Fibre to the Premises

Technical Feasibility of Providing Wholesale Access to Incumbent Fibre-to-the Premises (FTTP)

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Table of Contents

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List of Figures

Background and Introduction

The provision of telecommunication services by competitors to Canadian consumers is in large part dictated by the terms and conditions of wholesale services mandated by the Commission. In light of the obvious challenges in the provision of their own facilities, competitors are justifiably keen to see the mandate of new services to reflect the reality that over time, services will be delivered increasingly over fibre-optic facilities directly to the end user. Due to the historical market dominance by the incumbents of the needed rights of way (which is beyond the scope of this report), fibre-optic cabling and associated access-level equipment will continue to be installed almost exclusively by either the incumbent cable service providers, or incumbent telecommunications service providers. In addition, municipalities, multi-dwelling unit owners and office building owners generally do not favour or allow multiple pieces of telecommunications equipment to be installed by different service providers to enable the competitive provision of services in their premises. In light of these barriers, regulatory intervention is required to ensure a competitive local access market. An examination on the technical provision of fibre-to-the-premise (FTTP) – the focus of this report - is a critical element in order to understand and evaluate the suitability of a new or modified regulatory regime.

The specific technical question of the wholesale provision of FTTP has been identified and will be examined in the CRTC 2013-551[1] proceeding. This report will explore both the current methods of FTTP provisioning, as well as examine whether there are any technical considerations for incumbents in offering FTTP to third party service providers on a wholesale basis as well as the most technically efficient manner such access could be provided.

[1] Review of wholesale services and associated policies, Telecom Notice of Consultation CRTC 2013-551, 15 October 2013, as amended by Review of wholesale services and associated policies, Telecom Notice of Consultation CRTC 2013-551-1, 8 November 2013 (collectively "2013-551").

1. Methodology

Primary and secondary research were the key tools in developing this report's conclusions. Secondary research consisted of desk-based research into the current best practices for provisioning FTTP, as well as research into available vendor literature into the current technical capabilities of equipment commonly associated with FTTP services. Another source of data was the interrogatory responses from the incumbent carriers submitted on December 6th, 2013. This data also provided valuable insight into their current operations and capabilities, further strengthening the research undertaken.

Primary research involved confirming certain assumptions and capabilities of equipment vendors and network operator's practices in order to better understand the technologies they use, and how they use them. Secondary research results were sufficient in most case to provide the key information used in our analysis; thus, there was only minimal need to contact vendors / carriers directly.

2. Technical Primer

FTTP is essentially the provisioning broadband services to end-users, be they business or residential customers, using a pure fibre-optic network for the access. FTTP signals a departure from the various digital subscriber line (xDSL) and hybrid fibre co-axial (HFC) networks that are most well-known and which are used to deliver high-speed broadband Internet services today to customers. FTTP – as a purely fibre-optic delivery system - has significant advantages with respect to capacity, reliability, and the provision of new services to customers. With FTTP, optical fibre is used to distribute the signal all the way to a customer premises. From there, the distribution through a dwelling can be through either twisted pair, co-axial cable, Ethernet, wireless, or other transmission media.

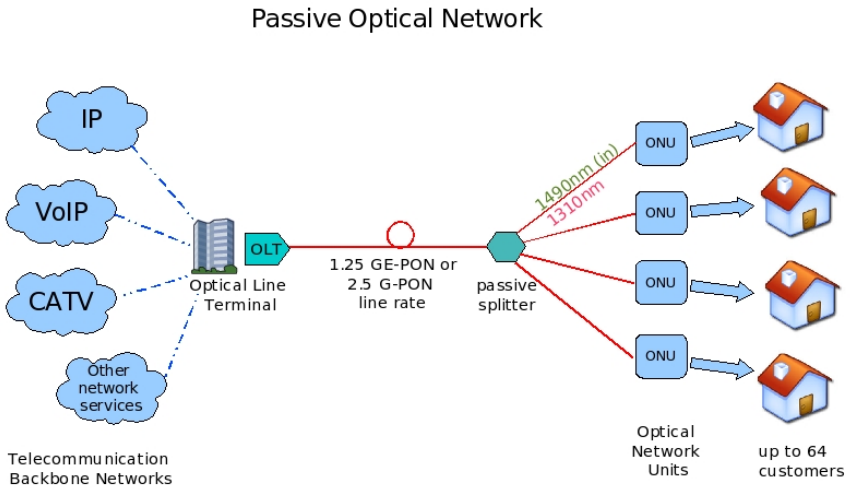
While fibre-optic technologies have been around for decades, operators have faced challenges in developing technical solutions which were both robust enough, and economically feasible to deploy in their networks.

Initially, two major categories of network architectures were proposed for use in FTTP deployments. One was known as Active Optical Networking (AON), which used

powered optical networking equipment in the architecture to allow for long distance transmission. The second category was known as Passive Optical Networking (PON), which used a point-to-multipoint architecture. AON systems were inherently more expensive due to the need for powered fibre-optic equipment throughout the access / last mile infrastructure. As a result, PON became the preferred architecture for deploying FTTP, as it used only passive optical components such as optical splitters, and was able to better take advantage of the existing network deployments of most carriers.

In Figure 1, we see a basic overview of PON architectures. The key elements to be aware of in these systems are the Optical Line Terminals (OLTs), passive splitters, and the Optical Network Units (ONUs), sometimes also referred to as Optical Network Terminals (ONTs) as well. These elements are the most important when examining the viability for incumbents to provide an equivalent wholesale service to third parties.

Figure 1 - Diagram of basic PON elements



At the far left of Figure 1, we are shown the OLT, which is the primary building block for PON systems. As shown in the diagram, various data signals are usually fed into an Ethernet switch, which in turn combines these signals into one optical signal, which then passes into the OLT for transmission into the PON. This piece of

equipment is housed in the carriers main facilities (either a head end location or central office).

Figure 2 - Motorola OLT

While the OLT handles all the different data streams in most cases, there are some variations on this basic configuration in the case of cable operators. This will be examined in a further section.

The next element, the passive optical splitter, is a piece of equipment that splits the optical signal into numerous identical optical streams. It is important to distinguish here between what happens in the downstream and upstream directions of the system. In the downstream direction (from carrier to customer), the data stream is in what is known as 'continuous mode'. All customers receive the same optical signal at the same time (although with encryption, it means each customer will only see the data it is entitled to see). In the upstream direction (from customer to carrier), data is transmitted in what is known as 'burst mode'. This means that from the optical splitter, if there are 10 customers connected, only 1 will be sending data upstream at a time (this is known as time division multiplexing – TDM). This prevents multiple signals arriving at the OLT at the same time with different data and power levels, which would lead to corrupted data.

Figure 3 – Splitter Housing

Optical splitters come in various shapes and sizes. These can be housed in cabinets on the ground, mounted on utility poles, or even be mounted in-line on aerial fibres. The key differentiator in characterizing optical splitters is the number of end-customers served (typically 16, 32, or 64). As these splitters do not require power, they have very low maintenance needs or costs. On the other hand, due to their passive nature, optical signals will not travel as far as if the architecture employed powered equipment.

Figure 4 - Example of an ONT

The third and final piece of equipment in a PON architecture is the ONT / ONU. This piece of equipment is installed at the end-users premises (home or business), and serves as the demarcation point between the carrier's network and the home network. The ONT is considered customer premises equipment (CPE), and is one of the reasons that end-user costs are cited as being quite high. The ONT has many important roles in the functioning of the PON. Within the ONT is the intelligence to filter the data stream to ensure that individual users can only access those data that are destined for them from the broadcast stream of the OLT. The ONT is also responsible for the synchronization between the OLT and ONU to ensure that upstream data is sent at the right time.

The ONT includes all the necessary interfaces to suit the particular needs of a carrier. This can include connections for Ethernet cabling, co-axial interfaces, regular phone line interfaces, etc. The equipment can be installed either outdoors or indoors, and also generally includes a battery backup to ensure proper functioning in the case of power outages. In addition to the ONT itself, service providers generally also provide a gateway device within the home. This equipment can include set-top boxes for television, routers for Internet access, and/or a multimedia terminal adapter (MTA) for VoIP phone services.

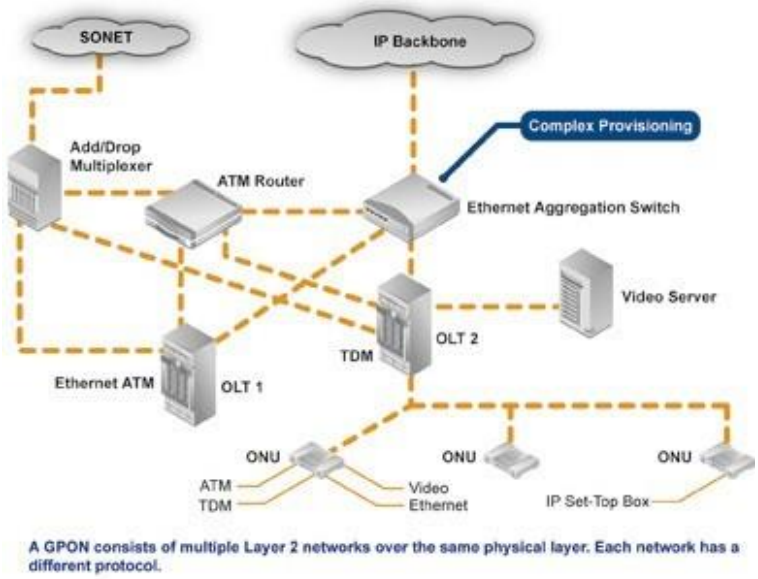
Due to its near-ubiquity in network deployments, the remainder of this section will focus on the variations that exist within PON architectures, exploring the different deployments in common usage within Canada and other jurisdictions.

2.1 GPON

In terms of technical standards, GPON is known as ITU-T G.984 Gigabit-capable Passive Optical Networks. GPON evolved at the International Telecommunications Union (ITU) from origins that were rooted in the Asynchronous Transfer Mode (ATM) PON standard G.984 (APON), which later evolved to broadband PON (BPON). In terms of bit rates offered using GPON, there are different options available, but the

industry has moved towards rates of 2.488 Gbps in the downstream direction, and 1.244 Gbps in the upstream direction. GPON is the technology of choice for many telecommunications-based companies. In the U.S. for example, Verizon utilizes GPON for its FTTP deployments.

Figure 5 - GPON Layer 2 Networks Diagram



One of the principal differentiators in a GPON architecture is how it actually deals with the transmission of the different types of data. GPON provides for virtual circuits to deliver different services to different locations. These are known as VLANs, and certain makes and models of OLTs can support thousands of VLANs. This feature was a key factor in GPON widespread adoption by telecom companies, as it was more readily adapted and integrated into their existing networks for delivering different services.

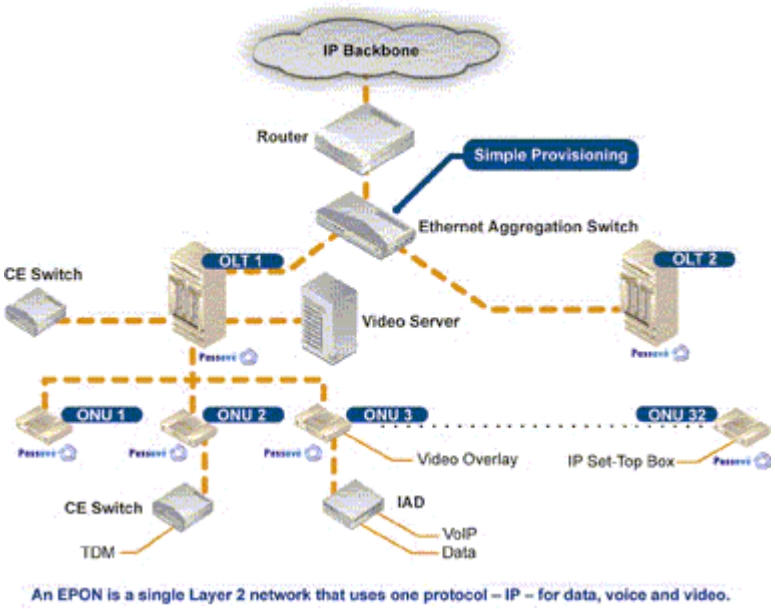
In terms of evolution of GPON, ITU-T G.987 has now defined a 10G-PON, which would increase the downstream speeds to 10 Gbps and upstream speeds to 2.5 Gbps. This evolution may be supported by existing devices within the GPON network, and therefore provides an upgrade path for carriers using GPON architectures.

2.2 EPON

The second main deployment class of PONs is Ethernet Passive Optical Networks (EPON). With respect to the standards, EPON is known as IEEE 802.3ah. While there has been debate over which of the two PON schemes is the 'best', they both provide

the same networking features. That is, EPON, like GPON, consists of an OLT, passive splitters, and the ONT. With respect to the bandwidth offered in an EPON architecture, the most common speed is a 1Gbps downstream and upstream speed (symmetrical). However, just as with GPON, developments are already underway for what is known as 10G-EPON, ratified as IEEE 802.3av. As the name implies, this new standard promises to deliver 10Gbps Ethernet based speeds. As EPON is based purely on Ethernet protocols, all services delivered over an EPON are purely IP/Ethernet based. This EPON feature in turn, generates key efficiencies, most notably the lack of 'translations' that data goes through, since most end-user equipment is natively Ethernet-based.

Figure 6 - Architectural view of EPON



While GPON has most noticeably been adopted by Telecom-based carriers, it would appear that many of the EPON deployments are coming from cable-based operators. This can be attributed in large part to the specification known as Data over Cable Service Interface Specification (DOCSIS) Provisioning of Ethernet Passive Optical Network, or DPoE. This specification allows for cable operators to continue using their well-understood DOCSIS back office provisioning systems with the newer EPON architecture.

As is the case with GPON, EPON also allows for the creation of multiple VLANs.

It is worth noting that this option to create VLANs within PONs may be the key to the provision of certain classes of new wholesale services to be offered over

PONs, and to ultimately deliver 'virtual FTTP' services to wholesale competitors.

2.3 WDM-PON

While the first two technologies (EPON and GPON) constitute the bulk of FTTP deployments globally to date, there does exist another technically-feasible PON solution that might provide an alternative to these two implementations - particularly in a 'greenfield' (new residential development areas) setting. Wavelength division multiplexing PON (or WDM-PON) is a technology-based implementation of a point-to-multipoint PON in which every end-user is provisioned a dedicated wavelength between the central office and the end point. While numerous equipment vendors are actively marketing the technology, there are no agreed-upon standards driving this development, and thus far there are no known commercial deployments.

In theory, with WDM-PON, there is enhanced security, as the system no longer relies on a secured point-to-multipoint implementation where the data is encrypted but visible on the line to all ONTs. Instead, the fact that individual wavelengths are available means that each ONT would be completely independent, and have its own direct optical path to the OLT. Another claimed improvement with WDM-PON is that distances between ONT and OLTs can be increased, allowing this type of system to be deployed in areas where the distances between central offices and end-users is greater than the current xDSL deployments allow.

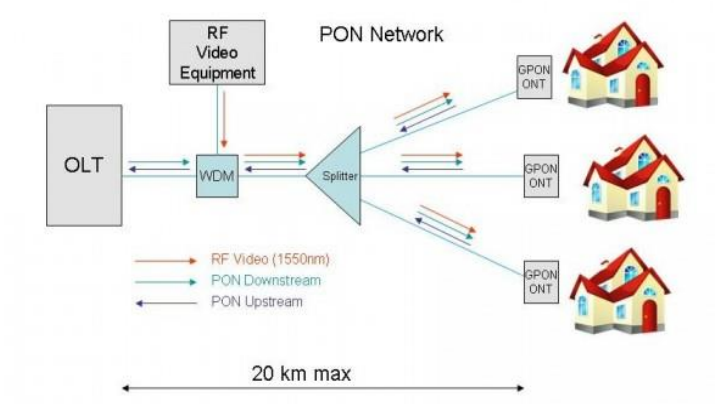
From a wholesale perspective, the benefit of a WDM-PON implementation could mean that once deployed, competitors could in theory, be provided on individual, separate wavelengths by operators, on which they could provide whichever mix of services they would like, without any of the data traffic crossing onto the other provider's network and thus be subject to traffic shaping. However, as this is non-standard technology at this time, and there are no commercially proved systems in operation, it is unlikely that this technology will prevail in the coming year. Furthermore, companies that have already deployed GPON or EPON are more likely to evolve towards 10G-PON or 10G-EPON rather than install yet another technology into their access networks.

In the future, should WDM-PON become more accepted, this technology could also be used to provide both retail and wholesale services.

2.4 RFoG

Radio-Frequency over Glass, or RFoG, is a technology employed by cable operators to allow fibre-optic equipment to be provided deeper into their networks in order to serve their customers next-generation services, as well as to offer these providers an upgrade path from their existing HFC systems to a pure fibre-optic PON system such as those described in the preceding two sub-sections. The primary use of RFoG systems is to allow the cable operators to continue to operate the same RF-based video distribution networks that they currently use, and take advantage of the additional wavelength usage in a PON architecture to deliver that video signal, as illustrated in Figure 7.

Figure 7 - RF injection into PON Network



Standards are currently in place for RFoG from the Society of Telecommunications Engineers (SCTE), which are also in the process of being approved by the American National Standard Institute (ANSI).

The key to RFoG solutions is the provision of CPE to allow the technology to be deployed commercially. ARRIS, a well-known equipment provider in the cable industry, is one such provider of the CPE that would be required. Figure 8 is an image of what is known as an RFoG ONU. This piece of equipment would be placed at a customers' home, and allows the optical signal to be split into separate RF (television-type) signals, and pure data signals.

From a network operator's perspective, the best part of the RFoG system is that it allows migration to a pure fibre network architecture without stranding the existing investments it has made in its HFC infrastructure. In a sense, RFoG becomes the ultimate 'node splitting' strategy, as the RFoG ONU is essentially a micro-node from the network's viewpoint.

Figure 8 - RFoG ONU from ARRIS

As with other PON technologies already discussed, RFoG ONUs could also be used in the wholesale context, as a competitor could simply make use of the Ethernet port from the ONU, while BDU services could still be delivered via the coaxial connections.

2.5 Non-Optical Solutions

In the sections above we have explored the technologies that are principally used for FTTP architectures. However, in the course of our research, it became evident that there are other technical solutions available to some operators that help them offer increased speeds to customers. Specifically, equipment vendors that have developed DSL technologies are particularly interested in protecting their business. As a result, technologies such as DSL Rings and VDSL 2+ with vectoring are being developed which may extend the useful life of the copper-based final access point.

This is relevant to the discussion of the technical market because it raises the question as to whether or not carriers will actually be deploying FTTP systems in the short-to-medium term. Research indicates that while most carriers are deploying some form of FTTP systems within their networks, they are doing so within specific criteria and only in limited deployments at this time. The principal reason for this is cost, as well as the accounting advantage of capturing more of the costs related to depreciating the residual value of the assets that they have already deployed.

When entering new markets where equipment has not yet been deployed (also known as greenfield markets), carriers are most likely to deploy FTTP systems. When there is no legacy infrastructure in place, the costs of deploying fibre-optic access

networks is not much different from a copper-based local loop, and can deliver more and better services than is possible using older copper technologies. However, where equipment has already been deployed (also known as brownfield markets), the decision criteria are more complicated, resulting in an opportunity for other technologies to be considered by carriers to deliver higher speed services.

Figure 9 below illustrates the possibilities that exist using newer technologies that take advantage of existing copper local loops and/or co-axial cable deployments.

Figure 9 - Speeds possible with legacy technologies

TECHNOLOGY	Deployed?	Theoretical Speed	Practical Speed
VDSL2	Yes	200 Mbps	20-80 Mbps
DSL with Vectoring	Trials	500 Mbps+	Unknown
DSL Rings	Trials	400 Mbps	Unknown
DOCSIS 3.0	Yes	Depends on # of channels	150-300 Mbps
DOCSIS 3.1	No	Up to 10Gbps	Unknown

While these new technologies will not be explored further in this report, it is worth noting that existing wholesale regimes would apply to these technologies, as they fall under the current regulations with respect to services being offered under the speed-matching decisions previously issued by the Commission. Put another way, investment decisions on which technology to deploy could depend partly on regulatory obligations, but in the opinion of this author, from a technical perspective, it would seem that whether or not a carrier chooses to deploy FTTP is more a function of the market, competitive pressures, and the existing infrastructure in place, rather than on regulatory constraints. Regardless of any regulatory obligations, investments will need to be made in the network in order for a carrier to evolve its service offerings.

3. Interrogatory Submissions

As part of the process set out by the CRTC, interrogatories were submitted to all of the incumbent cable and telecom carriers in Canada to gather data. This data will be used to inform the Commission and the participants in the proceeding to help them prepare their submissions and appearances at the eventual public hearing.

The final three questions (the '200 series' interrogs) were of particular use to this report, as they explored the nature of the access facilities being used by the incumbents to deliver services such as the broadband Internet services, IPTV services, and VoIP services. These questions also directly explored areas such as the technical architecture being employed to deliver these services, as well as a pointed question regarding the provision of FTTP. The questions most relevant to the analysis being carried out in this report have been reproduced below, and the responses will be examined in greater depth in the following sections:

> *201. With respect to the technologies the company is currently deploying in its network to support the provisioning of services that use broadband access:*
>
> > *a) Identify the major network technologies (e.g. Fibre to the node (FTTN), DOCSIS 3.0, Fibre to the premises (FTTP), etc.) deployed to support services that use broadband access and identify the retail services (e.g. Internet, IPTV, Video on Demand) provided and the range of upstream and downstream bandwidth requirements for each service.*
>
> *202. With respect to the technologies the company is planning to deploy in its network to support provisioning of services that use broadband access:*
>
> > *a) Identify the major technologies and/or technology upgrades planned to be deployed from 2014 to 2016 to support services using broadband access including high speed Internet access. Describe how each of these technologies will impact the high speed upstream and downstream bandwidth capability per end-user; and if the bandwidth is shared by a community of end-users, specify the average number of end-users per community.*
> >
> > *b) For the technologies identified in response to part a) above, identify other services planned to be offered over these technologies and the*

associated range of upstream and downstream bandwidth requirements. To the extent that TV distribution services are to be offered, indicate whether the services will be delivered as unicast, multicast, or broadcast.

c) For each technology identified in response to part a) above, provide schematic diagrams and identify the major components used. Further provide a description of each major component including its functions.

g) For each technology identified in response to part a) above, identify the criteria used to assess whether or not to implement the technology in the market, including provisioning guidelines, construction costs, services, revenues, competitive threat, and take-rate considerations. Explain whether and how the above criteria will be different for markets of different sizes.

203. In the event that the company currently deploys fibre to the premises (FTTP) in a serving area, (e.g. neighbourhood, community, business park, city):

a) Indicate whether the company will continue to provide retail and/or wholesale services over the existing access infrastructure (for ILECs, copper access, including fibre to the node (FTTN); for cable carriers, hybrid fibre coax access) in that serving area with supporting rationale. If yes, provide the company's plans to deliver services on both technologies.

b) Describe, with supporting rationale, how the company's FTTP architecture could be unbundled to provide a wholesale high-speed access service to competitors. The response should indicate the entry point(s) in the architecture where the competitor could gain access to support its end-users and specify any equipment limitations that could impact the type of wholesale service that could be provided.

3.1 Responses regarding architecture and technologies

The key input to this report from the interrogatories was the depiction – in varying levels of detail - of the technologies being used by the incumbents to provide their services on both a retail and wholesale basis. To those ends, respondents were quite helpful at providing schematics of their networks providing services. In particular,

there were a number of very helpful diagrams illustrating exactly which parts of the network existed where. This sort of information was useful for postulating the possible ability to create a wholesale FTTP product.

Cable Companies

For the most part, cable companies continue to provision their services using an HFC system. With this technology, they are utilizing DOCSIS 3.0 to provision broadband Internet services, capable of end-user speeds of up to 250Mbps in the downstream direction.

Three of the four Cable-based incumbents (Rogers Communications Partnership (Rogers), Shaw Cablesystems G.P. (Shaw), and Cogeco cable Inc. (Cogeco) alluded to limited FTTP deployments to date. Their focus remains on node splitting to achieve higher speeds to end-customers without the need to deploy a full FTTP solution. Videotron G.P. (Videotron), the fourth provider, stated that it has no intention of deploying FTTP, and is fully focused on the node-splitting exercise. Videotron makes mention of a 'pilot program' in one response, but does not provide clarity on whether this would be RFoG, EPON, or something else.

Figure 10 – COGECO Diagram Illustrating network used to provision services

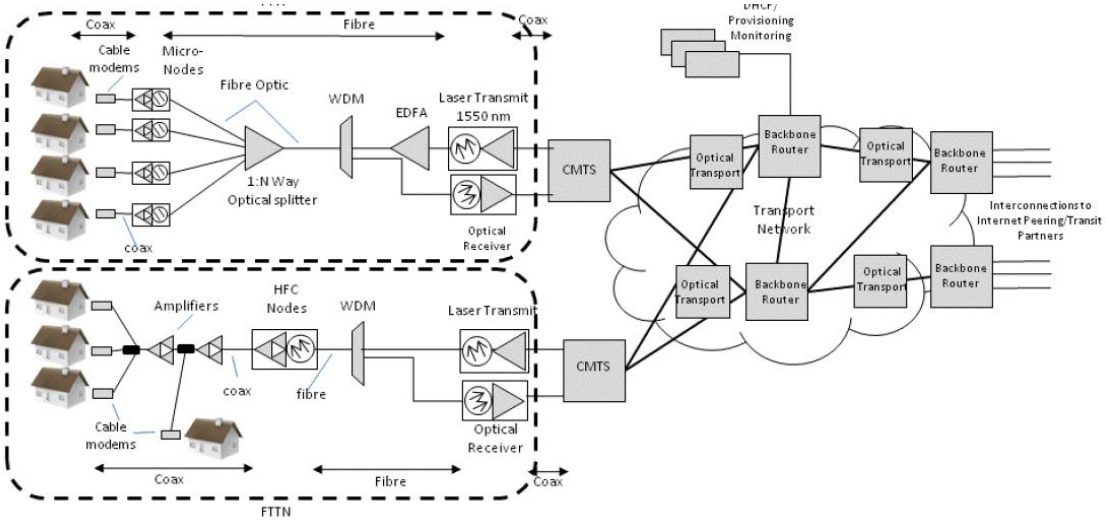
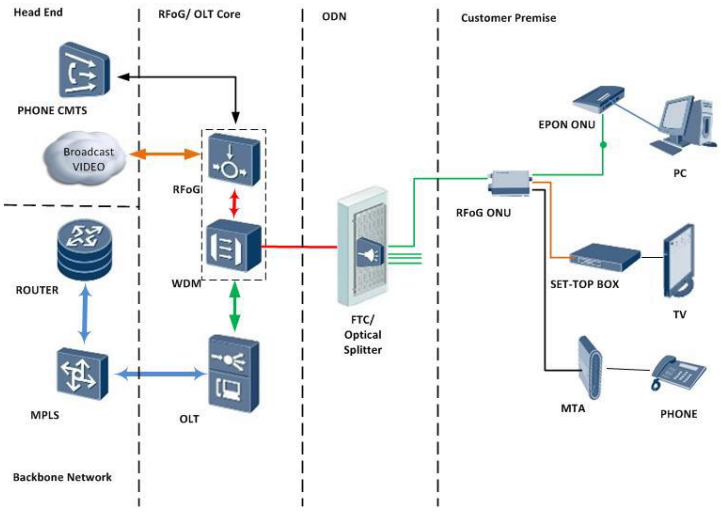


Figure 10 above is a good representation of what the various architectures deployed by the cable operators look like. In this figure, they label 'FTTP' in the top box and

'FTTN' in the bottom box. FTTN represents the current architecture used for the majority of Internet access connections in cable networks, including the provision of wholesale Third Party Internet Access (TPIA) services.

The principal difference between FTTP and FTTN in this diagram is the additional fibre-optics present deeper in the access networks, and the introduction of the 1:N Way Optical splitter (which is also present in the other architectures presented by incumbent telecom[2] companies. For additional clarity surrounding the provision of both television and Internet services on the cable companies' architecture, Shaw presented the following diagram (Figure 11).

Figure 11 – Shaw diagram illustrating its FTTP solution



Worth noting in this diagram is the usage of RFoG by Shaw. The other cable respondents did not provide this level of detail, so it is not clear if they are adopting the same approach for the delivery of their television signals. However, given the inherent benefit of using RFoG (namely support for both HFC and PON downstream

[2] By incumbent telecom companies or telecom companies we mean incumbent local exchange carriers, large and small.

from the head-end), as discussed above in Section 2.4, it would be a logical assumption that they are all at least examining this approach.

With respect to the specific PON solutions chosen by cable companies, the majority of submissions did not specify the nature of their PON systems. Shaw, as the exception to this, was clear that it was using an EPON system. This is consistent with the previous research that seems to indicate that cable carriers tend to gravitate to an EPON system.

Incumbent Telecom Companies

Incumbent Telecom companies appear to be actively pursuing FTTP solutions in order to respond to the perceived competitive threat posed to them by the cable carriers, who are deploying ever-larger broadband packages over their existing architectures. All of the telecom carriers responded that they were indeed using FTTP deployments in some areas of their network. The majority of respondents also provided some level of technical diagrams to explain the configurations of their networks.

In terms of the speeds of the offerings by the telcos[3], they appear to be striving to meet the competitive threats of cable rivals by offering speeds of up to 275Mbps (MTS Inc. and Allstream Inc. (MTS Allstream)), with averages around 50Mbps. Bell Aliant Regional Communications, Limited Partnership (Bell Aliant) and Bell Canada (collectively Bell companies)[4] claimed that the speeds they offer on FTTP is confidential information, but do note that IPTV is only sold when packaged with high speed Internet access. The Bell companies have previously claimed that they cannot separate their high-speed Internet access services from their IPTV services. In general, incumbent telecom carriers would appear to not wish to offer wholesale access that is purely data in a manner that could result in loss of revenue from their broadcasting subscriptions provided using IPTV technology.

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[3] Meaning the incumbent telecom companies.
[4] References to the Bell companies refer to the operations of those companies in Ontario and Quebec, whereas references to Bell Aliant on its own generally refers to the operations of Bell Aliant on its own unless otherwise noted.

While most telecom carriers did not wish to fully disclose the number of homes passed by their FTTP deployments, it would appear that Bell Aliant (primarily due to its deployments in the Maritimes) is the furthest ahead in terms of deployment, citing that by the end of 2013, it expects to have over 800,000 households passed by FTTP facilities[5]. MTS Allstream only released information up to 2008 publicly, and at that time had passed a total of over 350,000 homes. The Bell companies only stated that their IPTV service is available to 4.1million households. However, this service is available over both their FTTN *and* FTTP platforms, so it is not possible to see how many homes are actually served using FTTP.

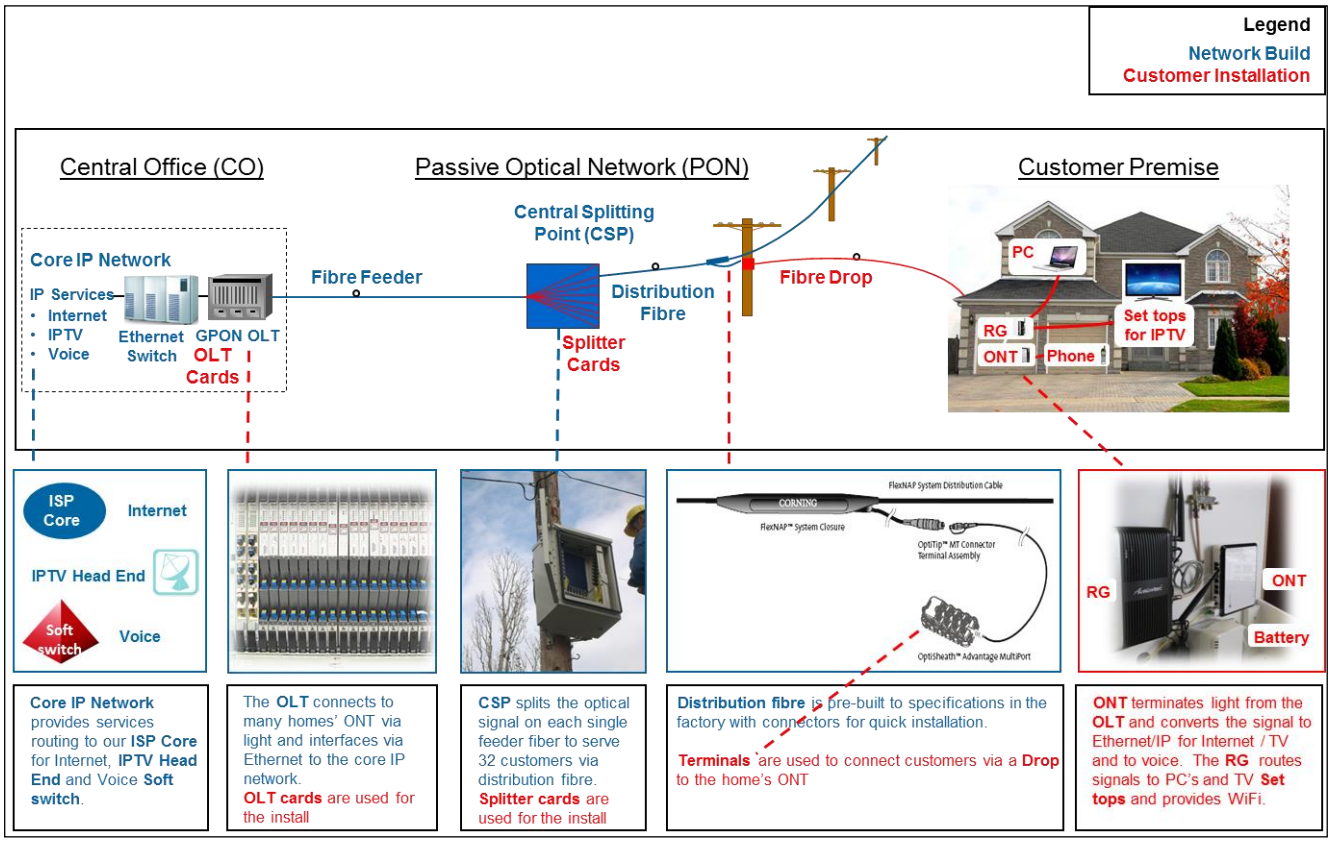
Beyond simply sharing the speeds offered on their FTTP platforms, some telcos were forthcoming about the actual provisioning of their PON networks with respect to the overall bandwidth, and number of end-users. Saskatchewan Telecommunications (Sasktel) and Bell Aliant together with Télébec Ltée[6] (Bell Aliant/ Télébec) confirmed that there is 2.48 Gbps of downstream capacity, and 1.24 Gbps of upstream capacity in the PON system. Sasktel shared that the average number of connected services is 28 per PON. Bell Aliant/ Télébec stated that the maximum number of users per PON is 32. These numbers are consistent with Nordicity's secondary research sources cited above.

In terms of the actual architecture and components in the system, Bell Aliant provided a helpful diagram in its response to Interrogatory 202(c)[7]. This image is reproduced below in Figure 12. The differently coloured text also helps to understand which components of the system are attributed to the general network build as compared to connecting customers upon receiving a service order. **Accordingly, when building out a PON in a neighbourhood, Bell Aliant, at least, deploys all the necessary fibre and core equipment at the outset. As customers sign up, Bell Aliant will add an OLT card, the fibre drop, the ONT, splitter card (if needed), and any in-house CPE.** Bell Canada submitted a similar image, without explicitly indicating that it follows the same procedure, but logically, it appears the

[5] For full response, see *Interrog response Bell Aliant/Télébec(CRTC)15Oct13-201 TNC 2013-551*, specifically part c.
[6] Which operates in portions of Quebec.
[7] Bell Aliant/Télébec(CRTC)15Oct13-202 TNC 2013-551.

procedure would be the same as that of Bell Aliant. It remains to be seen if other incumbent telecom companies also take this approach.

Figure 12 - Bell Aliant diagram of FTTP architecture



3.2 Responses regarding feasibility of providing wholesale FTTP

As part of the interrogatory process, the Commission also chose to ask a very pointed question with respect to what carriers would do with both their legacy equipment once they deploy a next generation PON architecture, and also asked the carriers to speculate on *how* a wholesale FTTP service could be offered. The carriers were clearly uncomfortable with responding to this question, but a few of them nonetheless did comply and provided useful input to this process.

Treatment of existing facilities

With respect to the first question regarding treatment of existing facilities that are being displaced by newer technologies, the majority of companies indicated that they would continue to offer both retail and wholesale services on their existing equipment in regions that are upgraded to FTTP technologies. However, a second message that permeated responses was the fact that this issue is more of a short-term answer, as most respondents indicated that in the long run, where dual facilities exist, they would embark on a campaign to migrate users to the FTTP architecture. Cable companies in particular were more definitive, with Shaw indicating that while it does not currently deploy FTTP anywhere where HFC exists:

> *"If Shaw were to replace any HFC facilities with FTTP we expect the HFC facilities would be removed or abandoned."*

It is the author's opinion that this practice would very likely become the norm for all players eventually, due to the higher costs associated with maintaining two separate infrastructures.

Feasibility of providing wholesale FTTP

The most contentious question centered on how a company's FTTP architecture could be "*unbundled*" to provide a wholesale service to competitors. The word unbundled was the Commissions own word. TELUS Communications Company (Telus), declined to answer the question at all citing opposition to the very notion, and has not considered how a wholesale service could be provided at all. Rogers claimed confidentiality, Cogeco did not answer the question, and Videotron indicated it had no plans to provide services using FTTP.

However, several other carriers provided valuable insights. Shaw, a cable operator, offered this answer:

> *"…our preliminary assessment suggests that it is technically feasible that TPIA could be provided over our FTTP facilities using EPON if an Internet Gateway device is installed within each FTTP location. The Internet Gateway would provide TPIA ISPs with access to a dedicated Ethernet port within the premise. We believe this could facilitate ISP access to Shaw Internet services in a manner similar to DOCSIS specification speeds currently available over our HFC network."*

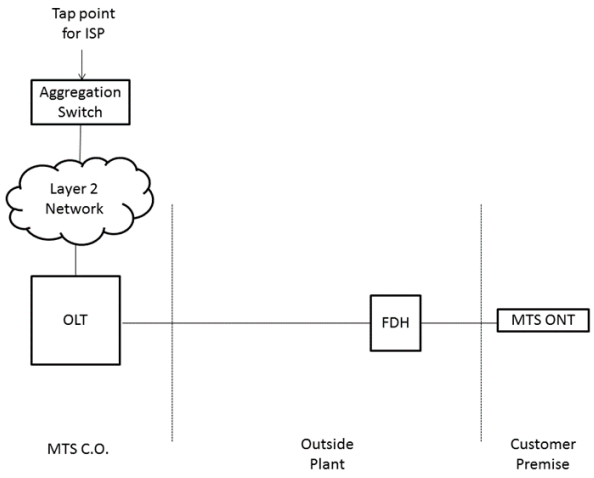
This response appears to be consistent with the research and findings outlined in Section 0 above. Specifically, by using the DPoE specifications, there would essentially be no difference in provisioning this wholesale service to end-customers, as the back-office provisioning is exactly the same from their perspective. This solution is perhaps the simplest implementation of any FTTP solution on a wholesale basis, but really would only apply to cable operators who are using an EPON solution.

Several telecom carriers offered responses to the question, with varying degrees of specificity. MTS Allstream provided a thorough explanation of one possible way to offer wholesale FTTP:

> *"MTS could unbundle its FTTP service by providing an Ethernet aggregation point with a layer 2 path between a wholesale internet service provider (ISP) and its end users. This is a similar architecture to MTS' VDSL Data Access Service (VDAS).*
>
> *While technically feasible, there are certain limitations associated with this option. A major limitation is that, at this point in time in Gigabit passive optical network (GPON) technology evolution,* ***the industry has no standard interoperability requirements for Optical Network Terminals (ONTs) and an ONT from one vendor will not work with an Optical Line Terminal (OLT) from another vendor.*** *Given this, MTS would be required to provide the ONT to the wholesale ISP. As a result, the demarcation point between MTS and the wholesale ISP would be different from the demarcation for VDAS. Moreover, MTS would be required to monitor and maintain the ONT (alarming, battery backup, etc.) on an ongoing basis, to ensure that it continues to be compatible with the network as upgrades are introduced. Such an approach differs from MTS' VDAS, where the wholesale ISP provides their own CPE equipment and is responsible for monitoring and maintaining it.*
>
> *MTS' FTTP architecture involves one passive optical network (PON) fibre splitting between up to 32 end users, with bandwidth sharing to deal with congestion from higher speed services. As a result this option could result in capacity sharing between MTS end users and the end users of one or more wholesale ISPs. Because of the broadcast nature of PONs this could have potential operational and/or security implications."* (Emphasis added.)

In addition to the text response, MTS Allstream also provided the following diagram to illustrate this approach:

Figure 13 - MTS Allstream proposed approach to wholesale FTTP



Examining the MTS Allstream answer, the first part, which discusses the VDAS, and a layer 2 path and an Ethernet access point, is consistent with the research findings indicating that GPON architectures are capable of offering multiple VLANs on a PON. These VLANs constitute exactly the layer 2 path to which MTS Allstream is referring. On the second point, regarding the point that MTS Allstream would need to provide and manage the ONT for the competitor, the current research also appears to support this notion at the present time. As the ONT is essentially part of the core networking equipment of the carrier, there is limited interoperability between different vendors' products at this time.

Depending on the ONT used by a carrier, there may also be a separate gateway (generally a router) in the end-users home. This piece of CPE could easily be provisioned by the wholesale provider on its own.

With respect to the final comment regarding potential security issues, this is one area which may not be a problem, as GPON systems generally use the

Advanced Encryption Standard (AES) on all the ONTs and OLTs, meaning that regardless of the VLAN configurations, there should not be any risk of traffic going to the wrong user. Furthermore, VLANs by their very nature, exist to help segment networks and offer enhanced security, so in effect, their use should actually serve to increase the security of the traffic.

In the Sasktel response, the same argument is made regarding the ONT located at a customers' end location. Sasktel stated that due to interoperability issues experienced with pairing the ONTs located at the customer premise and the OLT located in a SaskTel wire center, SaskTel would have to be responsible for installing and managing the end-user ONT. The ONT installed would have two RJ11 voice terminal ports used for voice services and four RJ45 Ethernet terminal ports designated for the demarcation of competitor high speed service.

Besides the ONT issue, Sasktel simply states that to provision a wholesale FTTP service, the company would aggregate end user accesses at a Competitor Ethernet FTTP High Speed interface (HSI) located in a designated SaskTel wire centre. **This explanation is very similar to the way in which the current GAS and HSA services are provisioned by telecom carriers, and therefore implies there is no significant technical issue that could not be overcome.**

The Bell companies and Bell Aliant / Télébec both responded in a similar fashion to the question, with both submissions essentially confirming the technical feasibility of offering wholesale FTTP services. **The author notes that, unlike in the case of FTTN, it is interesting that there were no claims of IPTV causing any technical difficulty in offering these services.**

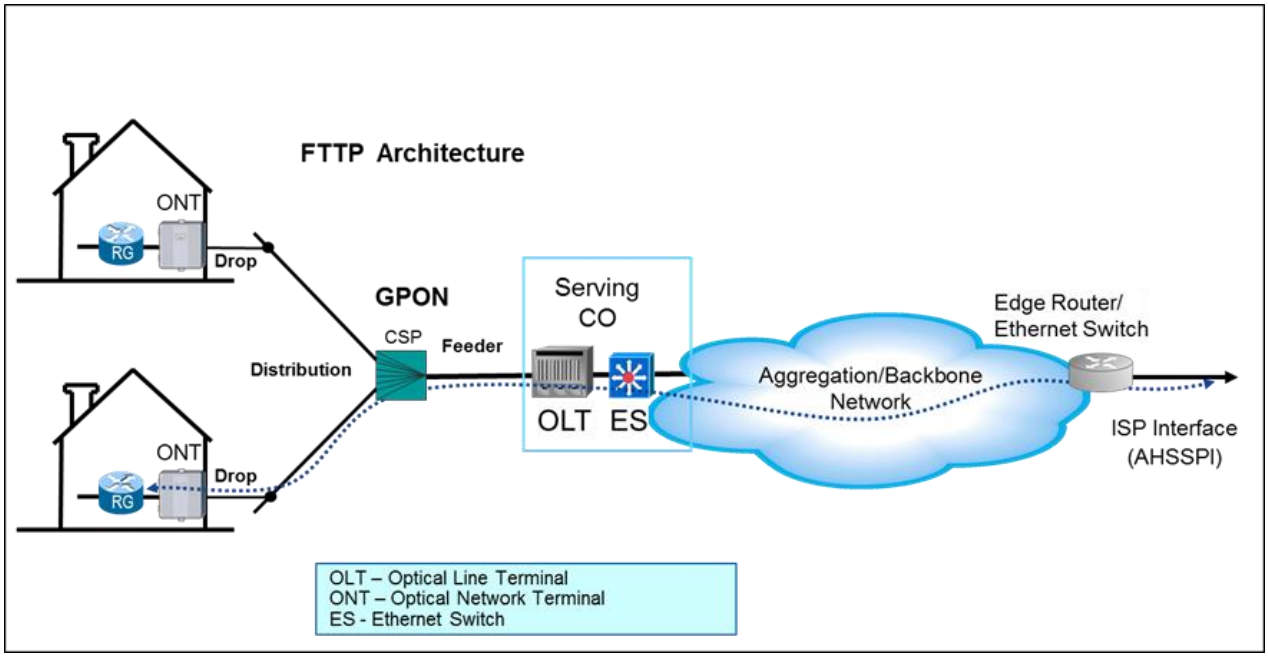
In response to the question, both the Bell Companies and the Bell Aliant / Télébec submissions state the following:

> *"Although more analysis would be required to confirm all the technical aspects, providing wholesale access to the FTTP infrastructure in a way similar to the way the Company offers its Gateway Access Service appears possible. As shown in the diagram below, an unbundled FTTP service could start at the customer premises and end at the ISP interface also known as the Aggregated High Speed Service Provider Interface (AHSSPI). The cost and timing associated with implementing such a*

wholesale service has not been sized and would require a technical design, new network elements (e.g. tunnel switches, routers), service development and testing."

The diagram they are referring to is reproduced below as Figure 14.

Figure 14 – The Bell Companies' and Bell Aliant / Télébec diagram for wholesale FTTP



While both the Bell companies and Sasktel share a similar discussion regarding how they can provide a wholesale FTTP service, they are not clear on specifically how this would be provided. While MTS Allstream alludes to the use of VLANs and layer 2 networking, the other companies do not state whether they would provide the service through the use of the Broadband Remote Access server (BRAS), or through a different router that would provide a layer 2 tunnel to the AHSSPI point. In the Bell Companies' response, they allude to the need for 'tunnel switches', which could logically be referring to the equipment needed to direct the VLAN traffic, in which case the service being provided is similar to the proposal by MTS Allstream.

Now that we have examined both the technologies used to provision the services and the views of the Canadian carriers on the associated issues, we can turn our focus to some of the findings from the technical application of regulatory frameworks in other best-practice jurisdictions and the feasibility of implementing such a wholesale FTTP service in the Canadian market.

4. International Deployments / Best Practices

In addition to researching the technology background and possibilities, Nordicity also investigated what best practices and deployments were being undertaken in other jurisdictions. The bulk of this research was intended to ascertain whether the issue of multiple parties sharing the same physical infrastructure had been examined and/or implemented in other parts of the world. In particular, the European Commission (EC) guidelines surrounding regulated access to next generation access (NGA) networks was a helpful guiding principle by which to examine the European context[8]. In addition, a closer look at the Australian National Broadband Network (NBN) was useful for two reasons: because a third party operates the infrastructure, and multiple carriers are able to offer services over it.

There were two main service branches that made sense to investigate further. The first is the so-called bitstream-type access. This type of service is the closest to the current Canadian wholesale high-speed Internet access regime. With bitstream access, the facilities-based operator provides the data access between the end customer and the competitor using the operator's facilities. The service is then handed off at one of a number of possible access points. With DSL-type services, this could be at the DSLAM, at an ATM-POP, or handed off at the IP layer. This is most similar to the GAS or TPIA models where the incumbents provision the actual service, and hand it off at the IP layer to competitors. Bitstream access is quite common in Europe.

The second type of access is generally referred to as Local Loop Unbundling. In addition to providing a bitstream-type access, most providers (specifically telecom operators) have been required to provide unbundled local copper loops. This resulted from the need to allow competitors to have access to the local loops in order to provide competitive local phone services. Over time, the use of these unbundled loops also led to the provision of high-speed Internet access services like ADSL where there was a significant number of customers, making it attractive for a competitor to build its own access facilities and use the unbundled local loops.

[8] For full details on the EC approach, see http://europa.eu/rapid/press-release_MEMO-10-424_en.htm

However, with increased fibre penetration in the access portion of networks, the utility of unbundled local loops became less clear. As a response to this problem, regulators have sought new unbundling regimes to ensure continued access to facilities by competitors. In this search, they realized that, due to the nature of the physical architecture being used in PON deployments, it was not feasible to recreate the unbundled local loop as it had been with the one-to-one nature of copper strands. As a result, a new concept was introduced, known as Virtual Unbundled Loop Access (or VULA). The development of these services arose specifically as a response to the EC recommendations regarding NGA[9]. Below we will examine these two ideas further as it pertains to FTTP networks.

4.1 Bitstream-type access

As early as 2009, Australia examined the question of wholesale access to its fibre-based architecture associated with the next-generation broadband initiative (NBN), which was to be operated as a structurally separate entity from any operators. As such, Australia had complete technical freedom to explore all available options without the considerable arguments present when discussing the creation of such services with incumbent operators. One particular paper was very helpful in discussing the bitstream-access services. This was known as: *NBN Co Consultation Paper: Proposed Wholesale Fibre Bitstream Products*[10]. The research and analysis in this study focus on the two main services that can be offered over GPON architectures. These are called *Local Ethernet Bitstream* (LEB) and *Aggregated Ethernet Bitstream* (AEB). Both of these services would be delivered as Ethernet products using a GPON architecture. The paper also points out that the technology will deliver a range of service features including security and Quality of Service (QoS), as well as IP multicast. Furthermore, the paper clearly states that wholesale products will support

[9] Full text of recommendations: https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&ved=0CD4QFjAC&url=http%3A%2F%2Feur-lex.europa.eu%2FLexUriServ%2F%2520LexUriServ.do%3Furi%3DOJ%3AL%3A2010%3A251%3A0035%3A0048%3AEN%3APDF&ei=oYHBUobeCOTe2AW9m4DoCQ&usg=AFQjCNFm3YMyuH1-v_N1ztPqB0LanWXwdw&sig2=u2xragPgzzwD-RrjxTWfDg&bvm=bv.58187178,d.b2I

[10] Full report can be found at: http://www.nbnco.com.au/assets/documents/nbn001-concept-paper-final-dec-09.pdf

access by multiple ISPs, a range of customer premises equipment (CPE) and will include an interface for analogue telephony.

The principal difference between local and aggregated Ethernet bitstream is the location where a service provider can interconnect to the network for the purpose of picking up its customer's traffic. With LEB, a provider can connect at a local Point of Interconnect (POI), which would be present in larger population centres. In AEB, the premise (which is more suitable to rural areas), is that where there is no competitive provision of backhaul, transport to another POI would be included on the national broadband network (NBN).

It is interesting to note that the services contemplated here are associated with Layer 2 connectivity (also known as the link layer in the OSI model), rather than Layer 3 connectivity (known as the network (IP) layer). Layer 3 services would be more recognized as a pure 'reseller' model, whereas Layer 2 lends itself to a model where the competitive service providers can create their own differentiated competitive offerings. As will be shown, Layer 2 services are essentially the same model being contemplated for all NGA models. Layer 2 most closely aligns itself with stated regulatory objectives globally for offering competitive differentiation, and ability to innovate, both of which have been stated goals of the CRTCs actions thus far, and a key aspect of their analysis of the market.

A key focus of the Australia NBN study was the analysis of the technical feasibility of various service layer options in comparison to the different objectives that are desirable in a wholesale services market. The diagram has been replicated below in Figure 15[11]. As can be seen, Layer 2 services, such as those contemplated for the Australian NBN, offer the best mix of options. Layer 1 services as shown in the diagram relate to so-called 'dark fibre' services, which would equate to a completely unbundled fibre option. These services are not practical in FTTP network deployments, as carriers are generally only deploying a single fibre to each end-customer premises. The exception to this would be if a carrier were to deploy WDM-PON, but as discussed in Section WDM-PON2.3, this is not likely scenario in the near- to

[11] Full report can be found at: http://www.nbnco.com.au/assets/documents/nbn001-concept-paper-final-dec-09.pdf

mid-term. As a result, these types of Layer 1 services are more suitable for large-scale transport and back-haul needs.

Figure 15 - Comparison of Service Layer Options

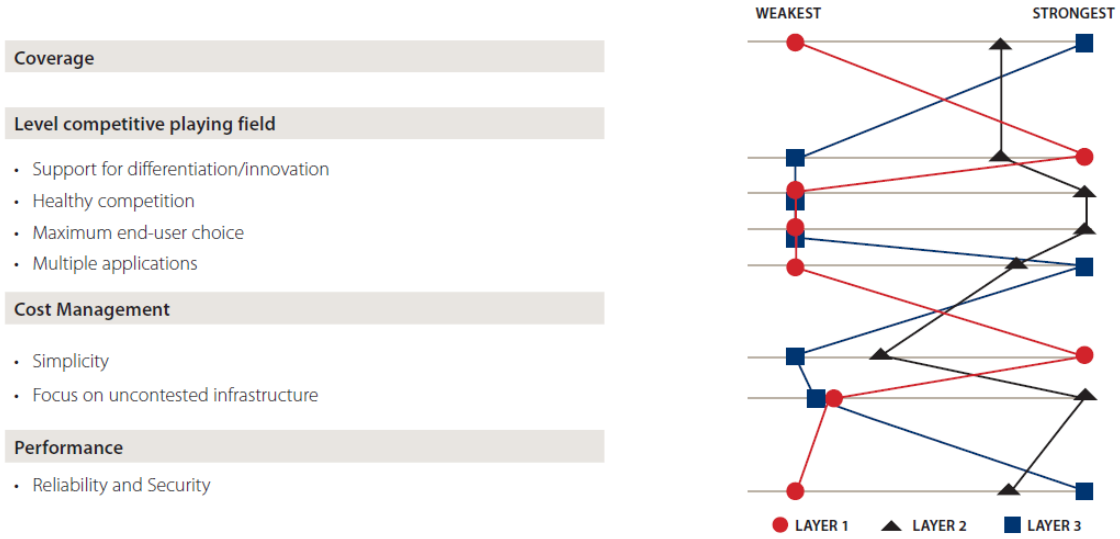
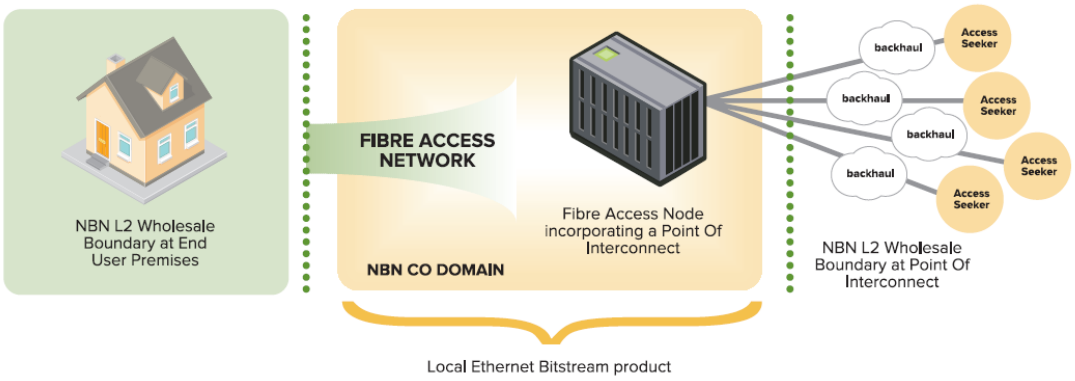


Figure 1Figure 16 below illustrates the concept behind the LEB product offering. Although the diagram is highly simplified, it nonetheless shares many similarities with the services already envisioned above for the provision of wholesale services in the Canadian market. Thus, it illustrates clearly the feasibility of offering such services.

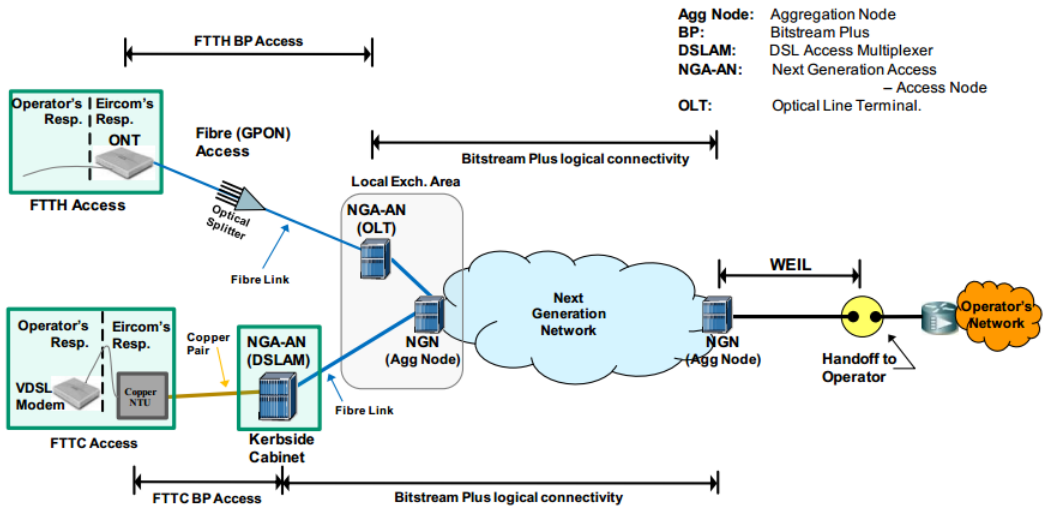
Figure 16 - Australia NBN Local Ethernet Bitstream Product



Another provider which examined the role of bitstream access in their networks was Eircom[12], the Irish incumbent telco operator. As with the NBN model, all the services contemplated in the bitstream access portfolio consist of Layer 2 services. Whereas the Australian plan for a NBN was not completely clear on the delivery of the services, and who would have responsibility for equipment, Eircom provided clear diagrams on the offerings. Figure 17 below describes the components that are clearly part of the bitstream access service. The assumptions underpinning this diagram are closely aligned with both the technical research conducted by Nordicity, as well as the interrogatory responses furnished by the service providers in the CRTC proceeding. In response to concerns regarding ONT ownership, Eircom notes that it would be responsible for the ONT. Furthermore, Eircom, in the documentation, states that with the bitstream services, it would be able to offer not only unicast, but multicast services as well.

[12] For full details of their NGA developments, including product descriptions, see http://www.nextgenerationaccess.ie/

Figure 17 - Eircom Bitstream Access Plus diagram



With respect to the ability to monitor usage, Eircom also notes that it undertakes capacity-based billing based on the 95th percentile bandwidth measurement. The implication is that existing billing systems should be relatively adaptable to accommodate any new wholesale services introduced through FTTP. Lastly, it is worth noting that the Eircom services explored also make use of Virtual Private LAN Services (VPLS), as was discussed in previous sections.

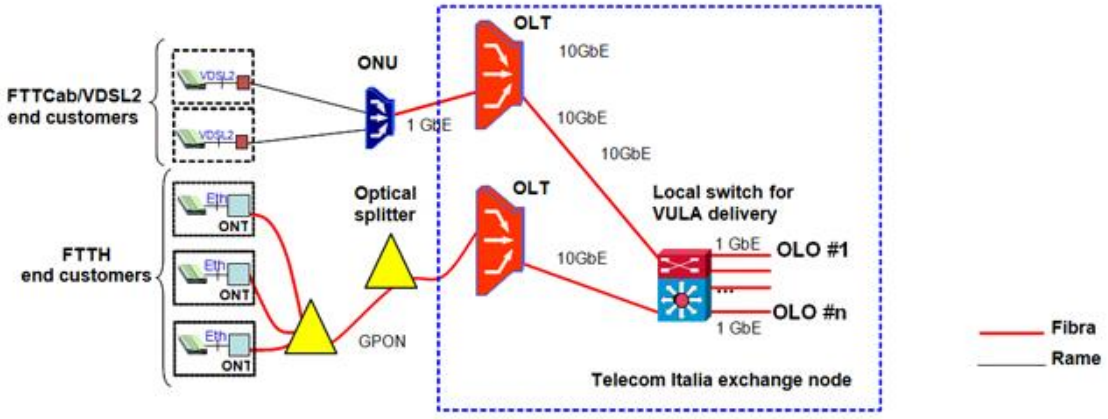
4.2 Virtual Unbundled Loop Access

The second type of service typically offered on a wholesale basis in FTTP deployments is VULA. While the service sounds quite different from bitstream access, the roots of VULA are very similar to bitstream, and in fact, could be considered a different branding of the same concept. Telecom Italia, another provider of national wholesale services, has a description of the main differences between the two service types[13]. In the case of VULA, there is no backhaul bandwidth component in the pricing of the service. Rather, VULA services can be picked up from every exchange point in the Telecom Italia network. In that sense, it

[13] Service description page from Telecom Italia found here:
http://www.wholesale.telecomitalia.com/catalogo_en/-/catalogo_aggregator/article/1039486

is more like the ADSL-CO service that was never introduced by the CRTC as a wholesale service. Telecom Italia also points out that in both cases: VULA and Bitstream access, it will install the ONT at the customer premises (consistent with all research done to date). Below is the Telecom Italia reference model for VULA. In this diagram, it is shown that each OLO (wholesale carrier), can pick up its end customer's traffic directly at any exchange node (central office in our terminology).

Figure 18 - Telecom Italia Reference Architecture for VULA



The only virtual local area network (VLAN) option available under the Telecom Italia VULA service is defined as a *dedicated bandwidth multi-CoS* (class of service) VLAN. By comparison, under the bitstream access service, up to 4 User VLANs can be associated to any access line: they can be either single-CoS or multi-CoS VLANs.

Eircom has also produced information with respect to what it calls their VUA (virtual unbundled access) solution, which is the same concept as VULA[14]. It was interesting to note that the product descriptions are virtually identical. Here is the text regarding both services:

> *… product range consists of Layer 2 Ethernet-only access products, giving the operator full control of network protocols and core transport solutions. Each product provides an enhanced broadband access service, between the service termination / demarcation point at an end-customer premises and a WEIL at an*

[14] Eircom VUA service brochure here: http://www.nextgenerationaccess.ie/resources/Proposed-Product-Description-Wholesale-NGA-Virtual-Unbundled-Access-v2.pdf

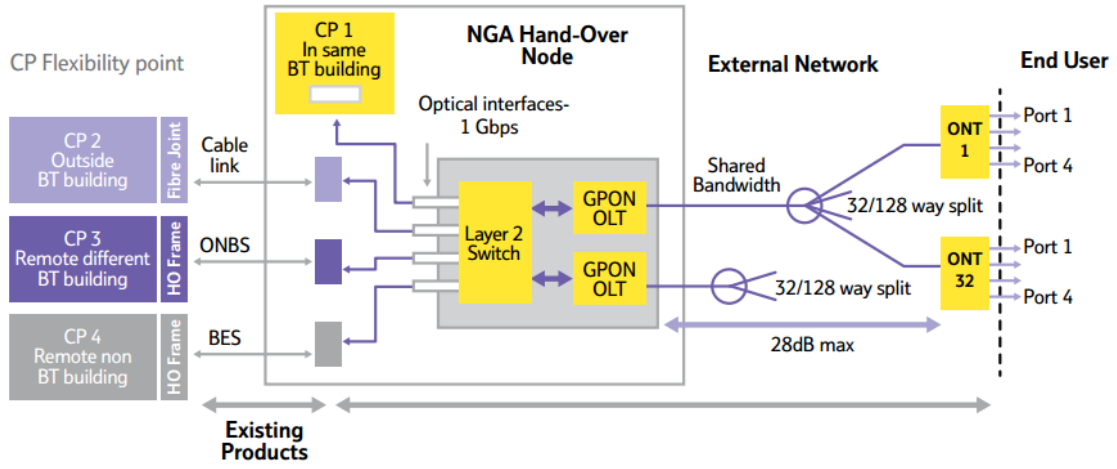
Operator's nominated handover point within the NGN Aggregation Node. All products support traffic-based Class of Service to allow time-critical applications, such as Voice over IP, be prioritised. Further flexibility is provided by including Multicast Support, for cost-effective distribution of TV and other broadcast services.

As can be inferred from the above, both service solutions are targeted towards allowing operators the most flexibility in service delivery. The only difference that seems to be pointed out by Eircom is in the nature of the billing arrangements. Whereas Bitstream services seem to imply a capacity-based billing model, the VUA service makes no mention of this, and the fact that this is a *dedicated bandwidth* VLAN, it would seem the reason is that the throughput is fully reserved. Once again, the parallel to this type of service in the CRTC models would be the HSA service as compared to the GAS service.

The final carrier to examine in the context of VULA is Openreach BT, the wholesale subsidiary of British Telecom in the UK. Openreach is a good proxy for VULA, as the concept of virtual unbundling, as adopted by the European Commission actually had its origins in the Office of Communications (OFCOM), the British regulatory agency. The name that Openreach has given to its highest-speed broadband access services is called Gigabit Ethernet Access over FTTP (GEA-FTTP)[15]. With this service, Openreach claims speed offerings of up to 330 Mbps to end-customers.

[15] Link to product brief on GEA-FTTP: http://www.openreach.co.uk/orpg/home/products/superfastfibreaccess/fibretothepremises/fttp/downloads/GEAFTTPFactsheet.pdf

Figure 19 - Openreach BT Diagram for GEA-FTTP



As shown in Figure 19, the functional implementation of GEA-FTTP is once again the same familiar solution that has been found across the board by other carriers, and is consistent with the technologies in use and being deployed in most FTTP network operations. In this diagram, CP refers to 'competitive provider'. As illustrated, a competitor can be either co-located within the CO where the OLT exists, or competitors can make use of other existing Openreach services to transport the traffic to a hand-off point convenient to them. As with the other services researched, Openreach uses a VLAN to deliver traffic between end customers and their competitive service providers. Openreach further makes the distinction that up to 2 competitive providers can provide voice and data services to each ONT in the network.

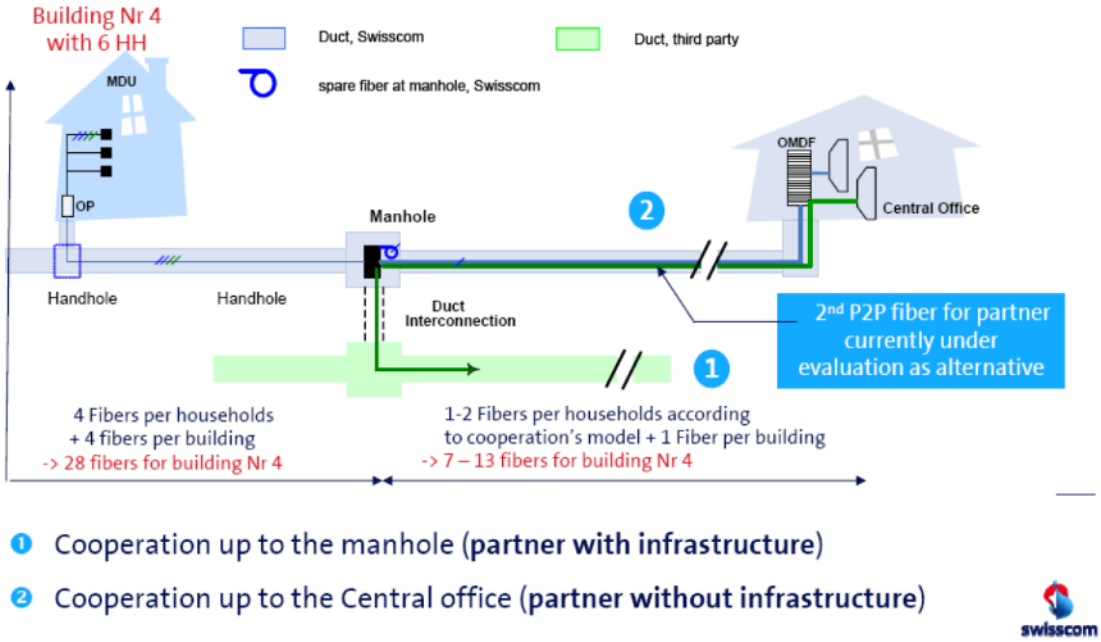
4.3 Fibre Sharing

There exists one other form of wholesale, or more specifically, co-operative deployment that exists in other jurisdictions. This model is that of fibre sharing. In the context of sharing, we are referring to a model where an incumbent operator deploys multiple fibre pairs to the same household, and then offers the 'dark' fibre strands for use by other operators, along with other facilities, such as the duct work or feeder fibre access. The main reason this approach has not been fully explored is

that thus far, no operator in North America has announced any plans to undertake such a strategy.

In Switzerland, under the scenario that utility companies were planning to deploy their own fibre networks, the incumbent operator Swisscom announced its intention to abandon VDSL deployments, instead focusing fully on FTTP, and a mufti-fibre deployment model, in which competitors could co-build this infrastructure with Swisscom[16]. Figure 20 below illustrates the general method in which Swisscom carries out these co-operative builds. When carrying out builds, there must be firm commitment from the partners before the building commences, and this results in any competitor having an indefeasible right to use (IRU) for the fibres they finance.

Figure 20 - Swisscom Multi-Fibre Approach



[16] Full description of arrangement explored in this paper: http://www.accc.gov.au/system/files/Dr.%20Karl-Heinz%20Neumann%20paper.pdf

Although this form of network unbundling would provide the purest form of competition, where each competitor would in essence have its own physical connection to the end-users, and also be responsible for its own complete network, the realities of the actual deployments made by Canadian carriers currently negates this as a viable option. Specifically, all of the incumbent carriers who have undertaken FTTP deployments have done so without seeking partnerships in the initiatives. When building FTTP networks, they appear to be focused on single fibre builds to each premises, rather than contemplating a multi-fibre scenario. As such the Swisscom scenario is presented here simply for completeness of the research undertaken.

5. Conclusions

At the outset of this project, we were asked to examine and provide recommendations on the most technically feasibly implementation of a wholesale FTTP service option in the Canadian context, taking into account the market and the players. This final section summarizes the findings and posits a recommendation for a solution that appears to be consistent with the CRTC's approach to wholesale regulation.

5.1 One-size-fits-all is a challenge

Throughout this report, numerous technologies were explored, as well as some of the unique implementations put forward by different carriers. One particular challenge in the Canadian market is the fact that the wholesale market extends not only to telecommunications operators, but also to cable operators. Both of these carrier types operate networks that are implemented in different ways, and ultimately use different technologies. Owing to these differences, their approaches to FTTP can and will differ. As we have seen, cable operators tend to deploy EPON systems, while the telecom-based operators are deploying GPON systems. In addition, the physical plants being used vary from carrier to carrier, and even from location to location, this includes underground cabling and aerial cabling variants.

However, on a positive note, all deployments that have been cited conform to our notions regarding PON. Namely, the chief building blocks of all systems consist of OLTs in the carriers' central locations, and ONTs at the end users' premises. While the specific vendors have not been explored, it is understood that all deployments make use of standards-based systems and protocols. This, combined with the proven wholesale deployments in other jurisdiction indicates favourably that there should exist a workable solution or solutions to offering a wholesale version of FTTP to competing carriers, should such a service be mandated. Furthermore, the timeline for implementation should be such that they can be deployed in a reasonable timeframe.

5.2 Anticipated obstacles

As with any new services or technologies, there are likely to be some obstacles to implementation. The key is to anticipate these obstacles, and look to overcoming them in an efficient way. One of the first items of note in the research was the issue faced with the end-user equipment. With other wholesale services (GAS and TPIA as examples), the principal equipment at the customer premises was the modem. **With the introduction of FTTP, there will now be an ONT at each end-user premises. In essence, the ONT is simply the equivalent of a miniaturized DSLAM or Node pushed out to the end users home. These act as demarcation points in a PON architecture, and are the ideal place to facilitate the hand-off to the competitor.**

Carriers are likely to claim challenges in implementing a non-vendor matched ONT at an end-user premises by a competitor. **In all the cases researched, the carriers in question did in fact provision their own ONT, and the costs of deploying such a unit are simply built into the pricing model for the wholesale service. This model makes technical sense, and will allow for a reasonably efficient introduction of a wholesale model.** In this respect, the current expectation would be that the incumbent carriers (at least for the time being) *would* install and maintain the ONTs themselves. Over time, should more standardization occur, and the technical situation change, it may be possible for wholesale customers to provision their own ONTs (as they do today with modems).

A second obstacle which has been raised in the past is that of carriers claiming they cannot offer high-bandwidth services to competitors over their FTTP architecture in parallel with their own IPTV service, as the bandwidth is reserved for the IPTV stream. The basis of this claim may lie in how they provision their systems, and in particular how many customers are served from a single OLT. **This problem can be addressed through deployment of an additional OLT by the carrier, and serving fewer customers from each OLT (or thought another way, offering more services on the same OLT). This practice is not unlike the practice of cable carriers performing node splitting to increase capacity to neighbourhoods. However, in this case, the split is done within the same location as the OLT resides. Again,**

this is not a problem that cannot be overcome easily, and is again a matter of proper cost allocation to the components used to deliver services.

A third obstacle is the question of how the introduction of any new wholesale services may lead to complications and conflicts with existing regulations, as well as what impacts they would have on current ordering, billing, and implementation systems. **Through the analysis and research carried out and summarized in other sections of this report, there is evidence that for some carriers, there would be almost no change to systems, as the services in place today in large part are similar. The implementation of new services would - at worst, be an enhancement of existing systems, not the creation of completely new systems.** The devil will be in the details of course, and careful examination of the costs cited, as well as deployment concerns will need to be examined by the CRTC.

5.3 Recommendation

In light of all the forgoing research and technical analysis, it has become abundantly clear that there is a clear path forward to the implementation of a wholesale regime utilizing FTTP that is compatible with the existing regimes that are already in place. As has been illustrated, much of the work has already been done, and a remarkable amount of documentation has already been released from other jurisdictions in an 'open data' format to help others understand how such a regime could be implemented. In the face of such information, it is difficult to imagine any carrier objecting on technical grounds to the introduction of new service models.

In the context of a specific technical recommendation, it is our contention that the wholesale service regime selected for implementation should most likely resemble the VULA regimes in place in other countries. That is, carriers should offer a VLAN-type service from the customer premises to the point of interconnection with the competing ISP using tagged VLANs of a fixed dedicated bandwidth size. The ONT would be installed and maintained by the incumbent, and the competitor should have a right to install its own routers as CPE should it choose to do so. The choice to implement a VULA-like option assumes the competitive, or self-supply of transport links as needed.

Should the competing carriers not have reliable access to transport, the above recommendation could be modified to replicate the existing model that includes an AHSSPI of sorts. Alternatively, it may make sense to request the wholesale regime for Ethernet transport be re-examined, as this would be a key input to competitors trying to bring all their traffic to one location, and could be costed as a separate component.

By using a VULA-type service, competitors should be given the most flexibility to offer differentiated services as they see fit, and not be subject to traffic-shaping measures on the access side of the network, as the VLAN becomes a known quantity to the incumbent, and is dedicated bandwidth.

In closing, there exist numerous technical solutions to this issue, and the option to give competitors their own direct access to customers via a dedicated VLAN is the most logical, technically feasible, and competitively neutral option.

6. 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