wireless IN BOSTON

Wireless Task Force Report

Broadband for Boston

Presented to:

The Honorable Thomas M. Menino

Mayor of Boston

Presented by:

Wireless Task Force

July 31, 2006

Preface

The Task Force emphasizes that the ideas and proposals outlined in this Report constitute the recommendations of the Task Force and are a reflection of members' hard work, thorough analysis, insightful deliberation and commitment to the public good. They do not, however, represent legal advice nor City of Boston policy, practice, program or protocol.

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- **Table of Contents:**

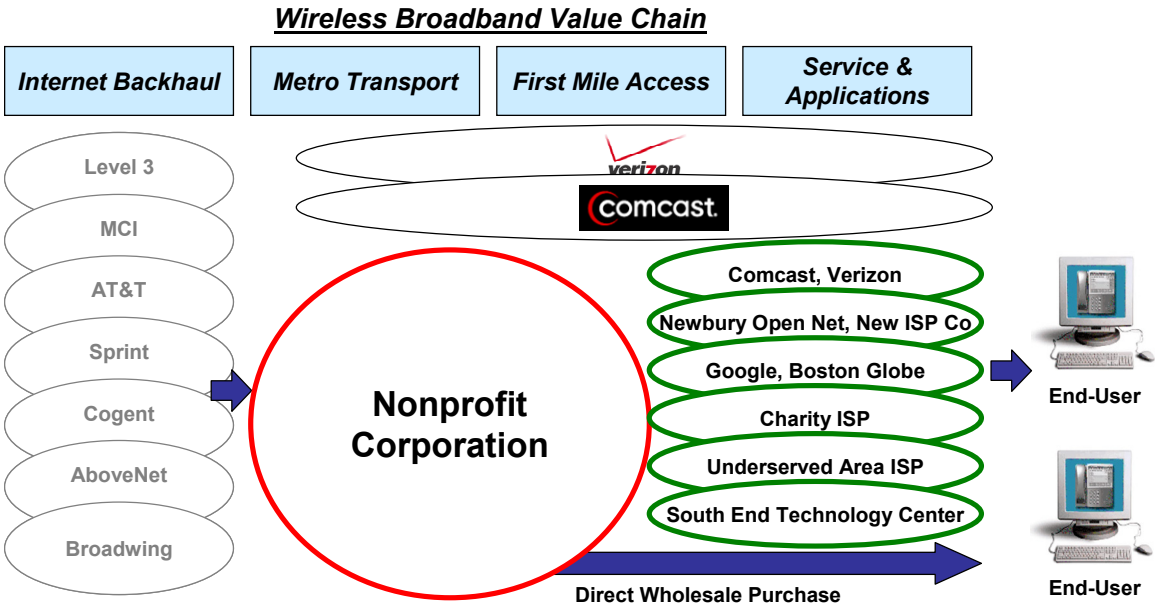
I. Executive Summary

Recommendation

The Task Force recommends that the City facilitate the introduction of a revolutionary carrier-neutral, open access, and wholesale-only business model to the wireless broadband value chain. As illustrated in the figure below, the City should identify a nonprofit corporation to own and operate a metro transport and wireless first mile access network in a manner consistent with the City of Boston's goals:

- Promoting economic development and stimulating innovation
- Ameliorating the digital divide
- Improving the quality and efficiency of City services

This structure will drastically lower the barriers to entry in the wireless broadband market, which historically has required large capital investments by every Service and Applications provider. By allowing existing ISPs, entrepreneurs, and community groups to access a city-wide network in creative ways, this structure will stimulate the creation of innovative fixed and mobile applications, driving increases in both broadband adoption and civic engagement within local communities.



To advance the deployment of the network, the City should bring together, with the nonprofit, potential partners who have a vested interest in the widespread deployment and adoption of an open wireless network, including (but not limited to)

- Application Providers – Yahoo, Google, Microsoft, Apple, AOL
- ISPs – AOL, Earthlink, Verizon, Comcast, Galaxy
- Retailers – BestBuy, Circuit City, Staples, Radio Shack

- Chipset Vendors – Intel, AMD, Atheros, TI
- Content Producers – Globe, Herald, CNN, Disney, NBC
- Equipment Makers – Cisco, D-Link, BelAir, Tropos, Sky Pilot
- PC & Server Makers – HP, Dell, Sun
- Game Console Makers – Sony, Nintendo, Microsoft
- Systems Integrators – IBM, HP
- WiFi Enable Device Manufacturers – Nokia
- Open Source Software Developers

This will create a new ecosystem for broadband and wireless communications that will leverage Boston's strong venture capital and educational resources.

The Massachusetts Technology Collaborative will also be a partner to this effort in Boston. In addition, this group's mission is to serve as a catalyst to replicate the success of Boston's approach throughout the Commonwealth.

The combined efforts of the Task Force members resulted in a recommended business and technical model that will use wireless to provide universal, low cost broadband access with the maximum possible competition in order to accomplish the City's three goals. The members of the Task Force contributed a significant amount of time to this effort which was instrumental to its success. The hiring of an experienced telecommunications consultant company, Altman Vilandrie, was key to the Task Force's success.

Necessary Network Characteristics

In order to address the City's goals, broadband access at adequate speeds must be affordable. The Task Force believes that prices for broadband – at $35 - $42 per month on average today – can be reduced to $15 for the same quality services. Broadband is a highly elastic good, and at these prices, its adoption within the City of Boston should increase dramatically.

There is little competition in the Internet access value chain. The Task Force recommends facilitating the creation of a network that opens a portion of this value chain up to greater competition, by making it economically feasible for anyone, including large national Internet Service Providers (ISPs), local companies, and nonprofits, to become a broadband provider, and sell applications and services to end-users.

Additionally, there are literally thousands of niche applications that local entrepreneurs and businesses will create if there is ubiquitous, open access to a wireless network. It is critical to understand that some of the most innovative applications may, in fact, be sensor or telemetry applications which typically require very little bandwidth. Therefore, the network should be open to the development of customized service plans, so that all entrepreneurs and businesses can choose broadband speeds that best fit their target application. Similar to the way the Internet enabled thousands of applications tethered to

the network, so too will this wireless network facilitate the creation of thousands of mobile applications.

Given the proliferation of end-user Wi-Fi enabled devices, the Task Force recommends that the First Mile Access portion of the network operate in the 2.4 GHz spectrum. This structure will reduce barriers for end-user adoption. Overtime, however, the network may evolve to support WiMAX or other standard-based interfaces.

The network must not discriminate between established applications and services, and the newer ones that local innovators will develop. Furthermore, because the Task Force wants to make this network as accessible as possible for all end-users' applications, it is extremely important that the network be standards-based with easily accessible technical interfaces – so that it is interoperable with all devices.

The City of Boston should not underestimate the importance of true ubiquity for the network. Not only must it be available to all residents regardless of income in the interest of ameliorating the digital divide, it should also be available to end-users in every City neighborhood – from the home and office, to the park and train station – in the interest of stimulating as much adoption and as many new applications as possible.

However, due to the complexity of engineering "in building" coverage, the Task Force recommends that the network be designed to bring the wireless signal up to building exterior walls. The end-user would then be responsible for propagating the signal inside, simply by purchasing an inexpensive in-home device. Some ISPs may choose to offer this device for free and assist those who need help.

The network will reduce the cost of existing city services, and make the deployment of new services more economical. This will improve the quality of life for residents, businesses, commuters, and visitors.

Business Model for Deploying the Network

The Task Force recommends that the city identify a nonprofit corporation to manage the construction and operation of the wireless network. The nonprofit will sell wholesale services to retail broadband providers, entrepreneurs, researchers, and anyone else who desires them. ISPs can use any business model they desire to sell broadband services and other applications that are far more innovative, specialized and localized.

The nonprofit corporation does not need to be responsible for the actual maintenance and operation of the network, which can be undertaken by a private partner.

The City should grant the nonprofit access to the necessary infrastructure to build the network – such as light-poles, traffic lights, and city buildings. However, since no City of Boston money will be used to deploy the network, the nonprofit must raise between $16M-$20M to fund its construction and initial operations. The technology available

makes possible a very inexpensive network relative to existing communications networks.

The City of Boston should be able to purchase network services. This solution will help the City to afford more wireless applications, while also increasing the model's sustainability. The Task Force believes that the City should pay for this wholesale access like any customer in order to avoid cross-subsidization problems seen in other cities, where residents are forced to pay for the City's use of the network.

Should the nonprofit succeed in generating revenues beyond those needed to cover its costs, a portion of theses excess revenues should be re-invested in the local community, with first priority going to digital divide programs, which will continue to focus on areas such as training, that are critical to reducing the digital divide even after lower cost access has been made available.

At the suggestion of community groups, the implementation of the network will not replace the many successful programs already addressing theses issues in Boston, but rather complement them, by giving them access to low-cost, wholesale bandwidth.

Risks

The Task Force acknowledges that its recommendation carries some risk.

The foremost risk is the City's ability to find a suitable nonprofit partner that has similar goals, the necessary expertise, and required funds to undertake this project. As has been shown, the cost of setting up the network is substancial. To help reduce this risk, the City should act as a broker between existing nonprofits, potential private partners, and philanthropic contributors.

There is also risk associated with the nonprofit's technical expertise and execution. The nonprofit must hire industry-knowledgeable management to execute the proposed business model. Deploying the network requires considerable knowledge of wireless technology, its marketplace, and politics. The City can provide assistance with the identification and recruitment of management talent.

Another risk involves the technology itself. The City of Boston cannot look to any major fully-deployed U.S. city-wide network because none yet exists. In addition, the technology is rapidly evolving, and long-term considerations can be difficult to predict. It is critical that the nonprofit, with the City's help, has a technology and spectrum evolution plan.

Lastly, existing competitors are likely to respond both operationally and legally. These existing Internet providers, landline and cellular alike, may react to the deployment of this network by innovating their technology, reducing prices, and introducing more flexible rate plans. In this case, the goals of the City of Boston will nonetheless be met.

The Task Force is concerned that parties may attempt litigation as a way to impede the development of this initiative. The City must prepare for this potentially unfortunate outcome.

Next Steps

It is critical that the city maintain the momentum of this project in the coming months. The Task Force recommends that the City appoint Bill Oates, the new CIO, and Steve Gag, the Mayor's Technology Advisor, to manage the creation of a committee that is charged with the identification of the nonprofit partner, the establishment of governance, and the formulation of a method for granting use of City assets to the nonprofit.

II. Introduction

Broadband powers today's economy, and affordable access is a critical component of participation in society and the economy. The cost of technology is falling, but universal access has become increasingly constrained by the recurring monthly costs that exist in the market today. The combination of universal access, high speed, and open interface standards presents the City with enormous possibilities. As FCC Commissioner Michael J. Copps has observed:

> Providing meaningful access to advanced telecommunications for all our citizens may also spell the difference between stagnation and economic revitalization. One study estimates that universal broadband access could add half a trillion dollars to the U.S. economy every year. Even that may be conservative. Broadband is already becoming key to our nation's systems of education and commerce and jobs and, therefore, key to America's future.

Mayor Thomas M. Menino understands that Boston's 600,000 residents and nearly one million daily visitors (commuters and tourists) need a ubiquitous, affordable, and open wireless broadband network. The Mayor believes this network should achieve three goals:

1. Promote Economic Development & Stimulate Innovation
2. Ameliorate the Digital Divide
3. Improve Quality and Efficiency of City Services

While no large urban city-wide Wi-Fi networks have been constructed, Boston is not alone in recognizing that it must seize this moment. Over the last two years, countless American cities have announced intentions to deploy wireless. Many of these cities are rushing into this opportunity without thoroughly understanding the implications of their decisions. Boston has chosen a more measured, research-based approach.

In February of 2006, Mayor Menino created the Wireless Task Force, which has recommended an approach for the implementation of a wireless network. This plan, as presented in this report, looks at Boston's immediate needs, and aims to serve the City in the long-term as well.

The Mayor's Wireless Task Force recommends that the City facilitate a paradigm-changing environment where many ISPs can compete to offer broadband, and entrepreneurs can access the network in creative and customizable ways. In order to achieve this change, the City of Boston should identify a nonprofit corporation willing to build and operate a wholesale wireless network, and grant it access to City infrastructure. The wholesale network will open a critical piece of the value chain, thus stimulating private investment and economic development.

The Task Force is co-chaired by Joyce Plotkin, president of the Massachusetts Technology Leadership Council, James Cash, retired professor of the Harvard Business School, and Richard Burnes, founder of the venture capital firm, Charles River Ventures. Plotkin, Cash and Burnes led 19 other highly qualified individuals from business, technology, academia, city government, and the community through a complex process of research, analysis, and deliberation to develop an extremely innovative set of recommendations.

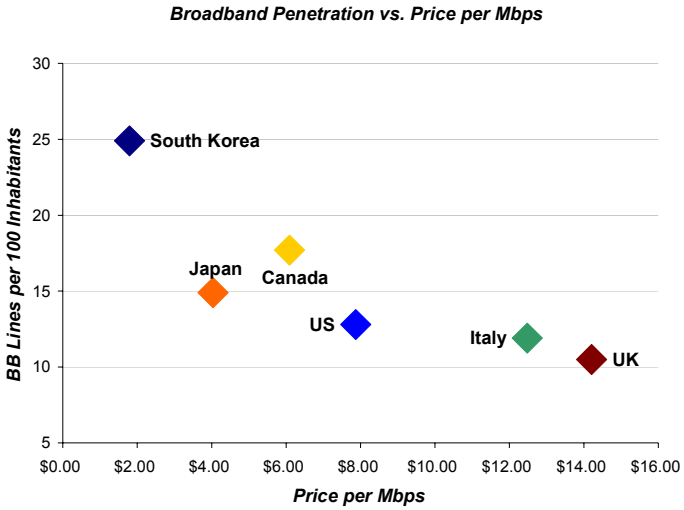
The Task Force established four sub-committees to accomplish its goal – Business Model, Technical Model, Community Process, and Infrastructure. The hiring of an experienced telecommunications consulting company, Altman Vilandrie, was critical to the Task Force's success, providing leadership, resources, expertise in wireless communications, and staffing the project on a day-to-day basis.

The combined efforts of the sub-committees resulted in a recommended business and technical model that uses wireless to provide universal, low cost broadband access with maximum possible competition in order to accomplish the City's three goals.

III. Background

- Global and US Backdrop

Today, only 39% of households in the US subscribe to broadband service, ranking the US 15th globally, falling from 4th in 2001. In countries such as Korea and Canada, private and public sector initiatives have allowed more citizens to enjoy broadband and the benefits of the information age at a fraction of the costs seen in the US. While average American monthly prices range from $35-$42, in Japan, to take another example, consumers can access an Internet connection that is more than 10 times faster than what is available in the US, for only $22 per month.



In researching its recommendations, the Task Force looked to these countries for keys to their success. It also interviewed leaders of other cities' wireless initiatives across the country.

Critical findings and resulting Task Force conclusions:

1. While the Task Force found that most cities share several of Boston's goals, stimulating innovation was rarely mentioned. Most cities largely believe that simply lowering the cost of access will be enough. The Task Force disagrees with this approach as will be shown below.

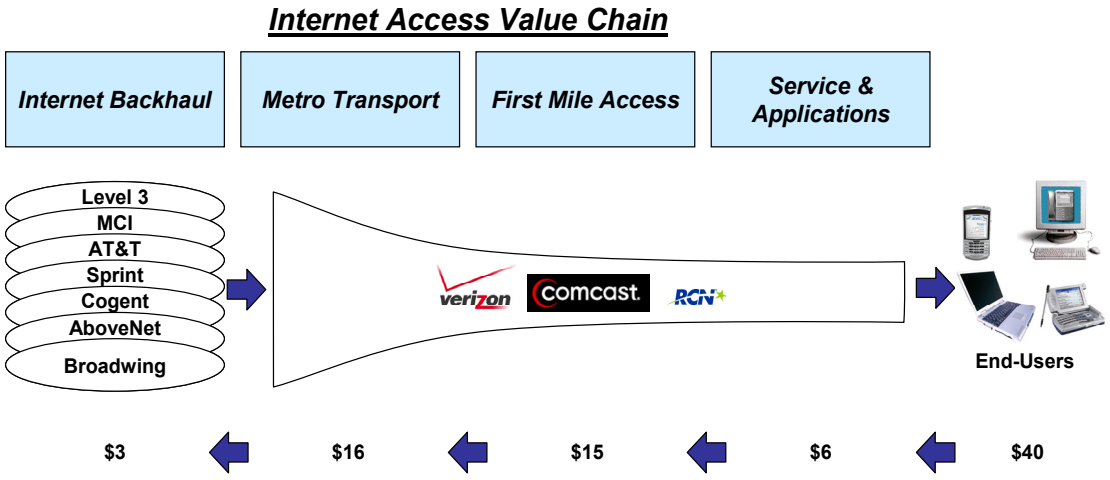
2. Another issue discovered by the Task Force is that many of the cities are planning to receive free broadband for city-government applications. This effectively creates a cross subsidization where residents, tourists, and business users are forced to pay for the city's use of the network. Although its occurrence is less frequent, this cross-subsidization phenomenon is also seen applied in digital divide areas. The Task Force feels this is not the best way to proceed in Boston.

3. In addition, the Task Force discovered that privately owned and operated networks minimally supported by the city currently are the most popular business models. Although these models seem promising in the short term, the Task Force believes that they may lead to a situation in which the goals of the City and network operator can diverge over time, and thus to increasingly difficult contract renegotiations.

4. Finally, the cities that included input from the public in their planning and implementation process were the most successful. This approach allowed them to be better informed about constituent needs and to avoid pitfalls. The Boston project incorporated community input from the beginning.

- Value Chain

The current value chain for the delivery of broadband access (bits) contains a bottleneck that reduces the opportunities for innovation, commerce, and competition.



While numerous companies offer Internet Backhaul – the physical connection to the cross-country Internet lines – at very competitive rates, only three companies compete in Boston's metro transport and first mile access portions of the value chain. Other broadband providers (ISPs) cannot economically enter the market and increase the competition for Services and Applications.

Of the $40 per month paid by consumers, these metro transport and first mile operators generally keep $37 and only $3 is actually used to purchase Internet backhaul. In other words, the majority of value captured from end-user revenue returns to the company that built the network into each home – not the source of the bandwidth.

Ironically, fixed-line broadband communications are already available to more than 90% of Boston residents. However, less than 40% of Boston households have adopted broadband, with 30% still using dial-up, and the remaining 30% going without Internet at home. There are also large descrepancies across neighborhoods. For example, the

penetration of broadband in the Back Bay is much higher than in Dorchester The opportunity for low cost, ubiquitous broadband is undeniable.

Another salient consideration is that existing access plans from cable modem, DSL, and cellular have limited opportunities for choice in customization, which does not allow entrepreneurs to purchase the appropriate bandwidth for their applications. For example, there are currently no broadband options that would economically support an electronic payment application for parking meters.

- Market and Device Evolution

A seamless network that facilitates end-user innovation will enormously enhance Boston's economic development and attractiveness. There is a tremendous opportunity for innovation in the wireless device and application marketplace. The primary factor slowing this innovation is a lack of standardized, affordable, and ubiquitous access. Some potential developments include:

  - All devices will have Internet connectivity allowing them to access real-time information and communication.
  - Wireless devices will be able to move seamlessly between cellular networks and Wi-Fi networks.
  - Peer-to-peer and trust groups will become increasingly important as consumers look for information.
  - Consumers will demand more bandwidth to support applications such as peer-to-peer, video streaming, Pod casting, and gaming.

IV. Business Model Recommendations

For well over a century, Boston has been at the forefront of technology development and invention, driven by its community of universities, corporations, and venture capital firms. Many of these inventions have resulted in radical changes to communications, including:

1876: The Telephone
1903: Marconi's First International Radio Transmission
1944: Mark I – The First Automatic Digital Computer
1972: E-Mail
1973: Ethernet
2005: The $100 Computer

Boston is an ideal place to implement cutting-edge technological change. Keeping with this theme, the Task Force has identified a highly disruptive business model that will create a unique and powerful platform for innovation. This model uses wireless to provide universal, low-cost broadband access with the maximum possible competition in order to achieve its goals of fostering economic development and innovation, reducing the digital divide, and improving the quality and efficiency of city services.

The deployment of a city-wide wireless network will create the ability for constant connectivity that is cheap and ubiquitous—at home, at work, anywhere. The defining characteristics of this new platform should be that it is affordable, secure and trusted, open to extension by end-users, and open to developers for millions of niche applications – the "long tail" – that typically aren't feasible for large carriers to develop. For example, Rhapsody has enabled its customers to purchase over 735,000 different songs, compared to only 39,000 available in WalMart.

Priority Items

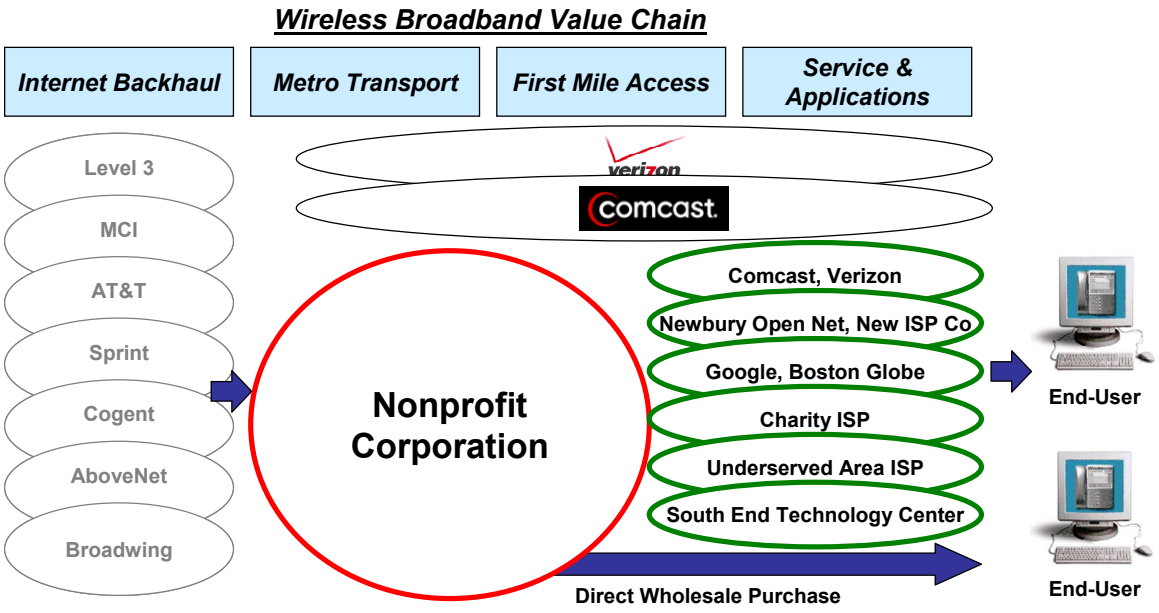
The Task Force recommends that the following items be a priority as this network is implemented:

- Ubiquitous – coverage is available everywhere
- Affordable, Scalable Pricing Models – much cheaper and more customizable than today's options
- Interoperable – access is consistent throughout the city
- Open to Extension by End-Users
- Open to Developers for Long-Tail Applications – published physical and application interface standards
- Uncensored – no site blocking
- Secure / Trusted
- Non Discrimination of Applications and Services.

In order to introduce the most competition possible, the City should implement a platform that opens the Metro Transport and First Mile Access portion of the value chain to all retail broadband providers equally on the network ("Carrier Neutral").

The Task Force recommends that the City identify and partner with a private nonprofit corporation created independently from any City agency. The City will entrust this partner with the funding, construction, and operation of a carrier neutral wireless network.

This nonprofit will sell wholesale services to ISPs and entrepreneurs, who then package these services to meet end-user needs, using any business model they desire, and providing marketing and customer care. In fact, it is the recommendation of the Task Force that the nonprofit avoid providing retail services (ISP, marketing, or customer care) directly to end-users, with the possible exception of digital divide areas as necessary and wholesale access to entrepreneurs and researchers. The ISPs can also deploy various value-added services such as security or anti-spam protection to increase their customer revenue.



Once the City has identified a nonprofit of its choosing, it should provide access to infrastructure, including city buildings, light poles, and fiber. The availability of this infrastructure, upon which radios will be installed, is critical to the success of the wireless network. This nonprofit corporation will fund the $16M-$20M construction of the network through donations, equity, and debt. However, the City may choose to help with fund raising in order to ensure the strongest possible implementation.

Given the importance of broadband to economic development and innovation, the State Legislature has created a council to develop and recommend strategies to achieve universal wireless internet, cellular, and broadband coverage expansion in every community in the Commonwealth. The Task Force believes that its recommendations can be expanded and adapted to encompass the rest of Massachusetts.

Broadband infrastructure today is just as vital for economic growth as transportation and electricity were in the past. Cities have always been in the business of facilitating the deployment of open infrastructure to advance private investment in applications and services. This recommendation is consistent with that theme.

- Governance

The relationship between the nonprofit and the City must be able to exist beyond political regimes and budgetary changes. Therefore, the nonprofit must be independently created, operated, funded, and managed. To ensure alignment of objectives, however, the Mayor of Boston and the City CIO should be able to appoint a significant number of representatives of the Board of Directors.

It is recommended that the nonprofit also have an Advisory Committee with pro rata representation of other covered cities based on population to facilitate the expansion beyond Boston's city limits, if desirable. This governance structure also has the benefit of preserving the nonprofit's flexibility to run an efficient and nimble organization.

The nonprofit should be managed by a qualified CEO and CIO. Because of their importance, the City must heavily scrutinize the leadership of potential nonprofit partners. The CEO should be entrepreneurial, and a knowledgeable, passionate supporter of the City's wireless goals. He or she should have an excellent understanding of the market for broadband and an understanding of City and wireless politics, in order to be able to interact well with a wide variety of stakeholders and potential partners. The CIO should also have an excellent understanding of the marketplace for purchase of metro network facilities. He or she should have a solid technical understanding of wireless hardware and software operations and of their implementation.

- Operations

The nonprofit does not need to manage all of the network's operations on its own. It should be allowed the flexibility to find private third-party partners to complete the physical build of the network, and, potentially, to provide monitoring and maintenance of the network.

Boston's Network Characteristics

- Scalable to the entire city
- Provides wireless services for residents, businesses, commuters, visitors, and government agencies
- Cost competitive to end users and economically viable to network owners and service providers
- Technologically advanced and cost effectively upgradeable
- Open to multiple service providers
- Able to operate certain key cutting edge applications
- No incremental cost to City of Boston to build or manage the network

Moreover, the nonprofit will not be in the business of providing retail service or customer care to end-users. As mentioned above, it will provide a carrier neutral wholesale network to sell services in bulk to ISPs (e.g. AOL, Earthlink) who will then resell to end-users. It is important to note, however, that anyone, including local companies, such as Newbury OpenNet, and nonprofits, such as the South End Technology Center, can be ISPs.

Despite being labeled a "wireless" network, a complex technical interplay of wired and wireless hardware and software will be required to provide the communications infrastructure.

The Task Forces operational recommendations address four issues that are critical to the success of this initiative:

Ubiquity: In order to build a truly ubiquitous network, the City must ensure that every outdoor location is within reach of a wireless radio. The network should be designed to bring the wireless signal to, at a minimum, the exterior walls of every building in the City. Customers, in turn, will have the option to bring the signal inside their homes or businesses by buying the proper device, today costing less than $100.

Bit Customization: The network should also be designed to have the flexibility to allow customized, affordable plans depending on the business model of the ISP, the innovative application of the entrepreneur, or individual customer need.

Open Access: The City should also require that the nonprofit corporation allow any organization or individual to apply to become a wholesale buyer on the network with minimal barriers to entry. There must, however, be a process to monitor the performance of individual ISPs to ensure compliance with laws and acceptable use practices.

Cross-Subsidization: The Task Force believes that cross-subsidization creates an unstable business model where risk is borne unequally by residents. To solve this problem, the Task Force recommends that City of Boston be able to purchase services on the network from the nonprofit at wholesale, volume discounted rates, and not receive them for free. These City purchases will increase the model's sustainability.

These simple changes will have a drastic impact on the development of new applications and innovations.

- Timing

The City should seek to begin implementing this network as soon as possible. The Task Force hopes that the nonprofit will be identified and the network deployed to the majority of residents within the next 12-18 months.

- Addressing the City's Goals

<u>Economic Development and Innovation</u>

The goal of fostering economic development and innovation is the most important for the City. Innovation and broadband are both integral parts of the City and State-wide economy. Based on a study by William Lehr, Marvin Sirbu, Carlos Osorio and Sharon Gillett, between 1998 – 2002, communities in which mass-market broadband was available by December 1999 experienced more rapid growth in employment, the number of businesses overall, and businesses in IT-intensive sectors.

With Boston's entrepreneurial spirit, constant infusion of talent from immigrants and students, and the support of local universities, the Task Force is convinced that the City is well positioned to be a leader with the deployment of a truly unique wireless network.

Just as the City has encouraged innovation in so many areas before, Boston should become the hub of wireless innovation for the world, and view this wireless network as an opportunity to leverage its scientific and technological resources to further foster this environment.

The result of the Task Force's recommendations will be:

- A proliferation of ISPs since significant financial investment in infrastructure will no longer be required, thus considerably lowering the barriers to entry.
- Greater experimentation of business models (ad-based, device-type, geographic, demographic, service).
- Increased innovation in new applications, devices, and services, particularly in the realm of peer-to-peer innovation.
- Increased attractiveness of Boston as a center for technology advancement by providing an incubator for experimental wireless municipal services.

Examples of potential new applications include:

- Handheld GPS guides for Freedom Trail walkers
- Wireless payments for on-street parking enabled by flexible low-data rate plans.
- Wi-Fi enabled cell phones, cameras, or music players that automatically synch with online storage
- Easily accessible community intranets

Digital Divide

The Wireless Task Force believes that ubiquitous, affordable broadband can serve as a catalyst for bringing extraordinary digital benefits to every resident. Access to the Internet opens doors for new job opportunities, unique applications, increased productivity, and lowered cost of living.

Yet, the need is not just for access. Boston has learned much from the digital divide-related programs it has conducted over the past 10 years. The Task Force recognizes that there are six major components of the digital divide.

1. Awareness – This prime component exists because many residents are simply not aware of the power

Internet in Public Schools

Between 1996 and 2001, Boston experienced an influx of resources to bring technology into its public schools. With leadership from Mayor Menino, the Boston School Committee, and Superintendent Thomas W. Payzant, BPS improved its student-to-computer ratio from 63:1 to 5:1 and wired all of its schools to the Internet — the first urban public school district to do so. Today, with 15,000 computers in 145 schools and most teachers trained to use technology as an instructional tool, technology is becoming a fundamental component of public education in the City of Boston.

of technology and how it can improve the lives of adults and children through better paying jobs and advanced education.

2. Motivation – Many residents who do not currently use technology lack the proper motivations to take advantage of existing programs, and learn about potential benefits. This stems from awareness.

3. Affordable Internet Access – The high cost of bandwidth is also a large reason for lack of adoption by Boston's residents.

4. Affordable Equipment – Internet access has no value without equipment, such as computers, PDAs, cell phones, personal media players (Ipod, Zune).

5. Training – Residents will need training to use computers and extract full potential of technology.

6. Technical Support – Residents must have a trusted party to whom to turn for technical assistance. The City must avoid taking a "set-up and forget" mentality that has crippled other cities' initiatives.

Many cities that produced plans for a network focused solely on the access component of the digital divide did little to address the core problem. As a result, the Task Force recommends a more comprehensive approach to addressing all six components of the digital divide.

At the suggestion of community groups, the implementation of the network will not replace the many successful programs already addressing theses issues in Boston, but rather complement them, by giving them access to low-cost, wholesale bandwidth. Examples of these groups include Technology Goes Home, dozens of technology centers, such as the Timothy Smith Centers, that provide access and training, the robust technology programming within the Boston Public Schools, and access at all public libraries.

Technology Goes Home

Mayor Menino's Boston Digital Bridge Foundation has established partnerships with Microsoft, Lexmark, HiQ Computers and Intel to expand access to hardware and increase computer literacy. Program participants can purchase a new computer and a printer for less than $15 per month through a special Bank of America no-interest, no-down payment loan program. The TGH program also provides parents and their children with 25 or more hours of basic technology training at no charge.

Driven by the Task Force's desire to stimulate economic development, the Task Force recommends that the nonprofit operator seek to provide bandwidth at the lowest economically sustainable price to the entire Boston community. This recommendation serves the two goals of increasing competition and digital inclusion. If the deployment is successful, the target end-user price should be less than $15 (as low as $7) per month at speeds of at least 1.5 Mbps, and increasing with demand and improvements to network technology. This cost will be for all users, with no cross-subsidization, which the Task Force believes to be counter-productive.

The existing digital divide-focused organizations support this structure as it removes the most difficult and expensive components of their efforts, network equipment and access. The research of the Task Force has shown that a broadband network has large capital and operational expenses, and residents would be better served if these expenses could be centralized, and the efforts of community groups could be more focused on marketing, training, and civic engagement.

Lastly, the Task Force recommends that a portion of any excess revenues, above those needed to cover the costs of running the network, be contributed by the nonprofit to existing digital divide programs within the City, such as the Boston Digital Bridge Foundation.

The following are examples of goals that the digital divide component of the Task Force's recommendation should accomplish:

- Expanding Technology Goes Home, a highly successful initiative by Mayor Menino and the Boston Digital Bridge Foundation that currently provides training and access to computer equipment to 800 families each year, to 5,000 families through the Boston Public Schools and community based organizations.

- Making Boston Public Library resources and BPS content available to every resident at home. MyBPS is a web portal that BPS teachers and administrators use to communicate and focus on teaching and learning in the classroom. Expanding this portal to include the over 100,000 members of the BPS community, including parents, teachers, community organizations, teachers and administrators will be an important outcome of the wireless initiative.

- Allowing nonprofit groups, many of which are building their own Wi-Fi networks, to focus their efforts on training and support instead of providing the Internet access.

City Services

Better and more efficient city services will enhance the quality of life of all residents, businesses, and visitors to the City of Boston. Therefore, the Task Force recommends an implementation where the network functions as an alternative provider of wireless services for the City. This would provide both an opportunity for the City to reduce the cost of existing wireless applications and to more cost effectively deploy new applications not currently in use by the City. While there are many possible applications, several examples include:

- Police cars with high bandwidth capability for real-time information such as viewing images from neighborhoods or busy intersections

- Fire trucks able to download blueprints, photos and maps of buildings while driving to an alarmed site

- Enabling a mobile workforce to increase productivity by pulling relevant information anywhere via wireless rather than having to return to the office

V. Technical Recommendations

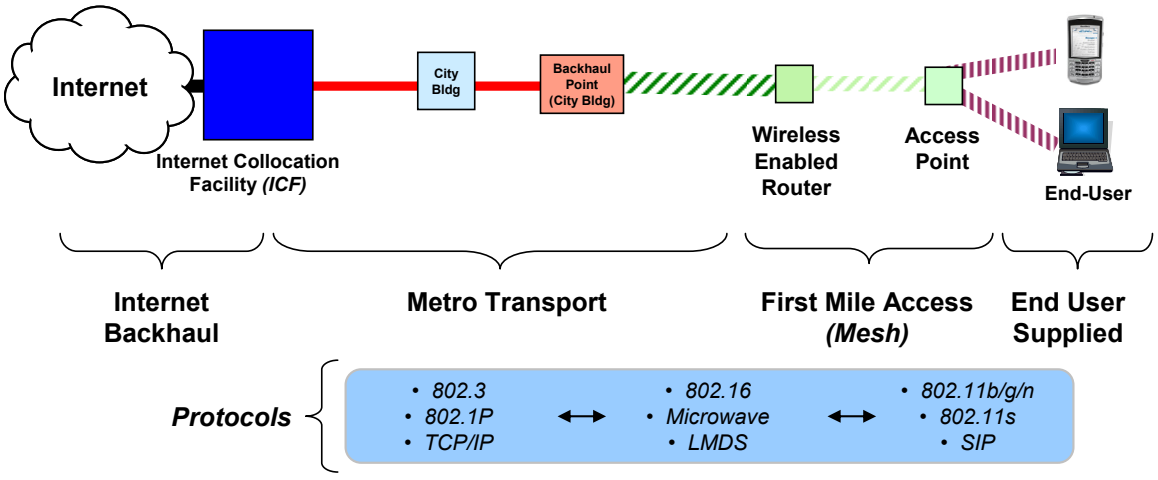
In addition to its stated goals, the Task Force took into account a number of factors in making its technical recommendations. These factors included the technology related to Wi-Fi mesh, the market for Internet access, expectations around the future of IP development, the benefits of open architectures, the Task Force's requirements for applications, and the overall network structure. These recommendations relating to the technical and functional aspects of the network deployment should serve the City well in meeting the evolving needs of citizens, visitors, businesses, and institutions, including the City itself.

- Network Structure

Consistent with the value chain above, the network can be viewed according to the following three-part diagram:

Metro Transport	***First Mile Access (Mesh)***	***Service & Applications***
▪ Transport of bits from the Internet to the neighborhood ▪ Fiber and various wireless technologies	▪ Transport of bits from the neighborhood to the end-user ▪ Mesh access points and connections to Metro Transport	▪ End-user service and support ▪ Billing and customer care ▪ VoIP, telephony, video, other

The Task Force recommends the use of multiple wireless nodes that will connect via a high-speed fiber connection to an Internet Collocation Facility (located at the Prudential or other central access point), where the network will connect to national Internet Access providers. These uplink nodes will connect using WiMAX (or other technologies) to various Wi-Fi access points that will interconnect with other Wi-Fi access points in a mesh formation.



The City should ensure that the nonprofit pursues a disaggregated approach to the construction of the network, utilizing City infrastructure, its own, and that of a partner.

- Spectrum Plan and Evolution

Given the proliferation of end-user Wi-Fi enabled devices, the Task Force recommends that the First Mile Access portion of the network operate in the 2.4Ghz spectrum. While this band is crowded and the potential for interference exists, the embedded base of end-user equipment requires its use in the near term.

Over time, however, the nonprofit and the City should work with chipset makers to identify a spectrum path that uses licensed bands but still provides affordable, standardized end-user equipment.

For the Mesh Transport portion of the network, the Task Force recommends that the nonprofit weigh the tradeoffs of using licensed spectrum compared to unlicensed 5.8GHz spectrum.

- Architecture Philosophy

The Task Force has developed a set of recommendations around the following two issues: 1) End-user technical interaction (interface) with the network, and 2) Overall network architecture. These recommendations will ensure that competition and innovation occur.

For the end-user interface, the network must be designed to bring the wireless signal to customer exterior wall; it is the customer's responsibility to propagate the signal within their residence (the "first yard"). Additionally, it is recommended that the network be designed to allow end-users to extend the network by bringing their own router / access points to act as mesh nodes. This type of mesh architecture will provide a truly unique platform for economic development, application development, and innovation.

To facilitate interoperability, the Task Force also recommends that the network operator investigate and adopt relevant mesh standards as they are made available by standards bodies, such as the IEEE. These standards will aid the evolution of peer-to-peer applications, consuming less overall bandwidth on the network. Peer-to-peer applications will also enable new forms of civic engagement, such as highly localized community portals and user groups.

For the network architecture, the Task Force has identified several key characteristics of the future network infrastructure:

- The use of standards-based protocols and hardware as defined by relevant standards bodies
    - Routing standards
    - Interface standards

- Network management standards

- Coverage to building exterior wall
  - End-users can extend network through the use of bridges and repeaters
- Support of peer to peer networking that allows for direct interconnection without having to leave the local network
- Support for a range of models, including sensors and telemetry applications – Throughput plans that can be customized according to the following criteria
  - Throughput – usage (Mb) caps, throughput (Mbps) caps, throughput (Mbps) guarantees
  - Geography – access to a specific radio or radios
  - Time of Day
- Geographic specific authentication
  - The First Mile Access portion of the network can authenticate log-on requests based on geographic location of the request
  - Enables potential ISP business model variations, such as a City-wide use plan vs. a neighborhood plan, vs. an at home plan
- Layer 2 interoperability within First Mile Access portion of the network
- Accessible interfaces at the First Mile Access and Metro Transport
- Support for community intranets
- The ability to establish roaming arrangements with other municipalities or a central clearinghouse
- Non-centralized authentication and authorization in event of disaster
- A requirement for the non biased treatment of packets from the Internet (network neutrality)
- Open access to any and all content on the Internet subject to currently accepted laws

These recommendations will facilitate the development of innovative business models and will support the business model proposed above. In this model, access to the network is open to any ISP, end-users are allowed to build and extend the network, and there does not need to be a single equipment type.

Application & Feature Support

The network must be open to all the ideas that exist today, as well as to those that might come along tomorrow. In light of that aim, the network must be a standards-based environment that supports all current IP applications. This standardized environment will facilitate the development of next generation applications.

There is one exception. Applications that are known or found to create problems or cause deficiencies will be denied.

- Mobility

Today, mobility in Wi-Fi technology is nomadic – that is, moving from place to place must be achieved through separate sessions. The fully mobile option – moving from place to place using a single session, as exists, for example, in cellular technology – is not standardized, and is not present in the mainstream marketplace.

Therefore, at this time, the Task Force recommends that the network support nomadic behavior of end-users, but not be required to support fully mobile behavior, given the complexity of these unproven systems. For example, an end-user today would not be able to move from Beacon Hill to the Financial District on a Wi-Fi enabled voice call. However, the end-user will easily be able to make that call within those neighborhoods.

VI. Implementation Recommendation

While the charge to the Task Force was to present a recommendation, the group felt it was important to begin to test the feasibility of its recommendations. As part of this feasibility assessment, the Task Force examined the possible implementation of a wireless network. While there is much work to do to make this project a reality, this effort demonstrated that the recommendation is feasible and that there are many potential partners willing to contribute resources in support of the Task Force's innovative approach. Key areas are elaborated below

- Organization Moving Forward

It is critical that the city maintain the momentum of this project in the coming months. The Task Force recommends that Bill Oates, the new CIO, and Steve Gag, the Mayor's Technology Advisor, should be the point people going forward. These two individuals should be involved in the creation and management of a committee that is charged with the identification of the nonprofit partner, the establishment of governance, and the formulation of a method for granting use of City assets to the nonprofit.

The Massachusetts Technology Collaborative will also be a very valuable partner in the implementation of the network. This agency can help in identifying talent, partnerships, and potential customers, as well as be a catalyst and enabler for deployment throughout the state.

- Legal Options

The Task Force recognizes there are legal issues that must be addressed and we recommend that the city fully investigate its options. Preliminarily, there do not seem to be any major roadblocks. The Task Force and City believe strongly that economic development and increased broadband adoption is critical to society.

Additionally, the Task Force is concerned that parties may attempt litigation as way to impede the development of this initiative. This outcome would be disappointing and would weaken Boston's position as a global leader in technology development.

- Transport and Mesh Partner Feasibility

The Task Force has identified, with the help of RCN and NSTAR, dark fiber to form the transport infrastructure, connecting City buildings in each Boston neighborhood. Using a detailed network design of the fiber ring and hub building and topographic characteristics, the Task Force optimized the deployment of buildings such that a 50 mile fiber ring can be assembled and lit with less than $2M of funding.

Vendors for mesh networking equipment, such as Motorola, Tropos, BelAir, Sky Pilot, and CUWin, also met with members of the Task Force. Nearly all expressed interest in

running pilot projects to demonstrate the performance of their equipment and several offered to donate equipment to cover underserved areas.

The Task Force also met with systems integrators for mesh build out and management, including IBM, HP, Cisco, and Siemens. These companies engaged in a laudable effort to help the Task Force develop an understanding of the costs associated with implementing and operating the proposed network. They are working on a few large municipal projects that showcase their ability to implement a city-wide wireless network in Boston. In discussions with the Task Force's members, the companies expressed interest in designing, building, operating, and maintaining the mesh network. None of the potential partners ruled out paying for some portion of the initial capital for the Mesh. While there were no formal negotiations, these potential partners were intrigued by the idea and may be willing to contribute expertise and assets to the effort.

ISPs, including EarthLink and Galaxy, will likely participate in this effort by purchasing wholesale bandwidth from the nonprofit and then reselling it to end-users.

The City should also bring together, with the nonprofit, potential partners who have a vested interest in the widespread deployment and adoption of an open wireless network. These partners would be most likely to see value in being associated with this innovative recommendation and, therefore, may be willing to contribute its success. These could include:

- Application Providers – Yahoo, Google, Microsoft, Apple, AOL
- ISPs – AOL, Earthlink, Verizon, Comcast, Galaxy
- Retailers – BestBuy, Circuit City, Staples, Radio Shack
- Chipset Vendors – Intel, AMD, Atheros, TI
- Content Producers – Globe, Herald, CNN, Disney
- Equipment Makers – Cisco, D-Link, BelAir, Tropos, Sky Pilot
- PC & Server Makers – HP, Dell, Sun
- Game Console Makers – Sony, Nintendo, Microsoft
- Systems Integrators – IBM, HP

Working together, these companies will create a new ecosystem for broadband and wireless communications that can leverage Boston's strong venture capital and educational resources.

- Funding Requirements

Based on the research of the Task Force, the network will likely require $16M-$20M of funding. $2M will be needed to fund the construction of the intra-City fiber network, $10M-$12M will be needed for the design, equipment purchase, and construction of the mesh network, and $4M will be needed to fund the ongoing operations of the network until it is cash flow positive.

At 10% penetration of households, a conservative estimate, the nonprofit can support a wholesale price of $9 per customer per month for a symmetrical 1.5 Mbps connection. Overtime, as competition increases and end-user support requirements decrease due to increased familiarity with broadband, retail prices will approach the wholesale price.

At 25% penetration, which does not seem unreasonable given the disruptive nature of the pricing model, the nonprofit can support wholesale prices of only $6 per customer per month for a 1Mbps connection. These modeling assumptions ignore the potential upside of the City or entrepreneurs purchasing services on the network.

The Timothy Smith Network has graciously agreed to fund the purchase of radios throughout the Old Roxbury neighborhood. The nonprofit should also approach other prominent Boston foundations to solicit donations or investments.

Additional fundraising opportunities include

- Co-branding the effort with an operating partner
- Selling "naming" rights to the effort
- Selling locations on the portal splash page

VII. Business Model Options

The Task Force categorized the city-wide Wi-Fi models being planned and deployed in U.S. municipalities today into five main types:

1) Community hotspot model – public/private decentralized model in which residents with broadband connections open their access points to each other's connections using a sharing model.
2) EarthLink model – private, exclusive model in which a single company builds, operates and sells retail monthly and one-time services to consumers, businesses and the city.
3) Google/MetroFi model – private, exclusive model in which a single company builds, operates and sells paid access and ad-supported free access.
4) Venue hotspots model – private, open model in which several companies build hotspot areas and sell access on a one-time or monthly basis.
5) Municipal build – public, exclusive model in which a city builds, operates and sells or gives access to its residents and visitors using taxpayer dollars.

Within these five types, there are two distinct model groupings:

For Profit - Model
"RFP" or "Franchise"

Details:
- Multi-vendor relationship with a city agency or non-profit – "Liaison"
- Private companies operate all parts of the value chain (with possible exception of digital divide)
- RFP or Franchise arrangement
- "Liaison" develops requirements, metrics, penalties

Risks:
- City or "Liaison" does not receive attractive bids
- Any vendor does not perform to requirements
- Limited innovation opportunities

Opportunities:
- Private market absorbs all market, technology, demand, and funding risks
- Low political / legal risk if vendor performs
- Faster time to market

Non Profit Model
Some Non-Profit Role in the Value Chain

Details:
- Non-profit participation in the value chain
  - Backhaul / transport at minimum
- Non-profit entity established with board and funding
- Private companies serve other value chain elements
- Non Profit conducts RFP to find private partners
- City has process to select non profit and establish asset grant

Risks:
- Non-profit must assume some market, technology, demand, and funding risks
- Significant political, legal, and execution risk
- Partner does not perform to requirements
- Non-attractive bids

Opportunities:
- Provides a unique platform for innovation
- Platform for state-wide expansion
- Universal digital divide support
- Control over execution, management, operations, partnerships, etc

The Task Force interviewed key participants of other Cities' wireless initiatives and planning across the entire country. Every city had a different primary goal and proposed solution for their requirements. Based on the Task Force's research on other cities, it found that there are five predominant goals:

- Increasing Digital Inclusion

- Stimulating Economic Development
- Increasing Competition
- Improving City Services
- Lowering the Cost of City Services

The chart below summarizes a number of wireless initiatives around the country.

City	Major Driver of Model	Assets Involved	Operating?	Business Model Selected
San Francisco	Free Access	Light Poles Buildings	No	EarthLink + Google
Philadelphia	Digital Divide			EarthLink + Open Access
Anaheim	Competition		Yes	EarthLink
Portland, OR	City Services	Light Poles Buildings	No	MetroFi + Open Access
Brookline, MA				MobilePro + Galaxy + Open
Aurora, IL				MetroFi + Open Access
Corpus Christi, TX	BB Availability	Fiber Light Poles Conduit Buildings	Yes	EarthLink + Open Access
St. Cloud, FL	Keeping $$ Local			Municipal
Chaska, MN	Competitiveness / Cost			Municipal
Nevada, MO	BB Availability			Municipal

VIII. Community Process

The Task Force set up a Community Process Sub-Committee, which was responsible for discovering public needs, desires and concerns about wireless Internet access. In conducting its research with other cities engaged in municipal wireless projects, the Task Force discovered that the most successful initiatives were those that included the public in the process.

The Task Force utilized a variety of strategies to solicit community input – holding a community-wide event, sponsoring an on-line survey, and working with and through business and community groups to make residents and workers aware of both the event and the survey.

Key Issues Identified:

The Task Force identified four issues of greatest concern to the Boston community:

1) Digital Divide
   A number of cities that have implemented municipal wireless attempted to address the digital divide by offering slower services for cheap prices. However, Boston's residents strongly feel that no residents should be penalized with slower speeds.

   Therefore, the Task Force has recommended that the baseline broadband offered by the network be at an adequate speed for all users' purposes. Although users may purchase faster speeds, the network will not offer a "slow" speed.

2) Training and Support
   Boston residents know that access to the Internet is not where the digital divide ends. They want to be sure that all users will be able to get training, technical help and customer support when necessary.

   The Task Force believes that existing foundations, organizations and city agencies that provide technology outreach can continue to fulfill this role.

   Moreover, the Task Force anticipates that ISPs will sell support to businesses and residents based on tiers. Free or affordable programs will be available for individuals who qualify, but others requiring more support will be able to purchase it.

3) Existing Community Networks
   At the Wireless Forum, many advanced community-based groups that have built their own wireless networks expressed concern about their role in a city with a ubiquitous wireless network.

The Task Force believes that the network will allow these community groups to invest their time and money in projects more helpful to their constituents than maintaining costly networks. In particular, the Task Force believes that their optimal role will be creating awareness (marketing) and providing training (support/technical knowledge) to residents, as discussed in the previous point. Community groups, which fully support these recommendations, would become a vehicle for the spread of the latest technologies.

4) Privacy & Safety

Many Boston residents are deeply concerned with privacy and safety issues, such as theft and indecency. While the Task Force is adamant about keeping the network free of censorship, it is equally adamant that ISPs and application providers adhere to all local, state, and federal law.

Its recommended solution is to change the format of the usually impossibly dense "terms of service" agreement. Instead, all vendors on the network will have to disclose fully the security issues involved with their service through an opt-in process with simple, clear and distinct items that must be accepted individually.

The May 6th Wireless Forum

On Saturday, May 6, 2006, the Wireless Task Force held an open community forum event at Wentworth Institute of Technology to engage Boston residents on the topic of wireless technology. The event was designed to educate, gain understand of the technology needs of city residents, and discover their possible uses for broadband Internet – enabled by wireless technology. Residents, community technology leaders, city officials and commercial vendors were in attendance.

Local Groups: ▪ Boston Public Library ▪ Museum of Science ▪ Boston Wireless Advocacy Group ▪ Boston Digital Bridge Foundation ▪ Boston Neighborhood Network Television **Schools:** ▪ Boston Public Schools ▪ Tech Boston ▪ John D. O'Bryant School of Math and Science **Community Groups:** ▪ Urban Edge ▪ Community Economic Development Asst Corp	**Community Groups:** ▪ Timothy Smith Network ▪ South End Technology Center @ Tent City ▪ Boston Main Streets ▪ DotWell ▪ Codman Square NDC ▪ Dimock Community Health Center ▪ Casa Esperanza, Inc. ▪ Inquilinos Boricuas en Acción ▪ Morgan Memorial ▪ Codman Sq. Health Ctr ▪ Mission Hill Neighborhood Housing Services ▪ Dorchester House ▪ Lena Park Community Development Corporation	**Community Groups:** ▪ United South End Settlements ▪ Whittier Health Center ▪ Veterans Benefits Clearinghouse ▪ Freedom House ▪ Fenway CDC ▪ Urban League ▪ Madison Park Development Corporation ▪ Roxbury Presbyterian Church ▪ Keen Development Corporation ▪ Citizens' Housing and Planning Association ▪ Nuestra Comunidad Development Corporation

The Task Force targeted the population already involved with and interested in technology (the mavens and early adopters with the biggest influence on the rest of Boston's residents). In attendance were interested residents, small business owners, community technology leaders, commercial vendors and city officials.

The Forum proved invaluable in showing the Task Force how community and small business leaders will incorporate the network into civic life. Organizations across the city's neighborhoods greeted the idea of a city-wide network with enthusiasm.

Essentially, the Forum allowed the Task Force to talk with a sample of the first wave of civic leaders, small business entrepreneurs and innovators, whose use of the network will help accomplish Boston's goals — stimulating the economy, ameliorating the digital divide, and improving city life.

Findings from the Forum

Below is a complete list of the major concerns and questions that were on the participants' minds. A number of salient issues were raised, and some promising applications of the network came to light:

	Theme	**Question/Statement**
•	Civic Engagement	There should be geographic-based portals to improve neighborhood communication.

Roslindale community leaders spoke of their plan to set up an on-line system to announce neighborhood events of all kinds — recent crime sites, construction projects, community activism events, and even street-sweeping. Their presentation generated considerable interest among other community leaders.

•	Alternative Models	Advertising-supported service?

Some entrepreneurs raised the question of whether they would be able to provide free Internet on an ad-supported service (customers would be exposed to ads while using the service).

•	Education	Nearly half of BPS' 145 schools have wireless networks.

TechBoston Academy provides a powerful example of how wireless technology can improve academic performance in public schools. The school boasts a 100% MCAS success rate. Headmaster Mary Skipper attributed this remarkable result to the school's emphasis on intelligently incorporating wireless technology into its curriculum and culture.

Other issues raised have already been discussed in this section, or elsewhere in this report:

Theme	Key Question/Statement
• Price	Will the service be more affordable than today's options?
• Speed	No "slow" connections to serve digital divide.
• Security	Will it be safe for my business?
• Content Safety	Will content be safe?
• Tech Support	Who will I call? Will it be affordable? Upgradeable?
• Existing Groups	What happens to our networks? Can we participate?
• Competition	Will the network be open or closed?
• Business Grade	Will businesses be able to pay for stronger services?
• Quality	How reliable will the network be?
• City's Role	Is it worth it for Boston to give valuable assets (buildings, light poles, etc. … on which a network can be built) over to this project?

How the Day Worked

The Forum attracted a strong showing of about 100 forward-thinking citizens, the 36 organizations listed above, and three commercial vendors. At the start of the event, these groups were able to mingle in a meet and greet over a buffet breakfast.

The event officially began with opening speeches, including a talk by Task Force co-chair Joyce Plotkin.

The Museum of Science provided a crowd-pleasing slide show, *Wireless 101*, that explained the technology behind wireless (a video is available online at http://www.cityofboston.gov/wireless/Wifi101.rm).

The main event, however, was two hours of in-depth discussion sessions led by industry and academic experts, community technology leaders and city officials. There were eight sessions in total:

1. Small Businesses
   Economic development and opportunities for SMBs and entrepreneurs
2. Wi-Fi Business Models and Technical discussion
   How are other city's using Wi-Fi and how should Boston use Wi-Fi
3. Speed and Price
   How can speed and price drive adoption and application uses?
4. Improvements to City Service
   How can city become more efficient and safe?
5. Mobility
   From cafes to parks, Wi-Fi and Internet on the move
6. Tools for Civic Engagement
   Can Wi-Fi enable better neighborhood and local government communication?
7. Wireless in the Classroom
   Impact of wireless and Internet access on schools and students

8. Wi-Fi, Wireless and Internet 101
   What is Wi-Fi and how can it enable the Internet?

Before and after the breakout sessions, community and local groups had booths set up to further their message about the importance of technology, and demonstrate its applications to residents.

The three vendors in attendance were EarthLink, Cisco Systems and BelAir Networks. These companies, which design, build or run wireless mesh networks, educated the participants about their products and services, thus providing the Forum's audience with a better idea of the wireless situation as it exists today.

Advertising for the Forum mostly took the form of direct mail to the organization's leaders, and fliers posted in their centers.

Students from TechBoston Academy served as the event's greeters, and took notes on the breakout sessions and opening speeches.

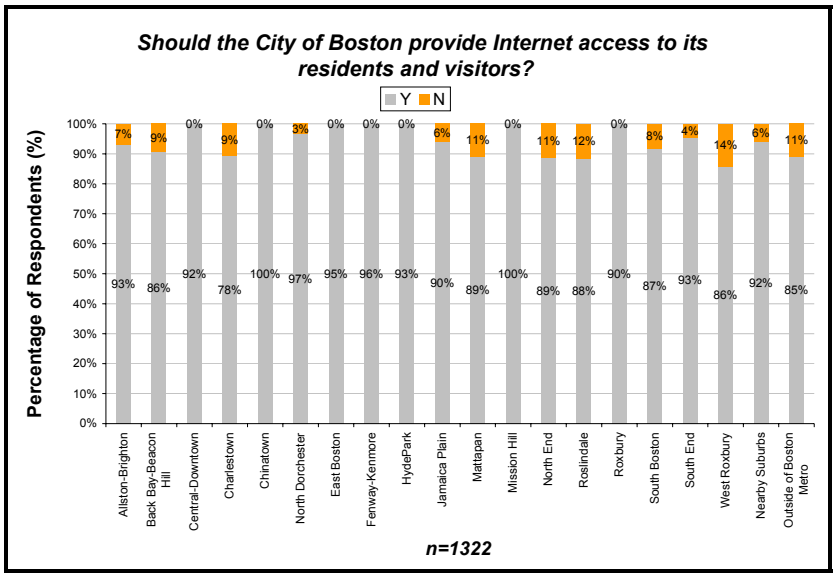
Wireless Survey

While the May 6th Wireless Forum focused on gathering information mostly from small business entrepreneurs and civic leaders, the wireless survey was aimed at the average Boston Internet user – whether resident, commuter or visitor.

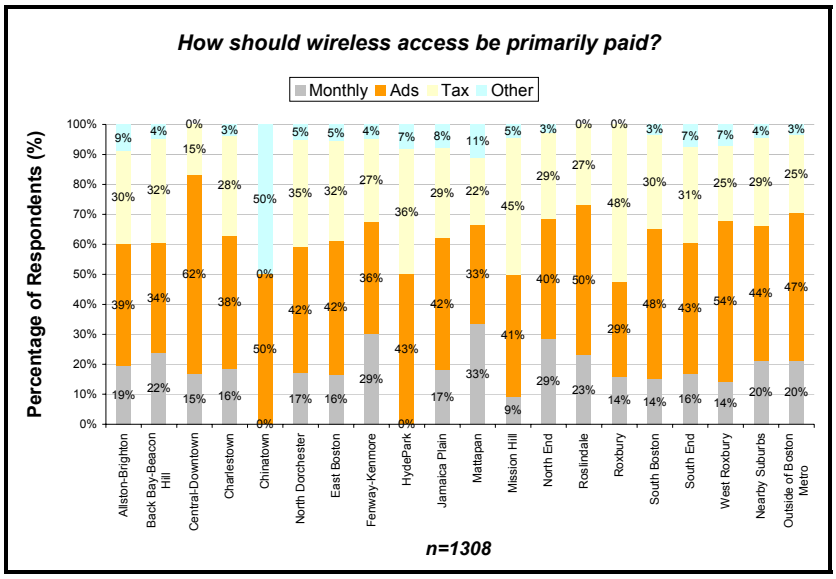
To reach this large audience, the Wireless Task Force launched a web-based survey. To advertise, the Task Force distributed 10,000 cards at heavily-trafficked intersections throughout the city, such as train and bus stations, public libraries, Fenway Park and the Boston Common. In addition, the survey was placed for one day on Boston.com's website, which 500,000 unique visitors surf each day.

Results from the Survey

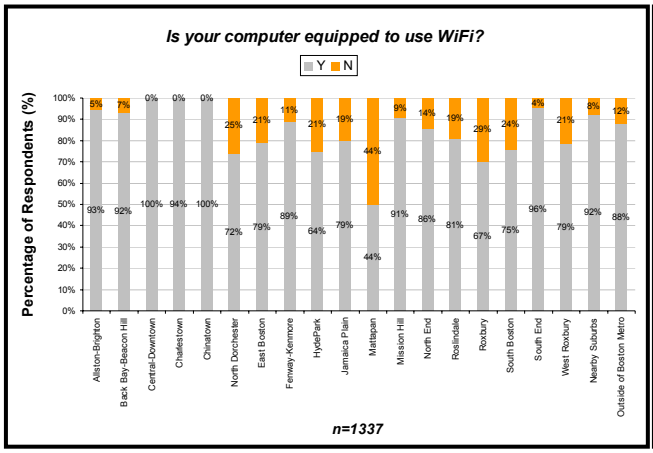
The survey attracted nearly 1,500 responses. While many of these were early adopters, the Task Force learned from this survey that the Boston metro area's Internet public is very enthusiastic about ubiquitous Wi-Fi. Although it expected this result, the degree of the enthusiasm was overwhelming.

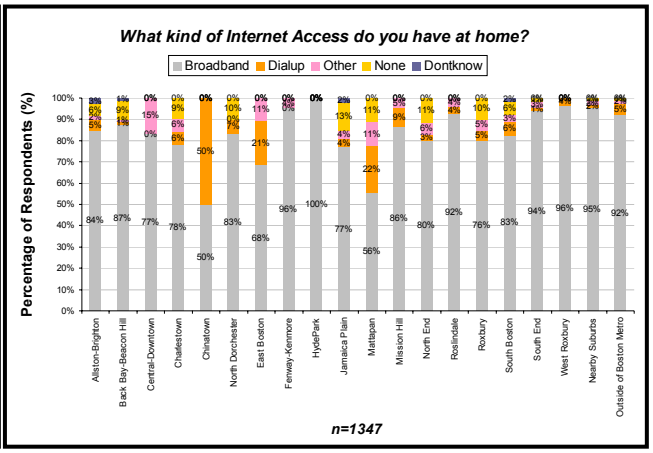


The Task Force also learned that overall Internet savvy users are most willing to pay for this service by watching advertisements (42%). Less popular options were taxes (29%) and end-user fees (19%).

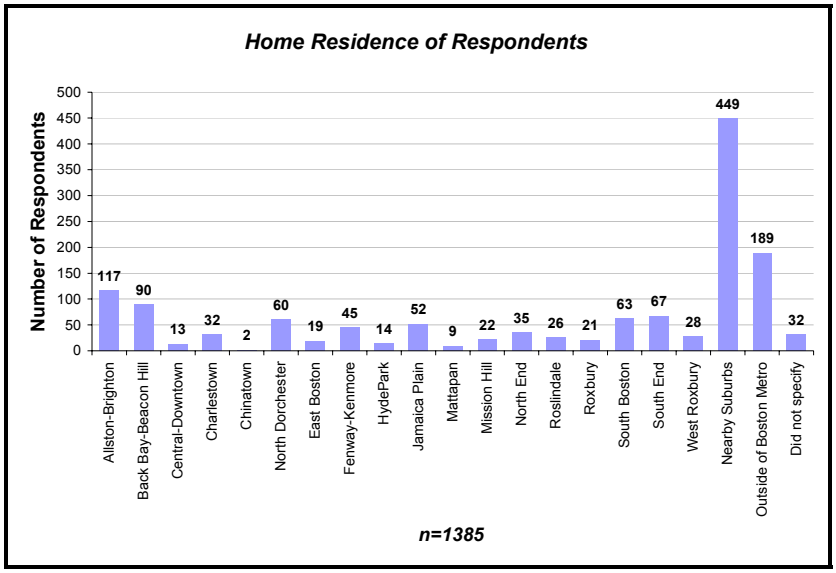


The Task Force found that most respondents had broadband at home and computers equipped to use Wi-Fi. This finding means that deployment of city-wide Wi-Fi could quickly be taken up by a large group of potential users.

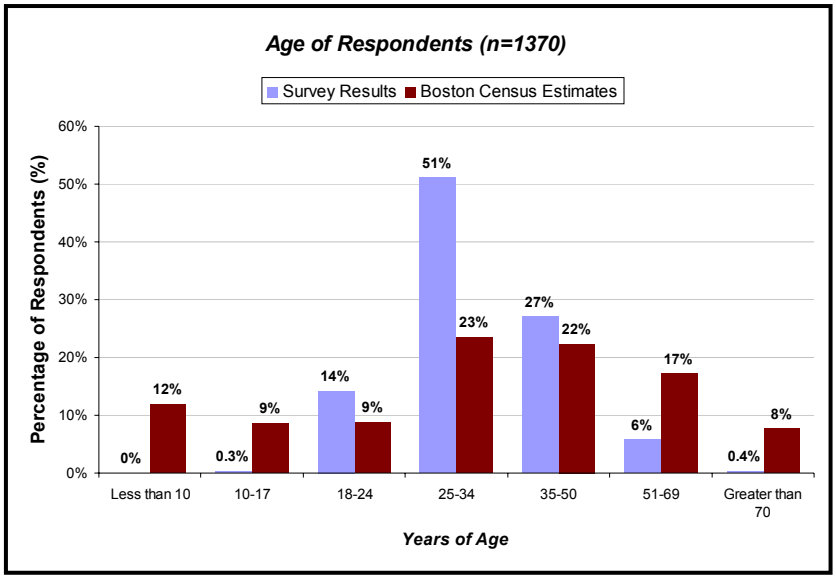




The Task Force was able to get the diversity of respondents that it wanted. It received 1,385 responses to the online survey. Respondents of the 10-minute questionnaire were from all neighborhoods of Boston, nearby suburbs and outside Greater Boston Metro area. Two-thirds (67.4%) of the respondents said they worked in Boston.



The online survey attracted a majority of young adults between the ages 25-34. The age distribution of the survey was younger than Boston's average age distribution. However, younger ages are more representative of the Internet use population.



Additional survey results in the Appendix section.

IX. Infrastructure Requirements

The Task Force's recommended network will need to use many of the City's physical assets, such as light poles and buildings, in order to cover the entire footprint of residences and businesses. However, access to these properties is not the only necessity:

- Network Design Assumptions
  - 2,250 radios – 45 per sq. mile
  - 50 route miles of fiber – 2 stranded
  - 20 central hub locations – Fiber/Wireless Interconnection
- Infrastructure Required
  - Light poles with power
  - Traffic lights with power
  - Rights to City buildings
  - And, in some network locations, rack space with back-up power supply
- Optional Infrastructure, but beneficial
  - Fiber, which has virtually unlimited capacity for transport of network data
  - Conduit space for additional underground fiber capacity
  - Towers with the proper RF characteristics for wireless propagation into the mesh network.

Inventory of Networks and Assets within the City

Existing Wireless Networks

a. Public: The Boston Public Libraries offer wireless Internet access free to the public at all of its branches. A majority of Boston Public Schools have wireless computing in all classrooms. The Rose Kennedy Greenway will have free wireless Internet coverage by the end of the summer. These networks are examples of public networks that exist and grow today from city-based funds and efforts.

b. Private: There are hundreds of private wireless access points in the city. From coffee shops to hotels, numerous companies offer fee-based wireless Internet connectivity. Some of these companies are local and home-grown such as Newbury Open Net (a wireless internet service provider based in the Newbury Street area). Large carriers such as T-Mobile, Boingo Wireless and Wayport are present in Starbucks and other business environments.

c. Public/Private: Community groups have constructed their own networks in Codman Square, Mission Hill, South End's Tent City, Madison Park and elsewhere. With community contributions and private donations of equipment, residents of small communities are using wireless internet today in their homes.

Existing Physical Assets and Limitations of Assets

Locations for Antennas: **[See Appendix: City Infrastructure Maps]**
No antennas exist today. These are their optimal locations.

- Buildings:
  The City has access to 467 buildings through the BPS, BPL, Fire Department, Police Department, Public Works, Parks, Inspection services, MIS and other agencies. These buildings, varying in height, are spread out all over Boston.

- Street Light Poles:
  There are over 9000 street lights in the City that are owned by NSTAR or Verizon Communications. Currently, the city has property rights to the armature on these light poles for providing light to the public. This armature would be the position for wireless radios to attach for the most optimal coverage and RF characteristics. A large amount of these lights use bank-switching (a single master switch for ON/OFF) for power. Bank-switching is a difficult challenge to construct around given that a city wireless network would have to operate 24/7.

- Traffic Lights:
  There are 824 city traffic signals systems throughout the city boundaries. While these are wholly owned by the City's Transportation Department and have existing power infrastructure, some lights are set at lower heights yielding non-optimal RF characteristics.

- Fireboxes:
  The Fire Department has emergency call stations placed at nearly every intersection of the city. These fireboxes are easily recognizable as poles by the red bulb light a top the white pole. There are 1,735 fireboxes scattered across every neighborhood in the city. While, they have connectivity, power and conduit, these lights are very low in height compared to other infrastructure properties. They are a valuable infrastructure asset where other properties do not exist.

Transport Assets **[See Appendix: City Infrastructure Maps]**

- Fiber:
  Access to fiber is essential to the longevity and scalability of a wireless network. The city has fiber but the fiber is not configured for use in a city-wide wireless network. It does not reach all major neighborhoods, and it is unclear if what does exist will be enough to support the city-wide network in

addition to the City's current and future uses of it (for example, for public safety).

- Conduit:
  Conduit access would allow the city to create a new fiber ring for the wireless network without expensive and disruptive street digging. However the city has access to only 22 miles of conduit that is not enough to provide the necessary coverage.

- Rights of way:
  Privileges to use the rooftops of city agency buildings, and space above light poles, traffic signals and fireboxes are necessary for the city to create an expansive network capable of reaching all residents. Rights of way will ease the process of implementing the best network possible.

- Towers, Spectrum:
  Currently, the City of Boston does not own any towers or wireless spectrum for specific wireless applications. However, RF propagation can be significantly increased using tall objects such as buildings and towers. Towers provide construction options for the city to achieve the best signal strength throughout the city.

  Spectrum is an expensive option to ensure non-interference with other networks or devices. Licensed spectrum grants exclusive use to radio waves. Unlicensed spectrum is open to all with rules set by the FCC. Wi-Fi is a technology standard that operates in unlicensed spectrum. The City has rights to 4.9GHz spectrum for public safety uses, but that frequency is far above the 2.4GHz unlicensed range, making it over twice as expensive to implement.

			Quantity	Stakeholder	Likelihood of obtaining asset	Outstanding Issues
First Mile Access	Access Points	Boston Fire Boxes	1,735	Boston Fire Department	Low-Medium	Low height, safety
		Boston Traffic Signals & Control Boxes	824 Signals 4,182 boxes	BTD	High	Intersections only Low height
		Street Lights	~9,000	NStar, Verizon, Boston	High (for a price)	Tariffs, Political/Legal, bank switches
Metro Transport	Hubs	Boston Buildings	467 total (135 on Comcast fiber)	Various Boston Departments	High	ROW, Negotiations
	Fiber	Boston Shadow Conduit	22 miles	Boston	Very High	Very Poor Coverage
		Boston/Comcast Fiber	118 miles	Boston/Comcast	Low	Not for municipal competitive/ commercial use
		Boston Transportation Fiber	53 miles	BTD	Unclear	Ubiquity
		Boston MIS Fiber	9 miles	Boston MIS	High	Very Poor Coverage, Capacity

Build Cost Assumptions:

- Fiber:

  50 miles of fiber (100 fiber miles for 2 strands) will be needed to connect all of Boston's neighborhoods. The costs for constructing laterals from city buildings to this fiber ring will be $500,000 - $1M.

- Interconnection Hubs:

  Wired – approximately 10 buildings would serve as hubs connecting to the fiber ring. $75,000 each building for equipment and construction.

  Wireless – approximately 20 buildings including the 10 wired would serve as wireless backhaul aggregation points. $35,000 each building for equipment and construction.

- Mesh Radios:

  Required radio density of 45 nodes per square mile. Costs of $5,000 for each radio and its installation yields $225,000 per square mile.

X. Detailed Technical Requirements of Model Value Chain Components

A. Reach

I. Metro Transport –

- Recommendation: Build or lease fiber access to a central location within all city neighborhoods. The remaining high-bandwidth coverage should be provided by wireless backhaul links using unlicensed 5.8 GHz or licensed technology. The Task Force believes fiber is much more scalable. Initially, wireless will be used where fiber is unavailable or uneconomical.
- Risks/Issues: Infrastructure construction to distant parts of the city is very costly to both build and to lease.

II. First Mile Access –

- Recommendation: Wireless signal should reach the outer most room's exterior wall/window.
- Risks/Issues: Some buildings are hard to access due to material, building height, and existing RF characteristics. Some units within a building still may not be able to access the signal.

III. Internet Service Provider (ISP) – N/A.

B. Coverage

I. Metro Transport – provide a backhaul connection between the Internet and each city neighborhood.

II. First Mile Access –

- Recommendation: The city's residential and commercial areas must be fully covered by the wireless mesh network.
- Risks/Issues: Full coverage of the city requires many radios.

III. Internet Service Provider (ISP) – N/A.

C. Throughput

I. Metro Transport –

- Recommendation: Enough bandwidth to support throughput for end-users on the First Mile Access portion of the network, subject to best practices for ensuring all end-user needs.
- Risks/Issues: Lighting the fiber for huge capacities may go underutilized during the early deployment phase of the wireless network.

II. First Mile Access –
- Recommendation: 1.5 Mbps symmetrical minimum speeds offered, which should increase over time, subject to consumer and business demand. The network should support access plans that have scalable throughput options, allowing end-users to determine their needs and requirements.
- Risks/Issues: Lower speeds would require less robust radios, but will have crippling effects on future bandwidth growth. Wireless bandwidth is shared by all, requiring additional radio deployments as adoption and throughput increase.

III. Internet Service Provider (ISP) – N/A.

D. Quality of Service (QoS)

I. Metro Transport –
- Recommendation: The network should have the ability to prioritize certain forms of traffic either through protocol tagging or VLANs. This will ensure the quality of city services and other mission critical applications even during capacity-constrained times.
- Risks/Issues: Organization and implementation of multiple prioritization schemes may be difficult.

II. First Mile Access –
- Recommendation: Similarly to the transport layer, QoS must be present in the mesh to facilitate reliable connections to the appropriate end-users.
- Risks/Issues: Mesh equipment must natively support latest and future QoS standards.

III. Internet Service Provider (ISP) –
- Recommendation: The same QoS built into the mesh must be resident at the end-user in order for the source of such data to receive priority throughout the network.
- Risks/Issues: Any voice or video real-time communication application requires reliable QOS.

E. Monitoring

I. Metro Transport –
- Recommendation: The transport layer should be monitored for performance, maintenance, and potential misuse.
- Risks/Issues: A technically-skilled group is required to monitor the network.

II. First Mile Access –
- Recommendation: With over 1500 radios proposed to support the city network; these must be monitored for outages and failures of any sort.
- Risks/Issues: Again, a technically-skilled group is required to monitor the network.

III. Internet Service Provider (ISP) – N/A.

F. Interoperability

I. Metro Transport –
- Recommendation: The transport layer must be able to tap into any national Internet Backhaul network to ensure a large pool of potential vendors.
- Risks/Issues: Access to certain Internet connection facilities will drive additional one-time and recurring costs.

II. First Mile Access –
- Recommendation: Mesh radios communicate with each other to move end-user packets around the network. These radios must have the ability to decipher packets and packet instructions alike. Single vendor of radios or multi-vendor approach with proven interoperability.
- Risks/Issues: Regarded as a major crux to communication technologies, interoperability will always be an issue with evolving networks. A network will perform at its best if interoperability rules are obeyed.

G. End-user Devices

I. Meshing –
- Recommendation: Standards-based (802.11g/802.11s) wireless devices should be approved and recommended as compatible with the Mesh city network.
- Risks/Issues: There are many vendor devices that conform to wireless standards but may perform differently in various environments.

II. Router repeater –
- Recommendation: For in-home coverage, end-users can use router repeaters (802.11g/802.11s) to capture signal and create further coverage to an area within the home.
- Risks/Issues: Router repeaters use the same technology (802.11g/802.11s in 2.4GHz band) as the city wireless network and can be competitive if too highly powered.

III. Network extension –

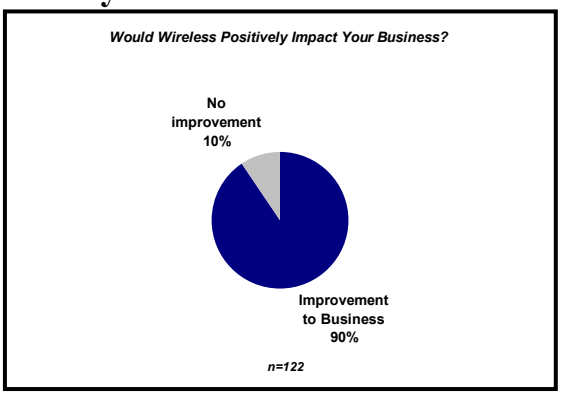
- Recommendation: Large network extension devices must be complementary to the city network and not competitive. The devices can be use to bring signal into places that have poor coverage due to building height and/or foliage. They may use 802.11a to receive large amounts of bandwidth from the city wireless network.
- Risks/Issues: Unsupported use of these devices could degrade the 5.8GHz wireless spectrum causing poor connectivity and bandwidth for all.

IV. Security and MAC authentication –

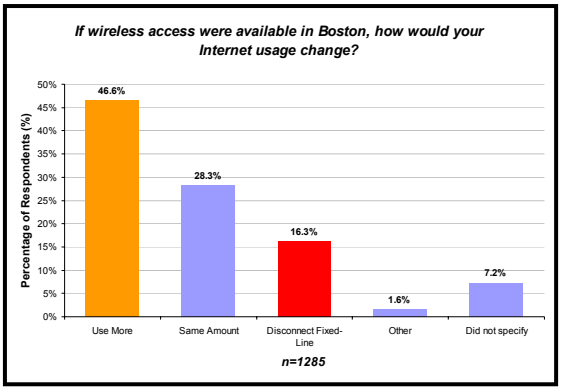
- Recommendation: Devices must be authenticated by encrypted password and MAC address matching by End-users. For devices without web browsing capability, MAC address authentication and numerical (e.g. PIN#) password security will be used.
- Risks/Issues: This would require users to register their devices before using their device on the network. This step may create confusion, but will aid in security/theft/recovery of these wireless devices.

XI. APPENDIX

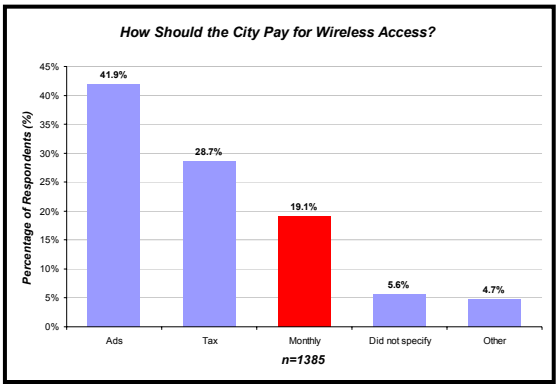
Survey Results



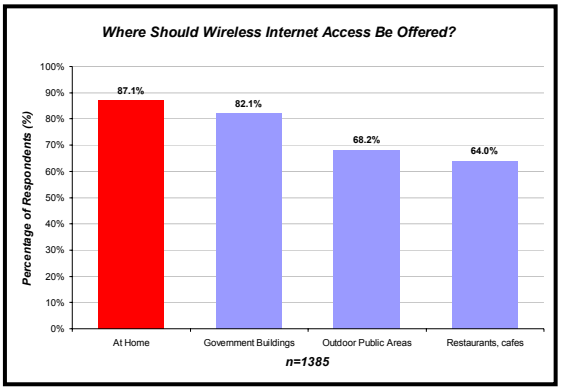
Respondents that were business owners claimed that wireless access would positively improve their businesses 9 times out of 10.



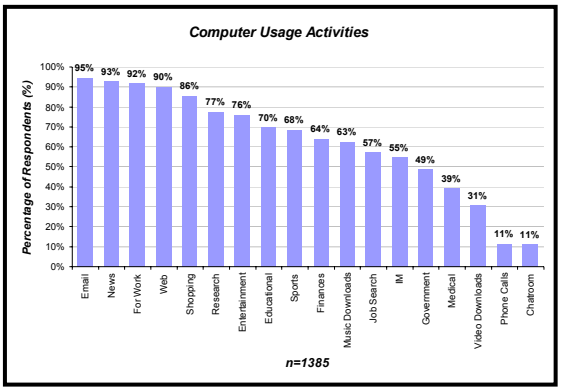
The Task force found that over 16% of the online survey respondents would disconnect their home access if wireless were available city-wide in Boston. Over 45% would sign up for wireless access and keep their home connection.



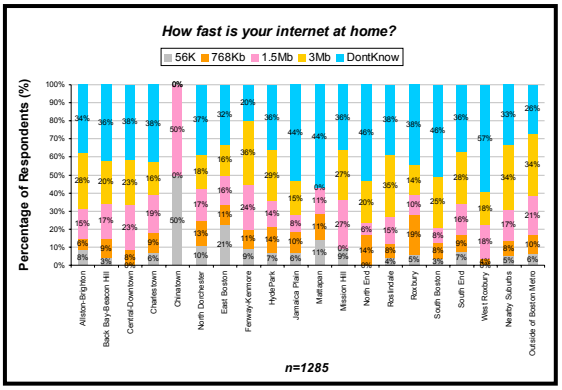
Nearly ninety percent of respondents would like to see the wireless access paid for by three different methods: 1) Advertisements 2) Taxes 3) Monthly Fees.



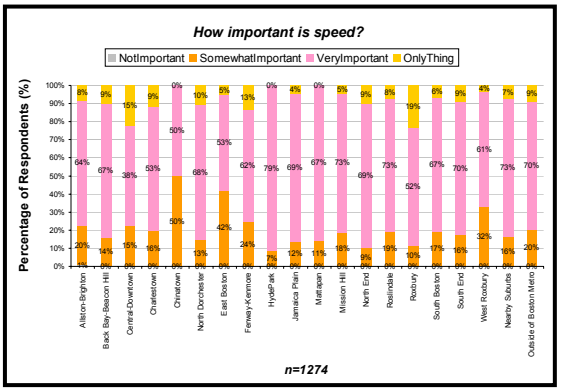
When asked where they would want wireless access, respondents chose home (87.1%) more often than other venues.



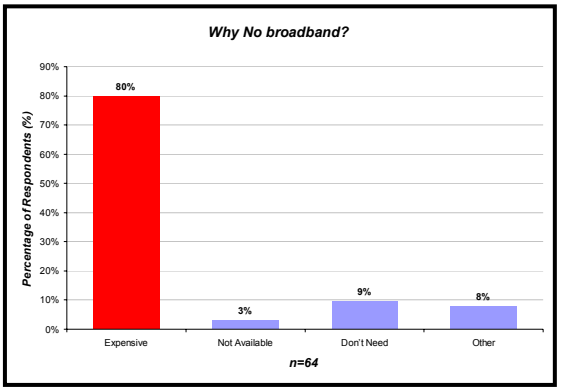
Activities used by survey respondents.



Surprisingly, many internet users do not know what speed they are currently buying.

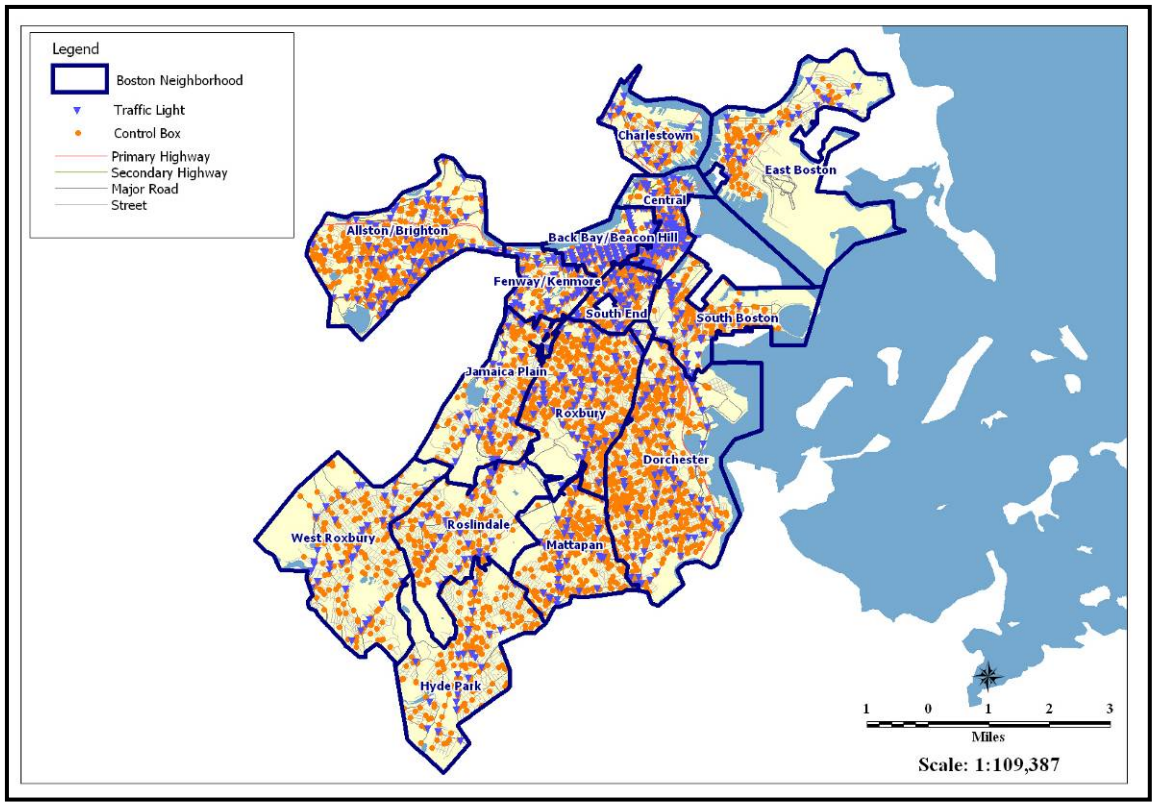


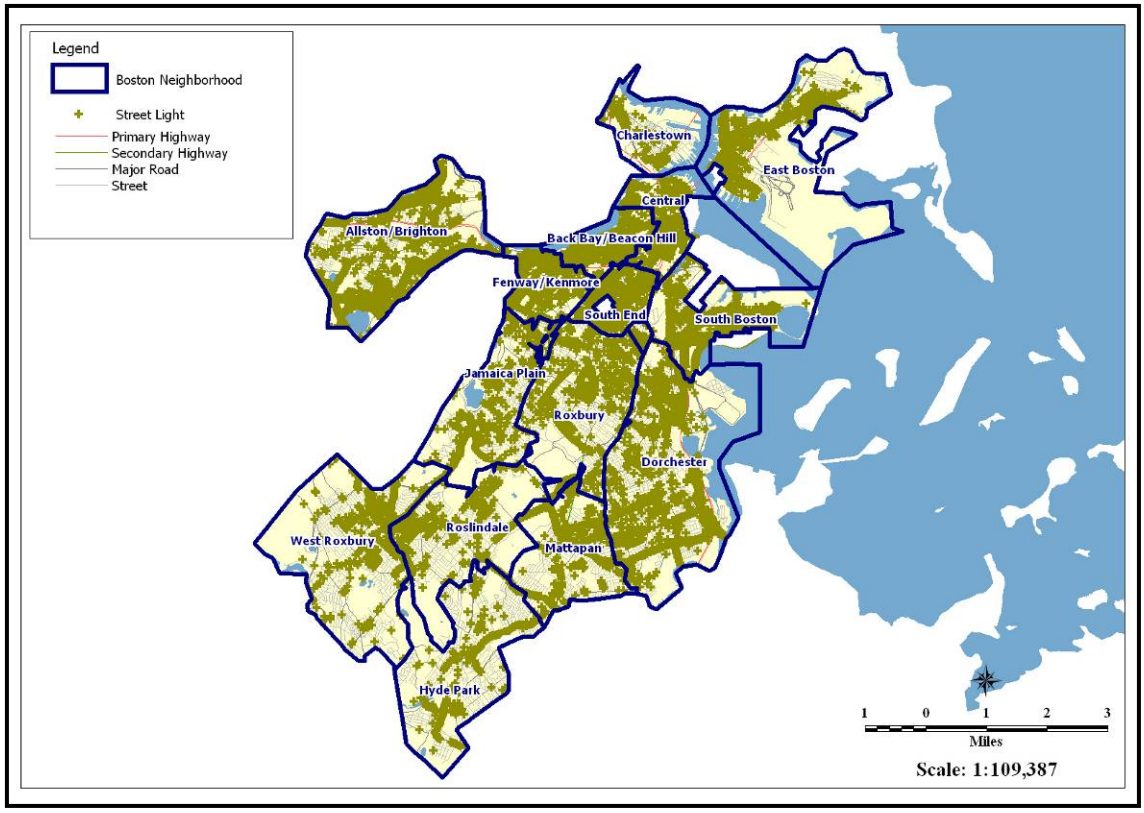
However, overall 67.3% of the respondents thought that speed was *very important*, and 7.8% thought it was the *only thing*.

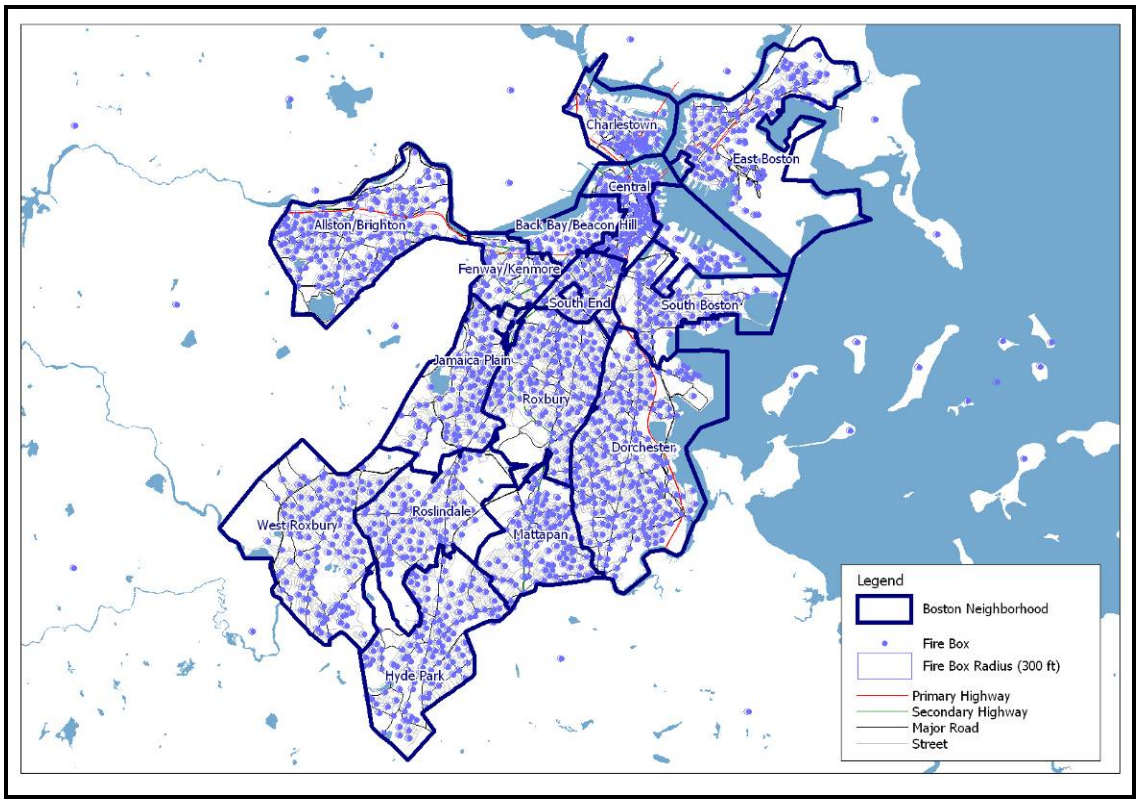


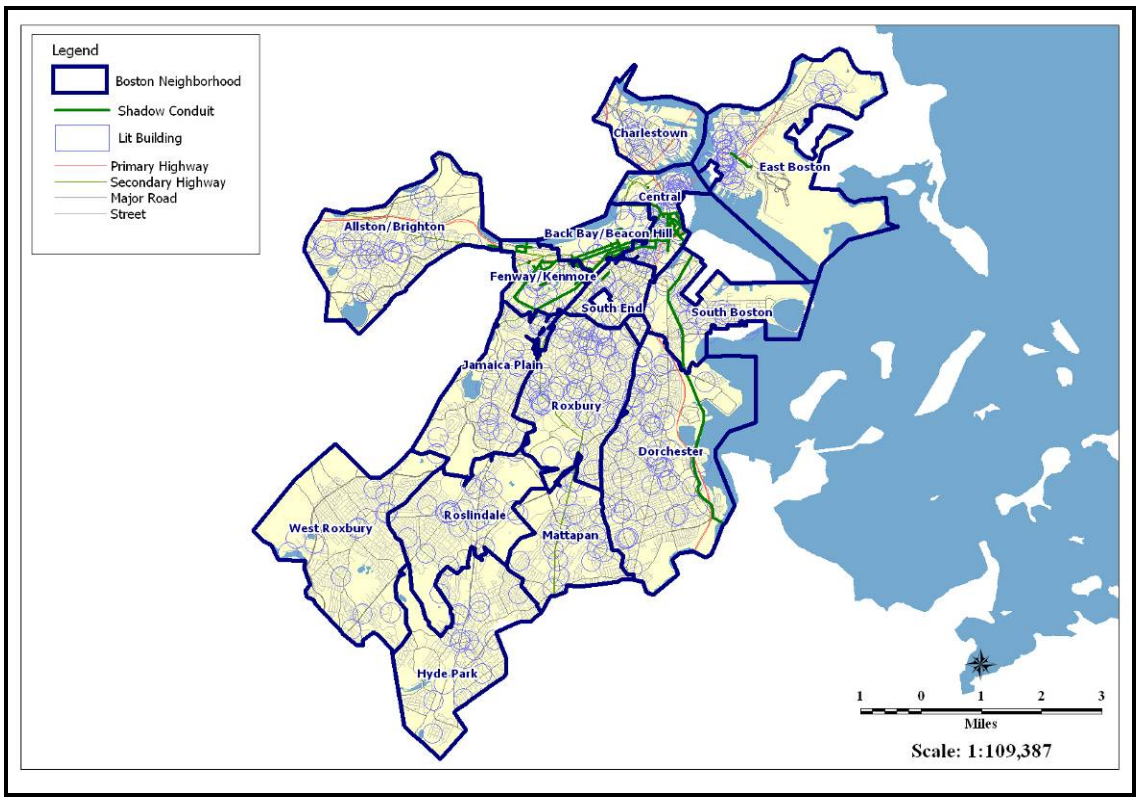
Lastly, of the few respondents who did not have broadband who took this survey, they cited that broadband was *too expensive*, as the primary reason why they have subscribed the service. There were very few who cannot subscribe due to lack of availability.

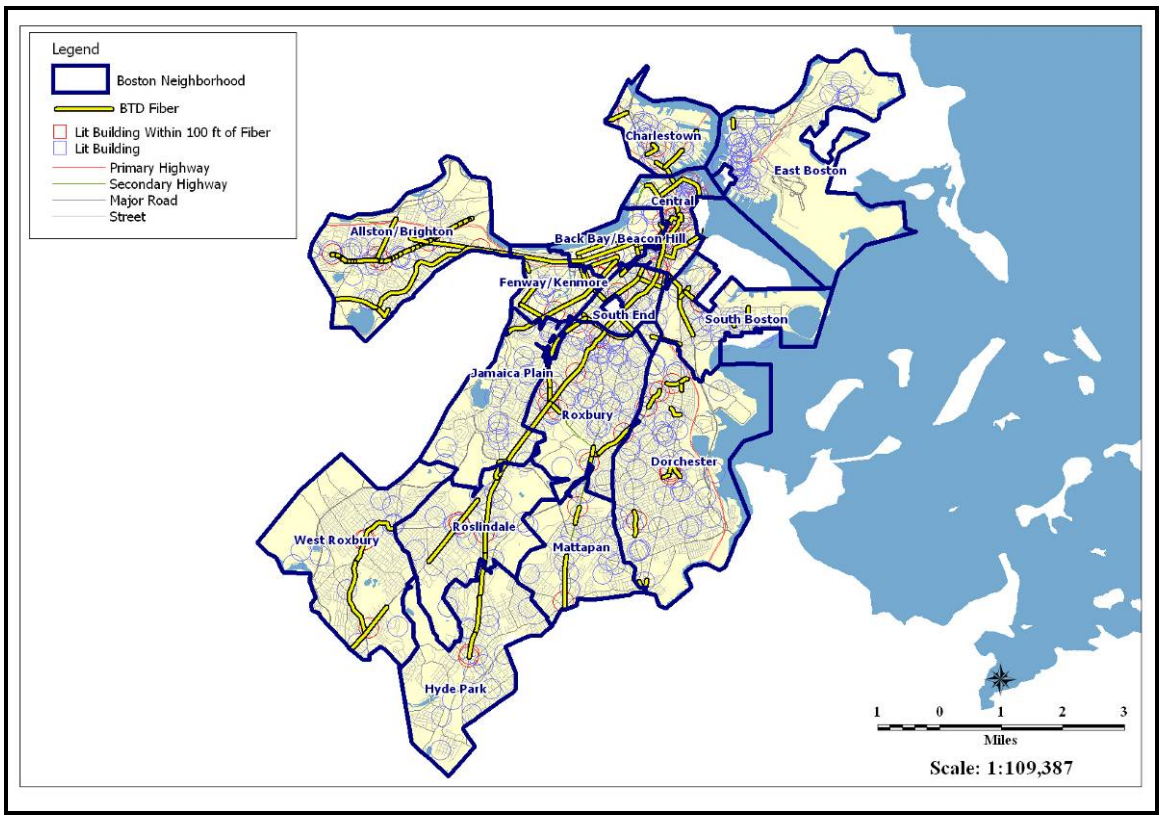
City Infrastructure Maps






Charlestown
East Boston
Central
Allston/Brighton
Back Bay/Beacon Hill
Fenway/Kenmore
South End
South Boston
Jamaica Plain
Roxbury
Dorchester
Roslindale
West Roxbury
Mattapan
Hyde Park
Legend
Boston Neighborhood
Fire Box
Fire Box Radius (300 ft)
Primary Highway
Secondary Highway
Major Road
Street


Legend
Boston Neighborhood
Shadow Conduit
Lit Building
Primary Highway
Secondary Highway
Major Road
Street
Charlestown
East Boston
Central
Allston/Brighton
Back Bay/Beacon Hill
Fenway/Kenmore
South End
South Boston
Jamaica Plain
Roxbury
Dorchester
Roslindale
West Roxbury
Mattapan
Hyde Park
1 0 1 2 3
Miles
Scale: 1:109,387


Legend
Boston Neighborhood
BTD Fiber
Lit Building Within 100 ft of Fiber
Lit Building
Primary Highway
Secondary Highway
Major Road
Street
Charlestown
East Boston
Central
Allston/Brighton
Back Bay/Beacon Hill
Fenway/Kenmore
South End
South Boston
Jamaica Plain
Roxbury
Dorchester
Roslindale
West Roxbury
Mattapan
Hyde Park
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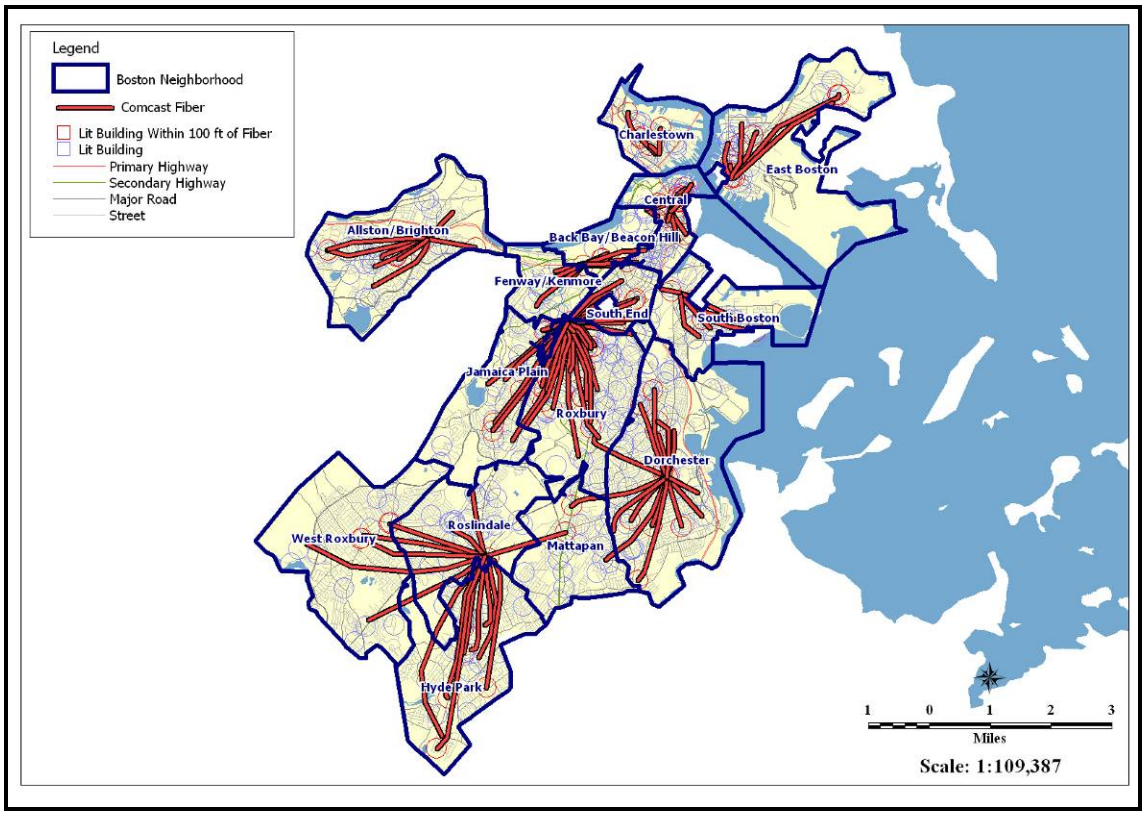
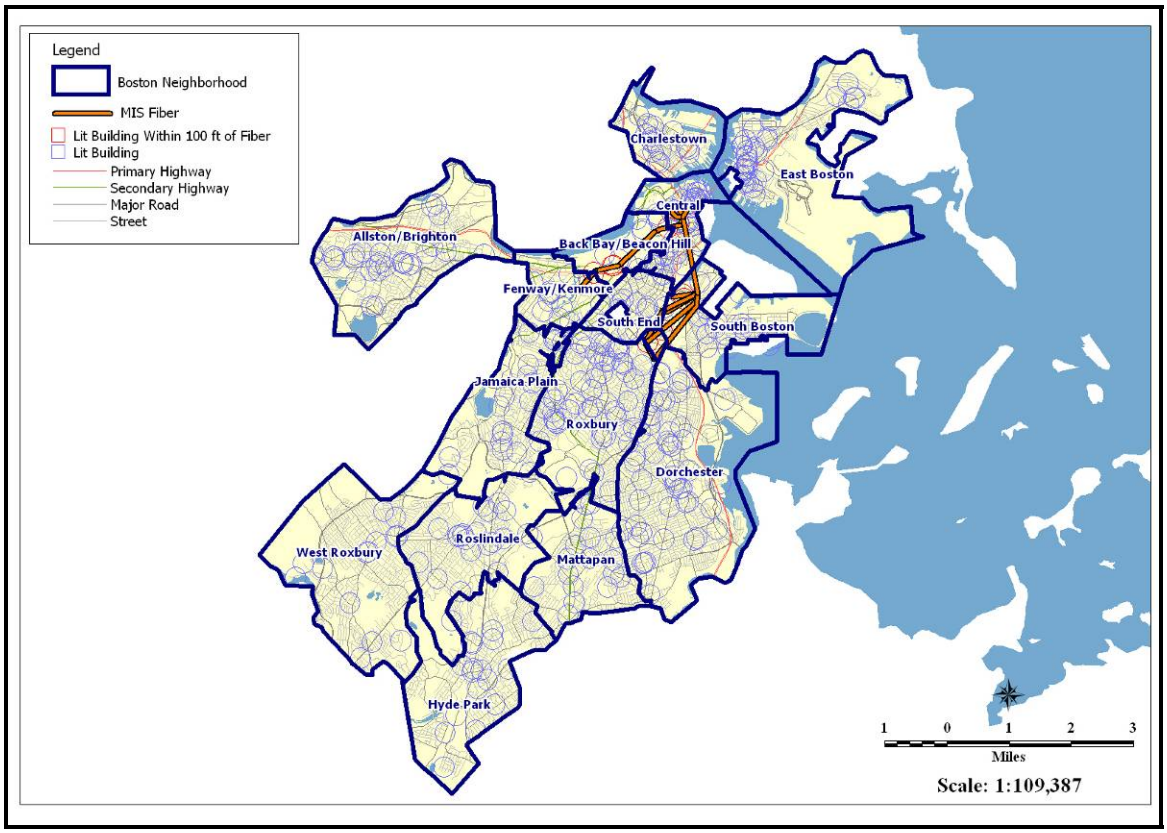
Miles
Scale: 1:109,387


Legend
Boston Neighborhood
Comcast Fiber
Lit Building Within 100 ft of Fiber
Lit Building
Primary Highway
Secondary Highway
Major Road
Street
Charlestown
East Boston
Central
Allston/Brighton
Back Bay/Beacon Hill
Fenway/Kenmore
South End
South Boston
Jamaica Plain
Roxbury
Dorchester
Roslindale
West Roxbury
Mattapan
Hyde Park
1 0 1 2 3
Miles
Scale: 1:109,387



Existing Boston Initiatives that Foster Computer Literacy

Computer literacy is a critical component of today's society. Boston has repeatedly demonstrated leadership and shown its commitment to providing resources that increase computer literacy and advance technology adoption. These pioneering efforts include:

- Technology Goes Home (TGH)
  Mayor Menino's Boston Digital Bridge Foundation has established partnerships with Microsoft, Lexmark, HiQ Computers and Intel to expand access to hardware and increase computer literacy. Program participants can purchase a new computer and a printer for less than $15 per month through a special Bank of America no-interest, no-down payment loan program. In addition, the TGH program provides parents and their children with 25 or more hours of basic technology training at no charge in addition to an introduction to financial literacy. More than 2,300 families have participated in this program.
- TechBoston
  TechBoston is a department within the Boston Public Schools that supports advanced technology courses in the district's high schools and middle schools. TechBoston has a small central staff that provides teacher training and classroom materials, works with corporate partners to fund equipment and training, and seeks grant money to further special programs. A staff member from the Boston Private Industry Council works with TechBoston to identify for high school students after-school or summer work in the technology industry. The TechBoston staff carries out this mission on three levels: 1.) structuring events to build technology awareness among younger students; 2.) providing classroom support and teacher professional development to improve teaching and learning; and 3.) working with the Boston Private Industry Council to place technology-skilled high school students in jobs and internships. TechBoston is funded by the City of Boston through the Boston School Department and receives additional support from foundations and corporations. TechBoston also receives support through Mayor Thomas M. Menino's Boston Digital Bridge Foundation.
- Project Refresh
  Project Refresh is the Boston Public Schools' (BPS) technology donation program that strengthens the district's ability to put technology resources into the hands of teachers and students. This initiative will augment BPS's efforts to create a sustainable computer life cycle model that provides schools with updated technology tools to help all students meet high standards and to close the achievement gap that exists among students of diverse backgrounds. By establishing new strategic partnerships with Boston's business community to acquire donated computers through annual commitments, Project Refresh represents an innovative approach to bridging the digital divide.
- Museum of Science Computer Clubhouses
  These were established in 1993 by The Computer Museum in collaboration with the MIT Media Laboratory. The Computer Clubhouse program helps young people acquire the tools necessary for personal and professional success at six centers spread across Boston.

- Timothy Smith Centers
  The Timothy Smith Centers are computer training centers established in 1996 by the city of Boston, through a bequest left to the city by longtime resident—Timothy Smith. The 39 centers located at various social service agencies and educational institutions in Greater Roxbury, provide more than one million hours of computer access to the community for a wide variety of programs including job training, educational enrichment and open access.
- CTCNet and Faith-Based Technology Centers
  These include 45 community technology centers spread all across the neighborhoods of Boston. The tech centers are located at social service agencies, community centers, and faith-based organizations. They are affiliated with TechMission, a national network formed in 2000 to support Christian community computer centers across the world to provide youth and adults with access, skills and relationships needed to succeed in the information age.
- South End Technology Center
  In partnership with MIT's Media Lab, the South End Technology Center links MIT student mentors and high school youth of color for training and exposure in five areas: Robotics, Fuel Cell Technology to build model solar cars, Computers to design and build small machines at MIT's Fab Lab, Videography, and Web Design and Software Applications.