Wireless Philadelphia™ Business Plan

Wireless Broadband as the Foundation for a Digital City

Presented to:

The Honorable John F. Street
Mayor—City of Philadelphia

Presented by:

The Wireless Philadelphia™
Executive Committee

9 February 2005

Preface

Disclaimer

The Wireless Philadelphia™ Business Plan is intended to provide general information on the Wireless Philadelphia™ project and is not an exhaustive treatment of the project. Accordingly, the information in this Business Plan is not intended to constitute legal, accounting, investment, consulting, or other professional advice or services. Competent investment, accounting, and legal advice/advisors should be obtained before making any decision or taking action based on this Business Plan.

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Acknowledgements

The Committee wishes to acknowledge the contributions made by the following organizations and individuals:

- Temple, Drexel and LaSalle[1] universities for their assistance in researching and contributing to the business plan, sourcing models, and marketing/communications plan respectively.

- Civitium LLC for business and technology advice to the Committee, execution of the citywide radio frequency (RF) study, preparation of the business plan, and recommendations to the Mayor.

- Intel Corporation for being a technology partner and contributing leadership through their vision for Digital Cities and financial support to enhance Philadelphia communities with wireless technology.

- Rob McNeil, principal of the Ronin Group for facilitation of focus groups and town hall meetings.

- The Rubenstein Company Associates, LP and Ten Penn Associates for providing temporary rooftop rights at Ten Penn Center for wireless equipment testing.

[1] Various materials developed by Temple, Drexel and LaSalle universities are incorporated into this business plan. Full versions of their reports may be available.

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Project Background

In July 2004, the City of Philadelphia announced the Wireless Philadelphia Project, with plans to become one of the largest wireless cities in the United States.

Wireless Philadelphia established a charter to strengthen the City's economy and transform Philadelphia's neighborhoods by providing wireless Internet access throughout the City. Wireless Philadelphia intends to create a digital infrastructure for open-air Internet access and to help citizens, businesses, schools, and community organizations make effective use of wireless technology to achieve their goals while providing a greater experience for visitors to the City.

In August 2004, the Honorable John F. Street, mayor of Philadelphia, appointed a seventeen-member Wireless Philadelphia Executive Committee ("the Committee") to serve as an advisory/advocacy group for wireless community networking through community outreach programs, communications with the press, and participation in meetings and conferences.

The Mayor's charter to the Committee was to develop a public and private partnership to achieve wireless access throughout the City to enhance economic development in neighborhoods, help overcome the digital divide, and improve quality of life for all Philadelphians. Specifically, the Committee was asked to assume a leadership role and work with the City to make this goal a reality by the following:

- Helping to develop a business plan and timeline for the project
- Providing input, analysis, critical review, and recommendations for the project
- Helping to formulate recommendations in several policy areas including fees, roles and responsibilities, extent of service, privacy, and security
- Identifying potential partners from the business community, the private sector, and from civic and institutional organizations
- Identifying funding opportunities in both the public and private sector
- Working with the City to pursue funding so the project is cost neutral to the City
- Identifying possible legal and regulatory barriers and help develop strategies to overcome them
- Providing a forum to discuss the possibilities and opportunities that wireless represents for the City and the various constituencies represented by members of the Committee
- Helping to identify how wireless technology can contribute to both the public and private well being of the City
- Helping to frame the story for why this investment is essential to both the economic well being of the City and its people
- Helping to develop a communications plan and outreach program in support of the effort

To meet these objectives, the Committee, chaired by City of Philadelphia CIO Dianah Neff, with the involvement of Philadelphia-area universities and private-sector companies, studied issues such as stakeholder analysis, requirements definition, business model scenarios, funding options, investment analysis, and technical architectures.

The benefits of making this transformative technology investment are broad and far reaching. First and foremost, the City embraced this initiative to remain a competitive location for businesses, a world-class center for education, and an attraction for visitors. The investment will also reduce the cost of delivery of public services. Finally, it is an essential element of a long-term strategy to invest in the human capital of the City: its workers, its residents, and perhaps most importantly, for the future of its children.

The City has already overcome a major hurdle in delivering a low-cost, ubiquitous broadband network. The passage of House Bill 30 by the legislature of the Commonwealth of Pennsylvania threatened to derail the project. Although the Governor signed House Bill 30 on November 30, 2004, the City negotiated a compromise with Verizon that allows the Wireless Philadelphia project to proceed.

This report represents the Committee's findings and recommendations and a detailed business plan to achieve the goals defined by the City.

Executive Summary

Introduction

For centuries, cities have been the early adopters of new technology, and it is by investing in these new technologies that cities became the great creative engines of commerce, culture, and society. Cities achieved this central role through railroads in the nineteenth century and automobiles in the twentieth century. For the twenty-first century, it will surely be the Internet and the content and services that the Internet delivers that will allow cities to remain cornerstones of the modern world. In less than a decade, this new set of technologies will be changing our daily lives from how we communicate to how and where we work, from how business is done to how we deliver city services, and from how we are educated to how we play.

We are truly in the beginning of a new age. Just as in past centuries, the cities that will prosper in this new age will be those cities that embrace and invest in this new technology. The opportunity now exists to bring the vast benefits of the Internet home to the city in which we live, our Digital City.

Philadelphia proposes to capitalize on this potential by leading an effort to create a wireless network that will provide high-speed, broadband wireless connectivity to all points within the City. Wireless access is rapidly changing how individuals and organizations connect to the Internet and is a transformative technology that will have multiple benefits across all segments of the economy and civic life.

The computer, telecommunications, and entertainment industries are investing billions of dollars on the expectation that wireless technology will be the catalyst for the next big wave of economic growth that will be bigger and different than any market change before it. Business leaders expect stunning growth. According to Goldman Sachs Equity research, the number of mobile connections worldwide will increase from 727 million at the beginning of 2001 to more than 1.7 billion by 2005.

Many businesses view wireless Internet access as an opportunity to increase productivity and better service their customers. Responding to this opportunity are over 430 dial-up Internet service providers in Philadelphia and over 93 individual wireless hotspots within the City providing Internet access at hotels, coffee houses, bookstores, cafes, and other public places. At these commercially provided hotspots, users must have an account or pay a daily user fee. Several other hotspots provide free access including the City of Philadelphia at Love Park, Ben Franklin Parkway, Reading Terminal, and Pennsylvania Convention Center in Center City. While wireless access continues to grow, today's patchwork of individual hotspots does not provide uniform coverage across the City. This lack of comprehensive and universal wireless access greatly limits the benefits of this new technology. It is here that the City can play the traditional role of government in providing the framework and initial investment needed to fully exploit this opportunity.

The areas of local government involvement in telecommunications networks include the authority to grant franchises and regulate the use of public right-of-way, the granting of permits for the construction of networks, and the regulation of zones for switching and other facilities. In addition to these jurisdictional matters, local governments have a practical reason to become involved in the provision of broadband services because the City is one of the largest single consumers of telecommunications services in the area.

In US history, cities and government have often made the initial key investment to provide a new public service: the Internet, city-owned electric, water and sewer, gas utilities, etc. Often governments have taken this step because private industry does not have the resources, vision, or economic incentives to provide the needed service or because it is in the public interest to provide this service universally to all its residents. The Committee believes the public sector will need to serve as the catalyst to ensure that affordable broadband Internet access is widely accessible to all the residents of Philadelphia.

Benefits

The benefits of making this transformative technology investment are broad and far reaching. First and foremost, the City must embrace this initiative if it is to remain a competitive location for businesses, a world-class center for education, and an attraction for visitors. Second, it is a needed investment to support the delivery of public services. Finally, it is an essential element of a long-term strategy to invest in the human capital of the City: its workers, its residents, and perhaps most importantly, for the future of its children.

Overcoming the Digital Divide

In Philadelphia, the Cox family – three generations of women sharing a rowhouse – gets high-speed Internet access for $10 per month. It has changed their world.

Taah (pronounced Tay-uh) was an unfocused third-grader whose father is in jail. Her mother Maya, who was 13 when she gave birth to Taah, was told at the time that she probably needed a kidney transplant. Theodora Cox, at 64, faced the added uncertainty of retirement.

Through One Economy Corporation, a pioneering nonprofit group, Theodora engaged in an eight-week training course, which allowed her to purchase a computer for $120 and get wireless broadband for $10 per month through the People's Emergency Center (PEC), a nonprofit social service group in Philadelphia.

Now Taah "is the technical director in her class". Maya and her mother researched kidney diseases and corresponded with patients and doctors in other countries, who are often more responsive than local doctors. And Theodora uses the Internet to help her sell a line of candles to people in the neighborhood. In the words of Gloria Guard, President of PEC, who provides wireless broadband access to over 50 homes in the neighborhood, "making technology available is like a pebble in a pond".

Source: "Program Bridges the Gap in Affordability of High-Speed Internet," *Washington Post*, August 9, 2004

Investing in the People of the City

A wireless network will be a strategic investment in the people of the City. It will provide an infrastructure that can assist in bridging the digital divide that prevents many individuals and families from obtaining the full measure of opportunities generated by the Internet because they can't afford the cost of wired broadband Internet access. This limits educational opportunities, job opportunities, and participation in many dimensions of modern society. Eventually it results in segments of the population forever lagging behind their peers. The potential of citywide wireless access to reinforce educational programs from elementary school through university may be the greatest long-term potential benefit to individual Philadelphians and to the collective health of the City.

A Competitive Location

Firms and organizations evaluate many factors when deciding where to locate and do business. The City must offer a competitive low-cost environment for firms. Providing wireless accessibility will be as important in the future as traditional utilities. An environment that attracts and keeps the knowledge workers who drive the economy of today is all-important. The economic development benefits of this strategy are clear and compelling. Not only will it make Philadelphia a better choice for firms to do business, it will enhance the desirability of the City's neighborhoods as a place to live.

Enhancing the Experience for Visitors

Wireless access is fast becoming the indispensable tool of the leisure or business visitor. Today's visitors are demanding 24/7/365 access to travel information and are using mobile devises to book flights, reserve rental cars, and make travel arrangements that only a few years ago would have been accomplished by phone or in person. Visitors expect to be able to look up maps and get directions, find retail shops, and read restaurant reviews while they wander Center City and visit Philadelphia's attractions. Citywide wireless access will become an essential component of a successful strategy to grow the hospitality sector of the economy. The benefits of this growth will include local employment and revenue for the City

Delivering Public Services

Governments are judged on how well they deliver low cost services to their constituents. For the past few years, Philadelphia, like many local governments, has used information technology and the Internet to transform how government business is done, how services are delivered, and how the City interacts with residents, businesses, and visitors. The City is aggressively pursuing wireless technology to improve service delivery and to reduce costs in many applications, from mobile data terminals in police cars to handheld devices that give service delivery workers an office in the field. Broadband wireless access throughout the City will empower service delivery in ways that have only begun to be explored.

Findings

Temple and Drexel Universities conducted extensive analysis to support the Wireless Philadelphia initiative. Their analysis supports the following conclusions:

- The stakeholder analysis shows that there is a need for low-cost broadband Internet access in the City above and beyond what is available today.

- There is significant evidence to suggest that efforts to serve underserved groups will only succeed with a comprehensive plan that includes broadband access, computers in the home, training, content, and a process that includes upfront involvement in decision-making and implementation.

- The demographic and projected-demand calculations show that there is a potential market for broadband access. However, the stakeholder analysis also shows that the demand must be paired with compelling applications. Simply providing access may not be sufficient for stakeholders. There should also be access to new and future applications such as video mail, voice-over Wi-Fi, and distance learning.

- It is unclear if, when, and at what price the private sector will provide such services and whether the services will provide universal or near-universal access, which is an important societal goal of the City.

- The best-practices analysis shows that in the majority of cases, city governments have acted as the catalyst for projects to provide broadband access to residents. However, most projects are small or are still under development. Although there is much we can learn from others, given the scale of the project in Philadelphia we will have to become leaders in the implementation.

- The best-practices analysis also shows that there are successful examples and the chance of success is good.

- Wireless access technology is maturing; however, it is already the most cost-effective solution for implementing broadband access (as compared to cable, DSL, and other technologies).

- Given the scale and the rapid evolution of wireless technology, the City will likely achieve greater success partnering with private sector specialists rather than implementing this project on its own.

- The challenges of technology and the risks of implementing a project that is not a core competence of the City suggest that private industry should play a major role in the funding, implementation, and ongoing operation.

- There will need to be substantial involvement by the City to ensure that the project gets off the ground and that underserved populations are targeted.

Recommendations

To accomplish the goal of designing, deploying, and managing a self-sustaining, high-speed, affordable, broadband network over a 135-square-mile area, the Committee makes the following recommendations:

- Create a nonprofit corporation to oversee the implementation of a Cooperative Wholesale™ business model. The Cooperative Wholesale model promotes public-private cooperation, creates increased competition for lower broadband prices in the market, and funds free cash flow for Economic Development and Digital Divide programs.

- The nonprofit receives startup funding from foundation grants, bank loans, and/or other non-city sources.

- The nonprofit, through an RFP process, outsources the design, deployment, management, and maintenance of a citywide wireless network to private companies.

- The nonprofit makes access to the network available for low wholesale fees to retail service providers, telecommunications companies, institutions and other nonprofit corporations.

- Service providers market the service to subscribers and provide customer service, billing, technical support, content, and other value-added services.

- Service providers make discounted rates available to low-income and disadvantaged residents as well as minority, women, disable-owned, and other small businesses.

- The nonprofit provides some level of free wireless Internet access to everyone living, working, or visiting the City in public spaces like parks and squares.

- The nonprofit uses its free cash flow to fund Economic Development and Digital Divide Programs aimed at getting PCs into low-income and disadvantaged subscribers' homes, making training programs available, and stimulating small business innovation and growth.

- The nonprofit builds key informational messages for distribution to multiple stakeholders, informing, educating, and familiarizing them with the benefits of the Wireless Philadelphia initiative through key marketing and public relations programs.

- The City provides the nonprofit with access to city-owned light poles and other assets.

- The City agrees to act as an "anchor tenant" for the network. The term anchor tenant refers to a commitment by the City to contract with the nonprofit for services such as business-class DSL, T-1, mobile data, and other services.

The Cooperative Wholesale model is unique in its ability to accomplish the social goals of Wireless Philadelphia, while at the same time promoting competition in and enabling rapid-growth broadband access. Rather than attempt to enforce government regulation of broadband pricing, the Committee believes that the availability of an alternative, low-cost broadband network and an increase in the amount and intensity of competition will result in more affordable broadband services.

Return-on-Investment

The proposed business model demonstrates that a $10 million investment to deploy a citywide wireless network will result in broadband access at dial-up prices and provide positive financial results. Through conservative assumptions, the model estimates that the nonprofit will break even in year four, build $4 million of working capital reserve for network upgrades and generate $5 million in free cash flow to support economic development and digital divide programs.

The table below demonstrates that the nonprofit Earnings Before Interest, Tax, Depreciation and Amortization (EBITDA) will be positive in year 1, cash flow positive in year 2, and break even in year 4.

Summary Economics	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Revenue ($M)	$8.2	$11.6	$12.9	$14.0	$14.5	$61.1
Operating Expenditure ($M)	$5.7	$8.1	$8.2	$8.4	$8.3	$38.6
EBITDA ($M)	$2.5	$3.5	$4.7	$5.6	$6.1	$22.5
Net Income ($M)	($0.9)	$0.1	$1.3	$2.1	$2.6	$5.2
Capital Expenditure ($M)	$10.0	$0.2	$0.1	$0.1	$0.0	$10.5
Working Capital Reserve ($M)	$0.0	$0.1	$1.3	$1.4	$1.4	$4.2
Free Cash Flow ($M)	($9.0)	($6.5)	($3.8)	$0.4	$5.0	$5.0

Table 1. Summary Economics

Business Plan Assumptions

The following table summarizes the key assumptions used in the development of this Business Plan.

Category	Assumptions
Business Model	The nonprofit owns and operates a wholesale wireless network providing: • Infrastructure and Internet connectivity • Network performance management • Tier 2 Customer Support • Network expansion and next-generation network deployment • Low-price retail services through low-cost wholesale access • $15M–18M line of credit available @ 8 percent • Limited number of free access zones in parks & public spaces

Category	Assumptions
	SPs will provide the following: • Customer marketing • Customer billing • First line of defense for customer care (Tier 1) • Service features (e-mail, newsgroups, subscriber authentication, etc.) • Enhanced services (e.g. Voice-over Wi-Fi) • Customer Premises Equipment (CPE)
ROI Objectives	Within five years, the nonprofit will: • Fund $4M capital reserve fund for future network expansion and upgrade • Break even on initial the investment • Fund $5M in free cash flow to fund economic development and digital divide projects • Be cost neutral to the City
Infrastructure	• 135 square miles • Wi-Fi access nodes mounted on street lights and other structural assets • Backhaul is a combination of pre-WiMAX and dedicated leased line • Public internet peering provided for SPs • Tier 2 Network Operations Center (NOC) • Equipment spares • Support best-effort 1-Mbps or better symmetrical service
Revenue	• Four SPs in first year • Subscriber uptake rates set below analyst forecasts and other examples • Wholesale pricing set to enable affordable retail rates • Price-sensitive subscribers will switch from dial-up and alternative services for price
Operating Expenses	• Nonprofit “sales resources” handle sales to SPs & management of the ongoing relationship • Marketing program funded for brand building, communications, and outreach • Network resources: engineering, architecture included • Wi-Fi cell-mounting rights and electrical costs • Network Infrastructure: maintenance for equipment

Category	Assumptions
	and software • Backhaul & public Internet access: dedicated backhaul with standard network engineering oversubscription design principles • Other expenses: general & administrative and bad debt • Headcount (not included in general and administrative)

Table 2. Business Plan Assumptions

Conclusion

Based on the Mayor's acceptance of the Committee's recommendations and with his approval to move forward, the Committee intends to work with the City of Philadelphia CIO to create the nonprofit, secure funding, issue a request for proposal (RFP) to design, deploy, and manage the network during the first quarter of 2005. The Committee expects that construction of the network will begin in summer 2005 and be completed by summer 2006.

The key to exploiting these networks is planning. The first communities to construct these networks will enjoy a number of important advantages over those that choose to delay or ignore the opportunity. The Committee believes it has done the appropriate planning, is pleased to present the detailed business plan, and is excited about the opportunity that lies ahead.

It is not often that a revolutionary technology comes along with an affordable price point that can meet the needs of such a broad array of stakeholders. Citywide wireless broadband technology will be the foundation for Philadelphia to become a Digital City. Wireless Philadelphia can become a reality—and the world is watching.

City of Philadelphia Profile

Overview

The City of Philadelphia is the center of a diverse economic region that has transformed itself in recent decades from a manufacturing-based economy to one now focused on services, biomedical and pharmaceutical research and development, international trade, education, health care, and information technology.

Philadelphia is a major international port with a significant concentration of oil refining, shipbuilding, and port-related industries. In recent years, the City has developed a strong hospitality industry with the development of the Pennsylvania Convention Center, a large entertainment industry, and three centuries of cultural attractions and institutions including the Philadelphia Museum of Art and the Philadelphia Orchestra and the first zoo in America.

The City has the second largest number of colleges and universities in the nation. Represented in the almost fifty institutions are Philadelphia University, Temple University, LaSalle University, St. Joseph's University, Swarthmore, Villanova, Haverford College, Drexel University, Thomas Jefferson University, and the University of Pennsylvania.

Philadelphia has a long historic tradition. It is the home to the Liberty Bell and Independence Hall, the site of the signing of the Declaration of Independence and the drafting of the nation's constitution. The City is rich in historic preservation as entire neighborhoods are being preserved to provide attractive desirable communities for twenty-first-century living.

It is fitting that Philadelphia take the lead once again by developing the first large-scale urban wireless environment.

Geography

The city-county of Philadelphia is located in southeastern Pennsylvania, at the junction of the Delaware and Schuylkill rivers, and covers approximately 135 square miles. It lies approximately 100 miles inland from the Atlantic Ocean and about halfway between New York City and Washington, DC.

Demographics

The City of Philadelphia has a population of 1,517,550 residents, 590,071 households, and 352,272 families residing in the City. The racial makeup of the City is 45.02 percent White, 43.22 percent African American, 0.27 percent Native American, 4.46 percent Asian, 0.05 percent Pacific Islander, 4.77 percent from other races, and 2.21 percent from two or more races. Eight and a half percent of the City's population is Hispanic or Latino.

The median income for a household in the City is $30,746, and the median income for a family is $37,036. Males have a median income of $34,199 versus $28,477 for females. The per capita income for the City is $16,509. In Philadelphia, 22.9 percent of the population and 18.4 percent of families are below the poverty line. Out of the total people living in poverty, 31.3 percent are under the age of 18 and 16.9 percent are 65 or older.[2]

[2] U.S. Bureau of Census, *2000 U.S. Census*.

Stakeholder Analysis

Process Overview

To explore the feasibility of a citywide wireless network, the Committee decided to collect and align the needs, requirements, and concerns of a diverse set of stakeholders throughout the community. To engage the many stakeholder groups in the planning process, the Committee facilitated several events to collect stakeholder input, including the following:

- Working with area universities and businesses to create a formal plan
- Meeting with community business leaders
- Providing a well-publicized public forum (town hall meeting) for residents to learn more about the initiative and to ask questions
- Setting up a series of focus groups to collect key stakeholders input
- Working with the Philadelphia School Board to understand the needs of families with children throughout the community

With each step, the Committee gained valuable insight to the issues important and relevant to fulfilling its mission. The stakeholder analysis followed a three-step process:

1) Identifying the important and relevant stakeholder issues
2) Gaining feedback from stakeholders within a focus group setting
3) Gathering opinions for current and potential users of a wireless network through a public town hall meeting

The Committee identified numerous stakeholders, considering not only their needs and requirements (the demand side), but also the assets and capabilities they could bring to the project (the supply side). Individuals representing the following groups were invited to participate in focus group discussions to survey their insight, vision and impressions of Wireless Philadelphia.

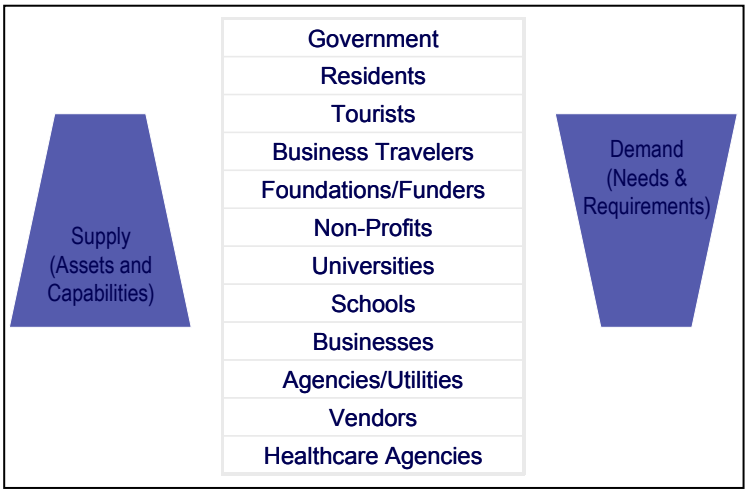


Figure 1. List of Stakeholders

To collect stakeholder input, focus groups were planned and organized by the Committee, Temple University's Fox School of Business and Management, and the Ronin Group. Approximately 110 individuals representing various stakeholder groups participated in the discussions. The focus groups were organized into the following:

- African American Chamber of Commerce: African-American-owned businesses
- Asian American Chamber of Commerce: Asian-American-owned businesses
- Community Network: Organized by the Institute of Civic Values, this group was comprised of civic outreach organizations and social service agencies.
- Greater Philadelphia Tourism Marketing Corporation: Tourism business sector
- Health Care Group: Doctors and medical professionals
- Higher Education: Administrators and faculty from area universities
- Education: Students from various local high schools, colleges and universities
- Hispanic Chamber of Commerce: Local businesses and nonprofit organizations
- Innovation Philadelphia: High tech, early start-up companies
- Greater Philadelphia Chamber of Commerce: Small-business group
- Universal Companies: A private corporation building low-income house and providing education to underserved areas in Philadelphia

The focus group questions were designed to gather input from stakeholders about their perception of the need for a wireless network, potential social and economic benefits, training and educational outreach, funding, sustainability issues, and the outcome of a "do nothing strategy."

The questions were organized into the following four sections:

- Introduction. Participants were asked to describe how they see the impact of technology on future generations. This question focused their participation away from their direct anecdotal experience toward thinking about how technology will be used in the future.
- Vision. Participants were directed to share their vision of a citywide wireless network. What are the benefits? Who are the beneficiaries? What challenges and barriers exist to preclude its success?
- City's Role. Participants were questioned about the appropriate role of the City and of other public and private agencies. Should the City make an investment into wireless communications? Should the government be at all involved in creating a wireless network? Why? Who should be responsible for its creation? What incentives can/should be created to move wireless initiatives forward? What happens if the City does not champion this cause?
- Implementation. The final section explored the details of building a robust, high-performance, scalable wireless network, the necessary training and promotion, and the expense to the user. In this section the facilitator directed each group toward measuring the impact of the network across various stakeholder groups.

Focus Group Survey Results

Participants in the focus group discussions represented views of many stakeholder segments. In addition to their own background with using computers, all brought to the discussion their experiences with different constituency groups; for example, the minority business leaders generated substantial discussion on how to best reach and serve those who live in low-income neighborhoods and may currently not use computers.

Of the approximately 110 individuals who participated, most (approximately 80 percent) are long-time computer users. These respondents have used computers at home and at work for more than five years. Sixty-two percent have wired broadband access to email and the Internet and 21 percent are already using wireless technology. Of this group, there were several people who do not use computers at home or at work; nine percent stated they did not have a computer at home and 4 percent did not have one at work.

Overall, this group is in favor of building a wireless network. 72 percent agree that wireless service will be useful and 93 percent believe that for the way they access the Internet, wireless service will be important. Furthermore, approximately 75 percent believe they will use the proposed wireless service and 92 percent believe it will be easy to access and use. The majority, 75 percent agreed that it was a good idea for the City to create a citywide broadband network.

The wide range of attitude toward technology was not surprising. The respondents were not all early adopters of technology; about one-third believed they are willing to try new technologies, one-third neither agreed nor disagreed with the question, and one-third believed they are not hesitant to try new technologies.

Philadelphia School District Survey Results

Overall Internet penetration in Philadelphia is estimated at 45 percent including 92,552 households with broadband and 173,076 households with dial-up.[3]

During October 2004, the school district distributed 5500 surveys to 60 schools throughout the City for distribution to parents; 1,931 surveys from 45 schools were returned[4]. The survey requested information regarding district families' computer ownership, connectivity access, and training needs. Highlights of the survey are detailed below.

Computer Ownership:

- Approximately 64 percent of households reported owning a computer. The percentage of home computer ownership reported varied from as low as 27 percent to

[3] Pew Internet & American Life Project, U.S. Census Current Population Survey of 2001, Centris Research, Scarsborough Research. Data are current estimates as of October 2004.
[4] Forty-nine schools returned surveys, however, the data sample from four schools was too small to include in this analysis.

as high as 95 percent. Results appear to show an inverse correlation between school poverty levels and percentage of home computer ownership.[5]

- Of those reporting having access to a computer outside of the home, the table below shows the relative frequency of each location selected[6]:

Response (Where do you go to use a computer?)	%
Library	36%
Residence of relative/friend/colleague	24%
School	24%
Work	13%
Other	4%

Home Internet Access:

- Approximately 58 percent of households reported having Internet access at home. The percentage of families having home Internet access varied from as low as 25 percent to as high as 93 percent. Again, results appear to show an inverse correlation between school poverty levels and percentage of home Internet access.[7]

- Of those reporting having access to the Internet outside of the home, the table below shows the relative frequency of each location selected:

Response (Where do you go to access the Internet?)	%
Library	37%
Residence of relative/friend/colleague	24%
School	22%
Work	13%
Other	4%

Computer Usage Trends:

Respondents were asked to provide information regarding their computer usage.

- Approximately 50 percent of respondents indicated that they use the computer to assist their children with their homework.[8]

- Respondents were approximately 2.5 times more likely to use their computer for tasks that required access to the Internet than for tasks that did not require access to the Internet. Approximately 64 percent of selected tasks required Internet access, 24

[5] $Y = -0.796x + 1.2025$, $R^2 = 0.4968$.
[6] Respondents were allowed to give multiple answers to this question.
[7] $Y = -0.8884x + 1.1782$, $R^2 = 0.5485$.
[8] Respondents were permitted to select multiple answers for this question.

percent of selected tasks did not require Internet access, and the remaining 12 percent of selected tasks were undetermined.

Community Training Needs:

- Half of respondents rated their computer skills as intermediate (49 percent), with 20 percent and 27 percent rating their skills as beginner and advanced, respectively.[9] Thirty-six percent had taken some type of computer training class.

- Respondents indicated interest in receiving training in many topics. The top three training needs were homework help (65 percent), computer basics (54 percent), and word processing (43 percent).

Focus Group Session Results

The focus group discussions provided many insights about the issues that are important to stakeholders and those insights served as a key input in the Committee's planning process. Overwhelmingly the stakeholders supported the wireless initiative. The majority echoed a sense of pride related to having Philadelphia be the first major city in the country to deploy a full wireless broadband network.

However, members of each group voiced concern about the large adoption and learning curve on behalf of many residents who have minimal computer literacy skills. Training, troubleshooting and outreach will need special attention with low skilled residents.

Other issues of concern associated with how the City will develop the necessary win-win partnership with private sector companies providing Internet service in the City.

Finally, in all groups, participants expressed concern that the system must stay current with technical standards and new technology.

Overall consensus was that the City is the only entity capable of initiating this work. It was understood that the private sector would not invest in building a citywide infrastructure reaching all neighborhoods. However, stakeholders strongly supported the notion that once the system is operating, the private sector be encouraged to partner with the City.

No one suggested that this initiative was worthwhile if tax revenues would finance the network's operation. Although there was no disagreement about users' willingness to pay for this service, participants could not identify a universal price. There was consensus that there needs to be a sliding scale of user fees to accommodate those who could not pay, but otherwise estimates for billing varied. Many agreed that the top price must be lower than the current price of DSL broadband.

[9] Four percent of respondents did not provide an answer to this question.

All groups expressed their concern that the City will not be able to keep up with the technology. The governing organization for the network must assure that it continues to grow with technological improvements.

Town Hall Meeting

Whereas the focus groups were comprised of Philadelphia community, business, and education leaders, there was still a need for a more inclusive perspective of how the wireless network will be used by residents of the City.

A town hall meeting was held at the Philadelphia City Hall on November 4, 2004. Overwhelmingly, participants supported the Wireless Philadelphia initiative. In general, comments reflected concern over addressing the digital divide by ensuring service and training to underserved populations, concern over ownership and the nature of public/private partnerships, and of the availability of financing for this venture.

Issues related to network ownership and finance created some apprehension in the discussions. Several participants voiced concern that the proposed budget is low for the scale of technology and that the proposal must address financial sustainability. The City was cautioned that in a tradeoff between cost and quality, quality is more important. Also, several comments echoed support for this initiative to be revenue neutral at no cost to the taxpayer.

Ownership of the network was another key area of concern. Two opposing opinions were voiced at the meeting. One group deemed it important for the network to be controlled by the City to assure freedom of expression and open access. Examples of how private ownership in other media has hindered open expression were brought into the discussion. Simultaneously, others support corporate ownership of the infrastructure thereby minimizing demand on the City's tax dollars.

Requirements Analysis

Wireless Philadelphia's intends to augment, rather than compete with, existing fixed broadband solutions such as DSL and cable. Whereas those technologies enable fixed use only, wireless technology provides the added benefit of support for nomadic, portable, and mobile use. See the examples below:

- Tourists and business travelers can benefit from having nomadic access to broadband services while visiting the City.
- City employees can benefit from nomadic and portable services to improve their productivity while performing field services such as surveying, inspections, social work, etc.
- Public safety employees can benefit from having immediate access to information while in the field.
- Residents can benefit from being able to better mix their personal and professional lives by using nomadic and portable access in public areas or on trains and buses.

An overview of the characteristics and relationship between these four categories of broadband service is provided below.

	Fixed	Nomadic	Portable	Mobile
Scenario	Res/Bus	Hot-spot	Cruiser	Cellphone
Provisioned	Address	Subscriber	Subscriber	Subscriber
Motion of Subscriber Unit	None	Little/None	<30 Mph	<100 Mph
Handoff (persistence)	None	None	300 ms (slow)	Real-time
In Motion Quality of Service	N/A	N/A	Degrading	Minimum Degrading

Table 3. Broadband Service Characteristics

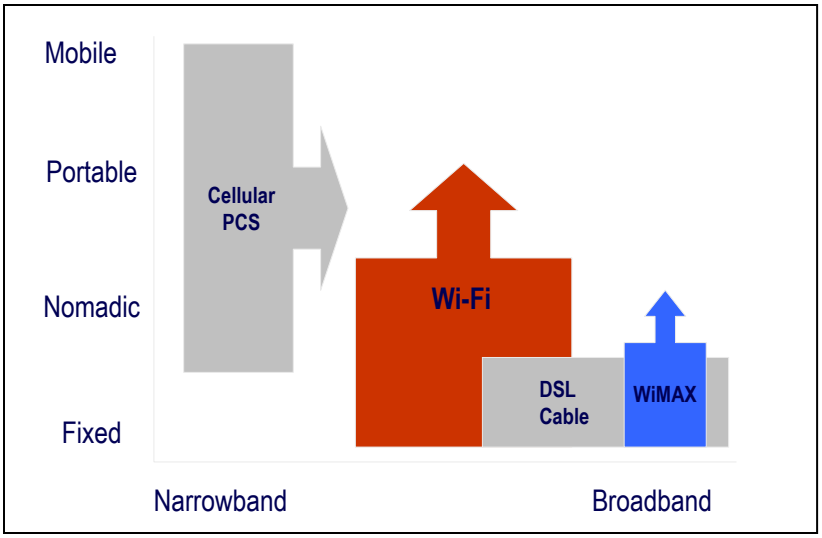


Figure 2. Relationship between Technologies, Service Types, and Performance

Mapping from Stakeholders to Service Requirements

The stakeholder needs listed above can be translated into a specific set of service requirements. The table below summarizes the service criteria in relation to the list of stakeholders. The remainder of this section describes each criterion in more detail.

	Cost	Longevity	Bandwidth	Throughput	QoS	Value Added Apps	Security	Roaming
City Government	✔	✔	✔	✔	✔	✔	✔	✔
Paying Residents	✔	△	✔	✔	✔	✔	✔	✔
Underserved Residents	✔	■	△	△	■	■	■	■
Large Business	△	△	✔	✔	✔	✔	✔	✔
Small Business	✔	✔	✔	✔	✔	✔	✔	✔
Health Care	✔	✔	✔	✔	✔	△	✔	△
Higher Education	✔	✔	✔	✔	✔	✔	✔	✔
K-12 Schools	✔	✔	✔	✔	✔	✔	✔	✔
Non-profits	✔	△	△	△	△	△	△	△
Tourists / Visitors	✔	■	✔	✔	✔	■	✔	✔

Table 4. Stakeholder Requirements

Costs

Cost per unit of usage, cost per user, and cost per potential user should all be considered. Subscription costs should be lower than current cable and DSL subscription costs in order to be competitive, attract users, and benefit the people of Philadelphia. To maximize market share, retail service providers should subsidize any one-time subscriber equipment costs where possible.

Longevity

The longevity of the technology being deployed was considered during the business planning process for Wireless Philadelphia. In the future, the decisions in this area will take into account only those technologies that have a clear roadmap towards standardization and upgradeability, with specific details about future applications and deployments. The financial model developed for Wireless Philadelphia includes a working capital reserve to provide for a complete replacement of the network in a seven to ten year timeframe.

Bandwidth and Throughput

Bandwidth and throughput are both critical for broadband networks. The design criteria for Wireless Philadelphia is to support an average throughput of 1 Mbps per user for standard residential and nomadic access, a rate which is deemed adequate to support typical uses of the network.

Quality of Service

While wireless services operating in license-exempt wireless spectrum cannot guarantee bandwidth and availability, it is important to note that most existing broadband offerings (such as DSL and cable) are often defined as “best effort” services.

The tremendous growth of wireless products and services operating in license-exempt spectrum over the past several years[10] demonstrates that subscribers routinely make tradeoffs between service levels and issues such as cost, convenience, ease of use, and geographic coverage.

Current generations of Wi-Fi and pre-WiMAX technologies can be architected to support prioritization of traffic, allowing voice or video traffic, for example, to receive priority over other data traffic.

[10] See http://telephonyonline.com/ar/telecom_unlicensed_kill_2/

Value Added Applications

The network should enable the development of applications to assist in areas such as public safety, transportation, education, healthcare, e-government, and public works. Examples of these include the following:

- Wireless cameras along with streaming video in vehicles that enable real-time surveillance of high-crime locations and high-traffic intersections
- RFID tags that wirelessly transmit from firefighter or police officer uniforms making the personnel easier to find in an emergency
- Wireless laptops that allow medical professionals to check a patient's records via a wireless network form the patient's home or in transit to the emergency room
- Wireless tracking devices to monitor public bus and subway locations or update schedule information kiosks at bus and subway stops
- Wireless connectivity integrated into parking meters to aid in fee collection, increase productivity, and allow citizens to use e-payment options

The low cost of the network will also save the City money by enabling them to replace their existing high-cost wired services with more cost-effective wireless solutions.

Security

Security of the wireless network was a concern for numerous stakeholders. Wireless networks can be protected through multiple layers of security and can be deployed with the following characteristics.

- Network access control through robust authentication
- Protection of wired assets from malicious wireless clients
- Protection of wireless clients from other malicious wireless clients
- Secure end-to-end transmission of sensitive data
- Secure network configuration and management

Note that the more secure the network is, the more complicated the provisioning process can become. Open access in parks and public spaces should limit the provisioning requirement to confirmation of an acceptable use policy and disclaimer.

Roaming

Roaming is the seamless movement from one access point to another without losing connectivity. Roaming can occur between the same operator's access points or between two or more operator's access points, as in a cellular voice network. Support for roaming is critical to support the emerging needs of field workers, public safety officers, and other groups.

Service Portfolio

Based on the requirements defined during the stakeholder analysis, the Committee recommends the network provide the following portfolio of services. Note that, based on the business model recommendations described later in this report, retail providers may choose to offer some or all of the services listed below and may choose to package or bundle services in innovative ways. Therefore, this should not be considered a comprehensive list of the service options available to all subscribers.

Service Types	Definition	Examples
Residential Fixed & Nomadic Service	Access for a single device, provisioned for primary use at a residence, with access throughout the City. Service features includes basic 1 Mbps symmetrical (upstream and downstream) access, e-mail, web support, etc.	Residential user with single desktop or single laptop, with support for roaming throughout the City[11] Discounted service to be made available to very low-income and disadvantaged subscribers.
Standard Business Fixed Service	Access for multiple devices, provisioned for primary use at a business location. Service features include basic access (services levels may vary by retail provider), email, hosting, etc.	Assumes businesses with <20 employees are target customers
University & Distance Learning Fixed & Nomadic Service	Same as Residential & Nomadic service	Discounted resident and non-resident student access, with same features as Residential & Nomadic
Premium Business Service	Same as Standard Business service plus features such as VPN, firewall, etc.	Assumes businesses with >20 employees are target customers
Occasional Use Nomadic Service[12]	Basic internet access for a daily or weekly fee	Tourists, business travelers
Secure Private Business Portable	Roaming access across city w/ service features such as VPN & firewall	Business customer employees, field workers
Secure Government Portable	Mobile access with service features such as VPN & firewall	Public safety officers, meter readers, surveyors, etc.
Secure Government Fixed	Fixed access with services such as secure (VPN & Firewall) access	Municipal office locations

Table 5. Service Portfolio

[11] Should a subscriber have a network in their home (wired or wireless), the Fixed Residential & Nomadic service will support the ability for multiple networked devices within the home to connect through a single residential access point. Should a subscriber require concurrent use of their residential network and nomadic use, they would require the Standard Business service.

[12] According to Greater Philadelphia Tourism Marketing Corporation (GPTMC), in 2003 24.2 million person-trips were made to the region (including business and leisure travelers). The bulk of the visits were to Philadelphia County. A person-trip is one person traveling 50 miles or more (one-way) away from home and/or overnight regardless of trip length. One person can make multiple trips and be counted each time ([cite GPTMC here, informing us of the type of information (publication? interview? e-mail? website?) and all other relevant information).

Business Model Analysis

Despite the hundreds of communities who have launched citywide wireless initiatives,[13] no consistent business model has emerged. Projects still vary greatly in the areas of funding strategy, governance models, value chain structures, technology approaches, and degree of public-private cooperation.

Description of Candidate Business Models

When considering the appropriate business model for Wireless Philadelphia, the Committee chose to analyze five distinct business models based on each model's ability to meet the defined objectives. A description of each model is provided below.

Public Community
A city, foundation, or coalition funds the design, deployment, and operation of a citywide wireless network and provides free access to all subscribers. This type of model often justifies the cost of the network as an "amenity" for residents and tourists.

Private Consortium
A private telecommunications company (or companies) funds the design, deployment, and operation of a citywide wireless network and charges fees to subscribers for its use. The city provides access to light poles and other city assets (potentially for a fee), agrees to act as an "anchor tenant" for the network, and optionally, negotiates with the private company to "regulate" rates for economically disadvantaged subscribers.

Cooperative Wholesale
A city funds the design, deployment, and operation of a citywide wireless network (which may be accomplished by outsourcing those services to private companies). The City receives value through reduced telecommunications costs by using the network to insource telecommunications services currently leased from private companies (e.g. T1 replacement). The City also makes the network available and charges fees on a wholesale basis to retail Internet Service Providers (ISPs), Wireless ISPs (WISPs), and other private telecommunications companies. Retail providers perform customer acquisition, customer care, technical support, billing, etc.

Public Utility/Authority
A public utility company (city-owned, private, or co-op) funds the design, deployment, and management of the wireless network and charges fees to subscribers for its use. The utility/authority may outsource services to design, deploy, and manage, but would typically leverage their existing resources for subscriber acquisition, customer care, technical support, billing, etc.

[13] See http://www.muniwireless.com

Nonprofit
A nonprofit organization is created and funds are raised through foundation grants, private donations, and in some cases, loans from a city or financial institution. The nonprofit outsources the design, deployment, and management of the network to private companies. The nonprofit may have a social charter to reduce the digital divide and may engage in other activities (coordination of training resources, programs to get PC in the home, etc.)

Analysis of Candidate Business Models

To evaluate which model was most appropriate for Philadelphia, the Committee defined and weighted the importance of several required (must) and desired (want) characteristics. The results of this weighted analysis are shown in the decision matrix below.

Score Legend	1-Poor	2-Weak	3-Average	4-Good	5-Excellent		
Characteristics	Must/Want	Weight	Public Community	Private Consortium	Cooperative Wholesale	Public Utility/Authority	Non-Profit
Free service in parks and public spaces	Must	15%	5	2	4	2	5
Low cost or free for disadvantaged	Must	10%	5	2	3	2	4
Ability to control fees/rates	Must	10%	5	2	3	2	5
Cost neutral for City	Must	15%	0	5	3	3	4
Ability to generate return/profit to City	Must	5%	0	4	3	3	3
Universal access/coverage	Must	15%	5	2	4	3	5
Help revitalize communities	Want	10%	3	4	4	2	4
Ability to respond to technology change	Want	10%	2	4	3	2	3
Service offerings	Want	5%	1	5	3	2	3
Time to set up governance structure	Want	5%	5	2	2	2	3
Total		100%	NA	2.3	2.735	1.79	3.35

Table 6. Business Model Decision Matrix

The above analysis resulted in the following outcomes:

- The Public Community model was eliminated due to its inability to support cost neutrality for the City.
- The Private Consortium model ranked low due to the social impact goals of the City (lower broadband fees made available for economically disadvantaged subscribers) and the inability of the City to influence those retail fees.
- The two high-ranking models, Nonprofit and Cooperative Wholesale, were analyzed further, resulting in the advantages/disadvantages shown below.

	Advantages	Disadvantages
Nonprofit	• Ability to dictate retail price for services • Can be funded through foundation grants and loans • Can engage in programs to accomplish social and economic development charter	• Expensive to operate and maintain due to retail subscriber acquisition, marketing, billing, support, etc. • Little cooperation with the private sector
Cooperative Wholesale (City-owned)	• Increased cooperation with private sector • Creates price competition in the market	• Requirement for government funding • Inability to dictate retail price for services

Table 7. Nonprofit and City-Owned Cooperative Wholesale Comparison

Business Model Recommendation

The Committee recommends that a hybrid business model be adopted, combining the best characteristics of the two high-ranking models above (Nonprofit and Cooperative Wholesale). A diagram and a more detailed description of this hybrid model, which the Committee will refer to generally as the Cooperative Wholesale model, is provided below.

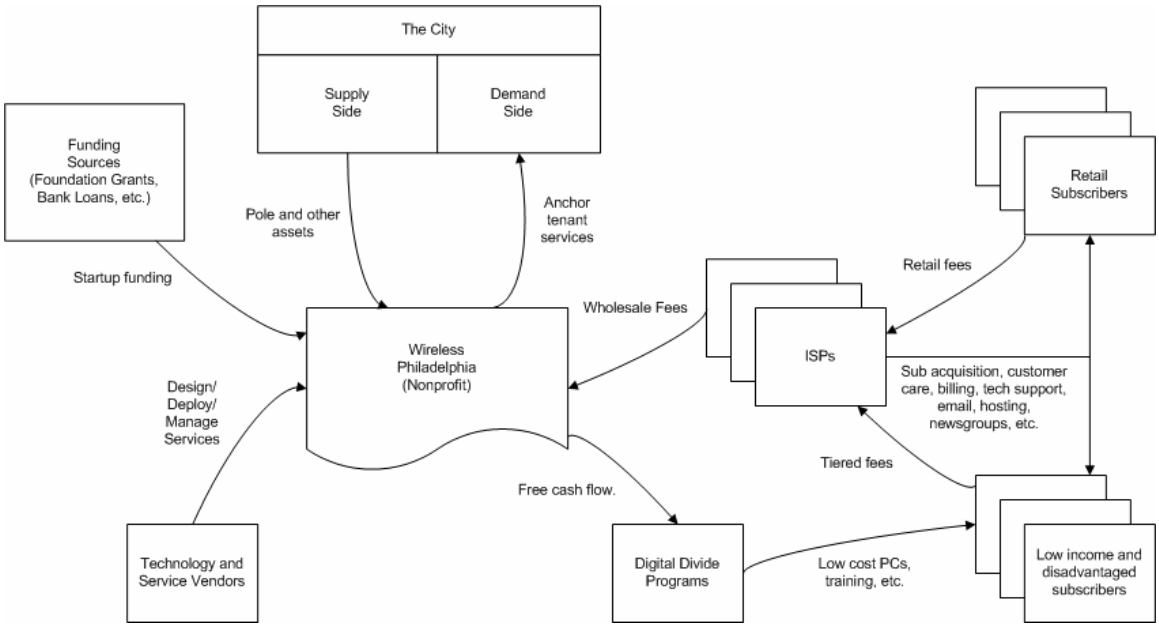


Figure 3. Cooperative Wholesale Model

- As a nonprofit corporation, Wireless Philadelphia receives startup funding from foundation grants, bank loans, and/or other non-public sources.
- The nonprofit, through an RFP process, outsources the design, deployment, and management of a citywide wireless network to private companies.

- The nonprofit makes access to the network available for low wholesale fees to service providers, telecommunications companies, institutions and other nonprofit corporations.
- Service providers market the service to subscribers and provide customer care, billing, technical support, content, and other value added services.
- Service providers make discounted pricing available to low-income and disadvantaged subscribers.
- The nonprofit uses its free cash flow to fund Economic Development and Digital Divide programs aimed at getting PCs into low-income and disadvantaged subscribers' homes and making training programs available to subscribers and businesses, etc.
- The City provides access to City-owned assets such as light poles and electricity.
- The City agrees to act as an "anchor tenant" for services such as nomadic outdoor access for field staff computers/hand held-devices and business-class DSL, T-1 and other basic access needs, where appropriate.
- The City transfers ownership of all relevant intellectual property (IP), trademarks, copyrights, etc., to the nonprofit as required to support the Business Plan.

Cooperative Wholesale Example

UTOPIA is a consortium of 14 Utah cities engaged in deploying and operating a wholesale network to every business and household (about 140,000) within its footprint. Operating at the wholesale level, it supports open access and promotes competition in all telecommunications services.

On 29 July 2004, UTOPIA secured $85 million in revenue bonds to finance Phase I of the network that will serve residents of 11 pledging member cities.

Source: http://www.utopianet.org/

Benefits of the Hybrid Model

- Creates an alternate broadband network at a low capital-cost-per-home-passed.
- Promotes lower broadband pricing through low wholesale rates and increased competition.
- Enables private sector service providers, telecommunications companies, institutions, other nonprofit corporations and local and minority businesses to launch new added-value services.
- Demonstrates a high degree of cooperation with the private sector.
- Creates cost savings for the City by aggregating their demand for certain services.
- Eliminates the need for Wireless Philadelphia to build expensive, high-cost services such as customer service, retail billing, and retail technical support.

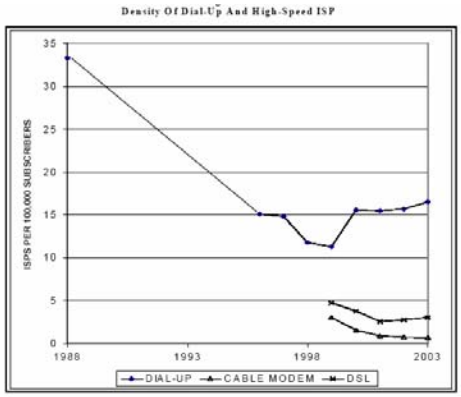
In addition to regional and national ISPs, the Committee expects wholesale access to the network to benefit local ISPs throughout the City. According to www.findanisp.com, an Internet directory of ISPs, 430 dial-up ISPs operate in Philadelphia.[14]

[14] See http://www.findanisp.com/isps/PA/philadelphia/16850/

In summary, the Committee believes the Cooperative Wholesale model is unique in its ability to accomplish the social goals of Wireless Philadelphia, while at the same time promoting competition in and enabling rapid growth broadband access. Rather than attempt to enforce government regulation of broadband pricing, the Committee believes that the availability of an alternative, low-cost broadband network and an increase in the amount and intensity of competition will result in more affordable broadband services.

On this point, Dr. Mark N. Cooper, director of research at the Consumer Federation of America, notes:

> "Approximately 95 percent of high-speed Internet access service customers are served by ISPs affiliated with either cable companies or telephone companies. This dominance is not the result of winning in a competitive market; it is the result of leveraging control of physical facilities.



Source: Dr. Mark N. Cooper

> Cable companies have not sold Internet service in any product and geographic market where they do not control a monopoly wire. Telephone companies have done very poorly as ISPs in the dial-up market. Consequently, 95 percent of the customers in the dial-up market take their service from independent ISPs—treating AOL as an independent in the dial-up market. In other words, incumbent monopolists have a 95 percent market share where they can leverage their market power over their wires, and a 5 percent market share where they cannot".[15]

Nonprofit Charter and Governance

[15] Mark N. Cooper, "Anticompetitive Problems of Closed Communications Facilities," quoted in "Open Communications Platforms: Cornerstone of Innovation and Democratic Discourse in the Internet Age," *Journal of Telecommunications and High Technology Law* (2003).

The charter of the Wireless Philadelphia nonprofit will be to achieve the goal of providing low-cost, high-speed, reliable wireless access throughout the City to enhance economic development in neighborhoods, expand the use of technology in all of the City's neighborhoods, and thereby improve quality of life for all Philadelphians. The Committee proposes the following organizational structure. The nonprofit will be governed by a Board of Directors (Board). The Board will be responsible for critical decision-making, fiscal management, operations, policy setting, and program planning. The Mayor of the City of Philadelphia will designate the initial eleven-member Board, one of which will be the chief information officer (CIO) for the City of Philadelphia. Board members will initially have varied multi-year terms and the CIO will serve ex-officio.

The Board will endorse a strict program compliance and ethics policy that require a minimum annual filing disclosure by each member. The Board will require an annual financial accounting audit conducted by a certified public accounting firm.

Nonprofit Leads Wireless Neighborhoods

In Pittsburgh, a collection of nonprofits developed a Wi-Fi network out of necessity after a local cable company's plan to lay fiber lines that would bring high-speed Internet access to community groups hit a snag.

More than 30 Pittsburgh-area nonprofits have signed on as network members, provided by Wireless Neighborhoods, which is the offspring of a working group of several area nonprofits that first got together to talk with the city and the cable company during the late 1990s. It's a partnership of several organizations including Three Rivers Connect and Information Renaissance, said Stephen MacIsaac, executive director, Wireless Neighborhoods.

The group has received important funding from the Heinz Endowments and state grants.

Source: NonProfit Times. See http://www.nptimes.com/Nov04/npt3.html

Board Charter

The Board will be charged with overseeing the establishment of measurable goals and objectives against the approved Wireless Philadelphia Mission Statement. The Board will have the authority to conduct and monitor the following:

(1) Financial management
(2) Oversight and management of initial installation and ongoing operations
(3) Policy setting
(4) Program planning
    i. Expand access to technology across all populations of the City
    ii. Promote tourism and other economic development
    iii. Empower neighborhoods to improve their communities through the use of technology
    iv. Reduce costs of government

v. Support low cost, universal wireless access for all

(5) Fundraising

The nonprofit will be responsible for developing a detailed financial plan and five-year budget, including additional detail on how free cash flow will be allocated towards core objectives like economic development and digital divide programs.

Note: Innovation Philadelphia, an existing Philadelphia-based nonprofit with a mission to enhance the global innovation economy of the City through technological leadership, has extended an offer to incubate Wireless Philadelphia to speed startup operations.

Additional operating details of the nonprofit's governance structure are included in Appendix F.

Financial Model

A comprehensive return on investment (ROI) analysis on the Committee's proposed Cooperative Wholesale business model demonstrates that a $10 million investment to deploy a citywide wireless broadband network will result in broadband access at dial-up prices and provide positive financial results. Through conservative assumptions, the model estimates that the nonprofit will break even in year 4, build $4 million of working capital reserve for network upgrades and generate $5 million in free cash flow to support digital divide programs.

This section provides a summary of the key model inputs and outputs that provided these results, including assumptions, revenue projections, cost estimates, cash flows, and a summary ROI.

Assumptions

- Wireless Philadelphia is a nonprofit, wholesale ISP deploying, owning, and operating a citywide wireless network.
- Best effort 1 Mbps or better symmetrical services is provided to residential subscribers through a ubiquitous deployment of Wi-Fi access nodes.
- A point-to-multipoint (pre-WiMAX) wireless and dedicated access infrastructure provides backhaul for 60 percent of the Wi-Fi network. Leased line services such as business-class DSL and T-1 provide the remaining 40 percent of the mesh backhaul.
- Free-access zones will exist in various parks and public spaces.
- The wholesale services include basic access and Tier 2 customer care.[16]
- The network must be cost neutral to the City.

Capital Expenditures

Capital expenditures are designed to be conservative. This is achieved by assuming limited discounts from any type of service or equipment provider and scaling equipment based on subscriber demand to support a quality end-user experience.

- The network will pass the 560,500 homes in Philadelphia at an estimated cost of $10 million (a capital cost of less than $19 per home passed) over five years.
- Capital expenditures include: NOC/POP,[17] Wi-Fi equipment, point-to-multipoint backhaul equipment and network design and deployment services.
- Year 1 capital expenditures will be sufficient to ensure a high-quality subscriber experience. For the business model to be deployed, $10 million is required in year

[16] Wireless Philadelphia's retail ISP customers will own the relationship with the end subscriber. In this scenario, the retail ISP acquires subscribers, bills subscribers, provides customer premises equipment (CPE), and provides other services such as Tier 1 customer care, e-mail, newsgroups, etc.
[17] Network Operations Center/Point of Presence includes servers, routers, switches, billing software, network management software, etc.

1 and $500,000 in years 2–5. Through a 10 percent of revenue working capital reserve, the business funds an additional $4 million in capital to support network upgrades and expansion.
- A spare equipment pool of 5 percent exists for the Wi-Fi and pre-WiMAX backhaul networks.
- Funding to launch the nonprofit is assumed available through foundation grants and/or bank loans at 8 percent per annum.

Revenue and Subscriber Acquisition

- Wireless Philadelphia will provide a multi-use network supporting the services described earlier in the Service Portfolio section.
- The financial model assumes Wireless Philadelphia contracts with four service providers in the first year and an additional three service providers in the second year. Target customers are those organizations seeking a migration strategy for their current base of dial-up subscribers, seeking to extend their network, or seeking to provide nomadic services. To be conservative, no further assumptions exist for the generation of revenue from the hundreds of other local ISPs currently doing business in Philadelphia.
- Pricing is set as low as possible to: (1) encourage lower broadband prices and create competition in the market, (2) meet economic development project funding objectives, (3) ensure the nonprofit business breaks even by the fourth year, and 4) ensure sufficient working capital is generated for future network upgrades. The pricing selected is designed to meet these goals and to allow service providers to provide a competitive offering after adding their costs and margins.

Retail Competitive Service Pricing	Projected Wholesale Rates	Competitive Alternatives	Target Retail Price (mo)	Competitive Retail Price (mo)
Residential Fixed & Nomadic	$9.00	Dial-up, Dial-up w/ accelerator, cable, DSL	$16–20[18]	$10–55
Standard Business	$30.00	Asynchronous DSL	$50–60	$120+
Premium Business[19]	$100.00	T1 w/ local loop and ISP	$150	$300+
University & Distance Learning Residential Fixed & Nomadic	$9.00	Dial-up, Dial-up w/ accelerator, cable, DSL	$12–16	
Occasional Use Nomadic	$4.50	T-mobile Wi-Fi, Hotel Accounts	$10/week	$10–15/day
Secure Gov. Portable	$27.50	CDPD, 1xEV-DO	N/A[20]	$40–80

[18] Discounts may be provided for very low-income and disadvantaged subscribers.
[19] The Premium Business and Secure Government Fixed services will bypass the Wi-Fi network and be serviced directly from the pre-WiMAX base stations.
[20] The nonprofit will provide the Secure Government services at the wholesale price. The City will provide Tier 1 help desk support, with calls escalated to the nonprofit for Tier 2 support.

Retail Competitive Service Pricing	Projected Wholesale Rates	Competitive Alternatives	Target Retail Price (mo)	Competitive Retail Price (mo)
Secure Government Fixed	$100.00	T1 w/ local loop and ISP	N/A[21]	$200+/month

Table 8. Service Pricing

- Acquisition of residential subscribers is expected from all types of households (i.e. dial-up subscribers, broadband access subscribers, and non-internet households).
- Based on input from industry sources,[22] citywide wireless service can expect a residential subscriber churn rate below competing Internet services.
- Service providers are expected to enjoy the benefits of incremental average revenue per user (ARPU) through the addition of enhanced services. The model makes no assumptions with respect to the revenues charged the service provider for the additional network traffic/infrastructure associated for these services.
- The table below outlines subscriber assumptions and initial ARPU. Based on the ability to drive a price penetration strategy of broadband at dial-up prices, the total subscriber acquisition equates to 13 percent of city homes in year 1 and grows to 22 percent by year 5.

Subscribers Analysis	Subscribers (K)				
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Residential & Low-Income	77.9	108.0	117.3	124.3	129.6
Standard Business	0.8	2.1	3.4	4.8	5.3
Premium Business	0.1	0.2	0.3	0.3	0.3
University & Distance Learning Fixed & Mobile	2.6	4.1	6.0	7.9	8.8
Occasional Use—Nomadic	3.6	3.6	3.6	3.6	3.6
Secure Government Portable	0.3	1.0	1.7	2.4	3.0
Secure Government Fixed	0.1	0.1	0.2	0.2	0.3
Total Subscribers	85	119	133	144	151

Table 9. Subscriber Analysis

With these low wholesale prices, the expectation is that service providers will be able incorporate the costs of the additional functionality described above, margin and still charge less than $20/month for retail residential services.

The price penetration strategy and nomadic aspects of this service make penetration rates of 13–22 percent achievable.

[21] Ibid.
[22] Interviews with service providers and industry analysts.

Wall Street Journal/Harris poll projects 65 percent of the homes nationwide have Internet access. Various analysts such as Pew, Goldman Sachs, Yankee Group project that 29 percent of broadband subscribers and 55 percent to 75 percent of dial-up subscribers will switch for price. Simple averaging of these price sensitive subscribers suggests a 27 percent penetration should be achievable.

At a $15.99 price per month, Chaska MN, through their Chaskanet citywide Wi-Fi initiative, achieved a 20 percent homes passed penetration in the first month.[23] Note that wired competitive broadband services were also available. By analysts forecast and Chaskanet's experience, the 13 percent penetration rate is very conservative.

Operating Expenditures

The operating assumptions are designed to ensure a high-quality user experience from both a network perspective and a Tier 2 customer perspective. Low operating expenses are enabled by the low capital costs for homes passed and backhaul infrastructure. Supporting assumptions are listed below.

- Headcount is included to support 7/24/365 Tier 2 Network Operation Center, network engineering, deployment, and architecture at fully loaded costs with year-over-year cost of living allowances applied. A sufficient number of headcount are included to support a network covering 135 square miles, 3,000 core network devices and 200,000 subscribers.
- Sales resources are budgeted to support service provider acquisition and to manage the ongoing relationship.
- Wi-Fi cell mounting rights and electrical costs are included.
- Monthly maintenance for equipment and software are included after year one.
- Backhaul is provided for the Wi-Fi access nodes through a combination of point-to-multipoint (pre-WiMAX) wireless and dedicated access.
- The model contains standard network engineering oversubscription design principles for backhaul and public Internet peering.
- Expenses such as general, administrative, and bad debt are included.
- Reasonable marketing and communications expenses are included to help build the wholesale brand. An assumption is made that the products will be co-branded with retail providers with retail service providers supplying funding for advertising and other marketing related programs.

Results

The business model demonstrates the ability for a citywide wireless network to deliver broadband access at dial-up prices and provide positive financial results. Through

[23] See http://www.chaska.net

conservative assumptions, the model estimates the nonprofit will break even in year 4 while building $4 million of working capital reserve network upgrades by end of year 5.

The table below demonstrates the nonprofit Earnings Before Interest, Tax, Depreciation and Amortization (EBITDA) will be positive in year 1, cash flow positive in year 2, and break even in year 4.

Summary Economics	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Revenue ($M)	$8.2	$11.6	$12.9	$14.0	$14.5	$61.1
Operating Expenditure ($M)	$5.7	$8.1	$8.2	$8.4	$8.3	$38.6
EBITDA ($M)	$2.5	$3.5	$4.7	$5.6	$6.1	$22.5
Net Income ($M)	($0.9)	$0.1	$1.3	$2.1	$2.6	$5.2
Capital Expenditure ($M)	$10.0	$0.2	$0.1	$0.1	$0.0	$10.5
Working Capital Reserve ($M)	$0.0	$0.1	$1.3	$1.4	$1.4	$4.2
Free Cash Flow ($M)	($9.0)	$2.4	$2.8	$4.1	$4.7	$5.0

Table 10. Summary Economics

- Economic Development and Digital Divide programs: The financial model provides up to $5 million of free cash flow for economic development and digital divide programs (e.g. PCs and training for low-income and disadvantaged individuals and small businesses). Additional digital divide project funding may be achieved through grants or by working with the retail ISPs to provide incentives.
- Cost savings: Additional cost savings in the financial model may be gained through vendor negotiations, nonprofit grants, and utilization of other shared City resources.
- Future revenues: Additional low-cost, high-margin revenues are not included. Examples include value-added services, roaming settlements, and higher-speed bandwidth tiers.

Outcomes and Measurement Criteria

Based on the defined goals of Wireless Philadelphia, the Committee recommends the following measurements be used by the nonprofit to gauge success towards achieving these goals.

Category	Outcome
General	Provide high-speed, low-cost broadband access for all residents and businesses
Social and Education	Free Cash Flow ($5M) supports 10,000 digital divide homes with the following: • Personal computers ($150–200 each) • PC and access training (8–10 hours per person) • Broader access to training and educational content • Improved parental involvement in student education
Small Business—Economic Development	Provide 25 training classes for minority, women-owned, disabled and other small businesses through cooperation with local chambers and other nonprofits • Internet use • Website development • Effective on-line marketing
Nonprofit—Outreach	• Distribute quarterly newsletters to various nonprofits and align charters • Work with content providers to develop local community portals • Work with other nonprofits to develop and deliver additional training
Intangible	Improve image of Philadelphia as a Digital City

Table 11. Outcomes and Measurement Criteria

Marketing and Communication Plan

Wireless Philadelphia intends to build key informational messages for distribution to multiple stakeholders informing, educating, and familiarizing them with the benefits of the Wireless Philadelphia initiative through key marketing and public relations programs.

The following tactics will be deployed to solicit support, buy-in, and to educate the citizens of Philadelphia about the benefits of the new Wireless Philadelphia project:

- Promote the project to the media with a full calendar of events including well-defined milestones and goals.

- Bridge the digital divide in neighborhoods by identifying the City's key community newspapers, fliers, newsletters, and block or neighborhood meetings as a means to deliver key Wireless Philadelphia messages. Identify neighborhood organizations to assist such as Philadelphia's Association of Community Development Corporations, citywide after-school programs, the Honickman Learning Center, as well as many other neighborhood programs.

- Promote Philadelphia's leadership in the use of wireless broadband technology through a concentrated marketing and advertising campaign to position Philadelphia as one of the leading digital cities in the world.

- Create strategic partnerships with select partners, vendors, and organizations to co-promote Wireless Philadelphia through joint marketing programs. Identify key investors to support, fund, and sponsor the Wireless Philadelphia initiative.

- Solicit and submit funding grants (seed capital/start-up) to the William Penn Foundation, Rockefeller Foundation, Pew Charitable Trust, the Philadelphia Foundation, the Annenberg Foundation, the Cigna Foundation, the Rohm Hass Contributions Program, PECO Energy, and the Samuel Fels Funds.

- Create co-marketing programs with service providers, locally, regionally, and nationally that are currently involved with providing Internet services.

- Seek sponsorship funding, marketing support, and equipment donations from regional and national companies including SAP America, Lockheed Martin, Unisys, Siemens, Vanguard, Advanta, IBX, Aramark, Towers Perrin, UPS, Cigna, local media (TV, radio, and print), Microsoft, professional sports teams, Southwest Airlines, Dell, Hewlett Packard, Sprint, and Advanta.

- Create a citywide outreach and public relations campaign to inform, educate, and communicate the impact of the Wireless Philadelphia initiative to the citizens of Philadelphia, public and private leaders, stakeholders, and the media.

Additional details on tactical marketing programs are included in Appendix F.

Political and Regulatory Analysis

There appear to be no external significant political and/or regulatory barriers to the Wireless Philadelphia project. There is general support for the aims of the project at the state and national level. Verizon, which has certain rights under recently enacted legislation, has agreed in writing to waive those rights, and all other regulatory bodies are local. If the City chooses to proceed with this initiative, it likely will be able to do so without regulatory impairment.

National Landscape

The White House publicly supports the rapid and universal deployment of affordable broadband access in America. On March 26, 2004, President Bush called for universal broadband access throughout the United States by 2007.[24] The President also stressed the importance of having competition among broadband providers to foster innovation, increase availability, and lower costs to end-users.[25]

The Federal Communications Commission (FCC) has stated that wireless in general and WiMAX specifically "has the potential to alter and further accelerate the evolution of broadband services."[26] FCC Chairman Michael Powell convened the Wireless Task Force in May 2004 to "study existing wireless broadband polices and make recommendations for possible improvements to promote the growth of both licensed and unlicensed wireless broadband services…and to provide increased competition in areas that already have access to broadband."[27]

The FCC has taken the following steps to encourage wireless broadband deployment:

- Increases the availability of unlicensed spectrum
- Streamlined the spectrum license application process
- Allowed higher power limits for wireless broadband networks in rural areas[28]

State and Local Landscape

In the last two years, more than thirty-one cities have deployed wireless broadband networks for public use and hundreds of cities have announced similar plans.[29] This trend has led to debate in many state legislatures and courtrooms about whether local governments should have the ability to provide such networks in "competition" with the

24 See http://www.heritage.org/Research/Regulation/hl852.cfm
25 See http://www.whitehouse.gov/infocus/technology/economic_policy200404/innovation.pdf
26 Jack Richards and Kevin Rupy, "WiMAX: The Next Big Step in Wireless Broadband?" *Keller & Heckman Report*, November 29, 2004, 3
27 See http://www.fcc.gov/wbatf/Welcome.html
28 Richards and Rupy, "WiMAX: The Next Big Step in Wireless Broadband?," 16–17.
29 Esme Vos, president of Muniwireless.com, quoted in Muniwireless.com, http://www.muniwireless.com.

private sector.[30] Currently, at least fifteen states have laws restricting in some way municipalities' ability to provide telecommunications and/or broadband services.[31]

Laws banning local governments from providing these services have been ruled constitutional. On March 24, 2004, the United States Supreme Court ruled that states could ban municipal governments from providing telecommunications service in *Nixon v. Missouri Municipal League*.[32] The Court found that a Missouri statute prohibiting local governments from providing telecommunications services did not violate the Communication Act, which states that "no state or local statute or regulation, or other State or local legal requirement, may prohibit or have the effect of prohibiting the ability of any entity to provide any interstate or intrastate telecommunications service."[33]

Pennsylvania House Bill 30

In the Pennsylvania legislature, House Bill 30 proposed restrictions on local political subdivisions planning to provide broadband service for a fee in section H:

> (1) Except as otherwise provided for under paragraph (2), a political subdivision or any entity established by a political subdivision may not provide to the public for compensation any telecommunications services, including advanced and broadband services, within the service territory of a local exchange telecommunications company operating under a network modernization plan.
>
> (2) A political subdivision may offer advanced or broadband services if the political subdivision has submitted a written request for the deployment of such service to the local exchange telecommunications company serving the area and, within two months of receipt of the request, the local exchange telecommunications company or one of its affiliates has not agreed to provide the data speeds requested. If the local exchange telecommunications company or one of its affiliates agrees to provide the data speeds requested, then it must do so within 14 months of receipt of the request.
>
> (3) The prohibition in paragraph (1) shall not be construed to preclude the continued provision or offering of telecommunications services by a political subdivision of the same type and scope as were being provided on the effective date of this section.[34]

[30] Douglas Jarrett and Kevin Rupy, "Municipal Interests in an Evolving Federal Broadband Policy," *NATOA Journal of Municipal Telecommunications Policy* (Spring 2004): 1–5 (See http://www.khlaw.com/admin/pubs/documents/Jarrett-Rupy%20Article.pdf
[31] See http://www.civitium.com/states.htm
[32] See http://www.techlawjournal.com/topstories/2004/20040324b.asp
[33] Ibid.
[34] See http://www2.legis.state.pa.us/WU01/LI/BI/BT/2003/0/HB0030P4778.pdf

- House Bill 30 was initially introduced to the Pennsylvania State House on April 23, 2003.[35]
- It passed the House on November 25, 2003, and was submitted to the Pennsylvania State Senate.[36]
- The Senate passed the bill on November 18, 2004, and the conference committee agreed on the final version on November 19, 2004.[37]
- Governor Edward Rendell received House Bill 30 on November 20, 2004, and signed it into law on November 30, 2004.[38]
- Before Governor Rendell signed House Bill 30, the City engaged Verizon in negotiations over its waiver of its right of first refusal. Verizon agreed to the City's demands for specific assurances. Following the adoption of the act, Verizon formally waived its statutory right.[39]

Impact to Wireless Philadelphia

Although many observers predicted that House Bill 30 would derail the Wireless Philadelphia initiative, the City and the Committee remained committed to the project. As a result, the City reached a written compromise with Verizon Communications in which they waived their right of first refusal, thereby allowing the Wireless Philadelphia initiative to move forward.[40]

Furthermore, the Committee's recommended business model results in no unfair competition from municipal providers, an issue that concerned supporters of House Bill 30. In fact, the Cooperative Wholesale model promotes direct delivery of services from the private sector to subscribers, while at the same time promoting competition in the market.

[35] See http://www.legis.state.pa.us/WU01/LI/BI/BH/2003/0/HB0030.HTM
[36] Ibid.
[37] Ibid.
[38] Ibid.
[39] See http://www.prnewswire.com/cgi-bin/stories.pl?ACCT=109&STORY=/www/story/12-01-2004/0002555963&EDATE=
[40] See http://www.philly.com/mld/philly/business/technology/10309583.htm?1c

Best Practice Analysis

Other City Projects

Numerous cities and metropolitan areas in the United States and elsewhere have announced or implemented projects to deploy wireless technologies citywide. The following section provides a summary of the lessons learned from these initiatives, with a focus on factors that are most relevant for Philadelphia. In addition to this summary, Appendix C includes further detail on the twenty-five referenced projects, including the following characteristics:

City	Consumer price
Country	Sponsor
Population	Objectives
Size	Model
Target	Technology
Timeframe	Drawbacks
Status	Notes
Cost	Contact

The majority of the projects identified are in the United States, although there is considerable interest and activity worldwide. Overall, most projects are in the planning or development stages. Several have been completed and are in full operation.

The table below provides a high-level summary of each project based on criteria identified as being most relevant for Philadelphia.

CITY/BEST PRACTICE	LARGE GEOGRAPHIC AREA	GEOGRAPHIC CHALLENGES/ INTERFERENCE	INNOVATIVE FINANCING MODEL	FREE INTERNET	SMALL STAFF SIZE	LOW BUDGET	STEP TOWARD BRIDGING DIGITAL DIVIDE	PARTNERSHIPS	SECURITY
Atlanta GA	X								
Austin TX			X	X	X	X	X		
Benton County WA									X
Boston MA				X				X	
Chaska MN									
Cleveland OH				X					
Grand Haven MI		X		X					
Las Vegas NV		X						X	
Los Angeles CA	X								
Marion IN							X		
Paris, France	X								
Pittsburgh PA					X				

CITY/BEST PRACTICE	LARGE GEOGRAPHIC AREA	GEOGRAPHIC CHALLENGES/ INTERFERENCE	INNOVATIVE FINANCING MODEL	FREE INTERNET	SMALL STAFF SIZE	LOW BUDGET	STEP TOWARD BRIDGING DIGITAL DIVIDE	PARTNERSHIPS	SECURITY
Rio Rancho NM	X						X		
San Diego County CA	X								
San Francisco CA		X		X			X		
Seattle WA		X							
York County PA	X			X					

Table 12. City/Best Practices

Appendix C also includes a more detailed analysis of four selected cities: Grand Haven MI, Rio Rancho NM, Las Vegas NV, and Houston County GA.

There are several traits that differentiate these projects. These traits are listed below, and the remainder of this section describes them in more detail.

- Type of applications
- Motivation for starting the project
- Underlying assumptions
- Implementation
- Cost
- Challenges

Type of Applications

Public Safety Applications
Wireless networks are used increasingly by public safety organizations. Police, fire, and ambulance departments benefit through the ability to prioritize mission critical traffic. Some of the benefits include augmenting security, improved response rates, and improvement to the existing backup communications network in disaster scenarios.

Large cities, such as New York and Los Angeles, have announced plans for wireless broadband networks to serve specific needs such as public safety.

Mobile Public Safety Example

Police officers in the city of San Mateo use high-speed wireless computer access in squad cars to give them instant access to key information that, they hope, will speed up the crime-solving process. Nearly every police unit in the city of San Mateo has been outfitted with high-speed wireless computing technology.

Lieutenant Hoss of San Mateo's Police Department says, "We can bring in information from sex offender data bases, gang member information, everything that an officer would normally have in the station is now in the patrol car". He can make up photo lineups to show to victims of crimes at the scene, or he can go out on the Internet to access organizations like the Polly Klaas Foundation.

The network is secured with several layers of protection. Police computer tech Larry Allhands says, "If somebody does try to hack into the system, then they'll hit another layer and each layer has intrusion detection so we can catch someone as they're trying to come in."

Source:

Voice Communications and Other Value Added Applications

Cities are increasingly offering applications such as voice communications over their wireless networks. This is especially true in underdeveloped areas where no adequate fixed line telephone service is available and in countries where mobile operators charge high rates for voice and data communications (e.g. roaming charges).

License-exempt citywide networks are a low-cost way to switch customers from fixed line and mobile operators. For example, Grand Haven, Michigan, is offering mobile voice-over Wi-Fi telephone service over its network. Within the next few months, unlimited voice-over Wi-Fi will be offered at an expected cost of $29.99.

Education

Another area where wireless networks have a significant impact is education. All levels of education are enhanced through these projects by offering anytime, anywhere learning. The wireless project of Rio Rancho, New Mexico enables virtual classrooms at the college and university level, resulting in increased enrollment. At the K-12 level, the networks provide an easy way for parents to communicate with teachers by allowing them to be more involved with their children's education and improves enrollment, producing a more educated community.

Motivation for Starting the Project

Bridging the Digital Divide

Wireless broadband networks provide an opportunity to bridge the digital divide. This is one of most common reasons for these projects as they offer low-cost broadband to areas where no service is currently available. Urban renewal plans benefit from this availability by attracting people to formerly undesirable areas.

When used correctly, the wireless network provides an easy-to-use communication tool while enhancing the quality of life of citizens in the area. Such a network can allow citizens to gain information, debate political issues, and participate in political processes

more easily. An example of such a network is Philadelphia's current wireless network at the Philadelphia Emergency Center (PEC). They have set up networks in houses, housing developments, and neighborhoods to enable residents to take advantage of shared networks.

Increased Convention Center Access
Cities want to increase their popularity as a tourist, convention, and business destination, which should result in a boost to the city's economy. Philadelphia's Convention Center deployed a wireless network two years ago and now provides free access in public spaces within the center, with a modest fee charged in the exposition area.

Economic Development
Cities such as Austin, Grand Haven, and Marion have set objectives for their wireless projects to attract businesses to the area. In Cleveland, Ohio, city workers demonstrate improved productivity and are more inclined to stay downtown during their lunch hour, thereby helping support local businesses.

Underlying Assumptions

Underlying most of the identified projects are an assumption that the City can offer wireless networks relatively easily. For example, by installing antennas on privately owned lampposts, traffic lights, and water towers as well as at subway stations, on public buildings, and at schools and libraries. A dense combination of antennas covers a broad area (citywide access) and antennas placed in high locations transmit signals out to these antennas to provide end user access.

In addition to their ease of installation, most cities recognize that standards-based equipment, volume manufacturing, and license-exempt spectrum have lead to lower cost for implementation.

Implementation

In many cases cities, counties, vendors, and nonprofit corporations have owned, managed, and/or supported the networks. In Austin, for example, a nonprofit takes equipment donations from manufacturers and resellers as well as from strategic alliances with businesses and public agencies to educate, advise, enable, and assist operators of public spaces in providing free wireless hotspots in Austin and the surrounding areas.

Concerning deploying the network, there have been cases in which the city set up the network, a local resident sets up their own networks with support from the city, and vendors have stepped in when asked. SFLan in San Francisco encourages consumers to buy their own equipment and install it on their rooftop to provide free access to their neighborhood.

Rural projects provide the most cost-effective method for delivering wireless broadband. Wireless costs less than wired alternatives for last-mile connectivity. York County,

Pennsylvania, saves $200,000 in annual communications costs by replacing wired T-1 with wireless.

Costs

In most cases, the initial goal was to offer free wireless broadband access to everyone. In a few cases this goal has been achieved, but most were quickly changed. Most of the networks now require a subscription to gain access. In order to stay competitive and draw customers, the subscription price must be less than currently charged by cable/DSL providers. Fees vary from project to project depending on the size and location of the network. Currently, consumer prices are as follows:

- As low as $5 for low speeds
- A maximum of ~$35 for DSL level speeds (384+ Kbps)
- Typically around ~$100 for higher speeds (1 Mbps)

For example, Grand Haven, Michigan, charges $20 for residential service with an option to add nomadic citywide access for an additional $5 and a one-time $149 antenna fee. The majority of the networks require an antenna be mounted on the building for indoor access. Tourists and business/convention visitors are offered day passes to permit access to the network for a limited time period. Many factors determine the cost of installation of the network such as population size and density, physical size of the area, and topology.

Challenges

- Different approvals are needed from several different organizations
- Right of way challenges
- Thousands of access points are needed to cover a full metropolitan area
- Line of sight is required for certain technologies
- Interference from other Wi-Fi networks, cordless phones, microwaves, and other devices that use same frequency spectrum

Summary of Best Practices

Few projects have been planned on the scale of Philadelphia, and to date, most large-scale geographic deployments have been limited to rural communities. Key observations include the following:

- The primary justifications and target use for most applications is to service underserved populations and for public safety.
- Access is typically citywide or countywide, but on a small scale.
- Countywide access projects typically have a low density of users.
- The appeal of an always-on broadband connection is now widespread and is no longer the domain of the privileged tech-savvy few.

- The most cost-effective way to deliver such services is through license-exempt wireless networks (low cost, low maintenance, easily deployed).

The implications for the Wireless Philadelphia project are listed below.

- There will need to be substantial involvement by the City to ensure that the project gets off the ground and that underserved populations are targeted.
- A public-only or a private-only implementation will find it difficult to overcome potential regulatory, implementation, financing, costing, technical, and management hurdles.
- A hybrid public/private implementation, such as the Cooperative Wholesale model described above, holds the most promise.

Technical Analysis

Introduction

Wireless broadband technologies have rapidly developed in the last few years so that it is now feasible to envision a cost-effective, reliable, and easy-to-use architecture that can provide access to a large number of residents.

However, there are still challenges with evolving standards and conflicting claims with respect to what different technologies can and cannot do. A wireless broadband initiative is a significant investment of time and resources for the City, and it is important to understand as part of the planning processes the different standards, potential obstacles, and technical requirements. The City and associated organizations have also conducted small pilot studies and they can also provide useful insights toward establishing a set of technical requirements.

Standardization has revolutionized broadband wireless access (BWA). The Institute for Electrical and Electronics Engineers (IEEE) has introduced a number of standards over the past several years, which have been the driving force behind recent BWA improvements.

Standards such as Wi-Fi and WiMAX are aimed at providing interoperability of products to lower equipment and component costs through integration and economies of scale. The maturity level of these standards plays an important role in the decision-making process. In a project of this scale, the technologies chosen should be standards-based when possible. If proprietary, pre-standard solutions are chosen, they should adhere to the majority of the ratified standards and should be easily and affordably upgradeable.

Overview of Available Technologies

Typically, citywide wireless solutions are deployed using point-to-multipoint (P2MP) links between base stations and subscriber equipment. A base station is an outdoor antenna connected to a wired backbone, which sends data wirelessly to subscriber equipment, eliminating the need for expensive wired backbones while providing cost-effective last-mile solutions. There are many wireless technologies available including Wi-Fi, Wi-Fi mesh, and, in the near future, WiMAX.

Wi-Fi

Wi-Fi (Wireless Fidelity) is a term used by the Wi-Fi Alliance to describe products based on the IEEE 802.11 specification for use in the Wireless LAN (WLAN). The Wi-Fi Alliance administers tests that certify product interoperability. A product is only Wi-Fi certified if it goes through the Wi-Fi Alliance. Characteristics of Wi-Fi include the following:

- Available through the IEEE 802.11a, 802.11b, and 802.11g specifications
- 802.11b was the first available and, thus, became the most widely deployed
- 802.11b can be used on a 802.11g network

Attributes	802.11a	802.11b	802.11g
Range	60 feet	300 feet	300 feet
Throughput (max)	54Mbps	11Mbps	54Mbps
Frequency	5 GHz	2.4GHz	2.4GHz
Modulation	OFDM	DSSS	OFDM
Compatibility	802.11a	802.11b	802.11g and b
Available	2001	1999	2003

Source: Wi-Fi Alliance, Wi-Fi Planet, Intel Corporation[41]

Wi-Fi Mesh

A Wi-Fi mesh, or ad-hoc network, consists of multiple interconnected nodes that provide a seamless architecture in the WLAN in which at least one node is connected to a backhaul connection. Characteristics of Wi-Fi mesh networks are listed below.

- Traffic may have the same destination but not necessarily the same path to get there
- Each node individually determines the best path while maintaining connectivity
- There are no standards currently in place for intra-mesh communication; all mesh networks are proprietary (except as it relates to the interface between the Wi-Fi mesh node and subscriber units, which is typically 802.11b)

WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) products are based on the IEEE 802.16 and ETSI HIPERMAN standards to provide high-throughput connections over long distances for the WirelessMAN. Equipment and component suppliers, to

[41] Wi-Fi Alliance, http://www.wi-fi.org/OpenSection/FAQ.asp?TID=2;
Wi-Fi Alliance, http://www.wi-fi.org/OpenSection/pdf/TGG_QA.pdf; Wi-Fi Planet, http://www.wi-fiplanet.com/columns/article.php/961181

promote the use and interoperability of 802.16 compliant products, formed the WiMAX Forum.[42] The IEEE 802.16 standard offers fixed, line of sight (LOS) links at speeds of up to 75 Mbps in licensed frequencies and transmits signals as far as 30 miles. Typically, WiMAX base-station installations cover 3–5 miles. Characteristics of WiMAX include the following:

- Designed to cover up to 30 miles, greater distances than the WLAN offering
- A wireless alternative to last-mile solutions such as DSL and cable
- An ideal solution for backhaul
- The capability to be used as a complementary technology to connect 802.11 hotspots

There are currently no WiMAX networks available due to a lack of interoperability testing of the WiMAX Forum, which is expected to occur in early 2005. The first wave of WiMAX products will be available in early 2005 based on the IEEE 802.16-2004 (previously 802.16REVd) specification—later followed by 802.16e.

	802.16-2004	802.16e
Benefits	Improved performance, ease of development, "handoff" between cells at "walk about" speeds	Enhanced mobility, more persistent connectivity similar to Wi-Fi today
Notes	Strong backing by Intel through upcoming Rosedale chip[43]	Intel announced partnership with Clearwire to develop and deploy future 802.16e products[44]
Expected	Early 2005	Late 2006 to early 2007

Source: Intel, Daily Wireless

Pilot Study Results

The City of Philadelphia has developed several pilot networks to evaluate performance characteristics and user acceptance for wireless broadband networks. These include networks in the following areas:

- From Love Park to the Philadelphia Art Museum
- The West Powelton/Saunders Park area of West Philadelphia
- The Norris Square area of North Philadelphia
- The Universal Homes re-development area of South Philadelphia

The Love Park network uses interconnected Wi-Fi mesh nodes spanning from the park to the Art Museum. This network was originally created with one node to support the Love Park area and has expanded to nine nodes. These nodes connect back to a single T-1 Internet connection in Love Park. The network allows users with Wi-Fi cards in their

[42] See WiMax Forum, http://www.wimaxforum.org/about
[43] See Intel, http://www.intel.com/pressroom/archive/releases/20041025net.htm
[44] See Daily Wireless, http://www.dailywireless.org/modules.php?name=News&file=article&sid=1284

laptop to connect anywhere in this area. Since being deployed in June 2004, more than 2,600 people have signed on to use the network, with a 20 percent increase in users each month.

The West Powelton/Saunders Park network is supported by the People's Emergency Center (PEC), a nonprofit organization. In this network, each node has two antennas: one unidirectional antenna to capture the signal from the base station and one omni-directional antenna to distribute the signal to the surrounding area. This network is also running on the 802.11b standard and to work properly, each node must be in a near line of sight to the base station. Currently, there are five nodes connected, covering a range of approximately two blocks each. Under normal circumstances, each base station can simultaneously support up to 100 subscribers.

The pilot projects have demonstrated the ability for inexpensive, standards-based, license-exempt wireless technologies to provide an affordable broadband solution that meet the needs of Philadelphia's citizens.

RF Study

The Committee recognized the need to validate that Wi-Fi and pre-WiMAX technologies can scale to meet the complex requirements and large geography of Philadelphia. In November 2004, the City commissioned a comprehensive radio frequency (RF) study. Between November 2004 and January 2005, spectral analysis was performed throughout the City, a test network was deployed consisting of a one-square mile Wi-Fi network and a pre-WiMAX backhaul, extensive outdoor and indoor site surveys were performed in the test area and a predictive propagation model was developed for the network.

The output of this study is designed to aid the City and the Committee in decision-making as the project moves forward. The results of the study should also serve as a valuable input for vendors who elect to respond to the planned request for proposal (RFP) to design, build and operate a citywide wireless network.

This section provides only a summary of the data collected during the RF study. Full details will be made available to parties who register to respond to an eventual RFP.

Summary of Findings

- As expected, a variety of devices and services are operating in the license exempt 2.4 GHz, and to a lesser extent, the 5.8 GHz bands throughout the City.

- No "show stoppers" were found in the RF environment throughout the City that would prevent a citywide wireless network using license exempt 2.4 GHz and 5.8 GHz spectrum from being deployed to meet the objectives defined in the Wireless Philadelphia Business plan.

- The density of Wi-Fi access nodes, given the urban morphology (land use) throughout the City will require intense planning and consideration by parties who respond to an eventual RFP.

- Indoor CPEs (wireless bridge equipment with high gain and/or directional antenna and transmit signal boosters) will be a firm requirement to provide residential and small business services throughout most of the City.

- In areas of dense morphology, such as the downtown business district, as well as neighborhoods consisting of many narrow alleyways between major city blocks, subscribers may often need to adjust their geographic position to establish robust and stable connectivity to the network.

- The testing suggested that the minimum performance and capacity assumptions for level-of-service (1 Mbps symmetrical) and over-subscription for nomadic and residential services should be adequate to support the 5-year subscriber projections defined in the business plan.

Spectral Analysis

The City assumes that an eventual citywide wireless network will make use of license exempt wireless spectrum, meaning that components of the network will transmit and receive radio energy without specific authorization, registration, or grant of a license from the Federal Communications Commission (FCC). In addition to common wireless networking technologies (i.e. 802.11a/b/g, Bluetooth, etc.), a variety of other services may also operate in license exempt bands, including:

- Cordless phones
- Computer peripherals
- Consumer electronics
- Sensors and controller devices
- Toys
- Radiofrequency Identification (RFID) equipment
- Ground penetrating radar
- Security systems for homes and businesses
- Keyless entry

For this reason, spectrum scans of the most common wireless networking frequencies (2.4 GHz and 5.8 GHz) were performed at 49 locations throughout the City.

The objectives for performing these scans were to:

- Ensure compliance with the FCC's Part 15 rules, which define the regulations under which an intentional, unintentional, or incidental radiator (transmitter) may be operated without an individual license.
- Identify potential sources of signal interference that could affect the performance or reliability of a citywide wireless network.
- Collect a sampling of data for existing services/carriers and signal noise for use in defining general characteristics of the entire city.

All scans were performed using a Bantam 425a handheld spectrum analyzer from Bantam Instruments. Each scan was performed for a five-minute duration at street-level (approximately one meter). Both average and peak signal strengths were recorded for each of the following bands:

- 2400 – 2500 MHz, which includes the frequencies used by 802.11b and 802.11g standards
- 5725 – 5825 MHz, the frequency used by many point-to-multipoint (P2MP) wireless solutions

Spectrum Scan Location Map

A map showing the location of each scan (indicated by red thumbtacks) and a table including the exact location coordinates is shown below. Locations were chosen arbitrarily in order to provide a diverse sampling throughout the 135 square miles of the City.

Spectrum Scan Location Detail

Location #	Latitude	Longitude	Cross Street
1	39.88269 N	75.25185 W	Burton Avenue
2	39.91216 N	75.26693 W	Chester Pike and Garvin
3	39.89661 N	75.23405 W	Bartam and Holstein Avenue
4	39.89588 N	75/18627 W	Langley Avenue
5	39.89169 N	75.17009 W	Constitution Avenue
6	39.91031 N	75.18134 W	Geary St and S. 20th
7	39.92414 N	75.16807 W	S.Broad and Snyder Avenue
8	39.94243 N	75.16232 W	Bainbridge and 13th
9	39.96481 N	75.15797 W	13th and Wallace
10	39.96916 N	75.12987 W	E Girard Avenue and E Columbia Avenue
11	39.98883 N	75.09000 W	Richmond St and Pickwick Street
12	39.98695 W	75.12536 W	Emerald and E Huntington St
13	39.99000 W	75.15879 W	W York St and N 16th ST
14	39.97390 N	75.18396 W	N 29th St and Cambridge
15	39.93945 N	75.19087 W	Grays Ferry Avenue and 29th St.
16	39.92417 N	75.22794 W	Elmwood Ave and 63rd St
17	39.94289 N	75.22743 W	S 53rd and Penridge St
18	39.96357 N	75.22425 W	52nd and Race
19	39.96258 N	75.26312 W	Brief Ave and West Chester Pike
20	39.98849 N	75.25263 W	E Township Line Road and E Lancaster Ave
21	39.98891 N	75.23322 W	Gainor St and N 54th
22	39.99117 N	75.18644 W	Dauphin and US 13
23	40.00992 N	75.19583 W	N Ridge and Calumet Street
24	40.01212 N	75.16057 W	20th and Butler St
25	40.01263 N	75.15259 W	W Pike St and 15th
26	40.02157 N	75.12768 W	W Wyoming Avenue and N Palethorp
27	40.03165 N	75.16761 W	Germantown Ave and E Bringhurst St
28	40.02988 N	75.18635 W	Rittenhouse St and Wissahickon Avenue
29	40.03569 N	75.22086 W	Hermitage St and Ridge Avenue
30	40.04941 N	75.23622 W	Ridge Avenue and Oriole St
31	40.06868 N	75.23704 W	Oldline Road and Caledonia St
32	40.06285 N	75.19308 W	Germantown Ave and Gowen Avenue
33	40.07774 N	75.17202 W	Michener Avenue and E Mt. Airy Avenue
34	40.10612 N	75.03335 W	Red Lion and Ferndale St
35	40.09865 N	75.01373 W	Haldeman Avenue and Foster Street
36	40.12102 N	75.01009 W	Kelvin Avenue and Byberry Road
37	40.10867 N	74.98632 W	Byberry Road and Black Lake Road
38	40.09811 N	74.98038 W	Fairdale Road and Rambler Road
39	40.07408 N	74.98420 W	Red Lion Road and Waldemire Drive
40	40.06454 N	75.04386 W	Roosevelt Boulevard and Strahle Road
41	40.07454 N	75.07548 W	Verree St and Stanwood St
42	40.05911 N	75.07708 W	Dungan St and Tudor St
43	40.04929 N	75.08445 W	Unruh Avenue and Whitaker Avenue

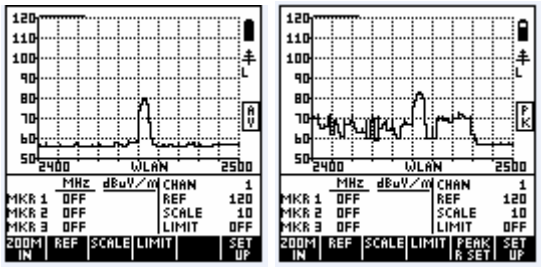
Location #	Latitude	Longitude	Cross Street
44	40.04681 N	75.12494 W	3rd Street and Chelton
45	40.05461 N	75.15651 W	Stenton and Beechwood St
46	40.01546 N	75.06114 W	Van Kirk St and Hegerman St
47	40.0937 N	75.06486 W	Bradford Street and Harbison Avenue
48	40.03728 N	75.02094 W	Torresdale Ave (at local prison)
49	40.04590 N	74.99442 W	Linden Ave and State Road

As expected, signal noise in the 2.4 GHz band was present in all locations where tests were performed. Despite the presence of this noise, only in the following locations did the "2.4 GHz Peak" scans show levels of noise that could be expected to cause meaningful interference with the 802.11b/g tier of a citywide network:

- Location 8, Bainbridge and 13th
- Location 9, 13th and Wallace
- Location 27, Germantown Ave and E Bringhurst St
- Location 28 - Rittenhouse St and Wissahickon Avenue
- Location 42 - Dungan St and Tudor St
- Location 45 - Stenton and Beechwood St

Even in the above locations where peak signal noise was elevated, the "2.4 GHz Average" scans for those locations showed low levels of noise. This implies that the peak noise was the result of "spikes", which current-generation 802.11b/g equipment can accommodate through various mechanisms.

Only Location 45, Stenton and Beechwood St, was found to have both a high average and high peak noise level that should be further investigated for a source of interference. Specifically, the 20 MHz band from 2428 to 2448 MHz, commonly referred to as Channel 6 within the 802.11b standard, was the problem area.



Location 45 – Stenton and Beechwood

In the 5.8 GHz band, signal noise was consistently very low in all locations tested. Only in Location 14, N 29th St and Cambridge, did peak noise in this band go above the typical "noise floor", and the average scan at that location showed no reason for alarm.

Predictive Propagation Modeling

In addition to spectral analysis sampling and physical site surveys conducted during this study, a *predictive propagation model* was developed to aid in forecasting and validating the coverage areas and performance assumptions in the Wireless Philadelphia business plan. The goal of this process was to create reasonably accurate predictions about RF propagation throughout the City without the time and expense of deploying an actual live network. While these models should not be used as the sole decision tool for decision-making, they do provide an additional source of information to aid the City, the Committee and vendors who elect to respond to the planned RFP.

To develop the model, propagation and visual mapping software called Radio Mobile 6.1 was used to analyze the terrain, topology, morphology (land use) and technical specifications for common wireless network equipment. The model attempts to represent the actual behavior of the RF signals when propagating between transmitters and receivers.

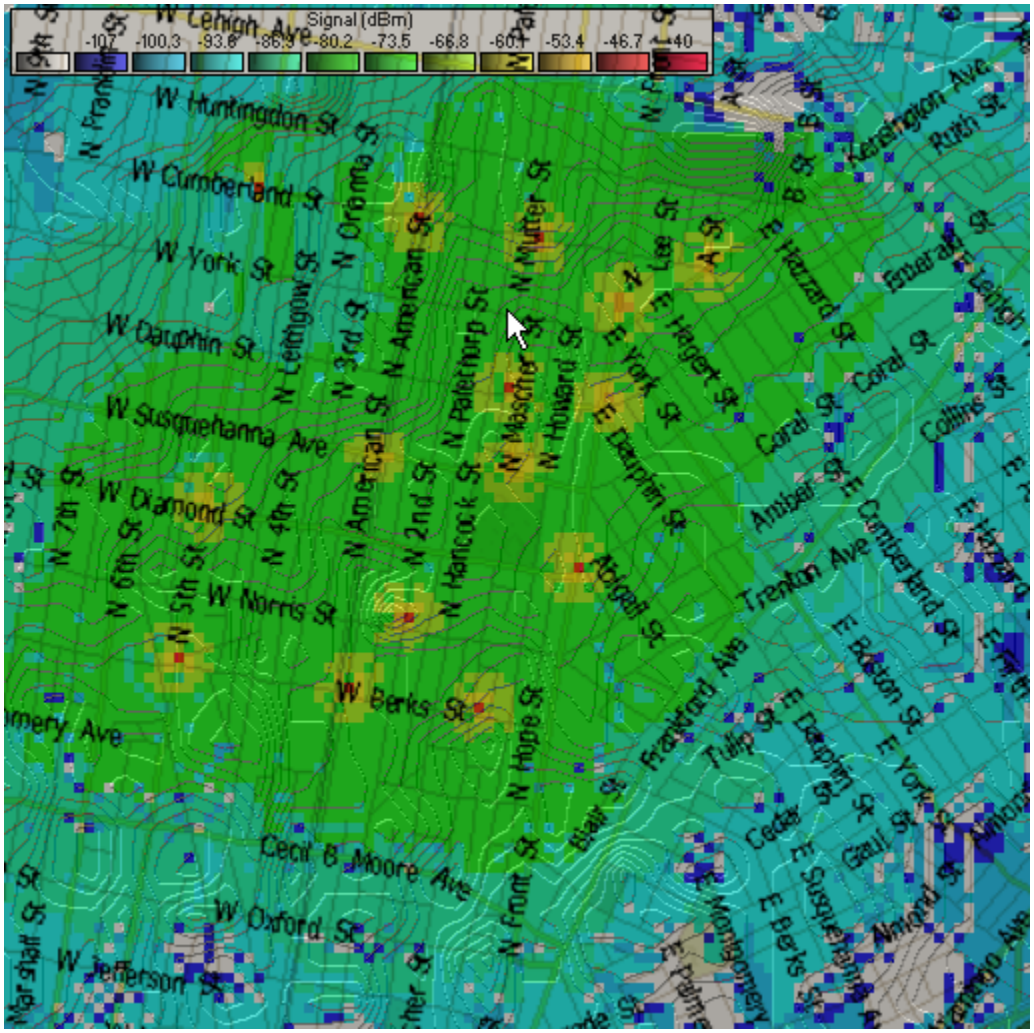
- Radio Mobile 6.1 was used for the propagation modeling.
- GTOPO30, a global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer), was used for digital terrain data.
- Morphology data was simulated using Radio Mobile by inputting percentage propagation loss due to common types of land use (urban, suburban, etc.).
- Network and system data such as transmit power and receiver sensitivity were input using technical specifications from Tropos Networks (the equipment vendor whose mesh equipment was used during the physical site survey testing).

While the models generated do provide some insight into how an assumed network will perform, it does not take into account the exact morphology (roads, trees, buildings, etc.) of each area modeled. For example, should a mesh node be located at an intersection in a dense urban area, the *actual* coverage pattern may resemble a "plus sign" due to the local clutter of buildings, however the model will reflect propagation as more of an *even circle* around the transmitter. Despite this shortcoming, the model can be extremely useful to better understand the impact of mesh node density, characteristics of CPE equipment, etc., key considerations for the Wireless Philadelphia business model. Assumptions for the model included:

- 18 mesh nodes (with the above characteristics) per square mile
- 30% morphology correction (urban land use)
- Frequency: 2450 MHz
- Base station (mesh node) Transmit Power: 1 Watt (29 dBm)
- Base station receive sensitivity: -98 dBm
- Base station antenna pattern: 360 degrees
- Base station antenna gain: 7.4 dBi
- Base station antenna height: 45 foot
- Cable loss: 4dB

- Far end (client) transmit power: 0.05 Watt
- Far end receiver sensitivity: -94 dBm
- Far end antenna pattern: 360 degrees
- Far end antenna gain: 2 dBi
- Far end antenna height: 3 feet
- Cable loss: 0 dB

Resulting Coverage Plot



The predicted coverage plot above estimates the coverage area and signal strength throughout the Norris Square neighborhood. These predictions generally match to the results obtained from the physical site survey (covered below), further validating that service beyond roughly a single major city block will in many cases require either adjustments to the subscriber unit location or the use of a high-gain subscriber antenna.

The City should also consider defining a broader predictive propagation-modeling requirement in RFP responses from vendors. This process will help to predict the nuances that may occur in different neighborhoods and if/when node density should be modified.

Physical Site Surveys

Any wireless technology exhibits irregular propagation characteristics when deployed in a real-world situation. Wireless signals are subject to fading, multi-path and various other factors that affect the signal's attenuation in a specific deployment area. For that reason, the spectral analysis and propagation models above can only provide predictions about coverage areas and performance.

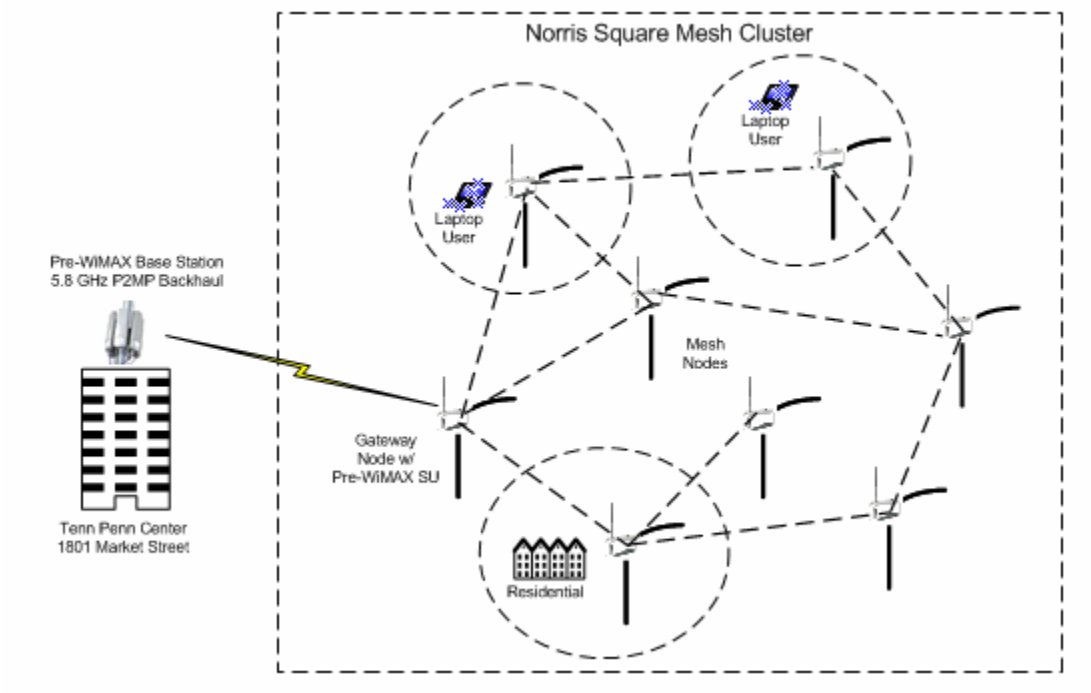
For this reason, a site survey was performed using an actual test network deployment in the City. The site survey included the deployment of vendor equipment and the use of measurement tools to more accurately study how these systems will perform in a typical neighborhood within the City.

Overview of Test Environment

- A test network was deployed in a one square mile area of the Norris Park neighborhood of Northeast Philadelphia.
- Seventeen Wi-Fi (802.11b) access nodes were deployed on light poles within the test area.
- A pre-WiMAX base station was deployed on a rooftop at the intersection of 18th and Market Streets in the Philadelphia business district. The base station was deployed atop the 28-story building at a height above ground level of 110 meters.
- One of the light poles in Norris Square (at the intersection of North American and Susquehanna) was designated as a "gateway node" and an additional pre-WiMAX subscriber unit was deployed to connect the Wi-Fi network to the pre-WiMAX base station (backhaul). The distance between base station and subscriber unit it 2.6 miles.
- The Wi-Fi gateway node and pre-WiMAX subscriber unit were connected together using Ethernet cabling.
- A DHCP (dynamic host configuration protocol) server was deployed along with the pre-WiMAX base station to provide IP address management for all radios and client devices.

A conceptual diagram of the test network, a map of all node locations and a table defining the nodes' exact locations are provided below.

Conceptual Diagram of Network



Map of Node and Gateway Locations

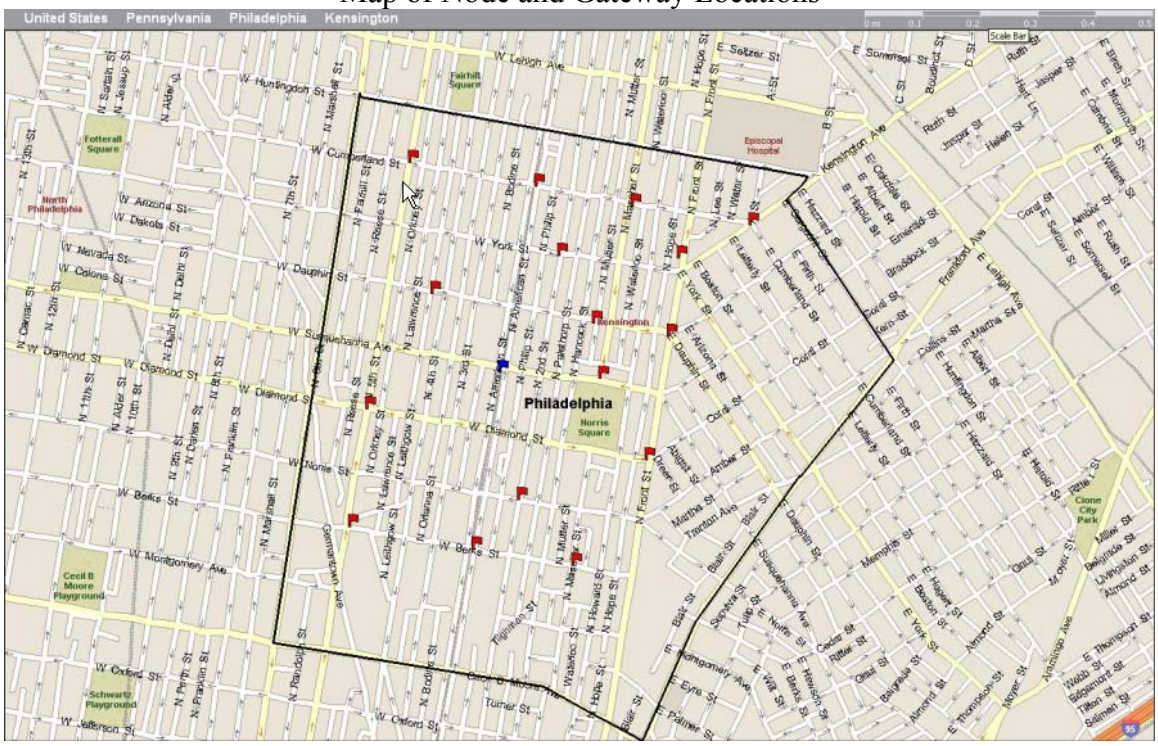


Table of Exact Node and Gateway Locations

East/West Cross Streets	North/South Cross Streets	Latitude	Longitude
West Susquehanna Street	**North American Street**	**39.98391**	**75.13786**
West Cumberland Street	North 5th Street	39.98902	75.14074
West Cumberland Street	North American Street	39.98851	75.13681
West Cumberland Street	North Mascher Street	39.98806	75.13371
West Cumberland Street	Kensington Avenue	39.98761	75.12945
West York Street	North 2nd Street	39.98777	75.12936
West York Street	North Front Street	39.98682	75.13164
West Dauphin Street	North Leithgow Street	39.98596	75.14004
West Dauphin Street	North Mutter Street	39.98517	75.13447
West Dauphin Street	North Front Street	39.98494	75.13202
West Susquehanna Street	North Mascher Street	39.98373	75.13439
West Diamond Street	North 5th Street	39.98297	75.14207
West Diamond Street	North Front Street	39.98173	75.13277
West Norris Street	North 2nd Street	39.98074	75.13709
West Berks Street	North 5th Street	39.97997	75.14286
West Berks Street	North American Street	39.97943	75.13850
West Berks Street	North Mascher Street	39.97905	75.13522

Equipment and Tools Specifications

Tropos Networks' 5110 Outdoor Wi-Fi Cell solution was used for all Wi-Fi access nodes. Technical specifications include:

- Standard: 802.11b for client and intra-mesh connectivity
- Frequency band: 2.4-2.483 GHz
- Modulation: DSSS (CCK, DQPSK, DBPSK)
- Transmit Power: 1 W (29 dBm)
- Optional TX Power: 200 mW (23 dBm)
- RX Sensitivity: -98 dBm (1 Mbps), -96 dBm (2 Mbps), -95 dBm (5.5 Mbps), -91 dBm (11 Mbps)
- Impedance: 50 ohms
- Antennas: 7.4dBi omnidirectional

Alvarion's BreezeACCESS VL standalone base station solution was used for backhaul connectivity from the gateway node. Technical specifications include:

Standard: None, pre-WiMAX 802.16a
Frequency band: 5.725 - 5.850 GHz
Radio Access Method: Time Division Duplex (TDD)
Output Power: -10 dBm to 21 dBm, 1 dB steps
Modulation: OFDM (BPSK, QPSK, QAM 16, QAM 64)
Antenna: 120°: 15dBi, Sector 120° horizontal, 6° vertical

For backhaul connectivity, a 6 Mbps BreezeACCESS VL subscriber unit (SU) from Alvarion was installed and connected to the gateway node using an Ethernet cable.

Ekahau Site Survey software version 2.1 was used to collect and analyze statistics for nomadic (outdoor with a standard laptop client device) use of the test network. Ekahau was installed on an Intel Centrino Tablet PC configured with an Orinoco Classic Gold 802,11b PCMCIA card. The Orinoco Gold card was chosen because of its ability to support scan rates of ½ second, critical for site surveys in which the laptop is in motion (driving at low-speed in this case). Technical specifications for the Orinoco card include:

- Frequency Channels: 2.4-2483 GHz
- Modulation: Direct Sequence Spread Spectrum (CCK, DQPSK, DBPSK)
- Nominal Output Power: 15 dBm
- Scan Rate: ½ second
- Receiver Sensitivity: –82 dBm (11 Mbps), -87 dBm (5.5 Mbps), -91 dBm (2 Mbps), -94 dBm (1 Mbps)

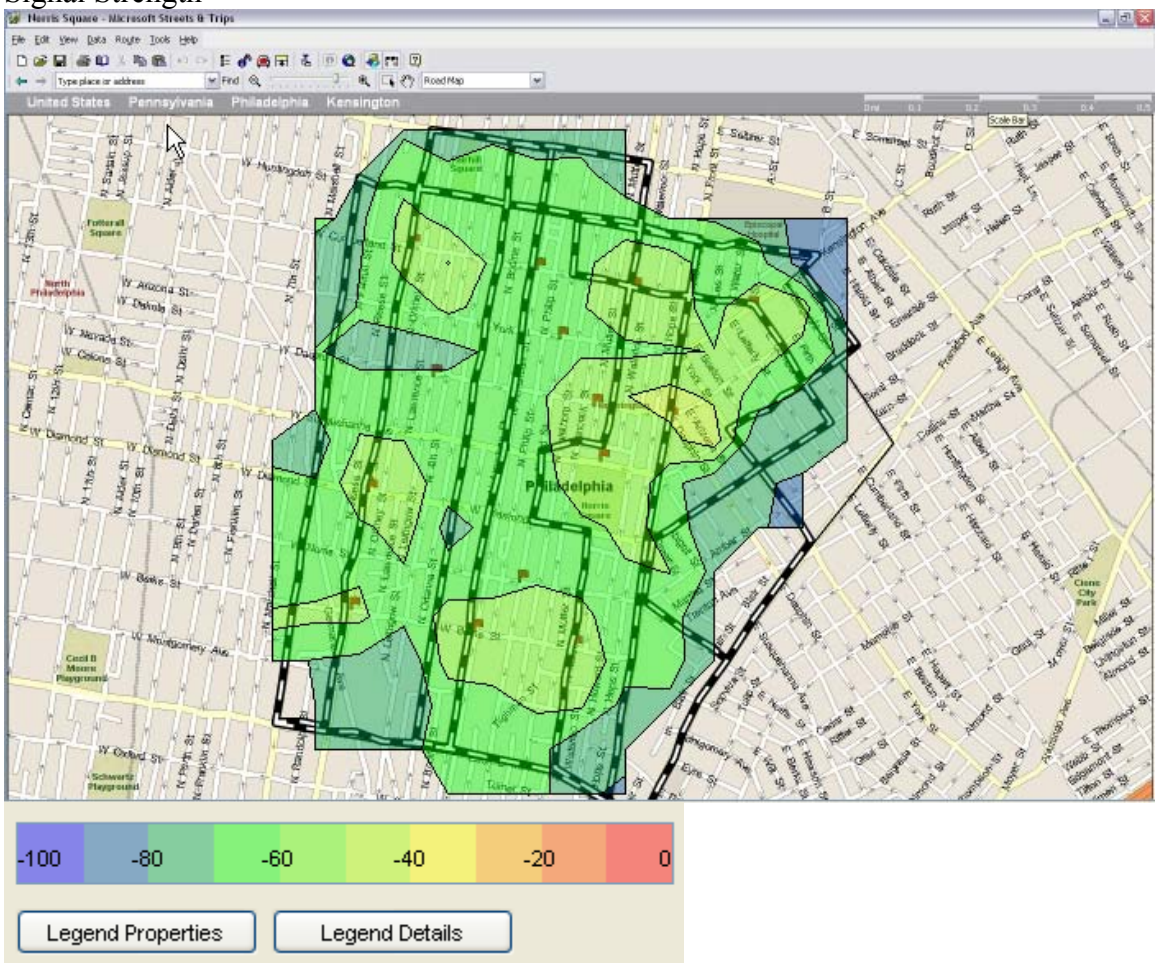
For residential (indoor connectivity from a fixed location) testing, a Hawking Technologies H-WU36D 802.11b USB wireless adapter, with a built-in high-gain, directional antenna was used. The USB adapter and antenna were connected to an Intel Centrino laptop device. Technical specifications for the Hawking adapter include:

- Frequency Channels: 2.4 TO 2.483 GHz
- Interface: USB
- Antenna: 6 dB Directional
- Modulation: CCK (11Mbps, 5.5Mbps), DQPSK (2Mbps), DBPSK (1Mbps)
- Horizontal Antenna Pattern: 80°
- Vertical Antenna Pattern: 80°
- Transmission Speeds: 1, 2, 5.5 and 11 Mbps
- Output Power: 14 ~ 17 dBm
- Receiver Sensitivity: 11Mbps: -82 ~ -85 dBm; 5.5Mbps : -85 ~ -88 dBm
- 2 Mbps: -88 ~ -91 dBm; 1 Mbps : -91 ~ -93 dBm

Driving Site Survey Results

A driving site survey was performed through the Norris Square deployment area in approximately 1/8th mile increments. During the survey, signal strength, signal noise ratio (SNR) and other data was collected.

Signal Strength



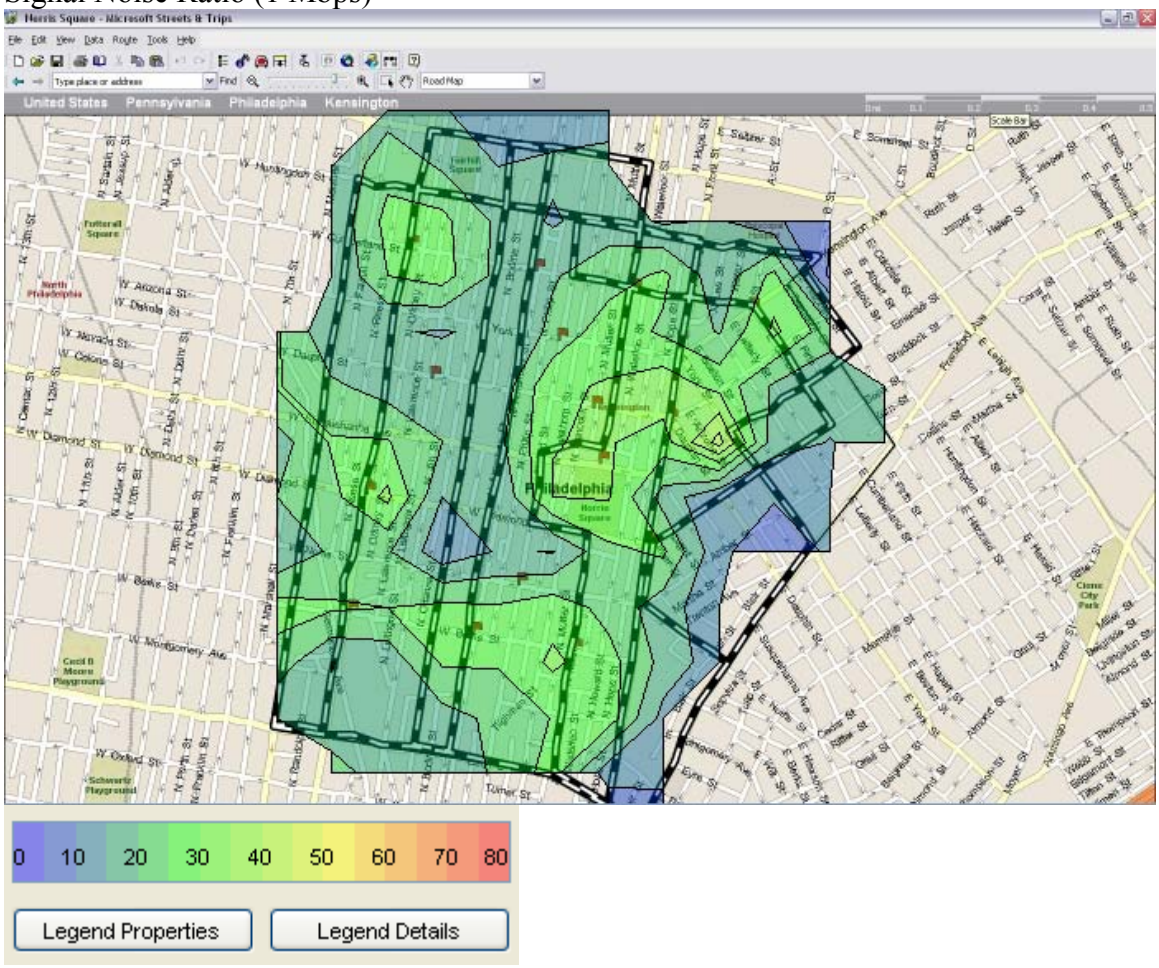
Signal strength ranged from –40 dBm to –80 dBm throughout the test area. The majority of locations in the coverage area registered in the –50 to –65 dBm range. The factors most affecting receive signal strength included:

- Proximity of the client device to the closest mesh node
- Amount of obstruction in the link path between the client device and mesh node

In most cases, signal strength was strong when the client device was within one block of a mesh node. However, the Norris Square area has a large number of North/South cross streets, creating several narrow alleyways within each block. With access nodes deployed only at the major block intersections, nomadic and residential use in the alleyways can be problematic.

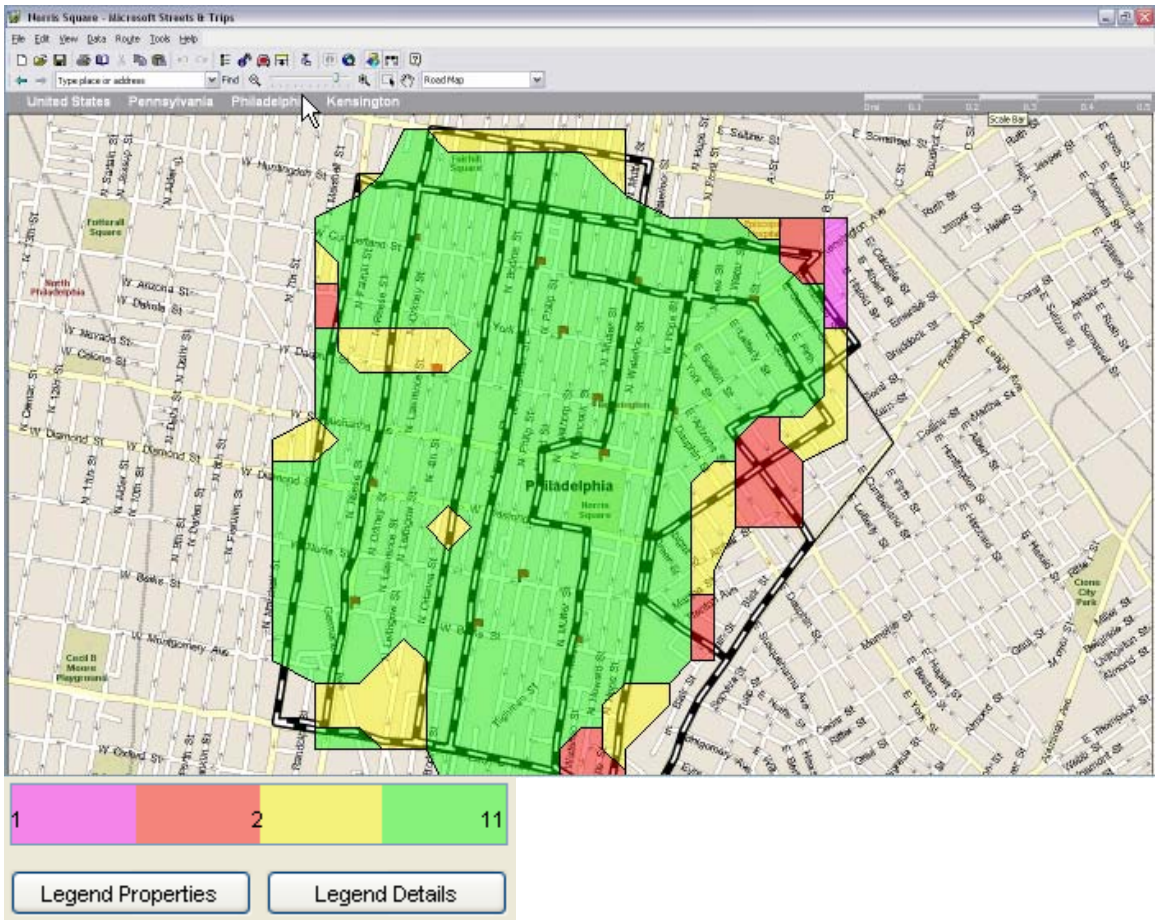
This can be mitigated through the use of high gain (and in some cases directional) antennas, which were included as an assumption in the business plan. Nomadic users who lack equipment other than a standard laptop device may be required to adjust their location.

Signal Noise Ratio (1 Mbps)



Signal to Noise Ratio (SNR) ranged from 50 dBm to 15 dBm throughout the test area. The majority of locations in the test area registered in the 25 to 35 dBm range, acceptable for typical nomadic use.

Data Rates

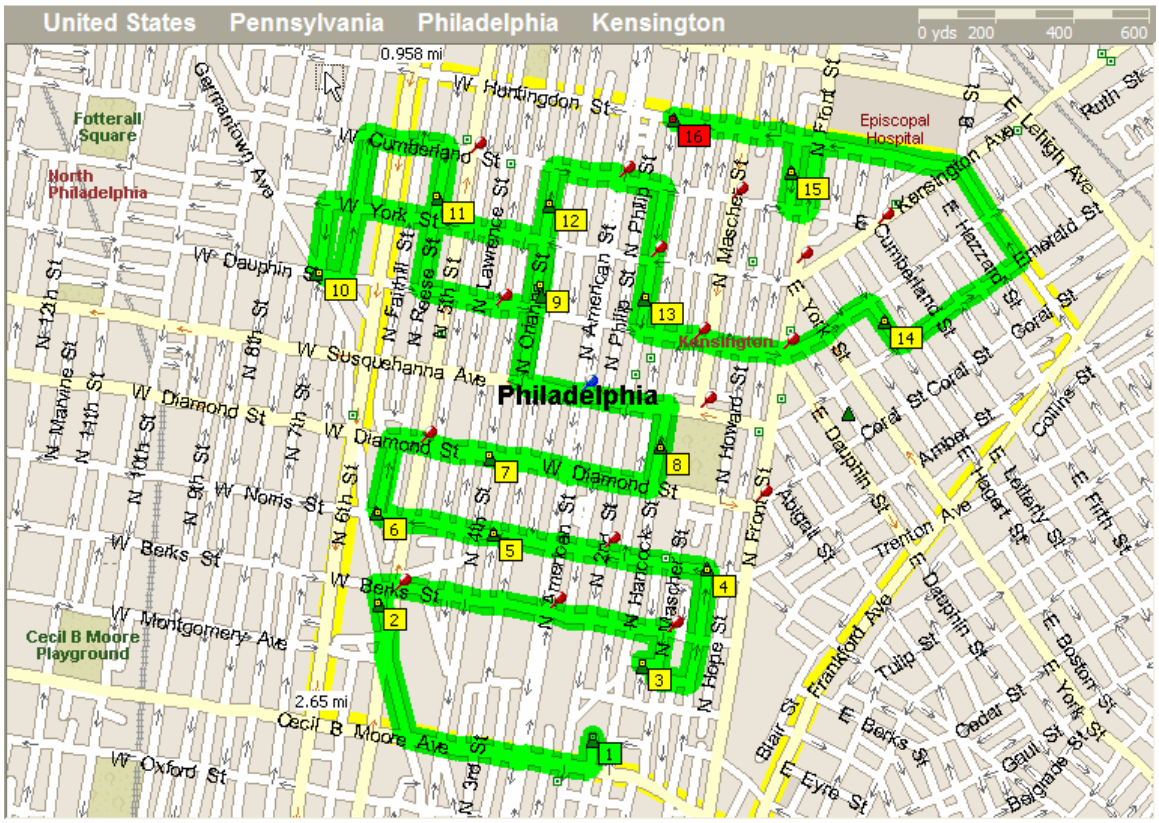


Raw data rates ranged from 11 Mbps to 1 Mbps throughout the test area. The majority of locations in the test area registered 11 Mbps. It should be noted that actual bandwidth available to users will be impacted by the quality of their connection, other network activity, congestion in the network, backhaul over subscription and other factors.

Stationary Surveys

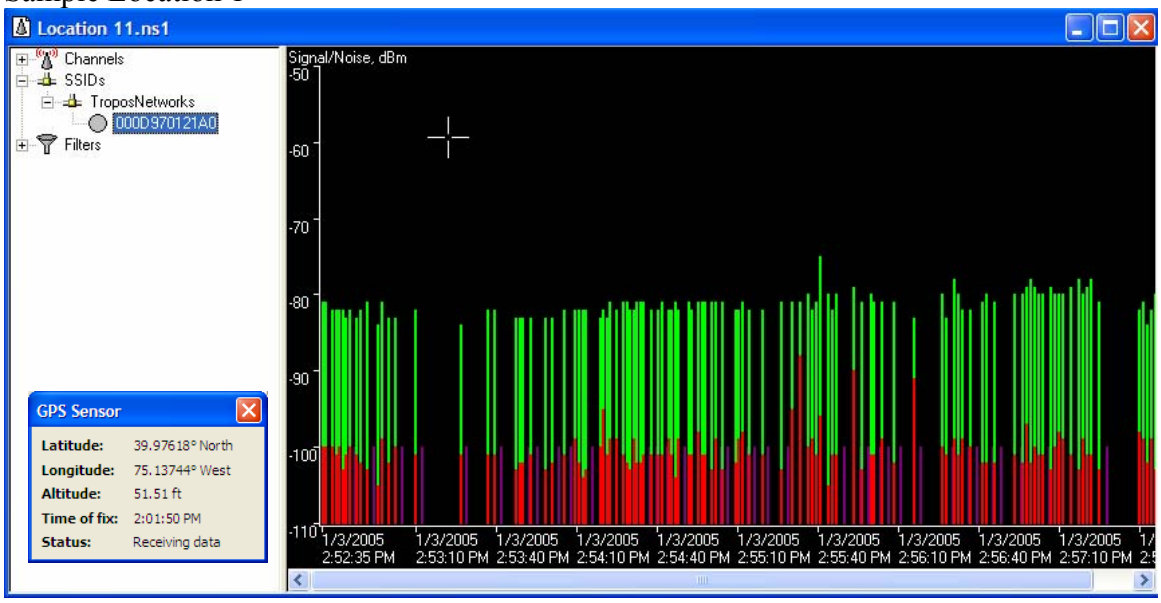
In addition to the driving site survey, 5-minute stationary surveys were performed at sixteen locations within the test area to collect additional data about nomadic use. The client configuration during these tests was identical to the driving survey; however NetStumbler version 0.4.0 software was used to create a log of results within each 5-minute scan.

The sixteen test locations are shown on the map below, indicated by yellow numbered boxes.



In the diagrams below, the X axis represents time and the Y axis represents signal strength (measured in dBm). Red bars indicate signal noise and green bars indicate signal strength from the mesh nodes. Generally speaking, the higher the delta between the red and green bars (calculated as Signal Noise Ratio or SNR), the better quality the connection.

Sample Location 1



Of the 16 fixed locations tested, 4 locations did not register a mesh node. This is due to the following reasons.

- 2 of the locations were well outside of the estimated coverage area (more than a major block away from the nearest node).
- 2 of the locations were in dense, narrow alleyways between major blocks. In these cases, moving the laptop location slightly to another area of the street resulted in nodes registering, however we chose to enforce the arbitrarily chosen locations for stricter testing.
- The receiver sensitivity of the Orinoco card used for testing was too low to register. It is expected that even in these cases, the addition of a high gain and/or directional antenna will mitigate the issue.

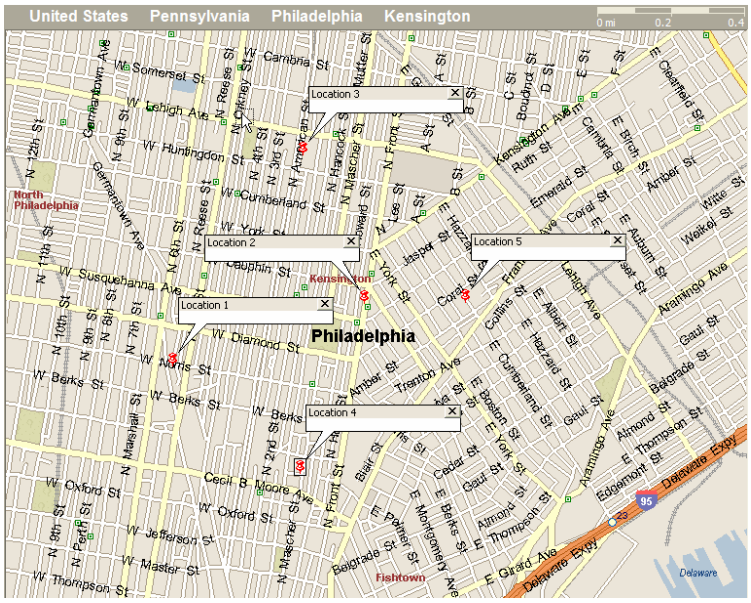
Of the 16 locations, 9 locations registered more than one access node. In these cases, the strongest node was used to collect the above data. The Signal Noise Ratio (SNR) for locations registering an access node ranged from 40 dBm to 10 dBm. Again, client device and antenna selection will in most cases determine whether adequate service can be achieved. Adding "gain" to the receiver sensitivity chain will in most of these cases result in adequate SNR.

Indoor Site Survey Results

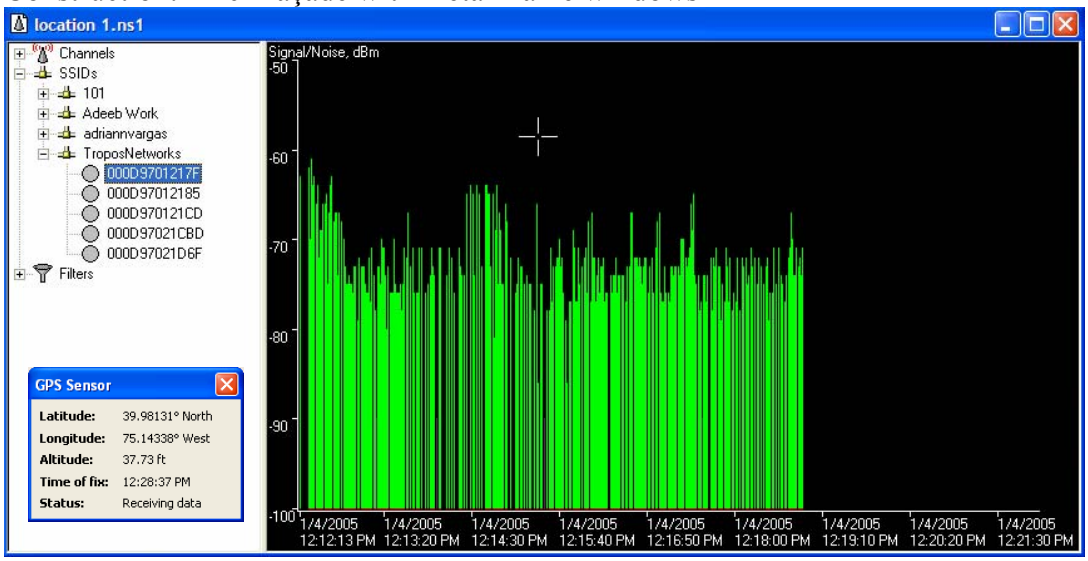
To better understand signal propagation and performance for indoor (residential and small business) conditions, 5 tests were performed from small businesses in the area. The process used was identical to the process for the outdoor fixed site survey described above, with the exception that the Hawking Technologies USB network adapter with a 6

dBi high-gain antenna was used instead of the Orinoco card. This roughly simulates the business plan assumption for the use of a wireless bridge CPE for residential use.

A map of the 5 test locations is shown below.



Sample Location 1 - LaundroMAX – Intersection of Germantown and Reese
Construction: Brick façade with metal frame windows



Indoor testing was very encouraging, with the exception of Location 5 where the path to the nearest access node was blocked completely by adjacent buildings and it was well outside the estimated coverage area for the test network. The noise floor for each location was substantially lower than the outdoor tests and SNR ranged from 20 dBm to 40 dBm.