# A Framework for Investigating the Value of Public Wireless Networks

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## Introduction

This paper investigates the value of deploying municipal wireless network infrastructure. By Vos's (2007c) estimate, there are more than 400 such networks, either deployed or in development in the United States. Many other wireless networks are operational, or being rolled out in cities around the world, including Toronto, London, Bologna, Singapore, Taipei and Perth. Developed by municipal governments, private providers or public-private partnerships, these networks are intended to serve the connectivity needs of local residents, tourists and business travellers.

Most of these networks propose, or currently deliver, high speed wireless internet connectivity to public spaces. The public component is frequently billed as an essential element of the network, as part of a digital divide or digital inclusion strategy (e.g. Ortiz & Tapia, 2006; The Wireless Philadelphia Executive Committee, 2005). While much work has been done to understand business models for the development of wireless networks and to assess various options for ownership of wireless infrastructures (see for example Bar & Galperin, 2004; Bar & Park, 2006; Fuentes-Bautista & Inagaki, 2005; Tapia & Ortiz, 2006; Tapia, Stone, & Maitland, 2005), it seems that in the frenzied environment of municipal wireless development, some fundamental questions remain unanswered: What is the purpose of public wireless networks? Do existing approaches to the delivery of public wireless networks result in the development of good public infrastructure?

At the 2006 Telecommunications Policy Research Conference, the Community Wireless Infrastructure Research Project team presented a paper outlining ideal characteristics for public broadband networks (Middleton, Longford, Clement, Potter, & Crow, 2006). At the 2007 conference, a more detailed desiderata for public broadband networks will be presented, explaining the key features that are required to develop broadband infrastructure that serves the public interest (Potter & Clement, 2007). This paper is based on the premise that broadband infrastructures can, and should, be developed so as to meet the needs of the public, and offers insights for assessing the value of current deployments of public wireless broadband networks. But it is motivated by a growing concern that wireless infrastructure, as currently deployed, may not offer the best means of providing broadband infrastructure that meets the standards of good public infrastructure.

The paper presents a framework for assessing the value of public wireless networks, by considering various dimensions of network usage. For instance, is the network intended to serve as a primary internet access point (e.g. digital inclusion projects) or does it provide secondary access (e.g. access "in between" home and office, including outdoor locations)? What is the bandwidth available to network users, and are there limitations on the sorts of activities that can be done on the network (e.g. is bandwidth limited at particular times of day? are activities like sending email or uploading files prohibited?)? What are users' needs for mobility, and are cloud or zone arrangements sufficient for people who require true mobile (not portable) connectivity? What types of devices are needed to access the networks, and are these the devices that users want to carry around with them on a daily basis? Are users willing or able to pay for network access?

There is no doubt that there is value in providing broadband network connectivity to homes and businesses, but is wireless infrastructure the best solution to provide primary access to the internet? Are deployments to public spaces like parks, and city streets useful? This paper explores the affordances of wireless networks, and provides a foundation for a more informed discussion as to what the role of communities and municipalities could be in infrastructure development. It suggests that objectives of connectivity and digital inclusion might be better met by pursuing alternative forms of infrastructure development (e.g. deployment of fiber networks for digital inclusion, and promotion of cellular technologies to support mobility). The paper shows that commercial developments are currently better at meeting some criteria of good infrastructure than municipal developments, and points to the challenges looming as commercial infrastructures become more widely available and more affordable. The paper concludes with a discussion of the policy issues relevant to creating the appropriate network infrastructures needed to deliver broadband in the public interest.

## Background and Literature Review

This paper focuses on public broadband networks. In the United States in particular, there has been a great interest among municipalities and some state governments in the development and deployment of broadband infrastructures that can provide internet connectivity to local governments and citizens. Lehr, Sirbu and Gillett (2006) note that governments have developed broadband infrastructure for three main reasons. The first is as a response to market failure, providing infrastructure to areas that would not be served by the private sector, or where there is limited competition among service providers resulting in inadequate levels of service. This motivation is frequently described in terms of bridging the digital divide (Gibbons & Ruth, 2006), or of ensuring 'digital inclusion' for local citizens (Neff, 2007). It can also be a strategy to lower prices for broadband connectivity, by introducing more competition into the marketplace (Waxenberg, 2007). A second rationale is that broadband networks are an essential part of public infrastructure, and as such, should be provided by municipalities just as they provide other infrastructure (roads, sewers etc.) (Center for Digital Government, 2005). The third reason is opportunistic. As Tapia, Maitland and Stone (2006) observe, municipal broadband deployments are becoming more common simply because technologies like Wi-Fi (wireless fidelity networks that provide connectivity over short distances) make it possible. Many municipalities have made extensive investments in the development of fibre networks and have existing applications that are used to deliver government services (Gillett, Lehr, & Osorio, 2006). Municipalities can achieve economies in infrastructure deployment by leveraging their existing infrastructure (e.g. fibre, telephone poles on which to mount wireless networking infrastructure) to provide wireless connectivity[1] to citizens. David Dobbin, the CEO of Toronto Hydro Telecom (the utility that developed a public wireless network in Toronto) reinforces this point, saying:

> Why build Wi-Fi? That was a big question the people asked us. Why would you build a municipal Wi-Fi network? Well, really what it came down to was leveraging our assets. We had assets in place, already in the ground, already on the streets, that made this a slam dunk for us. (Dobbin, 2007)

Local governments, especially those with municipal electric utilities, have provided communication infrastructures to citizens for many years, and in recent years have offered internet access to local businesses and residents (Gillett, Lehr, & Osorio, 2004). With lower costs of deployment, municipalities can offer more affordable broadband access to local residents and to small businesses, thereby encouraging economic development. Municipalities can also lower their own communications and service delivery costs by using wireless network

[1] Broadband infrastructures can provide access to the public internet, and can support direct networking among individuals (e.g. peer to peer file sharing, development of local networks to support community interests). The 'connectivity' that is referred to throughout this paper refers to connection to the public internet (for access to email, web browsing, file sharing, entertainment content etc.). The paper does not focus on the provision of 'content' on the internet (i.e. community-centric information, access to government services, movies, music, it simply considers the issues related to the development of infrastructure that allows people access to the internet.

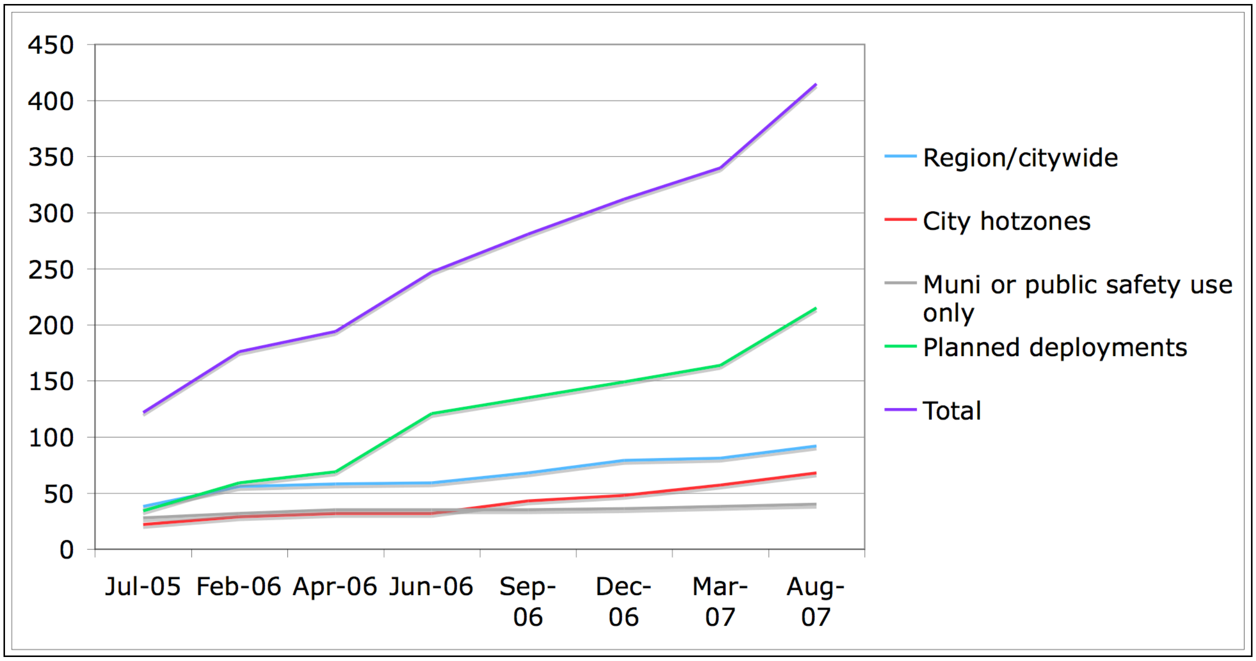
infrastructure to support municipal operations and service delivery (Bar & Park, 2006). In addition, the development of wireless infrastructures is also thought to promote economic development, as it entices businesses, commercial travellers and tourists to local municipalities where such infrastructure is deployed (Feld, Rose, Cooper, & Scott, 2005; Kelley, 2003).

Of interest in this paper are public broadband networks that provide service using wireless infrastructure (primarily Wi-Fi). Public networks are developed by local municipalities or other levels of government with an explicit purpose to provide infrastructure to citizens and communities. The networks can be used by anyone within the network coverage area (provided that they have an access device and are willing to pay an access fee, if there is one). The term 'municipal wireless' (which is sometimes shortened to 'muniwireless' or 'muni Wi-Fi') is used to describe these networks, which are assumed to be delivering broadband that is in the public interest (Potter & Clement, 2007). Ideally, broadband in the public interest will provide universal, affordable service, allowing citizens a choice of service provider (Lehr et al., 2006), and fostering community engagement (Middleton et al., 2006). Broadband in the public interest should be ubiquitous, useful and usable (Potter & Clement, 2007). Shein (2005) provides an overview of the development of municipal wireless networks in the United States. The Center for Digital Government (2005; 2006) (which is underwritten by IBM) has produced two reports to help municipalities understand the benefits of developing wireless infrastructures. Technical primers are provided by Sirbu, Lehr and Gillett (2006) and Lehr and McKnight (Lehr & McKnight, 2003).

Buffalo, MN was among the first municipalities to provide public wireless broadband service, with BWIG.net operational as early as 2002 (Brooks, 2002). Muniwireless.com, a website that bills itself as "the voice of public broadband," was established in 2003 ("New Website Gets Behind Municipal Wireless Projects," 2003), as increasing numbers of municipalities became interested in using wireless technologies to provide broadband access, or to extend existing services. By 2004, Shamp (2004) reported that there were 38 Wi-Fi clouds (areas of continuous network coverage within a specific location) and 16 Wi-Fi zones (where aggregations of hotspots provided non-contiguous connectivity at different locations within a geographic area) in the US, and the development of wireless infrastructures began to garner attention within the academic community (Bar & Galperin, 2004; Sandvig, 2004).

Despite efforts by the telecom industry to restrict the development of municipal wireless networks (Strover & Mun, 2006; Tapia & Ortiz, 2006; Tapia et al., 2005) as of August 1, 2007, muniwireless.com reports that there are 200 US cities and counties with operational wireless networks, and an additional 215 in the planning stages (Vos, 2007c). A further 40 localities are "seriously considering" wireless deployment in their communities. Figure 1 shows the growth in wireless deployments over the past two years.

FIGURE 1: GROWTH IN MUNICIPAL WIRELESS DEPLOYMENTS IN THE US, 2005 - 2007




Source: (Vos, 2007c)

There are municipal broadband networks that are used exclusively for government purposes and not open to the public (shown as "Muni or public safety use only" above). Examples include public safety and security networks (e.g. Emergency Management Services, Police, Fire), networked surveillance cameras and remote sensing systems (e.g. SCADA systems to monitor public utilities). Although operated by public agencies, these networks are not considered public networks in the context of this paper, as they do not provide connectivity to individuals or businesses. However, eighty percent of the operational municipal wireless networks identified by Vos (2007c) do include public access (i.e. these networks are not focused on municipal or public safety use only). In some projects there is an explicit agenda to help bridge the digital divide within the area of deployment (e.g. City of Philadelphia), in others public broadband access is offered as one of the features of the network.

The consulting company Civitium, a major player in the municipal wireless industry, identifies five 'business models' that communities or local governments might use to bring wireless network connectivity to local citizens (Informa UK, 2006; Neff, 2007). These business models describe the relationship between a government or community and the service provider that develops the wireless network. Four of these approaches are used to develop municipal wireless infrastructures[2]. In a *private consortium* arrangement, a private company enters an agreement with a municipality to develop a wireless network. The municipality may agree to subscribe to certain services and to act as an anchor tenant – "an influential organization in a network that owns the resources and "leases" network access to "tenants", (Center for Digital Government, 2005, p. 6) including for example community groups, businesses, educational institutions. It may provide access to municipal infrastructure to build the network. The network is developed to serve public spaces, and in some cases, to provide broadband connectivity to local citizens in their homes. Citizens pay a fee for use of the network directly to the private provider. There may be an arrangement in place to provide economically disadvantaged users with a reduced access fee. Earthlink and MetroFi are two companies that have been involved in many such deployments, in cities like Corpus Christi (TX), New Orleans, Anaheim, Milpitas (CA), Portland (OR), Cupertino and San Jose (CA). The network deployment models assume that revenues generated by access fees will fund network development, and provide an adequate return to the service provider (Kharif, 2007). In a *cooperative wholesale™* approach to network development, a municipality or region takes on the development and operation of the network itself (using government funds), and provides wholesale access to the network to local internet service providers (who can resell the bandwidth to community members). Examples include the UTOPIA network in Utah (www.utopianet.org), and Fredericton, New Brunswick's eZone (www.fred-ezone.ca). In some instances, a *public utility* takes on the development and operation of the network, potentially building on existing relationships with subscribers, who pay the utility a fee for accessing the network. The local government may subscribe to the network to support government activities. Examples include the Coldwater (MI) Board of Public Utilities (cbpu.com), Scottsburg, IN, and Owensboro, KY (Vos, 2004). Another approach is to form a *non-profit* organization to develop the network (e.g. Wireless Philadelphia). The non-profit may contract the network deployment and operation out to a private sector provider (e.g.

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[2] Daggett (2007) argues that privately owned infrastructure is not public. In the context of this paper, infrastructure developed in response to a municipal government and/or local community request for connectivity is considered within the umbrella of public infrastructure. Such infrastructure should be able to provide broadband connectivity that is in the public interest.

Earthlink), but provides the network specifications and negotiates pricing models that meet municipal needs.

The fifth approach identified by Civitium is a more organic one, that is typically not driven by local municipalities. In what is called a *grassroots public community* approach, a local community organization provides wireless connectivity to various locations within a community, usually free of charge. This sort of network does not support government service delivery, and does not generally provide ubiquitous network coverage across a geographic area. Community sponsored networks do provide public broadband access, but they do not develop municipal infrastructure. This type of network provisioning is considered further below, as an alternative mechanism for providing citizens with access to broadband.

In the US, there has been much interest in the business models used to develop municipal wireless infrastructures. Given the opposition to municipal wireless initiatives, this interest is understandable as state legislation has limited some options and required changes to planned deployments (Tapia & Ortiz, 2006). Although there are differences among business models for municipal wireless deployments, all models have the potential to develop broadband infrastructure that is in the public interest, enabling affordability and choice in internet connectivity, and open access to networks, among other attributes. Differences in local needs and variations in infrastructure builds mean that few networks are identical, but common affordances of public wireless broadband networks can be identified.

Municipal wireless networks provide the following:

- Network coverage to public spaces within a municipality. This may include parks, community centres, and open spaces (e.g. malls, outdoor squares). Some networks provide connectivity to interior locations, including residences.
- Open Wi-Fi connectivity, allowing anyone to use the network infrastructure, either for free or at a rate that is deemed affordable by the network provider. In general, users must provide their own infrastructure (e.g. laptop) to access the network. Some projects, especially those with a focus on extending digital inclusion, make provisions to assist potential users in acquiring, and learning how to use, access devices.
- Municipal wireless networks support basic internet services, including email, and web browsing. Other services (e.g. video downloads) may be restricted by the network provider.
- Access speeds of 1.5 - 2 Mbps are common. Some networks are symmetrical (equal

bandwidths for uploading files as for downloading). Networks may provide higher access speeds to citizens or businesses who are willing to pay for the service.

Municipal wireless networks were launched with great promise (Junnarkar, 2003), and there is consensus around the *potential* benefits of municipal wireless networks (Middleton et al., 2006). There is some evidence to support claims of increased government efficiencies as a result of wireless network deployments (City of Westminster, 2006; *Corpus Christi to Celebrate Completion of First Large-Scale Citywide Wireless Network*, 2006). As Fuentes- Bautista and Inagaki (2006) observe,

> The expansion of wireless broadband in public spaces can contribute to raising awareness of high-speed services, can provide means of connectivity for those who lack them at home, and can enhance online interactions among current users. These promises have yet to be delivered. (p. 408)

Indeed, as more networks become operational the benefits of public internet access provisions seem less clear (Belson, 2006; Hecht, 2007; Ross, 2006). Jesdanun (2007) reports that "many cities are finding their Wi-Fi projects costing more and drawing less interest than expected," noting that Earthlink has a total of only 2000 paying subscribers for its municipal wireless networks in four cities (New Orleans, Milpitas CA, Anaheim CA and Philadelphia).

Wireless networks are built with the assumption that they will be widely used by community members. Although it is estimated that operational networks have uptake rates of 1-2% of the local population, rather than the 15-30% anticipated in original business plans (Kharif, 2007), the Earthlink numbers would suggest that uptake rates are well below the 1% figure. Blomquist (2007), noting that broadband availability and adoption rates in the US are increasing rapidly as prices fall, points out that:

> In a little less than a decade, we've gone from the dominance of dial-up to deep market penetration by cable and DSL carriers, with wireless, cellular, satellite, and even broadband over power line joining the mix.

He then asks "Does a market as rich, varied, and competitive as this really need municipal Wi-Fi?" Strover and Mun (2006) reiterate that Wi-Fi was not designed as public access technology, but as a means of extending connectivity over short distances. Consumers who expected that their Wi-Fi networks would provide reliable connectivity have been disappointed. "We found that a lot of people have false expectations about how this system will work," says Corpus Christi, TX network manager Leonard Scott, noting that the service is not like "DSL and cable modems, [where] they plug it in and it works the same every day" (Waxenberg, 2007).

As companies like Earthlink "re-evaluate" their strategies in the municipal wireless market (Hegstad, 2007), consultants to the industry argue that the biggest benefits from municipal wireless will come through reducing the cost of delivery of government services (Waxenberg, 2007), rather than from providing broadband access to citizens. This may be true, or it may simply be a way to encourage continued investment in an industry that is not producing the anticipated return on investment. From the perspective of developing broadband infrastructures that are in the public interest, an important question is whether there is value in continued development of wireless infrastructure as a means to provide citizens with internet connectivity. Can wireless infrastructure provide citizens with high quality connectivity that is usable, reliable and affordable? This question is investigated below.

## Analytical Framework

Good public infrastructure meets the needs of its users. Are municipal wireless networks usable? Does the infrastructure provide basic connectivity to citizens? If basic connectivity is provided, is it reliable, and is it of sufficient quality to support the applications users wish to use? Is it affordable, and is it available where users require it, for use with their devices of choice? In order to understand the affordances and value of wireless networks, it is important to understand the environment in which they are deployed.

As noted above, there are four different organizational structures that are used to develop municipal wireless infrastructures. But the wireless networks developed by municipal providers are not the only sources of internet connectivity available in many communities. Telephone companies like Verizon and AT&T, and cable companies like Comcast, Cox and Time Warner offer DSL and cable broadband services. In addition, mobile broadband services are available using cellular technology, meaning that in many municipalities there are wired and wireless commercial alternatives to the broadband infrastructure provided by a municipal network. Another source of connectivity is provided at pay-for-use hotspots (Stone, 2003). T-Mobile provides hotspots at Starbucks locations around the US, AT&T offers basic wi-fi connectivity to their DSL subscribers at hotspots throughout the US and companies like Boingo Wireless which has developed a global network of hotspots.

Civitium suggests that grassroots public community organizations can provision municipal wireless networks, however, community organizations that do develop wireless infrastructures are not generally directly affiliated with municipal governments (Sandvig, 2004; Schmidt &

Townsend, 2003). With community wireless networks, provision of connectivity can be part of a larger effort to engage citizens in civic participation (Cho, 2006; Powell, 2006). Community sponsored networks take many forms, ranging from local venues like coffee shops sponsoring hotspots (Fuentes-Bautista & Inagaki, 2006), to informal, self organizing groups that wish to share their connectivity (Bina & Giaglis, 2005), to a more coordinated approach by a specific organization to provide hotspots across a city (e.g. Île Sans Fil in Montreal, Canada, Powell & Regan Shade, 2006), or even around the world (www.fon.com). In addition, Wong and Clement (2007) document informal (and often unplanned) Wi-Fi sharing in urban centres, observing that unsecured networks can be a source of free Wi-Fi connectivity.

The key point in this discussion is a recognition that in most municipalities, municipal wireless networks are not the only source of connectivity for citizens. In some instances, commercial providers (of wireless and wired infrastructure) have entered the market after the deployment of municipal infrastructure (e.g. in the city of Lompoc, CA, Jesdanun, 2007), and in others, community groups (e.g. Wireless Toronto, Île Sans Fil) have established free hotspots to 'compete' with pay hotspots. Returning to the questions of interest in this paper, how do municipal wireless networks provide value for citizens in an environment where connectivity is no longer scarce? Do municipal wireless network deployments provide broadband that is in the public interest? What types of users do they serve, and is Wi-Fi connectivity the best option to meet their needs? To address these questions, it is important to recognize and understand the variety in contexts of use for Wi-Fi networks.

Wi-Fi networks can be used to provide individuals with their primary source of internet access (e.g. to deliver connectivity to users in their homes), or as a secondary source of internet access (e.g. to provide connectivity to users moving around a city). Primary access is generally at a fixed location, whereas secondary access may be provided to portable and mobile devices. To date, Wi-Fi networks have been developed with either a pay-for-use or a free connectivity model. Depending on their financial circumstances and their need for connectivity at a given time, users can be categorized into those who are willing (or able) to pay for Wi-Fi access, or those who are unwilling (or unable) to pay for Wi-Fi.

These distinctions in usage contexts are important because they influence the nature of connectivity an individual requires at a particular time and location. While ideally citizens could have ubiquitous access to high quality, affordable internet connectivity, this is not yet a reality.

*Willingness to Pay: High/Low*

Municipal wireless network providers aim to deliver high quality internet services to citizens at a reasonable cost. Some small cities (e.g. Fredericton, NB; St. Cloud, FL) are able to provide free Wi-Fi to local residents and visitors, but it is generally agreed that free service can not be sustained without ongoing investment from the service provider, or without other revenue sources (e.g. advertising). As such, many municipal networks do charge for access to the service. Access fees are competitive with, or lower than, commercial providers' rates. However, within any given municipality, there are individuals who are either unable, or unwilling, to pay for connectivity. Those who are unwilling to pay are targeted for digital inclusion strategies, in which special arrangements are made to provide them with internet access devices, training and subsidized connectivity. As will be discussed below, the connectivity provided by such schemes is often not as robust as provided to paying customers. Those who are willing and able to pay have more choices about broadband infrastructure.

*Access Type: Primary/Secondary*

Wireless networks can provide users with primary or secondary internet access. Primary access is the user's main form of internet connectivity, usually providing connectivity to a fixed location (e.g. home, office). Secondary access can be thought of as *supplementary* access, providing connectivity to users when they are away from their primary access points. While it could be argued that there should be no distinction between primary and secondary access points in an 'anytime, anywhere' world, currently there are differences in service levels, and in expectations of availability and reliability of service based on the primary/secondary distinction. For example, users can expect that their primary service will be reliable and accessible at all times. While the same level of reliability is desired in secondary access, current experiences with public wireless networks indicate that service is patchy (non-ubiquitous), network uptime is not guaranteed and access speeds vary dramatically.

*Contexts of Use*

Figure 2 shows how access type and willingness to pay for service can be combined into a matrix to reveal four contexts of use for Wi-Fi networks.

FIGURE 2: WI-FI USAGE FRAMEWORK

| | | Access Type | |
|---|---|---|---|
| | | Primary | Secondary |
| Willingness to Pay | High | Internet Service Provider | Roaming Internet Service Provider |
| | Low | Digital Inclusion (Affordable Access) | Roaming Affordable Access |

The nature of wireless deployments and their users is complex. The imposition of a two by two matrix onto the environment has its limits, as it forces strict boundaries onto spaces that may be better represented as continua. However, the matrix does identify distinct contexts of use, which are not recognized in current discussions of municipal wireless networks. The identification of the four contexts of use is important as it provides a means for assessing the value of Wi-Fi for different user types, and for understanding the types of services currently being provided by municipal organizations, commercial, and community internet service providers. It is noted that individuals can be located in more than one quadrant at different times, and they may move from one quadrant to another as their personal circumstances change.

The lower left quadrant encompasses people who are outside the market for 'standard' internet service providers, but require a primary access point. This quadrant is populated by individuals who choose not to pay commercial internet rates, and by those who are on the 'wrong' side of the digital divide, i.e. those who are unable to pay for their internet connectivity. Service provision to this quadrant is typically framed in terms of 'digital inclusion,' and may include explicit strategies to develop digital literacy among users, and to assist users in obtaining the hardware and software needed to connect to the internet from their homes or other fixed access points. The upper left quadrant depicts a traditional 'internet service provider' approach to connectivity, where users buy access from an internet service provider, and the service is delivered to a fixed location. In the upper right quadrant, nomadic internet users like business travellers look for connectivity outside their homes or offices. These users are highly reliant upon connectivity, and are willing to pay a service provider for roaming access. In the bottom right quadrant, affordable internet service is provided in public spaces. Unlike fee-based service, the affordable services generally do not cover large geographic areas, thus that there is no universal roaming service available on a non-commercial basis. Instead, there is hit and miss connectivity, as individuals locate community network providers in their travels. The FON network represents an effort to provide widely available free connectivity, but to access the service for free, potential users must already have their own primary connectivity that they make available to other 'Foneros.' The discussion here excludes open hotspots that users may find in any urban location (Powell, Wong, & Clement, 2006). Such unsecured personal networks are not part of any organized effort to provide internet connectivity to individuals as they move around various spaces. There is no guarantee of availability of open personal networks, whereas there is an expectation that service will be available at 'organized' free hotspots. The lower right quadrant can be characterized as providing 'roaming affordable access.'

Although Wi-Fi networks are currently serving users in all four quadrants, it is not clear that Wi-Fi is the most appropriate way of meeting the needs of each of these diverse groups of users. As noted earlier, good infrastructure needs to be usable, reliable, of high quality, and it needs to provide service where users want service. To assess the extent to which Wi-Fi can satisfy user needs in these regards in each context of use, consideration will be given to location of use, mobility, network coverage, network speed and reliability, applications for use on the network, and available access devices. The assessment below is based on the author's experiences in using Wi-Fi networks in various locations around the world, on information provided by industry observers in their blogs (e.g. muniwireless.com, Wi-Fi Net News), on information gained at industry and academic conferences and on academic literature on infrastructure deployments. Each municipal wireless network offers a somewhat different set of affordances to its users, but the assessment below attempts to capture issues that are common within specific contexts of use.

## Assessing Public Wireless Broadband Infrastructures

This section offers an assessment of current municipal wireless networks in an effort to explore the extent to which such deployments provide broadband that is in the public interest. It considers the affordances of networks as they are currently provisioned, and also identifies alternative infrastructure choices that are available in some contexts. The diverse needs of multiple stakeholders are considered through the discussion of contexts of use.

*Location of Use*

As long as there have been mobile computers, there has been a romantic notion that taking advantage of mobility by using computers outside is a good idea. For years, advertisements have shown seemingly content workers sitting on the beach with sand in their toes and laptops on their laps, presumably hard at work, while family members frolic nearby. As broadband becomes available in outdoor spaces (a central offering of many public broadband networks), there is a widely held assumption that outdoor connectivity is useful. Indeed, Toronto Hydro Telecom recently commissioned a study showing that Canadian workers feel they do not spend enough time outdoors, prompting the CEO to call for a 'work outside' day (Toronto Hydro Telecom, 2007).

Despite the persistence of the idea of working outside, experiences using wireless internet connections outdoors reinforce the impracticality of this proposition. It is not impossible to use wireless internet connections outside, but there are many issues that make it difficult. Local weather conditions (rain, snow, cold temperatures) often mean that it is unpleasant to sit outdoors to access the internet. In bright sunshine, it is difficult to view the screen on a laptop. The availability and/or strength of wireless internet connections can vary throughout the year, as changes in foliage impact the wireless signal (wet leaves pose a particular problem for signal transmission). Sitting in the shade makes it easier to see the laptop screen, but harder to pick up a wireless signal. In addition, the ergonomics of outdoor wireless use are poor. Outdoor seating is not explicitly designed for laptop users, and it is rare to find outdoor electrical outlets to provide power for mobile devices (the 'Banc Wi-Fi' - wireless benches - in Paris are an exception, Grimaldi & Deleurence, 2007). Forrester Research reports that only 5% of people who have used Wi-Fi have used it outdoors (Cohen, 2007).

Visits to many areas served by outdoor internet connections show very limited usage of outdoor Wi-Fi networks. Even in Google's 'home town' of Mountain View, California, Google's free outdoor Wi-Fi network appears to have few users[3]. Elsewhere in the Silicon Valley the story is the same. Although the climate favours outdoor usage, it is the indoor hotspots that attract users. Many laptop users are found in cafés and libraries with free Wi-Fi access provided by the venue, but Wi-Fi provided by municipal projects often does not reach into buildings (Grover & Kharif, 2007). Even though the MetroFi networks available in California's Silicon Valley serve outdoor locations, it appears that the strategy now is to encourage potential users to purchase adapters (also known as boosters or wireless modems) so that they can use the Wi-Fi signals within their homes (www.metrofi.com/ faq_adapter.html). Earthlink also advises that a "Wi-Fi modem [is] recommended for in-home use" (www.earthlink.net/Wi-Fi) for its services in cities like Philadelphia, Corpus Christi, and Anaheim.

One place where outdoor Wi-Fi is popular is Bryant Park, New York. Although winter weather makes year round use challenging, summer visitors to this park can see many laptop users. It is somewhat difficult to know whether people are connected to the internet at any given time, but observed usage includes video chat using webcams, internet browsing and email. It appears that the Wi-Fi connectivity is reliable, and the shady location with many tables and chairs makes it possible for people to sit reasonably comfortably while connected to the internet. It is estimated that 150 people per day use the network (Carty, 2007). While outdoor Wi-Fi in Bryant Park is more heavily used than networks elsewhere, it is still noted that the overall usage is very low. As a point of comparison, a new bicycle rental service in Paris has more than 60,000 riders per day (Agence France-Presse, 2007). Bicycles and Wi-Fi are not the same, but as examples of public infrastructure, it seems that bicycles are more useful to a much wider group of people than is public Wi-Fi.

In summary, it is noted that one of the common aspects of public wireless network deployments, providing service to outdoor areas, does not appear to result in widespread outdoor usage. It is easy to set up wireless networks to serve outdoor areas, but because of the complexities of geography (e.g. the need for line of sight access to radios to pick up the signal),

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[3] This statement is based on the author's observations while visiting Mountain View in March 2007. Google's own network statistics do show that 95% of their mesh routers are in use on an average day, transferring 300 gigabytes of data (Ingersoll, Sacca, & Alder, 2007). This may seem like a large amount of data, but in a community of 25,000 homes (populated by technically savvy people), this data transfer rate is very small. A handful of users downloading movies and music could easily transfer 300 Gb of data on their own. What is of interest however is that users are using more than 100 different Wi-Fi devices to access the network.

combined with the impracticalities of actually working outside, the current value of outdoor wireless networks is questioned. As will be discussed further below, outdoor wireless would be more valuable if devices provided more convenient means of using the signal, and if coverage were more ubiquitous and supported true mobility. At the moment however, service is patchy, and signals tend to be unreliable. Despite being a key element in many public wireless deployments, there is little evidence that outdoor Wi-Fi is being used for public internet access.

In practice, what appears to be happening is that the outdoor wireless deployments are being used to provide connectivity to people in their homes. MetroFi's free, ad-supported service is available to anyone within the coverage area, and can be accessed using a wireless modem. Earthlink also provides a free service (called Feather Nest) in some cities. Both providers also offer paid services that compete with other internet service providers, generally offering lower speeds than available with DSL or cable connections. Earthlink offers low introductory prices, promoting the service as "a great way to get high-speed Internet at home for roughly the price of dial-up service" (www.earthlink.net/Wi-Fi/learnmore). But the regular prices for Wi-Fi-based high speed internet are comparable with the lowest rates for 'basic' or 'lite' DSL and cable internet services, both of which provide much more reliable connectivity, without the 'risks' of Wi-Fi (Earthlink provides potential customers with a list of 'service availability risk factors'). It is suggested that one of the benefits of using Wi-Fi for home internet access is that as part of their subscriptions users have access to the service while moving around their city. But this option is also offered by some DSL and cable providers (through deals with hotspot providers), and as noted above, outdoor connectivity provides limited value to most users.

Linking the discussion above to the contexts of wireless internet usage, it is noted that for those seeking a provider for their primary internet service, public wireless networks offer an alternative to commercial internet service providers. When used with a wireless modem to increase the signal strength for indoor use, the public wireless network service may be cheaper than DSL or cable internet connections, but technically it is an inferior alternative. Those who are able to pay are highly unlikely to subscribe to public Wi-Fi as their primary source of internet connectivity if other options are available (although it is noted that in some cases public Wi-Fi was deployed precisely because there were no other options). Those who are unable to pay can get access to a low-cost service, but this service may not be reliable and access speeds may be slower than commercial DSL and cable options. For those who are seeking secondary internet access, the disadvantage of public wireless networks is that they are generally designed to provide service outdoors. While there are some instances where the service is available indoors, and there are some cases where outdoor access will be sufficient to complete a specific task, public wireless networks do not provide a consistently reliable service, and they are not ubiquitous. People who require reliable secondary internet access have alternatives to public wireless, including mobile devices like BlackBerries or other smart phones, mobile broadband 'modems' (e.g. EV-DO, HSDPA cards) that work on the cellular data networks, commercial hotspots or internet cafés. Those unwilling to pay for mobile broadband services can use public wireless networks for their secondary internet access, but the location of service provision may not be convenient.

*Mobility*

Public wireless networks are thought to be valuable because they support mobile internet access. Setting aside the problems of location of use, it is true that wireless networking can provide connectivity in multiple locations away from a fixed internet access point. This is best described as *nomadic* access. Wi-Fi networks also provide *portable* access, supporting mobility at pedestrian speeds, allowing users to remain connected while walking around an area of connectivity (e.g. making a telephone call). True *mobile* access allows users to remain connected to a network at high speeds (e.g. while traveling in a vehicle), and is provided using the 802.16e WiMAX standard (WiMAX Forum, 2005), not Wi-Fi. There are some special deployments of mobile Wi-Fi, but these are exceptions. For example, the City of Albuquerque offers 'Rapid Ride' Wi-Fi internet service on city buses (www.cabq.gov/Wi-Fi/rapidrideWi-Fi.html).

For those using Wi-Fi as their primary means of internet connectivity, mobility is not a major concern. People who require true mobile access to the internet from all locations would be better served by technologies other than Wi-Fi. The mobile broadband services noted above support mobility, and although more expensive than public wireless networks, do provide users with reliable connectivity while in a moving vehicle, or at any indoor or outdoor location with cell phone coverage. At the moment, those wishing to have access to ubiquitous mobile internet connectivity need to be willing to pay for it.

*Network Coverage*

A second issue with mobility is related to network coverage. As users move around a geographic location, they may move beyond the range of a particular provider's network. Those using public networks for secondary access may find that network availability is problematic. This is a particular issue for people who travel. Public broadband networks cannot be relied upon as the sole source of secondary internet connectivity as there are many cities in North America without public wireless networks. Although free Wi-Fi can be found in many locations (sometimes by using an unsecured personal network), users may need to travel out of their way to locate it. The FON project (www.fon.com) is promoting secure worldwide sharing of personal internet connections, and if it were to reach critical mass, might provide a viable option for travelers looking for internet connectivity. However, basic issues regarding location of use remain important (do users sit outside Foneros' homes to access their Wi-Fi?), and given that there is no centrally managed network, the network is only as reliable as the individual nodes in it. Potential users may travel to a listed FON hotspot only to find that the network is unavailable. For those who are unwilling to pay for secondary internet access, FON is a reasonable alternative, but it is not likely to appeal to business travelers and others who need a reliable, easily accessible internet service everywhere they go. As noted previously, in order to use FON for free, an individual must be sharing his or her bandwidth through the FON network. This means that FON does not further the cause of digital inclusion, rather it extends the connectivity of those who are already connected.

Another challenge facing nomadic users is the need to manage multiple user IDs and passwords when using different public networks. For example, having an account with MetroFi in Portland, Oregon is not useful when traveling to Philadelphia or New Orleans where Earthlink provides the service. Given the lack of roaming agreements among public wireless providers, for travelers in the US it may be more expedient to use commercial Wi-Fi providers (e.g. T-Mobile, Boingo, AT&T). Their hotspots are available throughout the US (e.g. T-Mobile has hotspots in Starbucks coffee shops and Borders bookstores, AT&T hotspots can be found in McDonald's restaurants and at Barnes & Noble bookstores, coverage is also provided in many airports, hotels and other public spaces), meaning that an individual can roam around the country using a single ID and password. Unlimited usage is available for as little as $30 per month, and some commercial ISPs provide free basic Wi-Fi roaming as part of their broadband service. Unlike public wireless projects, commercial hotspots tend to provide service in indoor locations.

Considering the contexts of internet usage, network coverage is only an issue for primary internet access if the desired location for the primary service is not within a wireless coverage area. As long as connectivity is available, a user simply accesses the wireless network from his or her fixed location. Coverage is an important issue for secondary access. For the reasons described above, public wireless networks do not serve nomadic users well once they move beyond the geographic boundaries of a specific network. Commercial hotspots provide coverage in a greater range of locations, but for ubiquitous access, the technology of choice for those who can afford it is likely to be a mobile broadband solution. Internet cafés also provide connectivity for nomadic users, but as wireless networks proliferate it is expected that internet cafés will become less common.

*Network speed and reliability*

Wi-Fi networks use the IEEE 802.11 standard. Theoretically, 802.11g/n networks provide data transfer rates of up to 54 Mbps, but typical speeds are much lower. For most users, it is the speed of internet access that is relevant. MetroFi offers "up to 1 Mbps downstream and 256 Kbps upstream" (www.metrofi.com/services.html). Earthlink's basic service provides up to 1 Mbps and is symmetrical (providing the same bandwidth for downloads and uploads). Earthlink's 'Wi-Fi Extreme' service offers 'lightning fast' service, claimed to be comparable to DSL and cable speeds (in the 3 Mbps range) (www.earthlink.net/Wi-Fi). Toronto Hydro Telecom's OneZone networks claims that it provides speeds of up to 7 Mbps (www.onezone.ca/faq.html), but it is more typical for public wireless projects to offer network access speeds of about 1 to 1.5 Mbps for downloads, with upload speeds ranging from 256 Kbps to 1.5 Mbps.

There has been some testing of network speeds and the availability of connectivity at advertised locations. In Portland Oregon, Phillips and Senior (2007) found that the MetroFi network had the capacity to deliver the stated speeds, but that speed was restricted on occasion. Their testing showed that successful connections to the network could only be established 58% of the time. A report commissioned by the City of Portland notes much higher connection success rates (Uptown Services, 2007), but Senior (2007) explains that the equipment used in this report is not what is available in "common client devices," implying that ordinary users would not get the same results. In St. Cloud, Florida, where the municipality offers free Wi-Fi within the city limits, the Mayor, Donna Hart, describes the service as "very good in some areas. In some areas it's more like dialup. Of course, we never said the service was going to be high-speed Internet" (Ellison, 2007c). The City of Fredericton, in New Brunswick, offers free Wi-Fi that is described as "best effort." Although the network is usually functional, that there are no guarantees of service reliability and bandwidth is limited at certain times of day (Powell, 2007). As Fleishman (2007) notes, Wi-Fi networks were not designed for "outside in" usage, meaning that the signals do not travel well from outdoor deployment locations to indoor access devices.

Consulting firm Novarum has done extensive testing of North American wireless broadband networks, comparing cellular networks with municipal wireless initiatives (Novarum, 2007). They found that cellular networks (mobile broadband services provided by Sprint, Cingular and Verizon) provided better coverage than Wi-Fi, but that Wi-Fi services were faster. Only two municipal wireless projects (St. Cloud, FL, and Mountain View, CA) made the list of the top 10 wireless broadband services. When rating wireless broadband on performance alone, municipal wireless projects performed better, with Toronto Hydro Telecom's OneZone awarded top ranking for its high speed. (Novarum reported that the average connection in the OneZone provided 2.2 Mbps down/1.6 up, with some access points providing as much as 5 Mbps symmetrical connectivity.) Also of note is the fact that Philadelphia is well served by cellular broadband as well as by the Wireless Philadelphia project (deployed by Earthlink).

Wireless networks cannot guarantee the broadband speeds and reliability offered by commercial internet service providers. As noted elsewhere, Wi-Fi signals can be affected by the weather, whereas DSL and cable modem service is not. Wi-Fi signals are also subject to interference, and do not provide good coverage over long distances (Center for Digital Government, 2006). While it is the intention of public wireless projects to provide high quality service, the reality to date is that most public networks are not designed to provide primary access, and as such, the service quality does not always match commercial DSL and cable offerings. In some locations, DSL and cable modem service was not available when the public wireless network was first deployed (e.g. Fredericton), but in most instances, there are now commercial options available as well as the public offering.

For people looking for internet service provision to their homes or other fixed locations, the choice is between a more expensive commercial offering with higher bandwidth and greater reliability, or a less expensive (or free) public wireless offering with lower bandwidth and the likelihood of lower reliability. Commercial providers have no obligation to offer lower priced services to help bridge the digital divide, meaning that those who are unable to pay are more likely to rely upon public services. However, many DSL and cable companies offer 'lite' or 'basic' services (these are not always promoted on corporate websites) that provide always-on, faster than dialup connections at low cost, reducing the cost advantage of wireless. With a few exceptions (e.g. the robust Toronto Hydro Telecom wireless network), public wireless networks are not the best technical option for users seeking reliable primary internet access. For those using Wi-Fi to support secondary access, the issues of speed and reliability may be less important. Those who are not willing to pay for secondary internet access will find that the public Wi-Fi networks do provide better than dialup connectivity, when they are working. Those requiring a more reliable service for secondary access can pay to use other options (e.g mobile broadband, commercial hotspots, internet cafés). The speed of mobile broadband service is lower than Wi-Fi, but the service is reliable and much more widely available then public wireless (see evdomaps.com for assessment of mobile broadband availability in the US).

*Applications*

The speed and reliability of a broadband network impacts the nature of services that can be deployed on it. Quality of service (QoS) provisions allow the allocation of bandwidth for particular services, e.g. prioritization for voice or video packets (International Telecommunication Union, 2003; OECD Directorate for Science Technology and Industry, 2007a). Some municipal wireless network proposals include the deployment of QoS provisions for public internet access (e.g. Boston, Wireless Task Force, 2006). The Wireless Philadelphia business plan indicates that QoS is not important for underserved residents, although it is needed for paying residents, tourists and others (The Wireless Philadelphia Executive Committee, 2005, p. 26). The Center for Digital Government observes that "Wireless networks, particularly Wi-Fi, struggle to maintain a high quality of service (QoS) level" (Center for Digital Government, 2006, p. 17). Deployment of services using licensed spectrum makes it easier to guarantee QoS, but part of the appeal of Wi-Fi is that it can be deployed in unlicensed spectrum.

Current Wi-Fi network speeds (in the 1-2 Mbps range) support basic internet access, enabling email and web browsing. As consumers have found in their home usage however, new applications (e.g. downloading music and movies, accessing video on sites like YouTube) work more effectively with more bandwidth. In addition, the continued growth in internet content that is generated by users (OECD Directorate for Science Technology and Industry, 2007b) makes it more important for networks to provide high upstream bandwidth, to allow users to upload their content onto the web, as easily as they can download content from others. As television services continue their migration from over-the-air and analog cable to internet protocol TV (IPTV) (International Telecommunication Union, 2006), bandwidth demands will increase even further, and QoS guarantees will be essential. Upgrades will be needed to enable most existing Wi-Fi deployments to provide higher speed connectivity, leaving current users with bandwidth that is suitable for light internet usage (e.g. secondary access), but insufficient to support their primary connectivity needs. Users who have a choice of broadband providers and can afford to pay for the service will be better served by DSL or cable connections (and ultimately by fibre to the home). For users who cannot afford to pay for commercial broadband, Wi-Fi provides service that is better than dialup, but is not optimal. As noted earlier, the free or lower cost services offered as 'solutions' to the digital divide are not fast (e.g. the proposed free service in San Francisco only offers 300 Kbps download speeds) or are supported by advertising (e.g. MetroFi deployments), neither of which offers an ideal internet experience.

Voice over Internet Protocol (VoIP) telephony has long been touted as a killer application for Wi-Fi (see for example Cook, 2003; Linderholm, 2007), with the promise of free telephone calls for users with an appropriate device. As will be discussed below, devices that support Wi-Fi telephony are slow in coming to market, and in North America, cellular carriers are limiting device functionality to disable or impair the use of Wi-Fi. VoIP is an appealing application, but is difficult to use in the current North American context, especially given the lack of support for mobility and the patchy nature of network coverage.

Another problem is in using applications like email programs that require access to specific network configurations. Public wireless providers routinely block SMTP ports, making it difficult for people to use their existing email clients to send email (although they can use webmail). While this is a legitimate activity to stop spammers (and is done by commercial ISPs as well as public wireless providers), it is another example of how public wireless networks can offer suboptimal functionality to users. There are also reports of networks blocking services like BitTorrent (to better manage limited bandwidth availability), and providers are upfront about their actions in blocking 'inappropriate content' (FRIESEN, 2007).

Current wireless deployments do not support a full range of internet applications, and as such, are better suited for the provision of secondary access and light usage, than for primary access. Wi-Fi does not support applications that require high quality of service, meaning that those primary users who are unable to pay for more robust service get a "best effort" connection that may restrict their internet usage. For those seeking secondary access, but unwilling to pay, a "best effort" level of service may be acceptable.

*Access Devices*

One final issue to consider in assessing the usefulness of public wireless networks is the availability of access devices. While access devices are not provided as part of public infrastructure, their availability influences the infrastructure's usefulness. For nomadic use, the most widely used access device is a laptop computer. As discussed in the section on location of use, in many ways laptop devices are not ideal for nomadic use. They are portable (although some find the size and weight of laptops problematic, and would prefer not to carry one whenever possible), but screen visibility, battery life, and the ergonomics of use can create problems for usage away from home or office locations. To improve access to Wi-Fi from indoor locations, a wireless modem is recommended to supplement the existing wireless networking card.

The need for portable internet access devices was recognized more than a decade ago (Bartlett, 1994; Forman & Zahorjan, 1994; Gessler & Kotulla, 1995), but their development has been slow. There is much optimism around devices like Apple's iPhone (www.apple.com/iphone), and the Nokia N800 Internet tablet (www.nseries.com), both of which provide Wi-Fi connectivity. But the devices are expensive (>$500 USD), with small screens and awkward keyboards. The N800 operates only on Wi-Fi (although it can use a cell phone as a mobile data modem) and requires no service contract. It supports VoIP calls, but only using Gizmo or Skype (rather than acting as a 'normal' mobile phone that doesn't require software to make a call). The iPhone has been described as a 'brick' before it is activated. Although various hackers now claim to be able to activate the iPhone without a contract, out of the box an iPhone has no functionality at all. In order to use iPhone's Wi-Fi service (and even to use it as an iPod), a $60/month contract for mobile service is required (AT&T is the exclusive cellular provider for iPhones in the US), making 'free' Wi-Fi a rather expensive proposition. And while there are awkward work arounds to make VoIP calls, there is currently no built-in VoIP functionality.

Other VoIP phones also offer promise, but don't yet deliver full functionality. Handsets made by Skype and Vonage currently only work with networks that do not require any sort of login procedure, limiting their use on many public (and commercial) wireless networks (www.devicescape.com/pub). In the US, T-Mobile is now offering 'Hotspot @ Home,' a service in which customers buy hybrid Wi-Fi/cellular phones to use for voice calls. But the phones do not work on public wireless networks, they are limited to T-Mobile hotspots and to hotspots within customers' homes. In the UK, BT offers a similar plan, with Wi-Fi calls charged at 25% the rate of 'standard' mobile calls (i.e. Wi-Fi calls are not free), and service limited to home and BT hotspots. To date then, mobile carriers have been able to limit the functionality of Wi-Fi handsets. They are also limiting the interconnectivity between their customers and those using Wi-Fi phones, by disallowing calls to numbers provided by VoIP services, and some providers have disabled internet phone calls altogether on Wi-Fi devices (Vos, 2007b). In this environment, it is likely that the soon to be released Wi-Fi BlackBerry will also have some limitations on VoIP service.

The power of mobile operators is making the promise of Wi-Fi difficult to achieve. Limitations on devices make it difficult to use them for mobile telephony and data services on Wi-Fi networks. Vos argues that people want access to the internet everywhere (Vos, 2007a), but what many people want is free access. Wi-Fi does not fully deliver on the promise of open access to services like VoIP telephony, leaving users who are unwilling or unable to pay commercial service providers for mobile connectivity without good mobile service. Wi-Fi services are not able to meet people's expectations around freedom from mobile telephony contracts and charges. Secondary users happy with best effort services using semi-portable devices like laptops will find that they can make VoIP phone calls using Wi-Fi, but not with the ease and convenience afforded by mobile phones. For those who do choose to carry a laptop with them for secondary access, a mobile broadband card provides more reliable service over a wider coverage area than Wi-Fi, and does allow use of VoIP. The other alternative for those who are willing to pay for their secondary internet access is a mobile email device like a BlackBerry. It provides less computing functionality, but offers near ubiquitous, highly reliable connectivity.

For those using Wi-Fi as their primary source of internet access, the limitations on the mobility Wi-Fi devices are less problematic. Services like Skype and Gizmo can be used to place calls over Wi-Fi from laptops or desktops, and the lack of portability of the devices is largely irrelevant. What remains problematic though is the cost of access devices. For those with low incomes, laptops or portable devices like iPhones or internet tablets are likely out of reach.

*Summary*

There is no doubt that municipal wireless networks can be useful to citizens who require connectivity. The networks have brought service to underserved areas, offer affordable or free options for connectivity, and provide coverage in a variety of locations. But as the assessment above demonstrates, the usability of municipal wireless networks is compromised in some instances. There are often better means of connectivity available, especially to those who are willing and able to pay for service. Table 1 offers a brief description of a typical user within each context of use, and then indicates whether Wi-Fi deployments meet their needs on the criteria discussed above. Check marks indicate user needs are met well, Xs indicate poor service. A question mark indicates that service is adequate, but could be improved.

TABLE 1: SUMMARY OF AFFORDANCES OF MUNICIPAL WIRELESS NETWORKS, BY CONTEXT OF USE

| | Digital Inclusion (Affordable Access) | Internet Service Provider | Roaming Internet Service Provider | Roaming Affordable Access |
|---|---|---|---|---|
| Typical User | • 'underprivileged' e.g. impoverished, low literacy levels<br>• individual or household pays, subsidized | • 'average' consumer, household looking for an alternative to existing ISPs<br>• household pays | • knowledge worker, mobile sales representative, professional, business traveller<br>• individual or employer pays (fee is a business expense) | • freelancer, student, tourist<br>• individual pays (but reluctant to pay for service) |
| Location of Use | ✓ | ✓ | X | ? |
| Mobility | n/a | n/a | X | ? |
| Network Coverage | ✓ | ✓ | X | ? |
| Network speed and reliability | ? | X | X | ? |
| Typical Applications | ? | X | X | ? |
| Access Device(s) | ✓ | ✓ | ? | ? |

Municipal wireless networks do provide affordable connectivity to those seeking primary access at low cost. Assuming that users are able to boost the wireless signal, connectivity should be available inside their residences, allowing for a convenient location of use, and ensuring the necessary network coverage. As a primary access point, mobility is not required. While Wi-Fi can generally guarantee "better than dialup" speeds, Wi-Fi networks have not proven to be reliable. Speed is adequate for basic internet applications, but is not ideal to support many applications a typical user would wish to use at home (e.g. video uploads and downloads). Users may need assistance to acquire access devices, but Wi-Fi works well with desktop PCs or laptops. Overall, Wi-Fi provides better service than dialup internet, but efforts to extend DSL, cable or even fibre connections to those needing primary access at low cost would result in much better access speeds, greater reliability, and support for more bandwidth intensive applications (including IPTV and other entertainment services that are increasingly being delivered over the internet).

For people looking for an internet service provider to meet the connectivity needs of their household, Wi-Fi is an inferior option. Wi-Fi can provide service to households, but its unreliability and relatively slow speeds will be unacceptable to people who are willing to pay for their services. Although Wi-Fi can be cheaper, DSL and cable providers have reduced prices where Wi-Fi is available, meaning that the non-subsidized Wi-Fi price is often close to the prices charged by competitors. Muni wireless deployments were designed to encourage increased competition in infrastructure provision, but the result is that DSL and cable providers offer superior service for similar prices, making Wi-Fi an unattractive option for those who can pay. In the longer term, households will be best served with very high speed networks. Verizon already offers fibre to the home in some locations (www22.verizon.com/content/consumerfios), but fibre could also be provided by municipalities.

For mobile professionals, municipal Wi-Fi deployments are not particularly useful. Although there will be times when such individuals use these public infrastructures, they cannot be relied upon. Wi-Fi can offer faster network access speeds than mobile broadband alternatives, but problems in accessing the networks (e.g. outdoor usage is difficult, networks are not always available) mean that when connectivity is essential, alternative options must be sought. It is likely that serious 'road warriors,' those who travel extensively, will use either a laptop equipped with a mobile broadband card, or a BlackBerry-type device (or both) to ensure that they do have internet connectivity when and where they need it, to supplement the primary access they have at home and in the office. These secondary access options may be too expensive for some, but for people whose business interests rely upon connectivity, Wi-Fi does not deliver the ubiquity or guaranteed service they require.

Those who are reluctant or unable to pay for secondary internet access may be reasonably happy with Wi-Fi networks. Although the networks are difficult to use outdoors, outdoor use is not impossible. Coverage is spotty, but individuals may be able to locate access points that do meet their needs. The networks do not provide a good substitute for mobile telephony, but users with laptops can make VoIP calls at the secondary points of access. Given that the service is free, or low cost, users may be satisfied with best effort reliability, and slower network speeds. Assuming that such users do have primary access elsewhere, they can use the Wi-Fi networks for light use, and rely upon their primary point of access for higher speed, more reliable access to a full suite of applications.

The table provides a graphical representation of the extent to which municipal wireless networks do support various contexts of use, showing that wireless networks are useful in some regards, but not completely satisfactory for any group of users. In all usage contexts, there are better technical options, however, improved service comes at a cost. For those who are willing to pay, it appears that commercial service providers offer better service, if "better" is defined as being more reliable and more widely available. Those who are unable to pay the full costs of commercial internet access have access to subsidized or less expensive broadband through wireless networks. Access is certainly important, but wireless does not provide reliable service, and speeds are lower than offered by commercial providers (thus compromising usage). Furthermore, wireless networks are frequently deployed where there is already reliable, high quality infrastructure in place.

## Discussion

The analysis above shows that municipal wireless networks are not proving to be widely useful for citizens. There is no doubt that people like to get free internet access, but the reality of municipal wireless deployments is such that free access is often in inconvenient places (e.g. outdoor locations), or there are hidden costs to the service (e.g. purchase of wireless modem to boost signal, slower connectivity, advertisements interrupting internet browsing). Wireless networks were not designed to provide "outside in" service, but are being used as a means to extend broadband connectivity into citizens' homes. It is likely however, that people who are using municipal wireless networks to provide primary internet access are those who cannot afford commercial internet service provision. Although some networks were deployed to provide connectivity to un- or underserved areas, mobile broadband, DSL and cable are becoming more widely available, and there are fewer areas within the US where broadband service is not available. Given faster access speeds and more reliable connectivity, those who have access to commercial broadband services and can afford to purchase them will likely do so. The analysis above leads to the conclusion that people requiring primary internet access would be better served by fibre connections to their homes (regardless of their ability to pay), that those willing to pay for roaming internet service are currently better served by cellular infrastructure than Wi-Fi, and that Wi-Fi is an acceptable, but not ideal option for those looking for secondary internet access for free or at low cost.

Those most likely to use municipal wireless broadband networks are the disadvantaged, and those who already have good access elsewhere. There is no doubt that deployments of broadband infrastructure in the public interest should serve the disadvantaged, and continue to foster digital inclusion. However, without significant numbers of paying subscribers to deliver revenue to providers, the business models that allowed for free or subsidized access as part of digital inclusion strategies are not sustainable. In addition, advertising revenues are also likely to be lower than forecast, as fewer people use municipal wireless networks. As noted earlier, people will always gravitate to free internet access, but is it possible to deliver broadband infrastructure that is in the public interest and is free? There are substantial expenses involved in developing broadband infrastructures, thus it is important that the infrastructures meet the needs of potential users. Affordability is an important component of public infrastructure, but it is not the only component.

It appears that municipal wireless deployments are at a crossroads. As of late August, 2007, Earthlink looks to be retreating from the municipal wireless market (Panettieri, 2007), Chicago is delaying its network development (Ellison, 2007a), and the proposed development for San Francisco remains stalled (Letzing, 2007). Analysts are suggesting that the value in municipal wireless deployments is in government applications, not in the provision of infrastructure that offers connectivity to citizens (Waxenberg, 2007). Muniwireless.com, which has been relentless in its promotion of municipal wireless networks is now suggesting that plans to provide DSL service to citizens (e.g. the ConnectKentucky initiative) will not result in sufficient speed or reliability for the longer term connectivity needs of citizens (Ellison, 2007b). Calls for a US national broadband strategy argue that current broadband speeds are much too low (Communications Workers of America, 2007). Given that DSL connectivity is faster and more reliable than most municipal Wi-Fi networks, it would seem that the industry is beginning to publicly acknowledge that wireless technology deployments, that seemed like a good idea several years ago, are no longer the best way of providing infrastructure to citizens. Anthony Townsend, an early advocate of community wireless networks (Schmidt & Townsend, 2003) goes as far as to call Wi-Fi networks "the monorails of this decade: the wrong technology, totally overpromised and completely undelivered" (Jesdanun, 2007).

There is a danger that public involvement in the provision of internet access infrastructures will diminish as the private sector continues to provide higher quality, more reliable connectivity than has been provided through most public sector initiatives. But there are shortcomings to the private sector's approach to network provision, and it is important that development of good public infrastructure remain on the public agenda. This paper addressed elements of infrastructure development that enable basic connectivity, but as the Community Wireless Infrastructure Research Project has shown elsewhere (Middleton et al., 2006; Potter & Clement, 2007), there is more to the development of good broadband infrastructure than reliability, and quality of service. The private sector may do a good job of providing reliable infrastructure with reasonable quality of service guarantees, but it has no incentive to provide universal, ubiquitous coverage if it cannot generate sufficient returns doing so. A discussion of network neutrality is beyond the scope of this paper, but it is important that public infrastructure be secure, privacy enabling, open, neutral and non-discriminatory. It is also noted that there are cost advantages to citizens when broadband is provisioned as a public service, rather than as a private good (Clement, Longford, & McEwen, 2006). The business pressures of providing connectivity do not ensure that networks will be built to these standards, so it is important that alternative approaches to infrastructure development remain as a central concern for municipal governments and for local, state and national policy makers.

What options are there to advance the goals of achieving ubiquitous broadband connectivity that meets the criteria of good public infrastructure?

- One approach is to continue to work within the current frame of municipal provision of wireless infrastructures. Given the existing investment in infrastructure in many locations, it is important to consider how the affordances of such infrastructure can be improved. Issues of speed and reliability can be addressed with a redesign of networks to bring the fibre backbone closer to the end user. WiMAX technology is quite different from Wi-Fi, and the general practice is to deploy WiMAX in licensed bands of spectrum.

Most municipalities do not currently have access to licensed spectrum, but if it were possible to deploy WiMAX, it would mitigate issues of mobility, coverage areas, speed and reliability. WiMAX is still likely a transitional technology, but might prove to be viable to enshrine the principles of good infrastructure into broadband delivery in the short term.

- Another approach is to encourage more cooperation between the developers of community wireless networks and municipal services. Although community wireless developers may resist involvement with government projects, there is a case to be made that community wireless networks offer affordances of good public infrastructure. Combined with the resources of municipal governments they could potentially extend their networks to reach a wider group of citizens. But even with resources to do so, community members would need to be motivated to develop larger scale infrastructures. Municipalities do not necessarily need to take the lead on communications technology infrastructure development, but they are well-positioned to do so given their role as providers of other public infrastructures.
- Recognizing that fibre to the home or high speed cable networks will provide scalable, high speed, high connectivity service, it is sensible to take advantage of open access provisions. Rather than duplicating existing infrastructure by building municipally owned infrastructure, open access provisions (local loop unbundling) require incumbents to open their networks to competitors, who are then allowed to use and resell bandwidth on the network (Braverman & Frappier, 2003; OECD Directorate for Science Technology and Industry, 2003). The cooperative wholesale approach adopted by some municipal networks is also worth pursuing, as it acts in a similar way to share infrastructure among multiple users.
- Given the proliferation of access technologies, open access provisions can be extended to spectrum allocation (a point that Google is pushing as the FCC develops the rules for its next spectrum auction, Albanesius, 2007), allowing for the principals of good public infrastructure to be incorporated into the development of new wireless services.
- Municipal networks have tended to use Wi-Fi technologies, rather than 3G cellular ones. But cellular networks already have near ubiquitous coverage across the US (and throughout the developed world), suggesting that efforts to get access to these networks, or to the network infrastructure (e.g. cellular towers) could also bear fruit.

- A different approach would be for municipalities to abandon the provisioning of network infrastructure, and focus their efforts instead on encouraging commercial providers to adopt the practices and policies needed to ensure their networks provide broadband connectivity that is in the public interest. This approach could also proceed as a citizen led initiative, rather than as an action of a municipal or other government.

## Conclusion

This paper has shown 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 infrastructures. The paper also recognizes that municipal broadband networks do not operate in a vacuum, instead they operate in a competitive environment where users can get connectivity from commercial or community sources, in addition to the services offered by the local municipal network.

Regardless of the approach(es) taken to further develop broadband infrastructures that are in the public interest, it is important to promote and maintain the principles of good public infrastructure development. It is argued that there is a real danger that the objectives of developing strong public infrastructures will be lost as municipalities step back from their involvement in wireless networking projects. But municipalities are still well positioned to develop communication infrastructures, and could continue to leverage their existing assets (including fibre networks) to provide high quality infrastructure for local citizens. It is also noted that municipalities and/or community groups can work to influence commercial providers to incorporate affordances of good infrastructure into existing deployments. Municipal wireless networks may not solve the problems of delivering reliable infrastructure to citizens, but the underlying objectives should not be abandoned.

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