OCTOBER 2021

Future Proof:

Connecting Post-Pandemic Canada

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TABLE OF CONTENTS

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ABOUT PPF

Good Policy. Better Canada. The Public Policy Forum builds bridges among diverse participants in the policy-making process and gives them a platform to examine issues, offer new perspectives and feed fresh ideas into critical policy discussions. We believe good policy is critical to making a better Canada—a country that's cohesive, prosperous and secure. We contribute by:

- Conducting research on critical issues
- Convening candid dialogues on research subjects
- Recognizing exceptional leaders

Our approach—called **Inclusion to Conclusion**—brings emerging and established voices to policy conversations, which informs conclusions that identify obstacles to success and pathways forward. PPF is an independent, non-partisan charity whose members are a diverse group of private, public and non-profit organizations.

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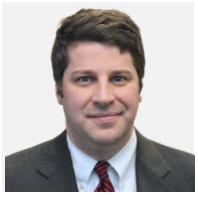
Peter has served in numerous posts in government, business, science and higher education. His varied public service career included positions as head of policy in the Office of the Prime Minister, and Special Advisor to the Secretary-General of the Organization for Economic Cooperation and Development (OECD) in Paris. He retired in 2010 as the founding president of the Council of Canadian Academies, an organization created to support expert panels that assess the science relevant to issues of public importance. Peter Nicholson is a member of both the Order of Canada and the Order of Nova Scotia.



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DENISE WILLIAMS

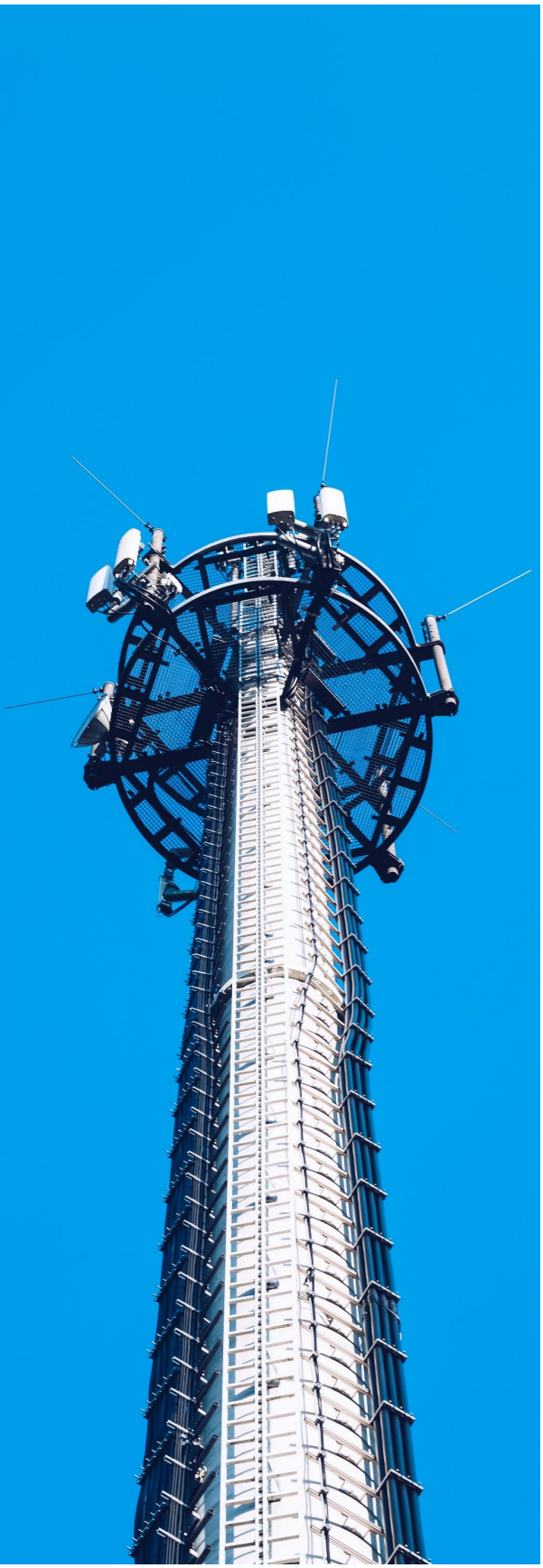
Denise Williams is Chief Executive Officer of the First Nations Technology Council. At the intersection of Indigenous sovereignty, technological advancement and a rapidly expanding technology and innovation economy, Denise has the privilege of working with Indigenous peoples, governments, academics, technology futurists and social change makers to map an ecosystem that will result in fair and equitable access to the tools and education required to lead digital transformation in the 21st century. Denise leads a theory of change that aims to ensure Indigenous peoples are leading in Canada's technology and innovation sector, and in building new connected economies.

THE PROCESS

In January 2021, the Public Policy Forum (PPF) launched a results-oriented process to map a future for Canada's digital infrastructure. As far back as the October 2016 report, titled Building the Future: Strategic Infrastructure for Long-Term Growth in Canada, PPF has wanted to broaden the interpretation of infrastructure to include digital infrastructure, which increasingly influences our future opportunity and prosperity. PPF's concerns have only been amplified through our pandemic project, Rebuild Canada.

PPF convened an expert panel to work with a broad array of relevant parties, including an advisory council, to produce a report focused on the opportunity of digital infrastructure. The expert panel's objective is to answer the question: What public policy measures are needed to ensure that Canada's digital connectivity infrastructure fully supports an inclusive, competitive post-pandemic economy?

PPF wishes to thank the expert panelists for their dedicated and thoughtful work on this report. PPF would also like to thank Dr. Catherine Middleton and Michelle D'Auray for their contributions. This report would not have been possible without the support of Clare Walker, writer of the report. Special thanks to the advisory council members, project sponsors and many experts who shared their time and knowledge with the panel and helped make this project happen.



EXECUTIVE SUMMARY

Two years after the federal government's release of a national connectivity strategy, Canada's need for high-quality digital infrastructure is more critical than ever. The COVID-19 pandemic demonstrated what happens when everyone is not given equal opportunity to participate in the digital economy, access education and essential public services, and be connected socially.

Connectivity is essential for a competitive economy that is increasingly reliant on data collection and flows, for access to services that are moving inexorably to digital platforms, and for nation-building. Digital connectivity plays a fundamental role in enabling communities to thrive economically and socially throughout Canada's vast geography. We must view digital connectedness as a right of citizenship—much the way we have historically viewed roads, postal service, electric power and basic telephone service.

In this paper we ask: What public policy measures are needed to ensure that Canada's digital connectivity infrastructure fully supports an inclusive, competitive post-pandemic economy? The answer is framed by what we believe are the two most significant issues:

1. Should Canada set a new goal for broadband Internet access to replace the current 50/10 minimum and, if so, what should the new goal be?
2. What public policy measures, if any, are needed to ensure that Canadian businesses and consumers obtain the full benefits of fifth generation (5G) wireless technology?

THE STATE OF DIGITAL CONNECTIVITY IN CANADA

In 2019, more than 1.9 million Canadian households lacked access to 50/10 residential Internet service.

Market forces are largely relied on in Canada to provide digital connectivity. But market forces alone have failed to provide the necessary high-speed Internet service to small or remote areas where customer density is insufficient to cover the cost.

In 2019, more than 1.9 million Canadian households (about 13 percent of the total) lacked access to 50/10 residential Internet service (broadband Internet speeds of at least 50 Mbps for downloads and 10 Mbps for uploads). Of those, more than 90 percent were in rural areas and a further 7 percent were in small communities. Urban Canada is virtually fully covered. There is considerable variation among the provinces and territories, reflecting differences in the proportion of populations in rural and small communities, and varying provincial and territorial government priorities.

Fewer than 35 percent of households on First Nations reserves had access to 50/10 in 2019. As is the case with many necessities of Canadian life, Indigenous Peoples are among the least well served with respect to Internet access. The federal government must engage with Indigenous Peoples on expanding broadband in their communities and on Indigenous ownership of broadband networks.

In October 2018, federal, provincial and territorial ministers agreed on the principles of a Canadian broadband strategy that represented a paradigm shift in approach—from broadband improvements via increments to a chosen access standard supported by an integrated national strategy. Action to universalize the 50/10 minimum standard has kicked into high gear, headlined by the federal government's commitment of $7.2 billion, and likely a comparable total from provincial and territorial governments and private sector partners. The federal government projects that access to at least 50/10 will be available to 90 percent of Canadian households by the end of 2021, to 98 percent by 2026 and to 100 percent by 2030.

A NEW OBJECTIVE FOR UNIVERSAL DIGITAL CONNECTIVITY

What's next? The 50/10 minimum standard is already largely obsolete given the widespread availability of much higher speeds in response to customer demand. Experience has shown that the appetite for Internet speed is virtually insatiable. Applications push bandwidth limits and greater bandwidth enables new apps in a self-reinforcing spiral that so far shows no limit.

Is a new numerical target higher than universal 50/10 therefore needed?

We believe that Canada should not set a new numerical minimum target. That is because, in a regime focused on a specific minimum target, Canadians in large population centres—who will always have access to the latest connectivity technology—will inevitably be at a relative advantage compared to the more dispersed population that would be assured only the minimum. This is unacceptable given the ever-increasing importance of digital connectivity, since unequal access translates into increasing disadvantage for certain areas and for certain groups of Canadians. For a service as essential as digital connectivity, and as was formerly the case with electric power and telephone service, all Canadians should be provided access to essentially the same quality of digital connectivity regardless of where they happen to live.

We recommend that:

Canada commit to universal provision of future-proof digital connectivity infrastructure—connectivity that is scalable, so it can support data rates that far exceed the needs that can be foreseen today.

We propose a universal connectivity objective—the percentage of homes and businesses with affordable access to future-proof digital infrastructure—that would give virtually every Canadian access to essentially the same capability, whether residing downtown in a major city or a remote Indigenous community.

Future proofing implies infrastructure that can accommodate the requirements of future applications through scaling up to higher speed and reliability at relatively low incremental cost. While no technology can be completely future proof, the pragmatic standard would be fibre to the home (FTTH) or its equivalent—i.e. a data pipe that can be scaled up with software and optoelectronics to provide almost unlimited capacity. It already appears that most of the new build to accomplish the 50/10 objective actually provides FTTH.

Market forces will continue to extend the footprint of future-proof bandwidth but will need to be augmented with public funds—a precedent already set with the continuing 50/10 rollout. In 2019, 61 percent of Canadian households had access to gigabit Internet service—i.e. upgraded cable or fibre to the home. It is reasonable to expect that the current trajectory of investment could provide future-proof FTTH to as much as 95 percent of Canadian households within the decade. The momentum that has now been established must continue and intensify.

Providing access to the equivalent of FTTH to every Canadian cannot be achieved at an acceptable cost with fibre to the last far-flung households. Assuming that FTTH may not be feasible for roughly 5 percent of households—about 700,000 to 800,000 homes—future proofing, in practical terms, will depend on a combination of fixed wireless access (using 5G technology) and the emerging generation of globe-spanning low-earth-orbit (LEO) satellites, such as Telesat's Lightspeed and SpaceX's Starlink. Although neither of

these wireless technologies can equal optical fibre, they have the potential to provide gigabit-per-second transmission to residential customers in sparsely populated areas.

Access to infrastructure in this paper refers to availability. But availability without affordability effectively means no access. The primary policy lever to promote affordable telecommunications services is to foster competition that will provide discipline regarding price-setting and service quality. In cases where governments provide subsidies to service providers, competitive pricing can be made a requirement. Such measures need to be complemented with broader policies and programs that raise income levels or provide income support to overcome poverty.

ACHIEVING CANADIAN LEADERSHIP IN 5G ACCESS AND APPLICATION

The rollout of the 5th generation of wireless has begun in earnest. It is forecast that, by the end of 2025:

- More than 40 percent of the world population will live in areas covered by 5G.
- 5G will account for more than 20 percent of global mobile Internet connections.
- More than 80 percent of mobile capital expenditure will be devoted to 5G.

Previous generations of mobile wireless (1G to 4G) primarily served person-to-person communications. 5G is industrial grade with the bandwidth and reliability to support mission-critical enterprise applications and demanding consumer uses. Its technical features will enable the Internet of Things (IoT) and applications that require very quick response (low latency) and fail-safe reliability in business and public services—e.g. telemedicine, autonomous vehicles, smart cities, automation of factories and precision farming. In short, 5G will create value where large volumes of data are generated and communicated—which is to say virtually everywhere in the economy and society of the future.

5G is a general purpose technology—an enabler of capabilities and of industries, much as electric power and digital computing were and are. 5G wireless should therefore be regarded as a strategic technology for Canada. More specifically, 5G will be essential to leverage the growing dominance of the so-called "intangibles economy"—where value resides in data, software, intellectual property, etc. In particular, 5G connectivity is emerging as one of the essential capabilities by which data is transformed into value. This justifies the use of public policy to support both 5G deployment and the firm-level adoption of new technologies that it will enable.

Private-sector investment has given Canada excellent connectivity infrastructure where profitability objectives could be met. But market forces alone will not achieve the full economic and social potential of 5G. Standing in the way are two market failures:

1. High-quality wireless geographic coverage is still not provided on all reasonably well-travelled roadways in Canada; and a 5G upgrade is likely to be much delayed in many smaller and remote communities.
2. Business and institutional users will invest in 5G applications only if the connectivity infrastructure exists, whereas the relevant 5G infrastructure investment can be justified only alongside a reasonable assurance of customer demand. Things risk remaining stuck at the starting line, especially given the long-standing reluctance of many Canadian businesses to lead in technology adoption.

The strategic question facing Canada today is: Will we be among the eventual leaders in 5G or will we be content to be a follower?

We recommend that:

Canada implement a national strategy to be among the global leaders in 5G with action by government to remove roadblocks on both the supply and demand sides.

Actions to encourage the early supply of 5G connectivity are primarily in three areas:

1. **Network rollout:** Some subsidies will be needed to ensure expanded geographic coverage and early buildout in small and remote communities. There is a powerful synergy between 5G provision and future-proof Internet access. This is because the extension throughout the country of fibre and LEO constellations such as Telesat's provides the backhaul capacity needed by 5G networks, while 5G-powered fixed wireless can provide future-proof Internet connectivity in many places where fibre cannot reach. The functionality of wired and wireless connectivity is converging, with 5G as a major step towards providing the equivalent of fibre through the air.
2. **Spectrum allocation:** Canada should allocate spectrum for 5G more nearly in step with the U.S. than is currently the case. In addition, the design of the 5G spectrum allocation process must take into account requirements to make the best use of 5G technology—e.g. by providing contiguous blocks of spectrum to support the highest speed. Spectrum policy should balance the objective to promote competition with the need to maintain the incentive to invest in new technology for which market returns are uncertain at the outset.
3. **Access to structures:** 5G implementation requires extensive access to poles, buildings and trenches—passive infrastructure—since large numbers of installed antennas are required to compensate for the short range of the signal when communicating at very high speed. Proactive measures to encourage co-operation in access to passive infrastructure will be needed to support the national 5G strategy.

The foregoing supply-side dimension of the strategy must be complemented with initiatives to strengthen the demand for innovative applications of 5G from industry and institutional sectors. The following are recommended:

- **Pre-competitive infrastructure to support development**—Many of the required steps are already being undertaken. For example, the governments of Canada, Ontario and Quebec, with industry partners, have invested $400 million to create a test bed infrastructure (ENCQOR) that is enabling hundreds of Canadian SMEs to develop 5G technologies and applications, and remove barriers to commercialization. Such initiatives need to be extended nationally and funded at increasing levels, including allocation of at least 5 percent of the proceeds of the recent 3.5 GHz spectrum auction ($450 million).
- **Pan-Canadian leadership**—A national 5G strategy requires the leadership of a 5G strategic advisory group with representation from equipment suppliers, service providers, key user sectors, as well as research and consulting fields.

INTRODUCTION

"Ensuring universal access to high-speed Internet and mobile wireless networks is essential for long-term economic growth, innovation, and social progress for all Canadians across the country, and fundamental to success in the modern digital world."

—Federal, Provincial and Territorial Ministers for Innovation and Economic Development on Connectivity, October 2018

Two years after the federal government's release in 2019 of a national connectivity strategy, the need for a reliable, high-quality digital infrastructure for Canada is more critical than ever. The COVID-19 pandemic has driven Canadians online to work, learn, shop, receive health care, be entertained, and stay in touch with families and friends. We have witnessed, in a compressed period, what happens when everyone is not given equal opportunity to participate in the digital economy, to access education and essential public services, and to be connected socially when in-person interactions are not possible. And the radical acceleration of the digital revolution is not slowing down. Canada is not going back to the pre-COVID world. As the economy and society recover, we must be deliberate and inclusive in how we shape the ongoing digital transformation to power economic competitiveness and enhance the well-being of every Canadian.

This paper addresses the present status and future prospects of digital connectivity infrastructure—the means by which digital information is transmitted electronically. It encompasses wireline and wireless methods of transmission delivered by the traditional telcos, cable companies, independent Internet service providers (ISPs), regional and new entrants, other non-incumbents and satellite operators.

Specifically, we ask: What public policy measures are needed to ensure that Canada's digital connectivity infrastructure fully supports an inclusive, competitive post-pandemic economy? The answer is framed by what we believe are the two most significant questions:

1. Should Canada set a new goal for broadband Internet access to replace the current 50/10 minimum and, if so, what should the new goal be?[1]
2. What public policy measures, if any, are needed to ensure that Canadian businesses and consumers obtain the full benefits of 5th generation (5G) wireless technology?

THE IMPORTANCE OF DIGITAL CONNECTIVITY

Before turning to broadband goals and 5G rollout, it is important to establish why digital connectivity is critical for Canada. Digital information—i.e. all forms of data encoded as 1s and 0s—is becoming the lifeblood of economies and societies, and is still in the early stages of development. We may think of a digital "infosphere" metaphorically as a global nervous system with microchips as neurons and the infrastructure of digital connectivity, analogous to axons and synapses, binding it all together.

More specifically, digital connectivity is essential for:

- A competitive, well-performing economy that is increasingly reliant on data collection and flows that interconnect people with one another and with machines, and machines with other machines.
- Access to services, both public and privately delivered (e.g. online education, telehealth, remote work, e-commerce, online entertainment) that are moving inexorably to digital platforms, potentially providing more efficient and widespread availability. The COVID-19 pandemic, by forcing much of the working world online, demonstrated the everyday potential of digital connectivity and underlined the necessity of equitable access to the capability. Post-COVID Canada will be an even more digitally connected Canada.
- Nation-building, due to the essential role of connectivity in enabling economically and socially viable communities throughout Canada's vast geography. Digital connectivity, by eliminating many of the barriers of time and distance, can permit more Canadians to choose where they wish to live and can facilitate community building from sea to sea to sea.

It follows that, in the 21st century, ubiquitous digital connectedness is essential the way roads, postal service, electric power and basic telephone service have historically been considered essential and thus have come to be seen as rights of citizenship. That is how digital connectedness must be seen today.

THE STATE OF DIGITAL CONNECTIVITY IN CANADA

To provide all Canadians with universal and affordable access to high-speed Internet and mobile wireless networks, the connectivity infrastructure must be:

- ☑ of high quality in terms of speed, reliability and resiliency
- broadly accessible throughout Canada
- affordably priced for service that meets a necessary standard

This paper deals primarily with issues related to the provision of physical access to digital connectivity. Affordability is also vitally important and can be addressed in part by public policy and programs for infrastructure provision—e.g. measures to foster competition among service providers, and incentives or requirements to provide affordable tiers of service. Such measures also need to be complemented with broader policies and programs that increase income or provide income support and help to overcome poverty.

PROVIDING DIGITAL CONNECTIVITY INFRASTRUCTURE

Market forces are largely relied on in Canada to provide digital connectivity, whereas, formerly, traditional telephone infrastructure and service was provided as a regulated monopoly.[2] In the Internet era, market competition has provided considerable discipline regarding price-setting, service quality and coverage, for reasons summarized in Box 1.

BOX 1: THREE FACTORS THAT STIMULATE COMPETITION IN THE INTERNET ERA

- **Technology characteristics inherent in Internet connectivity—i.e. the fact that the control and routing of digital information on networks employing the Internet Protocol is highly decentralized, whereas the traditional telephone network was built around massive central switches owned by regional monopoly providers (today's incumbent telcos). By contrast, the Internet enables the basic connectivity infrastructure to be shared among a variety of Internet service providers (ISPs).**
- **Facilities-based competition between the incumbent telcos and cable companies, each of which had separate networks that could be upgraded to provide very high bandwidth individual connections. The cable companies began with high-bandwidth connectivity to carry broadcast signals, whereas the telcos substantially upgraded their copper wire networks, which had been designed for low-bandwidth voice calls. The core of today's networks employs ultra-high bandwidth optical fibre.**
- **Regulatory policy that enabled new entrants and regional players to compete in specific markets. Maintaining competitive digital connectivity markets requires constant oversight and regulatory innovation.**

Market forces require constant regulatory and policy oversight in the face of the extraordinary pace of innovation in digital communications. Principal continuing areas of contention relate to the price of mobile service, the price and terms of access by smaller competitors to incumbents' connectivity infrastructure, and the provision of set-asides of wireless spectrum to support competition in certain market areas. These issues are the subject of a great deal of regulatory debate before the CRTC and Innovation, Science and Economic Development Canada (ISED). They involve detailed and often highly technical considerations that are largely beyond the scope of this paper.

Table 1 provides a summary profile of the Canadian telecommunications industry and its evolution between 2015 and 2019.

Table 1: Statistical profile of the Canadian telecommunications industry		
	2015	**2019**
Total industry revenue ($ billion)	**$47.8**	**$54.1**
Mobile share	49.5%	53.2%
Fixed Internet share	20.5%	25.0%
Other (e.g. local and long distance)	30.0%	21.8%
Market share (percentage of revenue)		
Large incumbent telcos	61.1%	56.7%
Cable-based carriers	31.3%	35.3%
Other facilities-based providers	4.1%	4.3%
Wholesale-based providers	3.5%	3.7%
Capital expenditure ($ billion)		
Wireline services	$8.2	$8.9
Mobile services	$2.2	$2.9
Spectrum purchases [a]	$3.0	$3.5
EBITDA margin (percentage of revenue)[b]		
Wireline services	35.0%	36.8%
Mobile services	44.6%	44.2%

Notes:

a. Spectrum investment varies substantially from year to year depending on the amount made available, e.g. total spectrum investment from 2015 through 2019 was $7.2 billion, of which 90 percent was in 2015 and 2019. The auction in the 3.5 GHz band in June 2021 (to support new 5G services) attracted investment of $8.9 billion.

b. Earnings before interest, taxes, depreciation and amortization (EBITDA) as a percentage of revenue—essentially the operating profit margin. Capital-intensive industries tend to have high EBITDA to cover relatively high depreciation and amortization of capital.

Source: 2020 Communications Monitoring Report (CRTC)

The data in Table 1 show that the large incumbents retain a great deal of market power owing to economies of scale and scope, as well as ownership of much of the underlying connectivity infrastructure—e.g. the large telco and cable companies captured 92 percent of industry revenue in 2019, the same share as four years

earlier. However, on a segmented basis, the picture is more nuanced. For example, the incumbent telcos lost revenue share between 2015 and 2019, while absolute revenue was almost flat at about $30 billion. Meanwhile, cable companies, which include several regional players, saw share increase by four percentage points and dollar revenue grow 27 percent to more than $19 billion in 2019. The mobile market share of those that are not the big three of Bell, TELUS and Rogers has grown modestly, from 8.1 percent to 9.8 percent from 2015 to 2019. In the fixed-Internet segment, where cable companies are considered incumbents, wholesale-based ISPs have grown their revenue share from 7.6 percent to 9.4 percent and absolute revenue by about 70 percent to almost $1.3 billion in 2019. Nevertheless, the overall picture is of a concentrated market, which is typically the case in capital-intensive industries.

A dynamic balance needs to be struck between regulation to promote competition and service reach, and maintaining the incentive to invest in evolving technology.

So far, the industry in Canada has invested heavily—about $10 to $12 billion annually (before wireless spectrum purchases). This is among the highest investment intensities, both per capita and as a percentage of revenue, among G7 countries.[3] As a result, Canada has among the best-quality networks for both broadband and mobile wireless. In fact, the incumbents typically compete on network quality criteria, often describing their networks as the fastest, but leaving out the fine print as to what, precisely, that means.[4]

Due to Canada's large and unique geography, market forces alone cannot deliver the necessary high-speed Internet connectivity to small or remote areas, where customer density is insufficient to recover the cost of connectivity infrastructure at a generally affordable price. Mobile service, meanwhile, is almost universally available to individuals: 96 percent of the population had access to the latest 4G service (4G LTE-A) in 2019. But geographic coverage is limited to areas of sufficient subscriber density. For example, while 88.8 percent of major roads and highways had 4G coverage in 2019, the quality of service is sometimes spotty (one bar). In view of Canada's growing reliance on mobile communications, improved coverage and reliability will need public policy support in situations where market forces alone fail to stimulate the required investment.

In the case of fixed-line broadband Internet service, governments have established, as an objective, a basic standard of service: access to at least 50 megabits per second (Mbps) download and 10 Mbps upload—the 50/10 minimum standard.[5] In Canada, this is currently deemed to be a universal requirement. It must be emphasized, however, that the physical availability of 50/10 does not imply that the service is necessarily being delivered to any particular household. Reasons for non-subscription vary, including affordability, which is discussed later.

Table 2 displays statistics on 50/10 connectivity in 2019, broken down in percentage terms by province and community size. To interpret the figures in terms of numbers of households, of the approximately 15.4 million households in Canada (2016 Census):

54 percent were in large centres (over 100,000 population)

9 percent in medium population centres (30,000–100,000)

13 percent in small centres (1,000–30,000)

21 percent in rural areas

If one assumes that the 2016 Census distribution was relatively little changed in 2019, the percentages in Table 2 show that approximately 1.94 million households lacked access to the minimum 50/10 standard. Of these, about 91 percent were in rural areas and a further 7 percent in small communities. Urban Canada is virtually fully covered.

Table 2: Availability of 50/10 Mbps with unlimited data

Percentage of households in Canada, 2019

Province/Territory	All	Large centres	Medium centres	Small centres	Rural	First Nations reserves
British Columbia	93.5	99.9	99.9	96.0	62.5	68.3
Alberta	87.8	99.7	99.2	94.5	33.2	19.6
Saskatchewan	71.1	100.0	99.9	88.7	23.9	1.7
Manitoba	73.0	98.7	100.0	81.0	14.4	2.0
Ontario	87.7	99.5	98.8	94.4	30.5	16.1
Quebec	91.8	99.8	99.8	95.2	65.2	62.8
New Brunswick	81.2	99.7	99.7	99.7	63.6	92.9
Nova Scotia	78.4	99.9	n/a	98.6	52.4	44.1
Prince Edward Island	61.3	n/a	100.0	100.0	33.3	30.4
Nfld. and Labrador	73.9	99.9	n/a	90.9	49.6	0.0
Territories	0.0	n/a	n/a	0.0	0.0	0.0
Canada	**87.4**	**99.6**	**99.4**	**93.1**	**45.6**	**34.8**

Large, medium and small centres have populations in the ranges of 100K+, 30-100K and 1-30K, respectively.

Source: 2020 Communications Monitoring Report

Table 2 also shows that while 87.4 percent of Canadian households[6] had 50/10 service in 2019, there was considerable variation among the provinces, reflecting in part differences in the proportion of population in rural and small communities. For example, 50/10 coverage in PEI, Saskatchewan and Manitoba was well below the national average at 61.3 percent, 71.1 percent and 73 percent, respectively. But the rural proportion cannot be the only factor explaining provincial variation. Although only 45.6 percent of rural households nationally had access to 50/10, the proportions in Manitoba (14.4 percent) and Saskatchewan (23.9 percent) were much lower due at least in part to the widely dispersed population in agricultural areas. Provincial government priorities would likely also have played a role in the regional variation across Canada.

Indigenous Peoples are among the least well served, particularly in Saskatchewan and Manitoba where only about 1.7 percent and 2 percent on reserves had access to 50/10 Internet in 2019.

The 2016 Census reported 134,000 First Nations households. In 2019, only 34.8 percent of households on First Nations reserves had access to 50/10, implying that approximately 90,000 were without. In addition, ISED estimates that 10,000 to 20,000 Inuit households do not have the 50/10 option. As is the case with many necessities of Canadian life, Indigenous Peoples are among the least well served with respect to Internet access, particularly in Saskatchewan and Manitoba where, in 2019, only 1.7 percent and 2 percent on reserves had access to 50/10. Meanwhile, in BC, Quebec and the Atlantic Provinces, access to 50/10 on First Nations reserves was roughly equal to the rural percentage.[7]

Box 2 provides one example of how an Indigenous community can operate its own high-speed network once connectivity is provided. There will be many other models of ownership and management of digital connectivity infrastructure, depending on circumstances and priorities that vary widely among Indigenous communities. The common requirement is that Indigenous Peoples not be placed at any disadvantage with respect to Canada's connectivity opportunities.[8] The federal government must engage with Indigenous Peoples on expanding broadband in Indigenous communities and on Indigenous ownership of broadband networks.

BOX 2: SIOUX VALLEY DAKOTA NATION, MB: COMMUNITY-OWNED/OPERATED BROADBAND

In 2010, the Sioux Valley Dakota Nation (SVDN), a community of 1,400 people in Manitoba with little to no connectivity, set out to build community broadband. It began by buying equipment, one item at a time, over several years. Dakota NET, a locally operated wireless ISP, became responsible for equipment and network operation, connecting customers, billing and maintenance.

To preserve its self-governance model, the community owns and operates every piece of infrastructure—from wires and fibre optics to broadband towers. This structure is now self-sustaining; the network pays for itself, services are kept affordable, and revenue generated remains in the community.

Since 2010, Internet speeds have gone from 512/256 kbps to 100 Mbps+ symmetrical speeds and beyond. The community is now able to tap into new economic opportunities and attract new businesses, while the lives of residents have improved significantly. For example, during COVID-19, they were able to access remote schooling and telehealth.

"It has absolutely created jobs," says Thunderbird-Sky, Dakota NET's manager. "We're going through a large growth phase right now—we're running fibre to every house in our community." The project will take place over the summer to future proof the community's network, and it will also provide jobs and training for summer students. "I found that the growth we've experienced has been extremely sustainable and manageable," he says. "Change is good, but change you can manage is better."

THE PARADIGM SHIFT IN GOVERNMENT SUPPORT FOR DIGITAL CONNECTIVITY

Governments in Canada were slow to foresee the true extent of the economic, social and cultural importance of digital connectivity. While the need for faster Internet and mobile service and broader coverage was promoted within industry and bureaucratic circles, public-sector funding was limited. It was not until late 2016 that the CRTC formally stated what had become obvious: that high-speed Internet access, and specifically at least the 50/10 standard, was necessary for people to fully access the economic and cultural benefits of the digital age.

Still, almost two years passed before federal, provincial and territorial ministers agreed (on October 26, 2018) on the principles of a Canadian broadband strategy to improve competitiveness and address the digital divide. This represented a paradigm shift in approach—from broadband improvements via increments to a chosen access standard supported by an integrated national strategy. Since then, action to universalize the 50/10 minimum has kicked into high gear, headlined by the federal government's 2019 Connectivity Strategy together with a number of federal and provincial funding commitments. These include Ottawa's Universal Broadband Fund (UBF), recently increased to $2.75 billion and having attracted some 1,900

applications by March 31, 2021. Table 3 itemizes $7.2 billion of federal government-related commitments since 2016 in support of universal 50/10 access.

Table 3: Broadband funding in Canada since 2016 to achieve 50/10 [a]

	$ million
Connect to Innovate	585
Universal Broadband Fund (UBF)	2,750
CRTC Broadband Fund [b]	750
Telesat capacity purchase [c]	600
Canada Infrastructure Bank (CIB) [d]	2,000
Other (various Infrastructure Funds) [e]	approx. 500
Subtotal: Federal sources (approximate)	**7,185**
Provincial and private investment [f]	6,500–8,000
Approximate total	**13,500–15,000**

Notes:

a. Funding spent or committed since 2016. Some funds can also support mobile in underserved areas. An earlier program, Connecting Canadians, provided $240 million but was not targeted on universal 50/10.
b. Funded by a levy on telecommunications companies.
c. Purchase of LEO capacity for satellite-dependent areas. Ontario has also partnered with Telesat to purchase capacity. Separately, Canada and Quebec have financially supported launch of Telesat's forthcoming "Lightspeed" satellite service with investments of $1.44 billion and $400 million, respectively, in the form of loans and equity.
d. Earmarked for lending (at a subsidized rate) by CIB, to be combined with funds from other sources (e.g. grants from UBF and private lending).
e. Rural and Northern Communities stream of Investing in Canada Infrastructure Program; First Nations Infrastructure Fund.
f. This estimate is very approximate and includes, for example, commitments totalling about $4.5 to $5 billion by Ontario and Quebec, support from several other provinces and private investment leveraged by public co-funding to achieve the universal 50/10 objective.

As noted earlier, there were approximately 1.9 million households—mostly rural and remote—still without 50/10 connectivity in 2019. The cost to close the gap is impossible to estimate precisely and rises very steeply to reach the final few percent. We have roughly estimated $13.5 to $15 billion as the amount spent or committed since 2016 by federal and provincial sources together with related private-sector investment.[9] This is considerably greater than previous estimates of $6 to $10 billion to reflect the facts that optical fibre is increasingly being connected directly to the home (Box 3) and there is now an expectation of better and more extensive mobile coverage. (While the latter is not directly related to the 50/10 Internet objective, it is

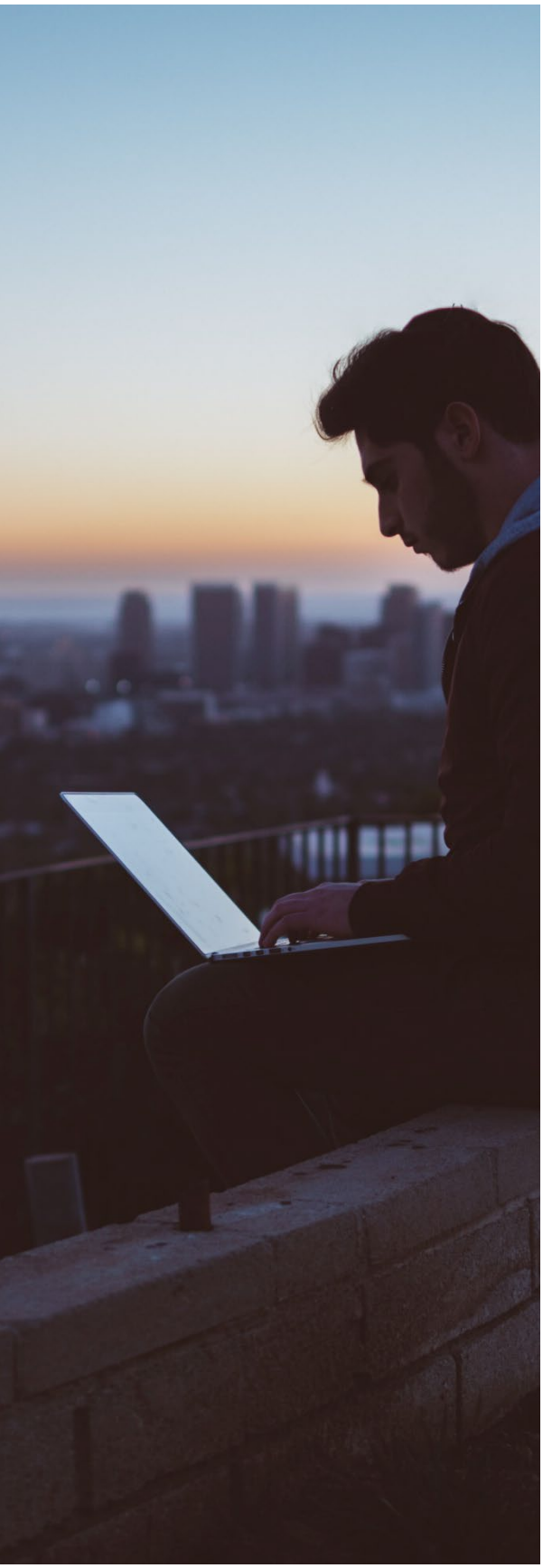
nevertheless integral to the national connectivity strategy.) The federal government projects that access to 50/10 will be available to at least 90 percent of Canadian households by the end of 2021, to 98 percent by 2026 and to 100 percent by 2030.

BOX 3: BRINGING BROADBAND TO RURAL NEW BRUNSWICK

In March 2021, the federal government announced more than $686,000 in funding—through the Rapid Response Stream of the Universal Broadband Fund (UBF)—to bring high-speed Internet to residents of Grand Manan Island, off the New Brunswick coast in the Bay of Fundy. This was augmented with almost $85,000 from Proximity Fiber, a new fibre to the home (FTTH) Internet service for rural communities delivered by Crave Technologies, which was already providing Internet service on the island.

Grand Manan's residents had complained about spotty cell coverage and Internet quality, speed and price for 20 years. These issues were magnified with the onset of the pandemic, with residents needing dependable connections for work, learning and medical care, and to enable small businesses to move online.

Proximity Fiber will offer baseline packages with speeds of 1,000 Mbps for both download and upload to 346 underserved households. It aims to supercharge and increase the bandwidth of its existing service by accessing the fibre-optic portions of the undersea power cables that were installed by NB Power in 2019 to connect the islands of Grand Manan, Campobello and Deer Island. Soon, residents of Grand Manan will be able to leapfrog several generations of technology and have future-proof Internet access equal to the best available anywhere.



A NEW OBJECTIVE FOR UNIVERSAL DIGITAL CONNECTIVITY

Assuming that the plan to achieve universal 50/10 is completed within the currently projected timeframe (e.g. 98 percent by 2026), what's next? Canadians living in cities and in many smaller communities already have access to far higher speeds—often 100 Mbps or more (Table 4). It is significant that most of those who already have access to 50/10—even in rural areas and on First Nations reserves—actually have access to 100 Mbps and above. This is a result of the trend to bring fibre as close as possible to the residence when access is being extended to underserved areas. For example, while only 34.8 percent of First Nations households had 50/10 access in 2019, almost all (93 percent) had access to at least 100 Mbps.

Table 4: Internet service speed by community size

Percentage of households in Canada with access (2019)

		Community size				
Available service speed	**Canada**	**Large**	**Medium**	**Small**	**Rural**	**First Nations**
10 Mbps +	97.2%	99.9%	99.9%	99.3%	87.1%	74.5%
50/10 (unlimited data) +	87.4%	99.6%	99.4%	93.1%	45.6%	34.8%
100 Mbps +	86.0%	99.4%	99.2%	91.1%	40.8%	32.5%

Source: 2020 Communications Monitoring Report

Before the pandemic, average monthly data use in Canada increased by 27 percent in one year, while average download speed increased by 40 percent—a trend that will inevitably continue.

The 50/10 minimum standard—although sufficient for most current uses[10] —is already largely obsolete given public expectations and the widespread availability of much higher speeds. Experience in Canada and abroad has shown that the demand for Internet speed is virtually insatiable. Applications like high-definition movie streaming and home videoconferencing, together with growing numbers of Internet-connected devices, are combining to take advantage of whatever new communications capability innovators make available. Applications push bandwidth limits, and greater bandwidth enables new apps in a self-reinforcing spiral that so far shows no limit. Although some bandwidth-hungry applications (like massive multi-player video gaming) may appear frivolous, they are often at the cutting edge of commercial investment in innovation because they drive revenue. Ultimately, they give rise to technology that enables vitally important services in areas of education, health and the workplace, as our experience with COVID has shown. Even before the pandemic, average monthly data use in Canada increased by 27 percent in one year, from 210 gigabytes per subscriber in 2018 to 265 GB in 2019, while average download speed increased by 40 percent, from 126 to 177 Mbps—a trend that has been witnessed worldwide and will inevitably continue.[11]

IS A NEW NUMERICAL TARGET HIGHER THAN UNIVERSAL 50/10 THEREFORE NEEDED?

The argument for an explicit target is that, unless there are defined commitments and accountability, other priorities for time and budget tend to predominate. The dilemma is that digital technology will continue to evolve rapidly. So, should we keep promulgating new minimum bandwidth standards—e.g. supplant 50/10

with 100/20—in an effort to keep everyone abreast of the rapidly evolving frontier of connectivity technology? Or should we take another path?

On balance, we believe that Canada should not set a new minimum numerical target for connection speed. That is because, in a regime focused on a specific minimum target, Canadians in large population centres—who will always have access to the latest connectivity technology—will be at a relative advantage compared to the more dispersed population. In other words, the tortoise would never catch up with the hare. That is unacceptable since, in view of the ever-increasing importance of digital connectivity, unequal access translates into increasing disadvantage for certain areas and for certain groups of Canadians. For a service as essential as digital connectivity, and as was formerly the case with electric power and telephone service, all Canadians should be provided access to essentially the same quality of service with respect to reliability and speed, regardless of where they happen to live. The 50/10 minimum does not deliver that.

We recommend that:

Canada commit to universal provision of future-proof digital connectivity infrastructure—connectivity that is scalable so it is capable of supporting data rates that far exceed needs that can be foreseen today.

The concept of future proofing implies infrastructure that can be readily scaled up to provide higher speed and reliability at relatively low incremental cost—e.g. once optical fibre is connected to the residence (which is the really expensive step), the connectivity services it can accommodate can be scaled up virtually without limit with successive generations of software and opto-electronics.[12] We are proposing a universal connectivity objective that will give virtually every Canadian access to essentially the same capability—whether they reside downtown in a major city or in a remote Indigenous community. The relevant metric would be the percentage of homes and businesses—regardless of location—with affordable access to future-proof digital communications technologies. This approach sidesteps the conundrum of setting a sequence of specific moving numerical targets for Internet access speed.

Although no technology can be completely future proof, the pragmatic standard would be fibre to the home (FTTH) or its equivalent—i.e. a data pipe that can be scaled up to provide almost unlimited capacity. It appears that most of the new build to accomplish the 50/10 objective actually provides FTTH (Box 3, above). It is essential that fibre continue to be extended to as many communities and households as possible to provide not only future-proof speed, but also very high reliability and low ongoing maintenance costs. Meanwhile, fixed wireless and satellite technologies can be expected to evolve to provide near-to-fibre experience in cases where FTTH would be prohibitively expensive to provide.

So, while FTTH clearly satisfies the future-proof connectivity objective, any connection (whether wired or wireless) that can reliably deliver approximately one gigabit per second to a household is sufficiently future

proof for practical purposes through the foreseeable future. We emphasize, however, that the essence of future-proof infrastructure is its scalability at relatively low incremental cost rather than any specific speed target. Scalable infrastructure, like FTTH, can accommodate higher and higher speeds in response to the requirements of future generations of applications.[13] So, while gigabit speed may be the marketing focus today, that may eventually be superseded and future-proof infrastructure will, by definition, accommodate.

Market forces will continue to extend the footprint of future-proof connectivity, but will need to be augmented with public funds as is being done with the 50/10 rollout.

ACHIEVING UNIVERSAL FUTURE-PROOF CONNECTIVITY

Market forces will continue to extend the footprint of future-proof connectivity but will need to be augmented with public funds as is being done with the 50/10 rollout. It was already the case in 2019 that 61 percent of Canadian households had access to gigabit Internet service, which included upgraded cable or fibre to the home.[14] The cable footprint covers close to 85 percent of Canadian households and will support gigabit speed within the next couple of years since this can be achieved at low cost wherever there is existing cable service. This is prompting competitive FTTH builds by telcos within their footprint, as well as in areas where they had not previously been present.

As Table 5 shows, residents of Ontario and the Atlantic Provinces who had 50/10 access in 2019 were actually very likely to have access to gigabit speeds. For example, 81.1 percent of New Brunswick households had gigabit access—only a shade fewer than the 81.2 percent that had at least 50/10. In Ontario, the gap was slightly larger: 87.7 percent with 50/10 versus 83.1 percent with gigabit access. The gap was significantly larger in Quebec and the four western provinces. For example, while 71.1 percent of households in Saskatchewan had 50/10 access in 2019, there was essentially no gigabit access. That said, where 200 Mbps was offered in 2019, the infrastructure was generally gigabit capable. Although commercial service at that speed may not yet be offered (due to business decisions by the service provider), it is expected to be introduced over time.

Clearly there is work to be done to provide all Canadians with future-proof Internet access—connectivity essentially equivalent to FTTH. The market will continue to support investment in the upgrade where customer density warrants, and most subsidized projects now being undertaken to fulfil the 50/10 objective will actually deliver FTTH. It is reasonable to expect, therefore, that the current trajectory of investment could provide future-proof FTTH or equivalent to approximately 95 percent of Canadian households within the decade. While this is a stretch goal, it is not unrealistic considering current trends and the fact that, even in remote areas, power and telephone lines could accommodate stringing fibre, thus significantly reducing installation costs. New construction, including resource projects, should provision fibre routinely during general infrastructure installation. Providing FTTH to 95 percent of households would be a remarkable

achievement in view of Canada's vast and challenging geography—a 21st century analogue of the nation-binding transcontinental railway almost a century and a half ago. The momentum that has now been established must continue and intensify.

Table 5: Percentage of households with gigabit access (2019)

Internet Service Speed	50/10+	200 Mbps+	Gigabit/sec
British Columbia	93.5	92.6	57.7
Alberta	87.8	81.8	33.5
Saskatchewan	71.1	56.8	0
Manitoba	73.0	64.2	12.1
Ontario	87.7	84.9	83.1
Quebec	91.8	86.5	54.2
New Brunswick	81.2	81.1	81.1
Nova Scotia	78.4	78.1	75.9
Prince Edward Island	61.3	60.3	59.3
Nfld. and Labrador	73.9	73.1	68.8
Canada	**87.4**	**83.6**	**61.1**

Source: 2020 Communications Monitoring Report

Providing universal access to the future-proof equivalent of FTTH will nevertheless be challenging, both technically and fiscally. Within the foreseeable future, it cannot be achieved at acceptable cost with fibre to every last far-flung household. On the assumption that FTTH will not be feasible for roughly 5 percent of households—about 700,000 to 800,000 thousand homes—future proofing will depend on a combination of fixed wireless access and LEO satellite coverage (Box 4).

Since FTTH will not be feasible for 5 percent of households, future proofing will depend on a combination of fixed wireless access and LEO satellite coverage.

Fixed wireless with 5G millimeter wave technology will be able to deliver extremely high speeds, but with limited range. Continuing improvements in both the technology and cost of fixed wireless can nevertheless be expected eventually to bring close to gigabit speed to many households beyond the reach of FTTH, especially in areas with flat, unobstructed terrain.[15] The choice between FTTH and fixed wireless comes down essentially to cost in the context of the total connectivity system. For example, if a wireless tower is already erected for mobile service in a particular area, it can also provide fixed wireless Internet access, provided suitable spectrum is available. But capacity may be limited by the requirement to also serve mobile traffic.

Where neither FTTH nor fixed wireless is feasible, the future-proof objective will have to rely on the emerging generation of globe-spanning LEO satellites which, in many sparsely populated areas, can dedicate large bandwidth, and thus high speed, to individual households. The LEO connection is nevertheless the most speculative element of a future-proof connectivity strategy owing to some lingering performance questions regarding how much speed can scale, and particularly the commercial viability of the currently planned constellations.[16] However, fibre and fixed wireless will not be able to reach everywhere and the global demand for bandwidth and coverage can only grow. Versions of LEO service are almost certainly here to stay, with the ultimate number of players limited by availability of appropriate spectrum.

It is prudent to enter a caveat that truly universal future-proof connectivity cannot be assured within specified time. But, if the last small percentage of households does not have access to a future-proof service, we can be confident that they can be provided with many times the 50/10 capability. Recall that basic telephone service—which was considered universal in Canada—remained effectively unavailable to 1 to 2 percent of the population until relatively recently.

Subsidies to extend future-proof access would be directed at the capital cost of communications infrastructure. Once installed, particularly if FTTH, the ongoing maintenance and marginal cost of service should be low enough in most cases to be covered by affordable monthly rates. In the case of high-speed LEO service for those without access to fibre or broadband fixed wireless, subsidized arrangements can be negotiated with the LEO provider as the federal and Ontario governments have already done with Telesat.

BOX 4: LOW-EARTH-ORBIT (LEO) SATELLITES

Satellite-based telecommunications have traditionally relied on satellites in geosynchronous orbit, approximately 36,000 km above fixed points on earth. This model will continue to have important uses. But it is not well-suited for today's Internet connectivity, which demands low latency (i.e. the time taken for a signal to traverse the network) and very high data transmission rates.

The solution is to position large numbers of satellites in low-earth-orbit, typically 400 to 2,000 km above the earth. This reduces the travel time of a speed-of-light signal to an LEO satellite by a factor of 25 to almost 100 relative to a geosynchronous satellite, thus reducing latency of typically more than a half second to a few 10s of milliseconds or less, and below the threshold of human perception.

LEO systems were first trialled in the 1990s but failed commercially for technical and financial reasons. Today—thanks to significant technological advances, reduced launch cost, better market opportunities and improved financing conditions (e.g. low interest rates and several deep-pocketed investors)—various LEO systems are planned and in commercial trials. The Starlink system, owned by SpaceX, is the most prominent. It has already launched beta trials in the U.S. and Canada, with plans initially to employ approximately 4,400 satellites—and much larger numbers eventually if its business model succeeds. Other systems include Amazon's Project Kuiper, One Web (a UK-India partnership), China SatNet and Telesat.

Telesat launched a single trial LEO in January 2018 and intends its Lightspeed service to employ 298 satellites, providing full global coverage by 2023–2024. Lightspeed will serve business and institutional customers in areas not adequately connected by fibre—e.g. ships at sea, aircraft and trucks, as well as ISPs that will connect households, mobile network operators offering 5G and public service customers (schools and hospitals). While Lightspeed will deliver a holistic community solution, Starlink will be focused on the residential consumer market in remote areas where its vast constellation of LEOs aims to deliver Internet speed and latency that will create a customer experience comparable to fibre in most circumstances.

INCREASING AFFORDABLE ACCESS TO DIGITAL CONNECTIVITY

The primary focus of this paper is the availability of access to infrastructure that can deliver high-speed Internet and mobile service. Access in this sense refers to availability. But availability without affordability is effectively no access. The affordability of any good or service depends both on its price and on a consumer's income. Affordability can, therefore, be increased by measures that:

- constrain or moderate price increases
- supplement the resources of lower-income individuals and families, including the provision of public access through Wi-Fi, libraries and municipal broadband

Measures that constrain price increases include greater competition among providers, technological advances that boost productivity and thus lower the cost of production, regulatory policies that directly affect price setting, and government "jaw-boning" to encourage lower prices, particularly for essential services like telecommunications. Many of the public policy measures that affect telecommunications prices are within the purview of the CRTC and ISED, whereas income supplementation policy and programs, which tend to have broad application, usually do not target specific purchase choices.[17]

The prices of mobile service plans have been more contentious than those of residential Internet in view of increasing reliance on smart phones and comparisons that generally show two things: first, that Canadian mobile prices are higher than those in most peer countries;[18] and, second, that prices set by Canada's national carriers are higher than those of regional competitors. The mobile pricing debate provides an example of the issues raised in the context of telecom affordability more generally. In the mobile case, the federal government in 2020 demanded that Rogers, Bell and Telus reduce the prices of their mid-tier mobile plans by 25 percent over two years or face regulatory action. This step was taken in the context of evidence that prices have nevertheless been declining.[19] Following an extensive review of wireless services across Canada, the CRTC has taken further steps to address wireless pricing. In April 2021, it issued a decision imposing conditions in the wholesale market to further competition and affirmed expectations of retail price reductions over time.

The primary policy lever to promote affordability of telecommunications services is to foster competition.

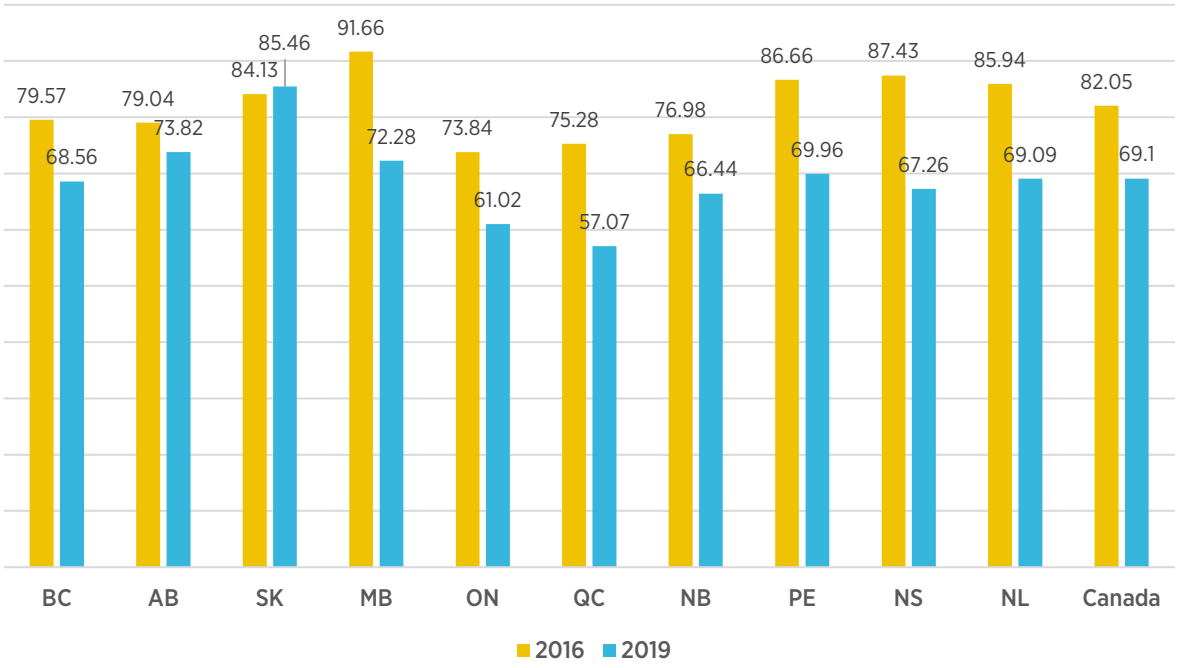
The primary policy lever to promote affordability of telecommunications services is to foster competition so as to provide discipline regarding price-setting and service quality. In cases where governments provide subsidies to service providers, pricing moderation can also be encouraged or required. For example, the selection criteria for the federal Universal Broadband Fund include the applicant's commitment to maintain reasonable pricing for at least five years (determined with reference to the CRTC's Communications Monitoring Report).

In recent years, retail prices for Internet access have been declining on average even as data volumes have grown markedly. For example, Chart 1 (based on data from the 2020 Communications Monitoring Report) shows that the Canadian average monthly price for 50/10 service with unlimited data declined by about 15 percent from $81 in 2016 to $69 in 2019. There were decreases in every province except Saskatchewan. These averages conceal substantial variation among communities and big gaps between the highest and lowest prices within a market. Fortunately, the comprehensive statistics on prices publicly available in

accessible form in the CRTC's Communications Monitoring Report permit detailed scrutiny of pricing trends at a granular level. Information transparency is one of the government's most effective tools in promoting fair and reasonable pricing behaviour. It is a very cost-efficient way to promote the public good.

There is growing recognition that quality digital connectivity is essential for full and inclusive participation in Canadian life. As the quality of Canada's digital infrastructure continues to match the world's best, affordability must not be allowed to become a barrier to access.

Chart 1: Average Price for 50/10 Service ($/month)



ACHIEVING CANADIAN LEADERSHIP IN 5G ACCESS AND APPLICATION

Wireless technology continues to evolve with successive generational labels overlaid on what is essentially a continuum of capability improvement. The fifth generation (5G) is the latest edition, but it will not be the last. 5G can be distinguished from earlier generations that primarily served person-to-person communications—from wireless voice calls in the first generation to the fourth generation "computer in your pocket" (Table 6). Fifth generation wireless, by contrast, is industrial grade, with the bandwidth and reliability to support mission-critical applications such as factory automation and autonomous vehicles, as well as demanding consumer uses (Box 5). From the perspective of public policy, the business uses dominate. That is what most distinguishes 5G from 4G and earlier generations.

Table 6: Five generations of wireless technology

Generation	Peak decade	Key innovations	Key new features	Average data speed
1	1980s	Cellular telephony (analog)	Voice calls on the go	No data
2	1990s	Digital radio transmission	Better sound quality, texting	64 Kbps
3	2000s	Packet network	email, GPS, global roaming, early smart phones	2 Mbps
4	2010s	Internet; smart phones	Hi-Def video; social media, interactive apps (Uber, Zoom, etc.)	30 Mbps (higher peak)
5	2020 +	Very low latency, high frequencies, spectral efficiency	Very high speed, reliability, capacity, cost and energy efficient, IoT, network slicing, industry digitalization	60 Mbps-Gigabit/s

The technical features of 5G will enable the deployment of vast numbers of sensors and data collection devices—the Internet of Things (IoT)—as well as applications that require very quick response (low latency) and essentially fail-safe reliability—e.g. autonomous vehicles, factory automation and many health applications. In short, 5G will support major steps in the evolution of the data-driven information economy.

The buildout of 5G, piggybacking on "4G-LTE Advanced", has enormous promise for emerging business and institutional uses.

4G is still sufficient for most retail purposes and continues to evolve. But the buildout of 5G, piggybacking for the time being on "4G-LTE Advanced", has enormous promise for emerging business and institutional uses and will thus be an increasingly important factor for competitiveness in many industries and public services. Anticipated use cases in Canada are wide-ranging, including, for example, smart cities, smart ports, telemedicine, real-time information for first responders, military and law enforcement, monitoring of climate change, drones and delivery, and maintenance/monitoring of remote industrial operations, such as mining, forestry, and oil and gas operations. In short, 5G will create value anywhere that large volumes of data are generated and communicated, which is to say virtually everywhere in the economy and society of the future.

BOX 5: WHAT IS NEW ABOUT 5G?

Innovations in the hardware and software elements of wireless technology evolve continuously. But commercial implementation occurs in discrete steps as capital based on earlier generations is eventually swapped out when it becomes insufficient for new applications and innovations. The fifth generation of wireless technology (both mobile and fixed) is an outgrowth of the latest manifestation of 4G evolution—4G-LTE Advanced Pro. These two generations will continue to coexist for some time. That said, 5G is a significant **advance** in several key respects:

- Much higher speeds, ranging from several hundred Mbps to more than a gigabit per second, although dependent on a great many variable factors. The increased speed of 5G is largely due to the use of larger blocks of spectrum made available by exploiting much higher radiofrequency bands, eventually in the range of 25–50 GHz and beyond.
- Much lower transmission latency—perhaps reaching a millisecond, versus the roughly 70 milliseconds typical of 4G.
- Ability to accommodate a very high density of connected devices—eventually up to a million per square kilometre, about 100 times the capacity of 4G.
- Ability to serve many different user requirements simultaneously through a procedure called "network slicing". 4G technology is essentially one size fits all, whereas 5G enables customized allocation of network resources to suit the particular application.

How do these technological advances translate to value for service providers and users? Perhaps the most immediate commercial motivation for the implementation of 5G networks is to reduce the cost, per gigabyte, of handling wireless mobile traffic that is growing at annual rates of 25 to 50 percent or more. The expected cost of data handling in 5G will be only 10 to 20 percent of the per unit cost with 4G.

On the near horizon are many business and consumer applications that are now made possible by the speed, latency, capacity and user customization that 5G affords. These tend to fall into three broad categories:

Massive IoT—applications that depend on low volume, are often sporadic, and feature communication with very large numbers of widely dispersed transmitters/sensors —e.g. tracking trucks and cargo containers, smart metering, environmental sensing, fitness wearables.	Ultra-reliable, very low latency (URLL)—applications that depend on instantaneous feedback with fail-safe reliability—e.g. traffic control and (ultimately) autonomous vehicles, factory automation involving remote control of robots and other machinery, (eventually) remote surgery or other high-touch medical procedures.	Enhanced mobile (and fixed) broadband (eMBB)—applications that rely on very high data rates—e.g. virtual and augmented reality, ultra-fast Internet connections (including via fixed wireless to complement fibre for future-proof connectivity).

Following are brief sketches that illustrate just a few of the many applications that 5G will support:

- **Autonomous connected vehicles**—The ultra-reliable low-latency communication of 5G networks will add a key element to the ecosystem of technologies needed to enable self-driving vehicles, especially in combination with artificial intelligence models that interpret traffic and mimic safe defensive driving. Increased numbers of smart cars coupled with 5G-enabled intelligent transportation systems will improve traffic flows and travel safety, while shortening the length of journeys. Onboard sensors will enable these automated connected vehicles eventually to be responsive and intelligent enough to travel safely and efficiently.
- **Climate change**—The potential of 5G to help combat climate change lies in making the wireless industry itself more energy efficient, enabling enhanced monitoring of the environment and resources, and creating a variety of new applications regarding how we live and work that reduce energy use and emissions. Despite mushrooming demand for mobile data, it is predicted that the full network's energy consumption can be reduced with implementation of vastly more energy-efficient 5G. Critical use cases of 5G technologies include improved traffic management; smart buildings employing IoT-based smart sensors that monitor and control lighting, air quality and temperature; smart water management, particularly in agriculture; smart grids, which improve monitoring, reduce energy losses, reduce outages and integrate electric vehicle charging; and enhanced remote working, which reduces commuter travel.
- **Precision farming**—Mobile IoT capabilities are already helping farmers increase crop yields and improve their quality by monitoring soil conditions, making better use of fertilizers/pesticides and improving the tracking of weather conditions. 5G-powered AI-assisted platforms will help farmers make even better decisions about food production by employing many more real-time data feeds through ubiquitous sensors. Better management of vehicle refrigeration conditions during transit will result in longer shelf lives for the delivered product. Intelligent agricultural platforms will also improve the effectiveness of connected drones, which are already being used for crop spraying, land management and aerial surveillance.

Although 5G is often over-hyped in marketing messages, there will in fact be many compelling retail applications—instant downloads, games (streaming and cloud), augmented and virtual reality, enhanced sports streaming, in-car entertainment and enhanced live performance experiences. These captivating applications will provide the early revenue streams that will help cover the cost of network buildout.

A GENERAL PURPOSE TECHNOLOGY POWERING THE "INTANGIBLES" ECONOMY

5G is a general purpose technology—an enabler of capabilities and of industries, much as electric power and digital computing were and are. 5G wireless should, therefore, be regarded as a strategic technology for

Canada, a portal to the future data-driven economy and society. That is why Canada needs to be among the global leaders in 5G use to support the innovation that is the key to economic competitiveness.

Can market forces alone be relied upon to motivate the early buildout and uses of 5G by Canadian business and public service providers?

Market forces alone will not achieve the full economic and social potential of 5G. Government incentives and supportive policies are needed to get the flywheel turning in time to make Canada a leader in high-potential application areas.

Investment by private-sector providers has given Canada excellent connectivity infrastructure in circumstances where profitability objectives could be met. But market forces alone will not achieve the full economic and social potential of 5G. Standing in the way are two market failures.

The first is that wireless geographic coverage of high quality is still not provided on all reasonably well-travelled roadways in Canada; and a 5G upgrade is likely to be much delayed in many smaller and remote communities. Although the commercial reasons for such gaps are apparent, when a service is of very high social and economic value, governments have a responsibility to act where market forces fail, as has already been shown by the government commitment to universalization of broadband Internet access.

The second is due to a "chicken or egg" conundrum. Business and institutional users will explore and invest in 5G applications only if the connectivity infrastructure exists. Investment in the infrastructure at this early stage, however, can be justified only by a reasonable assurance of sufficient customer demand. Things, therefore, risk remaining stuck at the starting line. The issue is particularly challenging in this country because Canadian business on the whole, despite notable exceptions, has been reluctant to lead in technology adoption generally. The evidence is clear in Canada's lacklustre business innovation and productivity performance.

The implementation and application of 5G wireless—a general purpose technology that will be at the heart of the data-driven economy and society—is too important for Canada to be stymied by a lack of sufficient incentives to overcome the reluctance of the private sector to make the necessary early commitments on both the supply and demand sides. It is necessary, for example, on the supply side, to build out Canada's 5G wireless footprint comprehensively along roadways and to small and remote communities; and, on the demand side, to develop and apply 5G innovation to improve business competitiveness and public and commercial services both domestically and for export.

Government incentives and supportive policies are needed to get the flywheel turning in time to make Canada a leader rather than a laggard in high-potential application areas. The selection of the target areas

and the design of the incentives is the stuff of industrial policy. While such policy has been out of favour for decades, it can be appropriate in cases where the strategic stakes are very high and a market failure can be clearly identified. The early implementation and application of 5G is such a case.[20]

The justification for industrial policy to promote early application of 5G capabilities by business and institutional users lies in the growing importance of the "intangibles economy"—an economy driven by assets such as intellectual property and data—and the pivotal role that 5G will play in facilitating Canada's intangibles economy. Countries with a critical mass of intangibles-oriented firms are the new sources of innovation, productivity and growth. Those still primarily relying on traditional tangible sources of growth are falling behind. The pandemic has only exacerbated this trend.[21]

One differentiating characteristic of the intangibles economy is a winner-take-all dimension. That is because intangibles like data and know-how can be collected or reproduced at practically zero incremental cost, thus enabling first movers to scale up rapidly and dominate a market before competitors gain a foothold. First-mover advantage is, therefore, crucial in markets where intangible assets play a key role.

High-quality digital connectivity infrastructure is table stakes for the intangibles economy. And, with the importance of first-mover advantage, it is essential that Canada is among the leaders in providing that infrastructure. 5G connectivity will be essential to support the implementation of technologies that leverage the foundational intangible asset: data and its communication. In a sense, data has become the new oil powering the intangibles economy. And 5G connectivity is an essential capability by which data is transformed into value. This justifies the use of public policy to support both 5G deployment and the firm-level adoption of new technologies that it will enable.

A NATIONAL STRATEGY FOR CANADIAN LEADERSHIP IN 5G ACCESS AND APPLICATION

The rollout of 5G internationally and domestically[22] has begun in earnest. The GSMA, which represents the interests of mobile operators worldwide, and is a widely cited source of industry statistics, has recently forecast the following through the end of 2025:

- More than 40 percent of the world population will live in areas covered by 5G.
- 5G will account for more than 20 percent of global mobile Internet connections.
- More than 80 percent of mobile capital expenditure will be devoted to 5G.

In addition, an EY survey of more than 1,000 executives across eight industries found that almost 75 percent of companies expect to incorporate 5G into their business processes by 2025.

The strategic question facing Canada today is: Will we be among the eventual leaders in 5G or be content to be a follower?

We recommend that:

Canada implement a national strategy to be among the global leaders in 5G with action by government to remove roadblocks on both the supply and demand sides.

The supply of 5G connectivity involves primarily the following:

- Incorporation into the network of "boxes" containing the hardware and software innovations that determine 5G's transformational capability. These can be purchased from global equipment suppliers and tailored by Canada's world-class ecosystem of telecom engineering talent. Provision of 5G also depends on adequate backhaul capacity—via fibre, microwave and satellite—to connect towers to the core network.
- Allocation of appropriate spectrum to take advantage of underlying technological innovations.
- Securing access to structures and spaces for mounting very large numbers of antennas and other infrastructure that constitute the physical skeleton of 5G.

The following policy measures constitute a strategy to promote broadly-based 5G infrastructure deployment.

Network rollout: Some subsidies will be needed to ensure expanded geographic coverage and early buildout in small and remote communities. This is the 5G analogue of the existing measures to extend high-speed Internet connectivity. In fact, some of the currently allocated broadband funds may be used to expand 4G-LTE wireless coverage on roads. This is a good start but should be expanded to encourage 5G access not only on roadways, but also in those small and remote communities where market incentives are insufficient.

Notably, 5G will greatly improve the speed of fixed wireless Internet access. This creates a powerful synergy between 5G and future-proofing strategies since the extension of fibre throughout the country, together with the impending availability of Telesat's LEO service, provides the backhaul capacity needed by 5G networks. Meanwhile, 5G-powered fixed wireless can provide future-proof Internet connectivity in many places where fibre cannot reach. Looking forward, we can see that the functionality of wired and wireless connectivity is converging, with 5G constituting a major step towards providing the practical equivalent of fibre through the air.

Spectrum allocation: The spectrum auction, completed in July 2021, allocated access in the 3.5 GHz band, considered to be the sweet spot for many 5G applications since it strikes a good balance between speed and propagation range.[23] Ultimately, much higher frequency bands will be made available and will support

ultra-high-speed capability, but be limited by shorter propagation distance and be subject to interference by solid objects as well as by foliage and precipitation.

Regarding spectrum allocation, Canada essentially must co-ordinate with the U.S. rather than try to lead the U.S. But a national 5G strategy requires that Canada proceed to allocate spectrum as nearly in step with the U.S. as possible.[24] And the design of the 5G spectrum allocation process must take into account requirements to make the best use of 5G technology by providing contiguous blocks of spectrum broad enough to support the highest speed—typically 80 to 100 MHz in the mid-band around 3.5 GHz, and approximately 1,000 MHz in the millimeter wave bands above 24 GHz. Spectrum policy in a national 5G strategy must balance the objective to promote competition with the need to maintain incentive to invest in new 5G technology for which market returns are uncertain at the outset.

Access to structures: 5G implementation, particularly in built-up areas, will need extensive access to poles, buildings and trenches (passive infrastructure) since large numbers of installed antennas are required to compensate for the short range of the signal when communicating at very high speed. Downtown areas of major Canadian cities are expected to require several thousand new antennas. Many siting locations belong to municipalities, power companies and private building owners, as well as to incumbent telcos. Those who own choke-point passive infrastructure have an incentive to charge what the market will bear for access. Proactive measures to encourage cooperation in access to passive infrastructure will be needed to support the national 5G strategy.

The foregoing outlines the initiatives to be taken by governments and service providers to implement 5G connectivity throughout Canada, from sea to sea to sea. It is essential to adopt a national collaborative approach analogous to what is being implemented to universalize high-speed Internet access.

This supply-side dimension of a national 5G strategy needs to be complemented with initiatives to strengthen the demand side, particularly for innovative applications that foster the competitiveness of industry and institutional sectors, thus resolving the earlier noted chicken or egg dilemma that otherwise could stymie early applications of 5G. The following is recommended:

At least 5 percent of the recent 5G spectrum auction windfall of $8.9 billion should be earmarked to support demand-side experimentation and testing of new 5G-enabled technologies.

Pre-competitive infrastructure to support development: The federal government, in collaboration with the governments of Ontario and Quebec, and with industry partners, have invested $400 million to create ENCQOR, which provides a test bed infrastructure that is enabling hundreds of Canadian SMEs to develop 5G technologies and applications (Box 6). This is building the essential ecosystem of talent and knowhow needed to maximize the value of Canada's 5G strategy and support new exports based on capability. Initiatives analogous to those underway in Ontario and Quebec need to be extended nationally and funded at increasing levels.

To finance the cost of extending the ENCQOR model as well as the Centre of Excellence for Next Generation Networks (CENGN), at least 5 percent of the recent 5G spectrum auction windfall of $8.9 billion should be earmarked to support demand-side experimentation and testing of new 5G-enabled technologies. This would represent an investment of $450 million by the federal government, but it could be expected to leverage complementary contributions from provincial governments and private sector partners. As a matter of public policy principle, earmarking a portion of auction revenues for demand-side innovation would recognize the interrelationship between infrastructure investment and end usage.

Pan-Canadian leadership: Movements need leaders. Knitting together and driving a pan-Canadian strategy in support of 5G requires a nationally representative 5G strategic advisory group with representation from equipment suppliers, service providers and key user sectors, as well as research and consulting fields.

The 5th generation of wireless technology is ushering in a new era of digital connectivity that is distinguished from previous generations by its breadth of applications in business and public service domains. Those countries that commit to early 5G development and deployment will be the leaders in the digital future.

BOX 6: ORGANIZATIONS/NETWORKS PROMOTING AND DEVELOPING 5G DEPLOYMENT AND APPLICATIONS

ENCQOR (Evolution of Networked Services through a Corridor in Quebec and Ontario for Research and Innovation)

ENCQOR has set up the first Canadian pre-commercial corridor of 5G digital infrastructure—a test bed for the development of innovative applications. A public-private partnership (involving the federal, Quebec and Ontario governments and business sponsors), ENCQOR has created five digital innovation hubs in Ontario and Quebec that provide an open platform where SMEs can experiment with developing and testing 5G ideas and technologies. The focus is on research and innovation in 5G disruptive technologies, adoption initiatives and systems uses, with five anchor firms helping to develop the expertise of smaller companies. The SMEs also receive financial support (up to half the cost of a project) and use-case impact assessments are completed at the end of a project.

To date, more than 700 SMEs have participated in the initiative through four streams for which applications are now closed: Technology Development (SME) Program, Technology Development (Academic) Program, TalentEdge Internships (more than 300 student internships with 5G) and Demonstration Program. The $400 million investment in ENCQOR comprises $67 million each from the three governments and $200 million from the anchor firms.

CENGN (Centre of Excellence for Next Generation Networks)

CENGN's mission is to advance technology innovation and industry growth through its test bed, technical expertise, talent development and partner ecosystem. It enables Ontario SMEs to test and validate technology products and solutions, removing barriers to commercialization. The focus is on the broader ICT sector, with network innovation critical for realizing the potential of 5G. To date, 55 commercialization projects have been completed.

CENGN is supported with $14 million over 2014–2021 from the federal government (through the Centres of Excellence), $63 million over 2014–2021 from the Ontario government (through the Ontario Centre for Innovation), plus contributions from members and partners. CENGN has 12 members (industry leaders in ICT and network solutions), 25 academic partners, 13 organizational partners and 11 industry associations.

5GCC (5G Canada Council)

Set up by the Canadian Wireless Telecommunications Association in late 2017, 5GCC is a cross-sectoral platform that supports an innovative 5G ecosystem through advocacy, research and collaboration. Its members include wireless carriers, network equipment providers, academia and other product and service providers.

CONCLUSION

Digital information has emerged as the prime mover of economies and societies. Consequently, this paper began with the aim of balancing economic and social objectives as part of an overall nation-building agenda. The idea was to break free from the tendency to see questions of digital connectivity either through the lens of economic efficiency or social equity—but not both. This blinkered view has contributed to a zero-sum dynamic in so much of the related policy debates.

Our emphasis on the balance of equity and efficiency has not only shaped the panel's research and analysis, but was also part of its DNA from the outset. The Public Policy Forum brought us together with diverse backgrounds and priorities precisely to shape a vision for Canada's digital connectivity that prioritized both equitable access and economic competitiveness. We have approached the subject on the premise that these objectives are not in tension, but instead are equally important and complementary elements of nation-building in the digital age.

The recommendations and observations throughout the paper are, therefore, not the result of compromises among panel members with competing personal preferences. We share a common view that they would help both to boost Canada's economic competitiveness and provide for more equitable and fair access to services and opportunities.

With the right set of policies and programs, Canada can have the digital connectivity infrastructure it needs to fully support an inclusive society and competitive economy far into the future.

ENDNOTES

[1] In December 2016, the CRTC (Canadian Radio-television & Telecommunications Commission) stated that a minimum requirement for residential Internet access should provide a speed of at least 50 megabits per second (Mbps) download and 10 Mbps upload. We will refer to this as the 50/10 minimum target or simply "50/10". The US FCC in 2015 set 25/3 as the minimum target. Most advanced countries have objectives of 25 to 100 Mbps (download) but often with less than 100 percent commitment for rural-remote areas. The UK government has recently adopted a target of one gigabit per second to 85 percent of households by 2025. In short, there is a multiplicity of national broadband coverage objectives, and the targets keep moving.

[2] In 2019, 96.5 percent of telecommunications revenue in Canada was from services not subject to CRTC price regulation (also called "forborne"). The percentages of various services forborne were as follows: mobile, 99.9 percent; fixed-line Internet, 97 percent; long distance, 98 percent; and local access, 83 percent. (Source: 2020 Communications Monitoring Report.)

[3] In 2018, Canada ranked second to the U.S. in telecom investment per capita (excluding spectrum purchases)—US$256 vs. $290—and second to Italy in investment as a percentage of revenue—23.3 percent vs. 26.7 percent (and the U.S. at 15.1 percent). Source: OECD.

[4] Several organizations benchmark network performance globally and according to methodologies that are not strictly comparable. Individual carriers naturally tend to pick the source that publishes the most favourable ranking. Nevertheless, there is broad consensus that Canada's mobile networks have among the world's fastest download speeds. For example, according to the most recent data from OpenSignal, TELUS, Bell and Rogers rank in the top 10 globally. (No U.S. carriers made the top 10.) At the same time, Canadian mobile providers ranked considerably lower with respect to the quality of streamed video and voice apps. International benchmarking also shows Canada among the leaders in the average speed of fixed-line broadband Internet.

[5] The terms "speed" (in bits per second) and "bandwidth" tend to be used interchangeably in communications engineering. This is because the amount of digital data (bits) that can be transmitted in an interval of time depends on the width of the "band" (or spectrum) of frequencies that are available to the transmitter. Hence, data transmission speed via electromagnetic waves is proportional to bandwidth, and broadband has come to be synonymous with high speed.

[6] Statistics based on households do not include persons who are institutionalized or homeless.

[7] There is statistical undercounting of First Nations households in that regular seasonal relocations may not be accounted for. In B.C., for example, there are 203 primary First Nations communities, as well as 307 secondary communities that should be considered in broadband access provision. (*A Plan for Rapid Connectivity*: The First Nations Technology Council, June 30, 2020)

[8] For example, the B.C. government's *Declaration on the Rights of Indigenous Peoples Act* stipulates an obligation to implement an action plan to achieve the Act's objectives. In a submission, entitled *Technology Underpins UNDRIP* (September 4, 2020), the First Nations Technology Council develops the

relationship of technology to the UN Declaration (UNDRIP) and posits that reconciliation must include digital equity for Indigenous people.

[9] Total private sector funding for broadband infrastructure in Canada is much greater when including unsubsidized investment undertaken in response to market opportunities.

[10] For example, streaming video in high definition requires download speed of 5–7 Mbps; Zoom group video conferences require 2–3 Mbps; Cloud gaming, 10 Mbps; and time to download a high-definition movie, 10 minutes. The present demand for much higher speed is driven in large part by the proliferation of Internet-connected devices in multi-person households.

[11] As traffic and speed grew significantly, average revenue per subscriber in Canada increased by a modest 2.3 percent, from $60.39 in 2018 to $61.76 a year later.

[12] The theoretical information-carrying capacity of a single optical fibre (approximately the diameter of a strand of hair) is practically unlimited. Speeds of hundreds of terabits per second (1 Tbps = 1,000 gigabits/sec) have been demonstrated and innovation continues to increase capacity. Optical fibre has many advantages beyond speed relative to transmission over metallic wire—e.g. it is not subject to electromagnetic interference, has less signal fade with distance, is lightweight and is lower maintenance.

[13] Fixed wireless can also become more future proof once towers are erected and high-capacity backhaul connectivity is in place (e.g. fibre, microwave or satellite). With that infrastructure in place, transmission speed can be steadily increased at relatively low incremental cost (provided high frequency spectrum is allocated) because software development and R&D costs are spread over the global market while equipment manufacture benefits from global scale economies.

[14] Not all FTTH has 1 gigabit offered at this time. But eventually, it will.

[15] The U.S. Rural Digital Opportunity Fund auction in 2020 permitted fixed wireless service providers to bid for subsidies in areas where they undertook to offer gigabit service. This demonstrates increasing faith in the capability of millimeter wave wireless to provide gigabit speed in rural areas when assisted by a subsidy acceptable to both government and the service provider.

[16] Initial financing for Telesat and Starlink is US$5 billion and $10 billion, respectively, although that can be compared with annual capital spending of CAD$8 to $10 billion on wireline service in Canada.

[17] An exception is the $13.2 million federal Connecting Families program that provides $10/month high-speed Internet for families that receive the maximum Canada Child Benefit. Funding supports provision of up to 50,000 refurbished computers and an online portal to access the program. Participating ISPs are not subsidized and offer the discounted plans voluntarily. In August 2021, the government announced agreements with several of Canada's largest ISPs to provide 50/10 and 200 GB of data for $20/month to qualifying seniors and families. Meanwhile, Telus and Rogers have offered $10/month Internet packages targeted at specific groups in their primary market territories.

[18] There is considerable debate as to appropriate pricing benchmarks for both international and domestic comparison—e.g. how to account for differences in service quality and the effect of population

distribution. The CRTC has noted that "with retail prices clearly trending downwards … the market is moving in the right direction … however, falling retail prices in Canada are part of a worldwide trend, because retail prices have also declined in other countries over the same period … Canadian retail prices have not fallen as much as they have in other jurisdictions, and remain above international benchmarks."

[19] For example, the mobile services price component of Canada's Consumer Price Index declined by 25 percent from January 2016 to December 2020, with most of the reduction occurring after late 2018.

[20] A good example is the willingness of the governments of Canada, Quebec and Ontario to invest significant funds in Telesat's LEO initiative not only to help bring 5G from sea to sea to sea, but also to capitalize on Telesat's related investment in talent, R&D, operations and production to create a built-in-Canada LEO solution that will build global competitiveness in 5G and its applications.

[21] Even in tangible economic sectors—e.g. manufacturing, agriculture, resource and energy production—the value added is increasingly being provided intangibly via R&D, software, data collection and analysis, industrial organization and marketing.

[22] In 2020, Rogers, Bell, Telus and Videotron all launched their first 5G mobile networks. Rogers' 5G network currently spans more than 700 communities. Bell has expanded 5G service to an additional 28 communities in Manitoba, Ontario and Quebec. By the end of 2021, Telus plans to reach more than 600 rural and urban communities in British Columbia, Alberta, Manitoba, Ontario and Quebec. Sasktel aims to roll out its 5G network in Saskatchewan in late 2021.

[23] There is an inherent trade-off between (i) the speed of wireless data transmission (which depends on the range of frequencies of the transmitted waves) and (ii) the propagation distance of the signal (which is limited as the wavelengths of the signal become shorter and thus more subject to interference). The product of the wavelength and frequency of every electromagnetic wave must equal the speed of light (300 million metre/second), which means that, as frequencies become higher (to transmit data more rapidly), the wavelengths become shorter, thus limiting range for any given level of input power. A signal in the 3.5 GHz band (3.5 billion cycles per second) will have a wavelength of about 8.5 cm, while a 40 GHz signal will have a wavelength of only about 7.5 mm.

[24] Canada-U.S. co-ordination is required for spectrum allocation in border areas to avoid interference. Canada has not been able to lead the U.S. in allocation of particular spectrum bands to support new generations of wireless technology since global equipment suppliers have keyed product development to the large U.S. market and, increasingly, to Asia and Europe.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