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# 5G AND CONNECTIVITY

A study commissioned by:  
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Authored by:  
Dr. Gregory Taylor, Associate Professor  
Department of Communication, Media and Film  
University of Calgary



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# INTRODUCTION: THE NEXT GENERATION

The “anytime, anywhere” ethos that drives media access today reflects our wireless world.

An upgrade in the technical infrastructure supporting our ubiquitous wireless devices has the potential to bring great change. It will impact not only the way people communicate but also how an increasing number of essential machines and devices exchange information.

5G promises to move mobile data at volumes and speeds beyond anything we have seen, greatly changing our increasingly connected lives. Significant matters of public interest are also involved in its development.

This study draws on published reports and original research to assess the potential for 5G and connectivity in Calgary. It explores the current environment and compares Calgary with select Canadian cities to establish our place in advancing applications of a nascent technology.

This evolution in mobile connectivity may prove to be the foundation for society-shifting developments, however, fundamental questions about this new technology, and the ensuing public policy implications, must be addressed.

One thing is certain: business and governments worldwide are embracing 5G. The mobile communications industry is certainly investing heavily.

Wireless spectrum, the public resource that underpins all mobile data, is being sold by governments around the world for mobile providers to expand 5G service. A 2020 auction of spectrum suited for 5G by the United States Federal Communications Commission, for example, generated \$80.9 billion US, almost double the previous record.<sup>1</sup>

While many of the benefits of 5G have yet to be fully realized, the telecommunications industry is confident it is a game changer for its fastest growing and most profitable sector; mobile. In 2019, the Canadian mobile sector generated revenue of \$28 billion while landline internet generated \$12.8 billion.

Mobile providers are aware consumers will pay for enhanced service: the average mobile revenue per subscriber increased from \$64.07 in 2015 to \$69.00 in 2019 as subscribers sought higher data plans.<sup>2</sup> This was before the arrival of 5G.



Presumably carriers expect consumers will pay even more for a truly exponential expansion in service.

The Government of Canada has jurisdiction over the spectrum carrying wireless data, but the technological specifics of 5G, including shorter range of signals on higher frequencies, require access to significant municipal infrastructure to achieve the leap in service.

The role of municipal governments in the development of this digital infrastructure is an important question and this report examines how municipalities are on both the physical and political front lines of the growth of 5G.

It also explores what Calgary is doing to be at the forefront of wireless innovation compared with other cities in five key areas: municipal fibre, public Wi-Fi access, local internet exchange points, 5G policy and digital action plan.

<sup>1</sup> Federal Communications Commission. (Jan 15, 2021) First Phase of Record-Breaking 5G Spectrum Auction Concludes. <https://www.fcc.gov/document/first-phase-record-breaking-5g-spectrum-auction-concludes>

<sup>2</sup> Canadian Radio-Television and Telecommunications Commission. (2020). Communications Monitoring Report. Retrieved from <https://crtc.gc.ca/pubs/cm2020-en.pdf>

# WHAT IS 5G?

5G is digital technology that promises exponential increases in the speed of data transfers that current mobile technology achieved with the leap to fourth generation or 4G wireless (also known as LTE, or Long-Term Evolution) a decade ago.

While forecasts vary, 5G promises greater speed (to move more data), lower latency (to be more responsive) and the ability to connect far more devices at once (for sensors and smart devices).

The 5G Council of Canada, an industry group of telecom operators, characterizes 5G as the “next generation” of mobile wireless standards and technologies. It says 5G will enable a fully connected mobile society and deliver unprecedented benefits to citizens, industry and government.

While current networks focus primarily on data transmission (e.g., throughput), 5G networks are being designed to provide faster transmission, ensure more widespread coverage, handle more connected devices and traffic types, and support different uses.

5G promises a range of new and improved services and applications across industries.

A fibre optic foundation is essential before the potential of 5G can be realized. It is even required for many of the experiments required to test the boundaries of the new technological paradigm.

Truly wireless technology is a misnomer.

At some point, usually below an antenna site, wireless data requires a wire. It is why deployment of fibre optic wires (strands of glass transporting data at the speed of light) is essential to accelerate 5G technology. 5G will not perform optimally with a copper-wire conduit, or Asymmetric Digital Subscriber Line (ADSL). Only fibre can handle the data flow required to achieve the transformative potential of 5G.

Most 4G technology used by Canadians in the past decade came from inventive uses of copper wires to deliver “high-speed internet.” However, it has a data ceiling well below the potential of 5G. Without a fibre foundation, a 5G network cannot be created.

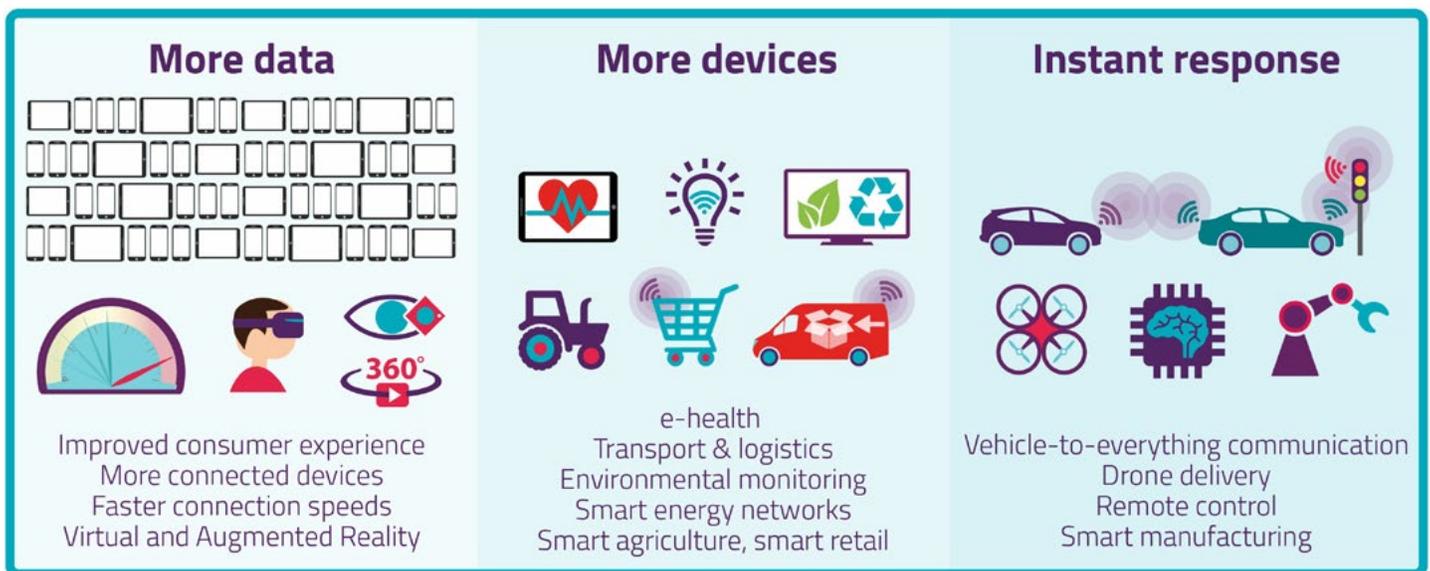


Figure 1. Description of benefits of 5G<sup>4</sup>

<sup>4</sup> Ofcom. (2021). What is 5G? Retrieved from <https://www.ofcom.org.uk/phones-telecoms-and-internet/advice-for-consumers/advice/what-is-5g>

The standalone 5G technical standard is newly in place as of 2020<sup>5</sup> and plentiful and affordable access to fibre networks remains critical to success. 5G can be deployed in three different parts of the spectrum:

- Low-band 5G spectrum (below 1 GHz) can potentially achieve speeds of 250 megabits per second (Mbps), or faster than current 4G but not the exponential increase promised by 5G advocates.<sup>6</sup> However, low band has greater coverage, so carriers need fewer towers.
- Mid-band 5G spectrum (1 –6 GHz) has broad geographic reach and speeds up to 1 gigabits per second (Gbps). Innovation, Science and Economic Development Canada (ISED) has auctioned 600 MHz (low) band spectrum in 2019 and plans auctions in the 3500 MHz bands in 2021 and 3800 MHz spectrum in the near future.<sup>7</sup>
- The very top speeds associated with 5G require millimeter-wave (or mmWave) technology, at the high end of the wireless spectrum. 5G in these frequencies could potentially enable 10-Gbps speeds; however, mmWave signals have a short radius and can be disrupted by common obstacles like trees, buildings and even rain. ISED released its Decision on Releasing Millimetre Wave Spectrum to Support 5G in June of 2019.

To make high frequency deployment practical, carriers must install large numbers of small access points rather than the few large cell towers used for 4G.



To achieve transformative 5G, service providers will need to work with municipal governments to gain access to essential local infrastructure such as streetlights and utility poles as the role of municipalities expands significantly.

True 5G benefits occur when carried at higher frequencies than is widely available in 2021. Higher frequencies will mean faster data transfers and higher capacity. A challenge of this technological advancement is the costly nature of 5G for municipalities.

## 5G Scenarios

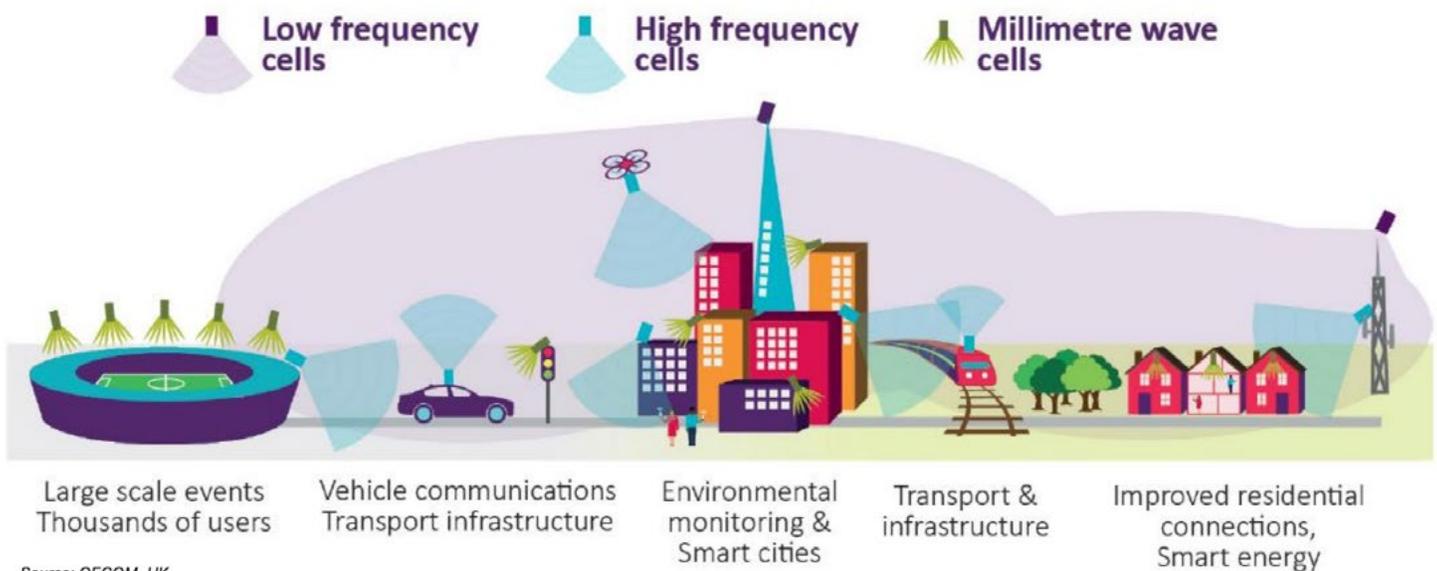


Figure 2. 5G applications with various frequency deployment<sup>8</sup>

<sup>5</sup> Koziol, M. (August 7 2020). 5G Just Got Weird. IEEE Spectrum. Retrieved from <https://spectrum.ieee.org/tech-talk/telecom/standards/5g-release-16> see also <https://www.itu.int/en/mediacentre/Pages/pr26-2020-evaluation-global-affirmation-imt-2020-5g.aspx>

<sup>6</sup> Finley, K., & Peatstein, J. (Sept 10, 2020). The Wired Guide to 5G. Wired. Retrieved from <https://www.wired.com/story/wired-guide-5g/>

<sup>7</sup> Innovation, Science and Economic Development (June 2019). Decision on Releasing Millimetre Wave Spectrum to Support 5G. Retrieved from [https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwap1/SLPB-003-19EN.pdf/\\$file/SLPB-003-19EN.pdf](https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwap1/SLPB-003-19EN.pdf/$file/SLPB-003-19EN.pdf)

<sup>8</sup> Gruppo Tim. (2017). Future use of millimetre waves for 5G Session 9: Towards the WTDC 2017 and WRC 2019. Retrieved from <https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2017/Spectrum%20Management/Simon%20-%20Future%20of%20millimetre%20waves%20in%205G%20v1.1.pdf>

# EVOLVING ENVIRONMENT

5G has great potential, but it is imperative to separate marketing from reality. 5G service offered in Canada in 2021 is a combination of 5G and 4G systems. A true, universal 5G network is still on the horizon.

“Anticipation continues to grow around the introduction of 5G which had been announced throughout 2019. However, limited capital expenditures were reported in 2019, and 5G has yet to be made readily available to Canadians across Canada,” said the 2020 Communications Monitoring Report from the Canadian Radio-television and Telecommunications Commission (CRTC).

The Government of Canada is working to advance 5G. ISED suggested the auction plan for 5G spectrum put forward in 2018 would place Canada in the Top 5 of its international peers in speed of deployment, ahead of countries like Australia or Germany.<sup>9</sup> ISED announced plans for three spectrum auctions by 2021 and deployment was under way in 2020<sup>10</sup>

5G service with major carriers was deployed in cities over spectrum in the 600MHz band and is also available using the 2,500 MHz band for 5G capable phones. The initial deployments had faster speeds but few of the other benefits from 5G. Technology journal PC Mag said in November 2020 “Canadian carriers have installed 5G on channels that they could have used for 4G.”

In 2021, across Canada, Bell, Telus and Rogers are utilizing spectrum primarily used for 4G networks to deliver their initial 5G service. Bell and Telus use the AWS-3 band (1755-1780 MHz and 2155-2180 MHz), while Rogers uses 600MHz and 2,100 MHz, and where it has ownership, 2,500 MHz band.

Higher frequency spectrum, such as the 3,500 MHz spectrum, is expected to be auctioned in Canada in 2021 after a COVID-related delay.

The long-term applications of 5G are still being imagined. The first 4G phones in the U.S. appeared in 2010 but applications with real impact arrived later. 4G enabled technologies, such as Snapchat, came in 2012 and Uber became widespread in 2013. Video conferencing over LTE became widespread around 2013.<sup>13</sup>

A degree of faith is involved when making a generational leap towards new infrastructure and Calgary’s approach involves

## COVID FRIENDLY

Calgary’s public Wi-Fi system had unforeseen benefits during the COVID-19 pandemic. While some municipalities reported people congregating around places to access Wi-Fi during lockdowns, Calgary could offer a wide range of access points and people avoided congregating at limited hotspots that would have caused COVID-19 transmission concerns<sup>12</sup>.



<sup>9</sup> Jackson, B. (June 6, 2018). 5G spectrum auctions to be complete by 2021, says Innovation Minister. IT World Canada. Retrieved from <https://www.itworldcanada.com/article/5g-spectrum-auctions-to-be-complete-by-2021-says-innovation-minister/406006>

<sup>10</sup> Bains, N. (June 6, 2018). Speech: 2018 Canadian Telecom Summit. Retrieved from <https://www.canada.ca/en/innovation-science-economic-development/news/2018/06/2018-canadian-telecom-summit.html>

<sup>11</sup> Langenberg, A. (June 29, 2020). Experts say 5G will eventually deliver, but a speed boost for now. The Wire

Report. Retrieved from <https://www.thewirereport.ca/2020/06/29/experts-say-5g-will-eventually-deliver-but-just-a-speed-boost-for-now/>

<sup>12</sup> Taylor, G., Anderson, K., & Cramer, D. (March, 2021). Municipal digital infrastructure and the COVID-19 pandemic: A case study of Calgary, Canada. Journal of Digital Media & Policy, 1(12).

<sup>13</sup> Segan, S. (2016). What is 5G? PC Magazine. Retrieved from <https://www.pcmag.com/news/what-is-5g>



laying a solid foundation to allow for opportunities for experimentation.

“The advent of 5G will allow entrepreneurs to create new technologies and products that we don’t even know we need yet. Ten years ago, most consumers didn’t have a smartphone; now most can’t live without them,” former U.S. Federal Communications Commissioner (FCC) Robert McDowell wrote in the Wall Street Journal in 2018.

With mobile speeds up to 100 times faster than 4G, 5G could enable driverless cars to avoid accidents, transform medicine through implanted medical devices, and produce smarter cities and energy grids through the Internet of Things (IoT), McDowell wrote. He said countries that build 5G networks first will be in a better position to experiment with and deploy tomorrow’s technologies.<sup>14</sup>

That said, there remain fundamental questions on what constitutes this new technology, and the ensuing social implications remain to be answered. Another FCC commissioner, and current acting FCC Chair Jessica Rosenworcel, wrote in Wired: “The heat-seeking headlines about 5G are hard to resist. But the reality on the ground needs attention, too.”<sup>15</sup> She advised caution and noted the problems of the U.S. rush to high spectrum deployment that offers little to rural regions.

## GREEN WAVE

The 5G Council of Canada, which represents mobile carriers, said in an October 2020 report a 5G network uses about eight to 15 per cent of the electricity of a 4G cell site. The report promises further greenhouse gas reductions from the millimetre-wave spectrum that may reduce energy consumption to one or two per cent of a 4G site.<sup>16</sup>

One indication of the increasing centrality of 5G to the communications industry came in October 2020 when Apple, long a holdout on 5G, announced its new line of iPhones equipped to work in a 5G environment.

<sup>14</sup> McDowell, R. M. (Sept 27, 2018). To Boost 5G, Keep the Industry Free. Wall Street Journal. Retrieved from <https://www.wsj.com/articles/to-boost-5g-keep-the-industry-free-1538088285>

<sup>15</sup> Rosenworcel, J. (June 18, 2019). Choosing the Wrong Lane in the Race to 5G. Wired. Retrieved from <https://www.wired.com/story/choosing-the-wrong-lane-in-the-race-to-5g/#guides:learn:more>

<sup>16</sup> Canadian Wireless Telecommunications Association. (2020). Telecommunications Industry Directly Contributes \$74.5 Billion Annually to Canada’s Economy and Supports 638,000 Jobs. According to New Report Retrieved from <https://www.cwta.ca/>

# 5G: CHALLENGES & OPPORTUNITIES

5G essentially promises three things: better service and speeds, IoT connectivity and latency improvements for critical services.<sup>17</sup> However, the 5G Council of Canada cites three challenges to widespread deployment; significant capital investment; availability of spectrum; and efficient regulations and processes.<sup>18</sup>

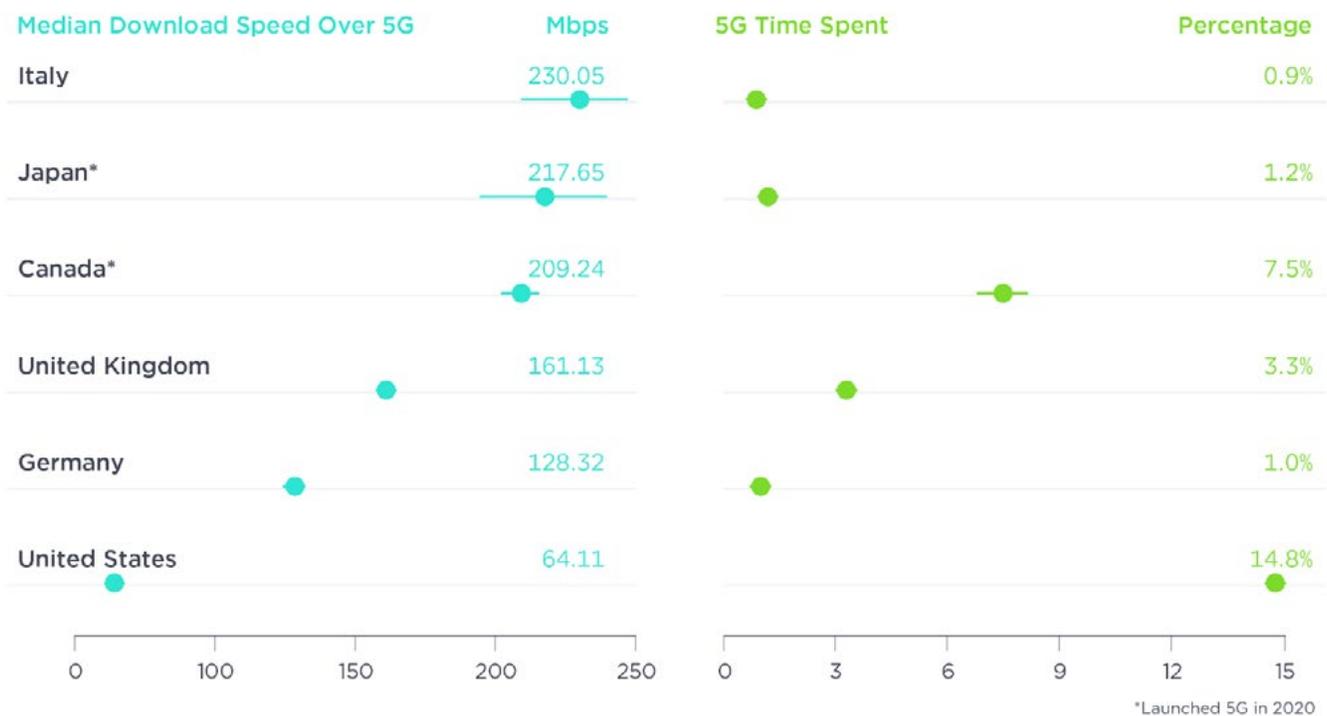
5G proponents cite the interconnection of machines and devices as a primary benefit (connected vehicles are touted as a significant breakthrough) though the technical standard required to make that possible was only finalized in 2020.<sup>19</sup> There is a strong correlation between the functionality of automated vehicles and 5G deployment, but as Forbes Magazine cautioned in 2018: "Autonomous cars will become a reality, but it won't happen until 5G data networks are ubiquitous."<sup>20</sup>

Yet, there is reason to be optimistic about Canadian mobile networks and the potential of 5G. The CRTC reported in 2019 Canadian telecommunication service providers generated more than \$100 million in revenues and spent \$11.9 billion on capital expenditures to upgrade networks, \$8.9 billion of which was spent on wireline networks.<sup>21</sup>

Canada has built impressive internet networks. Telus announced a \$16-billion multi-year investment in Alberta in 2019 and Shaw invested \$20 billion in its network in the last seven years.

Tests conducted in 2020 by Seattle-based Ookla on international 5G performance demonstrates that the 5G offered in Canada stands with some of the best in the world.<sup>23</sup>

## 5G Performance in G7 Countries with 5G in Q3 2020 Speedtest Intelligence® | Q3 2020



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Figure 3. 5G performance comparison in some G7 countries<sup>24</sup>

<sup>17</sup> 5G Council Canada, 5G Primer. Retrieved from <https://www.5gcc.ca/5g-primer/>

<sup>18</sup> Ibid.

<sup>19</sup> Kozlowski, M. (August 7 2020). 5G Just Got Weird. IEEE Spectrum. Retrieved from <https://spectrum.ieee.org/tech-talk/telecom/standards/5g-release-16>

<sup>20</sup> Khosravi, B. (March 25, 2018). Autonomous Cars Won't Work - Until We Have 5G. Forbes. Retrieved from <https://www.forbes.com/sites/bijankhosravi/2018/03/25/autonomous-cars-wont-work-until-we-have-5g/?sh=7f0a2c38437e>

<sup>21</sup> Canadian Radio-Television and Telecommunications Commission. (2020). Communications Monitoring Report. Retrieved from <https://crtc.gc.ca/pubs/cm2020-en.pdf>

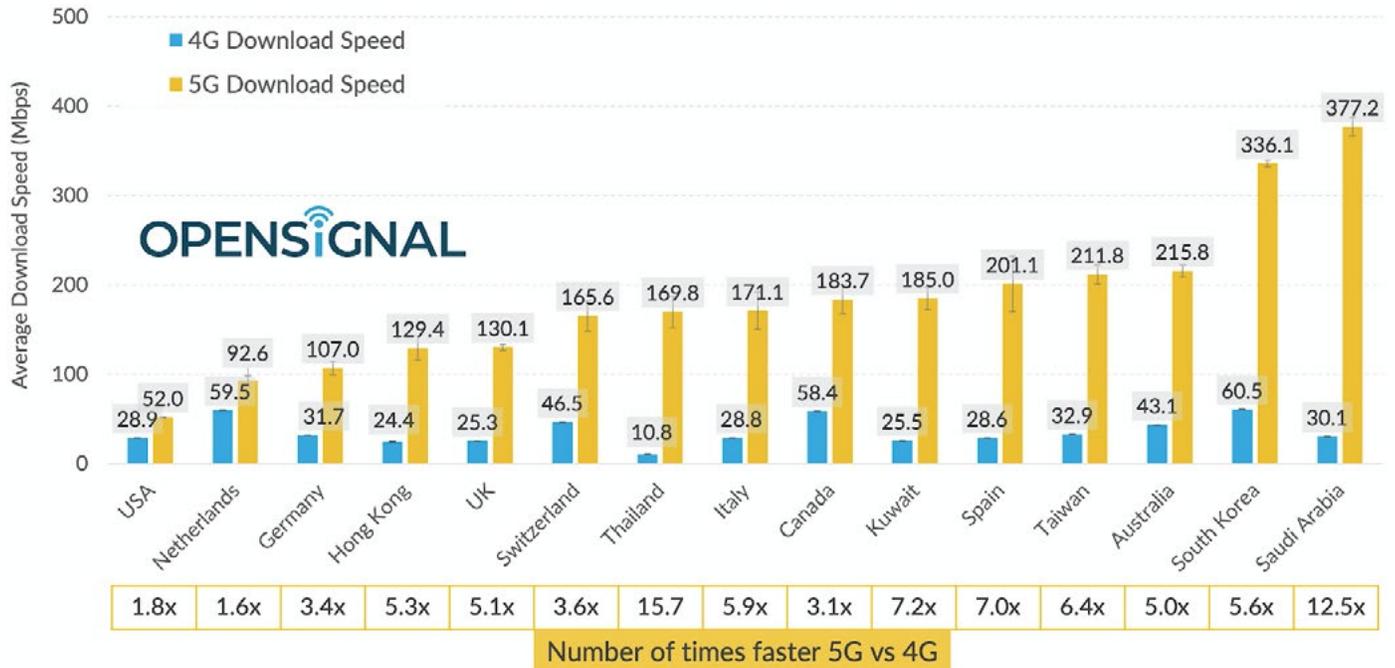
<sup>22</sup> Shaw Communications Inc. (May 27, 2020). Shaw Launches Fibre+ Gig: the Largest Deployment of Gigabit Speeds for Residential Internet Customers in Western Canada [Press release]. Retrieved from <https://www.globenewswire.com/news-release/2020/05/27/2039453/0/en/Shaw-Launches-Fibre-Gig-the-Largest-Deployment-of-Gigabit-Speeds-for-Residential-Internet-Customers-in-Western-Canada.html>

<sup>23</sup> Malik, A. (December 10, 2020). Canada had the third fastest 5G median download speed of G7 countries in 2020: report. Moblesyup. Retrieved from <https://moblesyup.com/2020/12/10/canada-had-the-third-fastest-5g-median-download-speed-of-g7-countries-in-2020-report/>

<sup>24</sup> Ibid.

A 2020 study by London-based Opensignal also placed Canada among the top performers for 5G, far ahead of traditional points of comparison, including the U.S. and U.K.<sup>25</sup>:

## In every country 5G users' real-world download speeds are much faster than 4G



Data collection period July 1 – September 28, 2020

Note: in Canada, Hong Kong, Taiwan & Thailand 5G services are very new and have only launched in 2020.

Figure 4. 5G speeds compared to 4G speeds<sup>26</sup>

### KEY TAKEAWAYS:

1. Without a strong fibre infrastructure, the potentials of 5G cannot be realized.
2. While 5G was launched in Canada in 2020, 5G is a technology in development in 2021.
3. Early 5G development in Canada shows promise.
4. The race to deploy 5G is not about who's first, but about doing it right.
5. 5G may prove to be a key paradigm shift, but we will not know for years.



<sup>25</sup> Fogg, I. (October 13, 2020). Benchmarking the global 5G user experience – October update. Opensignal. Retrieved from <https://www.opensignal.com/2020/10/13/benchmarking-the-global-5g-user-experience-october-update>

<sup>26</sup> Ibid

# CURRENT STATE IN CALGARY

The City of Calgary launched its Digital Strategy in 2015 to provide accessible services; pursue and build partnerships; be transparent; provide platforms for citizens to participate and value innovation. It then released the 2015 Fibre Infrastructure Strategy to support the Digital Strategy and highlighted the criticality of technological innovation in the 2019 economic strategy *Calgary in the New Economy*.

Since 2001, the City has built 550 kilometres of fibre network across all four of its quadrants on City-owned rights of way.<sup>27</sup> Calgary is deemed a non-dominant ISP by the CRTC. It leases access to its fibre but does not provide internet service or network equipment. The fibre remains dark until a service makes use of it.

“Typically, the buildout of broadband infrastructure has been left to the telecoms. But municipalities are closest to their residents and should be empowered to respond to their needs,” wrote consultants KPMG in August 2020 article for the *Globe and Mail*.<sup>28</sup>

Bell, Telus and Rogers say they have Calgary covered by 5G service. Their networks are built upon legacy ADSL copper wires and coaxial cable, complimented by investments in fibre deployment and spectrum licenses. Calgary-based Shaw Communications announced its 5G roll out for early 2021.<sup>29</sup>

## IN CASE OF EMERGENCY

The 2020 City of Calgary Fibre Infrastructure Strategy Annual Update reported: “When a city owns its fibre, it can respond with greater agility during extreme events. This was exemplified during the 2013 flood where a catastrophic loss in network resources was mitigated due to the control, agility and capacity afforded through City fibre.”<sup>30</sup>

It is estimated 80 to 85 percent of the cost of deploying fibre is putting the wire in the ground. In 2015, for example, the cost of installing fibre in Calgary that involved digging up roads was approximately \$200 per metre; whereas installing fibre into an existing conduit was about \$11 per metre.<sup>31</sup>

The City’s Fibre Strategy has been financially beneficial. The City of Calgary Fibre Infrastructure Strategy Annual Update for 2020 reported revenues surpassed the \$1 million threshold in 2019, a 180 per cent increase from 2015 and well above the \$180,000 projected.<sup>32</sup> However, fiscal challenges saw the budget reduced from \$20 million in 2015–2018 to \$8 million for 2019–2022.

## TELEPORTATION DEVICE

Researchers at the University of Calgary demonstrated the teleportation of a light particle’s properties between their lab on campus and the city’s downtown, six kilometres away in 2016.<sup>33</sup> The study received international recognition and would not have been possible without access to a dedicated fibre line.



<sup>27</sup> City of Calgary. (2020). Chief Financial Officer’s Report to Gas, Power and Telecommunications. <https://pub-calgary.escrimetings.com/filestream.ashx?DocumentId=122883> or <https://pub-calgary.escrimetings.com/filestream.ashx?DocumentId=123167>

<sup>28</sup> Benay, A. (August 28, 2020). Why cities are key to a connected Canada. *The Globe and Mail*. Retrieved from <https://www.theglobeandmail.com/business/commentary/article-why-cities-are-key-to-a-connected-canada/>

<sup>29</sup> Shaw Communications Inc. (2021). Shaw Mobile: about 5G. Retrieved from <https://support.shaw.ca/5/mobile-articles/shaw-mobile-about-5g/ta-p/20370>

<sup>30</sup> City of Calgary. (2020). Chief Financial Officer’s Department – Information Technology: Fibre infrastructure strategy annual update. <https://pub-calgary.escrimetings.com/filestream.ashx?DocumentId=122884>

<sup>31</sup> City of Calgary. (December 21, 2015). The City of Calgary – Submission Regarding Notice No. DGTP-002-2015. Petition to the Governor in Council concerning Telecom Regulatory Policy CRTC 2015-326 by Bell Canada. Retrieved from <https://www.ic.gc.ca/eic/site/smt-gst.nsf/waap/DGTP-002-2015-CityofCalgary-Submission.pdf?FILE/DGTP-002-2015-CityofCalgary-Submission.pdf>

<sup>32</sup> City of Calgary. (2020). Chief Financial Officer’s Department – Information Technology: Fibre infrastructure strategy annual update. <https://pub-calgary.escrimetings.com/filestream.ashx?DocumentId=122884>

<sup>33</sup> Fletcher, R. (September 20, 2016). Teleportation across Calgary marks ‘major step’ toward creation of ‘quantum internet’. *CBC News*. Retrieved from <https://www.cbc.ca/news/canada/calgary/calgary-teleportation-quantum-networking-city-hall-1.3770440>

Municipally owned fibre and private fibre infrastructure are not in competition. The City does not provide internet service but does provide broadband access.

Wireless service providers typically build their own 5G infrastructure to ensure network reliability and flexibility to build additional infrastructure in the future. Private businesses can use municipal fibre for testing applications and the City's fibre deployment was created with intentional excess capacity to facilitate future technology developments.<sup>34</sup>

The City's fibre network connects most municipal buildings, civic partners, non-profits and businesses deploying network applications. The City's fibre network manages light rail transit operations and a grid to ensure clean drinking water. It is open access, and the City advertises fibre network speeds and bandwidth capacity are virtually unlimited.<sup>35</sup>

Calgary is one of many cities exploring the creation of innovation districts that are potential 5G innovators.

A 2014 report "The Rise of Innovation Districts" from the Brookings Institution noted "In the United States, districts are emerging near anchor institutions in the downtowns and midtowns of cities like Atlanta, Baltimore, Buffalo, Cambridge, Cleveland, Detroit, Houston, Philadelphia, Pittsburgh, St. Louis and San Diego. They are developing in Boston, Brooklyn, Chicago, Portland, Providence, San Francisco and Seattle where underutilized areas (particularly older industrial areas) are being re-imagined and remade."<sup>36</sup> These districts serve to enable technology ecosystems with a foundation of digital infrastructure to support pilots and testing of new technologies and their applications.

The City is working to create a 5G application test zone in downtown Calgary. In collaboration with wireless service providers, it created guidelines and processes to test 5G, including drafting an open access policy for smaller wireless service providers to access the infrastructure.

In addition to local accelerators including Platform, Harvest Builder, Creative Destructive Labs-Rockies and others, Toronto-based MaRS, North America's largest urban innovation hub, announced it was in talks with the University of Calgary to create a hub to support Alberta's growing innovation economy.<sup>37</sup>

By encouraging experimentation along an extensive dark fibre foundation, Calgary positions itself at the forefront of what is to come.

## IoT SENSORS

Calgary is home to one of North America's First City-owned-Long Range Low Power Wide-Area Network (LoRaWAN). It gives the City, and businesses, an opportunity to experiment with IoT sensors that use LoRaWAN to keep informed of everything from air quality to soil conditions, to river activity.<sup>38</sup> It is a technology advancement that would not happen without the fibre base.



<sup>34</sup> City of Calgary. (2020). Access the City of Calgary's dark fibre. <https://www.calgary.ca/cfod/it/Pages/Dark-fibre.aspx>

<sup>35</sup> Ibid

<sup>36</sup> Katz, B., & Wagner, J. (May, 2014). The Rise of Innovation Districts: A New Geography of Innovation in America. Brookings Institution. Retrieved from <https://www.brookings.edu/essay/rise-of-innovation-districts/>

<sup>37</sup> MaRS. (Sept 23, 2020). MaRS seeking to bring hub model to Calgary to accelerate the innovation economy | Press release. Retrieved from <https://www.marsdd.com/media-centre/mars-seeking-to-bring-hub-model-to-calgary-to-accelerate-the-innovation-economy/>

<sup>38</sup> City of Calgary. (2020). Smart city story: Long range, low power technology. <https://www.calgary.ca/general/smartcity/lorawan.html>

# CALGARY COMPARED WITH CANADIAN CITIES<sup>39</sup>

Based on research for this study, and previous work by the author, the following criteria were used to determine a city's preparedness for development of 5G and overall connectivity.

**Municipal Fibre:** 5G moves at the speed of fibre. Municipal dark fibre is accessible to any party including private business. Municipalities regularly have cause to dig and it reduces a major expense of fibre deployment. Fibre availability is an essential indicator of a municipalities' 5G preparedness.

**Digital Action Plan:** An overarching strategy demonstrates commitment to a coordinated, intentional and comprehensive approach to 5G and connectivity. Strategies often identify critical risks and opportunities presented by 5G and provide confidence a municipality understands how to mitigate and manage these.

The Government of Canada launched the Smart Cities Challenge in 2017, with winners in various categories announced in 2019. Some Canadian cities still cite their Smart City plans as synonymous with a digital strategy; however, for purposes of this comparison, this report did not see Smart City plans as comparable to a clear digital strategy since those plans often were not accompanied by clear policy direction. Still, points from the Smart strategies are discussed in this section.

**Public Wi-Fi Network:** If a city is committed to a digital future, citizens must always be able to access connectivity. Since Canada has consistently high mobile rate costs in international comparisons, a public Wi-Fi network ensures no one is excluded. Public Wi-Fi is indicative of a connected city.

**Local Internet Exchange Point (IXP):** A local IXP ensures data largely avoids the expense and latency time of traveling to a host server in another city or country. Local IXPs can increase response speeds and offer an alternative to data traffic crossing jurisdictional boundaries such as the U.S. border to major exchanges such as Seattle. Public internet exchanges provide open, non-proprietary pathways for data to travel from one point to another.

**5G Policy Process:** A streamlined approach for wireless service providers and other businesses to deploy and test 5G eases administrative challenges, reduces costs and provides certainty. It also signals a municipality is interested in working with businesses, including development of policies, guidelines and processes related to building 5G infrastructure.

In the summer and fall of 2020, interviews were conducted with officials from seven municipalities in Canada. The purpose was to understand where Calgary stood in terms of 5G preparedness and overall municipal connectivity. Each municipality was asked similar questions:

1. Do you have your own municipal fibre?
2. Does your city have a formal digital strategy?
3. Do you have a broad publicly accessible Wi-Fi network?
4. Does the municipal government support the local IXP?
5. What is the permit process for 5G infrastructure access?

## CANADIAN CITIES: Points of Comparison

	Municipal Fibre Network	Digital Action plan or Strategy	Public Wi-Fi network	Municipal relationship with local IXP	5G specific agreement structures with City
Calgary	Yes	Yes	Yes	Yes	Yes
Vancouver	Yes	Yes	Yes	Yes	No
Edmonton	Yes	Yes	Yes	No	No
Winnipeg	No	No	Yes	No	No
Toronto	No	Yes	Yes	No	No
Ottawa	No	Yes	Yes	No	No
Montreal	No	Yes	Yes	No	Yes
Halifax	No	No	Yes	No	No

<sup>39</sup> Significant contributions from University of Calgary PhD student Katelyn Anderson.

# Calgary

Calgary's digital advantages go well beyond its extensive fibre foundation.

Calgary's municipal Wi-Fi network is an effective municipal-private partnership. In 2013, Shaw Communications was selected to construct a publicly accessible Wi-Fi network available to City-owned sites, including recreation facilities, parks and LRT stations.

The non-profit Calgary Internet Exchange (YYCIX) provides a free or low-cost option for community organizations and businesses to increase transfer speeds by increasing the quality and quantity of connections. The City of Calgary hosts some of the exchange's switches in its data centres, and any other entity leasing City fibre can cross-connect at no charge.

"With support from City Fibre Infrastructure, YYCIX has quickly become the fourth largest IX in Canada," said the 2017 Digital Infrastructure Update.<sup>40</sup> "An entire community can benefit from having a local IX ... those benefits include improved internet experience; encouraging competition, including smaller ISPs; lower prices; enhanced security, because traffic stays local; and attracting large technology companies and content providers."<sup>41</sup>

Along with local IXPs, processing of information at data centres is also crucial to reduce latency. In a 2018 article entitled *With 5G on the Horizon, Startups See Potential in Small Data Hubs* the Wall Street Journal noted the growth in "localized data centres to process data quickly for specific towns and neighborhoods".<sup>42</sup> How data centres are locally organized in a city will impact the performance of 5G.

When 13 of Bell's major data centres in Canada, including three in Calgary, were purchased by international group Equinix in 2020<sup>43</sup> Theo de Raadt, Network Manager for YYCIX, said "this is going to make a bigger difference in the internet (in Calgary) over the next four years than anything else that's going to happen."

De Raadt sees strong benefits for smaller and newer service providers offering 5G services which needs fast latency. Companies with relationships with Equinix elsewhere in the world may find it easier to establish in Calgary. The often-invisible elements such as data centres, exchange points and fibre offer a solid foundation for Calgary connectivity.

Calgary is working with wireless service providers on a new process for rapid 5G deployment with a streamlined approach to access City-owned infrastructure.<sup>44</sup> The City and ENMAX Telecommunications Services Inc. are working on a partnership to leverage assets such as streetlight poles and power poles to serve 5G.<sup>45</sup> By its very design, 5G will

require extensive coordination with municipal authorities. For example, access to streetlight posts and other city-owned infrastructure are required to provide the kind of short-radius, high data volume needed to realize the applications of 5G.

Calgary is leading the national movement for a coordinated effort to standardize the policy process of putting 5G infrastructure into the urban environment.



# Vancouver

The City of Vancouver's digital strategy is guided by a Smart Cities plan from a 2019 Infrastructure Canada competition.

The City received significant support when fibre optic cables were installed ahead of the 2010 Olympics and today it owns and operates more than 300 kilometres of fibre connecting more than 200 locations. Where the City does not have fibre, it leases from Telus.

The network has grown since 2015 thanks to a "dig once" program and now installs conduit as part of routine municipal construction. The City also has micro trench fibre built into sidewalks that, while fragile, is low cost to install. It is implementing IoT pilot projects, including using 5G to monitor street lighting, parking metres and locate traffic efficiencies, which includes building a conceptual model for smart vehicles.

Vancouver is the only city other than Calgary that has a formal relationship with its IXP, the Vancouver Internet Exchange (VANIX). The City has a presence within VANIX's main location at Harbour Centre, as well as in smaller subsidiary locations.

The City's public Wi-Fi network has more than 600 sites and has been run at different stages by Telus and Shaw. The City has offered incentives in permitting processes in underserved areas if the carrier includes public Wi-Fi as part of the project. The City is developing its plans to access to city infrastructure for 5G.

<sup>40</sup> City of Calgary. (2017). Chief Financial Officer's Department – Information Technology; Fibre infrastructure strategy annual update. <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=32757>

<sup>41</sup> Ibid

<sup>42</sup> FitzGerald, D. (September 12, 2018). *With 5G on the Horizon, Startups See Potential in Small Data Hubs*. The Wall St. Journal. Retrieved from <https://www.wsj.com/articles/with-5g-on-the-horizon-startups-see-potential-in-small-data-hubs-153680412>

<sup>43</sup> Equinix. (June 1, 2020). *Equinix to Expand Canadian Operations with US\$750 Million Acquisition of 13 Bell Data Center Sites* [Press release]. Retrieved from <https://www.equinix.com/newsroom/press-releases/pr/123952/Equinix-to-Expand-Canadian-Operations-with-US-Million-Acquisition-of-Bell-Data-Center-Sites/>

<sup>44</sup> City of Calgary. (2021). *Wireless infrastructure deployment – submit inquiry*. Retrieved from <https://www.calgary.ca/cs/its/wireless-infrastructure/wireless-infrastructure.html>

<sup>45</sup> City of Calgary. (2020). *Chief Financial Officer's Report to Gas, Power and Telecommunications*. <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=122883> or <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=123167>

## Edmonton

The City of Edmonton owns and operates more than 200 kilometers of fibre but does not lease to third parties. The City operates its network while Edmonton Transit has a separate network. The City sees its role as working with carriers rather than as a broadband service provider.

The City's Digital Action Plan was adopted in 2019 and a further report is due in 2021.<sup>46</sup>

The City's Open City public Wi-Fi network is operated by Shaw, provides 1,100 access points in the city. It is free but, for example, does not permit "Peer to Peer" program (e.g., BitTorrent, KaZaa, Gnutella, Morpheus).<sup>47</sup>

The City of Edmonton does not have a formal relationship with the Edmonton Internet Exchange (YEGIX). In 2020, peers of YEGIX included AXIA Connect, Cybera, Edmonton Public Library, Hurricane Electric, MacEwan University and University of Alberta.

The City is in discussions with telecommunication companies about its 5G permit process, specific to its fee structure and creating a competitive marketplace. It is examining rates, as the smaller 5G antennas do not take up as much real estate as existing infrastructure. However, more are required.

The vast majority of the City is covered by a municipal LoRaWAN that monitors soil moisture, gathers data on pedestrian traffic, provides connectivity to City facilities and traffic intersection signal controls. Rather than 5G, the infrastructure consists of six radio towers that use licensed and unlicensed spectrum frequencies. The project is like the LoRaWAN system in Calgary. The current pilot projects do not require immediate real time communication and positions the city well for the introduction of 5G.



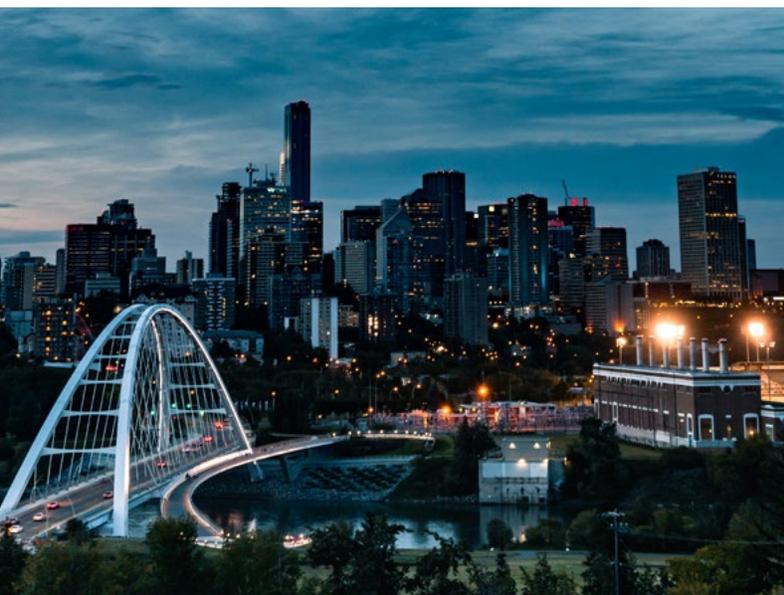
## Winnipeg

Winnipeg does not have its own fibre network, instead it predominantly leases fibre needed to operate. The City had a growing municipal fibre network but lost it when Winnipeg Hydro was bought by Manitoba Hydro in 2002, forcing the City to lease the network. In 2006, Winnipeg built a ring of shallow trench fibre throughout the City. Burying the fibre closer to the surface reduced costs on the initial installation and allowed for easier repair access. However, the repairs were frequent due to road construction and the fibre was vulnerable to extreme temperature changes in Winnipeg. This experience demonstrates the importance of local considerations; a one-size-fits-all strategy for fibre deployment is not always successful.

The Winnipeg Smart Cities was developed in 2018.<sup>48</sup> The strategy acts as a framework to develop a culture of innovation, identify Smart City opportunities and build an overarching digital framework.

Winnipeg's City Wi-Fi has 50 locations with no technical data caps. In addition, Shaw Go has 150 sites in the city. The City piloted free Wi-Fi on buses but discontinued it due to high cost. Winnipeg has two public internet exchanges, but the City does not connect with them or have a formal relationship.

Winnipeg does not have a permitting structure in place for 5G but is working to ensure the permitting process is effective as possible.



<sup>46</sup> City of Edmonton. (2019). Edmonton's Digital Action Plan 2019. Retrieved from [https://www.edmonton.ca/city\\_government/documents/CoE\\_Digital-Action-Plan.pdf](https://www.edmonton.ca/city_government/documents/CoE_Digital-Action-Plan.pdf)  
<sup>47</sup> City of Edmonton. (2021). Open City Wi-Fi. Retrieved from [https://www.edmonton.ca/programs\\_services/open-wifi.aspx](https://www.edmonton.ca/programs_services/open-wifi.aspx)  
<sup>48</sup> City of Winnipeg. (2019). Smart Cities Challenge Proposal. Retrieved from [https://winnipeg.ca/interhom/SmartCitiesChallenge/CoW-Smart\\_Cities.pdf](https://winnipeg.ca/interhom/SmartCitiesChallenge/CoW-Smart_Cities.pdf)



## Toronto

Toronto's digital action plan is not a formal document but consists of two pieces of strategy. One looks at internal processes, such as how the City can leverage data, guard against siloed decision making, and inform day-to-day decisions. The other revolves around digital infrastructure, including developing a strategy to enable coordinated response to outside proposals.

The City cites Toronto's competitive marketplace for internet service providers as why it has not offered its own municipal network. Most Torontonians have access to the CRTC's minimum speeds (50 megabytes per second download, 10 mbps upload) but affordability is sometimes a challenge.

The City has a limited public Wi-Fi network. Wi-Fi is available at a handful of civic centres, parts of public transit and City-owned recreation centres. Public libraries offer their own public Wi-Fi.

Toronto launched a low-income Wi-Fi project in 2020 with free internet access for 25 buildings across the city. With contributions from Cisco and Bell, it is implementing a fixed wireless system, by running fibre to rooftops and installing access points aimed at buildings.

Toronto has Canada's largest public internet exchange, TORIX, but the City does not have a formal relationship with the IXP. It also does not have a dedicated procurement process for 5G access but is looking to address rights-of-way concerns created by 5G.

In January 2021, Toronto launched a proposal to build a broadband network called ConnectTO similar to what Calgary developed over two decades to complement private service providers by filling gaps in fibre connectivity to underserved areas.

## Ottawa

The City of Ottawa does not own a substantial municipal network, but has some fibre assets, including for traffic operations as well as fibre owned by Hydro Ottawa. While there is "a lot of legend of dark fibre" due to the growth of Nortel in the 1990s, it is not prevalent and is already being utilized.

Ottawa's Smart City Strategy includes plans to assess the state of connectivity and provide a framework to ensure residents and businesses have access to affordable, high-speed internet. The plan was updated in 2019, introducing Open Ottawa Beta, a public data portal.

Ottawa is unique as much of the population of the Capitol Region is rural, which poses a challenge for delivering high-speed internet service. There is less incentive for investment as customers are spread out. Low band 5G has been discussed as a potential solution to solving rural connectivity issues.

Ottawa has a public Wi-Fi program, which is offered at 30 locations, including municipal recreation centres, as well as public Wi-Fi available at public libraries. It also has free public Wi-Fi on train platforms, operated by Telus.

Ottawa does not have a formal relationship with its public internet exchange, National Capital Internet Exchange, operating as Ottawa-Gatineau Internet Exchange. Ottawa is working on its 5G permitting process as carriers currently apply under the existing rights-of-way permit process.



## Montreal

Montreal is seen as a leader in 5G development. The City of Montreal won Infrastructure Canada's first Smart Cities challenge in 2019, which came with a \$50 million investment. The City's digital action plan, launched in 2015, calls for funding to fast-track fibre-to-the-home, an inventory of the City's available fibre and real-time transit data for citizens.<sup>49</sup>

The City does not have its own municipal network, but leases most of the fibre it uses. It has launched a review to reevaluate its existing fibre assets and future business plan.

Montreal has a large public Wi-Fi network that is a partnership between the municipality and ZAP and has 850 access points. The network is an evolution of non-profit, Ils Sans Fil, one of Canada's first public Wi-Fi networks. With the City's involvement, they reduce costs by building the fibre for Wi-Fi connection while doing municipal construction.

Montreal does not have a formal relationship with its public internet exchange, the non-profit Montreal Internet Exchange.

Montreal is working with providers to test 5G, gain insight into the technology and right-of-way permitting for 5G. The City is working in collaboration with Encqor, funded by the federal government, Quebec and Ontario, to create an open platform to test 5G technology and use cases. Encqor includes the City, university research centres and entrepreneurs to identify use cases and find solutions to challenges that arise as a consequence of 5G.

Montreal also has a pilot project zone downtown where it is testing 5G infrastructure. The aim is to create a "drag and drop" permitting solution to install 5G antennas on City infrastructure.



## Halifax

Halifax is assessing its fibre assets. While the city owns some dark fibre, the process aims to get a better sense of the state of municipal network infrastructure. The municipality's plan to create a report aimed at building a digital strategy was delayed by COVID-19 related budget cuts in 2020.

The City's Municipal Public Wi-Fi initiative has 10 locations, which are operated by Bell. In addition, the public Wi-Fi is available at Halifax Public Libraries. Halifax has an internet exchange, HFXIX, which has been operating since 2014, however the City does not have a formal relationship with it.

There is no dedicated permit process for 5G infrastructure and the City deals with requests on a case-by-case basis. Central to the City's review process is assessing the public versus commercial benefits for the technology.

## KEY TAKEAWAYS

1. Calgary is the only city in this survey that scored positively in all criteria.
2. There is intense competition to attract high tech industries and strategies for 5G and digital development vary greatly.
3. A city's connectivity options are more limited without a municipally owned fibre foundation.
4. There is no one-size-fits-all strategy. Local considerations must be factored into planning.
5. A city benefits from essential infrastructure elements including a formal relationship with the local internet exchange and data centres to support 5G.



<sup>49</sup> Montréal. (May 2015). Montréal: Smart and Digital City. Retrieved from <https://laburbain.montreal.ca/sites/villeintelligente.montreal.ca/files/plan-action-bvinn-ce-6-mai-2015-eng.pdf>

# CONCLUSION: BECOMING “CANADA’S MOST CONNECTED CITY”

There is no one path to building a connected city that provides opportunity for growth and experimentation in new mobile technologies, but there is strong reason to conclude Calgary is positioned to act as a centre for 5G development and application.

Calgary has a wealth of digital riches: excess fibre capacity allows more smaller or middle-size players to have more choice to reach wider locations or build up infrastructure they require. The City also assists with clear regulations and processes.

Calgary has an opportunity to make the claim to be Canada’s most connected city. In the past two decades, it demonstrated remarkable policy and process foresight that makes it an attractive place to develop 5G technologies and applications. As the comparisons with other Canadian cities demonstrate, Calgary is well positioned among its urban peer group.

The wireless world is changing rapidly and new opportunities are emerging.

The COVID-era has demonstrated that geographic proximity to the industrial centre of the digital world was no longer a central concern for a great number of workers. What matters is the quality of life and the ability to access reliable digital infrastructure.

In January 2021, a New York Times story headlined They Can’t Leave the Bay Area Fast Enough, chronicled the rapid movement of high-tech companies from the San Francisco area in search of better standards of living for employees.<sup>50</sup>

Perhaps some will look north, considering Canada was listed #1 for quality of life in a 2020 study by U.S. News and World Report, particularly being popular with millennials. Calgary has ranked in the top five most liveable cities in the world for each of the past 10 years in The Economist Intelligence Unit’s Global Liveability Index. In 2019, it was named the most liveable city in North America and fifth most livable in the world.<sup>52</sup>

However, none of these accolades will matter unless Calgary has the foundation to support a growing tech sector. There is still much work to do: in one 2020 study, Calgary ranked 51st of 100 cities worldwide in emerging ecosystems for business start-up opportunity.<sup>53</sup>

Calgary is also hardly alone in trying to attract new digital business opportunities.

For years, the City of Calgary has been making decisions to put itself at the forefront of Canadian municipal digital infrastructure with great opportunities for growth. Given the direct relationship between 5G and fibre, Calgary’s wealth of privately developed and municipally owned options should be attractive to potential 5G-based digital industries.

Calgary has positioned itself in such a way as to offer real strength and innovation in the development of 5G. The foundation is here. As this report demonstrates, there is ample evidence to say Calgary is a leading Canadian city in 5G preparedness and overall connectivity.

## KEY RECOMMENDATIONS

1. **Build for the future, not just 5G.** The underlying technology must be generationally agnostic. 6G is already in development.<sup>54</sup>
2. **Municipalities must be recognized for their essential role in getting this right.** 5G will have a major impact on municipal infrastructures such as streetlights and utility poles. Cities need a unified voice and a seat at the table with other orders of government for decisions that affect them.
3. **Government has a role to play; private sector infrastructure should not be the only option.** Partnerships with industry can work when municipalities work with the WSPs to develop guidelines and policies related to 5G, as the City of Calgary continues to do. Policy foresight is essential and this has been exemplified in Calgary.
4. **Dig once.** It is unfortunate we are still saying this in 2021. Fibre is cheap, digging is expensive.
5. **Adopt an “if you build it, they will come” philosophy.** There are no guarantees of success, however, without a solid technological and administrative foundation, there is little chance of making your city into a location of choice.

<sup>50</sup> Bowles, N. (January 14, 2021). They Can’t Leave the Bay Area Fast Enough. New York Times. Retrieved from <https://www.nytimes.com/2021/01/14/technology/san-francisco-covid-work-moving.html>

<sup>51</sup> U.S. News. (2020). Overall Best Countries Ranking. Retrieved from <https://www.usnews.com/news/best-countries/overall-rankings>

<sup>52</sup> Kaufmann, B. (September 4, 2019). Calgary edges out Vancouver and Toronto to rank as world’s fifth most livable city: the Economist. Calgary Herald. Retrieved from <https://calgaryherald.com/news/local-news/calgary-edges-out-vancouver-and-toronto-to-rank-as-worlds-fifth-most-liveable-city-the-economist>

<sup>53</sup> Startup Genome. (2020). Rankings 2020: Top 100 Emerging Ecosystems. Retrieved from <https://startupgenome.com/ecosystems/calgary>

<sup>54</sup> Segan, S. (December 11, 2020). What is 6G? PC Magazine. Retrieved from <https://www.pcmag.com/news/what-is-6g>

# LIST OF REFERENCES

1. Federal Communications Commission. (Jan 15, 2021) First Phase of Record-Breaking 5G Spectrum Auction Concludes. <https://www.fcc.gov/document/first-phase-record-breaking-5g-spectrum-auction-concludes>
2. Canadian Radio-Television and Telecommunications Commission. (2020). Communications Monitoring Report. Retrieved from <https://crtc.gc.ca/pubs/cm2020-en.pdf>
3. 5G Council Canada. 5G Primer. Retrieved from <https://www.5gcc.ca/5g-primer/>
4. Ofcom. (2021). What is 5G? Retrieved from <https://www.ofcom.org.uk/phones-telecoms-and-internet/advice-for-consumers/advice/what-is-5g>
5. Koziol, M. (August 7 2020). 5G Just Got Weird. IEEE Spectrum. Retrieved from <https://spectrum.ieee.org/tech-talk/telecom/standards/5g-release-16> see also <https://www.itu.int/en/mediacentre/Pages/pr26-2020-evaluation-global-affirmation-imt-2020-5g.aspx>
6. Finley, K., & Pealstein, J. (Sept 10, 2020). The Wired Guide to 5G. Wired. Retrieved from <https://www.wired.com/story/wired-guide-5g/>
7. Innovation, Science and Economic Development (June 2019). Decision on Releasing Millimetre Wave Spectrum to Support 5G. Retrieved from [https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/SLPB-003-19EN.pdf/\\$file/SLPB-003-19EN.pdf](https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/SLPB-003-19EN.pdf/$file/SLPB-003-19EN.pdf)
8. Gruppo Tim. (2017). Future use of millimetre waves for 5G Session 9: Towards the WTDC 2017 and WRC 2019. Retrieved from <https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2017/Spectrum%20Management/Simoni%20-%20Future%20use%20of%20millimetre%20waves%20in%205G%20v1.1.pdf>
9. Jackson, B. (June 6, 2018). 5G spectrum auctions to be complete by 2021, says Innovation Minister. IT World Canada. Retrieved from <https://www.itworldcanada.com/article/5g-spectrum-auctions-to-be-complete-by-2021-says-innovation-minister/406006>
10. Bains, N. (June 6, 2018). Speech: 2018 Canadian Telecom Summit. Retrieved from <https://www.canada.ca/en/innovation-science-economic-development/news/2018/06/2018-canadian-telecom-summit.html>
11. Langenberg, A. (June 29, 2020). Experts say 5G will eventually deliver, but a speed boost for now. The Wire Report. Retrieved from <https://www.thewirereport.ca/2020/06/29/experts-say-5g-will-eventually-deliver-but-just-a-speed-boost-for-now/>
12. Taylor, G., Anderson, K., & Cramer, D. (March, 2021). Municipal digital infrastructure and the COVID-19 pandemic: A case study of Calgary, Canada. *Journal of Digital Media & Policy*, 1(12).
13. Segan, S. (2016). What is 5G? PC Magazine. Retrieved from <https://www.pcmag.com/news/what-is-5g>
14. McDowell, R. M. (Sept 27, 2018). To Boost 5G, Keep the Industry Free. Wall Street Journal. Retrieved from <https://www.wsj.com/articles/to-boost-5g-keep-the-industry-free-1538088285>
15. Rosenworcel, J. (June 18, 2019). Choosing the Wrong Lane in the Race to 5G. Wired. Retrieved from <https://www.wired.com/story/choosing-the-wrong-lane-in-the-race-to-5g/?GuidesLearnMore>
16. Canadian Wireless Telecommunications Association. (2020). Telecommunications Industry Directly Contributes \$74.5 Billion Annually to Canada's Economy and Supports 638,000 Jobs, According to New Report Retrieved from <https://www.cwta.ca/>
17. 5G Council Canada. 5G Primer. Retrieved from <https://www.5gcc.ca/5g-primer/>
18. Ibid.
19. Koziol, M. (August 7 2020). 5G Just Got Weird. IEEE Spectrum. Retrieved from <https://spectrum.ieee.org/tech-talk/telecom/standards/5g-release-16>
20. Khosravi, B. (March 25, 2018). Autonomous Cars Won't Work - Until We Have 5G. Forbes. Retrieved from <https://www.forbes.com/sites/bijankhosravi/2018/03/25/autonomous-cars-wont-work-until-we-have-5g/?sh=7f0a2c38437e>
21. Canadian Radio-Television and Telecommunications Commission. (2 20). Communications Monitoring Report. Retrieved from <https://crtc.gc.ca/pubs/cm2020-en.pdf>
22. Shaw Communications Inc. (May 27, 2020). Shaw Launches Fibre+ Gig: the Largest Deployment of Gigabit Speeds for Residential Internet Customers in Western Canada [Press release]. Retrieved from <https://www.globenewswire.com/news-release/2020/05/27/2039453/0/en/Shaw-Launches-Fibre-Gig-the-Largest-Deployment-of-Gigabit-Speeds-for-Residential-Internet-Customers-in-Western-Canada.html>

23. Malik, A. (December 10, 2020). Canada had the third fastest 5G median download speed of G7 countries in 2020: report. Mobilesyrupt. Retrieved from <https://mobilesyrupt.com/2020/12/10/canada-had-the-third-fastest-5g-median-download-speed-of-g7-countries-in-2020-report/>
24. Ibid.
25. Fogg, I. (October 13, 2020). Benchmarking the global 5G user experience – October update. Opensignal. Retrieved from <https://www.opensignal.com/2020/10/13/benchmarking-the-global-5g-user-experience-october-update>
26. Ibid.
27. City of Calgary. (2020). Chief Financial Officer’s Report to Gas, Power and Telecommunications. <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=122883> or <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=123167>
28. Benay, A. (August 28, 2020). Why cities are key to a connected Canada. The Globe and Mail. Retrieved from <https://www.theglobeandmail.com/business/commentary/article-why-cities-are-key-to-a-connected-canada/>
29. Shaw Communications Inc. (2021). Shaw Mobile: about 5G. Retrieved from <https://support.shaw.ca/t5/mobile-articles/shaw-mobile-about-5g/ta-p/20370>
30. City of Calgary. (2020). Chief Financial Officer’s Department – Information Technology: Fibre infrastructure strategy annual update. Retrieved from <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=122884>
31. City of Calgary. (December 21, 2015). The City of Calgary - Submission Regarding Notice No. DGTP-002-2015, Petition to the Governor in Council concerning Telecom Regulatory Policy CRTC 2015-326 by Bell Canada. Retrieved from [https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/DGTP-002-2015-CityofCalgary-Submission.pdf/\\$FILE/DGTP-002-2015-CityofCalgary-Submission.pdf](https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/DGTP-002-2015-CityofCalgary-Submission.pdf/$FILE/DGTP-002-2015-CityofCalgary-Submission.pdf)
32. City of Calgary. (2020). Chief Financial Officer’s Department – Information Technology: Fibre infrastructure strategy annual update. <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=122884>
33. Fletcher, R. (September 20, 2016). Teleportation across Calgary marks ‘major step’ toward creation of ‘quantum internet’. CBC News. Retrieved from <https://www.cbc.ca/news/canada/calgary/calgary-teleportation-quantum-networking-city-hall-1.3770440>
34. City of Calgary. (2020). Access the City of Calgary’s dark fibre. Retrieved from <https://www.calgary.ca/cfod/it/Pages/Dark-fibre.aspx>
35. Ibid.
36. Katz, B., & Wagner, J. (May, 2014). The Rise of Innovation Districts: A New Geography of Innovation in America. Brookings Institution. Retrieved from <https://www.brookings.edu/essay/rise-of-innovation-districts/>
37. MaRS. (Sept 23, 2020). MaRS seeking to bring hub model to Calgary to accelerate the innovation economy [Press release]. Retrieved from <https://www.marsdd.com/media-centre/mars-seeking-to-bring-hub-model-to-calgary-to-accelerate-the-innovation-economy/>
38. City of Calgary. (2020). Smart city story: Long range, low power technology. <https://www.calgary.ca/general/smartcity/lorawan.html>
39. Significant contributions from University of Calgary PhD student Katelyn Anderson.
40. City of Calgary. (2017). Chief Financial Officer’s Department – Information Technology: Fibre infrastructure strategy annual update. <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=32757>
41. Ibid.
42. FitzGerald, D. (September 12, 2018). With 5G on the Horizon, Startups See Potential in Small Data Hubs. The Wall St. Journal. Retrieved from <https://www.wsj.com/articles/with-5g-on-the-horizon-startups-see-potential-in-small-data-hubs-153680412>
43. Equinix. (June 1, 2020). Equinix to Expand Canadian Operations with US\$750 Million Acquisition of 13 Bell Data Center Sites [Press release]. Retrieved from <https://www.equinix.com/newsroom/press-releases/pr/123952/Equinix-to-Expand-Canadian-Operations-with-US-Million-Acquisition-of-Bell-Data-Center-Sites/>
44. City of Calgary. (2021). Wireless infrastructure deployment – submit inquiry. Retrieved from <https://www.calgary.ca/cs/iis/wireless-infrastructure/wireless-infrastructure.html>
45. City of Calgary. (2020). Chief Financial Officer’s Report to Gas, Power and Telecommunications. <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=122883> or <https://pub-calgary.escribemeetings.com/filestream.ashx?DocumentId=123167>

46. City of Edmonton. (2019). Edmonton's Digital Action Plan 2019. Retrieved from [https://www.edmonton.ca/city\\_government/documents/CoE\\_Digital-Action-Plan.pdf](https://www.edmonton.ca/city_government/documents/CoE_Digital-Action-Plan.pdf)
47. City of Edmonton. (2021). Open City Wi-Fi. Retrieved from [https://www.edmonton.ca/programs\\_services/open-wifi.aspx](https://www.edmonton.ca/programs_services/open-wifi.aspx)
48. City of Winnipeg. (2019). Smart Cities Challenge Proposal. Retrieved from [https://winnipeg.ca/interhom/SmartCitiesChallenge/CoW-Smart\\_Cities.pdf](https://winnipeg.ca/interhom/SmartCitiesChallenge/CoW-Smart_Cities.pdf)
49. Montréal. (May 2015). Montréal: Smart and Digital City. Retrieved from <https://laburbain.montreal.ca/sites/villeintelligente.montreal.ca/files/plan-action-bvin-ce-6-mai-2015-eng.pdf>
50. Bowles, N. (January 14, 2021). They Can't Leave the Bay Area Fast Enough. New York Times. Retrieved from <https://www.nytimes.com/2021/01/14/technology/san-francisco-covid-work-moving.html>
51. U.S. News. (2020). Overall Best Countries Ranking. Retrieved from <https://www.usnews.com/news/best-countries/overall-rankings>
52. Kaufmann, B. (September 4, 2019). Calgary edges out Vancouver and Toronto to rank as world's fifth most livable city: the Economist. Calgary Herald. Retrieved from <https://calgaryherald.com/news/local-news/calgary-edges-out-vancouver-and-toronto-to-rank-as-worlds-fifth-most-liveable-city-the-economist>
53. Startup Genome. (2020). Rankings 2020: Top 100 Emerging Ecosystems. Retrieved from <https://startupgenome.com/ecosystems/calgary>
54. Segan, S. (December 11, 2020). What is 6G? PC Magazine. Retrieved from <https://www.pcmag.com/news/what-is-6g>