

Carnegie Mellon University – Heinz College

The Pittsburgh WiFi Project
The Hybrid WiFi Model Framework

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This report compiles research done by and recommendations from five Graduate students at Carnegie Mellon University’s Heinz College Schools of Public Policy and Management, Information Systems and Management, and Information Security Policy and Management. The report incorporates the following:

The Hybrid WiFi Model Framework
The City of Pittsburgh
Department of Innovation and Performance

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Project Components

Project Objectives

To access the feasibility of municipal WiFi in Pittsburgh. To design a network implementation plan.

Requirements and Constraints of the Project

The city faces certain constraints and had specific requirements for the project. The major constraints and requirements are:

- **Budget:** City is constrained by a limited budget. They are unable to provide funding for large upfront or sustaining costs.
- **Maintenance:** City prefers to outsource maintenance and labor associated with sustaining and managing the network to a third party.
- **Scalability:** Network must be scalable through the majority of the city limits.
- **Security:** Network must provide users with a defined level of security to ensure privacy for its users.
- **Legality:** City of Pittsburgh must comply with all state and federal laws.
- **Time:** City wants to implement a WiFi network in one year. The graduate students assigned to this project have from September 1, 2014 – December 12, 2014 to access the feasibility and to design an implementation plan.

Our Proposed Solution

Introduction to the Hybrid Model

The hybrid community municipal WiFi model (the Hybrid Model) is series of small scale community owned and funded mesh networks that draw on city resources to reduce the financial burden of starting and maintaining a WiFi network. Each community networks cover single neighborhoods or portions of neighborhoods throughout the city of Pittsburgh. Together the networks cover the majority of Pittsburgh's land area.

The Hybrid Model is designed to use mesh technology because mesh networks are the most cost effective network model. Mesh technology is easily expandable and scalable and is the easiest WiFi technology to maintain. Research shows that mesh technology is most often the technology used in municipal and community networks across the United States and Canada.¹

The Hybrid Model sources its bandwidth through bandwidth sharing and traditional ISP. Bandwidth sharing allows large companies and organizations to share a portion of its bandwidth with the community network for little or no cost. Bandwidth is a valuable, costly resource so receiving excess bandwidth from outside organizations will reduce the monthly cost of the network. In many cases bandwidth sharing will not provide a sufficient or consistent amount of bandwidth. In those cases, additional bandwidth needs to be purchased from the ISPs in the area. Comcast and Verizon supply the majority of bandwidth to the residents and businesses of Pittsburgh.

Implementing a Hybrid WiFi Model Using the Hybrid Model Implementation Framework

The Hybrid WiFi model is based on a series of frameworks that guide community members and network administrators through the various stages of network planning. The compilation of these frameworks and templates are called the Hybrid Model Implementation Framework. The framework includes:

- Partnership analysis
- Cost benefit analysis
 - Needs assessment
- Asset mapping methods
- Network planning
- Security and operations standards

Together these set of frameworks and deliverables provide a complete toolkit for starting a community WiFi implementation.

Traditional Models Will Not Succeed in Pittsburgh

The idea for the Hybrid Model was conceived because traditional municipal WiFi models do not succeed.² Pittsburgh should not create a traditional municipal WiFi network that covers the entire city. Several cities including Philadelphia, Atlanta, San Francisco, Chicago, Portland and Seattle tried to implement municipal-wide WiFi and failed. The primary reasons these networks failed is due to investors pulling out of the projects. The investors, MetroFi and EarthLink, anticipate 30%-50% of the population to use the service. In actuality only 2%-3% of the population use the service. ³Increases in mobile device ownership may increase this number to 5%-10% today. The high cost of the network in conjunction with low demand causes a poor return on investment and investors back out.

Community WiFi Models are More Successful and Sustainable than Municipal Models

Community and neighborhood Wi-Fi models have been successful where municipal models have failed. Case analysis of successful community WiFi implementations point to three characteristics of successful models:

1. Clear network objective at the onset
2. Accurate demand projections
3. A small launch site or pilot implementation

Clear objective

Community models often begin with an objective or goal. Organizers have a clear target demographic they are attempting to serve. Examples of objective include: economic development, education equality, or social benefits.

Demand

Community networks are often a response to existing demand for the service or a solution to a well-defined problem in the community. Community models do not face the low demand issues that cripple municipal WiFi networks because their network is designed specifically for their target users' needs.

Pilot area

Community networks are small implementations. It is not uncommon that a community network covers one main street or a few blocks. Municipal WiFi networks fail due to the high cost of creating and maintaining a large network that covers entire cities.

The Hybrid Model meets all the City's Constraints

The Hybrid Model meets all the city's requirements and constraints:

Budget

The burden of funding the Hybrid Model lies on the community implementing the model. The city provides primarily non-monetary resources. The model will be largely funded by grants. The city should provide access to city employed grant writers and help community organizers identify grants and tax incentives that fit their model's objective. The Hybrid network will also draw funding from sponsors and large business stakeholders in the targeted area. More information on identifying stakeholders and grants can be found in the Cost Analysis and Asset Mapping sections.

Maintenance

The burden of maintaining and operating the network falls on the community owners. Some community implementations are run by a corps of volunteers, by hired laborers or a mix of both. The entities that maintain the network will be specific to the needs and resources available to the community. More information on maintenance can be found in the Security and Operations Standards section.

Scalability

The Hybrid Model Framework is designed to be flexible and fit all potential implementation situations throughout Pittsburgh. This framework and the recommended technology are easily scalable city wide. Given high community involvement and stakeholder investment networks using this or similar frameworks can have similar coverage to that of a large scale municipal implementation.

Security

Securing a Hybrid Network is difficult because the city has no direct ownership over the network. The city does have leverage over the security of the network because it donates city owned resources. The security and operations framework lists a minimum security package for each implementation and methods that the city can employ to ensure those standard are being enforced. Specific details can be found in the Security and Operations section.

Legality

According to Pennsylvania House Bill 30, the city cannot monetarily benefit from a municipal WiFi implementation. Research shows incumbent ISP can sue cities and governments for creating municipal wide WiFi networks because they compete with free market practices. The Hybrid Model is owned by the community and is exempt from this state law.

Community WiFi Already Exists in Pittsburgh

There are two notable community and free access WiFi networks in Pittsburgh: The Downtown Pittsburgh Partnership and Wireless Shady Side. Both of these networks service a targeted area in Pittsburgh to promote economic growth and provide a public good. It is not a stretch of the imagination that many more neighborhoods and communities in Pittsburgh would find a community network attractive.

East Liberty is an Ideal Pilot Area to Test the Hybrid Model

Successful networks begin with a target area. East Liberty is an ideal pilot location for launching and testing the Hybrid Model. Attributes of East Liberty include:

- Economic development opportunities
- Resources and businesses
- Manageable size
- Social initiatives and public services

Economic Development Opportunities

The government has already shown interest in East Liberty for urban redevelopment initiatives.⁴ This shows that the city has a vested interest in the success of other economic redevelopment initiatives. Support from the city will help strengthen the legitimacy of the community network to potential stakeholders and users.

Resources and Businesses

East Liberty has hundreds of businesses and organizations that can benefit from the community network. These same businesses can also give to the network. Some larger businesses can provide bandwidth and others can act as root access sites and/or connection points.⁵

Manageable Size

East Liberty is relatively small but offers a large number of potential users. The area is 0.58 square miles. Most of the land area is densely covered by businesses, organizations and storefronts. There is a population of 6,000 residents. Due to retail and shopping draws such as Whole Foods, Target and

the shopping center the area gets substantial non-resident visitor traffic. It is easy to monitor the network performance over a short distance of 0.58 square miles. The network will be properly stress tested by the large number of users.

Social Initiatives and Public Services

East Liberty is the home to many social and non-profit organizations. Many community networks rely heavily on the engagement on community leaders to advocate for the creation and maintenance of the network.

Potential Issues with the Hybrid Model

There are potential risks and issues associated with the Hybrid Model. The primary issue is that this model has never been tried before so Pittsburgh does not have a model to compare to or benchmarks to follow.

The communities most in need of free WiFi access are also least likely to have the resources available to them to start a network. East Liberty is rich in resources but more residential areas will face steeper start-up and maintenance costs.

Large stakeholders, particularly bandwidth sharing entities, may not feel incentivized to share with the network. If the community does not have access to shared bandwidth the cost of the network increases dramatically.

The city needs to promote and market this idea to get communities engaged in the development process. Community leaders are the primary drivers of this model. If they are unformed or uninspired by the model the community has little chance of developing a network.

Potential Roles the City Can Have in the Hybrid Model

There are several ways the city can be involved in the community networks. Higher levels of city involvement means they will have more control over the network, its security and performance.

Roles include:

- Identifying grants and tax breaks for community networks
- Providing grant writers to assist network owners in their grant applications
- Reading legal contracts with bandwidth sharing stakeholders to ensure bandwidth sharing is allowed in ISP contracts
- Vetting the security administrator
- Providing access to GIS mapping data
- Allowing communities to use city owned light posts, traffic lights and municipal buildings as access points
- Collecting data and information on network design and implementation and sharing it with the community

Next Steps and Recommendations for the City of Pittsburgh

The city should create a website and begin promoting the idea of community networks. This website should include the Hybrid Model Framework along with the resources the city is willing to share to help start these networks.

Many small networks do not properly market their network and suffer from low users. Pittsburgh needs to market and celebrate each new implementation.

East Liberty is an ideal launch site for this network. The Asset Mapping section identifies key businesses and stakeholders. The city should reach out to these entities and promote the idea of a community network.

Partnerships

Partnership Analysis

The Office of Innovation and Performance is interested in the feasibility of partnering with an organization to develop and maintain a wireless network. Any collaborative arrangement begins with a framework for analyzing potential partners and realizing the feasibility, risks, and benefits associated with an alliance⁶.

A framework to analyze each potential service provider that will ultimately serve as a decision-making tool in a final implementation strategy can be used to support a partnership analysis.

1. Define an appropriate set of factors against which to evaluate potential partners and/or projects.

Three resource categories were used to identify success factors central to the City’s objective and to the develop evaluation criteria. First, the review considered Pittsburgh-specific data such as stakeholder expectations, strategic initiatives, and population data. Population data led insights into the City’s demographic make-up used to estimate potential demand for Wi-Fi in target areas. Next, the review included a thorough review of case studies on partnerships in similar initiatives. The final inputs included academic and professional literature from industry related segments to identify industry issues, trends, and strategies. The review and analysis led to 15 success factors central to the City’s objective for developing a wireless network.

Technology	Management	Product Development	Strategy	Financial Resources
Infrastructure	Technical Skills	Utility	Operational Strategy	Cost Structure
Security	Training	Competitive Advantage	Reputation	Reliability

2. Develop a SWOT analysis to facilitate decision-making.

Evaluating the potential of partnering with various technology service providers and projects involves assessing the congruence or fit of each entity’s resources, capabilities, and strategies with our project objective. To conduct an evaluation, it is important to consider what aspect of an organizations value chain could contribute to the city’s objective. A SWOT analysis can model the extent to which partners introduce threats or open opportunities. Such an analysis can be completed in Microsoft Excel using the SWOT Analyzer V2.1 platform. The SWOT framework developed from the aforementioned evaluation criteria considers dynamic aspects of the partnership that will change over time, and provides a mechanism to understand incompatible goals that could lead to a mismatch⁷. The framework assess strengths, weaknesses, opportunities, and threats through a series of questions and responses derived from the evaluation criteria. These questions can be tailored to suit the needs of the potential partner or evaluating community. An example application of the strength assessment is detailed below in Fig 1. The assessment was applied to the Commotion Project. The Commotion Project is an initiative to implement decentralized mesh networks in communities. The project has been implemented successfully in several cities including Detroit and in Brooklyn. Commotion provides a suite of free open source software for Wi-Fi enabled devices including mobile phones, laptops, and routers⁸.

Fig 1. Strength Assessment of Partners



The framework can be applied to assess potential partners, services, or projects that could add value to a Wi-Fi network. This process helps to identify the added value or gaps of partnering with an organization or project upfront. Ultimately, the framework serves as a decision-making tool to provide an in-depth assessment of each partner and quantifiable support for the best solution in an implementation plan.

Cost Framework

The objective of the “cost framework” is to provide communities with funding options, pricing strategies, and, measurement methods that can determine the performance of each model based on

the cost structure. The hybrid model reduces the responsibility of the City, as our recommendation suggests that some level of funding is required of the community. The steps of the framework are as follows:

- I. An exhaustive funding search that maximizes the amount of possible money collected for the model
- II. An assessment of the communities' resources and capabilities which will inform the community on what they will need to fund
- III. An analysis of the six components of the model that require financing, and the development of assumptions to determine how funds will be allocated to each component
- IV. A quantitative-based design that uses the allocation assumptions to price each of the six components
- V. An evaluation of the performance of the model using various measurement tools that will determine whether funds need to increase, decrease, or be reallocated

We used Microsoft Excel to create the pricing strategy and design, and the software, VensimPLE⁹, to create an example performance evaluation.

Funding

Literature Review

Of the WiFi models – city and community implemented – that are still existing today, the funding sources have been grants, community development centers, and, community assets, such as, public libraries and hospitals. Other successful financings have involved general and city capital improvement funds, parking revenues, district member dues, commodity contributions from the community, and public taxes.¹⁰¹¹¹²

Models that have failed relied upon advertisements (San Francisco), daily or monthly subscriptions from users (San Francisco), low-cost accounts for users (Philadelphia), and funding provided by Internet Service Providers (Philadelphia and other cities who were financed by EarthLink).¹³¹⁴

We have chosen to focus on grants, donations, and crowdfunding as funding opportunities due to the fact that the city prefers a model that requires the least amount, preferably zero, of investment of scarce city resources. In order to maximize the amount of funding, communities should seek assistance from all three of these opportunities.

Grants

The most feasible financing option for a Pittsburgh community is grants. Since grant funders typically have philanthropic giving patterns, it is necessary for the community to determine its objective for creating the model. Fig 2 shows five common objectives of cities that have an existing WiFi model.

Fig 2. Objectives of Existing City WiFi Models¹⁵¹⁶¹⁷¹⁸¹⁹

Public safety & city services	<ul style="list-style-type: none"> •Oklahoma •Ponca City •Philadelphia •San Jose
Job creation	<ul style="list-style-type: none"> •Los Angeles
Closing the digital divide	<ul style="list-style-type: none"> •Boston •San Francisco •Cleveland •Houston •Kansis City
Convenient service for citizens & visitors	<ul style="list-style-type: none"> •Boston •San Francisco
Economic development	<ul style="list-style-type: none"> •Englewood •Boston •Redhook

We have found local, state, and federal opportunities for Pittsburgh communities to use as a base for their grant research. Fig 3 provides the funding source, giving purpose, and standard monetary value of the grants (to the extent of publicly available information).

Fig 3: Local, State, and Federal Grant Opportunities²⁰

Source	Amount	Cause
Urban Redevelopment Authority	--	Low-income services & job creation

Community Development Centers	--	Community innovations & investments
U.S. Economic Development Administration	≥ \$100,000	Regional innovations/technical assistance
National Telecommunications and Information Administration	≥ \$4 million	Deployment of technologies for education, public safety, & sustainable economic growth
U.S. Department of Agriculture	≥ \$6 million	Telecommunications construction for job creation & economic growth
Google Pittsburgh	\$2,000-10,000	Increasing access to internet
Bush Foundation	\$10,000-200,000	Community innovation ²¹
HUD	Up to \$1 million	Expansion of economic opportunities & Development of communities for low- and moderate-income persons ²²
Wal-Mart Foundation	\$250-\$2,500	Sustainability, Career Opportunity, and women's economic empowerment ²³
Corporation for National & Community Service	\$200,000-1,800,000 each year for up to three years	Social innovations increasing economic opportunities for communities, education ²⁴
City of Pittsburgh Community Development Block Grant Program	--	Support to low and moderate income neighborhoods ²⁵
Pittsburgh Foundation	--	Innovative developments ²⁶ (must be requested by a nonprofit)

Donations & Crowdfunding

Along with grants, communities can solicit donations from local organizations, businesses, and community members. According to Forbes, crowdfunding is defined as a collaborative funding endeavor that allows individuals or groups to make donations to a cause typically through the web. In 2012, the “crowdfunding [industry raised \$2.7 billion for] 1 million campaigns globally...and \$5.1 billion [in 2014]” (Barnett, 2014). A 2014 article in the Journal of Business Venturing titled

“The Dynamics of Crowdfunding: An Exploratory Study” stated that crowdfunding is an effort that draws “on relatively small contributions from a relatively large number of individuals using the internet, without standard financial intermediaries” (Mollick, 2014). The U.S. Congress is currently “encouraging crowdfunding as a source of capital” (Mollick, 2014) for social ventures.²⁷

Below is a list of crowdfunding sites for fundraising that Forbes listed as the ten most popular amongst the 500 various sites. Each site contains a different model which will allow a community to determine which website best fits their goals.²⁸

- Kickstarter, Indiegogo, Crowdfunder, RocketHub, Crowdrise, Somolend, Appbackr, AngelList, Invested.in, and Quirky

Needs Assessment

Goal

The purpose of the needs assessment is to maximize the use of existing assets and to examine how community members can work collaboratively to produce the WiFi service. The needs assessment will identify opportunities to minimize costs and address funding gaps.

Definition

A comprehensive needs assessment:

- Is “a systematic set of procedures that are used to determine needs, examine their nature and causes, and set priorities for future action” (Office of Migrant Education, 2001);
- “Focuses on the capabilities of the community, including its citizens, agencies, and organizations” (U.S. Department of Health and Human Services, 2014);
- Focuses on the end result of a service (outcome), instead of the means of providing the service (process);²⁹
- Will use established methods and procedures to collect data;³⁰
- “Sets criteria for determining how best to allocate available money, people, facilities, and other resources” (Office of Migrant Education, 2001).;
- And is dependent upon the objective of the service.

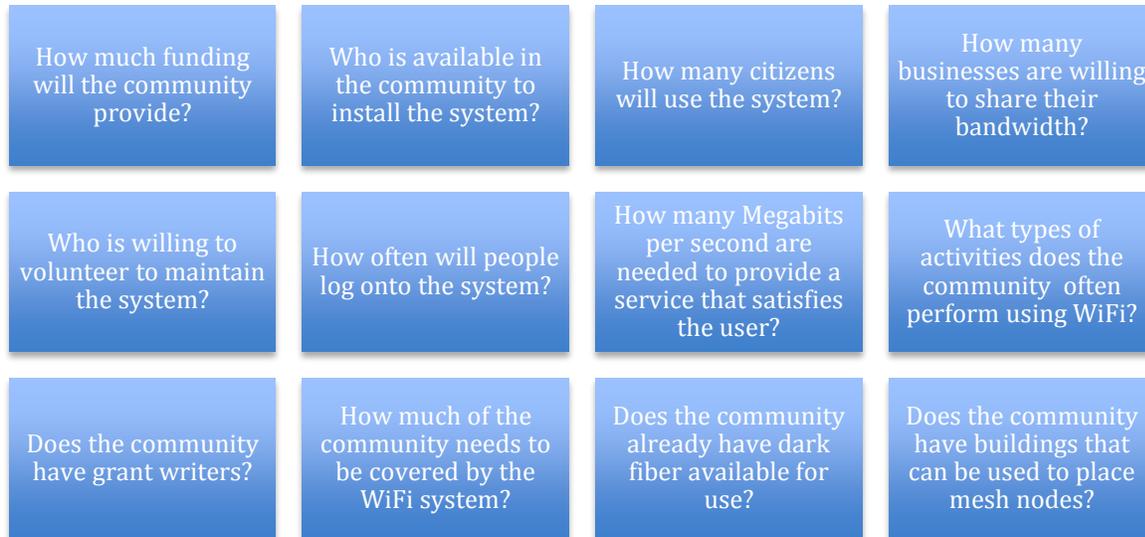
There are five techniques that can be used to collect data on the needs³¹³²:

1. Analyses of existing data using a literature review
2. Surveys
3. Key informant interviews – Interviewing key stakeholders and the target group
4. Community forums
5. Focus groups

Application to Hybrid Model

For the hybrid model, a needs assessment will determine and identify the readily available resources within the community so that fund allocation is more efficient. A needs assessment for the pilot area, East Liberty, can answer the questions in Fig 4 using the five data collection techniques.

Fig 4. Questions Addressed by a Needs Assessment on a Service that Provides WiFi for Economic Development in East Liberty



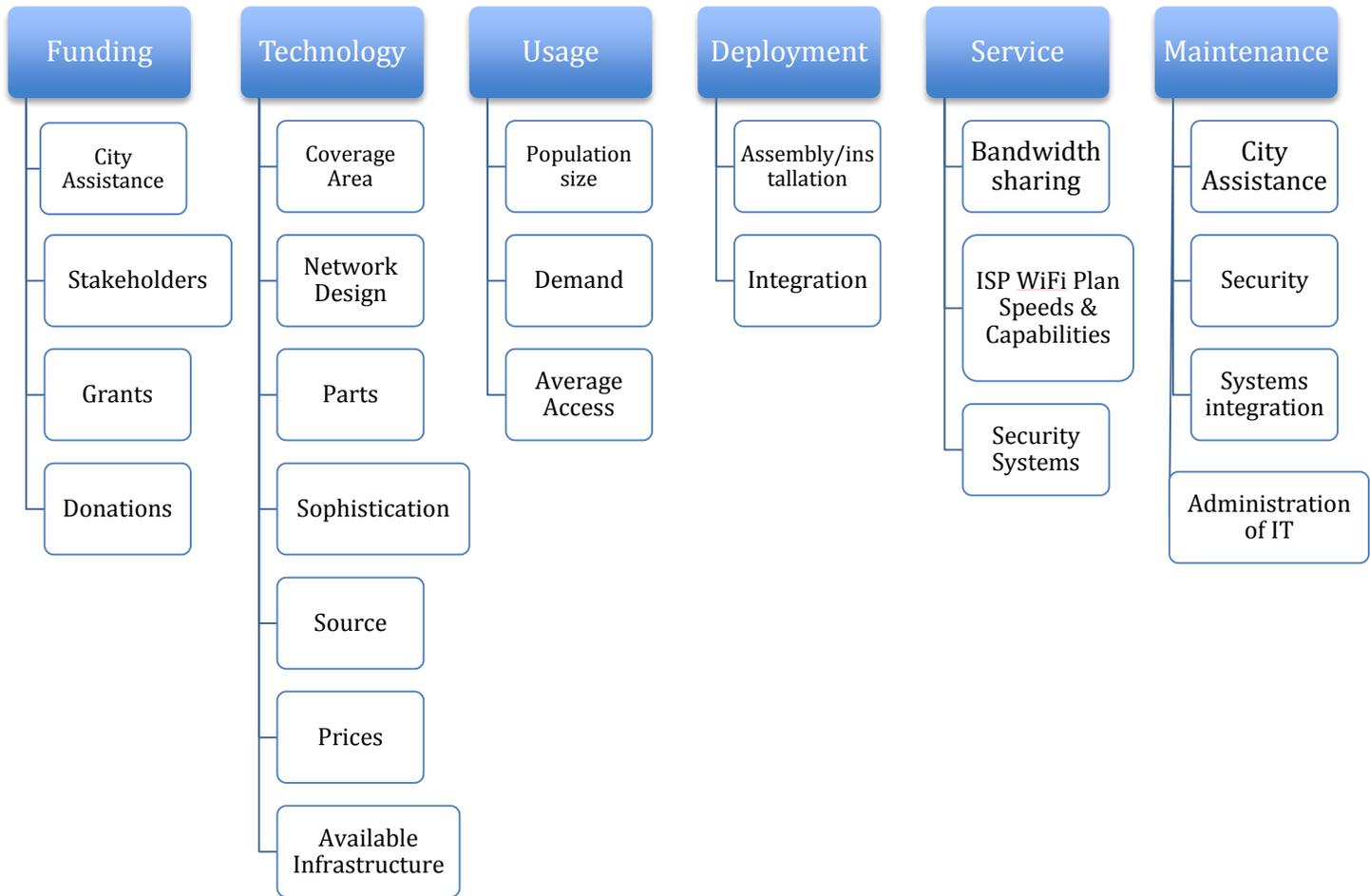
The questions outlined in Fig 4 will help inform the total projected amount of money needed to fund the model based on how much money is *still* needed after identifying the community’s resources, capabilities, and human assets in order to:

- Fund the service;
- Buy technology;
- Afford an Internet Service Provider (ISP);
- And pay for individuals to deploy and maintain the service.

Pricing Strategy

Once the community has determined its funding needs through the needs assessment, then it can develop assumptions and expectations about how the funds will be allocated. Given our literature review, we have found the six key components of a WiFi system. In Fig 5, we have illustrated the key components and listed the areas that need funding for the East Liberty model.³³

Fig 5. Six Components of Model to Consider While Strategically Allocating Funds



The pricing strategy for East Liberty will involve creating key assumptions for each of the above components based on the needs assessment, such as:

- Funding
 - City of Pittsburgh will not provide any financial assistance.
 - Community will rely upon grants, donations, and stakeholders to fund the system
- Technology
 - Community will use a mesh network to create WiFi system
 - Eighty-three nodes are required to cover the whole community given that the total area of East Liberty is 16,197,350 square feet and each node has a range of 500 feet – 10 root routers and 73 access points³⁴
 - Community will buy two extra access points as buffers
 - Community will use Cisco 4402 WLAN root routers that costs \$250/each³⁵
 - Community will use Cisco 1530 Aironet mesh access points that costs \$100/each³⁶
- Usage
 - Population of East Liberty is 6,001 people³⁷
 - 33% of WiFi users typically use the WiFi five times/week³⁸

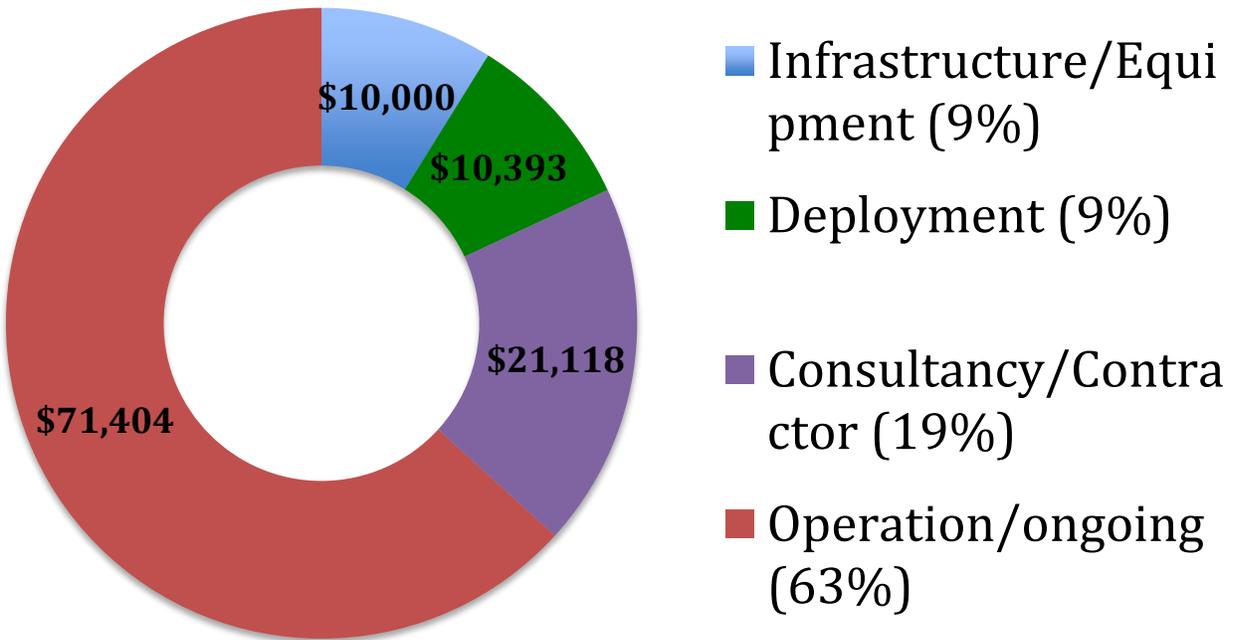
- 67% of WiFi users use one a week³⁹
- Users spend about 44 minutes on WiFi during each use⁴⁰
- 3 times the amount of users use WiFi at peak hours⁴¹
- Given the demand statistics, there will be about 182 on the community WiFi at any given time⁴²
- Since it is assumed that 70% of the WiFi will be provided through bandwidth sharing, the ISP costs only needs cover about 55 of the system's users
- ISP business bulk plan allows for 50 Mbps for \$110/month⁴³
- ISP plan is ideal for small businesses with moderate internet needs and allows for high volume transaction processing, file sharing, high performance emails with attachments, and moderate web browsing⁴⁴
- FCC standard bandwidth/person is 4 Mbps⁴⁵
- About 12.5 users can be served by each plan⁴⁶
- Community needs to buy about 5 ISP plans⁴⁷
- Deployment
 - Security systems will be free⁴⁸
 - Field installation partners are needed to set up the mesh equipment and their hourly salary is about \$30⁴⁹
 - Installation takes about 41.5 hours to complete work each week⁵⁰
 - Four installation technicians are needed⁵¹
 - Installation takes six months
 - Someone will need to install the security systems which takes one month
 - Security Integrators annual salary is about \$65,000⁵²
 - System integrator or network analyst is needed to stabilize the WiFi system
 - System integrator is only needed for one month and the average annual salary based on the City of Pittsburgh's employment site is about \$50,000⁵³
- Service
 - The businesses within East Liberty will provide 70% of the bandwidth of needed to provide the Internet
 - The remaining 30% of the bandwidth will be provided by an ISP
- Maintenance
 - Community needs to hire a security integrator and IT administrator part time to maintain system
 - Average annual salary of an IT Administrator is currently about \$66,000⁵⁴

Pricing Design

The pricing design, which can be created in Excel, calculates the costs of the six components. Appendix 3 shows the cost of East Liberty model given the assumptions outlined in the Pricing Strategy section. Appendices 4 and 5 demonstrate the method in which the assumptions were calculated.

The costs breakdown is illustrated in Fig 6 below. The majority of the costs are going towards labor and maintenance, which reflects this model is reliant upon manpower.

Fig 6. Cost breakdown for East Liberty (Total is approximately \$113,000)



Evaluation

The final step in the cost framework is to measure the performance of the system in order for the community to evaluate whether their pricing strategy is appropriate, and whether it needs to increase, decrease, or reallocate funds.

We have provided four methods of evaluation: an impact assessment, a financial analysis, a quality assurance assessment, and a strategy assessment.

Impact Assessment

An impact assessment will measure the social and economic outcomes of the system, and compare the outcomes (in monetary terms) to the costs. This is referred to as a cost-benefit analysis (CBA). A CBA is a “standard tool [used]...to evaluate investment and deploy capital in the most productive manner possible” (Wheelan,). Wheelan (YEAR) stated that the “most desirable [implementations] are those that provide the greatest benefits relative to their costs.”⁵⁵

To conduct a CBA, it is necessary to sum the “equivalent money value of the benefits” in order to compare the costs and benefits (San Jose State University, 2014).⁵⁶ It is necessary to convert all of the costs and benefits into one “single unit of measure, which is usually dollars” (Wheelan, 2014). However, since the benefits are likely to occur in some time after the costs are calculated, it is necessary to calculate the net present value, or discounted value, of the total benefit dollar amount before comparing it to the cost amount.⁵⁷ The CBA calculation is:

$$\text{Net Benefits} = \text{Total Benefits (in dollar amounts)} - \text{Total Costs (in dollar amounts)}^{58}$$

Fig 7 made using VensimPLE illustrates possible impact measures of the East Liberty model. Fig 8 contains a visual representation of calculating a return on investment (ROI) or net benefits (benefits minus costs) of the model.

Fig 7. Socio-economic Measures of Economic Growth

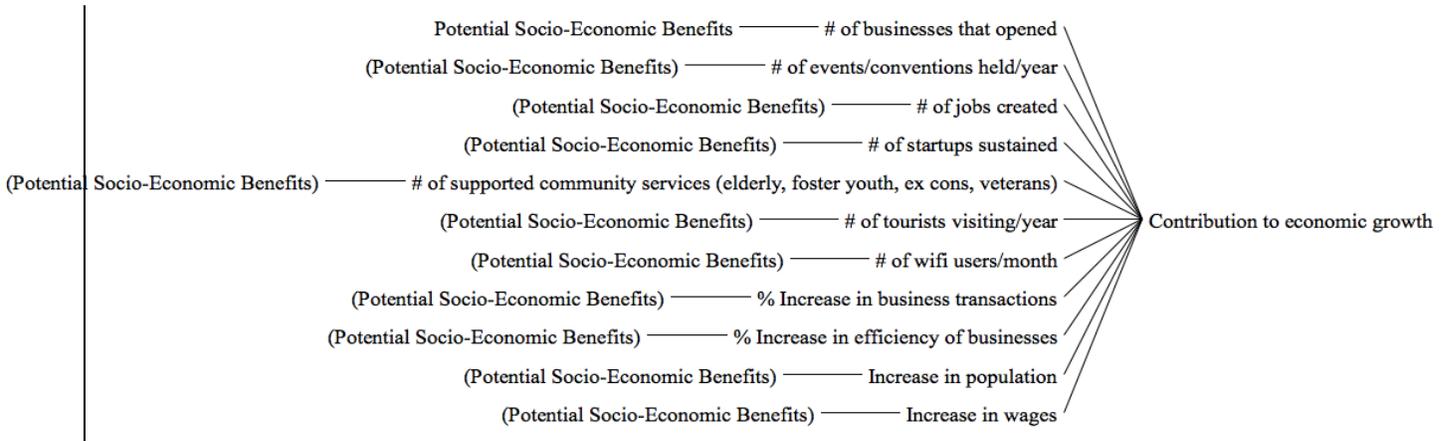
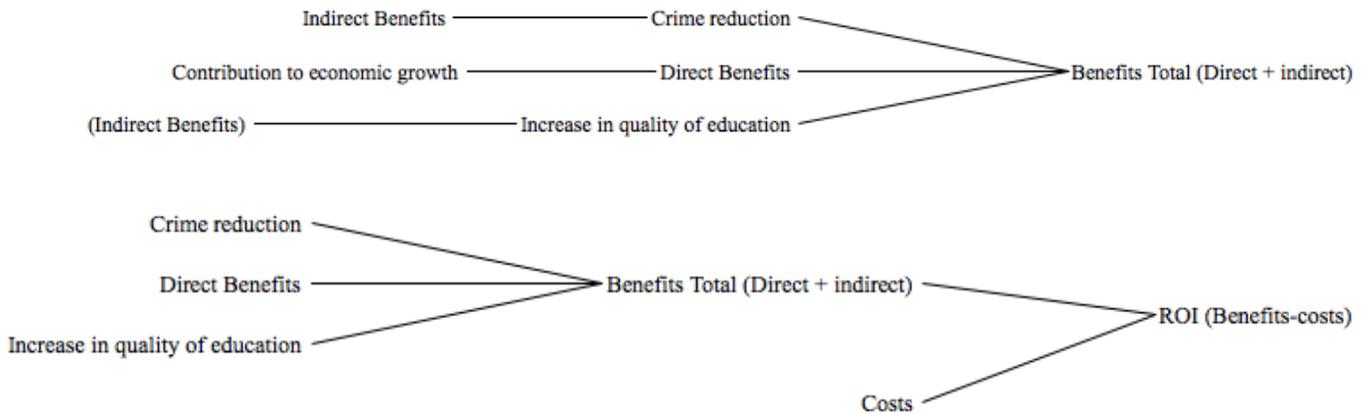
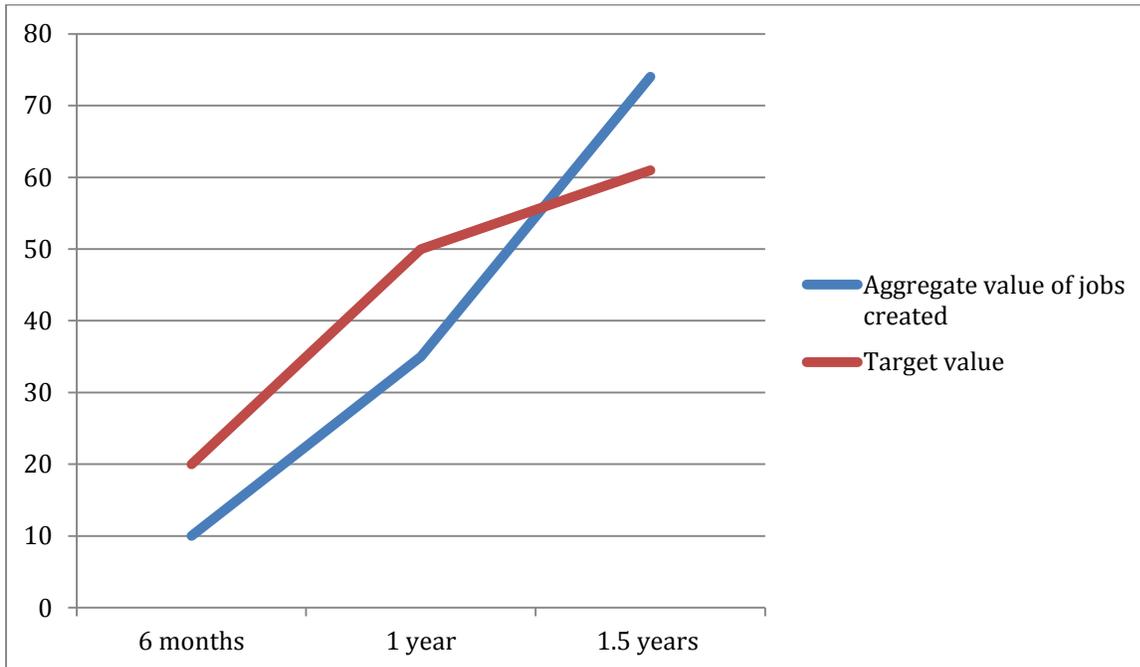


Fig 8. Cost Calculation for Net Benefits



To provide an example of how one of the socio-economic performance measures can be generated, see Fig 9 below. Fig 9 shows the expected value of the amount jobs created in order for the benefits to outweigh the costs versus the actual monetary value of the amount of jobs created. If the value of the jobs created does not reach the target, then the system is underperforming.

Fig 9. Impact Assessment Example: Monetary Value of Jobs Created vs. Targeted Monetary Value of Jobs



Financial Analysis

The cost-effectiveness analysis (CEA) of the pricing strategy will be evaluated by measuring the benefits against the costs without adding a monetary value to the benefits. A CEA requires summing up the total benefits of a unit of measure, such as the number of businesses opened per month. After the benefits are calculated (e.g., the number of businesses opened), the resulting number is divided into the total cost of the model. This will result in will result in a ratio that can be interpreted as dollars per businesses opened as a result the system. Low cost per unit of measure is more desirable than higher costs per unit of measure.

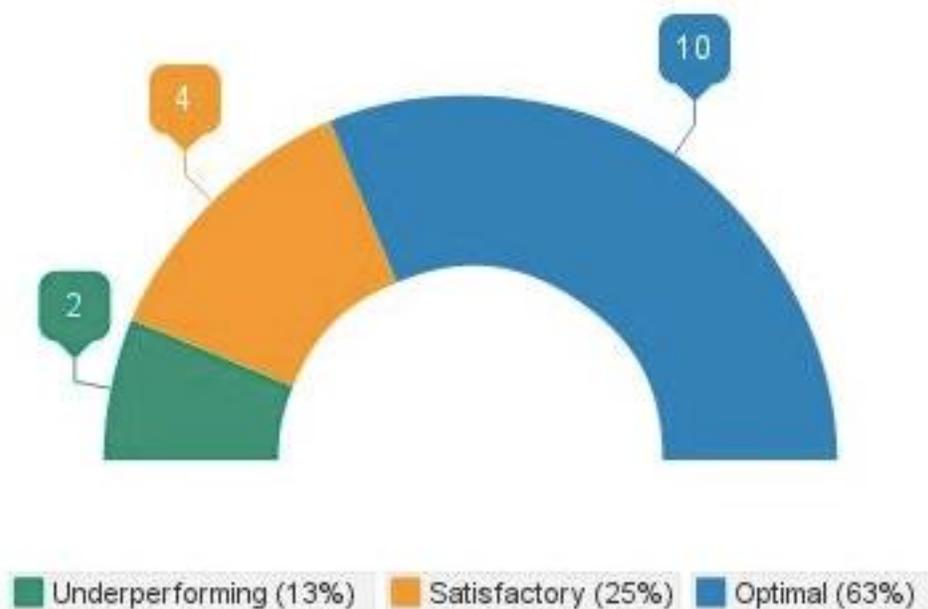
Following, the various cost-effectiveness ratios can be compared to determine how the model costs more or less per unit of outcome for each measure. For example, a community can compare the ratio of dollars per businesses opened to the ratio of dollars per tourists visiting East Liberty. This process will assist in identifying which of the measures is affected more by the amount of money invested into the system and can be used to determine whether funds should be allocated in a different way to better address the measures that are costing more per unit of measure.⁵⁹ To calculate the cost-effective ratio, use the following equation:

$$\text{Cost effectiveness}^{60} = \frac{\text{Total Costs}}{\text{Units of Effectiveness}}$$

Quality Assurance Assessment

The quality assurance assessment will compare the system's service component to user preferences. This will allow a community to determine whether more or less money needs to be invested in certain areas. An example of a performance measure is the amount of bandwidth provided to the user. The gauge in Fig 10 shows the speed preferences of the users collected through surveys. Users consider speeds ≤ 2 Mbps as underperforming, ≤ 4 as satisfactory, and $10 \geq x \geq 5$ as optimal. If a community is providing speeds of 4 Mbps, as in the East Liberty, it will need to consider investing in a more sophisticated Internet Service Provider Plan or buy more plans to service the amount of people using the system.

Fig 10. User Speed Preferences (in Mbps)

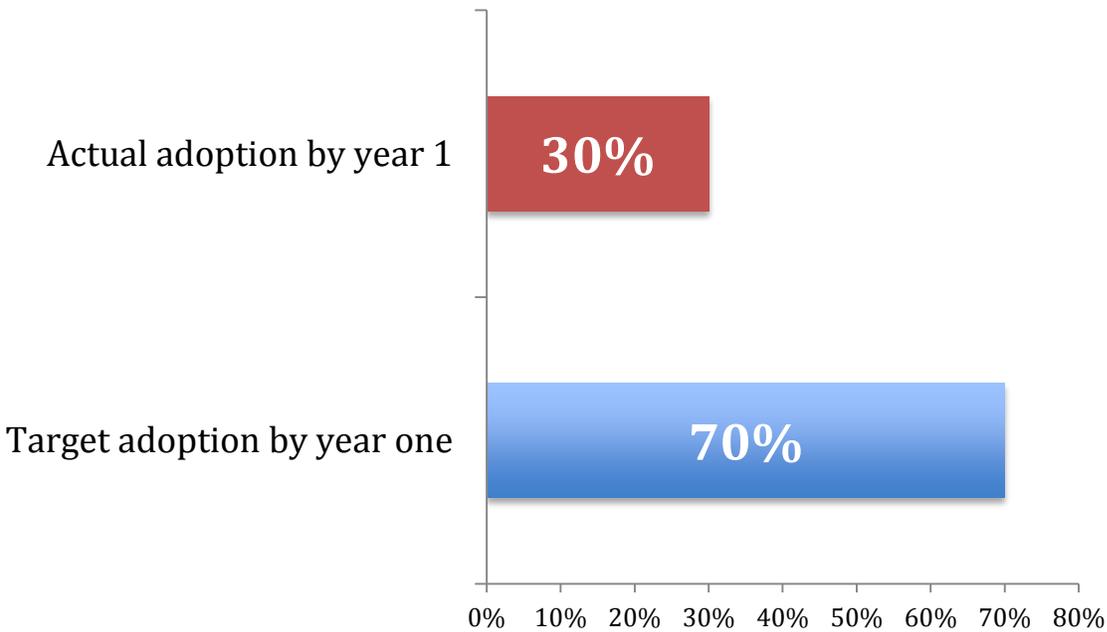


Strategy Assessment

This evaluation process is the most explicit – it collects data the model in order to determine whether the cost assumptions are feasible. For example, as in Fig 11, a community can measure the total number of users that logged onto the system in the first year of implementation. This number will be juxtaposed to the actual number of users that logged on by that time.

This will inform a community on whether to adjust the pricing assumption in order to lower or increase costs. If the adoption rate is lower than expected, a community can try to increase funds for the following year to spend more money on reaching new users. Another option is to lower the costs by making the assumption that the number will not increase in the coming year.

Figure 11. Adoption of WiFi System versus Projected Adoption (in percentage of population)



Asset Mapping

Assets are entities that serve as an advantage, support, resource or source of strength. Mapping is showing or establishing particular features. When we want to involve the community in building the network, we need to identify all potential assets. It is important to map these assets to understand the interconnections and ways to access them.⁶¹

In the model that we are suggesting, we want the community to contribute bandwidth and host access points. So, it is important to know the potential contributors. By knowing who would be part of the network, it will help us to build an efficient network that will cost us the least amount of money, as we can now plan to have least number of nodes and access points covering the maximum area.

A standard process for asset mapping is employed to design the network. First and foremost, we need to establish the need for Internet in the target region based on demographics and goals of the project. In the case of our pilot, we had already mentioned four reasons for why we have chosen this area. After this, we need to identify the community anchors (assets) that can support broadband service.⁶²

These include large bandwidth buyers like large/small businesses, hospitals, churches, community based organizations, libraries, schools, etc. These assets should be approached to figure out if they would be willing to participate in providing free public Wi-Fi in their neighborhood. Most businesses and other institutions have an incentive to participate, as they will be able to provide their customers with new benefits with out any significant additional cost. After we figure out the partners, we can design the network. It is important to consider physical characteristics, such as Terrain, elevation and alternate infrastructure for Technical planning.

Asset Mapping in East Liberty

We designed an asset map with ArcGIS for the proposed pilot project using the standard procedure. We identified all colleges/schools, large/small businesses, hospitals, churches and libraries as Internet service providers. We also identified the equipment access points and user access points. We hope to use the streetlights/traffic lights as hosts for the access points along with the ISP sources. We assume the major user access points to be parks and coffee shops, but also provide Internet to people at the other businesses and commuters.

Appendix 6 shows the available assets in East Liberty. We identified the assets that would be either willing to provide us with Internet or act as host for our nodes. Since, one of the goals of this project is economic development, we hope to involve all the businesses in the area. The green circles represent all the businesses in the area. It includes grocery stores, restaurants and non-profits. We have also identified the hospitals, libraries and schools that can act as Internet service providers.

The red circles represent the major stakeholders such as Google, Whole foods, Target, Starbucks and PNC bank, as they are some of the large bandwidth buyers. We have used the layers of trees and buildings to understand the barriers to line of sight between the access points. We can use these assets to build a network that can provide Internet to people in the area.

Most of the information used for building this map was available on the City of Pittsburgh website. The GIS department of City of Pittsburgh can make use of these resources to build similar maps.

The possible network designs are shown in Map 2. This map is designed using the following assumptions:⁶³

- Root access points – Major businesses that can share bandwidth
- Equipment used – Cisco 4402 & Cisco 1530 Aironet

- Assumed range of the nodes – 500 ft
- Bandwidth sharing – Places that have high concentration of businesses
- Bandwidth purchased – In residential areas

The map reflects a network structure in ideal conditions. The distance between the nodes might vary based on the distractions in line of sight between nodes. The root access points can actually accommodate 48 mesh access points (recommends only 25) and each node has a range of 1000 feet (Cisco). However, we have used conservative assumptions to provide the best signal possible and good bandwidth speed.⁶⁴

Different types of network designs are shown the map in Appendix 7. The yellow home icon represents Root access points. The red arrows show the path of Internet from root access points to the mesh access points. The network design can be customized based on the position of the root access points. If the root access point is towards the border of our target area. We will need to use the design that is south west of the map. In a similar way, different designs are shown that can be used based on the location of the root access point.

In our design, we are only using the 2-hop method as the bandwidth speed reduces by ½ when it hops from one to node to another. To make sure that the end user in the farthest node gets the minimum bandwidth speed we would like them to have, we are limiting our self to 2 hops. With this design, we will have a maximum of 12 mesh access points around one root access point.

We did not design any networks in the northern region to highlight that there are not many bandwidth-sharing organizations available. This is where we would probably have to buy bandwidth from an Internet service provider.

Network Planning

The objective of this framework is to provide communities with a uniform network planning methodology that is:

- Scalable to accommodate expansion and increased utilization.
- Modular for heterogeneous use.
- Flexible to maintain in light of evolving technologies.

Throughout the process, the City of Pittsburgh takes on the role of a coordinator to publish information and facilitate resource sharing amongst participating communities. This process is intended to help communities overcome previously encountered challenges, exchange donated resources such as bandwidth or other network assets, and share and communicate new ideas.

A community-based network planning framework is a four-phase cycle designed to progress through various neighborhoods. It begins with a plan to understand the community’s initiative such as economic development and end-user needs that correlate to that goal.

1. Planning

In phase I, organizers develop a baseline of applications and traffic. The baseline consists of the number of people to serve and the area to cover. Specifically, the planners and designers should understand the needs of network users, application system requirements, and traffic categorization tied to the community's initiatives. This process involves an assessment of the physical location, local assets, end-user activities such as web browsing, real time video streaming, and email, and security requirements. These assumptions are based on the main economic or business drivers behind the network strategy. For instance, while consistent performance and availability are important, some communities may prioritize flexibility or fast growth⁶⁵.

2. Design

Phase II involves creating a logical design that represents the basic building blocks and the structure of the network. This high-level design considers options for how to connect the local network to the broader internet. The high-level topology as shown in Appendix I describes elements needed for a network⁶⁶.

A hierarchical model is one common approach to logical design process. The hierarchy shown in Appendix I is simplistic and modular. The hierarchy facilitates scaling to a larger size without major design changes. The hierarchical model defines access to internet gateways, propagating internet connections, and connecting to the network. The model includes the following three abstract layers:

- The core layer defines how the community will connect to the broader network. The example model in Appendix I is intended to model an infrastructure-based wireless network. The network contains some fixed infrastructure including backhaul nodes, fixed routers, and cabling. In most communities, the core layer will be an extension or amalgam of existing infrastructure. The network design process includes an assessment of fundamental technology and protocols, as well as the capacity at which the network will operate⁶⁷.
- The distribution layer refers to devices that propagate the internet connection throughout the network. The example topology in Appendix 9 includes wireless networking with mesh routing capability to support multi-hop communication. Mesh refers to any technology that enables wireless systems to self-organize. Intermediate nodes can relay or forward packets from source to destination. In a wireless mesh network, only one node needs to be physically wired to an internet gateway. This device propagates the internet connection with capable devices in the vicinity creating a connectivity cloud. Nodes can operate at license-free ISM band 2.4GHz or 5GHz with speed from 2Mbps to 60Mbps. Mesh networks have several unique properties. First, nodes self-configure so the network automatically incorporates new nodes into existing structure without the need for network administration. Next, the network self-heals allowing users to join or leave as needed when nodes are inaccessible or decommissioned. The key benefit of this infrastructure is scalability and reliability⁶⁸.
- The access layer defines individuals or things that access the network. This phase includes characterizing network traffic previously defined during the baselining process (application systems, clients, servers, hardware, software, and transmission technology). This phase must

consider heterogeneous network devices with varying capacities. The majority of traffic is transmitted from clients to an internet gateway⁶⁹.

3. Optimization

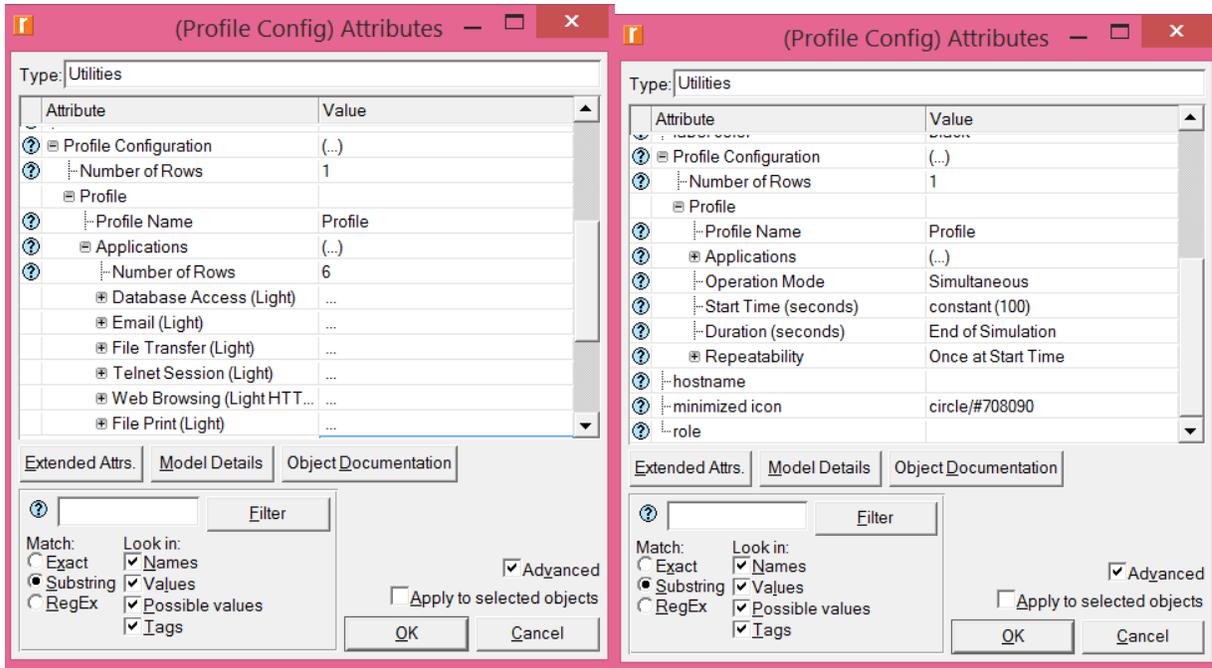
In phase III, the network integrator implements and optimizes assumptions. Since network planning is costly and complex, administrators should have an understanding of network performance and simulation is cost effective way to review scenarios and compare them against targets. This could mean predicting how the use of new applications or evolving technologies will effect traffic. Success indicators may include quality of service (QoS), performance, and availability measures. This function is complex and specific statistics used will depend on phase I and phase II.

Network administrators may use network management software to gain some insight into network performance, and traffic simulation is cost effective way to review scenarios and compare them against targets.

A test lab was configured to using the Riverbed Opnet IT Guru to examine how a community's network administrator might forecast traffic scenarios and interpret results. IT Guru is an object-oriented traffic simulation and event analysis tool used to evaluate network performance indicators. The results of each analysis are subject to interpretation against key objectives, and the resulting decisions depend on inferences, specific traffic scenarios, and community goals.

Since the City of Pittsburgh envisions a free public Wi-Fi network for academic and limited leisure use, the virtual lab includes HTTP, email, file sharing, and content databases. In addition, high- and low-intensity user profiles were configured to generate simultaneous connections for 10 minutes as shown in Fig 12. In community planning the scenarios should be tailored to need. Traffic capacities are a mathematical function of the model and vary by inter-arrival times exponentially distributed around a mean, number of bytes, and number of images. Network administrators can customize these features, but the process is complex and it requires some technical expertise.

Fig 12. Configured User Profiles

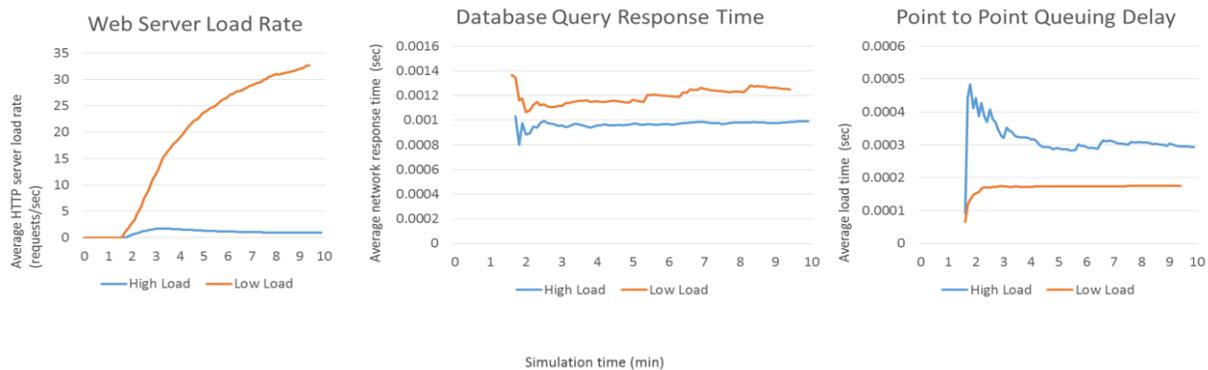


Scenario 1 considered average web page response times. In the high traffic scenario, response times increased by over 100% from the low simulation as shown in Fig 13. While the increase was fractional in proportion to the average response time in seconds, the magnitude of this statistic meaningful, particularly in high growth situations. On average, individuals expect a webpage to load in 3 seconds or less. When response times increase over 10 seconds users tend to abandon the site or the network⁷⁰. The results also indicate that the impact of higher traffic loads on certain applications can vary. Scenario 2 considered database query response times, which represent time elapsed between sending requests and retrieving responses⁷¹. In this example, high-intensity traffic increased response times by roughly 20% from low-intensity traffic.

Scenario 3 measured queuing delay or packet waiting times in the transmission queue. Measurements are taken from the time a packet enters the transmitter channel queue to the time the last bit of the packet is transmitted. Delays result from mismatches in the arrival and departure rate⁷². In this example, the wait initially times increased and eventually stabilized. However, if waiting queues exceed device buffers, then these delays can degrade network performance and result in dropped packets. While response times, query speeds, and queuing delay statistics are particularly useful if latency and congestion are of primary concern,¹⁷³ scenario modeling can be used to generate a myriad of performance measures.

¹ Cisco consumer survey on public Wi-Fi satisfaction reports that approximately 23% of public Wi-Fi users are dissatisfied with network speeds caused by latency and congestion (Cisco).

Fig 13. Response Times



Overall, traffic simulation can result in tangible benefits, and administrators may leverage analyses and results to:

- Justify a business need for content caching. Caching stores frequently used web pages and other content locally, using a cache engine. Web requests do not go out directly, they are first shunted by the router to the cache engine to see if they are available locally. Traffic volume is lowered since many frequently requested web sites can be retrieved from the cache without accessing the internet gateway⁷⁴.
- Estimate the impact of network security features such as virtual private networks (VPNs) to determine if there is degradation in performance. Users accessing VPNs increase packet latency due to the processes of encapsulation and decapsulation.
- Prioritize protocols and model the impact of network policies. For example, some agencies that donate bandwidth may mandate policy or usage restrictions. To comply with these requirements, the community's network administrator can set QoS policies to define maximum data rates by client or by traffic type. The administrator may prioritize mandatory requirements such as firewalls or encryption traffic over desirable requirements like video streaming or gaming.

The simulation results can contribute to the planning process and aid in measuring network performance with respect to user requirements. It is also feasible to stress test network utilization and traffic magnitudes. The results can be used to estimate bandwidth consumption and model the impact of changing technology, new application deployment, or system upgrades.

While test labs using the IT Guru software provide useful insight into small-scale network models and research, IT Guru is intended for academic use and it does not offer the full functionality of the commercial version. Since network performance is fundamentally limited by several parameters including node distance and trajectory, background noise, fluctuating interference (inter-cell and intra-cell), and bandwidth frequency range, and some of these features cannot be captured in the academic version of the software, community network designs should establish some minimum network planning standards and include precise modelling and site surveys conducted by certified and licensed network integrators where necessary⁷⁵.

Reconciliation

The final phase of the network planning framework reconciles the overall results and measure costs. At this point in the process, inefficiencies or flaws in initial assumptions can be addressed. The community organizers should revisit each step until the process results in a feasible design. Ultimately, the process culminates in a uniform network planning process to accommodate various communities, expansion, and increased utilization over time.

Establishing Strong Foundations of Cybersecurity

Often, security is added onto a model after an incident takes place or information is compromised. However, with wireless municipal WiFi, this would not be the correct approach. Public WiFi networks are easy targets for cybercriminals to take advantage of. The various attacks could manifest itself in several ways through sniffing or denial-of-service attacks. To remedy the threats stemming from cyberspace, security should be a major pillar in establishing municipal WiFi from the onset.

There are two main documents that are needed to guide networks on the ground to help them establish an adequate standard of security. There is the Administrator's Guide that seeks to inform an audience with some technical knowledge how to conceptualize the best ways to mitigate cyber threats. The goals of the Administrator's Guide is do the following:

- Successfully identify security objectives
- Describe various threat against your network
- Provide a mitigation strategy to fight cybercrime
- Keep cost low and rival proprietary solutions towards building your own security network
- Build your knowledge base

These objectives can change as the implementation process takes place. For example, proprietary solutions can be adopted to change out open source software as the network matures. Having proprietary software in the beginning may not be the wisest choice and there can be various ways in which open source may be the best option in terms of cost and/or learning curve.

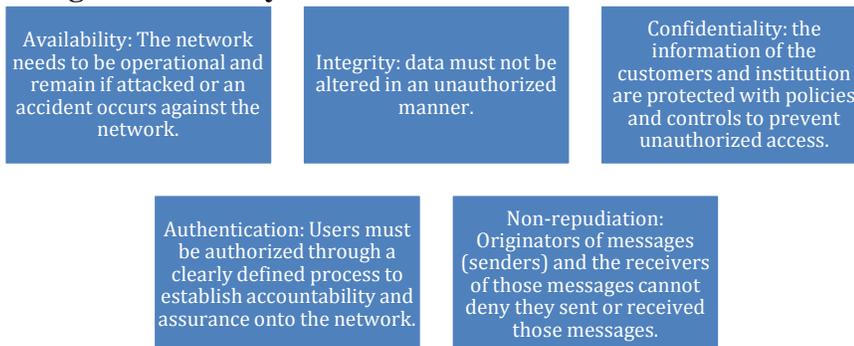
The user guide is for the end user to guide them through using the public WiFi system. It is short, easy, and should assuage the concerns they have with using a public WiFi system. Finally, it is an excellent way for the end user to be informed about the various risks and policies they have to adhere to.

In the following sections, the security section will delve deeper into these issues a little more. There will be examples of what needs to be examined more specifically like the OSI model and why this security framework was established in this particular way.

Security Criteria

In order to have a strong foundation of Cybersecurity, several security issues need to be incorporated. The National Institute of Standards and Technology (NIST), a world leader in Cybersecurity under the Department of Commerce, establishes several underlying models of security for government systems with NIST, SP800-33 seen in Table 1.

Table 1: Honing in on Security⁷⁶



The Administrator’s Guide

The guide attempts to be as comprehensive as possible. For example, a strategic model is laid out through the OSI model, which is a model that will aid administrators in conceptually understanding where the threats come from. The OSI or Open System Interconnection model is one of the best ways to guard against the various attacks because it standardizes network protocols for all computers, incorporates various network technologies, and has remained consistent since the development of the model in the late 1970s.⁷⁷ In addition, the city’s role is included for the following functions:

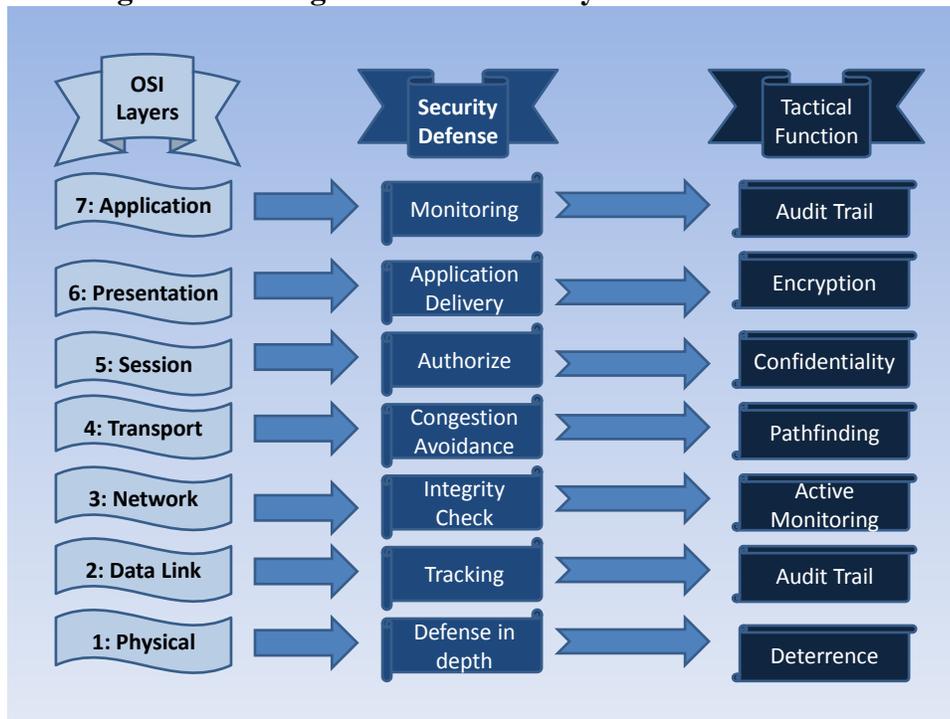
- Allow you to use their public infrastructure such as lights and poles to help install access points throughout the network.
- Provide guidance for establishing IT policies.
- Be available for other questions and concerns that can arise when establishing the wireless mesh network.
- Provide literature and networking to other wireless mesh networks.

Table 2: Providing a Security backbone

The OSI Model	
Level	Description
Layer 1: Physical	Defines the network in the “real world”
Layer 2: Data Link	Connects nodes
Layer 3: Network	Procedurally moves information within the nodes in a network
Layer 4: Transport	Transfers information from one host to one over networks
Layer 5: Session	Establishes and maintains connections
Layer 6: Presentation	Data translator
Layer 7: Application	What the end user interacts with

Throughout the guide various types of attacks such as a SYN and UDP flood are discussed. The OSI model is translated into security terms seen in the transformation from Table 2 to Figure 14.

Figure 4: Translating a Networking Model into security Terms



There is also guidance on rogue access points. These are some of the most common types of attack that should be addressed. This is done by going through each layer that describes the various threats and a strategic response to those threats. For example, one can example layer 4, the transport layer:

Layer IV: The Transport Layer

The transport layer attempts to send the data from layers one to three successfully to other networks.

Threat Vectors

Typical attacks could be SYN flooding and eavesdropping.

- SYN Flooding: When the three-way-handshake occurs, the process used to establish a connection between two computers, the attack could send an excessive wave of SYN packets. The SYN packet means synchronize and is a packet of information used to connect network together.
- UDP Flood: User Datagram Protocol (UDP) is connectionless with no handshaking dialogue. The attacker can use Low Orbit Ion Cannon to accomplish in a very short amount of time.

Strategic Response

The best way to defend against these attacks is using authentication mechanisms. For example, a checksum is a fingerprint that occurs between the two networks. A firewall can detect the various checksums that are coming in to see if they are available. If they are not, the firewall can deny and block the connections from taking place. The defenders can have a series of firewalls at different points to block unwanted transfer as well. This stops a UDP flood attack because they will have very little areas to actually flood on your network. Stopping these attacks requires active monitoring where you have to analyze the traffic requests coming in and deny them on the spot. You will often have to anticipate the attack before it can fully materialize on the network.

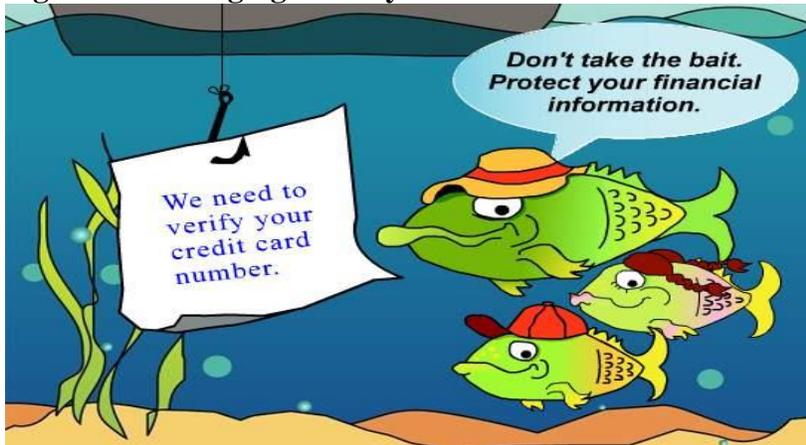
In essence, the guide tries to be as comprehensive as possible in a limited amount of space. The guide is set at 16 pages.

User Guide

Finally, a guide for users is included as marketing effort. There is a substantial amount of negativity regarding public WiFi. Building confidence in users and giving them the knowledge to secure themselves through a guide should help build the user base of the network and assuage the typical concerns with public WiFi such as being inherently insecure. For example, an article by DW, a news outlet on technology, reports public WiFi as inherently insecure and that users do not know what they are getting themselves into as many signed away their first-born child with the terms of service agreement.⁷⁸

However, the user guide attempts to rectify these concerns and is a customer oriented product. It is short at two pages and requires little knowledge to comprehend, unlike the security model for the administrators. The user guide takes them step-by-step on what they should know before they connect, as they connect, and what they are responsible for. It is very easy to understand and could easily be translated into an HTML page or a printed guide.

Figure II: Assuaging security concerns for the end user with the user guide



Conclusion

All in all, security is a significant issue that needs a roadmap. This roadmap is largely provided by the Administrator's Guide with the User Guide as an addition. These guides take time discussing the various types of attacks and concerns that could arise from establishing a success and safe public network.

Appendix 1. WiFi Implementations in Other Cities

	Philadelphia, Pennsylvania	Englewood, NJ	Kansas City, Missouri	Boston, MA	Redhook, NY
Attempts to Provide WiFi	2	1	1	2	1
Success or failure	Failure – Earthlink sold the system assets to Wireless Philadelphia and it is now used for public safety purposes. The system underperformed by not selling enough plans to its target population. Literature states that the city de-prioritized public inut and constituent interests. As well, the initial network build involved coverage in areas where customers did not have the financial resources to actually pay for the service.	Success	Unknown	Success	Success
Pilot area	Downtown Philadelphia	Downtown	Johnson County	Grove Hall (1.5 square mile area) – 30,000 residents	Redhook, Brooklyn – where broadband adoption rates are lower than the city average
Purpose for System	Provide low-cost Internet access to the poor	Economic development	Superior internet speed	Economic development	Initiate social change through youth engagement, close the digital divide, generate economic opportunity, facilitate access to essential services, and improve quality of life
Target population/Demand	The 300,000 households – about half of the city – that could not access the Web to perform basic economic activities such as applying to jobs. Also, city government branches and schools could pay for private access. Earthlink estimated between 50,000 and 80,000 subscribers by year two, but the system never went live.	Visitors at the hospital and surrounding businesses in downtown	Everyone, but low income areas needing affordable internet.	Businesses and general public, particularly those in underserved areas	Home internet Community collaboration Access to resources (employment and skills sharing) Local Information System Multilingual Services (Spanish, Arabic, Tagalog) Exploration through “gamification”
Usership data	Since network purchased from Earthlink by Wireless Philadelphia, users have increased from 10,000 to	This project has been implemented this year and have been	Google establishes the connection where people sign up for it	For the pilot area, about 7,700 daily users with a repeat visitor rate of 89%	100 users per week

	170,000.	reporting the users on the facebook page maintained by Englewood economic development center	and commit to Google Fiber's services (TV, Internet packages).		
Partners	Wireless Philadelphia, a nonprofit formed to oversee Earthlink's construction of network	Englewood Hospital and Medical Center, Bergen Performing Arts Center, TREECO and NVE Bank	Kansas City municipality	US Department of Housing and Urban Development's Choice Neighborhoods program	Open Technology Institute, FEMA, and NYC
ISP	Earthlink – charged \$20/month for private access and \$10/month for 25,000 low-income households.	Englewood Hospital and Medical Center	Google	Comcast	5GHz AirOS
Internet facts	Implemented 802.11 technology. Offered speeds of 1 Mbps for uploading and downloading	802.11 ac public Wi-Fi, allowing client device speeds to burst up to 100Mbps over fiber optic Internet bandwidth	1 gigabit upload and download speed.	Network provides speeds just fast enough to let users stream video at medium quality	Donated bandwidth Non-profit
ISP costs	Unknown	Bandwidth is shared by the hospital. So, they are no extra costs involved	City will be provided with services for free.	Unknown	Unknown
Network Type	Mesh	Fiber internet. Using hub and spoke for wifi	Fiber	Fiber optic network called BoNet– predominantly dark fiber	Mesh
Network costs	Earthlink estimated that the total infrastructure to cover the city would cost \$20 million; yet did not finish. Earthlink's investment was \$13.5 million.	75,000	Unknown, figures not released.		\$80/outdoor routers \$50/indoor routers
Infrastructure	Pilot area was 15-square miles and the entire city was 135-square miles. Before being shut down, the WiFi network had grown to 29 sites with a total of 4,500 spread throughout the city.	Ackrion, a Massachusetts-based company that provides "large-scale outdoor Wi-Fi solutions," implemented	Public Utilities	Interconnected outdoor WiFi hotspots using ~150 sites including 20 hubs/faps on a core ring (170 access points total). Expanding the system to connect	Ubiquiti Nanostation (outdoor) Linksys router (indoor) connected via Ethernet. Linksys router connected to RHI modem. Initial setup provided prototype opportunity for local RHI Wi-Fi

		and designed the system.		Boston's 20 neighborhoods using 130 access points for. Focus is on the Main Streets of each neighborhood.	applications. Access point + splash page + website hosted on local server = digital message board. -Ubiquiti Nanostation on nearby apartment building – resident donated electricity and connected to low power server hosting digital message board.
Policy/legal barriers	Incumbent broadband providers began to lower their pricing structure once the city's plans were announced. HB 30 was enacted in response to Philadelphia's network. Philadelphia was exempt due to a two-year grace period for municipalities.	No barriers	Several outlined in the latter half of the public agreement between Kansas City and Google.	--	--
Security methods	--	--	Typical security measures.	Content on the network is limited and users will be prevented from accessing pornography, piracy websites, gambling websites, or anything that might be considered malicious content.	--
Staffing	--	--	Google is establishing their own center, staffing numbers unknown.	--	Digital Stewards who are young adults from Red Hook ages 19-24, employed by the Red Hook Initiative to install, maintain, and promote the WiFi network. Stewards are trained in wireless network installation, software and hardware troubleshooting, and community organizing using a curriculum created by Open Technology Institute and Allied Media Projects.

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Appendix 2. Midterm Report

To: Debra Lam, Chief Innovation and Performance Officer
Dana Robinson, Network Analyst
Sylvia Harris, Deputy Director of Operations

From: Lindsey Parham, India Sutton, Ramer Pelayo, Terri Gibbs, Qingyi Cao, Kautilya Nalubolu

Date: October 23, 2014

Subject: City of Pittsburgh Wi-Fi Project – Midterm Report

Dear Mrs. Lam,

While it is feasible to implement

free, publicly accessible Wi-Fi within Pittsburgh's city limits, evidence suggests that actual demand for ubiquitous Wi-Fi could be lower than anticipated. Nonetheless, a comparable service provided to residents of select neighborhoods would provide a greater social and economic investment. In addition, studies support that oftentimes, residents with the most need for free Internet service also lack capable devices. Consider Verizon's Lifeline Program that made a significant impact by donating 12 million cell phones to low-income individuals, or the Pittsburgh's IPAD initiative for school-aged children. The amalgam of these facts lead us to believe that a more compelling issue in Pittsburgh is one of connectivity, as opposed to Wi-Fi access. In light of these findings, we propose to modify the scope of this project to address the issue of connectivity in Pittsburgh through a free Internet service within high-need areas, as well as a strategy to provide devices or other means to connect.

Background

Several municipalities have endeavored to implement free municipal Wi-Fi with limited utility. Specifically, both San Francisco and Philadelphia's public Wi-Fi projects were unsuccessful because the actual demand for Wi-Fi was much lower than anticipated. For example, the business model underlying San Francisco's Wi-Fi relied on advertisements and subscriptions for revenue. However, because of limited use, sales and advertising revenues were insufficient to cover the network's operating costs. The Wi-Fi service in Philadelphia suffered a similar demise.

In addition to utility concerns, legal barriers with respect to city-wide Wi-Fi are also evident. Pennsylvania State House Bill 30 mandates that a municipality offer local Internet service providers the right of first refusal. In its first attempt to create a municipal Wi-Fi system, Philadelphia was exempt from State House Bill 30 because it developed the system during a one-year grace period. However, in Pittsburgh this legislation is imminent.

Demand for Free Wi-Fi

A study published by the Pew Research Center indicates that approximately 1%-2% of residents are likely to find utility in free city-wide Wi-Fi and this usage would not justify the cost to implement and administer a network.² There are two primary reasons for this - trends in ownership of mobile Wi-Fi enabled devices and ready access to existing Wi-Fi sources, particularly at home, in public spaces and at work. Nearly 64% of adults in the United States own cell phones. We applied this statistic to all adults and Pittsburgh and found there are approximately 170,000 adults with smartphones. We determined this to be our maximum potential demand. We estimated anywhere from 15%-30% of these adults would use this service, about 25,000 - 50,000 users.

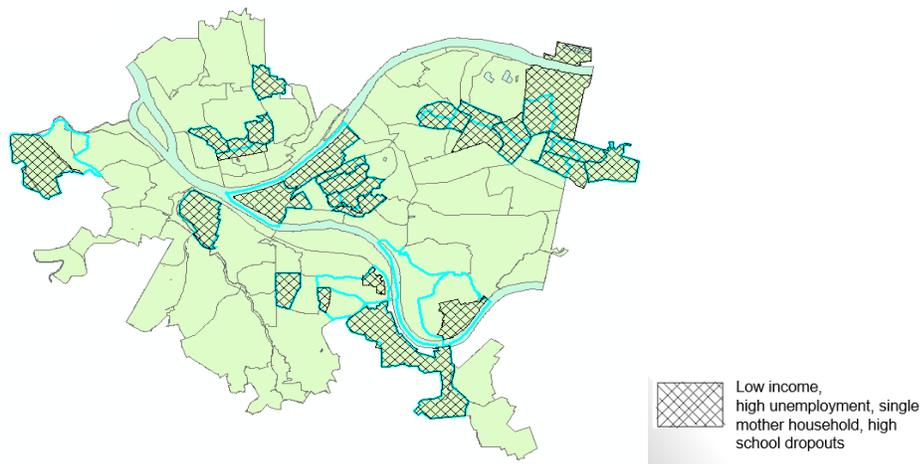
² Kharif, Olga. "Why Wi-Fi Networks Are Floundering." *Bloomberg Business Week*. Bloomberg, 15 Aug. 2007. Web. 12 Dec.

On the contrary, there are several economically and socially depressed neighborhoods in Pittsburgh shown in Figure 1.1. Residents of these areas often lack access to the Internet and capable devices for socioeconomic reasons, primarily related to education and income, as well as few community centers and businesses with hot spots or free access points. For instance, adults without a high school diploma or those earning than \$30,000/year are far less likely than to own a smartphone or have home Internet than the national average.

Figure 1.1 shows area considered severely distressed which fall under three of the four following requirements:

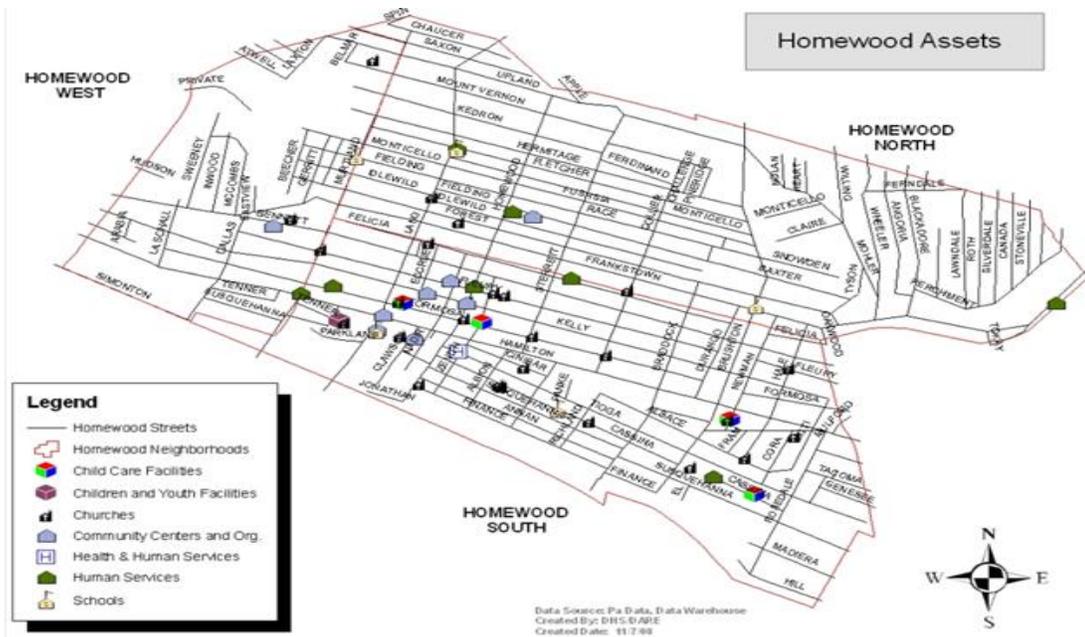
1. High poverty rate (27.4 percent or more);
2. High percentage of female-headed families (37.1 percent or more);
3. High percentage of high school dropouts (23.0 percent or more); and
4. High percentage of working-age males unattached to the labor force (34.0 percent or more).

Figure 1.1 Severely Distressed Pittsburgh Neighborhoods



Consider the Homewood neighborhood as an example. It is considered distressed, and Figure 1.2 shows the neighborhood also has few libraries, cafes, or non-profit organizations that provide free public Internet access.

Figure 1.2 Homewood Neighborhood and Public Access Points.



Sources of Funding

The most enduring and successful examples of municipal Wi-Fi involved community support, and government grants. In fact, an initiative to provide connectivity supported by a socioeconomic cause would qualify for more funding than a ubiquitous Wi-Fi service. Figure 1.3 details a list of need-based grants.

Figure 1.3 Need-Based Grants and Funding

Source	Amount	Cause
URA	--*	Low-income services & job creation
CDCs	--*	Community innovations & investments
U.S. EDA	≥ \$100,000	Regional innovations/technical assistance
NTIA	≥ \$4 million	Deployment of technologies for education, public safety, & sustainable economic growth
USDA	≥ \$6 million	Telecommunications construction for job creation & economic growth
Google Pittsburgh	\$2,000-10,000	Increasing access to Internet

the

Proposed Scope
Given demand

estimates, socioeconomic factors, and funding opportunities, a strategy to provide connectivity to high-need individuals would enrich the Pittsburgh community.

The deliverable should specifically address a strategy to provide new or recycled Wi-Fi devices or access centers, specific strategies could include:

- Implement an indoor/ outdoor mesh network in the targeted areas.
- Provide subsidized or free Wi-Fi to community centers, churches, and organizations.
- Provide subsidized or free Wi-Fi to low income households.

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Appendix 3. Costs of East Liberty WiFi Model Estimated Using Excel

Infrastructure/Equipment Costs	
Root router (WLAN Controller)	\$2,500.00
Mesh Access Points	\$7,500.00
Leasing municipal assets	\$0.00
<i>Total infrastructure/equipment Costs</i>	\$10,000.00
Deployment Costs	
Security Systems	\$0.00
Field Installation Partner	\$4,953.29
Installing Security Systems	\$5,440.17
Systems Integrator	\$4,440.33
<i>Total Deployment Costs</i>	\$10,393.46
Operational Costs (ongoing)	
Security integrator (part-time)	\$32,641.00
IT administrator (part-time)	\$32,987.50
Wireless Internet Service Provider (WISP) (look at the cost of the data rate)	\$5,775.77
Community Volunteers	
<i>Total Operational Costs</i>	\$71,404.27
Consultancy/Contractor Costs	
Needs assessment for design of survey	\$3,076.92
Needs assessment for survey administration	\$3,076.92
Simulation/Modeling Network	\$6,865.47
GIS mapping of assets	\$6,865.47
Cost analysis	\$1,232.81
<i>Total Consultancy/Contractor Costs</i>	\$21,117.59
Additional Add-ons	
Application Vendor	\$19,140.00
Application creation	\$25,000.00
<i>Total Additional Add-ons</i>	\$44,140.00
TOTAL COSTS	\$157,055.32
TOTAL COSTS WITHOUT ADD-ONS	\$112,915.32
TOTAL START UP COSTS	\$41,511.04

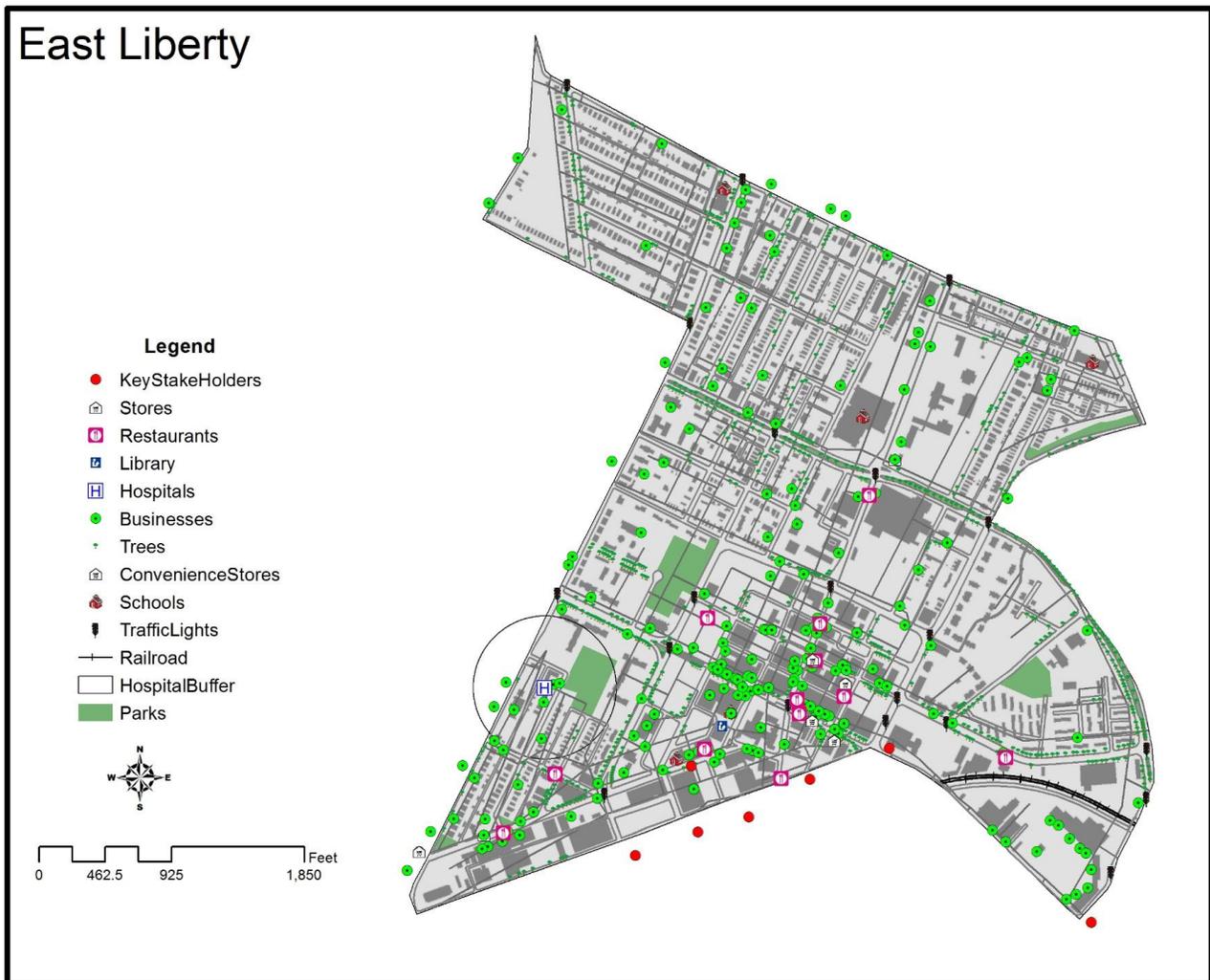
Appendix 4. Assumptions that Influenced Costs of the East Liberty WiFi Model

	A	B
71	Population of East Liberty (approximate)	6,001
72	Proportion of users that use more than once a week	33.00%
73	# of times 1/3 of population uses	5
74	minutes use of 1/3 pop	0.733333333
75	Proportion of users that use once a week	67.00%
76	# of times 2/3 of population uses	1
77	minutes use of 2/3 pop	0.733333333
78	Total number of hours of wifi use per week (for the 6,001 people in East Liberty)	10209.70133
79	Maximum number of hours used by population each week	1008168
80	Hours per week used using proportions	1.701333333
81	Percentage of people using wifi per week (Hours per week using proportions/total hours in one week)	1.01%
82	Percentage of people using wifi per week during peak usage (assuming 3 times the amount of users at peak hours than normal)	3.04%
83	Number of people on wifi at any given time	182.3160952
84	Assume 70% of internet/bandwidth is provided through bandwidth sharing	127.6212667
85	Number of Mega bits per second (Mbps) needed at any given time (assuming that each user only needs 1 Mbps)	
86	Number of Mbps needed from ISP (Assume will need ISP to provide 30% of bandwidth)	54.69482857
87	50 mbps for \$110/month	50
88	FCC standard bandwidth/person is 4 Mbps	4
89	Number of people served by each plan	12.5
90	Number of Plans needed for ISP providing 30% of internet	4.375586286
91	Cost of ISP/month	\$481.31
92	Cost of ISP/year	\$5,775.77

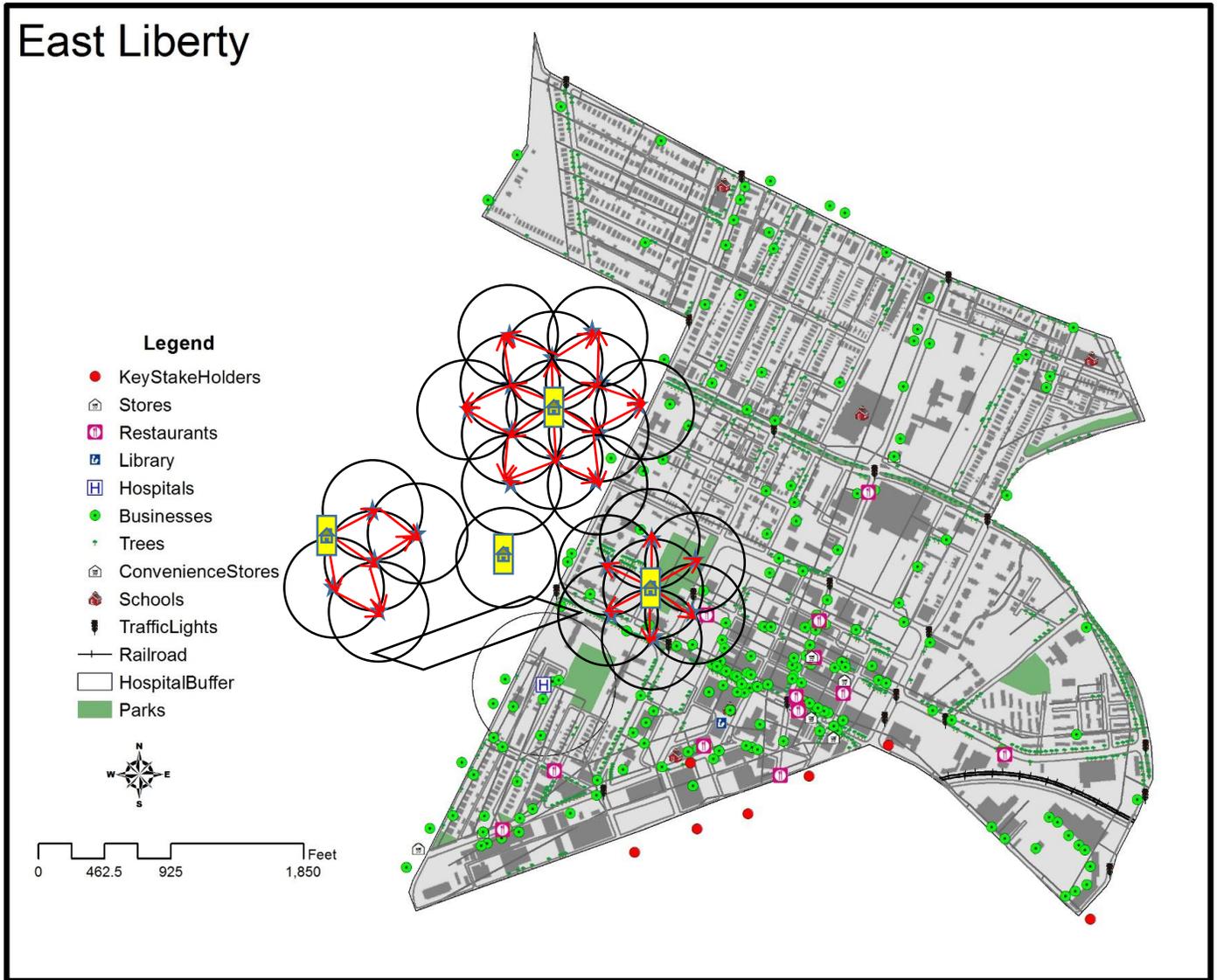
Appendix 5. Mathematical Equations Used to Calculate the Assumptions

	A	B
71	Population of East Liberty (approximate)	6001
72	Proportion of users that use more than once a week	0.33
73	# of times 1/3 of population uses	5
74	minutes use of 1/3 pop	=44/60
75	Proportion of users that use once a week	0.67
76	# of times 2/3 of population uses	1
77	minutes use of 2/3 pop	=44/60
78	Total number of hours of wifi use per week (for the 6,001 people in East Liberty)	=((B71*B72)*B73*B74)+((B71*B75)*B77)
79	Maximum number of hours used by population each week	=6001*7*24
80	Hours per week used using proportions	=(B72*B73*B74)+(B75*B77*B76)
81	Percentage of people using wifi per week (Hours per week using proportions/total hours in one week)	=B80/(24*7)
82	Percentage of people using wifi per week during peak usage (assuming 3 times the amount of users at peak hours than normal)	=B81*3
83	Number of people on wifi at any given time	=B82*B71
84	Assume 70% of internet/bandwidth is provided through bandwidth sharing	= 0.7*B83
85	Number of Mega bits per second (Mbps) needed at any given time (assuming that each user only needs 1 Mbps)	
86	Number of Mbps needed from ISP (Assume will need ISP to provide 30% of bandwidth)	=0.3*B83
87	50 mbps for \$110/month	50
88	FCC standard bandwidth/person is 4 Mbps	4
89	Number of people served by each plan	=B87/B88
90	Number of Plans needed for ISP providing 30% of internet	=B86/B89
91	Cost of ISP/month	=110*B90
92	Cost of ISP/year	=B91*12

Appendix 6. Map of Assets in East Liberty



Appendix 7. Map of Possible Network Designs in East Liberty



Appendix 8. Math for Asset Mapping

Number of nodes required for the Mesh Network

Area of East Liberty in sq.miles - .531 sq miles

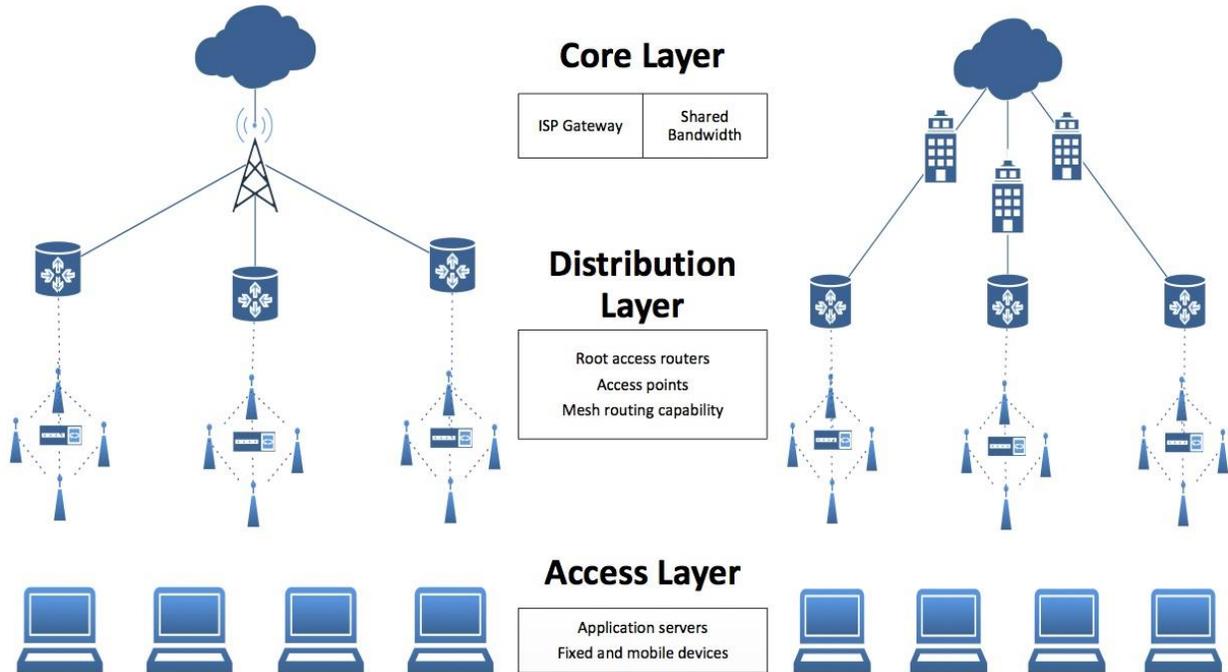
Area of East Liberty in sq.foot – 16,197,350

Range of the nodes = 500 ft (as suggested by Sakir as they will not cross the

$$\text{Number of nodes required} = \frac{\text{total area}}{\text{range of the node}(\pi r^2)} = \frac{16,197,350}{3.14 * 250 * 250} = 82.53 = 83 \text{ nodes}$$

Though the radius of the node is 500 ft., dividing with that radius will create a distance of 1000 ft between 2 nodes.

Appendix 9. Example of High-Level Network Topology



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- ¹ See Appendix 1 for a side by side case comparison of community implementations
- ² See Appendix 2 for the midterm presentation explaining why municipal WiFi is infeasible.
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- ⁴⁰ Cisco, *ibid.*
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- ⁴² This was calculated using a mathematical equation on the attached Excel document titled "Cost Analysis of East Liberty"
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