ctc technology & energy

engineering & business consulting

A Plan for Facilitating Equitable Access to Wireless Broadband Services in Seattle

Prepared for the City of Seattle
February 2017

Columbia Telecommunications Corporation

10613 Concord Street • Kensington, MD 20895 • Tel: 301-933-1488 • Fax: 301-933-3340 • www.ctcnet.us

Contents

Tables

Figures

Preface

Internet access is the infrastructure challenge of the early 21st century. The internet, and access to the information and services it provides, is responsible for economic growth, job creation, education, and a better quality of life. But, the internet only creates value for those who have affordable access and the digital literacy skills to use that access effectively.

The City of Seattle is committed to increasing the availability of competitive, affordable, and equal broadband internet access across the city by pursuing three strategies:

- **Reduce regulatory barriers**: Cities are competing with one another to attract high-speed broadband opportunities. To make Seattle more welcoming to these opportunities, the City is taking steps to increase access to city infrastructure and simplify our permitting processes.
- **Explore public/private partnerships**: Seattle continues to engage experienced commercial Internet Service Providers, exploring opportunities for improved Internet access in the city. These providers can lease unused fiber optic cable owned by the City of Seattle, known as "dark fiber", to help expand their service.
- **Explore municipal broadband**: In 2015, the City studied the feasibility of a city-operated fiber-to-the-premise municipal broadband solution. The study found the City could not finance the build out of a City-owned and operated municipal broadband utility funded only by rate-payer revenue at the time. The City continues to monitor federal funding opportunities that would make such a system financially viable.

This report on public Wi-Fi represents the City's commitment to explore public/private partnerships and increase broadband internet access across the city. In addition to this report, the City has issued a Request For Information (RFI), which solicits innovative solutions from the private sector to deliver increased access via wireless technologies to priority areas of the City. The results of the RFI solicitation will be released later this spring. The City will examine the information we receive and will determine which solutions we will pursue further.

Also in 2015, the City of Seattle released its Digital Equity Action Plan, which proposed strategies to reduce barriers to digital equity in three areas: increased access to the internet, increased digital literacy, and increased access to low-cost devices and technical support. For this report and the RFI, a range of City stakeholders prioritized areas of the City deemed important to improving digital equity. The feasibility of delivering wireless internet access to these areas is examined in this report as part of our commitments to bridge the digital divide.

This report describes a conceptual Wi-Fi network design that could provide Wi-Fi services to users across 12 high-priority areas and six parks in the City of Seattle. To achieve this proposed solution,

the report outlines a framework for developing private/public partnerships that take advantage of emerging technologies such as 5G wireless and fixed-point wireless. It also advises the City on strategies to ensure low-cost solutions are more available.

The report also makes recommendations regarding so-called “smart cities” technologies that can deliver wireless internet access in addition to sensing and monitoring environmental conditions, traffic patterns, and other aspects of urban activity. Data collected from these systems can inform and influence city planning and initiatives designed to improve overall quality of life for Seattleites.

The report also acknowledges and addresses the fact Seattle is a leader in the nation for protecting the privacy of its public. In 2015, the City designed a citywide Privacy Program to provide guidance and tools to City employees when working with personal information. The City strives to find a fair balance between gathering information to provide needed services and protecting the public’s privacy. As the City pursues partnerships to help deliver greater internet access, the City will ensure that business partners and contracted vendors who receive or collect personal information to deliver services must agree to the City’s privacy requirements.

1 Executive Summary

This report represents a strategic approach for deploying Wi-Fi and other wireless technologies as a tool for addressing Seattle's digital equity and digital inclusion needs. The plan balances the City's two key project goals: The need to serve the public by filling broadband gaps (due to lack of availability or affordability), and the need to deploy services through a financially sustainable business model.

The City must consider these goals in the context of several related and potentially complementary priorities, including: 1) enabling advanced broadband wireless deployments by the private sector; 2) the City's short- and long-term goals for private partnerships that encourage the delivery of smart city services; and 3) leveraging wireless communications infrastructure and services to enable the City to deliver its own smart city applications and enhanced services to the public.

While meeting the broadband connectivity needs of the City's low-income residents is the primary priority driving the strategy developed in this report, these secondary considerations—because of the considerable overlap—were also part of the analysis. And, as the analysis shows, these three areas are actually not just overlapping, but also self-supporting. Work in any of these three areas potentially enhances the others. Accordingly, while this report focuses on delivering service to low-income residents, it also identifies implications for private sector deployment of next-generation services and City deployment of smart city services.

1.1 Project Goals and Tasks

In its Digital Equity Action Plan, the City acknowledges the disparity between home broadband adoption rates and income levels: "of internet subscribers, only about a quarter of the lowest two household income groups (under $30,000) have cable internet, compared to two-thirds of households who make $100,000 per year or more."[1]

Through the ideals of the Action Plan and the strategies proposed in this report, the City aims to further the cause of digital inclusion, enabling broadband access for many, and narrowing the digital divide for its low-income residents.

This report was prepared in the fall and winter of 2016–2017. Over the course of this project, CTC Technology & Energy (CTC) performed the following tasks:

1. Researched lessons learned and best practices worldwide
2. Met with City agencies and examined the feasibility of leveraging diverse City assets

[1] https://www.seattle.gov/Documents/Departments/Tech/DigitalEquity_PhaseII.pdf Accessed January, 2017

3. Met with King County agencies to identify current programs, future plans, and potential areas of collaboration
4. Met with representatives of the University of Washington (UW), non-profits, and local institutions to share the City's vision and identify projects and possibilities for collaboration
5. Conducted outreach to private sector entities, wireless carriers, and internet service providers (ISP)
6. Prepared a Request for Information (RFI) to gather information and insight about the private sector's interest in contributing to the City's plans, and to identify the range of qualified partners that share the City's vision and might share in the City's risk
7. Explored potential public–private partnership models
8. Examined the feasibility of using the City's fiber optic network to support Wi-Fi
9. Researched the state of the art in Wi-Fi and wireless technologies
10. Developed a high-level financial and technical approach to fill the City's broadband gaps
11. Provided guidance and recommendations related to neutral-host distributed antenna systems (DAS)
12. Recommended outreach and engagement tactics for promoting Wi-Fi use

1.2 A Range of City Stakeholders Informed the Project

CTC conducted initial stakeholder interviews to understand the City's objectives, examine the feasibility of leveraging diverse City assets, identify current programs that support wireless initiatives, identify future plans that may support wireless initiatives, and identify potential areas of collaboration with King County and the University of Washington. The following agencies were represented in these meetings.

- Information Technology Department (ITD)
- Mayor's Office of Policy and Innovation (OPI)
- Downtown Parks Association (DSA)
- Office of Economic Development (OED)
- Department of Neighborhoods (DON)
- Seattle Division of Aging and Disability Services (ADS)
- Human Services Department (HSD)

- Seattle Department of Parks and Recreation (SPR)
- Seattle Department of Transportation (SDOT)
- Seattle City Light (SCL)
- King County IT and Transportation Departments
- University of Washington

As part of the information derived from the various stakeholder meetings, we understood the importance of wireless access to support the City's digital equity initiative and the need to provide wireless services to the general public. These particular needs helped us identify areas in the City that could most benefit from wireless access.

1.3 Lower-Income Seattle Residents Face Broadband Affordability and Availability Challenges

With 13.5 percent of the City's residents living below the poverty level,[2] affordability of broadband services remains a significant factor in the City's digital inclusion efforts. In this, the City follows national trends. For many American households that have not adopted broadband services, decisions regarding internet access "are often a choice between having internet service and having food."[3] In a 2015 Pew Research poll, 33 percent of respondents who did not have internet access at home cited the high cost of service as the main reason.[4]

It should be noted that monthly service costs are not the only prohibitive factor for non-broadband adopters. In the Pew Research poll, 10 percent of respondents cited the high cost of purchasing a computer as the reason they do not have broadband access. While investigating barriers to broadband adoption, Dailey et. al found "hardware and software costs, installation costs and deposits, equipment maintenance fees, transaction costs for disconnecting, and changes to subscription pricing all introduce additional—and often unpredictable—layers of cost."[5] For respondents to Dailey's surveys, these unanticipated costs "were often cited as reasons for dropping broadband at home."[6]

Current data products available in the City reflect these unpredictable layers of cost. One provider in Seattle advertises internet services with 25 Mbps maximum download speed for

[2] https://www.census.gov/quickfacts/table/RHI105210/5363000 Accessed January, 2017
[3] https://www.benton.org/sites/default/files/broadbandinclusion.pdf Accessed January, 2017
[4] http://www.pewinternet.org/2015/12/21/home-broadband-2015/ Accessed January, 2017
[5] http://webarchive.ssrc.org/broadband_adoption.pdf Accessed January, 2017
[6] http://webarchive.ssrc.org/broadband_adoption.pdf Accessed January, 2017

$39.99 per month. While its advertised price alone may be prohibitive to low-income individuals and families, the plan comes with further hidden charges:

- Activation fee up to $500 (total price not disclosed until after sign up).
- Promotional price increases to $49.99 per month after first year.
- Plan subject to early termination fee (price not disclosed).
- Plan price does not include equipment charges, which can be either a substantial upfront cost, or monthly "nominal fees."
- Plan allows 1 TB of data use per month, after which each 50 GB increment will cost $10 per month (not to exceed $200 monthly).
- All fees, other than the contracted monthly subscription fee, are subject to change at any time.[7]

In the first month of service alone, hundreds of dollars in potential costs serve as obvious barriers to adoption by low-income residents.

For subscribers who choose not to adopt home internet, data-only mobile broadband services provided by major wireless carriers are a potential alternative. However, the high cost of connectivity and adequate capacity can prove to be deterrents to even moderate-income subscribers. Similar to their wired counterparts, mobile broadband plans may incur fees that affect service affordability. Unlike most wired plans, mobile services charge by the amount of data transmitted, limiting their feasibility for high-capacity applications such as transmission of large files, videoconferencing, and extended content and media-rich Web browsing.

The cost of an entry-level mobile data product from a large carrier begins at $20 per month for 2 GB of data. Prices increase $10 per month per 2 GB additional data. Further charges include:

- $5 per month per device connected to the plan
- $10 per month per tablet connected to the plan
- $20 per month per hotspot connected to the plan
- $15 per each additional 1 GB of data
- Cost of device, tablet, or hotspot

[7] http://www.xfinity.com/locations/internet-service/washington/seattle.html Accessed January, 2017

Subscribers who do not want to be charged overage fees can choose to be "throttled" once plan data allowances have been used, slowing connection speeds to 128 Kbps—well below broadband speeds, and limiting functionality.[8]

Low-income residents may be able to obtain free devices that will connect to Wi-Fi networks provided by the City, community centers, and businesses through the federal Lifeline Assistance Program. These devices are Wi-Fi enabled and provided at no cost to low-income Americans who qualify. There is much anecdotal evidence of the devices' use in low-income and homeless communities both in Seattle and nationwide. While many Lifeline wireless carriers offer limited amounts of mobile data (50 to 500 MB per month),[9,10,11] there is generally no option to increase the amount of data on the plans. For homeless and low-income families, the device's internet functionality is dependent on the availability of Wi-Fi service.

1.4 The City-Prioritized Geographic Areas for Wireless Deployment

A range of City stakeholders collectively prioritized areas of the City for study and inclusion in the RFI the City issued to potential partners. As we prepared the RFI to engage the private sector and judge its interest in contributing to the City's plans, representatives of the City's digital equity program in the Seattle Information Technology Department to prioritize the identified areas to best meet the City's objectives. The priority areas include 12 locations deemed important to improving digital equity and six parks where wireless access would support various services and enable general use by the public.

The 12 digital equity locations are:

- Yesler Terrace
- High Point
- South Park
- Rainier Vista
- Othello
- Rainier Beach
- Lake City
- SW Roxbury Street Corridor
- 23rd Avenue Corridor
- Judkins Park

[8] https://www.verizonwireless.com/plans/data-only-plan/ Accessed January, 2017
[9] http://www.assurancewireless.com/Public/MorePrograms.aspx Accessed January, 2017
[10] https://www.safelinkwireless.com/Enrollment/Safelink/en/NewPublic/plan_features.html Accessed January, 2017
[11] https://www.entouchwireless.com/pages/free_phone_more_info Accessed January, 2017

- Jimi Hendrix Park
- Pratt Park

The six parks are:

- Camp Long
- Discovery Park
- Occidental Park
- Walter E. Magnuson Park
- Waterfront Park
- Westlake Park

See Section 3 for descriptions of each priority area.

1.5 Sample Design and Cost Estimate

The City's efforts to expand broadband access to digital inclusion areas and parks—including this strategic report, and the RFI the City issued to identify potential public–private partnerships—are focused on developing creative, sustainable options. To understand the scale of the effort needed to achieve the City's digital inclusion goals, we conducted an engineering analysis of the likely capital and operating expenses to serve these priority areas using the City's fiber optic network and Wi-Fi.

The public–private solutions that emerge from the City's RFI and outreach efforts may or may not use these technologies. But these designs and cost estimates offer an estimate of the City's cost if it were to solve the problem on its own. With those estimates as a baseline, the City can then understand the potential value of a partnership in terms of avoided cost (assuming that a viable partnership emerges to address some of these challenges).

We note, too, that there is additional value to the City that does not appear in this financial analysis—the value of broadband access in terms of education, job opportunities, civic engagement, and other positive impacts on people's lives.

CTC completed a conceptual Wi-Fi network design to provide Wi-Fi services to users across 12 digital equity areas and six parks in the City of Seattle. The combined network would require approximately 455 access point radios and approximately six miles of fiber, or the use of point-to-point access radios.

With this approach, the City and its partners can provide internet service in the outdoor areas of the digital equity areas and parks comparable to the highest standard of Wi-Fi that is provided in airports and public spaces, with the capability to expand to higher speeds.

The design includes a wireless local area network (LAN) controller for managing the network's customer access (such as billing, authentication, and security).

A fixed broadband network such as a public Wi-Fi network may eventually play a role in deploying the latest cellular mobile technology (i.e., 5G). Though 5G technology and standards have not been finalized, there is a likelihood that 5G would leverage existing commercial or public Wi-Fi networks.

Additionally, much of the expense of deploying a wireless network is in the site preparation. Future technologies may leverage the installed power, backhaul, and enclosures at the public Wi-Fi access points. Hence, in the future, a public Wi-Fi network may have a seamless integration with mobile networks.

1.6 Framework for Understanding Potential Partnership Opportunities

1.6.1 The Wireless Industry Seeks Access to Public Infrastructure

The City released an RFI to the private sector seeking creative ideas and approaches, and ways that private entities (both for-profit and nonprofit) are interested in working with the City to serve the priority areas. We do not yet have these responses, but once received, they will inform subsequent analysis that flows from this document.

Even absent the RFI responses, though, we recognize the potential impact of high-level wireless industry changes. The wireless industry is transitioning from support of basic telecommunications and internet-based services to the support of next-generation wireless platforms for the Internet of Things (IOT) and the deployment of 5G wireless technologies.

To achieve their 5G goals, carriers will require significant changes to the deployment methodologies they have used to date. The foundation of 5G infrastructure will be the creation of hyper-dense networks. From a wireless carrier perspective, this level of density demands major upgrades to macro tower sites and a deployment of massive numbers of small cell antenna sites throughout existing coverage areas. Over time, the network will require nearly 100 percent fiber connectivity.

Some analysts predict that small cell backhaul connection is expected to grow 1,280 percent, scaling from 75,000 sites to 960,000 by 2019.[12] Access to infrastructure is critical for carriers' successful densification of their networks.

[12] Richard Webb, "Outdoor Small Cell Backhaul an Over $2 Billion Market by 2020," HIS Report, June 2016, https://technology.ihs.com/579786/research-note-outdoor-small-cell-backhaul-an-over-2-billion-market-by-2020

In a sense, what is occurring in cities like Seattle is akin to a land-rush—an aggressive competition to be first to get access to wireless-enabling infrastructure—that is being carried out among the companies that sell services and infrastructure to the national mobile companies. For example, among competitive fiber providers, the first company to deploy fiber to support mobile communications is more likely to win follow-on contracts. While these infrastructure companies may not yet have contracts to provide infrastructure to a mobile communications provider, if they can demonstrate that they can deploy faster because they already have the permits (for wireless sites, fiber pole attachments, or both), they will frequently win the contract.

To these ends—to speed the land-rush—the wireless industry is aggressively seeking to reduce local authority over wireless siting and to reduce or eliminate local authority over siting of small cell and related infrastructure. The industry has lobbied both state and federal governments to preempt local authority. This could significantly reduce the City's negotiating power to obtain low-cost wireless service options to serve its low-income communities. See Section 5 for more details.

1.6.2 Wireless Technology Options

While many consumers equate wireless broadband with mobile access, fixed wireless technologies are an alternative for providing service when line-of-sight can be established between a base station and end user sites. Effectively analyzing potential partnership opportunities will require a clear understanding of the technical capacities, limitations, and expected evolution of the proposed wireless technologies.

Wired networks can be very expensive to deploy in an urban setting. In Seattle, crowded utility space on poles and in rights-of-way combined with the lack of green space can make citywide deployment extremely costly. Fixed wireless networks can potentially overcome some of these obstacles. Wireless ISPs (WISPs) have the potential to connect customers in a line of sight to base station antennas, which in Seattle so far has provided high-speed service to large multi-dwelling-unit buildings and office buildings. But WISPs are not yet able to offer connection speeds on a market-wide basis comparable to cable or fiber-to-the-premises (FTTP) built to each premises, and sometimes impose data caps on customers to manage limitations on capacity.

Cellular wireless carriers have been consistently increasing their data speeds with the rollout of faster and higher-capacity technologies such as Long-Term Evolution (LTE).[13] Some carriers now offer data plans with speeds comparable and in many cases greater than a typical residential customer's internet service.

[13] LTE is a 4G cellular wireless technology offering data speeds of typically around 30 Mbps.

Most businesses and residents will find that mobile wireless broadband has technological limitations relative to wireline. These include:

1) *Lower speeds.* At their peaks, LTE typically provides only about one-tenth the speed available from FTTP and cable modems. In coming years, LTE Advanced may be capable of offering Gbps speeds with optimum spectrum and a dense buildout of antennas—but even this will be shared with the users in a particular geographic area and can be surpassed by more advanced versions of wireline technologies (with Gbps speeds already provided by some FTTP providers today).

2) *More asymmetrical capacity, with uploads limited in speed.* As a result, it is more difficult to share large files (e.g., video, data backup) over a wireless service, because these will take too long to transfer; it is also less feasible to use video conferencing or any other two-way real-time application that requires high bandwidth.

3) *Stricter bandwidth caps.* Most service providers limit usage more strictly than wireline services. Though wireless service providers may be able to increase these caps as their technologies improve, it is not clear whether the providers will keep ahead of demand. A *Washington Post* article about Apple's iPad with 4G connectivity highlights the issue: "Users quickly are discovering the new iPad gobbles data from cellular networks at a monstrous rate. Some find their monthly allotment can be eaten up after watching a two-hour movie. That has left consumers with a dilemma: Pay up for more data or hold back on using the device's best features."[14]

From a residential customer's perspective, a mobile wireless data cap may still be sufficient for a light user of the internet. And, for certain users, higher connection speed may be considered a more desirable feature than unlimited, unfettered data.

5G represents a next stage in the evolution of mobile wireless technology, and is envisioned to provide much faster speeds then the current 4G technology (e.g., download speeds of approximately 10 Gbps). 5G is seen by many as a central component of machine-to-machine communications and the Internet of Things. 5G will also feature much lower latency—expected to be about 1 ms—which will be essential for future applications such as driverless cars. 5G should also greatly enhance a user's ability to stream HD video and will become essential if 4K video services are transmitted over mobile broadband networks.

[14] Cecilia Kang, "New iPad users slowed by expensive 4G network rates," *Washington Post*, March 22, 2012, http://www.washingtonpost.com/business/economy/new-ipad-users-slowed-by-expensive-4g-network-rates/2012/03/22/gIQARLXYUS_story.html?hpid=z2 (accessed October 2016).

5G also is also being designed to support a much greater device density per base station than current 4G technology. While 4G can connect thousands of devices per cell, anticipated 5G deployments using massive MIMO might allow for over a million devices to be connected to a single radio cell.

Planning and design and prototype testing of 5G technology is currently underway, but full deployment is not expected to begin until 2019 or 2020. See Section 6 for more details.

1.7 Recommendations

We recommend a range of short-term, mid-term, and long-term strategies for the City to consider to address the wireless needs of its low-income individuals and families. These recommendations are based on CTC's experiences, observations of innovative efforts in other cities, and collaborative efforts with City staff to develop creative new approaches to reducing digital inequities. We are hopeful that the City's request for information (RFI) to the private sector (which was prepared as part of this effort and that was released publicly in early 2017) will enable addition, revision, and refinement of this set of strategies.

See Section 8 for more details on these recommendations.

1.7.1 Short-term Strategies

The recommended short-term strategies are those that the City could implement relatively quickly and effectively to realize immediate or near-immediate results. These strategies capitalize on efforts at the community and governmental levels to effect more immediate advancement of the City's objectives. While the City begins to adopt projects of a larger scale, these strategies will encourage focused progress, alleviate some of the immediate challenges to growth, and demonstrate the City's commitment to its goals.

1. **Develop partnerships with wireless carriers seeking access to public property**

We recommend that the City consider a competitive process in which the City exchanges with private wireless companies use of public assets for wireless deployment in return for free services to low income Seattle residents.

2. **Create an "Adopt-a-Digital-Highway" program**

The City could consider the innovative approach of creating a digital version of the long-standing, widely-supported Adopt-A-Highway program to fund publicly available Wi-Fi. This option could allow for the City to incur costs for initial infrastructure build-out and seek private sponsorship to cover ongoing costs related to operations, support, and service.

1.7.2 Medium-term Strategies

After implementation of programs intended for more immediate results, we suggest the City shift its focus to medium-term goals. These strategies focus on collaboration between the City and other parties to provide solutions for Wi-Fi access in both low-income communities and the greater Seattle area.

1. **Develop a citywide authentication/federated identity program**

CTC suggests that the City's efforts include the exploration of ideas and technologies related to a citywide platform for federated identity management (potentially including single sign-on). A federated identity system allows users to log in to separate systems and organizations with a single set of credentials. For example, the City has past experience creating a framework for access to services with the My.Seattle.gov platform. A platform like that could be used to provide a federated identity that would allow users to log in to Wi-Fi as well as other services (such as public library access) using a Seattle City account.

2. **Negotiate wireless digital inclusion products that utilize existing mobile infrastructure**

We recommend that the City approach providers that are already in the business of providing Wi-Fi to use their existing (and emerging) systems to provide Wi-Fi to qualifying Seattle residents who do not already have home internet service. In particular, we recommend that the City approach incumbent providers to encourage it to develop a wireless digital inclusion product that is analogous to its well-regarded Internet Essentials program.

Though this strategy has not been pursued elsewhere, we envision a scenario in which a service provider might use its existing Wi-Fi deployment to offer Wi-Fi access to qualifying individuals for free or at a low cost.

1.7.3 Long-term Strategies

We recommend longer-term strategies to improve Wi-Fi coverage in the prioritized areas of Seattle and for lower-income residents of Seattle. These strategies maximize benefits from construction and improvement projects, and encourage strategic, active adaptation to future technologies. While these suggestions involve significant planning and effort by the City, they present potential longer-term, ideally long-lasting solutions to further the City's broadband communications and digital equity goals.

1. **Develop and expand the City's fiber as a platform for low-cost wireless**

We recommend that the City utilize its fiber optic plant wherever possible and expand it where possible, so as to develop and grow this critical asset over time. The City's existing and future fiber can be used to enable the City itself or third parties to provide free or low-cost wireless

services, particularly over low-cost technologies such as Wi-Fi, to the prioritized areas and to such locations as low-income, multi-dwelling public housing facilities.

2. **Evaluate all projects for inclusion of communications-enabling infrastructure**

We recommend that the City evaluate all relevant projects, both public and private, with regard to each project's potential to enable development of broadband services or broadband-enabling infrastructure. Localities undertake a wide range of efforts—capital improvement projects, public-private partnerships, and facilitation of private efforts—that hold potential to increase the volume of publicly and privately-owned assets in the community that can provide services or enable provision of services over time.

3. **Work with local banks to direct Community Reinvestment Act support toward broadband**

We recommend that the City consider working with local banks that have Community Reinvestment Act (CRA) obligations, in order to attract and direct CRA investments toward wireless in prioritized areas as a source of support for the strategies suggested in this report. Broadband projects are eligible for CRA funding in eligible areas.

1.8 Seattle's Privacy Policy Will Guide Future Steps

Implemented in 2015, the City's Privacy Program[15] represents a visionary commitment to the values and priorities of the community. Acutely aware of the concerns surrounding personal information, the City convened stakeholders from 15 City departments to develop best policies and practices. A Privacy Advisory Committee composed of privacy thought leaders from "academia, local companies, and private legal practice and community activist groups"[16] guided the development of the City's six Privacy Principles, culminating in a comprehensive Privacy Statement which outlines the City's "commitments about the collection and management of the public's personal information."[17]

The City's six Privacy Principles confirm the City's valuation of personal data, and affirm its commitment to protecting it:

1) We value your privacy.

2) We collect and keep only what we need.

[15] The privacy policy and statement is available in entirety: http://www.seattle.gov/tech/initiatives/privacy
[16] http://www.seattle.gov/tech/initiatives/privacy Accessed January, 2017
[17] http://www.seattle.gov/tech/initiatives/privacy Accessed January, 2017

3) We make available information about the ways we use your personal information at the time we collect it.
4) We are accountable.
5) We follow federal and state laws about information disclosure whenever we work with outside governmental agencies and in answering Public Disclosure Requests (PDRs).
6) Accuracy is important.[18]

The Privacy Policy sets an unmatched example for localities nationwide. Any project undertaken to drive the policy goals of this initiative will be analyzed in light of the Privacy Policy, and some will not meet the requirements. Commitments to privacy represent a cost in that certain kinds of initiatives that other cities can undertake cannot be adopted in Seattle. However, they also demonstrate a clear, measurable, and value-based means for evaluating how an initiative would align with the priorities of the community.

[18] http://www.seattle.gov/Documents/Departments/InformationTechnology/City-of-Seattle-Privacy-Principles-FINAL.pdf Accessed January, 2017

2 The Digital Inclusion Challenge for Lower-Income Residents of Seattle

With 13.5 percent of the City's residents living below the poverty level,[19] affordability of broadband services remains a significant factor in the City's digital inclusion efforts. For many American households that have not adopted broadband services, decisions regarding internet access "are often a choice between having internet service and having food."[20] In a 2015 Pew Research poll, 33 percent of respondents who did not have internet access at home cited the high cost of service as the main reason.[21]

It should be noted that monthly service costs are not the only prohibitive factor for non-broadband adopters. In the Pew Research poll, 10 percent of respondents cited the high cost of purchasing a computer as the reason they do not have broadband access. While investigating barriers to broadband adoption, Dailey et. al found "hardware and software costs, installation costs and deposits, equipment maintenance fees, transaction costs for disconnecting, and changes to subscription pricing all introduce additional—and often unpredictable—layers of cost."[22] For respondents to Dailey's surveys, these unanticipated costs "were often cited as reasons for dropping broadband at home."[23]

Current data products available in the City reflect these unpredictable layers of cost. One service provider advertises residential internet services with 25 Mbps maximum download speed for $39.99 per month. While its advertised price alone may be prohibitive to low-income individuals and families, the plan comes with further hidden charges:

- Activation fee up to $500 (total price not disclosed until after sign up).
- Promotional price increases to $49.99 per month after first year.
- Plan subject to early termination fee (price not disclosed).
- Plan price does not include equipment charges, which can be either a substantial upfront cost, or monthly "nominal fees."
- Plan allows 1 TB of data use per month, after which each 50 GB increment will cost $10 per month (not to exceed $200 monthly).
- All fees, other than the contracted monthly subscription fee, are subject to change at any time.[24]

[19] https://www.census.gov/quickfacts/table/RHI105210/5363000 Accessed January, 2017
[20] https://www.benton.org/sites/default/files/broadbandinclusion.pdf Accessed January, 2017
[21] http://www.pewinternet.org/2015/12/21/home-broadband-2015/ Accessed January, 2017
[22] http://webarchive.ssrc.org/broadband_adoption.pdf Accessed January, 2017
[23] http://webarchive.ssrc.org/broadband_adoption.pdf Accessed January, 2017
[24] http://www.xfinity.com/locations/internet-service/washington/seattle.html Accessed January, 2017

In the first month of service alone, pricing stipulations of at least $500 in "unanticipated" costs serve as obvious barriers to adoption by low-income residents.

For subscribers who choose not to adopt home internet, data-only mobile broadband services provided by major wireless carriers are a potential alternative. However, the high cost of connectivity and adequate capacity can prove to be deterrents to even moderate-income subscribers. Similar to their wired counterparts, mobile broadband plans are frequently rife with upcharges and unexpected costs. Unlike most wired plans, mobile services charge by the amount of data transmitted, limiting their feasibility for high-capacity applications such as transmission of large files, videoconferencing, and extended content and media-rich Web browsing.

The cost of an entry-level mobile data product from a large carrier begins at $20 per month for 2 GB of data. Prices increase $10 per month per 2 GB additional data. Further charges include:

- $5 per month per device connected to the plan
- $10 per month per tablet connected to the plan
- $20 per month per hotspot connected to the plan
- $15 per each additional 1 GB of data
- Cost of device, tablet, or hotspot

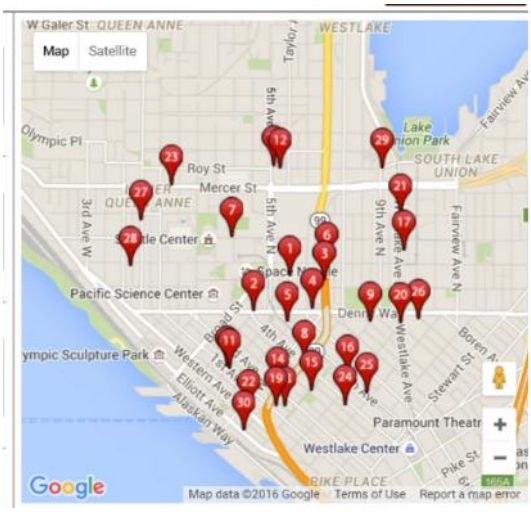
Subscribers who do not want to be charged overage fees can choose to be "throttled" once plan data allowances have been used, slowing connection speeds to 128 Kbps—well below broadband speeds, and limiting functionality.[25]

Low-income residents may be able to obtain free devices that will connect to Wi-Fi networks provided by the City, community centers, and businesses through the federal Lifeline Assistance Program. These devices are Wi-Fi enabled and provided at no cost to low-income Americans who qualify. There is much anecdotal evidence of the devices' use in low-income and homeless communities both in Seattle and nationwide. While many Lifeline wireless carriers offer limited amounts of mobile data (50 to 500 MB per month),[26,27,28] there is generally no option to increase the amount of data on the plans. For homeless and low-income families, often the device's internet functionality is dependent on the availability of Wi-Fi service in the City.

[25] https://www.verizonwireless.com/plans/data-only-plan/ Accessed January, 2017
[26] http://www.assurancewireless.com/Public/MorePrograms.aspx Accessed January, 2017
[27] https://www.safelinkwireless.com/Enrollment/Safelink/en/NewPublic/plan_features.html Accessed January, 2017
[28] https://www.entouchwireless.com/pages/free_phone_more_info Accessed January, 2017

3 The City Prioritized 12 Digital Equity Locations and Six Parks for Wi-Fi Service

Lower-income residents of most cities face twin challenges with respect to access to broadband services. First, their neighborhoods may not feature free Wi-Fi service. Indeed, free public Wi-Fi service tends to develop organically in wealthier neighborhoods. The anecdotal "OpenWiFIspots.com" identifies almost 350 free hotspots at coffee shops, restaurants, hotels, and other businesses across the City—including dozens in Queen Anne Hill:



Second, lower-income neighborhoods frequently have less robust infrastructure and less robust broadband service competition, particularly in small business and commercial areas (cable infrastructure in particular is lacking in small business corridors). And this lack of service is compounded by affordability challenges. A robust broadband service frequently lies beyond the means of lower-income members of the community.

As a result, opportunity exists for the City to increase digital inclusion and equity by promoting or deploying Wi-Fi service in lower-income neighborhoods where there are fewer coffee shops and restaurants offering Wi-Fi and where home-based broadband may be unavailable or unaffordable. In this way, the City may be able to close the gap for members of the community who are most likely to find themselves on the wrong side of the digital divide.

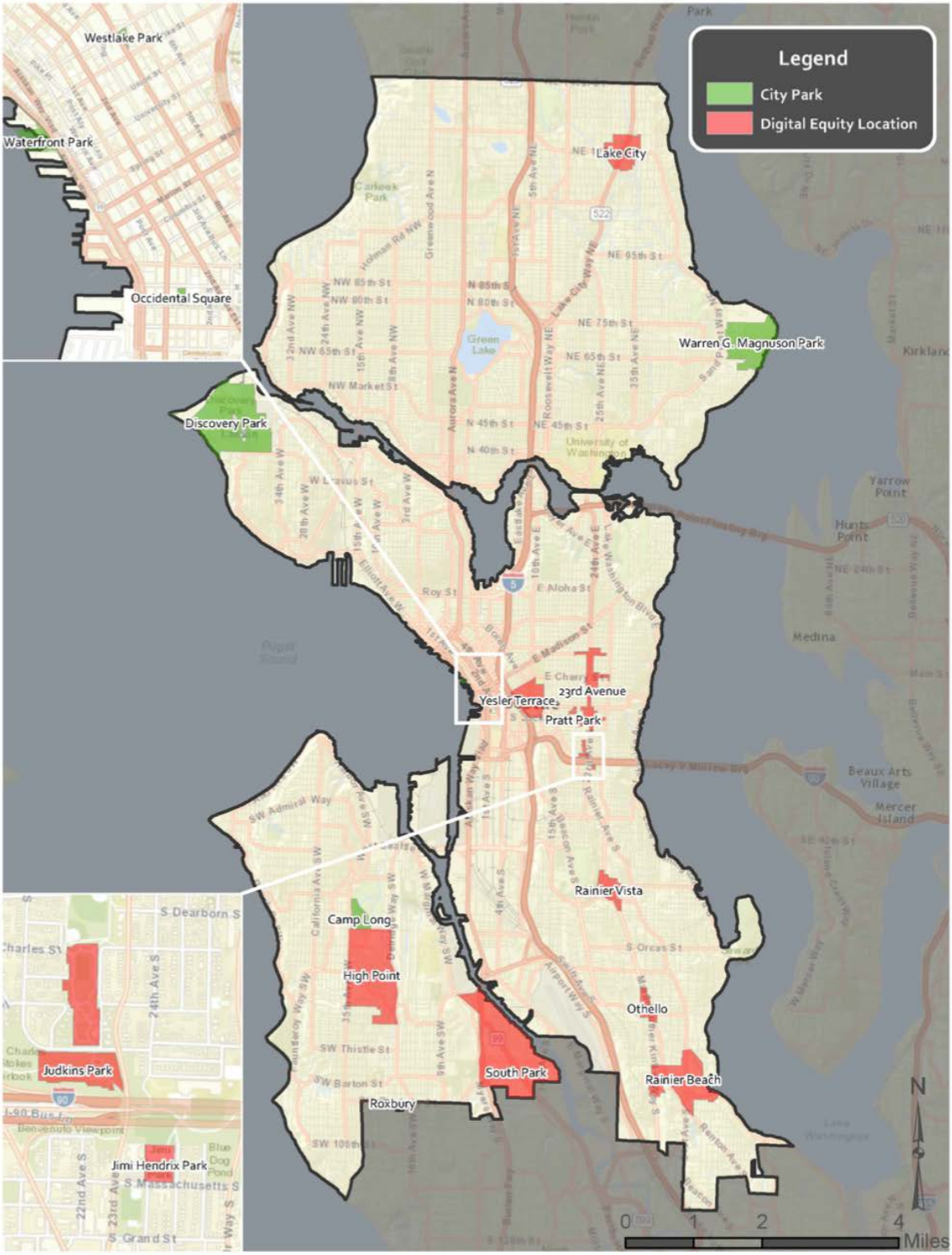
As a significant step toward achieving this goal, the City identified 12 disadvantaged districts/corridors and six City parks that are the focus for deploying low-cost or free wireless access. The City's decision to examine these areas in this report was informed by research conducted as part of the 2015 work of the Digital Equity Action Committee[29], by findings from

[29] https://www.seattle.gov/tech/initiatives/digital-equity/digital-equity-initiative

the 2014 Technology Access and Adoption survey[30], and by consulting with our partners in the Mayor's Office of Policy and Innovation, Human Services Department, and the Seattle Housing Authority.

[30] https://www.seattle.gov/tech/initiatives/digital-equity/technology-access-and-adoption-in-seattle-reports

Figure 1: Wireless Priority Areas



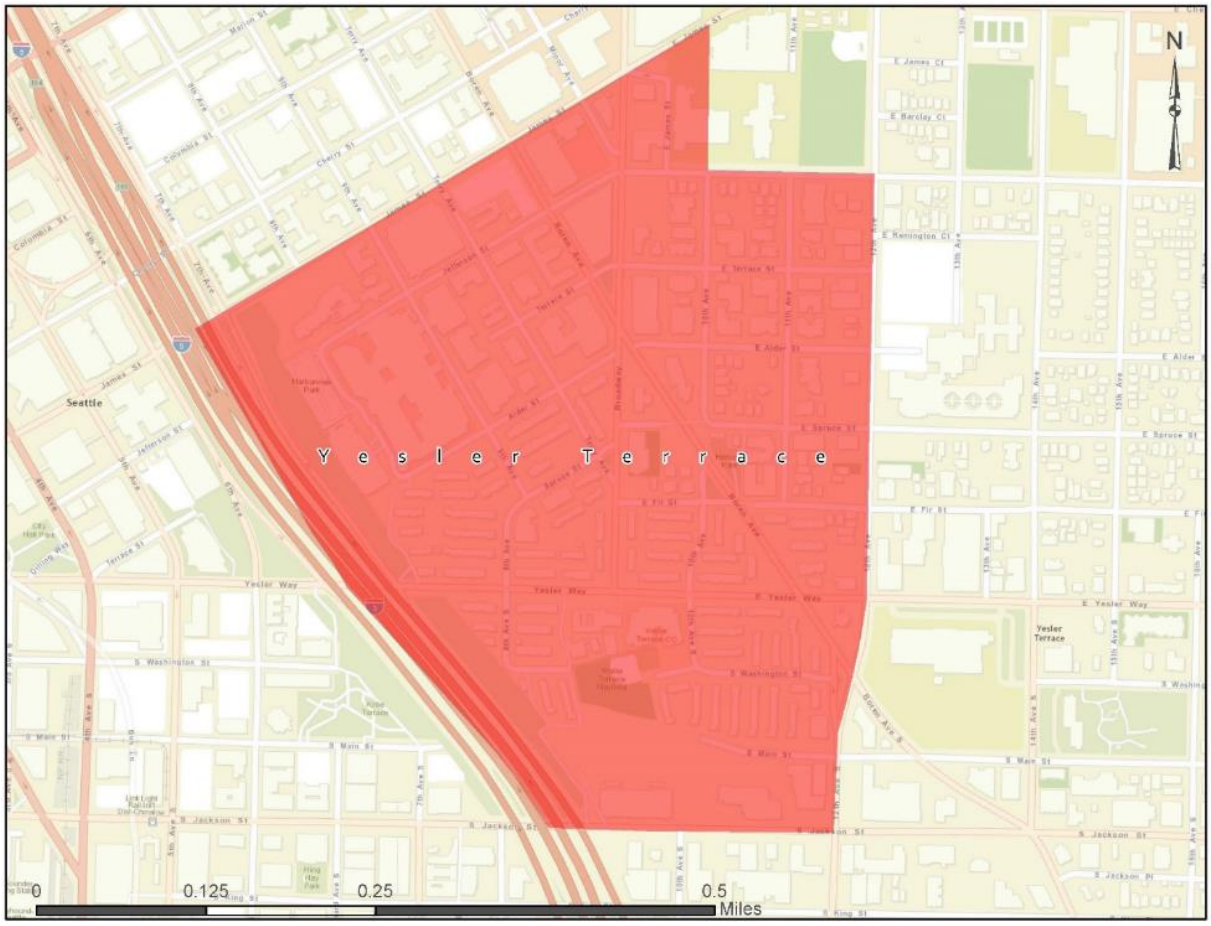
3.1 Digital Equity Locations

The City has identified 12 districts deemed important to improving access to the internet for lower-income members of the community.

3.1.1 Yesler Terrace

Yesler Terrace is a 30-acre site near downtown Seattle. Originally built in the 1940s as the City's first publicly subsidized housing, the area has been undergoing revitalization since 2013. The fully revitalized area will feature 4.3 million square feet of housing with more than 5,000 units, 900,000 square feet of office space, and 88,000 square feet of retail space. The redevelopment will continue the City's commitment to affordable housing: A minimum of 561 units will be set aside for very-low-income households earning less than 30 percent of the area median income (AMI), 290 units will be reserved for households earning less than 60 percent of the AMI, and 850 units will be reserved for households earning less than 80 percent of the AMI.[31]

Figure 2: Yesler Terrace

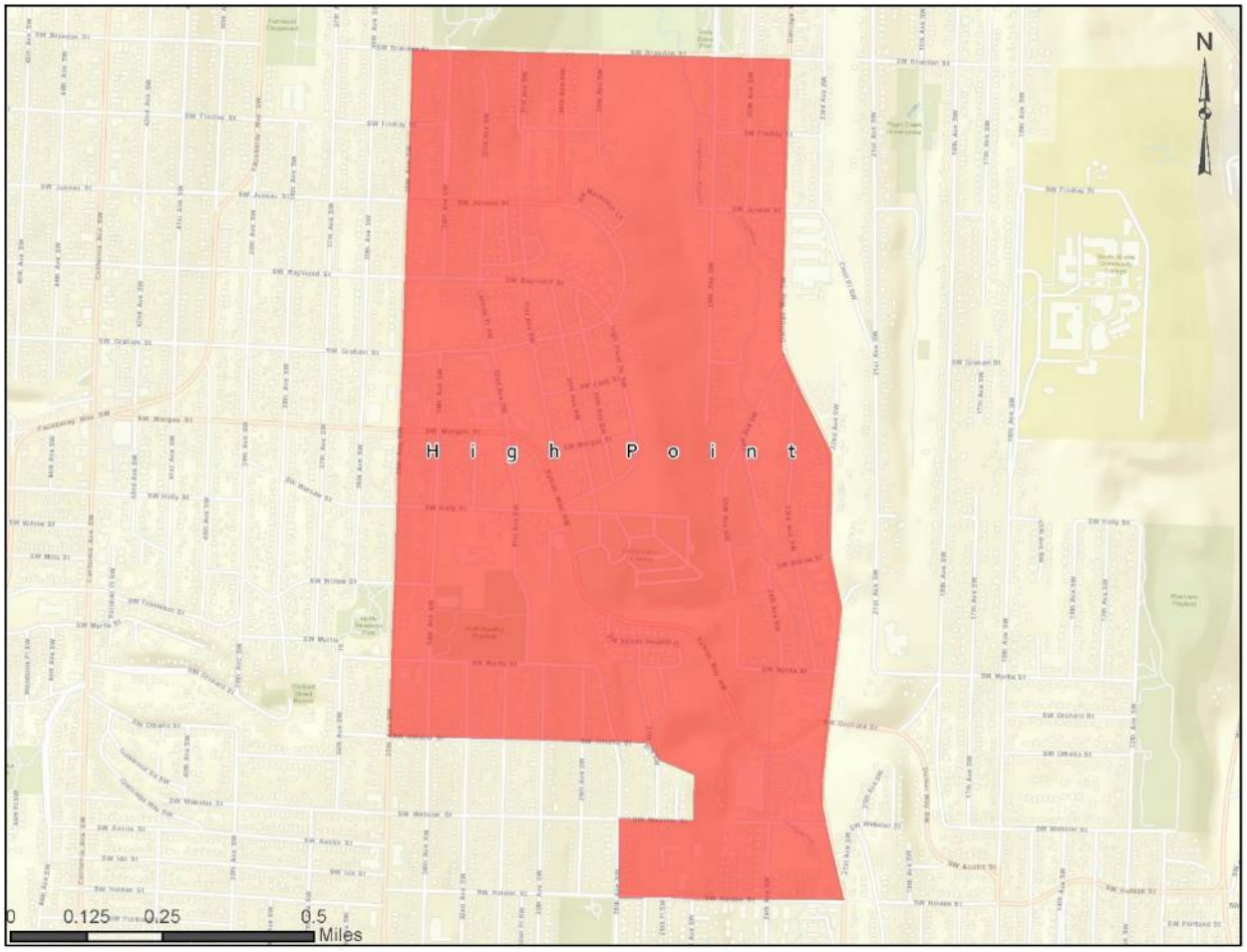


[31] Renewing Yesler's Promise, SEATTLE HOUSING AUTHORITY, http://seattlehousing.net/wp-content/uploads/2016/02/Final-8-page-brochure-revised-2-2.pdf (accessed September 19, 2016).

3.1.2 High Point

High Point is a .84-square-mile low-income neighborhood in Seattle. 2000 Census data revealed that more than 30 percent of residents in the community were living in poverty, compared to 11 percent citywide.[32] In 2004, the district underwent redevelopment after the City received funding from the U.S. Department of Housing and Urban Development's HOPE IV grant. The project's goals included improving the district while maintaining housing for all income levels. The redeveloped district includes 350 units of public housing set aside for residents with incomes of 50 percent of the AMI or lower. It also has 250 affordable rental units and 56 affordable for-sale units reserved for residents with incomes of 80 percent of the AMI or lower.[33]

Figure 3: High Point

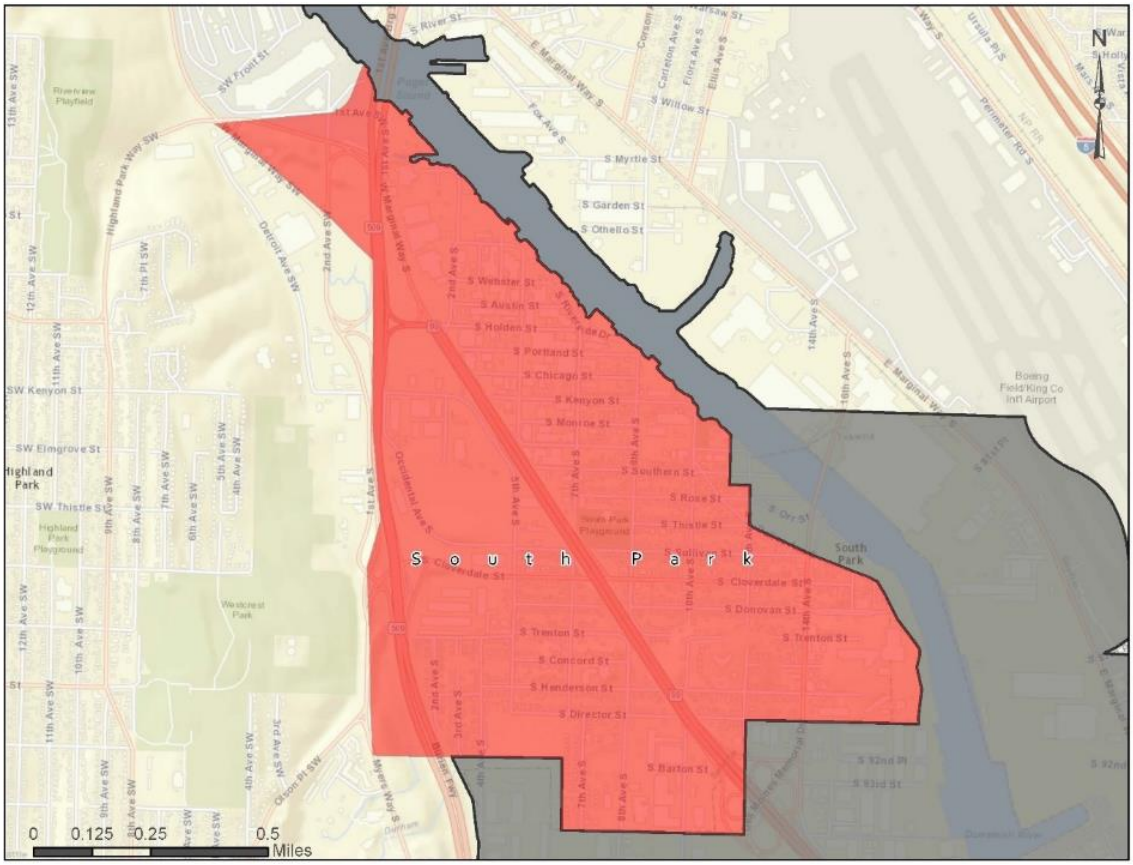


[32] Seattle's High Point Redevelopment Project, UNITED STATE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, https://www.huduser.gov/portal/casestudies/study_04092012_1.html (accessed September 19, 2016).
[33] High Point Redevelopment Plan, SEATTLE HOUSING AUTHORITY, https://www.seattlehousing.org/redevelopment/high-point/plan/ (accessed September 19, 2016)

3.1.3 South Park

South Park is a 1.2-square-mile low-income neighborhood with a population of 5,421. Over 29 percent of the neighborhood's residents live below the poverty level, which is more than twice the City average. The neighborhood's median household income, $46,593, is one-third lower than the City median.[34] The neighborhood is the center of the City's Hispanic community, with a population that is 42 percent Latino,[35] compared to 6.6 percent citywide.[36]

Figure 4: South Park



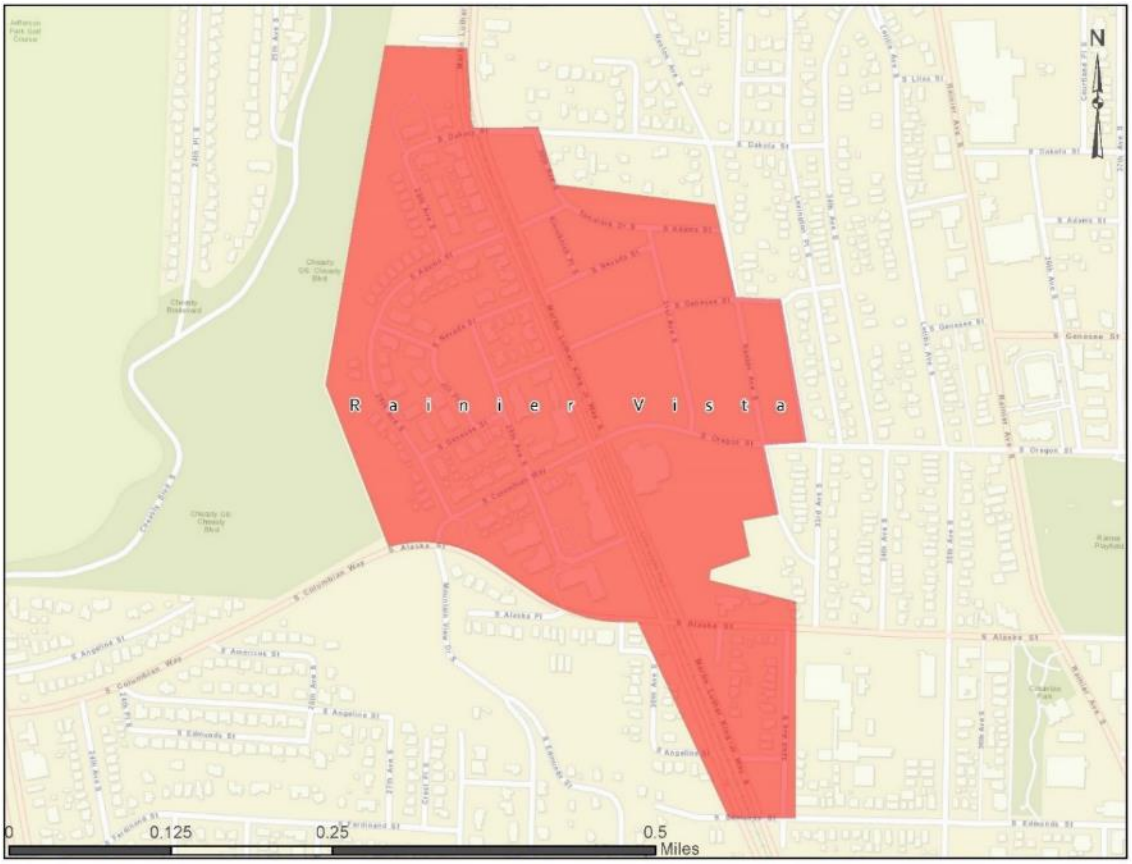
3.1.4 Rainier Vista

Rainier Vista is another area of the City where the HOPE IV grant helped to initiate redevelopment. Rainier Vista is one of the most diverse areas in the country, it is one of the communities that makes up the Rainier Valley district, where over 59 different languages are

[34] http://www.city-data.com/neighborhood/South-Park-Seattle-WA.html
[35] http://statisticalatlas.com/neighborhood/Washington/Seattle/South-Park/Race-and-Ethnicity
[36] https://www.census.gov/quickfacts/table/PST045215/5363000,00

spoken.[37] The area straddles Martin Luther King Jr Way S, one of the City's major traffic corridors. It is also adjacent to the Columbia City LINK station, a stop along the City's light rail system that provides services to downtown and the Sea-Tac Airport. The district offers several amenities for low-income residents including a Boys & Girls Club and a branch of Neighborhood House, a nonprofit organization that provides social services. In an effort to keep the redeveloped district open to all income levels, 251 units designated for public housing were set aside for residents with incomes of 30 percent or lower than the AMI, as were 226 units of affordable rental housing and 211 units of for-sale housing for residents with incomes of 50 percent or lower than AMI.[38]

Figure 5: Rainier Vista



3.1.5 Othello

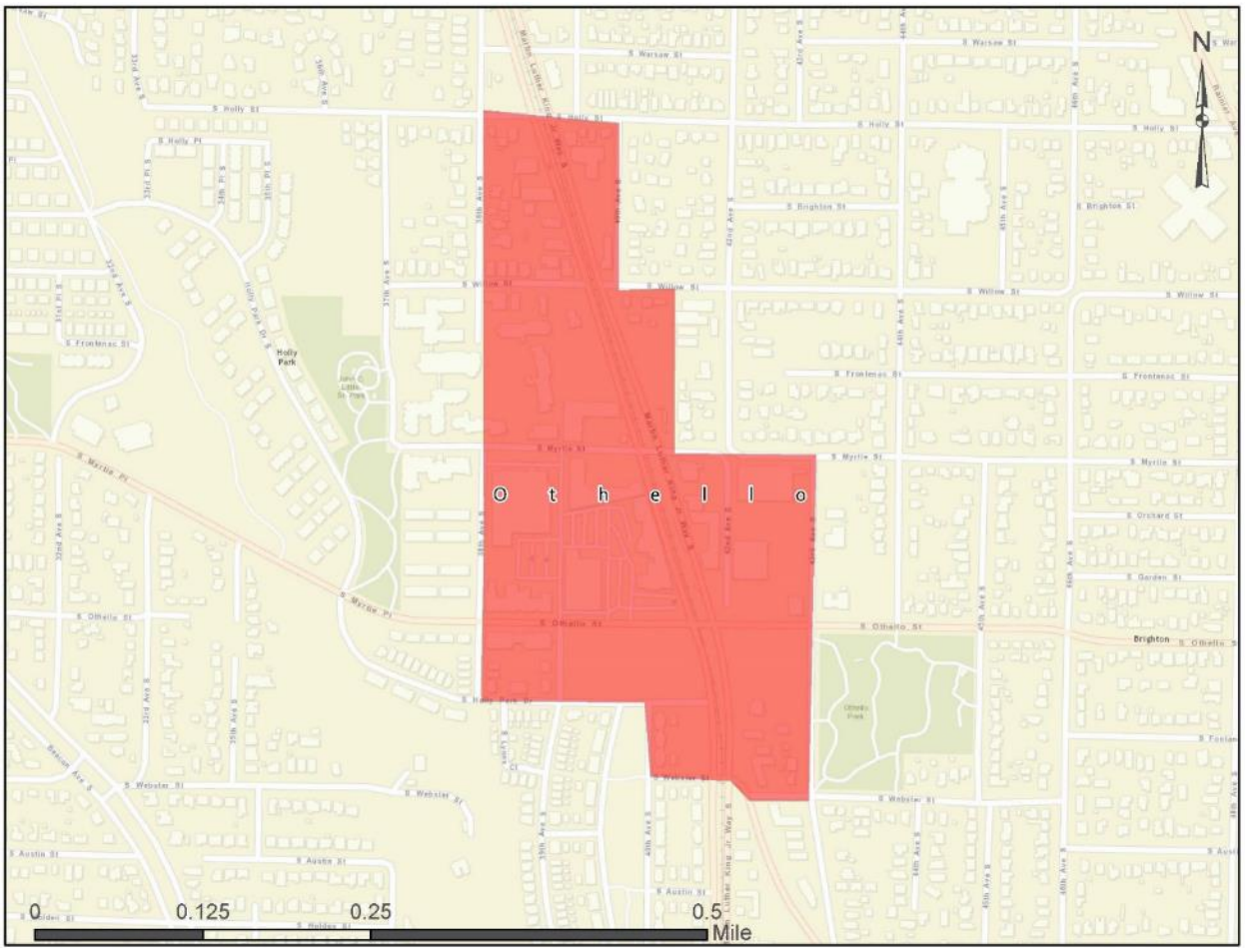
The Othello urban village is a destination for immigrants and refugees. It is a diverse area with residents speaking more than 40 different languages. The district serves as an "incubator" for a

[37] Seattle's Rainier Valley, one of America's 'Dynamic Neighborhoods', THE SEATTLE TIMES, http://www.seattletimes.com/opinion/seattles-rainier-valley-one-of-americas-dynamic-neighborhoods/ (accessed September 19, 2016)

[38] Rainer Vista Redevelopment Plan, SEATTLE HOUSING AUTHORITY, HTTPS://WWW.SEATTLEHOUSING.ORG/REDEVELOPMENT/RAINIER-VISTA/PLAN/ (accessed September 19, 2016)

diverse selection of family-owned small businesses, many of which run along the Martin Luther King Jr Way S, a heavily trafficked corridor in the City. In 2009, a LINK station was built in the district providing residents with light rail service to downtown Seattle and the Sea-Tac airport. The addition of the light rail has brought new economic development to the district and an influx of new residents.[39]

Figure 6: Othello



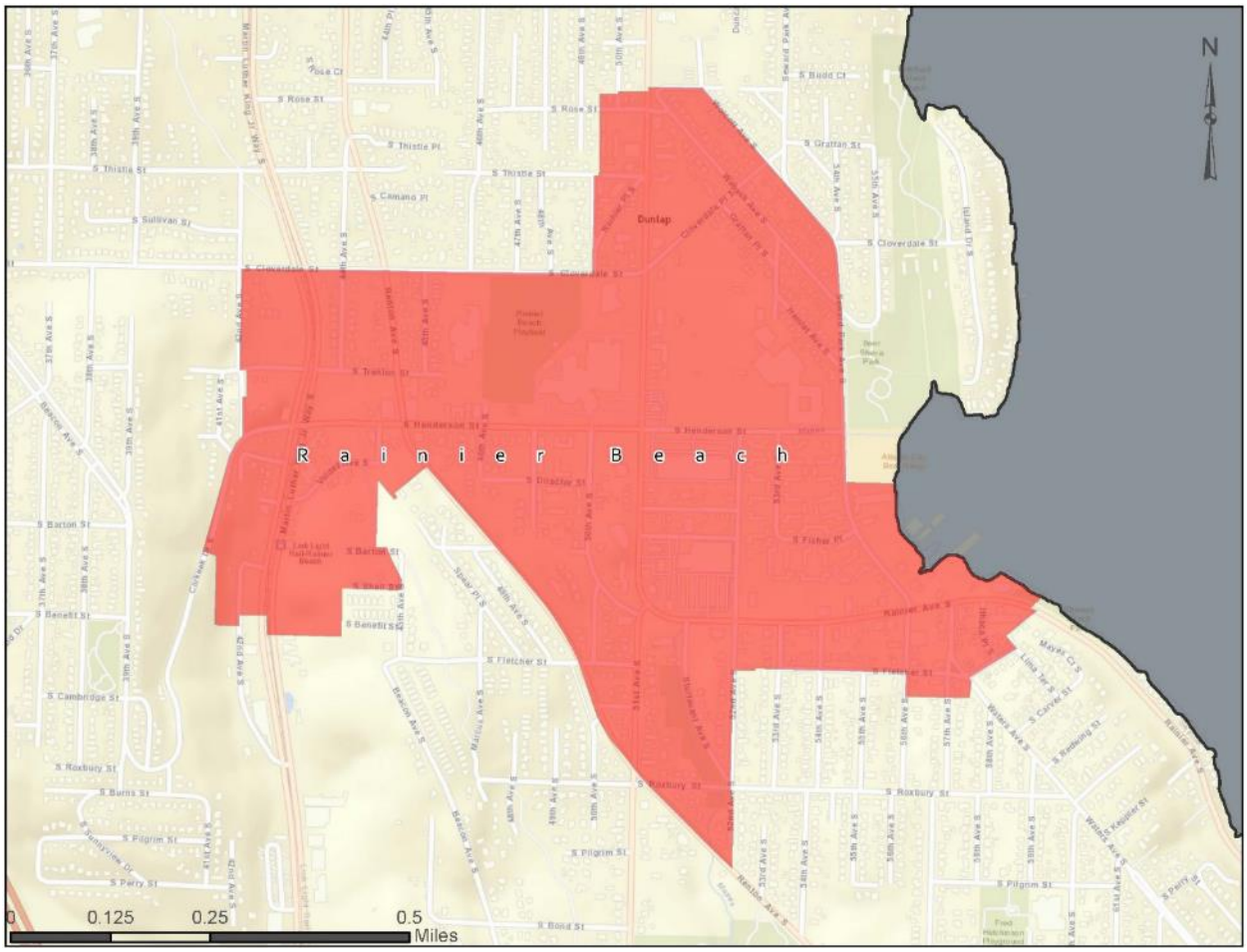
3.1.6 Rainer Beach

Rainer Beach is home to a diverse population of more than 5,000 residents. Rainier Beach is also one of the poorer neighborhoods in southeast Seattle with 21.8 percent of family households and 31.5 percent of non-family households living in poverty.[40] The neighborhood is comprised of

[39] Othello History, HELLO OTHELLO, http://www.helloothello.com/history/ (accessed September 19, 2016)
[40] Demographics, RAINIER BEACH ACTION COALITION, http://www.rbcoalition.org/neighborhood-information/demographics/ (accessed September 19, 2016)

four key areas where residents tend to gather and shop: Rose Street, Beach Square, Station Area, and the Historic Business District. Improvements are being made in each of these core areas to revitalize them and the neighborhood as a whole.[41]

Figure 7: Rainier Beach



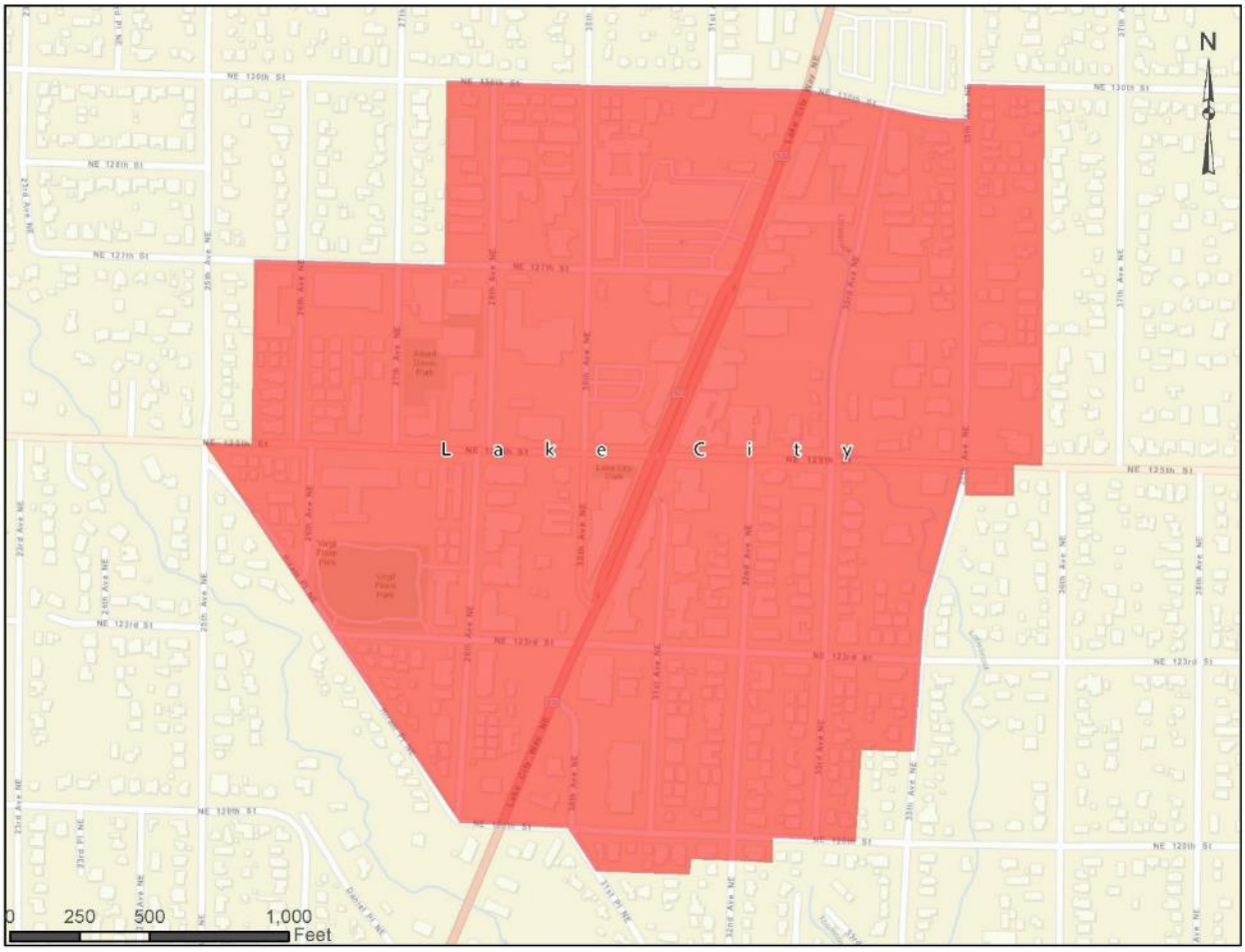
3.1.7 Lake City

The Lake City urban village is an area of the City that currently is targeted for improvement. On February 10, 2016, Mayor Murray announced that the City's Office of Planning and Community Development would work with the Lake City community to achieve their shared vision for the neighborhood. The community improvements will focus on economic development, transportation, housing, and human services. Specific improvements include better vehicular and

[41] Rainer Beach Neighborhood Plan Update, CITY OF SEATTLE OFFICE OF COMMUNITY PLANNING, http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/dpdd016764.pdf (accessed September 19, 2016)

pedestrian access within the community, additional housing for all income levels, and implementing strategies to create a healthy business district.[42]

Figure 8: Lake City



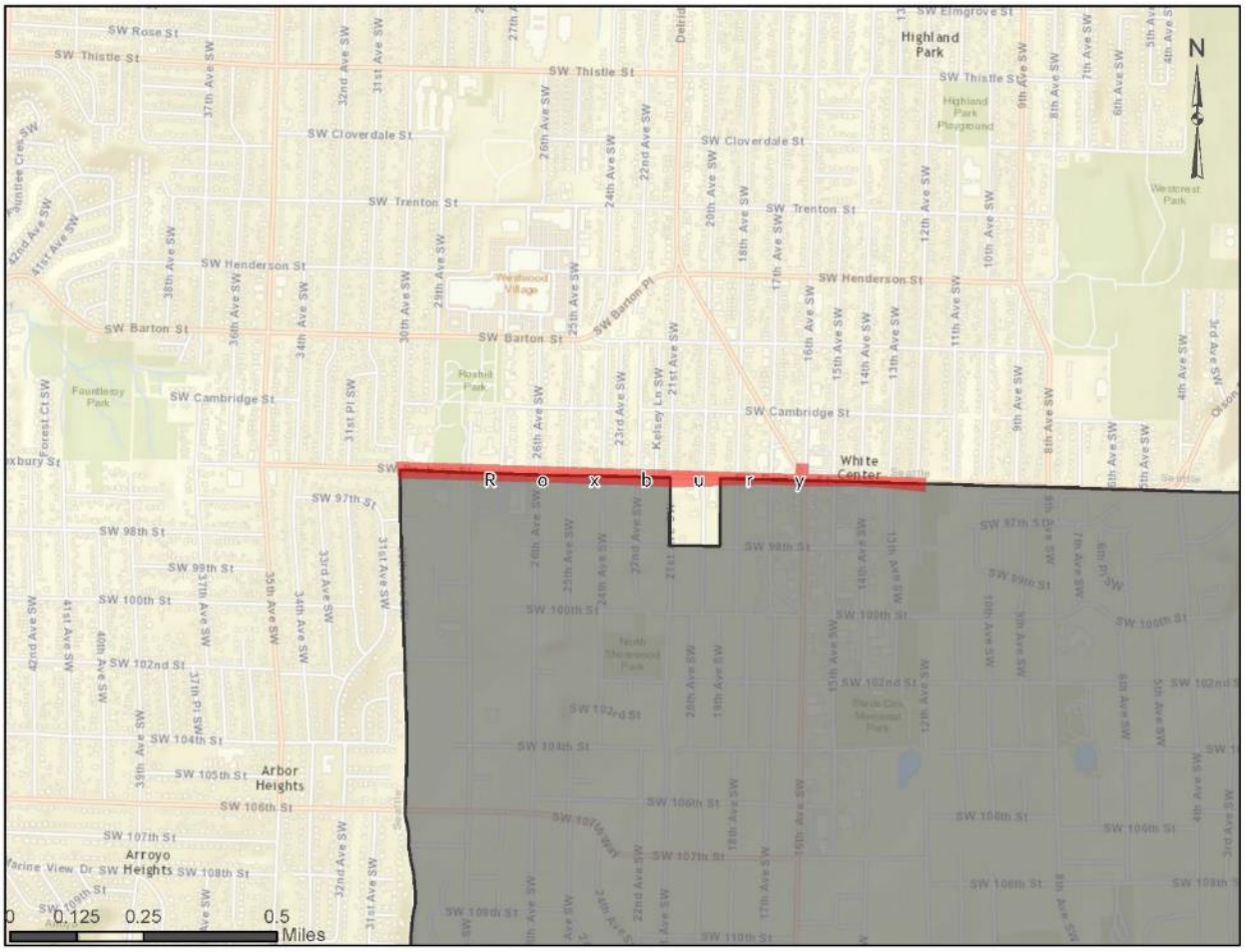
3.1.8 SW Roxbury Street Corridor

The SW Roxbury Street Corridor runs along the southern border of Seattle between the Westwood-Highland Park urban village and the neighborhood of White Center. White Center is a diverse community with approximately 32,000 residents. The 2010 census revealed that the City's population was 24.4 percent Asian and Pacific Islander, 21.5 percent Latino, and 8.6 percent

[42] Lake City Urban Design Framework, CITY OF SEATTLE OFFICE OF PLANNING AND COMMUNITY DEVELOPMENT, http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2422380.pdf (accessed September 19, 2016)

African American.[43] The Westwood-Highland Park Urban Village was created in the 1990s in an attempt to revitalize the area and has initiated growth and change to the area.[44]

Figure 9: SW Roxbury Street Corridor



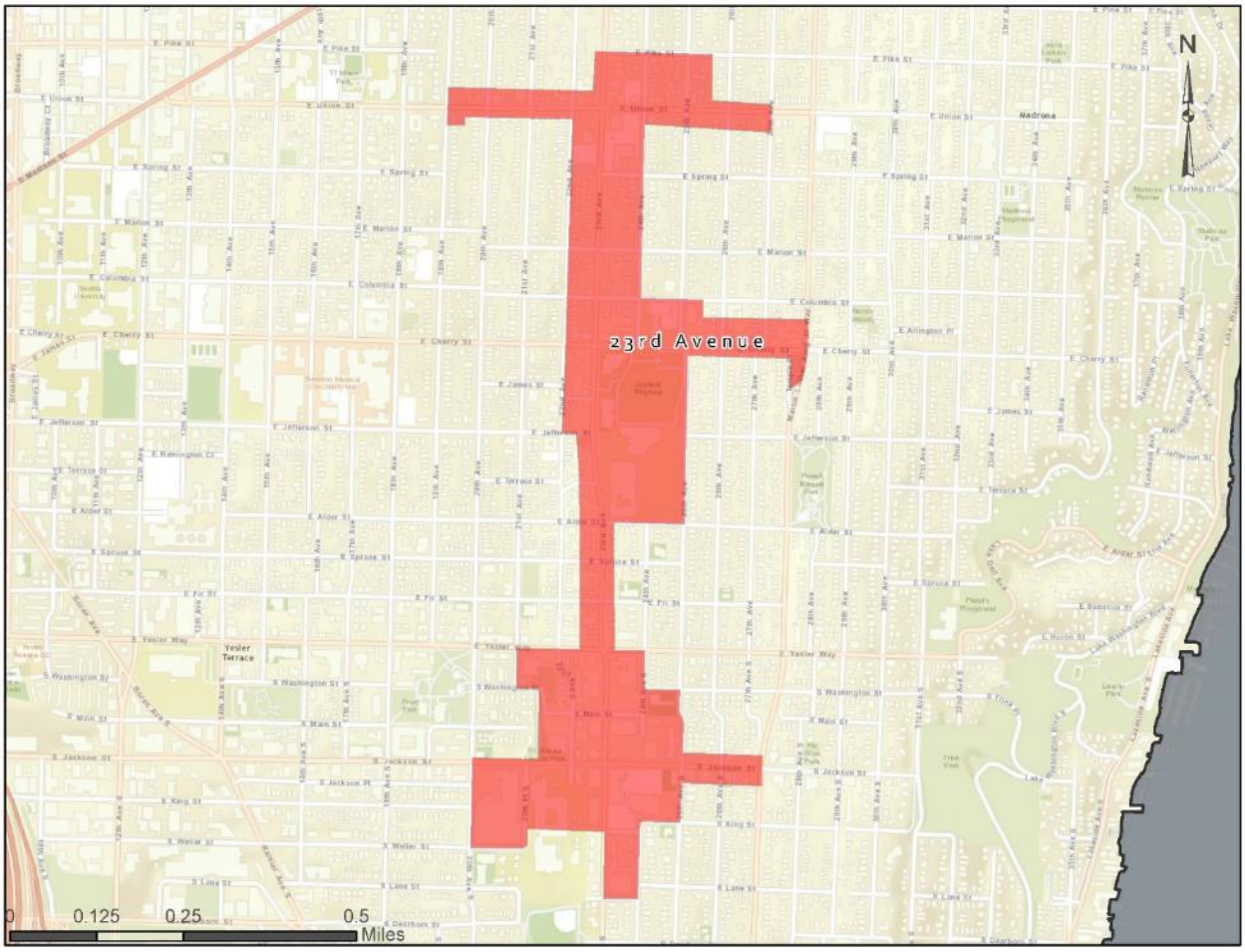
3.1.9 23rd Avenue Corridor

23rd Avenue is a highly-traversed corridor in the Central District, which connects three important community locations at the cross streets of Union, Cherry and Jackson. The corridor contains many business and institutions that are central to the African American community in Seattle.

[43] The Hood, VISIT WHITE CENTER, http://visitwhitecenter.com/the-hood/ (accessed September 19, 2016)
[44] The Westwood/Highland Park Neighborhood Plan Adoption Matrix, CITY OF SEATTLE DEPARTMENT OF PLANNING AND DEVELOPMENT, http://www.seattle.gov/Documents/Departments/Neighborhoods/Planning/Matrix/Westwood-Highland-Park-matrix.pdf (assessed September 19, 2016)

23rd Avenue is currently undergoing road construction to increase usability and safety in the corridor as part of a larger action plan to revitalize the area.[45]

Figure 10: 23rd Avenue Corridor (Central District)

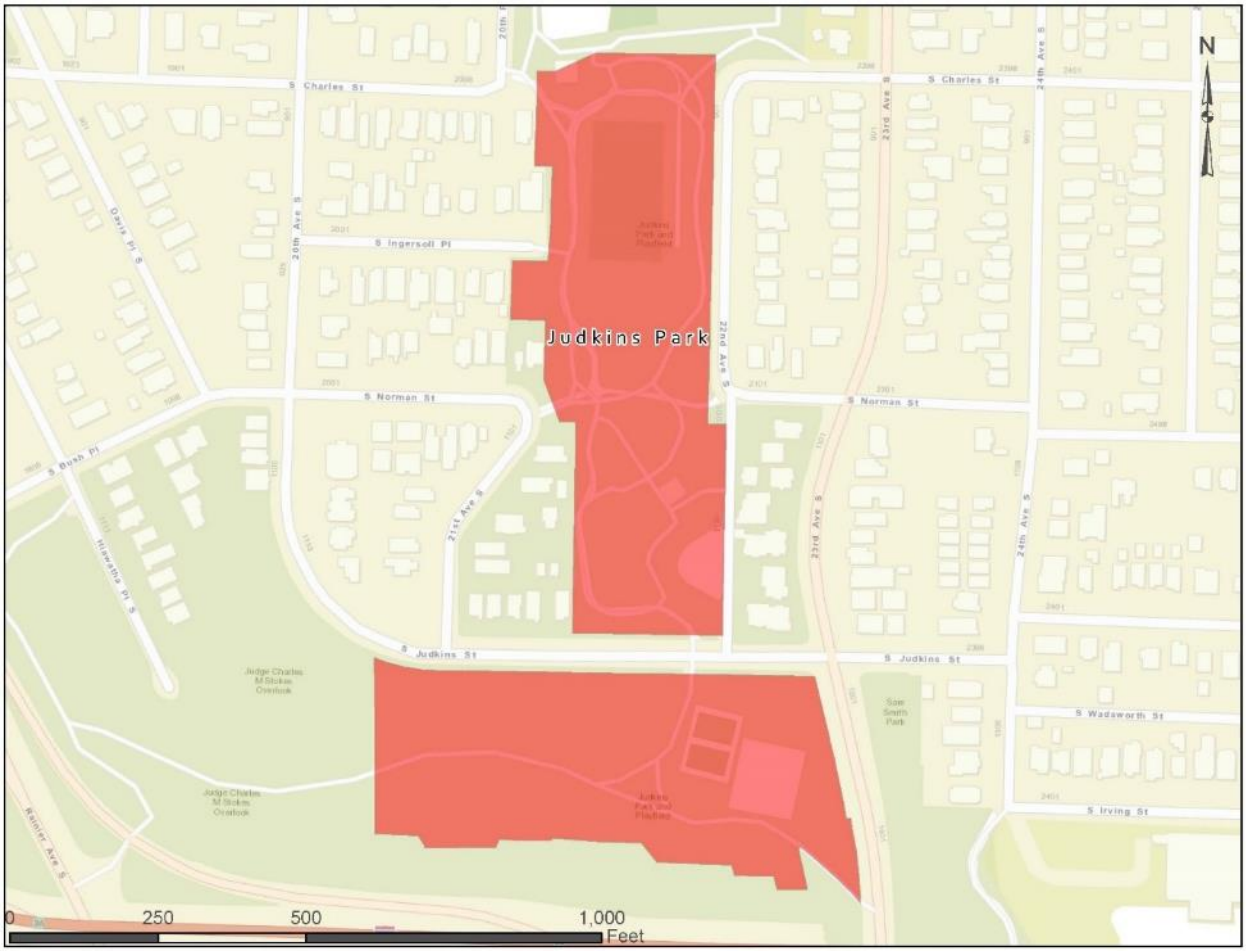


[45] 23rd Ave Action Plan, SEATTLE DEPARTMENT OF PLANNING AND DEVELOPMENT, http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2138415.pdf (accessed September 19, 2016)

3.1.10 Judkins Park

Judkins Park is located within Seattle's Atlantic neighborhood, one of the oldest neighborhoods in the City and only two miles from downtown. Highway construction during the 1960s through the early 1990s led to significant disruption in the neighborhood, preventing its economic growth. The area is racially diverse, with a majority minority population. Today, the area houses a number of social services agencies providing resources to City residents struggling with homelessness, addiction, blindness, and poverty. Its proximity to a network of green belts and trails make it an ideal location for connectivity.

Figure 11: Judkins Park



3.1.11 Jimi Hendrix Park

Jimi Hendrix Park is a two-and-a-half acre stretch of land in Seattle's Central District. The Central District has long been one of the City's most racially and ethnically diverse neighborhoods. Today, the neighborhood is home to nearly 30,000 residents. Construction of Jimi Hendrix Park was completed in summer 2016. The park is envisioned as a gathering place for people of different backgrounds to explore music and art and celebrate Seattle's cultural heritage. Rosanna Sharpe, executive director of the adjacent Northwest African American Museum said, "This destination shines brightly in the cultural landscape and serves as a beacon for the new formed Historic Central Area Arts & Cultural District."[46] As a central gathering place, the park is a priority area to provide public connectivity for residents and visitors.

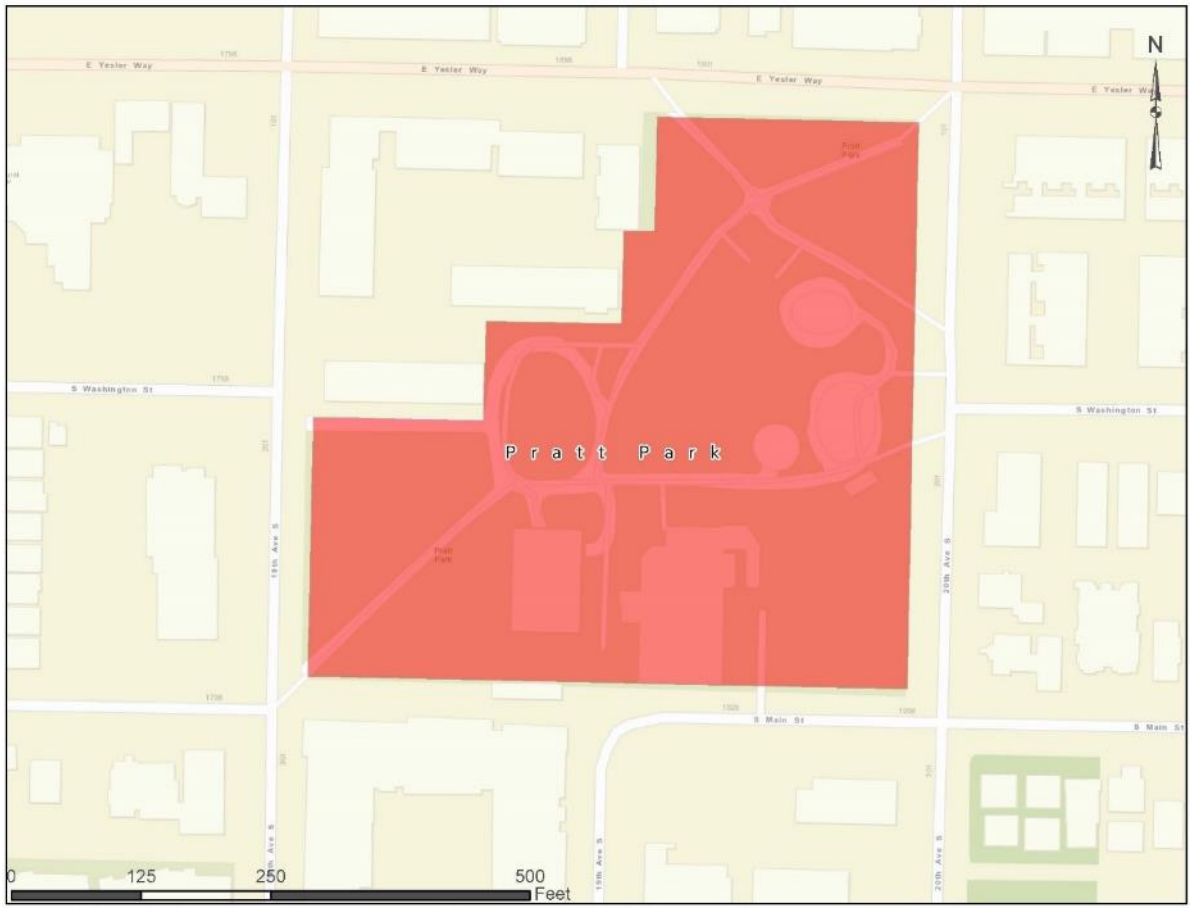
Figure 12: Jimi Hendrix Park

[46] News and Events, Jimi Hendrix Park Foundation, http://www.jimihendrixparkfoundation.org/news.php (accessed September 19, 2016)

3.1.12 Pratt Park

Pratt Park was established to provide open space adjacent to a low-income housing project.[47] Wireless access in this public space will provide critical connectivity to residents. The park features picnic tables, benches, a play area, a spray park, a basketball pavilion, a grassy area and an open field.

Figure 13: Pratt Park



[47] About: Pratt Park, CITY OF SEATTLE, http://www.seattle.gov/parks/find/parks/pratt-park (accessed September 19, 2016)

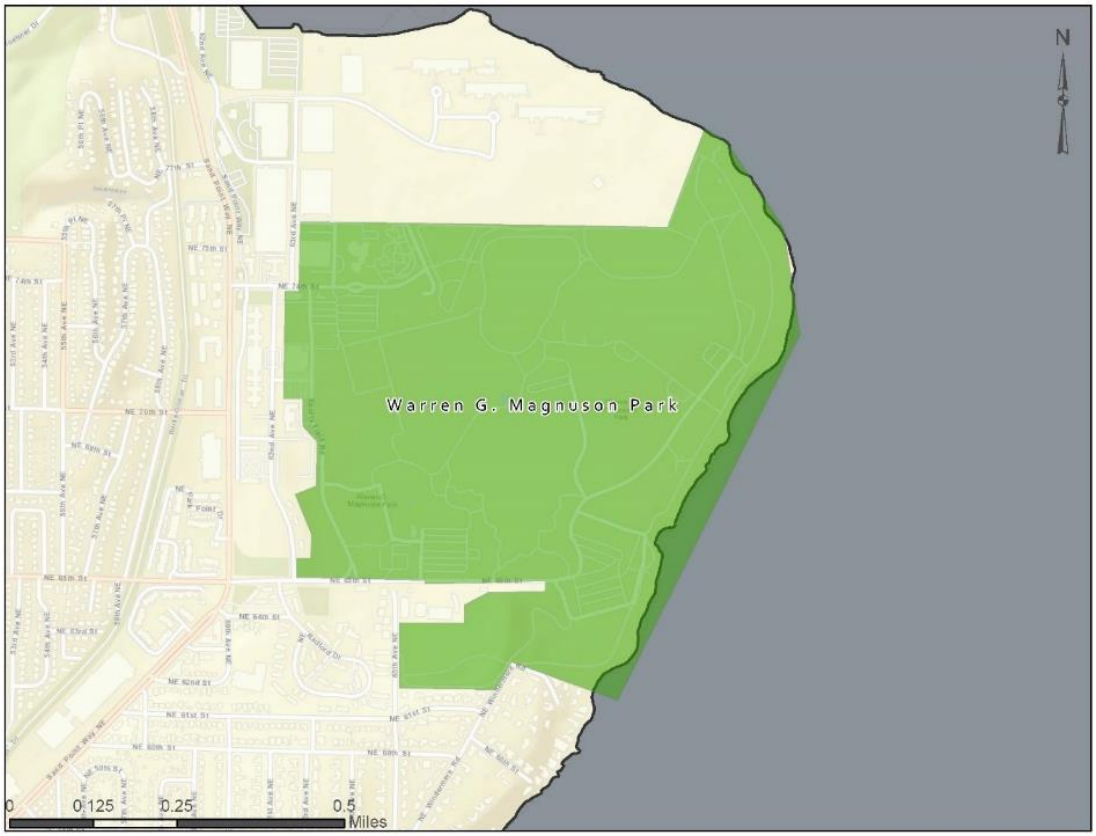
3.2 City Parks

The City identified six parks where wireless access would support various services and enable general use by the public.

3.2.1 Warren G. Magnuson Park

Warren G. Magnuson Park, located in the Sand Point neighborhood, features a range of amenities, including sports fields, a community garden, a swimming beach and over four miles of walking trails. The park was formerly a military base and has many landmarks and historical sites; its "historic district" features more than 20 structures built in the 1930s and 1940s including Building 30, a former airplane hangar that has been recently renovated. The hanger is a key component of the park as it is often rented out for special events, many of which feature merchants selling wares.[48] The current issue the park faces with the event space is the lack of cellular signal in the building, which impedes the merchants' ability to use Square and other kinds of financial transaction software on mobile devices. The geography and historical nature of the park pose barriers for wireless coverage.

Figure 14: Magnuson Park

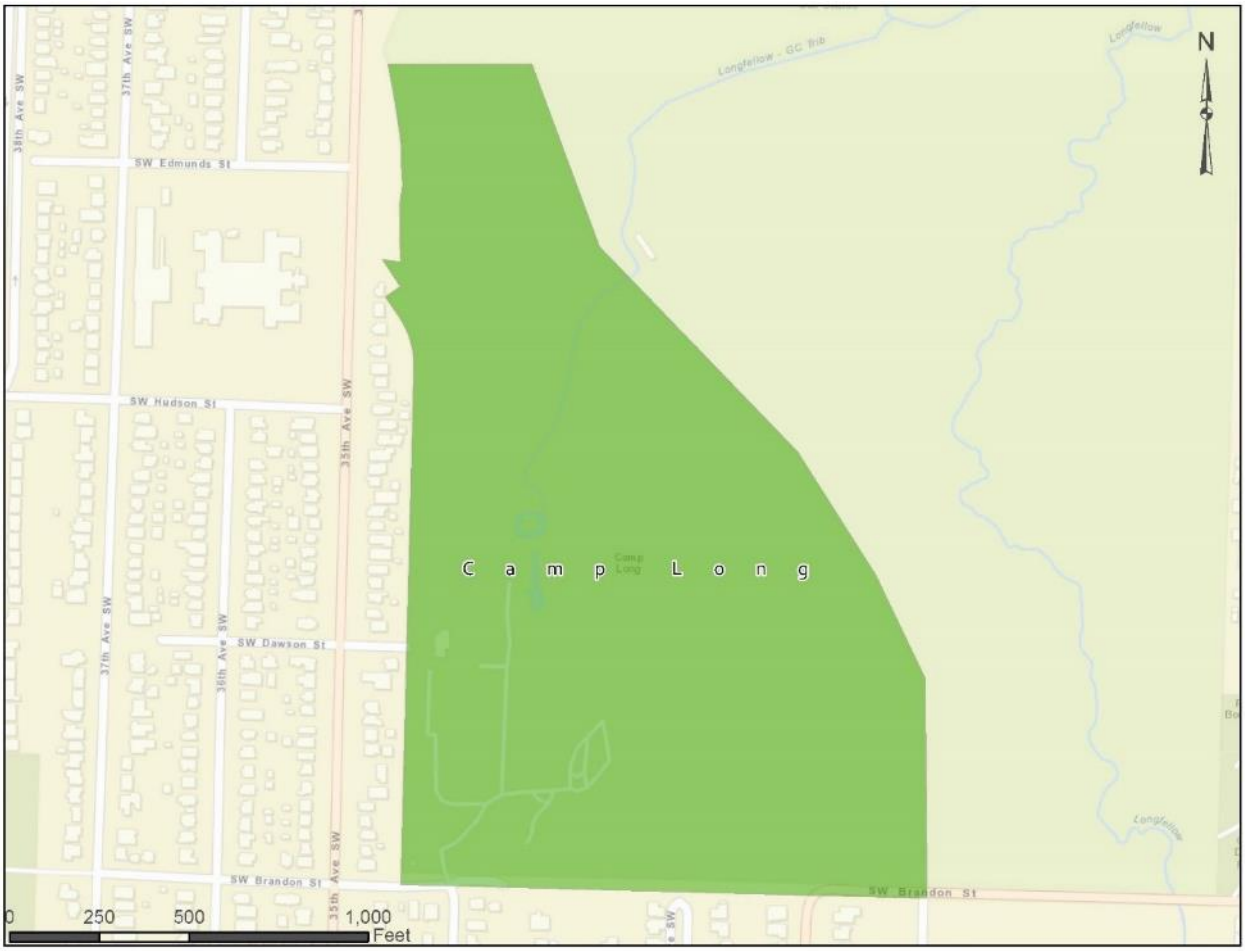


[48] About: Manguson Park, CITY OF SEATTLE, http://www.seattle.gov/parks/find/parks/magnuson-park (accessed September 19, 2016)

3.2.2 Camp Long

Camp Long, located in West Seattle, is a 68-acre park offering a range of amenities that allow visitors to hike trails, camp overnight in cabins, rock climb and learn about natural history. The park offers rentals of its facilities including a lodge with a meeting room, kitchen space, 10 cabins, two covered picnic areas, a group fire ring and a climbing rock. Park staff conduct environmental learning courses throughout the year.[49] The addition of wireless access would improve the park's learning courses and would make its available amenities become more desirable. The geography of the park may pose interesting barriers for wireless coverage at the extremities of the park property.

Figure 15: Camp Long

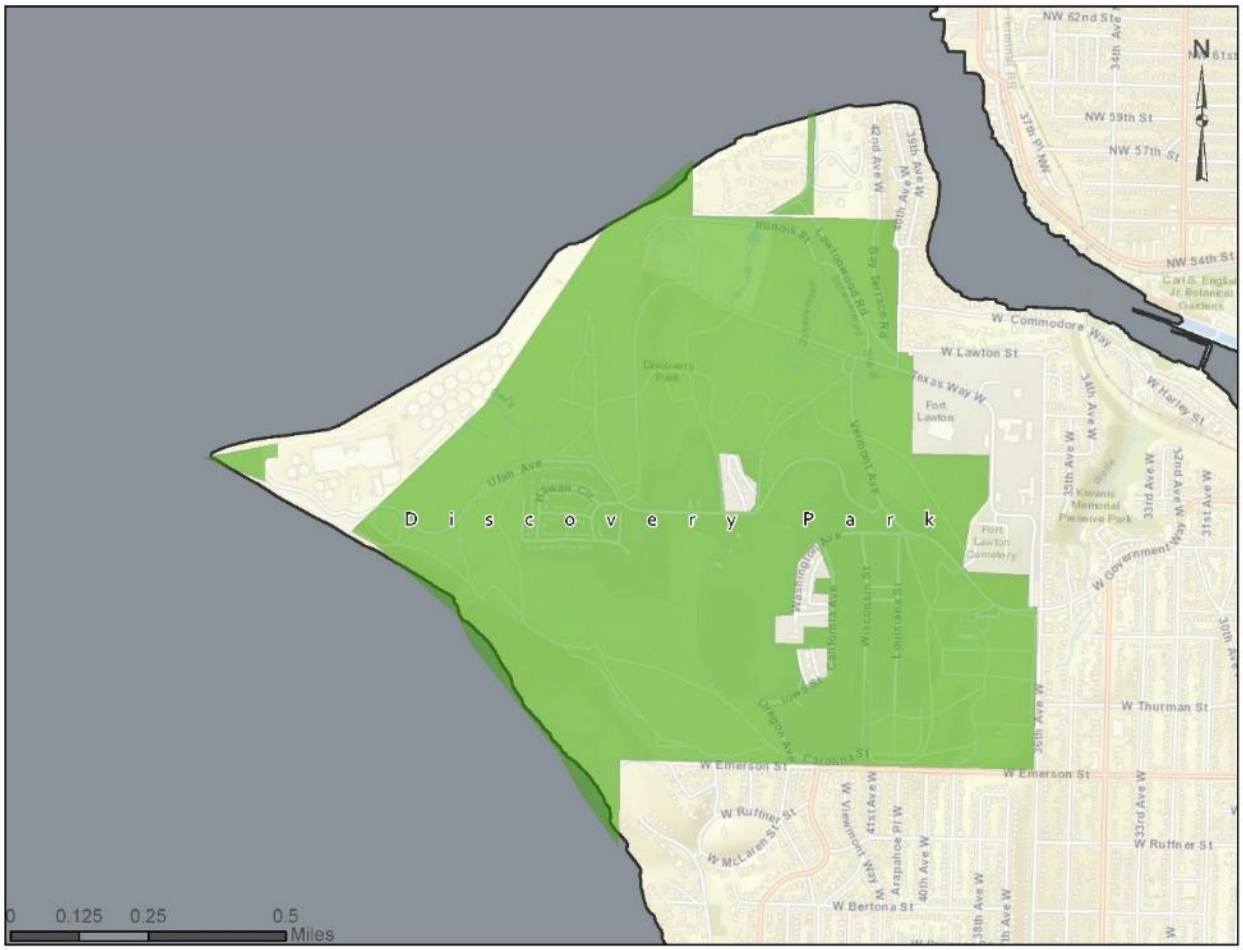


[49] About: Camp Long, CITY OF SEATTLE, http://www.seattle.gov/parks/find/centers/camp-long (accessed September 19, 2016)

3.2.3 Discovery Park

Discovery Park, located in the Magnolia neighborhood, is a 534-acre park situated along the northwestern edge of Magnolia Bluff overlooking the Puget Sound. The park offers environmental courses throughout the year.[50] The Discovery Park Environmental Learning Center is also located in the park and provides programs to enhance the learning experience.[51] The park is also used to hold ceremonies such as weddings and other special events. The addition of wireless access would improve the park's learning courses and would enhance the quality of the special event space.

Figure 16: Discovery Park



[50] About: Discovery Park, CITY OF SEATTLE, http://www.seattle.gov/parks/find/parks/discovery-park (accessed September 19, 2016)

[51] About: Discovery Park Environmental Learning Center, CITY OF SEATTLE, http://www.seattle.gov/parks/find/centers/discovery-park-environmental-learning-center (accessed September 19, 2016)

3.2.4 Westlake Park

Westlake Park is located in the heart of Seattle's retail district. Often considered the unofficial town square of Seattle,[52] the park's location attracts thousands of people each day. Extensive programing for the park is provided by the Downtown Seattle Association (DSA) and activities occur year-round on almost daily a daily basis. Some of the amenities the park provides include bistro-style seating, food trucks, fitness classes, ping pong, foosball and a reading room.[53] Wireless access would provide another useful amenity for the public and enhance the parks scheduled activates.

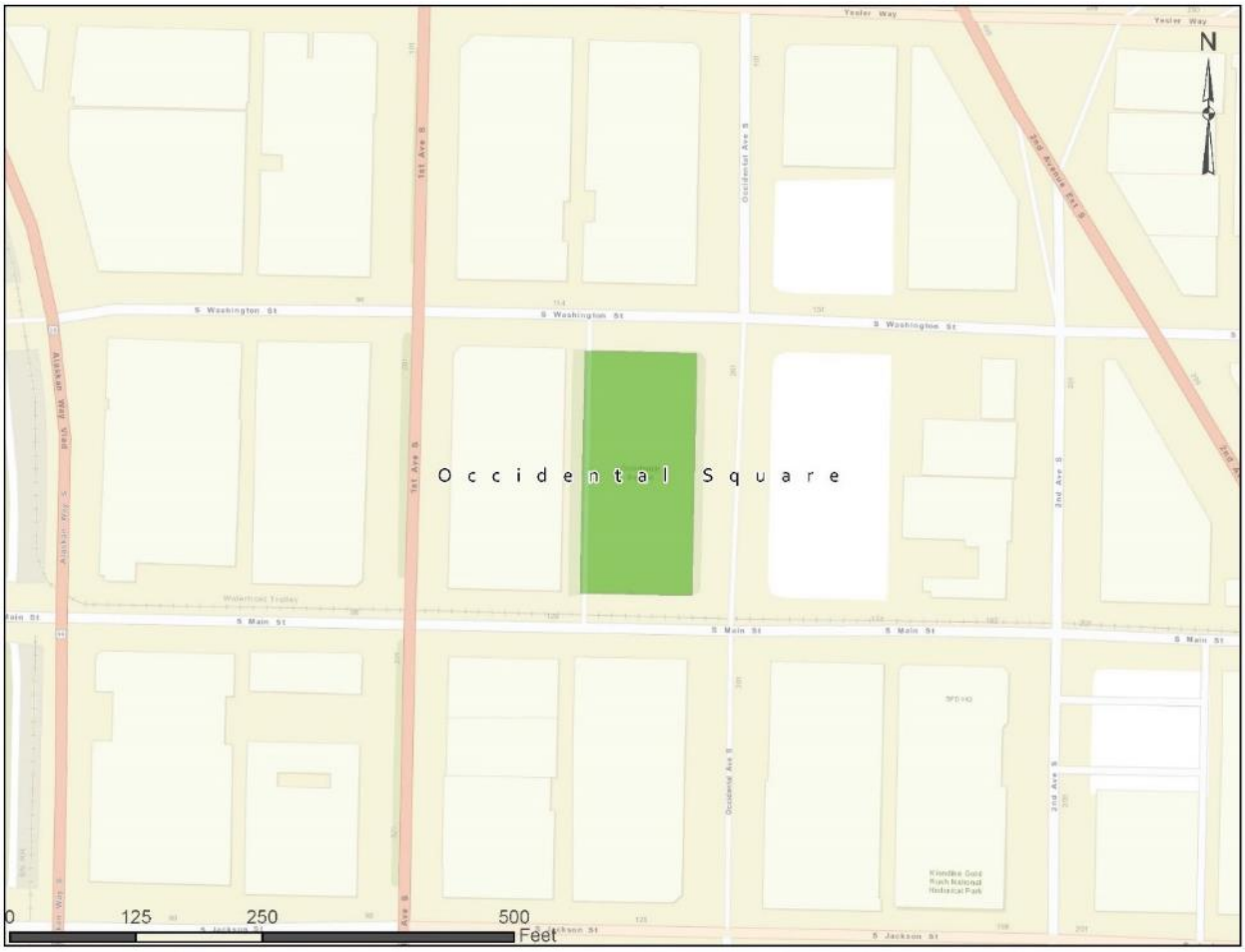
Figure 17: Westlake Park

[52] About: Westlake Park, CITY OF SEATTLE, http://www.seattle.gov/parks/find/parks/westlake-park (accessed September 19, 2016)
[53] Westlake Park, DOWNTOWN SEATTLE ASSOCIATION, http://www.downtownseattleparks.com/westlakepark (accessed September 19, 2016)

3.2.5 Occidental Square

Occidental Square is located in Seattle's historic Pioneer Square district. Activities are provided year around by the DSA. The Park's amenities include bistro-style seating, food trucks, fitness classes, refurbished bocce ball courts and a reading room.[54] Wireless access would provide another useful amenity for the public and enhance the parks scheduled activates.

Figure 18: Occidental Square



[54] Occidental Square, DOWNTOWN SEATTLE ASSOCIATION, http://www.downtownseattleparks.com/occidental-square (accessed September 19, 2016)

3.2.6 Waterfront Park

Waterfront Park is located between Pier 57 and Pier 59. The park features scenic views of the City skyline, Magnolia Bluff, the West Seattle Bridge, the Seattle harbor and Bainbridge Island.[55] The park amenities include picnic tables, ping pong, access to the Seattle Aquarium and the "Great Wheel" a 175-foot-tall Ferris wheel overlooking the Puget Sound. The park is within walking distance to Pike Place Market, one of the City's major attractions. Wireless access would provide another useful amenity for the public.

Figure 19: Waterfront Park

[55] About: Waterfront Park, CITY OF SEATTLE, http://www.seattle.gov/parks/find/parks/waterfront-park (accessed September 19, 2016)

4 High-Level Wi-Fi Network Design

The City's efforts to expand broadband access to digital inclusion areas and parks—including this strategic report, and the RFI the City issued to identify potential public–private partnerships—are focused on developing creative, sustainable options. To understand the scale of the effort needed to achieve the City's digital inclusion goals, we conducted an engineering analysis of the likely capital and operating expenses to serve these priority areas using City fiber and Wi-Fi.

The public–private solutions that emerge from the City's RFI and outreach efforts may or may not use these technologies. But this analysis offers an estimate of the City's cost if it were to solve the problem on its own. With those estimates as a baseline, the City can then understand the potential value of a partnership in terms of avoided cost (assuming that a viable partnership emerges to address some of these challenges).

We note, too, that there is additional value to the City that does not appear in this financial analysis—the value of broadband access in terms of education, job opportunities, civic engagement, and other positive impacts on people's lives.

4.1 Design Summary

CTC completed a conceptual Wi-Fi network design to provide Wi-Fi services to users across 12 digital equity areas and six parks in the City of Seattle. The combined network would require approximately 455 access point (AP) radios and approximately six miles of fiber, or the use of point-to-point access radios.

With this approach, the City and its partners can provide internet service in the outdoor areas of the digital equity areas and parks comparable to the highest standard of Wi-Fi that is provided in airports and public spaces, with the capability to expand to higher speeds.

The design includes a wireless local area network (LAN) controller for managing the network's customer access (such as billing, authentication, and security).

Additionally, much of the expense of deploying a wireless network is in the site preparation. Future technologies may leverage the installed power, backhaul, and enclosures at the public Wi-Fi access points. Hence, in the future, a public Wi-Fi network may have a seamless integration with mobile networks.

4.2 Technical Parameters

The primary goal of our network design is to provide a high-performance, robust, secure, and dependable user experience. The design covers outdoor areas for the general public use, but can also provide capacity for City use and for use by private partners.[56]

The service can connect devices such as laptops, tablets, smart phones, and sensors—any device with an Ethernet interface. That said, the service is not envisioned to be a replacement for residential broadband accounts, because the capacity requirements for a service equivalent to a residential wired service would require an extremely high density of access point radios.

The expected user applications are the same as in any public internet environment—a mixture of general internet access, email, music, and video. The network will also support new applications that may emerge; the network is designed to support, at a minimum, any application that "works" on a carrier LTE network.[57] Given this type of usage, each user should be able to simultaneously receive or send streamed video at 3 Mbps and the network should have low latency and jitter to support voice communications and other media.

The network as designed will not support heavy business-related activities, such as cloud hosting. It is not equipped in its current form to support vehicle automation. It is also not designed to support peak capacity scenarios such as supporting a large crowd during a concert in a park. However, for large planned events, there are several approaches for temporarily adding APs and other equipment to increase capacity.

The design uses omni-directional antennas that are directly connected to the APs to provide coverage to users in proximity to each AP (up to 500 feet). The APs are backward-compatible to older versions of the Wi-Fi standard (such as 802.11 a/b/g/n). However, a user with an older device will connect at lower speeds.

The selected network equipment is rated for outdoor use and is capable of withstanding harsh conditions. In this design, the network uses carrier class 802.11ac APs providing signal levels throughout the coverage areas stronger than -70 dBm.

APs are mounted approximately 20 feet above ground. In park areas they will be mounted on light poles or surrounding buildings. If necessary, the power service at the pole or mounting points will need to be augmented.

[56] For example, a partner seeking a network independent of the internet or commercial wireless networks may dedicate a portion of the network capacity for weather sensors, security services, and other machine-to-machine communication without significant impact on the Wi-Fi user experience.
[57] For example, the design considers "Pokémon Go" and other potential outdoor games.

The parks have some areas that are heavily wooded, where there is very light foot traffic. The coverage is not expected to cover all of these areas. However, in areas that are open and have infrastructure like benches, playgrounds, sports fields, or walking paths, good coverage is envisioned.

In digital inclusion areas, the access points could be installed on utility poles where they exist. If the existing utilities are underground, they could be installed on light poles. The power service at poles can be augmented as necessary at additional cost.

In the digital inclusion areas, the buildings are largely residential, small business, and retail. The coverage is provided in the outdoor areas, and does not necessarily penetrate to the inside of the buildings. Outside of the buildings, the users can directly connect to the network without additional equipment.

Residual signal may allow limited connections within some buildings, for example, in front rooms of frame buildings near the access points. However, in all cases, the occupants could use an antenna and repeater that could be mounted in a window. These could be bought by the user or issued by the City or the wireless provider for about $300.

Security will be designed with full consideration of best practices for public wireless networks, as discussed in Section 7.

4.3 Backhaul Connectivity

One of the key technical parameters and costs in a wireless network is the backhaul connectivity—the means of connecting the Wi-Fi network to the internet backbone and outside networks. Poor backhaul design, or backhaul that cannot effectively scale with increasing demand and changes in applications, is one of the main reasons why some public Wi-Fi networks are seen by the public as networks of last resort, and a reason why early city-driven Wi-Fi efforts were considered failures.

The network design envisions a mixture of new fiber optic connections, point to point wireless links, and the use of commercial Carrier Ethernet services to connect the areas, as described below.

It is envisioned the network will have one or more connections to the internet backbone at a central internet points of presence. In the Seattle area, bulk internet costs at these locations are typically in the $0.50/Mbps/month range. The network is designed globally with a 1:100 oversubscription per access point, which is a generous ratio for consumer internet. We estimate the average bulk citywide need to be 10 Mbps per access point, or 10 Gbps for a 1,000 access point network.

4.3.1 Digital Inclusion Areas

The pricing of backhaul is simplified by the placement of the access points in the right-of-way. This eliminates the need for fiber construction. Backhaul can use 250 Mbps Metro Ethernet to each of the insertion points.

Again, in the actual implementation, costs may be reduced if City fiber is present, or point-to-point wireless is used in conjunction with the Metro Ethernet service. This depends on the availability of line of sight and attachment points and can be determined as more detailed design is done.

4.3.2 Park Areas

For pricing purposes, we have included a budget for underground fiber construction from a point on the public right of way to one out of four APs, which are the bandwidth "insertion points" in the network. In cases, where this is not practical, point-to-point wireless links will be utilized. The design includes point-to-point 1 Gbps Ethernet connectivity to each of the insertion points. At the right of way, a hardened Ethernet switch is placed at a pole or handhole, where it connects to a commercial 1 Gbps Metro Ethernet service.

In the actual network implementation, it may be possible to use City fiber instead of the Metro Ethernet service. These possibilities can be determined as more detailed design is done.

4.4 Network Scalability and Upgrades

It is important to have a roadmap for network scalability and upgrade. As a general rule, wireless equipment such as Wi-Fi access points reach technological obsolescence after about five years, and are replaced by next generation technologies. The cost of AP replacement after five years is included in the operational budget as a replacement cost, in order that the budget fully consider sustainability. The budget also includes the software and security upgrades needed for the APs and controllers.

Since backhaul is based on dark fiber optics and managed fiber services, it already contains an upgrade roadmap. The fiber optics can increase in speed by replacement of relatively low-cost Ethernet switches (five-year replacement cost included).

The available managed fiber services will likely increase in speed with cost remaining the same, so maintaining the set budget will likely cover upgrading to next generation Ethernet services as needed. Likewise, the internet backbone cost will likely continue to decrease.

4.5 Design Areas

4.5.1 Digital Inclusion Areas

The digital inclusion areas included in the design are:

- Yesler Terrace
- High Point
- South Park
- Rainier Vista
- Othello
- Rainier Beach
- Lake City
- SW Roxbury Street Corridor
- 23rd Avenue Corridor
- Judkins Park
- Jimi Hendrix Park
- Pratt Park

We determined that the Digital Inclusion Area networks require 332 access points (APs) with approximately one out of four connected to backhaul. The below figure shows possible AP locations for the Yesler Terrace area. APs were placed in the right-of-way where possible to provide relatively easy access to power and backhaul. The other digital inclusion areas are designed in a like manner.

Figure 20: Yesler Terrace High-Level Wi-Fi Network Design Map

4.5.2 Parks

The parks included in the design are:

- Camp Long
- Discovery Park
- Occidental Park
- Walter E. Magnuson Park
- Waterfront Park
- Westlake Park

We determined that the parks networks require 121 outdoor wireless access points (APs) with approximately one out of four connected to backhaul.

Coverage was aimed at relatively open areas where the customer usage potential was the highest. The terrain and foliage present in certain areas, such as densely treed areas and cliffs have not been covered.

The connectivity range is up to 500 feet from the mounting location. Figures 2 to 7 depict possible locations of the APs (shown as white circles). The preliminary mounting locations have been selected along trails (whenever possible) and require a site survey and coverage modelling as next steps in a detailed design.

Figure 21: Discovery Park High-Level Wi-Fi Network Design Map

Figure 22: Walter E. Magnuson Park High-Level Wi-Fi Network Design Map

Figure 23: Westlake Park High-Level Wi-Fi Network Design Map

Figure 24: Camp Long High-Level Wi-Fi Network Design Map

Figure 25:Waterfront Park High-Level Wi-Fi Network Design Map

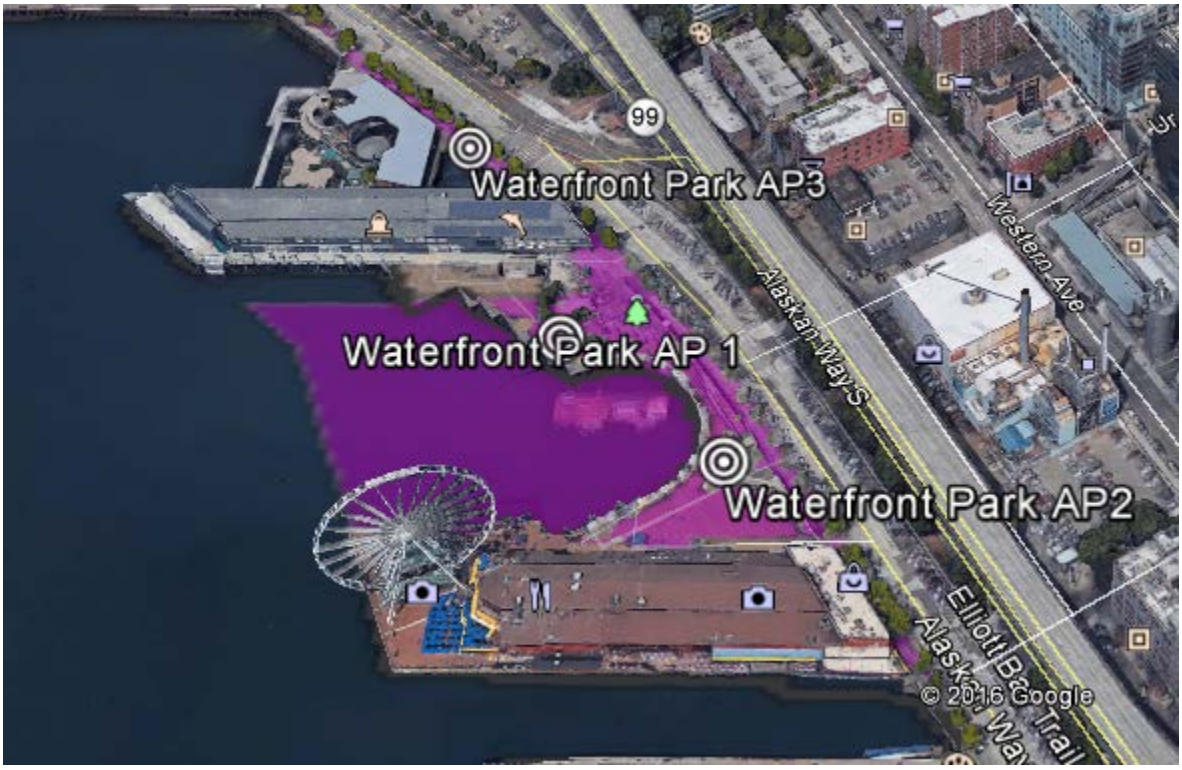
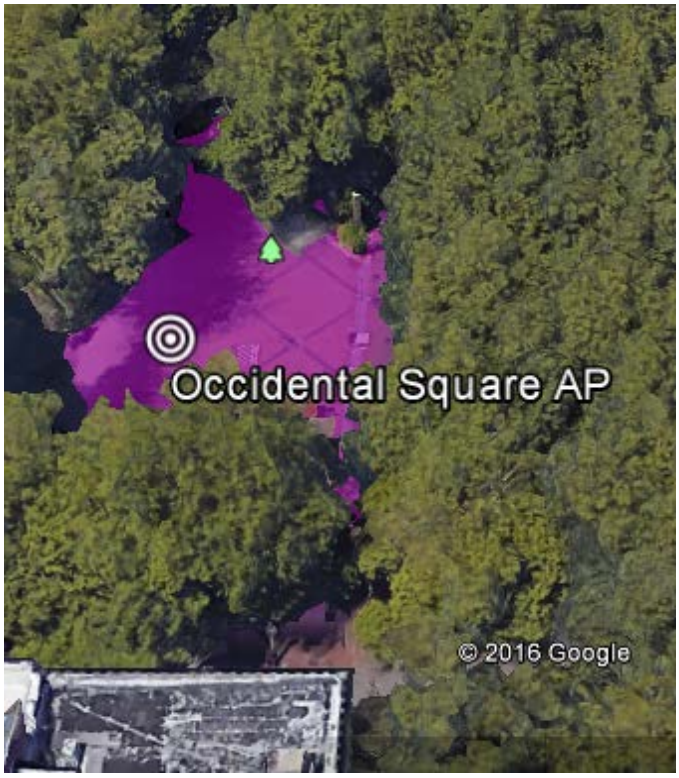


Figure 26: Occidental Park High-Level Wi-Fi Network Design Map



5 The State of the Wireless Market

The way we access the internet has changed dramatically over the past decade. The rapid proliferation of smartphones and tablet computers has fueled an explosive growth in demand for mobile bandwidth. Increasingly, people access bandwidth-intensive applications, like media streaming and video calling, from their mobile devices. Globally, mobile traffic is expected to increase 12- to 15-fold from 2012 to 2018.[58]

In many areas of the country, wireless carriers are making major investments in their mobile networks to try to keep up with customer needs.[59] In the sections that follow, we identify some of the key technical and economic issues facing the wireless market nationwide.

5.1 The Densification of Cellular Networks

While the transition to LTE technologies allows wireless carriers to expand the capacity of their existing macro-cell towers, tower upgrades alone will not keep pace with growing demand. In high-density urban areas, investment in new towers has begun to level off. Instead, major carriers are investing heavily in small cell sites and distributed antenna systems (DAS).[60] Small cell deployments increased 140 percent in 2015, with the growth rate expected to continue to swell.[61] Although 5G standards will not be set until 2020, many experts expect small cells to be the basis of 5G deployments in urban areas.[62]

While there have been some misleading claims about 5G making fiber obsolete, the reality is that fiber will serve as the backbone of 5G deployments, with wireless backhaul in some cases augmenting, not replacing fiber.[63] Companies like Zayo and Crown Castle have invested heavily

[58] Phillip Tracy, "Moving in-building forward with shared infrastructure and neutral host," *RCR Wireless News,* November 1, 2016 http://www.rcrwireless.com/20161101/carriers/in-building-neutral-host-tag31

[59] Keith Carls, "Next Generation Cell Towers Coming to an Area Near You," *KEYT,* May 25, 2016, http://www.keyt.com/news/santa-barbara-s-county/next-generation-cell-towers-coming-to-area-near-you/87615564

[60] Martha DeGrasse, "Crown Castle spends more on small cells than on new towers," *RCR Wireless News,* December 16, 2015, http://www.rcrwireless.com/20151216/network-infrastructure/crown-castle-spends-more-on-small-cells-than-on-new-towers-tag4

[61] Kelly Hill, "Five factors improving small cell economics," *RCR Wireless News,* June 29, 2016, http://www.rcrwireless.com/20160629/network-infrastructure/five-factors-improving-small-cell-economics-tag6-tag99

[62] Amy Nordrum, "5 Myths about 5G" *IEEE Spectrum*, May 25, 2016, http://spectrum.ieee.org/tech-talk/telecom/wireless/5-myths-about-5g

[63] Jiansong Gan, "LTE In-Band Relay Prototype and Field Measurement," IEEE, July 16, 2012, http://ieeexplore.ieee.org/document/6239938/. See also, Balaji Raghothaman, "System Architecture for a Cellular Network with UE Relays for Capacity and Coverage Enhancement," *InterDigital*, January 13, 2012, http://www.interdigital.com/research_papers/2012_01_13_system_architecture_for_a_cellular_network_with_ue_relays_for_capacity_and_coverage_enhancement

in fiber networks to serve as backhaul connections for cellular sites.[64] Instead of relying on a handful of fiber connections to towers and base stations, carriers now want fiber (or at least gigabit-capable) backhaul connections to as many small cell and DAS sites as possible. While some carriers are expanding their own fiber holdings, network densification efforts will inevitably force carriers to rely heavily on other dark fiber providers for backhaul connectivity.[65]

5.2 Economic Challenges for Small Cell Deployment

As with all broadband deployment, the transition to denser cellular networks has first concentrated in dense suburban and urban areas, where the potential return on investment is highest. In many places, the cost of backhaul connections and the difficulties involved with site acquisition continue to make deployments challenging and expensive.

The high cost of constructing fiber remains a major hurdle for the small cell business model. Dark fiber providers are working closely with carriers to build metro fiber rings that pass through targeted areas, but the buildouts often take 18 to 24 months to complete, and a single contract with an anchor tenant is often not enough to justify the investment. In order to make the investment pay off, fiber-backhaul providers often try to sign up multiple tenants along their fiber routes.[66] Some also offer lit and dark fiber services to owners of buildings that their extended networks pass, further helping to improve the business case for the investment in fiber.[67]

The high cost of getting fiber to small cell nodes has led Sprint to embrace a wireless backhaul strategy for its densification efforts. While this will allow the company to cut deployment costs in the short term, analysts predict that if network traffic continues to increase, the company will eventually need fiber backhaul to its cell sites.[68]

Municipalities can take a number of actions to encourage equitable deployments of small cell sites, and eventually 5G wireless networks. While local oversight is important to ensure that small

[64] Samantha Bookman, "Zayo's small cell, backhaul investments poised to pay off," *Fierce Telecom*, April 20, 2016, http://www.fiercetelecom.com/telecom/zayo-s-small-cell-backhaul-investments-poised-to-pay-off-as-5g-iot-come-to-fore

[65] Sean Buckley, "Verizon's 5G plans could spell dark fiber opportunity for Zayo, Level 3, others," *Fierce Telecom*, April 26, 2016, http://www.fiercetelecom.com/telecom/verizon-s-5g-plans-could-spell-dark-fiber-opportunities-for-zayo-level-3-others

[66] Kelly Hill, "Crown Castle on the small cell business case," *RCR Wireless News,* June 14, 2016, http://www.rcrwireless.com/20160614/network-infrastructure/crown-castle-small-cell-business-case-tag6-tag99

[67] Sean Buckley, "Zayo's Caruso: Tower backhaul tenants provide FTTT, enterprise upsell opportunities," *Fierce Telecom*, May 11, 2016, http://www.fiercetelecom.com/installer/zayo-s-caruso-tower-backhaul-tenants-provide-fttt-enterprise-upsell-opportunities

[68] Martha DeGrasse, "Sprint Looks to wireless backhaul to cut costs," *RCR Wireless News,* March 13, 2016, http://www.rcrwireless.com/20160313/carriers/sprint-wireless-backhaul-tag4

cell sites are relatively unobtrusive and fit with the character of neighborhoods,[69] amending city codes to include rules specifically for small cell deployments in the public right-of-way will help clarify the siting process for carriers.

Cities are also beginning to replace aging infrastructure with new infrastructure that is specially designed to make small cell deployments quicker, more affordable and less aesthetically intrusive. Streetlights can be an ideal spot for a small cell site, but most current small cell designs can only support a single service provider, and constructing fiber and power to the site can be expensive. New York is in the process of replacing 250,000 streetlight poles with multi-tenant poles, capable of serving all four major carriers. The streetlights will contain a single antenna, managed by a neutral host. New York City's wireless strategist expects tenancy on the City's priciest poles to cost around $650 per month.[70] Los Angeles and San Jose have also begun deploying fiber-connected, small-cell-ready streetlights, known as SmartPoles, through a smart city partnership with Phillips and Ericsson.[71]

City assets that are in close proximity to available dark fiber or conduit will be particularly valuable to carriers as they search for economical ways of deploying small cells. Cities with extensive fiber assets will be able to capitalize on the growing demand for fiber backhaul by leasing fiber or conduit to carriers.

Ideally, it would be beneficial for cities to let the wireless community know where fiber, conduit and other assets may be available, which may strengthen the business case for private carriers to deploy in underserved areas that might otherwise be too expensive to serve. If municipalities can offer affordable dark fiber services in these areas, it may help ensure small cells are deployed equitably.

5.3 Wi-Fi's Integration with Cellular Networks

Where demand for mobile data services has outpaced supply, Wi-Fi has become an important tool to help fill in gaps in adequate coverage. Wireless carriers use data allowances and throttling to encourage customers to offload their traffic to Wi-Fi networks when available. Wi-Fi hotspots

[69] Omar Masry, "10 Key Issues for California Cities and Counties on the Challenges of Small Cells & 'Not So Small Cells,'" *Medium*, September 17, 2016, https://medium.com/@omarmasry/10-key-issues-for-california-cities-counties-on-the-challenges-of-small-cells-not-so-small-c9e966f257a#.480cy0qq2

[70] Martha DeGrasse, "New York prepares for surge in small cell deployment," *RCR Wireless News,* December 1, 2015, http://www.rcrwireless.com/20151201/network-infrastructure/new-york-prepares-for-surge-in-small-cell-deployments-tag4

[71] Sue Marek, "Ericsson, Philips team with San Jose on LED lighting project," *Fierce Telecom,* December 10, 2015, http://www.fiercetelecom.com/installer/ericsson-philips-team-san-jose-led-light-pole-project

are proliferating in urban areas across the country, and recent technological advances will likely make them an even more significant source of wireless bandwidth in the future.

Using the updated IEEE 802.11u standard, the Wi-Fi Alliance created the Passpoint certification for routers. Passpoint-certified routers, or "Hotspot 2.0," allow mobile devices to roam onto and off of Wi-Fi networks much like they do on cellular networks. Once users download credentials from a service provider onto their devices, the devices will automatically connect to the service providers' Wi-Fi hotspots when available. [72] Passpoint also gives Wi-Fi hotspot service providers the ability to sign roaming agreements with one another, enabling customers to seamlessly roam onto other providers' networks without having to reenter a password. Certified devices automatically use Advanced Encryption Standard (AES) encryption over the wireless interface, offering more security than traditional hotspot connections.[73]

The technology is still young, but Time Warner (which has since been purchased by Charter) has been using it to allow customers to automatically connect to its network of hotspots since 2014.[74] Boingo is also using Passpoint to allow its customers (and customers of its roaming partners, including two Tier 1 wireless carriers) to automatically roam onto its hotspots in many major airports across the country.[75] Recent municipal Wi-Fi projects in New York City,[76] San Francisco, and San Jose[77] all rely on Passpoint-certified routers, providing users with seamless roaming and a more secure connection.

Some new entrants into the wireless industry are beginning to use Wi-Fi networks to compete with traditional wireless carriers. Mobile virtual network operator (MVNO) services like Republic Wireless, Ting, and Google's Project Fi all use a "Wi-Fi first" approach that encourages customers to connect to Wi-Fi networks whenever available. These companies have agreements with major carriers, allowing their customers to roam onto partners' cellular networks when Wi-Fi is not

[72] "Wi-Fi CERTIFIED Passpoint," *Wi-Fi Alliance,* http://www.wi-fi.org/discover-wi-fi/wi-fi-certified-passpoint
[73] "Wi-Fi CERTIFIED Passpoint (Release 2) Deployment Guidelines Rev 1.1," *Wi-Fi Alliance*, December 7, 2016, https://www.wi-fi.org/download.php?file=/sites/default/files/private/Passpoint_R2_Deployment_Guidelines-v1.1.pdf
[74] Kevin Fitchard, "Time Warner Cable bets on easy and secure Wi-Fi, rolling out Hotspot 2.0 networkwide," *GigaOm*, April 16, 2014, https://gigaom.com/2014/04/16/time-warner-bets-big-on-easy-and-secure-wi-fi-rolling-out-hotspot-2-0-across-its-network/
[75] Dan Peltier, "Boingo Adds Major US Cell Carrier to Make Wi-Fi Faster at US Airports," *Skift*, Aug 5, 2016, https://skift.com/2016/08/05/boingo-adds-major-u-s-cell-carrier-to-make-wi-fi-faster-at-u-s-airports/
[76] Mike Dano, "LinkNYC's free Wi-Fi could threaten cellular carriers with Passpoint roaming, speedy connections," *FierceWireless*, January 20, 2016, http://www.fiercewireless.com/wireless/linknyc-s-free-wi-fi-could-threaten-cellular-carriers-passpoint-roaming-speedy-connections
[77] Tammy Parker, "Ruckus helps San Francisco, San Jose launch public Hotspot 2.0 Wi-Fi service," *FierceWireless*, January 29, 2014, http://www.fiercewireless.com/tech/ruckus-helps-san-francisco-san-jose-launch-public-hotspot-2-0-wi-fi-service

available.[78] Although none of these companies have major Wi-Fi footprints at this time, their customers can take advantage of existing Wi-Fi networks in their homes and offices, as well as any free, public Wi-Fi networks. The LinkNYC consortium[79] and other hotspot providers[80] are experimenting with new approaches to ad-supported, free, public Wi-Fi, and the successful models will likely proliferate in urban areas across the country in the next few years.

While these initial "Wi-Fi first" MVNO services have failed to capture a significant portion of the wireless market, industry analysts expect the entrance of large cable companies into the wireless market to make more of a splash.[81] As part of a 2011 spectrum sale, Verizon agreed to allow Comcast, Time Warner Cable, Cox, and Bright House to act as MVNOs using Verizon's network. In September, Comcast announced it would begin offering mobile service in mid-2017.[82] Charter, which purchased Time Warner Cable earlier this year, has also announced it will enter the mobile market in the near future.[83]

Using their Wi-Fi, fiber and cable deployments, cable companies are offering Wi-Fi to customers within their service areas. Comcast has over 14 million Xfinity Wi-Fi hotspots. Some of these are in public places; others are customers' home routers, which have an optional "guest mode" that make them available to nearby Comcast customers.[84] The company's core hybrid-fiber coaxial (HFC) network could also provide backhaul connections for Wi-Fi or small cell deployments by non-Comcast entities.[85]

Many of the major cable companies have also agreed to a Wi-Fi roaming alliance, giving cable customers the ability to roam onto other cable companies' hotspots.[86] For example, when

---

[78] http://www.nashvillechatterclass.com/switch-heres-google-project-fi-compares-carriers/18008/

[79] For more about the LinkNYC initiative, see the Case Study section of this report.

[80] DJ Pangburn, "A startup is using a mesh network to bring free Wi-Fi to Philadelphia," *The Verge*, January 4, 2016, http://www.theverge.com/2016/1/4/10695912/a-startup-is-using-a-mesh-network-to-bring-free-wifi-to-philadelphia

[81] Daniel Robinson, "Should You Switch? Here's How Google's Project Fi Compares to Other Carriers," *Nashville Chatter,* October 31, 2016, http://www.lightreading.com/services/mobile-services/analysts-more-than-bullish-on-comcast-mvno/d/d-id/722840

[82] Chris Welch, "Comcast confirms plans to launch mobile phone service in 2017," *The Verge, September 20, 2016,* http://www.theverge.com/2016/9/20/12986872/comcast-mobile-network-verizon-mvno-2017

[83] Diana Goovaerts, "Charter Also Eyeing Wireless Service Via Verizon MVNO Deal," *Wireless Week,* September 22, 2016, https://www.wirelessweek.com/news/2016/09/charter-also-eyeing-wireless-service-verizon-mvno-deal

[84] Chris Welch, "Comcast confirms plans to launch mobile phone service in 2017," *The Verge, September 20, 2016,* http://www.theverge.com/2016/9/20/12986872/comcast-mobile-network-verizon-mvno-2017

[85] Mari Sibley, "Analysts More Than Bullish On Comcast MVNO," *Light Reading, April 22, 2016,* http://www.lightreading.com/services/mobile-services/analysts-more-than-bullish-on-comcast-mvno/d/d-id/722840

[86] "CableWiFi Alliance Survives Consolidation," *Rethink Wireless,* June 11, 2016 http://rethink-wireless.com/2016/07/11/cablewifi-alliance-survives-us-consolidation/

Comcast customers travel to Cox territory, they can connect (automatically, if their devices are Hotspot 2.0 compatible) to Cox's Wi-Fi hotspots. Even if Comcast customers choose a different mobile service provider, they can still use the extensive Cable Wi-Fi network to avoid the higher cost of cellular data.

While Wi-Fi has traditionally been seen as a backup to cellular networks, the lower cost of transmitting data over Wi-Fi networks is quickly making it the first choice for mobile broadband users where Wi-Fi is available.[87] Where commercial cellular providers have bandwidth limits and per-bit pricing, cellular networks are becoming a more expensive backup to be used when Wi-Fi is not available.

5.4 The Impact of Millimeter Wave Technology on Fixed Deployments

In Seattle, the cable and telecom companies generally enjoy a duopoly, which can reduce competitive pressure to invest in network improvements or expand service to unserved areas. Wave G provides a third option for fiber-to-the-premises (FTTP) service within Seattle, providing citizens with an alternative to Comcast and Century Link. Currently the service is only available to a select subset of the population as it is deployed almost exclusively to large multiple dwelling units such as apartment and/or condo buildings. This service is mostly offered in the downtown Seattle area, but is available in West Seattle and a few other areas in the City. The Wave G FTTP service provides a direct fiber connection to the building and connections to the individual units via 100BaseT, 1000BaseT Ethernet, or vDSL. Wave G is provided in two tiers of speed, 100Mbps symmetrical and 1Gbps symmetrical. Neither tier a is subjected to data transfer cap, allowing users to consume freely without worry of additional charges.

In a select group of markets, Google Fiber was seen as a welcomed new entrant. When Google announced it would start offering service in a city, the local cable and telecom incumbents often responded with a flurry of new investment and price cuts.[88]

However, the Google Fiber experiment appears to be paused for now, and Google has suggested quite publicly that it is not going to build FTTP going forward, including in many of the cities that it had selected for consideration for fiber builds in previous years. As with many things, Google is a very private company and its plans are not evident publicly. Just as we were never privy to how it selected cities for consideration, we are currently not privy to its plans going forward.

[87] Mari Sibley, "Analysts More Than Bullish On Comcast MVNO," *Light Reading, April 22, 2016,* http://www.lightreading.com/services/mobile-services/analysts-more-than-bullish-on-comcast-mvno/d/d-id/722840

[88] Olga Kharif, "Google Gets Beaten to the Punch by AT&T on Super Fast Broadband," *Bloomberg Technology*, April 25, 2016, https://www.bloomberg.com/news/articles/2016-04-25/google-gets-beaten-to-the-punch-by-at-t-on-super-fast-broadband

What we do know is that many cities that were hopeful that Google would build fiber have been disappointed and are now looking at alternatives.

Although no one can be sure what Google Fiber will look like in the future, its recent acquisition of the fixed wireless ISP Webpass likely offers a hint. Webpass uses wireless backhaul technologies to offer broadband speeds up to 1 Gbps to customers in multi-dwelling units (MDU). The service, which currently is priced at $60 a month, relies on fixed millimeter wave (mmWave) antennas to send massive amounts of data over short distances, along direct lines of sight.[89]

Exactly how Google will integrate mmWave radios into its access strategy remains to be seen, but it is clear that wireless backhaul will play an important role going forward. Google Fiber President Dennis Kish has publicly stated that the company will take a hybrid approach in the future, relying on both wired and wireless technologies to deliver gigabit speeds to end users.[90]

The shift in Google Fiber's strategy is just one example of how recent advances in mmWave technologies are changing the economics of broadband deployment. Facebook is working with mmWave radios as part of its attempts to connect the unconnected and underserved across the globe.[91] AT&T recently announced that it plans to use mmWave radios along powerlines to provide backhaul connections to small cell and DAS sites, as well as to offer multi-gig residential services.[92] In Santa Cruz, California, local ISP Cruzio used $50,000 worth of mmWave radio transmitters to deliver gigabit speeds to 15 commercial and multi-dwelling-unit residential locations, primarily in the downtown area. The project allowed the company to avoid the high cost of wired construction in urban areas and deliver upgraded service just three months after the project was announced.[93]

The high cost of building to the end customers' premises has made it hard for new entrants to compete with incumbent providers. While mmWave radios may not always be able to match the

[89] Jon Brodkin, "Google Fiber is Now a Fiber *and* Wireless ISP," *arsTechnica,* October 3, 2016, http://arstechnica.com/information-technology/2016/10/google-fiber-now-owns-a-wireless-isp-but-isnt-giving-up-on-fiber/

[90] Jon Brodkin, "Google Fiber is Now a Fiber *and* Wireless ISP," *arsTechnica,* October 3, 2016, http://arstechnica.com/information-technology/2016/10/google-fiber-now-owns-a-wireless-isp-but-isnt-giving-up-on-fiber/

[91] Neeraj Choubey and Ali Yazdan Panah, "Introducing Facebook's new terrestrial connectivity systems - Terragraph and Project ARIES," *Facebook Code*, April 13, 2016, https://code.facebook.com/posts/1072680049445290/introducing-facebook-s-new-terrestrial-connectivity-systems-terragraph-and-project-aries/

[92] Bernie Amason, "AT&T Touts New Transformative Broadband Experience with AirGig Technology," http://www.telecompetitor.com/att-touts-new-transformative-broadband-experience-with-airgig-technology/

[93] James Atkinson, "Santa Cruz gets gigabit broadband with Siklu mmWave wireless tech," *Wireless Magazine*, July 4, 2016, http://www.wireless-mag.com/News/41667/santa-cruz-gets-gigabit-broadband-with-siklu-mmwave-wireless-tech-.aspx

speeds of an FTTP or DOCSIS 3.1 HFC system, they can potentially deliver gigabit speeds at a much lower cost to deploy because the very last segment of the fiber or coaxial cable connection is replaced by a wireless link. This creates an opportunity for new entrants to enter the fixed internet market. The startup Starry has plans to use mmWave radios to build a nationwide fixed wireless ISP, capable of delivering gigabit speeds at a fraction of the price consumers currently pay.[94] Starry CEO Chet Kanojia predicts that the lower cost of Starry's network buildout will allow it to turn a profit with just 5 to 10 percent of the market share, rather than the near 50 percent that most wired buildouts require.[95]

[94] Kevin Eck, "Where is He Now? Aereo Founder Chet Kanojia Looking to Disrupt Another Industry," *Ad Week*, October 24, 2016, http://www.adweek.com/tvspy/where-is-he-now-aereo-founder-chet-kanojia-looking-to-disrupt-another-industry/180606

[95] David Talbot, "Wireless, Super-Fast Internet Access Is Coming to Your Home," *MIT Technology Review,* May 16, 2016. https://www.technologyreview.com/s/601442/wireless-super-fast-internet-access-is-coming-to-your-home/

6 Wireless Technologies and Siting Options

While many consumers equate wireless broadband with mobile access, fixed wireless technologies are an alternative for providing service when line-of-sight can be established between a base station and end user sites. In the sections below, we describe the technical capacities, limitations, and expected evolution of fixed and mobile wireless technologies.

6.1 Fixed Wireless

Wired networks can be very expensive to deploy in an urban setting. In Seattle, crowded utility space on poles and in rights-of-way combined with the lack of green space can make citywide deployment extremely costly. Fixed wireless networks can potentially overcome some of these obstacles. Wireless ISPs (WISPs) have the potential to connect customers in a line of sight to base station antennas, which in Seattle so far has provided high-speed service to large multi-dwelling-unit buildings and office buildings. But WISPs are not yet able to offer connection speeds on a market-wide basis comparable to cable or FTTP built to each premises, and sometimes impose data caps on customers to manage limitations on capacity.

Even as wireless technologies continue to advance, they will still lag the performance available from fiber optics, simply because of the relative technical challenge with spectrum and line-of-sight in providing high-capacity connections wirelessly.

6.1.1 Technical Capacity and Limitations

Most wireless networking solutions using the unlicensed and semi-licensed 2.4, 3.5, 5.0, and 5.8 GHz bands require the antenna at the customer premises to be in the line of sight of the base station antenna. This can be a problem in areas with dense vegetation or multiple tall buildings. WISPs often need to lease space at or near the tops of radio towers or tall buildings; even then, some customers may be unreachable without the use of additional repeaters. And because the signal is being sent through the air, climate conditions like rain and fog can impact the quality of service, particularly at even higher frequencies (like mmWave).

Wireless equipment vendors offer a variety of point-to-multipoint and point-to-point solutions. Point-to-multipoint solutions are more affordable to implement and are typically used in a WISP environment. However, because many users share the same bandwidth, point-to-multipoint solutions limit the capacity of the network, particularly in the upstream, making the service inadequate for applications that require high-bandwidth connections.

Fixed point-to-multipoint wireless systems built with off-the-shelf equipment today tend to have a downstream aggregate capacity between 100 and 250 Mbps. With innovations like higher-order multiple input, multiple output (MIMO) antennas, and the use of spatial multiplexing, these capacities will likely increase across vendors to as fast as 750 Mbps. It is important to note that

this is the aggregate capacity; bandwidth will be shared among the users connected to a single base station—which, depending on the engineering, could be dozens or hundreds.

Point-to-point solutions can readily reach 1 Gbps speeds over short distances with line of sight and are not shared by multiple users, but the cost of a point-to-point solution generally limits it to serving large buildings or businesses.

6.1.2 Factors Impacting Quality and Speed of Service

The following factors will determine a fixed wireless customer's service speed and quality:

- **Wireless equipment used:** Different wireless equipment has different aggregate bandwidth capacity and uses different spectrum bands, each with its own unique transmission capabilities.
- **Backhaul connection**: Although the bottleneck tends to be in the last-mile connection, if a WISP cannot get an adequate connection back to the internet from the tower, equipment upgrades will not be able to increase available speeds beyond a certain point.
- **Unobstructed line of sight:** Most wireless networking equipment require a clear, or nearly clear, line of sight between antennas for optimum performance. WISPs often lease space near the tops of radio towers in order to cover the maximum number of premises with each base station. In mountainous regions, many premises may not have a clear line of sight to a radio tower.
- **Weather conditions and foliage:** Depending on the spectrum used, weather conditions like rain or fog may cause interference. Also, line-of-sight paths that are clear during the winter may be obstructed by foliage during the warmer months.

6.1.3 Future Capacity and Lifespan of Investment

Wireless equipment generally has a lifetime of about five years, both because exposure to the elements causes deterioration, and because the technology advances rapidly, making equipment from a decade ago mostly obsolete. The cost of deploying a wireless network is generally much lower than deploying a wireline network, but the wireless network will require more regular investment.

6.1.4 Millimeter Wave Technology

A relatively new wireless technology, millimeter wave (mmWave) is capable of multi-gigabit speeds. The term refers to wireless signals with frequencies on the electromagnetic spectrum between 30 GHz to 300 GHz; the name comes from the length of the wavelengths for that spectrum, ranging from 1 millimeter to 10 millimeters.

The high frequency of a millimeter wave allows for increased channel bandwidth, making it ideal for sending large amounts of data. However, the technology suffers from poor propagation, requires line of sight between the endpoints, and has a limited range. It is also highly susceptible to interference from weather; even at short distances, rain, fog, or snow can disrupt the transmission.

The high frequency of millimeter wave also means that it has a low beam-width—which in turn means that it can be transmitted by a relatively small antenna, currently down to six-inch diameter. This allows for equipment to be deployed on traffic lights, utility poles, and rooftops. The directional characteristics of the beam allows for multiple systems in the millimeter wave bands to be engineered in close proximity to one another without causing interference.

The 60 GHz band, which is unlicensed in the U.S., is capable of delivering gigabit speeds, but it is especially affected by atmospheric absorption, limiting its range to under a few kilometers. The 71-76 GHz, 81-86 GHz, and 92-95 GHz bands do not suffer from the same level of atmospheric attenuation that limits the 60 GHz band. While those bands have a longer range, their use requires an FCC transmission license.

Millimeter wave technology has potential for many telecommunications applications, including Wi-Fi and small-cell backhaul, and the augmentation of fiber buildouts to homes and commercial buildings. One example of deployment of millimeter wave technology to augment an FTTP buildout is in Santa Cruz, California; a local ISP, Cruzio, partnered with Siklu, a company that provides millimeter wave equipment, to extend the coverage of Cruzio's fiber network to reach community locations where conventional deployment would be too costly. Cruzio connects fifteen locations in the downtown area, mostly businesses and multi- dwelling-unit residences.

6.2 Mobile Wireless

Cellular wireless carriers have been consistently increasing their data speeds with the rollout of faster and higher-capacity technologies such as Long-Term Evolution (LTE).[96] Some carriers now offer data plans with speeds comparable and in many cases greater than a typical residential customer's internet service.

6.2.1 Technical Capacity

Mobile wireless providers operate a mixture of third-generation (3G) and fourth-generation (4G) technologies. The service providers typically provide devices (telephones, smartphones, air cards, tablet computers) bundled with 3G or 4G services. Devices may not be easily portable from carrier to carrier, because differences in the configuration of devices used by the carriers limit

[96] LTE is a 4G cellular wireless technology offering data speeds of typically around 30 Mbps.

compatibility of the devices (discussed below). Therefore, the purchase of a device may restrict a user's choice of service providers.

The strict definition of 4G from the International Telecommunications Union (ITU) was originally limited to networks capable of peak speeds of 100 Mbps to 1+ Gbps depending on the user environment.[97] According to that definition, 4G technologies[98] are not yet deployed. In practice, LTE technology is called 4G and represents a speed increase over 3G technologies as well as a difference of architecture—more like a data cloud than a cellular telephone network overlaid with data services. The ITU and other expert groups have more or less accepted this.[99]

Table 1: Typical Performance for Advertised 2G/3G/4G Services

Applications	**Technology (Download/Upload Service Speeds)[100]**		
	2G/2.5G–EDGE/GPRS, 1xRTT (128 Kbps–300 Kbps/ 70 Kbps–100 Kbps)	3G–EVDO Rev A, HSPA+ (600 Kbps–1.5 Mbps/500 Kbps–1.2 Mbps)	4G –LTE (1.5 Mbps–30 Mbps/500 Kbps–5 Mbps)
Simple text e-mail without attachments (50 KB)	Faster (2 seconds)	Faster (1 second)	Faster (<1 second)
Web browsing	Faster	Faster	Faster
E-mail with large attachments or graphics (500 KB)	Average (14 seconds)	Faster (3 seconds)	Faster (1 second)
Play MP3 music files (5 MB)	Slower (134 seconds)	Average (27 seconds)	Faster (7 seconds)
Play video files (100 MB for a typical 10-min. YouTube video)	Slower (45 minutes)	Average (9 minutes)	Faster (3 minutes)
Maps and GPS for smartphones	Slower	Average	Faster
Internet for home	Slower	Average	Faster

[97] "Development of IMT-Advanced: The SMaRT approach," Stephen M. Blust, International Telecommunication Union, http://www.itu.int/itunews/manager/display.asp?lang=en&year=2008&issue=10&ipage=39&ext=html (accessed October 2016).
[98] Such as LTE Advanced, under development.
[99] "ITU softens on the definition of 4G mobile," *NetworkWorld*, December 17, 2010, http://www.networkworld.com/news/2010/121710-itu-softens-on-the-definition.html (accessed October 2016).
[100] This table assumes a single user. For downloading small files up to 50 KB, it assumes that less than 5 seconds is faster, 5–10 seconds is average, and more than 10 seconds is slower. For downloading large files up to 500 KB, it assumes that less than 5 seconds is faster, 5–15 seconds is average, and more than 25 seconds is slower. For playing music, it assumes that less than 30 seconds is faster, 30–60 seconds is average, and more than 100 seconds is slower.

6.2.2 Limitations

Most businesses and residents will find that mobile wireless broadband has technological limitations relative to wireline. These include:

1) *Lower speeds.* At their peaks, LTE typically provides only about one-tenth the speed available from FTTP and cable modems. In coming years, LTE Advanced may be capable of offering Gbps speeds with optimum spectrum and a dense buildout of antennas—but even this will be shared with the users in a particular geographic area and can be surpassed by more advanced versions of wireline technologies (with Gbps speeds already provided by some FTTP providers today).

2) *More asymmetrical capacity, with uploads limited in speed.* As a result, it is more difficult to share large files (e.g., video, data backup) over a wireless service, because these will take too long to transfer; it is also less feasible to use video conferencing or any other two-way real-time application that requires high bandwidth.

3) *Stricter bandwidth caps.* Most service providers limit usage more strictly than wireline services. Though wireless service providers may be able to increase these caps as their technologies improve, it is not clear whether the providers will keep ahead of demand. A *Washington Post* article about Apple's iPad with 4G connectivity highlights the issue: "Users quickly are discovering the new iPad gobbles data from cellular networks at a monstrous rate. Some find their monthly allotment can be eaten up after watching a two-hour movie. That has left consumers with a dilemma: Pay up for more data or hold back on using the device's best features."[101]

From a residential customer's perspective, a mobile wireless data cap may still be sufficient for a light user of the internet. And, for certain users, higher connection speed may be considered a more desirable feature than unlimited, unfettered data.

Mobile broadband is only available where cell service exists. Furthermore, there are some areas where the cell service is relatively weak, where terrain or building walls block the signals, or where upgrades have not taken place, and the broadband service is limited to slower service with speeds comparable to telephone dial-up. In contrast, "4G" LTE mobile data service is available with download speeds up to 30 Mbps and upload speeds up to 5 Mbps.

For playing videos, it assumes that less than 5 minutes is faster, 5–15 minutes is average, and more than 15 minutes is slower.

[101] Cecilia Kang, "New iPad users slowed by expensive 4G network rates," *Washington Post*, March 22, 2012, http://www.washingtonpost.com/business/economy/new-ipad-users-slowed-by-expensive-4g-network-rates/2012/03/22/gIQARLXYUS_story.html?hpid=z2 (accessed October 2016).

For most residential users, video streaming is the largest use of data. Use of streaming online video on smartphones, TVs, and tablets through applications like YouTube, Netflix, Hulu, HBO Go, and other over-the-top (OTT)[102] services continues to increase. If a mobile broadband carrier offers 20 Mbps speed and an 8 GB data limit, a user could only stream YouTube videos for six hours or watch two movies on Netflix before reaching the data cap. This is a major limitation for the average customer.

6.2.3 5G Technology

5G represents a next stage in the evolution of mobile wireless technology, and is envisioned to provide much faster speeds then the current 4G technology (e.g., download speeds of approximately 10 Gbps). 5G is seen by many as a central component of machine-to-machine communications and the Internet of Things. 5G will also feature much lower latency—expected to be about 1 ms—which will be essential for future applications such as driverless cars. 5G should also greatly enhance a user's ability to stream HD video and will become essential if 4K video services are transmitted over mobile broadband networks.

5G also is also being designed to support a much greater device density per base station than current 4G technology. While 4G can connect thousands of devices per cell, anticipated 5G deployments using massive MIMO might allow for over a million devices to be connected to a single radio cell.

Planning and design and prototype testing of 5G technology is currently underway, but full deployment is not expected to begin until 2019 or 2020.

[102] "Over-the-top" (OTT) video content is delivered over the internet by a third-party application or service. The ISP does not provide the content but provides the internet connection over which the content is delivered.

7 Framework for Analyzing Wireless Opportunities

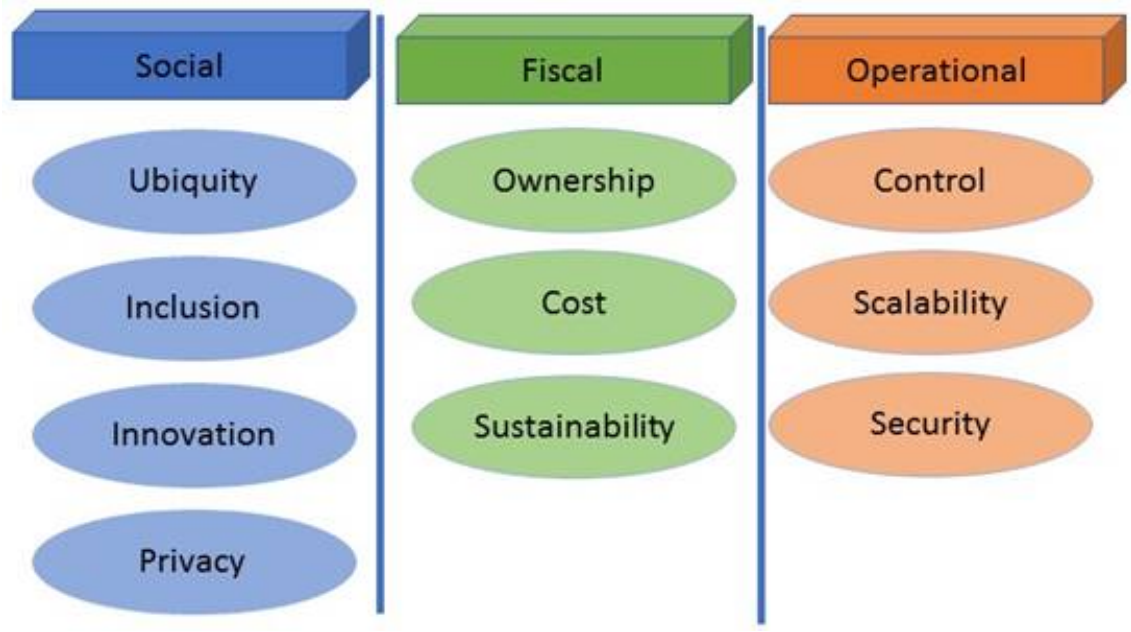
As wireless opportunities arise for the City and its residents, it will be important to evaluate them against the goals driving the City's wireless equity strategy. In a given scenario, these goals may align—but they also may conflict with one another. This analysis seeks to help the City understand the interplay between common objectives so that it can evaluate potential opportunities in light of its goals, its prioritization of goals, and how the goals interact with each other.

There are numerous possible outcomes associated with different objectives, and this analysis offers a framework by which the City can determine what it believes will best serve its unique needs and have the best impact on the community. This analysis does not seek to urge the City in any particular direction, but takes into consideration the City's articulated goals, and offers a framework for how to evaluate potential public–private partnership models for the City working with private entities to further this initiative and a broad array of wireless efforts.

7.1 Goals to be Considered in the Framework

As a means of understanding the full range of City priorities in this area, we divided the City's goals (as they have been expressed to us by stakeholders consulted during preparation of this document) into three categories: social, fiscal, and operational (Figure 20). We then analyzed how these goals relate to each other.

Figure 27: Network Goals by Category



7.2 Summary of Analysis of Goals and Their Relation to Each Other

In summary, depending on the model, the City's full range of objectives may align perfectly with each other, overlap, or have no impact on each other. For example, the goal of **performance** interacts favorably with the goal of **ownership** but not at all with other objectives such as moderating or minimizing **cost**. In another example, the goals of **privacy** and **control** will align perfectly, but both of these are likely to be at odds with the goal of moderating **cost** because those latter goals point toward private solutions (if possible) which reduce City control and may entail private sector interests in monetizing user data.

Given the focus of this initiative (and the policy objectives that led Seattle IT to commission this report), we suggest that **ubiquity** (i.e., access for all, regardless of income level) and **inclusiveness** (i.e., affordability) are likely to serve as the primary goals the City will consider in evaluating wireless opportunities.

From the other categories, **sustainability** and **performance** are likely to be the factors that best support **ubiquity** and **inclusiveness**, as long-term support for the effort (sustainability) and comparable quality of service to that received by higher income members of the community (performance) are critical to ensuring both equitable access (ubiquity) and affordability (inclusiveness) for lower income residents of Seattle.

Given Seattle's status as a privacy-sensitive community, the **privacy** filter will also be critical. We note, however, that privacy may not align at all with avoidance of **cost** – as many private companies that may commit to providing free hardware or services may seek to monetize that "donation" through collection and sale of data (as is occurring in the LinkNYC program discussed in the Appendices to this report).

7.3 Discussion of Goals as Evaluation Criteria

To enable an informed decision process, we analyzed the goals by placing them in three scoring categories: optimal, acceptable, and least desirable.

7.3.1 Ubiquity

We live in an increasingly connected society. For the City, this means that enabling broadband access in all neighborhoods is a necessity, not a benefit. But such necessity conflicts with the current state of the market. Unfortunately, digitally-segregated neighborhoods have become the norm in most communities, with a strong disadvantage held by lower-income areas.

Carriers prioritize wireless coverage in areas where a higher density of its subscribers live, work, shop, and play. Similarly, cable companies have begun replacing modems with models that have additional radio transmitters to provide access to subscribers on other devices outside of their homes. Companies also aggressively market business-class internet to establishments in these

dense subscriber neighborhoods or in areas that subscribers are likely to frequent. Carriers continue to densify the areas frequented by their subscribers, and offer DAS solutions for major retail and entertainment venues and transportation hubs. None of these carrier investment patterns deliberately aligns with the City's ubiquity and equity goals, even if they do sometimes coincidentally support each other.

Assuming ubiquity as a priority, the City will need to consider the risk and cost associated with deployment in the priority areas so as to ensure access to services by all, not only those who are well-served by carrier infrastructure. This model presents capital and operating costs (as are described in our engineering section above), and creates challenges around sustainability.

Rating	***Criteria***
Optimal	Service is brought to all neighborhoods and available to all residents, businesses, and institutions in the community. The technology deployed is equally scalable and all sites have fiber backhaul to accommodate growth and migration to 5G.
Acceptable	The areas identified as targets for digital equity and inclusion are connected by deployment of a fully scalable solution with fiber backhaul, or a plan has been presented for the City to use its own fiber in the future.
Least Desirable	Access and quality of service is based solely on commercial providers' priorities, which are dictated by return on investment calculus that is opaque to City decision makers. The best, most extensive service emerges in more affluent areas, high-traffic commercial corridors, and areas with highest subscriber base with top tier wireless data plans. Neutral hosts and third-party infrastructure providers only deploy in areas the MNOs (mobile wireless service providers) deem important for densification efforts.

7.3.2 Inclusion

Inclusion is a function of affordability. Large segments of the population are vulnerable to being priced out of a digital society, even in an area as well-connected as Seattle.

As a society, we have created a digitally-connected world where a wide range of essential everyday functions is online and designed with an expectation that everyone has ubiquitous access; this range of functions includes government services, educational resources, applications for finding housing, scheduling of medical appointments, health monitoring, prescription refills, commerce, bus schedules, and monitoring our children's homework and progress in school.

For students, lack of access may mean being able to do homework only at libraries, community centers, or the local coffee shop. For working families, lack of broadband service may mean an inability to access City services or job opportunities. For homeschooling families, lack of broadband may mean lack of access to the video-based curricula that homeschoolers rely on. For entrepreneurs who can't afford home-based broadband, lack of access may mean having to run a home-based company from the public library where free bandwidth makes possible the critical online tasks inherent in running a new business.

Prioritizing investments and partnerships that offer provisions for those residents who cannot afford subscription-based services is critical to inclusion.

Among the City's options in this area are to deploy its own wireless system in the prioritized areas, partner with a private entity to fund and manage free wireless service in the prioritized areas, or a hybrid of the two in which the City and private entities allocate tasks, responsibilities, and costs.

Rating	***Criteria***
Optimal	Access to high-speed wireless broadband is both robust and broadly available to all residents of Seattle, regardless of their income-level. Carriers make long-term commitments to provide these services to low-income residents at little or no cost. Prioritized areas have both affordable, carrier-grade products available and free products that meet reasonable performance parameters.
Acceptable	Short to medium-term commitments are made by public and private entities to provide free or very-low costs services in certain areas or to individuals that meet certain eligibility criteria.
Least Desirable	The status quo as of this writing prevails. Existing products and services are available to lower-income Seattle residents through federal subsidy programs such as Lifeline and carrier-sponsored low-cost programs. These programs are not long-term commitments by communications carriers and even the federal Lifeline program is considered threatened under new leadership at the FCC. Free wireless service is available to lower-income residents of Seattle only in an ad hoc fashion around public facilities and in certain commercial establishments.

7.3.3 Scalability

In an era of 5G, the Internet of Things, and smart cities, the challenge is to design a network that can scale for exponential growth in traffic. The network must be able to support a large array of connected devices, including those yet to be invented, over a large decentralized environment with a population and an ecosystem of devices that becomes more and more reliant upon it daily. This scalability is as important in low-income areas as in any other part of the City, so as to preserve and protect the ideals inherent in the **ubiquity** goal.

Rating	***Criteria***
Optimal	Deployment of next-generation capabilities in the priority areas that is comparable to other areas of the City. Upgrades to support future 5G capabilities will be soft upgrades, or simple plug-and-play module replacements or add-ons. Wireless infrastructure includes fiber backhaul whenever possible to ensure that capacity is easily scaled and can evolve with new standards and technology. Initial designs should include a high degree of overhead capacity be built into the design from the start. Carrier partner agreements should be positioned in similar fashion to an IRU agreement, with predetermined parameters for equipment upgrades and refreshes as scheduled based upon manufacturer specifications. Sponsorship agreements should be for a minimum of five years, and require renewal commitments 12 months before the expiration of the term.
Acceptable	A network that supports current 4G LTE carrier requirements has been deployed in targeted areas and is integrated with the areas that carriers have identified as densification priorities.
Least Desirable	The network meets today's need to provide Wi-Fi in targeted areas and is acceptable for current traffic requirements and perceived near-term growth. Further investment may be needed for long-term capacity demands and to support future 5G applications.

7.3.4 Financial Sustainability

One of the City's most critical goals is financial sustainability for the efforts that arise from this initiative. The ideal scenario is one in which a ubiquitous, inclusive, and scalable wireless network is feasible not only for a short time-period but into the future.

Past City deployments include a pilot program that was funded through short-term grants and lacked the ability to stand on its own through a reliable funding mechanism. To accomplish the goals of this initiative, provision should be made for long-term support of network services and infrastructure. In addition to making sure that necessary equipment maintenance upgrades and refreshes are included, a City-owned program should include staffing resources.

To secure as much stability as possible, private sector commitments to programs such as "adopt a digital neighborhood" should be in multi-year increments.

Rating	***Criteria***
Optimal	The City's private partner commits to operate and maintain the network, including upgrades and costs, considering needs for capacity growth and migration to fiber backhaul, and includes provisions for wear and tear, vandalism, and weathering. The City can monitor performance and plan upgrades to increase capacity. Equipment upgrades and refreshes are predetermined and executed as scheduled.
Acceptable	Either the City or the private partner operates and owns the technical solution, while the other party makes a long-term commitment to maintenance support to account for necessary replacements and any other issues.
Least Desirable	Whether the commitment is by a private entity or the City, the funding does not extend beyond initial capital expenses and, as a result, operations and maintenance support are spotty and necessary equipment upgrades and refreshes are not undertaken. Over time, the network falls into disrepair.

7.3.5 Performance

To ensure that the low-income beneficiaries of this program are truly helped by this initiative, the City would benefit from quantifiable, measurable data in order to benchmark network performance as a means of ongoing evaluation. Ideally, the City will develop a clear set of analytics, including:

- System performance – Outages, latency, chronic issues
- Utilization trends – Traffic flows and peak threshold performance

These will inform the City's priorities and strategies for changes in capacity, urban development, new smart city implementations, revitalization, event planning, and network hardening. As the network operator implements these strategies, performance is analyzed, and informs new policies and strategies.

In addition to quantifiable analytics, the City should also be able to gauge user feedback for problematic service areas and performance issues. Additionally, developers that are trying to make IoT and smart city devices function on the network may be another source of quantitative feedback regarding performance.

Network functionality depends on a virtuous cycle of performance. With a focus on the user experience, seamless procedures incent both public and private investment. This investment encourages innovation and political support, which encourages communication and high-quality performance. High-quality performance leads to a positive user experience, and the cycle repeats itself. To enable this cycle, facilitation and communication should be prioritized.

Rating	***Criteria***
Optimal	The City actively works with its partner(s) to assess and prioritize the performance of the network. The City can track and analyze performance metrics, and is able to strategize and adapt policies and priorities based on ongoing developments as the network evolves.
Acceptable	Network performance meets industry-standard criteria, the specifics of which may be dictated by partner(s), with City input. Partner(s) share performance metrics with the City. Network performance is dependable and scalable to adapt to increasing capacity, demand, and applications, and continues on a virtuous cycle of sustainability.
Least Desirable	Network performance is dictated by partner(s), the specifics of which are dictated exclusively by partner(s) and are opaque to the City. Utilization of the network is "best effort," and performance data are not made available to the City.

7.3.6 Ownership and Control of Assets

Retaining ownership of networks assets mitigates performance risk by increasing control over the network infrastructure. If the City retains complete control of the assets, it can determine performance metrics and make determinations about which providers, if any, can offer services over the network. It can also determine privacy and security policy. Similarly, it can select price points to support consumer affordability and service speeds to enhance performance.

But all of these come at a cost. Ownership and control increase financial risk by placing much or all of the cost of the effort on the City with little or no role for the private sector in sharing costs.

Rating	***Criteria***
Optimal	Regardless of the ownership structure, the City holds a high degree of control over what equipment is used, and how it is operated and maintained. The City has authority over design, engineering, utilization, and reservation of capacity.
Acceptable	The private partner owns, operates, and maintains network equipment, while City is involved in a mutually beneficial discussion of standards, with agreed-upon capacity made available for the network users.
Least Desirable	Partner owns, operates, and maintains network equipment, and services are based only on "best-efforts." The City does not have any level of control over standards, capacity, or design.

7.3.7 Cost

Cost factors in network deployment include initial construction, ongoing operations, and necessary equipment refreshes, as well as financing costs if any are necessary. While this strategic approach is designed to catalyze public-private partnerships that will enable long-term, sustainable internet access solutions for Seattle's lower-income residents, the City may choose to undertake the cost of the initiative so as to secure some of the other goals, including control and performance.

Rating	***Criteria***
Optimal	Partner funds a large part of network deployment, minimizing the City's costs. Sponsorships generate a large amount of capital for network investment.

	Funding sources and revenues from potential IoT and cloud applications enable the network to grow sustainably.
Acceptable	City and partner negotiate a reasonable sharing of capital and operating costs for the network deployment.
Least Desirable	City required to fund large portions of the network, assuming high amount of risk. Otherwise, City is bound to accept "best effort" network as partner dictates.

7.3.8 Innovation

Technological and social innovation is woven into the fabric of Seattle's identity. Solutions implemented should be both forward-looking and innovative. They should take into account the inevitable evolution of the services that they will provide and account for increased capacity and bandwidth demands.

Rating	***Criteria***
Optimal	Network design, infrastructure, and employed technologies are forward-looking and innovative. The network not only delivers Wi-Fi, but also takes into account that it is the enabling platform upon which all future 5G mobile solutions will be based.
Acceptable	Network design and infrastructure are state of the art, and can evolve in the short term.
Least Desirable	Network design, capacity, and capability are adequate to meet the demands of today's users using today's technology. The network's ability to scale and adapt to growing demands is uncertain.

7.3.9 Privacy

As we grow more connected, we are at greater risk for surrendering our privacy. We are well-aware that information transmitted through websites and mobile apps is vulnerable to access by others. We often trade basic privacy for the convenience of access to public Wi-Fi hotspots in coffee shops, libraries, airports, hotels, hospitals, restaurants, sporting venues, and other public places.

Threats to security and basic privacy are emerging as urban centers expand integration of smart city technologies. These technologies rely on automated sensors and algorithms that improve efficiency, engagement, productivity, and sustainability. Additionally, many of these technologies rely on applications that also generate enormous amount of data.

Reliance on sponsors to have an affordable network will often come with a certain expectation of branding and product placement. These strategies frequently contradict the City's goals with regard to collection and use of personal data, and should be fully analyzed before sponsorship opportunities are implemented.

The projects that arise from this initiative will, pursuant to existing City policy, consider each opportunity with regard to the privacy principles set forth in the City's Privacy Statement.

Rating	***Criteria***
Optimal	Access to the network requires either no login, or requires multi-factor authentication and encryption. User data, activity and behavior is not captured, shared, or collected.
Acceptable	Access to the network includes some level of encryption. Users must acknowledge their privacy exposure at sign-in or enrollment, and be given a means to see what data has been collected. Each login to the network is a standalone "transaction" that must be purged so that user profile data cannot be compiled.
Least Desirable	Users of the network are subject to data collection per the partner's privacy standards. Users must acknowledge at sign-in or enrollment what their privacy exposure is. User data, activity, and behavior may be captured, shared, or collected.

7.3.10 Security

Ideally, any network infrastructure built under this initiative will take advantage of the most current security practices and technologies. A robust security policy and practice will enable the network operator to protect the usability and sustainability of the network while reducing risk to the City and its residents. It is important to note that security is largely a process, not a product or feature that can be purchased and that the practice of security is constantly evolving.

We note that security, like many of the other goals, is to some degree not aligned with a City goal to reduce costs. In the event of private funding or deployment, this is an area over which the City may not have as much control as it would ideally like.

Though individual vendors and security professionals take different approaches to security, we have outlined some common issues facing large public Wi-Fi networks that should be addressed in the event that Wi-Fi is among the technologies used in furtherance of the goals of this initiative. This is based on our experience with large, enterprise-grade Wi-Fi networks and the features available in products currently offered by industry-leading vendors.

Authentication and Policy Enforcement – Authentication is how users log in to the network and policy enforcement determines what that user is permitted to do on the network. For example, a policy may restrict guests to accessing only City websites; another policy could prevent users from accessing the management network.

Traffic Policing – Traffic policing allows the network operator to restrict certain types of traffic or certain applications that may be deemed inappropriate or harmful. For example, it may block outgoing email traffic in order prevent the network from being used to send email spam.

Broadcast Traffic Suppression – Network protocols that are designed to make it easy for devices to discover one another on the same network are not desirable on a large, public network. By restricting this traffic, the network operator can cut down on "noisy" protocols that may overwhelm the network and make it harder for users to intentionally or unintendedly interfere with one another.

Radio Frequency Analysis – Radio Frequency Analysis allows the network operator to monitor the radio space around their wireless access points. This can be used to optimize radio signal strength, spot interference, and to mitigate various attacks that can be performed with wireless devices.

Usage Control – Usage control prevents individual users from monopolizing network resources and making the network feel slow or unusable for others. As an example, "airtime fairness" prevents a wireless radio from being slowed down by a legacy or deliberately malicious wireless connection.

Hotspot 2.0 and 802.11u – These emerging technologies greatly improve wireless roaming (devices switching between different access points) and the ability to seamlessly create a secure connection between the wireless access point and the user's device.

Rating	***Criteria***

Optimal	New connection points are methodically evaluated for security risks and appropriate mitigations for each connected system have been developed. Network operator, City, connected devices, and users are protected from internal and external threats. Reporting and security audit capabilities are automated and readily available and accessible.
Acceptable	Industry standard authentication, user management, traffic policing, and broadcast suppression are implemented along with basic bandwidth and access point monitoring.
Least Desirable	No security measures are implemented, and network users are subject to the same security available on public networks today.

8 Strategies and Recommendations

This section of the report recommends a range of short-term, mid-term, and long-term strategies for the City to consider to address the internet-access needs of its low-income individuals and families.[103] These recommendations are based on CTC's experiences, observations of innovative efforts in other cities, and collaborative efforts with City staff to develop creative new approaches to reducing digital inequities. We are hopeful that the City's request for information (RFI) to the private sector (which was prepared as part of this effort and that was released publicly in early 2017) will enable addition, revision, and refinement of this set of strategies.

8.1 Short-term Strategies

The recommended short-term strategies are those that the City could implement relatively quickly and effectively to realize immediate or near-immediate results. These strategies capitalize on efforts at the community and governmental levels to effect more immediate advancement of the City's objectives. While the City begins to adopt projects of a larger scale, these strategies will encourage focused progress, alleviate some of the immediate challenges to growth, and demonstrate the City's commitment to its goals.

8.1.1 Develop Partnerships with Wireless Carriers Seeking Access to Public Property

We recommend that the City consider a competitive process in which the City exchanges with private wireless companies use of public assets for wireless deployment in return for free services to low income Seattle residents.

The City of Seattle owns and maintains assets that are suitable for mounting of small cell, DAS, or 5G attachment. These assets could be a means by which the City exchanges value and opportunity with the private sector—enabling wireless companies to access public assets for deployment of wireless services in return for provision of services to lower income residents of Seattle in partial payment for use of the public assets.

In the current environment, commercial carriers are actively engaged in efforts to obtain access to assets such as City-owned utility poles, light poles, and traffic signal poles as part of their densification efforts for deployment of cellular networks. By identifying these assets ahead of time and taking a strategic approach to providing access, the City may be able to negotiate

[103] CTC notes that these recommendations are based on knowledge of communications technology, industry trends and patterns, and the economics of communications network deployment and operations. We are not a law-firm and are not qualified to assess whether there exist legal impediments to the recommendations made here. As with any such project, and particularly in light of the changing regulatory environment for local authority in the wireless area, we write these recommendations with the expectation that the City's legal counsel will provide the relevant legal analysis.

agreements that would support its goal to provide services to lower income residents and in targeted areas.

Unlike local governments, communications carriers do not prioritize ubiquity or equitable access, neither of which necessarily aligns with shareholder value. As a result, absent City involvement, carriers will deploy next generation wireless services only in places where return on investment and monetization are certain. The City can strategically enable access to its infrastructure as a catalyst to ensure digital inclusion is prioritized and ubiquitous access is achieved. Without this encouragement, wireless carriers may never build advanced networks in certain neighborhoods. In the long term, such uneven deployment patterns could exacerbate digital gaps in neighborhoods that are already underserved.

The process contemplated here would involve a series of steps. First, the City's pending RFI will hopefully elicit concrete and innovative suggestions from companies that seek access to City assets regarding their ideas for partnering with the City to effectuate the goals of this initiative; these ideas can partially inform later steps in this process.

Second, the City of Seattle can work to identify, inventory, and map the relevant assets and to determine their value to the private sector.

Third, based on the data developed in the first two stages, the City could consider issuing a request for proposals (RFP) to the private sector for access to certain public assets in partial exchange for services to lower income residents. Hopefully, the opportunity presented and the competitive dynamic would result in creative proposals for partnerships between public and private sectors. For example, a private entity might propose any of the following:

- A managed Wi-Fi solution provided by the carrier, in which some or all of the prioritized areas get open, free wireless access over some guaranteed period of time
- Equipment or funds provided by the carrier to the City, that are then used by the City to build and operate a City-provided Wi-Fi solution in some or all of the prioritized areas
- Free cellular data plans for eligible individuals to be issued in similar fashion as digital inclusion plans offered by internet service providers

While there is no guarantee that this type of RFP effort would necessarily result in the types of collaborations we envision here, we note that (as is discussed extensively above) the wireless industry is heavily invested in gaining access to public assets as it densifies its mobile infrastructure. Creative companies that are willing to work with public entities might find that this strategy is preferable to the current efforts to gain access to public assets in less collaborative ways. In an optimal situation, the interests of public and private entities can align through efforts

such as that recommended here, and even if the private sector chooses not to respond to the City's efforts, the City likely has little to lose in testing this opportunity through a competitive process.

8.1.2 Create an "Adopt-a-Digital-Highway" Program

The City could consider the innovative approach of creating a digital version of the long-standing, widely-supported Adopt-A-Highway program to fund publicly available Wi-Fi. Adopt-A-Highway is a civic program through which companies are able to contribute to their communities and receive public recognition for doing so. In a similar fashion, the City could create an "Adopt-A-Digital-Highway" program as a source of sustainable funding for free public Wi-Fi.

Since its inception in the 1980s, the Adopt-a-Highway program has allowed organizations to keep a section of highway litter-free by providing volunteers or funding for paid workers who keep the area clean—an expensive task for a transportation department do on its own. In return for their support, these organizations have their names posted on signs along that section of highway. More than 48 states have Adopt-A-Highway-type programs in place.

A digital version of the Adopt-A-Highway program could offer organizations an opportunity to sponsor free public Wi-Fi in exchange for recognition and credit for civic engagement. The recognition could take the form of a logo on a landing or login page, a website that Wi-Fi users will be redirected to immediately after connecting, and/or physical signage marking the areas where free Wi-Fi is available.

In addition to providing sustainable funding for the Wi-Fi service, this model would have the added benefit of promoting a sense of community ownership, as this will be a service supported by civic-minded members of the local community.

In traditional Adopt-A-Highway program, the Department of Transportation owns and maintains the highway itself, and sets standards and protocols for cleaning that are adopted by companies and non-profits that choose to participate. With Adopt-A-Digital-Highway, the City could similarly own the "highway" itself, potentially utilizing its backbone fiber network for aggregation and backhaul. It would also design and set the standards for deployment of the wireless network and establish key hubs and aggregation nodes. In the last mile, it would rely on third parties (the adoptive companies) to either provide and maintain the Wi-Fi services or simply provide sustaining funding for the City to do the same.

8.1.2.1 Funding Models

A key distinction in this type of sponsorship program is whether the Adopt-A-Highway Program (AHP) model or a Sponsor-A-Highway (SHP) model is used. In an Adopt-A-Highway model, participants are directly responsible for the labor of keeping their sections of highway clean. The

Department of Transportation may provide training and equipment, but the participant supplies the labor. In a Sponsor-A-Highway program, the participant provides funds needed to pay a contractor to keep the highways clean.

For a free Wi-Fi service, there would be trade-offs between the adoption and sponsorship models. An adoption model may require less effort on the City's part because the adopting company or non-profit would have direct responsibility for running the wireless network according to the City's standards. This may also allow opportunities for potential sponsors, such as a community college, that might more easily provide the skilled labor necessary to run a large Wi-Fi network than the funds to do so. On the other hand, the City might have less control and visibility over how the network is run. The City would also need a contingency plan to cover any potential gaps between adopting entities. Much as an un-adopted highway might accumulate litter, an unmanaged Wi-Fi network would mean degradation or loss of service—which might discourage public use. Because of these factors, this option may be more suitable for larger partners that are interested in sponsoring the entire network for several years.

A sponsorship model would allow the City to select a contractor or existing ISP to run the Wi-Fi network and rely on "adoptive" sponsorship funds to cover the cost in return for public recognition. This model is similar to programs that have sponsored free Wi-Fi at airports and other large public venues. For many years, companies such as Google, Microsoft, Yahoo!, and eBay have offered free Wi-Fi in airports, on flights, in hotels, and in well-trafficked public places.[104]

This sponsorship approach allows for more consistency in how the network is run, regardless of how often sponsors change or whether there is a gap in sponsorship. This would also make it easier to split up sponsorships, allowing outside organizations to sponsor specific areas of the City or to choose specific types of advertising, such as physical signage or a branded landing page. The City could also "bundle" Wi-Fi service areas together, pairing priority areas with high-traffic areas that might be more desirable to private adopters from a recognition perspective. By centralizing management and expansion of the network, the City may also be able to take advantage of the scale of the project with higher-volume purchases, standardized parts, and a single point of contact with the chosen vendors for purchasing and technical support.

8.1.2.2 Controls and Standards

Regardless of the funding strategy used, the City could establish design and engineering standards to ensure compatibility and manageability. There are also centralized parts of the

[104] "Google, Yahoo, eBay, Microsoft's Bing offering free WiFi to travelers," *International Business Times*, November 10, 2009, http://www.ibtimes.com/google-yahoo-ebay-microsofts-bing-offering-free-wifi-travelers-343759 (accessed Jan 2017)

network, such as a controller and management platform, that each Wi-Fi-enabled area could have in common (because running each area separately would incur unnecessary cost and complexity).

If the City pursues a sponsorship model in which the City itself or a contractor installs and maintains the network, it should still develop these standards to ensure consistent service across areas. The City may wish to develop standards in the following areas:

- Power and network backhaul delivery
- Eligible devices, especially in terms of compatibility with central controllers
- Installation aesthetics
- Uninterruptable power supplies
- Routers and switches used for service delivery
- An equipment refresh cycle to ensure the system is kept in good working order

8.1.2.3 Recent Wi-Fi Deployments as a Model

We recommend the City use Google's recent contribution of Wi-Fi access points as a model for the Adopt-A-Digital-Highway program. In April 2016, as part of the Mayor's Digital Equity Initiative, Google pledged $344,000 to provide Wi-Fi access at all 26 community recreation centers run by Seattle's Parks and Recreation department.[105] In December 2016, Google completed installation of the wireless access points. These sites have internet access provided to them as part of the 2015 franchise renewal agreement with Comcast. Though this deployment is primarily focused on indoor spaces, the model could inform the Adopt-A-Digital-Highway program.

8.2 Medium-term Strategies

After implementation of programs intended for more immediate results, we suggest the City shift its focus to medium-term goals. The strategies contained in this section focus on collaboration between the City and other parties to provide solutions for Wi-Fi access in both low-income communities and the greater Seattle area.

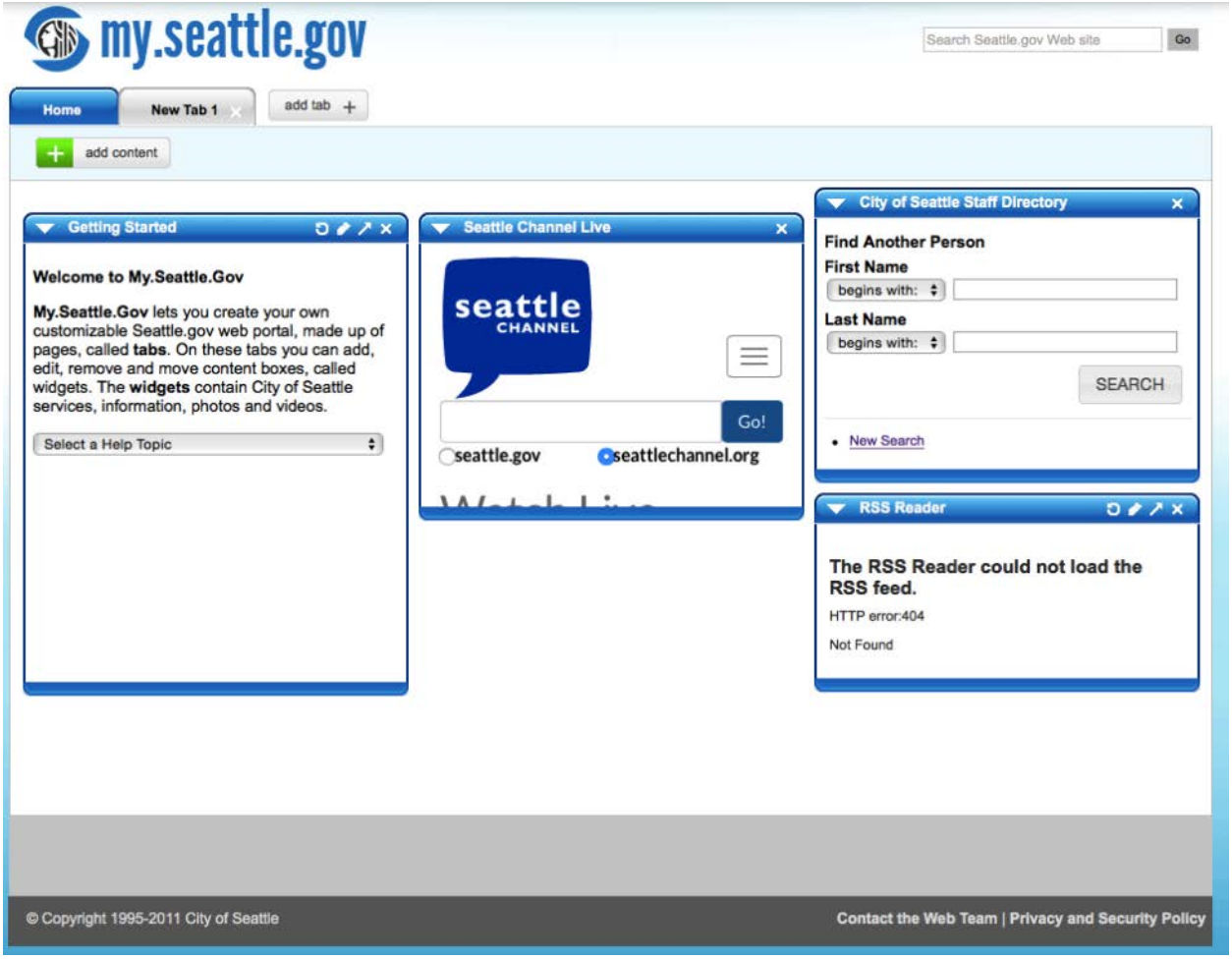
8.2.1 Develop Citywide Authentication/Federated Identity Program

CTC suggests that the City's efforts include the exploration of ideas and technologies related to a citywide platform for federated identity management (potentially including single sign-on). A federated identity system allows users to log in to separate systems and organizations with a single set of credentials. For example, the City has already created a framework for access to services with the MySeattle.gov platform (Figure 27). This platform, or one like it, could be used

[105] http://crosscut.com/2016/03/mayor-murray-and-google-announce-partnership-for-digital-equity/

to provide a federated identity that would allow users to log in to Wi-Fi as well as other services (such as public library access) using a Seattle City account.

Figure 28: My.Seattle.Gov Sign-in Page



A federated Seattle City user account could also provide an easy way for new and existing Wi-Fi providers to participate in the City's free Wi-Fi offering. Using this same technology, Seattle residents could be allowed to log in to Wi-Fi hot spots provided by the City or by other participating organizations.

To offer a federated identity, the City would run a user database where individuals could sign up for an account. The City would then allow a non-City entity that is providing Wi-Fi service to check Seattle City account credentials as a way to authenticate users anonymously. This system would be similar to the methods used by several popular online services like Facebook, Google, and Twitter but would emphasize protection of privacy and minimize information sharing with third-parties.

For example, a user can create an account on the music streaming service Spotify by logging in with an existing Facebook account. In this case, the Spotify account will be separate from, and not managed by Facebook (though Facebook may automatically provide some user information to Spotify and vice versa). The Spotify service simply checks the person's Facebook account credentials for authentication. Cable TV providers also offer similar federated ID services that allow cable subscribers to access streaming content directly from content providers like HBO or Comedy Central.

Figure 29: Spotify Login Page

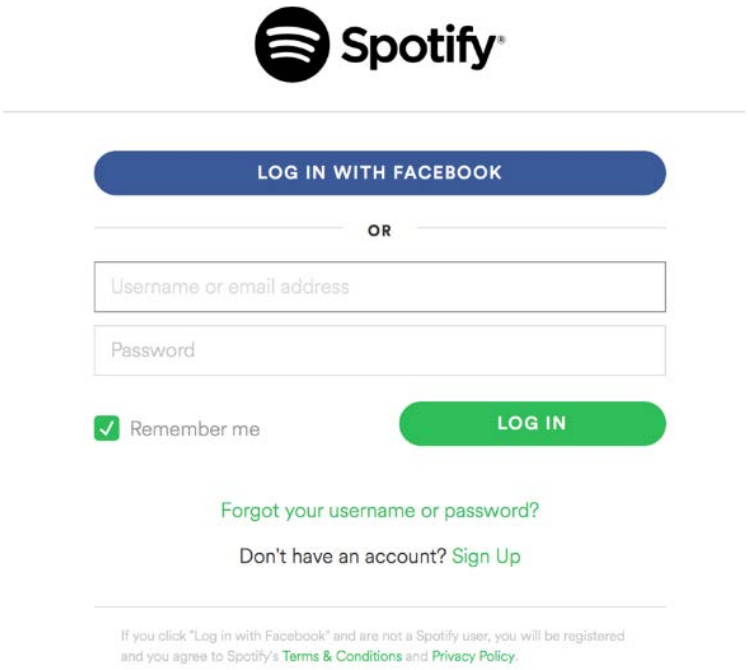
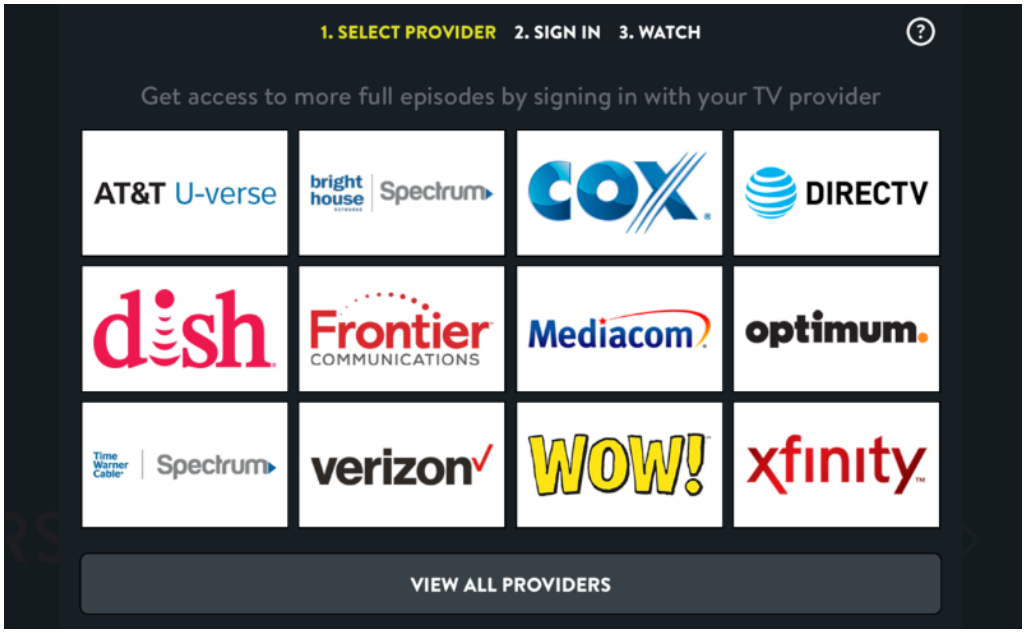


Figure 30: Comedy Central iOS App Login Page



Another example of this type of federated identity is the Eduroam[106] Wi-Fi service. Eduroam is a service that allows students and employees at higher-education institutions worldwide to log in to wireless networks at other participating institutions using the login information from their home institutions. For example, a professor from the University of Washington can log in to the Eduroam Wi-Fi network at The George Washington University in Washington, D.C., without setting up a guest account or ever talking to the IT department at the new location. Eduroam is available at institutions across the United States and in more than 70 countries worldwide.

8.2.1.1 Separation of Service and Identification

A key feature of these federated identity systems is that the account used for authentication and the service being accessed are kept totally separate unless the two services elect to share information. For example, Spotify never sees a user's Facebook password and Facebook cannot see what that user does on Spotify.

That said, while the accounts making use of the federated ID are separate, the centralized account can be set up to provide certain information about a user to the service provider. For example, Seattle City accounts may indicate whether the users are Seattle residents, whether they are City employees, or whether they are under 13 years old. This information could be used by the Wi-Fi network operator to determine which security policies should be applied to the user.

[106] www.eduroam.org/what-is-eduroam/

In the Eduroam example, the professor would use her University of Washington credentials, but the IT department at George Washington University would control how the professor connects to the network. The IT department might allow Eduroam users to access the internet through its wireless network, but prevent them from accessing internal services that are restricted to local students and staff.

Similarly, a business could provide Wi-Fi to users with a Seattle ID without allowing those users access to the business' internal network, by automatically placing Seattle City users on a separate guest network. The business could also prioritize traffic from its own users to avoid service degradation due to heavy use by free Wi-Fi users. Businesses that provide paid Wi-Fi access, such as hotels or airports, could allow users with a Seattle City account to connect to their networks for free while still requiring others to pay for access.

8.2.1.2 Recent Developments in this Area

The National Institute of Standards and Technology is currently overseeing a pilot program aimed at researching new forms of identity management. The goal of the program is to foster innovation to make critical services more accessible and convenient while streamlining security.

The program sponsor operating under NIST is the National Strategy for Trusted Identities in Cyberspace (NSTIC).[107] The initial pilot program awarded grants in August 2016 totaling $15 million to six recipients focused on securing services run by state governments and health care providers.

Additionally, the University of Washington has been heavily involved in the Trust and Federated Identity working group that is part of the higher education community for several years and is a program sponsor of Eduroam. As a growing number of higher-education resources and services are offered online, the users of these services increasingly expect to have access at various locations, from multiple devices. Advanced identity management allows institutions to provide reliable, secure access without a proliferation of credentials.

The parallel to basic services offered to residents is very similar. Examples of this include social services, e-government, education, career and housing assistance, and technical assistance.

8.2.1.3 Privacy Concerns

Wi-Fi service is often offered as a convenience to guests and to attract customers, but as big data analytics have advanced, Wi-Fi services are now also used to gather data about users. These data can be used by the Wi-Fi provider or sold to another company to track, analyze, and capitalize on user habits and trends. This may be done to maximize customer experience, provide additional

[107] NIST Trusted Identities Group, https://www.nist.gov/itl/tig

services, or to sell targeted advertisements.[108] Given the City's concerns about privacy, these factors should be considered as a potential risk of this approach.

While the FCC addressed many of these concerns through its adoption of Broadband Consumer Privacy Rules in October 2016,[109] the future of the implementation of those rules is not certain given likely changes in leadership at the FCC in the Trump Administration.

8.2.2 Negotiate Wireless Digital Inclusion Products That Utilize Other Entities' Mobile Infrastructure

We recommend that the City approach providers that are already in the business of providing W-Fi to use their existing (and emerging) systems to provide Wi-Fi to qualifying Seattle residents who do not already have home Internet service. In particular, we recommend that the City approach service providers to encourage them to develop a wireless digital inclusion product that is analogous to existing wireline discount service program.

Though this strategy has not been pursued elsewhere, we envision a scenario in which a service provider might use its existing Wi-Fi deployment to offer Wi-Fi access to qualifying individuals for free or at a low cost. CTC has had preliminary conversations with a service provider about the viability of this strategy and are hopeful that the company will respond to the City's RFI.

Given that some service providers already offer discount wireline digital inclusion programs, this strategy may only require extending wireless access to users who do not purchase home service in areas that the City has prioritized.

Such a strategy may also be of interest to companies that sell access to Wi-Fi hotspots in public areas. In partnership with the City, they may be willing to offer free or reduced-cost services to lower income members of the community.

8.2.2.1 Background Regarding Discount Internet Programs

A program such as this would not require the City to maintain user accounts as in the above federated identity scenario. Rather, the service provider would manage access, though criteria for program eligibility would ideally be determined between the City and the company. In one scenario, the City would maintain a user database of customers eligible for the service; in

[108] Mobile Internet 2.0: Monetizing Public Wi-Fi via Business-to-Consumer Relationships, http://www.cisco.com/c/dam/en/us/products/collateral/wireless/mobility-services-engine/lippis_report_bn.pdf (accessed Jan 2017)
[109] https://www.fcc.gov/document/fcc-adopts-broadband-consumer-privacy-rules

another, it would negotiate eligibility with the company and then serve as a representative of consumers who seek access in their interactions with the company.

In 2011, Comcast launched the Internet Essentials program to provide internet service to qualifying families for $9.95 per month based on their children's participation in the National School Lunch Program.[110] Since then, the program has expanded to include certain qualifying individuals who receive assistance from the U.S. Department of Housing and Urban Development (HUD), seniors who receive public assistance, and students who have received Pell Grants and who are enrolled at a community college.

Similarly, CenturyLink offers Internet Basics, which also provides internet access to qualifying customers for $9.95 per month for 12 months and $14.95 per month after 12 months.[111]

In 2016, AT&T launched a similar program, called Access From AT&T, that provides internet service to qualifying individuals for $10 or less per month. More service providers are offering similar programs, and organizations like EveryoneOn[112] and CheapInternet.com have sprung up to help people locate programs in their area that offer internet service at a reduced cost.

8.2.2.2 Background Regarding Comcast's Emerging Mobile Wireless Network

In recent years, Comcast has begun installing modems in customers' homes that act both as a wireless router for the customer and as a hotspot for Comcast's emerging mobile product that is available to any Comcast customer. The Comcast Wi-Fi network is separate from the customer's own home wireless network and does not count against the home customer's data usage. Comcast has also begun installing outdoor hotspots in some cities to expand Wi-Fi coverage. To non- customers, Comcast offers two free 60-minute sessions per month and sells additional time as "access passes" in increments ranging from $2.95 for two hours to $54.95 per month.

8.3 Long-term Strategies

This section outlines longer-term strategies to improve Wi-Fi coverage in the prioritized areas of Seattle and for lower-income residents of Seattle. These strategies maximize benefits from construction and improvement projects, and encourage strategic, active adaptation to future technologies. While these suggestions involve significant planning and effort by the City, they present potential longer-term, ideally long-lasting solutions to further the City's broadband communications and digital equity goals.

[110] Comcast Internet Essentials https://internetessentials.com/about
[111] CenturyLink Internet Basics http://www.centurylink.com/home/internetbasics/
[112] everyoneon.org

8.3.1 Develop and Expand the City's Fiber as a Platform for Low-Cost Wireless

We recommend that the City utilize its fiber optic plant wherever possible and expand it where possible, so as to develop and grow this critical asset over time. The City's existing and future fiber can be used to enable the City itself or third parties to provide free or low-cost wireless services, particularly over low cost technologies such as Wi-Fi, to the prioritized areas and to such locations as low-income, multi-dwelling public housing facilities.

Expansion of the City's fiber assets opens up a range of options to support the digital equity goals the City has identified. The fiber—and the low-cost internet bandwidth that the City can provide with it—makes up the critical "backhaul" component of a network designed to offer services to low-income residents. With fiber in place to a facility or neighborhood—and internet bandwidth available over that fiber—the City can work with the private sector to deploy the wireless equipment locally, or can do so itself.

8.3.1.1 Background Regarding Seattle's Existing Fiber Assets

Over the past 20 years, Seattle worked collaboratively with King County, the University of Washington, and neighboring cities to construct extensive publicly-owned fiber optics to connect public facilities in the City and county. The key stakeholders came together in a consortium of 20 public entities that share ownership, responsibility, and use of this fiber. At the advent of this process, members of the consortium enacted several mechanisms to enable collaboration and efficiency in construction. Designed in part to allow for shared cost construction, the consortium affords each public agency control over its assets and the confidence that unknown entities would not start using its assets or assets it relies on. This approach is a best practice for collaboration and made it possible for multiple public entities to realize the efficiencies of working together rather than building many standalone networks at a much greater cost.

This approach was innovative and revolutionary both then and now, enabling very efficient deployment of public fiber resources—and the City and its partners in the collaboration have realized not only savings over time (relative to leased circuits) but also much higher bandwidth than was available to other cities and significant operational benefits and efficiencies.

The approach, however, while efficient from a public sector-use perspective, was not conducive to private sector use of the assets, which was not contemplated at the time the collaboration began (and is still not an option for some of the public entities in the partnership).

Other challenges with respect to private use of the fiber arise from the design of the assets and the arrangements between the members of the consortium about which assets can be used for non-public purposes such as leasing to the private sector. Only certain fibers in certain routes are available to Seattle to lease to private entities, and those routes are frequently segmented and not continuous or otherwise optimized for private use. Further, though the City owns substantial

fiber, multiple City agencies control various parts of it. With appropriate attention to management, control, and security, we believe the ongoing consolidation under Seattle IT may resolve this. If fiber is not part of that consolidation, we recommend that it be considered in the interests of efficiency and optimization.

8.3.1.2 Potential for Expanding the Flexibility of the Fiber to Increase Private Use

Changing the restrictions on the fiber would entail significant coordination and agreement among 20 entities. If this is a priority, we recommend a joint strategic effort to see if there is a less restrictive approach that is acceptable to all parties. However, it is important to note that there may not be sufficient fiber count in some routes to accommodate private leasing, so reconsideration might prove a challenge as a technical matter as well as from an organizational standpoint.

One alternative could be for Seattle to "overlash" fiber (i.e., to place a new cable of fibers on the existing aerial attachments by "lashing," or winding, the new cable around the existing fiber cables that are shared with the other public entities in the consortium). Overlash, which is lower in cost than building new fiber with its own attachments, could take place in certain key routes that would facilitate private wireless services on a long-term basis under this initiative. If the RFI responses suggest value to the City in doing so, a cost/benefit analysis would be warranted. It may also demonstrate that some of the routes, even though segmented, are still useful to the private sector. If extension of those routes is of interest to private entities, we also recommend a construction cost estimation effort and a cost/benefit analysis.

8.3.1.3 Potential for City Use of the Fiber to Provide Backhaul for Free Private Wireless

We anticipate particular value of extending the City's fiber to public housing buildings, and then partnering with the private sector for free wireless in the buildings. Using this strategy, the City and Seattle Housing Authority could collaborate to extend fiber to the premises at sites to which the Housing Authority has already committed to provide technology infrastructure (such as Yesler Terrace, High Point, Rainier Vista and New Holly,)[113] and provide wireless connectivity through partnership with a private entity.

Because the City owns considerable fiber infrastructure, it is well-positioned to provide fiber connections to some qualifying locations in a cost-effective manner. By extending the City's existing fiber network to select existing locations and providing upstream bandwidth, the City could create a platform on which private entities could build cost-effective Wi-Fi solutions to serve low-income residents.

[113] Available: http://seattlehousing.org/news/releases/2015/ConnectHome/ Accessed January, 2017

Based on our knowledge of Wi-Fi deployment in subsidized housing, providing the bandwidth and required fiber backhaul is, in many ways, the most costly and challenging part of such a project. By providing last-mile fiber and bandwidth, the City would significantly reduce the cost of offering Wi-Fi in housing, community centers, and other locations that serve low-income residents. This may enable the building owner to provide free Wi-Fi service by simply installing wireless routers or may enable a third-party to provide Wi-Fi service at a reduced price or in exchange for advertising opportunities.

We note also that public housing facilities are eligible locations for Community Reinvestment Act (CRA) funding, which is discussed below.

8.3.1.4 Case Studies of Programs that Utilize Fiber to Support Wireless Services in Low Income Housing

This recommendation builds on a number of successful efforts to date, as well as on efforts the City of Seattle has taken to support broadband deployment in public housing facilities. During the Obama administration years, the U.S. Department of Housing and Urban Development (HUD) launched the ConnectHome program. Through the initiative, HUD has worked with ISPs, nonprofits, and private organizations to provide families living in public housing facilities with broadband access, digital literacy training, and electronic devices.[114] As a member of ConnectHome's pilot project, Seattle now encourages "all new projects funded by HUD to be equipped with the appropriate technology to support broadband."[115]

Other localities have employed this strategy with impressive results. A decade ago, the city of San Francisco leveraged its 170 miles of existing fiber to create the Community Broadband Network (CBN). By using its own fiber, and partnering with local non-profits to procure network equipment, the city now provides Wi-Fi at 38 San Francisco Housing Authority sites, 24 Senior Technology Centers, and a variety of city buildings (including City Hall), as well as a handful of other non-profit-run sites that serve low-income populations.

For a more detailed discussion of the ConnectHome program and the city of San Francisco's CBN, please see Appendix C.

8.3.2 Evaluate All Projects for Inclusion of Communications-Enabling Infrastructure

We recommend that the City evaluate all relevant projects, both public and private, with regard to each project's potential to enable development of broadband services or broadband-enabling infrastructure. Localities undertake a wide range of efforts—capital improvement projects, public-private partnerships, and facilitation of private efforts—that hold potential to increase the

[114] http://connecthome.hud.gov/ Accessed January, 2017
[115] http://www.geekwire.com/2015/city-of-seattle-plans-broadband-options-for-low-income-residents-as-part-of-obamas-connecthome-initiative/ Accessed January, 2017

volume of publicly and privately-owned assets in the community that can provide services or enable provision of services over time.

In coordinating with these other initiatives, the City can expand its own broadband-enabling infrastructure in a cost-effective way by engaging in joint construction efforts, by installing wireless access points along with street-side fixtures, by choosing fixtures and street furniture designed to facilitate access point installations, or by installing necessary infrastructure such as fiber backhaul where the opportunity presents itself.

Installation of fiber offers the most obvious, and tested, means of expanding infrastructure on this opportunistic (but strategic) basis. The City has already successfully deployed fiber in cost-effective, efficient ways through the regional public sector collaboration described above. Similar principles and efforts can be applied to other kinds of collaborative opportunities to benefit from projects underway in the public rights of way.

For example, the City could leverage the ongoing development by the communications industry of unique structures and antenna housing concepts that are designed to facilitate 5G wireless deployment and simultaneously address community concerns about aesthetics. (The transition to 5G may mean that on virtually every block there will be some type of antenna, mounted potentially on buildings, utility poles, light poles, or standalone structures. These new antennas are expected to be smaller than traditional antennas and mounted at lower heights, closer to the end user devices. This will mean that aesthetics and concealment are more important than ever).

We therefore recommend that the City consider working with companies that are deploying this kind of new infrastructure as a means of deploying infrastructure of its own that can, over time, serve the digital equity goals of this initiative.

By way of illustration, we offer the following examples of the kinds of new infrastructure the City can leverage for these purposes:

8.3.2.1 Street Furniture Replacement

The City can reduce the cost and improve the aesthetics of future wireless deployments by coordinating Wi-Fi hotspot installation with the deployment of street furniture and smart city devices.

As the City adds or upgrades street furniture such as bus shelters, park benches, and other amenities for public use, the City can both reduce the cost and improve the aesthetics of future wireless deployments by seeking street furniture solutions that will accommodate wireless equipment, including City or privately-owned Wi-Fi hotspots.

Manufacturers are beginning to develop smart furniture solutions that can offer capacity for carrier antennas, Wi-Fi service, and mobile charging. These features can be critical to advancing the digital equity goals of this initiative.

Smart street furniture also offers other technical benefits that align with other City goals. For example, new models of bus shelters can serve as digital information kiosks, displaying city maps and information and providing real-time information regarding traffic, transit, and events. A number of cities have tested these types of innovations, including Paris, France[116] and Sydney, Australia.[117] Other models of smart street furniture enable air quality monitoring and pollution reduction.[118]

8.3.2.2 LED Light Posts

While there is great concern about how additional towers may change the aesthetics of a neighborhood, modernized lighting is often a welcome upgrade, as long as the size of the structure is proportional to its place and position in the City. As Seattle converts its outdoor lighting to LED, it might consider integrating small cell and Wi-Fi antennas into the new lighting infrastructure. The City of Los Angeles has deployed 100 Philips SmartPoles, LED street lights fitted with 4G LTE radios, that will not only provide improved connectivity, but will align with the mayor's key priorities of creating services hubs that can adapt to the changing needs of neighborhoods over time.[119] On the carrier side, Verizon recently announced the acquisition of Sensity, a company focused on advanced LED lighting control and smart city applications,[120] an acquisition that is likely to help it extend its small cell infrastructure while deploying LED hardware in cities.

8.3.2.3 Façade-Mounted Antenna Systems

The communications industry is also developing mechanisms for concealing antennas that are mounted on roof edges or building facades, where they are noticeable and have impact on aesthetics. Companies camouflage or conceal their antennas to address community and property owner concerns to preserve the look of the building or protect the historical characteristics of a

[116] Available: http://www.jcdecaux.com/en/Innovation-Design/JCDecaux-s-Intelligent-Street-Furniture Accessed: January, 2017
[117] Available: http://www.smh.com.au/business/property/intelligent-street-furniture-to-boost-smart-city-concept-20161102-gsggrc.html Accessed: January, 2017
[118] Available: https://nextcity.org/daily/entry/nyc-smart-pedastals-fight-pollution-power-fire-trucks Accessed January, 2017
[119] http://www.philips.com/a-w/about/news/archive/standard/news/press/2015/20151106-Los-Angeles-is-the-worlds-first-city-to-deploy-Philips-SmartPole-Street-Lighting.html
[120] Source: Sensity/Verizon news release, http://www.sensity.com/pressrelease/verizon-acquisition-sensity

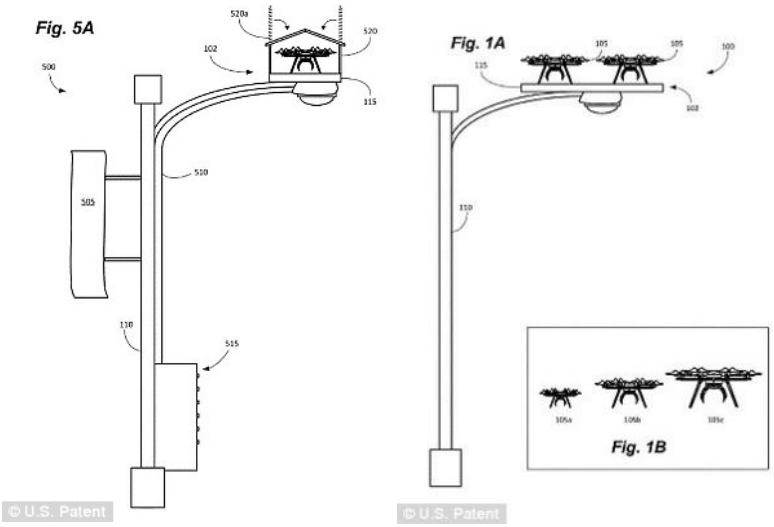
neighborhood. This requires use of materials that will not interfere with the antennas functionality, which may vary based upon the frequency band in use.[121]

As companies approach the City with permit applications and designs for these concealed antennas, there may be opportunity for the City to negotiate partnerships with the company so as to place its own infrastructure at the same time, particularly if the concealing mechanisms on roof edges and facades hold sufficient space.

8.3.2.4 Street Light Drone Docking (Amazon)

In July 2016, Amazon was awarded a patent that envisions utilizing vertical structures such as lamp posts, cell towers, and utility poles as docking stations for drones (Figure 30).[122]

Figure 31: Amazon Patent Drawing – Street Light Drone Docking Station



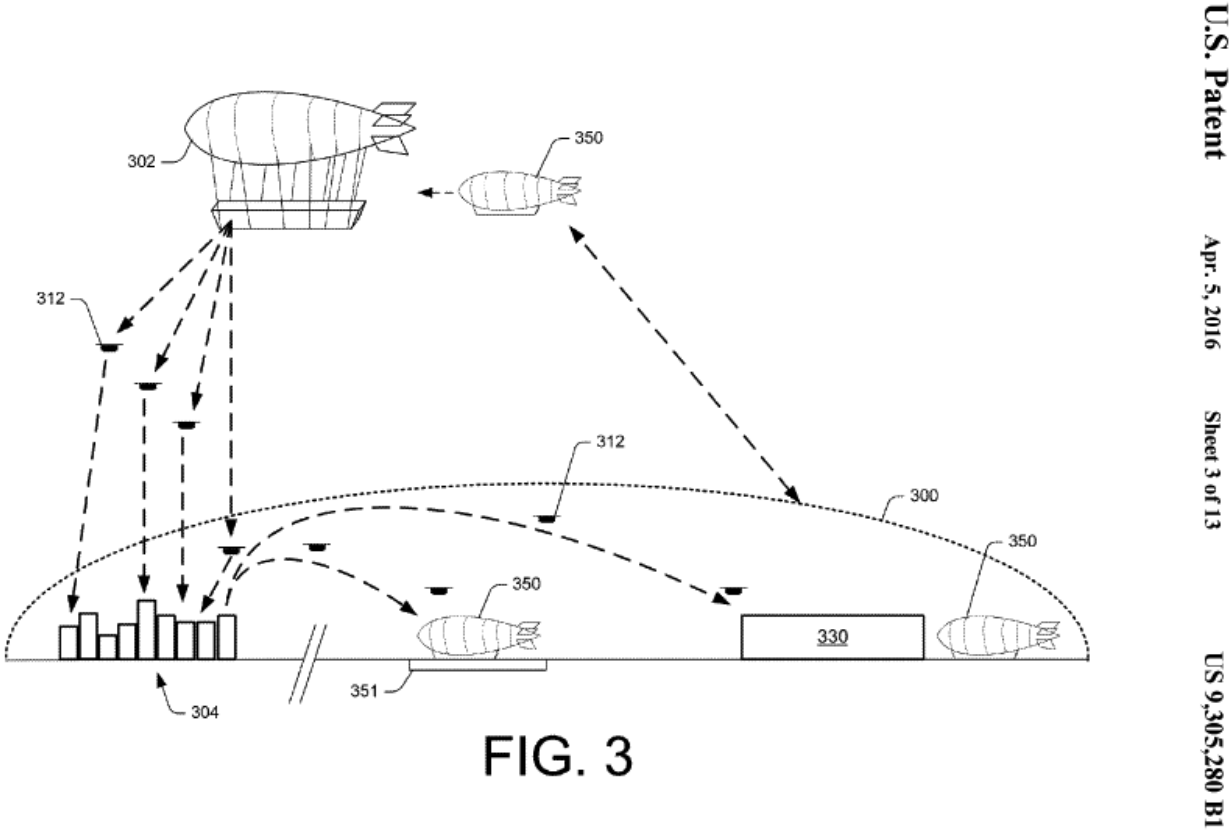
This docking plan is part of Amazon Prime Air's broader strategy for delivery of goods by unmanned aerial vehicles and potentially, airborne fulfillment centers (Figure).[123]

The docks will allow the drones to recharge and communicate with control systems; for this system to work, some form of communications service will be required between the docking station and drone, as well as to central control systems. Amazon's patent application notes that it is developing radio communications systems for communication and control of the drones.[124]

---

[121] Source: https://www.ijedr.org/papers/IJEDRCP1401017.pdf Accessed January, 2017
[122] Source: U.S. Patent Office, http://patentyogi.com/wp-content/uploads/2016/07/US9387928.pdf
[123] Source: U.S. Patent Office, http://patft1.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=9305280.PN.&OS=PN/9305280&RS=PN/9305280
[124] Source: FCC ELB System https://apps.fcc.gov/els/GetAtt.html?id=186544&x= Accessed January, 2017

Figure 32: Amazon Patent Drawing – Airborne Fulfillment



This initiative represents the kind of technology that will emerge in coming years that could deliver opportunity for the City to further its digital equity goals because the supporting infrastructure needed to operate the docking stations could also be supportive of the City's goals for wireless deployment. As currently conceived in the experimental stage, this project will require wireless communications in the immediate area for communications among drones and docking stations, will require backhaul and communications to central control systems (potentially over fiber to the poles or through other wireless equipment), and will most likely involve wireless coverage over a substantial geographic area to support ubiquitous delivery.

Amazon has filed for experimental authority with the FCC to begin testing these technologies in the state of Washington.[125] The tests are slated to begin in-building at the company's headquarters in Seattle and then move for the next phase to an undetermined location in or near Kennewick, Washington.

[125] http://www.businessinsider.com/amazon-wants-government-permission-to-run-mystery-wireless-tests-in-rural-washington-2017-1 Accessed January, 2017

CTC recommends that the City begin discussions with Amazon, to explore possible opportunities to work in collaboration and whether the Amazon docking deployment would support City goals in digital equity.

8.3.3 Work with Local Banks to Direct Community Reinvestment Act Support toward Broadband

We recommend that the City consider working with local banks that have Community Reinvestment Act (CRA) obligations, in order to attract and direct CRA investments toward wireless in prioritized areas as a source of support for the strategies suggested in this report. Broadband projects are eligible for CRA funding in eligible areas.

CRA funds are not awarded directly through an application process. Rather, CRA-obligated lenders prioritize investment opportunities to meet their CRA obligations in the relevant area.

8.3.3.1 Background Regarding the Community Reinvestment Act

Congress passed the CRA in 1977 to encourage financial institutions and private lenders to mitigate the disparity that had been created by redlining in communities with less than 80 percent median income of the area (low- and moderate-income (LMI) communities) nationwide.[126] The CRA was designed to address the inequalities that had been created in areas where lenders had underserved, ignored, or refused loans to businesses and residents. This act, known as "redlining," was understood to have created a cycle of poverty by restricting access to capital based on impermissible factors.

The law is intended to ensure that financial institutions "help meet the credit needs of the communities in which they operate, including low- and moderate-income neighborhoods, consistent with safe and sound operations."[127] FDIC-insured lenders are evaluated periodically by appointed governing bodies (including the Federal Reserve, Federal Deposit Insurance Corporation (FDIC), the Office of the Comptroller of the Currency (OCC), and Federal Financial Institutions Examination Council (FFIEC)) to make sure they are providing credit services to the entirety of the community.

Depending on the results of an institution's evaluation, reviews repeat on a performance-contingent schedule. Lenders with a "satisfactory" or "outstanding" rating may have a period as long as 60 months between reviews.[128] During this time, members of the public may submit

[126] *Code of Federal Regulations*, Community Reinvestment Act, Title 12, sec. 228.12 (1978)
[127] *Code of Federal Regulations*, Community Reinvestment Act, Title 12, sec. 228.21 (1978)
[128] Available: https://www.federalreserve.gov/communitydev/cra_about.htm Accessed January, 2017

evaluations, comments, and concerns directly to the institution or the reviewing body, who will pass the information to the institution.

To incent investment in LMI communities, results of the evaluation process are taken into account when considering financial institutions' applications for deposit facilities.[129] While the CRA contains no criminal or civil liability provisions, enforcement of the Act resides primarily in deposit facility applications and risk of reputation damage.[130]

8.3.3.2 Broadband Infrastructure is Eligible for CRA Funding

The potential for meeting CRA obligations with investment in broadband has emerged over the past year or two. The July 25, 2016 Federal Register offers as an example of an eligible investment "a new example describing an activity related to a new or rehabilitated communications infrastructure in recognition that the availability of reliable communications infrastructure, such as broadband Internet service, is important in helping to revitalize or stabilize underserved nonmetropolitan middle-income geographies."[131]

In its 2016 report: "Closing the Digital Divide, a Framework for Meeting CRA Obligations," the Federal Reserve Bank of Dallas presents a "toolkit for bankers looking to bring digital opportunity to underserved, rural and tribal communities." This report argues that broadband projects lead to development of local infrastructure, workforce, small businesses, healthcare, and housing. It encourages investment entities to invest in such projects both as a matter of development and as a means to fulfill CRA obligations.

[129] *Code of Federal Regulations*, Community Reinvestment Act, Title 12, sec. 228.11(b) (1978)
[130] Available: http://www.bbcmag.com/minneapolis/docs/presentations/Wed-Oct-19/500pm/Herwig-Timothy.pdf Accessed January, 2017
[131] https://www.gpo.gov/fdsys/pkg/FR-2016-07-25/pdf/2016-16693.pdf Accessed January, 2017

Appendix A: Request For Information

The following Request for Information (RFI) was issued on January 30, 2017. Responses from vendors are due on February 28, 2017. CTC will review the responses and issue a separate report at a later date.

Appendix B: Case Studies of Municipal Wireless Projects

New York City, New York

Reinventing the Phone Booth

Until recently, payphones were an indispensable part of the urban landscape. Over the last half century, companies installed thousands of pay phones across New York City's five boroughs under franchise agreements with the City. The payphone gave every New Yorker the ability to make and receive calls and access 911, 311, and 411 services from any street corner. Phone booths also provided the city with a significant source of revenue (in recent years, far more from advertising than from the phone itself.[132])

As more of the public began carrying mobile phones, the pay phone began looking like a relic of a past age. The cost of making a call at the phone was far more expensive than through most mobile calling plans, or through Voice over Internet Protocol (VoIP) calling services, like Vonage and Skype.

New York City first tried adding Wi-Fi hotspots to payphones in 2003, but the initial pilots proved financially unfeasible.[133] In 2012 the city held a design competition, inviting companies to share their vision for the phone booth of the future.[134] This led to an official RFP, through which the city partnered with a consortium of tech companies known as CityBridge.

The public-private partnership is now on its way to replacing NYC's payphones with fiber-connected LinkNYC kiosks. As of October 2016, there are 400 kiosks in use across the five boroughs, with another 7,500 planned in the next few years. Already more than 576,000 have signed into the kiosks' internet service with their devices.[135]

Using Ads to Fund an Upgrade

In the partnership agreement, the city agreed to provide the sidewalk real estate, including access to underground conduit. The CityBridge consortium took on the cost of designing, installing and maintaining the terminals, and connecting them to fiber. In exchange, CityBridge

---

[132] Stan Alcorn, "Want Free Wi-Fi in New York? Get Near a Payphone," *NPR, All Tech Considered*, July 24, 2012, http://www.npr.org/sections/alltechconsidered/2012/07/24/157284146/want-free-wi-fi-in-new-york-get-near-a-pay-phone

[133] Ibid.

[134] Will Oremus, "Michael Bloomberg Wants to do Something Cool With New York's Phone Booths," *Slate*, December 5, 2012, http://www.slate.com/blogs/future_tense/2012/12/05/reinvent_payphones_new_york_challenges_techies_to_design_a_better_phone.html

[135] Ivan Pereira, "LinkNYC: Free Wi-Fi use at kiosks surpasses 576,000 people,"*amNewYork,* October 4, 2016, http://www.amny.com/news/linknyc-free-wi-fi-use-at-kiosks-surpasses-576-000-people-1.12401191

shares the advertising revenue with the city. The city is guaranteed at least $500 million over the course of the 12 year franchise agreement.[136]

The companies involved expect the kiosks to generate more ad revenue than a normal billboard because of the access advertisers will have to user information data. Advertisers can use IP address, GPS location and browsing history to tailor their ads to whoever is around the terminal at any given time.[137] Instead of buying a static billboard to advertise a new feature film, a movie studio can purchase ad space for 15 seconds after someone uses a kiosk to search for movie times. Although the city does not share personal information with advertisers, giving them access to the data stream enables far more lucrative, targeted advertisements.

In the initial partnership agreement, Titan was responsible for handling the advertising, Control Group would take care of the user interface, Qualcomm would provide the chips and many of the underlying technologies for the kiosks,[138] Comark Corporation's CIVIQ Smartscapes would build the physical kiosk (according to Antenna Design's design) and Transit Wireless would provide the fiber connection.[139]

However, Google's Sidewalk Labs has since led a group of investors in purchasing Titan and Control Group, merging them into a single company called Intersection, focused on bringing free public Wi-Fi to various types of urban infrastructure. In a Wired article on the acquisition, Colin O'Donnell, cofounder of Control Group, explained, "The thing about cities is no two are the same. Maybe we're replacing a phone booth in New York, but it might be adding services to a bus shelter in Philadelphia or a bike share in San Francisco."[140]

Sidewalk Labs continue to develop their kiosks, and have partnered with US department of Energy's Argonne National Laboratory to test a variety of different types of monitoring devices, including environmental and air pollutant sensors.[141] In subsequent proposals to other cities, Sidewalk Labs has offered to cover the cost of the kiosks if partnering cities take on the cost of installation, connecting them to fiber, provide a hardware refresh fund and cover ongoing

---

[136] Craig Campbell, "LinkNYC: Free is a Good Price," *Governing*, February 4, 2016, http://www.governing.com/blogs/bfc/col-new-york-city-linknyc-internet-kiosk-privacy.html
[137] Ibid.
[138] "Qualcomm Solutions Support Free Public Wi-Fi with LinkNYC," February 9, 2016, https://www.qualcomm.com/news/onq/2016/02/09/qualcomm-solutions-support-free-public-wi-fi-linknyc
[139] Miranda Neubauer, "City selects six-company group to build payphone wi-fi network," *Politico,* November 17, 2014, http://www.politico.com/states/new-york/city-hall/story/2016/05/city-selects-six-company-group-to-build-payphone-wi-fi-network-051356
[140] Issie Lapowsky, "Google's Next Moonshot: Lining City Streets with Wi-Fi Hubs," *Wired,* June 23, 2015, https://www.wired.com/2015/06/google-next-moonshot-wifi-hubs-sidewalk-labs/
[141] Mark Harris, "Inside Alphabet's money-spinning, terrorist-foiling, gigabit Wi-Fi kiosks," *recode*, July 1, 2016, http://www.recode.net/2016/7/1/12072122/alphabet-sidewalk-labs-city-wifi-sidewalk-kiosks

maintenance, power and bandwidth costs. Cities will be able to choose whether or not to include advertising, but if they do, Sidewalk Labs will install the screens, place the ads and split the estimated $60,000 in annual ad revenue from each kiosk with partnering cities. If Sidewalk's financial predications are accurate, ad-enabled kiosks can become revenue positive for cities in just two years.[142]

LinkNYC Kiosk's Expanding List of Services

The new kiosks are made of durable aluminum, "built to withstand extreme heat and cold, rain, snow and flooding, earthquakes, vandalism and theft; all while conforming to ADA standards."[143] The kiosk includes a multi-functional android tablet with touch screen display, two 55-inch HD advertising screens, two USB charging ports, directional speaker and microphone, headphone jack, tactile keyboard and braille lettering and a 911 button that immediately connects the kiosk to emergency services.

Through a partnership with Vonage, the tablets provide free calling to anywhere in the US, including access to 911, 311, and 411 services. People can use the tablet to get maps and directions and to access city services.[144] Initially, the tablet included a web browsing feature, but LinkNYC has pulled this service in response to complaints that individuals were hogging the terminals, and in some cases, using the tablet to access inappropriate content. After pulling the web browsing service, LinkNYC found that tablet usage increased by 12 percent and reports of individuals monopolizing the dropped 82 percent.[145]

LinkNYC emphasizes that the program is still in beta. They will continue to expand (or contract) the services available on the tablet based on public feedback.[146] New services can be added remotely through a software update. At the beginning of October, LinkNYC added the ability to register to vote from the tablet.[147] Once the kiosk and fiber connection are in place, the increased marginal cost of providing a new internet-based service is negligible.

In addition, the Links provide a platform that the city can use as it pursues its Internet of Things strategy. Qualcomm has stated that the Links are designed to allow hardware to be swapped out or added in according with the City's needs. With simple upgrades, the Links could become a

[142] Ibid.
[143] https://www.link.nyc/assets/downloads/LinkNYC-Fact-Sheet.pdf
[144] https://www.link.nyc/assets/downloads/LinkNYC-Fact-Sheet.pdf
[145] http://www.amny.com/news/linknyc-free-wi-fi-use-at-kiosks-surpasses-576-000-people-1.12401191
[146] https://www.link.nyc/assets/downloads/LinkNYC-Fact-Sheet.pdf
[147] http://www.amny.com/news/linknyc-free-wi-fi-use-at-kiosks-surpasses-576-000-people-1.12401191

"backbone to connect lighting systems, smart meters, traffic networks, connected cameras and other IoT systems."[148]

Free, Fiber-Powered, Wi-Fi Narrows the Digital Divide

Most people who use the kiosks never actually approach the terminal. They sign on to the LinkNYC hotspot network with their own device from up to 150 feet away.[149]

The kiosks currently provide speeds up to 300 Mbps[150] and can support hundreds of Wi-Fi users at a time. The kiosks' each have a fiber connection, making the Wi-Fi service endlessly upgradable as users' bandwidth demands continue to grow. The embedded routers all are equipped with Hotspot 2.0, allowing users with Hotspot 2.0 enabled devices to automatically connect to nearby hotspots and enjoy automatically encrypted browsing.[151] Thanks to a roaming agreement the City signed with other cities, users can use their same profile to automatically connect to public Wi-Fi networks in San Francisco, San Jose and Singapore.[152]

The de Blasio administration hopes the free service will help narrow the digital divide amongst New Yorkers. Natalie Grybauskas, a spokeswoman for Mayor de Blasio has stated, "When we set out to bring Wi-Fi to sidewalks at no cost to taxpayers, we aimed not just to replace outdated pay phones with something more useful, but to provide free services to all residents, including the one in five New Yorkers who don't have broadband access at home."[153]

While the city does not collect personal information about who uses the service, anecdotal evidence suggests that the kiosks are proving especially useful for New Yorkers living on the street. The kiosks allow them to charge their phones, connect with friends and family and look for employment and housing opportunities.[154]

It remains to be seen how well the free Wi-Fi service will bridge the digital divide. While the service makes the internet far more accessible to New Yorkers who struggle to afford internet service from a private provider, the hotspot signal is not designed to penetrate through walls. For a student trying to complete a homework assignment, having access on the street corner is

---

[148] http://www.pcworld.com/article/3041453/hardware/users-will-get-faster-free-wi-fi-from-hubs-in-new-york.html

[149] "Frequently Asked Questions," *LinkNYC,* https://www.link.nyc/faq.html#wifi-for-business

[150] Devindra Hardawar, "LinkNYC's Free Gigabit Wi-Fi is Here, and it is Glorious," *Engadget,* January 19, 2016, https://www.engadget.com/2016/01/19/linknyc-gigabit-wifi-hands-on/

[151] "Frequently Asked Questions," *LinkNYC* https://www.link.nyc/faq.html#whynetworks

[152] "Wireless Broadband Alliance Launches City Wi-Fi Roaming Project," *Wireless Broadband Alliance,* August 23, 2016, http://www.wballiance.com/wireless-broadband-alliance-launches-city-wi-fi-roaming-project/

[153] Karen Matthews, "Wi-Fi? Why Not? Homeless are Avid Users of NYC's Free Kiosks," *Mobile Tech Today,"* August 25, 2016, http://www.mobile-tech-today.com/article/index.php?story_id=132004M4VL4C

[154] Ibid.

hardly comparable to having access inside the home. The New York Public Library's effort to make mobile hotspot available for parents of public school students for the entire school year is designed specifically to address the needs of eligible school students.[155]

Still, the LinkNYC consortium has figured out a way to use advertising revenue to subsidize an extensive, fast, free Wi-Fi network across the city, making abundant bandwidth far more accessible to everyone on the streets of New York.

Kansas City, Missouri

When Google announced that Kansas City would be the first place to receive Google Fiber service, the city became a central point of the expansion of fiber broadband. In response, AT&T, Time Warner and other commercial providers serving the city engaged the public with faster speeds and competitive pricing.[156]

As we have detailed in other publications, Kansas City made several policy decisions that made it a good candidate for a new entrant such as Google Fiber.[157] However, adding another private ISP did not solve all of the city's networking needs, nor has it eliminated the digital divide.[158] The city continues to take steps to improve access.

Public-Private Partnership Provides Free Wi-Fi Downtown

In May, 2016, Kansas City, Sprint, and Cisco announced a public-private partnership that would bring free public Wi-Fi to Kansas City's 2.2 mile streetcar line, and provide a backbone network for the city's Internet of Things (IoT) sensors.

As laid out in the agreement, the city provides utility power and access to certain real estate, fiber optic cable, equipment and backhaul capabilities to Cisco. Cisco will then sublicense some of these assets in order to build out a Wi-Fi network along the downtown corridor.

In exchange for covering the cost of installing and maintaining the Wi-Fi network, Sprint shares the capacity of the network with the city. The city subdivides its portion of the network capacity

---

[155] "Library Hotspot," *New York Public Library*, http://hotspot.nypl.org/

[156] Frank Morris, "In Kansas City, Superfast Internet and a Digital Divide," *NPR; All Tech Considered*, March 9, 2015, http://www.npr.org/sections/alltechconsidered/2015/03/09/390392782/in-kansas-city-superfast-internet-and-a-digital-divide

[157] "Gigabit Communities; Technical Strategies for Facilitating Public or Private Broadband Construction in Your Community," *CTC Technology & Energy* January 2014, http://www.ctcnet.us/wp-content/uploads/2014/01/GigabitCommunities.pdf

[158] Frank Morris, "In Kansas City, Superfast Internet and a Digital Divide," *NPR; All Tech Considered*, March 9, 2015, http://www.npr.org/sections/alltechconsidered/2015/03/09/390392782/in-kansas-city-superfast-internet-and-a-digital-divide

between a free, public Wi-Fi network, internet enabled kiosks and the city's network of IoT sensors.[159]

The connected kiosk project is currently more limited in scope than the LinkNYC project. The city installed 25 kiosks, and limited their functionality to "accessing city services, current events, entertainment."[160]

The city's portion of the network will serve as the backbone for the city's IoT efforts. Using Sensity's NetSense platform, the city has already installed 200 smart streetlights along the streetcar line. The streetlights automatically adjust lighting to save on energy costs and reduce light pollution. Cameras embedded in the lights use the IoT portion of the network to transmit video footage for public safety and security applications.[161] The City hopes to add water and trash monitoring sensors to the network in the next few years.[162]

Using Millimeter Wave Technology to Extend the Reach of Fiber

Even with multiple fiber providers and free Wi-Fi downtown, many low-income Kansas City residents continue to find the internet out of reach. The partnership with Sprint only covered a 2.2-mile stretch of downtown, and even while the presence of Google Fiber has prompted competitors to lower their prices and improve service offerings in many neighborhoods,[163] as of May 2016, Google Fiber service was only available in 80 percent of Kansas City.[164] In some parts of the city, the potential return on investment has not proven high enough for wired ISPs to build or upgrade their services.[165]

Such was the case in the city's historic East Side. To address the lack of internet access, the City partnered with the Urban Neighborhood Initiative, KC Digital Drive, Next Century Cities, and Siklu

---

[159] Mark Davis, "KC streetcar route includes free outdoor Wi-Fi from Sprint," *The Kansas City Star,* April 29, 2016, http://www.kansascity.com/news/local/kc-streetcar/article74688742.html

[160] "Sprint Launches Free Wi-Fi Service as Part of Kansas City's smart city Initiative," *Sprint Newsroom*, May 5, 2016, http://newsroom.sprint.com/news-releases/sprint-launches-free-wi-fi-service-as-part-of-kansas-citys-smart-city-initiative.htm

[161] "Sprint Launches Free Wi-Fi Service as Part of Kansas City's smart city Initiative," *Sprint Newsroom*, May 5, 2016, http://newsroom.sprint.com/news-releases/sprint-launches-free-wi-fi-service-as-part-of-kansas-citys-smart-city-initiative.htm

[162] Henry Grabar, "How Will Kansas City Run Its Plugged-In, Sensor-Filled Future," *Next City*, October 6, 2015, https://nextcity.org/daily/entry/kansas-city-streetcar-smart-city-connected

[163] Scott Canon, "AT&T to match Google Fiber speeds, prices in Kansas City and suburbs," The Kansas City Star, February 15, 2015, http://www.kansascity.com/news/business/technology/article10441850.html

[164] Mark Bergen, "Google Fiber is the most audacious part of the whole Alphabet," *recode*, May 11, 2016, http://www.recode.net/2016/5/11/11613308/google-fiber-alphabet

[165] Frank Morris, "In Kansas City, Superfast Internet and a Digital Divide," *NPR; All Tech Considered*, March 9, 2015, http://www.npr.org/sections/alltechconsidered/2015/03/09/390392782/in-kansas-city-superfast-internet-and-a-digital-divide

Communication to use millimeter wave (mmWave) wireless technology to extend the reach of KC Web's existing fiber backbone in order to provide free high-speed service to residences in three east side neighborhoods, encompassing three to four square miles.[166] The pilot project will use mmWave radios to serve as a wireless backhaul from the fiber backbone to receivers attached to selected high points (tops of buildings, poles, antennas, etc.) in the neighborhood. The connection can then be distributed further through Wi-Fi or other local area network technologies.

The project seeks to create a sense of community ownership over the network. KC Digital Divide will provide digital literacy training to members of the community, and will also train members of the community to expand and maintain the network to help ensure future sustainability of the project and provide workforce skills.[167] Service will be provided for free, "to help serve as an onramp to the internet by eliminating a cost barrier to getting online."[168]

The City has played a minimal role in the partnership so far, with the Urban Neighborhood Initiative coordinating the effort and Siklu donating much of the technology. If the pilot project proves successful, the City could step in to help scale the effort to other underserved areas.[169]

ConnectHome and ConnectED

Kansas City has also benefitted from new federal programs that aim to narrow the digital divide. In 2015, the White House announced its ConnectED initiative, a program that aims to bring together technology companies, non-profits and officials from every level of government to get 99 percent of student access to the internet by 2018.

As part of the initiative, Sprint recently announced it would provide mobile hotspots with a 3 GB per month download limit to 200,000 students per year for the next five years.[170] While the initiative will eventually be available to students in seven to 10 cities, the free service will first be available to students in Kansas City.

---

[166] Josh Helmuth, "More free public Wi-Fi coming to Kansas City, Missouri," *KSHB*, May 25, 2015, http://www.kshb.com/news/local-news/more-free-public-wi-fi-coming-to-kcmo

[167] Ibid.

[168] Tania Bashes, "Siklu, the Urban Neighborhood Initiative, and KC Digital Drive Announce Gigabit Projects Using Fiber Like Wireless," *Siklu,* May 24, 2016, http://www.siklu.com/announce-gigabit-project-using-fiber-like-wireless/

[169] Josh Helmuth, "More free public Wi-Fi coming to Kansas City, Missouri," *KSHB*, May 25, 2015, http://www.kshb.com/news/local-news/more-free-public-wi-fi-coming-to-kcmo

[170] Andrew Pestano, "Sprint, White House to provide broadband device, service to students," *UPI* October 11, 2016, http://www.upi.com/Business_News/2016/10/11/Sprint-White-House-to-provide-broadband-device-service-to-students/1851476199989/

As a compliment to the ConnectED initiative, the White House launched ConnectHome in partnership with the US Department of Housing and Urban Development (HUD). Through the initiative, HUD plans to work with ISPs, nonprofits and private organizations to provide families living in public housing facilities with broadband access, training and computers. The initiative also gives Cities the flexibility to use HUD's Choice Neighborhood Implementation Grants to fund local broadband initiatives.

In February, 2016 HUD announced that Google Fiber had agreed to connect five public housing authorities in Kansas City to its fiber network and provide free service for residents. The non-profit Connect for Good will provide on-sight and residents can buy refurbished computers for as little as $55 though Surplus Exchange.[171]

These federal initiatives have helped coordinate the efforts of private companies, non-profits and local governments to tackle the digital divide. Seattle is already one of 28 communities participating in the initial ConnectHome pilot project.

San Francisco, California

Background

The City of San Francisco has used wireless technologies to bridge the digital divide for more than a decade. The Department of Technology dedicated a staff member to work on improving internet access for low-income housing communities. Although the efforts were given limited budget, DT staff were able to leverage the City's existing 170 miles of fiber to bring high-speed connectivity to several public housing sites. DT used the fiber to create the backbone of the City's Community Broadband Network (CBN).[172]

Using the CBN, the City became its own ISP and began providing wireless broadband service to low-income individuals and families, as well as to CCSF personnel while they are at work. The CBN has continued to grow and add users over time, now providing Wi-Fi at 38 San Francisco Housing Authority sites, 24 Senior Technology Centers, and a variety of City buildings (including City Hall), as well as a handful of other non-profit run sites that serve low-income populations. The quality and speed of service varies from site to site, with some sites enjoying a direct connection to CBN fiber, while other sites are forced to connect via a wireless bridge.[173]

[171] "Kansas City takes the lead in closing the digital divide," *The Kansas City Star,* February 3, 2016, http://www.kansascity.com/opinion/editorials/article58281088.html

[172] Interview with Mike McCarthy, Wi-Fi Engineer/Senior Policy Analyst for Department of Technology, City and County of San Francisco, October 6, 2016

[173] Ibid.

The CBN fiber terminates in a commercial data center, where the cost of bandwidth is competitive. By owning its own fiber and wireless radios, the City can continue to expand the network increase capacity with limited additional capital costs. When the City determines that another site or neighborhood needs better or more affordable internet access, it does not need to wait for a private company to do it for them. DT can construct the fiber or set up the wireless bridge itself.[174]

Partnering with Non-Profits

In order to deliver high quality service to a growing set of users, DT staff have worked closely with non-profits and volunteer network consultants. Since the beginning of the CBN, Internet Archive has served as a critical partner for the City's network. The CBN fiber terminates at a commercial data center, where it connects to Internet Archive's network. As a result, CBN user IP addresses come from Internet Archive, rather than from the City. This protects the reputation of the City's own IP addresses. In the event that someone uses the CBN Wi-Fi to engage in activities like spam or a denial of service attack, the City's own store of IP addresses will not be blacklisted.[175] Through this arrangement, DT also avoids having to deal with Digital Millennium Copyright Agreement violation letters.[176]

DT staff has also worked closely with non-profits that provided services for low-income individuals and families. As a registered 501(c)(3), non-profits can receive donations more efficiently than a city government. In many of the public housing sites, non-profit partners purchased the necessary networking equipment at a 90 percent discount from TechSoup, a website that helps non-profits access donated hardware from major equipment manufacturers, like Cisco. The non-profits then handed the equipment off to DT staff for configuration and installation.[177]

DT staff also worked with non-profits to apply for grants to cover the cost of wireless access points in sites that serve low-income populations. When Compass Family Services received money from Twitter to cover the cost of wireless access points in some of its shelters, DT staff provided technical guidance for the deployment. The cost for the CBN to provide backend connectivity to the site was negligible.[178]

---

[174] Ibid.
[175] Ibid.
[176] It is important to note that even if the City was to provide users with IP addresses, they would not be responsible for users DMCA violations. See the EFF's whitepaper on Open Wi-Fi and Copyright for more information: https://www.eff.org/files/2014/06/03/open-wifi-copyright.pdf
[177] Interview with Mike McCarthy, Wi-Fi Engineer/Senior Policy Analyst for Department of Technology, City and County of San Francisco, October 6, 2016. For more on TechSoup: http://www.techsoup.org/joining-techsoup
[178] Ibid.

The Wireless Networking Learning Curve

The CBN currently serves far more users than it was additionally designed for, and many of the switches are in need of an upgrade. DT staff acknowledge that they rely heavily on pro-bono technical support from private networking consultant Tim Pozar and his team at TwoP for both network design decisions and ongoing maintenance issues.[179]

DT staff have also learned a great deal about what it takes to deliver a wireless signal to end users in crowded urban environments. Some of the wireless access points used in early deployments relied exclusively on the 2.4GHz band of spectrum, which major tech companies now admit is too crowded to offer adequate performance, especially in crowded urban areas.[180] Mike McCarthy, DT's Wi-Fi Engineer and Senior Policy Analyst, encourages any other municipality or non-profit to purchase dual band equipment that can switch from the 2.4GHz band to the 5GHz spectrum bands. "Dual band radios are twice as expensive but ten times more effective in the field."

Working in the context of public housing buildings, where routers are installed in hallways but providing service to users behind closed doors, DT staff gained extensive real-life experience with Wi-Fi and wireless RF. In retrospect, Mike McCarthy wishes he'd used a Wi-Fi network design tool, like Ekahau,[181] to ensure that the access points are positioned in a way that delivers the signal everywhere people are likely to need it.[182]

DT has worked with the SF Public Housing Authority and non-profits to make sure that every time a building that may want connectivity is renovated, it is done with networking needs in mind. Pulling extra cable when a new security camera system is installed or adding Ethernet jacks to every room go a long way towards ensuring that once a building is connected to the CBN, the signal actually makes it to the end users.

Although some older portions of the network leave room for improvement, DT staff use what they have learned to improve newer deployments and share what they learn with their non-profit partners.

Setting Itself up for Future Success

The CBN serves as a backbone for the City to use as it continues to expand its public wireless service. When the mayor's office decided it wanted to provide free Wi-Fi along the busy Market

[179] Ibid. For more on TwoP: http://twop.co/#projects
[180] Owen Williams, "Apple and Cisco acknowledge that 2.4Ghz Wi-Fi is too unreliable and crowded, *The Next Web,* February 2016, http://thenextweb.com/apple/2016/02/04/apple-and-cisco-acknowledge-that-2-4ghz-wi-fi-is-too-unreliable-and-crowded/
[181] For more on Ekahau's Wi-Fi planning service: http://www.ekahau.com/wifidesign/ekahau-site-survey
[182] Interview with Mike McCarthy, Wi-Fi Engineer/Senior Policy Analyst for Department of Technology, City and County of San Francisco, October 6, 2016

Street Corridor, it briefly entered in to negotiations with AT&T before deciding that DT could provide a better quality service itself.[183] Thanks to wireless access point donations from Ruckus Wireless and fiber backhaul donated by Layer42 Networks, DT was able to provide peak speeds up to 50 Mbps both up and downstream for $500,000.[184]

In 2014, Google approached the City about providing a gift of $600,000 to offer public Wi-Fi in 32 City parks.[185] The one caveat was the company did not want to cover ongoing maintenance costs associated with operating the network. Having the CBN already in place made it easy for the City to accept the gift. The funds covered the cost of installing wireless access points in the park. Adding the parks to the CBN did not add significant maintenance costs.[186]

As of 2014, the total wireless network maintenance budget, including the free service on Market street and in public parks, was just $120,000.[187] Mike McCarthy readily admits that the network was deployed without a clear plan to sustain it. The network has grown far beyond the initial vision for the project, with 1,800-1,900 unique connections daily as of 2015.[188] Network support is limited to Mike McCarthy and a team of volunteers. While the individuals involved have managed to get a huge amount done with a limited budget, more resources will likely be necessary to sustain and expand the network in the years ahead.

Looking towards the future, Mike McCarthy is excited about how recent advances in millimeter wave (mmWave) wireless backhaul technology could allow the City to extend the reach of its fiber network, providing fiber-like speeds to the many portions of the CBN that are not physically connected to fiber.[189]

---

[183] John Cote, "S.F. rolls out 3 miles of free Wi-Fi along Market Street," S.F Gate, December 16, 2013, http://www.sfgate.com/bayarea/article/S-F-rolls-out-3-miles-of-free-Wi-Fi-along-Market-5067616.php

[184] Liz Gannes, "San Francisco Gets Fast ,Free Public Wi-Fi on Market Street," *Wall Street Journal; All Things D,* December 16, 2013, http://allthingsd.com/20131216/san-francisco-gets-fast-free-public-wi-fi-on-market-street/

[185] Marisa Lagos, "S.F. Rolls out free WiFi in public spaces throughout the city," *SF Gate*, October 1, 2014, http://www.sfgate.com/politics/article/S-F-rolls-out-free-WiFi-in-public-spaces-5792159.php

[186] Interview with Mike McCarthy, Wi-Fi Engineer/Senior Policy Analyst for Department of Technology, City and County of San Francisco, October 6, 2016

[187] Jonah Lamb, "Market Street free Wi-Fi is mostly a success- if you know about it," *The Examiner*, January 27, 2014, http://archives.sfexaminer.com/sanfrancisco/market-street-free-wi-fi-is-mostly-a-success-if-you-know-aboutit/Content?oid=2687958

[188] "Towards an Understanding of Best Practices in Community Wireless Networks," *Freedman Consulting*, May, 2015, https://tfreedmanconsulting.com/wp-content/uploads/2016/05/BestPracticesinCommunityWireless.pdf

[189] Interview with Mike McCarthy, Wi-Fi Engineer/Senior Policy Analyst for Department of Technology, City and County of San Francisco, October 6, 2016