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This document is generally current as of December 2017.

2018-05-02

# 1. Introduction

The Eastern Ontario Regional Network (EORN) was originally created as a not-for-profit corporation controlled by the 13 County and Single Tier municipalities that make up the Eastern Ontario Wardens' Caucus. The Caucus represents 750,000 rural residents. The majority of the region's separated cities have subsequently become part of the Project, and EORN now represents more than one million rural and urban residents spread out over 52,000 square kilometres. EORN's objective was to extend broadband coverage and improve internet speeds across the region.

Internet infrastructure is varied and complex. While the internet itself has become easy to use and navigate, few people can appreciate how digital signals from around the world reach them in their homes and businesses. This document serves as a guide to understanding the different technologies used to deliver internet services in Eastern Ontario.

The Eastern Ontario Regional Network Project Phase 1 was a \$175 million project funded by Canada, Ontario, the EOWC, and the private sector. EORN brought together a combination of technologies to improve access to as many people as possible with available funding dollars. It was completed at the end of 2014 and continues to provide access to high-speed broadband services across much of the 52,000 square kilometers of our region. EORN is recognized across the country and around the world as a highly successful public-private partnership and as model for others to consider.

Before the EORN Broadband project started in 2010, almost 30% of all households in Eastern Ontario had either no access to broadband or limited access with basic dial-up service less than 1.5 Mbps. At the end of construction, with a variety of technologies, the EORN Broadband project was able to reach of 89% of the households with up to 10 Mbps service.

Estimates at the time indicated that to provide Fibre to the Home solutions to reach an equivalent coverage would cost about \$1.2B (~4.5 times more than what was available).

Population density is a critical factor in delivering broadband services. While the peace and quiet of rural life is an important lifestyle choice for many residents in Eastern Ontario, the distance between neighbours reduces the revenue opportunity for service providers, and in many areas, results in limited or no service coverage. This market failure is not only a private sector issue but requires contributions and support from all levels of government – municipal, provincial and federal to address the gap.

When EORN started in 2010, broadband speeds were defined as 1.5 Mbps download. In 2011, the Canadian Radio-television and Telecommunications Commission (CRTC) set target speeds for all Canadians of 5 Mbps download and 1 Mbps upload. In December 2016, the CRTC has redefined broadband internet (both fixed and mobile) as a basic service, and set a universal service objective that by 2021, 90% of all Canadians should have access to internet speeds of at

## Population Density Affects Availability of Technology

- Wireless internet providers use radio waves to provide internet access to homes and businesses. Typically, they need to serve an area with more than five households per sq. km to deliver such services economically.
- Wired providers generally require at least 25 households per sq. km, with a minimum of 100 households contiguous, and nearby associated infrastructure.

## Up to

One reality with subscriber packages, is that in many technologies the provider's contracts actually refer to "up to" the speed listed. The package may be referred to as a 10/1 package but the actual speeds delivered may be less at various times of the day due to network demand. EORN has advocated that the CRTC hold telecoms to greater accountability for deliver the speeds and services that customers are paying for.

least 50 Mbps download and 10 Mbps upload, with access to an unlimited data package. The Federation of Canadian Municipalities is also proposing that broadband should be defined as a utility.

Broadband technologies and the consumer demand continue to rapidly evolve. Information in this report is generally current as of late 2017.

## 1.1. Demand

The demand for internet data continues to grow significantly as shown in Figure 1. Canadian and Eastern Ontario demand continues to grow proportionally.

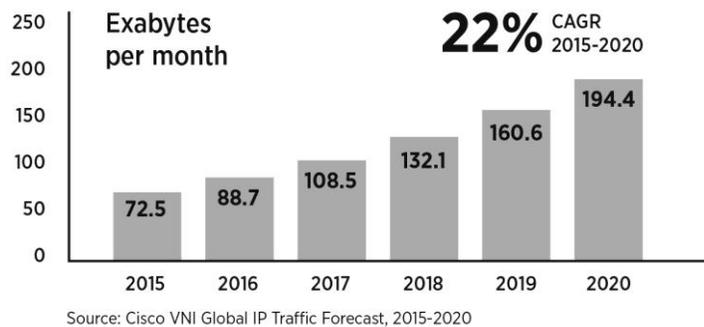


Figure 1: Cisco VNI Forecasts 194 EB per Month of IP Traffic by 2020

A significant proportion of this increase in demand is the continuing growth in video traffic, in applications as well in consumer usage of services such as Netflix. Consumers, who used to subscribe to TV services such as satellite or cable, are now dropping these services and relying exclusively on their internet service. In addition, where households used to have one or two TVs watching programming, there are often devices in every set of hands.

In 2014, a survey of internet usage in Eastern Ontario, commissioned by EORN, 48% of those surveyed indicate that they spend 10 hours or more per week on the internet at home.

Some internet providers are engaged in a marketing war, as to who has the highest speeds available. Several Canadian providers are advertising speeds of 1 Gbps. While this may be available, almost no residential or small business subscriber can actually use this type of speed. More importantly even if it was available, the rest of the internet cannot respond with equivalent performance.

A user's internet experience, like accessing a web page or watching a video, depends on many factors (as shown in Figure 2)– beyond the speed of connection. These would include the device's capabilities, the number of devices in their household, their local network within the house, their internet service, backbone traffic, and the server hosting the application, and the return path.

### Download – Upload Speeds

- Refers to the data transfer rate or how fast data is sent or received
- Download refers to the rate information is sent to the subscriber
- Upload – is from the subscriber to the Internet...
- Generally, a higher Download speed is important as more data is received than usually sent

Each of these impacts the delay and the speed of service seen on the user’s device. This complexity sometimes makes it difficult for a service provider to diagnose a problem.

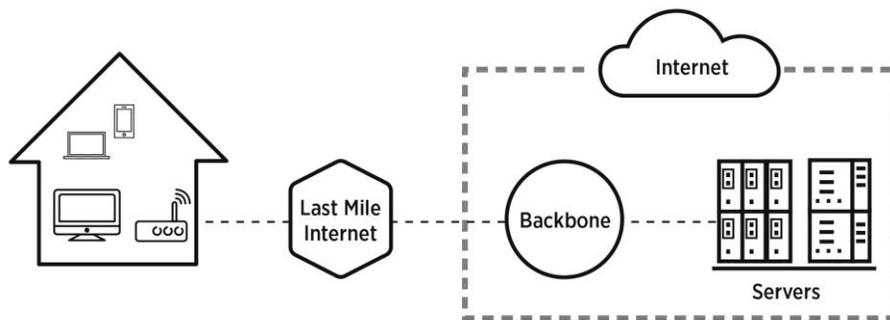


Figure 2: Complexity of Internet Service

Download Speed	Upload Speed	User Type	Types of Usage	
4-6 Mbps	.5 - 1 Mbps	Single User Basic Service	Email Web Browsing Music Streaming	File Sharing (small) Internet TV (1 user)
6-10 Mbps	1 Mbps	Single User Service	Online Gaming (1-2 users)	Video Streaming (1-2 users)
10 – 15 Mbps	1-2 Mbps	Basic Family	2-3 users High Def TV Streaming	
15-50 Mbps	2 – 10 Mbps	Multi-Use & More Typical Urban Speeds	2-3 higher demand users Cloud based applications Smart Home Applications (surveillance etc)	
50+ Mbps	10 Mbps	2021 CRTC Objectives	CRTC Objective for 90% of households in Canada by 2021	
200 + Mbps	20 + Mbps	Aspirational Objective	Expected family usage for next 10 years, including High Def TV	

Figure 3: Internet Speeds and associated Usage (as of 2017)

Figure 3 provides a realistic internet speed requirement for usage. Some households, and businesses will exceed these demands based on their own specific usage patterns.

Data caps are another critical component in the user demand equation. A data cap is the total amount of data that a subscriber can consume over a period of time before the provider either limits the service or starts charging more. Data plans usually allow subscribers to choose the amount of data they want to use within a fee structure. Some providers have plans that allow unlimited usage. In general data caps are one tool used to manage the volume of data used in the network.

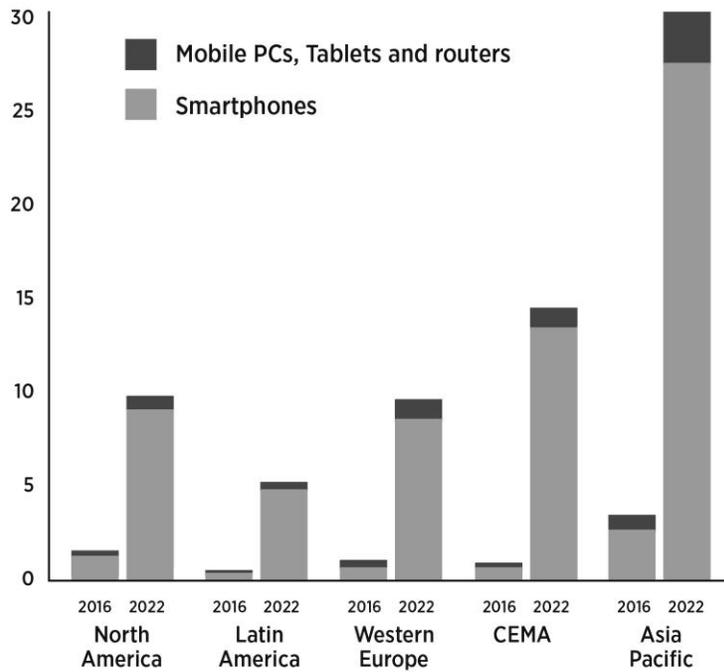
All the major service providers provide tools to help a potential subscriber estimate their data requirements, and provide warnings when the limit is approached.

### DATA CAPS

- CRTC Universal Service Objective by 2021 is to have at least 1 package with unlimited data caps available to subscribers
- Monthly usage of a family with a mid-range package (~15 Mbps) can average 100 GB with capped packages
- Internet intensive but no Netflix family of 2 averages 50 GB per month

### Mobile Demand

While fixed data demand continues to grow, demand for mobile data is also growing significantly. One report is expecting six-times growth by 2022. This expected growth highlights the need for ongoing investment.



Source: Ericsson Mobility Report November 2016

Figure 4: Global mobile data traffic (Exabytes per month)

## 2. Backbone and Internet Connections

The internet as we understand it today is a world-wide network of devices that allow humans and other devices to communicate amongst themselves, to access and share data. To manage the sheer scale of this, it is divided into various levels of smaller networks that connect with each other. In some situations, these smaller networks or subnetworks are distinct physical networks owned by a provider, or they may be virtual networks running partially or wholly on another provider's physical equipment.

An internet backbone is defined as the major data routes (generally provided by a fibre network) that connect a service provider's infrastructure. EORN and its partner built a fibre backbone network throughout Eastern Ontario with 160 Points of Presence (POPs) as part of the initial Broadband Project. Note that there are other fibre backbones serving parts of the region. The POPs provide an access point to the backbone fibre, from which service providers can access the internet. Backbone may also be referred to as transport fibre.

A common analogy is the backbone is like a major highway with limited access points or onramps. These onramps are the only way to safely and legally enter the major roadway, from smaller local roads. There are limited access points to a backbone network, and these are known as POPs.

In Eastern Ontario, many of the service providers' networks connect to the Internet at a transit point or an Internet Exchange Point (IXP) in either Toronto (151 Front Street) or in Ottawa.

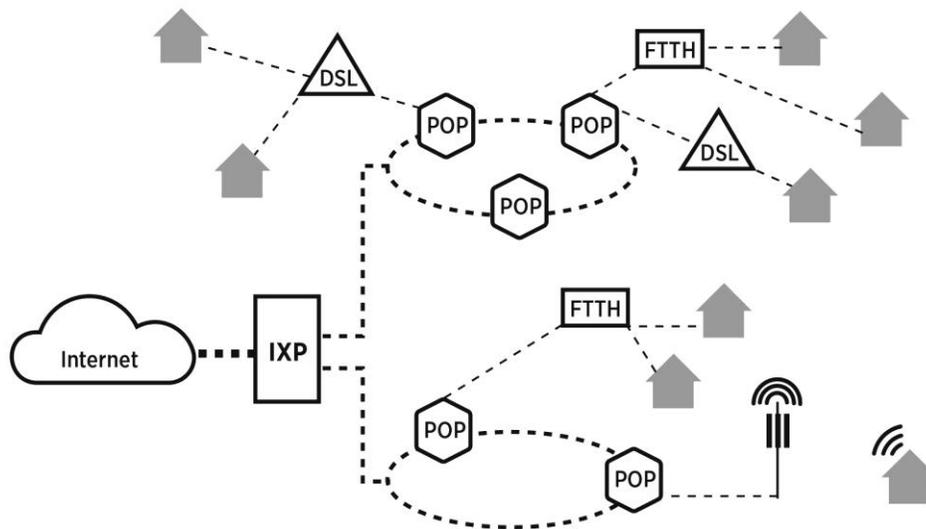


Figure 5: Backbone

From a simplistic perspective, Acme internet provider connects to the fibre backbone at a POP, and buys service over the backbone to connect to the IXP or transit point. Or they may have their own backbone network that they connect to that connect directly with an IXP. Or they may peer (share) with another service provider, sharing transport ultimately connecting again at the IXP or transit point.

### 3. Spectrum

Radio Spectrum is the continuum of frequencies that characterize radio signals or radio waves. In Canada, spectrum is regulated by the federal ministry of Innovation, Science and Economic Development (ISED), following the general direction of the International Telecommunications Union (ITU). As a limited and valuable resource, spectrum must be managed to limit interference between different types of uses.

Different parts of the spectrum are allocated to different uses, from aeronautical navigation, mobile cell, fixed wireless, baby monitors, garage door openers and AM-FM radios. Some frequency ranges are licensed, and as a result use is controlled and some are unlicensed and free and open to any use. For instance, the spectrum used for Wi-Fi is unlicensed, typically in the 2.4 and 5 GHz ranges. Mobile services operate in licensed spectrum such as 2.1 or 2.6 GHz bands or in the newly allocated 700 MHz band.

#### Measurement

- Frequencies are measured in cycles per second or Hertz (Hz).

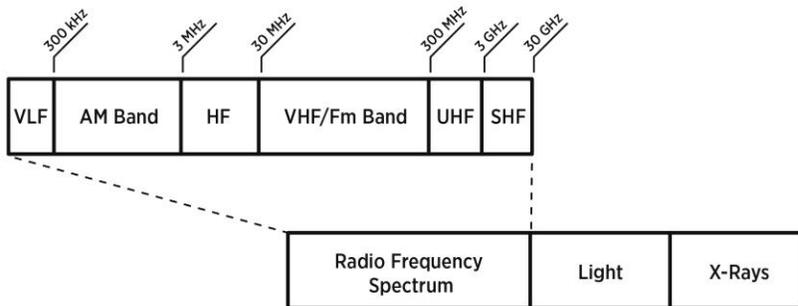


Figure 6: Radio Frequency Spectrum

Lower frequencies or wavelengths travel further through obstacles such as trees, while higher frequencies can carry more data but travel over shorter distances, when using similar radio technology.

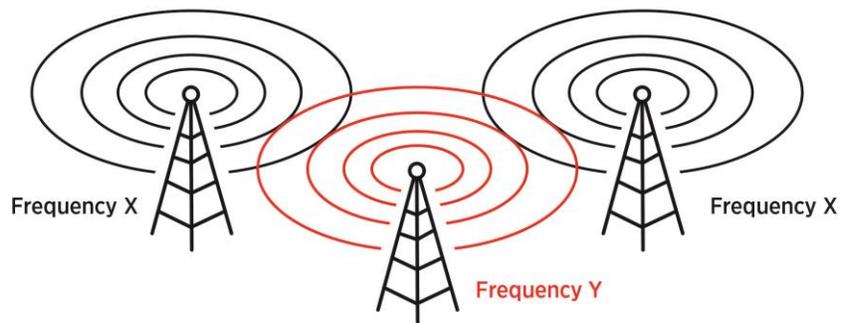


Figure 7: Simple Wireless Network

A radio network is designed so that radios broadcasting in the same frequency do not overlap with each other and cause interference with each other, but radios in a different frequency can overlap as shown as in Figure 7. It makes network design complicated, and when available frequencies are in short supply, difficult to add new radios and new capacity.

The issue of spectrum is important in Eastern Ontario to all wireless service providers:

- Fixed wireless providers who use unlicensed spectrum, must always be monitoring their networks to be aware of other providers who are broadcasting in the same frequency bands and potentially causing interference with their customers.
- Sufficient licensed spectrum may not be available in high-demand areas, creating capacity limits.
- Some smaller service providers may not be able to afford to buy spectrum.
- Cell or mobile carriers are also concerned about the enormous growth in the demand for mobile data, and the associated need for additional spectrum to support this demand.

## 4. Access Technologies

Access Technologies refers to the variety of ways that the internet service is delivered to a residence or business or another consumer. Each type of technology provides different levels of service to the consumer, has different types of costs to deploy and operate, and is suitable for different types of environments. There may also be different price ranges for the consumer.

Figure 8 below shows the relative infrastructure cost for the major access technologies as compared to household density, and identifies what industry generally agrees is the most appropriate based on overall business case. While one can argue that a wired technology is usually a customer choice based on overall service, it is not affordable infrastructure for low-density rural or remote potential subscribers.

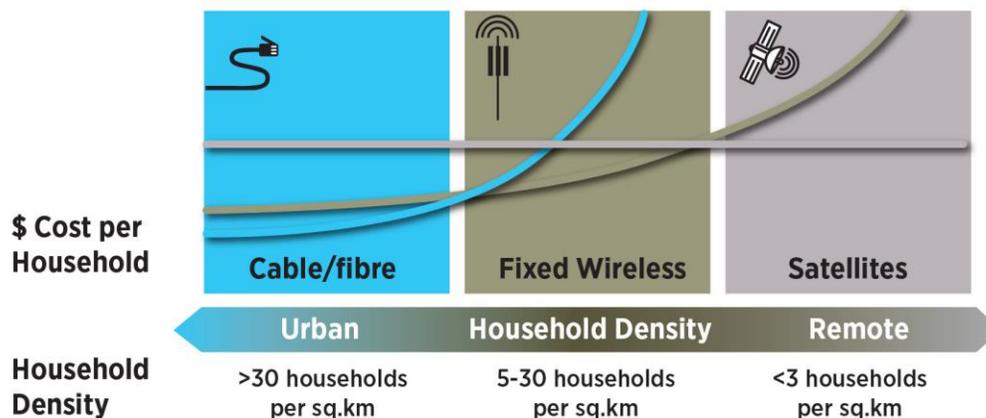


Figure 8: Cost of Access versus Household Density

### Modem

A modem is a device that connects a personal or home network to the service provider's infrastructure. It converts the service provider's cable, DSL or other signal into the standard Ethernet output used in a local network.

### Router

A router connects multiple networks and routes traffic between them. It allows multiple local devices to use one physical Internet connection, and also allows the local devices to talk to each other. The devices can be connected by Ethernet cables connected directly into the router, or more commonly through wireless or Wi-Fi connections. In addition, the router also provides some protection for the local network and devices, by making it look like all traffic from the local network is coming from one device. That is, each local network device has its own local IP address provided by the router, while the router uses the external IP address assigned by the Service Provider. An IP address is a unique identifier assigned to each device in a network.

Many service providers are providing combined modems and wireless routers, simplifying network setup.

The following sections describe technology commonly in use in Eastern Ontario, and are also summarized in Figure 9.

Technology	Description	Advantages	Disadvantages
Satellite	Service provided through radio broadcast from satellite and received by a small satellite dish located on the house or business	<ul style="list-style-type: none"> <li>• Region-wide coverage</li> <li>• Most cost-effective way to provide coverage to low-density areas</li> </ul>	<ul style="list-style-type: none"> <li>• Latency (delays)</li> <li>• Data caps</li> <li>• Service slows down under load</li> <li>• Costly and long time to deploy new satellites</li> </ul>
Mobile Wireless (Cell)	Service provided through broadcast from radios located on towers to mobile device such as Cell Phone	<ul style="list-style-type: none"> <li>• Coverage in major populated areas and major roads</li> </ul>	<ul style="list-style-type: none"> <li>• Generally high data costs impact usability</li> </ul>
Fixed Wireless	Service provided through broadcast from radios located on towers to fixed device (antenna/modem)	<ul style="list-style-type: none"> <li>• Cost-effective way to provide coverage to medium-density areas (about 30 household per sq. km.)</li> </ul>	<ul style="list-style-type: none"> <li>• Performance affected by number of users on tower</li> <li>• Line of sight required and impacted by trees and topography</li> </ul>
Wi-Fi - Public	Multiple radios serve PCs, tablets & enabled devices in public spaces	<ul style="list-style-type: none"> <li>• Generally free for all users in a public area</li> </ul>	<ul style="list-style-type: none"> <li>• Shared service with no guarantee of speed or capacity</li> <li>• Data is not secure</li> <li>• Limited speeds and capacity</li> </ul>
DSL	Service provided over existing copper telephone lines to subscribers, generally in EO services fed by fibre to the node	<ul style="list-style-type: none"> <li>• Service not affected by load</li> <li>• Cost effective installations in existing infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>• Speeds affected by distance to DSL equipment</li> <li>• Limited to 50 Mbps within 500 meters of DSL equipment</li> </ul>
Fibre to the Home	Service provided by fibre to the home, capable of providing ultra broadband speeds (greater than 100 Mbps)	<ul style="list-style-type: none"> <li>• Service not affected by load</li> <li>• “future proof”</li> </ul>	<ul style="list-style-type: none"> <li>• Expensive initial installations</li> </ul>
Cable	Service provided using cable to the building, newer installations moving fibre into the neighborhood nodes	<ul style="list-style-type: none"> <li>• Can provide ultra broadband speeds if engineered correctly</li> </ul>	<ul style="list-style-type: none"> <li>• Expensive initial installations</li> </ul>

Figure 9: Summary of Access Technology Characteristics

## 4.1. Satellite

Satellite service is provided through satellites in geosynchronous orbit which transmit through radio waves a signal containing the internet traffic to an antenna (dish) on a residence or business. Signal transfer is two-way, both upload and download. Ground stations or gateways transmit signal to the satellite and provide the connection to the internet. This link is effectively the backhaul.

There are three models for satellite communication: backhaul communication, residential TV distribution and consumer “last mile.” Satellites can and do provide large bandwidth data transmissions or backhaul for remote communities, and businesses. Sometimes this includes the remote transmission of live streams for news or sporting events. Satellite TV distribution is available for subscribers, using different types of satellites. The focus of this report is on the use of satellite for residential and small-to-medium business broadband internet consumers. As of June 2017, there are six satellites providing broadband data service to Eastern Ontario, including four with high capacity.

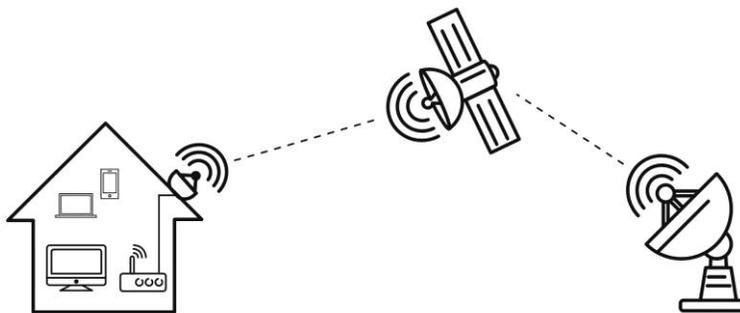
Satellite technology is an effective method of serving areas with low-population density, or that are hard to reach. In EORN, our original design target for satellite service was for areas with household density of less or equal to three households per sq. km, while industry suggests that it is effective for households of 6 or less per square kilometre. In Eastern Ontario, satellite was used across the entire region, to reach residents who could not get a land-based service.

Satellites will transmit in multiple beams, where each spot beam serves a specific oval shaped geographic area. For instance, the new Xplornet satellite serves all of EO in two beams. At installation, subscribers are assigned to a specific beam, and must also have line of sight to the satellite. The high-speed satellites transmit in the Ka-bands (26.5-40 GHz).

Current satellite services are suitable for a full range of internet services from email, browsing, and basic voice and video calling. Speeds are from 300/100 kbps to 25/10Mbps. Delays inherent to transmission and associated latency can be problematic in some situations for VPNs and gaming.

Satellites are a limited resource, and there is a fixed amount of capacity on each satellite that must be shared across all users. It takes about five years to design, build and launch new satellites. Capacity is fully purchased by service providers years before launch. Data transfer caps, and other restrictions are used to manage the limited satellite resources.

Satellite service in Eastern Ontario became very popular with the launch of the high-capacity satellites in 2012, such that within just three years they were fully subscribed. As existing subscribers demanded more services, these satellites became oversubscribed. The launch of two new satellites in 2016 and 2017 will offer relief.



*Figure 10: Satellite Service*

## 4.2. Wireless

Service	Technology Description	Speeds	Characteristics
Mobile Wireless (Cell)	Radio from tower to mobile device such as cell phone	<ul style="list-style-type: none"> <li>• 5-10/0.5 Mbps on LTE</li> <li>• Up to 25 Mbps</li> </ul>	Very dependent on number of users on the local tower and backhaul
Fixed Wireless	Radio from tower to fixed device (antenna/modem)	1.5/0.2 to 25/5 Mbps depending on radio technology – 100Mbps to be available soon	<ul style="list-style-type: none"> <li>• Dependent on number of users on tower</li> <li>• Modem and tower radio locked to same frequency</li> <li>• Service depends on having line of sight to radio tower</li> </ul>
Wi-Fi - Home	Wireless router in your home services PCs, tablets & enabled devices	Limited by speed of internet service	<ul style="list-style-type: none"> <li>• Limited to 50-meter radius generally</li> <li>• Unlicensed spectrum of 2.4 or 5 GHz</li> </ul>
Wi-Fi - Municipal	Multiple radios services PCs, tablets & enabled devices in public spaces	Determined by Municipal Strategy	Uses same technology as home Wi-Fi – but equipment engineered for public use

Figure 11: Summary of Wireless Technologies

### 4.2.1. Mobile

Mobile Service or cell service is the provision of communications capabilities through radio systems with the consumer using a portable handheld device. The consumer or user can move or be mobile and maintain the call or service, as long as they have coverage from the carrier or supported through roaming agreements. Devices can include cell phones, tablets, laptops, equipped vehicle.

The technology supporting this continues to evolve. 3G technology providing cell coverage and limited data capability continues to be available throughout Eastern Ontario, with gaps where one or the other or both major carriers have no coverage. The most current technology deployed is 4G or more specifically known as LTE (Long Term Evolution), which started to rollout in 2011 and is now widely available. LTE provides large data capacity. Until recently an LTE network had to coexist with a 3G network, as any voice calls had to be carried on the 3G network, leaving the 4G network to handle data more efficiently. However, voice over LTE (VoLTE) is starting to rollout. 5G technology, or Fifth Generation, is the upcoming technology (with initial deployment in the early 2020s), which will facilitate the Internet of Things.

The service is delivered by radios and associated antennas that broadcast in various licensed radio spectrum. This equipment may be mounted on large 150-meter or higher towers, smaller towers, building roofs and even in the case of microcells on street lamps. The location is determined by the provider to maximize their coverage area. More frequently these days the tower sites are connected to the network by fibre links or fibre backhaul, although in some areas they may be backhauling through a point-to-point radio connection to another tower that is fibre connected. The ongoing increase in data consumption is driving more and more sites to be fibre connected.

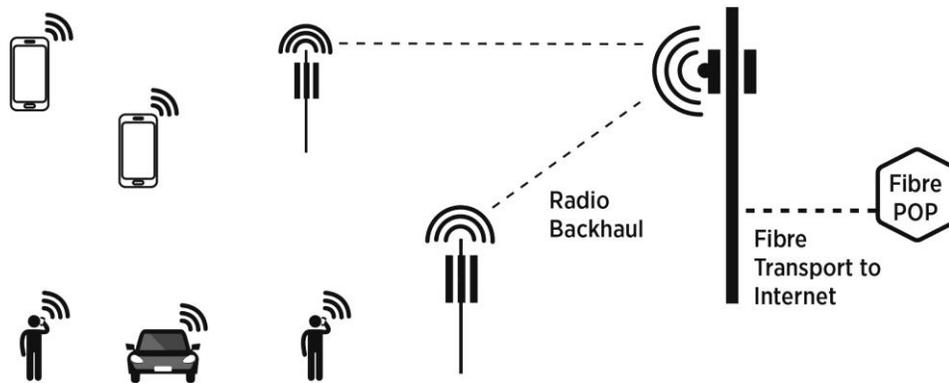


Figure 12: Mobile Wireless

Mobile is also a shared service consumed by all users that are connected to a specific tower. The more users connected at that instance to the tower, the more radio capacity and backhaul capacity that is consumed. Generally, this means less data speeds available, sometimes it means a longer time to get a dial tone or your call may get dropped as you travel from one location and are transferred to a new tower. In 3G technology, it may also mean that the coverage area of the tower is reduced, as more users are on the system. Towers are designed to accommodate both the expected load from residents in the towers coverage area, as well as a load factor from mobile users that travel through. In some locations, such as lakes or tourist areas, there is high seasonal demand.

#### 4.2.2. Fixed Wireless

Fixed wireless is an internet connection that is delivered via a radio service to a fixed location such as a home or business. The receiving antenna is mounted on the exterior of the building, small tower on the roof or a standalone antenna with wired connection to the modem located in the house.

Fixed wireless is the most economical way of providing broadband internet service to rural Eastern Ontario. With the right network, service offerings can be up to 100Mbps, although currently most subscribers are currently receiving at maximum up to 25 Mbps. Service is dependent on proximity to the tower, line of site and tower loading.

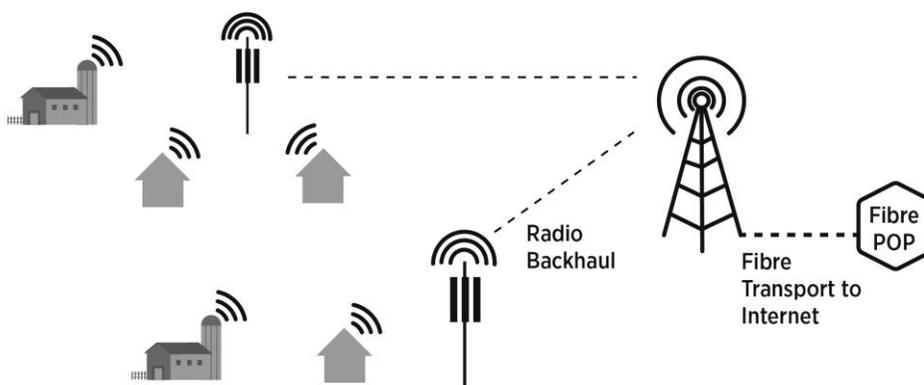


Figure 13: Fixed Wireless

Towers, their associated radios, and the tower backhaul, are designed to serve a certain number of subscribers and the anticipated amount of data that they are expected to use. This engineering design is based on usage patterns. As subscribers add more devices, and use larger amounts of data than expected, the radios on the tower and tower backhaul can become oversubscribed and fail to deliver the expected performance. Service providers have various ways to solve this problem including: adding more towers with radios, adding more radios to the tower, increasing the backhaul capability and updating existing radios. Unfortunately, many of the radio solutions require the use of additional spectrum, which may not be available in some parts of Eastern Ontario.

### 4.2.3. Wi-Fi

Wi-Fi is a technology for wireless local area networking. It provides the ability for devices to communicate with each and connect to an internet service. The technology is based on a set of engineering standards, known as the IEEE 802.11 standards.

Many internet providers offer an integrated modem and wireless router for home and small business subscribers. The range of a typical Access Point (AP) or hotspot is about 20 metres depending on the building structure.

Wi-Fi networks commonly use 2.4Ghz spectrum, and more currently 5Ghz.

Municipalities or private providers often provide Wi-Fi in public spaces, such as arenas and downtown cores. This attracts economic opportunities, serves local residents, and in some major areas can help to reduce the load on the mobile network.

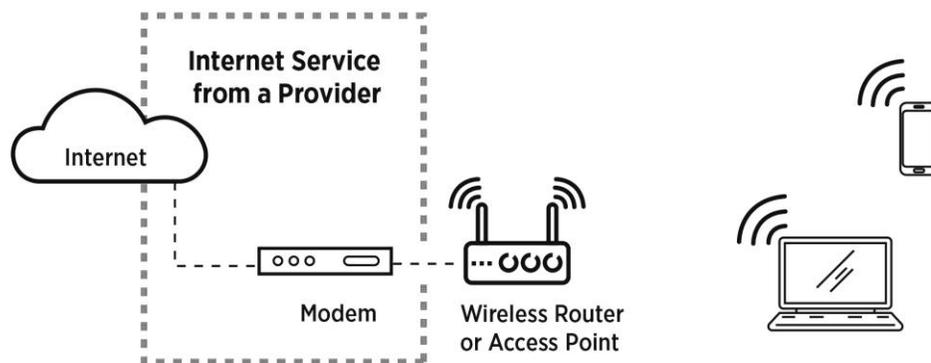


Figure 14: Wi-Fi Service

## 4.3. Wired

Wired technologies continue to be the consumer choice in providing internet services. Generally, and if properly engineered, these technologies provide consistent and reliable service to the end consumer, and provide higher speeds.

Service	Technology	Speeds	Characteristics
DSL - ADSL - VDSL	Uses copper telephone wires	1.5/0.2 to 50/10 Mbps	Speed varies based on distance to Equipment (either central office or remote)
Fibre to the Home (FTTH)	End-to-end fibre to house or business	Up to 1 Gbps	Fully scalable – no loading issues
Hybrid Fibre Coax	Fibre-to-neighbourhood pedestal – shared coax cable to house or businesses	Up to 60/10 Mbps (possibly higher)	Speed will vary based on load/number of users on shared cable

*Figure 15: Summary of Wired Technologies*

#### 4.3.1. DSL

Digital Subscriber Loop or DSL is a way of providing internet service over copper wire into your home or business. Signal is transmitted over copper wire from the DSL equipment (DSLAM) in a central office (CO) or remote to a modem in the customer premise. This is over the same copper loop as telephone service is provided, and the both internet service and phone calls can occur simultaneously. In addition to speed, this originally differentiated DSL service from the older Dialup internet service, where you could only have a voice call or a dialup internet call but not both simultaneously.

Speed provided depends on the distance that the signal must travel over the copper loop. The service can reach subscribers as much as 10 km away dependent on the quality of the copper infrastructure, with speeds under 1 Mbps, while 50 Mbps can be available within 0.5 km of the equipment.

Different types of DSL technologies (ADSL, HDSL, VDSL ...) exist with different characteristics and age of technology. VDSL is generally the technology used in eastern Ontario. The higher speed DSL services of 10Mbps plus are only available where the DSL equipment is fibre connected to the Internet.

Unlike some other services, DSL performance isn't impacted by other users in the neighbourhood, because the copper line is dedicated to the household. It can only be affected by the distance from the DSL equipment, and the quality of the copper lines that serve the household. If the backhaul from the DSL equipment is not engineered properly or using older ATM technology, users may see reduced performance at certain times of the day. Note that with any last-mile service, the number of devices connected within the household will impact each user's performance.

#### 4.3.2. Fibre to the Premise

A fibre to the home or business (FTTH or FTTB) or premise (FTTP) internet connection is provided via fibre all the way from equipment at a central location (known as the Central Office) to the Optical Network Terminal (ONT) at the customer's premise. Fibre to the Home solution is currently viewed as the optimum solution for consumers in more densely populated areas.

This is different from some other services that use fibre to subdivision, and then provide services to the premise via either coax or copper loop.

### Technology

In fibre-based technology, the digital signal is converted into light and reflected along a fine glass strand. Multiple strands are bundled together into a fibre cable.

Fibre-based technology can transmit larger amounts of data over longer distances than any other medium.

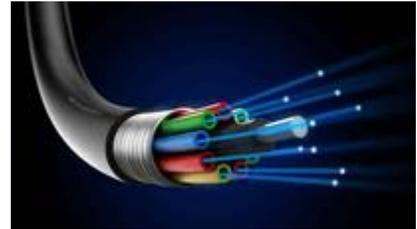


Figure 16: Multi-strand Fibre Cable

There are two major methods for providing this service on a general consumer basis, GPON (and its family) architecture and Active Ethernet. GPON (Gigabit capable Passive Optical Network) is a Point to Multi-point technology that uses unpowered or passive fibre optic devices, to split or consolidate the service from multiple endpoints or subscribers to the CO as shown in Figure 17. It is technically a shared service, but if engineered and managed correctly, it can provide Gbps speeds to end users. It is an efficient and cost-effective technology to deploy fibre to residential and small business consumers, as it reduces overall the fibre deployment required, and the amount of equipment at the central office.

Optical Network Terminal (ONT) or Optical Network Unit (ONU) in multi-tenant locations terminates the fibre service at the subscriber’s location. Optical Line Terminal (OLT) is the transmitting component of the GPON network in the CO. Other components of the GPON network may include fibre and splitters known as the Optical Distribution Network (ODN).

The Active Ethernet-type technologies use a dedicated fibre through to the equipment in the Central Office. It’s more expensive to build, but requires less engineering management over time as the network demand grows.

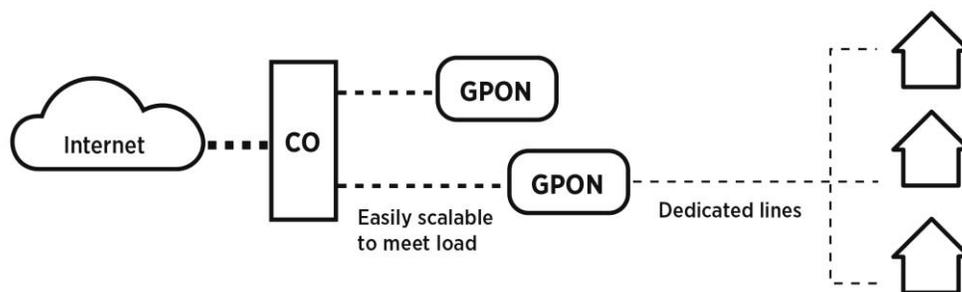


Figure 17: GPON Architecture

Symmetrical services (equal download and upload speeds) are possible, but are generally not offered by the service providers as there is currently little consumer demand, and it simplifies the SP overall engineering.

The fibre cables can be either buried or provided aerially attached to utility poles, or some combination of both.

In multi-tenant locations, such as apartment buildings or condo units, fibre is brought directly onto the premise to distribution box or ONU, and fibre or potentially Ethernet is then run by a contractor into each unit.

EORN's partners in Eastern Ontario are deploying GPON based solutions.

### **Consumer**

FTTH services provides the highest speeds at reasonable costs to the end user. Its service quality should not be generally affected by other use in the community or by weather.

In addition, the consumer is usually offered what is called a triple play bundle – internet, phone and classic TV, over the same service. In some areas where the service provider also provides the regulated phone service, the copper-based phone service is being replaced by a fibre-based service with the same functionality.

### **Municipal Project Opportunities**

While FTTP services are being rolled out by several service providers in the region, with more expected over time, these builds are generally costly. In some areas with municipal contributions, the rollout can be advanced, but an ongoing revenue stream is required.

#### **4.3.3. Cable**

Modern cable technology is now capable of matching the services offered on Fibre to the Home, when engineered and managed correctly. The technology can provide downstream speeds of 1 Gbps. It is different from the older cable technology that was one directional and could only be used to distribute television services.

With modern cable technology networks, fibre is run from a control centre or 'headend' to the optical node, and then transformed from an optical signal to one that can be carried over cable. These optical nodes will support anywhere from a few hundred homes to a thousand or so, depending on the type of services that subscribers are using. As the demand in a neighborhood grows, these neighborhoods can be split and served directly by their own fibre connection.

DOCSIS is the name for the protocol used in the industry. The DOCSIS protocol inherently limits the protocol to asymmetric services (download and upload are different speeds) as different from a fibre service.

The cable network is shared amongst the users in a neighbourhood, so one extreme user can impact everyone else's performance. With competition, many carriers including EORN's partners now manage their networks with strong internal SLAs, such that capacity issues are looked for and are addressed quickly by splitting neighbourhood networks, and bringing fibre closer to the household.

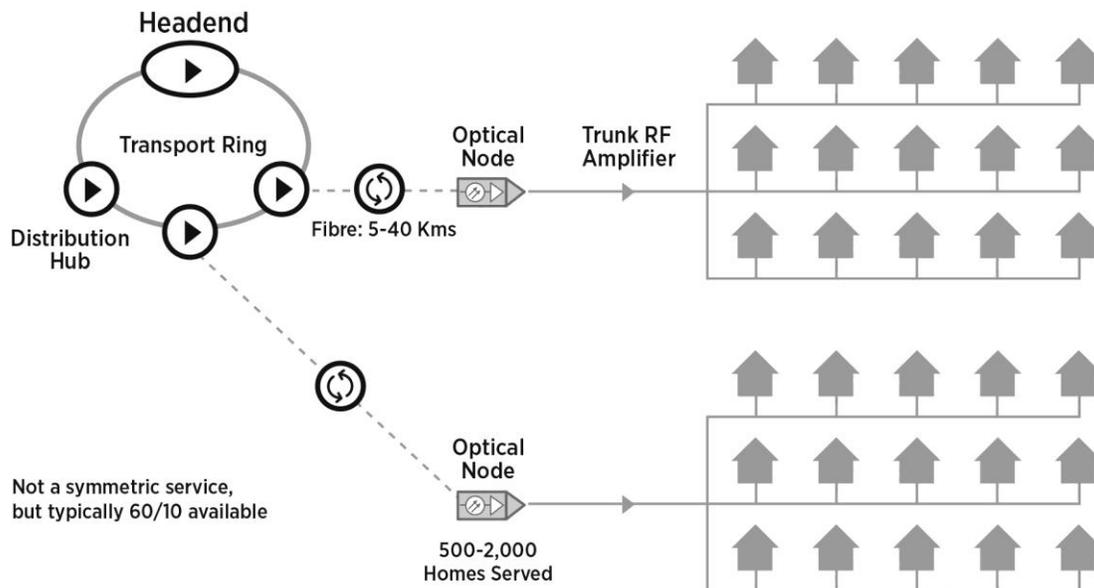


Figure 18: Cable Architecture

#### 4.3.4. Dedicated Fibre

Many major businesses, offices and some major retail sites have a dedicated fibre connection from the Central Office (CO) or POP directly into the business. This can provide dedicated symmetrical speeds from 50 Mbps to 1Gbps or more and unlimited data. With this dedicated service, and associated higher quality of service and support processes, these services generally cost significantly more on a monthly basis although they continue to come down in price due to programs like EORN’s Municipal broadband procurement program. In addition, the subscriber usually will have to pay a construction and installation fee that depends on the distance that dedicated fibre must be installed.

#### 4.3.5. Other Technologies

Many creative technologies have been developed over the last 20 years to deliver high speed services, including distribution over power lines, small mesh networks, and other developments. While each has their niche value, generally they are not scalable, will not deliver the speeds and capacity required by modern consumers, and are not cost effective on a large scale.

## 5. Public Safety Networks

EORN is also seeking to address the need for a Public Safety Network. A Public Safety Network refers to a communications network used typically by police, fire and paramedics. In addition, there may be public works, border officials, Ministry of Natural Resources and military personnel using one or more of these networks. It is usually meant to serve a mobile group of users, such as police or paramedics, as they proceed in their vehicles to a scene, while communicating with dispatchers or communicating with others at a scene.

As with all types of service, the technology is evolving rapidly. Equipment in the field ranges from analog-based “Push-to-Talk” systems to elaborate digital trunk systems with many features. These are all referred to as Land Mobile Radio (LMR) systems. In Ontario, these systems are being operated in a variety of models. Some are province run, through contracts to a major telecom provider, others are direct leases from a service provider, while others are owned and operated by local service groups. The networks are voice only with limited data traffic such as SMS messaging (texting).

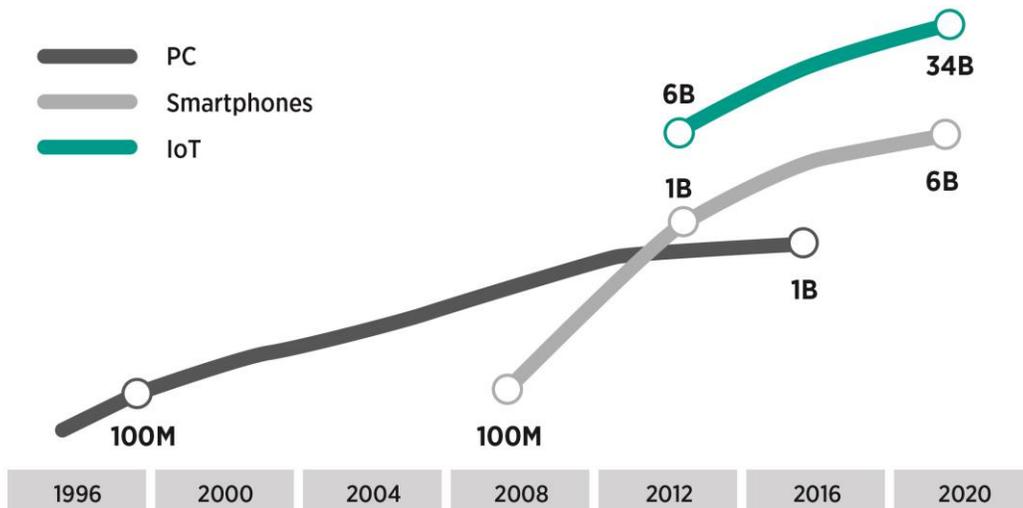
The federal government has recognized the need for an interoperable ubiquitous Public Safety Broadband Network (PSBN) that would meet the future needs of public safety workers across Canada. In doing so, it has dedicated 20 MHz of 700 MHz band spectrum to a PSBN, and is in the process of defining the overall model for governance and usage. This would provide much needed data services and further facilitate the use of video streaming, images and documents transfer required by public safety workers now and in the future. A similar network using the same spectrum is being developed in the United States and is known as FirstNet. While expected to be LTE-based, the Canadian government has recently said that the spectrum use will be technology neutral.

## 6. Internet of Things – not so distant future

According to a recent Gartner Report about 20.8 billion interconnected things will be in use worldwide by 2020, while other studies are showing more than 34 billion (see Figure 19). This Internet of Things (IoT) will range from household appliances and devices controlling in-home temperatures, lights, blinds and security systems, to sensors in municipal roads that manage traffic patterns and autonomous vehicles, to robots in factories. The growing number of items that are being connected in every industry is driving significant ongoing demand for capacity.

### Internet of Things (IoT)

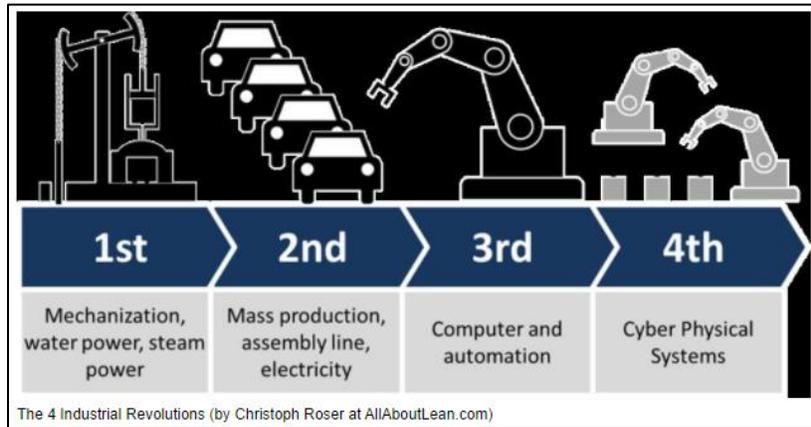
Inter-networking of physical devices, vehicles, buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data, often without human interaction



Source: IDC, Ericsson, Goldman Sachs Global Investment Research

Figure 19: Growth in Connected Devices

The Internet of Things will enable the fourth Industrial Revolution and change yet again the world economics where amongst other things, there will exist smart factories in which machines are augmented with web connectivity and connected to a system that can visualize the entire production and supply chain and make decisions on its own (Figure 20).



*Figure 20: IoT will enable 4th Industrial Revolution*

### 5G Mobile Networks

Applications like vehicle operations, and sensor-driven decision-making drive both a need for ultra high reliability and ultra-low latency. While the current 4G LTE technology addresses some of these needs, it's only the next generation of 5G networks that will be able to meet these not-so-far in the future demands in communications. 5G will be a significant economic enabler.

There are 5G trials and demos ongoing across the world now, but the current view is that real deployments will start as early as 2020. Deployments all assume an LTE-base.

## Definitions

Active Ethernet	Type of access service that provides Fiber to the Home through dedicated fibre between the home and the Central Office.
Analog or Analog signal	A signal where the information is transmitted in a continuous wave form, as opposed to digital signal where the information is sampled.
ARPU	Average Revenue Per User – a measure of revenue used by telecommunications companies.
ATM	Asynchronous Transfer Mode - Packet-based switching technology developed in the late 1980s and into the 1990s used to transmit both voice and data.
Band 14	The 20 MHz of 700 MHz spectrum allocated to Public Safety.
Bit(s)	Basic unit of digital information used in communications, in mobile context. Mbps (Megabits per second) represents speed of transmission.
Byte(s)	Unit of digital information consisting of 8 bits, in mobile context. MB (Megabyte) represents amount of data transferred.
Backhaul	Generally, refers to the portion of the network between the backbone and the access edge, in mobile context refers to the network between the tower and the backbone, and may be either wireless or fibre.
Backup	Involves copying and archiving of computer data so it may be used to restore the original after a data loss event.
BB	Broadband – high-speed internet access.
Cable	Generically defined as an insulated wire, set of wires, or fibre optic strands, used to carry telecommunications signals. More specifically may refer to the type of access technology using the DOCSIS protocol to provide Internet services.
Capacity	Ability of the network to provide a specific level of data service to a defined number of users.
Coverage	The geographic area where a wireless tower can provide service, or the area served by a wireline service.
CCTS	Commissioner for Complaints for Telecommunication Services – responsible for resolving complaints between consumers and service providers.
Cellular network	Used interchangeably with mobile to refer to a communication network where the last link to the user is wireless, and the user’s receiver or handset may be portable.

Central Office	Location where historically the telephone switching equipment or exchange was located. In addition it is now often the site of a POP and fibre connections.
Cloud Cloud-based Services	Applications, services, and other resources provided over the internet using equipment and software maintained offsite by third parties.
CO	See Central Office
Co-location	In a cellular network, it refers to the location of a service provider's radios and equipment on another provider's tower.
CPE	Customer Premise Equipment – includes handsets, vehicle- mounted radios, dispatch center equipment, etc.
CRTC	Canadian Radio-television and Telecommunications Commission – an independent public authority in charge of regulating and supervising Canadian broadcasting and telecommunications industries.
Data Cap	Term used to describe the practice by service providers of limiting the amount of data that a subscriber can transmit or receive on a monthly basis.
demultiplex	The opposite of multiplex, which is the combining of multiple signal streams into one signal over a single shared media such as a fibre cable.
Dialup Internet	Early technology that allowed internet connections to be made over the telephone line. Could not make a simultaneous voice call. Maximum speeds were 9600 bits per second (9.6 kbps).
Digital Signal	A signal where the information is encoded in a pattern of bits at each sampling point.
Download	Typically, the transfer of data from the internet to a residence/subscriber's computer or device.
Downstream	Refers to download speed.
Deferral Account	A CRTC-regulated program that required Bell Canada to set aside funding to provide internet services to less-populated rural areas. The program completed effectively in 2015 with the build and rollout of mobile broadband to the deferral areas, with specific pricing.
Distributed Denial of Service Attack (DDoS)	The malicious flooding of a server or network resource with large numbers of attempted connections with the intent to deny normal users the ability to get service.
DOCSIS	Data Transmission Standard used by the cable industry.
DSL	Digital Subscriber Loop – a way of providing internet services over copper telephone lines.

DSLAM	Digital subscriber line access multiplexer - equipment located in the Central Office that terminates and consolidates the subscriber lines for DSL services, and hands off to other networking transports.
Ethernet	Technology protocol commonly used to allow computers and devices to talk to each other on networks.
Exabyte – E Byte	A measure of data size equal to 1000 <sup>6</sup> bytes
Fibre	Generally used to describe optical fibre which is a flexible thin glass strand used to transfer light signals. It enables the transfer of large amounts of data over long distances
Fibre to the Home FTTB FTTH FTTP FTTX	Fibre to the <b>H</b> ome/ <b>B</b> usiness/ <b>P</b> remise/ <b>X</b> —a set of terms for bringing fibre service to homes, small-to-medium businesses and other sites. Very high-speed connections are possible. Service level agreements and packages are generally lower than a dedicated fibre connection (often symmetrical, meaning same upload and download speeds).
Firewall	A network security system that monitors and controls the incoming and outgoing network traffic based on predetermined security rules. It is typically located on a router.
FirstNet	The name of the federal public safety broadband network in the United States.
Fixed Broadband	Term used to describe the delivery of internet services from an antenna usually on a tower to a fixed location, such as a receiver on someone’s house, as opposed to mobile broadband which connect devices as they travel.
Frequency	Refers to the particular wave band at which a system broadcasts.
Gaming	Used in this document, to refer to the practice of –internet- based games involving one or more players. It requires immediate response times, and large data transfers.
geosynchronous	Refers to the orbit of a satellite that is positioned and remains over a specific area of the earth/
GB	Giga Byte – a measure of data size equal to 1000 <sup>3</sup> bytes
GPON	Gigabyte Provisioned Optical Network - a specific type of Fibre to the Home technology.
GSMA	An industry association that represents the interests of mobile operators, including handset and device makers, software companies, equipment providers and internet companies, as well as organizations in adjacent industry sectors.
HD	High-definition video

HFC	See Hybrid Fibre Coax
HSPA	High-Speed Packet Access - a third-generation (3G) mobile broadband communications technology.
Hybrid Fibre Coax	Refers to the cabling infrastructure used by cable companies to provide internet service.
ICT	see Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
Information and Communications Technology (ICT)	Refers to the application of computers to store, retrieve, transmit and manipulate data, often in the context of a business or other enterprise.
Internet of Things (IoT)	The network of physical devices, vehicles, buildings and other items that are embedded with electronics, software, sensors, actuators, and network connectivity to enable them to collect and exchange data.
Internet Protocol (IP)	A set of rules governing the format of data sent over the internet or other networks.
IP Address	A unique identifier assigned to each device in a network. External IP addresses are assigned by the Service Provider, and may be either dynamic (changing regularly,) or static (the address doesn't not change and is often used for services such as VPNs or hosting file servers).
ISED	The federal Ministry of Innovation, Science and Economic Development Canada (formerly Industry Canada)
IXP	Internet Exchange Point – where independent networks interconnect directly to each other.
LAN	See Local Area Network
Latency	Measure of the time of delay that occurs when a digital file or signal is sent and when it is received.
LMR	Land Mobile Radio
Local Area Network	Refers to a network (usually Ethernet) that connects devices within a building, such as a home or office.
LTE	Long Term Evolution - generally referred to as 4G evolution of wireless communications.
MMS	Multimedia Messaging Service – based on SMS (text messaging), but allows the transmission of video and images.

Mobile network	Used interchangeably with cellular to refer to a communication network where the last link to the user is wireless, and the user's receiver or handset may be portable.
Mobile Broadband	Term used to describe the delivery of internet services from an antenna usually on a tower to a mobile location such as a mobile handset, where the service will continue function uninterrupted as the user moves locations
Modem	A device that connects a personal or home network to the service provider's infrastructure, and converts the SP signal to Ethernet.
Multiplex	Combines multiple signal streams into one signal over a single shared media such as a fibre cable.
MVNO	Mobile Virtual Network Operator – uses other service providers equipment through wholesale agreements to provide service.
ONT	Optical Network Terminator
Optical Network Terminator	Device that terminates the fibre optic line, demultiplexes the optical signal and converts it into its component parts (telephone, TV and internet).
Outside Plant	Generic term that refers to the equipment located outside of a Central Office and a customer premise, such as buried or aerial cable or lines, connection points and other equipment.
OSR	Over Subscription Ratio – used to set the capacity of a network design, ratio of potential demand to capability.  In network design, the Over-Subscription Ratio (OSR) is a factor that is applied to oversubscribe a channel with more users than the channel could otherwise support the same number of users simultaneously. For example, if a channel has a capacity of 10Mbps and each user is provisioned for a 1Mbps service, the channel could handle 10 simultaneous users. With an OSR of 10:1, the same channel supports 100 users. The assumption is that on average only 10 of the 100 users would be using the channel at the same time so there would be no perceived degradation in service.
Peer	To peer a network with another service provider allows two providers to share common assets and mutually benefit. Often done at no cost to the providers.
Point to Point	Refers to a broadcast from one place or point to another single point.
Point to Multipoint	Refers to a broadcast from one place or point to many locations
POP	Point of Presence – access point to the core or backbone network.
Propagation	Characterizes how a radio signal travels, as a function of distance, frequency, terrain and other characteristics.

Public Safety Network	Telecommunications mobile network used by public safety workers such as police, fire, paramedics and public works.
PSBN	Public Safety Broadband Network
Public Safety Broadband Network	Public Safety Network that can provide the capability of large volume data transmissions such as video
PTT	See Push-to-Talk
Push to-Talk	A type of radio device that requires the user to push a transmit button when and while they are talking
Router	Allows the interconnection of multiple networks and the routing of traffic between them. There are many types, including high-capacity types used in backbone networks, to simple low-cost devices used in the home to connect multiple devices in a local network the internet
Service Provider	A generic term that refers to an organization that provides internet services.
SMB or SME	Small to Medium Businesses or Enterprises
SMS	Short Message Service - formal name for text messaging and are limited to 160 characters. SMS messages are only sent over cellular networks.
SP	See Service Provider
Spectrum	Refers to a range of radio frequencies
Streaming audio or video	An internet data download that allows a multimedia file to be played back without being completely downloaded first, so consumers can watch a video while it's being downloaded to their computer. With live streaming, the stream is occurring in real time, as the event is occurring.
Symmetrical	In telecom, it refers to a signal that is transmitted in equal speeds in both the download and upload direction.
Terrestrial Service	Used to describe internet service that is provided through ground based infrastructure, as opposed to satellite.
Trunked	Trunked radio system provides a more efficient use of radio channels by assigning channels to groups instead of users. When a user wants to talk, they are assigned a free channel within the group.
UBB	See Ultra Broadband
Ultra Broadband	Refers to internet services with download speeds greater than 100 Mbps.
Upload	Typically, the transfer of data from a residence/subscriber to the internet.
VDSL	Very High Bit Rate digital subscriber line
VoLTE	Voice over LTE –protocol that supports voice directly in the LTE service.

VPN	Virtual Private Network
WACC	Weighted Average Cost of Capital
Wireless	Radio-based communication that operates without a physical wire connection.
Wi-Fi	Used to describe a radio technology that allows devices to connect to a local area network wirelessly.
5G	Fifth Generation of Mobile Technology – will provide significant bandwidth improvements over current 4G (generally LTE) technology. Also provides ultra-low latency, high reliability and security.
700 MHz Spectrum	With respect to this document, it is a frequency range allocated to mobile use. The majority of it has been allocated to commercial carriers, but a specific 20MHz section known as Band 14 has been allocated to a Public Safety Broadband Network in both the U.S. and Canada
802.11	IEEE 802.11 is a set of specifications for Wi-Fi connectivity