ICT Infrastructure as Public Infrastructure: Connecting Communities to the Knowledge-based Economy & Society

Final Report of the Community Wireless Infrastructure Research Project

October 2008

Acknowledgements

The production of this report has been made possible through a financial contribution from Infrastructure Canada. The views expressed herein do not necessarily represent the views of the Government of Canada.

We thank Infrastructure Canada for supporting this research.

This project was also supported by Ryerson University, University of Toronto, and York University.

Principal Investigator: Catherine Middleton, Ryerson University
Co-Investigators: Andrew Clement, University of Toronto
Barbara Crow, York University
Graham Longford, University of Toronto*

Research Assistants*
Kiera Chion, York University
Adam Fiser, University of Toronto
Rhonda McEwen, University of Toronto
Neal McIntyre, Ryerson University
Tammy Miller, York University
Amelia Bryne Potter, Ryerson University
Alison Powell, Concordia University
Cliff Vanderlinden, York University
Matthew Wong, University of Toronto
*Affiliation at the beginning of the project.

Assistance with web site maintenance was provided by Andrew Young and Hong Tai Lee, Ryerson University. The web site (www.cwirp.ca) is hosted by the Faculty of Information Studies, University of Toronto.

Research Partners
We acknowledge the enormous contributions made by our research partners, and thank them for sharing their experiences and expertise in the development of public ICT infrastructure. We learned a great deal through our engagement with each project.

City of Fredericton: Don Fitzgerald, Maurice Gallant, Mike Richard
Île Sans Fil, Montreal: Benoit Grégoire, Michael Lenczner
K-Net: Brian Beaton, Brian Walmark, Franz Siebel
Wireless Nomad: Damien Fox, Steve Wilton
Industry Canada: Prabir Neogi

Report Content
This report was compiled by Catherine Middleton, drawing on documents produced by the CWIRP research team.

Executive Summary

This report provides a summary of findings from the Community Wireless Infrastructure Research Project. This research investigated the development of public broadband infrastructure, and was conducted from April 2006 to March 2008 by a team of researchers from Ryerson University, York University and the University of Toronto. This summary offers excerpts of the report, to highlight our key findings.

The specific questions that guided our research were as follows:

- What is the rationale for publicly-owned and/or controlled ICT infrastructure?
- What examples of public ICT infrastructure exist in Canada today?
- What are the different models and best practices of public ICT infrastructure in terms of deployment, technology choice and innovation, investment, governance, adoption and use?
- What are the public benefits of community-based/public ICT infrastructure provision?
- What public policies and supports are necessary to promote and sustain public ICT infrastructure?

We addressed these questions through case study work with our research partners (The City of Fredericton, Île Sans Fil in Montreal, K-Net and the Lac Seul Wireless Network in North Western Ontario, and Wireless Nomad in Toronto), as well as through extensive study of the broader context for public ICT infrastructure development.

Our research identified seven reasons for developing public broadband infrastructure:

- Broadband internet access is an essential service
- Public broadband access can spur economic development
- Public broadband networks can improve efficiency within municipalities
- Municipal broadband networks can stimulate competition and improve service in local telecommunications markets
- The deployment of public broadband networks improves citizen access to the internet and can help to bridge the digital divide
- Public broadband networks can increase civic engagement both on and offline
- The development of public broadband services can encourage local innovation

A review of current public broadband infrastructure developments in the United States and Canada shows various ownership and governance approaches, and highlights the roles played by municipal and community entities in developing infrastructure that serves the needs of local communities. For instance, in the U.S., there are examples of free broadband access provided as a public service, broadband provided according to a public utility model, broadband developed by community groups to reach underserved areas (e.g. low income households), broadband developed for use by municipal governments to support municipal operations, and broadband networks developed in partnership with the private sector, in an often unsuccessful attempt to provide cities with new infrastructure at low cost.

In Canada, we studied infrastructure developed by municipal and community groups, a hybrid municipal-community organization, and a private sector provider. Our main findings are

summarized below:

- Few of the networks we studied actually delivered essential infrastructure – most of them delivered secondary internet access, which is a useful service, but not essential.
- We did not find extensive evidence to support claims that investment in broadband infrastructure resulted in economic development outcomes, but believe that there are some likely benefits in this area.
- With respect to improving efficiencies within municipalities, this was not evident with the use of wireless technologies at the two municipal-level networks we studied. But in Fredericton, efficiency benefits are realized through the deployment and use of the community broadband fibre network.
- The development of the fibre network in Fredericton was also a catalyst for improved infrastructure provision by the private sector, which increased service and lowered costs in the city after it built the fibre network.
- The only project that explicitly addressed increasing accessibility was the Lac Seul Wireless Network.
- The community networks provided some opportunities for community engagement, but the municipal projects had no specific functionality to encourage broad-based civic participation in community life.
- The most innovative groups were Île Sans Fil (which engaged a group of volunteers in technical development) and Wireless Nomad (which worked on a smaller scale to find new technical solutions to sharing internet connectivity). K-Net is certainly an innovative organization, but there was less evidence of local innovation in the Lac Seul First Nation. Fredericton was innovative in building its community network, and in seeing the opportunity to build a Wi-Fi network to extend benefits to the community.

There were other benefits achieved through the development of wireless broadband infrastructure that were not identified in previous research. For instance, a benefit for Fredericton (with the fibre network) and the Lac Seul First Nation was that they were able to develop infrastructure that suited the specific needs of their communities. Rather than depending on the market to provide service (which it had not done in either case), these communities determined what they needed, and then went ahead and built it. In addition, the projects all contributed to increased quality of life for those who used them. In an urban context, it can be very convenient to have internet access in a secondary location, and people are particularly pleased when such access is provided free of charge.

The Canadian case studies, coupled with an overview of the recent U.S. experiences in developing public broadband networks lead to the following observations regarding the development of public ICT infrastructure.

- The private sector will continue to develop broadband infrastructure, but the need for alternative infrastructure that better suits the needs of local communities and municipalities will persist.
- To ensure that the potential benefits of public ICT infrastructure are actually realized in network deployments, the design process must explicitly identify the desired outcomes, and attention must be paid to achieving them.
- A public access component is not necessary to justify investment in broadband infrastructure. Stand-alone networks that support municipal applications can provide

value through increased service efficiencies and decreased operational costs.

- Many municipalities have existing capacity for infrastructure development embedded in their municipal utilities. They may also have access to a fibre network that can be leveraged to provide broadband services to community members.
- When developing public broadband infrastructure for communities that already have broadband access, the public infrastructure must provide users with equal or better functionality (e.g. improved conditions of use, decreased price, higher speeds) in order for it to be adopted. Users will only pay for access if it provides a reasonable quality of service.
- Technology choice must be guided by objectives regarding network coverage and location of use. But in general, we have found that Wi-Fi is limited in its capacity to support primary network access. To provide reliable, high quality network access, projects should consider the use of more robust technologies.
- Although it is relatively easy to set up a public access network using Wi-Fi, such a network may provide few benefits to the community overall (especially if the network only serves outdoor areas).
- The community networking movement's focus on building community and engaging network stakeholders can be extended into the development of municipally-led projects. In building public infrastructure, it is important to understand what network characteristics best suit the needs of each community, and community engagement contributes greatly to this process.
- The development of public broadband infrastructure can involve significant innovation, and may provide opportunities to empower community members by increasing their technical skills. Development of local capacity to build and support networks is especially important for rural and remote areas.
- It is difficult to build high-quality, reliable, sustainable infrastructure by relying on individuals sharing their network connections. Community-led projects that focus on ground-up networking building can benefit from the resources of municipal entities, to enable service provision on a larger scale.

Our research suggests that broadband networks developed in the public interest should be: ubiquitous and universal, widely useful, usable, accessible, affordable, reliable, high quality, healthy, cost-effective, accountable and responsive, secure, privacy enabling, open, neutral and non-discriminatory. We conclude that there is no single best way to develop public ICT infrastructure that meets these standards, but recognize that the development of good public broadband infrastructure cannot be left to market forces alone.

Infrastructure developed by the private sector does not generally support open network access, or provide users with neutral, non-discriminatory network access. It may not offer ubiquitous service. The private sector does not focus on delivering affordable infrastructure – for-profit companies will charge what the market will bear – nor does it allow for user input into governance or respond directly to its users needs. This does not mean that the private sector develops bad infrastructure, on the contrary it can offer high quality, reliable, useful, widely available, and secure service. But the needs of the public are not being fully met by infrastructure that is built in response to current market forces.

Community and municipal groups are experimenting to build infrastructure that better serves the needs of the public, but they require a supportive policy environment to continue to make progress with infrastructure development, especially in face of technological change. Recognizing that access to good broadband infrastructure – infrastructure that provides the full range of public benefits – is an essential service, policies should be developed and implemented that will:

- foster innovation in infrastructure development (e.g. allow experimentation with new technologies, encourage new developers);
- provide public broadband developers with access to spectrum that enables more robust broadband infrastructure development;
- facilitate the development of fibre broadband networks that allow open access;
- create increased competition among providers, allowing new entrants into existing broadband markets, and encouraging competition from new broadband technologies;
- continue to allow third-party access to existing DSL and cable infrastructure;
- enable users to access broadband networks on a neutral and non-discriminatory basis, regardless of access technology;
- encourage private-sector broadband providers to incorporate the characteristics of good public broadband infrastructure in their commercial offerings;
- enable collaboration among public broadband providers to allow for coordinated approaches to larger scale projects;
- provide support for community groups, municipalities and others to continue to develop public infrastructure that meet their needs; and
- deliver programs that provide affordable broadband access and training to new users, so that all Canadians have access to this essential infrastructure.

The advent of new mobile broadband technologies, and an anticipated shift away from existing fixed line infrastructure (DSL, cable) toward fibre optic services will lead to changes in the broadband industry structure, and provide an ideal opportunity to influence future developments to ensure enhanced public benefits. Specifically, as the industry structure changes, it is essential that non-market providers (municipalities, community groups and others) continue to play a role in infrastructure development. Public broadband providers must have access to new wireless spectrum, to allow for continued competition and innovation in service delivery. Steps must also be taken to encourage all broadband developers to incorporate the principles of good broadband infrastructure in future deployments. Finally, as broadband network access is an essential service, efforts must be increased to extend public broadband access to areas of Canada that are currently without service, and to ensure that all Canadians are able to achieve the full benefits of good public broadband access.

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Introduction

The *Information and Communication Technology (ICT) Infrastructure as Public Infrastructure* project[1] commenced in April 2006, to investigate issues related to the development of ICT infrastructure as public infrastructure. We began the project with the assumption that "access to advanced information and communications technology (ICT) infrastructure, such as broadband internet and wireless networks, is vital to the socio-economic well-being of cities, regions and nations in the global knowledge-based economy."[2]

Although Canadians were early adopters of broadband technology, the availability of broadband infrastructure has been influenced primarily by market forces. By 2005 it was becoming clear that this approach was insufficient to provide adequate infrastructure to all Canadians.[3] In proposing the research project, we argued that "the vital importance of ICT infrastructure to Canada's national interest, the failure of market forces alone to ensure universal access to broadband technology, and the historical precedent set by large scale public infrastructure during the industrial era invite consideration of the desirability and feasibility of governments and/or communities developing, controlling and maintaining advanced ICT infrastructure as a form of public infrastructure."[4]

The specific questions that guided our research were as follows:

- What is the rationale for publicly-owned and/or controlled ICT infrastructure?
- What examples of public ICT infrastructure exist in Canada today?
- What are the different models and best practices of public ICT infrastructure in terms of deployment, technology choice and innovation, investment, governance, adoption and use?
- What are the public benefits of community-based/public ICT infrastructure provision?
- What public policies and supports are necessary to promote and sustain public ICT infrastructure?

As the project progressed, we addressed these questions through our case study work with our research partners (The City of Fredericton, Île Sans Fil in Montreal, K-Net and the Lac Seul Wireless Network in North Western Ontario, and Wireless Nomad in Toronto), as well as through extensive study of the broader context for public ICT infrastructure development. Our focus throughout the research was on the development of public broadband infrastructure, with specific examples provided through the investigation of wireless broadband infrastructure development.

This report provides an overview of the key findings of our research. It is meant as a guide and supplement to the collection of case studies, papers, presentations and other resources (e.g. bibliography, list of internet links, technology guide) found on the project website, www.cwirp.ca. The report begins with a discussion of the reasons for developing public broadband infrastructure, and outlines the types of providers involved in broadband infrastructure development. We then provide an overview of public broadband infrastructure development in the past few years. This discussion highlights various models used to deploy public ICT infrastructure, presenting examples of public infrastructure in use in the Canada and the U.S. We then synthesize our case study findings, using them to illustrate actual benefits in developing public broadband infrastructure and to note missed opportunities and future areas of improvement. This is followed by our 'desiderata' for developing broadband infrastructure

that is in the public interest. This incorporates recommendations for best practices, and outlines issues that should be incorporated into policy development.

We conclude that the continued development of good public broadband infrastructure should not be left to market forces. As we enter a period of investment in new mobile and fibre optic broadband technologies, there is an opportunity to adopt new approaches and enable new types of providers to contribute to the development of good public ICT infrastructure. Considered action must be taken to ensure that all Canadians have access to essential broadband infrastructure.

Defining Public Broadband Infrastructure

One of our first tasks was to develop a working definition of public broadband infrastructure. Although we focused primarily on wireless infrastructure, a basic understanding of public broadband infrastructure was required. Broadband networks can be defined in terms of speed or in terms of functionality. What is important in defining *broadband* is a recognition that it is a moving target, with speed requirements increasing in step with the availability of broadband applications and content. The most basic definition is that broadband networks provide connectivity at speeds that are faster than dial-up service, but this is a very low threshold to meet.[5] In 2001, Canada's National Broadband Taskforce suggested that:

> Based on today's technology and applications, high-speed broadband is defined as a high-capacity, two-way link between end user and access network suppliers capable of supporting full-motion interactive video applications delivered to all Canadians on terms comparable to those available in urban markets by 2004. A minimum symmetrical speed of 1.5 megabits per second per individual user is currently required to support these applications. Leading up to 2004 and beyond, new applications such as peer-to-peer file interactions and video conferencing will increase individual user demand for symmetric bandwidth in the 4-to-6 Mbps range. Public and commercial facilities will require much higher bandwidth, ranging from this minimum to several hundred times more, depending on their size and user needs.[6]

Putting this definition in context, it was estimated that as of 2007, 93% of Canadian households had access to broadband service, with approximately 72% of households actually subscribing (i.e. choosing to use a broadband network).[7] More than 50% of broadband subscribers pay for services advertised as providing download speeds greater than 5 Mbps.[8] Although such services are not generally symmetrical, many Canadians do now have access to the sort of broadband infrastructure envisaged by the National Broadband Taskforce in 2001. Most North Americans currently get their broadband services from private sector cable or telecommunications companies.[9] But residential broadband services provided by commercial internet service providers (ISPs – e.g. Bell, Rogers, Shaw, Cogeco, Vidéotron) are not examples of *public* broadband infrastructure.

What is public broadband infrastructure then?[10] As noted, we began our research with the assumption that access to broadband networks is becoming an essential service for Canadian households, and more broadly, that the widespread availability of broadband infrastructure, for use by citizens, governments and businesses is a key component in developing a knowledge-based economy. A central element of public infrastructure is that it is developed with the public interest in mind. As Infrastructure Canada states, public infrastructure is "infrastructure that provides collective benefits for Canada and for Canadians."[11] Public broadband infrastructure is

made up of broadband networks developed to provide benefits to the public. Public broadband infrastructure meets the communications needs of citizens, communities, businesses, governments and other organizations in society, enabling access to information, applications and services.

Our research suggests that a broadband network developed in the public interest should be: ubiquitous and universal, widely useful, usable, accessible, affordable, reliable, high quality, healthy, cost-effective, accountable and responsive, secure, privacy enabling, open, neutral and non-discriminatory.[12] (These characteristics are defined in detail later in the report.) Ideally, networks in the public interest would meet all of these criteria, but individual communities of users will address these objectives in different ways, and will choose to value some network characteristics over others.

Public broadband networks can be developed with various business models (e.g. with private sector involvement, by community groups, with public ownership) and technologies, but not all broadband networks serve the public need fully. To return to the example of residential broadband, we argue that broadband services offered by commercial ISPs are not developed with the public interest in mind. Such networks certainly deliver some of the desirable features of public broadband, but are not necessarily accessible, affordable, open, neutral, accountable and/or responsive to user needs. For instance, there is very little competition in the Canadian broadband market, and Canadians pay higher prices for lower speed connections than do their counterparts in many other OECD countries.[13]

In summary, in investigating public broadband infrastructure, we were looking to understand how information and communication technologies could be developed to provide citizens, governments and businesses with the high speed internet connectivity necessary to enable them to participate in a knowledge economy. As public infrastructure, it would need to be developed in ways that would provide benefits for all Canadians.

The Rationale for Public ICT Infrastructure

The primary rationale for public investment in ICT infrastructure is to ensure that such infrastructure is developed to meet the needs of the public. In the case of public broadband networks, investments are made to meet public needs that are not being filled by other broadband providers. For example, a public broadband network could provide connectivity to areas not served by the private sector, or it could provide service on a more affordable basis. Our research identified seven main arguments used to justify public investment in broadband infrastructure. Each is outlined below, followed by a brief discussion explaining how some of these arguments apply primarily to networks developed by municipalities, and others to those championed by community groups.

Broadband internet access is an essential service

This rationale for public investment in ICT infrastructure is based on the assumption that, in the twenty-first century, the internet and other communication networks and devices are essential services.[14] As such, it is argued that access to broadband service ought to be treated as a basic amenity provided by a public utility, just as other basic amenities such as electricity, water, roads, sidewalks and street lights often are. Accordingly, communities and municipalities that remain un- or underserved by market forces must fill the gap in order to ensure that they can offer residents, businesses and other local institutions the kind of modern infrastructure they need.

Many municipal governments and municipally-owned utilities already own, manage and maintain essential and technologically sophisticated services including electricity, roads and bridges, public transit, traffic and street lighting, water purification, and waste management. There is a history of municipal ownership of telecommunications and information infrastructure,[15] with many municipalities and rural communities successfully operating telephone networks in the early days of telephony. It is suggested that municipalities that own and operate public utilities are likely to possess the skills and capacities necessary to build, operate and administer a broadband network,[16] making it feasible for municipalities to become involved in providing public broadband access.

Public broadband access can spur economic development

The development of ICT infrastructure can lead to improved economic outcomes.[17] Public broadband networks are thought to encourage competitiveness and productivity by, among other things, reducing telecommunications costs incurred by local businesses, residents, large institutional bandwidth users (e.g. hospitals, power utilities, universities), and local governments. The availability of fast and reliable broadband connectivity is increasingly important for potential investors in a community, as well as by existing businesses considering relocation.[18] The presence of a fast and reliable network infrastructure helps communities retain existing businesses while also attracting new ones. Municipal broadband and wireless schemes can also be used to brand communities as 'hip,' 'innovative,' and 'hi-tech' and to market them to investors, tourists and skilled workers.[19] It is noted however that broadband networks alone are not sufficient to foster economic development. Supporting elements in a community, like the presence of a highly skilled workforce, are required to realize the benefits of broadband.[20]

Public broadband networks can improve efficiency within municipalities

It is argued that municipal broadband networks save municipalities and taxpayers money by making city services more efficient and cost effective, for instance by saving on the costs of telecommunications services. Wireless networks may offer an economical means of providing access to services,[21] including new automated and mobile work processes for employees (e.g. having employees such as building inspectors report from the field, thus saving on fleet and gasoline costs). In addition, wireless networks are frequently used to provide public safety applications.[22] The development of a wireless network may make financial sense based on the municipality's need for service alone. Such savings help municipalities save money, reduce upward pressure on tax rates and, ultimately, attract and retain investment.[23]

Municipal broadband networks can stimulate competition and improve service in local telecommunications markets

Broadband consumers in many markets have been subjected to poor service and high prices by incumbent telecommunications firms, who have had little incentive to invest, improve service or keep costs down. Some U.S. research shows that where municipalities have entered local telecommunications markets, consumers have benefited from increased competition, better service and lower prices.[24] In contrast to arguments that suggest that municipal control of broadband networks reduces or eliminates the possibility of alternative service provision, municipalities' involvement in network provision can lower entry barriers for private sector providers and provide an opportunity for increased, not decreased, supply and service in local communities.[25]

The deployment of public broadband networks improves citizen access to the internet and can help to bridge the digital divide

This argument is strengthened when wireless technologies are used to extend the reach of a public broadband network. Many public wireless deployments explicitly offer improved access to the internet, making promises to help reduce the digital divide by providing "universal and affordable broadband internet access to their residents."[26] The availability of public wireless can help to connect individuals to the information society and knowledge economy, by reducing economic and/or geographic access barriers, a point that was central to the development of the Wireless Philadelphia network.[27]

But while wireless networks have the potential to make it easier to access the internet for a lower cost and in more places, their availability will not necessarily help to bridge the digital divide. Wireless networks are often built first for areas where high usage is expected, and where many people already have broadband access.[28] In addition, many other factors (including time constraints, availability of computer hardware, technology literacy, financial priorities, and awareness of the potential benefits of the service) determine whether or not wireless will be used even if it is available.

Public broadband networks can increase civic engagement both on and offline

There is a long history of community networks being developed to provide access to local information and services, and to support local civic engagement.[29] Community networks serve both as sites of civic participation (in which community members are engaged in the development, management, and maintenance of the network through essential volunteer activities such as serving on committees, providing technical support and training, or engaging in content development) and as enablers of civic participation (by providing services and supports, including access to and training on ICT equipment and software, information and communication services like internet service provision, email/listserv/web hosting, community directories, and electronic discussion forums).[30]

Earlier community networks were not based on broadband technologies, making access difficult for some. Municipal and community wireless networks can extend access to community information, making it easier to inform and engage citizens about local politics and community issues. In addition, it is suggested that the provision of free Wi-Fi in public spaces can revitalize and re-populate parks, pedestrian walkways, outdoor cafes, and civic squares by attracting citizens, tourists and mobile workers equipped with wireless devices.[31]

The development of public broadband services can encourage local innovation

Municipalities, consumer co-ops and other community-based organizations have played an historic role in the technological development, diffusion and provision of telecommunications, radio and energy services.[32] Community-based technology initiatives have been important in the development and diffusion of computing and the internet as well, initially among early-adopters, and later among regions and populations un(der)served by the private sector. Today, community and municipal networks, along with "disorderly groups of amateurs" continue to break ground in technological innovation and the diffusion and popularization of emerging technologies, including Wi-Fi and open source software.[33] The development of wireless networks has encouraged innovative partnerships between public and private sector participants.[34]

Public Broadband Network Developers: Municipal and Community-Led Approaches

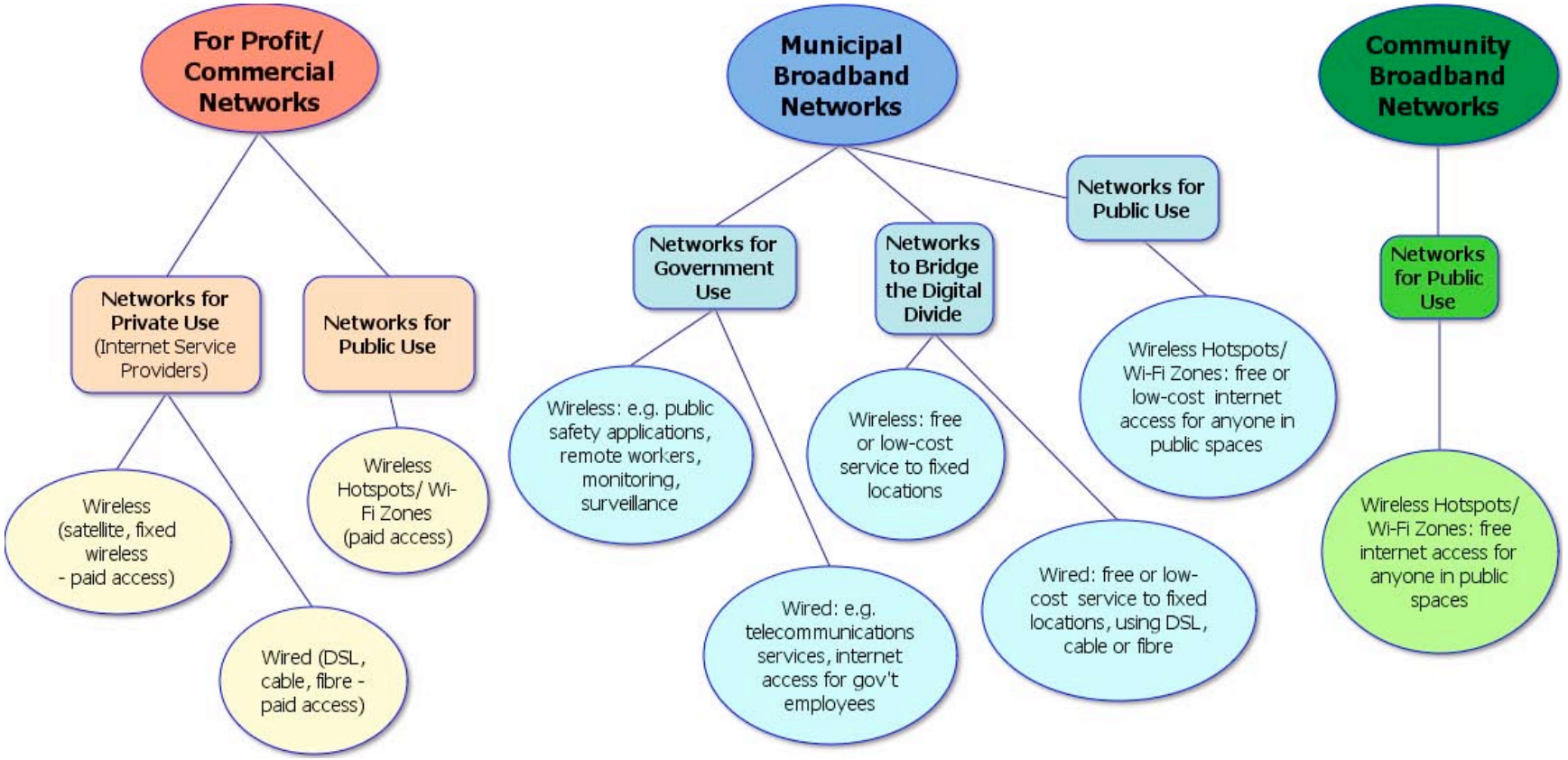
To this point, we have not explained who is involved in public provision of broadband infrastructure. It may be assumed that public broadband is provisioned only by public agencies, for example local or regional governments. But if public broadband is defined in very broad terms, it can be argued that some commercial broadband service providers offer elements of public broadband in their products. Additionally, our research also highlights the important role played by community groups in developing public broadband services, primarily using wireless technologies.

Because public broadband networks are being developed by multiple players, there are different agendas at play, and networks are built to suit different priorities. Figure 1 provides an overview of three types of networks that can provide the public with broadband access and offer services to support municipal governments. For profit, commercial networks are developed by internet service providers who sell network access to businesses and individuals (considered 'private use' here because such connectivity is provided to private spaces like offices and homes). In addition to these private networks, commercial internet service providers may also offer broadband connectivity in public places (e.g. a fee-for-use Wi-Fi hotspot at a coffee shop or airport). Note that providing broadband connectivity in a public place is not necessarily the same as providing broadband that meets the public interest, but it is important to recognize that municipal and community broadband networks are not the only sources of public broadband connectivity available.

As explained above, municipalities that build public broadband networks can experience efficiencies in delivering government services. As such, municipalities do build broadband networks to support government activities, for instance providing connectivity to remote workers, and providing telecommunications services (telephone, internet access) to all employees. Networks for government use may use wired or wireless technologies, or some combination of both. In Canada, the City of Fredericton's 'Community Broadband Network'[35] is an example of a broadband network that provides connectivity to city offices and public buildings. Additionally, a public use network, the Fred-eZone, is promoted as a means of encouraging economic development in the city. By developing its own infrastructure, Fredericton stimulated competition in the market resulting in decreased prices for commercial internet service.

The City of Fredericton is explicit that their network was not designed to reduce the digital divide in the city. While it is likely that the eZone network does provide internet access to people who would not otherwise have access (and this city is not opposed to this outcome), the city makes no promises about the long-term availability of the network, or its reliability. In contrast, the opportunity to increase broadband access for citizens was a major impetus for developing the wireless network in Philadelphia, although this has not been fully realized. Both the Philadelphia and Fredericton networks do support public use, by providing internet access at hotspots in public places throughout the cities.

FIGURE 1: PROVIDERS OF PUBLIC BROADBAND NETWORKS



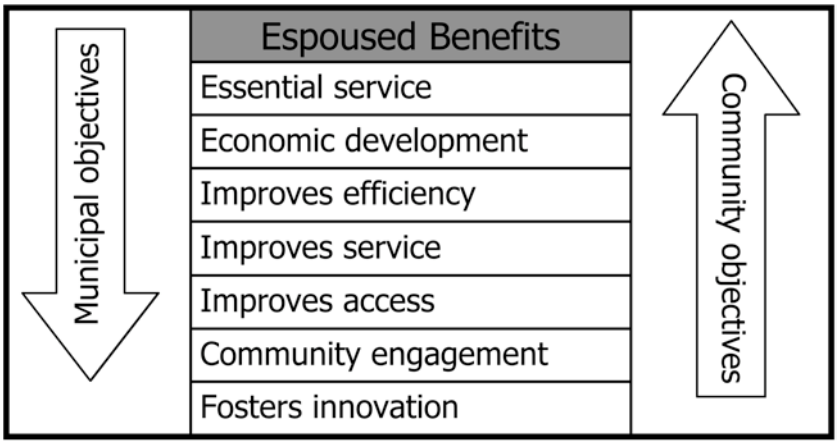
Municipal broadband networks that offer public use are similar to community broadband networks. What is different however is that community networks are developed by local volunteers committed to developing a resource for the community.[36] The primary focus is not on efficiency or economic development, but on providing a service that offers value to a local community, starting with free internet access. Community networks often provide access to local information and content, encouraging online community engagement and interaction among citizens. The organizations that build community networks are training grounds for individuals interested in this type of technology, and encourage local innovation. Île Sans Fil is the best-known example of a community network in Canada, and has encouraged the development of community networks elsewhere in the country (e.g. Wireless Toronto, OGWifi in Ottawa, and ZAP in Québec and Sherbrooke).

Figure 1 identifies three distinct providers of public broadband networks, and shows that broadband infrastructure can be developed for general public use, to help bridge the digital divide or improve overall accessibility, and to support government services. We note that not all researchers would agree with this categorization of network providers. Colleagues in the U.S. describe 'municipal-community hybrid' networks,[37] arguing that the distinctions between the bottom-up approach that characterizes community networking projects, and the top down approach of municipalities are no longer relevant in a context where both groups work together to build infrastructure.[38] In the Canadian context, our research shows that the distinction between municipal and community broadband networks remains clear, with limited evidence of collaboration between the two types of network developers. We believe that it is critical to understand the differences in these two approaches to network building, to ensure that the best of both worlds can be retained in future efforts to build broadband infrastructure. As is shown in the diagram below, the priorities of municipalities and communities are different, but both can contribute to the development of better public broadband infrastructure.

Summary: What is the Rationale for Public Broadband Networks?

Figure 2 presents a summary of the espoused benefits of public broadband networks, providing insights into why such networks are developed. We suggest that the primary motivators for the development of *municipal* broadband networks are found at the top of the figure. As grassroots organizations, c*ommunity* broadband networks are motivated primarily by the benefits that are found at the bottom of the figure. Motivations for developing public broadband networks coalesce around desires to improve citizen access to information and communication technologies. It is not our intent to suggest that municipalities are disinterested in the benefits at the bottom of the figure, or that community network organizations are disinterested in those at the top. Rather, the figure points out that the basic motivations for network development within the two types of deployments are different, reflecting different priorities and objectives. Recognition of this point allows for contextually appropriate assessment of both municipal and community networks. In the longer term however, what is important is that regardless of its provider, a public broadband network does deliver benefits to its users.

FIGURE 2: ESPOUSED BENEFITS OF PUBLIC BROADBAND NETWORKS [39]



We will return to this model when assessing current deployments of public broadband infrastructure. We also discuss observed benefits that are not incorporated into this model, and then outline a list of desired characteristics for broadband infrastructure that will provide public benefits. But first we provide some context for the our research on wireless broadband infrastructure.

Research Context: The Promise of Wireless Networks and the Public/Private Broadband Debate

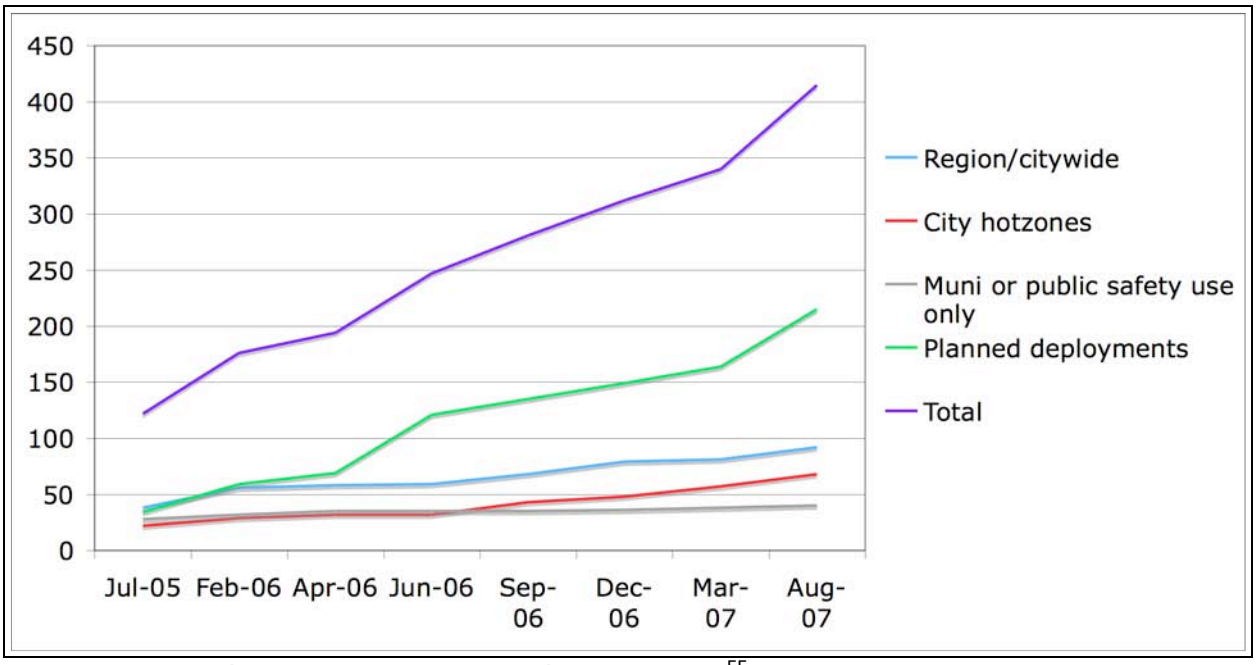
The section above describes the motivation for municipalities and communities to develop their own broadband networks. In the past decade, hundreds of municipalities and communities across North America and around the world have begun planning and deploying their own networks, experimenting with a range of technologies including fibre, broadband over power lines,[40] and wireless, to provide citizens with internet connectivity.

At the time this research project was proposed, wireless technologies were seen as having great potential for use in developing public broadband infrastructure. The IEEE 802.11b standard enabled the creation of wireless local area networks (WLANs), commonly known as Wi-Fi networks, that can be used to provide multiple users with a broadband connection. (See Appendix 1 for a list of readings describing broadband and wireless technologies.) Wi-Fi makes it possible to provide network coverage to an extended area[41] without the need to provide a wired connection to each user. Using licence exempt/unlicensed spectrum,[42] the networks can be set up by anyone. In comparison with the cost of wiring internet connections, WLANs are thought to be a cheap way of providing infrastructure.

Community groups in San Francisco (Bay Area Wireless User Group), Seattle (SeattleWireless), British Columbia (BCWireless), Champaign-Urbana (CUWiN), New York (NYCWireless) and London (Wireless London) were among the first to use wireless technologies to build "community owned and operated networks and collaborative user spaces,"[43] providing citizens with free access to the internet and to local information. A 'community wireless networking' movement emerged, and its participants continue to gather annually at the International Summit for Community Wireless Networks, where they share their experiences in network and community building.[44]

Cities like Taipei, Taiwan,[45] Tallin, Estonia, [46] Albuquerque, USA,[47] and Fredericton, Canada[48] were among the early municipal leaders to develop Wi-Fi infrastructure to provide citizens with broadband internet access in public places. By 2005, it was evident that enthusiasm for 'municipal wireless' was growing, with one report showing almost 100 networks planned or deployed in the US, and 65 international projects already in operation.[49] Ambitious plans for citywide Wi-Fi networks were developed for Boston,[50] Philadelphia,[51] San Francisco,[52] Toronto,[53] and elsewhere.[54] As is seen in Figure 3, growth continued through 2007. Our initial investigations were informed primarily by the developments in the United States, as there were few public broadband projects going ahead in Canada at the time.

FIGURE 3: GROWTH IN MUNICIPAL WIRELESS INTERNET PROJECTS IN THE U.S. (2005-2007)



Source: muniwireless.com 2005, 2006 and 2007 reports[55]

The data in Figure 3 come from muniwireless.com, a website that offers analysis of the municipal wireless sector. As the figure shows, municipal wireless networks are being developed for multiple purposes. In 2007, there were about 200 operational wireless networks in cities and counties around the US, with an additional 215 in the planning stages.

The case for municipal wireless seemed clear cut.[56] The benefits listed in our discussion of the rationale for developing public broadband networks were widely quoted by municipal leaders and by the technology companies and consulting firms advising them:[57] broadband connectivity is an essential service, and by deploying their own networks municipalities could benefit by increasing the effectiveness of public service delivery, spurring local economic development, stimulating local competition for infrastructure development (thus increasing the supply of infrastructure), and providing free or subsidized network access to members of the community who were unable to afford commercial access rates.

But not surprisingly, early municipal Wi-Fi efforts in the U.S. were met with resistance from commercial telecommunications providers, who argued that municipalities should have no role in the development of broadband infrastructure. Labeling municipal entry into the

telecommunications market as unfair competition, the telecommunications sector challenged the rights of municipalities to develop infrastructure to meet local needs. For example, the City of Philadelphia's plans for a municipal wireless network were almost thwarted by the lobbying efforts of Verizon, which resulted in a Pennsylvania state law that prohibited the development of any further municipal networks.[58] A policy debate about the role of government in the telecommunications industry ensued, and various U.S. state legislatures proposed bills either allowing or disallowing the development of municipal wireless networks. (See Appendix 2 for references that address this debate.) When we proposed the research, we anticipated that a similar debate might take place in Canada, but this has not transpired.

As of late 2007, it became obvious that the business model underpinning many network deployments was not sustainable. If data were available for 2008, it would show a sharp decline in projects in the US, as well as a shift away from city hot zones in favour of networks solely for municipal use. Earthlink and Metro-Fi, companies that had been involved in many high-profile wireless broadband deployments in the US, exited the market, leaving planned networks undeveloped (e.g. in San Francisco), or discontinuing service and seeking buyers for their networks (e.g. Philadelphia, New Orleans, Silicon Valley, Corpus Christi, TX, and Portland, OR). Although many community-led efforts continue to thrive, the future for municipal wireless projects, especially those developed in partnership with the private sector, is less clear. Appendix 3 provides a list of resources related to the decline of municipal wireless networks.

One of the reasons for the decline in the municipal broadband sector was a realization that some of the initial models for developing public infrastructure were not sound. In the section below, we discuss various approaches to developing public broadband infrastructure, focusing initially on the U.S. as more projects were developed there than in Canada.

Examples of Public Broadband Infrastructure: United States

Municipal Broadband Networks

United States-based consulting group Civitium advised many municipalities on the development of their networks, and suggested that there were five viable organizational models for public broadband networks. These were: i) a grassroots, community-based operation; ii) a non-profit model; iii) a 'cooperative wholesale approach', where a municipality built the network and provided wholesale access to it; iv) a public utility model, where the municipality operated the network as a utility; or v) a private sector partnership, where the municipality contracted with a private sector firm to develop a broadband network, sometimes with an expectation or understanding that there would be no cost to the municipality.[59]

Returning to our overview of the providers of broadband networks in Figure 1, we suggest that Civitium's organizational models all apply to the development of municipal broadband networks. According to Civitium, municipalities could adopt any one of these five approaches to build networks for government use, for public use, and to bridge the digital divide. These five models were widely recognized, but most were not actually used in developing municipal wireless networks. As we indicated earlier, we believe that community networks are developed with a different approach than municipal networks, and that it would be implausible for a municipality to lead the development of a grassroots, community-based operation.[60] The City of Philadelphia (one of the first large cities in the U.S. to propose a large-scale municipal wireless project) initially planned a hybrid approach that would see a non-profit agency operating a cooperative

wholesale network, but by the time the contract was awarded, the city had decided to work with private vendor Earthlink to develop the network.[61] (As already mentioned, in mid-2008, Earthlink withdrew from Philadelphia, and sold its wireless assets to a group of local investors who are continuing to operate the network.) A non-profit approach was also recommended in Boston,[62] where a pilot project is now operational.[63]

Figure 3 shows that there are many broadband infrastructure projects in the U.S. Work by Ethos Group, on the 'Better Broadband Toolkit' suggests that there is a wider variety of approaches for infrastructure development than recognized by Civitium.[64] It is beyond the scope of this report to attempt an extensive review of American projects,[65] but we do offer some brief examples of projects developed according to different business models, and comment on the reasons for their success or failure.

In some cities, broadband infrastructure is provided as a basic service. This is true in St. Cloud, Florida, where a city-owned network provides free Wi-Fi to citizens in their homes. 77% of residents had registered for the service one year after its launch, saving a significant amount annually by using the city service rather than buying access from a ISP.[66]

It is quite common for municipalities whose Municipal Electric Utilities (MEUs) already provide communications services to become involved in developing broadband infrastructure. MEUs have an advantage in entering the broadband business because they typically have access to conduits and/or utility poles, vehicles to provide servicing, and a relationship with local businesses and consumers. [67] For example:

- The Electric Plant Board in Glasgow, Kentucky was the first public utility in the U.S. to develop a municipal broadband network. It has offered internet connectivity to local businesses and to residents since 1995.[68]
- Chaska, Minnesota is another small town that developed wireless broadband infrastructure. Funded by a loan from Chaska Electric Utility, the city extended an existing fixed wireless network that already provided connectivity to local government and businesses. This new network, built with mesh technology, offers citizens residential broadband access at lower rates than cable or DSL providers. The network is also used by the local police force.[69]
- To stop businesses from leaving town because of the lack of broadband infrastructure, the City of Scottsburg, Indiana, developed a wireless network that provides business and residential internet access in five counties. This infrastructure is operated by Citizens Communications Corporation, a utility company owned by the city.[70]

In an open access infrastructure model[71] (a variant of a cooperative wholesale approach), one entity, in some cases a municipality, builds and owns the basic network infrastructure. This entity then sells access to this infrastructure at a wholesale rate to providers who offer a variety of services directly to users. This approach is important because it can ensure the basic infrastructure is in the hands of a responsible and equitable entity. By allowing all kinds of traffic equal access to this basic infrastructure, open access models can promote competition by leveling the barriers to entry and creating a level playing field for a wide variety of service providers. In addition, open access architecture that allows service providers and others to purchase bandwidth based on their needs can help to stimulate innovation of new services and devices, as well as support a full range of municipal, monitoring, safety, and internet services.

- In Burlington, Vermont, the electrical utility cleared various legal hurdles to enter the telecommunications industry. It has taken a step-by-step approach to building an open access fibre network, starting in 2002 by providing for the city's internal telecommunications needs, then expanding to serve schools, local businesses, and finally, residents.[72]
- In Utah, sixteen cities have joined together as the Utah Telecommunication Open Infrastructure Agency (UTOPIA), to finance a large-scale, publicly-owned open access fibre network. The network is currently operational, with internet service available from four providers.[73]
- Tacoma, Washington's Click! Network[74] is an open access cable network owned and managed by the municipal power utility. The network was primarily built to serve the utility's core functions, but also provides communication services to Tacoma residents and businesses via service providers that purchase wholesale access to the network. This network has attracted business to the city, increased competition in the telecommunications sector, and is regarded as a success by the local community.[75]
- In Europe, the City of Amsterdam has embarked on a large-scale fibre-to-the-home (FTTH) project, built on an open access model. Completed as planned the network could serve 420,000 businesses and residences by 2013 for the cost of €300 million. The network is likely to increase overall competition in the broadband market, will address issues of rising demand for faster broadband, help to bypass the local loop bottleneck, and overturn the short-term strategy of current broadband infrastructure owners to avoid investment in network improvements. Although it is probable that the network will negatively impact the incumbent broadband operators if they take no action, the project is unlikely to receive regulatory opposition from the European Commission, which is expected to support open access build-outs in Europe as a way to enhance the region's global competitiveness. In addition to Amsterdam, other European cities and countries including Paris, Vienna, Cologne, Denmark, Norway, Spain and Sweden are undertaking or plan to undertake publicly-led FTTH build-outs.[76]

Broadband networks can also be used for meter reading, public safety, monitoring, emergency services, and other applications. Using wireless technologies can improve the efficiency and reliability of these operations, which can, in turn, result in significant cost savings for such city services. For instance:

- NYCWiN, New York City's soon-to-be-launched public safety network, is an example of the significant investment that cities are willing to make in infrastructure to support municipal applications. The network cost $500 million to build, and will connect police and fire operations to services like real-time video through devices such as vehicle modems and handheld units.[77]
- The City of Corpus Christi, TX, was an early adopter of wireless applications for municipal services. The city originally built the citywide wireless network to provide meter reading, emergency response, and other city services, and plans to add more.[78]

The examples provided above show how broadband infrastructure can be developed to provide a variety of benefits to the public, including increasing availability and reducing costs of internet access, improving delivery of government services, and creating opportunities for economic development. While each municipality or region has chosen to develop infrastructure in a unique way, the projects are generally based on developing services to address identified public

needs. The benefits of the projects are clearly identifiable, and are built on a strong understanding of the local context. These projects are backed by sound financial plans, and where the expenditure of public funds is required, there is a solid justification for the expense.

The Failure of the Public-Private Partnership Approach for Wireless Broadband Development

In contrast, there is another municipal approach to wireless broadband infrastructure that has been less successful. (Appendix 3 provides a detailed list of resources on this topic.) Many of the high profile U.S. projects involved some form of public-private partnership, and these partnerships have often proven to be flawed. (The network being developed in Minneapolis is a rare example of a successful project developed in this manner.[79]) It is likely that these partnerships emerged as a response to the real and anticipated legislation opposing municipal involvement in the telecommunications sector.[80] They also appeared to offer a means for cities to develop public infrastructure with limited expenditure of public funds.

The principle behind this approach was that a private company (or companies) would fund the design, deployment and operation of a network, and generate revenues by charging fees to subscribers. In return, a municipality would provide access to city assets such as light poles, and might also agree to act as an anchor tenant for the network (meaning that they would purchase services from the provider). In some instances (e.g. Wireless Philadelphia), the municipality might also negotiate with the private provider to offer affordable rates for low-income users, and the provider might offer some limited form of access (e.g. low speed, or with advertising) to the public free of charge. This model seemed to offer cities a low-risk way of developing infrastructure, but as Civitium (an architect of some of these projects) concluded earlier this year:

> By the end of 2007, the prospect of major cities using a low-cost wireless technology to solve a wide range of economic, social and internal needs, while at the same time introducing new broadband competition and openness to their markets, under a business model that presented little taxpayer risk – appeared to be, as many had suspected – too good to be true.[81]

One problem was that although wireless infrastructure can be relatively inexpensive to build, this cost is not insignificant, and the private sector partners must be able to recoup their investments through selling subscriptions to their networks. It was common for wireless networks to be proposed in locations where cable and DSL providers had already established and paid off sizeable infrastructure investments, and had a solid customer base.[82] The wireless operators tended to overestimate the market share they could achieve, apparently ignoring the fact that wireless connections are generally slower than cable or DSL connections and tend to be less reliable, meaning that users had little incentive to switch to wireless services that were neither significantly better nor cheaper.[83] In addition, cities were not keen to sign anchor tenancy agreements, making it very difficult for the private sector partners to generate revenue from their investments. The end result was that the two companies most involved in municipal wireless projects, Earthlink and Metro-Fi, have completely withdrawn from the sector, abandoning many projects, and leaving cities like Philadelphia, Houston, New Orleans, Portland, San Francisco and other locations in the Silicon Valley to reconsider their options.

Community Wireless Networks

Community wireless networks take a completely different approach than municipal projects, developing networks from the ground up, on a small scale, often through the use of volunteer labour and 'hacked' equipment. Community networking groups began to use Wi-Fi shortly after the standard was developed, building on the traditions of community media building like rural co-operative phones and ham radios[84] to develop alternatives to commercial internet service provision. In the U.S., the community wireless networking movement is supported by groups like the New America Foundation,[85] Ethos Broadband,[86] the FreePress[87] and the Media Access project.[88]

Among the pioneering community wireless groups in the U.S. are Champaign-Urbana Community Wireless Network (CUWiN), NYC Wireless and Seattle Wireless. As explained on CUWiN's website, the mission of community wireless networking is "to develop decentralized, community-owned networks that foster democratic cultures and local content. Through advocacy and through our commitment to open source technology, we support organic networks that grow to meet the needs of their community."[89] CUWiN began by developing a wireless network in the City of Urbana, IL. As an organization, CUWiN has also become a powerful voice for the community network movement, has led the development of software for building community mesh networks, and has encouraged partnerships among non-profit groups, researchers and community organizers to advance the cause of community wireless networking.

The members of NYCWireless, founded in New York City in 2001, have also been strong advocates for the development of community-based wireless infrastructure. They have developed free wireless internet access in more than ten parks and open spaces in the city of New York, and more recently have focused on work with non-profit housing organizations to provide affordable internet access to residents in low income housing.[90] Seattle Wireless believes that "ordinary people can build a network without recurrent fees that is not beholden to any commercial telecommunications provider."[91] The group has developed hotspots throughout the city of Seattle, building a network that provides internet access and also supports voice over IP telephone calls at its hotspots (providing an alternative to cellular phone service). There are many other community wireless groups providing internet access throughout the U.S.[92] These groups have been successful because they develop infrastructure that meets very specific community needs. Working on a small scale and relying on volunteer labour, the groups are able to develop useful infrastructure at a low cost.

FON and Meraki offer another approach to developing community networks. Both of these could be considered hybrid private sector-community developers. Neither is U.S.-centric in its operations, but we include them here as additional examples of community broadband (some might call their approach 'pseudo-community' broadband). Essentially, these companies provide hardware and software to promote community broadband networks, but do so on a for-profit basis. FON originated in Spain, with the idea that individuals willing to share their bandwidth could access the networks of other willing 'sharers' around the world. Anyone can join FON's network, by purchasing a FON router and connecting it to an existing broadband connection. This creates a FON hotspot, accessible by other FON members for free, and on a pay-per-use basis for non-members. Members can find FON hotspots on a map, and connect to them while away from their own connections. While this model sounds appealing, in reality the approach

does not work well to provide potential users with reliable broadband connections.

Meraki is a company that provides hardware and software to enable easy development of mesh networks. Their products make it simple for communities to legally share broadband connections, but some community wireless developers are wary of Meraki's corporate approach.[93] In order to develop a Meraki network, the hardware must be configured through Meraki's servers, meaning that the community developers do not have full control of the network. Recent price increases for Meraki hardware have left potential users wary of hidden costs that may arise in order to maintain a Meraki network once developed, but the technology has been used successfully in various locations.[94]

We conclude that neither of these approaches enable the development of broadband networks that fully meet the public's needs.[95] There is potential in using wireless technologies to share existing broadband connections, but more work is needed to ensure that the networks provide reliable, high quality, sustainable broadband access.

Summary

This section highlights a variety of approaches for building public broadband infrastructure in the United States. Some models have been more successful than others, but all contribute to the increased availability of broadband infrastructure, and demonstrate that it is possible for municipal and community groups to develop infrastructure to suit their own needs. Municipal and community groups have different ways of developing infrastructure, with fewer resources generally available to community groups, but both are able to build viable infrastructure that provides benefits to the public.

Examples of Public Broadband Infrastructure: Canada

Wireless Broadband Networks

The state of wireless networking in Canada up to 2006 is discussed by CWIRP contributor Alison Powell and our colleague Leslie Shade in *Government Information Quarterly*'s special issue on wireless broadband.[96] They describe growing interest in developing wireless networks in Canadian communities, but it is noted that some of the projects they identified were not completed. A list of Canadian initiatives is outlined in Appendix 4, with some examples provided below.[97]

Fredericton's Fred-eZone and Toronto's One Zone are the first large scale Wi-Fi networks in Canada. The Fred-eZone is operated as a municipal service offering free internet access to anyone in Fredericton, whereas the Toronto project is a for-profit venture that charges users for internet access, initiated by Toronto Hydro Telecom. Toronto Hydro Telecom was recently sold to Cogeco Cable, and it appears that the One Zone network will continue to operate as part of the Cogeco Data Services subsidiary. Telecom Ottawa developed a small Wi-Fi network in downtown Ottawa, but it is not citywide. Like Toronto Hydro Telecom, Telecom Ottawa has also recently been sold (to Atria Networks), and its Wi-Fi network remains operational. Neither Toronto nor Ottawa's networks focus on delivering broadband services in the public interest, although as will be discussed below, there was potential to develop this infrastructure in different ways to provide public benefit. The Province of Saskatchewan provides Wi-Fi in the downtown areas of major cities in the province. Other cities, including St. John, NB, and St. Albert, Alberta also offer wireless access. The City of Vancouver recently decided not to proceed

with plans for a municipal wireless network.

Community Wireless

Montreal's Île Sans Fil ('wireless island') was one of the first community Wi-Fi networks in Canada. Led by a small group comprised mainly of technicians, Île Sans Fil (ISF) provides free internet access in cafés and public spaces around the City of Montreal. ISF has been influential in the development of other community Wi-Fi networks in Canada, including Zone Accès Public Quebec, BC Wireless, Ottawa-Gatineau Wireless and Wireless Toronto.

In Toronto, Wireless Toronto has had limited success in providing free internet access. It does have hotspots at several public parks and at the St. Lawrence Market, but overall its impact has been small. Wireless Nomad is a Toronto-based cooperative internet service provider that offers residential internet services to a small base of customers. What is unique about Wireless Nomad is that it provides customers with secure Wi-Fi routers that enable them to share their wireless connections with anyone within range of the router. Wireless Nomad also offers free hotspots in a few locations around the city.

Other Broadband Infrastructure

The Kuh-ke-nah Network (K-Net) is an initiative of Keewaytinook Okimakanak (KO), a non-profit tribal council in Northwestern Ontario. K-Net is one of the first Aboriginal networks created, developed, and maintained mostly by First Nations peoples in Canada.[98] Established in 1994, K-Net operates and manages a community broadband network that serves 25 First Nations, in more than 60 aboriginal communities, over an area of 385,000 square kilometres. K-net services and applications include teleconferencing, telehealth, education, community e-centres, promoting economic development in the region.[99] It provided organizational and technical support to the Lac Seul First Nation, helping it develop a wireless network to bring broadband connectivity to its community. It is difficult to categorize K-Net, but it is probably best described as following a hybrid community-municipality approach.

On the commercial side, Bell, Telus and Rogers offer co-branded, fee for use hotspots in many hotels, coffee shops and other public spaces across the country. There have also been some hybrid commercial-municipal projects. For example, Bell, Nortel and the Township of Chapleau in Northern Ontario, partnered to create 'Project Chapleau,'[100] providing a one year trial of free internet access to local residents (as a precursor to internet provision at commercial rates) and developing a portal to help the community exploit the use of information technologies for economic development.

UTelcos (utility telcos) are providers of telecom services created and in many cases owned by electric, gas or water utilities. The majority of utelcos in Canada are in Ontario, and they have extensive fibre-optic networks that provide telecommunications services primarily to municipalities, schools, universities and hospitals.[101] Utelcos do not provide public broadband infrastructure, as we have defined it. But given their extensive fibre-optic networks, they have the capacity to provide public broadband, by offering an alternative source of broadband supply to households, for example. In Ontario, Atria Networks, which is jointly owned by hydro utilities in Guelph and Waterloo Region has been buying up the telecommunications assets of local utilities (including Hamilton, Ottawa, Peterborough), in an effort to acquire telecommunications networks that serve the whole province. As well as providing fibre-optic broadband connectivity to businesses, local government offices, school boards and other organizations, Atria offers free

Wi-Fi in public libraries in the cities it serves,[102] as well as paid Wi-Fi at hotspots in Ottawa and the Waterloo-Wellington region.[103]

Summary

Municipalities in Canada did not rush to develop wireless broadband infrastructure. Through 2006 and early 2007 there was great interest in the potential for municipal involvement in broadband development, [104] but there was more caution in Canada than in the U.S. We are not aware of any major new initiatives currently underway to develop municipal wireless infrastructure in Canada. The City of Fredericton's eZone continues to be widely studied as an example of municipal broadband infrastructure, and interest in Toronto's One Zone remains high. On the community side, Île Sans Fil has established an international reputation as a community wireless group that knows how to encourage local businesses and organizations to develop hotspots. Its software for managing public hotspots has been taken up by groups around the world, allowing them to combine community content with network access, just as in Île Sans Fil's hotspots in Montreal. K-Net has also been studied extensively, as an exemplar of broadband development in a remote region.

Canadian Case Studies

When this project began, we proposed a series of case studies to understand the development of public broadband infrastructure in Canada. Our case study partners (Fred-eZone, K-Net, Île Sans Fil, Wireless Nomad) were selected to represent a diversity in approaches to developing wireless public broadband infrastructure. At the close of our project, it is interesting to note that each of the projects we identified in 2005 is still operational, and that these projects remain the most prominent examples of public broadband network development in Canada.

A brief description of each of our cases was provided above. We note that our research on the Toronto Hydro Telecom network, the One Zone, relied upon secondary data. Despite repeated attempts, we were unable to establish a working relationship with the company. Given the nature of their project however, it was important to include it in our study. Although Toronto Hydro Telecom and its One Zone network have now been sold to Cogeco Data Services, we refer to it here as the Toronto Hydro Telecom network, as it was developed under its auspices. Working with K-Net, we studied the Lac Seul Community Wireless Network as a specific example of wireless broadband development in a remote area. This network is owned by the Lac Seul First Nation, not by K-Net, but K-Net was very instrumental in its development.

After reviewing print and web sources of information on each of our cases, the four investigators visited each site, and met with the network developers. Follow-up visits, by student research assistants and/or investigators, took place after we developed an initial understanding of each case. Being able to visit each site proved invaluable, as it helped us gain a broader understanding of the scope and complexity of public infrastructure developments in Canada.

We also continued to monitor the public broadband 'industry' around the world, keeping track of new projects, new technologies, and new models for developing broadband infrastructure. One of the tools we used to support this process was the social bookmarking site *delicious.com*, where all members of our research team could save web bookmarks. This site, at www.delicious.com/cwirp is still active, and provides links to more than 650 websites related to the development of public broadband infrastructure. We also found the muniwireless.com and

Wi-Fi Networking News[105] blogs very helpful and provided links to newsfeeds for these and several other blogs on our website.

A detailed summary of findings for each of our case studies is provided on the CWIRP website, at www.cwirp.ca/resources.php. In this report, we focus on synthesizing the results, showing points of similarity and difference across the cases, and highlighting key findings related to the development of broadband networks that are in the public interest. We begin with a description of the basic characteristics of public broadband networks, and then use these features to compare each of our cases (see Table 1 below).

Characteristics of Public Broadband Networks

Geographic location: The location of public infrastructure installation is important because the availability of commercial broadband infrastructure is influenced by location. Urban areas in Canada are generally served by commercial Internet Service Providers (ISPs), but citizens in rural and remote areas have more difficulty in getting basic internet access. It often costs more to provide service in rural and remote areas, and these costs are passed on to users in instances where service is provided.

Type of infrastructure: As illustrated in Figure 1 above, there are various different approaches to providing infrastructure. In general, infrastructure is provided by municipal organizations, community networking groups, or by commercial entities. Our cases cover all of these types of networks.

Location of service: This refers to the physical space(s) covered by the network. Our research has demonstrated that outdoor wireless networks are not very usable, and as such, do not provide particularly useful public infrastructure.[106]

Purpose of service: Wireless networks can be used to deliver government services, to support government operations (e.g. remote monitoring of sensor data, surveillance, support for remote workers) and to provide individuals with access to the internet, and to each other (peer-to-peer connections). In our case studies, the focus has been on providing internet access and peer-to-peer connectivity (functionality used in the Lac Seul case).

The concept of primary versus secondary access is an important one, and appears not to be well-understood by developers of municipal wireless networks hoping to generate revenue by acting as internet service providers.[107] A network that provides primary access is an individual's main source of internet access. For most users, primary access would be in their homes, and the expectation is that such access would be reliable, of high quality, and would not limit the types of applications available to the user.[108] Most users pay for this internet access, but in some instances it is subsidized, or provided free of charge as part of a program to improve accessibility. Our research shows that Wi-Fi technology does not provide good primary access.[109]

In general, people's expectations are lower for secondary internet access, and Wi-Fi works reasonably well in this context. Secondary access would be provided to people away from their place of residence or business, and is more likely to be used for short periods of time for non-essential tasks. Willingness to pay for secondary access is lower than for primary access. For people who do need highly reliable secondary access, and are willing to pay for it, there are

better choices than Wi-Fi (e.g. smart phones or laptop cards operating on cellular data networks).

It is often forgotten that internet protocols can be used to operate networks that are not actually connected to the internet. Applications can support local communications and service delivery over a broadband network, without any need for internet connectivity.

Technical configuration: Wi-Fi technology was thought to be a relatively cheap and easy means of providing internet access. It can be deployed to cover large geographic areas. In simple terms, the basic configuration involves attaching a Wi-Fi access point to a broadband connection, to provide a Wi-Fi signal that can be picked up with a Wi-Fi equipped laptop, PC, or mobile phone. The Wi-Fi signal is transmitted over licence exempt spectrum, meaning that anyone can set up a Wi-Fi network. The broadband connection that powers the Wi-Fi signal is called the 'backhaul,' and it can be provided using a fibre-optic, DSL, cable or wireless broadband connection. To cover larger spaces, more access points are added to the network. Some municipalities use licensed spectrum[110] to provide wireless backhaul for their Wi-Fi networks, for example by using a hub-and-spoke system to provide backhaul in areas unserved by fibre. Mesh networking can also be used, to share the signal between access points, meaning that not all access points need backhaul connections. Appendix 1 lists resources that describe the technical aspects of creating wireless and broadband networks.

Early plans for municipal networks frequently underestimated the number of access points required to provide service to particular geographic areas. Problems also arose because Wi-Fi signals do not pass through wet leaves, making networks unreliable and requiring redesign. It was also found that some utility poles used for mounting access points did not have sufficient power to supply the access points, or were incapable of supporting the weight of the access point. All of these issues contributed to higher costs than initially anticipated for Wi-Fi networks.

In addition to the technical aspects of installing Wi-Fi access points, many network operators also wanted to have some way of managing access to their network. Various software options exist to allow network managers to control access, for example by requiring a login process prior to use. Île Sans Fil developed its own open source access control software, wifidog, which is used by many other community networking groups. Commercial products are also available.

Network quality and specific applications supported: Users expect their primary internet access point to be available at all times, with broadband connection speeds. They also expect that they can run any application or service over this network. But actions by commercial internet service providers to restrict users' online activities are becoming more common. A potential strength of a public broadband service is that the conditions of use are not set by a commercial provider, meaning there is a possibility for the service to better meet the needs of its users. However, there are costs in providing unlimited bandwidth, and there are legitimate reasons for public broadband providers to manage the traffic on their networks (e.g. to provide quality of service guarantees to allow videoconferencing and telehealth services sufficient bandwidth to work over a wireless network).

Network costs: Civitium[111] estimates that a capital expenditure of approximately $150,000 (USD) is required to provide Wi-Fi access to a square mile of territory. Costs include backhaul, wireless networking equipment, site surveys to determine the best network configuration, and

installation. It is suggested that mesh networks can be deployed much more cheaply (e.g. using Meraki hardware). Approaches that do not involve blanket coverage of geographic areas are much cheaper, and may be more effective if they focus on delivering coverage to indoor, rather than outdoor areas.

Usage costs: To access any Wi-Fi network, a potential user must have a suitable access device, like a laptop computer or a mobile phone. In places where Wi-Fi signals reach indoors, desktop computers can also be used for network access. This is an important point, as it must be noted that a substantial investment in an access device is required to access 'free' Wi-Fi.

Community wireless networks generally provide free Wi-Fi, as do many municipal services. Some municipal networks provide(d) advertising-supported 'free' access, with an option to pay for a service without advertisements.[112] Services that charge for use often offer three pricing options: hourly, daily, and monthly, similar to the pricing plans for commercial services.

Reduce the digital divide: As indicated in the earlier discussion of the rationale for developing public broadband infrastructure, it is possible to use these infrastructure to increase accessibility. Philadelphia's wireless network is the best-known example of a network that was deployed with an express purpose of reducing the digital divide. Specifically, it aimed to provide internet access to low-income community members, by coupling wireless connectivity with a program to provide home computers and training on how to use the internet. Simply deploying a network is not enough to reduce the digital divide. In order to reach those who are not connected to the internet, it is necessary to ensure that they have a usable access device, and sufficient training to use the internet. Related to the point made earlier about primary internet access, one problem with using wireless networks as a means of bridging the digital divide is that they typically do not provide high quality internet service to indoor locations. For wireless networks with a specific focus on improving accessibility, steps need to be taken to ensure that network signals actually reach potential users inside their residences.

Characteristics of the Case Study Networks

Table 1 provides a summary of the main characteristics of each of the networks we studied. The networks operate in a range of geographic locations and with a variety of ownership models. Four of the five networks provide network access in indoor locations, all provide service to outdoor locations. Only two of the five provide reliable primary internet access, with the others focusing on access for individuals away from their places of residence or work.

Each network provides a different type of service to a different group of people. Although all the networks use wireless technologies in some form, there is a mix of licensed and licence exempt spectrum deployed, and fibre broadband networks are used to provide the backhaul (the underlying connectivity) to some networks. In Fredericton's case, the eZone is made possible because of the fibre network operating in the city. Île Sans Fil relies upon commercial internet service providers to provide connectivity for its hotspots, whereas the One Zone uses it own fibre network. Lac Seul's network is reliant upon backhaul in Sioux Lookout, 40 kilometres away from the community. Wireless Nomad is able to operate because of Canadian telecommunications regulations that require telephone companies to sell access to their broadband networks on a wholesale basis.

The networks were deployed for different reasons. Both the Fred-eZone and the One Zone could be described as opportunistic models, in that they use existing broadband infrastructure to provision their Wi-Fi networks. Their philosophies of service are fundamentally different however – the City of Fredericton promotes free Wi-Fi as part of the city's infrastructure, whereas Toronto Hydro Telecom saw its Wi-Fi network as a way to capitalize on its investment in fibre technology, by charging people for access. Despite these differences, both are viewed as a means of promoting economic development in their respective communities. The Lac Seul network also promotes economic development, in a more direct fashion, by enabling community members to create economic opportunities through their use of the internet. It also fosters community engagement, by connecting citizens to each other, for example through the myknet.org personal homepages. Wireless Nomad was founded with a view to provide a better option for people looking for secondary internet access, but has ended up operating primarily as a regular internet service provider (ISP). Île Sans Fil began developing internet access in cafés around Montreal because its founders believed that there should be free Wi-Fi available in cities, and that Wi-Fi could be used to engage artists and creative individuals in local communities.

The costs of deploying the networks vary substantially, from almost nothing in Montreal, to $2,000,000 in Toronto. For its $2,000,000 investment the One Zone has developed a technically robust network, but given that it primarily serves outdoor areas, we believe that usability is compromised and the number of potential users is severely limited. Its costs of deployment are also significantly higher than estimates for similar networks in the U.S. In contrast, although ISF does not offer the ubiquitous coverage that One Zone does, it does offer reasonable connectivity to users, free of charge, in locations like cafés where it is pleasant and comfortable to use the network. Likewise, Fredericton's network is also used primarily in indoor locations, where locals and visitors can enjoy free Wi-Fi access. The costs of provisioning the Lac Seul network reflect the challenges of serving remote communities, and also incorporate extensive investment in access devices and training, needed to enable local community members to use their broadband infrastructure effectively.

The table shows that the free networks are offered on a 'best effort' basis, meaning that there are no guarantees of reliability or availability. For example, in Fredericton, the city discourages people from mentioning the availability of eZone access in residential locations when advertising rental properties. As the network managers note, they could move a Wi-Fi radio one day, and cut off access to that property. The eZone is not designed to be a regular internet service provider, and does not offer support to its users. In contrast, the One Zone does offer customer support, and while it does not offer quality of service guarantees for applications like videoconferencing, it does allow any type of data transfer on its network. In ISF's case, network reliability is dependent upon the quality of the network at each hotspot, and on the technical skills of the hotspot host. ISF does provide technical support, but with a limited core of volunteers it can take some time for a hotspot to be fixed if it stops working.

TABLE 1: COMPARISON OF BASIC CHARACTERISTICS OF CASE STUDY INFRASTRUCTURE

	Fred-eZone, Fredericton, New Brunswick	**Lac Seul First Nation, Northern Ontario**	**Île Sans Fil (ISF), Montreal**	**Wireless Nomad, Toronto**	**One Zone, Toronto**
Geographic location	Small urban centre	Remote northern First Nation community	Large urban centre	Large urban centre	Large urban centre
Type of infrastructure	Municipal	Hybrid - Municipal/community	Community	Community and Fee for Service	Fee for Service
Network owner	City of Fredericton	Lac Seul First Nation	Software provided by ISF (voluntary organization), hotspot spaces provided by small businesses	Co-operative owned by members. No paid staff, but despite co-op structure the network founders act as de facto owners.	Toronto Hydro Telecom, sold to Cogeco Data Services (2008)
Location of Service	Indoor and outdoor public spaces, including local hotels, malls, truck stop	Community centres, Band Council offices, individual residences	Primarily indoors in cafés, some outdoor coverage in parks	Primarily indoors: individual residences (each acting as a hotspot), some public hotspots	Outdoor public spaces in downtown core

	Fred-eZone, Fredericton, New Brunswick	**Lac Seul First Nation, Northern Ontario**	**Île Sans Fil (ISF), Montreal**	**Wireless Nomad, Toronto**	**One Zone, Toronto**
Purpose of service	To promote Fredericton's reputation and encourage economic development, provide secondary access to residents and visitors.	To provide the primary source of internet access for communities in the Lac Seul First Nation.	To provide secondary internet access to anyone in the vicinity of a hotspot.	To provide primary internet access to individual residences, and secondary access at public hotspots. The business started with a view of providing a better alternative to commercial hotspots, but now operates primarily as a residential ISP.	To provide secondary internet access for local residents, workers, visitors (and promote economic development), and could also provide primary access for condo dwellers in the downtown core. Leverage investment in fibre optic network to provide a return to the corporation.
Technical configuration	Uses excess capacity from the Fredericton Community Network (fibre broadband). Service at hotspots is provided with Wi-Fi, backhaul to community network is mainly wireless. Radios installed on city utility poles and towers. Uses licensed spectrum in 4.9 GhZ or 5.4 GhZ bands for backhaul.	K-Net as internet service provider, wireless backhaul from Sioux Lookout using 3.5 GHz licensed spectrum. There is no fibre available in these communities. Licensed spectrum is used to provide QoS (quality of service) for videoconferencing, telemedicine, and voice over IP applications. Wi-Fi provides network access to local residents, and to the distance education centres in each community.	Each hotspot is created by installing a specially configured Wi-Fi router on the host's broadband connection (e.g. DSL/cable). This router provides a Wi-Fi signal for use at the host location. Hosts use a business internet subscription, which allows network sharing.	Internet service is provided to each subscriber through a standard DSL connection (purchased on a wholesale basis from a reseller). A specially configured router is used to create a secure hotspot for each subscriber. Within the house, the subscriber can use a wired or wireless connection to their DSL service.	Uses licence exempt spectrum with mesh architecture to provide ubiquitous outdoor coverage in a 6 km^2 area in downtown Toronto. Backhaul is provided by Toronto Hydro Telecom fibre network. Radios are mounted on city utility poles (owned by Toronto Hydro), hampered with lack to power to the poles.

	Fred-eZone, Fredericton, New Brunswick	**Lac Seul First Nation, Northern Ontario**	**Île Sans Fil (ISF), Montreal**	**Wireless Nomad, Toronto**	**One Zone, Toronto**
Network quality and specific applications supported	No QoS guarantee, network offered on 'best effort' basis. Bandwidth is restricted during business hours. The network is configured to provide good access for email and web browsing, but does not support high bandwidth applications like peer-to-peer file sharing.	Network is engineered to support applications like videoconferencing and telehealth which require quality of service guarantees. The remote location makes it difficult to service the network, and equipment is subject to weather-related problems. Users have access to K-Net services, including local community applications like email and web pages.	Quality is dependent on the network host's broadband connection. The wifidog portal encourages interaction among users within a café, also enables hotspot host to promote local content. HAL (Hubs des Artistes Locaux) was developed to encourage users to share text, images and sound, but is not currently operational.	All home subscribers can share their internet connections with Wi-Fi. Their primary internet connection is provided by DSL and provides a highly reliable service. Wireless Nomad's terms of service explicitly allow network sharing and operation of servers, unlike commercial ISPs.	No restrictions on network usage. High speed, reliable service, judged by an independent third-party assessor to provide the best wireless broadband in North America (2007).

	Fred-eZone, Fredericton, New Brunswick	**Lac Seul First Nation, Northern Ontario**	**Île Sans Fil (ISF), Montreal**	**Wireless Nomad, Toronto**	**One Zone, Toronto**
Network Costs	Total cost for deploying the network is estimated at $450,000, which includes a $250,000 in-kind contribution of wireless equipment from Cisco. On-going costs are covered by the city's telecommunications budget.	Initial costs were $600,000, of which $500,000 was provided by FedNor, and $100,000 by the Lac Seul Band Council. This figure includes purchase of computers and videoconferencing equipment, and cost of staff. Additional funds (~$80,000) were provided through SchoolNet and the e-Communities partnership, used to redesign the network to allow for QoS applications. The network manager was paid $30,000 per annum.	Hotspot hosts pay $50 per year to belong to ISF, and then pay a commercial internet service provider a monthly fee. All development work is done by volunteers. As there is no central network to maintain, costs are low.	The co-op attempts to operate on a cost-recovery basis, but has accumulated $16,000 in debt, part of which is owed to their previous DSL wholesaler.	Costs of the building the network are estimated at $2,000,000 (for approx. 2.3 mi^2 area, much higher cost than Civitium's estimate). Toronto Hydro purchased the street lights in the City of Toronto for $60,000,000, and allowed Toronto Hydro Telecom to use these lights to mount wireless networking equipment.
Usage Costs	Free access for anyone within the network's reach.	Free access for anyone within the network's reach.	Free access for anyone within the network's reach. As hotspots are often in businesses, most users will purchase something (e.g. coffee) when using the hotspot.	Hotspot use is free. Subscribers pay $150 to purchase the Wireless Nomad modem and DSL router, and then pay a monthly fee of $32.95.	Pay-for use service: • Hourly: $4.99 • Daily: $9.99 • Monthly: $29.00

	Fred-eZone, Fredericton, New Brunswick	**Lac Seul First Nation, Northern Ontario**	**Île Sans Fil (ISF), Montreal**	**Wireless Nomad, Toronto**	**One Zone, Toronto**
Reduce the digital divide?	No explicit focus on accessibility. Potential users must have a Wi-Fi enabled laptop or smart phone.	Yes, by bringing internet access to an unserved community, and providing access to the internet at local community centres for those without home computers.	No explicit focus on accessibility. Potential users must have a Wi-Fi enabled laptop or smart phone.	No explicit focus on accessibility. Potential hotspot users must have a Wi-Fi enabled laptop or smart phone. Subscribers pay a similar monthly fee to that charged by commercial internet service providers.	No explicit focus on accessibility. Potential users must have a Wi-Fi enabled laptop or smart phone. Initial plans suggested revenues from Wi-Fi network access would be paid as a dividend to City of Toronto.
Other comments	In the City of Fredericton, the wireless service is a considered basic infrastructure, like parks or sidewalks. There is a strong belief that access to this infrastructure should be free.	K-Net's expertise in acquiring funding for ICT infrastructure was crucial to the development of the Lac Seul Wireless network. The network could not have been built without K-Net's technical support.	Web site is bilingual, supports French and English users.	Wireless Nomad's residential internet service operates in a manner similar to commercial ISPs. Its subscribers are mainly disaffected Bell and Rogers subscribers, looking for an alternative provider, and favouring the co-op approach.	The initial motivation for the network was to enable connection to all homes in the City of Toronto to read their smart electricity meters. This project was abandoned, as were plans to cover a wider area of the city, and promote residential broadband access.

The Lac Seul network is the only one of our cases where there is an explicit focus on providing access to an underserved population. In Fredericton's case, the development of the fibre network that serves the local community did help to improve commercial and residential internet access in the city, but the eZone itself has no mandate to increase internet accessibility among the citizens of Fredericton. Wireless Nomad provides primary internet access, but as its offerings are similar to the commercial ISPs, it can make no claims to be reducing the digital divide. Like the eZone, ISF and the One Zone enable secondary internet access, which provides additional internet access to those who already have access somewhere else.

Case Summary

Unique Features and Critical Success Factors

The case studies show that each network was developed in unique circumstances, meaning that none of them are easily replicated. For instance, although the founders of the Fred-eZone have generously shared their experiences in creating their wireless network with cities around the world, it would be difficult for many other cities to do what Fredericton has done. One of the keys to Fredericton's success is that it built a fibre broadband network to support the needs of its community and to lower telecommunications costs for the city. It did not begin by building a wireless network, it developed the network as somewhat of an afterthought, to make use of the existing broadband network's excess capacity. It would be difficult for other cities to follow this model, unless they also had access to a broadband network to provide backhaul capacity for a wireless network. It is also noted that the eZone was not designed to deliver government services, provide local content, or to provide internet access to citizens in their homes (although some people can access the network from their residences), thus in many ways it does not offer particularly useful public infrastructure. Nevertheless, the service is popular and is used in locations throughout the city by locals and by tourists (as well as by drivers passing through the truck stop on the edge of town). In the Fredericton case, although it is the Wi-Fi network that has garnered the most attention, it is the broadband network that is the true example of good public ICT infrastructure, not the Wi-Fi network. The fibre network helped to lower the cost of broadband connectivity at a business and institutional level in the city (and encouraged competition in the ISP market), and allows the city full control over how the network is managed and used. This is a very valuable asset for the city of Fredericton.

The Lac Seul Wireless Network is the only network that we studied that was designed to deliver community and municipal services, and to provide internet access for the local government. Although its location and exposure to the harsh Canadian environment mean that the network is not as reliable as its designers and users would like, when it is working it does have the capacity to provide telehealth and videoconferencing services, connecting people to services outside their local community. Through its affiliation with K-Net, it also provides a way for people in the community to engage with their friends and family who live in other regions. However, without the support of K-Net, it would not have been possible to build this public infrastructure. Getting access to funding for network development, user equipment and training was essential, as was the technical expertise provided by K-Net. This network is also unique among our cases because it was designed to provide primary internet access to people, thereby increasing accessibility and reducing the digital divide.

Île Sans Fil's model has worked very well in Montreal. But Wireless Toronto, a group with a similar philosophy and approach to providing Wi-Fi to communities, has not been so successful

in Toronto.[113] The keys to Île Sans Fil's success include a core group of highly committed volunteers with the technical skills needed to develop their access control software (wifidog), and the promotional skills necessary to encourage business owners to become hotspot hosts, coupled with the café culture of Montreal, where a large contingent of artists and freelance workers welcomed the availability of wireless internet access. ISF has acted as a training ground for its volunteers, encouraging innovation in open source software development and facilitating experimentation in the community building aspects of wireless networking. But the organization is criticized for its limited view of community – this group of young, white, mainly francophone, men has built networks for use in places they want to go. In other words, it can be suggested that the greatest beneficiaries of the ISF network are the network developers themselves, who have found ways to get wireless internet access at the locations they frequent in the city. Despite this criticism, it is certainly true that the hotspots are used by many people who had no involvement, or interest in network development. Île Sans Fil has fostered a culture of hotspot use in the City of Montreal, and in the process has raised expectations as to the broader availability of wireless infrastructure across the city, not just in selected hotspots. ISF is now working with the City of Montreal directly to increase internet availability throughout Montreal.

Wireless Nomad is the least complex of our case studies. It is a small operation, and although it had some promising ideas about developing mesh networks to share internet connections throughout the city, it has not yet been able to develop these. What can be learned from Wireless Nomad is that it is extremely difficult for a small group of people, with a limited budget, to develop good alternatives to commercial internet service providers. Wireless Nomad has succeeded in providing its users with a less tightly controlled form of internet access (e.g. enabling sharing, allowing users to run servers), which can be considered a small step toward delivering broadband connectivity that is truly in the public interest. It is very important to note that Wireless Nomad is able to act as an internet service provider because of regulations that force incumbent telecommunications companies to sell wholesale internet access capacity to new market entrants. This situation would not be possible in the U.S.

Toronto Hydro Telecom's One Zone was launched with much fanfare, and according to Mayor David Miller, signified "the beginning of a new era in telecommunications in the City of Toronto."[114] But we found that the network was not very usable, and as a commercial service, was not differentiated from other commercial hotspot providers. In promoting the One Zone, Toronto Hydro Telecom was always very clear that as a private corporation, albeit with the City of Toronto as its 'sole shareholder's shareholder,' it would need to recoup its investment in network infrastructure by charging fees to users. This project was not about improving internet accessibility for Torontonians, or about improving the quality of their internet services. It was a business proposition for Toronto Hydro Telecom. However, it was noted that profits from the One Zone (if there were any), would be returned to Toronto Hydro, which pays an annual dividend to the City of Toronto. As such, it was argued that the network could indirectly help to benefit the City of Toronto and its citizens. We believe that the network could have been designed and operated using a public utility model, which could provide direct benefits to Torontonians by reducing their internet access costs substantially, and offering them service on conditions that were more favourable to the users than those of commercial ISPs. Now that the network has been sold to Cogeco Data Services, which is not indirectly owned by the City of Toronto, there is no incentive to move forward with this approach.

Each of these models of developing broadband infrastructure has its strengths and weaknesses, and some opportunities to create infrastructure that better meets the needs of the public have been overlooked. In each case, there are critical success factors that enabled the infrastructure development, but these are not always easily replicated. Additionally, some of the models would not be easily extended to provide service on a larger scale. These points are summarized in Table 2.

Although the projects all extend broadband infrastructure in the communities they serve, Île Sans Fil, the Fred-eZone and the One Zone are simply adding additional capacity to areas that already have service. There is no doubt that many people enjoy being able to use the internet while in a convenient indoor location, for example at hotspots in Fredericton, Montreal or Toronto, but arguably this is not an essential service. This internet access may improve perceived quality of life in these communities, but given that the service is offered on a 'best effort' basis, it can not be considered sufficiently reliable for individuals to consider replacing their existing commercial internet access arrangements.

Assessing the Benefits of These Network Developments

Earlier in this report, we described the potential benefits that could be achieved through the development of public broadband infrastructure. Drawing on this list of potential benefits, the last row in Table 2 highlights the public benefits actually provided by each of the wireless networks we studied. The Lac Seul network, developed through the support of K-Net and various government funding agencies, is the one that provides the most benefits to its community of users. This is because it provides service where none was previously available. As a municipal-community hybrid, the network can support municipal operations as well as encourage community development. The other networks did not deliver this combination of benefits.

The two networks offering municipal level services, the Fred-eZone and the One Zone, both provide supplementary network access, and may contribute to local economic development. In both cases however, there is potential for the networks to do more than they are doing. They could explicitly tackle the digital divide and find ways to extend service to those without access, and could also use the networks as a platform for government service delivery. This has been considered in Fredericton, but has not happened because of difficulties in finding the right equipment to work with its wireless network. With the change of ownership at One Zone, this is no longer a possibility.

Although it operates primarily as a commercial ISP, Wireless Nomad is philosophically grounded in the community wireless networking movement. ISF and Wireless Nomad both encourage community engagement and innovation through their networking efforts. Wireless Nomad's ISP business provides an essential service to its subscribers, with conditions more favourable than commercial ISPs.

TABLE 2: COMPARATIVE ASSESSMENT OF CASE STUDY PROJECTS

	Fred-eZone, Fredericton, New Brunswick	**Lac Seul First Nation, Northern Ontario**	**Île Sans Fil (ISF), Montreal**	**Wireless Nomad, Toronto**	**One Zone, Toronto**
Strengths	Very popular service for local residents and tourists. Thought to enhance the reputation of the city among visitors, and businesses considering relocating to Fredericton. Stable infrastructure provides reliable service at popular locations in the city.	Provides access to communities that could not previously connect to the internet and to K-Net services.	Very popular service, hotspot hosts are happy with increased business. Provides opportunities for engaging local artists and community members. Has developed useful infrastructure on a very low budget, with volunteer labour.	Provides an alternative to commercial ISPs. Offers a way to share internet connections in local communities.	High quality network, ubiquitous coverage in downtown core.
Weaknesses and Missed Opportunities	This network could be used as a platform for delivery of government services, and to foster community engage-ment. Although it is not in the current mandate, it would be possible to use the network as means of bridging the digital divide, e.g. by providing access for citizens with limited means.	Geographic location makes it difficult and expensive to maintain the network. Given the challenges in maintaining the network, if it were possible to train local people in network maintenance this would increase the communities' technical capacity and improve service availability.	Narrow definition of community, develop-ers built a network they'd like to use. Opportunity to engage a broader set of citizens in network building and design.	Highly reliant upon the skills and energy of the two founders. Bandwidth costs make it difficult to operate on cost recovery basis. Early efforts to build mesh networks failed, but founders will try again with Meraki hardware.	Despite ubiquitous coverage, since the network is engineered to work outdoors, usability is limited. No obvious target users, suggesting revenues will be low. Missed opportunity to offer internet connectivity on a public utilities model, which could lower cost and improve service for citizens of Toronto.

	Fred-eZone, Fredericton, New Brunswick	**Lac Seul First Nation, Northern Ontario**	**Île Sans Fil (ISF), Montreal**	**Wireless Nomad, Toronto**	**One Zone, Toronto**
Critical Success Factors	The eZone was made possible because the City of Fredericton (e-Novations) owned the community fibre network. The city was in good financial shape, and a supportive city council approved the eZone project.	Leadership from K-Net and Band Council, support from funding agencies.	Enthusiasm of the volunteers. Café culture in the city of Montreal, coupled with many freelance workers interested in free Wi-Fi.	Wireless Nomad's success is tenuous, and it only continues because of work of founders. Subscribers are attracted by the idea of a co-op ISP, as an alternative to commercial providers.	Technical expertise in engineering the network enabled the development of a high quality network. Access to light poles and fibre backhaul made the service possible.
Replicable?	Yes, with access to backhaul, and support of local citizens (to approve network costs). In practice, there are few other examples using this approach.	Not easily. The challenges of getting network funding are enormous, and technical installation is difficult. Ideally remote communities will be better served in future by a coordinated initiative (e.g. U-CAN).	Yes. This sort of model is in place in other cities, including Toronto, but few have been as successful as ISF.	Yes, but it is very difficult to build a business as a co-op ISP, and little incentive to do so.	Yes, by well-financed municipalities. But not recommended given low revenue generating prospects, unless a similar network were redesigned to provide good coverage of indoor locations.

	Fred-eZone, Fredericton, New Brunswick	**Lac Seul First Nation, Northern Ontario**	**Île Sans Fil (ISF), Montreal**	**Wireless Nomad, Toronto**	**One Zone, Toronto**
Sustainable? Scalable?	Yes. This approach is sustainable as it is operated by the city as part of its IT infrastructure. This means there is a budget and staff to keep the network operational. It could be scaled to cover a larger area.	The challenge here is to maintain the network. Consistent funding is required for sustainability, and additional funds would be needed to increase the network footprint.	ISF has managed to maintain its hotspots reasonably well over the past few years. But as it relies on volunteer labour, it must keep a core of motivated volunteers in order to sustain the network. Work is also needed to keep hotspot hosts as part of the network. The project can be scaled, but the current approach could not provide ubiquitous coverage.	Without paid staff dedicated to building this business, it cannot grow substantially. There is no guarantee of sustainability.	If the network is reliant upon operational profits for continued operation, it will not be sustainable. If it is funded by its owner, it is sustainable. The network can be further developed to cover a large area provided funding is available.
Type(s) of public benefits provided	- may contribute to economic development (hard to verify this claim) - stimulated development of competitive services - could be used to improve efficiency of service delivery, but this is not currently happening - supplements network access, but does not add capacity for underserved groups - innovation evident in the development of the fibre broadband network	- provides an essential service - contributes to economic development - provides access to government services - reduces the digital divide - encourages community engagement - may foster innovation	- supplements network access, but does not add capacity for underserved groups - encourages community engagement - fosters innovation among network developers	- provides an essential service (as an ISP) - limited supplemental network access through hotspots - encourages community engagement (through co-op structure) - fosters innovation among network developers	- may contribute to economic development (hard to verify this claim) - could be used to improve efficiency of service delivery, but this is not currently happening - supplements network access, but does not add capacity for underserved groups

Overall, these case studies show that it is difficult to build wireless broadband infrastructure that realize the full range of potential benefits attributed to public broadband infrastructure.

- It is widely agreed that good broadband connectivity is an essential service, and our case studies do not contradict this argument. However, we note that few of the networks we studied actually delivered essential infrastructure – most of them delivered secondary internet access, which is a useful service, but not essential.
- In terms of economic development, although the case could be made that some of the networks we studied contribute to economic development, we did not find extensive evidence to support these claims.
- With respect to improving efficiencies within municipalities, this was not evident with either the eZone or One Zone, the two municipal-level networks we studied. Fredericton continues to investigate opportunities to use the eZone for municipal services, and has certainly gained efficiency benefits through the deployment and use of the community broadband fibre network.
- The development of the fibre network in Fredericton was also a catalyst for improved infrastructure provision by the private sector, which increased service and lowered costs in the city after it built the fibre network.
- The only project that explicitly addressed increasing accessibility was the Lac Seul Wireless Network. In all the other cases, the networks provided supplemental internet access. (This was true even of Wireless Nomad's ISP operations, as their customers could easily get broadband service from other providers.) ISF, eZone, One Zone, and Wireless Nomad's hotspots all enabled people who already had access to get online in more places, but made no direct efforts to assist in bridging the digital divide.
- The community networks provided some opportunities for community engagement, but the municipal projects had no specific functionality to encourage broad-based civic participation in community life.
- The most innovative groups were ISF (which engaged a group of volunteers in technical development) and Wireless Nomad (which worked on a smaller scale to find new technical solutions to sharing internet connectivity). K-Net is certainly an innovative organization, but there was less evidence of local innovation in the Lac Seul First Nation. Fredericton was innovative in building its community network, and in seeing the opportunity to build a Wi-Fi network to extend benefits to the community.

There were other benefits achieved through the development of wireless broadband infrastructure that were not identified in previous research. For instance, a benefit for Fredericton (with the fibre network) and the Lac Seul First Nation was that they were able to develop infrastructure that suited the specific needs of their communities. Rather than depending on the market to provide service (which it had not done in either case), these communities determined what they needed, and then went ahead and built it. In addition, the projects all contributed to increased quality of life for those who used them. In an urban context, it can be very convenient to have internet access in a secondary location, and people are particularly pleased when such access is provided free of charge. In all the cases but the One Zone, the networks were developed to fill a perceived void in market offerings. The One Zone network was a market offering.

All of the broadband infrastructure projects we studied provided some benefits to their local communities, and to the individuals and/or groups that built the networks. But with the

exception of Lac Seul, where the network does provide access to an essential service, the benefits provided by the other networks are somewhat limited. The infrastructure is certainly nice to have, and those who use it think it offers a valuable service. But in the urban projects, the networks do not have huge user bases, and thus only a small proportion of people who could potentially benefit from the use of this infrastructure actually benefit from its availability.

Unlike some of the more ambitious projects in the United States, the networks we studied were developed with relatively low expenditures. In bringing service to an underserved area, the Lac Seul project warranted public investment, and provided the broadest set of public benefits among our cases. Of the urban projects, only the Fredericton project involved investment of public funds, and this investment was approved by the City Council. Although the benefits of the urban projects were more limited, so too were the public expenditures. ISF and Wireless Nomad (with its hotspots) both provided beneficial infrastructure at no cost to the public. Toronto Hydro Telecom's investment was more substantial, but did not make direct use of public funds (as noted earlier however, given the structure of Toronto Hydro and its Telecom subsidiary, the ultimate shareholder is the City of Toronto).

Each of these projects offers lessons on building public broadband infrastructure. The Lac Seul network provides the most benefit to its community, but its circumstances are quite unique and its accomplishments are not easily repeated elsewhere in the country. The other networks provide value primarily in terms of supplementing individuals' internet access, but do not make significant contributions to the development of permanent broadband infrastructure.

As was shown in Figure 1, public broadband networks should support government use, public use and enable those who are not connected to the internet (and as a result unable to participate in the knowledge economy) to get access and become competent users. If these networks are to be built with public funds, with the expectation of providing a range of public benefits, what characteristics should they have? This question is addressed in the section below, with a summary of our work on the desiderata for broadband in the public interest.

A Desiderata for Broadband in the Public Interest

One of the questions we posed at the beginning of our research was "What are the different models and best practices of public ICT infrastructure in terms of deployment, technology choice and innovation, investment, governance, adoption and use?" The Canadian case studies show that existing projects provide some value to the communities they serve, but we believe that there are possibilities to develop networks with broader reach, that provide more extensive benefits to the population overall. We have highlighted various models of public broadband network development, and believe that future best practices should be guided by careful consideration of desirable outcomes.

We use the term 'desiderata' for our list of desirable characteristics for broadband networks that are developed in the public interest.[115] As noted above, if broadband networks are to be developed with public funds, it is important that they be designed in ways that maximize the opportunity for public benefit. But broadband networks developed in the public interest may be publicly or privately owned, and publicly or privately operated. Such networks can be achieved with many types of business models, and may be achieved differently in each community, perhaps using different technologies, based on local priorities and constraints. There is no 'one best way' to develop broadband infrastructure, but regardless of ownership and operational

structures, there are fundamental principles that should be incorporated into the design of broadband infrastructure.

We believe that the desiderata can play a valuable role now – as new broadband infrastructure is being shaped. The items in the desiderata may be considered obvious, raising questions as to the value of presenting them as a desiderata. The reason that this list is valuable is that much existing broadband infrastructure does *not* exhibit these characteristics. In identifying these crucial elements of good public broadband infrastructure, we can provide guidance to the development process of broadband networks. The desiderata also helps to shift the debate – away from whether the public or private sector is better suited to own and operate these networks – to questions of what network characteristics, regardless of public/private involvement, will best serve users. As a key infrastructure for economic, social, and civic participation it matters over the long term how these networks are being designed, built, and managed. Furthermore, the desiderata can be used a reference point in developing public policy to guide new broadband infrastructure developments, and to inform the regulatory process in regards to current practices.

Principles for Broadband Networks in the Public Interest

Our research suggests that a broadband network developed in the public interest should be ubiquitous and universal, widely useful, usable, accessible, affordable, reliable, high quality, healthy, cost-effective, accountable and responsive, secure, privacy enabling, open, neutral and non-discriminatory. Each of these characteristics is defined in Table 3 below.

TABLE 3: PRINCIPLES FOR BROADBAND NETWORKS THAT BENEFIT USERS

Principle	Definition	Types of Users Affected	Achieved Through	Time Frame
Ubiquitous & Universal	Service coverage should include every household, business, organization, public space, tourist destination, and public transit corridor in the network's coverage area, within the limits of what is technically feasible. Ultimately, the service should be universal, that is, it should reach every person when and where they need it.	Especially users currently without service, and mobile users.	Network design, policy.	Long-term goal.
Widely Useful	Good infrastructures allow for a wide range of applications that people find useful in conducting their daily affairs. While some of the most important ones can be anticipated and designed for, others will emerge over time.	All users.	Network design.	Long-term goal.
Usable	Ideally infrastructures 'disappear' in the sense that they can be taken for granted – always ready to be used effortlessly, but never getting in the way of the immediate task at hand.	All users.	Network design.	Long-term goal.

Principle	Definition	Types of Users Affected	Achieved Through	Time Frame
Accessible	Access to the system should be as barrier-free as possible, accommodating a wide range of cognitive and physical disabilities. The service should also accommodate a community's linguistic diversity. Conducting user needs analysis at the design stage and providing technical support can help to ensure that a network is accessible.	Especially users with disabilities, non-official languages, non-standard legal or economic status.	Policy.	Short-term goal.
Affordable	In order to ensure universal access for all, including low-income households, the service should be available at affordable rates (e.g. $10 per month) and preferably for free. Ideally, the service should provide free access to basic broadband service (e.g. 1.5 Mbps for both upload and download), with the possibility of fees for premium, higher speed services to support high bandwidth uses.	Especially low-income users.	Network design, business model.	Short-term goal.
Reliable	The service should be as reliable as the other common utilities, such as water, power, and the telephone, with clear performance standards established (99.99% availability, 4 hours mean time to repair).	All users.	Network design.	Short-term goal.
High Quality	The service should maintain a good standard of throughput and response time for streaming or other time sensitive transmissions requiring particular Quality of Service (QoS) standards (e.g. public emergency, telemedicine). However, these should not be discriminatory in the sense of allowing the network provider to favor arbitrarily some communicants over others or permit inspection of packet content.	All users.	Network design, policy.	Short-term goal.

Principle	Definition	Types of Users Affected	Achieved Through	Time Frame
Healthy[116]	Electromagnetic radiation emissions associated with Wi-Fi network equipment shall be within known safe limits, and should be routinely monitored. Given that Wi-Fi power levels are relatively low and their placement in relation to human bodies is no more hazardous than existing sources of electro-magnetic radiation (e.g. mobile phones), there should be no additional concerns with wireless. However, the health risks of unusual situations, such as powerful transmitters in close proximity to the body, should be identified.	Applies particularly to wireless network infrastructure. Children and people sensitive to electro-magnetic radiation are most affected.	Policy.	Short-term goal.
Cost-Effective	Independent of the pricing for affordability mentioned above, public infrastructures should make efficient and effective use of the resources they require to offer service. A cost-effective network is one that is economically worthwhile in terms of what is achieved for the amount of money spent.	All users.	Network design, business model, community oversight.	Short-term goal.
Accountable & Responsive	Mechanisms of governance and citizen oversight and control to ensure that the service and its operator are responsive to citizen input and needs on issues ranging from network repairs to new service innovation.	All users.	Network design, community oversight.	Short-term goal.
Secure	State of the art technology and best practices should be adopted to ensure that personal communication and internet browsing are secure against unwarranted interception. Non-intrusive means should be incorporated into the service to protect users against spam, viruses, spyware, etc. Reasonable, lawful means should be adopted to protect users against illegal content (e.g. child pornography, hate speech).	All users.	Network design.	Short-term goal.

Principle	Definition	Types of Users Affected	Achieved Through	Time Frame
Privacy Enabling	Operation of the service shall be fully compliant with applicable privacy laws and best practices. No personally identifying information shall be collected beyond that which is necessary to ensure access to and operation of the network. The service should enable both pseudonymous and anonymous use. Location-based and other services requiring additional personal information may be offered on a strictly voluntary, opt-in basis.	All users.	Network design, policy.	Short-term goal.
Open	The service should be designed to maximize openness at various levels (e.g. openness to a variety of access devices, the use of open source software, and all kinds of content, applications and services).	All users.	Network design, policy.	Short-term goal.
Neutral & Non-Discriminatory	No restrictions on access to lawful content/services, and no discrimination on the basis of content or services (e.g. P2P networks) beyond what is necessary for efficient network operations.	All users.	Network design, policy.	Short-term goal.

Applying the Principles

This checklist of principles can be used as a tool when designing and assessing broadband networks, to help gain a better understanding of how and whether such networks provide benefit to members of the public. Specifically:

- The tool can be used by people with various relationships to a project, such as: those directly involved in the network design and deployment, policymakers, consulting partners, researchers, independent assessors, and community members.

- The tool can be used at different stages of a project, including: network design, assessing a business plan, developing and assessing RFPs, long-term planning, and evaluating a planned or operational network.

- The tool helps its users to think through the complexities that result from the fact that the network characteristics prioritized on the checklist are not achieved in isolation from each other. These characteristics can be mutually reinforcing, for example, a ubiquitous, open network is likely to also be widely useful. However, in many situations network designers will face trade-offs among desired characteristics. For instance, many of the desired features of broadband networks in the public interest, notably universality, ubiquity, and

high quality may be costly to achieve, potentially undermining affordability. Because public wireless networks should be cost effective, the development of viable business models for service provision is essential. Thus, when assessing business models, an understanding of the context of the network deployment, and a balance between the principles, is crucial.

In summary, the desiderata does not provide communities with a 'one size fits all' model for network building, but with a set of core principles that can help communities to develop their own strategies to build the best networks for users. The tool can help planners to determine and prioritize goals for a local broadband network, to develop network design principles that meet multiple objectives at one time, and to assess trade-offs between desired network characteristics to create a network that fits the needs of the community.

The desiderata provides insights into how public broadband infrastructure can be developed in ways that free users from the constraints imposed by commercial internet service providers. For instance, public infrastructure can support open network access, allowing for multiple innovative uses of network capacity without requiring innovators to actually build a network. It can allow users to deploy any applications they like (tiered access pricing schemes may be necessary). A public broadband network can provide more cost effective service, removing the profit motive from network development, and reducing community and individual access costs and ensuring that access is extended to everyone. It also facilitates community engagement, through accountable development and responsive operational practices.

Best Practices for Developing Public ICT Infrastructure

As noted elsewhere in the report, there is no single best way to develop public ICT infrastructure. Our Canadian case studies, and our overview of the recent U.S. experiences in developing public broadband networks lead to the following observations regarding the development of public ICT infrastructure.

- The private sector will continue to develop broadband infrastructure, but the need for alternative infrastructure that better suits the needs of local communities and municipalities will persist.
- To ensure that the potential benefits of public ICT infrastructure are actually realized in network deployments, the design process must explicitly identify the desired outcomes, and attention must be paid to achieving them. For instance, the purpose(s) of the network must be clearly understood, so that the deployment will deliver the anticipated benefits. As a simple example, if the network is to provide primary access to users, then the technology must be designed to provide service indoors.
- A public access component is not necessary to justify investment in broadband infrastructure. Stand-alone networks that support municipal applications can provide value through increased service efficiencies and decreased operational costs.
- Many municipalities have existing capacity for infrastructure development embedded in their municipal utilities. They may also have access to a fibre network that can be leveraged to provide broadband services to community members.
- When developing public broadband infrastructure for communities that already have broadband access, the public infrastructure must provide users with equal or better functionality (e.g. improved conditions of use, decreased price, higher speeds) in order for it to be adopted. Users will only pay for access if it provides a reasonable quality of service.

- Technology choice must be guided by objectives regarding network coverage and location of use. But in general, we have found that Wi-Fi is limited in its capacity to support primary network access. To provide reliable, high quality network access, projects should consider the use of more robust technologies. (WiMAX may be promising in this regard, but has not been tested extensively, fibre is also an option and may be affordable if developed according to a public utility model.)
- Although it is relatively easy to set up a public access network using Wi-Fi, such a network may provide few benefits to the community overall (especially if the network only serves outdoor areas). The cost of network development must be weighed against actual benefits delivered. Public access Wi-Fi networks frequently serve areas where connectivity is already available. As such, they do not generally help to resolve the digital divide, and funds may be better spent on more targeted programs to meet the needs of specific users.
- The community networking movement's focus on building community and engaging network stakeholders can be extended into the development of municipally-led projects. In building public infrastructure, it is important to understand what network characteristics best suit the needs of each community, and community engagement contributes greatly to this process.
- The development of public broadband infrastructure can involve significant innovation, and may provide opportunities to empower community members by increasing their technical skills. Development of local capacity to build and support networks is especially important for rural and remote areas.
- It is difficult to build high-quality, reliable, sustainable infrastructure by relying on individuals sharing their network connections. Community-led projects that focus on ground-up networking building can benefit from the resources of municipal entities, to enable service provision on a larger scale.

Reflections on the Future Development of Public Broadband Infrastructure

Our research looked at current developments of public broadband infrastructure, but it is also important to consider the ways in which the landscape for public broadband infrastructure may change in the future. There are several pertinent observations in this regard:

- Although many consumers in North America already have broadband access, provided by the private sector, this service is usually provisioned with DSL or cable.[117] These technologies provide adequate service today, but it is generally understood that in the longer term, higher capacity will be needed, likely to be provided by optical fibre connections. In the U.S., Verizon is alone among ISPs in building fibre infrastructure, offering fibre connections to the home with its FiOS product.[118] To date, no Canadian ISPs have indicated that they will develop residential fibre broadband. If fibre to the home becomes the standard (this point is discussed in Appendix 7), there will be opportunities to change the structure of the broadband provision industry, allowing for new options that provide greater benefits to the end user.
- In addition to demand for greater bandwidth in the home, there is a growing demand for more mobile access to broadband infrastructure. Mobile broadband access is currently provided by the cellular industry, rather than internet service providers (although the major Canadian ISPs operate in both markets). Fourth generation mobile technologies[119] may become the standard for mobile broadband, but mobile operators have been heavily criticized for their uncompetitive pricing, and lack of innovation.[120] If

mobile broadband technologies can provide adequate service, some users may adopt mobile broadband as their primary source of broadband, rather than continuing their subscriptions to fixed services (DSL, cable or fibre). But there is a danger that users may be less well-served by mobile broadband operators than by existing DSL or cable service providers, as existing broadband regulations do not apply in the cellular data market. Although mobile broadband brings new competition to the broadband services market, at present there is no way for municipal or community groups to deploy this infrastructure, likely limiting the range of public benefits that will be on offer.

- The reason that community and municipal groups have been able to easily develop broadband infrastructure using Wi-Fi technology is that this is licence exempt or unlicensed technology. There are no legal or technical barriers to using Wi-Fi, which explains its popularity. But the next generation of wireless technologies (being developed by the private sector) require licensed spectrum. This requirement effectively shuts out community and municipal infrastructure developers, unless provisions are made to make additional unlicensed spectrum available,[121] or to reserve licensed spectrum for such groups. This issue is discussed in Appendix 8.

Policy Considerations

Our research has outlined the benefits of developing public broadband infrastructure, identified ways in which public infrastructure can be built, and outlined the desirable characteristics of public infrastructure. To enable the development of public infrastructure that reach their full potential in terms of providing public benefit, it is not sufficient to rely upon market forces.

As is shown in our desiderata, infrastructure developed by the private sector does not generally support open network access, or provide users with neutral, non-discriminatory network access. It may not offer ubiquitous service. The private sector does not focus on delivering affordable infrastructure – for-profit companies will charge what the market will bear – nor does it allow for user input into governance or respond directly to its users needs. This does not mean that the private sector develops bad infrastructure, on the contrary it can offer high quality, reliable, useful, widely available, and secure service. But the needs of the public are not being fully met by infrastructure that is built in response to current market forces.

Community and municipal groups are experimenting to build infrastructure that better serves the needs of the public, but they require a supportive policy environment to continue to make progress with infrastructure development, especially in face of technological change. Recognizing that access to good broadband infrastructure – infrastructure that provides the full range of public benefits – is an essential service, policies should be developed and implemented that will:

- foster innovation in infrastructure development (e.g. allow experimentation with new technologies, encourage new developers);
- provide public broadband developers with access to spectrum that enables more robust broadband infrastructure development;
- facilitate the development of fibre broadband networks that allow open access;
- create increased competition among providers, allowing new entrants into existing broadband markets, and encouraging competition from new broadband technologies;
- continue to allow third-party access to existing DSL and cable infrastructure;
- enable users to access broadband networks on a neutral and non-discriminatory basis,

regardless of access technology;

- encourage private-sector broadband providers to incorporate the characteristics of good public broadband infrastructure in their commercial offerings;
- enable collaboration among public broadband providers to allow for coordinated approaches to larger scale projects;
- provide support for community groups, municipalities and others to continue to develop public infrastructure that meet their needs; and
- deliver programs that provide affordable broadband access and training to new users, so that all Canadians have access to this essential infrastructure.

This list outlines actions that will support the development of better broadband infrastructure, but it is not an exhaustive list. In identifying further policy initiatives, the key is to focus on creating conditions that encourage innovation, collaboration and community engagement among a wide variety of infrastructure providers.

Conclusions

We have learned a great deal about public ICT infrastructure over the course of this project. Our research highlights the benefits that can be achieved through public development of broadband infrastructure, and documents the extensive progress made by community and municipal groups in the United States and Canada. Working with research partners in Canada, we provided detailed insights into four wireless projects (Fredericton eZone, Île Sans Fil, Lac Seul Wireless Network/K-Net and Wireless Nomad), and also investigated Toronto's One Zone.

The Canadian examples show the importance of understanding and embracing local context when developing public infrastructure. The networks we studied provide real benefits to local communities, but we also revealed missed opportunities that, if acted upon, would provide even greater benefits to the public. On the question of network technologies, Wi-Fi can be effective in providing secondary internet access, but is not sufficiently robust to deliver primary internet access. Municipalities can investigate the possibilities of adopting a public utility approach to developing fibre broadband, in some instances leveraging broadband assets that are already available locally. Infrastructure development efforts to date have been successful, but have resulted in a patchwork of networks. A more coordinated approach between communities, and all levels of government is recommended in future. Municipalities and communities both have roles to play in developing broadband infrastructure, and can learn from each other's successes.

We have provided a list of desired characteristics for broadband infrastructure developed to serve the public interest, noting that some of these characteristics are not found in infrastructure that is provided by the private sector. We conclude that allowing the future development of public broadband infrastructure to be driven by market forces alone would result in further development of infrastructure that does not fully meet the needs of the public.

The advent of new mobile broadband technologies, and an anticipated shift away from existing fixed line infrastructure (DSL, cable) toward fibre optic services will lead to changes in broadband industry structure, and provide an ideal opportunity to influence future developments to ensure enhanced public benefits. Specifically, as the industry structure changes, it is essential that non-market providers (municipalities, community groups and others) continue to play a role in infrastructure development. One necessary action is to

guarantee that public broadband providers have access to new wireless spectrum, to allow for continued competition and innovation in service delivery. Steps must also be taken to encourage all broadband developers to incorporate the principles of good broadband infrastructure in future deployments. Finally, as broadband network access is an essential service, efforts must be increased to extend public broadband access to all areas of Canada that are currently without service, and to ensure that all Canadians are able to achieve the full benefits of good public broadband access.

Appendix 1: Background Reading on Broadband and Wireless Technologies

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Appendix 2: The Private-Public Broadband Debate – Selected Resources on Broadband Policy and the Case for and Against Municipal Broadband Networks

The archives of the Telecommunications Policy Research Conference contain many papers addressing this topic: http://www.tprcweb.com/node/24.

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Appendix 3: The Decline of Municipal Wireless Networks

CWIRP Resources

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  http://w2i.com/resource_center/the_w2i_report__weekly_newsletter/news/p/id_160

- "A Framework for Investigating the Value of Public Wireless Networks." Paper presented at the 35th Research Conference on Communication, Information and Internet Policy, September 2007. Catherine Middleton.
  Paper: http://www.cwirp.ca/files/middleton_tprc_2007.pdf
  Slides: http://www.cwirp.ca/files/middleton_tprc_2007_slides.pdf

  This paper shows that current municipal wireless deployments are not meeting the needs of many of their potential users, leading to questions about the value of the networks that have been built to date. The paper outlines a framework for use in identifying different contexts of network use, and then applies the framework to elicit an understanding of how various types of users can benefit from the development of wireless infrastructure.

- "How Usable Are Outdoor Wireless Networks?" Forthcoming in the *Canadian Journal of Communications*, Amelia Byrne Potter, Neal McIntyre, Catherine Middleton

  This paper highlights usability problems for outdoor wireless networks, providing evidence to suggest that deployments that focus on outdoor access are not likely to meet users' needs.

Blogs

Muniwireless: www.muniwireless.com
Wi-Fi Net News: wifinetnews.com
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Other Resources

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Appendix 4: Canadian Wireless Networks

This appendix provides a summary of operational community and municipal wireless networks in Canada, as of mid-2008. This list is also available online: delicious.com/cwirp/wireless_in_canada.

British Columbia

- BCWireless: www.bcwireless.net

  "The British Columbia Wireless Network Society is an organization dedicated to building public Wireless Networks. We research, develop and operate Wireless Networks with a strong community oriented focus."

- Vancouver:
  - City of Vancouver: *The City has been considering the issue of deploying a municipal wireless network for sometime. The City Council voted in April 2008 to "postpone further work on searching for a private partner to co-build and manage a municipal wi-fi network, due to the costs and business risks highlighted by supplier responses to the Request for Expressions of Interest (RFEOI) PS08004 – Community Wireless Broadband Initiative." Various reports from city staff are available online:*

    Crocker, M., & Wallace, S. (2007). *Options for Deployment of a Municipal Wireless Network*. Vancouver: City of Vancouver. vancouver.ca/ctyclerk/cclerk/20070201/documents/ csb2complete.pdf

    Wallace, S. (2007). *Revised Approach for the Deployment of a Municipal Wi-Fi Network*. Vancouver: City of Vancouver. vancouver.ca/ctyclerk/cclerk/20070612/documents/a10.pdf

    Wallace, S. (2008). *Municipal Wireless Network Update*. Vancouver: City of Vancouver. vancouver.ca/ctyclerk/cclerk/20080513/documents/a9.pdf

  - Free the Net: www.freethenet.ca

  Free Wi-Fi hotspots in Vancouver, operated by Vancouver Open Network Initiatives: vonic.ca. Vancouver Open Network Initiatives responded to Vancouver's request for expressions of interest in developing a network to serve the City of Vancouver.

  - Vancouver Wi-Fi MUG: vancouver.wifimug.org

  Listing of coffee shops that offer free wireless access in Vancouver.

Alberta

- Alberta Supernet: www.albertasupernet.ca/the+project/the+network/technology.htm
  Portions of the Alberta Supernet are connected using fixed wireless technology, but the Supernet does not provide wireless access throughout the province.

- Calgary: www.wirelesscity.ca/city/bins/content_page.asp?cid=4834-1612-1618
  "The Calgary Wireless City Showcase Hotspot offers four separate Access Zones in downtown Calgary."

- Edmonton: www.edmonton.ca/wireless-edmonton.aspx
  "eZones are provided by the City of Edmonton as part of a public wireless Internet pilot project."

- Grande Prairie (City): www.cityofgp.com/citygov/dept/purchasing/rfp/broadbandwireless.htm
  An RFP has been issued to build network to "Improve municipal government services, enhance public safety applications and communities through increased access to high speed mobile data, stimulate economic development by attracting business, and provide a broadband wireless service option to the citizens of the City."
- Grande Prairie (County): www.countygp.ab.ca/municipal/countygp/countygp-website.nsf/AllDoc/3A67CE5B8C34C4C38725740100621441?OpenDocument
  "The County of Grande Prairie has partnered with G.P.N. Wireless Networks Ltd. to bring high speed internet to rural areas which currently do not receive this service."

- St. Albert: www.stalbert.ca/admin/contentx/default.cfm?PageId=11650&hdrmenu=1925
  "St. Albert FreeSpot is a pilot project by the City of St. Albert, to provide free wireless Internet access to the public in a specific area. The goals of the project are to:
  · Provide a convenient public service to users;
  · Stimulate economic development and tourism by drawing visitors to the coverage area; and
  · Promote St. Albert's image as a high-tech community; and
  · Test the feasibility of wireless devices for municipal use."

Saskatchewan

- Moose Jaw, Prince Albert, Regina and Saskatoon: www.ito.gov.sk.ca/wireless-internet
  Free wireless internet at various locations (hotspots) in the four major cities in the province.

Manitoba

- Winnipeg:
    - City of Winnipeg: www.mts.ca/portal/site/mts/menuitem.a275cbc6dbb0d4e50e14081031248a0c/?vgnextoid=8d77d4c1d2fcb010VgnVCM1000000408120aRCRD&vgnextchannel=b90ecc878fc81010VgnVCM1000000408120aRCRD&vgnextfmt=default

      The City of Winnipeg partnered with MTS Allstream to provide Wi-Fi in city libraries and at the Pan-Am swimming pool. This is a paid service, but the City receives a portion of the revenues: www.winnipeg.ca/cao/media/news/nr_2007/nr_20070910.stm

    - Wi-Fi Winnipeg: web.archive.org/web/20070629152848/http://www.wifiwinnipeg.ca

      Wi-Fi Winnipeg was a community group working to establish free Wi-Fi hotspots in the city. It appears to be defunct.

Ontario

- Hamilton: www.wirelesshamilton.com/index.shtml

  "The wirelesshamilton.com project is a pilot initiative built to test the value of wi-fi technology in meeting the business needs of a number of community partners. This pilot will also provide wireless access to the public through wirelesshamilton.com at a number of locations across the City." This project runs until the end of 2008.

- Kitchener-Waterloo, Cambridge: www2.atriawifi.com/WiFi/Availability_wat_region.cfm

  Paid Wi-Fi service.

- Ottawa:
    - Atria Networks: www2.atriawifi.com/WiFi/Availability_ottawa_region.cfm

      Network purchased from Telecom Ottawa in 2008, offers paid Wi-Fi access around Ottawa.

    - Ottawa-Gatineau Wi-Fi (ogWiFi): wiki.ogwifi.ca

      "ogWiFi is a non-profit Community Wireless Network (CWN)/ Infrastructure with members on both sides of the Ottawa River. [It is] dedicated to bringing no-fee wireless Internet access to the Region. [It aims] to build a Community Communication Infrastructure to bridge the public and private spaces of our cities."

- Toronto:

    - One Zone High Speed Internet: www.onezone.ca

    Built by Toronto Hydro Telecom, this network is now operated by Cogeco Data Services. It offers paid access in a 6 square kilometre zone in downtown Toronto.

    - Wireless Nomad: www.wirelessnomad.com

    Wireless Nomad is a cooperative internet service provider that enables its subscribers to securely and legally share their bandwidth with others using Wi-Fi. It also offers free hotspots at various locations around Toronto.

    - Wireless Toronto: www.wirelesstoronto.ca

    "Wireless Toronto is a not-for-profit community group dedicated to bringing no-fee wireless Internet access to Toronto. [Its] aim is to encourage the growth of wireless networking and to build community in interesting and innovative ways."

Quebec

- Montreal: Île Sans Fil www.ilesansfil.org

  "Île Sans Fil is a non-profit community group devoted to providing free public wireless internet access to mobile users in public spaces throughout Montreal, Canada. We believe that technology can be used to bring people together and foster a sense of community. In pursuit of that goal, Île Sans Fil uses its free public access points to promote interaction between users, show new media art, and provide geographically- and community-relevant information."

- Montérégie (Montreal South Shore): Montérégie Sans Fil auth.monteregiesansfil.org

  "This network currently has 20 deployed hotspots. 15 hotspots are currently operational. 4 hotspots aren't monitored so we don't know if they are currently operational."

- Québec: www.zapquebec.org

  Zone Accès Public Québec: ZAP Québec wants to make Québec a wireless city, where many free internet access points help to make the city more dynamic and enjoyable for those who live or work in Québec, or visit the city.

- Sherbrooke: www.zapsherbrooke.org

  "ZAP Sherbrooke is a non profit organization created by the Pôle Universitaire with the mission to promote free wireless internet access points in the Sherbrooke area. Our goal is to have the City of Sherbrooke listed as one of the cities offering the highest number of free wireless internet access points to its citizens and visitors in the most popular public areas and commercial buildings."

New Brunswick

- Fredericton: Fred-eZone www.fred-ezone.ca

  "Fredericton, New Brunswick has integrated traditional and wireless technologies to create Fred-eZone, a free, community-wide Wi-Fi network providing residents, visitors and businesses with mobile broadband access from virtually anywhere within the city. The network enables Fredericton to better differentiate itself from other cities and towns, increasing its ability to attract and retain 'knowledge industries' looking for a location that offers an innovative, productive and exciting environment."

- Moncton: www.moncton.ca/Wi-Fi

  This is a pilot project using mesh technology, and covering parts of the downtown core. Dan Babineau, Director of Information Systems for the City of Moncton, won ITAC's IT Community Hero Award for his work in developing this network. (see www.moncton.ca/Government/Media_Room/News_Releases/Moncton_wins_IT_Hero_Award .htm).

- Saint John: freespots.ca/find-freespots.cfm

  "Freespots is the public Wi-Fi service for the City of Saint John, New Brunswick, that covers the city with free wireless internet."

Nova Scotia

- Chebucto Community Net: wifi.chebucto.net

  "The Chebucto Community Net Wifi Project aims to create a new kind of high speed network access for the community, hosted by the community itself. The general public would be able to connect to this wireless network and access the websites of Halifax Region information resources and business websites as well as N.S. Provincial and Federal government websites for no charge."

- Nova Scotia Public Libraries: wireless.library.ns.ca

  Many public libraries in Nova Scotia offer free public wireless access.

Prince Edward Island

- Charlottetown: WiFiCharlottetown
  web.archive.org/web/20080214114802/http://www.wificharlottetown.org

  It appears that WiFiCharlottetown is no longer active. WiFiCharlottetown was "an informal group of people interested in the proliferation of free and open wireless internet access in Charlottetown, Prince Edward Island. Some of us are participating by contributing our knowledge and expertise (like this website, for example). Others are contributing their bandwidth from their home DSL or cable connection. Others are contributing financially by helping buy and distribute WiFi access points around the city."

Appendix 5: Case Study Resources

The following articles and presentations provide additional descriptions of the public broadband infrastructure built by the Fred-eZone, Île Sans Fil, Lac Seul Community Wireless Network, and Wireless Nomad, as well as the infrastructure built by Toronto Hydro Telecom. A study of Wireless Toronto is also noted.

Fred-eZone

Middleton, C., & Crow, B. (2008). Building Wi-Fi Networks for Communities: Three Canadian Cases. *Canadian Journal of Communication*, 33.

Powell, A. (2008). *Co-Productions of Community, Technology and Policy in the North American Community Wireless Networking Movement*. Unpublished PhD Thesis. Concordia University, Montreal.

Île Sans Fil

Middleton, C., & Crow, B. (2008). Building Wi-Fi Networks for Communities: Three Canadian Cases. *Canadian Journal of Communication*, 33.

Powell, A. (2008). *Co-Productions of Community, Technology and Policy in the North American Community Wireless Networking Movement*. Unpublished PhD Thesis. Concordia University, Montreal.

K-Net/Lac Seul

Fiser, A., Clement, A., & Walmark, B. (2005). The K-Net Development Process: A Broadband Model for First Nations Community Networking. *Proceedings of Telecommunication Policy Research Conference*, Arlington, VA.

Fiser, A., & Clement, A. (2008). The K-Net Broadband Deployment Model: Enabling Canadian Aboriginal Community Control of Telecom Infrastructure through Relationship Building and Heterogeneous Engineering. *Proceedings of IEEE International Symposium on Technology and Society (ISTAS)*, Fredericton. 1-14.

Middleton, C., & Crow, B. (2008). Building Wi-Fi Networks for Communities: Three Canadian Cases. *Canadian Journal of Communication*, 33.

Toronto Hydro Telecom One Zone

Clement, A., & Potter, A. B. (2008). Saving Toronto Hydro Telecom's One Zone Project from Itself: Alternative Models for Urban Public Wireless Infrastructure. *Journal of Community Informatics, 4*(1).

Clement, A., & Potter, A. B. (2008, 31 March). Toronto's Wireless Network Has Fallen Behind Other Cities; as a Public Utility, Toronto Hydro Telecom Could Supply Internet to Homes across Toronto*. Toronto Star,* p. A8.

Clement, A., Longford, G., & McEwen, R. (2006). Toronto Hydro Telecom's One Zone: Commercial Competitor or Public Utility? Presentation to the *34th Research Conference on*

Communication, Information and Internet Policy. Arlington, VA.

Potter, A. B., McIntyre, N., & Middleton, C. A. (2008). How Usable Are Outdoor Wireless Networks? *Canadian Journal of Communication, 33*.

Wireless Nomad

Wong, M. (2006). *Sharing Wireless Internet in Urban Neighbourhoods*. Unpublished Masters Thesis: Faculty of Information Studies, University of Toronto.

Wong, M., & Clement, A. (2007). Sharing Wireless Internet in Urban Neighbourhoods. In C. Steinfeld, B. T. Pentland, M. Ackerman & N. Contractor (Eds.), *Communities and Technologies 2007: Proceedings of the Third Communities and Technologies Conference*. London: Springer-Verlag.

Wong, M. (2008). Wireless Nomad: A Case Study in Co-Operatively Managed, Shared Urban Residential Wireless Internet Service Provision. Presentation to IEEE International Symposium on Technology and Society. Fredericton, NB.

Wireless Toronto

Cho, H. H.-N. (2008). Towards Place-Peer Community and Civic Bandwidth: A Case Study in Community Wireless Networking. *Journal of Community Informatics, 4*(1).

Appendix 6: The Wi-Fi Health Debate

This is a summary of Chion, K. (2007). *Wi-Fi Health Effects: A 'Full Spectrum' Controversy* available on the CWIRP website.

As public ICT infrastructure extends to remote Canadian communities, the literature on the health effects of radiofrequency (RF) radiation grows likewise. Documented symptoms include tinnitus, insomnia, headaches, chronic fatigue, and respiratory issues, among others. Bioeffects involve DNA breakages, disruptions to enzyme activity, cell membrane function, and metabolism.[1] While the recent folding of municipal wireless networks in San Francisco, Chicago, Houston, and St. Louis cannot be directly attributed to the growing grassroots movement against all forms of electromagnetic field (EMF) radiation, the mounting opposition has worked effectively to place the issue of health effects closer to the top of the agenda in ongoing community wireless projects.

In Canada, the Radiation Protection Bureau of Health Canada's Safety Code 6 regulates the health effects of RFs. For the general public who could be exposed for 24 hours a day to RF fields, the maximum threshold is one-fiftieth of the lowest level of exposure that could cause harm.[2] The Toronto Health Department's guideline for public exposure limits is based on the siting of cellular telephone base transmitters, and a 1999 Board of Health report, which led to the city's adoption of a "Prudent Avoidance Policy," setting current limits to 100 times lower than the threshold in Safety Code 6.[3]

Controversy over the long-term biological impacts of wireless communications technology exists as part of the larger debate on the health consequences of a variety of infrastructure and consumer devices like power lines, microwaves, and radio towers. Since January 1, 2004, Lakehead University's president, Dr. Frederick Gilbert has stalled the campus wide roll-out of Wi-Fi, citing uncertainties over the technology's health implications. The campus remains Wi-Fi free today.[4] When Toronto Hydro Telecom made the Spring 2006 announcement that the downtown core would soon be fitted with Wi-Fi access points, cautionary articles appeared in the local media focusing on the health implications of the non-ionizing, lower-frequency range of the spectrum occupied by Wi-Fi.[5] News reports in the last year or so also cite examples in the United Kingdom and the United States where parents successfully lobbied or sued school boards that deployed wireless networks without consultation with the community such as the Oak Park Elementary School District lawsuit in Cook County, Illinois.[6]

While a number of recent studies support both sides of the debate, the two most frequently cited reports, conducted by the World Health Organization (WHO) and the California Public Utilities Commission (CPUC), fail to find conclusive scientific evidence to link RFs with negative health consequences. In 2006, CPUC reviewed and upheld the results of its June 2002 study with the added implementation of a prudent avoidance policy.[7] In 1996, the WHO created the International Electromagnetic Fields (EMF) Project to investigate health risks and arrived at similar results.[8] However, Canadian scientist Magda Havas, frequently referenced to demonstrate the adverse biological impact of electromagnetic radiation, links the development of certain cancers and lymphoma tumours to RF exposure at levels well below the thresholds set by international and domestic guidelines.[9]

The call for a Precautionary Principle on EMFs has been supported in writing by the European

Union and the WHO.[10] This initiative has been bolstered by the International Commission for Electromagnetic Safety (ICEMS) at its 2006 conference, with the Benevento Resolution. The Precautionary Principle emphasizes preventative mitigation of possible negative health impacts by shifting "the burden of proof from those suspecting a risk to those who discount it."[11] This approach has been championed by grassroots organisations like the San Francisco Neighborhood Antenna-Free Union (SNAFU) and The Canadian Initiative for Safe Wireless, Electric and Electromagnetic Policies (SWEEP). These groups suggest variable levels of implementation of the precautionary principle, ranging from an immediate moratorium on the new deployment of wireless technology, a more comprehensive review of existing regulations, to the creation of an independent, scientific monitoring system to document the accumulated long-term effects of RF emissions levels.[12]

Endnotes

[1] City and County of San Francisco. Board of Supervisors. (2007). *Analysis of Health and Environmental Effects of Proposed San Francisco Earthlink Wi-Fi Network.* Havas, Magda. Case No. 2007.0097e.

[2] Health Canada. Environmental Health Directorate Health Protection Branch. (1999). *Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3 Khz to 300 Ghz. Safety Code 6.0. Catalogue No. H46-2/99-237e.* Ottawa: Minister of Public Works and Government Services.

[3] Macfarlane, R. (1999). *Health Concerns of Radio Frequency Fields near Base Telephone Transmission Towers*. Toronto: Toronto Public Health.

[4] Lakehead University. (2004). Wi-Fi Policy. .

[5] Vasil, A. (2006, 9-15 March). Wi-Fi's Electric Shock. *NOW Magazine*.

[6] Beschizza, R. (2006, 12 December). Wi-Fi as a Health Hazard. *Wired*.

[7] California Public Utilities Commission (CPUC). (2006). Opinion on Commission Policies Addressing Electromagnetic Fields Emanating from Regulated Utility Facilities. Decision 06-01-042.

[8] Repacholi, M. (2007). WHO's Health Risk Assessment of ELF Fields. *Radiation Protection Dosimetry, 106*(4), 297-299.

[9] City and County of San Francisco. Board of Supervisors. (2007). *Analysis of Health and Environmental Effects of Proposed San Francisco Earthlink Wi-Fi Network.* Havas, Magda. Case No. 2007.0097e.

[10] European Union Precautionary Principle. Brussels. (2000).

[11] International Commission for Electromagnetic Safety (ICEMS). (2006). Benevento Resolution. Benevento, Italy.

[12] San Francisco Neighborhood Antenna-Free Union. (2007). Goals.

Appendix 7: Fibre to the Home

Wong, M. (2007). Fibre to the Home: A CWIRP Background Paper.

Introduction

With the current trend towards high-bandwidth digital services such as the Internet and High Definition television, network operators, service providers, and governments are increasingly turning to Optical Fibre technology to support this demand. In this background paper I will begin by briefly describing Fibre to the Home (FTTH) and the various forms of fibre networking applications and architectures. Following this overview, I will then discuss the issues related to fibre deployment and implications for future fibre roll-outs.

What is optical fibre?

Optical fibre is a glass or plastic filament designed to guide light along its length. With the traditional copper wiring used in telephones and television cables, electrical signals are passed along the wire. With fibre, a light-emitting diode or laser diode is used to pulse light at one end of the fibre, which then travels (at the speed of light) along the length of the fibre using a principle known as total internal reflection. The received light pulses are then translated into electrical signals using photoelectric sensor units. Glass fibre had been used to displace copper wiring since the late 70's (Shumate, 1989).

Mayhew, Page, Walker, and Fisher (2002) summarize a number of key advantages of fibre cables over traditional copper wiring:

1. much higher bandwidth capability (compare several Gbps transfer versus approximately 8 Mbps download and 640 Kbps upload with ADSL)

2. can transmit data over long distances with comparatively less signal loss

3. smaller (in diameter) and lighter than copper, which affects their installation, handling, and transportation

4. unlike copper wiring, fibre does not corrode and can withstand long periods of water immersion without failure

5. optical fibre transmission is immune to interference from signals carried on other fibres or metallic transmission paths within the same or adjacent cables

6. optical signals are not affected by radio frequency emissions or generate any themselves (pg.92)

In comparison, the same authors cite that the two main disadvantages of fibre optics are the difficulty of joining together and terminating fibre filaments, necessitating more skilled labour and more expensive tools, and the generally greater cost per cabled fibre compared to cabled copper pair[1] (Mayhew, Page, Walker & Fisher, 2002, pg. 93). However, the greater cost of cabling may be mitigated by the fact that greater numbers of customers can be served with less fibre cabling than copper wiring.

How is fibre used?
Generally speaking, fibre is used as the conduit for "core" network operations for telecommunications and network service companies, government facilities, academic institutions, and other organizations requiring or selling high-capacity bandwidth. Fibre is used to link exchanges or data centres together with high-speed transfer. For example, the Canadian Advanced Networks and Research for Industry and Education (CANARIE) network, CAnet 4, uses OC-192 (Optical Carrier level 192, approximately 10 Gbps) optical networks to link provincial research networks throughout the country.[2] Branching out from exchanges like these are "access" networks where connections are used for comparatively smaller applications like offices and neighbourhoods. In Canada, Rogers Communications Inc. offers fibre services to businesses[3] and Bell Canada offers their "Optimax" fibre services to both businesses and home consumers.[4] The local exchange may provide this access using traditional copper wiring (i.e. telephone based DSL or cable based services). For television this may go into a set-top receiver box and for Internet, to a cable or DSL modem which then connects via Ethernet cabling to a computer. The combination on fibre and copper is known as a hybrid line.

This general description gives way to a variety of different, more specific, fibre optic network architectures. These may be applied in a variety of different ways in addition to FTTH. There is also Fibre to the Premises (FTTP), Fibre to the Curb (or kerb in British English, FTTC/K), and Fibre to the Node (FTTN). All of these types of applications refer to the level at which the fibre terminates and copper wiring may or may not take over. Koonen (2006) described the different kind of fibre architectures as (1) point to point, (2) active star, and (3) passive star.[5] Point to point means a fibre connection directly from the local exchange to the termination point, in the case of FTTH, directly to the home. This results in the maximum amount of bandwidth available to the consumer at a cost of higher service fees, and the requirement of as many fibre terminals as customers. Active star architecture uses a single fibre to carry all traffic to an "active node" which is located close to the end users, then individual fibres take over to additional nodes in homes or street-level cabinets. The active node takes care of the switching and transmission. In a passive star architecture, the active node of the active star is replaced with a passive power splitter/combiner that then feeds the branching fibres. This is also known as a Passive Optical Network (PON). However, this means that the receiving device in the home needs to be more complex to perform operations similar to what the active node would have done. In industry terms, this home device is referred to as Customer Premises Equipment (CPE).

Issues in Fibre Deployment
In terms of fibre deployment to customers, there are generally two kinds of scenario. The first is what is known as a "green field" situation where there is a new development with little to no existing copper infrastructure. For example, according to Kettler, Kafka, and Spears (2000) in the south-eastern United States prior to 1995, Bell South had deployed copper cables as the infrastructure of choice for new developments. However, after 1995, Bell South decided that FTTC "had reached the point where its life cycle cost was lower than that of copper for new builds, and FTTC became the preferred architecture" (Kettler, Kafka & Spears, 2000, pg.108). As a result, by the beginning of 1999, over 200,000 lines of FTTC had been installed in new builds. More recent numbers indicate that Bell South has deployed FTTC to 1.3+ million customers with Verizon deploying FTTP (homes, multi-dwelling units, businesses) to over 3.6 million homes with an estimated 500,000 subscribers (Wagner et al., 2006).

The other scenario is the replacement or rehabilitation of existing copper lines. As copper cables deteriorate with age, some after decades of use, it becomes necessary to replace them. Often, the process of installing new fibre in place of copper is expensive, not just because it involves digging up and exposing the ductwork which holds the copper, but because new fibre then needs to be rolled out in its place. As one Bell Canada report indicates when considering deploying a hybrid fibre/copper connection, "the operational savings do not fully offset the high costs of electronics, service migration costs and potentially negative customer impacts, thus limiting this option to areas of severely degraded copper plant" (Di Michele & Huppe, 2006). In other words, introducing fibre where the copper connections are still in operational condition is too expensive and should only be pursued when the copper lines are in dire need of repair or replacement anyway. As an alternative, however, areas can also be served by using aerial deployment (e.g. telephone poles). Using aerials usually means less ductwork would need to be exposed, reducing the amount of damage and construction that would be required.

Another key issue in fibre deployment is one related to the costs of deployment: determining an appropriate business model for deploying it to the consumer. While demand for bandwidth for Internet connectivity and high definition television are on the rise, some remain sceptical about the need for such high bandwidth capacity as fibre running directly to consumers' homes. For example, Tompkins et al. (2000) wrote that "to assume we will need this bandwidth running into our backyards is another issue…the demand for bandwidth is generated by the services and applications that can be provided by service providers" (pg.112). They add that in addition to the high initial cost of deploying fibre all the way to the home, the CPE is usually more expensive as well (Tompkins et al., 2000, pg. 121). Frigo, Iannone, and Reichmann (2004) also introduce a different perspective on the capabilities of fibre. In their paper they discuss the importance of the perception of bandwidth. For example, in activities like surfing which require bandwidth in bursts for downloading a page, followed by a period of viewing that page, a consistent, high-capacity bandwidth may not be necessary. They note that

> consumers are expected to be concerned more about the services and their cost than about the technology that delivers them…as a result, the tremendous bit rate potential of FTTH is mostly unused when applied to the services consumers pay for today…this begs the question of whether newer non-Web services such as peer-to-peer large file transfers and streaming applications on conventional media will become a driver for a replacement technology (S18).

As one example, consider that Bell Canada's Total Internet Max/Optimax service utilizes FTTN and then VDSL2 lines to the home, which provide speeds of up to 16 Mbps. However, as of November 2007, this costs $100/month compared to their 7 Mbps regular service at $50/month. Perhaps it is an important question as to whether customers will perceive enough difference to pay twice as much. To note one last difference between fibre and copper services, fibre will not operate in a power failure like standard copper phone lines would. In the case of an outage, backup power would be required to maintain a telephone connection.

FTTH Going Into the Future

Despite some of the noted issues about how and where to deploy fibre, it seems indisputable that fibre will continue to be deployed. Wagner et al. (2006) predicts that we can expect "100 [Mbps] service projected by this data to have a few million subscribers by 2010, and another higher service offering of GbE [Gigabit Ethernet] projected to be penetrating the customer base by 2016" (pg.4527). While there might be some issues with finding suitable applications to take

advantage of such high bandwidth, it also seems likely that eventually those applications will exist, whether they are Internet-based or through high definition streaming video or perhaps some as of yet undeveloped technology. Consider that Shumate (1989) noted that fibre was envisioned for "conventional video and high-definition television, and for still-frame displays for information retrieval or catalog shopping" (pg.46). Perhaps we may not even know what applications are in the near future, but it is likely to expect that they will need more bandwidth than we presently use, not less. Finally, Tompkins et al. (2000) speculate that

> FTTH/B [building] is likely to be more successful when the decision comes down to more than just economics. For municipalities, there is a sense of future proofing the network for the good of the community -putting in the best possible network because their community wants it and the services it can provide. Not to say that economics is not a factor, but it may be less of a factor when the town allows the utility or itself to amortize the equipment over 10 years and the fibre over 20 years. Playing with those numbers at $50 per month can easily justify a FTTH/B network with room to spare. (121)

Indeed, in this way, despite what might kinds of applications might be developed, FTTH can ensure their accommodation in the future.

Endnotes

[1] Telephone lines use a twisted-pair of copper wires, whereas cable television uses co-axial copper cabling.

[2] See http://www.canarie.ca/advnet/index.html

[3] See http://www.shoprogers.com/business/data/TLS.asp

[4] See http://www.bell.ca/enterprise/EntNews_newsLetter_Sep2006_8.page (consumer services) and http://www.bell.ca/shop/Sme.Sol.Internet.Optimax.page (business services). Consumer services use FTTC and then switch to conventional copper lines, although of higher capacity than standard DSL.

[5] See this reference for helpful diagrams of these architectures. See also Frigo, Iannone, and Reichmann (2004) for additional diagrams.

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Frigo, N. J., Iannone, P. P., & Reichmann, K. C. C. (2004). A View of Fiber to the Home Economics. *IEEE Communications Magazine, 42*(8), S16-S23.

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Koonen, T. (2006). Fiber to the Home/Fiber to the Premises: What, Where, and When? *Proceedings of the IEEE, 94*(5), 911-934.

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Appendix 8: Spectrum Policy in Canada

This is a summary of Longford, G. (2007). Open Spectrum and Community Wireless Networking in Canada: A Preliminary Review of the Policy and Regulatory Landscape. Presentation to Social Science Research Council and Free Press Media Policy Research Pre-Conference. Memphis, TN., available on the CWIRP website.

Spectrum Policy in Canada: A CWIRP Background Paper
Graham Longford and Matthew Wong

Introduction

In this background paper we will first briefly describe the spectrum and its operation, followed by how the spectrum is used. We will then provide an introduction to spectrum policy, including how policy is specifically handled in Canada. This will focus on the current trend towards spectrum auctions which we feel is unfairly biased towards incumbent providers. Finally, we will conclude this backgrounder by discussing the future of spectrum management and policy in Canada, in particular, the implications of auctions and "market forces"-oriented policy for community, municipal, and rural broadband.

What is the spectrum?

Electromagnetic radiation is a natural feature of the world which occurs when materials vibrate and transfer energy into their surroundings[1]. There are different kinds of energy which are classified in a *spectrum* of electromagnetic radiation. This spectrum is ordered by increasing *frequency* (vibrations per second), measured in *Hertz* (Hz). In the electromagnetic spectrum frequencies tend to be very high, so the Hertz unit observes standard metric prefixes, e.g. kilohertz (kHz, 1000 Hz), megahertz (MHz, 1 million Hz), gigahertz (GHz, 1 billion Hz). The frequency of particular waves, along with other characteristics such as its wavelength, greatly affects the properties of that wave. This phenomenon is responsible for the existence of visible light, microwaves, x-rays, and so on. The length and frequency of radio waves has a significant impact on their performance and utility for a given use or function. Signals associated with low frequencies and longer wavelengths are more desirable because they propagate farther using less power, are less susceptible to disruption and interference from natural phenomena such as rain, fog, and leaves, and have superior ability to penetrate solid objects such as walls and buildings. These characteristics make lower frequencies particularly ideal for long distance applications such as broadcasting and wireless telecommunications infrastructure for serving rural and remote communities.

How is the spectrum used?

Just as the spectrum is classified by frequency for scientific purposes, so too is it classified for management purposes as well. After all, when devices broadcast electromagnetic signals on the same frequency, interference can result. Interference causes errors for devices trying to process the signals into data. Too much interference can block a signal altogether. As a result of this, particularly since many frequencies are used for services or functions that affect many people (e.g. television and radio stations), the spectrum is managed by governing bodies. Different countries respective national governments also use parts of the spectrum for national security and public safety uses.

Gow & Smith (2006) describe spectrum management as a three-step process of allocation,

allotment, and assignment (pg.11). In this process, the spectrum is divided up into frequency bands which are allocated to different kinds of services, broadly classified. Then the bands are divided up into blocks of frequencies, which are allotted based on specific kinds of services and technical requirements. The blocks are then assigned to a specific kind of service, usually by licensing or authorizing the block to a provider. This has also been described as the "command and control" method of spectrum management (Xavier & Ypsilanti, 2006). In Canada this is handled by Industry Canada and in the United States by the National Telecommunications and Information Administration (NTIA) for Federal use, and the Federal Communications Commission (FCC) for non-Federal use. While nations manage spectrum individually, in order to plan and maintain the interoperability of devices worldwide, the International Telecommunications Union (ITU) helps to coordinate spectrum use on the international stage.

More recently, regulators in the U.S., U.K., Europe and Canada have experimented with designating and allocating small slices of the spectrum for "open," "unlicensed," or "license-exempt" use, as part of a broader trend toward the liberalization of spectrum policy and regulation. Beginning in the 1970s and 80s, for example, some regulators began to allow unlicensed operation of radio devices in the Industrial, Scientific and Medical (ISM) band at 2.4 GHz to accommodate the proliferation of wireless consumer products such as cordless phones, garage door openers, baby monitors, and microwave ovens. In the late 90's, IEEE 802.11 standard wireless Internet began to use this spectrum as well. In 2003, member states participating in the World Administrative Radio Conference (WRC), sponsored by the ITU, approved a new allocation of open spectrum in the 5-6 GHz range.

Introduction to Spectrum Policy

The importance of spectrum management to national operations and interests means that government control over this resource must be guided by policy. In the past, policy was influenced by the fact that demands on spectrum were low and technology could make use of only limited portions of the spectrum. More recently however, with the increasing demand of numerous technologies, such as cellular phones, digital television, and wireless Internet, spectrum for broadcasting and supporting these services and technologies has become a critical commodity. Forge and Blackman (2006) predict that in the next 25 years, "the user population worldwide is set to grow significantly, leading to a massive expansion in demand for service [and] the future will also see demand for new types of services that will require much wider bandwidth to support richer content" (pg.6).

This recent shift in spectrum demand has generated a lot of concern with the existing licensing techniques. Criticisms of the command and control method include that (1) it does not ensure spectrum is used efficiently (or even used) after licenses are issued, (2) the system of granting licenses is too slow and inflexible, (3) licensees are prohibited from changing spectrum use to offer new services, (4) it limits innovative uses of new technology, and (5) it is too restrictive on the entry of new technologies (Xavier & Ypsilanti, 2006, pg.34). In the last few years, in order to address these concerns, the FCC, Industry Canada, and other national governing authorities have looked to *spectrum auctions* to deal with the growing demand for spectrum.

Spectrum Auctions

Spectrum auctions were first practiced in New Zealand in 1989 and then the United Kingdom in 1990 (Jain, 1999). The United States legislated spectrum auctions in 1993. The concept of auctioning to determine the "highest valued use" (Coast, 1959, quoted in Faulhaber, 2006) has

become a key factor of the spectrum auctions. Jain (1999) noted that the 1993 U.S. auction for Personal Communication Services (PCS) netted $20 billion in revenues. In the recent Third Generation (3G) auctions in Europe, €100 billion were accumulated, with over €50 billion for Germany alone (Forge & Blackman, 2006). In Canada, to date there has been three auctions, starting in 1999, for various parts of the spectrum[2]. Some estimates the value of the licenses acquired since 1999 total over $1.7 billion[3].

Some authors have noted the advantages of spectrum auctions including their relative speed compared to previous competition hearings, the "transparency" of auctions in that "they avoid potential and actual government decisions that are biased towards or against individual industry players", and that they "ensure spectrum ends up in the hands of those who value it most" (quotes from Grünwald, 2001, pg.726). At a recent conference on Mobile Business, the President and CEO of the Canadian Wireless Telecommunications Association gave a speech advocating the use of spectrum auctions as "enlightened regulation" and that an "open spectrum" auction would "level the playing field" and allow for the "full potential of market forces" (Barnes, 2007). He went on to suggest that government-imposed "artificial measures" (1) created an economic distortion of the marketplace, (2) could cost taxpayers hundreds of millions of dollars in lost revenue, and (3) may undermine investments in research and new technologies (Barnes, 2007).

However, spectrum auctions can often be problematic, and by no means have all auctions gone smoothly. New Zealand's first auction featured a problematic bidding system (Grünwald, 2001) and in the U.S. there were cases in the auctions where bidders defaulted or declared bankruptcy immediately after the auction (Faulhaber, 2006). Snider (2007) also documents a number of other problems in the American auctions in what he called the "$480 billion Spectrum Giveaway." From a public interest perspective spectrum auctions have been criticized for a number of reasons, not least of which is their tendency to encourage the concentration of spectrum ownership in the hands of deep-pocketed incumbent carriers. By encouraging the inflation of spectrum prices, auctions place spectrum beyond the reach of potential new entrants and community and nonprofit bidders who cannot match the resources of major incumbents. Consumers are hurt in the process, as the concentration of spectrum ownership undermines competition, keeps prices high and discourages the development of new services (Geist, 2007; Rose & Lloyd, 2006; Melnyck, 1997). Governments, meanwhile, have little incentive to improve spectrum auctions that have netted them billions of dollars in revenue in recent years.

Among the few mechanisms available to curb the worst excesses and outcomes of spectrum auctions are the use of spectrum "set asides" (spectrum set aside for use by new entrants and/or communities) and "spectrum caps" (which limit the amount of spectrum that a firm can hold). These mechanisms are what Barnes termed "artificial measures." With most community wireless networking initiatives limited to using existing unlicensed spectrum in increasingly crowded, relatively high frequency bands in the 2.4 GHz and 5 GHz ranges, their ability to expand and develop new applications is hindered (Lakshmipathy, 2007; Meinrath, 2005). An increased emphasis on spectrum auctions and property rights in spectrum threaten to undermine efforts to improve access to the open spectrum on which community wireless networking initiatives depend. As Meinrath warns, "wireless technologies and the public airwaves that are this medium's lifeblood are rapidly being cordoned off, made proprietary, and licensed -a process being driven by a desire to maximize profit margins, not serve the public

good" (Meinrath, 2005). Additional spectrum is required to satisfy the social requirements of Canadians, in order to meet the needs of under-and unserved communities, and to satisfy growing demand for access to spectrum from citizens and communities themselves.

The Future of Spectrum Management and Policy in Canada

In 2005 the Canadian government launched the Telecommunications Policy Review Panel (TPRP) which was a public consultation on the future of Canadian telecommunications policy. This consultation concluded in March, 2006 with dozens of submissions from various academic, and community groups, as well as telecommunications and cable corporations voicing their perspectives. The 3-person TPRP issued a final report, calling for less regulation and increased reliance on market forces in order to promote the growth and competitiveness on Canada's telecommunications industry. Included in the TPRP's report are a discussion of spectrum policy and a number of recommendations regarding spectrum regulation, utilization and management designed to ensure access to sufficient spectrum to meet demand for new wireless services and in order to extend broadband connectivity to all rural and remote communities in Canada. Among the TPRP's recommendations was an endorsement for releasing more spectrum for licence-exempt applications and use. However, the panel also recommended a great reliance on market forces in the allocation of spectrum (i.e. more auctions). Such a continued use of auctions for spectrum can only reinforce the disadvantageous position in which community/municipal and broadband projects find themselves in with respect to access to spectrum.

The recommendations of the TPRP are currently being reviewed by the Conservative government. Early indications are that, along with U.S. policy developments, the TPRP report will exercise a strong influence on the direction of future telecommunications policy making, including spectrum policy, in Canada[4].

Endnotes

[1] For an excellent primer on radio basics, see Gow & Smith, 2006.

[2] See Longford, 2007, pages 9-10 for a review of Canadian spectrum auctions and policy.

[3] Completed auction information available from Industry Canada's Spectrum Auction website: http://strategis.ic.gc.ca/epic/site/smt-gst.nsf/en/h_sf01714e.html.

[4] See also Longford, 2007, pages 18-19 for a further discussion of the TPRP's recommendations.

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Endnotes

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[35] Note that the community broadband network is not the Fredericton eZone wireless network. This is the fibre network operated by E-Novations, a company owned by the City of Fredericton. The Community Broadband Network in Fredericton provides bandwidth to the Fred-eZone. To avoid confusion with our definition of a community broadband network as one that is provided by a community group, rather than a municipality, we will refer to Fredericton's community broadband network as a fibre network. See Powell, A. (2008). *CWIRP Case Study Map: Fred E-Zone*. Community Wireless Infrastructure Research Project.

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[55] Vos, E. (2005). Muniwireless.com July 2005 Report; Vos, E. (2006). Muniwireless.com 29 December 2006 List of US Cities and Regions; Vos, E. (2007). Muniwireless.com: 31 March 2007 List of US Cities and Regions; Vos, E. (2007). Muniwireless.com: 1 August 2007 List of US Cities and Regions.

[56] A detailed review of the literature discussing the benefits of community and municipal broadband networks is provided in Middleton, C., Longford, G., Clement, A., Potter, A. B., & Crow, B. (2006). *ICT Infrastructure as Public Infrastructure: Exploring the Benefits of Public Wireless Networks.* Proceedings of Telecommunications Policy Research Conference, Arlington, VA.

[57] Center for Digital Government. (2005). *Building the Untethered Nation: A Strategic Guide for Communities on Wireless Technology and Broadband Infrastructure*. Folsom, CA: Center for Digital Government.

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[58] See Donahue, H. C. (2004, 15 December). Reining in Municipal Wireless, Broadband: The Pennsylvania Story. *Telecom* Policy *Report*.

[59] See Civitium. (2005). *Wireless Broadband: The Foundation for Digital Communities - Community Guidebook*, Informa UK. (2006). *Municipal Wireless Broadband: New Business Models and Technologies Transforming the Broadband Market*. London, and Neff, D. (2007). Local Wireless Networks - a Prerequisite for The Future. *Public Management, 89,* 10-14.

[60] What is more likely is that a municipality becomes involved in supporting such a network, after it has been created. This was the case with CUWiN, in Champaign-Urbana, IL

(http://www.cuwin.net/projects/urbana). Île Sans Fil is now consulting with the City of Montreal to determine ways they could work together to further extend wireless access in Montreal.

[61] See Jain, A., Mandviwalla, M., & Banker, R. D. (2007). *Can Governments Create Universal Internet Access? The Philadelphia Municipal Wireless Network Story*. Washington, DC: IBM Center for The Business of Government.

[62] Wireless Task Force. (2006). Wireless in Boston.

[63] Boston Announces Completion of First Wireless Pilot. (2008, 2 April). *Government Technology*. ("Boston Announces Completion of First Wireless Pilot,")

[64] Potter, A. B. (2007). *Business Models for Local Networks*. Ethos Group.

[65] See http://ethostoolkit.net/example/alpha for a partial list of broadband projects. Blogs provide a good source of information on wired and wireless broadband projects. See for instance http://www.dailywireless.org, http://www.muniwireless.com, http://wifinetnews.com and http://w2i.com.

[66] Fleishman, G. (2006). St. Cloud Says 77% of Households Registered for Free Wi-Fi.

[67] Gillett, S. E., Lehr, W. H., & Osorio, C. A. (2006). Municipal Electric Utilities' Role in Telecommunications Services. *Telecommunications Policy, 30*(8-9), 464-480.

[68] Glasgow's network was initially designed to help manage its electrical distribution system and to provide cable television service to the community. See http://www.glasgowepb.net/faq.html, http://www.epblan.com and Carlson, S. C. (1999). A Historical, Economic, and Legal Analysis of Municipal Ownership of the Information Highway. *Rutgers Computer & Technology Law Journal, 25*(1), 1-36.

[69] More detail on this network can be found in Scott, B., Chesley, R. E., Lakshmipathy, N., Ramachandran, K., & Barranca, M. (2005). *Profiles of Municipal and Community Broadband Networks*. Northampton, MA: Free Press., Techatassanasoontorn, A., & Tapia, A. (2007). Can a City Manage Broadband Infrastructure? An Organizational Learning Perspective. Presentation to Communication, Information and Internet Policy Conference. Washington, DC. and Tropos Networks. (2007). Chaska.Net and Tropos Unwire Chaska, Minnesota.

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[72] Mitchell, C. (2007). *Burlington Telecom Case Study*. Minneapolis, MN: Institute for Local Self-Reliance.

[73] See http://www.utopianet.org/what/about.html and Cherry, S. (2006). A Broadband Utopia. *IEEE Spectrum, 43*(5), 48-54.

[74] http://www.click-network.com/AboutUs/tabid/88/Default.aspx

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[76] van der Woude, D. (2007). *An Overview of Fiber: European (Muni and Other) Fiber to the Home and Fiber Backbone Projects*. City of Amsterdam.

[77] Mottl, J. (2008). NY Muni Wireless Network Launch in Sight.

[78] City of Corpus Christi. (2007). Corpus Christi Wireless Applications.

[79] http://www.ci.minneapolis.mn.us/wirelessminneapolis, and Wireless Minneapolis. (2006). *Municipal Broadband Initiative Business Case*. Minneapolis, MN: City of Minneapolis. This project is discussed in detail in Civitium. (2008). *The Future of Municipal Broadband: Business, Technology and Public Policy Implications for Major U.S. Cities*. Alpharetta, GA.

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[81] Civitium. (2008). *The Future of Municipal Broadband: Business, Technology and Public Policy Implications for Major U.S. Cities*. p. 4.

[82] Bast, J. L. (2004). *Municipally Owned Broadband Networks: A Critical Evaluation* Chicago: The Heartland Institute.

[83] Wu, T. (2007). Where's My Free Wi-Fi? Why Municipal Wireless Networks Have Been Such a Flop. *Slate*.

[84] Coe, L. (1996). *Wireless Radio: A Brief History*. Jefferson, NC: McFarland.

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[85] http://www.newamerica.net/programs/wireless_future/broadband_policy_and_community_wireless

[86] http://www.ethoswireless.com/

[87] http://www.freepress.net/taxonomy/term/79

[88] http://www.mediaaccess.org/issues/open-access/

[89] http://www.cuwin.net/about

[90] http://www.nycwireless.net/about/

[91] http://seattlewireless.net/

[92] See http://freenetworks.org/ for a partial list.

[93] Meinrath, S. (2008). What's Wrong with Meraki? Black Box Technologies, Lock-in, & Hidden Costs. (2008)

[94] Case studies are discussed in a Meraki forum at forums.meraki.com/viewforum.php?f=9. The Socalfreenet uses Meraki technology: http://socalfreenet.org/

[95] For a full discussion of these two approaches, see Middleton, C. A., & Potter, A. B. (2008). *Is It Good to Share? A Case Study of FON and Meraki Approaches to Broadband Provision.* Proceedings of International Telecommunications Society 17th Biennial Conference, Montreal.

[96] Powell, A., & Shade, L. R. (2006). Going Wi-Fi in Canada: Municipal, and Community Initiatives. *Government Information Quarterly, 23*(3-4), 381-403.

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[101] Buckler, G. (2004, 23 September). Networking on the Grid: With Services That Are Cheap and Based on a Proven Infrastructure, Utility Companies across Canada Are Becoming a Viable Choice for Providing Broadband Solutions*. Globe and Mail,* p. B14.

[102] http://www.atrianetworks.com/community.php

[103] http://www2.atriawifi.com/WiFi/default.cfm

[104] The Strategy Institute ran the Wireless Cities Summit in Toronto in January 2007. It was attended by representatives from many Canadian municipalities. http://www.strategyinstitute.com/012307_wireless_cities/dsp_wireless_cities.php. ITAC's 1st Canadian Municipal Wireless Applications Conference & Exhibition, held in Toronto in May 2007, was also well-attended.

[105] wifinetnews.com

[106] These points are made in Middleton, C. A. (2007). *A Framework for Investigating the Value of Public Wireless Networks*. Presentation to 35th Research Conference on Communication, Information and Internet Policy (TPRC). Arlington, VA. and Potter, A. B., McIntyre, N., & Middleton, C. A. (forthcoming). How Usable Are Outdoor Wireless Networks? *Canadian Journal of Communication*.

[107] Earthlink and Metro-Fi both tried to make money from selling primary internet access to consumers using their Wi-Fi networks. The Wi-Fi service was inferior to existing DSL and cable options, so subscription rates were very low. Revenue from Wi-Fi subscriptions was supposed to pay for the development of the networks, but without this revenue, their business models did not work.

[108] Unfortunately, as the network-neutrality debate reveals, many internet service providers do now impose some limits on the ways in which individuals can use their networks (e.g. slowing down certain types of traffic, like bit torrent or voice over internet protocol sessions). This is a disadvantage of infrastructure that is controlled by the private sector.

[109] Middleton, C. A. (2007). *A Framework for Investigating the Value of Public Wireless Networks*. Presentation to 35th Research Conference on Communication, Information and Internet Policy (TPRC). Arlington, VA.

[110] Municipalities have access to licensed spectrum for public safety use.

[111] See Civitium. (2008). *The Future of Municipal Broadband: Business, Technology and Public Policy Implications for Major U.S. Cities*. Alpharetta, GA. www.civitium.com/LIBRARY/tabid/57/Default.aspx.

[112] e.g. Metro-Fi's now defunct service in Portland, Oregon.

[113] See Cho, H. H.-N. (2008). Towards Place-Peer Community and Civic Bandwidth: A Case Study in Community Wireless Networking. *Journal of Community Informatics, 4*(1), for some insights into Wireless Toronto's operations.

[114] Miller, D. (2006). Office of the Mayor of Toronto Wi-Fi Announcement.

[115] A detailed discussion of the public broadband desiderata is provided in Potter, A. B., & Clement, A. (2007). *A Desiderata for Broadband Networks in the Public Interest.* Proceedings of 35th Research Conference on Communication, Information and Internet Policy, Arlington, VA.

[116] See Appendix 6 for a summary of research on the health impacts of wireless networks.

[117] For information on Canadians' choices regarding broadband service providers, see CRTC. (2008). *Communications Monitoring Report*. Ottawa: Canadian Radio-television and Telecommunications Commission.

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[120] Geist, M. (2008). Canada's Wireless Crisis.

[121] For instance, by allocating the 'white spaces' vacated by analog television for unlicensed, open uses. See http://wirelessinnovationalliance.org/index.cfm, Calabrese, M. (2008). Broadcast to Broadband – Unlicensed Access to Unused TV Channels? *IEEE Internet Computing, March/April*, 71-75, and Geist, M. (2008). Canada's Wireless Crisis.