The Department of Innovation, Science and Economic Development is scheduled to launch its consultation on the 3,500 MHz band this summer, but no date for the auction has been set. The auction for the 600 MHz band will be held in March 2019.

There is certainly political pressure on the Government to hold these auctions and release the spectrum, but there are also crucial public policy questions that need to be discussed. These spectrum bands are in many ways the last “beachfront property” that the Government owns, and they have the potential to bring in billions of dollars in public revenue. 5G will also provide the digital infrastructure required by Industry 4.0, and will be a driving force for Canada’s Innovation Agenda and economy.

In anticipation of these auctions, ICTC would like to ask a few pertinent questions, spurring discussion on how Canadians can fully benefit from fifth-generation mobile.

## Policy questions

### Do you cap the sale?

The government of South Korea will auction off the 3.5 GHz and 28 GHz bands on June 15, 2018.<sup>27</sup> The country will distribute the spectrum evenly amongst its three operators, rather than allocating more spectrum to the highest bidder. The government has also decided to limit bid amounts to prevent the auction from being overly competitive and exhausting bidders’ resources.<sup>ii</sup> The policy objective here is that lower spectrum costs will allow service providers to keep more of their capital available for deployment of 5G infrastructure and services. This is a popular policy position amongst service providers across the world, yet it comes with the disadvantage of bringing in less revenue for the government.

Canada could benefit from the billions of dollars that these auctions are likely to bring. The 2014 auction of 700 MHz brought in nearly \$5.3 billion, and the 2015 sale of AWS-3 spectrum brought in \$2.1 billion.<sup>28</sup> It is not unreasonable to assume that these two 5G spectrum

ii It should be noted that South Korea is regarded to have the fastest and some of the least expensive telecommunications services in the world. While this is due to several factors, the competitive nature of South Korea’s telecommunications industry cannot be overlooked. This should be kept in mind when comparing its policies to those of Canada or other nations where such conditions do not exist.

auctions could fetch a similar price for the Government of Canada—providing the investment dollars necessary to stimulate the development and wide adoption of 5G services and applications by SMEs, and enable access to rural and remote communities, among many other benefits. That in turn will generate additional economic and job growth.

The decision of whether to place a cap on the upcoming spectrum auctions is certainly critical when balancing the industry versus societal and larger economic interests.

### How can service providers monetize their investments?

The cost to deploy 5G infrastructure and services can potentially be significant. Boston Consulting Group reports that mobile players have invested an aggregate of \$1.8 trillion in CapEx and R&D from 2009 to 2013, and they are expected to invest an additional \$4 trillion between 2014 and 2020.<sup>29</sup> Regardless of whether the Canadian government places a cap on spectrum bids or not, service providers will need customers to deploy 5G technology and see a return on their investment.

Traditionally, mobile has focused heavily on everyday consumers who pay for talk, text, and data packages. It is likely that early 5G deployment will also use this business model and market its increased speed and capacity as its chief selling features. However, 5G will also have significant industrial applications and need to develop business cases in these less traditional verticals.

Ericsson has already identified over 400 use cases for industrial 5G, noting a significant shift from consumer-heavy and industry-light to a more balanced interest from both groups in 5G.<sup>30</sup> Qualcomm recently published a report projecting that 5G will enable more than \$1.1 trillion in sales for the health market alone by 2035. With all of this potential revenue, service providers will have to develop concrete business cases in the industrial space.

Service providers could also collect, analyze, and re-sell data that enters their networks via the multitude of connected IoT devices. Cisco estimates that there will be 50 billion connected devices by 2020, so the quantity of data that will flow through these networks is substantial and offers incredible revenue potential.<sup>31</sup>

The need to identify, test and prove the feasibility of industrial business cases will be essential to the scalability of 5G. This is perhaps why so many commercial testbeds are open to SMEs and other non-consumer players. As service providers continue to deploy upgraded networks, they should be cognizant of the need to monetize 5G technology and of the potential for revenue-generating applications within the industrial space. Such approaches can potentially stimulate the development of a larger ecosystem of innovation partners and business models.

### To whom do you sell?

5G is distinct from previous generations of mobile in that its applications and benefits are so well situated for industry. This raises a unique question: could a non-service provider potentially buy spectrum? For example, in the last 700 MHz spectrum auction in the United States, Google was allowed to bid for C-block spectrum and offered up a \$4.6 billion bid.<sup>32iii</sup>

iii While Google did not ultimately buy the spectrum, the company did force Verizon to open up its networks (an issue that Verizon had previously gone to court over with the Federal Communications Commission, in order not to do), allowing Google to significantly expand the usability of its Android devices.

This 2008 auction widened the net, allowing other companies to enter the telecom space and offer competitive services and applications. It is not unreasonable to expect in such a scenario that even autonomous vehicle industry giants may enter this space, given their reliance on 5G to offer innovative services in autonomous driving, infotainment, and many others. While such an approach could potentially drive bid prices higher, it may also open the door for innovative services and benefits for Canadians.

### *Do you have a set-aside?*

In March of this year, the Government announced it would set aside 43 percent of the spectrum for regional players in its upcoming 600 MHz auction. The previous government used a set-aside in the 2008 AWS (Advanced Wireless Services) auction, and subsequent governments have made similar decisions to set aside spectrum, with the policy objective of fostering competition and lowering prices. This set-aside will allow companies such as Shaw's Freedom Mobile, SaskTel, Eastlink and Vidéotron to bid for spectrum without Bell, Rogers or Telus being at the table and running up the prices.

The current government shows no signs of deviating from this policy, despite strong opposition from the big three and others, who argue that set-asides delay the use of spectrum and give public money to companies who do not need it. For instance, the Montreal Economics Institute stated that the set-aside for the 600 MHz auction would "...essentially constitute public subsidies that are either lost to weak new entrants that consistently fail, as was the case with Wind, Public Mobile and Mobilicity, or wasted on established regional players that would have the means to bid for the spectrum at full value."<sup>33</sup>

The Government's decision to foster competition also extends to affordability. The Boston Consulting group reports that the cost of network infrastructure per megabyte fell by 95 percent as second-generation mobile transitioned into third generation. There was another decrease of 67 percent when we upgraded from third generation to fourth.<sup>34</sup> Other reports have indicated that the technology used in 5G can be cheaper to deploy, and that this will contribute to cost reductions.<sup>35</sup> With this in mind, one can assume that 5G will lower the cost per megabyte. However, Canada still pays some of the highest mobile rates in the world<sup>36</sup> and we may continue to see higher rates for 5G than that of other countries.

Should the Government continue with its policy of setting aside spectrum for the 3,500 MHz auction, it must continue to explain to consumers and policy critics how this fosters competition, lowers pricing, and increases access.

### *How do you serve rural and remote communities?*

The Government has long played a role in incentivizing service providers to deploy into rural and remote parts of Canada. There have been various programs which deliver "final mile" services to rural communities and Northern Canada, where it may not otherwise be economically feasible for service providers to do so. Advocates such as the University of Calgary's Gregory Taylor have raised the issue of disproportionate services being delivered to rural versus urban Canadians. During the Consultation on Spectrum Outlook 2018 to 2022, he recommended that the Government set deployment targets for rural areas.<sup>37</sup> He also argued that the Government should re-examine the Remote Rural Broadband Systems (RRBS) policy, which he believes could help bridge the rural-urban divide, if properly employed.

The first major deployment of 5G will most likely take place in Vancouver, Toronto, Ot-



tawa and Montreal, where there have already been testbeds and pilot programs developed. However, service providers have been increasingly looking to provide rural communities with 5G. For example, Huawei's and Bell's "Wireless to the Home" project aims to bring 5G to rural locations in Ontario and Quebec by the second quarter of 2018. These will be trial runs, but may help prove the business case for rural 5G.

With the emergence of smart cities and as the benefits and business cases for 5G begin to crystalize, some communities are opting to invest in these upgrades themselves. The city of Morden, Manitoba recently announced it would be phasing in Morenet, which is a 5G service built and maintained by the city. The project is funded via tax dollars and users need only pay a \$400 installation fee.<sup>38</sup> The Morenet project is estimated to cost between \$300,000 and \$400,000 and will bring upload and download speeds of 100 MB per second within the next few years. By 2021, this will ramp up to 1 GB per second.<sup>39</sup>

Projects such as Morenet demonstrate that 5G may be the solution to cheap and ubiquitous final mile deployment. Some have argued that the 5G characteristics of high capacity and high bandwidth with very low latency make it ideal to eventually replace fixed-line broadband.<sup>40</sup> With large players investing in rural 5G and developing testbeds, the business case for 5G final mile may be more feasible than first thought.

As the Government prepares to auction off the 3,500 MHz spectrum band, it will need to ensure that all Canadians benefit from 5G technology. This may occur organically as non-federal government actors begin investing and deploying, or it may require more direct intervention on the Government's part.

## Final Thoughts

The sale of the 600 and 3,500 MHz spectrum bands will be a defining moment for the Government. These bands will help to deploy the next generation of telecommunications technology, and bring with it trillions of dollars in economic opportunity. 5G's importance to the Canadian economy and the Innovation Agenda cannot be understated, as it will provide the backbone for numerous new technologies and enable smart cities and Industry 4.0 to flourish. It is critical to ensure an environment that encourages large scale adoption.

With this as a backdrop, the Government must turn its mind to how it can auction off this spectrum in a way which truly benefits all Canadians. This will require the challenging task of balancing multiple needs including generating public revenue, fostering competition, deploying the infrastructure quickly, and finding a way to include rural and remote communities. If service providers have any hope of scaling the technology, they must develop strategies to entice wide adoption and monetize 5G. This will mean creating non-traditional business partnerships and forging a much closer relationship with industries across Canada.

## Endnotes

- 1 Karen Campbell et al., The 5G economy: How 5G technology will contribute to the global economy (IHS economics & IHS technology, January 2017): 16, <https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf>.
- 2 Ibid, 19.
- 3 Ibid.
- 4 Ibid.
- 5 Accenture Strategy, How 5G can help municipalities become Smart Cities: 1, [https://www.accenture.com/t20170222T202102\\_w\\_us-en/acnmedia/PDF-43/Accenture-5G-Municipalities-Become-Smart-Cities.pdf](https://www.accenture.com/t20170222T202102_w_us-en/acnmedia/PDF-43/Accenture-5G-Municipalities-Become-Smart-Cities.pdf). Note: the report indicates that this will be realized after a 7 year buildout period, but no specific year is provided.
- 6 Ibid, 4.
- 7 “5G to offer \$27 bn biz opportunity for India by 2026: Ericsson,” The Economic Times, last modified May 22, 2018, <https://economictimes.indiatimes.com/tech/internet/5g-to-offer-27-bn-biz-opportunity-for-india-by-2026-ericsson/articleshow/64273620.cms>
- 8 Julio Bezerra et al., “The Mobile Revolution: How Mobile Technologies Drive a Trillion Dollar Impact,” The Boston Consulting Group (January 2015): 9, <https://www.bcg.com/en-ca/publications/2015/telecommunications-technology-industries-the-mobile-revolution.aspx>.
- 9 Emeka Obiodu and Mark Giles, The 5G Era: Age of boundless connectivity and intelligent automation (GSMA Intelligence, February 2017): 10, <https://www.gsmainelligence.com/research/2017/02/the-5g-era-age-of-boundless-connectivity-and-intelligent-automation/614/>.
- 10 Campbell et al., The 5G economy, 13.
- 11 Joe Barrett, 5G Spectrum Bands (Global Mobile Suppliers Association, February 2017), <https://gsacom.com/5g-spectrum-bands/>.
- 12 Ibid.
- 13 DotEcon Ltd and Axon Partners Group, Study on Implications of 5G Deployment on Future Business Models (March 2018): 24, [https://bereg.europa.eu/eng/document\\_register/subject\\_matter/bereg/reports/8008-study-on-implications-of-5g-deployment-on-future-business-models](https://bereg.europa.eu/eng/document_register/subject_matter/bereg/reports/8008-study-on-implications-of-5g-deployment-on-future-business-models).
- 14 Ibid, 28.
- 15 Ibid, 40.
- 16 Ibid, 47.
- 17 Ontario Centers of Excellence, “CENGN and OCE Join Forces with Government

of Ontario to Create Advanced Networking Capabilities for Innovators, Firms Across the Province," January 25, 2018. <https://www.newswire.ca/news-releases/cengn-and-oce-join-forces-with-government-of-ontario-to-create-advanced-networking-capabilities-for-innovators-firms-across-the-province-671129233.html>.

18 Ibid.

19 Ibid.

20 The Canadian Press, "Canadian Government Partners with Digital Heavyweights to Prepare for 5G Future," The Toronto Star, March 19, 2018, <https://www.thestar.com/business/2018/03/19/public-private-investment-to-create-5g-wireless-telecommunication-corridor-for-ontario-and-quebec.html>.

21 Ibid.

22 Rogers Communications, "Rogers and Ericsson Partner to Bring 5G to Canadians," April 16, 2019, <https://about.rogers.com/2018/04/16/rogers-ericsson-partner-bring-5g-canadians/>.

23 Ibid.

24 Huawei Canada, "Huawei enables Bell Canada's Wireless to the Home trials that put Canadian rural customers on the path to 5G," February 27, 2018, <https://www.newswire.ca/news-releases/huawei-enables-bell-canadas-wireless-to-the-home-wtth-trials-that-put-canadian-rural-customers-on-the-path-to-5g-675262803.html>.

25 The Canadian Press, "U.S companies announce 5G launch dates, but Canadian telecoms stay mum," Canadian Broadcasting Organization, April 1, 2018, <http://www.cbc.ca/news/business/5g-wireless-technology-launch-dates-1.4601594>.

26 Catherine Stupp, "Europe in "terrible hurry" as pressure mounts in global race for 5G," Euroactiv, February 26, 2018, <https://www.euractiv.com/section/digital/news/europe-in-terrible-hurry-as-pressure-mounts-in-global-race-for-5g/>.

27 Dylan Bushell-Emblin, "South Korea to hold 5G auction June 15<sup>th</sup>," Telecomasia.net, May 7, 2018, <https://www.telecomasia.net/content/south-korea-hold-5g-auction-june-15>

28 Rose Behar, "ISED Canada says a 600 MHz auction will take at least two more years," MobileSyrup, April 28, 2017, <https://mobilesyrup.com/2017/04/28/ised-canada-says-600mhz-auction-will-take-least-two-years/>.

29 Bezzara et al., "The Mobile Revolution," 35.

30 Ericsson, The Industry Impact of 5G: Insights from 10 sectors into the role of 5G, January 2018, <https://www.ericsson.com/assets/local/narratives/networks/documents/report-bnew-18000486-rev-a-uen.pdf>

31 Bezzara et al., "The Mobile Revolution," 27.

32 Mashable, Sean P Aune, January 19<sup>th</sup>, 2018 Sean P. Aune, "What exactly does Google want from the 700 MHz auction?," Mashable, January 19<sup>th</sup>, 2008, <https://mashable.com/2008/01/19/what-exactly-does-google-want-from-the-700-mhz-auction/#2m->

[WQmND5COq8](#).

33 Montreal Economic Institute, "Spectrum set-aside will bring more distortion to wireless market, not consumer benefit," March 28, 2018, <https://www.iedm.org/78536-spectrum-set-aside-will-bring-more-distortion-wireless-market-not-consumer-benefits>.

34 Bezzara et al., "The Mobile Revolution," 27; DotEcon Ltd and Axon Partners Group, Implications of 5G Deployment, 23.

35 Campbell et al., The 5G economy, 10.

36 Nordicity Group Ltd, "2016 Price comparison study for telecommunications services in Canada and select foreign jurisdictions," Canadian Radio-television and Telecommunications Commission (CRTC), March 22, 2016, <https://crtc.gc.ca/eng/publications/reports/compar/compar2016.html>.

37 Gregory Taylor, "Consultation on Spectrum Outlook 2018 to 2022," Canada Gazette Part 1, Vol. 151, No. 42 (Oct 21, 2017): 7-8, [https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/SLPB-006-17-Dr-Gregory-Taylor-CR.pdf/\\$FILE/SLPB-006-17-Dr-Gregory-Taylor-CR.pdf](https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/SLPB-006-17-Dr-Gregory-Taylor-CR.pdf/$FILE/SLPB-006-17-Dr-Gregory-Taylor-CR.pdf).

38 CBC News, "Manitoba city of Morden may be 1<sup>st</sup> in country to offer internet as service for residents," Canadian Broadcasting Corporation, April 5, 2018, <http://www.cbc.ca/news/canada/manitoba/morden-morenet-free-internet-1.4607183>.

39 Ibid.

40 "How to Get Last Mile Connectivity Technology Right," NetComm Wireless Limited, accessed June 3, 2018, <https://www.netcommwireless.com/news/article/how-get-last-mile-connectivity-technology-right>.

## Work Cited

Accenture Strategy. How 5G can help municipalities become Smart Cities. [https://www.accenture.com/t20170222T202102\\_w\\_us-en/acnmedia/PDF-43/Accenture-5G-Municipalities-Become-Smart-Cities.pdf](https://www.accenture.com/t20170222T202102_w_us-en/acnmedia/PDF-43/Accenture-5G-Municipalities-Become-Smart-Cities.pdf).

Aune, Sean P. "What exactly does Google want from the 700 MHz auction?" Mashable, January 19<sup>th</sup>, 2008. <https://mashable.com/2008/01/19/what-exactly-does-google-want-from-the-700-mhz-auction/#2mWQmND5COq8>.

Barrett, Joe. "5G Spectrum Bands." Global Mobile Suppliers Association, February 2017. <https://gsacom.com/5g-spectrum-bands/>.

Behar, Rose. "ISED Canada says a 600 MHz auction will take at least two more years." MobileSyrup, April 28, 2017. <https://mobilesyrup.com/2017/04/28/ised-canada-says-600mhz-auction-will-take-least-two-years/>.

Bezerra, Julio, Wolfgang Bock, François Candelon, Steve Chai, Ethan Choi, John Corwin, Sebastian DiGrande, Rishab Gulshan, David Michael, and Antonio Varas. "The Mobile

Revolution: How Mobile Technologies Drive a Trillion Dollar Impact.” The Boston Consulting Group, January 2015. <https://www.bcg.com/en-ca/publications/2015/telecommunications-technology-industries-the-mobile-revolution.aspx>.

Bushell-Emblin, Dylan. “South Korea to hold 5G auction June 15<sup>th</sup>.” Telecomasia.net, May 7, 2018. <https://www.telecomasia.net/content/south-korea-hold-5g-auction-june-15>.

Campbell, Karen, Jim Diffley, Bob Flanagan, Bill Morelli, Brendan O’Neill, and Francis Sideco. “The 5G economy: How 5G technology will contribute to the global economy”. IHS economics & IHS technology, January 2017. <https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf>.

DotEcon Ltd and Axon Partners Group. Study on Implications of 5G Deployment on Future Business Models. March 2018. [https://berec.europa.eu/eng/document\\_register/subject\\_matter/berec/reports/8008-study-on-implications-of-5g-deployment-on-future-business-models](https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8008-study-on-implications-of-5g-deployment-on-future-business-models).

Ericsson. The Industry Impact of 5G: Insights from 10 sectors into the role of 5G. January 2018. <https://www.ericsson.com/assets/local/narratives/networks/documents/report-bnew-18000486-rev-a-uen.pdf>.

Gardiner, Bryan. “Google calls 700- MHz auction a major victory for consumers.” Wired, March 20<sup>th</sup>, 2008. <https://www.wired.com/2008/03/google-calls-70/>.

Huawei Canada. “Huawei enables Bell Canada’s Wireless to the Home trials that put Canadian rural customers on the path to 5G.” February 27, 2018. <https://www.newswire.ca/news-releases/huawei-enables-bell-canadas-wireless-to-the-home-wtth-trials-that-put-canadian-rural-customers-on-the-path-to-5g-675262803.html>.

Montreal Economic Institute. “Spectrum set-aside will bring more distortion to wireless market, not consumer benefit.” March 28, 2018. <https://www.iedm.org/78536-spectrum-set-aside-will-bring-more-distortion-wireless-market-not-consumer-benefits>.

NetComm Wireless Limited. “How to Get Last Mile Connectivity Technology Right.” Accessed June 3, 2018. <https://www.netcommwireless.com/news/article/how-get-last-mile-connectivity-technology-right>.

Nordicity Group Ltd. “2016 Price comparison study for telecommunications services in Canada and select foreign jurisdictions.” Canadian Radio-television and Telecommunications Commission (CRTC), March 22, 2016. <https://crtc.gc.ca/eng/publications/reports/compar/compar2016.html>.

Obiodu, Emeka and Mark Giles. “The 5G Era: Age of boundless connectivity and intelligent automation.” GSMA Intelligence, February 2017. <https://www.gsmaintelligence.com/research/2017/02/the-5g-era-age-of-boundless-connectivity-and-intelligent-automation/614/>.

Ontario Centers of Excellence. “CENGN and OCE Join Forces with Government of Ontario to Create Advanced Networking Capabilities for Innovators, Firms Across the Province.” January 25, 2018. <https://www.newswire.ca/news-releases/cengn-and-oce-join-forces-with-government-of-ontario-to-create-advanced-networking-capabilities-for-innovators-firms-across-the-province-671129233.html>.

Rogers Communications. "Rogers and Ericsson Partner to Bring 5G to Canadians." April 16, 2019, <https://about.rogers.com/2018/04/16/rogers-ericsson-partner-bring-5g-canadians/>.

Stupp, Catherine. "Europe in "terrible hurry" as pressure mounts in global race for 5G." Euroactiv, February 26, 2018. <https://www.euractiv.com/section/digital/news/europe-in-terrible-hurry-as-pressure-mounts-in-global-race-for-5g/>.

Taylor, Gregory. "Consultation on Spectrum Outlook 2018 to 2022." Canada Gazette Part 1, Vol. 151, No. 42 (Oct 21, 2017). [https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/SLPB-006-17-Dr-Gregory-Taylor-CR.pdf/\\$FILE/SLPB-006-17-Dr-Gregory-Taylor-CR.pdf](https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/SLPB-006-17-Dr-Gregory-Taylor-CR.pdf/$FILE/SLPB-006-17-Dr-Gregory-Taylor-CR.pdf).

The Canadian Press. "Canadian Government Partners with Digital Heavyweights to Prepare for 5G Future." The Toronto Star, March 19, 2018. <https://www.thestar.com/business/2018/03/19/public-private-investment-to-create-5g-wireless-telecommunication-corridor-for-ontario-and-quebec.html>.

The Canadian Press. "U.S companies announce 5G launch dates, but Canadian telecoms stay mum." Canadian Broadcasting Organization, April 1, 2018. <http://www.cbc.ca/news/business/5g-wireless-technology-launch-dates-1.4601594>.

The Economic Times. "5G to offer \$27 bn biz opportunity for India by 2026: Ericsson." Last modified May 22, 2018. <https://economictimes.indiatimes.com/tech/internet/5g-to-offer-27-bn-biz-opportunity-for-india-by-2026-ericsson/articleshow/64273620.cms>.