Wireless Substitutability

Examination of the Substitutability of Wireless for Wireline Broadband Connectivity

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1. Background and Introduction

The CRTC is in the midst of a review of the regulatory status of wholesale telecommunication services,[1] and has also recently launched a proceeding to investigate whether there needs to be any new wholesale services introduced in the context of wireless services[2]. Both of these proceedings require an examination of the state of both wireline and wireless services provided to consumers.

One of the aspects of the overall communications space being looked at is whether or not wireless services can, or might, become substitutes for traditional wireline services. The context and rationale is that if they are indeed substitutes, then wireless and wireline providers operating in the same geographic area can be considered true competitors, therefore lessening the need for regulation of either of these services.

The notion of substitutability has been examined by the Commission in the past, but lacked a thorough technical and economic assessment, instead relying on anecdotal evidence and testimony. As an example, in Telecom Regulatory Policy 2011-291[3], the CRTC noted that:

> *"The Commission considers that, in forborne exchanges, the advanced state of mobile wireless competition has resulted in high-quality **voice** service at increasingly competitive prices. In this regard, the Commission finds that mobile wireless **voice** services are substitutes for wireline **voice** services in forborne exchanges."*

It is important to note that in the context of this policy, the issue was limited to **voice** services, but in the time that has passed since then, some incumbents argue that this substitutability is not limited to voice, but also includes data, or Internet access services.

As a result, CNOC retained Nordicity to prepare an expert report based on technical and economic (pricing) evidence regarding the extent to which wireless and wireline services may act as substitutes for each other.

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[1] Telecom Notice of Consultation CRTC 2013-551: http://crtc.gc.ca/eng/archive/2013/2013-551.htm.

[2] Telecom Notice of Consultation CRTC 2014-76: http://www.crtc.gc.ca/eng/archive/2014/2014-76.htm.

[3] Telecom Regulatory Policy 2011-291: http://www.crtc.gc.ca/eng/archive/2011/2011-291.htm.

2. Methodology

For the purposes of this report, Nordicity has relied on two forms of secondary research. Namely, Nordicity relied on an examination of the technologies used to provide services, as well as a comparison of the various pricing options that lead to the substitutability comparison.

For this report, Nordicity conducted both technical as well as economic research to support its conclusions. It is our belief that a combination of these two methods form a strong basis to demonstrate that wireline and wireless services remain complementary in most cases, and shall remain that way for the foreseeable future.

Nordicity is relying on historical data, as well as examining near-term technical developments. In addition, Nordicity also analyzed data regarding consumer behaviours and data consumption patterns, which are critical to illustrating the difference between home-based usage of services as compared to mobile-based usage.

This secondary research therefore focused on three key areas:

1. **Technical research** – A key aspect of this examination included researching the technologies in use today, and in the near future to deliver wireless and wireline services. This included exploring concepts such as spectral efficiency and fibre-optic capacity to assess the ability to deliver data-intensive services to end users. The intention of this research is to factually explore the technical capabilities of the various wireline and wireless platforms to deliver Internet access services with comparable quality of service. In our evaluation of wireless technologies, distinctions will also be made with respect to Wi-Fi versus cellular platforms.
2. **Consumer research** – To better understand the notion of substitutability, it is important to report on consumer expectations and behaviours. This phase of the research and analysis focused on how people tend to use wireless and wireline services, and explore where there is commonality, as well as uncover the major differences in usage. Distinctions were made with respect to Wi-Fi vs. mobile wireless (i.e. cellular) usage. Different usage patterns will lead to greater non-substitutability.

3. **Service offerings** - We also analyzed and compared key features, quality of service and pricing of both wireline and wireless service offerings (focusing mainly on data-intensive services) – both on a standalone and bundled basis. This lead to an examination of the costs incurred by consumers for various wireless or wireline services in different realistic scenarios. This research illustrated the true costs of using either wireline or wireless services as substitutes. The intention of this research was to validate whether there are significant differences in the service offerings that would indicate non-substitutability.

The combination of all three phases of research and analysis clearly illustrate the problems associated with treating wireless and wireline services as perfect substitutes, particularly in the Internet access market in most scenarios.

3. Technical Comparison

To begin the assessment of the substitutability of wireless and wireline services, we must first examine what are the specific technologies in question, and what are their inherent service capabilities in different settings. To those ends, we will explore all of the major technologies that are being used today to deliver a wide breadth of services, including voice services, Internet access, and broadcasting content. The objective is to understand how well each technology can cope with the demands placed on it by data-intensive applications such as 2-way communications and video services.

Before examining each technology individually, we present a table highlighting the current theoretical and practical speeds of a number of wireless and wireline technologies, along with a companion chart, illustrating the evolution over time of various wireless and wireline technologies. More specifically, we are examining the way speeds have changed over time, and what differences exist between the wired and wireless technologies employed to deliver services. Data for these charts were extracted from numerous sources, including theoretical speeds from standards bodies, as well as market research from sources such as Rysavy Research[4].

Figure 1 – Throughput speeds for various technologies (Nordicity Research)

Technology	Medium	Theoretical Speed	Practical Speed
VDSL2 (FTTN)	Wireline	250 Mbps	25-100 Mbps
DOCSIS 3.0	Wireline	n x 38 Mbps*	50-250 Mbps
FTTH	Wireline	10 Gbps+	1 Gbps
HTS Satellite	Wireless	1 Gbps	1.5-15 Mbps
LTE-A	Wireless	Up to 1 Gbps	5-20 Mbps**

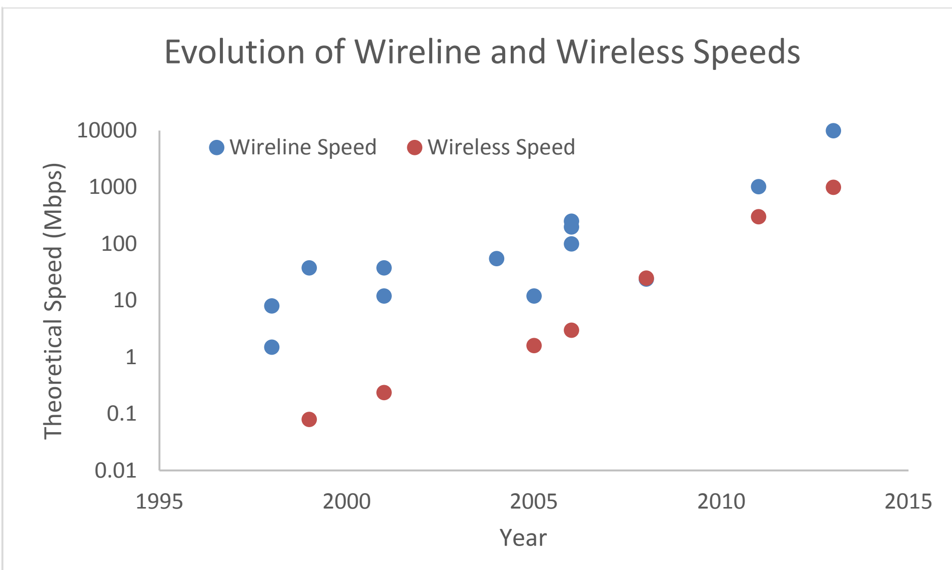
* For DOCSIS 3.0, multiple channels are used together.

** There are many variables which contribute to practical speeds, explored below.

[4] One excellent source is the 'Mobile Broadband Explosion' paper, updated most recently in August 2013, which can be found at: http://www.rysavy.com/Articles/2013-08-4G-Americas-Mobile-Broadband-Explosion.pdf..

In Figure 1, the table illustrates a range of technologies, and the practical speeds that the consumer can expect to achieve when purchasing or using them. As we'll explore in further sections, wireless services are often not sold by a particular speed, but rather by a volume of usage. Regardless, the table illustrates that generally speaking, wireline technologies feature greater speeds than wireless technologies from an end-user perspective. To further illustrate this point, Figure 2 is a scatter plot showing different wireline and wireless speed offerings in different years. The y-axis is a logarithmic scale, and the general trends indicate that over the years, wireline technologies have consistently out-performed wireless technologies by a factor of 10.

Figure 2 - Scatter Plot of Speed by Year (Rysavy, Nordicity Research)



Using these 2 figures as our starting point, we will now examine the specific technologies that are contained in these figures, and expand further on their detailed characteristics, and suitability for delivering a range of services.

3.1 DSL Technologies Explored

Digital Subscriber Line (or DSL) technologies are the technologies that telephone companies have been using since the late 1990s to offer broadband Internet access to consumers. Many people will remember the venerable '1 Meg Modems' that were introduced which were capable of delivering Internet access speeds of 1-1.5 Mbps.

Figure 3 - Nortel Networks 1-Meg Modem

At the time, the revolution was also the fact that this access was provided independently of landline phone services, meaning in one household, people could use the Internet and their telephones at the same time, thanks to the technologies being used to provide each service. Prior to this, most homes relied on dial-up networking.

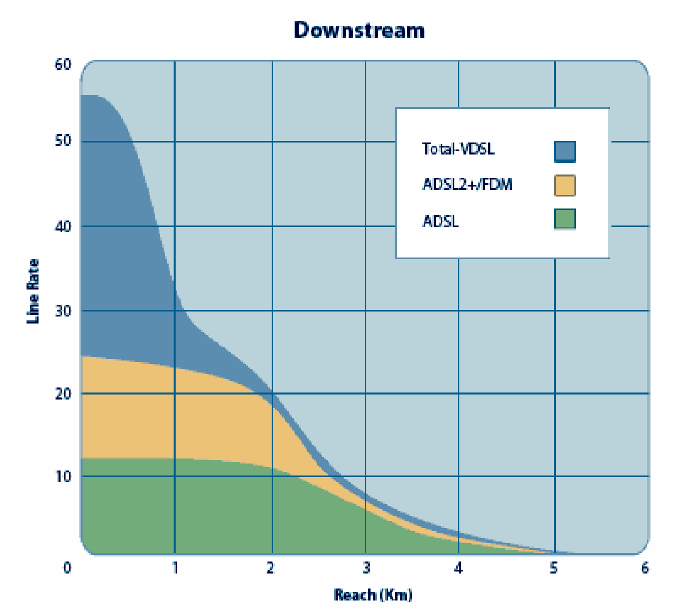
As a baseline, DSL uses the existing copper wiring that telephone companies install to homes to provide phone services, but separate the phone signal and DSL signal into two separate streams on the same copper wiring. DSL takes advantage of the fact that the signals used for the DSL services can travel along the copper at much higher frequencies than those used for telephone services.

DSL services have been in a constant state of evolution from 1998 until the present day, with the main goal to provide ever-higher downstream and upstream speeds. There are many 'flavours' of DSL, starting with ADSL, all the way through the VDSL2+ with vectoring and pair bonding. Regardless of the technology name, all of the services are delivered using agreed-upon standards ratified by the International Telecommunications Union (ITU).

There are two features worth noting about DSL which affects the performance experienced by end users. The first is the fact that DSL connections are generally mapped as a 1:1 relationship between users and the equipment serving them. Practically, this has been marketed by stating that the connection is 'not shared' with anyone else. In other words, if you have a 1Mbps connection, you can reasonably expect to attain that speed regardless of the time of day. While this was a defining characteristic several years ago, this difference is not as marked today, as a result of rising speeds and increasing capacities of all technologies in use today.

The second, and more important aspect of DSL is the fact that services are affected by distance. Although there is a 1:1 mapping of the user and serving equipment, signals degrade as they travel through copper, meaning that the overall speed experienced decreases the further you are from the serving equipment. This is highlighted in the figure below.

Figure 4 – Impact of distance on speed of xDSL (Wikipedia)



Evolution to FTTN

As a result of this sensitivity to distance, service providers have been moving the DSL serving equipment closer and closer to their end-users, which results in greater speeds. Whereas equipment was traditionally located in what is known as the Central Office (CO), this equipment was made smaller, and located in 'remote COs' within neighbourhoods, and eventually within roadside cabinets. Rather than using copper wires to reach this equipment from the main offices, telephone companies have turned to using fibre-optic cables, which have far greater capacity, and can carry signals much further without degradation. This shift is referred to as fibre-to-the-node, abbreviated as FTTN.

Figure 5 - DSL Cabinet in a neighbourhood

Indeed, through the use of these technologies, companies have been able to offer a full suite of services, including voice services, broadband Internet services, as well as broadcast television services using Internet protocol television (IPTV). The movement towards FTTN by providers allows increasing speeds without incurring the high costs of replacing the aging copper loops that currently go to each home in a neighbourhood. This also allows them to continue to offer the same copper-based telephone services to those homes as well.

As a result of these developments, most telephone companies are able to offer broadband Internet services at speeds of up to **50Mbps** today using existing copper plant. We will explore service offerings in greater detail later in the report.

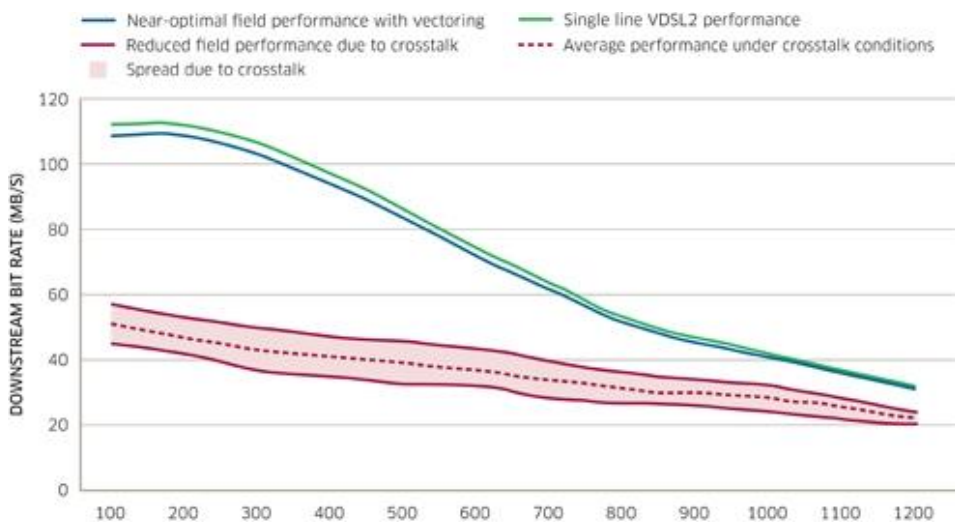
Vectoring, Bonding and Other Developments

Although much is being said for developments in implementing fibre-to-the-home (FTTH), there are still developments in the current copper-based DSL services, as many telephone companies look to extend the life of their existing facilities. To those ends, new techniques such as vectoring[5] and pair bonding are being used. Vectoring, in essence, is 'noise cancelling' for DSL. Vectoring helps to clean up the signals at either end of the copper link to get greater speeds over longer distances, therefore achieving speeds closer to theoretical maximums rather than the typical speeds seen in the field. The main culprit of poor signals over distance is 'crosstalk',

[5] For a thorough explanation from Alcatel-Lucent, an equipment vendor see: http://www2.alcatel-lucent.com/techzine/boosting-vdsl2-bit-rates-with-vectoring/.

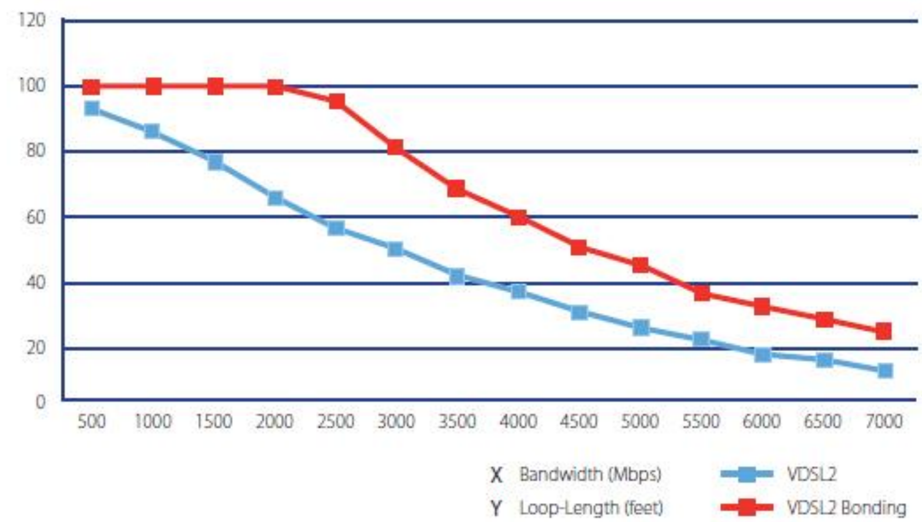
which is essentially the interference on a signal travelling down a copper wire. Crosstalk is caused by the fact that there are other copper wires in the same physical cable. This is very noticeable in telephone wiring, as the cables contain multiple strands of copper in the same cabling.

Figure 6 - Impact of Vectoring on real-world VDSL2 performance (Alcatel-Lucent)



Pair bonding, as the name implies, enables the use of multiple pairs of copper wires to be joined together to deliver services to end users. Most homes are pre-wired with at least 2 pairs of copper wires, originally installed to allow more than one phone line to be connected to a home. Pair bonding therefore can allow the speeds experienced by an end user to increase by a multiple of however many copper pairs they have at their disposal in the home. Commercially, equipment is available to support bonding using up to 8 copper pairs. Pair bonding enables one of two things in different scenarios. It can enable either a greater speed at a given distance, or enable a given speed to be offered at a greater distance from the serving equipment.

Figure 7 - Impact of pair bonding on VDSL2 performance (ZyXel)



Apart from vectoring and bonding, there are other, newer technologies under development to continue to increase the performance that can be attained over copper loops. Examples include 'DSL Rings' (pioneered by a Canadian company[6]) and 'Phantom Mode' DSL[7]. All of the foregoing are helping push speeds to 300Mbps at distances of up to 400m from serving equipment, which can deliver rich media experiences and multi-play bundles of services. However, as we will explore later in the report, even these speeds will be no match for the abilities present in pure FTTP deployments.

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[6] For more information on DSL Rings, see: http://www.genesistechsys.com/.

[7] Phantom mode is being developed by Alcatel-Lucent (amongst others): http://www.alcatel-lucent.com/products/phantom-mode.

3.2 DOCSIS Technologies Explored

Data Over Cable Service Interface Specification (DOCSIS) technologies are the set of standards that allow traditional cable distribution companies to offer broadband Internet access services to their customers. Originally created and deployed at around the same time as DSL technologies by the telephone companies, DOCSIS was the technology that allowed cable carriers broadband Internet access services over their existing infrastructures that competed with those offered by the telephone companies. DOCSIS infrastructure makes use of existing cable company coaxial cable infrastructure.

Figure 8 - DOCSIS 1.1 Modem

In a cable television system, the television signals were traditionally sent down the coaxial cables from the head ends as analog 'channels'. Each of these channels would carry a television station to end users in a unidirectional fashion, with all subscribers getting the same signal.

When DOCSIS was introduced, cable operators replaced one of these channels with a data stream. This channel was further split into downstream and upstream directions, to allow for 2-way data traffic (with the upstream portion being significantly smaller).

Much the same as DSL, DOCSIS was initially served directly from the central locations, in this case main cable head ends. As a result of the cable architecture, the overall capacity of the DOCSIS system was 'shared' amongst the number of subscribers on the same main line from the head end. Early releases of DOCSIS allowed 38Mbps of downstream capacity, but depending on how many customers were sharing a connection, the realistic speeds attained were much lower. In those early days, it was common for DSL to perform better in some communities, and DOCSIS to perform better in others. This was mainly a function of the number of connected users, which could also vary throughout the day. For cable companies, when many customers were connected at the same time, the speeds they experienced would be a fraction of what they might expect. The DSL network in those days was better equipped to handle larger numbers of users in an area.

DOCSIS did however have at least one notable advantage over competing technologies. DOCSIS was much less distance-sensitive than DSL. The main reason for this is that the cable infrastructure (as opposed to copper phone lines) had *always* been intended for high frequency signals. To be able to deliver reliable signals to end-users, cable operators use amplifiers to boost the signals on the signal path. As a result, performance was limited more by the distance between amplifiers, not the pure distance from a head end.

Over time, DOCSIS standards have also evolved. Below is a table showing the main DOCSIS releases, when they were introduced and their capabilities.

Figure 9 - DOCSIS Releases and Capabilities (Wikipedia, FTTH Council)

Standard name	Common name	Downstream rate	Upstream rate	Release Year
ITU J.112 Annex B	DOCSIS 1.0	38 Mbps	9 Mbps	1997
ITU J.112 Annex B 2001	DOCSIS 1.1	38 Mbps	9 Mbps	1999
ITU J.122	DOCSIS 2.0	38 Mbps	27 Mbps	2001
ITU J.222	DOCSIS 3.0	n x 38 Mbps	n x 27 Mbps	2006
TBD	DOCSIS 3.1	10 Gbps	1 Gbps	2013

The first major revision to DOCSIS was DOCSIS 2.0, which focused on improving the upstream speeds supported. This change made it possible for cable operators to begin selling new services including Voice over IP (VoIP), in order to compete with telephone companies in that market segment. It also enabled other two-way services such as video services like Skype. However, even this improvement was not able to compete effectively with advances in the DSL space at the time. As a result, work was undertaken to develop DOCSIS 3.0, whose main feature was the fact that operators could now use more than one of their traditional 'TV channels' to deliver these services. As a result, each additional channel used to deliver service carried the same amount of traffic. The number of channels used is a business decision on the part of the cable operator, as the trade-off is a decrease in the number of television services that can be distributed to subscribers. At this point in Canada, the highest speed offering using DOCSIS 3.0 is a 250Mbps service offered by Shaw[8].

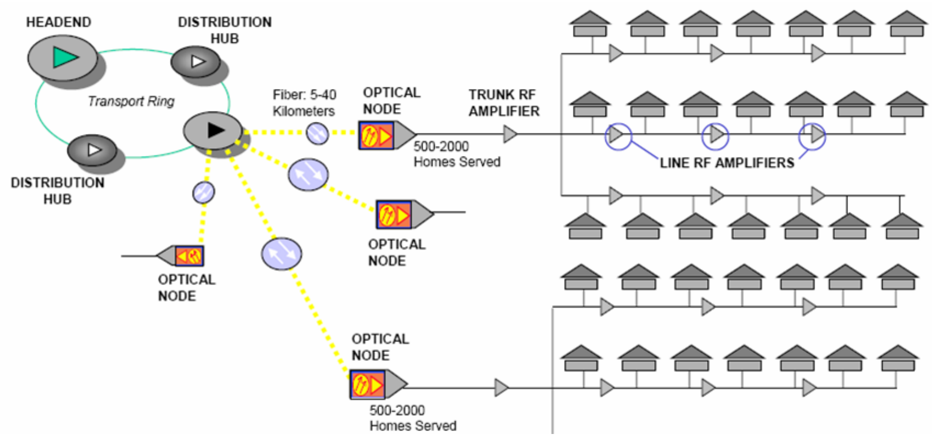
As shown in the table, there are even further developments underway for DOCSIS which are promising speeds of 10Gbps in the downstream direction, and 1Gbps in the upstream direction. However, it is worth noting that although the DOCSIS 3.1 specification is out, actual deployments are still a few years away, with trials predicted to take place starting in 2016. Furthermore, to deliver on these promised speeds, operators would need to completely shift in how they deliver video services. The main idea is that providers will eventually move all of the traditional television services into the IP space, and at that point DOCSIS 3.1 could be used to fully deliver the voice, video and broadband Internet services to customers[9]. However, in practice, cable operators may also choose to deploy a full FTTP solution as well, and are making steps do so by undertaking trials of the technology. We will explore FTTP technologies, and its role as the 'ultimate end goal' for service providers in a later section.

Again, as with the development and evolution of DSL technologies, cable services are no longer being delivered to customers using purely co-axial cables. Operators have also undertaken steps to deploy fibre-optics into their network infrastructures. This has given rise to what is referred to as hybrid fibre-coaxial networks (HFC). In an HFC network, rather than serving customers directly from a head end by coax cables, they are now served by a remote 'node' closer to the community. From the head end, fibre optics run to the node. From the node, service is then delivered to the customer using coaxial cable. This is similar in nature to the FTTN services we described in the DSL section.

[8] Details of Shaw's various plans can be found here: http://www.shaw.ca/internet/plans/

[9] There are numerous articles discussing this, including Light Reading: http://www.lightreading.com/cable-video/docsis/docsis-31-whats-next/d/d-id/708425

Figure 10 - Diagram of HFC Network



In order to be able to offer greater speeds to customers, cable operators undertake what is referred to as 'node splitting'. The idea of node splitting is to serve an ever-smaller number of homes from a single node. Recall that due to its shared nature, the service level and sustainable rate of DOCSIS technologies depend on the number of active subscribers on each coax cable segment. By increasing the number of nodes, cable operators are able to reduce the number of homes served by these coax segments from what used to be several thousand homes, down to 500, 250, 100, or even lower as needed. As with FTTN deployments, they are able to do this without needing to upgrade the 'last mile' infrastructure going to the homes themselves, and avoid deploying costly new equipment to every subscriber.

To conclude, the services being offered over the cable carriers' infrastructure will continue to evolve and improve over time, offering very high speeds and reliability to the end users. The services will continue to be tailored towards delivering bandwidth-intensive services to consumers, including video services and 2-way video conferencing services.

3.3 Fibre to the Home (FTTH) Technologies Explored

In both of the previous technologies we have explored, we examined their evolution and discussed that both DSL and DOCSIS technologies are pushing fibre-optic cables and technologies further and further into the neighbourhoods where customers are being served. We also saw that one of the principal limiting factors in both technologies was the legacy infrastructure in place for the 'last mile' connectivity, which are the twister copper pairs for DSL, and the coaxial cables in the cable operators' networks.

We will now examine the newest technologies that are being deployed to users to enable the highest speeds and greatest capacity. Namely, we are talking about using fibre optics to deliver services all the way from the serving offices to the end users. Fibre optics are very useful for delivering signals as they have very high capacity, and have very low loss. Signals can travel very great distances without the need to amplify them. As a result, they are an attractive network evolution route for service providers planning their next-generation equipment deployments to serve customers in new communities, or to upgrade services to existing communities.

Figure 11 - Optical Fibre Strands with near-limitless capacity

While fibre-optics themselves have been around for decades, it is only in the last 20 years or so that the cost to produce the cables, and the equipment used to connect to them, have lowered in price enough to make this a viable technology for delivering services to individual homes. Prior to this, the technology was focused more on building the large backbone networks of national telecommunications carriers, and linking continents via submarine cables. In the intervening years, there have been many developments in both standards and technologies, not to mention market shifts that have made it clear that this technology is likely the future of connectivity.

In a previous report prepared by Nordicity for CNOC (*Fibre to the Premises: Technical Feasibility of Providing Wholesale Access to Incumbent Fibre-to-the-Premises*), we have examined in more detail some of the more prominent types of deployments that make use of fibre-optics. Most relevant to this discussion are deployments of passive optical networks (or PONs) that are used to deliver services to homes and businesses. While it is possible to carry greater capacities, most PON deployments in neighbourhoods deliver speeds of between 2.5-10Gbps downstream and 1.25-2.5Gbps upstream, shared between 32 to 128 users. This enables service providers to offer retail packages with downstream speeds of between **150Mbps to 1Gbps**.

As the technologies mature and lower in price, it is not hard to imagine that these speeds will to continue to increase over time, in order to deliver even richer media experiences and full 2-way communications at very high data rates. FTTH is being hailed as a future-proof technology, in the sense that it is relatively straightforward to change the equipment connected to the endpoints of an optical fibre to take advantage of advances, without needing to deploy new wiring.

Figure 12 - Image of Google Fiber Products

Nordicity

The main attraction of deploying FTTH is the fact that it is ideally suited to deliver consistent, very high speeds. These types of speed are used to provide a wide range of services, while simultaneously supporting a large number of devices connected to the same connection. In other words, with these high speeds, a provider could offer an extensive television service, home automation, remote data storage (backup services), true high definition video conferencing, and having multiple people in the same house taking advantage of these services at the same time.

Figure 13 - Fibre Optic Cable Installation in a Roadway

While most people would agree that FTTH is the eventual end-state of communications connections to the home, it will take some time to get there. The required investments can be quite large, and depends in large part on the existing infrastructure in place. For the time being, deployments are generally limited to new developments, or areas that feature aerial access (wires strung on utility poles). This is to avoid the need to bury new cables in existing neighbourhoods, which is both costly and time consuming.

In the end, it is hard to imagine a technology better suited to delivering services that will meet the growing needs of consumers in the future on an efficient basis. Once network operators make the required network investments, they have the ability to manage and grow the networks with the needs of consumers, and not be limited by issues such as signal loss or spectrum shortages.

3.4 Satellite Technologies Explored

In the previous three sections, we have focused on the wireline technologies being used to deliver services to consumers. These technologies have proven themselves to be readily adaptable, and capable of delivering very high quality services to end-users. We now turn our focus to wireless technologies, starting with a technology that is out-of-this-world. Literally.

Satellite technologies have been used for many years now to deliver a range of services to consumers in all parts of the world. They are well known to the broadcasting industry in particular, as that has been the primary means to deliver content around the world. Satellite technologies have also been used for many direct-to-home (DTH) television subscription services.

Figure 14 - Equipment needed to Receive DTH Signals

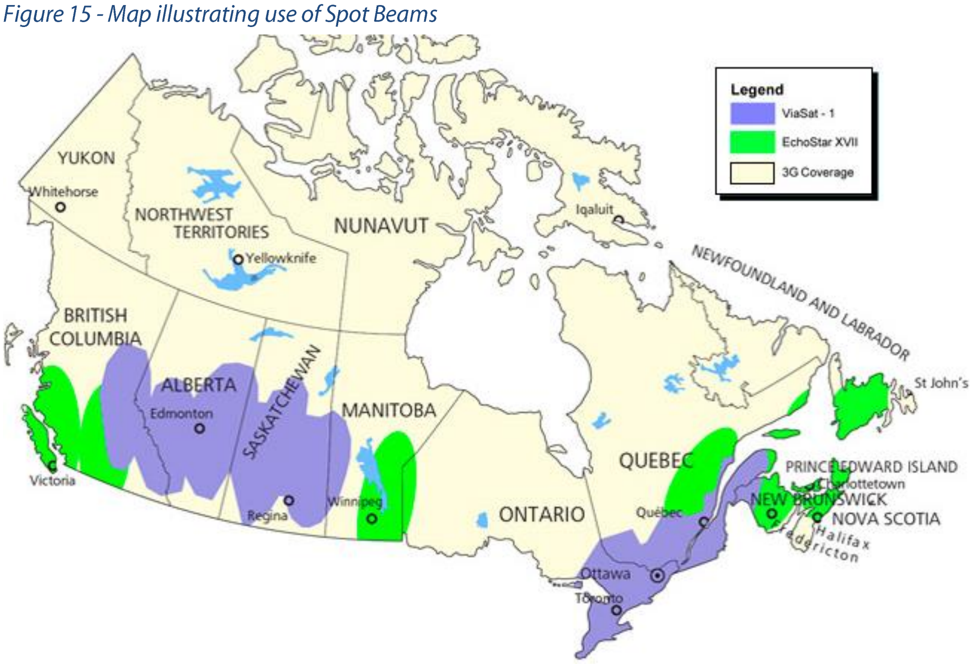
The attraction to satellite is due in part to the fact that with a single piece of equipment in the sky (albeit a very pricey piece of equipment), a service provider can distribute a signal to an incredibly large area and population contained therein. This approach has been very useful when the service provided is unidirectional in nature, and wishes to reach many people. Such is the case when DTH providers deliver TV services to the most rural and remote reaches of the world. All subscribers will typically need to do is install a satellite dish (as small as 50cm wide), ensure it is pointed at the right satellite, and connect to the correct equipment for usage.

Satellites were not used to deliver Internet services until 2003. At that time, the types of speeds being offered were in the range of 1-3Mbps maximum per user, and real-life usage resulted in speeds that were much lower still.

As with other technologies, satellite presents its own drawbacks when used to offer services. One drawback of satellite services is that they can be affected by weather. With heavy rain or snow, signal strength will be degraded, leading to a corresponding decrease in performance. Additionally, satellites feature a fixed capacity, which is not upgradeable once the satellite has been launched, and this capacity must be shared by all users and services. Finally, and most pertinent to satellite Internet service offerings, they feature a high 'round-trip time' (RTT), which is very noticeable in any 2-way communications. This is the time it takes for data to go from a user at one end, up to the satellite in orbit, back down to the earth at what is called a ground station, through to the end location, and back the same way. What this can amount to in terms of a voice conversation is a delay of between ½ and ¾ of a second from the time you speak and the time the person on the other side hears you. This delay is at least 25 times longer than the delay you'd experience using wireline technologies.

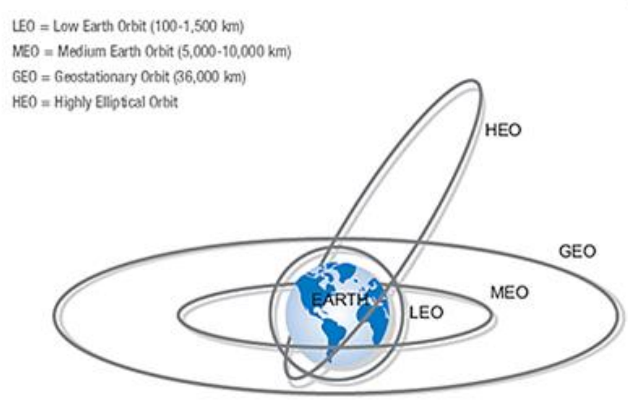
In spite of these drawbacks, there are many areas in the world that have little other choice when it comes to getting their communications services, and are therefore reliant on these technologies. As a result of this reliance, satellite companies, as with other technologies, have been working on evolving and improving the services they can offer through innovative new techniques and equipment.

Figure 15 - Map illustrating use of Spot Beams



The latest satellite systems that have been launched (referred to as high throughput satellites – HTS) feature far greater capacity than the generation before them, and have also evolved to feature what is known as ‘spot beams’. These spot beams can in effect ‘focus’ a portion of the satellite’s overall capacity in a targeted area, rather than serving a huge land mass. These combined innovations now allow service providers to offer broadband Internet access services at speeds of up to **15Mbps**, at rates that are tolerable to those that require such speeds.

Figure 16 - Examples of Satellite Orbits



Beyond the current satellite technologies in existence today, there are other possibilities for the future to introduce new classes of satellite, known as either low-earth orbit (LEO) or mid-earth orbit (MEO). These types of satellite would be much closer to the earth, which would therefore lower the latency, and also allow much greater speeds. However, these systems would require a greater number of satellites to provide the required coverage, acting as a sort of ‘constellation’. While several projects have been proposed, thus far none have been fully funded and deployed for use in Canada. In our view, these approaches are unlikely to be deployed for some time. A main reason for this is the capital intensity associated with launching new satellites, and for LEO and MEO deployments specifically, the complexity associated with operating a large number of satellites concurrently for service delivery.

3.5 Fixed Wireless Technologies Explored

We will now turn our focus to fixed wireless technologies. These technologies focus on delivering primarily broadband Internet access services to customers located in areas that are not served by ***any*** wireline services. They have been used to furnish services to cottages, farms, and other rural areas.

To assure a certain level of quality, fixed wireless services tend to rely on licenced spectrum. That is to say, this is spectrum which is paid for by the service provider, and to which it has exclusive access. This protects these service providers from harmful interference from other service providers. The spectrum used for fixed wireless services can be in the same frequency bands as mobile wireless services, but generally speaking, the licensing associated with spectrum is dedicated to its intended usage. For example, the recently-auctioned 700 MHz spectrum is designated for mobile wireless services, whereas the 3500 MHz spectrum was offered for auction in 2004-5 with the specific purpose of being used for fixed wireless services.

Figure 17 - Typical Fixed Wireless Antenna

From the point of view of equipment requirements for the end-users, a fixed wireless service will require an antenna to be installed / mounted at the customer premises, and pointed towards another remote antenna (i.e. the base station) which is used to provide the service. From the remote antenna, data will be carried further into the core network through fibre optic cables, wireless technologies, or leased facilities from other providers.

There is a high degree of variability in the speeds that users can attain using fixed wireless. The main variables that factor into the expected speeds are the distance a user is located from the remote antenna, and the type of equipment being used, as well as the specific spectrum in use. Speeds that are typically offered in the Canadian market range between 1.5Mbps and

3Mbps for residential offerings[10], but these offerings can rise to 100Mbps and beyond[11] when dealing with business clients with specific requirements for high-bandwidth services. There are also examples in other markets, such as the NBN in Australia, which are planning to offer services with speeds of 25Mbps to end-users using fixed wireless[12] in areas that cannot be served by wireline technologies.

Fixed wireless services can be delivered as either point to point (1:1), or point to multipoint (1:n) configurations. Point to point services are usually deployed for business customers, whereas point to multipoint is used to deliver DSL-like services to a small number of customers served by the same tower.

Due to the ability to do a 1:1 mapping of end-customer to remote antenna, there is a lot of flexibility in the ability to offer greater speeds to clients that require it. When looking at future developments in the fixed wireless space, it is conceivable that improvements in spectrum utilization and pricing of equipment will lead to the ability to serve more customers with greater speeds over time.

Eventually, we may see a convergence of the fixed and mobile wireless market in some respects, as the technologies and standards converge towards using long-term evolution (LTE) standards. This will most likely occur in the residential, point to multipoint implementation of fixed wireless. With increased penetration of mobile wireless technologies, home users may opt to use mobile wireless services rather than subscribing to a fixed wireless service. The use of such universal standards will ultimately lower the costs for the consumer equipment that is being used, and will also enable a more efficient roll-out of services.

As a final note, it is worth re-iterating that fixed wireless services are used in areas that are lacking wireline facilities. This is mainly in more rural areas of Canada. As such, they will continue to play an important role in the delivery of broadband access to Canadians.

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[10] Taken from Xplornet http://www.xplornet.com/plans-pricing/residential-location/

[11] Taken from speed offerings from Terago: http://www.terago.ca/business-high-speed-internet.html

[12] Fact sheet from the Australian NBN on fixed wireless: http://www.nbnco.com.au/assets/documents/fixed-wireless-factsheet.pdf

To re-state this point another way, there is a reason that you do not see fixed wireless services offered in urban markets. There is simply no way to allow high capacity fixed wireless systems to scale in dense populations. In that sense, this is another indication that wireless technologies simply cannot technically act as substitutes to wireline technologies. Instead, fixed wireless technologies and services are better thought of as complimentary products to wireline technologies.

In summary, this technology, while it shares characteristics with both mobile wireless and wireline services, is generally used in a different market. It is not typically used where wireline alternatives are available.

3.6 Mobile Wireless Technologies Explored

One technology that has grown in leaps and bounds over the last decade is that of mobile wireless technologies. The basic technologies to enable mobile wireless services have been around for decades, but at the time of their introduction, it is unlikely that anyone foresaw the evolution of the services, and the ubiquity with which they would be deployed. Originally envisioned for the purpose of making phone calls, it didn't take long for the technologies to enable new services such as paging, text messaging, simple data transfers, all the way to the rich Internet experiences available on today's advanced smartphones and tablets.

Figure 18 - Early Mobile Phone System

As with satellite and fixed wireless services, mobile wireless technologies rely on the use of radio spectrum to enable 2-way communications. As with DSL and DOCSIS, mobile wireless technologies have also benefited from very robust sets of standards that are constantly being updated and enhanced. Earlier in the development of mobile wireless standards, there were competing standards forcing carriers to make decisions on the network equipment they would deploy. Each standard had its own roadmap and capabilities. However, in recent years, there has been a move to converge the various standards into one universal standard. The purpose of this is to ensure that efforts are not duplicated, and that engineers can focus their research on efficiently improving wireless network capabilities[13].

As with fixed wireless networks, mobile wireless networks feature remote antennas (using either towers or rooftop installations), which are connected to the core network, and end-user devices that have their own antennas to communicate with these remote antennas. The main difference is that for fixed wireless, the antennas at

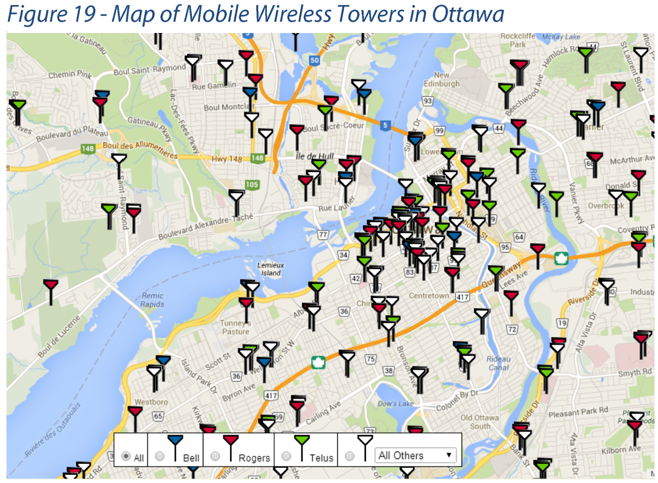
[13] For a much more thorough exploration into the history of mobile wireless standards and evolution, we recommend "*Mobile Broadband Explosion*" a report by Rysavy Research from August 2013 for 4G Americas. The full report can be found here: http://www.rysavy.com/Articles/2013-08-4G-Americas-Mobile-Broadband-Explosion.pdf.

the customer-side are semi-permanent installations to assure service quality, whereas for mobile wireless network, consumer-side antennas are designed for portability and mobility.

Nowadays, the devices being used on mobile wireless networks includes pagers, feature phones, smartphones, tablets, laptops, USB keys, routers, home alarm systems, video monitoring equipment, and the list goes on. A prime difference between fixed wireless and mobile wireless networks is that, as the name implies, end user equipment is meant to be used on the move. The ability for devices to be in motion and maintain communication involves very sophisticated networks with high fault tolerance and ability to respond to changes rapidly.

As with all other network technologies, there are certain trade-offs when using mobile wireless technologies. They have their own unique set of limitations imposed by both the spectrum used and the equipment deployed. As with any network, the coverage, or reach, of mobile networks is only as good as the proximity of equipment to the end-users. For mobile wireless, this means the number of, and quantity of remote wireless antennas to users. These antennas have two very important characteristics:

Figure 19 - Map of Mobile Wireless Towers in Ottawa



1. <u>*Capacity*</u>: Each mobile wireless site can only handle a fixed number of connections at any given time. If there are too many users attempting to connect in one area, some will be unable to do so
2. <u>*Reach*</u>: Transmitters are limited in the maximum power they can output, which limits how far a signal can actually propagate

When looking at capabilities of mobile wireless networks, reach is the most complicated characteristic to quantify. CISCO, in its most recent report, has summarized some of the challenges with wireless reach and coverage:

> *"There are several variables that affect the performance of a mobile connection. Roll out of 2G/3G/4G in various countries and regions, technology used by the cell towers, spectrum availability, terrain, signal strength, and number of devices sharing a cell tower. The type of application being used by the end user is also an important factor. Download speed, upload speed and latency characteristics vary widely depending on the type of application, be it video, radio or instant messaging."*[14]

Additionally, Motorola, another well-known wireless equipment provider, characterized the various signal loss factors in the following way[15]:

> *"Figures 1 and 2 illustrate effects of signal path loss suffered by radio signals due to factors such as free space loss, multipath, buildings and vegetation, diffraction and the general atmosphere. These factors affect the performance of radio transmission and have led the drive for the development of new adaptive modulation schemes and techniques which aim to compensate for these environmental factors, delivering more capacity and better range in an inherently noisy environment full of obstacles."*

Figure 20 - Motorola Figures 1 and 2 Referenced Above

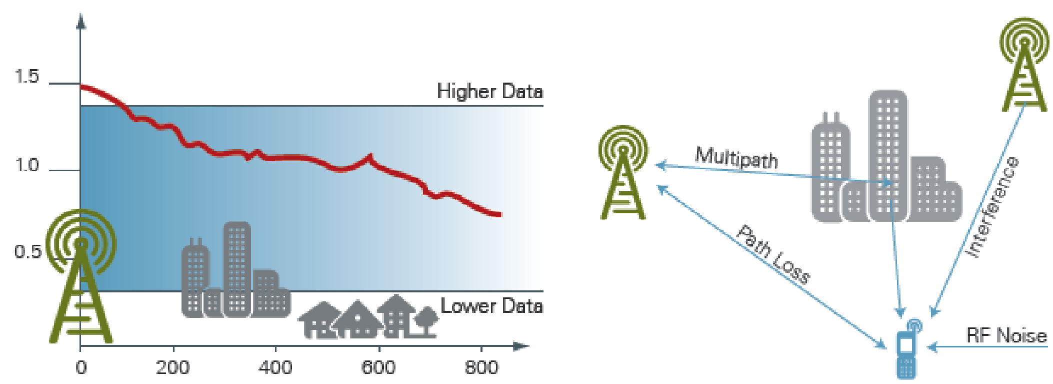


Figure 1 – Data throughput adjusted based on radio conditions

Figure 2 – Radio environment challenges

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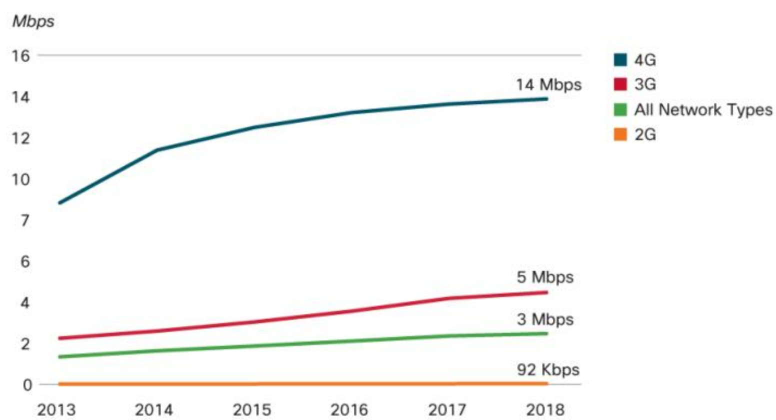
[14] *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018*, page 21

[15] Reference is on page 4 of the full report from Motorola which can be found at: http://www.motorolasolutions.com/web/Business/_Documents/static%20files/Realistic_LTE_Experience_White_Paper_FINAL.pdf

Different spectrum ranges also feature different characteristics. Some are better suited to traveling greater distances, while others are better at penetrating obstacles such as building walls, etc. The net effect of the different variables is that end-users face a lot of uncertainty regarding the real-world performance of mobile wireless connections. In the introduction to the technology section, we illustrated that mobile wireless networks are capable of speeds of >100Mbps today, reaching 1Gbps in the near future. However, these were the *theoretical* maximums that are possible with the technology. Real world experiences result in much lower actual speeds.

Figure 21 - Typical End-user speeds by wireless technology (CISCO)



To demonstrate the actual end-user speeds that mobile wireless users are more likely to experience on a day-to-day basis, CISCO prepared a 5-year forecast tracking the current speeds experienced in mobile wireless networks in different standards in use today, with 2G being the older data standards and 4G representing the latest LTE and LTE-Advanced networks in operation. It is interesting to note that even in 2018, the prediction is that most users would typically expect to use services that require 14 Mbps or less. These types of speed, as we'll see further in the report, exclude the ability to use the latest services being offered today, let alone any services that will be commonplace by 2018. Corroborating this chart is data presented by Rysavy, which indicates that typical download speeds using LTE are in the range of 6.5-26.3 Mbps, and upload speeds are typically on the order of 6-13 Mbps[16].

[16] See Table 5 on page 31 of Rysavy report linked in footnote #13.

In spite (or because of) the limitations, mobile wireless services will continue to see innovation and development in the coming years. There are a number of techniques being developed today that attempt to deliver faster services to a greater number of people.

Some of the techniques, as listed by Rysavy[17] include:

- Using more / different spectrum: Unfortunately this is a finite resource
- Increase spectral efficiency: Unfortunately, there are theoretical limits, and we are actually approaching these
- Create 'asymmetrical' links: In recognition that downstream traffic is 5x to 10x greater than upstream traffic
- Use more small cells: Use of new smaller antennas located in many more locations to offer 'blanket coverage' where needed
- Traffic management / QoS: To encourage heavy users to migrate usage to off-peak hours or offer option to prioritize certain traffic types

While these techniques will improve services to customers, and allow even greater numbers of consumers to use mobile wireless services on a day-to-day basis, there is little proof that such technologies would ever replace the need for wireline services within the home for high-capacity data consumption such as streaming video.

With respect to video, there is a final element to consider with respect to mobile wireless services. While they have been generally designed and deployed for what is known as point-to-point services there are recent developments with wireless standards to enable 'multicast' or broadcast-type services using the mobile wireless network. These developments are geared towards allowing providers to diversify their service offerings to include broadcast type video services, which would be better for the delivery of content being consumed en masse by subscribers. Such programming could include sporting events or news services. While not fully commercialized, these technologies have been demonstrated and hold some promise. A possible trade-off associated with offering such services is that the

[17] See page 14 of Rysavy report linked in footnote #13

mobile wireless service provider would still need to dedicate some of its spectrum to this new service, which would reduce the overall spectrum available for other services.

Furthermore, due to these technical limitations, deployments will likely be targeted towards allowing consumers to 'stay connected' to important content they want <u>when they are not at home</u>. Scenarios include times such as during commutes on public transit, car road trips for passengers, etc. Regardless, this technology will ultimately lack the capacity required to actually become a substitute for services such as IPTV (and will therefore have limited content available), as explained above in the context of capacity limitations of mobile wireless systems.

Figure 22 - LTE Multicast Demo: 2014 Superbowl

3.7 General Conclusions on Technology

After having examined the various technologies being used to deliver voice, video, and broadband services, it has become clear that from a technical perspective, mobile wireless networks are unlikely to ever be able to deliver the same level of services to end users. This is principally owing to the lack of capacity that will be available in mobile wireless networks as compared to the wireline networks in the present and future. To start this section, we displayed a chart showing the trends of speed over time of mobile wireless and wireline technologies. To summarize the difference in these capabilities, we present a quote from the Mobile Broadband Explosion paper by Rysavy Research[18]:

> *"Relative to wireless networks, wireline networks have always had greater capacity and historically have delivered faster throughput rates. Figure 5 shows advances in typical user throughput rates and illustrates a consistent 10x advantage of wireline over wireless technologies."*
>
> *"Over time, wireless networks will gain substantial additional capacity … but they will never catch up to wireline."*

This difference in capacity / speed becomes most apparent when actually using the technologies in person. While most technologies can boast very impressive numbers when examining their theoretical capabilities, the practical realities are often very different, as we explored in the individual sections above.

For the context of this report, discussing the substitutability of wireline for wireless technologies is principally an investigation into whether or not ***mobile*** wireless technologies can be readily used as a substitute for wireline technologies. As we explored above, when examining **fixed** wireless technologies, there exists a possibility for substitution, arising as a result of the nature of fixed wireless services, which focus on a one to few (or one to one) connection model rather than a one to many model (as is the case in mobile wireless). Furthermore, the deployment and usage of fixed wireless services is limited to areas that specifically do NOT have adequate wireline connectivity.

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[18] http://www.rysavy.com/Articles/2013-08-4G-Americas-Mobile-Broadband-Explosion.pdf (at page 12)

With respect specifically to the point of fixed wireless services acting as a substitute for wireline services, we note that fixed wireless solutions are being deployed to deliver services comparable to lower speed wireline services. The nature of the service (and its associated costs) make it an imperfect substitute for anything beyond basic residential Internet services. While it is technically capable of delivering higher speeds, these services, due to deployment and service costs, are limited to business users with very specific needs that can afford what amounts to dedicated data connections. As a result of the foregoing, we conclude that in the long run, fixed wireless services will not scale to the capabilities available in pure fibre optic technologies, let alone FTTN or DOCSIS 3.0 deployments.

As another point, the substitutability comparison of technologies is the same whether we are considering home-based users or business / SME usage.

In light of all the foregoing, subsequent sections will focus on only mobile wireless technologies and services, rather than including satellite technologies and fixed wireless solutions. The underlying assumption here is that both satellite and fixed wireless services are targeted to areas that lack substantial wireline facilities, and are not offered in densely populated urban / suburban areas. As a result, there is no reason to conduct further comparisons, as they cannot, de facto, be considered as substitutes to wireline services, as they are likely the ***only*** option available to customers served by these technologies. On the other hand, mobile wireless and wireline services do tend to operate in the same areas, and this is the area of interest for this report.

With the above in mind, we will close this section by examining the differences in capacity between fibre optic cabling and wireless spectrum. As mentioned above, there is a finite limit to the amount of data that can be sent over a wireless link, based on the spectrum utilized. This limit is determined by what is known as Shannon-Hartley Theorem[19], which determines the theoretical upper limit on data throughput based on the bandwidth used, the signal power and average noise in the signal. The figure below illustrates the TOTAL theoretical capacity for ALL the

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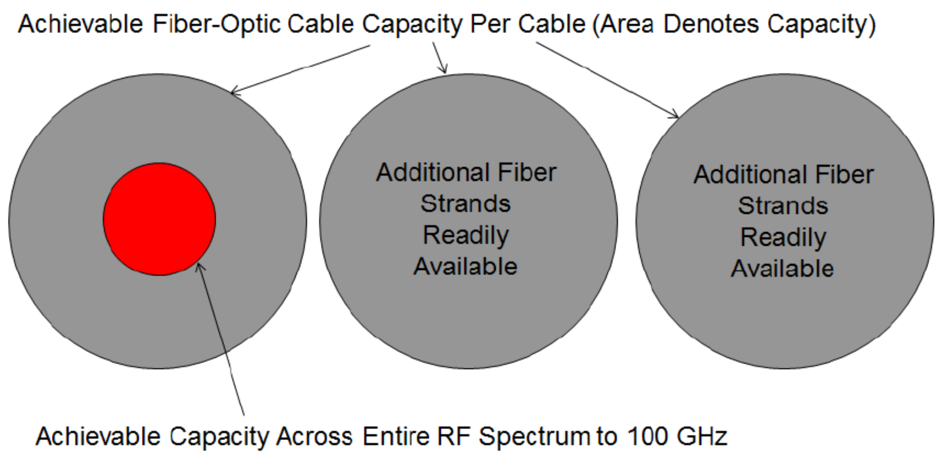
[19] For more information on the Shannon-Hartley theorem, see: http://www.princeton.edu/~achaney/tmve/wiki100k/docs/Shannon%E2%80%93Hartley_theorem.html

spectrum up to 100GHz (of which mobile wireless is a very small slice) compared to the capacity per fibre optic strand.

Figure 23 - Illustration of Spectrum Capacity Compared for Fibre-Optic Strand Capacity



The illustration in Figure 23 is a stark reminder that from a technical and physical perspective, mobile wireless networks will simply never have the capacity that can be realized by wireline systems, particularly fibre-optic based systems such as FTTH deployments. Each user would essentially require its own private, dedicated wireless tower to deliver the same throughput achievable with home-based FTTH connections. Such a deployment is not economically feasible.

To close this section, we will re-visit and build on the table presented at the opening of this section, and add in an additional ‘comments’ column, based on the discussions from previous sections.

Figure 24 - Technology Comparison of Practical Speeds and Limitations

Technology	Medium	Practical Speed	Comments
VDSL2 (FTTN)	Wireline	25-100 Mbps	Reaching limits of practical speeds without moving to FTTP
DOCSIS 3.0	Wireline	50-250 Mbps	Shift in video delivery needed to achieve higher speeds
FTTH	**Wireline**	**1 Gbps**	**Highly scalable, but costly; likely end-point for most networks**
HTS Satellite	Wireless	1.5-15 Mbps	Services areas without wireline facilities and costly to expand
Fixed Wireless	Wireless	1.5-150 Mbps	Services areas without wireline, exists as separate market
LTE-A	**Wireless**	**5-20 Mbps**	**Practical capacity limitations inhibit ability to replace wireline**

4. Market Discussion

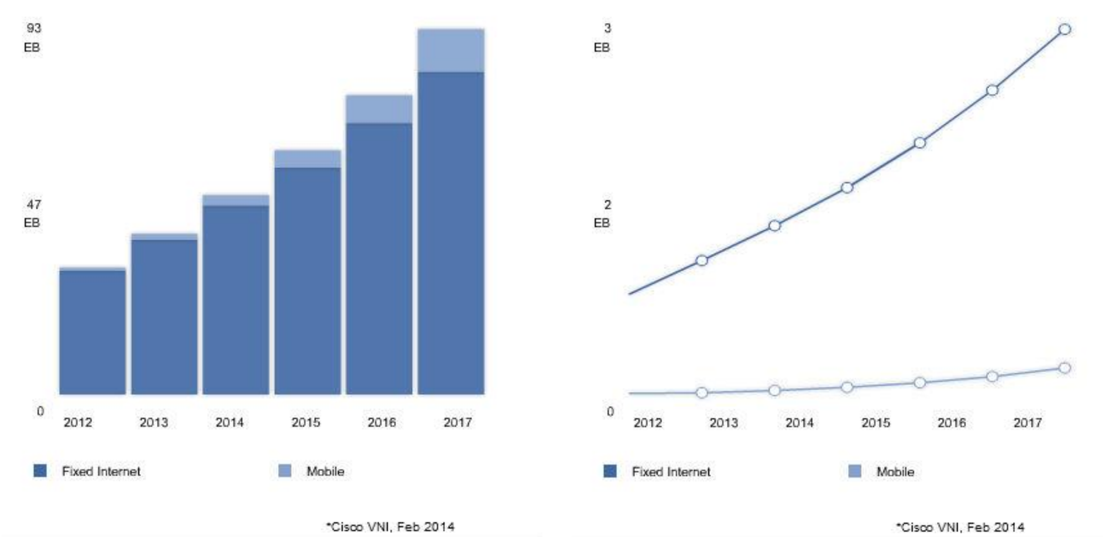
Now that we have examined the various technologies used to deliver wireline and wireless services to consumers, this section will take a brief look at the overall services market. In particular, we will comment on user trends regarding consumption of data, as well as the way that services are being marketed and sold to customers. This approach focuses on how people actually use various available services. We will focus the discussion to general mobile wireless services and home-based wireline services, and specifically to data consumption trends and usage of Internet access services.

4.1 User Trends

The most obvious and significant user trend is the absolute growth of data consumption on all platforms. The growth is driven by a few key factors. Firstly, the services that are being offered and used by consumers are increasing in sophistication and bandwidth needs. Secondly, consumers themselves are increasingly using multiple platforms to consume the content they want (e.g., watching television programs using traditional television / BDU service offerings, but also watching video content online through set-top boxes or mobile devices). Between different device classes, the types of content being consumed may vary, but the overall volume continues to increase. Concurrently, the absolute numbers of users on new platforms is also increasing. Combine all of these trends together, and we can see why traffic volumes are projected to grow dramatically on both wireline and wireless platforms.

Below are a two graphs that illustrate this growth trend on a global basis, as well as Canada specifically. Both of the graphs project both the mobile Internet and wireline Internet traffic growths. As can be seen, both are growing steadily year over year, with no indications of slowing down. At present, wireline Internet traffic greatly outstrips that of mobile Internet, but it is worth noting that wireline technology is more mature, and services are nearly ubiquitous in many parts of the world.

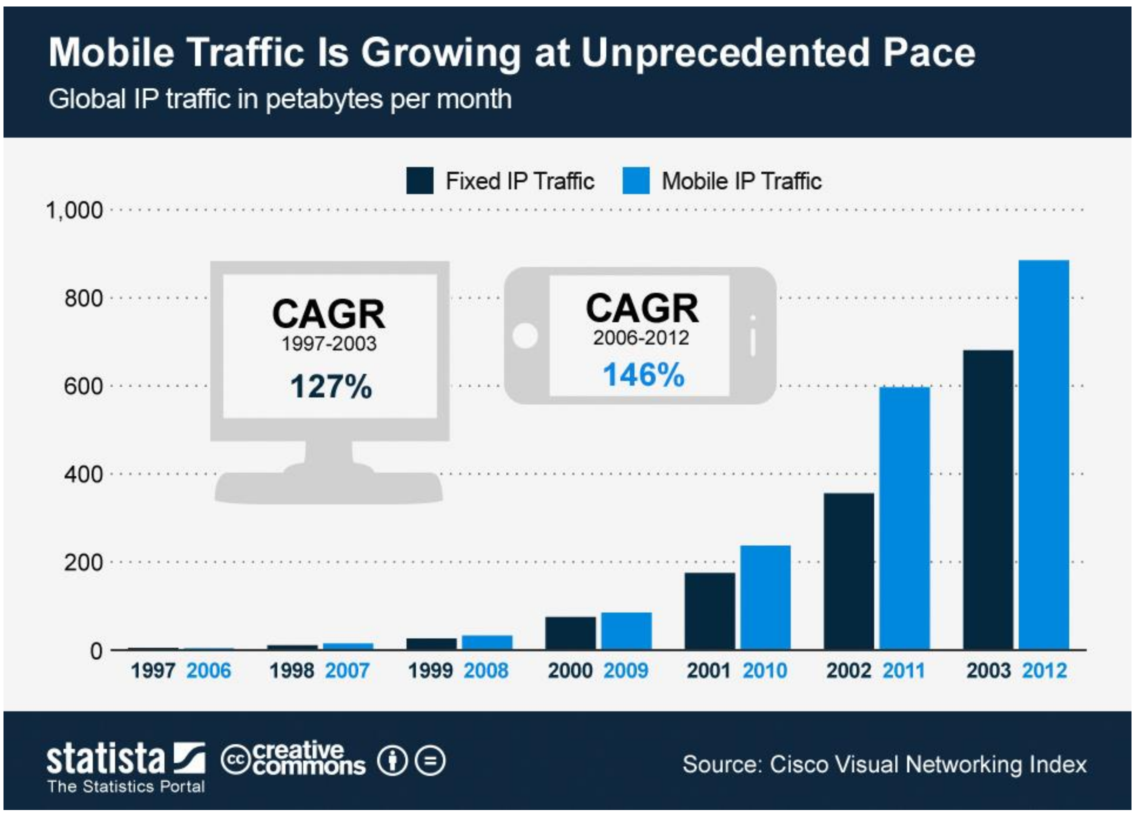
Figure 25 - Projected Traffic Growth Globally (Left) and in Canada (Right) (CISCO)



To reconcile the actual growth rates of both, the site Statista examined data produced by CISCO for prior years to compare the annual growth rates of both wireline and mobile wireless Internet side-by-side. For the comparison, they looked at data from the earliest appearance of each technology. For wireline Internet traffic, they started with 1997, which is when dial-up Internet was prevalent. For mobile Internet, they started with 2006, which is when the very first feature phones were introduced that enabled some form of web access. Comparing both, they showed wireline Internet traffic had grown at a 127% compound annual growth rate (CAGR) in its first 6 years, whereas mobile Internet traffic had grown at a 146% CAGR. The illustration demonstrates that both technologies grew at astonishing rates after their introduction, with mobile growing faster in its infancy. The higher CAGR for mobile

Internet can be explained by the fact that by 2006, there was an increased familiarity with these technologies, leading to more rapid adoption and usage. Nonetheless, the picture does nicely illustrate that both modes of connectivity have grown in a significant manner.

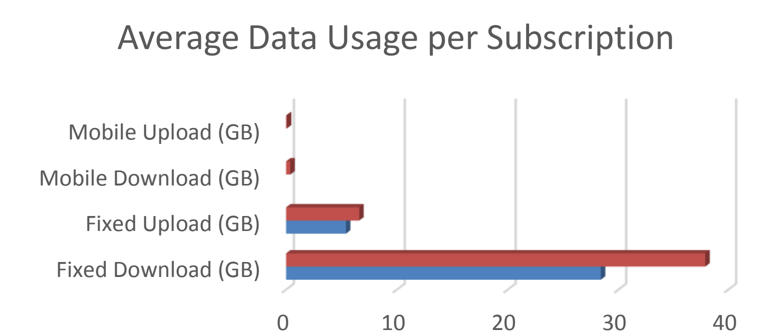
Figure 26 - Comparison of Growth Rates of Mobile and Fixed IP Traffic (CISCO / Statista)



The dimension that is not illustrated in either of these graphs is the number of connections that are assumed, and hence the actual usage per person or household. One key difference between mobile and wireline usage is also the fact that mobile subscriptions are generally associated with a single individual, whereas wireline Internet subscriptions are often shared in a household, and can accommodate multiple users. In other words, while a user may stream a video on a mobile connection, the use of the connection will be limited to that one activity. For a wireline connection it is entirely conceivable that there could be one or more users streaming high-definition content on different devices, and other individuals using their computers for gaming or video calls, etc. In Chapter 5 we will examine in greater detail the exact usage for various services.

As a starting point, we will examine the typical volumes of usage for both wireline and mobile Internet connections on a subscription basis.

Figure 27 - Average Data Consumption for Fixed and Mobile Broadband (CRTC / Sandvine)

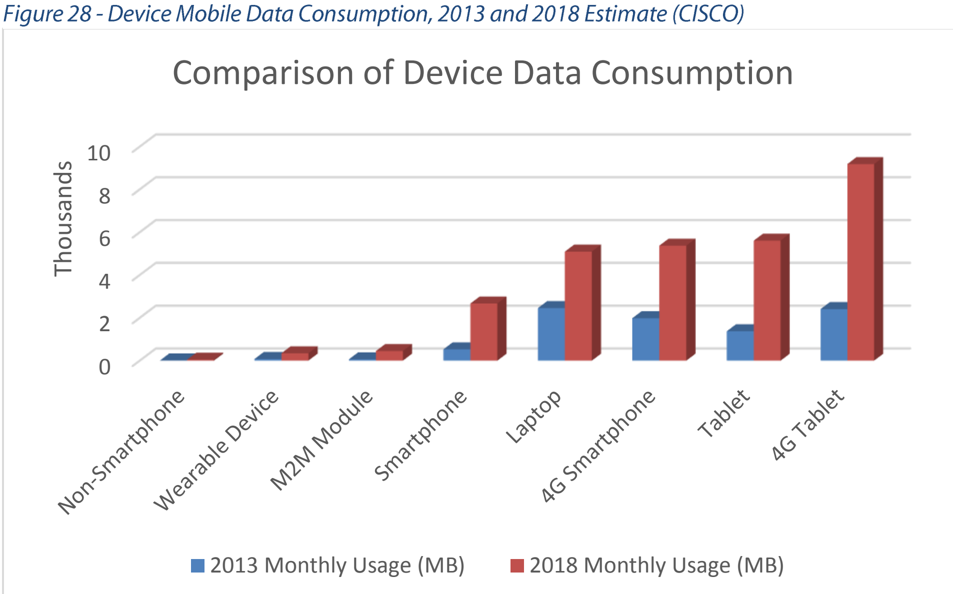


	Fixed Download (GB)	Fixed Upload (GB)	Mobile Download (GB)	Mobile Upload (GB)
Sandvine Data (2013)	37.9	6.6	0.3848	0.0676
CRTC Data (2012)	28.4	5.4		

From looking at this data, we see that data consumption on mobile platforms is much lower than on wireline platforms. The Sandvine Data indicates a difference of two orders of magnitude (100x difference). This is a significant difference, and one which examined from a services pricing perspective (in Chapter 5).

As a final note on user trends, it is interesting to note that different devices tend to promote different volumes of data usage. CISCO has attempted to quantify the impact of different devices on volume of mobile data consumed, by examining the usage trends in 2013, as well as predicting usage in 2018. CISCO concluded that the more advanced the capabilities of the device (and ease of use), the greater the mobile data consumption will be. Tablets featuring a 4G (LTE) cellular connection are expected to lead the way in consumption by 2018, owing to their characteristics of both utility and ease of use.

Figure 28 - Device Mobile Data Consumption, 2013 and 2018 Estimate (CISCO)



4.2 Service Trends

In the previous section, we have examined the various user and usage trends for mobile and wireline networks. We will now briefly examine the service trends in the industry. For most comparisons on technologies, price and usage, we are focusing on broadband Internet services. However, it is worth noting that a full range of services is currently being offered on wireline facilities, and wireless facilities are moving closer and closer to being capable of delivering a full suite of services.

Specifically, we already know that voice services can be delivered on all networks, both in the form of Voice over IP (VoIP) technologies, and traditional mobile voice and interconnection with the PSTN. The final piece of the multi-play bundle is therefore the question of broadcast video services. IPTV services are clearly being delivered today using FTTN and FTTP networks (as discussed in Chapter 3). In addition, we know that cable networks are delivering the triple play of voice, video and Internet. That leaves mobile wireless. At this moment, there are only limited video-specific offerings on mobile platforms, and these are generally tailored video experiences making use of Internet video delivery. Presently, there is no clear indication that mobile wireless operators intend to offer full-fledged broadcast distribution services using their mobile wireless networks. As explained in Chapter 3, this may not be feasible from a technical perspective.

That being said, it is clear that whether or not traditional broadcasting services are delivered over wireless networks, the usage on all platforms is clearly skewed towards the consumption of video content. Sandvine, as part of its Global Internet Phenomena Report[20] created lists of the most used services for both wireline and mobile networks. Specifically, they examined the peak-period usage. The first table is for wireline network usage.

Figure 29 - Top Applications used on Fixed Networks during Peak Period (Sandvine)

	Upstream		Downstream		Aggregate	
Rank	Application	Share	Application	Share	Application	Share
1	BitTorrent	36.35%	Netflix	31.62%	Netflix	28.18%
2	HTTP	6.03%	YouTube	18.69%	YouTube	16.78%
3	SSL	5.87%	HTTP	9.74%	HTTP	9.26%
4	Netflix	4.44%	BitTorrent	4.05%	BitTorrent	7.39%
5	YouTube	3.63%	iTunes	3.27%	iTunes	2.91%
6	Skype	2.76%	MPEG - Other	2.60%	SSL	2.54%
7	QVoD	2.55%	SSL	2.05%	MPEG - Other	2.32%
8	Facebook	1.54%	Amazon Video	1.61%	Amazon Video	1.48%
9	FaceTime	1.44%	Facebook	1.31%	Facebook	1.34%
10	Dropbox	1.39%	Hulu	1.29%	Hulu	1.15%
		66.00%		76.23%		73.35%

sandvine

Table 2 - Top 10 Peak Period Applications - North America, Fixed Access

From this table, it is evident that over ¼ of all the traffic flowing through wireline networks is Netflix traffic during peak periods. In fact, by conservatively totaling all of the obvious video sources (Netflix, YouTube, MPEG, Amazon Video, and Hulu),

[20] Full report can be found here: https://www.sandvine.com/trends/global-internet-phenomena/

almost half of all peak-period traffic is video-specific. In other words, regardless of whether actual broadcast services move to a pure online platform, video consumption is significant.

Figure 30 - Top Applications used on Mobile Networks during Peak Period (Sandvine)

	Upstream		Downstream		Aggregate	
Rank	Application	Share	Application	Share	Application	Share
1	Facebook	20.62%	YouTube	17.69%	YouTube	16.65%
2	YouTube	13.20%	Facebook	15.44%	Facebook	16.62%
3	HTTP	12.64%	HTTP	14.07%	HTTP	13.74%
4	SSL	11.11%	MPEG - Other	7.92%	SSL	8.59%
5	Pandora Radio	5.19%	SSL	7.84%	MPEG - Other	7.27%
6	MPEG - Other	5.11%	Google Market	5.99%	Google Market	5.75%
7	Google Market	4.95%	Pandora Radio	5.03%	Pandora Radio	5.07%
8	Instagram	3.52%	Netflix	5.01%	Netflix	4.36%
9	Netflix	2.19%	Instagram	3.53%	Instagram	3.53%
10	iTunes	1.59%	iTunes	3.16%	iTunes	2.80%
		80.12%		85.68%		84.40%

sandvine

Table 4 - Top 10 Peak Period Applications - North America, Mobile Access

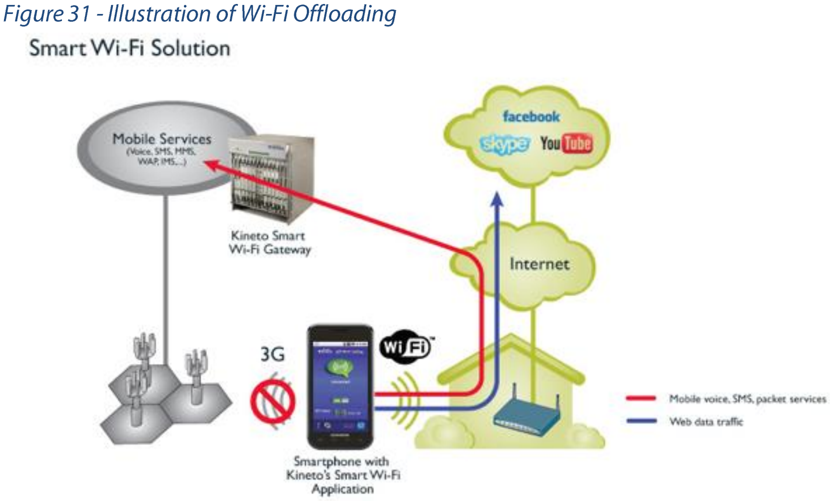
The second table relates specifically to mobile networks. Here again we do see the presence of video applications, with YouTube taking the top slot. Interestingly, Netflix falls far lower in the list. This is indicative that mobile users tend to prefer short-form content over longer episodes when using a mobile platform. This report will not propose an answer as to why this is, but reasons could include the greater costs associated with consuming long-form content over wireless networks, or the desire to watch longer form content on bigger screens (i.e. the 'lean back' experience). In the context of total volume of traffic being attributed to obvious video services in this table (YouTube, MPEG, Netflix), the total this time is only about 28%.

Regardless of which video service is on top, it is clear that both mobile and wireline networks need to continue to grow to enable the delivery of video content to consumers. Consequently, network providers continue to invest greater amounts of capital yearly to expand their networks to support the growth of traffic due to video consumption. By contrast, if one were to examine the overall contribution that a voice service might have on the volumes of traffic, it is unlikely that this would even register. For this reason, we will continue to focus on broadband (and video).

4.3 Role of Wi-Fi in Service Delivery

At this point in the report, it is worth raising the role that Wi-Fi networks play in a substitutability analysis. While Wi-Fi network are indeed wireless in nature, it is important to note that Wi-Fi networks generally need to connect to wireline networks in order to carry the data to their destination. There is a term used quite often in the industry called 'Wi-Fi offloading'. In essence, this means allowing a Wi-Fi network to help move the traffic from mobile devices off the mobile wireless network and onto wireline networks. This is particularly helpful to mobile wireless network operators, as it helps to ensure that the mobile wireless networks, with their scarce spectrum resources, are utilized most efficiently.

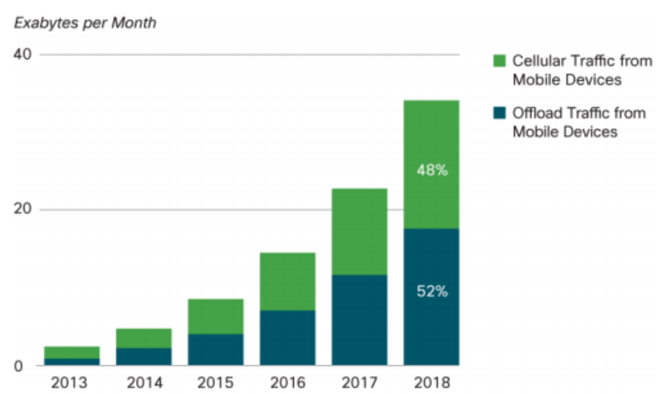
Figure 31 - Illustration of Wi-Fi Offloading



Wi-Fi offloading is made possible due to the fact that most end-user devices that connect to mobile wireless networks also have built-in Wi-Fi capabilities. The idea of Wi-Fi offloading is used by many as an explanation of how mobile wireless networks will be able to cope with the high rates of growth in traffic. However, at the same time, it is worth pointing out that this feature would not, in fact, help further an argument regarding substitutability, particularly in the home. Quite to the contrary, this trend seems to indicate the opposite. After all, in a home, Wi-Fi offloading would only be possible if an individual actually subscribed to a wireline service ***in addition*** to a mobile wireless service. As Wi-Fi offloading is a very useful technique for furthering the capabilities of the mobile wireless networks of today (and the future), the existence and use of this technique constitutes strong evidence of the lack of substitutability of wireless and wireline networks.

Leading equipment providers have estimated the overall volumes of traffic that may be carried by Wi-Fi networks instead of mobile wireless networks in the future. CISCO, which produces detailed forecasts specifically regarding mobile wireless networks[21] estimates that by 2018, 52% of all the traffic generated by mobile devices will be carried in part by Wi-Fi networks.

Figure 32 - Wi-Fi Offloading Forecast to 2018 (CISCO)



This movement towards Wi-Fi offloading by both network operators and end-users only further illustrates the very real limitations that exist within mobile wireless networks, and why they are unlikely to ever become perfect substitutes for wireline connectivity.

[21] For the complete CISCO VNI Whitepaper, please see: http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.pdf

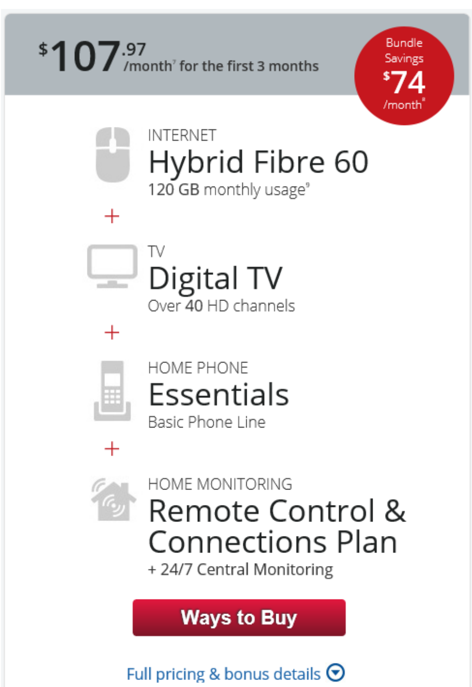
5. Service / Price Comparison

To complete the report, it is important to compare wireline and wireless service pricing. While we have examined the notion of substitution from a purely technical point of view in Chapter 3, the reality is that consumers may not compare services solely though that lens. As such, we felt it practical and instructive to create sample scenarios around customer needs and usage patterns, with a view to examining the cost of providing services in each scenario using mobile wireless technologies compared to wireline technologies.

5.1 Product Marketing Comparisons

Before creating the scenarios which will be used for pricing comparisons, we will briefly examine the manner in which both wireline and wireless services are currently marketed / structured. While undertaking the research for this section, it became evident that these services are created somewhat differently, and generally structured with different usage / purposes in mind.

Figure 33 - Sample Bundling Promotion

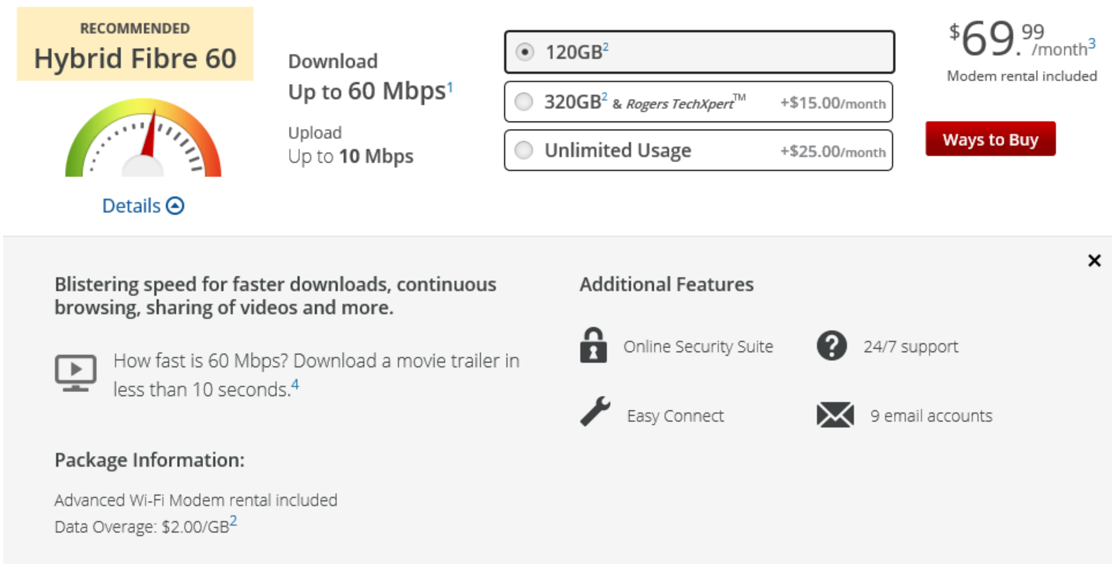


At a high level, we can summarize the method of creating and marketing the different services as follows:

<u>Wireline Services</u>

Wireline services are typically sold according to the speeds that a subscriber might expect to attain over the physical connection. Along with a marquee speed, most plans feature a bit cap (in GB / month). If these caps are exceeded, users will pay a nominal fee per GB for overage (or have the option of pre-purchasing capacity in fixed blocks). In addition to having the ability to buy the wireline broadband package, providers will often offer discount incentives for bundling these services with complementary services such as broadcasting or voice communication services.

Figure 34 - Sample Marketing for Wireline Broadband Plan



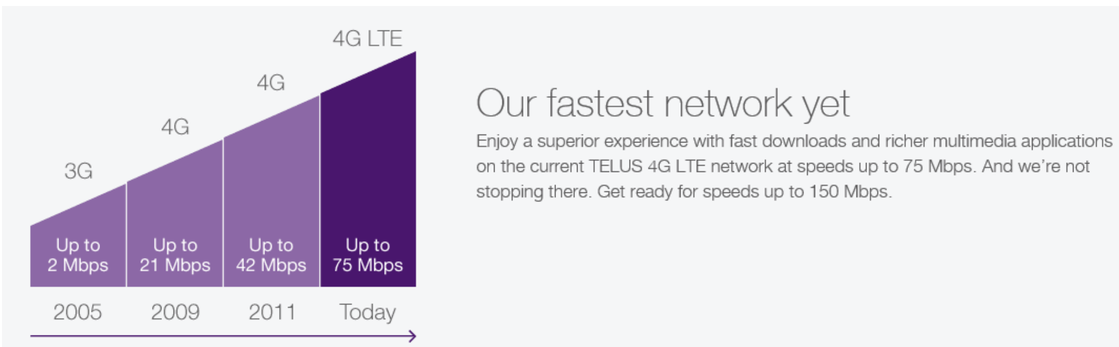
Wireless Services

In contrast to the wireline services, wireless services don't feature marquee speeds in the actual packages being offered. Instead, the focus is on offering the data capacity used by a subscriber. Speeds, where they are referenced, are in context to the *capability* of the network, but not guaranteed. This is consistent with our discussion regarding the technologies and the physical characteristics of mobile wireless networks. As a result of the capacity based service, most providers are offering rolling pricing, in which one begins with a fixed amount of usage for the month which if exceeded will automatically 'roll over' into the next tier.

Figure 35 - Sample Wireless Hotspot Device

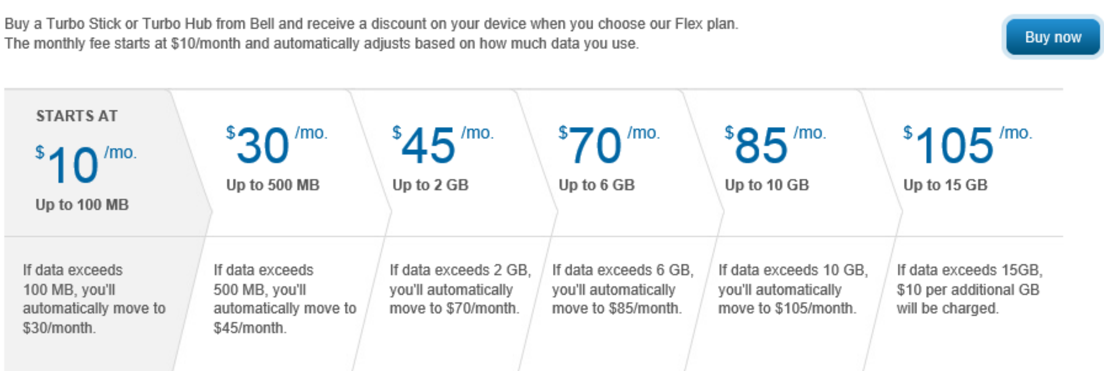
Wireless packages also tend to feature discounts on purchasing equipment to use with the service for two-year plan commitments. Examples of equipment are either handsets, tablets, USB dongles, or hubs. Additionally, there are often add-on options for voice services including fixed numbers of calling minutes, text messages, and voicemail features.

Figure 36 - Sample Mobile Wireless Speed Explanation from TELUS



And finally, as with the wireline services, all carriers offer the option of bundling the wireless services with other product offerings including cable TV offerings and landline voice services.

Figure 37 - Sample of Roll-over Pricing for Mobile Internet



5.2 Developing Scenarios

In order to create meaningful price comparisons, we will first create a number of scenarios related to typical usage of broadband services. This usage will be tied to usage of specific applications, time spent using them, as well as the possibility of concurrent users. The intention of these scenarios is to examine if there are scenarios where wireless services could serve as a substitute for wireline services, despite evidence that from a purely technical standpoint the two cannot be considered substitutes. In this way, we are modeling *real world* substitutability, or *practical* substitutability.

To begin, we must establish the speed and data usage of various popular activities that make use of both wireline and wireless services. Earlier, we looked at data from Sandvine regarding the most popular applications during peak period on both wireline and wireless services. It was evident that both audio and video applications were responsible for the majority of data usage. The table on the following page details the assumed requirements of different online services, collected from different sources, including the CRTC, the FCC, and Rysavy Research.[22]

[22] CRTC data taken from the 2013 Communications Monitoring Report (Table 6.1.1)
http://www.crtc.gc.ca/eng/publications/reports/policymonitoring/2013/cmr.htm
FCC data taken from OBI Technical Paper No.4 (Exhibit 9)
http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-300902A1.pdf
Rysavy data taken from Mobile Broadband Explosion paper (Table 1)
http://www.rysavy.com/Articles/2013-08-4G-Americas-Mobile-Broadband-Explosion.pdf

Figure 38 - Connectivity Requirements for Various Services (CRTC, FCC, and Rysavy)

SOURCE	Application	Required Speed (Mbps)	Required Capacity (MB/hr)
Rysavy Research	Basic Web Browsing	0.0625	28.125
Rysavy Research	Audio Streaming	0.1	45
CRTC	Streaming Audio	0.13	58.5
Rysavy Research	Low Resolution Video	0.2	90
FCC	Basic Web Usage	0.2	90
FCC	Streaming Audio	0.2	90
FCC	VoIP Services	0.2	90
FCC	Basic Streaming Video	0.3	135
CRTC	YouTube (240p)	0.31	139.5
Rysavy Research	Basic Video Telephony	0.375	168.75
FCC	Basic Online Games	0.4	180
CRTC	Netflix (Good)	0.62	279
FCC	Basic Video Conferencing	0.8	360
Rysavy Research	Rich Media Web Browsing	1	450
FCC	SD Streaming Video	1	450
CRTC	YouTube (720p)	1.3	585
FCC	Advanced Web Usage	2	900
Rysavy Research	Full Screen Video	3	1350
CRTC	Broadcaster Web Streaming	3.1	1395
Rysavy Research	HD Online Streaming	5	2250
FCC	HD Streaming Video	5	2250
FCC	Advanced Gaming / Video Conferencing	5	2250
CRTC	Netflix (Best)	5.8	2610
Rysavy Research	Full HD Video	16	7200

While the list in the previous table is not exhaustive, it serves as a good starting point. For the purposes of creating our scenarios, we will simplify the above table and use the following generalized requirements when looking at the speed and capacity requirements. These figures were created through roughly averaging the above quoted numbers, and are meant to be 'typical' requirements, neither maximums nor minimums.

Figure 39 - Simplified Usage Requirements for Modeling

Application	Required Speed (Mbps)	Required Capacity (MB/hr)
Audio Streaming	0.15	67.5
Video Streaming to Handhelds	0.5	225
VoIP / Skype Usage	0.5	225
Web Browsing	0.82	369
Online / Console Gaming	2.2	990
Video Streaming to Computer	3.9	1755
Video Streaming to TV	7	3150

For the purposes of this exercise, we are assuming that the most bandwidth-intensive activity would require a speed of 7Mbps. While we have demonstrated that this speed is theoretically possible using a wireless connection, it is worth pointing out that at present, this is not a speed that most wireless subscribers would be able to achieve (particularly within a house) on a consistent basis for a prolonged period of time. For comparison, Figure 40 lists the average speeds reported by different organizations for wireline and wireless subscribers.

Figure 40 - Average Reported Speeds by Platform (CRTC, Akamai, Net Index, and CISCO)

Source	Technology	Download Speed (Mbps)	Upload Speed (Mbps)
CRTC	Wireline	12.5	2.0
AKAMAI	Wireline	3.6	-
Net Index	Wireline	20.8	5.8
CISCO VNI	Wireless (Tablet)	4.5	-
CISCO VNI	Wireless (Smartphone)	3.9	-
AKAMAI	Wireless	0.6-9.5	-
Net Index	Wireless	14.1	5.0

Unfortunately, this table illustrates another issue with technology and capability comparisons. Each reporting entity may have different methodologies. For example, the CRTC figures are a blended average of the subscribed speeds of residential users (in other words 'advertised speeds'). Net Index uses extensive crowd-sourced data, but as a result, is not representative of purely residential numbers. Furthermore, others simply don't reveal detailed methodology, and whether values are 'average' or 'peak', and for wireless results, it is unclear whether this captures Wi-Fi usage in the tests as well, which would skew results. All this is to simply state that for the purposes of our examination, we will simply assume that wireless connections **can** handle the speed requirements that are implied by our scenarios, **even though at present, we are doubtful they could reliably deliver those speeds for high-intensity applications**.

With this in mind, we have created four scenarios we will use in the next section for the purpose of pricing comparisons. As a side note, it is obvious that a wireline connection could support the needs of a wireless user, so we are focusing specifically on replicating wireline / household usage over wireless services as offered today. Also, for the purposes of comparison, these scenarios envision users that are using their wireline or wireless services to receive all of their services. In other words, this envisions users that have 'cut the cord', and receive only broadband services for household video and telephony needs.

Scenario 1		
Light, occasional use, single-person dwelling		
Application	Hours / month	Total Capacity
Audio Streaming	5	337.5
Video Streaming to Handhelds	5	1125
VoIP / Skype Usage	10	2250
Web Browsing	20	7380
Online / Console Gaming	2	1980
Video Streaming to Computer	5	8775
Video Streaming to TV	0	0
TOTAL USAGE IN GB		**21.34**

Scenario 1 depicts a typical individual living alone in either an apartment or condo. This individual has chosen to forego a cable subscription or landline phone in favour of simply using their smartphones' capabilities for providing Internet access and even creating a Wi-Fi 'hotspot'. As the usage indicates, the activities are limited to a few hours of streaming audio and video to the user's wireless device in the month, along with using Skype to have conversations with friends and families. The main activity would be casual web browsing, which is still less than an hour per day. Finally, there is only video streaming to a computer, and not to a large screen HDTV.

Scenario 2		
Moderate use, single-person dwelling		
Application	Hours / month	Total Capacity
Audio Streaming	20	1350
Video Streaming to Handhelds	10	2250
VoIP / Skype Usage	10	2250
Web Browsing	20	7380
Online / Console Gaming	10	9900
Video Streaming to Computer	10	17550
Video Streaming to TV	10	31500
TOTAL USAGE IN GB		**70.49**

Scenario 2 still depicts a typical individual living alone, but builds on their usage habits to reflect more content consumption. Again, this individual has chosen to forego a cable subscription or landline phone in favour of simply using mobile wireless services, but is savvier in connecting it to different devices. As the usage indicates, the activities are the same, but illustrate higher usage. This individual will be listening to streaming music typically in the mornings when getting ready for work, as well as perhaps while cooking / cleaning. This user also consumes more video content. This person will watch an hour of TV streamed as HDTV two to three times per week, and do the same for streaming to a computer. The user's time is split between these activities and surfing the web and gaming. Interestingly, these figures are still well below the average values for TV consumption (>50 hours per month) and Internet usage (52-80 hours per month) reported in the CRTC's 2013 Communications Monitoring Report[23].

[23] TV Consumption from Table 4.3.2 on page 77; Internet usage from Table 6.2.3 on page 186 http://www.crtc.gc.ca/eng/publications/reports/policymonitoring/2013/cmr.htm.

Scenario 3		
Moderate use, multi-person dwelling		
Application	Hours / month	Total Capacity
Audio Streaming	30	2025
Video Streaming to Handhelds	30	6750
VoIP / Skype Usage	20	4500
Web Browsing	30	11070
Online / Console Gaming	20	19800
Video Streaming to Computer	10	17550
Video Streaming to TV	20	63000
TOTAL USAGE IN GB		**121.77**

Scenario 3 depicts a typical household with 2 or more users, typified by either a couple living together or a small family with little online usage. While the overall consumption again builds from Scenario 2, the per-person usage is actually lower, and reflects lighter usage. As the usage indicates, the activities are the same, but illustrate higher usage for some categories, such as audio streaming and video streaming to handhelds. This reflects the trend towards individual usage for some services, and shared usage of others, such as watching streaming TV programs together at the same time. Once again, the hours depicted are far below national averages for consumption, in recognition that a household who 'cut the cord' may not value TV consumption as greatly as other households.

Scenario 4		
Moderate to Heavy use, multi-person dwelling		
Application	Hours / month	Total Capacity
Audio Streaming	50	3375
Video Streaming to Handhelds	40	9000
VoIP / Skype Usage	20	4500
Web Browsing	40	14760
Online / Console Gaming	30	29700
Video Streaming to Computer	40	70200
Video Streaming to TV	50	157500
TOTAL USAGE IN GB		**282.26**

Scenario 4 again depicts a multi-user household with 2 or more users, typified by either a couple living together or a small family with heavier online usage and video consumption. This household, while still consuming less overall TV programming and internet usage than national averages, nonetheless has multiple active users of these services. This household may have more than one television in use (e.g. secondary TV in a bedroom or other room). Nonetheless, there is still both individual usage for some services, and shared usage of others, as with Scenario 3. The goal of this scenario was to create a high-end usage scenario which approaches the higher limits of a wireline usage scenario today. At >280 GB of household consumption, this would be a truly 'wired' household.

These four scenarios will form the basis of the pricing comparisons in the next section.

5.3 Scenario Pricing Comparisons

In this final section, we'll examine the actual costs of substituting a wireless service for a wireline service in the context of actual usage, as defined by the above scenarios. For the purposes of choosing service offerings for the comparisons, we will use 3 wireline packages, and 3 wireless packages.

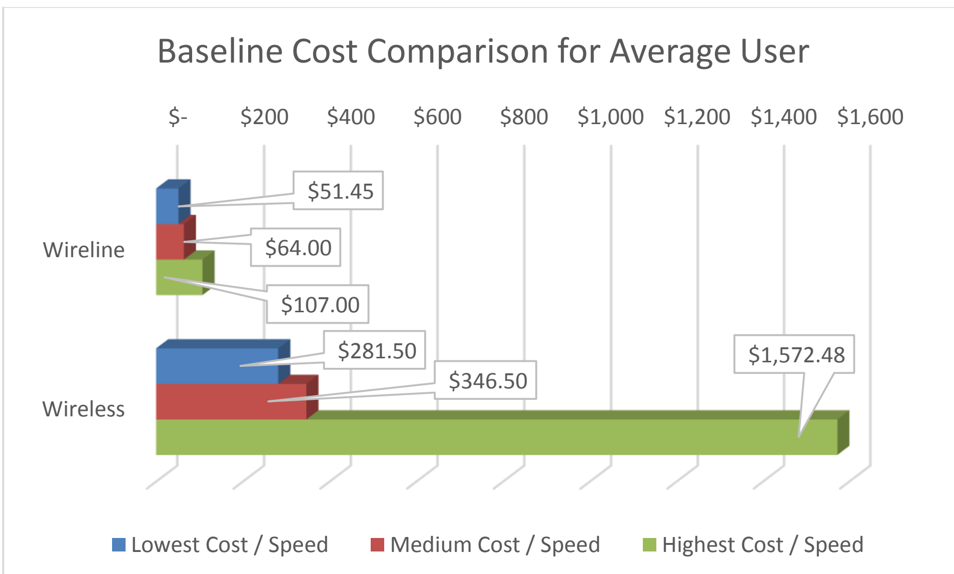
With respect to the wireline pricing packages, we have chosen three different generic speed tiers. A 5-6Mbps service offering, a 25Mbps service offering, and a 50+ Mbps service offering. With each package, we have listed a base price, a bit cap, and an overage charge. These numbers are based on averages of the currently-listed non-promotional rates for the incumbents Bell, Rogers and TELUS[24], and are typical of the most prevalent service types available in most markets. Each of these companies, as discussed above, offer their wireline services based on a speed tier targeted specifically for home usage.

For the wireless pricing packages, we again used the Bell, Rogers and TELUS, since these are the dominant national providers for the provision of mobile wireless services. In this instance, due to variability in pricing, we chose to feature the specific packages offered by each carrier. In this case, we chose the absolute best value package available from each, generally targeted to what is known as 'turbo hub' users. As discussed above, these devices are marketed to offer connectivity to several users / devices within a home. However, it is worth noting that the same pricing exists for users that have smartphones or tablets. Each package is sold by a fixed capacity, rather than speed. While each company features 'roll-over' pricing, we used the highest tier package (i.e. best value per unit capacity), as in every scenario, the capacity needed exhausted the pre-defined capacity of every service tier.

[24] All pricing was sourced directly from the websites of each carrier, as of April 2014.

For a baseline comparison, we prepared the following chart, which illustrates the current costs that an ‘average’ user would expect to pay for **wireless** services based on the current average usage on **wireline** platforms today. This comparison averages the values from Figure 27 above, which results in combined upload / download usage total of 39.2 GB per month.

Figure 41 - Baseline Monthly Costs for Average Wireline User to Substitute with Wireless Service



We will now look at each of the four scenarios developed above for a sense of what it may cost to substitute a wireless service for a wireline service.

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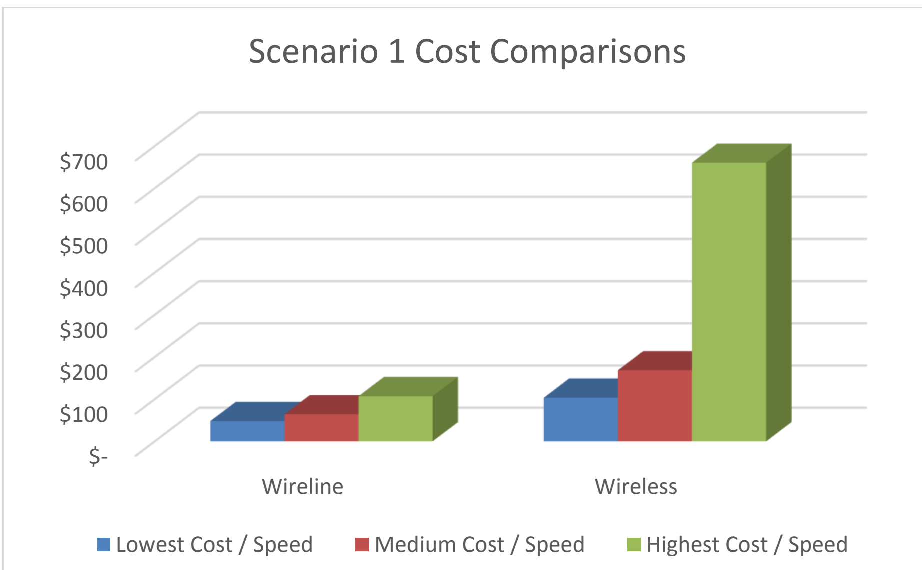
Scenario 1

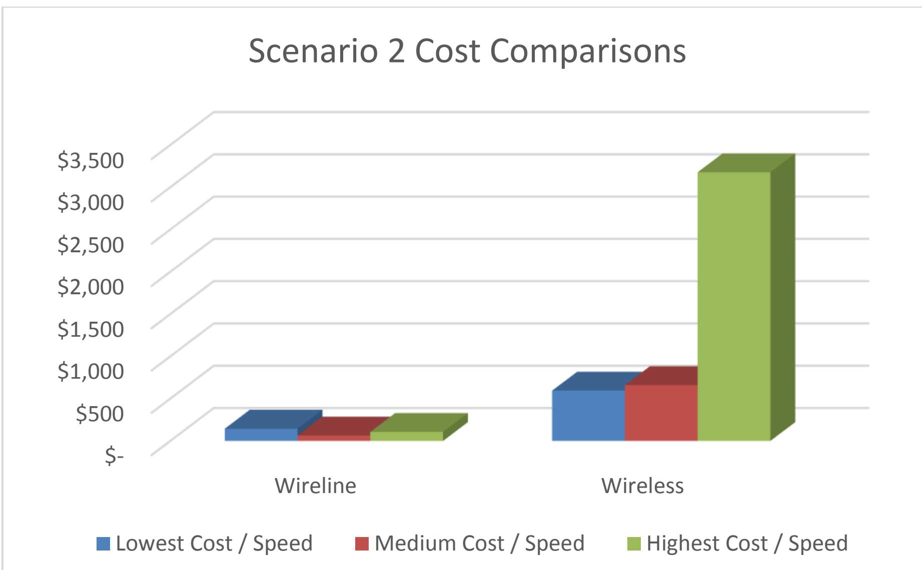
Service	Capacity Included (GB)	Excess Capacity Used (GB)	Overage Cost ($/GB)	Base Cost	Overage Cost	Total Cost
Wireline 5-6 Mbps Plan	38	0.00	$ 3.00	$ 48.00	$ -	$ 48.00
Wireline 25 Mbps Plan	140	0.00	$ 2.00	$ 64.00	$ -	$ 64.00
Wireline 50+ Mbps Plan	400	0.00	$ 2.00	$ 107.00	$ -	$ 107.00
ROGERS Mobile Flex Rate for Hubs	20	1.34	$ 10.00	$ 90.00	$ 13.35	$ 103.35
BELL Mobile Internet Flex Plan	15	6.34	$ 10.00	$ 105.00	$ 63.35	$ 168.35
TELUS Mobile Internet Flex	10	11.34	$ 51.20	$ 80.00	$ 580.38	$ 660.38



In Scenario 1, we can already see that for one provider at least, the option of using mobile wireless services has become quite expensive. In fact, apart from the 50+ Mbps plan wireline offering, all wireless options were more expensive than the wireline options.

Scenario 2

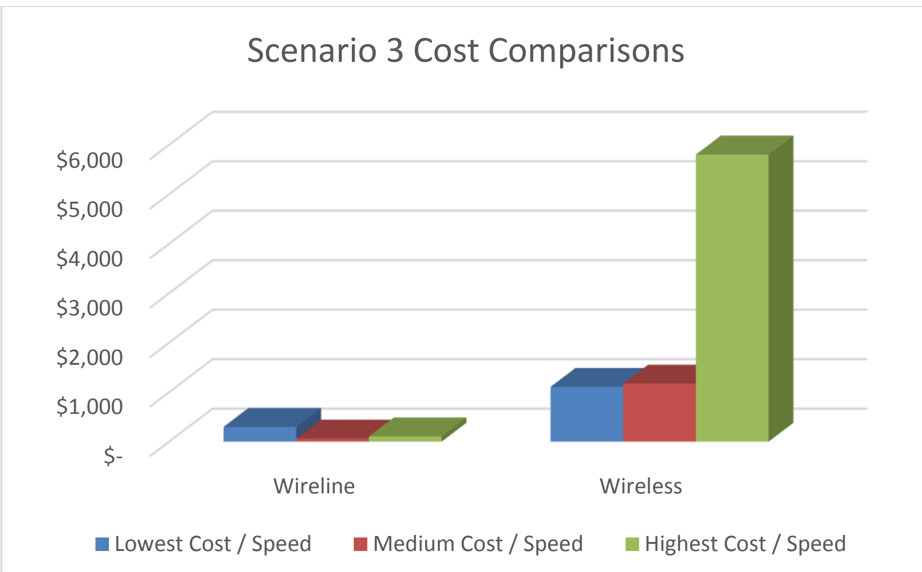
Service	Capacity Included (GB)	Excess Capacity Used (GB)	Overage Cost ($/GB)	Base Cost	Overage Cost	Total Cost
Wireline 5-6 Mbps Plan	38	32.49	$ 3.00	$ 48.00	$ 97.46	$ 145.46
Wireline 25 Mbps Plan	140	0.00	$ 2.00	$ 64.00	$ -	$ 64.00
Wireline 50+ Mbps Plan	400	0.00	$ 2.00	$ 107.00	$ -	$ 107.00
ROGERS Mobile Flex Rate for Hubs	20	50.49	$ 10.00	$ 90.00	$ 504.88	$ 594.88
BELL Mobile Internet Flex Plan	15	55.49	$ 10.00	$ 105.00	$ 554.88	$ 659.88
TELUS Mobile Internet Flex	10	60.49	$ 51.20	$ 80.00	$ 3,097.00	$ 3,177.00



In Scenario 2, the differences in pricing become readily apparent. While this is already more capacity than may be used by a typical home today, it is not uncommon, and will be much more common in the future. Prices for wireless are around 5x more expensive than wireline.

Scenario 3

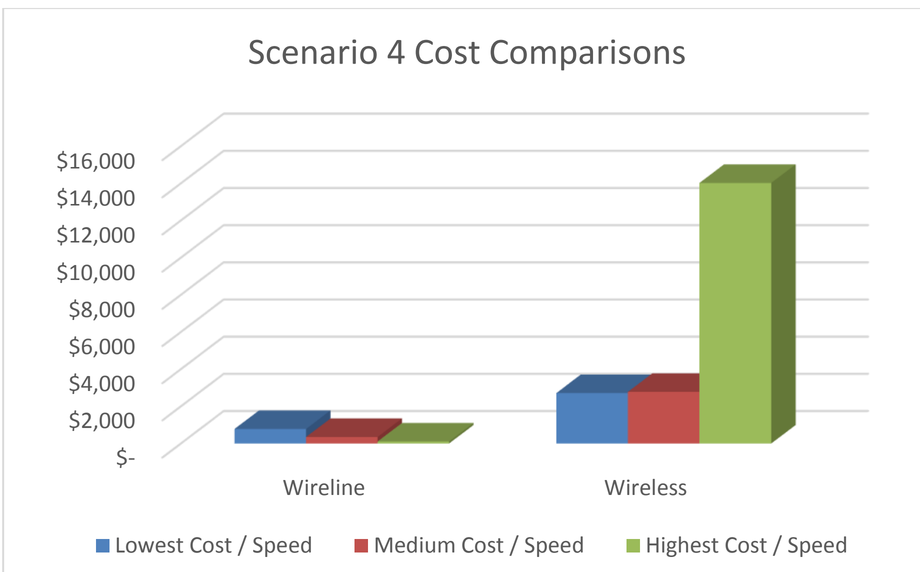
Service	Capacity Included (GB)	Excess Capacity Used (GB)	Overage Cost ($/GB)	Base Cost	Overage Cost	Total Cost
Wireline 5-6 Mbps Plan	38	83.77	$ 3.00	$ 48.00	$ 251.32	$ 299.32
Wireline 25 Mbps Plan	140	0.00	$ 2.00	$ 64.00	$ -	$ 64.00
Wireline 50+ Mbps Plan	400	0.00	$ 2.00	$ 107.00	$ -	$ 107.00
ROGERS Mobile Flex Rate for Hubs	20	101.77	$ 10.00	$ 90.00	$ 1,017.72	$ 1,107.72
BELL Mobile Internet Flex Plan	15	106.77	$ 10.00	$ 105.00	$ 1,067.72	$ 1,172.72
TELUS Mobile Internet Flex	10	111.77	$ 51.20	$ 80.00	$ 5,722.75	$ 5,802.75



In Scenario 3, the comparison no longer seems fair at all. In this scenario, it is interesting to note that in 2 of the 3 wirelines packages, the included bit cap has still not been exceeded, while for the wireless plans, overage charges exceed $1,000. Overall costs are now at least 10x more for wireless.

Scenario 4

Service	Capacity Included (GB)	Excess Capacity Used (GB)	Overage Cost ($/GB)	Base Cost	Overage Cost	Total Cost
Wireline 5-6 Mbps Plan	38	244.26	$ 3.00	$ 48.00	$ 732.78	$ 780.78
Wireline 25 Mbps Plan	140	142.26	$ 2.00	$ 64.00	$ 284.52	$ 348.52
Wireline 50+ Mbps Plan	400	0.00	$ 2.00	$ 107.00	$ -	$ 107.00
ROGERS Mobile Flex Rate for Hubs	20	262.26	$ 10.00	$ 90.00	$ 2,622.61	$ 2,712.61
BELL Mobile Internet Flex Plan	15	267.26	$ 10.00	$ 105.00	$ 2,672.61	$ 2,777.61
TELUS Mobile Internet Flex	10	272.26	$ 51.20	$ 80.00	$ 13,939.75	$14,019.75



In Scenario 4, it would seem there is no conceivable rationale for considering wireless with today's pricing and service options. On the 50+ Mbps wireline plan, we have still not exceeded the bit cap, leading for a monthly charge of $107, while at even the best wireless prices, the same usage would cost over $2,700 per month.

6. Conclusions

Having examined the question of substitutability from both a technical perspective and a pricing perspective, we present some concluding thoughts on the overall question of whether wireless services can serve as a substitute for wireline services.

6.1 Technical Limitations of Wireless as a Substitute

Although wireless technologies have evolved a great deal, and offer greater capacities and speeds than ever before, it is important to note that so have the wireline technologies. In addition, the needs of users also continue to grow and evolve. Both from a practical, and theoretical technical assessment, wireless technologies cannot act as substitutes for wireline technologies. At the fundamental level of capacity, the medium is simply not capable of handling the volumes of data for a mass audience.

While the backhaul and backbone networks that serve the wireless network can handle ever-larger capacity thanks to the use of fiber optics, the radio access network (RAN) itself is a limiting factor. In order to deliver greater capacity and/or speeds to end users, the volume of antennas that would need to be deployed would be very large, in order to serve fewer customers / connections per tower.

Also, beyond the pure capacity limitations present in the RAN of a mobile wireless network, additional flags would be raised by the limitations based on geographic coverage, as well as higher constraints around time-of-day usage when many users are trying to connect to the network. However, rather than looking at these factors in greater detail, the report focused on the overarching category of 'capacity' under which these other considerations also fall.

6.2 Real-world Limitations

Suspending the question of whether you could *technically* serve people with equivalent speeds and volumes of data, we also examined the pricing implications of attempting this substitution. In the scenarios developed, and even in a baseline case using today's real world usage numbers, there was a very large discrepancy in the prices paid for wireline and wireless services.

At present, the conclusion drawn is that the manner in which services are being marketed and priced today make it infeasible for a user to substitute a wireless connection for a wireline connection at a reasonable cost to the user. The scenarios presented assumed the very best pricing options available from the wireless providers today. Such pricing would need to radically change for this situation to be any different, which seems unlikely to occur, given the capital intensity of overbuilding the wireless infrastructure in order to support the huge increases in demand such a shift would impose. Furthermore, even if the pricing did drop substantially, as shown earlier, the technical limitations indicate the infrastructure could not even be upgraded to a sufficient size to support the demand growth.

6.3 Final Thoughts

One could easily assume from the evidence presented in this paper that there are absolutely no cases where we feel that wireless services can serve as a substitute for wireline services. However, that would be incorrect. There are, in limited cases, areas where we do feel *some* consumers may find it possible to substitute one for another. Such cases include:

- Users primarily interested in **voice communications** (as previously demonstrated to, and accepted by the Commission when examining the question of wireless substitutability in the context of phone services).
- Users who are **the absolutely lightest data consumers** (i.e. not using the Internet as their content medium), using only the bare applications such as email, checking the weather, perhaps browsing news highlights (text, not video or image rich.)
- Users **who have no other option**. There are areas of the country that are served only by wireless technologies. In fact, these were previously approved by the Commission for deployment to serve as 'broadband services'. However, it is important to note they had to meet only the basic broadband requirement of 1.5 Mbps. As we have shown, this is not a speed which will allow users to enjoy a rich experience. Furthermore, such speeds are not even at the level envisioned by the government of Canada in its Digital Strategy, which indicates a minimum speed of 5 Mbps should be delivered.

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Finally, it is important to note that except for users who are present in areas where **only** wireless service are available (which includes areas served by satellite services and fixed wireless services), there is no geographic nexus that will pre-determine where certain users would employ mobile wireless services as a wireline substitute.

The realities of the market are such that consumers will ultimately decide whether or not they fall into one of the first two cases listed above. While a given geographic area may contain a small percentage of users who fall into these categories, this correlation would not imply causality. In other words, the movement of some to adopt a mobile wireless service *instead* of a wireline service in an area does *not* imply that the services are substitutable in that area. The reality is that in areas in which wireline options are present, mobile wireless options are not truly substitutable for a meaningful portion of the population.

7. Appendix – CVs of Report Authors

CV OF STUART JACK

Stuart Jack is a Partner and Director of the Ottawa Office of Nordicity Group Limited, a leading telecommunications consultancy.

Previously, Stuart held senior management positions in pre-eminent telecommunications regulatory agencies and consultancies. With PricewaterhouseCoopers, Stuart was a Director in the Information, Communications and Entertainment (ICE) Practice. With CBC, the Canadian state-owned broadcaster, Stuart was a Senior Manager in the Corporate Planning Division dealing with issues such as asset acquisition/divestiture, distribution systems and Executive Information System (EIS). With the CRTC, as Senior Manager, Marketing and Economic Analysis, Stuart provided advice to upper management and Commissioners regarding conditions of licence and competitive licensing processes and was part of the staff team in many major regulatory hearings. As Regional Telecoms Officer, he dealt with the carriers and the public and provided advice on carrier rates, QoS, etc.

EDUCATION

Stuart's academic qualifications include an MBA in Marketing and Finance from Concordia University's Business School, a M.Sc. from Institut national de la recherche scientifique (Université du Québec) and an Honours B.A. from Queens University.

AREAS OF SPECIALIZATION

Stuart specializes in advising policy and regulatory agencies and firms on frameworks, procedures and processes in the ICT, telecommunications and media industries. In the wider context, he has deep understanding of technology, market and financial issues that drive investment and competition strategies.

Stuart has led numerous project teams which have advised spectrum regulators, incumbents and new entrants on spectrum valuation and pricing, spectrum swaps, market demand, capacity, licensing obligations, impact of new technology, launch of new services, competitive licensing processes, and competitive positioning. Stuart has consulted extensively in the global market in telecommunications.

PROJECT EXPERIENCE

Examples of consulting work in which Stuart assumed key responsibilities:

Projects for Regulatory Agencies and Policy-makers

For Industry Canada, Stuart led a project team in the comprehensive review and assessment of the mandatory tower and site sharing, and roaming provisions implemented for Cellular, PCS and AWS spectrum licensees in late 2008. The purpose of the assessment was to what extent the framework was achieving its stated policy objectives, namely: to provide all players the opportunity to offer national service coverage to their subscribers; to encourage facilities-based competition; to limit the social impacts of the proliferation of new towers; and to facilitate new competitive entry by endeavouring to speed up network deployment.

The assessment was based on a multi-staged methodology, including:

- A literature review of the Industry Canada policy and its objectives;
- File review of quantitative and qualitative information on tower sharing and roaming experiences to date provided by Canadian licensees;
- International benchmarking of other tower sharing and roaming frameworks; and
- A review of other mandated Canadian governmental or agency processes.

The assessment was incorporated into the Ministry's assessment of the current framework and preparation for potential consultation with stakeholders on the tower sharing and roaming framework.

For Industry Canada, Stuart led a project team in the study of the competition in global satellite markets, practices for assigning satellite licences and setting the economic value of licenses. The team examined the potential benefits (setting market prices, coverage requirements, administrative efficiency, etc.) of auctions, first-come-first serve and comparative reviews as licensing processes as well as their pertinence for Canada. The study results were used by IC to assess its current licensing processes and in consultation with stakeholders.

For Industry Canada, Stuart led a project team in the study on the market value of fixed and broadcasting satellite spectrum in Canada.

The purpose of this assignment is to establish market-based valuation and fee-structure for Canadian satellite spectrum. Industry Canada (the "Department") recognizes that the existing apparatus-based fee regime for satellite spectrum licensees is no longer adequate. The status quo, (i.e. continuing with the current fee structure) is not a realistic option for various reasons. The structure – originating in the 1970s and codified in 1978 – is based on the implicit value of a terrestrial voice telephony circuits. The last update to the fees was completed in 1994 and the fee levels are neither the equivalent of existing administrative costs nor the market value of the satellite spectrum governed by these licences. The basis for setting the licence fees was raised as an issue during the Department's recent consultation on the revisions to the Framework for Spectrum Auctions.

The study results were used by IC to prepare for the transition towards a transparent, equitable, market-based spectrum licensing regime and to determine the applicability of corresponding revised fee structure going forward.

For Industry Canada, Stuart led a project team in the valuation of Point-to-Area (PTA) radiocommunications spectrum. Nordicity led the assignment along with a partner consulting firm, Network Strategies Ltd. As part of the assignment, a comprehensive review of Industry Canada's Technical and Administrative Frequency Lists (TAFL) database was undertaken to identify:

- The utilization rate of each of the PTA bands
- Identification of bands with excess demand or congestion
- Identification of uses and users in each of the PTA bands
- Identification of the current equipment in use and the estimation of current equipment's' age
- Visual map representation of each of the license assignments across Canada

The output of the data analysis was used to develop an economic model for the valuation of the congested PTA bands and a $/kHz/year valuation was derived for these bands. The purpose of this exercise is to implement a regime of Administrative Incentive Pricing (AIP) for radio-communication spectrum and implement a fee schedule that will encourage the highest economic use of the spectrum for the un-auctioned bands.

Nordicity's report was incorporated into the Ministry's assessment of the current framework and preparation for potential consultation with stakeholders on the spectrum valuation.

For Public Safety Canada, Stuart led the study team in the analysis of the technical, financial and governance requirements for new 700MHz regional and national public safety agencies operating over LTE networks. The report completed in April 2012 has been released to provincial, first responders and spectrum stakeholders.

For the CRTC, the Canadian telecommunications and broadcasting regulator, Stuart has led project team in a number of projects

- Analysis of competition in the Canadian and international distribution markets.
- Analysis of the impact of additional advertising inventory on market rates and broadcasters' profitability

For Telus, Stuart led a study on Competition and Incumbency An analysis of Canada's Communications. The study examined the methodology used by the OECD in its benchmarking study on Competition in the Global Wireless Industry, Canada's ranking and applicability of parameters (number of devices, plans, intensity of usage, number of service providers). Telus filed this report as evidence with Industry Canada, and the report was also referenced by other carriers.

For CITC, the Saudi telecommunications regulator, Stuart undertook a reference interconnection offer (RIO) study including benchmarking of interconnection tariffs in 18 best practice jurisdictions, analysis of STC's original interim and revised RIO proposals including costing data and other justification, analysis of interveners' submissions to the Public Consultation process and drafting recommendations for the RIO tariff decision. The results of this study enabled CITC decisions on interconnection pricing and future requirements for costing information from applicants. In addition, Nordicity provided support to the CITC during its negotiations with the incumbent, in arriving at its final decision on interconnection tariffs.

For CITC - the Saudi telecommunications regulator, Stuart undertook a benchmarking analysis of Quality of Service parameters and values / thresholds required of service providers by National Regulatory Agencies (NRAs) in 15 best practices countries as well as the sanctions imposed by NRAs on service providers if they fail to meet the QoS targets. The results of this study enabled CITC decision on the selection of appropriate QoS measures and sanctions.

For BTA- Botswana Telecommunications Authority, Stuart led project teams to:

- Analyze the consumer equity and competitive impacts of the incumbent's per second billing proposal to the Regulator,
- Prepared an industry consultation on competition and service obligations and,
- Develop the organizational structure, process flows a new Consumer Affairs Department (CAD) within the BTA
- Recommend the appropriate division of roles & responsibilities between the new CAD and the operators.

For the Bahamian Public Utilities Commission, Stuart led project teams on a number of projects:

- Review a number of wireless ISP applications to determine the appropriate technical, economic and legal conditions for licensing and corresponding fee structure for licensees;
- Review and rank technical, marketing and financial aspects of applications for a fixed wireless licence in the 2100 & 2500MHz bands.
- Study of the Potential Wireless Market in the Bahamas and Benchmarking to Comparable Markets.

For the IBA, the South African broadcasting regulator, Stuart undertook a number of projects to assist the Regulator

- Evaluate the viability and growth in the broadcasting market and identify key parameters for a competitive licence hearing
- Expert advisory to the regulator during the competitive licensing process (public hearing) for new off air conventional broadcaster and setting of licence terms.
- Evaluation of competitive bids.

For the Spectrum Management Authority of Jamaica, Stuart led study teams in a number of projects:

- Development of a fee structure and schedule for fixed and mobile satellite services. A comparative analysis of satellite fees in best practice jurisdictions was undertaken and data was normalized and adjusted for the Jamaican market conditions, cost of service, GoJ revenue objectives and best regulatory practices.
- Assessment of the mobile market and corporate values of specific cellular frequencies from the perspective of the GoJ and the operators in order to provide a valuation range. The data was used by the regulator for negotiation of spectrum 'swaps' as well as setting benchmarks for spectrum management. The project team also examined the likely impact of new technological and consumer trends on spectrum demand.

For USAID and the Jamaican Ministry of Posts, Telegraphs and Telecommunications, Stuart led a project team to build the technical, financial, legal and strategic planning functions for a new Spectrum Management Agency.

For the Cyprus Ministry of Communications and Works – responsible for telecoms policy and regulatory functions, Stuart led project teams in a number of assignments:

- Undertake market capacity study to identify the optimal number new cellular (GSM_ operators,
- Prepare tenders for the licensing of new operator(s).
- Provide the technical data and advice for the design of a Frequency Allocation Table (data derived from consultation with key current and potential users, ITU, neighbouring jurisdictions and best practices)
- Advise on the design of a spectrum monitoring network and provide system specifications. The Project Team defined short and long term spectrum monitoring and direction finding requirements; provided measurement procedures and reports that the spectrum monitoring system should generate; and, recommended enforcement practices for the spectrum monitoring program.
- Recommend a reserve price for the auction of new cellular license concessions.

For MPA&I - the Trinidad & Tobago Ministry of Public Administration and Information and TATT - the new telecommunications authority, Stuart led the project team, which provided:

- Audit of current usage of wireless usage,
- Comparison of existing usage with licensing data base,
- Consultation with key stakeholders on current and potential spectrum technologies and business plans,
- Advice on market and financial evaluation in licensing and licensing processes,

- Advice on the design of the frequency allocation table based on consultations with current and potential users, neighbouring jurisdictions, ITU and global best practices,
- Advice on monitoring system specifications, evaluation criteria, procurement and technical evaluation of bids,
- Advice on integration of monitoring into full AAFMS system (including engineering, licensing and billing software and hardware components).

For the South African Department of Communications, Stuart undertook a number of projects:

- Analyze and provide policy guidance for the 'convergence' of IT, telecom and broadcasting industries. This process included benchmarking international policy and regulatory initiatives, technological developments, evaluation of current and potential business models of the SA industry under various policy scenarios.
- Advise on financial, competitive, technical aspects in the Green/White Paper process for the preparation of new broadcasting legislation.
- Feasibility study regarding the development of a dedicated educational channel for South Africa. The study involved: a benchmarking study of international educational initiatives, a situation analysis of technology enhanced educational initiatives in South Africa and Africa, an overview of the country's access technologies and infrastructure, an assessment of potential sources of income and proposed conceptual financial models. The purpose of the channel was to address issues of access and equity of quality education throughout South Africa, specifically its rural and underprivileged communities.
- Stuart appeared before the CRTC as an expert witness on the economic impacts of simultaneous substitution for the Writers Guild and Directors Guild, as part of a joint submission with the Canadian Film and Television Producers Association (CFTPA)
- For CanWest Global - now Shaw Communications, Stuart assisted in the development of the business plan and appeared before the CRTC as an expert witness for on the economic impacts of licensing new conventional broadcasting stations in British Columbia and Quebec.
- For UK DCMS, Stuart was part of the project team hired by the Department responsible for Ofcom to validate costing data and evaluate the economic and financial impacts of alternative regimes for rights of way ('wayleaves') on landowners and telecoms operators.

Projects for Governments, Associations, Operators and Service Providers with Regulatory and/or Policy Focus

For Canada's 3 territorial governments: Yukon, NWT & Nunavut, Stuart led the project team in a major study of connectivity in the three territories: Yukon, NWT and Nunavut. This required modeling of the network backbones and access to the 75 northern communities and determination of connectivity standards that meets the user group needs. The dynamic optimization model developed in the course of the project enabled the team to identify the costs and least cost solution for any connectivity standard, size of community and user group profile.

In parallel, the Consultant's study team undertook primary (survey and focus groups) and secondary research (literature review and benchmarking) in order to provide an overview of broadband connectivity in Canada's North and in other best practice northern jurisdictions. The study team has identified key issues with respect to access and use of broadband-enabled information and communication technologies (ICTs) by northerners and northern organizations. The Consultant's team identified sustainable financial models for the suggested connectivity and well as strategies for implementation and stakeholder engagement.

The study will be used by the territorial and federal policy-makers and funders to better understand connectivity needs, impacts of connectivity on economic development and quality of life in the 3 territories, to evaluate alternative connectivity strategies, identify related costs and benefits as well as to evaluate various project proposals. Lessons learned from this project are expected to help guide future initiatives in expanding the availability of broadband ICTs, in developing and delivering relevant content, and in ensuring that northerners have the capabilities and local support services to harness these technologies.

For the Katimavik Regional Government (KRG), Stuart is leading a project team in the evaluation of economic and social impacts of current service and changes in connectivity in Nunavik. The study incorporates primary (focus groups, interviews, survey) and secondary research (literature review and benchmarking). The study results will be used by KRG agencies in planning for enhancements in health, education, justice and other services, for economic development, preparation of briefs to upper levels of government for funding and partnerships and negotiations with current and potential service providers.

For the Regional Municipality of Ottawa Carleton, Stuart led a project team to identify strategies to extend the local calling area in the region in cooperation with Bell Canada. The project team provided technical and financial analysis of various options and recommended a preferred solution.

For CIEL, a satellite services provider, Nordicity assisted CIEL in the preparation of its application for a new satellite with bandwidth in the C, ku, and ka frequency bands. The team assessed Canadian demand for two distinct market segments: broadcasting services, primarily the launch of and conversion to HDTV; and broadband Internet services to the underserved communities in Canada. Stuart led the study of the broadband Internet. He provided demand and costing forecasts, regulatory and policy scenarios, examined the potential impact of competitive, technological and consumer trends. A business model encompassing costs (including spectrum bandwidth) and revenues was developed.

For Midi-Sat, an applicant for a South African pay satellite license as part of the Nordicity team, Stuart assisted in the preparation of its bid for satellite-based subscriber television service. Nordicity was involved in all aspects all the application-development process, including the preparation of the technical plan, subscriber forecasts, and business plan. Stuart led teams in the study of the satellite and ground facilities, costing of the spectrum (transponder capacity), data market applications and competing technologies such as broadband over power line (BPL).

For Midi-Sat, an applicant for a South African pay satellite licence, Stuart as part of the Nordicity team, assisted in the preparation of the submission to the ICASA – the telecom and broadcasting regulator. This brief recommended a cautious approach to licensing new satellite pay TV providers in the country based on a benchmarking study.

For Vodacom, the South African GSM operator, Stuart led a project team to analyze the operator's wireless distribution network, compare wireless operators' efficiencies and usage of spectrum capacity enhancing techniques and the need for additional spectrum in congested areas. This study was subsequently incorporated into the operator's brief to ICASA, the regulatory agency to make the case for the release of additional spectrum in congested areas.

For the Israeli cable association, Stuart analyzed and prepared a regulatory brief on issue of vertically-integrated ownership and bundling of programming as potential barriers to entry in Israel and foreign markets.

Projects for Operators and Service Providers with Technical, Market and Business Analysis as Primary Focus

For CWTA - the Canadian Wireless Telecommunications Association, Stuart leads the project team in the analysis, and the publication of the annual report on the economic impacts (direct, indirect, induced and spill-over) of the Canadian wireless industry in the Canadian economy.

For Tbaytel, an incumbent operator providing communication services across northwest Ontario, Stuart led the project team in the analysis of the capacity of the existing network to handle current and projected traffic, the migration strategy to HSPA and LTE and the analysis of alternative spectrum acquisition strategies (auction, sublicensing, and acquisition). The report completed in April, 2012 provided Tbaytel management with critical information for their capital investment plans and corporate strategy. Stuart is also leading a follow on study of the proposed auction rules announced by the CRTC for the upcoming 700MHz auction.

For EastLink a Halifax-based communications service provider with holdings across the country, Stuart led the project team in the analysis of existing infrastructure held by EastLink's (fiber, cable plant) and Rogers - its cellular services partner in the Maritimes, the adaptation of EastLink's sales network to new cellular services, the roll out of AWS wireless services and the negotiation of tower sharing versus build options.

For Stentor Resource Centre Inc., the Canadian consortium of telecom operators, Stuart provided market and financial analysis as part of the business case for the provision of cable-type services.

For Craig Broadcasting, Stuart provided advised on the business case and auction strategy in the development of the firm's new fixed wireless network (MDS / MCS) in Manitoba and British

For Sentec, the South African wireless and broadcasting signal distributor, Stuart helped identify the demand and valuation of wireless services and potential strategic business lines and partnerships for the repositioning of Sentec's distribution assets for wireless services.

For Ericsson, Stuart provided primary research for the strategic positioning of new health services delivered through broadband technologies.

For Nortel Networks, a global telecommunications equipment supplier, Stuart provided analysis of key ISP and cable ISP market sectors for the firm, its principal clients and its competitors. This analysis was used by Nortel to help train its sales force and to validate marketing strategies.

Regulatory Projects with Focus on Auction and Other Licensing Processes

For TbayTel (project in progress), Stuart is project director to develop a bid simulation and tracking tool (BSTT) to model the impact of combinatorial clock auction rules in the upcoming 2014 Industry Canada 700MHz auction under various competitive bidding scenarios, in order to assist the regional telecommunications firm in preparing and in implementing its bid strategies prior to, and during the auction event respectively. Nordicity and its subcontractor Carleton University's Centre for Quantitative Analysis and Decision Support (CQADS) worked together to develop the BSTT. Nordicity's proprietary software and analytical framework is based on Industry Canada's rules and algorithms, and factors in the potential bid strategies of competing bidders and the complex interaction of bidders, the auction manager, and the auction framework.

For EastLink, a new entrant in the Canadian wireless telecommunications market, Stuart led the auction advisory team in preparation of its auction strategy, the development of bid tracking and forecasting model as well as bidding support during the 2008 Canadian Auction of Spectrum Licences for Advanced Wireless Services and Other Spectrum in the 2 GHz Range. The bid team analyzed data from previous AWS and cellular auction results in the US and Canada. The impact of various potential causal factors on bid prices ($/Mb/pop) were considered: market size, spectrum band, economic cycle and whether the winning bid was by a newco or an incumbent. As well, we examined bid behaviour (number of rounds, increments to decisive and final bids) in various markets. The auction team developed various gaming strategies to best exploit the auction rules and minimize the impact of competitors' strategies. Overall, there were some two dozen competitors bidding on hundreds of blocks of spectrum over 331 rounds of bids in the May 27th – July 21st 2008 period.

For the Telecoms Authority of Trinidad and Tobago (TATT) Stuart lead a combined PwC-Nordicity-Fasken project team to assist the regulator in running the April 09, auction of broadband wireless access (BWA) spectrum. Nordicity provided the key technical, auction process and management professionals, PwC Trinidad client liaison and Fasken-Martineau (legal). Stuart was overall lead of the auction team, and assisted the Authority in the preparation of the auction rules, bidders' agreements, and other documents; In the preparation phase, starting November, 08, Stuart reviewed and improved upon rules, procedures and documentation (bidders' agreements) developed for the previous October, 07 AWS auction, and provided training on auction rules to bidders and legal advice to the Authority on bidders' challenges. In designing the auction rules, care was taken in the design to minimize potential 'gaming' of the auction rules and to favour robust bidding strategies by bidders. In managing the auction, the Auction Manager monitored bidders' competitive bidding strategies and advised the Authority on bid increments, bidders' behaviour, and challenges to rules and transition from Phase 1 – price-based bidding to Phase 2 – allocation of spectrum blocks. At the conclusion of the auction, 26 blocks in 3 bands: 700MHz, 2.3GHz and 2.5GHz were successfully auctioned to Digicel (Ireland), TSTT (government & C&W) and Green Dot (Trinidad).

For the Telecoms Authority of Trinidad and Tobago (TATT) in the context of the October 07 auction of broadband wireless access (BWA) spectrum, a combined project team of PwC Trinidad (project lead, audit), Nordicity (technical, auction process and manager) and Fasken-Martineau (legal) provided advice. Stuart provided advice on the organization and management of the auction including the reserve price (benchmarking analysis of spectrum auctions in other jurisdictions), likely winning bid prices, minimum bid increments and bidder behaviour. This successful auction event resulted in the licensing of new players Telstar Cable System Limited in the 12 GHz band, and Green Dot Limited in the Lower 700 MHz band.

For the October 07 auction of broadband wireless access (BWA) spectrum, the Telecoms Authority of Trinidad and Tobago (TATT) hired PwC Trinidad (contract prime, audit), Nordicity (technical, auction process and manager) and Fasken-Martineau (legal). Stuart provided overall management of the auction team, and assisted the Authority in the preparation of the auction rules, bidders' agreements, and other documents; providing advice on the reserve price and minimum bid increments and during the auction event, managed the auction process and provided regulatory expertise. This successful auction event resulted in the licensing of new players Telstar Cable System Limited in the 12 GHz band, and Green Dot Limited in the Lower 700 MHz band.

PROFESSIONAL MEMBERSHIPS & ACTIVITIES

Stuart is a Board member of the Canadian Telecommunications Consulting Association (CTCA) and a member of the Community of Telecommunications Consultants (CTC). He is actively involved with Ottawa University's MBA program, Concordia's John Molson School of Business (alumnus). He has successfully completed courses offered by the Professional Management Institute (PMI) and the Canadian Evaluation Society (CES).

Stuart has presented, participated in panels on ICT, telecoms and broadcasting issues at industry conferences (Insight Canada, CTCA, CTC, CTU - Caribbean Telecommunications Union), Commonwealth Telecoms Association, Commonwealth Broadcasting Association, RABC - Radio Advisory Board of Canada), Conference Board of Canada, etc. He has also led numerous workshops and presentations to industry associations and provided training seminars to foreign telecoms regulators overseas and in Canada (for Industry Canada).

LANGUAGES

English written and oral: native.

French written and oral: excellent

CV OF STEPHAN MEYER

Stephan Meyer is the Director of Technology at Nordicity Group Ltd.

Stephan has a bachelor's degree in Electrical Engineering, with a specialty in communications systems and networks, and extensive experience in both the private sector and public sector through various positions. He has a strong background in technical analysis and network design, and a strong ability to communicate this analysis to a broad audience. He has experience in designing large communications networks, as well as creating complex public policy dealing with technology areas.

EDUCATION

BSc.Eng. (Electrical Engineering), University of New Brunswick, Fredericton, NB, CANADA

AREAS OF SPECIALIZATION

As an engineer and technologist with both private and public sector experience, Stephan is called upon to assist in all projects that have a technology or technical component. His experience allows him to easily move between the business and policy aspects of a problem, to the technical aspects, and explain the challenges and solutions to audiences from both sides. Stephan's passion is communication networks and in particular the Internet, its governance, and its impact on the global economy. Stephan has a strong understanding of all technologies used to deliver broadband services, from cellular, wireless, fibre-optic, microwave, and satellite technologies.

WORK EXPERIENCE (Nordicity)

Stephan recently completed a project with the three territorial governments of Canada headed by the Government of Yukon and CanNor for the creation of an engineering optimization model for improved broadband connectivity in the three northern territories: Yukon, the Northwest Territories and Nunavut. He evaluated the network connectivity and technical requirements to improve connectivity for each territory using a detailed economic and engineering optimization model. The work also includes fully documenting the assumptions built into the models, as well as explaining the methodology behind the engineering optimization model.

Stephan is also working with a regional telecommunications service provider, to assist them with their bidding strategy for the upcoming 700MHz spectrum auction. In collaboration with the Carleton Centre for Quantitative Analysis and Decision Support (CQADS), they have created a detailed auction simulation tool to prepare the client for their participation in the auction. The work will also include working with the client on a comprehensive simulation of auction conditions prior to the actual auction taking place, and advising them of the strategies to employ in the process.

Stephan has also recently completed work for DCMS in the UK regarding an analysis of their wayleaves regime (known also as rights-of-way). In this project, Stephan performed technical assessment of the various regimes being studied, including the usage of utility poles for use by telecommunications common carriers.

Other recent project work involves researching and reporting on the state of broadband connectivity for rural Canadians for the Federation of Canadian Municipalities.

WORK EXPERIENCE (Prior to Nordicity)

Policy Work (Select)

Stephan was the lead and overall manager of the process culminating in the publication of the CRTC's policy regarding Internet Traffic Management Practices, the so-called 'Net Neutrality' policy of Canada (see: CRTC Telecom Regulatory Policy 2009-657).

Stephan was also responsible for key aspects of the CRTC's decision regarding the Obligation to Serve for telecommunication service providers. Specifically, Stephan led the creation of the broadband speed targets for all Canadians of 5Mbps downstream and 1Mbps upstream by 2015, regardless of geographic location. (See: CRTC Telecom Regulatory Policy 2011-291)

In his over 9 years working at the CRTC, Stephan was an integral part of many project teams for various regulatory processes, the majority of which were focused on broadband service delivery. In these processes, Stephan was the primary technical resource responsible for interpretation of submissions made by various stakeholders, as well as preparing technical interrogatories to be sent to parties. Stephan was also often called upon to prepare and deliver presentations to the CRTC Commissioners on various technology issues, to assist them to prepare for hearings, as well as to better understand the telecommunications and media space in general.

Project Work (Select)

Stephan initiated, led and oversaw the completion of a pilot project undertaken by the CRTC designed to measure and evaluate the actual broadband speeds received by Canadian consumers (Broadband Performance Measurement Project). The project has since been expanded into a national initiative by the CRTC and forms part of their key data gathering on the state of broadband in Canada.

As a network engineer, Stephan was instrumental in the design and implementation of numerous regional, national, and even international fibre-optic network builds for various telecommunications carriers. One example is the engineering design of Level 3 Communications' fibre-optic networks in the US and in Europe, valued at over $1Bn. The technologies in which Stephan was most conversant for these projects include SONET systems, DWDM systems, ROADMs, OADMs, MEMs, tunable lasers, optical amplifiers and regenerators.

Additionally, Stephan carried out detailed engineering design work for several International telecommunications companies deploying wireless networking systems, in countries such as Morocco, Trinidad and Tobago, and Venezuela. Technologies employed for these projects included microwave systems, Wi-Max systems, and other line-of-site (LOS) technologies.

PUBLICATIONS / SPEAKING ENGAGEMENTS

Speaker at Telecom 2013 Conference, Toronto, ON (October 2013): "Small is Big, Old is New: Technology Developments in the Telecom Space"

Speaker at ISP Summit, Toronto, ON (November 2012): "Broadband Performance Measurement – Is Canada's Insatiable Broadband Appetite Being Satisfied?"

Speaker at ARIN Public Policy Meeting, Dallas, TX (October 2012): "IPv4 Allocation Implications in Canada"

Published author, Journal of Law & Economic Regulation, Vol.5, No.1, 2012 CeLPU, South Korea "Finding Balance, Net Neutrality Policies of Canada"

Speaker at OFC, Anaheim, CA (March 2002): "Quantification of Wavelength Contention in Photonic Networks with Reach Variation"

PREVIOUS WORK HISTORY

Prior to joining Nordicity, Stephan was the Manager of Network Technology at the Canadian Radio-television and Telecommunications Commission (CRTC). At times, he also held the positions of Acting Director, Engineering and Technology, and Acting Director General, Convergence Policy.

In the private sector, Stephan held roles at various telecommunications equipment vendors, both established large players, and start-up companies. These roles included Sales Engineer at Dragonwave, Network and Sales Engineer at Movaz Networks, Network Planning Engineer and Business Development at Innovance Networks, and Manager of Emerging Global Carriers at Nortel Networks.

LANGUAGES

English (fluent)

French (fluent)

German (functional)

Spanish (rudimentary)

CITIZENSHIP

Canadian

Swiss