Appendix A

TORONTO BROADBAND STUDY

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APPENDIX

Glossary

Broadband	An always-on, high-speed connection to the Internet through the facilities of an ISP that provide[s] download throughput of greater than 1 Mbps (2009). For the purpose of this report, broadband is defined as 50 Mbps download, 10 Mbps upload, as per the CRTC's universal service objective (2016).
Cable	Refers to ISPs or other services provided via coaxial cable.
CO	Central Office. A switching centre where local loops are terminated and switched.
DAS	Distributed Antenna System—basic infrastructure used to deliver in-building wireless services.
DSL	Digital Subscriber Line. Copper, phone-line-based internet services.
Dark Fibre	Optical fibre infrastructure that is in place, but is not connected to in-service transmission equipment.[1]
"Digital Divide"	Commonly understood as the gap between those that have ready and affordable access to information and communications technology, and those that do not.[2]
Digital inclusion	Defined as residents having access to a high-speed internet connection, internet-connected devices, software, emerging technology and workspaces, as well as the *skills* required to use technology to address their needs.
Digital literacy	The ability to use current, emerging, and new wave information and communication technologies to find, evaluate, create and communicate information requiring both cognitive and technical skills.
Fibre	Shorthand for "optical fibre"—the medium and technology associated with the transmission of information as light pulses guided over a filament of transparent dielectric material, usually glass or plastic[3]
FTTH/FTTP	Fibre To The Home/Fibre To The Premises. Describes a fibre optic line being delivered directly to a household or business.
FTTN	Fibre To The Node/Neighbourhood. Describes a fibre optic line being delivered to a local "central office" or other neighbourhood node.
Gbps	Gigabits per second, a measure of internet speed. One gigabit is equal to one thousand megabits.
In-Building Wireless	A telecommunications solution used to extend and distribute wireless services within a building.

ISP	Internet Service Provider
Latency	The time it takes for a message to travel from one point in the network to the next. Usually measured in milliseconds.
Lit Fibre	Optical fibre infrastructure attached to in-service transmission equipment. (See also “Dark Fibre”)
LTE	“Long Term Evolution”. A standard for mobile broadband communications, part of the fourth generation of mobile telecommunications technology (4G).
Mbps	Megabits per second. A standard measure of internet speed.
Narrowband	A narrowband network provides internet connectivity in a different and smaller frequency range than broadband internet.
POP	Point Of Presence.

Executive Summary

Over the last half-decade, politicians and citizens in the City of Toronto have identified fast, reliable, accessible and available internet connectivity as a priority for economic development and social equity. As part of the modern global economy, there is a recognition that the citizens and businesses of Toronto need connectivity that is world-leading in its speed and accessibility. In response, the City's Information Technology and Economic Development Departments undertook an initiative to assess broadband availability and usage in Toronto, and to provide strategic priorities to improve broadband internet accessibility, affordability, and availability. This study aims to provide a foundation of understanding and knowledge of broadband infrastructure in Toronto, and how the City can facilitate and encourage the expansion of this infrastructure to meet anticipated demand, and to ensure access and affordability for businesses, residents, and visitors.

By many measures, broadband internet and data usage is growing consistently and substantially amongst Canadians. This growth in usage has been led by the rapid adoption of newer, higher-speed and higher-capacity devices such as smartphones and tablets. Smartphone penetration in Canada has gone from just over a third in 2011 to more than 70% in 2015. Furthermore, according to Cisco projections, mobile data traffic will grow five-fold from 2016 to 2021 to 340 Petabytes per month (the equivalent of 85 million DVDs per month)[4]. Mobile data is poised to become the preferred form of broadband connectivity for consumers into the future. This has serious implications for existing broadband network providers.

For the purposes of this report, broadband is defined using the "universal service objective" declared by the CRTC in December 2016, based on speeds of 50 Mbps download and 10 Mbps upload.

The report investigates current infrastructure in the City of Toronto, including wireline (fibre and other), wireless (cellular and Wi-Fi), data centres, and other important infrastructure. Some of the key findings through this investigation are as follows:

- CRTC-defined broadband speeds are technically available to all households in Toronto
- Pricing is the barrier to accessibility of 50 Mbps broadband speeds.

- Broadband affordability will become the new catalyst for the evolution of the "digital divide" in Toronto from *access* to *affordability* as the predominant influencing factor.
- The vast majority of the City of Toronto is well-covered by cellular broadband. Further enhancements of the existing 4G/LTE and upgrades of 3G equipment are expected in the next year.
- More than 70% of 9-1-1 calls are made from mobile devices.
- Open Wi-Fi networks, although ubiquitous in dense areas of the city, is currently a patchwork of providers which can be difficult to access.
- Toronto is Canada's internet and broadband hub, hosting most of the infrastructure backbone and providing key gateways into the United States and the rest of the world.
- The City's Agencies, Boards and Commissions (ABCs) have been able to provide more broadband access to Torontonians through partnerships with private companies and through proactive initiatives with seemingly minimal risk.

As a result of these key findings, several strategic recommendations are made for the City of Toronto to take action on. These include:

- Leverage assets to help introduce and expand new infrastructure competitors to the marketplace, aside from Bell and Rogers.
- Improving access to broadband for low-income residents by strengthening the "Connected for Success" program
- Leverage assets to help introduce and expand new infrastructure competitors to the marketplace, aside from Bell and Rogers.
- Facilitate collaboration and partnerships between non-profit broadband entities and major broadband infrastructure providers.
- Include In-Building Wireless Systems in requirements for new construction.

More strategies and summaries of each are provided towards the end of the report.

Finally, a number of case studies and best practices from Toronto and the rest of the world are provided as examples of ways that the City can act on the key findings and recommendations.

1 What is Broadband, and Why Is It Important?

Defining Broadband

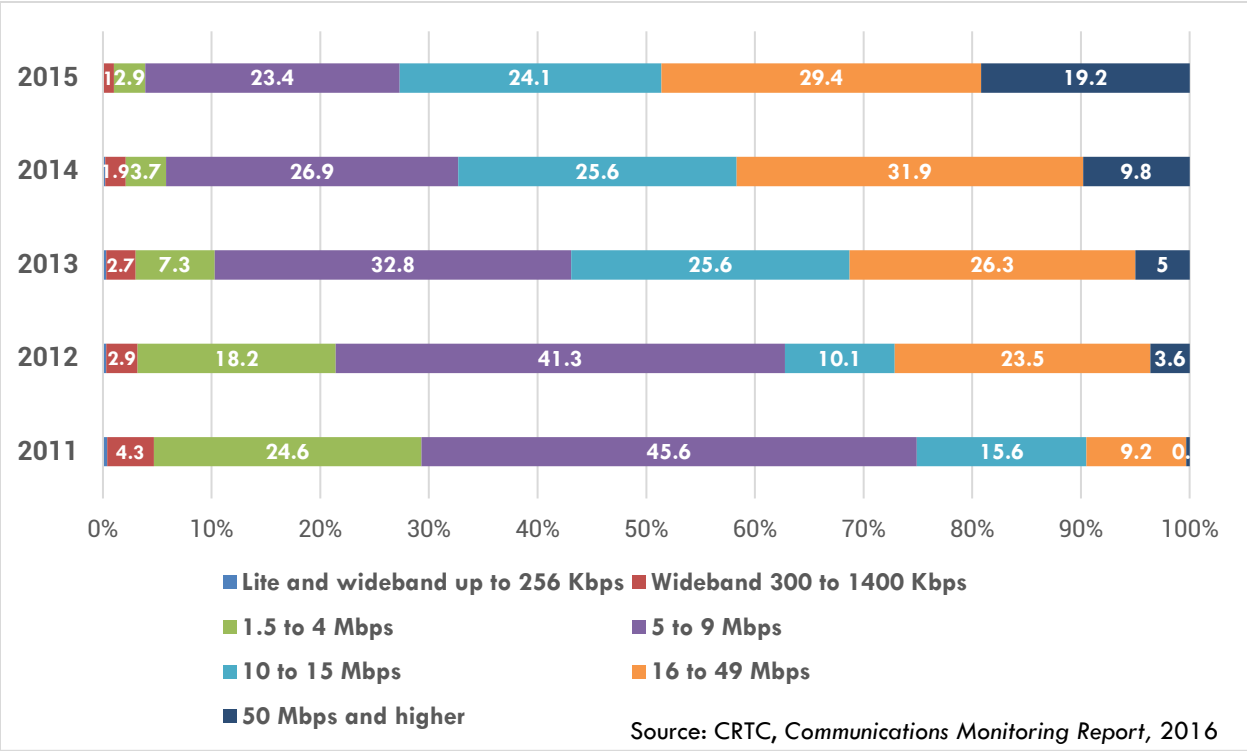
There are widely varying definitions of what "broadband" means practically. In the most basic sense, broadband internet is a type of access to the internet that is: a) always on; and: b) faster that traditional phone-line-based dial-up internet service. Given that much of the developed world has moved well beyond dial-up internet services, most definitions of broadband now have to do with the speed of the internet service being provided. (Speed is measured in megabits per second, or "Mbps".) The Canadian Radio-Telecommunication Commission (CRTC) glossary defines broadband as *"an always-on, high-speed connection to the Internet through the facilities of an ISP… that provide[s] download throughput of greater than 1 Mbps,"* although this definition was last updated in 2009.[5]

CRTC's "universal service objective" (December 2016) establishes minimum access speeds of 50 Mbps download and 10 Mbps upload throughout Canada

More recently, the CRTC established a "universal service objective" that all Canadians should have broadband internet access, at a specified speed. For "fixed" (wired) broadband access, the CRTC determined that the minimum available speeds should be 50 Mbps download and 10 Mbps upload.[6] Throughout this report and in order to be consistent, when broadband internet is mentioned, this is the standard that is being referenced.

An updated broadband standard is sensible given the subscription trends to internet services in Canada overall. As shown in the chart below, based on data gathered by the CRTC, Canadians are increasingly subscribing to higher-speed internet services. Nearly 50% of Canadian subscribers have a service 16 Mbps or faster, while over the last 5 years, subscription to 50 Mbps or faster services has grown from almost non-existent to 19.2% of subscriptions.

Figure 1 – Residential Internet service, one-month subscriber distribution (%), by advertised download speed



Source: CRTC, *Communications Monitoring Report*, 2016

Broadband internet connections come in many forms, but can be divided into two main delivery methods: wired and wireless. Within each delivery method, there are several sub-methods that are distinct and worthy of discussion.

Investment in Broadband Accessibility & Affordability as a Key Element to Smart City Development & Job Creation

While the Internet has transformed everything from how people search for a job to how people communicate with friends and family, cities are looking to use digital technology to address stubborn challenges such as reducing poverty, promoting economic development, and making local governments more accessible and efficient. The Intelligent Community Forum (ICF) describes this transformation as the era of "Smart City Development." At the heart of this transformation lies the core investment that supports its growth – broadband infrastructure. The ICF claims that for a City to be "Smart" it requires that existing broadband infrastructure is accessible and adoptable by all parties (residents, businesses, and the public sector).

Recent trends worldwide have pointed to the several benefits of accessible and adoptable broadband networks. In many cases, the ICF describes that an accessible and adoptable broadband network can act as a tool in helping cities to attract skilled workers and enable opportunities for innovation and new competitive edges.[7] The ICF goes on to also describe benefits to schools, resident and research interests, as these parties are able to access improved tools, access global connections and improve their community involvement.

Globally, investment in broadband technology, infrastructure and networks is leading business opportunities and establishing new jobs. Research has shown that companies which adopt broadband-based processes can improve employee productivity.[8] In Cornwall, UK, four years after the implementation of a broadband development program, the business sector saw an increase of 10% in yearly growth and an annual increase of 7% in productivity compared to the rest of the United Kingdom.[9] Broadband connectivity also opens up possibilities for more advanced hope-based businesses, replacing the economic need for a traditional workplace.[10] Broadband also allows for faster and automated information flow between companies, increasing the specializing of knowledge-intensive activities. In Europe, this change in the business environment shifts 725,000 jobs annually from traditional economic sectors to business sectors (e.g. IT services, engineering, accounting, and financial services).[11]

In terms of city investment, the development of municipally run broadband networks provides structured business development and job creation opportunities. The City-owned broadband connection in Chattanooga, Tennessee expanded its business community and established new employment opportunities to its residents through the creation of an innovation corridor with a world-class smart-grid internet network.[12] In the first 10 years of the creation of the network it established over 3,600 new jobs. As a result of this investment, a nationally renowned call center relocated its head office to Chattanooga because the networks maximum connection speeds were higher than the company's previous headquarters. Further, companies in neighbouring communities have expanded into the Chattanooga to take advantage of the network. Businesses in the area credit the city network with some of the company's success. The investment in broadband also helped to attract computer engineers, tech entrepreneurs, and investors and helped to create an environment suitable for venture capital. For example, local

entrepreneurs established a venture incubator, Lamp Post, which provides capital and mentorship to start-ups.[13]

In Chanute, Kansas, its municipal network provides a 10Gbps fiber-optic broadband ring around the municipality which generates $600,000 per year in leasing contracts with telecomm providers that enables the network to continuously be reinvested and upgraded. [14] The network has been credited in attracting high tech manufacturing firms and retention of large design firms.[15]

In Lebanon, Virginia, following investments in broadband infrastructure through its public-private utility company (Bristol Virginia Utilities), has seen its broadband access and affordability greatly improve. The public-private utility company is responsible for creating and laying the fiber connections alongside other city utilities and contracts out separate output levels to a variety of telecomm providers. The result has led to an interesting market dynamism that has providers focused on both higher speed and usage users and smaller market affordable basic services. The result of the investment helped Lebanon develop a series of high-tech hubs where under the same building different speeds could be prioritized without impacting performance on the overall network.[16]

In Toronto, broadband connection and investments into internet infrastructure play a critical role in both economic development and job creation. A recent report by Economists Incorporated for Bell Canada pointed to the creation of 3,783 sustained new jobs from the Fiber-to-the-home (FTTH) project in Toronto alone (both direct and spin-off) and has the potential to generate $3 billion in higher economic outcome for the City.

Connecting residents to jobs is of critical importance for the overall competitiveness of the City as well as in providing employment opportunities for residents. In the Workforce Development Strategy for Toronto, a number of priorities emerged related to connecting residents to jobs, including the use of public sector developments as employment opportunities, the use of online tools to support job matching, and ensure that services available to job seekers get the best outcomes for unemployed residents. The report also identifies a number of priorities related to enhanced business supports; including providing increased support for entrepreneurs as well as using public sector developments to gain labour market intelligence. Enhanced internet access would benefit entrepreneurs working at home or in weak-signal areas of the

City and is an opportunity for generating employment and economic growth throughout the City.

The strategy also speaks about the intrinsically required broadband access to support training and enhanced business support opportunities for residents and businesses. This includes launching new digital innovation hubs and programs (like Digital Main Street), increasing services related to expanding digital access and literacy, and increasing the number of learning labs in public libraries as highlighted in the TO Prosperity: Toronto Poverty Reduction Strategy and the TO Prosperity 2017 Work Plan. These actions work to provide opportunities for all residents and businesses to gain needed employment and business skills.

Responding to the Pressures of the Digital Economy

The Information and Communications Technology Council of Canada (ICTC) in 2016, reported that in the next 3-5 years, the adoption of smart and connected technologies, such as the Internet of Things (IoT), will exponentially reshape all aspects of the economy, including how essential city services are delivered.

The 2017 Federal Budget responded to this by proposing new investments that will assist Canadians in accessing digital learning opportunities, improve internet inclusivity and make home internet access more affordable for low-income families. Digital skills widen Canadian's access to a world of possibilities. The 2017 Budget proposes $29.5 million over the next five years for a new Digital Literacy Exchange program. The program will support non-profit organizations to implement initiatives that teach basic digital skills, including how to use the Internet safely and effectively, at pre-existing facilities such as public libraries, refugee housing complexes and senior's homes. The program will focus on vulnerable groups such as low-income individuals, families and seniors.

Most Canadians are already online, but many low-income families face financial barriers to access, such as the cost of purchasing a computer and the high cost of an Internet connection at home. The 2017 Budget proposes to invest $13.2 million over five years, starting in 2017–18, in a new Affordable Access program, which will help service providers offer low-cost home Internet packages to interested low-income families. As the cost of computer hardware is also a barrier for some families, a target of 50,000 computers refurbished

through the existing Computers for Success Canada program will also be distributed to families, along with the low-cost Internet packages. To better understand how Canadians use digital technology, the 2017 Budget also proposes to allocate $5 million over five years, starting in 2017–18, for Statistics Canada and private sector-led surveys on the impact of digital technology in Canada.

According to the Economist Intelligence Unit, Canada is tied for 8th out of 75 countries in terms of Internet inclusivity. Canada as a whole does particularly well on measures of Internet affordability – ranking first overall, although caution should be used when national statistics rather than local data is used. Canada is also successful in terms of Internet quality and availability and in terms of having local and relevant Internet content. An area where Canada can improve, however, is by addressing digital divides that result in some Canadians being underserved by the digital economy. The Digital Literacy Exchange and Accessible Technology Development programs proposed in 2017 Budget will enable Canada to make progress in this important area.

Research has shown that cities that have invested in broadband accessibility and affordability experience numerous social-economic benefits, where residents have reported improved labour market conditions, businesses reporting increased economic growth, government services reporting improved access, efficiencies and enhanced civic participation. Investment in broadband accessibility and affordability allow individuals to search for jobs, submit applications, and communicate to employers online. Investment into broadband connectivity has made medical care and medical information more convenient and more accessible, allowing access to training professionals at lower costs. Increased broadband speed has made access to services possible and efficient, including real-time information sharing between service providers and users. Broadband connectivity enables access to lower-cost online education and training opportunities. It enables an inclusive education for people with disabilities, allowing for enhanced support inside and outside the traditional classroom. Household internet access has also been correlated to better educational performances in children and young adults.

Additionally, investment in broadband accessibility and affordability has enabled citizens to get informed on issues related to community, social and economic development within their municipalities. Governments are

increasingly turning to web-based opportunities to communicate and share information with residents.

Broadband connectivity also allows for new ways of citizen engagement, through online town meetings, social media, and feedback mechanisms. These opportunities eliminate barriers related to physical distances, travel costs and other challenges which face citizens who want to have their voice heard. In Toronto, the TO Prosperity: Toronto Poverty Reduction Strategies prioritizes the need to improve broadband access to support low-income residents and the need to support a seamless social support program. The Toronto Youth Equity Strategy highlights the need to ensure services are delivered in a continuous way, particularly for mental health and substance abuse. The Toronto Public Library 2016-2019 Strategic Plan also prioritizes the need to respond to a growing digital economy, recent initiatives are being proposed such as launching new digital innovation hubs and programs, increasing services related to expanding digital access and literacy, and increasing the number of technology learning labs as highlighted in the TO Prosperity: Toronto Poverty Reduction Strategy and the TO Prosperity 2017 Work Plan.

2 Broadband Trends

The most important trend in broadband is ubiquitous and constant connectivity, and businesses' and consumers' desire to be constantly connected at fast speeds. This trend coincides with a general move from wired to wireless connectivity for everyday uses of broadband. This desire to be connected will continue to be the driver of competition, innovation, and expansion of broadband networks into the future.

There are several other trends, or important developments, in broadband that the City of Toronto should be aware of so that staff and council can respond appropriately.

Broadband over LTE (Wireless)

As illustrated in Figure 3, current LTE speeds are already in excess of the CRTC's broadband standard. This means that, in many cases, a user's broadband access will be faster on LTE when compared to their typical wireline

access. As speed is the first priority for users, they will tend to migrate some of their use to broadband over LTE.

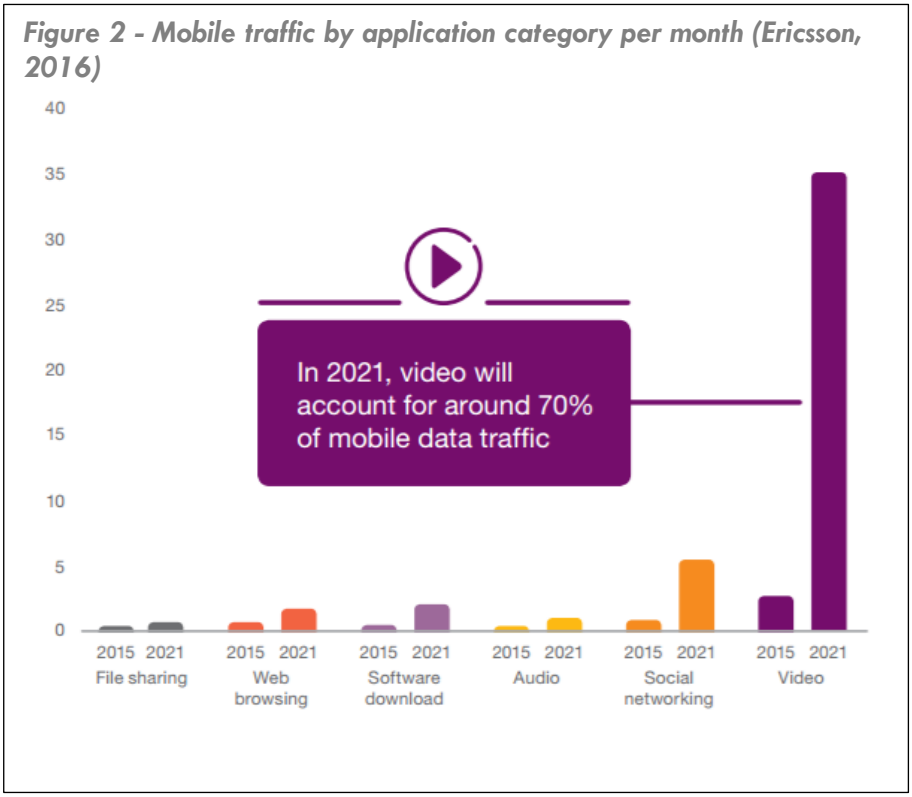
Several carriers, including Xplornet, and Verizon and AT&T in the United States, are using wireless technologies to expand outside of major centres, instead of installing fibre. This is because they can deliver "broadband" internet (50+ Mbps) via wireless at a much cheaper cost compared to fibre.

This wireless opportunity to expand broadband still exists in Toronto, and is in a fledgling state with small players. In order for this opportunity to be capitalized upon, it must be competitive with wireline services. As wireline infrastructure is already so developed throughout the City, initial capital for wireless carriers is the main impediment to widespread broadband over LTE services. Internet of Things (IoT) providers, referenced later in this section, could initiate the build-out of these kinds of networks.

5th Generation Carrier Wireless (5G)

Currently in the City of Toronto, 4G/LTE service has been launched by all three major network providers in Toronto (Bell, Rogers & Freedom), using compatible wireless devices. While 4G is delivering broadband speeds in excess of the 50 Mbps standard, consumer demand for data is leading to wireless network capacity issues. Globally, Cisco expects mobile data traffic to expand sevenfold between 2016 and 2021.[17]In order to meet this excessive demand for data, work has already started on the next

Figure 2 - Mobile traffic by application category per month (Ericsson, 2016)



generation of wireless broadband technology—5G.

Data use is being driven by frequent viewing and sharing of video through social media platforms such as Facebook, Instagram and Snapchat, as well as the growing popularity of video streaming services such as Netflix. The academic sector also uses a growing amount of data (for example: 4K resolution video streaming/collaboration). By 2021, Ericsson projects that video (including embedded video in social media platforms) will account for approximately 70% of mobile data traffic (Figure 2).[18]

Standards for 5G are still in development globally, but targets are for gigabit speed, with the objective of improving coverage and capacity, and significantly reducing latency,. The 5G networks would be deployed primarily through a higher density of "small cells" and in-building distributed antenna systems, in addition to traditional towers.

Due to the growth of 5G technology, the City of Toronto will see an increased demand from traditional carriers for use of city infrastructure (street poles, buildings, etc.). Already at this pre-5G stage, the inclusion of or provision for distributed antenna systems (DAS) inside new office and residential buildings has become common.

Full deployment of 5G technology in Canada is not expected until 2020 at the earliest, however some carriers have already begun preparations for the equipment changes that will be required.

Internet of Things (IoT)

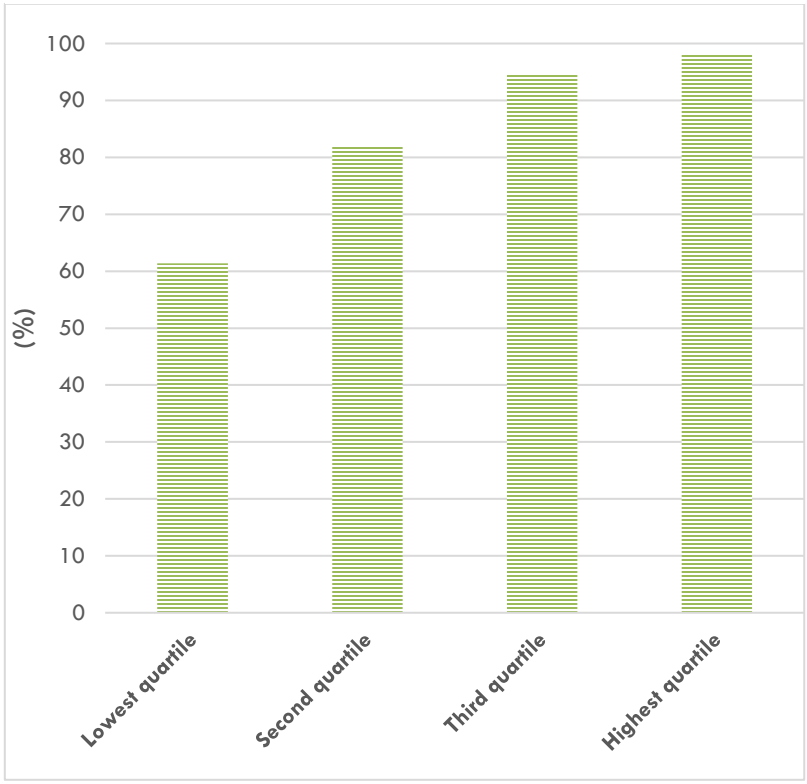
Defined as "the interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data"[19], IoT promises to change the way we live. In particular, by installing transmitters and sensors on infrastructure, performance metrics can be collected and used to improve, repair, or otherwise change the infrastructure or the way services are delivered In particular, new smartphone apps have and will appear that enable new delivery of city services, either on the City's initiative or through private developers. The collection and use of data gathered through these apps or through sensors is one of the key planks in any Smart City strategy.

As part of IoT, the evolution of new untraditional wireless networks (non-cellular and non wi-fi) will occur to enable machine-to-machine communication (M2M). Networks, either on licensed or unlicensed spectrum, will be developed by the private sector to carry this type of M2M traffic.

The "Digital Divide"

Digital Divide is a blanket term used to describe the gap between those that have access (through service availability, but especially affordability, etc.) to information and communications technology (ICT), and those that do not. In the context of broadband in the City of Toronto, "digital divide" is usually used to refer to the unaffordability of high-speed internet access for people with lower income.

Figure 3 – Household access to broadband (5 Mbps) internet at home by income quartile, Ontario



According to Statistics Canada data, about 60% of the lowest quartile of income earners in Canada have access to broadband internet at home (using 5 Mbps, the old standard). This compares with the highest income quartile, of which 98% have access to broadband at home[20].

In addition, ACORN, a social advocacy organization, surveyed members in 2016 and found that 83.5% of those surveyed found internet access to be "extremely expensive". The same survey found that 59% of respondents paid for internet by forgoing other household expenses[21]. Results from a survey of users during the first phase of the Toronto Public Library's Hotspot Lending Pilot reported that 79% of participants did not have internet access at home due to the high cost of connectivity. Furthermore, over two-thirds of participants reported that their

annual household income was less than $30 000. The hotspot lending program proved to be a success in helping to bridge the digital divide, with about half of respondents indicating that the hotspot helped with educational goals, and 36% reporting that it helped them with employment.

However, the CRTC's definition of "broadband" has changed twice over the last decade, making it a "moving target" of sorts. As "broadband" becomes more affordable, at the same time, the standard of what "broadband" is moves to a higher speed. Lower-income individuals will have access to older connections and slower speeds when compared with higher-income individuals. It is the cost of the service itself that will always drive the digital divide.

The digital divide is being addressed somewhat through programs such as Rogers' "Connected for Success" low-cost internet service, and through Toronto Public Library hotspot lending and wi-fi programs, which will be described later in this report.

Government-owned Broadband Networks

There are numerous regions in Ontario who have observed the large investments being made by broadband providers in cities like Toronto, but have not seen similar investments made in their community. (As the largest city in Canada, Toronto does not have this issue—carriers focus their attention and resources on the largest consumer and business markets.) In many cases, this non-investment in more rural areas is due to a lack of a commercial business case for the provider. As a result, smaller municipalities have banded together into groups such as EORN (Eastern Ontario Regional Network) and SWIFT (South-Western Integrated Fibre Technology) to plan, fund and build broadband networks in their communities.

EORN and SWIFT have both been able to acquire funding from senior levels of government by demonstrating the need and formulating an executable plan of delivery. The networks themselves become government-owned and operated, similar to other crucial infrastructure like water and wastewater systems or electricity.

Gigabit Speed Availability

Although 50 Mbps is the CRTC's relatively new standard for what is considered broadband speed, the majority of providers (especially in Toronto) have moved beyond this target to make 1000 Mbps, or 1 Gbps, the objective.
As will be demonstrated in this report, gigabit speeds are already widely available in Toronto via cable or fibre internet services, and are being advertised heavily by some providers. For wireless providers, gigabit speeds will be the objective as 5G technology is implemented across their networks.

3 Jurisdiction & the City's Role

Before breaching the subject of the status of wired and wireless broadband in the City of Toronto, it is critical to understand the historical and present-day jurisdictional context within with the City has operated and will operate in.

History & Context

The telecommunications industry, including both wired and wireless technologies, is a federal responsibility in Canada. This is in part due to a recognition that it is a utility of critical importance to the daily lives of Canadians across the country, like defence, railways and highways.

Originally, telecommunication carriers were required to provide wired service at "just and reasonable" rates, without discrimination, with an implicit bargain that carriers could operate on a monopoly basis. This has changed through the last half of the 20th century, as governments recognized the growing importance of telecommunications, the variety of services that could be offered through telecommunications, and the growing use of wireless technologies. Successive federal governments have more recently moved the industry from a monopoly/oligarchy to a more competitive regulatory structure.

When it comes to wireless telecommunications specifically, the need for federal oversight is quite clear. As radio waves move about in the air, without regard for jurisdictional borders or boundaries, over-arching management of licensed spectrum and the wireless industry is required in order to ensure the integrity of the system and to prevent interference.

Both wired and wireless telecommunications have been enshrined as exclusively federal jurisdiction through multiple Supreme Court rulings,

including *Toronto Corporation v. Bell Telephone Co. (1905)* and *Alberta Government Telephones v. (Canada) Canadian Radio-television and Telecommunications Commission (1989)*. In both cases, the Supreme Court found that the federal government had sole jurisdiction over telecommunications carriers throughout the country. More recently, in *Telus Communications Co. v. City of Toronto (2007)*, the Ontario Superior Court held that municipal by-laws do not apply to telecommunications, specifically antenna sites.

Present-Day Regulations & Jurisdiction - Wireless

Although telecommunications are exclusively within the federal government's jurisdiction, the responsibly ministry (Industry, Science, & Economic Development, or ISED) believes that it is "important that antenna systems be deployed in a manner that considers the local surroundings". As a result, all installations of antenna systems and antenna-supporting structures are regulated by ISED's CPC 2-0-03 document, most recently updated in 2014. The CPC sets out a process that must be followed by any proponent of an antenna system. This process includes:

- Investigating sharing or using existing infrastructure;
- Contacting the land-use authority (LUA) to determine local requirements for antenna systems;
- Undertaking a public notification and addressing relevant concerns; and:
- Satisfying ISED's general and technical requirements.

Municipalities are encouraged to produce their own protocols or policies for consultation that reflect local preferences or requirements. Proponents are required to follow municipal protocols or policies where they exist; if local requirements are believed to be "unreasonable", ISED can be contacted for "guidance". Where municipal protocols do not exist, proponents are required to follow ISED's Default Public Consultation Process[22]. The City of Toronto has had its own Protocol since 2008, which was last updated in 2013.

Generally speaking, this balancing of federal jurisdiction with local interests has worked well to prevent unsightly or overly large installations in areas deemed sensitive (i.e. residential areas or schools) and to provide opportunity for input from local residents, while providing a timely and fair process for proponents to follow.

The City's role is to process applications for antenna systems in a timely and fair manner, respecting the federal jurisdiction while holding proponents to a standard that does not include the application of municipal by-laws.

Present-Day Regulations & Jurisdiction - Wired

Although telecommunications are exclusively a federal jurisdiction enforced through Sections 42-44 of the *Telecommunications Act*, the actual administration of the physical plant of fibre and other wired infrastructure is accomplished at the municipal level. This is because the City of Toronto controls its own rights-of-way and issues permits for construction and other utility activities within these rights-of-way. It is up to each facilities-based competitor, licenced by the CRTC, to negotiate terms with a municipality for access to its ROWs. However, if a carrier cannot reach an acceptable agreement with the municipality, then the CRTC can enforce its own conditions upon the municipality.

The CRTC has supported the idea of establishing Public Utility Co-ordinating Committees (PUCC) in the interest of joint planning and co-ordination of work in ROWs. This is a recognition of the fact that many ROWs, especially in downtown areas, have limited physical capacity for new infrastructure. The City of Toronto has its own PUCC of which most operators in Toronto (both public and private) are members[23].

A City Transportation Services staff report[24] summarizes the general principles governing the relationship between carriers and municipalities in Canada:

- "Canadian telecommunications carriers and distribution undertakings (i.e. cable TV companies) have the right, subject to the consent of the owner, to enter upon and break up highways and other "public places" for the purposes of constructing, maintaining or operating their networks and may remain there as long as necessary for that purpose.
- Where companies cannot obtain consent on terms acceptable to them, the CRTC has jurisdiction to determine disputes between companies and municipalities having jurisdiction over highways and public places to grant permission on any conditions it determines.
- While municipalities are entitled to recover all costs incurred as a result of the companies' use and occupation of municipal property, the CRTC has determined that it is "inappropriate" that companies be charged "rent" or any other fee in the nature of land-based occupation charge."

To summarise, the federal government through the CRTC maintains jurisdiction in this area, and can dictate terms of an agreement between a carrier and a municipality, although the municipality is entitled to recover all costs incurred as a result of a carrier's use of a ROW.

City's Role in Jurisdictional Context

As a result of the exclusive federal jurisdiction over wired and wireless telecommunications in Canada, the City of Toronto's role is limited. In the case of wireless, the City can write policies and procedures for proponents to use in the construction of antenna systems. On the wireline side, the City has control over its own right-of-ways and the process of permitting for work to occur inside these ROWs.

Otherwise, in general, the City's role is limited to influence and leverage. As the country's largest population centre, and sixth-largest government, Toronto does have some power in this regard with both the federal government and the carriers themselves.

Past measures taken by Toronto City Council have included motions that reflect the recognition of this influence. These motions have included commenting on CRTC decisions, encouraging the CRTC to enforce some sort of service upon those it regulates[25], and asking the government to make decisions that would be favourable to more competition amongst carriers[26] and better services for consumers.

While the City has seen some limited success through these measures, it should continue to use its influence to advocate for more competition amongst carriers and ISPs, and streamlined regulations governing installation of infrastructure.

4 Wired Broadband Infrastructure

Introduction

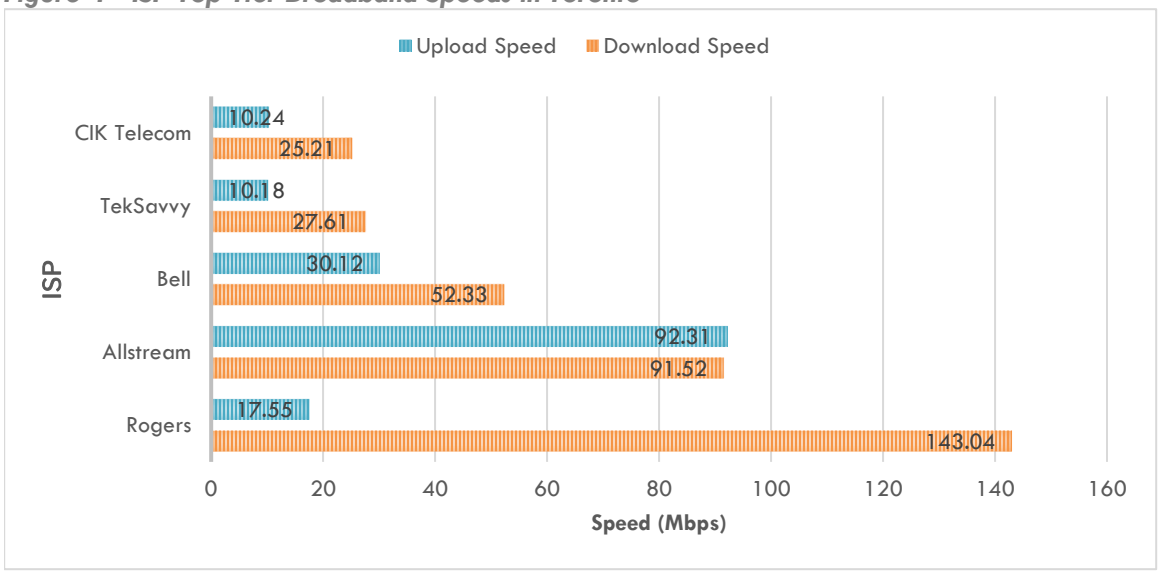
Wired broadband, variously referred to also as cable, DSL, or fibre internet, is the method by which most Torontonians would have first experienced broadband internet. In fact, for most Torontonians over the age of 25, their first internet experience would have been over a wired connection, albeit a phone line-based dial-up service. The term "broadband", while technical in origination, became popularised when it was used to market new internet services in the 1990s that were not dial-up and were therefore not limited to 56 Kbps.

In Toronto, popular wired broadband services were first offered by Rogers Cable and Bell Canada in the 1990s. While there have been many changes in the industry and in technology over the last two decades, these two companies remain the primary providers of wired broadband to Toronto households.

Speed

According to data compiled in 2015 by Ookla Speedtest[27], a free internet speed-testing application and website, both Bell and Rogers have been attaining CRTC-defined broadband speeds for download and upload since

Figure 4 - ISP Top-Tier Broadband Speeds in Toronto



Adopted from "Ookla SPeedtest: Toronto, Ontario Fastest Broadband and Mobile Network Awards", 2015

2015. The other ISP in the top 3, Allstream, provides broadband internet services to businesses only. Distributors, such as TekSavvy and CIK Telecom, pay CRTC-regulated tariff rates to use Bell and Rogers' infrastructure.

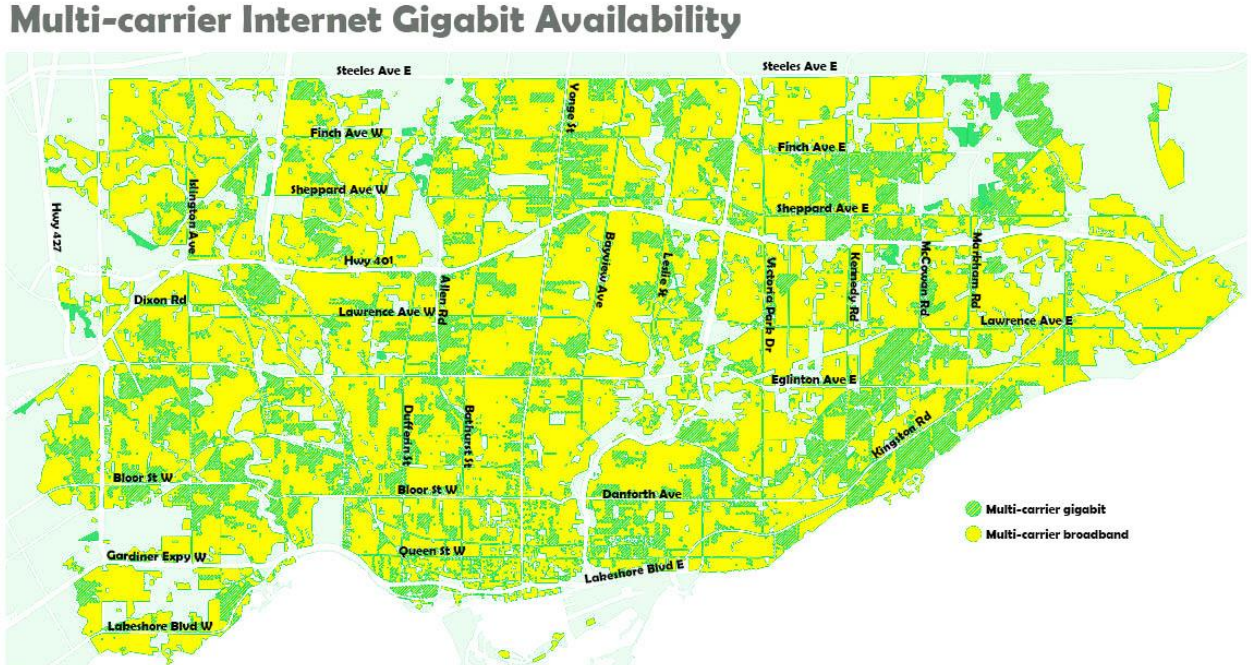
Rogers is well ahead of competitors when it comes to top-end download speed. This is expected to become more competitive over the next year as Bell works to upgrade hardware and re-wire whole neighbourhoods in Toronto for high-speed "gigabit" fibre.

Coverage

As per data collected and presented in Table 1, CRTC broadband speeds are available through multiple ISPs in Toronto, as well as reseller ISPs. Generally speaking, where Bell and Rogers have built infrastructure (which is most, if not all of Toronto), there is CRTC broadband coverage.

During the period of this study, Rogers announced that "burstable" (i.e. speed up to, not constant) gigabit speed is available in almost its entire Toronto footprint (households and businesses included). Data sourced from Rogers and Bell indicates that wireline broadband is available throughout Toronto, with gigabit speed availability becoming more common (shown in green in Figure 5).

Figure 5 – Gigabit and broadband availability map



Affordability

While it is indeed positive that CRTC-defined broadband speeds are being provided to some in Toronto, not all can afford the monthly fees of a 50+ Mbps service. However, as competition for customers continues, hardware is upgraded, and average speeds increase, it should be expected that this level of service becomes the bottom tier provided.

CRTC data suggests that, across Canada, internet services provided by non-incumbent ISPs make up about 12% of the subscriber base.[28] This means that, in Toronto, Bell and Rogers (as the main incumbent ISPs) together likely have a market share of between 80-90%. As the predominant providers of wired broadband in Toronto, Bell and Rogers' pricing is 38% higher than the average retail price of reseller ISPs. The average price of the service offered by Bell and Rogers is $81.47, which on an annual basis is just over 2% of the average household income (2011 census data for the Toronto CSD). The average retail price of base, un-"bundled" broadband internet service amongst reseller ISPs in Toronto, according to publicly available data, is $58.95. The price for Bell and Rogers, on average, would go down if a customer were to "bundle" the service with other services these companies offer (i.e. landline phone, TV), however the overall cost a customer would pay is more. The prices shown are

Table 1 – Broadband (50 Mbps) services offered by carriers in Toronto

ISP	Technology	Advertised Download Speed (Mbps)	Advertised Upload Speed (Mbps)	Data Limit (GB/mo)	Price
Bell	**DSL**	**50**	**10**	**250**	**$84.95**
Rogers	**Cable**	**60**	**10**	**200**	**$77.99**
Distributel*	DSL	50	10	300	$64.95
Distributel*	Cable	60	10	300	$64.95
TekSavvy*	DSL	50	10	200	$46.95
Acanac*	DSL	50	10	350	$53.95
Acanac*	Cable	60	10	350	$63.95
EBOX*	DSL	50	10	1000	$57.95
EBOX*	Cable	60	10	1000	$59.95
Beanfield Metroconnect	Fibre	250	250	Unlimited	$56.50

**Note: These are discount carriers who lease the "last mile" from Rogers & Bellat wholesale rates regulated by the CRTC.*
***Prices do not include modem rental, installation, or other fees.*

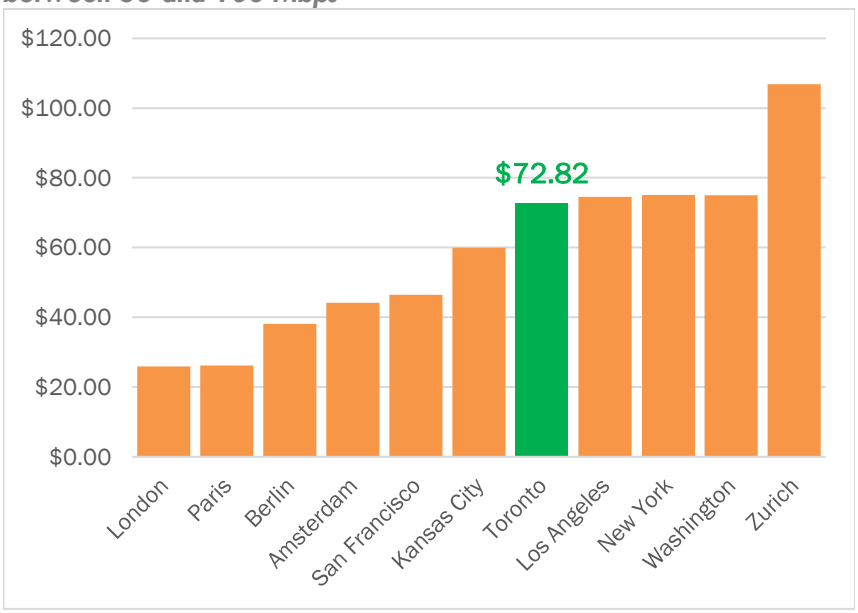
for an un-"bundled" service, to reflect their true price.

Table 1 summarises the base "broadband" services offered by selected carriers in Toronto, and their prices.

Beanfield Metroconnect, meanwhile, deploys their own fibre network, and provides faster speeds at a lower price than resellers and Bell and Rogers, with no usage caps.

The average price in Toronto for home broadband services at speeds between 50 and 100 Mbps is $72.82, which is above average compared to select peer cities. (Through using a different methodology, this study arrived at a similar average price as our analysis in Table 1.) According to 2014 data from the Open Technology Institute[29], the average monthly price of these services in Toronto is in the middle range for North American peers, but well above the average price for European peer cities, which is $48.26 (Figure 5). Overall, these services are offered at a much less expensive rate in Asian and European city peers.

Figure 6 – Average monthly price, home broadband services between 50 and 100 Mbps



This above-average pricing compared to select peer cities can be explained by a lack of serious competitors to the major providers, and a pricing strategy that uses speed as its basis. (The higher speeds that a consumer theoretically desires are always priced at a higher rate.)

Wired technology is the most-used method of connecting to broadband in Toronto for households and businesses alike. ISPs are investing in equipment and new fibre and will be eager to capitalise on these investments. The

reliability, speed and cost of wired broadband makes it an attractive technology for the City to continue to encourage investment in.

Methodology

There are limited sources of information and data on wired broadband networks in Canada. Locations of POPs, COs, and other network infrastructure, as well as fibre networks, are closely guarded by proponents due to competitive reasons. The Canadian Radio-Television Commission (CRTC) has collected data on broadband infrastructure across Canada, using 25 km^2 hexagons. However, this data is limited to the availability of types of broadband service in these hexagons. Therefore, this data is of limited utility for the purpose of this report, as the areas are not small enough for a study area the size of the City of Toronto.

All other data was collected through internet sources, publicly available research, news services, and stakeholder engagement.

Consumer-Oriented Wired Broadband

Bell Canada

Bell Canada's broadband offerings have traditionally been limited by DSL technology, and as such, most Torontonians can currently only technically access speeds of up to 50 Mbps download. In some areas, 25 Mbps download is the highest *advertised* speed available, however customers can acquire up to 50 Mbps download through negotiations with Bell.

The advent of broadband has pushed Bell to make infrastructure changes, since DSL is limited in its capacity and speed. Starting in the early 2000s, Bell has upgraded its infrastructure to the neighbourhood node level (known as FTTN) throughout Toronto, which allows for the maximisation of copper wire and twisted pair DSL infrastructure, without upgrading the "last mile". While this is not considered fibre-based broadband (FTTH), Bell uses the brand name "Fibe" for all of its internet services in Toronto.

Bell is currently in the process of expanding its FTTH network in Toronto, through an investment of more than $1.4 billion. Four neighbourhoods in Toronto are the first to receive it due to the multitude of new buildings—

Harbourfront, Distillery District, Willowdale, and Regent Park. The initial focus of the program is and continues to be installation of fibre in Multi-Dwelling Units (MDUs—apartment buildings and condominiums).

According to Bell, they have been partnering with Toronto Hydro to use their network of poles across the city to deploy the majority of the Gigabit Fibe project (CHRONOS). Approximately 70 per cent of the coverage will be enabled through using these poles, while the remaining percentage will be deployed via trenching.[30]

As this is a complex and costly infrastructure initiative, Bell's objective is to have gigabit service to all Torontonians by 2020. Currently, the project is behind schedule due to unanticipated challenges in construction and trenching. In particular, Bell is experiencing delays in approvals from MDU administrators in processing paperwork and negotiating rates for installation and use of building space for equipment. There have also been scheduling and co-ordination issues with contractors, partners (such as Toronto Hydro), and contractors.

In summary, Bell Canada's most popular base internet service is 25 Mbps in all areas of Toronto, with a mostly unadvertised 50 Mbps download speed available in the majority of the service area. Through the CRONOS project, Bell's objective is to have gigabit service to their entire Toronto service area by the year 2020.

Rogers Cable

Since the advent of cable television services in the 1980s, Rogers has consistently been growing its footprint in Toronto, which is also the home of its headquarters. In 1990, Rogers subsidiary Rogers Cablesystems started deploying hybrid fibre-optic/coaxial cable, which was being adopted across North America at the time[32]. This foresight allowed the delivery of a full suite of digital services and broadband internet. Rogers Cable and their broadband services are available everywhere in the City of Toronto. In fact, download speeds of 100 Mbps are available to its entire Canadian service area[33]. During our study period, Rogers announced that "burstable"—as in "up to", rather than constant—gigabit speed broadband is available in almost its entire Toronto service area (see Figure 5). In addition, over 45% of Rogers' residential internet customers are subscribed to speeds of 100 Mbps or more.[34]

While Rogers can deliver on broadband speeds (as defined by the CRTC) throughout its entire Toronto service area, it still needs to remain competitive with former DSL-based services which are more likely to deliver FTTH in the near future. While DSL-based providers are having to upgrade old copper lines to fibre, Rogers Cable can use its existing infrastructure while upgrading its back-end equipment.

Rogers Cable delivers its broadband services using the DOCSIS standard (Data Over Cable Service Interface Specification), developed by CableLabs, a consortium of cable companies. This standard is regularly updated, and the technology allows for greater speeds. However, it is much more dependant on the number of "channels" a customer is permitted to use. As such, while DOCSIS 3.1 (the most recent standard) is technically cable of speeds of 10,000 Mbps download and 1000 Mbps upload, Rogers Cable and other cable-based broadband services will not make this available to consumers. Usage is also much more "neighbourhood"-based, meaning speeds can be affected by the number of users in one's neighbourhood or those on the same node.
In conclusion, Rogers Cable's broadband network and broadband speeds are available to all households and businesses in the City of Toronto. Continued improvement in speeds are expected as other carriers' FTTH services are expanded and subscription prices are reduced.

Table 2 – Summary of DOCSIS technology iterations

DOCSIS Version	Release Date	Maximum Downstream Synchronization Speed (Usable Speed) (Mbps)	Maximum Upstream Synchronization Speed (Usable Speed) (Mbps)
1.x	March 1997/April 1999	42.88 (38)	10.24 (9)
2.0	December 2001	42.88 (38)	30.72 (27)
3.0 (4 channel)	August 2006	171.52 (152)	122.88 (108)
3.0 (8 channel)	August 2006	343.04 (304)	122.88 (108)

Other Consumer-Oriented Wired Broadband

Beanfield Metroconnect

Beanfield Metroconnect, also known simply as Beanfield, is an independent fibre-based ISP in operation since 1988. Being independent means that they

build, own and operate their entire fibre network. This makes them relatively unique amongst Toronto-based broadband ISPs.

Although coverage is limited to a select few areas of downtown, Beanfield's coverage area has consistently increased on an incremental basis. A primary focus of their business is servicing MDUs in high-density areas of the city, such as Liberty Village and the Distillery District. Since 2011, Beanfield has partnered with Waterfront Toronto (an agency of the Government of Canada, the Government of Ontario, and the City of Toronto) to build a fibre-based high-speed broadband network throughout Toronto's new waterfront communities. As part of the partnership agreement, Beanfield is required to operate the network to a globally-competitive standard. For ten years beyond the completion of the last building, the Beanfield network must be "on par with that of the top seven networks globally in terms of wholesale price and performance".[35]

Beanfield does not plan to establish a fibre network to every household in Toronto—in fact, the expansion of their network is dependant on Toronto continuing to increase in density and Torontonians continuing to choose to live in MDUs. One of the major ways Beanfield chooses to expand is through customer initiative to "sign up" residents in their building. If Beanfield receives enough "inquiries" regarding service in a particular building close to their existing network, they will find it easier to make a business case to expand into this building. As they do not use any other carriers' fibre network, expansion of their coverage area is entirely up to how fast Beanfield decides to deploy its infrastructure.

As the network is entirely fibre-based, Beanfield's base residential package offering is 250 Mbps download and upload, and no usage caps. More expensive packages offer 500 Mbps and 1000 Mbps (1 Gbps) speeds. Business packages are also available at speeds of 10, 100, 1000, and 10,000 Mbps.

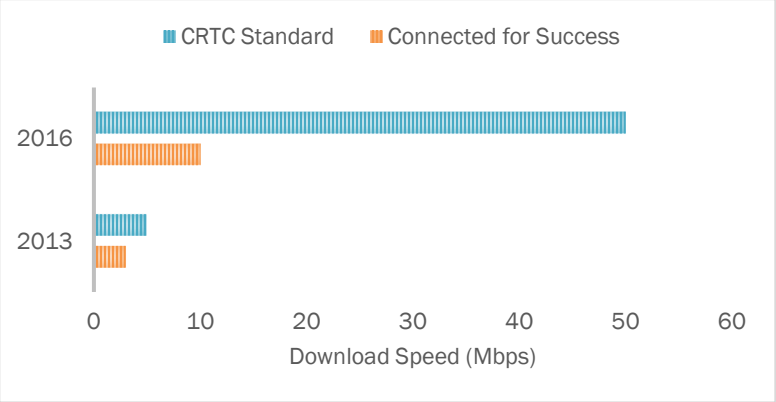
Connected for Success

Rogers is the major provider of internet services to Toronto Community Housing buildings. While this is a benefit in that all residents have broadband available to them, subscription costs can be prohibitive, thus reducing accessibility. In Canada, average internet penetration is over 80 per cent, while in Toronto Community Housing in 2013, it was only 20 per cent[36].

In response to this situation across Canada, Rogers established the "Connected for Success" program in 2013, which provides cable internet access to residents of rent-subsidized non-profit housing (in Toronto, this means tenants of Toronto Community Housing buildings), for a price of $10/month plus tax. The service started by offering 3 Mbps download speed in 2013, when CRTC's definition of broadband was 5 Mbps download. Currently offered are speeds of up to 10 Mbps (download) and 30 GB of usage per month, which is 20% of the CRTC's new standard, vs 60% when it first launched.

"In Toronto Community Housing buildings, internet penetration was only 20 per cent"

Figure 7 – Connected for Success download speed offering compared to CRTC standard



While this program should be commended for providing access to the internet for underprivileged and disconnected residents of Toronto, the speeds provided no longer meet the standard for "broadband" services, as defined by the CRTC, and slower relative to the new broadband standard compared to when it first launched.

Key Findings

- CRTC-defined broadband speeds are technically available to all households in Toronto
- Prices for reseller broadband internet are similar to select North American peer cities, however are costlier than global peers. The average price for Bell and Rogers broadband internet is above the North American average, and well above the global average.
- Pricing is the barrier to accessibility of 50 Mbps broadband speeds.

Recommended City Strategies or Actions

1. ***Strengthen the "Connected for Success" program.***
   The "Connected for Success" program has helped many residents of Toronto Community Housing connect to the internet in an affordable way. However, this program fails to deliver true broadband. The City and its agencies should encourage Rogers to strengthen this program with speed availability in accordance with the CRTC's current broadband standards, so that true broadband speeds are accessible and affordable to the City's lower-income residents.

2. ***Advocate for reseller ISP access to all new infrastructure.***
   As discovered through our Key Findings, accessibility to broadband through affordability is a real issue in Toronto. One of the ways to reduce the costs of broadband services to consumers is to foster competition amongst ISPs. Bell and Rogers have advantages based on their legacy rights to right-of-ways and poles that they can use to expand their fibre networks. By supporting CRTC decisions related to wholesale access to high-speed networks (i.e. Telecom Regulatory Policy 2015-326[37]), Toronto can reduce impacts on its already-crowded right-of-ways and create a more competitive environment for ISPs, ultimately resulting in lower prices for Torontonians.

3. ***Leverage assets to help introduce and expand new infrastructure competitors to the marketplace, aside from Bell and Rogers.***
   Bell and Rogers have legacy access rights to the City's right-of-ways and some poles, as well as other infrastructure. This immediately puts smaller ISPs and resellers at a disadvantage and is a disincentive for companies other than Rogers and Bell to invest in high-speed broadband infrastructure. The City should ensure that either all interested parties have equal access to infrastructure, or that investment in new infrastructure is co-ordinated and shared amongst ISPs.

4. ***Establish public-private partnerships.***
   As per Recommendation #3 above, the City has leverage it can be using to create partnerships with the private sector to expand access to affordable broadband infrastructure and enable competition. While some of the city's ABCs are already demonstrating a capacity to accomplish

this, the City has been less “free” to pursue these opportunities. Through ongoing efforts to reform the City’s procurement process, public-private partnerships should be able to play a larger role in the future of equitable broadband services delivery.

5 Wireless Broadband Infrastructure

Introduction

Wireless broadband is delivered through three different methods described in more detail in this report: mobile (cellular), fixed wireless, and Wi-Fi.

Mobile, or cellular, is a provision of wireless voice and data services over licensed frequencies. As the operators use licensed frequencies, their business falls under the jurisdiction of the federal government (through the CRTC and the Ministry of Industry, Science and Economic Development). Three major carriers operate wireless networks within Toronto's boundaries (Rogers Wireless, Bell Mobility and Freedom Mobile). All other operators are resellers utilising one of these networks. (Telus Mobility operates on the Bell Mobility network in Ontario through a national roaming agreement.)

Fixed wireless is the distribution of broadband connectivity from a wired source through a point-to-point (PTP) or point-to-multi-point (PTMP) network system. The wireless signal used for this delivery can be licensed or unlicensed. The signal transmits from one fixed point and is received at another fixed point. Speed and capacity is limited by the wired connection at the source of the transmission.

Wi-Fi, while similar to fixed wireless, is a distribution of wired broadband through a wireless access point using only unlicensed frequencies. A further distinction from fixed wireless is that it uses non-line-of-sight (LOS) technology, and is received by common devices (i.e. laptops, smartphones, tablets). The speed and capacity of the connection is limited by the wired connection at the source.

As the premier economic hub of the Canadian economy, Toronto has long been the focus for wireless network operators in terms of improving the coverage and capacity of their networks. However, even with this large investment over the last decade or more, network densification is a significant issue being faced by all operators, including Wi-Fi and fixed wireless. The consumption of data amongst Canadians is growing at a rapid rate—for instance, in 2016, mobile data traffic grew by 41%. It is especially an issue for mobile (cellular) operators, who saw mobile data traffic grow 2.2 times faster than fixed IP traffic in 2016.[38]

The project team undertook a thorough review of existing wireless broadband infrastructure in the City of Toronto, which is detailed in the sections to follow.

Methodology

Infrastructure information is available through Industry, Science and Economic Development (ISED) Canada, (formerly Industry Canada) and their Spectrum Management database. The information used in this section pertaining to the location of cellular/wireless broadband infrastructure was most recently updated in March 2017.

Data was also compiled from OpenSignal, an app smartphone users can download onto their devices that constantly monitors the performance of their wireless connection. OpenSignal creates propagation maps from this data, illustrating where users have deficient coverage for a specific carrier.

Cellular Broadband

Cellular broadband is delivered through radio antenna equipment mounted on existing structures and purpose-built telecommunication towers. Fibre lines are fed to the majority of these sites to ensure broadband speed and capacity is delivered to nearby customers. Prior to the advent of digital networks, huge areas of coverage could be provided by relatively few pieces of infrastructure, or tower sites. In the early 1990s, a large portion of central Toronto's coverage was provided through installations on the CN Tower. Today, there are more than 1700 equipment sites in Toronto alone—that's approximately one installation for every 1500 Torontonians. This number will continue to grow, as carriers seek to improve their networks, as technologies change, and as capacity constraints remain a problem. There are only three mobile (cellular) carriers operating in Toronto: Bell Mobility, Rogers Wireless and Freedom Mobile. (Note, Telus Mobility service in Toronto has been provided through the Bell Mobility network since 2009). Maps 7-7A depict the overall network of wireless infrastructure in the City, while Maps 8-10 depict the networks of these three major wireless carriers in Toronto. Note that a number of "reseller brands" operate in Toronto, and these brands are wholly owned subsidiaries of the

There are over 1700 cellular equipment installations in Toronto

major carriers and do not operate their own networks. (For example, Chatr and Fido are Rogers brands; Koodo is Telus; and Virgin is Bell Mobility.)

As telecommunications is a federal jurisdiction, final approval and regulation of the placement of these installations rests with ISED. Installations using existing towers and buildings can be built without seeking local government consent, while purpose-built structures must seek "concurrence" from the City of Toronto under its *Telecommunication Tower and Antenna Protocol* (2013). The ISED standard for delivery of a local decision of 120 days, however this timeline is regularly exceeded due to processing, public sentiment against infrastructure, separate and related policies (for example, "Prudent Avoidance"), and other delays.

Speed

4G/LTE coverage was introduced in the City of Toronto in 2011 by Rogers Wireless[39] and Bell Mobility[40].. Since then, the carriers have worked to improve upon 4G/LTE coverage by replacing old equipment, enhancing existing tower/antenna sites, and adding new sites to increase the capacity of the network.

Within the last decade, new entrants have built networks in Toronto starting with 3G. The surviving new entrant, Freedom Mobile (formerly WIND Mobile/Globalive Wireless) is in the process of upgrading its network to 4G, starting with the Toronto market. Having four competitive wireless service providers is very positive for the Toronto economy, as the increased competition can lead to quicker improvements being made to networks.

In terms of speed, a recent study has shown that Canada's main carriers average 4G/LTE speeds faster that the worldwide average. According to OpenSignal, Canadian 4G/LTE download speed was 10 Mbps faster than the global LTE average of 17.4 Mbps[42]. Network statistics also from OpenSignal indicate that the average connection speed in Toronto amongst the 4G/LTE carriers is even higher, around 33 Mbps.

With the evolution of wireless technology, broadband over wireless (or broadband over LTE) is fast becoming an alternative to traditional wired broadband facilities. Broadband over wireless target speeds for mobile (cellular) providers is 1 Gbps download. This speed will increase the mobility of gigabit broadband and act as an enabler for future technology, without any financial

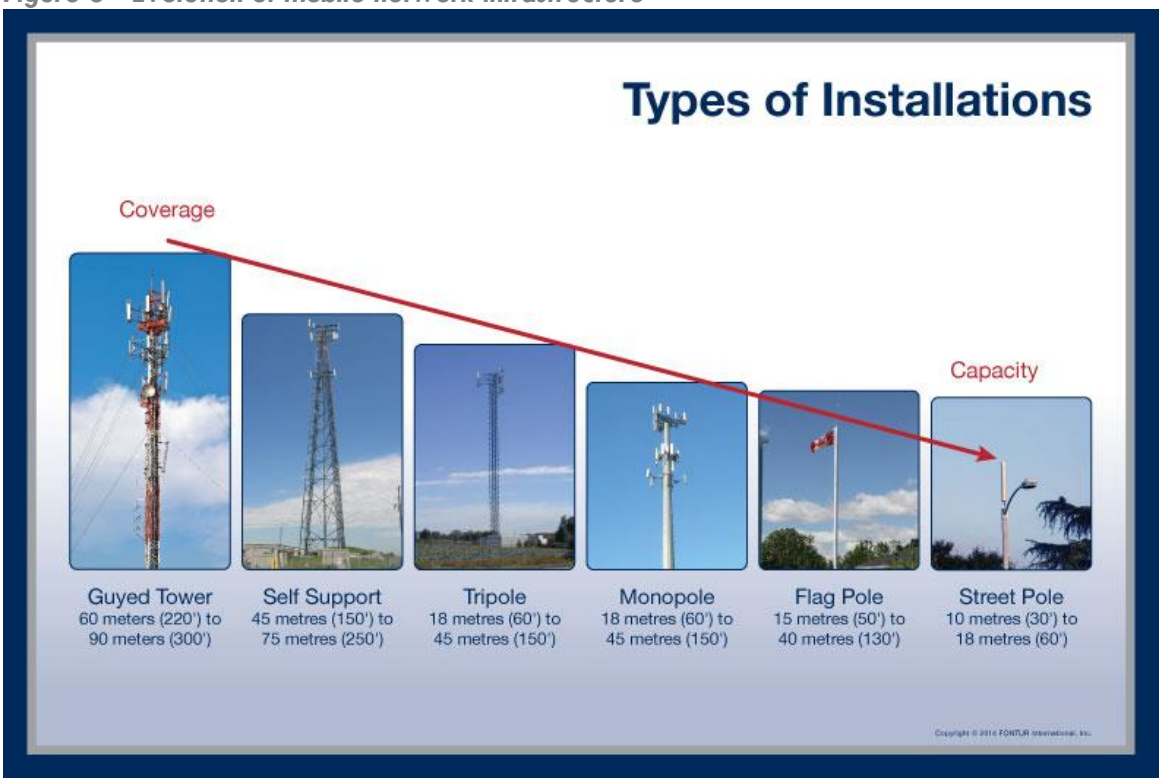
investment required of the City. For instance, downloading an entire movie to a mobile device will occur in less than a second when gigabit speeds are implemented.

Coverage

Data collected through OpenSignal, ISED, and stakeholder interviews showed that Toronto is well-served by Bell Mobility and Rogers Wireless in terms of 4G/LTE networks, with the exception of a few areas. Freedom Mobile, is still growing its network in Toronto, and in its infancy it has already run into capacity issues. Mobile (cellular) networks are in a constant state of evolution, as no sooner than 4G/LTE has been deployed, the need for 5G is already on the horizon. The primary purpose of mobile networks has changed over time. The initial purpose of mobile was the provision of voice calling inside of a car, and now the next generation purpose is ubiquitous broadband data speed, coverage and capacity. This growth in data is clearly shown in Figure 9, with voice growth being static for the past 5 years, and data growing by 60% in the last year alone.

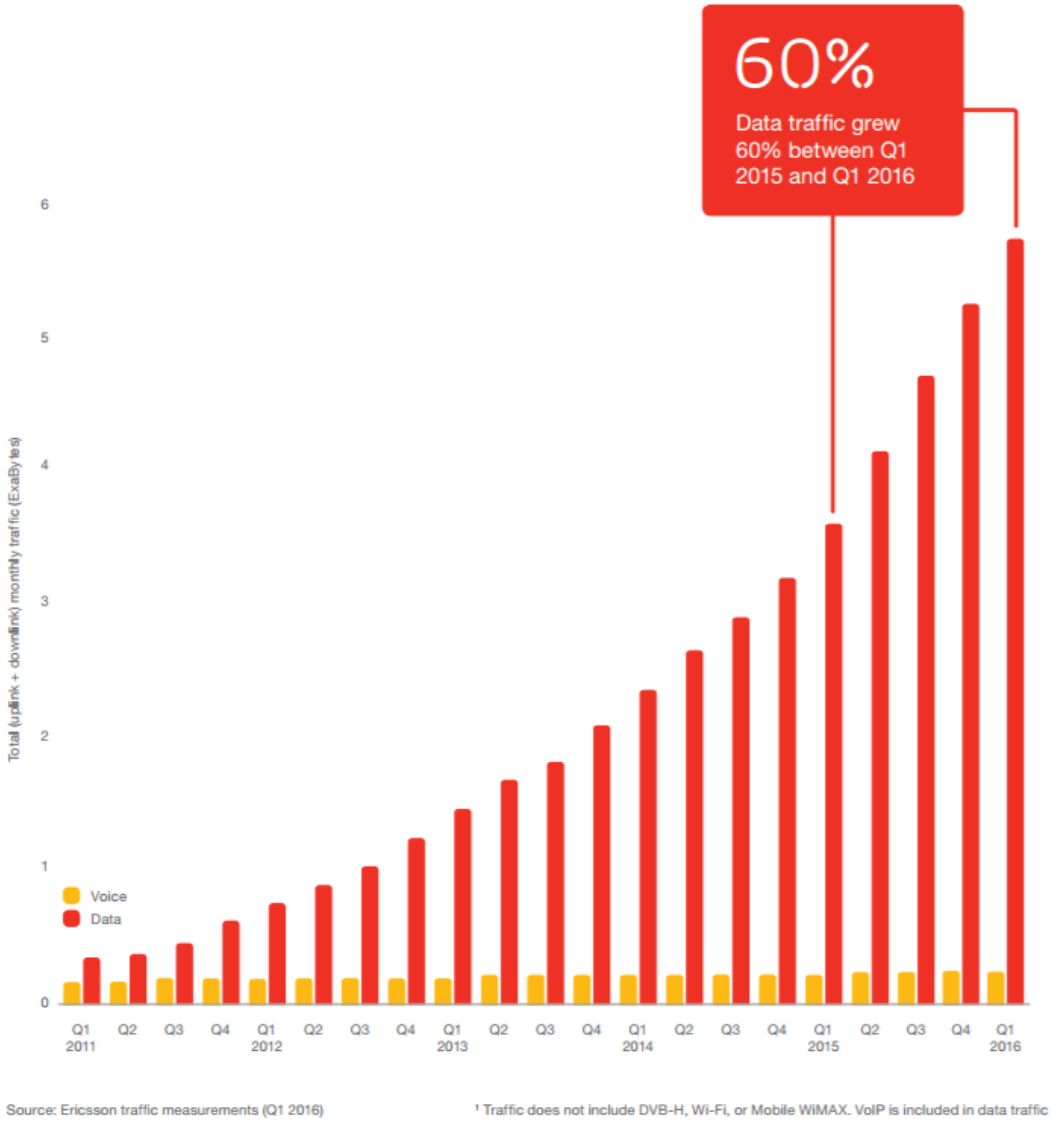
Ericsson predicts that by 2021, monthly data usage per North American mobile device user will jump by seven times to 22 GB per month. This thirst for mobile data has significantly impacted mobile networks, requiring significant capital expenditure on densification of sites in order to meet consumer demand. The provision of mobile broadband data speed and capacity has driven the cell site closer to the end user. This is not new to mobile networks, as shown in the evolution diagram (Figure 8). However, the evolution of mobile data utilisation predicts a need for the deployment of thousands of new "density" telecommunication sites in the City of Toronto (i.e. small cells). Small cells is "an umbrella term for operator-controlled, low-powered radio access nodes… [that] typically have a range from 10 meters to several hundred meters."[43]

Figure 8 - Evolution of mobile network infrastructure



Current mobile network sites shown on Maps 8-10 do not illustrate a significant number of gaps in high-level coverage footprints for the major carriers. This visual is deceiving however, as coverage shrinks exponentially with data utilisation on a site-by-site basis. This means that from the same location, coverage for streaming video at 2:00 p.m. (i.e. a quieter time of day) may not be an issue, while placing a voice call at 6:00p.m. (i.e. a busier time of day) may not be possible.

Figure 9 - Mobile data and voice traffic, worldwide



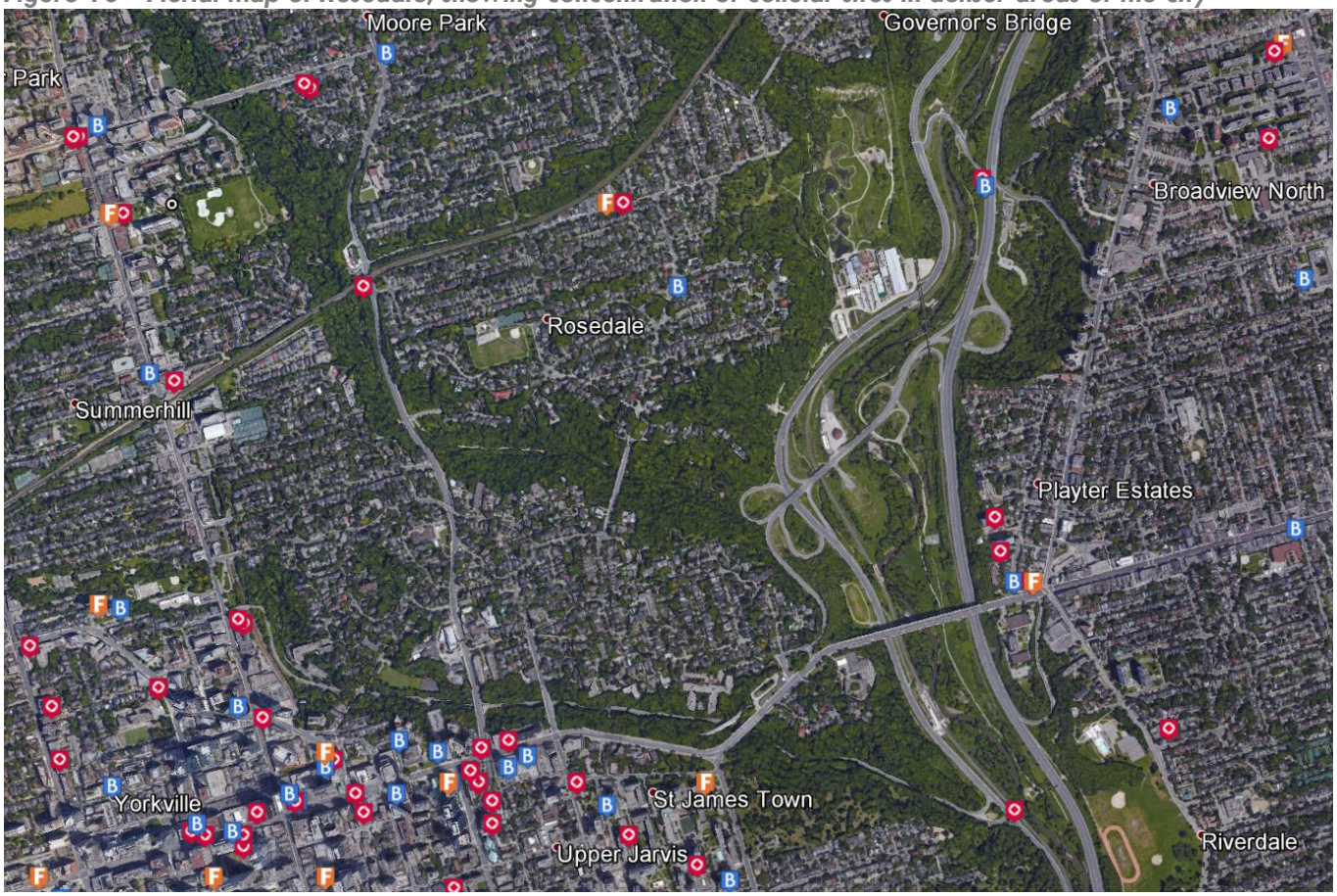
Source: Ericsson, 2016. *Ericsson Mobility Report.*

Mobile broadband carriers tend to share similar coverage issues due to limitations of available infrastructure for network sites (see Figure 10, for example). Key factors limiting deployment of wireless sites in Toronto are:

- Local opposition to infrastructure (NIMBYism)
- Topography
- Appropriate infrastructure access
- The Prudent Avoidance policy
- Political ramifications imposed on current protocol
- Aesthetic considerations

- Land or property availability/willingness of land owners to host equipment

Figure 10 - Aerial map of Rosedale, showing concentration of cellular sites in denser areas of the city



Source: ISED Spectrum Database, Google Maps

The strategies around the next phase of mobile broadband sites will vary by wireless carrier. However, the objective of ubiquitous broadband coverage will be shared amongst Bell Mobility, Rogers Wireless, and Freedom Mobile.

Affordability

Mobile broadband requires significant monthly investment on the part of consumers. The average advertised monthly price of a cellular phone plan in Toronto with at least 1 GB of data included was $61 in 2017. Including the device in the cost (using a Samsung Galaxy S8 as the comparable across carriers) resulted in an average monthly cost of $94. Table 3 summarises plan prices with and without devices for the major carriers and resellers in Toronto.

Affordability is also affected by the rapid evolution of devices used to access the latest wireless broadband technology. Devices can quickly become out of date and operate at below-standard broadband speed when new networks (such as 4G/LTE or 5G) come on-line. The cost to upgrade to the latest smartphone technology can be upwards of $500.

Table 3 - Prices of cellular plans with at least 1GB of data/month in Toronto

Carrier	Talk & Text	Data	Advertised Monthly Price*	24-month Cost, incl. Device**
Freedom	Unlimited	4GB	$40	$1800
Koodo	500	1GB	$55	$2324
Fido	500	1GB	$65	$2269
Virgin	500	1GB	$65	$2374
Telus	300	1GB	$65	$2425
Bell	300	1GB	$70	$2184
Rogers	300	1.5GB	$70	$2489

*Prices as of May 2017.
**Samsung Galaxy S8 used as sample device.

Mobile broadband prices are also based on data throughput (i.e., how much data is included in a plan) unlike wired broadband, which is based mostly on the speed of the service. Therefore, although an individual would have access to broadband speeds through their wireless device, their ability to use the service in a cost-effective manner is limited by the data throughput provided with their plan.

Globally, Canadian prices for mobile or cellular broadband are generally found to be on the high end of comparative industrialised nations. The CRTC and ISED commission an annual comparison study of Canada's telecommunication services versus select foreign jurisdictions' services. Although it is challenging to compare rates across jurisdictions due to vastly different regulatory environments, "service baskets" are used to draw a relatively fair comparison. The most recent study found that Canadian mobile cellular rates are, on average, higher than those in other jurisdictions. Out of six service baskets (1 being the least expensive service option, 6 being the highest), Canadian prices are highest in service basket 1, second highest in 3-6, and third-highest for service basket 2.[44] This continues to be the case even after the introduction of an additional competitor to the marketplace, which already reduced rates in Toronto.

The monthly price of a mobile broadband service is almost equivalent to a wired broadband subscription. An average consumer in Toronto who uses both

wired broadband and wireless broadband would therefore have a monthly bill of more than $150. This represents the minimum cost of the "Anything, Anywhere, Anytime, Anyway" (4A) connectivity objective of many Torontonians. This cost also represents the consumer costs for "smart city" access, as smart city apps and IoT become mainstream, risking a further deepening of the "digital divide" in Toronto.

An average consumer in Toronto would have a broadband bill of more than $150/month

While the prices of wired and wireless plans are similar in absolute price, a 1GB wireless connection is highly limiting to the user. The cost impacts of increasing data throughput on a wireless connection are much higher than those associated with increasing speed for fixed IP or wired data connections. As previously stated, mobile data growth is outpacing fixed IP (including Wi-Fi) data growth, thus increasing gaps in affordability of broadband. In addition, according to Bell Mobility, 39% of mobile device users prefer mobile data to Wi-Fi, due largely to the ease of use when compared to log-in time, access and connectivity issues, etc. that plague Wi-Fi installations. Extrapolating on these trends, mobile data will continue to grow to a point where it will become the preferred, if not only form of broadband connectivity for consumers in the future. This consumer reliance and inclination towards mobile data will only serve to further exacerbate the broadband affordability issue.

The "gaps" in wireless broadband coverage, as identified through our research based on the ISED Spectrum Database plotted in Maps 8-10, have little to do with socio-economic factors. Wireless carriers do not target specific neighbourhoods based on affluence, but rather on the number and density of users. Gaps are more likely to be caused by topographical and land-use compatibility challenges, and in fact, wealthier neighbourhoods are more likely to have poorer wireless service. This is for multiple reasons, generally speaking:

- Low-rise and low density structures are predominant in wealthier areas, limiting appropriate infrastructure placement; and
- Wealthier neighbourhoods are often in topographically varied and well-treed areas, making wireless coverage more challenging.

Wireless broadband affordability will become the new catalyst for the evolution of the digital divide in Toronto from access to affordability, as the predominant influencing factor.

Prudent Avoidance Policy

The City of Toronto's Prudent Avoidance policy, implemented in 1999[45], asks telecommunication tower and antenna proponents to provide estimates of radiofrequency exposure levels for their installations, and to limit those levels to 100 times below Health Canada's standard (Safety Code 6). The policy, in effect an additional layer of regulation on top of federal guidelines, is unique in the world. While written to be voluntary for carriers to comply, in practice it is enforced by City staff as a requirement of the process. In 2013, the Medical Officer of Health recommended that the policy be discontinued, based on the fact that it "[did] not confer a health benefit to the residents of Toronto"[46]. This recommendation, however, was not endorsed by the City's Board of Health and as a result, the policy remains in place.

Prudent Avoidance, although well-intentioned, could seriously impact the future implementation of "smart city" technologies based around wireless infrastructure. Meeting Safety Code 6 guidelines involves a cumulative assessment of all pre-existing wireless emissions, in addition to the emissions from any new installation.

As wireless broadband (including Wi-Fi) is a very fluid and rapidly-changing industry, the City should ensure it is kept up-to-date on the challenge that Prudent Avoidance presents and its limiting effect on the expansion of broadband networks as technology evolves.

Fixed Wireless Broadband

"Fixed wireless" services are those that use either licensed or unlicensed spectrum to provide communications services to a fixed location. Commonly used in rural areas where long distances are required to be covered and costs of laying fibre are restrictive, these types of installations are relatively uncommon in Toronto. Consumer-based fixed wireless does not appear to be a viable business in Toronto due to ease of access to wired broadband for reseller ISPs through CRTC-regulated tariff rates. Primarily, fixed wireless systems are offered as solutions to businesses looking to add a more affordable high-speed broadband connection to their building where costs for laying fibre offered by a wired ISP are seen as prohibitive. Fixed wireless systems are also commonly used to add redundancy to their connections as well as connecting between multiple buildings to create a local-area network.

As fixed wireless is uncommon in urban areas, there are not many fixed-wireless service providers operating in the City. The largest is TeraGo Networks, whose sites are concentrated in and around many of Toronto's employment districts. TeraGo's clients are businesses only—no residential services are provided.

It is not expected that fixed wireless services will be a prevalent factor in the future of broadband services in Toronto, beyond providing redundancy and office-to-office connections for businesses. However, it could be used, for example, by the City to provide broadband connections between buildings, depending on line-of-sight capability.

In-Building Wireless

Access to mobile data coverage is the cornerstone of anything "Smart". The way people use technology influences the way infrastructure is built. Today, 80% of mobile device use originates indoors, and so systems that provide wireless connectivity inside of buildings are a critical part of "smart buildings" and "smart cities".[47]

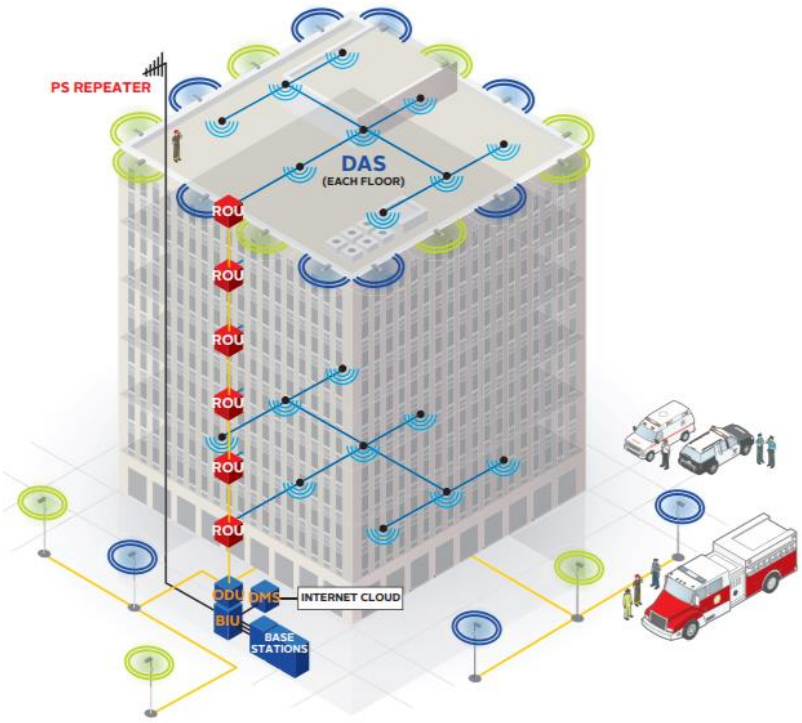
The enablement of wireless communications 'everywhere' is fast becoming a challenge, as the growth in mobile data continues to be driven by consumer appetite for "Anything, Anywhere, Anytime, Anyway". This appetite for the "4A" world is the catalyst for Wi-Fi deployments and has pushed the need for wireless coverage and capacity from outdoors to indoors, closer to the user. The need to get closer to the user is driven by the evolution of available spectrum—early cellular operated at lower frequencies and offered better penetration, however broadband-based wireless (including Wi-Fi) operates at higher frequencies which offer poor penetration of buildings.

Each "smart" device now uses a factor of 120x more data than a traditional flip phone

The impact of mobile data growth on traditional outdoor wireless networks is a significant problem globally. The number of users has grown, the number of devices per user has grown, and the capability of each device has grown. The average number of on-net devices per user is already greater than 1 with forecasts over 3 by 2020[48]. Each device now uses a factor of at least 120x more data than the traditional flip cell phone of a few years ago. Considering these

facts, it should be recognized that the throughput required on outdoor wireless networks is tremendous. In addition to this, wireless signal loss occurs when trying to penetrate any building materials, further degrading the ability of wireless broadband operators to satisfy consumer "4A" demands for wireless broadband.

Figure 11 - An example of an in-building wireless DAS system



Source: SOLiD, 2016. *In-Building Wireless and Public Safety Imperative.*

This creates a need for wireless infrastructure within buildings and facilities. Wireless in-building infrastructure has basic network components that can accommodate all forms of wireless signal.

While there are numerous methods to deploy these components (which often vary depending on the objective), a Distributed Antenna System (DAS) is the basic infrastructure required for the provision of wireless signals throughout a building. There are four key services inside of buildings that require the distribution of wireless signals:

1. Public Safety Communications
2. Building Automation
3. Wi-Fi
4. Mobile voice and data

"Well over 70% of all 9-1-1 emergency calls are placed from a wireless device"

In particular, public safety inside of buildings has become a key motivator for the installation of in-building wireless systems. Statistics gathered from public safety answering points (PSAPs) in 2013 indicate that over 70% of 9-1-1 emergency calls were placed from wireless devices—this number is certainly higher today[49]. Codes and regulations in many jurisdictions have caught up to this reality and now provide standards for level of radio service in buildings. For instance, the International Fire Code,

Section 510.01, requires that new buildings have radio coverage inside consistent with existing outdoor radio coverage[50]. Numerous municipalities have enacted by-laws to ensure public safety radio coverage inside buildings—for example, Port Coquitlam (By-Law No. 3738) and Surrey (By-Law No. 15740) in British Columbia.

Overall, in-building wireless represents an opportunity for the City to further its "smart city" mandate, using its jurisdiction to encourage multi-platform DAS systems to be built throughout Toronto. By encouraging the co-ordinated and widespread implementation of in-building wireless, Toronto can create for itself a competitive edge against peer cities, while also enhancing public safety and wireless broadband access. The City is not currently active in this area.

Wi-Fi Hotspots

There are very few reliable data sources available on publicly-available, free Wi-Fi hotspots. However, based on the data that is available, it is likely that there are thousands of Wi-Fi hotspots in Toronto.

All 100 Toronto Public Library branches provide free access to Wi-Fi. Some other City facilities, such as City Hall and Civic Centres, also have open Wi-Fi networks, however application of these services is inconsistent and does not provide coverage throughout the buildings. Most arenas and community centres do not currently provide the service.

The City of Toronto has a complicated past with Wi-Fi networks and its role in providing the service. In 2006, the former Toronto Hydro Telecom launched a Wi-Fi service covering 6 km^2 of the downtown core. Initially a pilot project, it eventually became a paid service ($30/month) and gradually the number of users declined. The network was subsequently sold to Cogeco and dismantled.

Various City Council members have also put forward proposals for the City to pursue installation of Wi-Fi hotspots in public spaces. Most recently, after an unsuccessful effort in 2013, in 2015 Council and the Economic Development Committee adopted a proposal to investigate the feasibility of building a Wi-Fi network in parks, squares, Toronto Community Housing buildings, and privately-owned public spaces[51]. The justification for this effort was: to project an image of a "tech-friendly city"; to improve tourism and provide an amenity for tourists; and to overcome the "digital divide" with Wi-Fi at TCH buildings.

Some carriers also operate their own network of Wi-Fi hotspots, normally in partnership with retailers/restaurants. For example, Bell Mobility offers over 200 free Wi-Fi hotspots in McDonalds', Tim Hortons, and Chapters/Indigo locations within the City of Toronto[52]. In many cases, users can access these hotspots without being in the store or restaurant or purchasing a product. That said, businesses normally have a certain expectation for users of Wi-Fi to purchase a product.

Digital Main Street

Digital Main Street is a partnership between Toronto Association of Business Improvement Areas (TABIA), the City of Toronto, and Kinetic Café. It is a program that helps enable mostly retail businesses to utilise digital technologies and tools to engage with customers and grow their business.

Recently, several pilot projects using Wi-Fi technology have emerged from this program. Toronto's BIAs understand that Wi-Fi and internet access are key to economic development. However, BIAs are often volunteer or part-time based organizations, meaning it is difficult in some cases to develop initiatives that require capital or other resources. Through Digital Main Street, Bloor West Village BIA partnered with companies including Turnstyle, PeopleFlow and GenWave to install a Wi-Fi mesh network along the BIA's retail strip on Bloor Street West in 2016. This network is being used to identify and track consumers through their mobile devices to observe how they move in and out of a space—so that a business can get a sense of how often people visit their store, how long they stay, and where they come from. This is the primary use of the Wi-Fi network, as opposed to providing Wi-Fi hotspots as a public service, which becomes a secondary benefit of the infrastructure. Note that the infrastructure was installed on BIA-owned street furniture (decorative light standards) in the public right-of-way.

In 2017, the Queen West BIA is planning something similar to coincide with their planned streetscape improvements. In this particular case, Wi-Fi will be provided in and around two new "parkettes", areas at the corner of Queen Street West and smaller, one-way side streets reclaimed from live traffic lanes or street parking lanes.

These partnerships through Digital Main Street and TABIA serve as a model for the City, as a public good (Wi-Fi) is provided with limited capital expenditure and governance responsibility on the part of the City.

Key Findings

- The vast majority of the City of Toronto is well-covered by cellular broadband. Further enhancements of the existing 4G/LTE and upgrades of 3G equipment are expected in the next year. Mobile broadband will continue to be expanded and upgraded by major carriers, with little or no encouragement or involvement by the City of Toronto.
- Wireless broadband affordability will become the new catalyst for the evolution of the digital divide in Toronto from access to affordability, as the predominant influencing factor.
- Historically, the City of Toronto has implemented layers of regulation to the deployment of wireless infrastructure (i.e. Prudent Avoidance). The effectiveness of the City's protocol depends on the execution of its requirements in a timely manner.
- The few coverage gaps that exist can be attributed mainly to topography and land-use constraints, rather than socio-economic factors.
- In many areas of Toronto, the speed of cellular broadband (4G/LTE) networks is faster than average DSL/Cable/fibre offerings.
- Fixed wireless services are uncommon due to the near-ubiquitous access to wired broadband in Toronto.
- More than 70% of 9-1-1 calls are made from mobile devices.
- 80% of mobile use originates and terminates indoors, making in-building wireless a key cornerstone of any "smart city".
- Open Wi-Fi networks, although ubiquitous in dense areas of the city, is currently a patchwork of providers which can be difficult to access.
- Organizations such as BIAs are providing free Wi-Fi by their own volition with little to no government support required.

Recommended City Strategies or Actions

1. *Institute a regular review of the City's Telecommunications Protocol to ensure it is up to date.*

   Currently, the City's protocol for telecommunication towers and rooftop antennas is not part of a regular review process. A review of the protocol to ensure relevance and desired outcomes is recommended to take place at least every two years, due to the rapid evolution of wireless network technology. The review, administered by the City's Planning department, should provide for an accounting of how many applications were submitted, how many installations were approved, as well as an update of any database the City keeps regarding cellular installations. The review should also consider any issues with processing times and identify opportunities to simplify the evaluation process.

2. *Remove the "Prudent Avoidance" measure from City regulations.*

   This extra layer of regulation of electro-magnetic frequency (EMF) radiation of wireless equipment has been found to be unnecessary by the City's Medical Officer of Health, time-consuming and costly to enforce. Furthermore, it does not improve the health or safety of Torontonians, as the federal government's existing Safety Code 6 regulations are widely viewed as being cautious and adequate. Removing this extra layer of regulation would free up staff resources as well as allow wireless broadband providers to improve the speed and capacity of their networks more quickly in response to demand.

3. *Leverage existing City assets to improve speed, coverage and capacity.*

   The City should be open to allowing third-parties to locate wireless broadband equipment on and in City-owned poles, buildings, right-of-ways, and other assets. Permitting this should generate revenue for the City, while allowing third-parties to improve coverage and capacity indoors and outdoors. (Some agencies/departments of the City are already leveraging assets—e.g. TCHC leases hundreds of its rooftops to carriers for equipment). A thorough review in this regard should be undertaken by the Real Estate Services Department in conjunction with the City's IT and Economic Development & Culture Departments. Part of the City's openness to this type of infrastructure should include a willingness to work with all types of third-parties, not just incumbent or larger wireless broadband providers.

4. ***Include In-Building Wireless Systems in requirements for new construction.***
   Other jurisdictions have instituted municipal by-laws that require consideration of in-building radio and wireless coverage for new construction. This is important for a number of reasons stated previously in this section, but most of all for public safety purposes. Many developers are already including in-building wireless systems in their building designs. These systems are not built to any specified standard, and are often dictated by cost, not system delivery. Therefore, standards should be established by the City (as they are in other jurisdictions) to ensure a minimum level of service availability can be expected to avoid potentially unsafe conditions. Unlike other jurisdictions that have adopted in-building wireless by-laws, the City should include provisions for mobile accessibility on these systems. A co-ordinated approach to in-building wireless could also give Toronto a competitive "smart city" advantage.

5. ***Allow ubiquitous, free public Wi-Fi to become an economic development opportunity in the City of Toronto via free-market forces.***
   Free ubiquitous public Wi-Fi deployed by the City of Toronto is of limited benefit to Torontonians or the City's economy. The development of Wi-Fi in Toronto should be allowed to occur organically through private investment, without funding or deployment by the City.

6. ***The City and its ABCs should deploy strategic managed Wi-Fi in appropriate venues with appropriate pricing structures.***
   The economic benefit of ubiquitous, free Wi-Fi is questionable. However, there are certain social benefits to the provision of Wi-Fi for uses such as checking email, applying to jobs, doing research, or reading the news. This type of activity should be encouraged and allowed through the provision of Wi-Fi in libraries, community centres, employment centres, and similar community hubs. Use of Wi-Fi for other purposes (such as online gaming, high-quality video streaming) should be regulated through pricing.

6 Commercial Data Centres

Introduction

As Canada's economic hub, Toronto is also home to a growing amount of data centres and/or carrier hotels. The most up-to-date information suggests that the City is home to over 40 such hubs, somewhat concentrated in the downtown core[53]. These data centres provide opportunities for ISPs, telecommunication carriers, and other service agencies to exchange internet traffic, as well as acting as regional fibre hubs and hosting content on servers.

Commercial Data Centres in Toronto

The largest data centre or carrier hotel in Canada is at 151 Front Street West, one of eight carrier-neutral facilities in North America[54]. This data centre is home to the Toronto Internet Exchange Community (or TorIX), a not-for-profit Internet Exchange Point that is the 17th-largest by number of peers in the world (fourth-largest if multi-city Internet Exchange Points are counted separately)[55]. Recently, Toronto has seen investment in new data centres and carrier hotels at an increasing rate. As the central hub of the internet in Canada, it is critical for data centres to be located close to the downtown core, so as to limit latency[56].

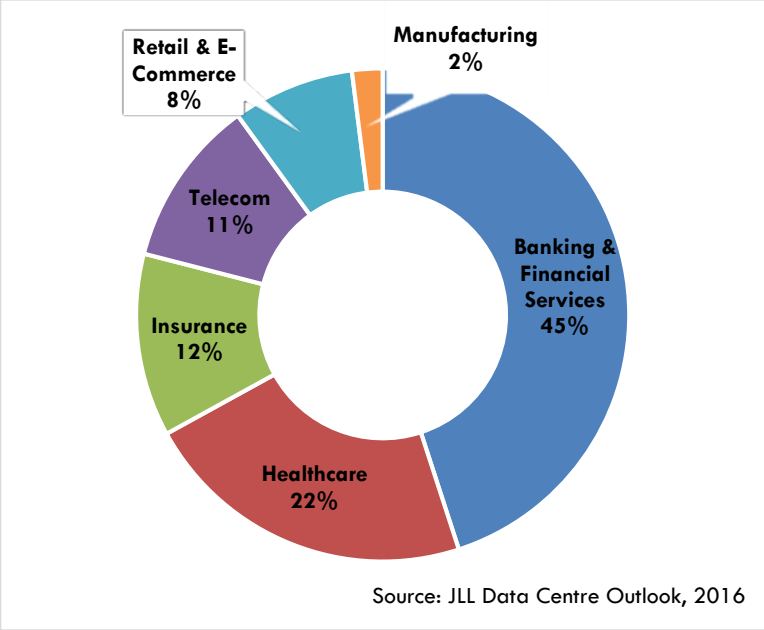
Toronto Internet Exchange Community (TorIX) is the fourth-largest single-city internet exchange point in the world

In the past, it was common for large corporations to maintain their own data centres within their own office buildings, for example. However, corporate-run data centres have declined in use since 2014, largely because of limited space being available and high lease rates[57]. The result is that more businesses are opting to use the services of a data centre.

Although Toronto has a built-in advantage as the financial and business centre of Canada, there are risks to continued growth in data centres. Electricity costs are a primary concern of data centre operators, due to the heavy consumption required to keep electronic equipment running, secure, and cool. In Ontario, hydro rates are on average twice that of rates in Quebec, for instance. Here again, certain areas of Toronto have an advantage—some data centres in

Toronto, including 151 Front Street West, use Enwave's Deep Lake Water Cooling system. This system allows building owners to cut electricity usage, reduce capital and maintenance costs, and free up more leasable area in the buildings themselves.

Figure 12 – Data Centre Demand in Toronto by Industry, 2016



Commercial data centres are particularly important to Toronto's booming film production sector, which employs more than 25,000 people and results in investments of more than $1 billion in Toronto[58]. It is critical for a feature film being shot in Toronto, which can be around 1 petabyte in size[59], to have close and reliable connections to data centres. These connections allow managers to share the film between studios and other post-production facilities quickly and securely.

Within the last decade, Toronto's tech sector has grown and is now primarily based in the downtown core. As many of these businesses are "cloud-based"—that is, reliant on data centres—being in proximity to these data centres is important to their business operations.

It is likely that Toronto will continue to act as host to commercial data centres and carrier hotels as long as they are a necessary part of internet infrastructure.

Key Findings

Commercial data centres and carrier hotels are important pieces of internet and broadband infrastructure. The following is a summary of our key findings:

- Toronto is Canada's internet and broadband hub, hosting most of the infrastructure backbone and providing key gateways into the United States and the rest of the world.

- There are over 40 data centres and carrier hotels in the City of Toronto, primarily concentrated in the downtown core.
- Continued growth in this area is expected as Toronto's status as an internet hub will remain intact and demand for non-corporate data space and cloud services grows.

Recommended City Strategies or Actions

1. ***Promote Toronto's strength and prominence as a North American internet hub.***
   Advertising and promoting Toronto as an attractive place for data centres and carrier hotels will help the City leverage existing infrastructure, enhance the City's global brand, and create employment opportunities.

2. ***Maintain a database of existing and future commercial data centres.***
   Commercial data centres have been demonstrated to be key to the success of specific film and technology-based industries, many of which run their businesses based on "cloud" infrastructure (data centre-driven storage and operations solutions). A database of data centres including information such as capacity, geographic location, average costs, etc. may be useful tool for the City's Economic Development department to continue encouraging growth of Toronto's burgeoning tech sector.

7 Other Broadband Infrastructure

Introduction

There are several unique wired and wireless networks that either are already used for or can be used for broadband services that the City should be aware of. These are often crucial pieces of infrastructure that have helped Toronto grow into a hub for finance, research, technology and education. Maintaining and facilitating the expansion of these networks, and fostering partnerships among network owners, is critical if Toronto is to maintain its status as a leader in these areas.

For the infrastructure that the City owns or has owned, it is recommended a further analysis of the ownership status and state of repair for each of these pieces of infrastructure is undertaken.

Methodology

Information about these existing networks was gathered through consultation with various stakeholders, City departments, and downloads from the City's Open Data portal. It is quite possible that more infrastructure could be discovered, as many of these are legacy systems operated by singular departments or organizations.

Infrastructure

Hydro One Telecom

This provincially-owned corporation uses its right-of-ways through Toronto and Ontario, spanning more than 4000 kilometres, to provide broadband data services to businesses and government organizations.

Hydro One Telecom's fibre network is laid mostly underground in Toronto through the major hydro corridors including Gatineau, and above-ground in the Finch Hydro Corridor. Fibre is also laid along the Lakeshore East and West railway lines and the Weston subdivision. Hydro One Telecom's network is mapped in Map 4, and information was obtained from their corporate website.

Allstream/Zayo Canada

Allstream provides fibre-based wired broadband services to the business community in the City of Toronto, as part of its 30,000-kilometre national fibre network. As described in Figure 3, top-tier download speeds offered by Allstream are second only to Rogers in Toronto, and upload speeds are the highest. Upload speed is particularly important to businesses, for things like video conferencing, cloud-based data back-up, and exchanging large files.

Headquartered in Toronto, it is now owned by American-based global wholesaler of broadband connectivity Zayo, but continues to provide services to businesses and governments. Under the new ownership structure, the provision of broadband services will be through the Allstream brand, while the fibre assets are to be held in a new separate entity, Zayo Canada.

Zayo's infrastructure is publicly available information on their corporate website for information purposes only. Maps 6 and 6A provide a snapshot of Zayo's fibre network in Toronto, which closely resembles other similar networks, such as Cogeco.

Cogeco Communications

Cogeco was the first cable company in Canada to offer "high-speed" internet services. It is the 8th-largest cable operator in North America, with operations in Quebec, Ontario, Pennsylvania, Florida, Maryland/Delaware, South Carolina and Connecticut[60]. It provides both residential and business services in this areas through its broadband fibre networks. Also included under the Cogeco Communications umbrella is Cogeco Peer 1, which provides information technology services to businesses with its data centres and fibre network.

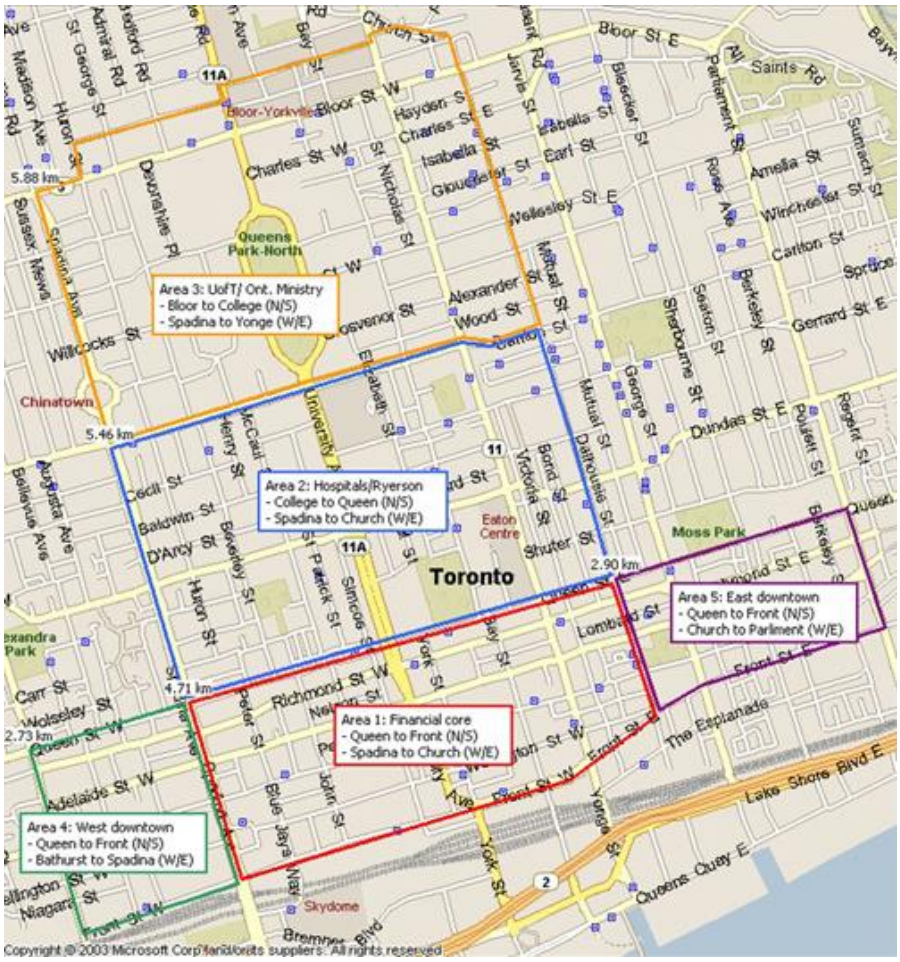
Using information provided by Cogeco, Maps 3 and 3A illustrate Cogeco's fibre network in Toronto. Starting in the downtown core, a large part of the fibre is laid along Yonge Street and following the Yonge-University subway line. Other portions of the network are laid along railway corridors and hydro transmission corridors, as is typical for fibre networks.

Toronto Hydro Telecom

In the early 2000s until its sale to Cogeco in 2008, Toronto Hydro had a subsidiary called Toronto Hydro Telecom Inc. (THTI) through which as built

both a fibre network across the city as well as a Wi-Fi zone in downtown Toronto. A map of these networks is included in Figure 13[61].

Figure 13 – THTI's One Zone Wi-Fi network phases.



The Wi-Fi service, branded as "One Zone" was announced in March 2006 and went "live" the following September. The first phase of the project included Wi-Fi coverage for six square kilometres of downtown Toronto, and envisioned blanketing all of Toronto in subsequent phases. However, only the first phase was rolled out before THTI was sold to Cogeco in 2008. Cogeco continued to operate the Wi-Fi network for a number of years after their purchase, however no upgrades appeared to have been made over this time. Subsequently, the technology became outdated, and as of 2015, Cogeco stated that they were almost finished decommissioning the service[62].

The sale of THTI included both the One Zone Wi-Fi network (Figure 12[63]), as well as THTI's over 500km of fibre laid throughout the city. Cogeco remains the owner of the fibre network. See appendix, Maps 3-3A.

Toronto Public Library

As mentioned previously in this report, the Toronto Public Library (TPL) helps Torontonians access the internet in several ways. On a daily basis, the TPL

hosts 10,000 connections, making it one of Toronto's most used agencies. This translates into 10.5 million connections per year. In 2016, The TPL provided Wi-Fi access at all branches not just during opening hours, but 24 hours a day, 7 days a week. This led its Wi-Fi usage growing 23% year-over-year, with 3.9 million Wi-Fi sessions occurring. See Appendix, Map 11 for a detailed illustration of the TPL's libraries and their connection speeds.

Wi-Fi usage in Toronto Public Libraries grew by 23% in 2016

Over half of the TPL's 100 branches have gigabit internet connections and there are more than 1800 computers available to the public for internet access. Based on a survey of library computer users, 27% of users do not have regular personal access to a computer connected to the internet, other than the library, and 67% of Wi-Fi users surveyed come to the library to work or study. This illustrates the "digital divide" and the economic necessity of public libraries as community connection points.

A new program through the TPL is allowing residents to check out home Internet service in addition to their books. In partnership with the City and Google, the Toronto Public Library has introduced a Wi-Fi hotspot lending program located in neighbourhoods with large numbers of low income households. Participants of the program can borrow the hotspots for up to six months at a time and can use 10GB of data per month.

The program was launched as a pilot project in 2016, with expectations of a full access program beginning this year. The TPL has received a tentative approval for program funds this year and have secured Google and Rogers as funding partners, who would also provide additional dollars for the program. The TPL expects to introduce 550 Wi-Fi hotspots.

The TPL is also launching its revamped 'Bookmobiles' that will provide service to some of the city's most vulnerable and isolated residents. The upgraded mobile trailers will be equipped with free Wi-Fi, large computer screens and tablets assisting residents to get online and access frequently used services such as apply for jobs and conducting research.

As an agency of the City of Toronto, the TPL has more flexibility in its provision of Wi-Fi to the general public. There are policies and protocols in place at the City regarding security and privacy that the TPL does not have to concern itself

with that create a more streamlined access point. In particular, the network is administered separately from the City. This issue manifests itself in the contrast between City-run Employment Centres, where users have to retrieve a new Wi-Fi access password every hour, and the TPL, where Wi-Fi use is essentially open and unlimited.

TPL locations are illustrated in Map 11, using information provided through the City of Toronto Open Data portal. Information regarding the TPL's broadband services was provided through consultations with TPL staff.

Toronto Transit Commission

The Toronto Transit Commission (TTC) has also, on its own initiative, started to provide free Wi-Fi in its stations, and is working towards providing it in tunnels in 2018. In 2012, BAI Canada was awarded an agreement with the TTC that provides them with exclusive 20-year access to subway tunnels and stations, outdoor stations, RT stations, streetcar tunnels and maintenance facilities. BAI Canada has since built 74km of wired fibre to 50 of the TTC's subway stations, which are outfitted with a Wi-Fi service called "TCONNECT". While there is community benefit in that free Wi-Fi is provided, it also means that each subway station connected essentially becomes a fibre POP (point-of-presence). BAI Canada is building dark fibre capacity into their network for future growth in usage and potential future uses for both BAI Canada and the TTC. There are plans to extend Wi-Fi coverage and Freedom Mobile coverage into the tunnels over the next 2-3 years.

The TTC offers a good example of the type of agreement other departments and ABCs could undertake with the private sector. The Commission has taken on minimal risk and no capital costs, while extracting public benefit (free Wi-Fi for customers and cellular coverage potentially throughout the system) from the proponent, BAI. The TTC is being paid $25 million over the 20-year term for BAI to have exclusive access to the TTC's tunnel infrastructure. Through this agreement, there is potential for BAI to have the ability to provide additional public benefit through the provision of a fibre network that is extensive as the TTC's subway network.

Ontario Research & Innovation Optical Network (ORION) and GTAnet

ORION is a not-for-profit broadband network initially supported by the provincial government (now self-sustaining) that provides access and connectivity for research and education facilities throughout the province. Given that Toronto is home to numerous universities, colleges, and hospitals, the ORION network and its Toronto partner GTAnet have a huge footprint in Toronto.

ORION enables transmittal of data at speeds "1000 times faster that publicly available internet networks"[64] which is a huge asset to research and education facilities. ORION's total optical fibre is upwards of 8200 kilometres long, and as such it is the largest privately owned and operated research & education network in the world[65].

Although now privately owned and operated, it was originally funded by the provincial government, and most of its clients are government-subsidized institutions such as universities, colleges and hospitals.

Established in 2002, GTAnet provides connectivity, support, and services to a network of universities, colleges, cultural institutions and teaching hospitals in the Greater Toronto Area, representing 40% of Ontario's research activities. GTAnet universities' sponsored research income is valued at over $1.03 billion per year, which amounts to more than 15% of Canada's research activity overall.

GTAnet's network uses 640km of dark fibre covering a 185km route through the GTA to connect its members to two main PoPs, located at the University of Toronto (St. George Campus) and York University. In addition, GTAnet fibre connects both PoP sites to 151 Front Street West, providing a connection to both ORION and commercial ISPs. Through our stakeholder consultation with GTAnet representatives, we acquired schematics of their fibre network, which is illustrated in Map 5. As is shown, the network infrastructure follows rail and hydro corridors, as well as the subway system.

Value for its members is created through peering directly with two international Tier-1 ISPs and volume purchasing of commercial content provider services. Members are able to subscribe to any amount of bandwidth they may require.

As an organisation, GTAnet is very interested in partnerships that help expand the network to other public institutions and to incorporate new locations such as smart communities, innovation hubs, libraries, community centres, and the like. This is particularly true currently, as GTAnet's Indefeasible Rights of Use (IRU) agreement expires within the next 10 years.

For GTAnet, inexpensive access to physical fibre and routing is considered "mission-critical". Without this access, thousands of researchers, educators, medical professionals and students would not have quick and high-quality access to internal and external research resources, and would not be able to share their knowledge effectively. GTAnet is rich in network-building expertise, and poor in funding mechanisms. As a result, the organisation is continually looking for more partnership opportunities.

Various Underground Infrastructure

During the report research process, the team was provided with some utility mapping data via the City's Engineering and Construction Services department. This mapping included the conduits and cabling of Bell Canada and Rogers Cable, data maintained by the Digital Map Owners Group (DMOG). The DMOG system covers only the old City of Toronto, and the data provided consisted only of the two Bell and Rogers layers (i.e., no right-of-ways, curbs, building envelopes, etc.) The intent for gathering this data was to be able to illustrate the true nature of wired broadband infrastructure in Toronto. It was a challenge to draw any hard conclusions from this data, as it did not include other layers in the DMOG data set, nor the areas of the City covered by City Utility mapping (CUMAP).

The project team decided to map a neighbourhood to serve as an example of what might be possible if all data from DMOG and CUMAP were made available in an intuitive format. Maps 12 and 12A shows the neighbourhood of Parkdale-High Park with an overlay of the Bell Canada and Rogers Cable layers provided through DMOG.

Mapping detailed city infrastructure is time-consuming and tedious with the existing information offered by Open Data Toronto. Some sections are available, however, formatting the information collected cannot be easily rendered into visuals for analysis. For example, the utility cut permit information Open Data provides does not differentiate between underground or above ground data. It

has more than 600 separate categories for installation type, many of which are duplicates. For utility cut permits, there are more than 50,000 data points from the last 2-3 years alone.

It is recommended that a system be set in place that allows contractors to file information in a specified format rather than manually enter descriptions at their discretion. This would help users of this dataset to manipulate and delineate raw data.

The City's Information & Technology Department should work with Open Data, the DMOG, and others internally to make this data more accessible to pertinent external stakeholders. Currently, a single map from DMOG costs up to $420 for an interested party to have produced, and the user must also sign a data release form. The City sells these maps under an agreement with the DMOG map owners (Bell Canada, City of Toronto, Enbridge, Hydro One Networks, Rogers Cable, Toronto Hydro and the TTC), and the amount is set allowing for full cost recovery. The City may not wish to make this part of its Open Data portal, however it would be useful to many others outside of the DMOG to have more ready access to this information through an alternative subscription-based data portal that would not require staff resources to retrieve a map.

Key Findings

- There are duplications in existing fibre installations that could be consolidated and used to create partnerships amongst non-profit and for-profit broadband providers.
- Demand for Wi-Fi and broadband access in public areas (such as the Toronto Public Library) is extremely high and continues to grow.
- The City's Agencies, Boards and Commissions (ABCs) have been able to provide more broadband access to Torontonians through partnerships with private companies and through proactive initiatives with seemingly minimal risk.
- GTAnet is interested in partnerships that help expand the network to other public institutions and to incorporate new locations such as smart communities, innovation hubs, libraries, community centres.

- The City is a co-owner of digitized maps of underground and above-ground utilities, but access to these maps is restricted by cost and format.

Recommended City Strategies or Actions

1. ***Form collaborative partnerships with public and non-profit broadband providers in the GTA to expand the reach of existing networks.***
   There is a lack of understanding amongst broadband providers and the City of Toronto in terms of what infrastructure exists and the innovative ideas proponents (such as GTAnet) have for expanding their networks. The City should work to foster new and collaborative relationships with providers and indeed amongst the providers themselves, so that access to high-speed broadband can be expanded.

2. ***Explore opportunities to leverage City assets to allow for the expansion of broadband and a reduction in duplication.***
   Through stakeholder consultation, this point came up repeatedly. The City has a role to play in terms of opening up its assets for non-profits, public agencies, and other third-parties to use in the provision of infrastructure. The TTC set a positive example with its partnership with BAI, through which free Wi-Fi is provided in most subway stations, and cellular coverage will soon be provided in tunnel areas. Permitting equipment on City assets has a potential to benefit these providers, citizens and visitors to Toronto, as well as the City itself.

3. ***Improve accessibility of digital utility mapping.***
   By opening up and improving access to the City's digital maps of utilities to a key group of stakeholders and interested parties, the City could help these stakeholders realize new opportunities for consolidation, rationalization and overall improvement of underground and above-ground infrastructure. The City's Information & Technology department should assess internally how best to change the current structure.

4. ***Conduct a workshop with Council to inform them of emerging telecommunications trends.***
   In light of the complexity of the issues related to telecommunications and the need for Council to make major decisions in this regard, workshops for Councillors and their staff should be delivered, as soon as possible, to

provide information on: emerging telecommunications trends; private sector activity in the field; Right-of-Way management issues; municipal activities in telecommunications nationally and internationally; legal issues; and risks, and opportunities.

5. ***Where possible, adopt Wi-Fi access practices from the TPL across applicable City divisions and facilities.***
   While not without issues of its own, the TPL's relatively open access policy for Wi-Fi in its facilities has shown that there is a great demand and need for access to affordable, high-speed internet access. Where opportunities exist, such as the City's employment centres, to improve upon current Wi-Fi access, the TPL should be seen as an example.

8 Case Studies

The most vital cities in the world enable their communities with leading-edge technology that engages, informs, and empowers. These cities are evolving on the commitment to building modern infrastructure, smart communities, and technological advancement. At the same time, these cities are faced with pressures, often derived from limited resources and capacity, which pause or slow the advancement of technology. With global markets working on an exponential digital scale and citizen expectations of digitized products and services, most cities are putting in place smart city strategies or digital strategies that will build both infrastructure and programs that will keep them relevant.

Today, it is increasingly less costly and less complex for cities to build and maintain their own fibre optics networks than to lease bandwidth from carriers. The cost of building fibre networks is dropping rapidly and cities are periodically examining whether there is a business case for switching from carriers to a city-owned/supported communications network. This issue is more complicated and involves fundamental decisions about the role of municipal government relative to the private sector. Some major cities are building city-owned dark fibre networks either through a utility, existing dark fibre networks or by the creation of a new agency or enterprise. In some cases, these cities have access to substantial federal or provincial/state funds. Other cities are building fibre optic networks on a for-profit basis and are competing

directly with the private sector. Others are creating networks intended to operate on a non-profit or cost-recovery basis. Some are building networks intended to reach every home and business, while others are building to meet internal city needs, and are sharing or marketing surplus capacity.

The case studies presented in this section are intended to ensure that Toronto is receiving informed decisions on the types of recommendations, policy directions and broadband models that other communities in North America are providing. Specifically, two communities stand out:

1. City of Kitchener
2. City of Chicago

In each of these cities, city administration has created digital strategy or technology plan centered on enhancing the community's ability to respond to the pressures of the digital economy. These case studies are then followed by broadband delivery models focused on Wi-Fi Zones and an EORN paper on estimates towards the cost of Municipal Wi-Fi.

City of Kitchener Digital Strategy and Broadband Delivery

Building a smart city takes vision, commitment, and collaboration. In Kitchener, the implementation of its digital strategy focuses on four themes that improve its delivery of broadband to its constituents. The four themes are: Connected, Innovative, On Demand, and Inclusive.

The theme of connectedness centres on offering communications infrastructure with the access and capacity required to remain globally competitive, reimaging wireless access as a more seamless service, and looking beyond traditional uses for existing infrastructure and integrate emerging sensor technologies. To make this happen the City of Kitchener started by positioning itself as an easy to access, low risk market for new investments in fibre optic broadband and wireless networks. It is working towards this goal by determining current levels of internet and wireless service available within Kitchener (a task completed for the City of Toronto in this report) and opening-up municipal assets to service providers though the use of policy tools and streamlining processes to create new partnership opportunities for community and commercial benefit. The City has also made strategic investments in public Wi-Fi access in all its facilities and major green spaces. This project includes the establishment of a narrowband network through the LED street light conversation project, that serves as a foundation for future smart city initiatives. The narrowband

network will help the city control the lighting, which it says will reduce electricity consumption and greenhouse gas emissions—but more importantly, it provides a smaller capacity line that bolsters Wi-Fi connectivity by providing more points of interest across the community. The next phase of work includes taking the technology and deploying it towards other unique opportunities, such as connected sensors in the city's parking, stormwater and utility enterprises. Lastly, through these advancements Kitchener is encouraging regional stakeholders to use its community as an incubator to pilot smart tech projects on their own (ex. autonomous vehicles).

The theme of innovation focuses on bringing about a positive change that has the potential for significant impact. The key to innovation for Kitchener is to create an environment where people are excited to collaborate and feel supported to succeed; this includes empowering all individuals and providing every citizen an equal footing when it comes to broadband and digital divide. To make this happen, Kitchener has created a new business relationship model for IT that generates more awareness of the services it provides and on how projects are prioritized. A large part of Kitchener's success has been due to its relationships with its post-secondary institutions. Through a memorandum of understanding, Kitchener and its local post-secondary institutions have been leading smart city research and projects across the region. This includes collaborating on the advancement of regional broadband infrastructure (WREPNET) and connecting with City agencies such as the Kitchener Public Library to build digital literacy initiatives, expand makerspaces in City-funded facilities and supporting area businesses build an online presence.

The theme of on-demand reflects the need to consistently meet the demands of public expectations. For Kitchener, this means continuing to expand the availability and access of its services digitally. To make this happen, the City has developed an organization-wide approach to data management that provides guidance on what data to collect an example of this includes expanding the City's open data catalogue to allow for 3rd party smart tech projects using City analytics. The City has also placed a large emphasis on reviewing its e-services to support the creation of a single sign-in, where users can visit one location and access multiple municipal services. Included in this review is the identification of new programs and initiatives that can enhance online engagement and customer service.

The theme of inclusiveness focuses on ensuring that access to technology is a given right and that digital literacy of a community is elevated through collaboration with public and private organizations. To make this happen, the City has been working with community organizations to identify public access needs, and collaboratively addressing them. The City has also established a new service level standard for public tech and internet access across the city. Other collaboration initiatives include working with Economic Development to co-support community based tech programming, and working with the local tech sector to promote digital inclusion initiatives with City-based agencies like the Kitchener Public Library.

Associated Broadband Network: WREPNet – Waterloo, Ontario

Assisting the City of Waterloo's implementation of its digital strategy is the use and access to the Waterloo Region Education and Public Network (WREPNet). WREPNet is a co-operative partnership between the Region of Waterloo, City of Kitchener, the City of Waterloo, the City of Cambridge, the local school boards, Region of Waterloo library boards and Conestoga College.[66] WREPNet assists with and delivers and operates an affordable, dedicated, high speed fibre optic network to the educational and public sector institutions within the Region of Waterloo. This fibre optic network is widely used and has continued to grow, up from the original 227 sites to over 325 sites since its launch in 2000.[67]

The original vision behind the development of WREPNet was to link public organizations in the Waterloo region via a dedicated high speed network. Prescient International Inc. partnered with Waterloo Region District School Board (WRDSB) and the Waterloo Catholic District School Board (WCDSB) to design and implement the network. After development of the business case and design of the network, tenders were requested to find sub-contracts to assist with the implementation of the network.

The City of Kitchener and each partner shares in the development, operation and maintenance cost of the network. Requirements of the partnership included the creation of a governance body comprised of committees and teams, with all WREPNet partners. The governance body was established to facilitate business and technical planning processes for development of the network. It was also established to ensure the thorough participation of all WREPNet partners in the processes used to define technical solutions and make business decisions.

While the details of the partnership cost are not available for public review, the advantages for the City of Kitchener is streamlined access to the transfer of not only research data between the schools and public facilities but also the reduced costs of broadband utilities across City departments and services and provide new internet-based products and services directly to the community.

Lessons Learned

In reviewing Kitchener's digital strategy, several recommendations emerge that would support the City of Toronto's advancement of its digital services and broadband access.

1. The City of Toronto would benefit from a review of its process and policies surrounding partnerships and broadband technology. In Kitchener's case, reviewing its internal process and policies, the City found it beneficial to experiment and allow for the provision of tech-based research projects on its infrastructure. A quick win for the City of Kitchener was the narrowband network on streetlights that will allow Kitchener to monitor and program efficient electricity consumption.

2. Toronto's commitment to growing its open-data catalogue will allow for the creation of innovative tech applications as individuals and businesses look to create digital solutions for the City to adopt. A lesson learned from City of Kitchener surrounding innovation would be its relationship with post-secondary institutions with regards to smart city research and projects. In Kitchener, post-secondary institutions are exploring how the City can deliver goods, services and solutions through digital platforms. The MakerExpo that the City and post-secondary institutions host is a culmination of student-graduate-city agency ideas that are backed by feasibility assessments and recommended action plans. If successful, these projects often receive funding from both the post-secondary and City.

3. Broadband infrastructure among Toronto-based post-secondary institutions is already transferring research data among its peer network. The City of Toronto, like the City of Kitchener, would benefit from accessing the infrastructure to ensure the streamline movement of data between public facilities. Working towards a co-operative partnership between GTAnet, the MUSH sector can enhance the City's delivery of e-services and access to broadband.

City of Chicago Technology Plan and Broadband Delivery

Research indicates that municipalities like Chicago will not be able to cost-effectively run a broadband network. The scope and size of these places produce a large price tag for any single municipally run investment, especially when the competitions in these cities between carriers hold a stronghold in these marketplaces. In response to this research, the City of Chicago crafted a Technology Plan that covers five broad strategies, and provides 28 targeted initiatives to support them in enhancing the broadband investments. These main strategies include building next-generation digital infrastructure, fostering tech education through "smart communities," and providing for efficient and open government, civic innovation, and tech sector growth. Of these five strategies, the first two provide an essential foundation for any place that seeks opportunity through technology. The other three are growth strategies that build on this foundation to foster positive outcomes. The Plan is clear about these expected outcomes as well, with seven impact areas listed. On the government side, the Plan calls for reduced costs and improved services. Most goals, however, are geared towards social and economic opportunities for Chicago's residents. The Plan lists increased resident engagement, access, and skills, as well more jobs and STEM professionals (Science, Technology, Engineering, and Math), as top objectives.

The Plan's foundational strategies boil down to two goals: making sure everyone has access to the internet, and ensuring they know how to use it. Chicago has already had some success here: as part of Comcast's Internet Essentials program, it has doubled the number of low-income households receiving discounted high-speed broadband, making it Comcast's largest program in the nation. The city also sits at the convergence of massive Internet trunk lines, making it a key node in the web's worldwide infrastructure. However, widespread connectivity can only go so far if residents don't have the skills to use it. For the past several years, Chicago has run a program with federal stimulus funding called Smart Communities (SC). The program works to increase digital access and use by families and businesses in five low-income neighborhoods. Operations include computer training classes, family and business centers, and public computer centers. To implement these SC operations, Chicago teamed up with the Smart Chicago Collaborative and Local Initiative Support Corporation (LISC), and received additional support from the MacArthur Foundation. While federal funds have largely ended for the program, Chicago plans to build upon its original five neighborhoods by

making “every community a smart community,” expanding such services citywide.

The next three broad strategies build upon the first two, and unite several initiatives that have already been in progress. These three strategies focus on the adoption and application of broadband across the city. The Plan’s third major strategy encapsulates these ongoing commitments, which have been managed by the City’s Department of Innovation and Technology (DoIT). DoIT’s Open Data Portal and predictive analytics platform have transformed how the City uses data, and will continue to grow. While DoIT is a key player for government-specific initiatives, much of the Plan goes beyond the department’s mission and capabilities. In the past few years, Chicago’s number of “civic hackers” has exploded, along with the city’s startup and tech scene. The Plan’s fourth initiative is meant for civic tech innovators to develop solutions to city challenges with city data. This brings us to the Plan’s fifth strategy: maintaining a growing startup and tech scene to ensure its place in the Chicago economy.

The Plan’s essence is simple: Chicago is identifying its strongest tech assets, building partnerships with them, and embracing a structure that favors cross-sector collaboration over unilateral action. The model is one that can be carried out by cities across the world.

To begin with, Chicago has many assets: it is an intellectual and research hub, giving it a strong base for talent; it has a diverse business community and broad customer base; and: it even has favorable physical and geographic features for technology, such as being a crossroads for the Internet and having a favorable climate for data centers. The key to maximizing these assets is a deep coalition of organizations that are willing to collaborate to improve the city. These include the city’s many universities, research centers, corporations and non-profits.

Chicago’s Wireless Internet Zones (WIZ)

Chicago Wireless Internet Zones (WIZ) are locations throughout Chicago where free public wireless (Wi-Fi) networks are available. These networks are provided by the City of Chicago in order to promote and develop wireless technology and offer a flexible means of communication. Wireless Internet Zones are available at all 79 Chicago Public Library locations and in other public places around the

city including the Cultural Center (78 E. Washington), Daley Plaza (50 W. Washington), and Millennium Park (55 N. Michigan).[68]

While available, the City does caution users about the limitations of its Wi-Fi zones. Firstly, the wireless network is not secure and the City cannot guarantee the safety of any traffic across its wireless network. Information sent to or from your laptop can be captured by anyone else with a wireless device and appropriate software, within up to three hundred feet. The City is also not able to provide technical assistance to users and there is no guarantee that one will be able to make a wireless connection.

There have been conversations about abandoning the project as costs associated with maintenance continue to rise. [69] Chicago could not reach agreement with service providers after offering free use of street lamps for radio transmitters in exchange for a network built, owned and operated by providers at no cost to the city.

Lessons Learned

In reviewing and conversing with Chicago's Department of Innovation and Technology, several recommendations emerge that would support the City of Toronto's advancement of its digital services and broadband access.

1. To support next-generation infrastructure throughout the city, Chicago reviewed its infrastructure policies to determine how it could inexpensively grow its conduit structure. Chicago determined that throughout its street reconstructions, residential street lighting or other civic infrastructure repair it would create conduits large enough to accommodate multiple broadband providers. This provides a comparable solution that could be reflected in Toronto. In addition, the City of Toronto could incorporate specs for conduits into City and sister agency projects as well.

2. In Chicago, DoIT, obtains advance notice of private utilities' projects from the Office of Underground Coordination. The City of Toronto through its permitting policies can request advanced notice prior to construction start to ensure ample time to evaluate and coordinate additional broadband infrastructure.

3. The City of Chicago, through its building code, has encouraged the construction of 'smart buildings' by inserting vertical cabling standards, communications room standards, horizontal cabling standards and rooftop antennae facilities. Chicago also incentivizes private-sector developers who go beyond the standards and include additional broadband technology into the building.

Broadband Delivery Models Centered on Wi-Fi Zones

Rhyzome Networks and Downtown Stratford's Wi-Fi Zone

The Wi-Fi system in Stratford, Ontario has made the whole city a broadband connectivity hotspot. Rhyzome Networks, the city-owned internet service provider (ISP), launched an initiative in 2015, which provides free wireless access throughout the downtown area. Users can connect to Stratford_Free at speeds up to one megabit per second (1Mbps), which is suitable for e-mail, web surfing and some light video, but is not intended for streaming full-length, high-definition movies. It is considerably slower that what Rhyzome offers to its business and residential customers through its retail network.

In terms of costs, Stratford's Wi-Fi zone is one of the few in Canada that can sustain itself due to Rhyzome Networks providing cost-saving pricing, although this is only sustained due to the limited strength of its public Wi-Fi. Details on figures are limited but generally, the cost of Wi-Fi zones in small downtowns in Canada range from $30,000 to $50,000 upon initial creation and have over $100,000 in costs per year in backhaul, security and maintenance requirements.[70]

eZone and Fredericton's Wi-Fi Access Points

Fred-eZone, Fredericton's public Wi-Fi network provides residents, visitors and businesses with mobile broadband access from virtually anywhere within the city. It has been integrated into Fredericton's economic development strategy to support the city's smart identity. Fredericton sees Fred-e Zone as a symbol of a vibrant community that can retain young people and attract new immigrants. It is intended to inspire success and prosperity.

Fred-eZone Wi-Fi access points are hosted at municipal facilities such as such as libraries, rinks, parking structures, water towers, traffic signals and

streetlights, with the City's fibre optic ring as a host network. There are over 100 access points in the network.

As the ISP managing the community network, e-Novations makes unused network capacity available to the Wi-Fi zone, so as to incur no incremental cost. E-Novations also use a mix of licensed and unlicensed spectrum for "backhaul" connection to the community fibre network. The network uses Motorola and Cisco equipment, and allows Cisco to promote its products directly to the City's citizens.

The innovators and players behind eZone view their Wi-Fi network as public infrastructure akin to sidewalks. As such they budget the maintenance of the Wi-Fi network within its public infrastructure allocation. Interestingly, the eZone approach has not been replicated widely. Few other municipalities have the combination of success factors present in Fredericton: strong local champions, support for development of a locally owned fibre network, favourable city finances, and a supportive local council.

Île Sans Fil Wi-Fi Network in Montreal

Montréal's cultural richness, as well as its long history of engagement with sustainability issues and national independence, have influenced the development of the Île Sans Fil community Wi-Fi network (ISF). ISF is a group made up of about 20 core volunteers, with more than 500 additional volunteers keeping up with the project through their mailing list.[71] As a non-profit group, ISF is committed to providing free public wireless Internet access in public spaces in Montréal. ISF implemented its first free hotspot in July 2003 at Café Laika—centrally located in what is considered to be a funky and hip neighbourhood, the Plateau. The Café serves as a beacon site and is one of ISF's most frequented and longstanding free hotspots.

ISF funds itself by enabling local businesses and community organizations to extend their existing Internet connections by paying a small fee to ISF. In return the host gets the hardware necessary to create a hotspot, some technical support, and a listing in ISF's directory.[72]

ISF has been one of the most successful community Wi-Fi networks in Canada. Montréal's long history of community activism and advocacy for communication networks and the place of the café in street culture in Montréal

are significant factors in sustaining an environment for Wi-Fi. Recently, ISF has entered into an agreement with the City of Montréal to cover the downtown core with ISF's network.

LinkNYC

LinkNYC is a Wi-Fi network designed to cover New York City with free Wi-Fi services. In 2014, the New York City Department of Information Technology and Telecommunications (DOITT) requested proposals for how to convert the city's over 7,000 payphones into a citywide Wi-Fi network. The awarded contract would require the operator to pay $17.5 million or 50 percent of gross revenues, whichever is greater to the City of New York every year.[73] The Wi-Fi network largely relied on its advertising interface to generate revenue and pay for itself.

The first kiosks were deployed in January 2016. Each kiosk or Link is equipped with a gigabit speed, encrypted Wi-Fi connection with a 150-foot (50m) range. The kiosks include USB charging stations and free calling, through a partnership with Vonage. An integrated touchscreen provides maps and information about city services and a digital display shows advertising and public service announcements.

Since deployment, there have been several concerns about the kiosks' features. Privacy advocates have stated that the data of LinkNYC users can be collected and used to track users' movements throughout the city. There are also concerns with cybercriminals possibly hijacking the kiosks, or renaming their personal wireless networks to the same name as LinkNYC's network, in order to steal LinkNYC users' data. In addition, prior to September 2016, the tablets of the kiosks could be used to browse the Internet. In summer 2016, concerns arose about the tablets' browsers being used for illicit purposes; despite the implementation of content filters on the kiosks, the illicit activities continued, and the browsers were disabled, ultimately moving from a platform that was designed to mitigate the digital divide to an advertised enriched hotspot.[74]

City of Ottawa Community Champions Program

The City of Ottawa Community Champions Program is a successful partnership between EION/ IceNet Wireless and The City, providing 25 free Wi-

Fi sites in public gathering spaces in major recreation facilities and administrative buildings in Ottawa.

Through this program, The City of Ottawa granted EION Wireless exclusive rights to provide free Wi-Fi in 25 city facilities. In exchange for exclusive venue rights, EION installed the Wi-Fi infrastructure, including access points, wiring and backhaul services, maintains the network, provides technical and bilingual customer service support and provides the city with monthly revenue including a percentage of advertising revenue.

EION, with its partner IceNet Media, provides advertising on digital displays at city facilities where free public Wi-Fi is offered. For example, at the Nepean Sportsplex, a very active city sports complex, IceNet presents ads on displays to be viewed by all those who see the display. This is a larger audience than that using the free Wi-Fi and viewing splash screens on mobile devices, generating larger ad revenue. IceNet also displays public service announcements on behalf of the city on the digital displays.

The city of Ottawa also contracts with IceNet to provide Wi-Fi service in some meeting rooms and rental spaces. In these cases, the incremental facility rental fees from the availability of Wi-Fi cover the cost of the Wi-Fi.

Lessons Learned

Municipal public Wi-Fi is typically provided as a public service but there are some opportunities to generate revenue and have 3rd parties build the infrastructure. These practices are not new and have been successfully completed in Toronto. The contract between BDI and the TTC is an example of an ad-revenue funded public Wi-Fi network.

The biggest concern for the City of Toronto will be its ability to police and ensure public safety over any public Wi-Fi network. Reflecting on the New York City LinkNYC program, a large component of its recent setbacks and inability to complete its intended mandate has been the difficulty in ensuring public safety. The City of Toronto would benefit from an independent Wi-Fi network safety study that would establish a set of protocols for any future Wi-Fi network build.

Financial Implications: Public Wireless Networks

Cost Implications

Designing, engineering and costing a wireless broadband deployment involves design decisions about many variables, including coverage, density, topology, existing spectrum and type of service. These decisions affect both equipment and technology choices. Cost data for deploying municipal Wi Fi implementations is not readily available. While high-level figures have been quoted, cities and ISPs do not volunteer confidential cost data and revenue forecast details. High-level cost information quoted in media stories often reflect pricing scenarios and assumptions which are more positional statements than contract pricing.

In 2005, Jupiter Research (a private consulting firm based in North America) conducted surveys and conversations with vendors and 83 cities that had deployed some form of a wireless network. Jupiter Research concluded that "the average cost of building and maintaining a municipal wireless network is approximately $70,000 CAD per square kilometre". Local sources suggest this cost figure is too low and would likely be significantly higher today.

Installing a single access point in a controlled indoor environment is a fairly simple undertaking. An outdoor installation raises many more challenges because of environmental factors, mounting locations, heating/sheltering needs, power source and backhaul requirements. Implementing and managing a city-wide wireless broadband network providing both indoor and outdoor connectivity is a complex undertaking with many unknowns that need to be surveyed, engineered and constantly monitored. There are significant costs to establishing and maintaining ongoing operational management processes for a large-scale, multi-service, pay-for-use network implementation. The magnitude of each identified activity or business process is a function of the geographic area to be covered, the number of users and service levels being planned. Each has associated capitals expenditures and operational costs which must be factored into any business case.

High-Level Cost Calculations

Estimated costs for a number of scenarios are outlined in Table 4 below. In the absence of specific requirements, the cost estimates provided for the purpose of this analysis are high level and based on a large number of assumptions.

Table 4 – High-level cost calculations for public Wi-Fi

Cost	Coverage Area	Assumptions	Rationale
In excess of $50 Million	City-Wide Mesh deployment	Carrier grade with all supporting business processes, billing, customer care, security, content filtering, etc.	Industry standard of $70,000 CAD/sq km. Edmonton contains 684 sq km.
$70,000 /sq km Minimum plus ongoing operational expenses	Hot Zone (multiple Access Points) Mesh deployment	Costs can vary greatly according to the terrain, the type of coverage, the service grade designed for and the technology set deployed. This figure is on the low side, with limited coverage.	As above, costs will likely be significantly higher because of lower economies-of-scale and urban vs. rural coverage challenges.
$9,000 each	Single Access Point Outdoor	City install in/on a City-owned facility using the facility's connection to the City network to provide public access to the Internet; no on-call support.	An example would be Wi-Fi service in Churchill Square. It would likely require 4 APs, for a total of approximately $27,000.
$6,000 each	Single Access Point Indoor	City indoor install — same as above	An example would be an AP at City Hall.
$6,000 plus $7,200 yearly	Single Access Point — Indoor	Commercial ISP installs Indoor	AP = approx $6,000 plus monthly backhaul charge of $600. Equals $13,000 in year 1 and $7,200 annually afterwards; plus customer pays usage charges.

Revenue Risks

While high-level costs can be estimated based on a large number of assumptions and constraints, user demand and revenue forecasting is much less accurate and thus riskier in the absence of an in-depth market analysis. There are a number of key observations from the research that indicate large-scale municipal Wi-Fi initiatives can be a financially high-risk undertaking.

Municipal networks must often seek subscription based and pay-for-usage revenue streams, in addition to other more creative funding, in order to be viable. This requires a carrier-grade network offering competitive services and a value proposition better than existing networks in order to gain market share.

Given that the Toronto market is well served and the user communities currently have multiple service options, the need to capture a significant user base in the face of a competitive marketplace is a high risk.

The following points illustrate the revenue risks that the City of Toronto may need to overcome:

- *Willingness to Pay*: While the number of hotspots is growing, the willingness to pay is not keeping pace. Best practice research indicates that while online consumers were aware of public hotspots, only 6% have used the service in a public place, and only 1% have paid to use it in a public place;
- *Competition*: Government-sponsored broadband will have to compete with incumbents, such as telecommunication companies, cable companies and other ISPs who already have a substantial head start. To retain market share they may employ powerful marketing tools and introduce or expand loyalty programs, service bundling, etc.;
- *Limited Market*: Existing Wi-Fi vendors have already explored all the commercially viable, strategic locations and high-use target markets. A municipal initiative may not attract enough users to make the business viable;
- *Marketing Focus*: In the face of dynamic competition and swift technology change, the network owners must adopt professional private-business management and marketing practices and processes in order to ensure a positive customer experience and a compelling value proposition;
- *Continuous Innovation*: The market requires continuous innovation — improving the price point and service offerings to ensure the value proposition remains compelling and customer churn (whether due to Price, Selection, Service, or Innovation) is managed;
- *Price/Performance*: Market share can only be achieved if the price/performance combination is viewed by the consumer as being superior to what the competition offers. If the technology and performance level is the same – a big assumption for a new entrant – then the only lever a municipal initiative has is to lower the price point to buy market share.
- *Capital Requirement*: The incumbent telecommunication and cable companies have depth of capital and are in a better position to build and update their networks.

In summary, the barriers to entry are much more formidable against entrenched competition than most municipalities realize.

Wi-Fi Zones

Wi-Fi Zones as found in town centres, typically involve networks with hand-off of signal from one access point to the next, as the user moves around the area served. The cost of this type of network will depend on the area to be served,

the level of service to be delivered, access to fibre or DSL backhaul services and access to vertical real estate on which to place antennae. If the town has suitable structures in place, such as water towers, light standards, or buildings, constructing new towers may not be necessary. Whether the network is owned and managed internally or by a third party will affect operating cost. Typically, an RFP is issued for this type of network build, if it is to be done by a third party. Some ISPs will own the network and charge a monthly fee for network management. Alternately, the town can own and operate the network once it is deployed. Costs for town centre Wi-Fi Zones deployed in Eastern Ontario have ranged from $50,000 for about 10 APs to $75,000.

9 Summary of Recommended Strategies & Actions

Wired Broadband

1. ***Strengthen the "Connected for Success" program.***
   The "Connected for Success" program has helped many residents of Toronto Community Housing connect to the internet in an affordable way. However, this program fails to deliver true broadband. The City and its agencies should encourage Rogers to strengthen this program, so that true broadband speeds are accessible and affordable to the City's lower-income residents.

2. ***Advocate for reseller ISP access to all new infrastructure.***
   As discovered through our Key Findings, accessibility to broadband through affordability is a real issue in Toronto. One of the ways to reduce the costs of broadband services to consumers is to foster competition amongst ISPs. Bell and Rogers have advantages based on their legacy rights to right-of-ways and poles that they can use to expand their fibre networks. By supporting CRTC decisions related to wholesale access to high-speed networks (i.e. Telecom Regulatory Policy 2015-326[75]), Toronto can reduce impacts on its already-crowded right-of-ways and create a more competitive environment for ISPs, ultimately resulting in lower prices for Torontonians.

3. ***Leverage assets to help introduce and expand new infrastructure competitors to the marketplace, aside from Bell and Rogers.***

Bell and Rogers have legacy access rights to the City's right-of-ways and some poles, as well as other infrastructure. This immediately puts smaller ISPs and resellers at a disadvantage and is a disincentive for companies other than Rogers and Bell to invest in high-speed broadband infrastructure. The City should ensure that either all interested parties have equal access to infrastructure, or that investment in new infrastructure is co-ordinated and shared amongst ISPs.

4. *Establish public-private partnerships.*

The City has leverage it can be using to create partnerships with the private sector to expand access to affordable broadband infrastructure. While some of the city's ABCs are already demonstrating a capacity to accomplish this, the City has been less "free" to pursue these opportunities. Through ongoing efforts to reform the City's procurement process, public-private partnerships should be able to play a larger role in the future of equitable broadband services delivery.

Wireless Broadband

1. *Institute a regular review of the City's Telecommunications Protocol to ensure it is up to date.*

Currently, the City's protocol for telecommunication towers and rooftop antennas is reviewed on an ad-hoc basis. A review of the protocol to ensure relevance and desired outcomes is recommended to take place at least every two years, due to the rapid evolution of wireless network technology. The review should provide for an accounting of how many applications were submitted, how many installations were approved, as well as an update of any database the City keeps regarding cellular installations. The review should also consider any issues with processing times and identify opportunities to simplify the evaluation process.

2. *Remove the "Prudent Avoidance" measure from City regulations.*

This extra layer of regulation of electro-magnetic frequency (EMF) radiation of wireless equipment has been found to be unnecessary by the City's Medical Officer of Health, time-consuming and costly to enforce. Furthermore, it does not improve the health or safety of Torontonians, as the federal government's existing Safety Code 6 regulations are widely viewed as being cautious and adequate. Removing this extra layer of regulation would free up staff resources as well as allow wireless

broadband providers to improve the speed and capacity of their networks more quickly in response to demand.

3. ***Leverage existing City assets to improve speed, coverage and capacity.***
The City should be open to allowing third-parties to locate wireless broadband equipment on and in City-owned poles, buildings, right-of-ways, and other assets. Permitting this should generate revenue for the City, while allowing third-parties to improve coverage and capacity indoors and outdoors. (Some agencies/departments of the City are already leveraging assets—e.g. TCHC leases hundreds of its rooftops to carriers for equipment). A thorough review in this regard should be undertaken by the Real Estate Services Department in conjunction with the City's IT and Economic Development & Culture Departments. Part of the City's openness to this type of infrastructure should include a willingness to work with all types of third-parties, not just incumbent or larger wireless broadband providers.

4. ***Include In-Building Wireless Systems in requirements for new construction.***
Other jurisdictions have instituted municipal by-laws that require consideration of in-building radio and wireless coverage for new construction. This is important for a number of reasons stated previously in this section, but most of all for public safety purposes. Many developers are already including in-building wireless systems in their building designs. These systems are not built to any specified standard, and are often dictated by cost, not system delivery. Therefore, standards should be established by the City (as they are in other jurisdictions) to ensure a minimum level of service availability can be expected to avoid potentially unsafe conditions. Unlike other jurisdictions that have adopted in-building wireless by-laws, the City should include provisions for mobile accessibility on these systems. A co-ordinated approach to in-building wireless could also give Toronto a competitive "smart city" advantage.

5. ***Allow ubiquitous, free public Wi-Fi to become an economic development opportunity in the City of Toronto via free-market forces.***
Free ubiquitous public Wi-Fi deployed by the City of Toronto is of limited benefit to Torontonians or the City's economy. The development of Wi-Fi in Toronto should be allowed to develop organically without funding or deployment by the City.

6. ***The City and its ABCs should deploy strategic managed Wi-Fi in appropriate venues with appropriate pricing structures.***
   The economic benefit of ubiquitous, free Wi-Fi is questionable. However, there are certain social benefits to the provision of Wi-Fi for uses such as checking email, applying to jobs, doing research, or reading the news. This type of activity should be encouraged and allowed through the provision of Wi-Fi in libraries, community centres, employment centres, and similar community hubs. Use of Wi-Fi for other purposes (such as online gaming, high-quality video streaming) should be regulated through pricing.

Data Centres

1. ***Promote Toronto's strength and prominence as a North American internet hub.***
   Advertising and promoting Toronto as an attractive place for data centres and carrier hotels will help the City leverage existing infrastructure, enhance the City's global brand, and create employment opportunities.

2. ***Maintain a database of existing and future commercial data centres.***
   Commercial data centres have been demonstrated to be key to the success of specific film and technology-based industries, many of which run their businesses based on "cloud" infrastructure (data centre-driven storage and operations solutions). A database of data centres including information such as capacity, geographic location, average costs, etc. may be useful tool for the City's Economic Development department to continue encouraging growth of Toronto's burgeoning tech sector.

Other Broadband Infrastructure

1. ***Form collaborative partnerships with public and non-profit broadband providers in the GTA to expand the reach of existing networks.***
   There is a lack of understanding amongst broadband providers and the City of Toronto in terms of what infrastructure exists and the innovative ideas proponents (such as GTAnet) have for expanding their networks. The City should work to foster new and collaborative relationships with providers and indeed amongst the providers themselves, so that access to high-speed broadband can be expanded.

2. ***Explore opportunities to leverage City assets to allow for the expansion of broadband and a reduction in duplication.***

   Through stakeholder consultation, this point came up repeatedly. The City has a role to play in terms of opening up its assets for non-profits, public agencies, and other third-parties to use in the provision of infrastructure. The TTC set a positive example with its partnership with BAI, through which free Wi-Fi is provided in most subway stations, and cellular coverage will soon be provided in tunnel areas. Permitting equipment on City assets has a potential to benefit these providers, citizens and visitors to Toronto, as well as the City itself.

3. ***Improve accessibility of digital utility mapping.***

   By opening up and improving access to the City's digital maps of utilities to a key group of stakeholders and interested parties, the City could help these stakeholders realize new opportunities for consolidation, rationalization and overall improvement of underground and above-ground infrastructure. The City's Information & Technology department should assess internally how best to change the current structure.

4. ***Conduct a workshop with Council to inform them of emerging telecommunications trends.***

   In light of the complexity of the issues related to telecommunications and the need for Council to make major decisions in this regard, workshops for Councillors and their staff should be delivered, as soon as possible, to provide information on: emerging telecommunications trends; private sector activity in the field; Right-of-Way management issues; municipal activities in telecommunications nationally and internationally; legal issues; and risks, and opportunities.

5. ***Where possible, adopt Wi-Fi access practices from the TPL across applicable City divisions and facilities.***

   While not without issues of its own, the TPL's relatively open access policy for Wi-Fi in its facilities has shown that there is a great demand and need for access to affordable, high-speed internet access. Where opportunities exist, such as the City's employment centres, to improve upon current Wi-Fi access, the TPL should be seen as an example.

10 Next Steps Requiring Further Study

It is recommended that the following items receive further attention from future City of Toronto studies so that a comprehensive and complete understanding of broadband within the City can be reached.

Value Proposition of Free Wi-Fi

Although information in this report suggests that City provision of public Wi-Fi is not something that should be a priority, there is an understanding of the fact that free public Wi-Fi is continually debated as something to be implemented by a so-called "smart city". As a result, further discussion is needed to elaborate on the value of such a service. This study should include an examination of the need, the potential economic benefits, the issues of management, infrastructure requirements, and governance structure within the City of Toronto.

Strategy for Building Infrastructure

A further analysis should be undertaken with respect to the assets owned by the City of Toronto and its Agencies, Boards and Commissions (ABCs) and how these assets could be leveraged to the advantage of Toronto's citizens and businesses. There appears to be numerous partnership opportunities with broadband proponents and carriers that are not currently being seized upon. This should be a cross-departmental initiative that includes Finance, Real Estate Services, IT, Economic Development, Parks, Public Works, and Planning staff. Using City infrastructure to help deliver improved broadband holds revenue opportunity for the City and potential economic benefits through quicker and more co-ordinated broadband infrastructure builds.

Exploration of Infrastructure Planning

Previous sections of this report have identified the fact that there is little co-ordination of broadband infrastructure building. Much of this appears to be due to the lack of inter-departmental co-operation and well-established "silos" maintained by legal and political will within the City government. A further assessment of these barriers to co-ordination and partnership related to infrastructure would be useful.

Facilitation of Competition & Growth in Broadband

The optimum measure to decrease the cost to households and businesses of true broadband services is to have a direct and intense competitive environment amongst providers of these services. Currently in the City of Toronto, there are too few providers building their own networks, and thus a heavy reliance on major carriers. The fees collected by the major carriers from distributors result in a broadband pricing structure that is not as competitive as it should be. In order to ensure lower-cost access to true broadband services, the City of Toronto should further investigate ways to foster competition and encourage providers to expand their networks.

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