City of Dublin
OHIO, USA

BROADBAND

CITY COUNCIL WORKSHOP

April 15, 2019

EVERYTHING GROWS HERE.

AGENDA

1. How does Dublin, Ohio compare at a regional, national, and global level relative to internet speeds and capacity?

2. What challenges does broadband access/speed pose for the future of technology and work?

3. What does the City of Dublin have relative to broadband?

4. What has prohibited or otherwise caused Dublin to hesitate deploying Dublink further that it currently has?

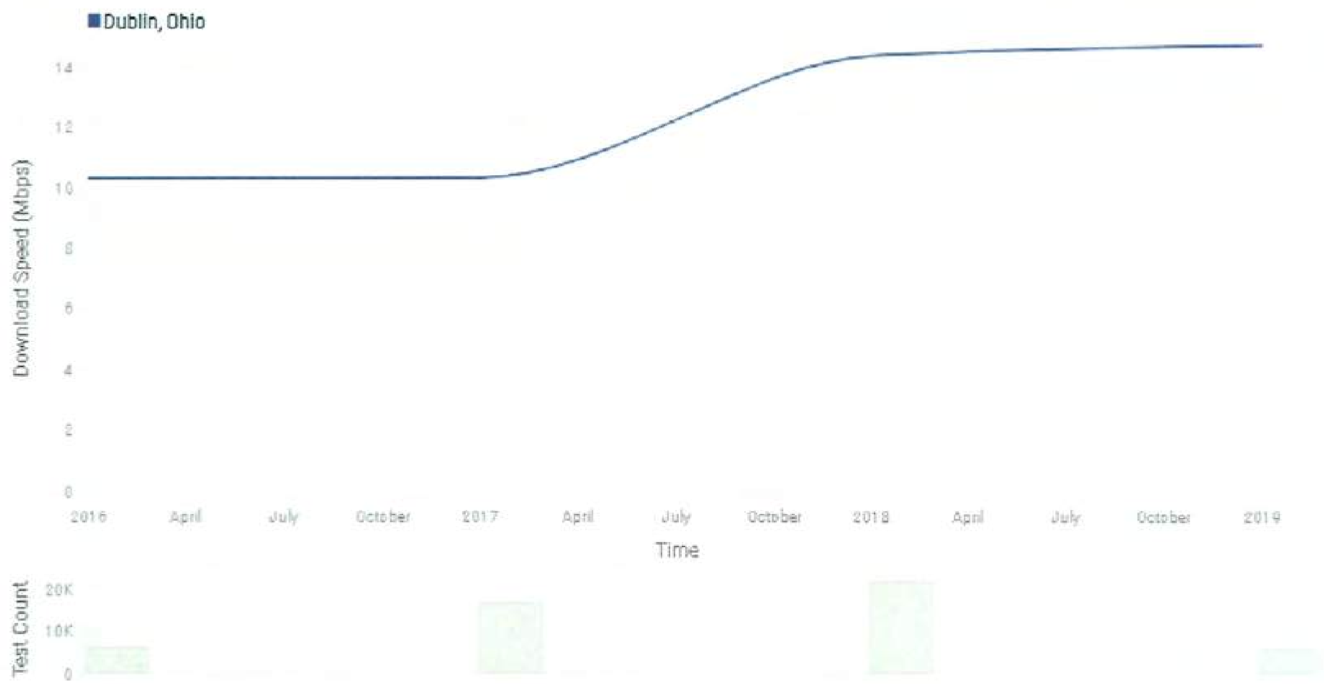
5. How have some other cities addressed their broadband situation?

City of Dublin OHIO, USA

DUBLIN BROADBAND SPEEDS

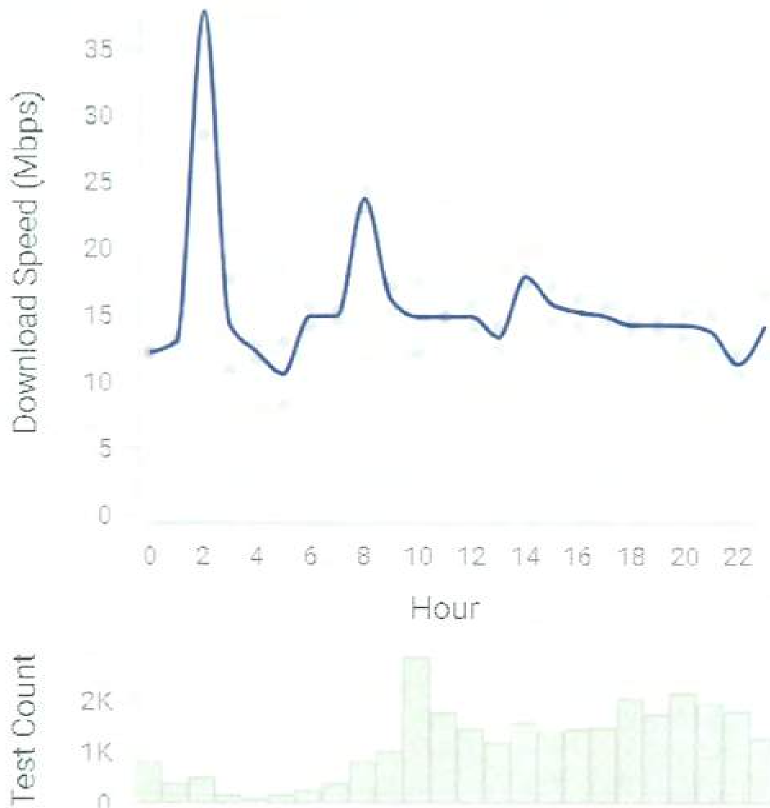
OFFICE OF THE CITY MANAGER

ANNUAL AVERAGE DOWNLOAD SPEEDS



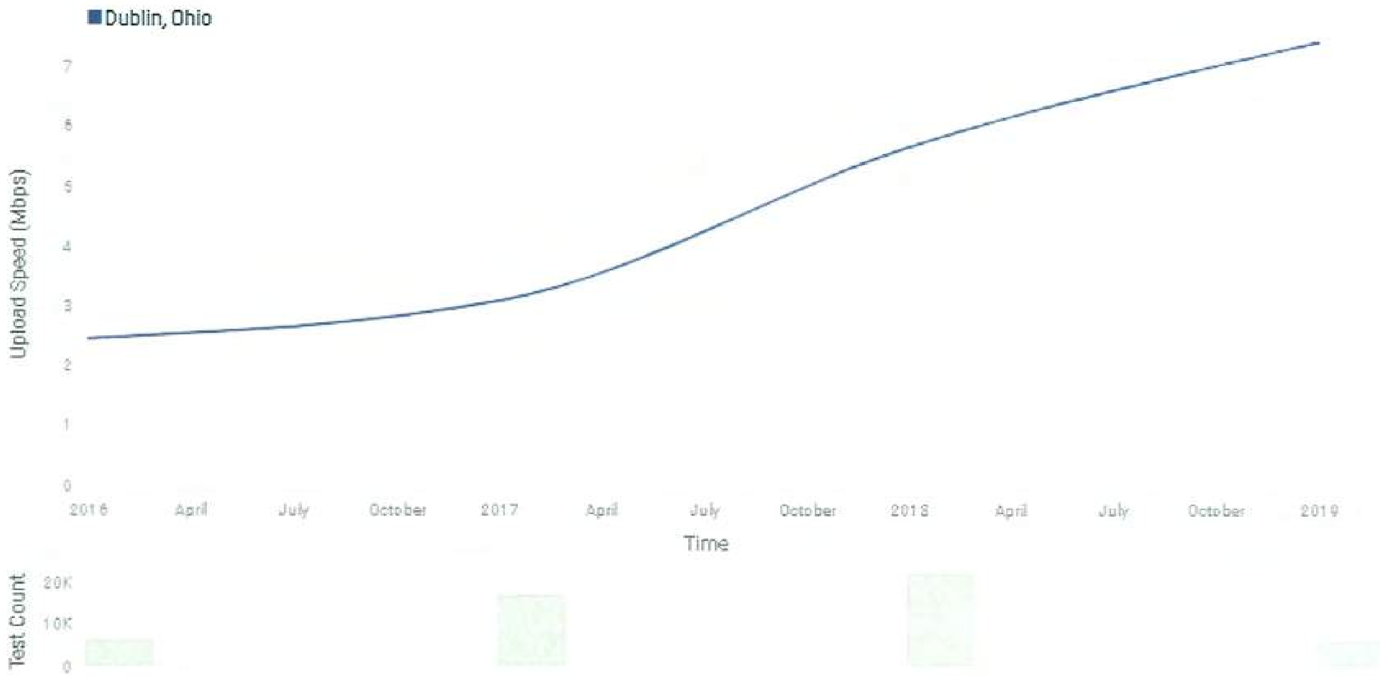
EVERYTHING GROWS HERE.

HOURLY AVERAGE DOWNLOAD SPEEDS



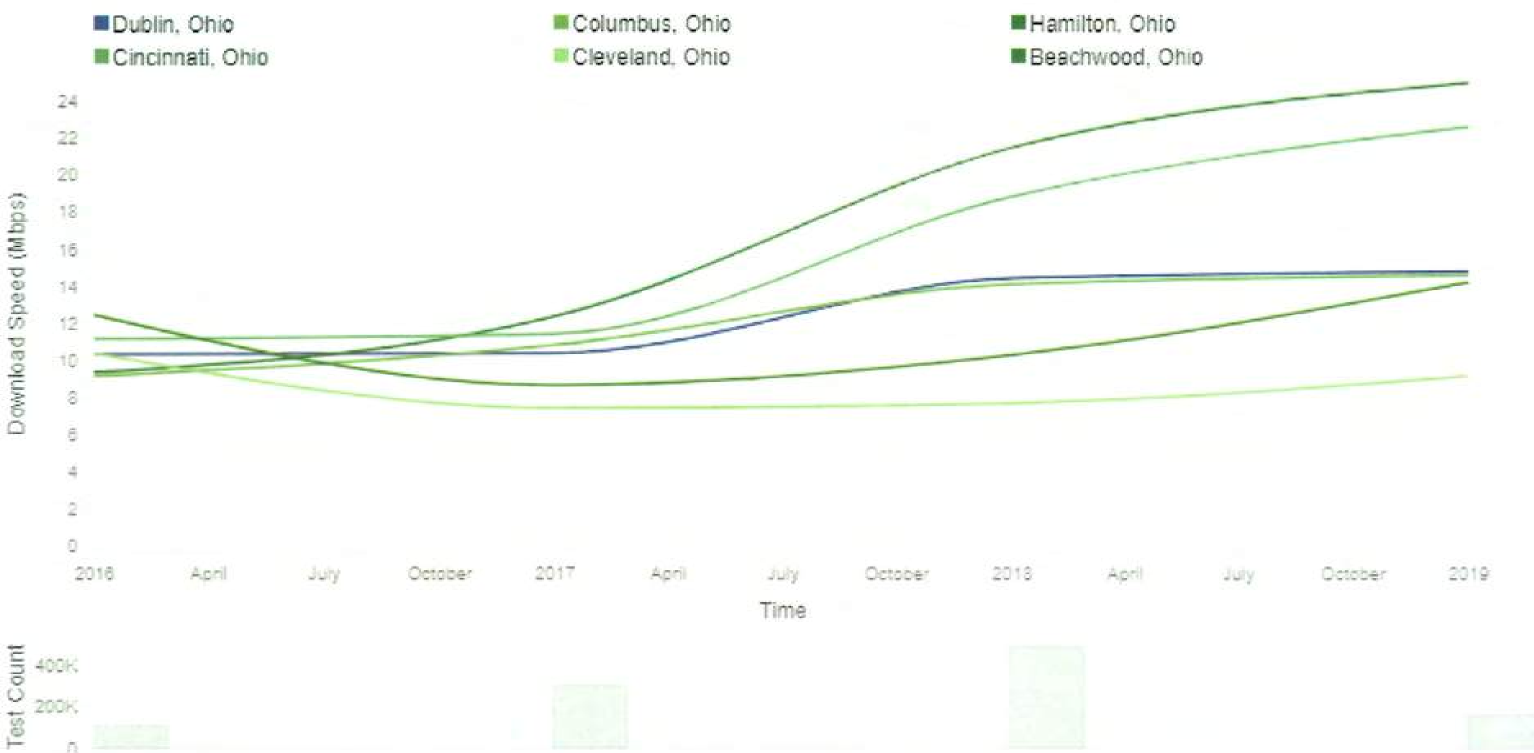
EVERYTHING GROWS HERE.

ANNUAL AVERAGE UPLOAD SPEEDS



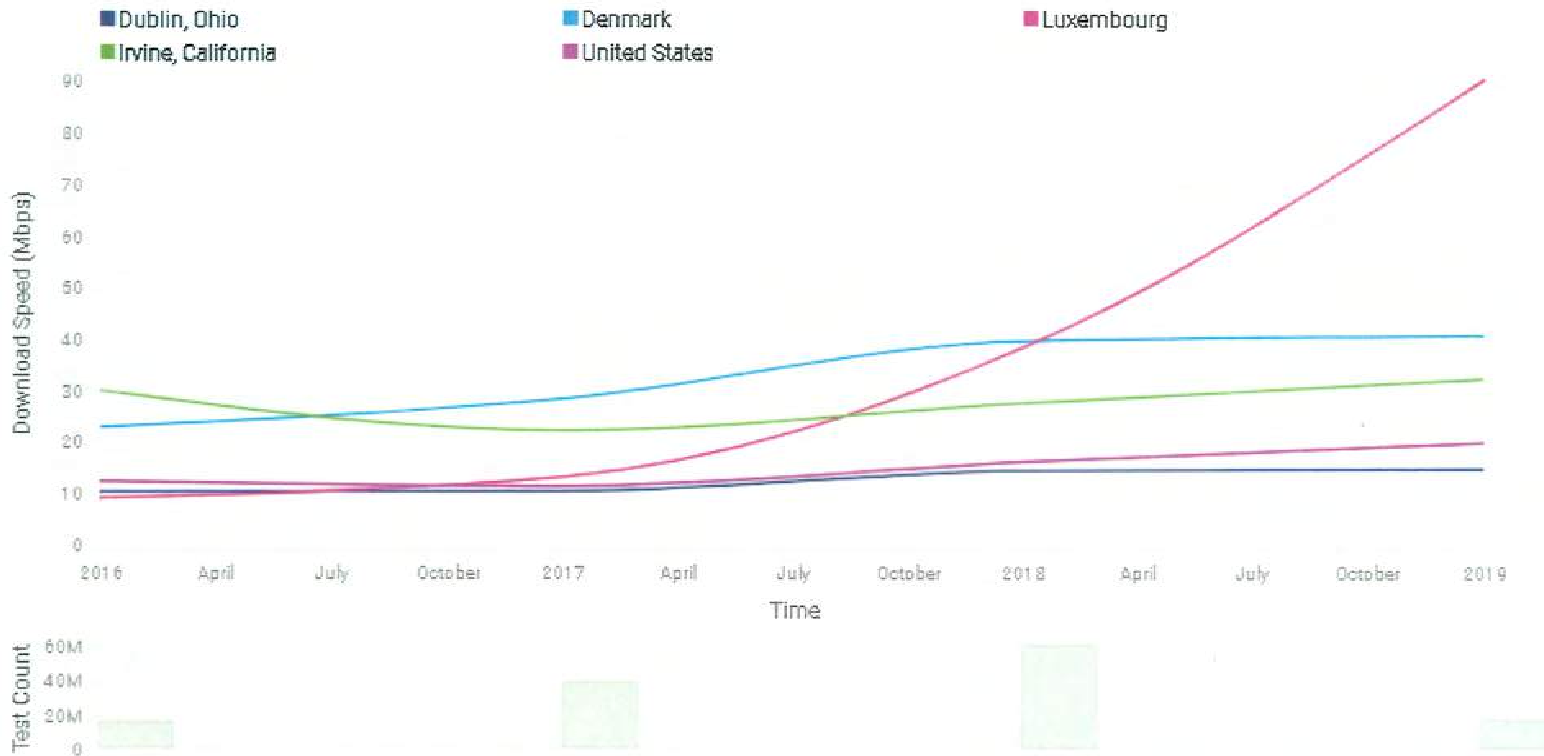
EVERYTHING GROWS HERE.

STATEWIDE COMPARISON



REGIONAL COMPARISON

INTERNATIONAL COMPARISON



EVERYTHING GROWS HERE.

NATIONAL AVERAGE

Country speeds

Fixed Broadband Speeds
Q2-Q3 2018 United States

Download Mbps	Upload Mbps
96.25	32.88

24,283,160
Unique Users

66,695,645
Samples

115,445,472
Tests

3,232,473,216
Data Points

SPEEDTEST

OOKLA

EVERYTHING GROWS HERE.

City of Dublin OHIO, USA

DUBLIN PROVIDERS

Spectrum

City Coverage 100.0%

Fastest Speed 120 Mbps

CABLE

- 89.99 Mbps is the average speed for Spectrum in Dublin.
- Spectrum has a customer rating of two and a half.
- Spectrum offers 3 plans.

View Plans

Frontier Communications

City Coverage 12.2%

Fastest Speed 24 Mbps

DSL

- Frontier markets 5 plans.
- Current customers have rated Frontier at two stars out of five.
- Frontier does not leverage data caps in Dublin.

View Plans

AT&T TV • Internet

City Coverage 92.1%

Fastest Speed 100 Mbps

DSL

- Some AT&T Internet plans have data caps.
- Packages from AT&T Internet are DSL.
- 48.76 Mbps is the average speed for AT&T Internet in Dublin.

View Plans

AT&T Fiber

City Coverage 7.6%

Fastest Speed 1,000 Mbps

FIBER

- Dublin has 4 plan choices through AT&T Fiber.
- Service by AT&T Fiber is limited to 7.58% of Dublin.
- AT&T Fiber has two and a half stars.

View Plans

WOW!

City Coverage 69.1%

Fastest Speed 50 Mbps

CABLE

- Existing customers rate WOW! at three out of five stars.
- WOW! speeds are higher than the weighted average by 35.7%.
- Plans do not include data limits.

View Plans

Dublin is the

39th

most connected city in Ohio ahead of Amlin, Hilliard, Lewis Center, Plain City, and Powell.

The "Connected" metric is a citywide average based on FCC data showing the density of broadband options at the census block level.

EVERYTHING GROWS HERE.

BROADBAND SPEED COMPARISONS

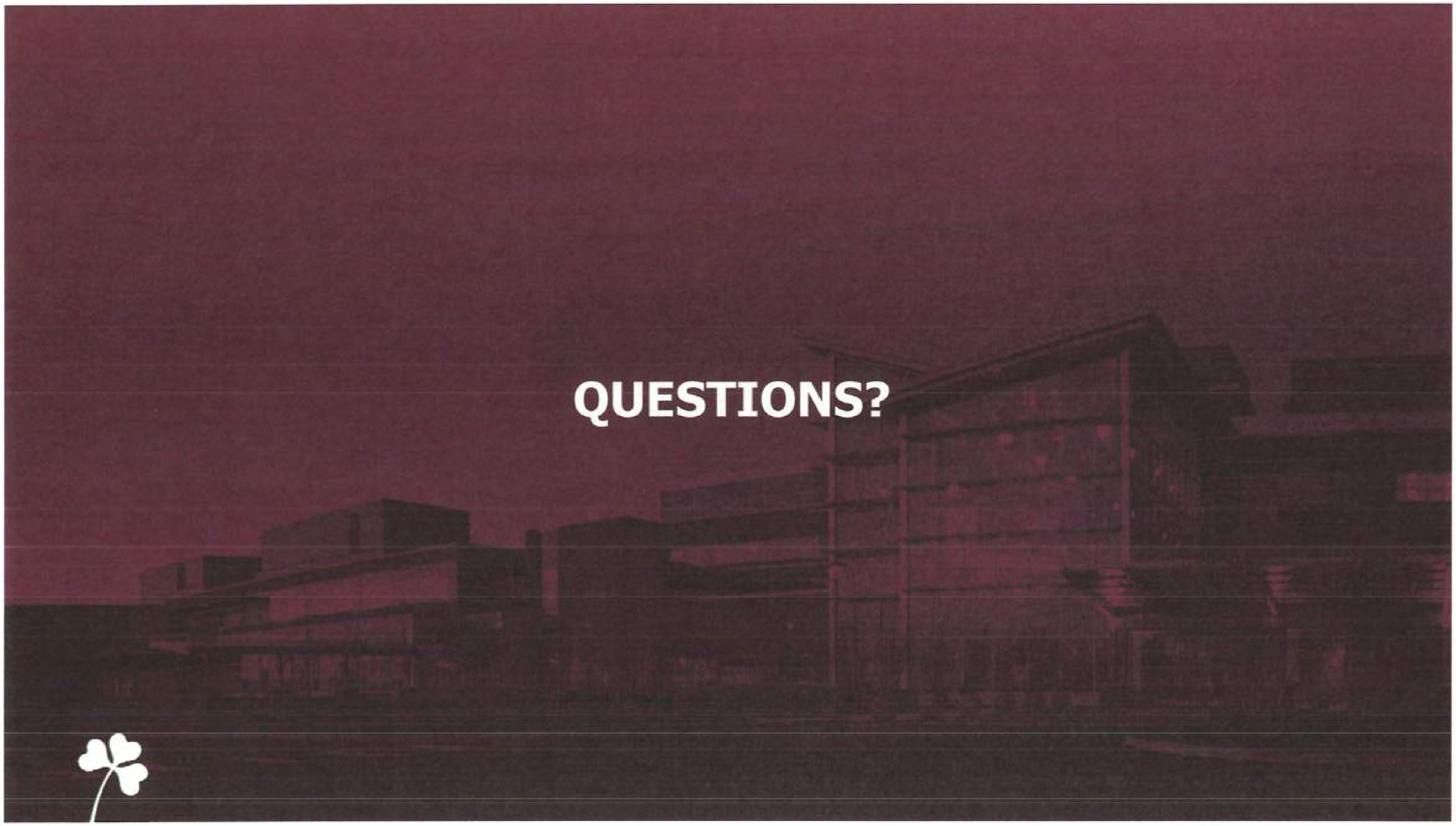
Dublin, OH
5.7 mbps **Up**
14.4 mbps **Down**

Luxembourg
18.5 mbps **Up**
38.4 mbps **Down**

U.S. Average
4.9 mbps **Up**
16.1 mbps **Down**

Palo Alto, CA
5.5 mbps **Up**
31.1 mbps **Down**

Netherlands
10.8 mbps **Up**
25.6 mbps **Down**

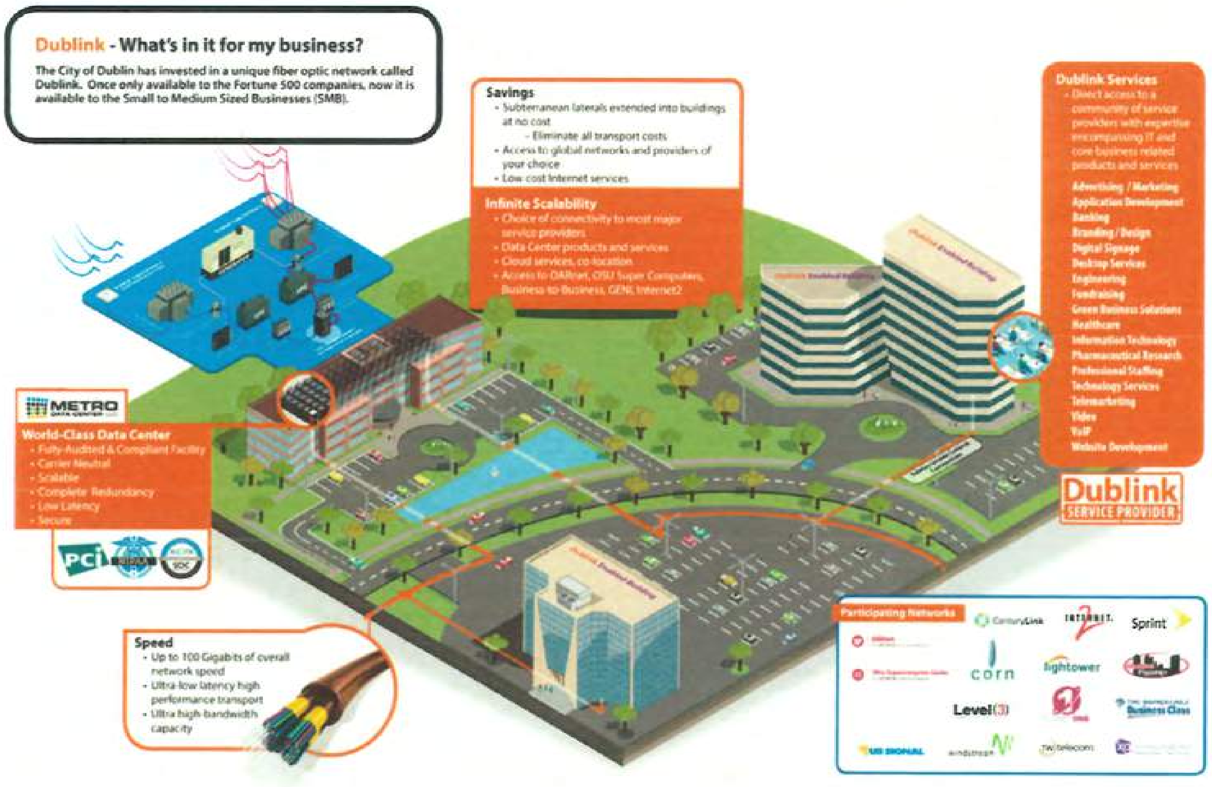

QUESTIONS?

City of Dublin OHIO, USA

What challenges does broadband access/speed pose for the future of technology and work?

- Current and future trends
- Remote work
- Cloud computing
- Cybersecurity

What does the City of Dublin have relative to broadband?



EVERYTHING GROWS HERE.

City of Dublin OHIO, USA

What has prohibited or otherwise caused Dublin to hesitate deploying Dublink further that it currently has?

Greg Dunn
Special Legal Counsel

City of Dublin
OHIO, USA

Dublink TRANSPORT

How have some other cities addressed their broadband situation?

City of Dublin

Office of the City Manager
5200 Emerald Parkway • Dublin, OH 43017-1090
Phone: 614.410.4400 • Fax: 614.410.4490

Memo

To: Members of Dublin City Council

From: Dana McDaniel, City Manager

Date: April 10, 2019

Initiated By: Nick Plouck, Management Assistant
Kirby Dearth, Office of the City Manager intern

Re: Council Work Session – Broadband

Background

At the scheduled Council work session for Monday, April 15th, Council will begin a discussion regarding your strategic goal on broadband. Staff suggests certain questions to consider around this subject to possibly help with this conversation. The following is a list of these questions and resources to be provided as part of the packet of information for this work session.

How does Dublin, Ohio compare at a regional, national, and global level relative to internet speeds and capacity? In an effort to provide a baseline for how Dublin compares to other communities in regards to internet speed, staff has provided a broadband speed comparison brief. This comparison includes Dublin internet data, and how it compares to leaders throughout Ohio, the United States, and the rest of the world. Staff would like to review this information briefly with Council at the start of the work session.

What challenges does broadband access/speed pose for the future of technology and work? The future of technology and how/where people work is an important factor when considering the City's economic sustainability. Recognizing that there is a link between broadband and economic growth, staff has attached four articles around this topic.

What does the City of Dublin have relative to broadband? While Dublin may lag behind when it comes to residential broadband speeds, the City does own a robust fiber optic highway known as Dublink. Included in the packet is an overview of the Dublink fiber network, and an inventory of current Dublin residential internet providers. As a complement to the service provider information, staff has also included results from a community broadband survey conducted in 2016.

What has prohibited or otherwise caused Dublin to hesitate deploying Dublink further that it currently has? Greg Dunn, Special Legal Counsel, will be on hand to discuss some of the issues that cities should be aware of relative to the deployment of broadband and the competitive environment.

How have some other cities addressed their broadband situation? As Council considers the future of broadband in Dublin, it may be helpful to see what other communities have done to address the challenges of broadband connectivity and speed. Staff has included a few recent feasibility studies that have been conducted by municipalities across the country.

Recommendation

For information only. Staff will continue to add to the library of material on this topic as Council's discussion continues.

City of Dublin

Office of the City Manager
5200 Emerald Parkway • Dublin, OH 43017-1090
Phone: 614.410.4400 • Fax: 614.410.4490

Memo

To: Members of Dublin City Council

From: Kirby Dearth, City Management Intern

Date: April 10, 2019

Initiated By: Dana McDaniel, City Manager

Re: Dublin Ohio Residential Broadband Speeds Comparison

Background

In an effort to inventory the current degree of connectivity, the Office of the City Manager explored average speeds within the City of Dublin and other communities around the world. We have found that the best data available outside of a contracted study of our community is derived from reported results of residential speed tests. Organizations such as Broadbandnow and Measurement Labs compile data from multiple speed test websites to provide specific location averages over time. Their reports are contingent on the number of unique end-users testing their speeds in a given location. Therefore, the data serves as a general indication of speeds experienced in a locality, not a variable-free conclusive statement of service. Comparing this data serves to highlight where Dublin internet stands and to showcase the existing gaps in service quality, not the specific speed differentials between communities.

The City of Dublin is currently served by 8 residential internet service providers (ISPs), with 99% of residents having access to multiple service providers. The largest provider serving Dublin residents is Spectrum, advertising 120 Mbps broadband service available to 100% of the community over copper lines. AT&T is the second largest provider, advertising 100 Mbps packages over their DSL network that covers 92.1% of Dublin. Additionally, AT&T operates fiber infrastructure that covers 7.6% of the community, advertising speeds up to 1,000 Mbps without a monthly data cap. According to Broadbandnow and the FCC, this small percentage of the city is the only portion that has access to residential fiber (Figure 1).

Although 100-megabit service is available to most residents, the average speeds of Dublin residential connections do not reflect such service levels. ISPs advertise "up to" speeds, indicating that the advertised speed is not entirely guaranteed. Speeds fluctuate due to data traffic congestion during peak hours. ISPs often throttle speeds to maintain network stability, systematically reducing the available bandwidth to a residence. According to 17,445 speed tests compiled by the Measurement Lab, the City of Dublin's residents on average experienced a download speed of 14.4 mbps in 2018 (Figure 2). Although the City of Dublin experienced a faster average download speed than the State of Ohio, the City performed below the national average and continues to do so into the early months of 2019 (Figure 2). In comparison, Fairlawn Ohio's average 2018 download speed totaled 38.8 Mbps due to the increasing availability of residential fiber via the City's municipal fiber project (Figure 3). Additionally, Irvine, California's 2018 download speed averaged 27.6 mbps (Figure 3). As a recipient of google fiber, a majority of residents have access to one gigabit (1,000 mbps) internet services. The above average performance of these cities can be partially attributed to the increased availability of broadband services over fiber infrastructure.

While Dublin's average residential speeds struggle to compete with some of the faster American cities, the gap in competition widens when considering the countries with the fastest download speeds in the world. With a population of 527,000, Luxembourg is one of the smallest countries in Europe; however, this has not stopped them from building a fiber to the home national network. In 2017, the fiber network passed more than 60% of those residing in the country, with 25% subscribing to the service. This has led to Luxembourg being ranked the fastest country in the world by a 2016 international study of weighted broadband speeds conducted by the FCC. In 2018, the national average download speed of Luxembourg was 38.4 mbps, almost three times as fast as the City of Dublin's (Figures 4 & 5). The government of Denmark also owns and operates a national service provider, prompting a ranking of 8th on the FCC's list of fastest countries and a 2018 national average download speed of 39.7 mbps (Figures 4 & 5).

Despite the fact that average download speeds highlight actual speeds experienced, they do not account for customers choosing slow service packages even though faster speeds are available. By considering the 90th percentile of speeds, one can more accurately compare the speeds available to a community. The 90th percentile of Dublin speeds for the month of March 2019 reached 46.62 mbps. In comparison, the top 9 fastest cities in the United States experienced 90th percentile speeds over 600 mbps (Figure 6). Nine Mile Falls Washington was the fastest city in the country, with a 922 mbps 90th percentile download speed (Figure 6). Only 2 Ohio cities made the top 100 list last month. Independence was ranked number four, with a download speed of 685.60 mbps, while Carrollton placed 82nd with 342.62 mbps.

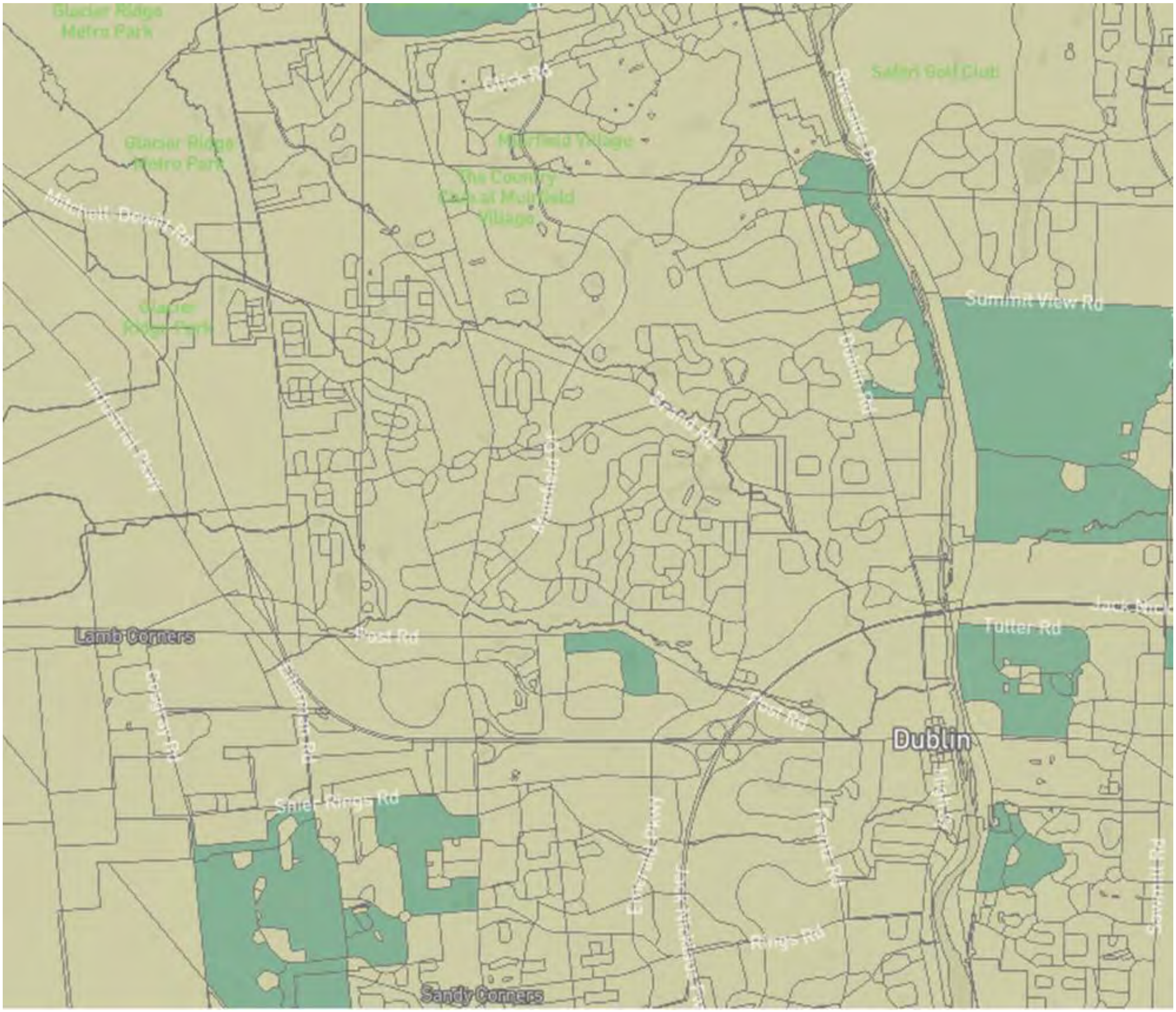
The U.S. national average download speed presented by Measurement Lab (16.1 mbps) accounts for both wired and wireless connectivity. This is not entirely comparable to the City of Dublin, as 99% of residents are served by a wired service provider. This consideration makes it necessary to compare city statistics to other fixed broadband statistics. By categorizing speed tests based on infrastructure, speed reports published by Speedtest.net separate the speeds of wireless based and fixed broadband based service performance. Their Q2 and Q3 2018 report places the U.S. national average for fixed broadband download speeds at 96.25 mbps (Figure 7). This data was derived from over 24 million unique users and a total of 115 million tests. In comparison, the 90th percentile of Dublin residential speeds for the month of March (46.62 mbps) is less than half the national fixed broadband average, indicating that even some of the fastest speeds experienced in the City are well below the national average.

Recommendation

For Informational Purposes Only

Figures

Figure 1 ([Courtesy of the FCC]())



Number of Residential Fiber Broadband Providers

Figure 2 (Courtesy of Measurement Labs)

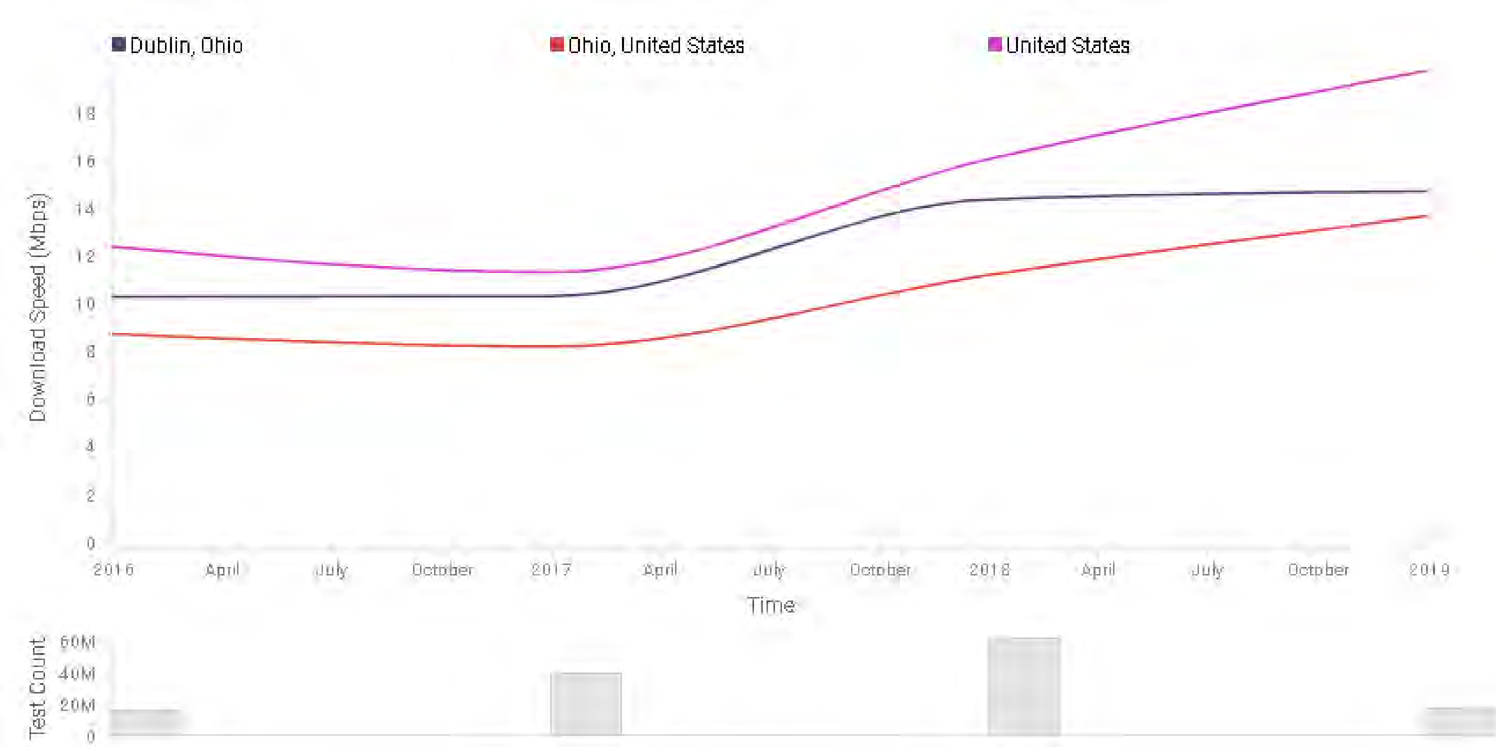


Figure 3 (Courtesy of Measurement Labs)

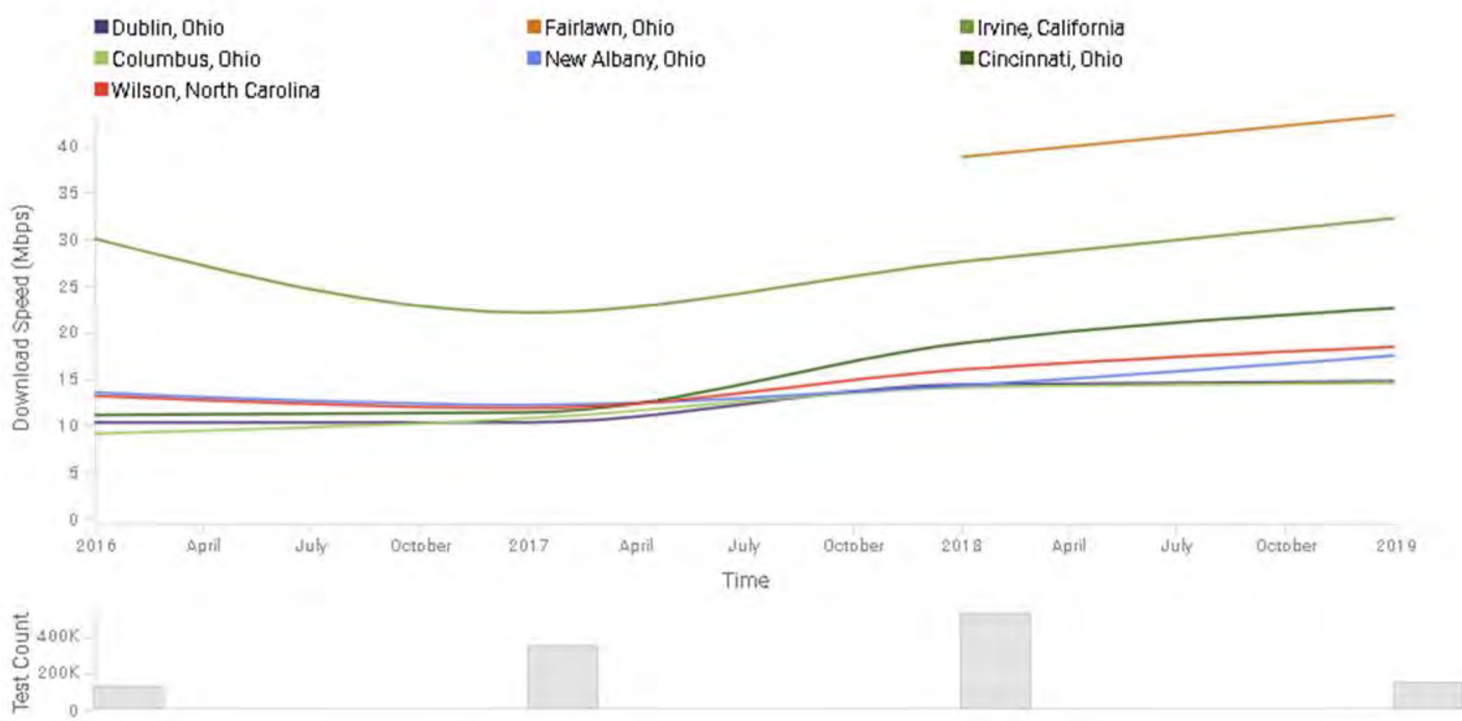


Figure 4 (Courtesy of Measurement Labs)

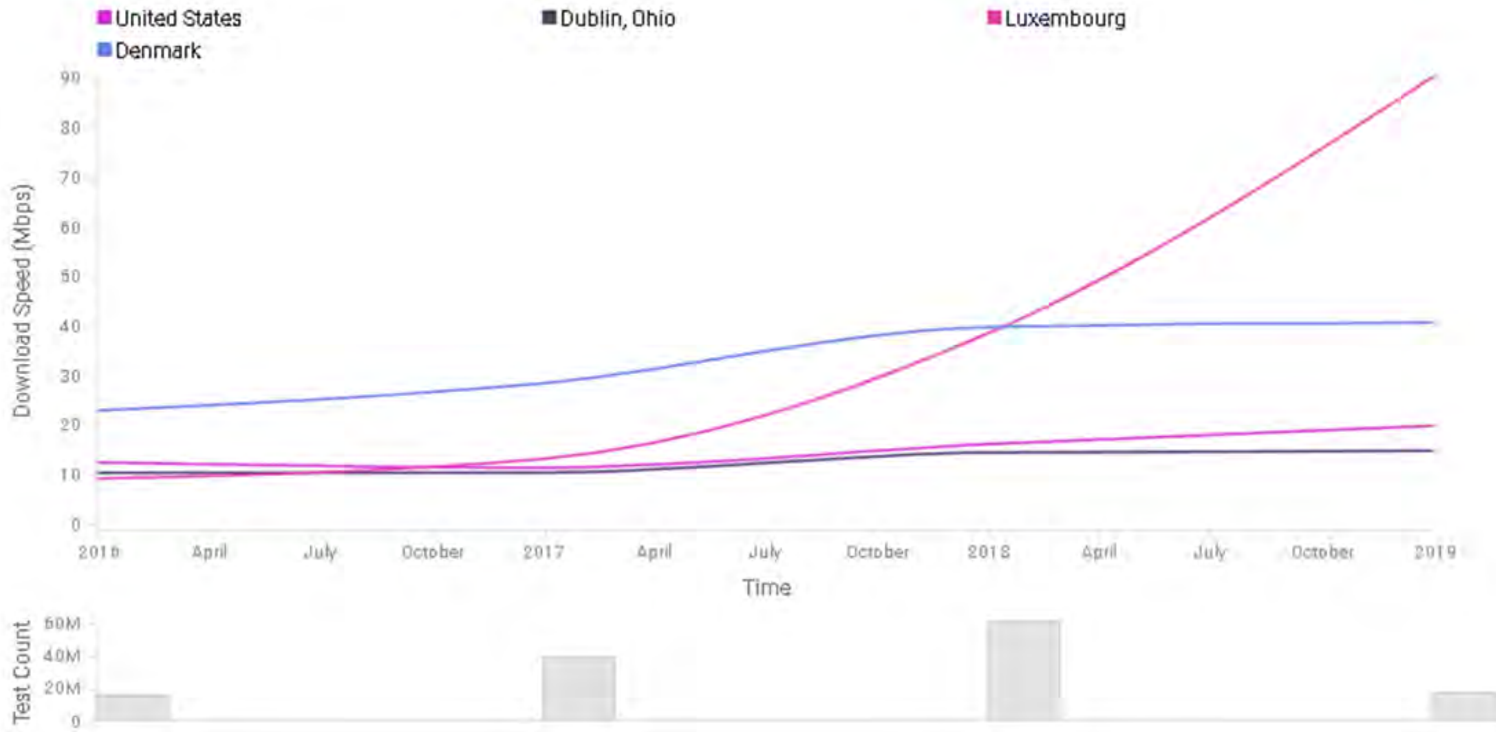


Figure 5 (Courtesy of the FCC 2016)

COUNTRIES RANKED BY MEAN (WEIGHTED) DOWNLOAD SPEED 20

Rank	Country	Average download speed
1	Luxembourg	375.78
2	Japan	102.34
3	Iceland	90.36
4	South Korea	86.98
5	Switzerland	79.58
6	Sweden	73.81
7	Netherlands	67.54
8	Denmark	61.49
9	Spain	57.86
10	United States	55.07

Table 1: Data via 2018 FCC International Broadband Data Report

Figure 6 (Courtesy of Broadband Now)

FASTEST CITY LEADERBOARD: MARCH, 2019

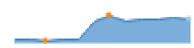
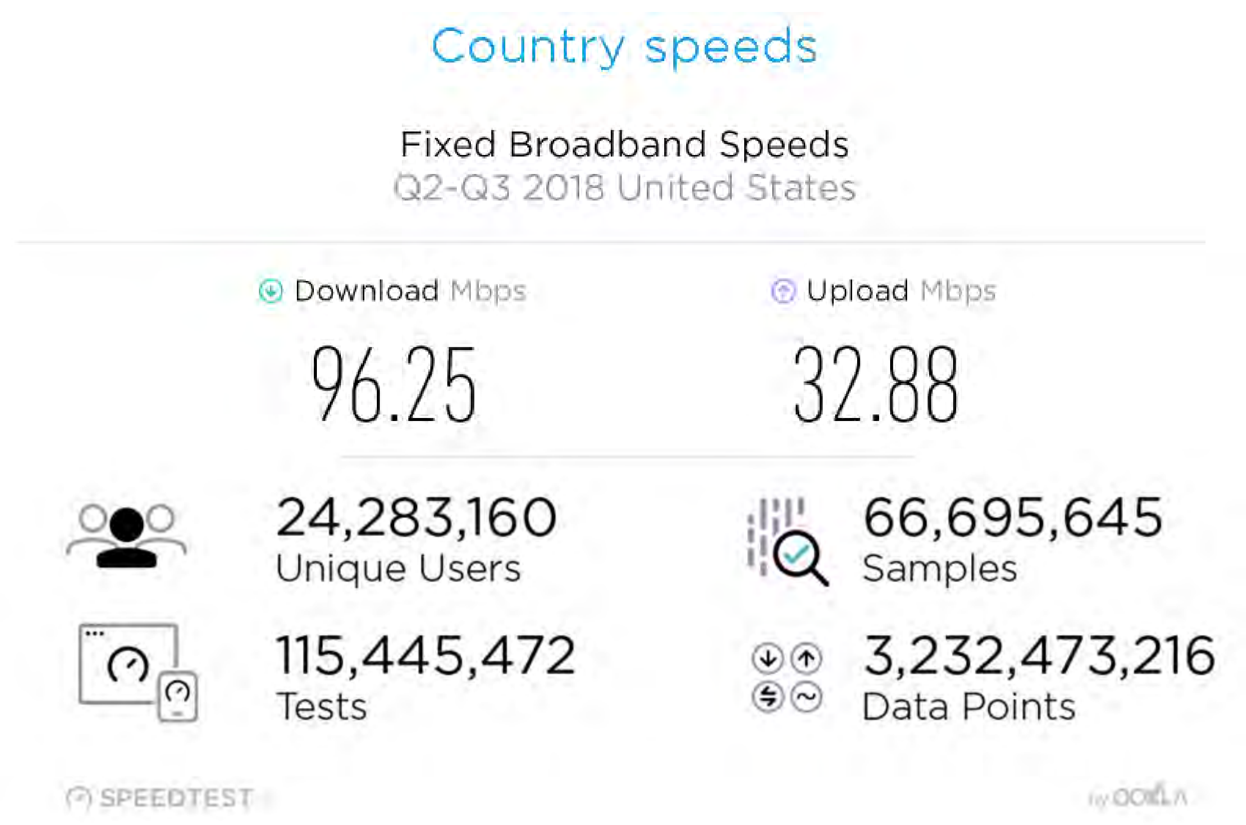
Rank	City	Download Speed	Speed over time	No. of Providers
1 -	Nine Mile Falls (Washington)	922.39 MBPS		18
2 ↑	Bluemont (Virginia)	838.48 MBPS		13
3 ↓	Hoschton (Georgia)	739.69 MBPS		11
4 ↑	Independence (Ohio)	685.60 MBPS		23
5 ↑	Rumson (New Jersey)	680.11 MBPS		10
6 ↓	Piedmont (Oklahoma)	662.01 MBPS		13
7 ↓	North Arlington (New Jersey)	660.18 MBPS		15
8 -	Gurley (Alabama)	658.93 MBPS		14
9 ↓	Fort Lupton (Colorado)	644.32 MBPS		12

Figure 7 (Courtesy of Speedtest.net)



21,649 views | Dec 21, 2018, 07:45am

10 Remote Work Trends That Will Dominate 2019

Abdullahi Muhammed Contributor
Careers
I cover smart freelancing, the gig economy and remote work.

2019 Remote Work Trends. PEXELS.COM

Remote work is no longer a privilege. It's become the standard operating mode for at least 50% of the U.S. population. Virtual retreats are no longer attributed solely to progressive startups. Traditional employers are finally on-board and ready to propose a flexible work arrangement higher up the pipeline.

2019 will further reinforce the current global shift towards “remote-friendly” workplaces and dictate a few more unique trends.

1. Employer expectations of digital skills are shifting from basic to advance

The demand for technology-savvy professionals now extends well beyond the software development space. According to fresh data from LinkedIn, general tech skills – web design, social media management and so on – are among the fastest growing in-demand skills. Whereas basic digital literacy – fluency with email software tools and word processing software – witnessed the fastest decline compared to other skill groups. Companies now expect employees to be more comfortable with all sorts of digital tools, even for entry-level positions and more so for remote employees. So if you are just considering the transition, make sure that your technical skill set is up-to-date and you know how to run a virtual office.

2. “In-the-office” days may become more popular

No, it’s not because more employers want to micromanage their remote teams. Quite on the contrary, employers are finally starting to address the mental health factor more seriously. The biggest reported struggle of remote work is lack of community - 21% of remote workers named “loneliness” as one of their main on-the-job issues.

To address this, companies are now encouraging remote members to come back to the office at least once per week. And this strategy gives results – Gallup poll estimated that the “visiting” employees tend to be more engaged and fulfilled when compared to their 100% remote or full-office counterparts. Such members are more likely to have friendships at work and state that their job includes opportunities to learn and grow.

3. Workplace cybersecurity will move upstream

This year, a lot of large companies have fallen prey to cybersecurity attacks and Internet giants (think Facebook) reported massive data breaches. While large corporations already have a good grip on security policies for remote employees, smaller employers have been leaving this area neglected. A new survey says that 38% of remote workers hired by SMEs do not have the technological support or expertise they need when working at home or in a public space. Interestingly enough, an additional 18% of respondents say that they would have been concerned as an employer about IT security. Rightfully so, as 72% of breaches actually occur at companies with under 100 employees.

In 2019, smaller companies should really catch up on their IT security. A good start is to develop unified security policies for both in-house and remote employees; restrict access to sensitive data to those who try to access it from public Wi-Fi networks and explore new-gen security tools, especially those powered by the blockchain technology.

4. Employers should start addressing the "trust issues"

E&Y survey revealed that less than half of global professionals trust their current employer, boss or team/colleagues. While the survey only included responses from in-house team members, the trust factor often gets more complicated for remote team members. Working solo, without regular access to company updates and the "water cooler" corporate chit-chat, can amplify the employee's exclusion from the work process and make them question whether they are treated fairly or not.

The same survey indicated that unfair employee compensation, unequal opportunity for pay and promotion, lack of leadership, a work environment that does not promote collaboration are the key reasons for low trust. Promoting more transparency and collaboration between remote/in-house teams and management should become the new norm for 2019.

5. Having a specialization is a must

The era of generalists is over. Most employers are now after talent with specific skill sets: 78% of HR managers said that most skills will become even more niche in the next 10 years. Possessing those coveted skills means that you will remain in high-demand and have a lever during salary negotiations. Most employers are ready to pay the top dollar for hiring and retaining a remote candidate, whenever they cannot find certain expertise locally.

6. Legislature changes may lead to more remote work opportunities

FASB/IASB accounting changes are due to take effect on 1 January 2019 in the US, affecting every company that leases commercial real estate. A lot are now forced to seek alternative solutions for accommodating their offices. As a cost-optimization strategy, savvy businesses may choose to switch to telecommuting and hire new personnel on a remote basis. Gartner also estimates that "choose-your-own-work-style" decisions do not just lead to operational savings, but as well boost employee rates by more than 10%. So a lot of employers will likely diversify their work policies.

7. More training for remote staff

This year, employers have finally recognized the fact that the lack of meaningful learning and progression opportunities leads to high attrition rates. In 2019, this line of thinking also extends towards remote teams. Micro-learning and self-paced learning programs are bound to get more traction as more employers realize the incremental benefits of nurturing and re-engaging existing teams.

8. Get prepared for Gen Z competition

By 2020, Gen Z will comprise 36% of the global workforce. Being digital natives, who grew up in an internet-centric society, the members of this generation are likely to be more comfortable with newer technology and more inclined to seek remote or flexible working arrangements, rather than pursue traditional corporate roles. Account for the competition that's coming.

9. Nomadic remote workers will find new bases

Co-working spaces became the usual habitat of the remote worker. In 2019, the travel-seeking remote employees may finally succeed in combining their need for a decent Wi-Fi with an affinity for some pool time. Selina a hotel chain, mashing up high-end suites with dormitory rooms in the same building, along with coworking spaces is expanding to the US and Europe. After successfully testing their operational model in Latin America markets, the company secured a new building in Miami and is now location-scouting in Portugal.

10. Remote work is expected to grow stronger in 2019

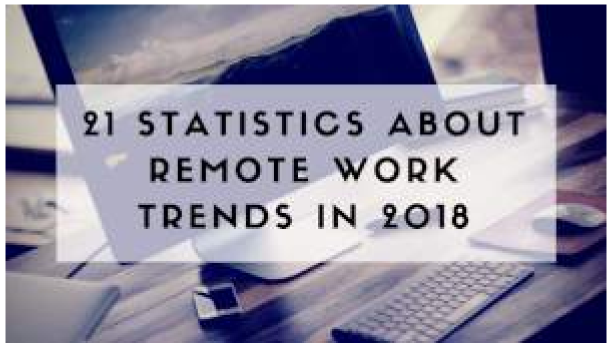
All signs indicate that we are nowhere close to hitting the plateau. Businesses across public and private sector increasingly recognize the benefits of hiring and retaining remote workers. Societal trends with millennials and Gen Z also push more businesses towards adopting more flexible working policies and allowing at least partial telecommute. If you are planning to transition to remote work, 2019 may be just the right time to do so.

Follow me on Twitter and visit my website for more resources to market and grow your business online.

Abdullahi Muhammed Contributor

I am a writer, entrepreneur and the proud founder and CEO of Oxygenmat. I graduated summa cum laude from University of Ilorin with a degree in Law, winning the award of ...
Read More

7
SEP
2018



BRIGEDA

21 Statistics About Remote Work Trends In 2018

In 2018, the term "digital nomad" has garnered a lot of attention. Social media has created a fantasy of being able to travel the world while working remotely, and more or less have all of your dreams come true. But just how realistic is this image? According to an article from Silicon Republic, remote working will rival fixed office locations by 2025.

It's not an all-or-nothing situation, however. While some companies do allow their employees to work from home full-time and have seen success with this model (Automattic has over 650 employees, but had to close its office in San Francisco because no one was showing up), others have completely banned the practice, like Yahoo! did in 2013.

remote work seems to overall be on the rise, particularly in certain industries such as tech.

1. Regular work-at-home, among the non-self-employed population, has grown by 140% since 2005, nearly 10x faster than the rest of the workforce or the self-employed.

2. An increase in remote work could help bridge the gender gap in the tech industry. 56% of women in the tech industry leave their jobs mid-career, and 51% of women say being a working mother made it difficult for them to advance in their careers.

3. In fact, remote companies have four times as many female CEOs than non-remote companies.

4. In 2016, Dell announced its plans to further expand its telecommuting and remote work initiatives, citing the $12 million in annual savings from reduced office space costs.

5. Although several companies think an open-office plan encourages collaboration, most employees would prefer to work remotely.

6. Because of the ever-advancing tech industry, skills are becoming more specialized. As new technological innovations such as artificial intelligence (AI) and robotics take hold, the vast majority (67 percent) of hiring managers agree that companies will need to invest in re-skilling to prepare workers for the jobs of tomorrow.

7. There are five jobs available per one software developer. Listing a job as "remote optional" will help attract more applicants.

8. When looking for a job, over 50% of developers said being able to work remotely was a priority.

home more frequently than that. The highest job satisfaction was reported by developers who are completely, or almost completely remote.

10. In 2017, Austin had over 60% of its tech job offers going to workers outside of Texas, while San Francisco had over 30% going to workers outside of the city.

11. Austin software company Enola Labs conducted an ROI study and found that employees spent a cumulative 77 hours per day commuting. Upon these findings and consensus from the team, leadership decided to allow the software development team to works nearly 100% remotely, enabling the company to hire the best talent, boost morale, and cut costs.

12. 56% of startups worldwide have outsourced their work, contributing to the demand for remote workers.

13. 74.92% of respondents from a 2018 State of Software Development Survey said remote work is already allowed at their company.

14. In 2015, an estimated 300,000 full-time employees in computer science jobs worked from home in the US. Computer science employees are likely to spend much more time working from home than people in other fields.

15. In 2016, 57% of employees in the computer/IT industry reported some time working remotely. Computer and IT employees rank just below the transportation industry in work-from-home frequency, at 61%.

16. In the State of Remote Work in 2018 Report by Buffer, 43% of respondents said they only combine work and travel between 1% and 10% of the year. Most people surveyed were in the tech industry.

17. 2 out of 3 respondents in a survey conducted by Polycom Inc said they are more productive working remotely than when they worked at an on-site office. 3 out of 4 respondents said working remotely helps them with work/life

18. At the end of 2017, Workfront CEO Alex Shootman predicted not just more remote workers, but holograms in the workplace. Only time will tell for this one.

19. According to research by Gartner, organizations that embrace remote working will increase employee retention rates by 10%.

20. In a 2017 study by IT solutions company Softchoice, 74% of 1,000 office workers surveyed said they would leave their job for another that offered the option of more remote work.

21. According to a report by Workforce Futures, 83% of employees feel they do not need an office to be productive.

Brigeda Hernandez is the Marketing Assistant at Enola Labs Software , a software development company based in Austin, TX. Brigeda enjoys writing about technology and its impact on business processes and everyday life.

Companies Hiring Remote Business Administrators

7 Companies Currently Hiring Remote Data Entry Specialists

SkipTheDrive

Employers FAQ About Contact Blog Affiliate Disclosure Terms Privacy

CLOUD COMPUTING 101

October 4, 2018 / 0 Comments / in Blog, Cloud Computing, Collaboration, Technology / by Joseph Talamantez

As you prepare for 2019 and beyond, Cloud Computing should be part of every technology discussion for your business. Today the "Cloud" means everything and anything. So, what is Cloud Computing and what does it *really* mean for you and your business?

WHAT IS CLOUD COMPUTING?

Let's define Cloud Computing.

Cloud computing is the Delivery, using the Internet or a Direct data connection, of Network-Based Services hosted in a Multi-Tenant Environment.

What does this mean?

Network-Based Services – this is a service running on a network. Usually networked in a datacenter, not your own.

Using the Internet or another Direct data connection – You are accessing this service from a remote location from the source. You are using it over the Internet or another data link.

Hosted in a Multi-Tenant Environment – Hosted means it is running on someone else's hardware and they are just making a service available to you. Multi-tenant means the provider is 'hosting" many users at the same time. They serve multiple tenants.

For example, look at Gmail. The provider (Google) manages the software and the hardware running Gmail. You just use the service from a distance over the Internet. Cloud computing is just a form of outsourcing when you use Gmail, you outsource your email application to Google.

There are three major kinds of Cloud Computing Services

- SaaS – Software as a Service
- IaaS – Infrastructure as a Service
- PaaS – Platform as a Service

Software as a Service is probably the most common use for Cloud Computing. A company will run Cloud-based software similar (or identical) to a premise-based, boxed software solution. Some advantages of SaaS are

- No expensive hardware (server) needed to run the program
- No updates or patches to maintain
- Easier support
- Equal fixed monthly costs

SaaS works well for software applications you use all the time. You pay monthly (or annually) whether you use the product or not. On the downside, there are applications I use only a couple of times a year. It is tough to justify paying for them each month over and over. For these types of applications, I found the alternative open source or "buy once" substitutes.

Infrastructure as a Service – IaaS is using hosted hardware, usually virtualized, running in a datacenter to conduct business. If physical (not virtualized) hardware is used or needed, it is usually purchased and co-located in a datacenter to be used like IaaS. IaaS is a suitable alternative for most on-premise computing functions that can be virtualized.

Closely related to IaaS is Desktops as a Service (DaaS). With DaaS, a host vendor provides access to virtual desktops (VDI) from a Public or Private Cloud. DaaS can take the place of your local PC or workstation or supplement them. Instead of buying a computer for each employee, you can buy a cheap connection device (thin client) and provide access to a virtual desktop running in a datacenter to handle all your Desktop computing needs.

Platform as a Service is the least used of these three types of Cloud Computing. Businesses will deploy applications using programming languages, libraries, services, and tools managed and maintained by a hosting provider. The end user does not manage or control the underlying Cloud infrastructure but controls the deployed applications running on the Cloud Platform.

WHAT IS PRIVATE CLOUD COMPUTING AND HOW IS IT DIFFERENT FROM THE PUBLIC CLOUD COMPUTING?

There are many companies offering services over the public Internet; these are public Cloud providers. I am sure you are familiar with many of them, from social networking sites like Twitter and Facebook to strictly business applications like Office 365 and Salesforce CRM.

A Private Cloud solution is also accessed over the Internet or a dedicated private circuit. In contrast, a private Cloud usually connects two locations, the customer and the provider, and is housed in a private datacenter. A Private Cloud is generally dedicated to a single company. A Private Cloud can take the place of premised based servers and desktops. You can run just about any hardware or software in a Private Cloud. A Private Cloud is generally more flexible and customizable than a Public Cloud. You can run your entire business from a Private Cloud environment, not just a single application.

Most companies use a mix of traditional, Public, and Private Cloud services, a Hybrid Cloud. Keep in mind, with a Hybrid Cloud you must manage multiple Cloud vendors. There is no one best solution, do what makes the most sense for your business. Use the Cloud Services you need to support your business objectives and implement them as needed.

WHY SHOULD I USE CLOUD COMPUTING?

Cycle of Technology

All technology follows an adoption path according to the cycle of technology. With new technology adoption, there is a continuous cycle of value. New Technology provides a *competitive advantage*. As a technology grows older, the competitive advantage eventually diminishes to a point it becomes a *competitive necessity*, everyone has it and needs it and uses it. Finally, for those that continue to use older technology well past its useful life, technology becomes a *competitive disadvantage*. You are losing productivity by using outdated obsolete technology.

Don't spend time, money and effort on technology that doesn't give you a competitive advantage.

> *"Technology has reshaped Industry. Briefly, these technologies provided real advantages. But as their availability increased and their cost decreased, they all became ubiquitous commodities. From a strategic standpoint, they no longer mattered."*
> *– Nicholas Carr*

Conventional Technology has become a commodity and no longer provides a competitive advantage.

Technology is analogous to the electric grid. Companies used to own and maintain their own power generation facilities until they realized it was faster, cheaper and easier to simply buy their power from a utility company. They outsourced power generation. That is exactly what is happening to conventional technology today, it is being outsourced to the Cloud. We outsource many things, you drive a car, you don't build one, some of us don't even make coffee anymore, we outsource it to Starbucks.

There are advantages to outsourcing your technology needs to a Private Cloud Computing Provider.

- There are great "economies of scale", especially in a multi-tenant environment. This can lead to lower costs.
- Business Critical Applications are being 'Cloud Enabled' at a rapid pace. You can run your entire business from the Cloud.

- Well managed datacenters offer greater flexibility to expand and contract quickly and offer services that are less expensive to rent rather than to own.
- You can focus on Business, not IT. Cloud Computing provides stable IT spending.
- You pay for ONLY what you use. You plan for today's needs and scale up later as your needs grow. You don't pay for extra capacity you don't need today or may never need.
- Cloud Computing is infinitely scalable – not only can you easily scale up, but you can *scale down* as well. This is one of the most powerful advantages of Cloud computing. The ability to shrink as well as grow. You cannot do this with physical hardware. You buy it, you own it.
- Because it is multi-tenant, you can use Enterprise class hardware at a Small Business price.

WHY CLOUD COMPUTING NOW?

Source: Gartner 2014 [https://www.gartner.com/newsroom/id/2819918]

This chart is the 2014 Gartner Hype Cycle for Emerging technologies. We have been talking about the Cloud for several years. Why Cloud Computing now, what has changed?

- Bandwidth costs are still falling.

- Most major business functions have moved to the Cloud.
- You can run your entire business from the Cloud.

The hype is over, and Cloud Computing is ready for prime time.

According to the Gartner 2014 Hype Cycle, Cloud Computing will reach the Plateau of Productivity (mainstream adoption) by 2016-2019. Cloud Computing is poised to be the driving force for business productivity. It is here now and ready to use.

IS MY DATA SAFE IN THE CLOUD?

Is your data safe in your office? What happens if your data is in your physical office and there is a fire/flood/hurricane (Sandy)? If you're worried about risk, buy insurance to protect against risk. Cloud computing has a lot of insurance built in.

- Your data is housed using redundant hardware. The hardware is designed to be risk tolerant. In most cases, you would not even notice a datacenter hardware failure.
- Your data is backed up at least daily, probably more often, and you can go back and retrieve any deleted files and projects.
- Your data is replicated to multiple datacenters (geo-redundant).
- Cloud computing providers are in the business of keeping their client's data protected. Their systems and practices are more redundant and more secure than 99% of businesses doing it themselves.

HOW DO I USE THE CLOUD TO GAIN A COMPETITIVE ADVANTAGE?

Using the Cloud – Infrastructure as a Service / Desktops as a Service

Running your entire IT infrastructure including your desktops in the Cloud is a new way to think about technology. The future is using connected devices. You can run almost any application, perform almost any task in the Cloud. Software and hardware as we think of it today is going away. The Cloud is the future in desktop computing, delivered as a service.

Using the Cloud – Infrastructure as a Service / Servers and Networks

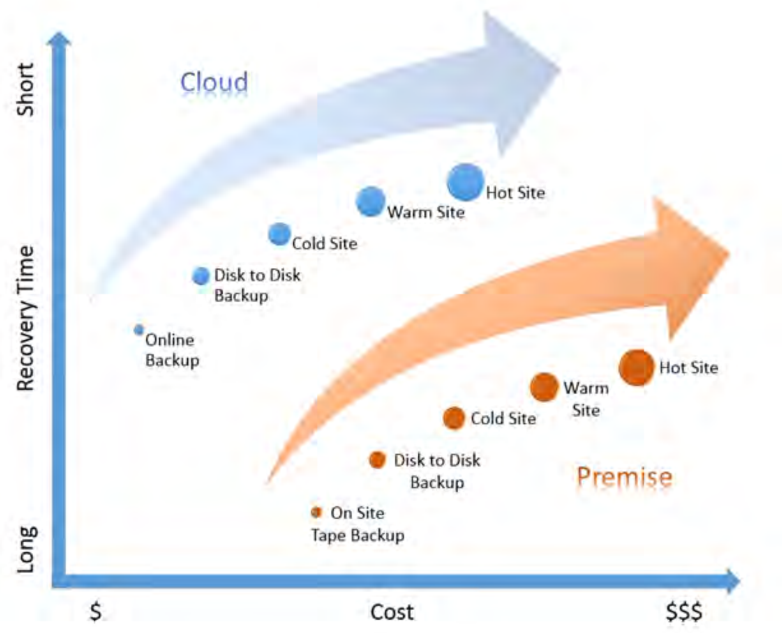
You can run your entire IT Infrastructure in the Cloud. You can run servers in the Cloud, switches, your entire network. Using Cloud Computing you don't need premise-based servers or PCs any longer, you can connect to the Cloud Infrastructure using thin clients. Thin clients are small cheap connection devices that don't break or wear out. You can eliminate nearly all your on-premise IT equipment.

Using the Cloud – Online Backup

You back up your files, right? Backup is a critical IT function. Unfortunately, everyone has a backup horror story. The best practice for backup is to copy your backup offsite. You should always have three copies of your data, the original, a local on-premise copy, and a copy offsite.

Whether you use tape, CD, or disk backup you need to get those backups OFFSITE. Backups are useless if they are destroyed along with the rest of your office. Cloud backup is a perfect way to easily get backups offsite. Obviously, if your whole IT infrastructure is already in Cloud then you don't have any local data to back up.

To back up to the Cloud is easy, you install backup software onto the local hardware and it periodically and automatically copies your data to the Cloud.



Disaster Recovery Options Compared

Using the Cloud – Disaster Recovery and Business Continuity

The Ultimate Disaster Recovery (DR) solution is a Hot Site hosted in the Cloud. A Hot Site completely replicates all your on-premise hardware and data in the Cloud. It is ready to use and updated continuously. It is also less expensive than a premise-based DR solution.

We had clients in New York who lost everything when Hurricane Sandy hit. Their office buildings were closed, the power was out, but their technology was working and safe in the Cloud datacenter. They just worked from home until their office was usable again. They did not experience any downtime or a single problem. When things returned to normal, they moved back to their office and resumed work without missing a beat.

Using the Cloud – Consolidation / Centralization

For a company with multiple locations, it is easy to see how the Cloud changes the game. If you have three locations, chances are, you have 3 times the hardware and probably a lot of duplicate data. Scale this up, 5 locations, 10 locations, 100 locations. The numbers get big very quickly. A business can consolidate and greatly reduce the amount of hardware used to support their business.

Not only can a business reduce costs, but also complexity. By moving from distributed IT to centralized IT in the Cloud, a business reduces the amount of hardware needed while increasing hardware utilization. The savings are evident, by reducing the amount of hardware and maintenance, you reduce costs.

Using the Cloud – Cloud Collaboration Hub

Working on a big project with other firms? You can store all your project data in the Cloud and make it available to each firm. A Cloud Collaboration Hub allows multiple firms to work in real time on shared projects. This is accomplished using secure private connections to a Cloud Workspace hosted in a datacenter. This type of collaboration creates a robust and secure environment and allows firms to work together while keeping their intellectual property safe and secured.

Benefits of the Cloud Collaboration Hub:

- Privacy and security of Intellectual Property.
- Real-Time Collaboration and file sharing
- Reduced project “latency”, improved project productivity.
- Accelerated project information visibility
- Mobility, accessible from anywhere

Using the Cloud – Hosted Phones

Fire the phone company. You can have your phone system in the Cloud. You can save real money by moving your phone system to Cloud. In addition to saving money, you reduce maintenance costs. Your phone system works over your data connection. Office moves are a breeze, just unplug your phone, take it with you and plug it in at your new office and you are ready to go. You are completely location independent. A hosted phone system has all the typical phone options found in a premise PBX, call forwarding, find me follow me, voicemail, all features of a PBX without a PBX. The sound is HD quality. Your voicemail and faxes can be sent directly to email.

With hosted phones you have Built-in Business Continuity – if your Office is closed for a week, you can work from anywhere, take your phone with you or use a full-featured mobile phone app. Are you on the phone all day? You can use a softphone running on a PC and a headset to manage all your calls, you don't need to buy phone handsets or wireless headsets.

Communication as a Service – You have free 4-digit dialing between all your offices, there are no charges between locations on the same system. Incoming calls are free as well. You only pay for outgoing and long distance but the price per minute is very competitive and you can buy prepaid minutes to save even more.

Using the Cloud – Hosted email / Office

Is there anyone who does not use Cloud-based email for your personal email? When it comes to email, individuals are ahead of business. Today, there is little reason why any business should be running their own email servers and managing their own email. Using Office 365 or G Suite, you have business productivity applications bundled with business email at a very competitive price. These are very compelling reasons to move your business applications and email to the Cloud without any downside. In most cases, you can reduce costs as well.

Using the Cloud – Helpdesk

Remote assistance technologies and the ability to time shift make Helpdesk an easy fit for the Cloud. You can get Helpdesk support from a Cloud-Based Provider 24/7/365. Outsourcing your helpdesk is an easy and low-risk way to move to the Cloud.

Using the Cloud – Mobility

Using the Cloud, you have complete mobility, connect from any device, from anywhere you have a data connection. (which is almost everywhere these days) Work sharing, hoteling and job sharing are all enabled by increased mobility.

But my boss says, "No way I am going to let my employees work from home!"

There have been numerous studies about telecommuting that show productivity increases the more mobile the workforce. Increased Mobility and Cloud Computing also support Bring Your Own Device (BYOD) and Choose Your Own Device (CYOD) further reducing IT expenses.

Using the Cloud – Software as a Service – SaaS

Run your software from the Cloud. Virtually any software that runs on a desktop will run on a Virtualized Cloud Desktop. Many major business applications now offer Cloud options. SaaS allows you to stabilize your software cost. You can increase and *decrease* the number of seats of each application. You reduce maintenance costs and are always running the latest version. You run your application from anywhere you have data connectivity. SaaS makes you more mobile and flexible.

Using the Cloud – Video Conferencing / Web Conferencing

Video conferencing works great for small meetings, up to 25 participants. There are several Cloud-based Video / Web Conferencing applications available. They offer many options for video, they interface with phone systems for participants that don't have access to a web camera. Video conferencing works very well for smaller meetings up to about 25 participants. If you have more than 25 users, the advantage of seeing the participants gets lost in the quantity/quality of the interaction. But for small team meetings, it is ideal. You get more face time with your clients.

Using the Cloud – Hosted wireless

The Cloud is great for hosting wireless, centralized management of wireless resources. With the Cloud, you have one place to control and manage content, security, and access.

HOW IS THE CLOUD TRANSFORMING WORK?

Sustainability

The Cloud reduces the need for non-renewable energy. When businesses move IT from on-site facilities to consolidated Cloud datacenters, it saves energy and cuts pollution — just as relying on power companies is better for the environment than if everyone ran their own power plant.

As a vendor, we also make sure our datacenters are running as green as possible. We use renewable green energy sources – hydroelectric power and passive cooling whenever possible.

Innovation

Cloud-based collaboration drives Innovation. Innovation creates a competitive advantage. The Cloud supports and promotes collaboration.

Data Storage needs are growing exponentially

As bandwidth improves more centralization is possible. Data Centralization reduces the need to duplicate data in multiple locations. It also allows you to deduplicate and reduce the total amount of storage needed. And storage in the cloud is infinitely scalable. (practically speaking)

Mobility – Remote access

Work from anywhere –home, hotel, airplane, client office, anywhere you have an Internet connection which is almost everywhere. Connect using any device, Smartphones, Android, IOS, Macs, PCs. You are device independent.

Security

With security, the key is to assess risk. Are premise-based computers, networks and servers better protected than Cloud-based assets? In most cases, the answer is no. Cloud Providers invest far more on security than the average business can, it is their business. But what about Government / Cloud Provider snooping? Make sure you read and understand Privacy Policies and insist on absolute privacy for your business data. You will have more flexibility and more privacy using a Private Cloud rather than a Public Cloud. For example, as a Private Cloud Provider, we will not allow government access to your data without informing you first and not without proper legal authority. Your data belongs to you. Period.

Budget

Using the Cloud must make sense from a financial point of view. What is the return on your investment? Many factors affect your ROI, download our free white paper to determine your Cloud ROI. We'd love to have an opportunity to help you save money.

HOW DO I CHOOSE A CLOUD PROVIDER?

Ask a potential Cloud Provider these questions:

- Mature Services Offering – Are they "Full Service" or do you need to do most of the work?
- Data Center Operations Excellence – Do they own/operate their own Data Center?
- Committed Ownership – will they be around in years to come?

- Geographical reach – Can they service all my locations?
- Internal Engineering Expertise – Do they have the right people with the right knowledge?
- Established Client Base – Are they a healthy organization? Financially stable?

Assess

What is the next step after you have chosen a provider? This first step is assessing your needs. What are your needs? Where are you today? Where do you want to be? A good Cloud Provider can help you develop an assessment.

An Assessment is a deep dive into the current state of your technology with specific recommendations on improving your IT Infrastructure and Operations. Remember your Technology Initiatives must align and support your Business Goals.

Identify Gaps

During this assessment, look at all aspects of your technology and your business and identify ways to improve productivity, save money and protect your business.

Recommendations

Next, identify specific recommendations to improve your technology. Create a plan for improving PCs, your network, network servers, security, backups, email, wireless, printing, all things technology related.

Also, consider how you can *use* technology to build your business.

Implementation

Once you have identified your initiatives, meet with your Cloud Provider and develop a plan for implementation. The plan takes into consideration your priorities, your time and your budget. Prioritize and budget and then develop a schedule to get it done. The faster you can implement, the faster you can realize the benefits and savings afforded by moving to the Cloud.

Service and Support

Finally, make sure you have on-going support. No technology is 100% foolproof, you will need help at some point.

Advance2000 provides a 24 / 7 /365 Help Desk and can provide your staff with any type of IT Support. We offer 4 different levels of support from Basic Support all the way up to full Managed IT services. You determine how much support you need and then buy what you need. We also provide Full Turnkey Support whether you are hosted in Cloud or still using equipment in your office.

SOUNDS GREAT, HOW DO I GET STARTED IN THE CLOUD?

We'll leave you with **ONE BIG IDEA**. Centralizing and Outsourcing your Technology is called the "Cloud".

Cloud = Scalability, Mobility, Agility and Speed

Is there anything you could do better in the Cloud?

- Identify your Business Objectives; is your technology supporting those objectives?
- Are you using old outdated technology?
- Is your technology putting your company at a Competitive Disadvantage?

Cloud Computing can help.

What's next? Do you have questions? Contact us today. [http://www.advance2000.com/contact-us/]

[http://www.advance2000.com/it-strategy-assessment/]

Tags: digital transformation, technology

Share this entry

You might also like

Technology in Construction Benefits

Technolog in Constructi Benefits

9 Digital Transformation Statistics That Every Business Should Know

9 Digital Transformation Statistics That Every Business Should Know

Your School Connected: E-Rate Updates for 2019

Your School Connected: E-Rate Updates for 2019

0

REPLIES

BUSINESS NEWS DAILY
Small Business Solutions & Inspiration

Build Your Career » Home Office

Communication Technology and Inclusion Will Shape the Future of Remote Work

By Sammi Caramela, Writer *December 27, 2018 06:00 pm EST*

Credit: Alex Brylov/Shutterstock

Right now, I'm sitting on my couch sipping freshly brewed coffee and enjoying a bowl of oatmeal. My house is warm, my clothes are comfortable and casual, and – oh yeah – I'm working at my full-time job.

A decade ago, this setup was far less common. Most employers would have balked at the idea of employees regularly working from home.

This might still be the case for some companies, but with today's emerging tech and inclusive culture, we have much more flexibility. Some businesses have fully remote teams, while many others allow their employees to work remotely at least once a week. This arrangement is only expected to grow.

How remote work has evolved

There was a time when working from home as the modern workforce knows it wasn't even a possibility. If your colleagues and business partners wanted to get in touch with you when you were out of the office, they couldn't email, text or instant-message you. You would've needed to provide an alternate phone number (or pager or fax number) and communicate that way. And full-time "remote" positions were different from what they are today.

"Ten years ago, remote employment basically meant a telemarketing or customer service position at below minimum wage," said Samantha Lambert, director of human resources at website design company Blue Fountain Media. "It rarely was connected with a full-time career. Now, technology affords us the ability to get the same job done, no matter where in the world we are. [It has] enabled us to be in contact with co-workers or clients at any time."

One of the most helpful technologies for seamless remote work is videoconferencing. Live video feeds help out-of-office workers see and speak to one another in real time, anywhere they are, which is the next best thing to a face-to-face meeting. But this capability wouldn't be possible without the widespread broadband internet adoption of the past 10 to 15 years.

Certain companies have even done away with renting a traditional office and instead run their business out of a shared coworking space to accommodate their largely remote workforce.

"Shared office spaces, where remote employees can gather to work, have been created and are more widely available in different cities," Lambert said. "This in itself represents the growing amount of remote workers in recent years."

The current state of remote work

Because of these advances in communication technology and internet access, teleworking has become a fairly accepted practice in many offices, both in the U.S. and globally. This type of work isn't done entirely from home either. Remote workers turn to coffee shops or coworking spaces, and some even travel the world while maintaining their career goals.

"The modern workforce is increasingly mobile, collaborative [and] dynamic, and comprises multi-generations, all with differing communication preferences," said Stacey Epstein, CEO of Zinc. "These workers span multiple industries … all who represent unique challenges when it comes to staying connected while on the job."

However, we are still seeing some resistance from companies across the board. Many are unwilling to adapt to this arrangement, while others allow remote work just once or twice a week, or as an exception for a few employees.

Additionally, according to a survey by Buffer on remote work, 78 percent of remote workers said their companies don't cover internet costs, and 76 percent don't pay for coworking spaces for their employees.

On the other hand, this saves companies money while allowing workers the freedom to create their own schedules and work from wherever they please. It can be a win-win situation.

What the future holds

FastCompany predicts that, as the workforce becomes more progressive, virtual tools, like mobile remote-working tools and virtual reality conferencing, will become the preferred form of communication – even over face-to-face meetings.AI will also likely play a major role in managing remote staff.

Keeping these advancements in mind might put companies at ease. The transition into managing a remote workforce can seem daunting, but with the right tech and hardworking employees, it can be a seamless process – and fighting the change may do more harm than good.

Many employees now expect remote work opportunities. In fact, according to Buffer, 90 percent of current remote workers plan on working remotely for the rest of their careers. Because of this increasingly popular trend, some refuse to accept an onsite position, knowing they can find a more convenient and flexible gig elsewhere.

Current organizations should instead make improvements to their remote work policies and capabilities. If a company is concerned about productivity and performance issues associated with a companywide ability to work from home, Lambert recommends creating standard key performance indicators (KPIs) for both management and employees. This way, she said, remote team members are aware of expectations, and their performance can be monitored.

Additional reporting by Nicole Fallon. Some source interviews were conducted for a previous version of this article.

Sammi Caramela

Sammi Caramela has always loved words. When she isn't working as a Business.com and Business News Daily staff writer, she's writing (and furiously editing) her first novel, reading a YA book with a third cup of coffee, or attending local pop-punk concerts. Sammi loves hearing from readers - so don't hesitate to reach out! Check out her short stories in Night Light: Haunted Tales of Terror, which is sold on Amazon.

YOU MAY ALSO LIKE

5 Issues Your Company's Telecommuting Policy Should Address

Choosing a Business Phone System: A Buyer's Guide

Choosing a Video Conferencing Service: A Buyer's Guide

PRODUCT AND SERVICE REVIEWS

Best Recruiting Software for Small Business

Best Call Centers and Answering Services for Businesses in 2019

Best Document Management Software and Systems 2019

BUILD-YOUR-CAREER | SEE ALL »

5 Issues Your Company's Telecommuting Policy Should Address

Choosing a Business Phone System: A Buyer's Guide

Support Your Employees by Creating a Family-Friendly Workplace

Choosing a Video Conferencing Service: A Buyer's Guide

101 Reasons Being an Entrepreneur Rocks

200 Fifth Avenue, Second Floor
Waltham, MA 02451
info@businessnewsdaily.com

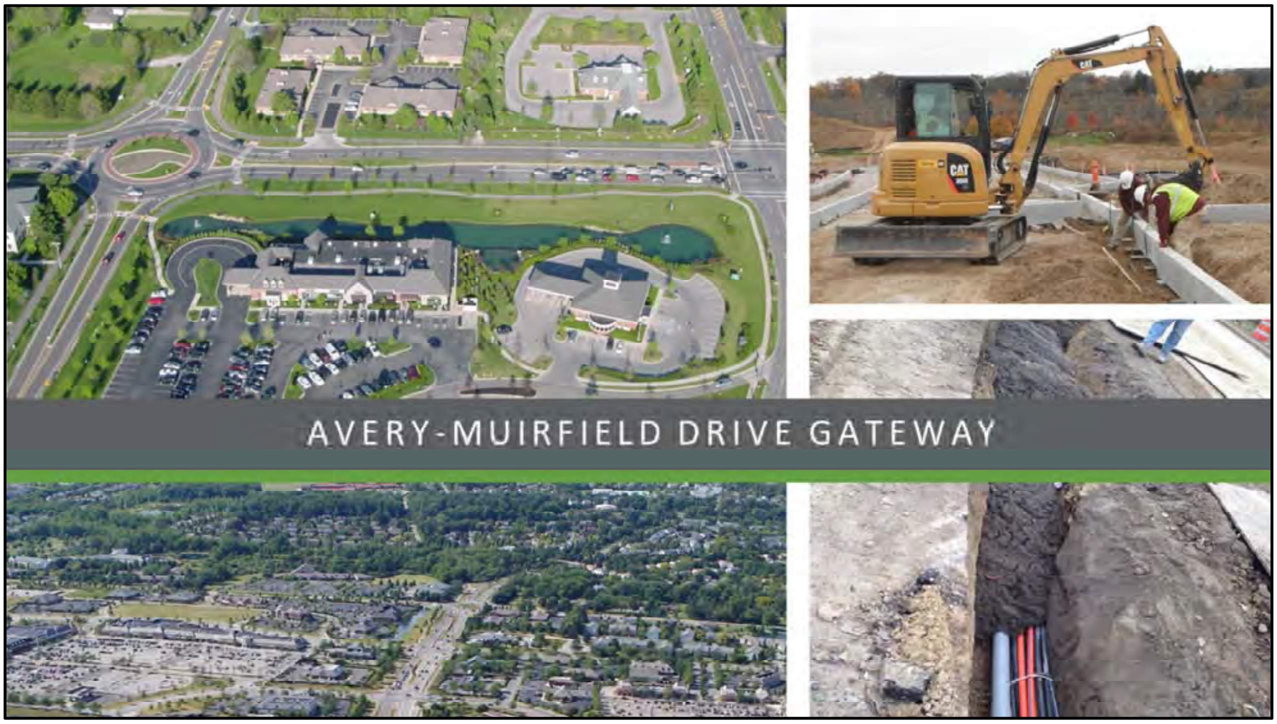
Thank you for inviting me to share with you information about Dublink, Dublin's 100 gigabit fiber network. Dublink moves more data, cheaper and more efficiently, than almost any other broadband technology. Dublink has evolved into a three-pronged strategy that I will share with you today.

In Dublin, we like to think we're smart. We make opportunities, then we seize them. That's how we've become the intelligent, innovative and connected community we are today. Today I'm going to tell you our Dublink story, which has made Dublin more "connected" than most cities across the US – and around the globe.

First, a little about Dublin. Dublin is a suburb just northwest of Columbus, Ohio. We have 45,000 residents, 3,000 businesses, and a daytime/business population of 70,000.

Dublin sits on about 24 sq. miles.

We are a corporate headquarters community and home to the 2014 President's Cup.

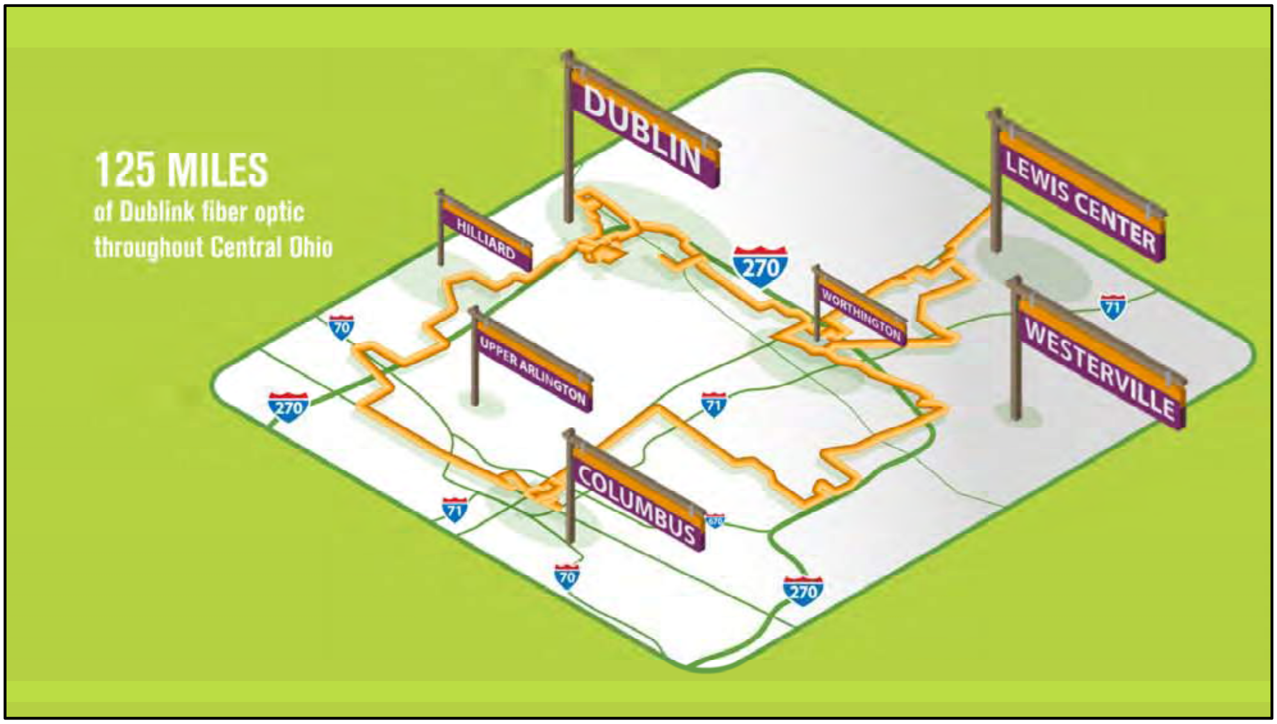


We started deploying our own fiber network in the mid-nineties. It was for a very pragmatic reason: **To preserve right of way**.

We were building beautiful new boulevards as attractive gateways to our community, only to have them ripped up as the telecommunication carriers laid new lines. We wanted to have more control over what was going into our right of way – and when.

By owning and installing our own conduit and fiber we could still enable multiple competitors to serve their customers. But they would have to do it by hooking into the large conduit we installed in our own right of way – instead of burying who knows how many fiber lines.

This allowed us to minimize road construction headaches for our customers – but also presented an opportunity: a redundant, robust broadband service we could provide to companies interested in locating here.



Today we have 125+ miles of at least 96-count Dublink fiber, which is nearly 100% underground conduit shown here in orange. This extensive network connects to 10+ data centers.

We read about other cities that plan to do this or that.

We're unique: we are already doing it, and <u>have</u> been for more than two decades.

Dublink is a three-pronged strategy.

We own and share services. The City uses fiber connectivity for its own purposes – from providing high speed data access to our employees to sharing public safety services with other municipalities. This lowers our own costs and lowers costs for our neighbors, too.

We generate revenue. We lease “dark” fiber to companies – this is basically the pipe that gives companies access to the various telecommunications competitors.

We leverage Dublink for strategic economic development. We give away “dark” and “lit” fiber to retain and attract new companies and jobs. “Lit” fiber means there is full broadband connectivity – data is being transmitted.

Here's an example. We established the Central Ohio Research Network -- or CORN -- in partnership with the Ohio Academic Resource Network (OARNet) in **2005.**

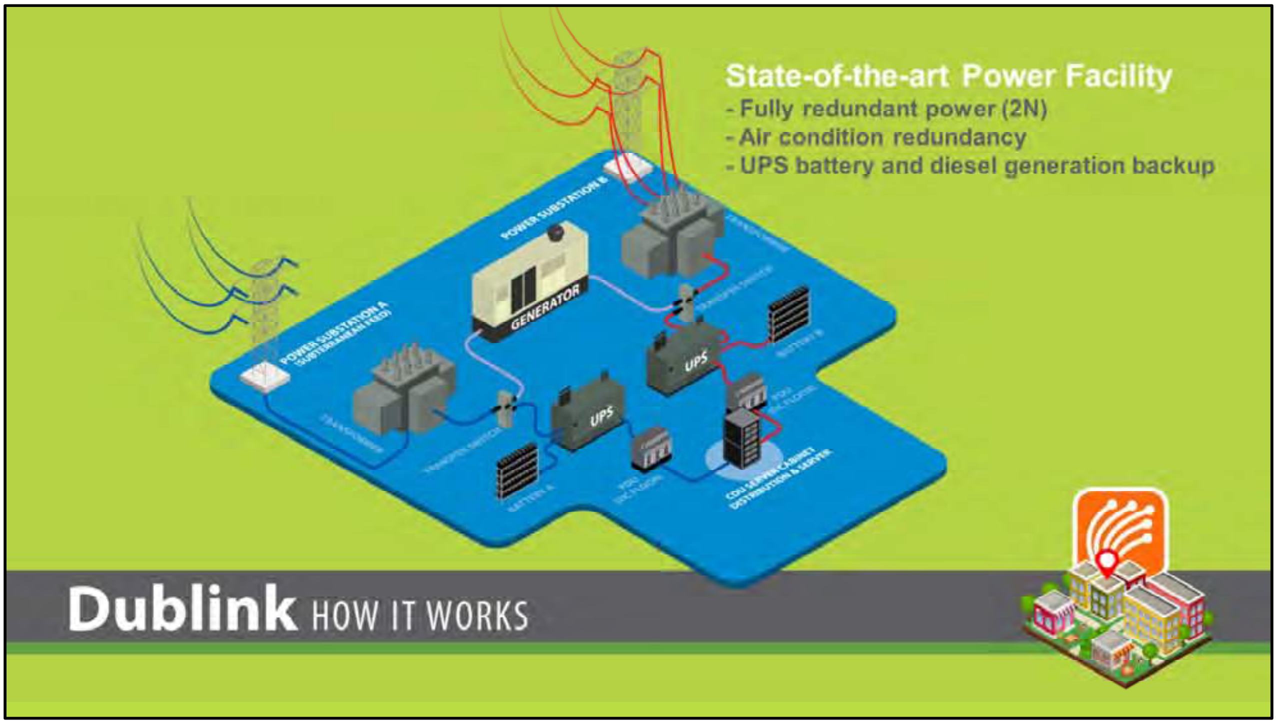
The City of Dublin **gave** OARNet 4 fibers on the 125-mile Dublink footprint, including all the data centers, businesses and carriers. OARNet connected the fiber to its 100-Gig backbone and internet2. This has resulted in a great, long-term partnership.

The CORN network gives our companies access to university campuses, research institutions in Ohio and beyond, and federal laboratories – or infinite knowledge at their fingertips.

Another strategic economic development investment is Dublink Transport, where we **are giving away access** to 100 gigabits of fiber to companies in one of our City's Legacy Office Parks. Called the Metro Office District, there is approximately 7 million square feet of commercial office space that was built in the 1980s and 1990s. By offering companies located here access to Dublink for free, these aging buildings can compete with newer buildings throughout Dublin and the region.

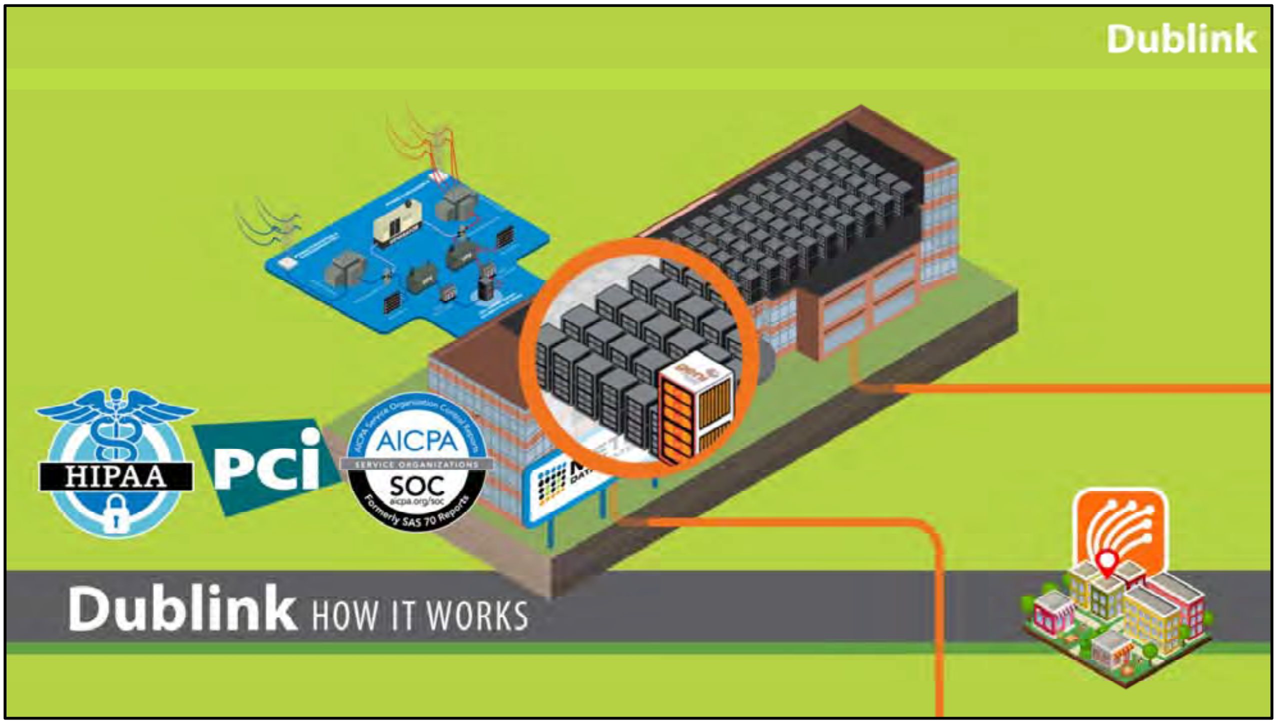
The City of Dublin built the fiber pipeline from each building to the Metro Data Center, located in the Metro Office District. From there, companies have access to 13 internet carriers without having to pay for the transport infrastructure. These options give companies negotiating power to get the most competitive price for the highest quality internet, billed monthly by the carrier.

Let me tell you a little more about the Metro Data Center and how Dublink Transport works.



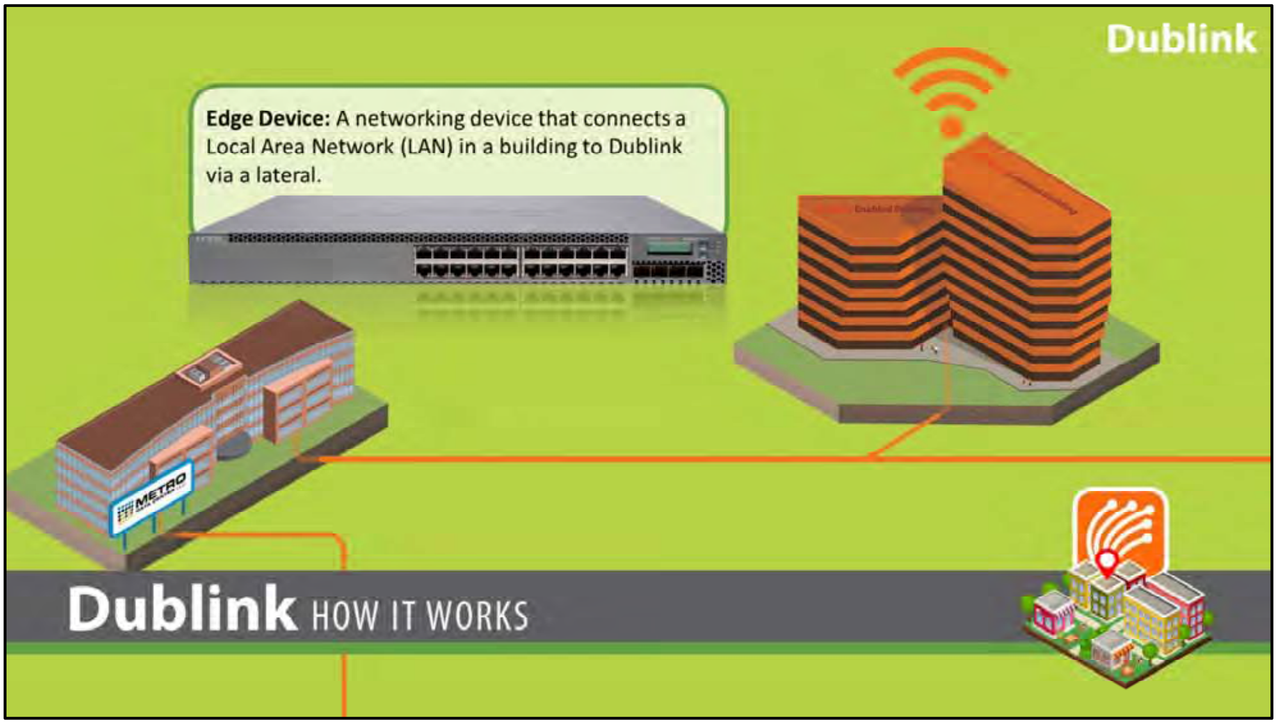
The Metro Data Center is a state-of-the-art data center with electric & air conditioning redundancy and multiple back-ups.

There are 2 different power substations that feed into the data center and also connect the 125+ miles of Dublink 100 gigabit fiber throughout Central Ohio. This provides redundant power feeds. There are also dual UPS subsystems with 10 hours of battery backup and a diesel generator capable of 36 hours of sustained power.



The Metro Data Center provides cold row containments cabinets to house the Dublink network racks. This highly secured data center provides customers with full hand scan biometric security, recorded surveillance, 24/7 client access and fire suppression.

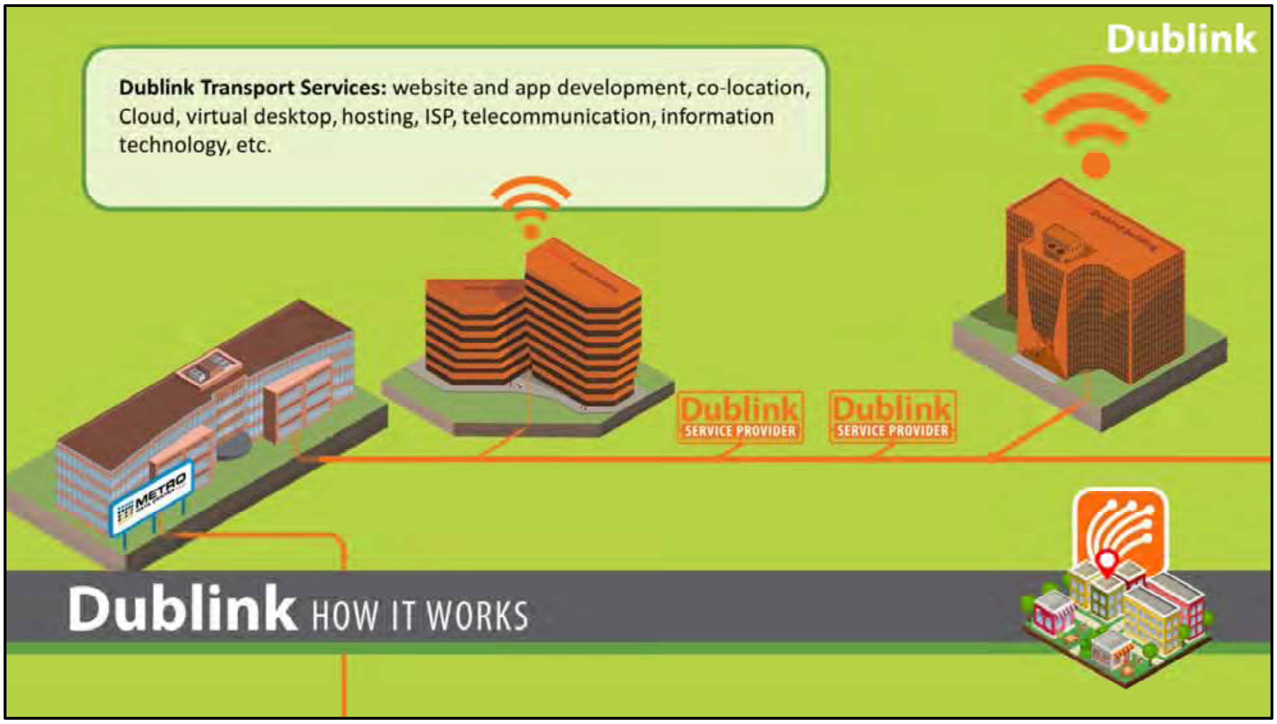
Additionally, Metro Data Center has a GENI (pronounced “Genie”) rack which enables access to Internet2.



Dublink Transport is the lateral pipe that runs from the street into the building. This is paid for by The City of Dublin. It carries the high-speed data to and from Metro Data Center at no cost to the business owner. Inside the building, the City also provides connectivity through a free "Edge Device" router. Direct Connection in addition to WIFI is possible.

Metro Data Center provides businesses access to 13 internet carriers.

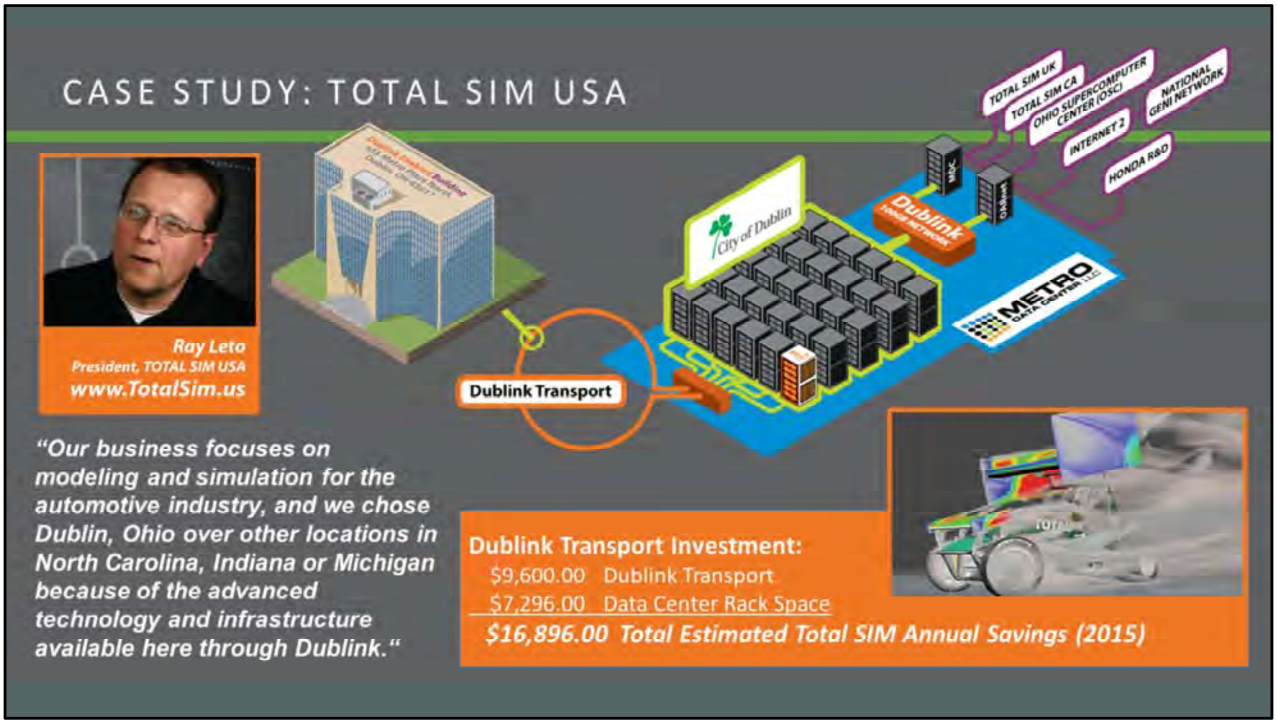
The business owner still has to pay monthly internet fees to a private carrier, but because all those carriers are competing for the business, the business owner has a lot more affordable options.



Throughout the network there are many service providers offering Dublink-connected businesses with support for everything from co-location & Cloud access to brand development and marketing.

Buildings throughout the Metro Business District are being ”Lit” daily. Many other Dublin districts are slated to receive Dublink connectivity soon.

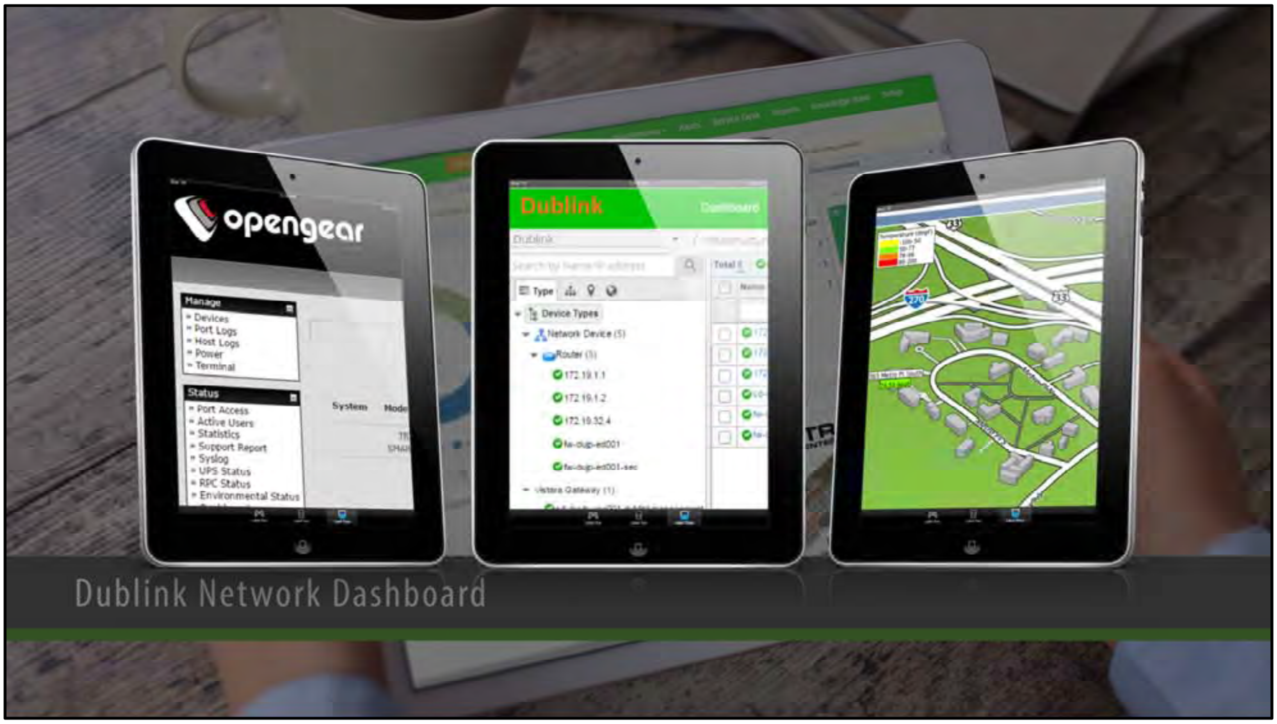
Here are the participating networks and carriers businesses have access to via Dublink Transport in the Metro Office District.



One high-bandwidth tech company is already taking advantage of Dublink Transport.

TOTAL SIM USA is a Computational Fluid Dynamics design team that takes innovative design ideas from initial concept to high-performance reality. The company uses both Dublink Transport and Metro Data Center Rack Space. It accesses OARnet and the data center's GENI rack for its high data consumption modeling and prototyping work. The City of Dublin investment saves Ray's company about $17,000 a year! This is a key reason why TOTAL SIM USA chose to locate in Dublin over locations in North Carolina, Indiana or Michigan.

Most companies today use an average of ½ to 1 gigabit of internet speed to operate. With access to 100 gigabits, TOTAL SIM will be able to grow their use of data for years to come.



The entire Dublink Transport infrastructure is closely monitored with an Intranet Access Dashboard. We can monitor network projects, infrastructure, maintenance, status, provide real time reports and usage and even a weather map overlaying the lit buildings.

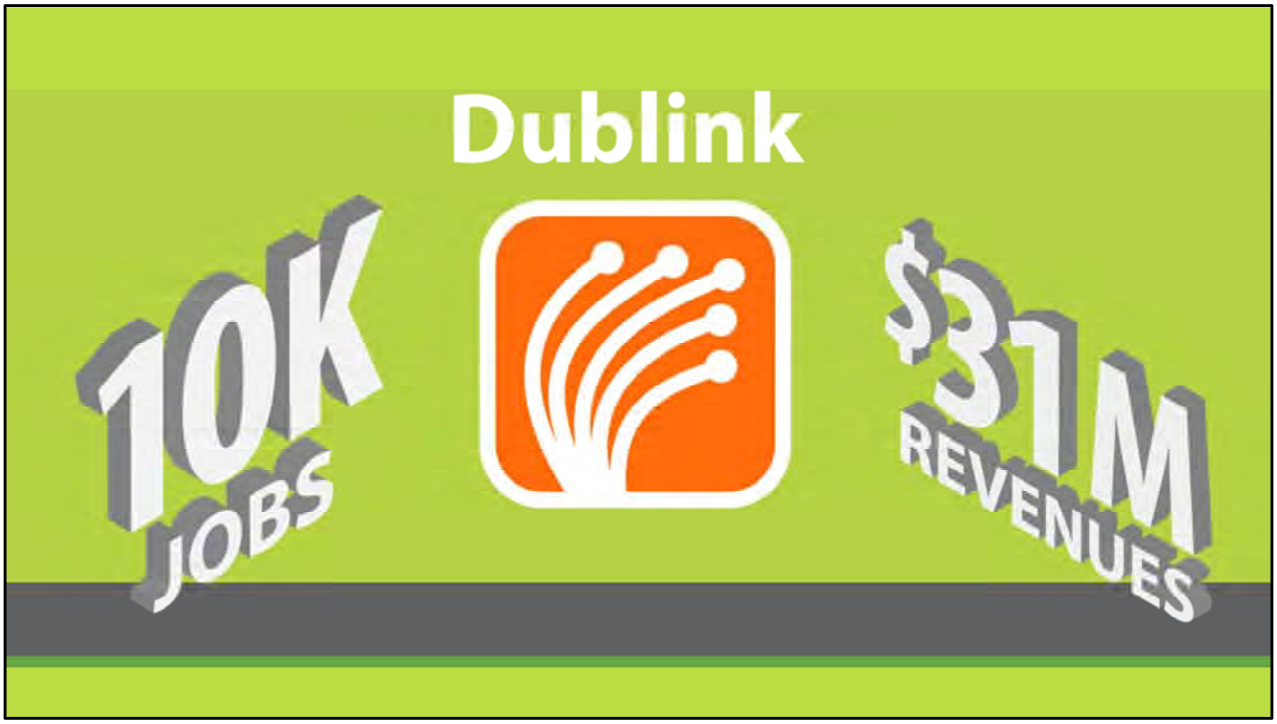
Ohio Health Story

Another example of the City of Dublin using Dublink to retain and attract jobs in Dublin is its partnership with Ohio Health**.** OhioHealth connects hospitals, corporate and business support offices and other medical facilities, data centers and more via Dublink, **which the City of Dublin provided access to for free**. This allows OhioHealth central medical record sharing, conferencing among medical teams, monitoring critical beds from a central location, etc. It allows Dublin to keep a major employer.

In addition to giving access to Dublink away for free to retain and attract new businesses, we also lease Dublink to generate revenue. We lease "dark" fiber to companies – this is basically the pipe that gives companies access to the various telecommunications carriers.

Here are some of the companies that lease or use Dublink. This helps them operate their own network at significantly reduced cost.

The currently leased fiber will generate $2.2 million in revenues for Dublin over the life of the leases.



It’s just an estimate, but we believe Dublink has helped us add nearly 15,000 jobs since we started leasing and giving businesses the right to use the fiber. As for our participating companies currently under executed agreements, we estimate $31 million in revenues to the City through income tax.

Internally, we learned early on the value of running our IT infrastructure over Dublink. By operating our own IT fiber backbone, we've saved $4 million over 10 years. At least.

We also use Dublink to share services with other municipalities for improved public safety:

We share radio systems with Delaware, Worthington and Hilliard, and we are also consolidating 911 public safety dispatch systems – saving us all money.

In the future, we will also interconnect Emergency Operation Centers.

So you've learned how Dublink helps us:

1) Own and share services, 2) generate revenue and 3) leverage Dublink for strategic economic development.

What's next?

We are establishing the Global Institute for the Study of the Intelligent Community to capture best practices and lessons learned with Dublink. This will ensure knowledge capture and knowledge transfer to others around the globe. This raises our Dublin brand and profile, and helps Ohio become more intelligent, too. This positions us and our state to grow.

Connected, Autonomous Vehicles

We will be extending the Dublink 100 gigabit network in the US 33 corridor between Dublin and East Liberty. We will also install 70+ micro-cell devices. Together, these investments will make connected and autonomous – driverless – vehicle testing possible.

This initiative will complement the City of Columbus' Smart Columbus grant application for the $50 million US Department of Transportation Smart Cities grant. These dollars are game changes and will attract even more high tech companies to the region. We are also partnering with OSU Center for Automotive Research, Battelle, Union County and others to pursue other funding and testing opportunities in the US 33 corridor.

This is an exciting time for Dublin and its Central Ohio partners.

Our City Council assumed risk early on but it we are experiencing tremendous payoff. We are promoting competition. We are creating revenues and avoiding costs. We're leveraging our investment to retain and attract businesses. We are being recognized for being intelligent, innovative and connected as one of the smartest cities in the US and the world. And we are going to provide a high speed/high capacity broadband environment for generations to come.

RESIDENTIAL INTERNET PROVIDERS IN DUBLIN

Spectrum

City Coverage 100.0%

Fastest Speed 120 Mbps

CABLE

- 89.99 Mbps is the average speed for Spectrum in Dublin.
- Spectrum has a customer rating of two and a half.
- Spectrum offers 3 plans.

View Plans

AT&T Internet

City Coverage 92.1%

Fastest Speed 100 Mbps

DSL

- Some AT&T Internet plans have data caps.
- Packages from AT&T Internet are DSL.
- 48.76 Mbps is the average speed for AT&T Internet in Dublin.

View Plans

WOW!

City Coverage [illegible]

Fastest Speed 50 Mbps

CABLE

- Existing customers rate WOW! at three out of five stars.
- WOW! speeds are higher than the weighted average by 35.7%.
- Plans do not include data limits.

View Plans

Frontier Communications

City Coverage 12.2%

Fastest Speed 24 Mbps

DSL

- Frontier markets 5 plans.
- Current customers have rated Frontier at two stars out of five.
- Frontier does not leverage data caps in Dublin.

View Plans

AT&T Fiber

City Coverage 7.6%

Fastest Speed 1,000 Mbps

FIBER

- Dublin has 4 plan choices through AT&T Fiber.
- Service by AT&T Fiber is limited to 7.58% of Dublin.
- AT&T Fiber has two and a half stars.

View Plans

FIXED WIRELESS PROVIDERS

BRESCO BROADBAND

City Coverage
80.1%

Fastest Speed
50 Mbps

FIXED WIRELESS

- Bresco Broadband is a fixed wireless broadband provider.

View Plans

SATELLITE INTERNET PROVIDERS

Viasat | exede

City Coverage
100.0%

Fastest Speed
30 Mbps

SATELLITE

- Viasat offers a satellite alternative in Dublin.
- Viasat plans start at $50.

View Plans

HughesNet

City Coverage
100.0%

Fastest Speed
25 Mbps

SATELLITE

- HughesNet packages start at $59.99/month.
- HughesNet sells a satellite alternative in Dublin.

View Plans

Approximately

99%

of Dublin residents are serviced by multiple wired providers.

Surprised? If so, share this on:

This coverage statistic is based on a mix of FCC and private provider reporting in the past two quarters.

Fiber Availability:

8%

of people living in Dublin have residential fiber service available to them.

Surprised? If so, share this on:

Fiber coverage data is sourced from FCC Form 477 filings and cross-validated through BroadbandNow with private datasets and direct provider reporting.

Dublin is the

39th

most connected city in Ohio ahead of Amlin, Hilliard, Lewis Center, Plain City, and Powell.

Surprised? If so, share this on:

The "Connected" metric is a citywide average based on FCC data showing the density of broadband options at the census block level.

As of this month,

43017

Is the zip code with the fastest average download speed in Dublin.

Surprised? If so, share this on:

Zip-based speed averages are calculated from M-Labs consumer speed tests run by IP addresses in the area.

Initial Broadband Survey Findings

Dublin Broadband Consortium Survey

In Cooperation with City of Dublin

12/23/2016

Summary Findings

Initial findings of the survey results distributed to all neighborhoods within the community

Executive Summary

Many have said that the world in the 21st Century has five utilities: gas, electric, water and sewer, telephone and telecommunications. Along with roads, these are necessary to provide the services that residents and businesses in a community require to fully function in the modern world. Telecommunications has been the newcomer, specifically in residential market, over the last 20 years or so since technology has made it much more affordable to have devices in the home, whether computers, tablets or a number of other interconnected devices. These days, it is imperative that the connectivity of these devices advances accordingly. The days of providing dial-up and cable are slowly becoming obsolete as residential consumers require the speeds that broadband connectivity provides for their work and entertainment comparable to their business counterparts in the community. As more people work from home, whether occasionally or primarily, this request becomes much more important.

Executive Summary

Dublin is recognized in the country as a forward thinking community, a true leader and a place where companies and people look to relocate to. Unfortunately, there is a huge problem here with the current residential telecommunications coverage in the city. While businesses have a leading edge alternative by connecting to fiber through Dublink, residents are still stuck in a myriad of service providers with low customer service, low service reliability and a lack of competition. A simple post in the social media site *Nextdoor* late in 2015 provided one of the longest thread ever with hundreds of responses. It caught the attention of the city and triggered a series of events to gather more information, starting with some meet and greet coffees at a local coffee shop. A group of attendees banded together to form the Dublin Broadband Consortium (DBC) whose goal is to find a way to partner with the city in finding short and long-term solutions to these issues. As part of the DBC meetings, the city partnered with the group to provide an opportunity to residents to participate in a survey to measure the current residential telecommunication environment in the city limits. The DBC generated the survey which the city then made available to residents. The survey generated the highest number of responses the city has ever received on any topic, with over 1,300 residents (and even some non-residents) providing feedback.

Executive Summary

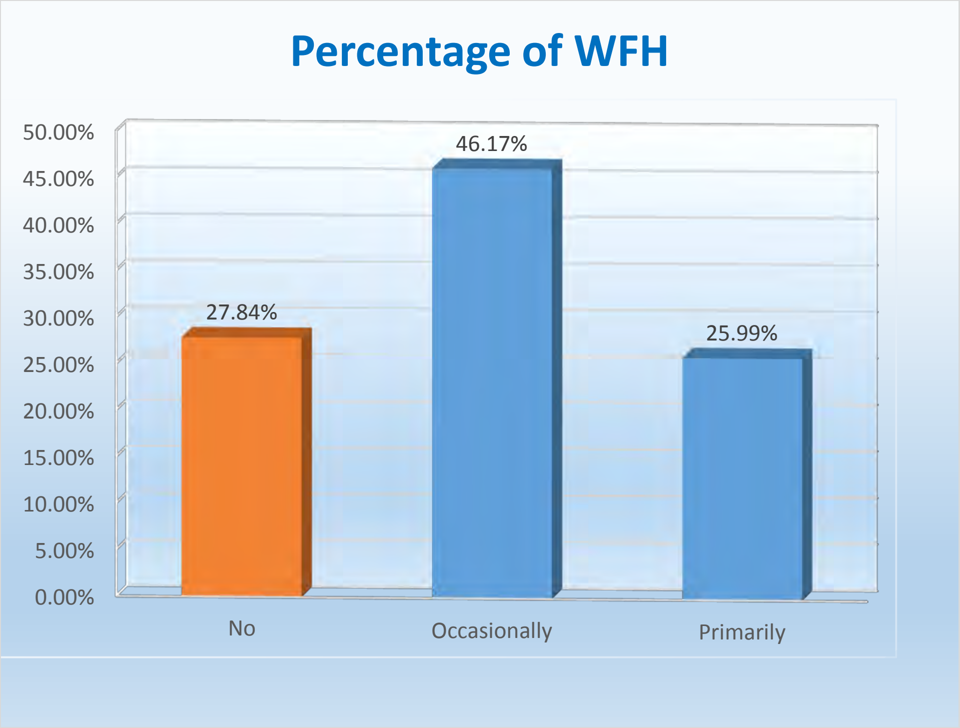
The results of the survey confirm our suspicions. Service quality is generally graded poorly among residents. The attached power point provides the data analysis but the main points is that currently residents are unhappy with the lack of competition (reflected mostly in cost complaints), the reliability of service, and the customer service when calls have to be made to the provider's help desk for technical support. The service provider who has the deepest market penetration consistently has the lowest satisfaction grades, whether being the only provider for a neighborhood or when competing directly with others for service.

Executive Summary

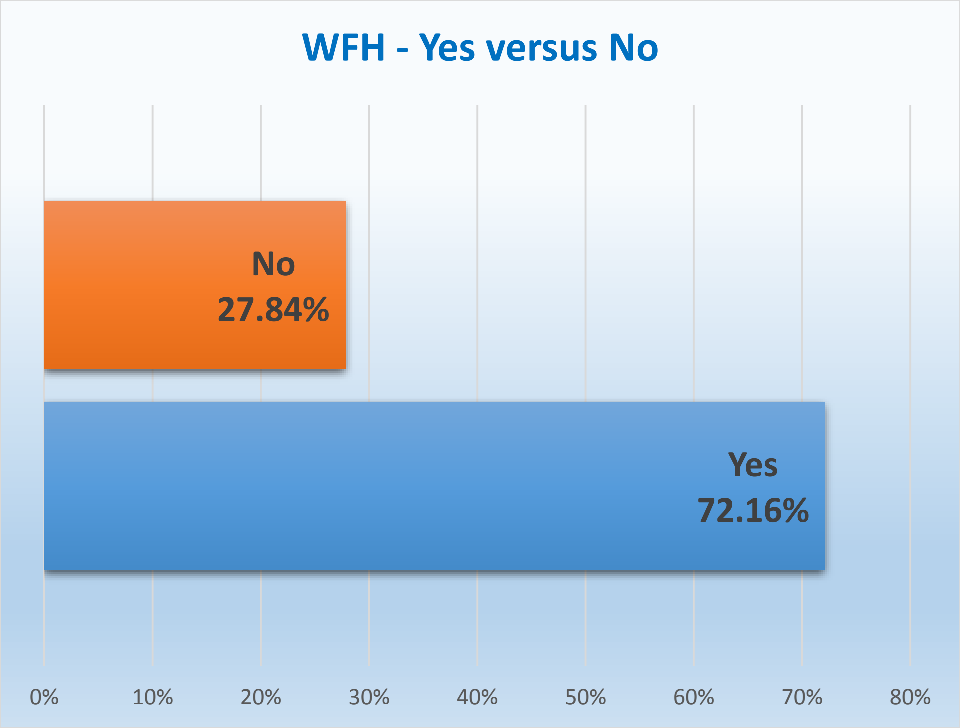
Where do we go from here? The residents, as Dublin taxpayers, demand to be heard. Many struggle with being able to work from home while some even have had to move their work location out of their home to a location outside the city because of the lack of reliable and fast service. In the short-term, we are looking for the city to request from current providers that if they provide services to the city, there should be uniformity of service across the neighborhoods. We need consistent service options so that a resident of one neighborhood doesn't become a second class citizen to his neighbor down the street because of limited competition available to him. In the long-term, we need to partner with the city in finding a viable residential broadband solution. The level of involvement from the city is to be determined but we know we can't get changes done for the benefit of residents without this partnership.

Work From Home Percentages

WFH percentages based upon how often



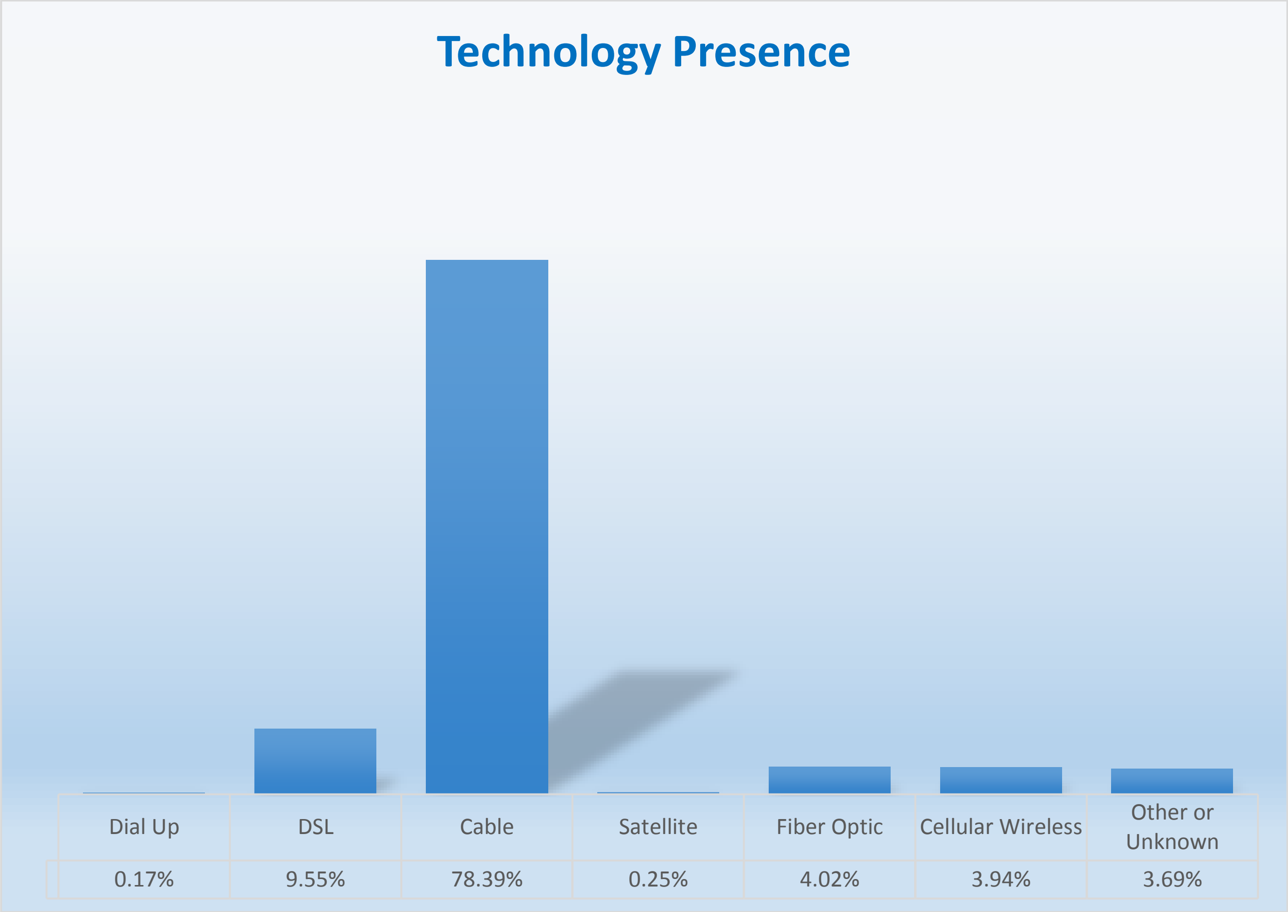
Percentage of WFH anytime



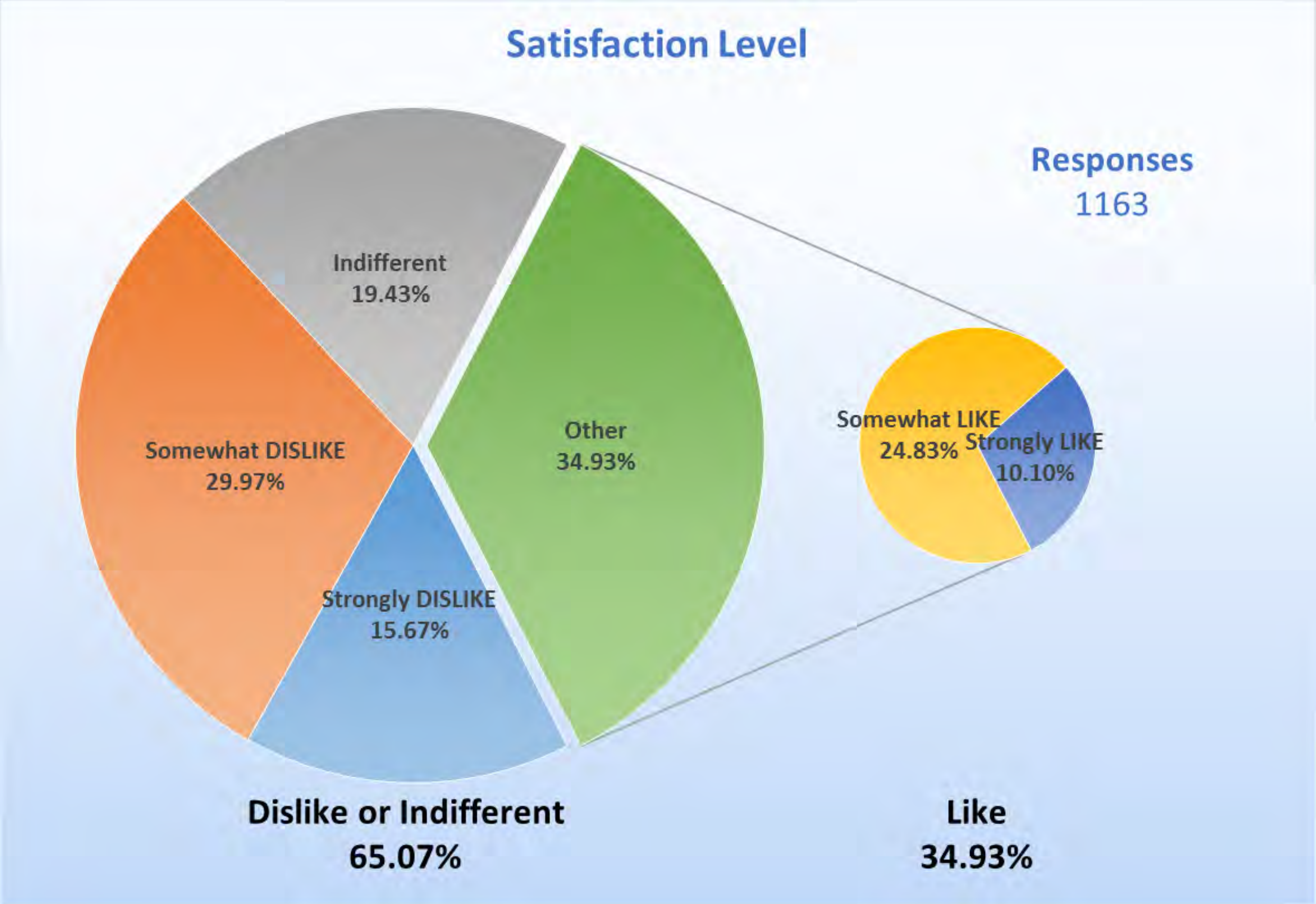
Technology Presence within Community

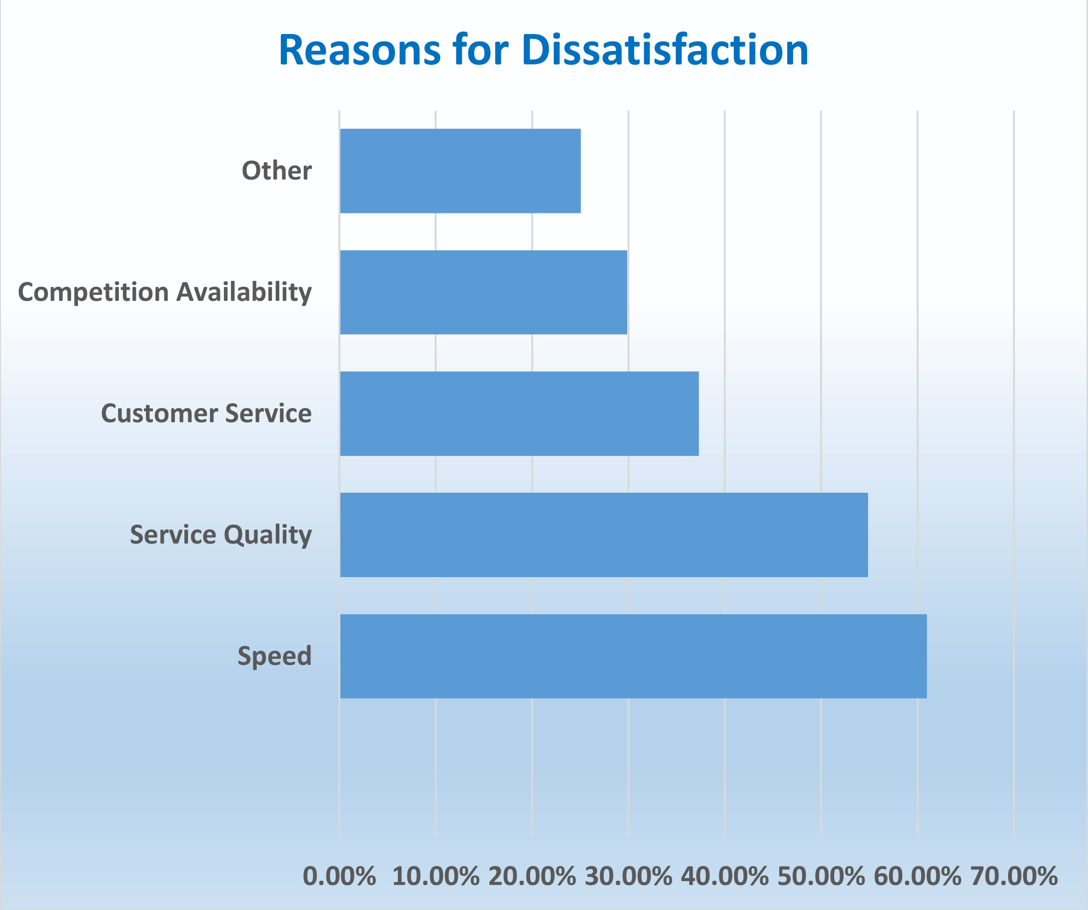
- Technology presence throughout the residential community consist of primarily cable, followed by DSL, both of which are the current standard offerings from ISPs.

- Note that fiber optic is the next leading technology, which is becoming more common in the mainstream, and is considered the next technology to come

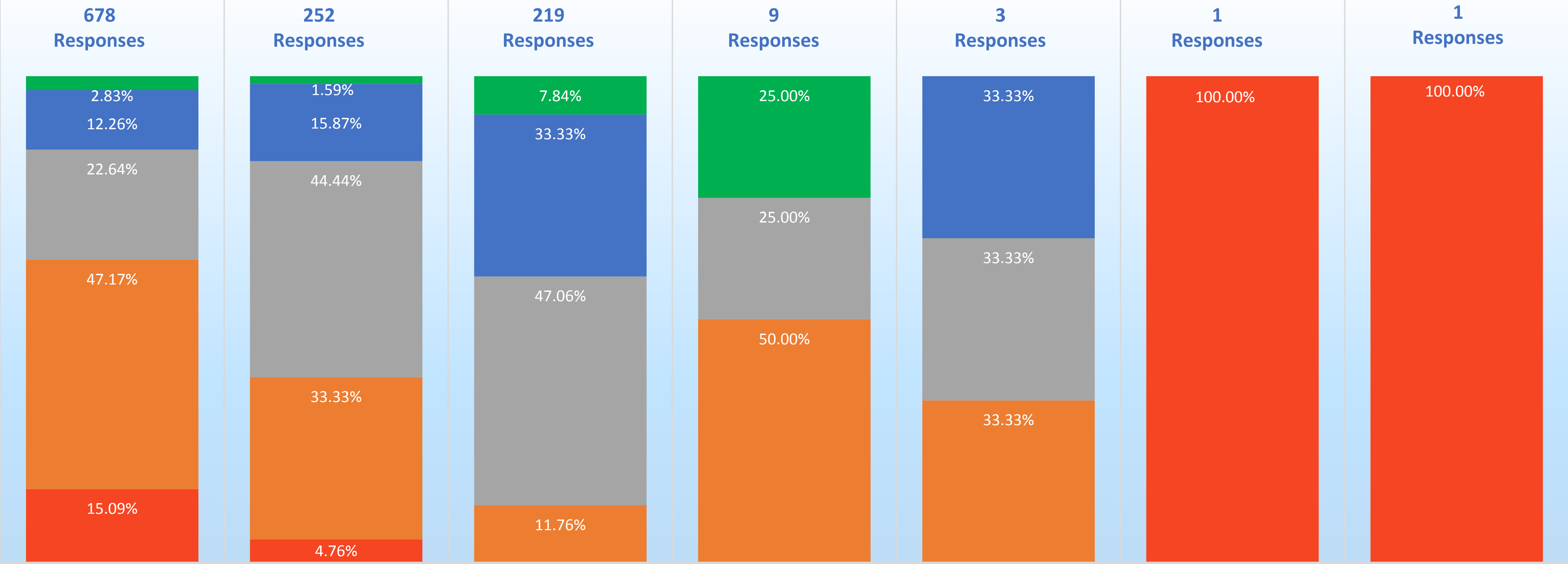


Overall Satisfaction Level





Provider Satisfaction

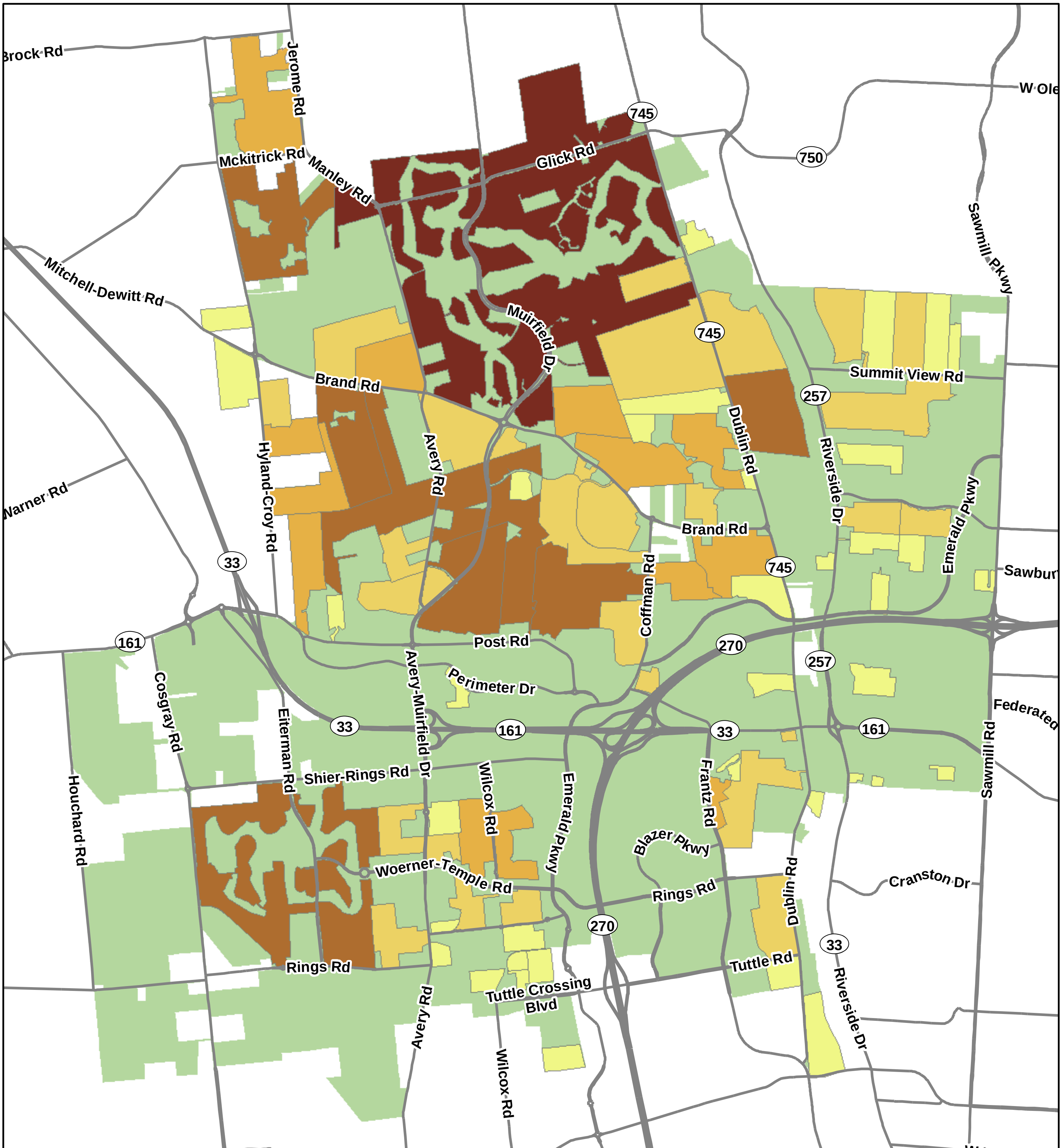


	Time Warner Cable	AT&T	Wide Open West	Verizon	Earthlink	Direct TV	Frontier
5 Strongly Like	2.83%	1.59%	7.84%	25.00%	0.00%	0.00%	0.00%
4 Somewhat Like	12.26%	15.87%	33.33%	0.00%	33.33%	0.00%	0.00%
3 Indifferent	22.64%	44.44%	47.06%	25.00%	33.33%	0.00%	0.00%
2 Somewhat Dislike	47.17%	33.33%	11.76%	50.00%	33.33%	0.00%	0.00%
1 Strongly Dislike	15.09%	4.76%	0.00%	0.00%	0.00%	100.00%	100.00%

Recommendation of Current Provider

- Despite the low satisfaction level, users indicate they are indifferent about recommending their provider

	Time Warner Cable	AT&T	Wide Open West	Verizon	Earthlink	Direct TV	Frontier
Satisfaction	2.7	3.0	3.6	3.0	3.0	1.0	1.0
Recommendation	4.6	5.5	6.7	5.3	5.7	1.0	1.0
Sum of Responses	678.0	254.0	219.0	9.0	3.0	1.0	1.0



Broadband Survey Respondents

In DECEMBER? of 2016 the City of Dublin hosted a survey of internet availablity and speeds. It was met with a great response of almost 1200 participants from all around the City! Here, you can see from where the responses came.

12/14/2016

City of Dublin

Subdivisions

# of Respondents

- 1 - 5
- 6 - 15
- 16 - 30
- 31 - 50
- 51 - 152

FairlawnGig:

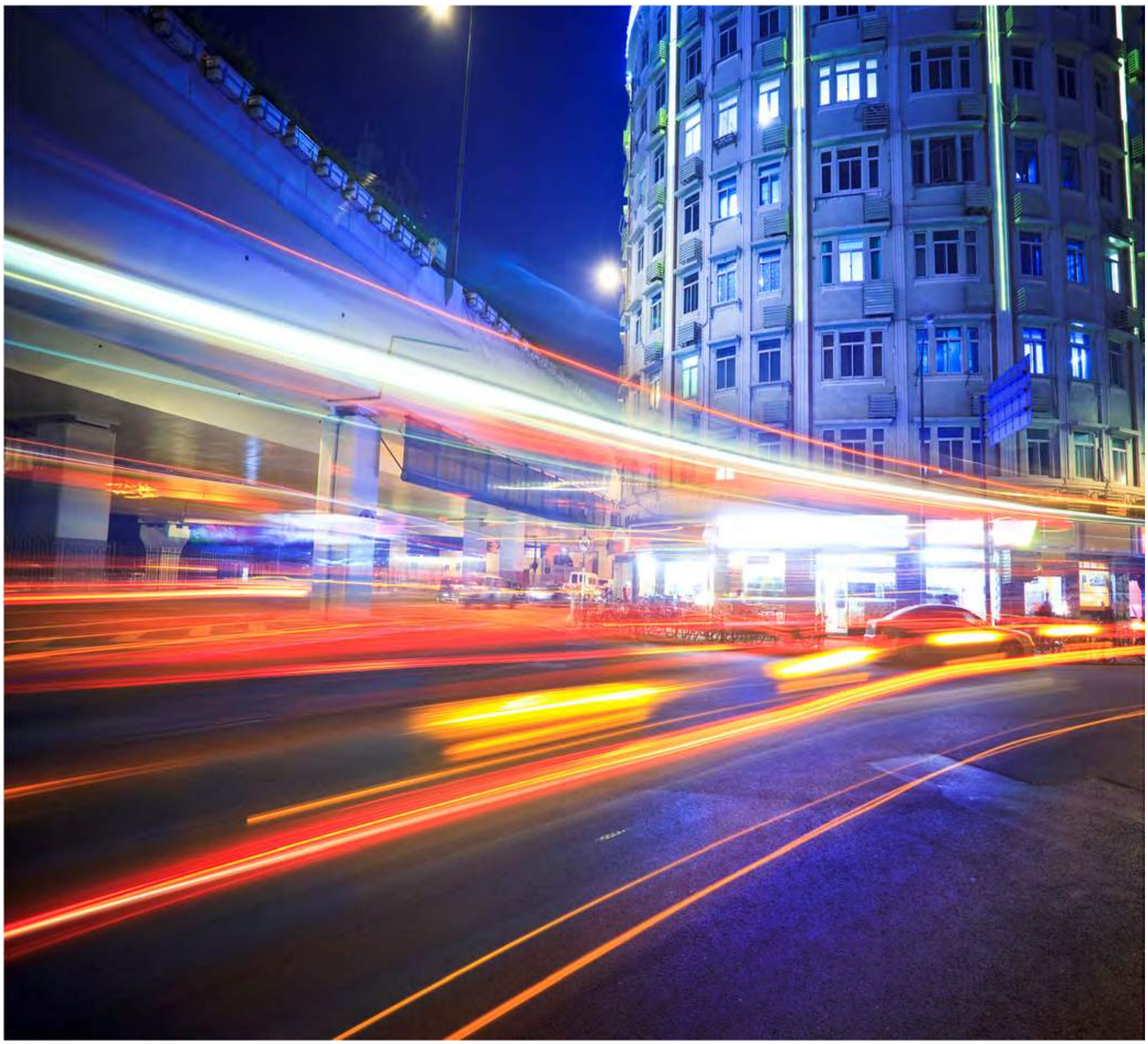
Engineering and Design Study ("EDC Study")

Fujitsu is a trusted partner to a broad spectrum of customers across all industries, enabling them to realize the maximum value from their communications networks.

For: City of Fairlawn, OH
Date: 01/05/2016

www.us.fujitsu.com/telecom

3487 S. Smith Road
Fairlawn, OH 44333
Web: www.FairlawnGig.info



FUJITSU NETWORK COMMUNICATIONS | 2801 Telecom Parkway Richardson, Texas 75082 | Phone: (972) 479-6000

Table of Contents

Appendices

1 Executive Summary

Introduction

This Engineering Design Contract (EDC) is intended to provide the City of Fairlawn with total cost to design, build, operate, manage and maintain a wireless and fiber optic network that will provide high-speed broadband services to the businesses, residents and visitors of the City of Fairlawn (the "City") and the adjacent Akron-Fairlawn-Bath Township Joint Economic Development District ("JEDD").

The City of Fairlawn is an Ohio municipal corporation with approximately 7,500 residents and the third highest number of service and retail companies in Summit County, Ohio. Over 30,000 people come to Fairlawn every day to work and shop and a number of major corporations are located within the City and the JEDD. It is the Mayor of Fairlawn's vision to strengthen and improve the available information technology resources in the City of Fairlawn by creating a municipal broadband utility that will deliver the most reliable and fastest internet access services possible at competitive prices for all business, residents and visitors. Under the brand name of FairlawnGig, this municipal broadband service will advance the following purposes:

- Make world-class, broadband internet services available to all residents, businesses and visitors in the City of Fairlawn and the JEDD at reasonable prices.
- Create a competitive advantage for attracting businesses, residents and visitors to the City of Fairlawn and the JEDD.
- Promote commercial and residential growth and stimulate economic development in the City of Fairlawn and the JEDD.
- Provide a carrier-grade wireless network that would improve the Fairlawn experience for approximately 30,000 daily visitors.
- Encourage entrepreneurial, high tech ventures to locate in Fairlawn.
- Encourage competition by making the fiber optic network open and available for use by other internet service providers.
- Improve city services and public safety communications, awareness and responsiveness.

Current State of the Network

The current Broadband (BB) network providers include local exchange carrier providers AT&T and Frontier, who both offer Digital Subscriber Line (DSL) technology[i] over copper cabling. Time Warner is the current Cable TV operator providing a BB service over existing hybrid fiber-coaxial cables via a

[i] DSL technology is used over aged and obsolete copper cable pairs and is limited to less than 24 mbps in optimum conditions.

technology called DOCSIS[ii]. Additionally, the big four wireless carriers (AT&T, Verizon, T-Mobil and Sprint) offer LTE 4G mobile service throughout the serving area. Due to high-cost usage based billing, these carries are not an option for high bandwidth customers as the rates charged are not affordable for home (residential) or business (commercial) use. The City spans the outer edges of each of the wireline carriers as well as Time Warner, meaning no single regulated utility or CATV offers complete coverage across the City and JEDD service territory.

The City is the only entity with a plan for ubiquitous fiber optic infrastructure capable of offering 1Gbps service to the entire City of Fairlawn and JEDD. When completed, the proposed infrastructure will provide initial capabilities between 1Gbps and 100Gbps throughput speeds.

From a customer service perspective, the existing service providers fall short of meeting or exceeding customer expectations. The constituents have voiced their dissatisfaction with existing providers, prompting the Mayor to take action.

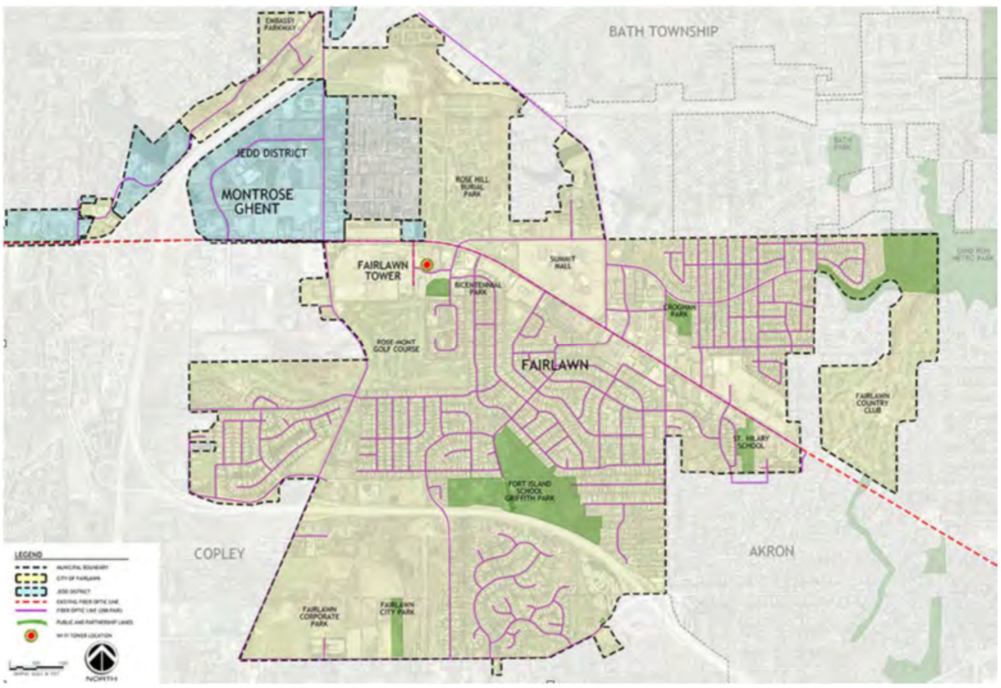


Figure 1: Map of City of Fairlawn

Goals

The project goals and objectives for the City of Fairlawn are:

- Promote commercial and residential growth and stimulate economic development in the City and the JEDD.

[ii] DOCSIS – provided high-bandwidth data transfer to existing CATV system over hybrid fiber-coaxial infrastructure.

- Provide a carrier-grade wireless network that will improve the Fairlawn experience for approximately 30,000 daily visitors to the area.
- Draw in entrepreneurs and high tech ventures.
- Improve City services and public safety communications, awareness and responsiveness.

In this regard, the City of Fairlawn has selected Fujitsu Network Communications ("Fujitsu" or "FNC") to investigate and recommend the necessary steps to design, build, construct, finance, operate and maintain this network. In this report, FNC will define in detail the proposed network and the associated cost to build and operate this network. Furthermore, FNC will clearly outline the roles and responsibilities of all project partners (see Appendix titled **Responsibility Matrix**), including the Anchor Service Provider (ASP) who will be responsible for the day-to-day retail and wholesale customer operations.

Guiding Principles

Universal Access: All businesses, residents, other governmental and non-profit institutions and visitors in the City of Fairlawn and the JEDD will have broadband "Carrier-Grade" internet access.

An Open Network (Consumer Options): Multiple providers will offer services on the open FairlawnGig wireless and fiber optic network, giving subscribers a choice of services.

Consumer Choice and Affordability: The services provided will be priced at a competitive level. More options will stimulate competition for broadband services and will create cost savings for the City.

No New Taxes or Assessments: The City is not proposing any new taxes or special assessments to pay for FairlawnGig. The City's broadband utility will be funded through private financing and revenues from operations.

Challenges

The FairlawnGig project poses many challenges beyond meeting the $10M budget request and the aggressive EDC schedule, of which will be discussed later in this report. Typical challenges on a project of this magnitude would include obtaining environmental permits, construction permits, easements and Rights-of-Way. Fortunately, these challenges are mitigated by the City providing all of the above, excluding environmental permits, which should be mitigated by constructing in previously disturbed soil (existing roads and other underground infrastructure).

The project has only one major challenge, crossing Interstate 77; however, discussions with the Department of Transportation (DoT) indicates a process that could streamline the effort by boring beneath the interstate, thus avoiding traffic management along a major US freeway.

The wireless service will encounter line-of-site (LOS) difficulties due to heavy seasonal vegetation in some areas. Our mitigation effort includes connecting wireless equipment access points via the fiber optic cable infrastructure.

Challenges by incumbent carriers/competitors are anticipated. This project is prompted due to the lack of investment and improved service levels for the City. However, the project may require applying for interconnection for connecting to their infrastructure, such as pole attachments, which are typical areas for behavior meant to create project delays.

Finally, Ohio winters can be severe and are a likely reason for a schedule slip. The current plan includes a 76 week (19 month) construction schedule. In discussions with the City, it is likely that we can construct from late March until December. Once permits are approved, we will meet with the City to collectively finalize a workable schedule that takes into account weather delays. One possible option to mitigating weather impacts is to construct the underground infrastructure first, then connect aerial drops as service requests are taken.

The Project Partners

Figure 2: Project Partners

The project partners will develop the FairlawnGig infrastructure to deliver critical community fiber and wireless services consistent with other projects, not only in the state of Ohio, but throughout the nation. Please see Appendix titled **Responsibility Matrix**.

FNC, along with its project partners, will maximize the value of the infrastructure for the City of Fairlawn by:

Committed, Collaborative Partnership: The FairlawnGig network is a priority project for all project partners who are committed to being collaborative, long-term partners. The proposal will require a close working relationship between the partnership and the City of Fairlawn.

Leverage State and Local Resources: Our partnership combines global market leadership along with an existing long-term Ohio-based company with local presence. FNC, as the design-build contractor, has completed many large scale projects throughout the nation and has a demonstrated track record of both utilizing and developing the capabilities of local subcontractors.

2 Financial Models

Funding Source

The City has elected to fund the project from the Development Finance Authority of Summit County ("DFA"), formerly known as the Summit County DF. The debt service will be in part, separate from the financial analysis contained in this EDC report. Originally the City was pursuing a Public Private Partnership (PPP), or traditional debt financing. Unfortunately, neither proved to work as the PPP type of financing was not a large enough dollar amount to attract financiers and the traditional debt route would not have obtained financing due to the risk associated with a third provider competing for customers.

The City of Fairlawn will service debt from their existing general fund budget. Terms of this debt will be between the City and the DFA. The City at some point to be determined will share in the revenue received from the Anchor Service Provider; however, these commercial terms will be negotiated after the EDC is completed.

Capital

The primary purpose of this EDC is to determine what the FairlawnGig network would cost to build an FTTx and wireless networks to provide 100% coverage and 100% connectivity to every home and most businesses in the City and JEDD. Large Business complexes are passed only and will require further BICSI Certified Engineering in coordination with the owner of each facility; typically these costs are passed through to the facility owner in the form of a nonrecurring charge.

The FNC team conducted extensive research and analysis at deriving cost, this included a detailed design of the network conducted by qualified Professional Engineering firms. This EDC will show cost components, each designed to help the City determine best course of action.

For the purpose of the EDC, FNC is providing two separate views of network infrastructure costs:

1. The first view is fulfilling the initial request from the city of 100% coverage with 100% homes passed, and with 100% drops connected to Optical Network Terminal's (ONT) on the side of the home (100% Connected).
2. The second view displays results of 100% coverage with 100% of homes passed, with a projected 35% (35% Connected) of homes connected to the ONT to match the pro-forma penetration rates (unit projections, revenues, and expenses).

The FNC design specification included a 100% underground fiber-optic network infrastructure, with aerial drops; note some areas within the footprint will be 100% underground up to the ONT on the side of the home. This would include newer areas where underground utilities are already in place.

The FTTx network includes the network infrastructure costs (Material, Labor, Construction Management, Program Management), and Network Support costs which includes fleet, splicing trailers, splicing tools, and OSS systems. The total cost for these items are below:

Initial Cost to build first 18 months

Network Infrastructure Cost for 100% Connected - $11,955,448

Includes:

- OSP Construction $7,299,535
    - OSP Construction, Network Integration
- Wireline Electronics $4,335,757
    - Wireline Installation, Interoperability Lab, Turn-up and Test
- Wireless Electronics $320,156
    - Wireless Installation, Turn-up and Test

Network Refresh Between year 8 and 10 - $2,304,644

Refresh includes:

- Wireline Core Routers
- Wireline OLTs
- Installation, Turn-up and Test
- Decommissioning and de-installation of current equipment
- Circuit migration from current platform to new platform
- Interoperability testing
- Network Integration

Electronics over time become obsolete due to either age, or more likely changes in technology, typically when equipment reaches end of life, replacement costs are lower and you get the benefit of improved technology.

NOTE: All estimates are subject to final negotiations with project partners, timing of construction, and final executive approval by FNC Senior Leadership Team.

Initial Cost to build first 18 months

Network Infrastructure Cost for 35% Connected - $9,936,060

Includes:

- OSP Construction $6,774,464
    - OSP Construction, Network Integration
- Wireline Electronics $2,838,448
    - Wireline Installation, Interoperability Lab, Turn-up and Test
- Wireless Electronics $323,148
    - Wireless Installation, Turn-up and Test

Network Refresh between year 8 and 10 - $1,978,500

Refresh includes:

- Wireline Core Routers
- Wireline OLTs
- Installation, Turn-up and Test
- Decommissioning and de-installation of current equipment
- Circuit migration from current platform to new platform
- Interoperability testing
- Network Integration

Electronics over time become obsolete due to either age, or more likely changes in technology, typically when equipment reaches end of life, replacement costs are lower and you get the benefit of improved technology.

NOTE: All estimates are subject to final negotiations with project partners, timing of construction, and final executive approval by FNC Senior Leadership Team.

Forecasting Periodic Network Refresh Costs

Network Refresh is defined as the periodic replacement of hardware and/or software to assure continued supportability throughout its lifecycle. Without a technology refresh, there is no ability to adequately maintain and sustain aging systems over a prolonged service life.

The network refresh will involve the periodic replacement of Wireline network elements, both hardware and software, to assure the infrastructure is able to reliably deliver bandwidth to users and meet the performance standards over the project lifecycle. Wireless equipment will require on-going replenishment, therefore, is considered outside the scope of this network refresh.

Fujitsu has proposed resilient equipment with planned long and useful lifecycles. FNC recommends a full Wireline platform refresh every 8 years. The technical capabilities of network elements are developing at a rapid rate, such that market leading speeds in one period are considered slow or average in another. Periodic review sessions should be held to discuss changes in network technology and the potential impact that these changes may have on the network's functionality and maintainability.

Any technology changes will be seamlessly incorporated into Fujitsu's overall refresh program, in which it organizes and manages the refresh implementation from equipment procurement to turn-up and testing. Fujitsu's involvement also ensures continuity, so that the entity that installed the equipment is also responsible for servicing it and supporting the user.

The collaborative refresh strategy will be a combination of technologies, processes and tools to ensure that all stakeholders have the necessary infrastructure to successfully execute their business plans relying on high speed, reliable fiber infrastructure.

NOTE: All estimates are subject to final negotiations with project partners, timing of construction, and final executive approval by FNC Senior Leadership Team.

Financial Forecast

The business model assumes potential customer availability of 2595 residential customers, 860 customers living in multi-dwelling units (MDU's), and 807 commercial customers[1], note the design count differs from what the city provided; FNC and the City will meet to address this discrepancy.

Customer Penetration estimates- 40% for Residential, 35% for /MDU's, and 35% Commercial. These estimated amounts are based upon feedback and experience from service providers who have experience being the third competitor in market. These amounts may be conservative; however, pro-forma is better off as showing conservative amounts at this time even though customer survey results indicate a potential upside as customers want better and faster service, at a reduced price.

For the purpose of this EDC, FNC completed two analysis, the first as if the City was the infrastructure owner and operator; this view demonstrated that a traditional ISP business operation with $10M debt could never get to net income positive, primarily due to customer take rates in a competitive market. The second analysis is with an ASP showing revenues and expenses only. The ASP pro-forma

[1] Potential customer availability amounts provided by City of Fairlawn

analysis is a best estimate until a provider is named and commercial terms can be negotiated. We expect negotiations to occur in early January

In this ASP business model we are representing the view from the Access Service Provider perspective of the FairlawnGig project. We project installation intervals of 50, 25, and 10 per month for Homes, MDU's and Businesses respectively. This will continue until we get to our projected take rates of 40% for homes and 35% for MDU's and Businesses. After factoring in 3.6% yearly customer churn, along with a 2.5% Cost of living adjustment after year 2; charging retail prices of $79 for ResidentialGig and $99 for BusinessGig, this project has a $2.49 Million positive cumulative cash flow over 15 years, and is cash flow positive starting in year two. The city of Fairlawn will subsidize the Operations and Maintenance cost of the network for the first 3 years, with the ASP taking over these costs beginning in year 4 which is reflected on the accompanied income statement.

Service Offerings - FNC recommends a 1Gbps service offering to residents and businesses. The alternative, multiple service speed offerings creates a "me too" offering and subject to many competitive threats, such as speed and price competition. The City of Fairlawn is investing in a state of the art fiber infrastructure and should differentiate itself from the competition.

Suggested Pricing – FNC suggests pricing based upon analysis of the Fairlawn market as well as, nationwide analysis as discussed in marketing section. The price for the 1Gbps is $79.00. FNC predicts cumulative installations in year 1 of service will be 848 customer, and 1385 by year 2; ultimately a 1621 customers predicted by year 15.

Customer penetration (take rates), service offerings, and pricing are all dependent upon final negotiations between the City, FNC and the ASP. FNC for purposes of the EDC committed to provide information useful to the City for a go/no go final decision. FNC will provide sensitivity analysis at the City's request during our joint meetings in January. FNC understands much of the pro-forma is based on the City desired outcome from these negotiations, and is committed to alter pro-forma as needed to facilitate our commitment.

Projected Customers

PROJECTED CUSTOMERS	Max. Potential Customers	Take Rate	Projected Customers		Max. Potential Customers	Take Rate	Projected Customers
Potential Customers-Residential - FTTp	2,595	40%	1,038	Potential Customers-Commerical - FTTp	807	35%	282
Potential Customers-Residential - MDU	860	35%	301	Potential Customers-Guest Wireless	0	0%	-
POTENTIAL RESIDENTIAL CUSTOMERS	3,455		1,339	POTENTIAL COMMERCIAL CUSTOMERS	807		282

INSTALLATIONS:	Start Month	Month 1 Connects	Connects/Month	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
New Customers-Res. - FTTp	6	75	75	525	513	-	-	-	-	-	-	-	-	-	-	-	-	-
New Customers-Res. - MDU	6	25	25	301	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Customers-Comm. - FTTp	6	10	2	22	24	24	24	24	24	24	24	24	24	24	20	-	-	-
Guest Wireless	6	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				848	537	24	24	24	24	24	24	24	24	24	20	-	-	-
BILLED ACCOUNTS:																		
Ave. Customers-Res. - FTTp				153	891	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038
Ave. Customers-Res. - MDU				52	275	301	301	301	301	301	301	301	301	301	301	301	301	301
Ave. Customers-Comm. - FTTp				12	34	58	82	106	130	154	178	202	226	250	274	282	282	282
Ave. Customers-Comm. - Wireless				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				217	1,200	1,397	1,421	1,445	1,469	1,493	1,517	1,541	1,565	1,589	1,613	1,621	1,621	1,621
CUMMULATIVE INSTALLATIONS:																		
Cumm. Customers-Res. - FTTp				525	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038	1,038
Cumm. Customers-Res. - MDU				301	301	301	301	301	301	301	301	301	301	301	301	301	301	301
Cumm. Customers-Comm. - FTTp				22	46	70	94	118	142	166	190	214	238	262	282	282	282	282
Cumm. Customers-Comm. - Wireless				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				848	1,385	1,409	1,433	1,457	1,481	1,505	1,529	1,553	1,577	1,601	1,621	1,621	1,621	1,621

PRODUCT MIX - % OF INSTALLS	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Residential - % of Installed Services															
FairlawnGig Gig (1000 Mbps)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Guest Wireless	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Commercial - % of Installed Services															
FairlawnGig Business Gig (1000 Mbps)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
COMM. TEL. - SIP TRUNKING (10 LINES/SUB)	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
COMM. TEL. - HOSTED PBX (25 LINES/SUB)	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%

Table 1: Projected Customers

Projected Revenues

REVENUES															
Residential - Revenue	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**
FairlawnGig Gig (1000 Mbps)	146,150	876,426	1,262,894	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	146,150	876,426	1,262,894	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372	1,269,372
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Churn - Disconnect Fee	95	516	721	723	723	723	723	723	723	723	723	723	723	723	723
Churn - Connect Fee	126	687	962	964	964	964	964	964	964	964	964	964	964	964	964
Residential - Revenue	**146,371**	**877,629**	**1,264,577**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**	**1,271,059**
Commercial - Revenue	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**
FairlawnGig Business Gig (1000 Mbps)	14,454	40,392	68,904	97,416	125,928	154,440	182,952	211,464	239,976	268,488	297,000	325,183	335,551	335,551	335,551
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,454	40,392	68,904	97,416	125,928	154,440	182,952	211,464	239,976	268,488	297,000	325,183	335,551	335,551	335,551
Commercial - Revenue	**14,454**	**40,392**	**68,904**	**97,416**	**125,928**	**154,440**	**182,952**	**211,464**	**239,976**	**268,488**	**297,000**	**325,183**	**335,551**	**335,551**	**335,551**
GRAND TOTAL - ALL REVENUE	**160,825**	**918,021**	**1,333,481**	**1,368,475**	**1,396,987**	**1,425,499**	**1,454,011**	**1,482,523**	**1,511,035**	**1,539,547**	**1,568,059**	**1,596,242**	**1,606,610**	**1,606,610**	**1,606,610**

Table 2: Projected Revenues

Operating Expense Assumptions

To be included upon conclusion of negotiations between the City, FNC and ASP

Financial Statements

Incomes and Cash Flow Statement – the City as the infrastructure owner and operator

INCOME STATEMENT

	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15
REVENUES	209,286	1,147,144	1,339,963	1,368,475	1,396,987	1,425,499	1,454,011	1,482,523	1,511,035	1,539,547	1,568,059	1,596,242	1,606,610	1,606,610	1,606,610
COST OF GOODS SOLD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GROSS PROFIT	209,286	1,147,144	1,339,963	1,368,475	1,396,987	1,425,499	1,454,011	1,482,523	1,511,035	1,539,547	1,568,059	1,596,242	1,606,610	1,606,610	1,606,610
%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Per Cust.	$ 962.79	$ 956.05	$ 959.17	$ 963.04	$ 966.77	$ 970.39	$ 973.89	$ 977.27	$ 980.55	$ 983.74	$ 986.82	$ 989.78	$ 990.85	$ 990.85	$ 990.85
OPERATING COSTS	296,529	918,157	1,195,418	1,207,384	1,219,588	1,232,038	1,244,741	1,257,705	1,270,937	1,284,445	1,298,238	1,312,262	1,324,002	1,334,684	1,345,687
EBITDA	(87,244)	228,987	144,545	161,091	177,399	193,461	209,270	224,818	240,098	255,102	269,821	283,980	282,608	271,926	260,923
INTEREST EXPENSE	268,883	262,865	256,681	250,327	243,799	237,090	230,198	223,116	215,839	208,362	200,680	192,786	184,675	176,341	167,778
DEPRECIATION	313,598	626,939	709,415	709,735	710,055	710,375	710,695	705,301	688,954	688,798	689,118	689,432	689,537	689,537	689,537
INT., DEP SUBTOTAL	582,480	889,803	966,096	960,062	953,854	947,466	940,893	928,417	904,793	897,160	889,798	882,218	874,212	865,878	857,315
EBT	(669,724)	(660,816)	(821,551)	(798,971)	(776,455)	(754,005)	(731,623)	(703,599)	(664,695)	(642,058)	(619,977)	(598,239)	(591,605)	(593,953)	(596,392)
INCOME TAXES	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PROPERTY TAXES	68,001	98,089	98,125	98,161	98,197	98,233	98,269	98,305	98,341	98,377	98,413	98,443	98,443	98,443	98,443
NET INCOME	(737,725)	(758,905)	(919,676)	(897,132)	(874,652)	(852,238)	(829,892)	(801,903)	(763,036)	(740,435)	(718,390)	(696,682)	(690,048)	(692,396)	(694,836)
Per Cust.	$ (3,393.79)	$ (632.49)	$ (658.32)	$ (631.34)	$ (605.30)	$ (580.15)	$ (555.86)	$ (528.61)	$ (495.16)	$ (473.12)	$ (452.10)	$ (431.99)	$ (425.57)	$ (427.02)	$ (428.53)
%	-352%	-66%	-69%	-66%	-63%	-60%	-57%	-54%	-50%	-48%	-46%	-44%	-43%	-43%	-43%

Table 3: Income Statement – City as Owner and Operator

CASH FLOW

Cash Flow Statement (DIRECT)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Cash Received	$ 10,209,286	$ 1,147,144	$ 1,339,963	$ 1,368,475	$ 1,396,987	$ 1,425,499	$ 1,454,011	$ 1,482,523	$ 1,511,035	$ 1,539,547	$ 1,568,059	$ 1,596,242	$ 1,606,610	$ 1,606,610	$ 1,606,610
Cash Payments	$ (296,529)	$ (918,157)	$ (1,195,418)	$ (1,207,384)	$ (1,219,588)	$ (1,232,038)	$ (1,244,741)	$ (1,257,705)	$ (1,270,937)	$ (1,284,445)	$ (1,298,238)	$ (1,312,262)	$ (1,324,002)	$ (1,334,684)	$ (1,345,687)
Interest Received (Cash at Bank)	$ -	$ 2,902	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Interest Paid (Debt)	$ (268,883)	$ (262,865)	$ (256,681)	$ (250,327)	$ (243,799)	$ (237,090)	$ (230,198)	$ (223,116)	$ (215,839)	$ (208,362)	$ (200,680)	$ (192,786)	$ (184,675)	$ (176,341)	$ (167,778)
Interest Paid (LOC)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Tax Paid	$ (68,001)	$ (98,089)	$ (98,125)	$ (98,161)	$ (98,197)	$ (98,233)	$ (98,269)	$ (98,305)	$ (98,341)	$ (98,377)	$ (98,413)	$ (98,443)	$ (98,443)	$ (98,443)	$ (98,443)
Cash Flow From Operating Activities	$ 9,575,872	$ (129,064)	$ (210,260)	$ (187,397)	$ (164,597)	$ (141,863)	$ (119,197)	$ (96,603)	$ (74,082)	$ (51,637)	$ (29,272)	$ (7,250)	$ (511)	$ (2,859)	$ (5,298)
Capital Expenditure	$ (9,066,846)	$ (4,011,656)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,090)	$ -	$ -	$ -
Proceeds From Sale of Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cash Flow From Investing Activities	$ (9,066,846)	$ (4,011,656)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,800)	$ (4,090)	$ -	$ -	$ -
Dividends Paid	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Drawdowns	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Repayments	$ (218,844)	$ (224,862)	$ (231,046)	$ (237,400)	$ (243,928)	$ (250,636)	$ (257,529)	$ (264,611)	$ (271,888)	$ (279,365)	$ (287,047)	$ (294,941)	$ (303,052)	$ (311,386)	$ (319,949)
Cash Flow From Financing Activities	$ (218,844)	$ (224,862)	$ (231,046)	$ (237,400)	$ (243,928)	$ (250,636)	$ (257,529)	$ (264,611)	$ (271,888)	$ (279,365)	$ (287,047)	$ (294,941)	$ (303,052)	$ (311,386)	$ (319,949)
Net Cash Flow	$ 290,182	$ (4,365,583)	$ (446,107)	$ (429,597)	$ (413,325)	$ (397,299)	$ (381,526)	$ (366,014)	$ (350,770)	$ (335,802)	$ (321,119)	$ (306,281)	$ (303,563)	$ (314,245)	$ (325,247)
Opening Cash at Bank	$ -	$ 290,182	$ (4,075,400)	$ (4,521,507)	$ (4,951,103)	$ (5,364,428)	$ (5,761,727)	$ (6,143,253)	$ (6,509,267)	$ (6,860,037)	$ (7,195,838)	$ (7,516,957)	$ (7,823,238)	$ (8,126,801)	$ (8,441,046)
Change in Cash	$ 290,182	$ (4,365,583)	$ (446,107)	$ (429,597)	$ (413,325)	$ (397,299)	$ (381,526)	$ (366,014)	$ (350,770)	$ (335,802)	$ (321,119)	$ (306,281)	$ (303,563)	$ (314,245)	$ (325,247)
Closing Cash At Bank / Overdraft	$ 290,182	$ (4,075,400)	$ (4,521,507)	$ (4,951,103)	$ (5,364,428)	$ (5,761,727)	$ (6,143,253)	$ (6,509,267)	$ (6,860,037)	$ (7,195,838)	$ (7,516,957)	$ (7,823,238)	$ (8,126,801)	$ (8,441,046)	$ (8,766,293)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Labor, Payroll Taxes, Benefits	-	216,365	440,446	448,394	456,581	465,014	473,699	482,645	491,859	501,350	511,126	521,194	531,565	542,247	553,249
Project Setup and Management	-	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Network Support	245,345	471,690	496,690	496,690	496,690	496,690	496,690	496,690	496,690	496,690	496,690	496,690	496,690	496,690	496,690
Marketing & Communication	6,976	63,357	72,998	74,424	75,849	77,275	78,701	80,126	81,552	82,977	84,403	85,812	86,330	86,330	86,330
Administrative	44,208	156,745	175,284	177,876	180,468	183,060	185,652	188,244	190,836	193,428	196,020	198,566	199,417	199,417	199,417
GRAND TOTAL	296,529	918,157	1,195,418	1,207,384	1,219,588	1,232,038	1,244,741	1,257,705	1,270,937	1,284,445	1,298,238	1,312,262	1,324,002	1,334,684	1,345,687

Table 4: Cash Flow Statement – City as Owner and Operator

Balance Sheets:

***Note: A balance sheet will not be provided in this EDC due to the split of responsibilities between the City (debt and network expenses, with no revenue) and the ASP (revenues and expense, minimal capital, and no debt*)**

Income and Cash Flow Statement - ASP as service provider)

To be updated concluding negotiations between the City, FNC and ASP

Current Projection

INCOME STATEMENT

	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15
REVENUES	160,825	940,972	1,400,989	1,473,698	1,542,012	1,612,821	1,686,207	1,762,254	1,841,050	1,922,683	2,007,248	2,094,408	2,160,711	2,214,729	2,270,098
COST OF GOODS SOLD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GROSS PROFIT	160,825	940,972	1,400,989	1,473,698	1,542,012	1,612,821	1,686,207	1,762,254	1,841,050	1,922,683	2,007,248	2,094,408	2,160,711	2,214,729	2,270,098
%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Per Cust.	$ 966.88	$ 981.71	$ 1,007.78	$ 1,037.09	$ 1,067.14	$ 1,097.90	$ 1,129.41	$ 1,161.67	$ 1,194.71	$ 1,228.55	$ 1,263.21	$ 1,298.68	$ 1,332.58	$ 1,365.89	$ 1,400.04
OPERATING COSTS	396,912	458,946	748,656	1,406,972	1,447,755	1,489,755	1,533,009	1,577,559	1,623,444	1,670,709	1,719,398	1,769,481	1,817,278	1,864,199	1,912,368
EBITDA	(236,087)	482,025	652,332	66,726	94,257	123,066	153,198	184,695	217,605	251,974	287,850	324,926	343,434	350,531	357,729
INTEREST EXPENSE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DEPRECIATION	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INT. DEP & TAX SUBTOTAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EBT	(236,087)	482,025	652,332	66,726	94,257	123,066	153,198	184,695	217,605	251,974	287,850	324,926	343,434	350,531	357,729
INCOME TAXES	-	144,608	195,700	20,018	28,277	36,920	45,959	55,409	65,282	75,592	86,355	97,478	103,030	105,159	107,319
PROPERTY TAXES	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NET INCOME	($236,087)	337,418	456,633	46,708	65,980	86,147	107,238	129,287	152,324	176,382	201,495	227,448	240,404	245,371	250,410
Per Cust.	($1,419)	$ 352.03	$ 328.47	$ 32.87	$ 45.66	$ 58.64	$ 71.83	$ 85.23	$ 98.85	$ 112.70	$ 126.81	$ 141.03	$ 148.26	$ 151.33	$ 154.44
%	-147%	36%	33%	3%	4%	5%	6%	7%	8%	9%	10%	11%	11%	11%	11%

Table 5: Income Statement – ASP as Service Provider

CASH FLOW

Cash Flow Statement (DIRECT)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Cash Received	$ 160,825	$ 940,972	$ 1,400,989	$ 1,473,698	$ 1,542,012	$ 1,612,821	$ 1,686,207	$ 1,762,254	$ 1,841,050	$ 1,922,683	$ 2,007,248	$ 2,094,408	$ 2,160,711	$ 2,214,729	$ 2,270,098
Cash Payments	$ (396,912)	$ (458,946)	$ (748,656)	$ (1,406,972)	$ (1,447,755)	$ (1,489,755)	$ (1,533,009)	$ (1,577,559)	$ (1,623,444)	$ (1,670,709)	$ (1,719,398)	$ (1,769,481)	$ (1,817,278)	$ (1,864,199)	$ (1,912,368)
Interest Received (Cash at Bank)	$ -	$ -	$ 1,013	$ 5,590	$ 6,113	$ 6,834	$ 7,763	$ 8,913	$ 10,295	$ 11,922	$ 13,805	$ 15,958	$ 18,392	$ 20,980	$ 23,643
Interest Paid (Debt)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Interest Paid (LOC)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Tax Paid	$ -	$ (144,608)	$ (195,700)	$ (20,018)	$ (28,277)	$ (36,920)	$ (45,959)	$ (55,409)	$ (65,282)	$ (75,592)	$ (86,355)	$ (97,478)	$ (103,030)	$ (105,159)	$ (107,319)
Cash Flow From Operating Activities	$ (236,087)	$ 337,418	$ 457,646	$ 52,298	$ 72,093	$ 92,980	$ 115,002	$ 138,200	$ 162,619	$ 188,304	$ 215,300	$ 243,406	$ 258,796	$ 266,351	$ 274,054
Capital Expenditure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Proceeds From Sale of Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cash Flow From Investing Activities	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Dividends Paid	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Drawdowns	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Repayments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cash Flow From Financing Activities	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net Cash Flow	$ (236,087)	$ 337,418	$ 457,646	$ 52,298	$ 72,093	$ 92,980	$ 115,002	$ 138,200	$ 162,619	$ 188,304	$ 215,300	$ 243,406	$ 258,796	$ 266,351	$ 274,054
Opening Cash at Bank	$ -	$ (236,087)	$ 101,330	$ 558,976	$ 611,274	$ 683,367	$ 776,347	$ 891,349	$ 1,029,549	$ 1,192,168	$ 1,380,472	$ 1,595,772	$ 1,839,178	$ 2,097,973	$ 2,364,324
Change in Cash	$ (236,087)	$ 337,418	$ 457,646	$ 52,298	$ 72,093	$ 92,980	$ 115,002	$ 138,200	$ 162,619	$ 188,304	$ 215,300	$ 243,406	$ 258,796	$ 266,351	$ 274,054
Closing Cash At Bank / Overdraft	$ (236,087)	$ 101,330	$ 558,976	$ 611,274	$ 683,367	$ 776,347	$ 891,349	$ 1,029,549	$ 1,192,168	$ 1,380,472	$ 1,595,772	$ 1,839,178	$ 2,097,973	$ 2,364,324	$ 2,638,378

Table 6: Cash Flow Statement – ASP as Service Provider

Assumptions

- Financials are based on FNC's current understanding of the project and are subject to change as necessary to meet requirements to satisfy design parameters, construction restrictions, ASP decisions, scope of project and terms and conditions.

3 Anchor Service Provider (ASP)

FNC has been requested to design and build an Open Access fiber optic network infrastructure capable of providing both wholesale and retail service to all service providers interested in using the network assets. The first step in the process is to find a single Anchor Service Provider (ASP). The City does not currently possess the skill set, resources, or operating support systems to become the ASP.

The ASP is responsible for service activation and service assurance for retail, commercial and wholesale service offerings. This includes, but is not limited to repair requests, service provisioning, monthly billing, call centers and tier 1 help desks (technical assistance). The ASP owns the infrastructure from the network ONT, located on the side of the premise, into the home or business. FNC's Network Operation Center (NOC) is responsible from the ONT back into the head-end equipment located at the City's Data Center, as well as the entire wireless infrastructure. The ASP will serve as the single point of contact for customers in lieu of direct contact with the City.

Prior to performing our search for an ASP, FNC first developed the prerequisites the service providers must possess to be considered:

- Five or more years as a full-service broadband provider.
- Ability to provide a level of customer service, equal to or greater than current providers.
- Existing back-office systems and resources to operate as a facilities-based carrier.
- Capable of providing not only retail service, but also commercial and wireless services.
- Knowledge of selling and provisioning services at the wholesale carrier level.

FNC interviewed three potential anchor service providers. The first provider did not meet all the requirements and was limited to residential services only. Although it was believed they could scale fast, FNC felt they would be better served as a retail provider buying services from the ASP. The second provider, a very large company who operates in the state, has not fully vetted their role as a partner operating someone else's network. The third provider is a current operator within Ohio, who is very interested and capable of operating the infrastructure.

FNC continues to evaluate the third potential provider to be the ASP. They own a broadband network in Ohio as well as have existing back office functions and support systems capable of taking on the scale of customers that comes with the FairlawnGig network. Using this third provider and all their current operating support systems should save the project over $1M in avoidance of operating systems and the time needed to port these operating systems.

FNC requested this third potential provider to perform due-diligence on this opportunity. They have verbally committed to become the ASP, provided all the commercial terms are acceptable. Fujitsu is optimistic that the terms and conditions will be mutually beneficial to all interested parties. Upon review of this third provider's input, FNC will establish a Teaming Agreement (TA), begin process mapping, jointly review service offerings and begin work on commercial agreements with the City. FNC may or may not be a party to agreements between the ASP and the City. FNC may serve as the City's advisor/agent overseeing the ASP.

After an unknown period, the City could provide an opportunity for other service providers to lease network infrastructure assets to provide their services over an open-access network.

4 Design and Build Architecture Models

FairlawnGig FTTx network is designed to serve over 4,000 customer end points at 1Gbps or higher speeds comprised of various customer types including residential, visitors, businesses and large corporations. The proposed FTTx network will also provide backhaul wireless Wi-Fi based traffic to connect to and provide a larger, extendable internet connectivity footprint to its customers.

Outside Plant (OSP) Design and Equipment Locations

OSP Design

Fujitsu deployed OSP design resources to Fairlawn, OH on October 4th, 2015 to begin gathering field data. These resources gathered information such as linear measurements and offsets, existing utilities and obstructions, addresses, existing electrical, CATV and telephone service to structures. The initial field deployment for data gathering was completed at the end of October 2015.

Concurrently, Fujitsu back office personnel divided the City provided AutoCAD-based, scaled utility drawings into manageable sections to develop updated fiber routes. Fujitsu added a fiber design layer on top of the original drawings with a scale factor of 1:50. The completed OSP design requires an estimated 800+ updated drawings. See Appendix titled **DA-1007 31 Sample AutoCAD Drawing** for a sample updated AutoCAD drawing.

Using the City provided map, FNC engineers plotted a core fiber ring route covering most areas of the project area. In conjunction with our OSP engineering partners, Fujitsu subdivided the City into twelve Distribution Areas (DA). Each DA will be served by its own Local Convergence Point (LCP) splitter cabinet. For the City's larger commercial customers, the fiber counts coming from the Data Center will not be split at the LCP but will transmit through the cabinet and terminate directly at the customer site - allowing Ethernet services (speeds in excess of 1Gbps) to be offered.

Some notes from the OSP design:

- All cabling has been designed to be placed below ground level except for some drops that are designed to be placed aerially.

- An underground structure has been designed consisting of one 3” HDPE conduit that is connected to 24” x 36” tier 22 (22,500 lbs. vertical design load) split lid or 30” x 48” tier 22 split lid hand holes. The larger hand holes are used at branch splicing and LCP cabinet locations and the smaller hand holes are used at selected pedestal locations. The proposed depth of the conduit is 36” below grade.
- 1 ¼” HDPE conduit will be used for drops and terminal tails. In some instances the smaller 1 ¼” conduit will be used in conjunction with the larger 3” conduit and in other instances it will be used in lieu of the larger 3” conduit.
- A multiport terminal will be mounted inside the 10” diameter pedestal. The multiport terminals come in 2, 4, 6, 8 and 12 port sizes. The pedestal will be installed near the base of a power pole and have one short section of 1 ¼” HDPE conduit placed from the base of the pedestal over to the pole and then stubbed up approximately 18”. The stubbed up conduit will be protected by a U-Guard riser. This will allow for the drops to be run from the terminal inside of the pedestal, over to the pole, cleated up the side of the pole and then hung aerially to the houses or businesses. A second 1 ¼” HDPE conduit can be installed from the same pedestal to the next pole so that drops can be pulled through, cleated up the pole and then hung aerially to the houses or businesses. This design allows for eight houses or businesses to be served from one 12 multiport terminal, while leaving spare terminal capacity for growth or maintenance.
- An all dielectric, ribbon construction, gel-free fiber optic cable design is proposed. The use of ribbon, gel-free fiber cable will speed up the splicing process. Wherever a dielectric cable is placed, a tracer wire will also be installed, so the cable can accurately be located by electronic means in the future.
- This design proposes that the entire buried section be bored using Horizontal Directional Drilling (HDD) techniques. This construction method will speed up the installation timeframe, reduce restoration costs and have less impact on the public. Typically, the hole is drilled to the desired distance, the drill bit is detached and it is replaced with a reamer head that shapes the hole to the correct diameter as it is pulled back. The conduit(s) is attached to the reamer head and pulled back towards the HDD rig. The HDD operator must use a calibrated, steerable drill bit and provide an As-Built bore log to the engineer.

• The design suggests 1.5 fibers per residence, which translates to a 12 port terminal to accommodate approximately eight residences. This allows for any potential growth or maintenance requirement while also sizing the terminals, cable sheaths and LCP cabinets with appropriate spare capacity.

• The design proposes 1.25 fibers per Multi Dwelling Unit (MDU) which translates to a 12 port terminal to accommodate approximately nine to ten apartments/condos. This allows for any potential growth or maintenance requirement while also sizing the terminals, cable sheaths and LCP cabinets with appropriate spare capacity.

• The design advices 1 fiber per small business unit.

- Finally, the design recommends 2 or 4 fibers per medium to larger business units. Fiber coils with assigned fibers will be left in front of these buildings and the final design will occur when the customer requests service.

Please see the Outside Plant Bill of Materials in the Appendices titled **OSP BOM 100 Percent Take Rate** and **OSP BOM 35 Percent Take Rate**.

Equipment Locations (Cabinets / Huts) Recommendations

The recommended LCP cabinet is the Corning LS series with distribution sizes of 288, 432, 576 & 864 fiber (see Appendix titled **OptiTect_Local_Convergence_Cabinet_LS_Series** for pictures and further information). These cabinets also offer “pass-through” capabilities for high-bandwidth applications. There will be one Local Convergence Cabinet per Distribution Area (DA) in the OSP design. Each cabinet will be installed on top of a cast-in-place, 6” thick concrete pad. Standard concrete pad sizes will be 4’ x 5’ for the 288 and 432 cabinets and 5’ x 6’ for the 576 and 864 cabinets. A 30” x 48” x 36” tier 22 split lid hand hole will be placed next to each cabinet for OSP cable splicing. The hand hole will be connected to the cabinet with (2) 3” HDPE conduit, one conduit for the feeder cable and the second conduit for the distribution cable(s). The feeder cable will carry fiber counts that emanate from the OLT(s) in the City Data Center and transported to the cabinet via the core ring. Each feeder fiber count will be split into 16 distribution fiber counts by the dual 1 x 16 splitter modules installed in the cabinet and transported to the end user by distribution cables. Additionally, each cabinet will be placed in the public right-of-way as far back from the roadway as practical.

Note: final results from detail engineering indicates a discrepancy in address counts provided by the City of Fairlawn; true up will need to take place with the City.

Pole Attachments

OSP Cable pole attachment counts for the OSP design include both mainline and spot/drop pole attachments. See below Table 7 – Pole Attachments. Pole attachment rates are still being negotiated with Ohio Edison, current annual rate is $4.69 per attachment. Once negotiated the annual expense will be added to the business model; for now assume an annual amount of $3,329.

DA #	Mainline Pole Attachments	Spot/Drop Pole Attachments	Comments
DA1001	0	0	
DA1002	103	6	
DA1003	11	3	
DA1004	8	1	
DA1005	241	20	75 of the poles will have aerial cable attached
DA1006	40	6	17 of the poles will have aerial cable attached
DA1007	134	18	
DA1008	5	0	
DA1009	12	5	
DA1010	50	37	
DA1011	0	0	
DA1012	10	0	
Total Pole Attachments	**614**	**96**	**710 total wireline pole attachments**
Notes:			
Mainline Pole Attachments - will have drop attachments only			
Spot/Drop Pole Attachments - will have aerial cable and drops attached in the rear easement			

Table 7: Pole Attachments

Construction and Project Management Plan

The overall project schedule is 86 weeks; this includes prerequisite functions such as the bidding and award process for ISP, OSP and wireless construction activities and permitting. The permitting time cycle is staggered through the schedule to allow the governing authorities processing and approval time without overwhelming resources. The OSP construction schedule is 76 weeks to complete the approximately 358,000 feet of route construction. This equates to a conservative weekly production of approximately 4600 feet, consistently with 4-5 crews working 5 to 6 days per week.

The primary project components: data center, feeder ring and main wireless base stations are given highest priority so testing can be completed as distribution areas are completed and come online. Distribution area 1012 appears first in the schedule sequence to provide service to the hotels and areas inhabited by the Republican National Convention participants scheduled for July 18-21 2016.

The Distribution areas replicate consistent logic with the goal of keeping construction crews active with no down time. Consideration is also given to constraining activities within a manageable area, so construction impact to the community is contained as we move through the city footprint with restoration completing in a timely manner.

Please see Appendix titled **Preliminary Fairlawn Gig Project Schedule** for further detail.

Wireline Architecture and Network Design

Network / Subscriber Layout

The FairlawnGig fiber network is designed to have one single Data Center (DC) and 12 Distribution Areas (DA) forming a ring topology, see Figure 3 below. Each of these areas will be serviced from the DC. The DC will be located at the Fairlawn Tower site and host all the active electronics for the FTTx access and Internet core connectivity. It will also be a peering point for the network to the Internet Service Providers (ISPs).

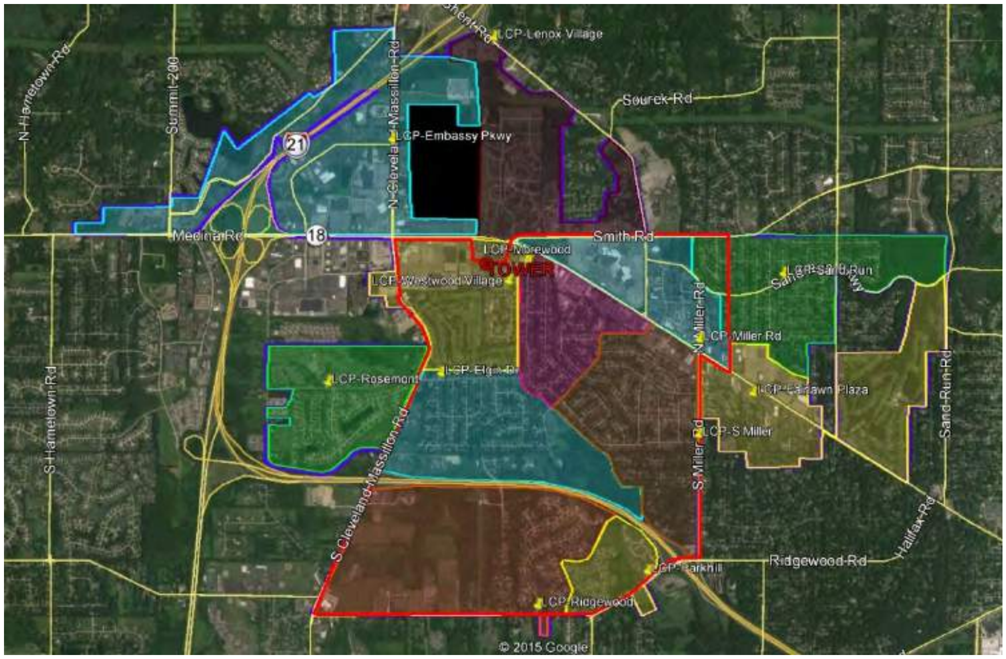


Figure 3: Ring Topology Map

The DAs are serving four main types of subscribers:

- Single Family Units (SFU)
- Multi Dwelling Units (MDU)
- Businesses (BUS)
- Wi-Fi Access Backhaul (WAB)

The approximate distribution of total subscribers into these types is given in Table 8 below. The network subdivides Business (BUS) subscribers in three different levels:

- Small Businesses (S-BUS).
- Medium Businesses (M-BUS).
- Large Businesses (L-BUS).

DA #	DA Name	LCP Size	Line total of SFU,MDU BUS	SFU	MDU	BUS	Comments
DA1001	Westwood Village	432	276	15	157	104	
DA1002	Morewood Rd	864	493	264	182	47	
DA1003	Lennox Village	288	77	17	30	30	
DA1004	Miller Rd	288	236	0	32	204	
DA1005	Sand Run Pkwy	864	719	719	0	0	
DA1006	Fairlawn Plaza	576	437	45	261	131	
DA1007	S Miller Rd	864	535	277	255	3	
DA1008	Parkhill	432	284	83	200	1	
DA1009	Ridgewood Lakes	432	252	216	28	8	
DA1010	Elgin Dr	432	311	304	0	7	
DA1011	Rosemont Ridge	432	285	180	104	1	
DA1012	Embassy Pkwy	576	418	0	0	418	
	Spreadsheet Total			2,120	1,249	954	

Table 8: Distribution Areas

GPON/Active-Ethernet & Switched Ethernet Access Architecture

FairlawnGig will utilize a hybrid design approach to create a state of the art network design, serving the needs of different types of customers, while being cost effective and efficient. Considering the number of potential subscribers and the capacity needed for the planned services, FNC recommends use of Gigabit Passive Optical Network (GPON) for single family units, multi-dwelling units and for small/medium businesses. Large businesses are expected to require larger capacity and security; therefore, FNC recommends using an Active Ethernet (AE) design for large businesses. Both GPON and Active Ethernet designs incorporate the same type of FTTx electronics. For large businesses with varying service level requirements and speed diversity of 1G/10G, FNC recommends use of Switched Ethernet services that terminate directly on the OSI Layer 2 switches to provide premium services.

The SFU, MDU and S-BUS subscribers will be served over the GPON distribution plant, see Figure 4 below. The GPON distribution will utilize an OLT system at the DC and employ the fiber plant to reach all DAs. The GPON OLT will provide connectivity from ONT to OLT with ~1G/2G uplink and downlinks. Depending on the number of subscribers in each DA, a multiple number of splitters will be located at each DA distribution LCP. The splitter ratio will be 1:16 for relatively high bandwidth service. SFU and S-BUS client sites will host a corresponding ONT, whereas MDU subs will have 1:4 MDU ONT for shared service.

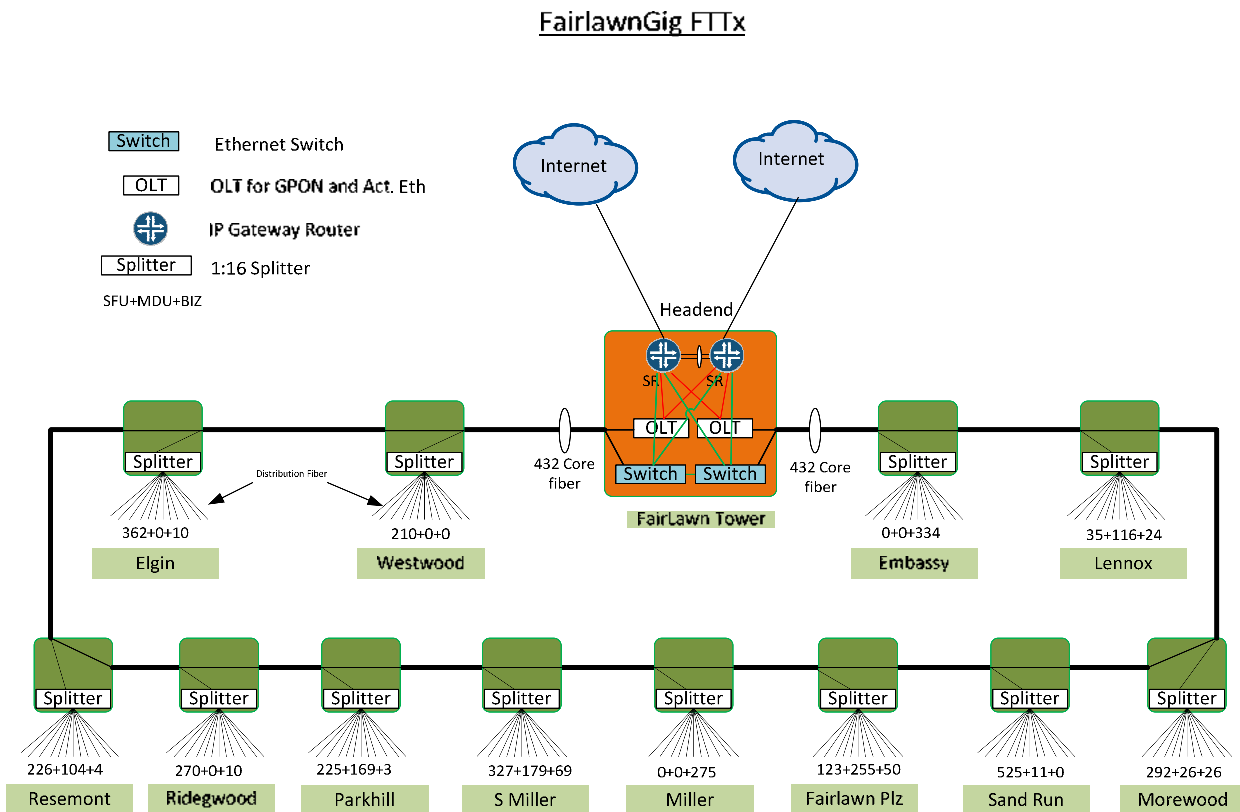


Figure 4: GPON Distribution Plant

The M-BUS subscribers will be served over 1GE Active Ethernet, see Figure 5 below. The M-BUS subscribers will receive 1GE AE service directly from the DC OLT over a dedicated fiber pair bundled in the same fiber plant and utilize a corresponding ONT at their own location to receive the service.

The L-BUS subscribers will receive their 1GE/10GE Ethernet service with a direct home-run from a redundant pair of Ethernet Switches located at the DC for high availability. The L-BUS service will also be protected at the network level by redundant fiber through both east and west routes over the ring.

The Wireless Wi-Fi Access Backhaul (WAB) utilizes GPON plant with 1:4 splitters. On DC side, the WAB subscribers will share the OLT and Internet peering.

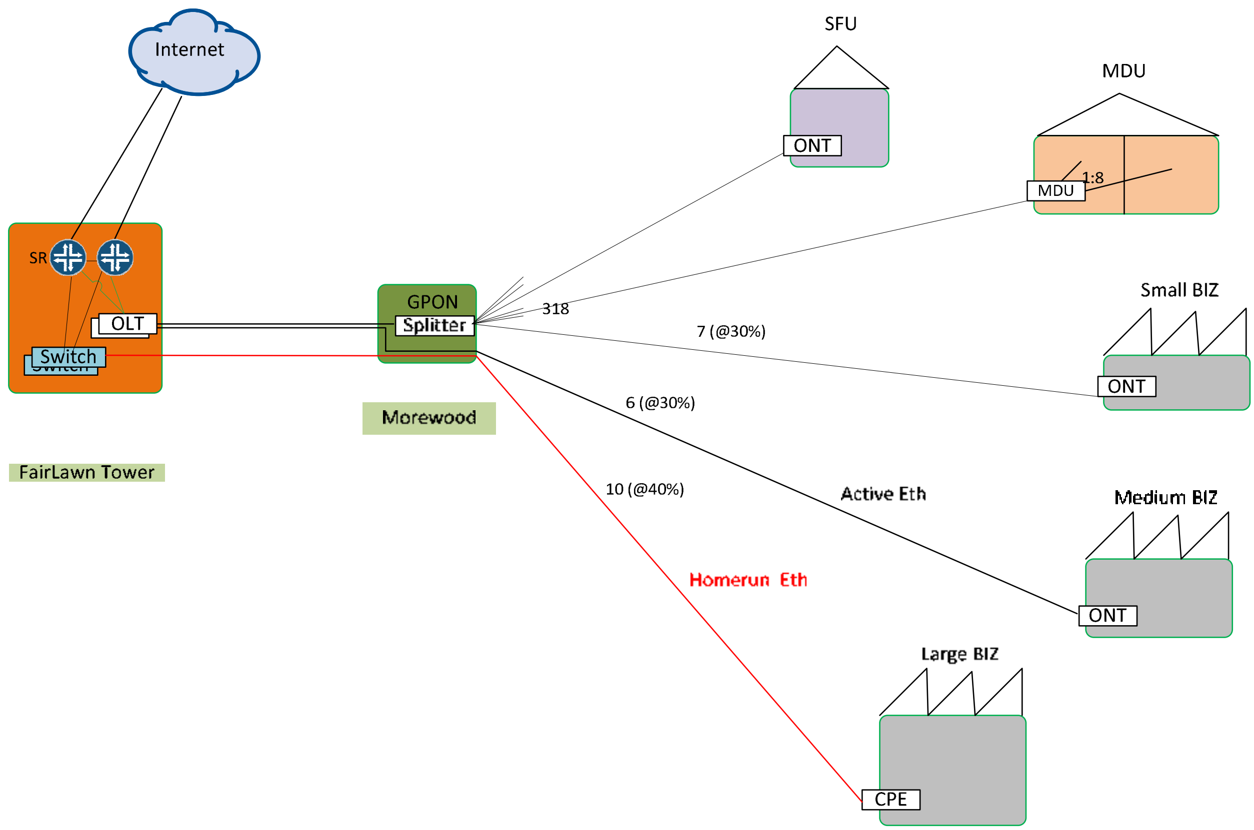


Figure 5: Fairlawn Fiber Distribution Network Services

The optical power budget for GPON deployments will determine the exact split ratios and ONT distances from the DC. The optical power loss increases, as the distance between OLT and subscribers' ONT increases. Each component, including the fiber cable itself, degrades the signal. Attenuation is the term used for describing the amount of signal degradation. The plan for both GPON and Active Ethernet deployments should include optical power budget considerations that show how each optical module affects the signal attenuation including passive splitters. The power loss may vary by manufacturer. Testing should be done before and after each component is added. Matching the actual signal attenuation with the theoretical values helps identify problems such as significant bends in fiber, connector loss from back reflection (the contact between the face ends of fiber in a connector, or a splice), incorrectly matching UPC (Ultra Physical Contact) and APC (Angled Physical Contact) connectors, etc.

The complete Core and Access design and the number of OLTs used are dependent on the customer base density. Table 8 above gives us a good approximation at this point, but we understand that the exact numbers may change.

Internet Peering

The connectivity to the ISPs will be provided through a pair of Core Routers at the Data Center. These core routers will be fully redundant connecting to redundant, OLT modules for high level service availability. This architecture makes the FairlawnGig Network an Open Access Network at the DC.

The Fairlawn ISP connectivity design needs to be reliable and redundant with the following objectives:

- Improve resiliency
- Reduce cost
- Improve performance
- Improve utilization
- Predictable performance by ensuring outbound and inbound traffic flows through the same path

The above objectives lead to the following industry accepted routing topologies briefly explained below:

Topology-driven Routing Topology:

This form of routing topology is optimized to the maximize performance and utilization of links. In this routing policy, all routes are accepted without attribute modification. Therefore, all the routes to the network are equally measured and compared sequentially as per BGP protocol standards to determine the path of the network.

Primary/Secondary Routing Topology:

This Internet edge architecture is designed to reduce cost and improve resiliency. Therefore, these networks have designated primary (actively used) and secondary (standby) ISP connections. Such a topology is referred to as strict primary-secondary. Some topologies use the secondary ISP connections for specific routes, also known as loose primary-secondary routing. Such deployments are a trade-off between cost and resiliency versus the additional flexibility gained by sending specific traffic through the secondary links.

Load Shared Routing Topology:

With this topology, the Internet edge architecture is optimized for optimal utilization. It designates a large range of routes to each ISP connection. When designing this routing topology, it is important to pay particular attention to failure scenarios in any ISP link, as such failures will result in all traffic falling back to a surviving ISP link and this may result in performance degradation. A more dynamic load shared routing scheme will involve routing based on a variety of metrics such as bandwidth over the ISP that advertises the most preferable route to the destination.

The FairlawnGig Network will peer with two ISPs through two Core Routers. External Border Gateway Protocol (eBGP) is used between Fairlawn Core Routes and ISPs and Internal Border Gateway Protocol (iBGP) is used between Core routers with Primary/Secondary routing topology as described above. The Primary ISP link will be used mainly for inbound and outbound traffic and the secondary link will serve as a redundant option or to load balance certain traffic or prefixes if required. BGP attributes Local Preference and AS-Path prepend are utilized to influence outbound and inbound traffic.

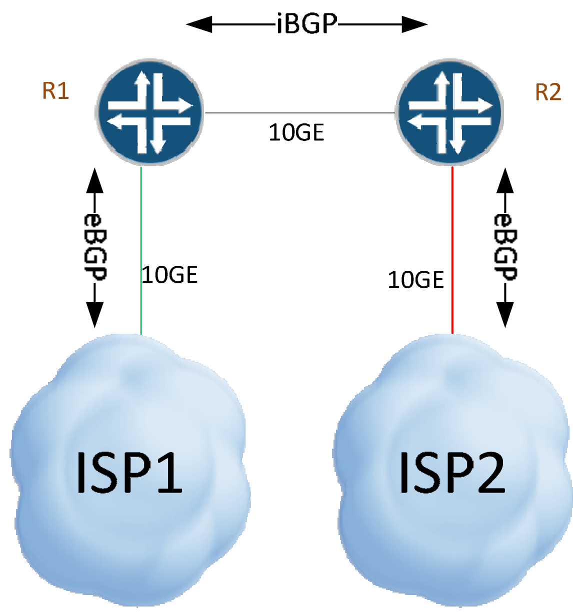


Figure 6: Internet Peering

Services

Residential GPON Access Service

Residential high speed data will go through GPON Access Network. Outdoor GPON ONTs will be deployed at the residence, which will connect to OLTs placed in the Data Center (Fairlawn Tower) location. Customer CPE/Gateway devices will connect to ONTs. Residential services will be serviced at 1.2Gbps uplink and 2.4Gbps downlink speed. Internet traffic for residential services will be in the best effort class of Quality of Service (QoS). Different speeds can be defined based on pre-defined profiles and network policies. Access demarcation will be the ONT.

Small Business (S-BUS) GPON Service

Home based small businesses can opt for high speed data through GPON Access Network. The characteristics for this service will be similar to Residential GPON Access Service, but it can have a higher priority in the network for better performance. This type of traffic can be classified into Assured Forwarding Class. The ONT will be the demarc device.

Medium Business (M-BUS) Active Ethernet Service

Business AE Service will use a dedicated/unshared Ethernet link on the FTTx network. AE ONT will be placed outside the business premises offering further connections to the customer premise. AE will connect to the DC OLT at 1Gbps up/down. Similarly to GPON, the AE business customer can be classified into Assured Forwarding for differentiated service. However Active Ethernet is not oversubscribed at the access level and uses the dedicated Ethernet port on the OLT. The AE ONT will be the demarc device for this service.

Large Business (L-BUS) Switched Ethernet Service

Large Business Switched Ethernet Service is primarily focused on the commercial customers with a stringent requirement of 1Gbps/10Gbps speeds and a requirement for the fiber and path redundancy.

Path redundancy will be provided on the core fiber path, access and drop fiber links. Redundant fiber may share the same fiber cable in folded ring scenarios. Customer will connect to the DC Ethernet switch at 1Gbps or at 10Gbps. Diverse fiber pairs will connect customer traffic back to the DC. Fairlawn will provide CPE devices as the demarcation point. Data on the switched Ethernet is unshared, dedicated and service will have the option to provide various levels of custom features and speed profiles. The type of CPE and management requirements will be determined on a case by case basis, constructed on exact customer requirements.

Wi-Fi Access Backhaul (WAB) Service

Wi-Fi Access Backhaul is a non-commercial service. The FTTx network will be used to enable Wi-Fi access throughout the City of Fairlawn by providing the backhaul capacity to access points. Please refer to the Wireless RF Analysis and Design section below for the details.

Security

Security of the network is critical, especially on the Core Routers due to its IP visibility. Firewall filters are used with appropriate policies to protect BGP sessions and routing instances. Also, control plane of core routers is protected from ICMP Pings against Denial of Service (DoS) attacks. Access to the Routers and Switches is recommended to use SSH connectivity to access remote devices. The following is a brief list of initial security parameters.

- Protect control plane of routers.
- Protect control plane of switches.
- Use encrypted access of remote devices.
- Avoid creating L3 interfaces on switches (other than for testing etc.)
- Protect BGP sessions.

Exact policies will be determined as part of the detailed architecture design and configurations.

IP Planning

The architecture assumes employing a mix of IPv4 and IPv6 schemes into the FTTx architecture for residential and commercial services. The detailed IP planning will be based on IPv4 and IPv6 address blocks. The City of Fairlawn will be responsible for providing the appropriate IPv4 and IPv6 address blocks and Autonomous System (AS) numbers.

Vendor Evaluation

FNC divided the evaluation process into two phases for the benefit of this project:

1. Initial qualification and vendor selection phase - As part of the initial qualification, FNC selected and proposed vendors based on their compatibility to meet the required features and price offering.
2. Detail comparison and competitive pricing phase - As part of this future qualification phase, FNC is open to consider other vendors that the City of Fairlawn or the Anchor Service Provider team may recommend. In this phase of the evaluation process, FNC may issue an RFP to

qualifying equipment vendors for the electronics equipment required for the FairlawnGig project. Based on the results of this second phase, FNC will provide a final recommendation.

Selection of the electronics equipment and final vendors will not affect the FairlawnGig access and core network design; however, it may minimally affect the installation parameters.

Wireless (RF) Analysis and Design

Preliminary design and measurement efforts for the proposed wireless network have been completed. Based on the field measurement and computer modeling, Wi-Fi coverage can be provided to the entire City of Fairlawn using fewer than 200 Wi-Fi Access Points (APs). However, existing utility poles in the City cannot provide sufficient vertical infrastructure to provide coverage to the entire City of Fairlawn and JEDD. Additional pole or rooftop deployments would be necessary.

There are two options for providing backhaul capacity to Wi-Fi access points: fiber and fixed wireless.

- Fiber backhaul provides high bandwidth and high reliability. Thus, Fujitsu recommends that Wi-Fi access points be connected via fiber for backhaul whenever and wherever possible. The primary drawback is that the time-to-deployment for fiber will be much longer.
- Wireless backhaul, with the advantages of fast deployment and low cost, should serve as an option where fiber backhaul is not available. The following three points should be taken into consideration:
  - The license-exempt frequency band specified for this purpose allows for sufficient network performance only when line-of-sight (LOS) exists between the access point and the serving base station. Sufficient service quality will not be possible in areas where a LOS condition cannot be achieved, for example, when an access point location is shrouded by heavy foliage.
  - License-free spectra are available for use by the general public as well as by any commercial or governmental organization. As such, devices operating in these frequency bands are vulnerable to external interference. Wireless backhaul links are of particular concern, since an outage of a backhaul link will affect all AP units under that base station sector's coverage footprint. This is obviously a more critical outage than would be the case if only a single AP were to be in outage.
  - Wireless backhaul is the traffic bottleneck and will limit the overall network throughput performance. Consequently, APs using wireless backhaul will experience lower throughput compared to APs with fiber backhaul.

Fujitsu's fiber planning team has designed a ubiquitous fiber footprint allowing for a sufficient amount of fiber infrastructure to accommodate the backhaul needs for the vast majority of Wi-Fi access points. Since it takes time to deploy the fiber, it is recommended that areas with heavy foliage be given priority in the fiber build schedule, since they cannot be effectively reached wirelessly. The primarily open commercial areas and parks can be served quickly via fixed wireless backhaul. As fiber infrastructure is deployed in more and more locations, the number of Wi-Fi APs that will use wireless backhaul will dwindle, which will have the effect of relieving (or at least not exacerbating) capacity utilization in the wireless backhaul portion of the network.

Areas with fiber infrastructure or areas with heavy foliage will use fiber infrastructure for backhaul of Wi-Fi access points. Public areas where Wi-Fi access is desired and areas not expected to receive fiber for some time can be serviced wirelessly, so long as line-of-sight (LOS) to a serving base station location can be achieved.

RF Design Summary Findings

Fujitsu's site location surveys, field RF measurements, and subsequent RF modeling indicate that significant wireless coverage is possible using existing vertical infrastructure, assuming all assets identified can be used. There are, however, insufficient site locations to provide ubiquitous coverage throughout the City of Fairlawn.

Fujitsu has completed the preliminary wireless assessment based on currently available information, which continues to evolve. One of the key dependencies is the use of Ohio Edison's pole assets. We presently assume that all poles are available for use by the City's wireless network; however, it is likely that a significant number of those poles will eventually be deemed unavailable for use. Ongoing discussions between the City and Ohio Edison are expected to provide further insight going forward.

Recommended next steps to solidify the wireless design include:

1. Confirm availability and usage conditions for base station and access point locations. Ohio Edison pole locations are of critical importance, as previously noted.
2. Confirm high, medium, and low priority coverage areas for the wireless network as well as redundant AP connectivity requirements, in light of the fiber construction schedule and viability of wireless backhaul in particular areas. This could also include identification of specific early-build service locations.
3. Identify additional infill sites as required.
4. Rerun RF coverage predictions to ensure design objectives are being met.
5. Make a final determination of backhaul method (wireless or fiber) for each access point location. Additional site surveys may be required.
6. Perform final capacity and frequency planning and finalize equipment bill of materials.

Efforts to date have provided a great deal of insight into the viability of the wireless network envisioned by the City. However, there is more to be done to complete an initial wireless build plan and it is possible that the wireless network could continue to evolve during the deployment of the network. For greater detail, please see Appendix titled **RF Measurement and Design for Fairlawn Wi-Fi Network**.

Wireless Pole and Tower Structures Recommendations

Fujitsu conducted a site selection survey, which consisted of a physical tour of Fairlawn, to identify vertical assets that would provide suitable mounting locations for wireless networking equipment in support of the wireless portion of FairlawnGig. As a result, thirty-two the City traffic lights, three tornado sirens and 100 Ohio Edison utility poles were surveyed.

Site locations were recorded and photographs taken. Fujitsu generated Google Earth files incorporating photos and illustrating the positions of these assets. This data was used in the development of the RF propagation predictions provided and discussed in the RF Design document, Appendix titled **RF Measurement and Design for Fairlawn Wi-Fi Network**. All data collected has been provided for additional reference.

Of the 135 pole structures identified, 114 were used in the initial RF design to provide coverage to the City. City-owned assets were preferred with Ohio Edison assets used where City assets were not available. Those sites not used were close enough to other access point locations, so their inclusion would not contribute significantly to overall coverage.

The vertical structures identified will not be sufficient to provide ubiquitous coverage to the City. We estimate that coverage of all targeted areas can be achieved with fewer than 200 access points, though many end users would have connectivity available from only one access point. Another 50 to 100 APs would be required to achieve redundant coverage of the area. Fujitsu intends to continue collaboration with the City of Fairlawn to refine and enhance the site list. This will include validating availability of Ohio Edison poles and identifying additional City, commercial and residential structures that may be used to expand wireless coverage.

Rights of Way (ROW) and Easements Recommendations

All ROW and easements identified during this study require no additional work or expense as the City is providing at no charge to the project. All of the GPON Splitter Cabinets will be distributed throughout the City and JEDD. There are 12 Distribution Areas (DA's) planned, each with a small cabinet located on the City of Fairlawn's property. These DA locations and associated naming/numbering convention are described in greater detail in the OSP section above. The head-end equipment, where the DA Splitter Cabinets will be terminated, is located on existing City property adjacent to the City's Services Department and below the 280ft tower.

The wireless equipment will be mounted on the existing tower and throughout the City. The preliminary wireless design calls for four base station locations as well as 114 Wi-Fi Access Points throughout the City. City-owned or controlled assets will be the preferred mounting location for APs. Access Points may also be mounted on existing Ohio Edison utility poles where available. The City is negotiating separately with Ohio Edison for pole attachment fees and power to operate each AP. As of this writing, negotiations are still pending, once completed FNC will add to the City expense budget. It is anticipated that additional APs will be mounted on City, commercial, or residential property for coverage infill; however, we anticipate these attachments to be at no charge to the City.

Primary electrical power and back-up power to service all electronic equipment will be located at the main head-end location at the Data Center (Tower location); as a result there will be no incremental power expenses in the financial model. It should be noted, however, that each Wi-Fi Access Point will consume approximately $3 worth of electricity per month and, as mentioned previously, fees have yet to be negotiated with Ohio Edison. Power will also be required at the wireless base station locations, which have been identified as: the Fairlawn Tower, Dellagnese Building, Akron Water Tower and Stark Knoll Building.

Network Fiber Management Tool Recommendations

The FairlawnGig infrastructure will have over 55.5 miles of fiber optic cable and over 114 wireless Access Points potentially servicing homes and businesses, making fiber strand and wireless asset inventory management an essential part of the FairlawnGig network management process. The fiber records management tool to support the FairlawnGig infrastructure shall be provided by the ASP as part of their anchor service provider responsibility. FNC and the ASP will jointly manage the FairlawnGig infrastructure using the management system which is licensed and operated by the ASP. As part of a new process, the project partners will provide daily network add, moves and changes to network assets as part of the day to day operations, keeping the inventory current at all times. This OSS platform allows all project partners to manage their workforce, as well as track fiber and wireless physical and logical levels.

The ASP software must include a complete array of telecom specific CAD tools and give users the ability to integrate and correlate data from existing billing, accounting, trouble ticket, GPS tracking and network monitoring applications with a geographically correct land base map of all network elements.

5 Operations and Maintenance Plan

This will be finalized when final negotiations are completed between the City, FNC, and ASP. Please note the level of service provided below is FNC standard service offering. FNC is in the process of creating a new service level designed to meet the cities affordability range.

Interoperability Lab Services

Overview - FNC will build the lab for continuous testing and verification and conduct the end-to-end interoperability testing of the FairlawnGig network. The lab will be maintained by FNC at the completion of the Construction Period.

- Lab Objectives
  - Support interoperability testing.
    - Current and future new software release validation testing and verification.
    - Feature testing for current and future requirements.
    - Smooth, seamless, least interrupted feature and software rollouts.
    - Test and preempt against software bugs, apply bug fixes and check against network vulnerabilities.

- Interoperability Testing (“IOT”) Objectives
    - o Perform interoperability testing between all network elements, including ONTs, OLTs, wireless APs, wireless base stations and core router.
    - o Perform interoperability testing between external connection, peering points and devices.

Scope - Test Methodology. FNC will develop a requirements document for identifying, testing and validating necessary functional areas. We will develop the test plan for execution, maintain version control of test documents and report all results. Any new services, architecture changes or additions that are requested by the City must be mutually agreed upon and managed through a Change Management Procedure.

Testing will be contingent upon available support from peering networks or vendors for equipment not required to be provided by FNC. This may include, but not limited to external transport node, router and switches.

Test Reporting - Upon completion of the testing, FNC will document the test results in a report which will contain the following:

- Test Requirements
- Test Architecture
- Test Use Cases
- Test Methodology
- Relevant Test Configuration
- Test Results
- Test Conclusion

Scope Exclusions - Testing will be limited to items directly pertaining to the FairlawnGig network infrastructure performance, but excluding any third party infrastructure provider’s fiber and COLO equipment and cabling. Testing of issues external to the FairlawnGig network are excluded, including but not limited to customer applications, features, equipment and configurations.

End Customer Support Requirements

The customer service experience is critical to the success of this project. FNC has proposed a full-service management and maintenance offering to deliver carrier-grade Internet service expected by residents and businesses along with affordability. The biggest impact to customer experience is equipment breakdown; FNC has recommended a 10 business day hardware replacement for business and residential subscribers.

Fujitsu’s Managed Network Services provides 24x7x365 remote monitoring, management notification, troubleshooting and provisioning services from our world-class US-based Network Operations Center

(NOC). These services bring carrier-class operations to critical network infrastructure composed of selected third-party equipment.

With Fujitsu Maintenance Services, you can protect your network assets with technical assistance, software upgrades, preventative maintenance, spares management and on-site maintenance.

Managed Network Services (MNS)

For network core and business customers, Fault Management encompasses detecting, isolating and restoring incidents for the managed devices. For residential customers, Event Management provides real-time remote event monitoring to ensure the detection and notification of events. Performance management provides monitoring, evaluation and reporting of managed devices, network status and activity to ensure efficient operations of the network and devices. Inventory, device and circuit tracking is the detailed recording and updating of information that captures hardware, software and circuit configuration details. Optionally, FNC offers a Provisioning service for moves, adds and changes of hardware, software and circuit configuration to ensure that changes are done accurately with minimal risk of service disruption.

Maintenance Services

FNC recommends the following Maintenance Services:

- ***Fujitsu Technical Assistance Center (FTAC)*** – this team is your point of contact for resolving network issues. The FTAC is staffed by experienced communications engineers with extensive technical qualifications. The FTAC operates 24/7/365 to support the Fujitsu selected third-party equipment.
- ***Repair and Return services*** - failed equipment is refreshed and repaired, even if your equipment is out of warranty. This provides significant savings in comparison to out-of-warranty repair fees.
- ***Advance Hardware Replacement*** - spares are on hand when you need them. The City can keep spare costs down because you can request delivery of FNC replacement equipment. Our delivery service minimizes downtime (quicker restoration) due to faults and failures.
- ***Outside Plant Break Fix*** - provides FNC technicians when needed to assist resolving service affecting incidents.
- ***Routine Preventative Maintenance*** - entitles you to scheduled site visits to keep your network in optimal working condition. Routine Preventive Maintenance involves non-service affecting tasks of equipment to ensure ongoing network efficiency.
- ***Software Subscription*** - provides critical service-enabling features and capabilities. If upgrades are not made, you may adversely affect your ability to roll out new services. Coverage comprises new software releases including functionality, feature enhancements and necessary modifications plus a deployment of software upgrades.

Upon review of our service offerings, FNC can further customize the solution to meet the City's needs and maximize the value to your constituents.

Recommendations

Managed Network and Maintenance Services (100% & 35%)										
		MNS				MSP				
	Hardware	Fault Management	Event Management	Performance Management	Provisioning Service	Advance Hardware Replacement	Technical Assistance Center	Repair & Return	Software Subscription	Routine Preventative Maintenance
Wireline Fiber Network										
- Residential	ONT		X		X	10BD SLO	X	X	X	
- Commercial Customer	Router/Switch OLT ONT	X		X	X	10BD SLO	X	X	X	X (Router/Switch only)
Wireless WIFI										
- Base Stations	Base Station	X			X	10BD SLO	X	X	X	X
- WAPs	Access Point	X			X	10BD SLO	X	X	X	
Outside Plant Break Fix										
- Underground (Core)		55.5 Miles	10 qty incidents per year		True-Ups Yearly					
- Ariel (Drops)		4,262 Drops	10 qty incidents per year		True-Ups Yearly					

Table Key

10BD	Ten Business Day Service Level Objective
AHR	Advance Hardware Replacement
OSM	On-Site Maintenance
TAC	Technical Assistance Center
R&R	Repair and Return
SW	Software Subscription
MNS	Managed Network Services
OSP	Outside Plant Break Fix

Table 9: Recommendation of Managed Network Services

This table covers both the 100% take rate and 35% take rate models. There is no difference in the recommended services; however, the covered device counts for these services differ as follows:

- 100% take rate model: 2,812 Residential ONTs; 882 Commercial/Wireless ONTs; 31 Core Mgmt/OLTs; and 114 WAPs
- 35% take rate model: 1,219 Residential ONTs; 274 Commercial/Wireless ONTs; 31 Core Mgmt/OLTs; and 114 WAPs

For detailed information of the above recommended MNS and Maintenance Services, please see Appendix titled **Managed Network Services and Maintenance Services Descriptions.**

Network Operations Administrator

The City has requested FNC provide network infrastructure management (Administration) on the new FairlawnGig network. In this role, FNC will oversee capital planning, organize and direct technical operations on both FTTx and wireless infrastructure, make decisions that positively impact the new state-of-the-art network and ensure the level of service specified by the City of Fairlawn is met at all times. Additional responsibilities are to ensure Open Access compliance with technical specifications for FTTx and wireless network, act as the technical liaison between the FairlawnGig network and the Anchor Service Provider, connecting providers and infrastructure owner.

This Administrator role will provide:

- Capital Management/Oversee Capital Requests - Road moves, service requests, growth projects, maintain annual capital budgets, as well as specify electronic refresh cycles. Prepare annual network CAPEX budgets for the City.

- Service Assurance and Activation - Review and analyze all service results, coordinating network and anchor service provider reporting and taking appropriate action to remedy out of tolerance service metrics.
- Financial Results Management - Monthly review of P&L report, recommend corrective action where necessary and administer revenue sharing component.
- Network Expenses - Review and approve network expenses for the City to pay. This will include, but not be limited to, joint pole attachments, cable locate, network interconnection and break-fix.
- Schedule and coordinate meetings - Partner meetings to discuss state of network, make critical network impacting decisions, review financial outlook and revenue sharing.

Operating Structure

Organizational Structure

The project partners' organizational structure demonstrates the seamless collaboration across all the functions and the potential lifecycle benefits by having key contractors involved across both the design-build and operations phases.

Figure 7: Organizational Structure

The following service descriptions are a high level overview of FNC's additional capabilities:

Project and Program Management

At FNC, we understand the importance of providing comprehensive project management aimed at maximizing value and flexibility while minimizing cost and risk. Successful project delivery is based upon our ability to recognize and accept responsibility for project success by conducting appropriate project charter and planning and proactively managing communication, scope, risks and issues.

The FNC Program Management Office (PMO) - The FNC Program Management Office (PMO) serves as the central communications center for all project activities and resources. The PMO will have a clear understanding of the goals, objectives and milestones of each project and will provide recommendations that will assist in facilitating consistent and repeatable processes across multiple projects. The primary objective of the PMO is to ensure successful performance of all network deployments by providing support services such as mentoring, in-flight risk reviews, methodology practices, tools and resource optimization techniques.

The FNC Senior Program Management Team - FNC also provides market-specific support to its project managers through Senior Program Managers with expertise in industry practices and requirements unique to a customer's individual organization. These certified professionals have over 150 years of combined experience in the global telecommunications arena. They participate in management-level strategic planning, risk management, escalations and documentation development for programs in their respective markets, while closely monitoring the On-Site Project Manager's productivity, business skill levels and performance.

The Assigned Project Manager - The FNC Assigned Project Manager (PM) will be the focal point of the entire project – covering all aspects of Planning and Deployment activities and will be the City of Fairlawn's central point of contact throughout the entire project lifecycle. Throughout the process, in addition to regularly issuing the updates and reports defined in the project Communication Plan, the PM also performs multiple implementation support functions, including scheduling with customers and supplier(s), generating and distributing required forms and documentation management.

Deliverables for each project include:

- Project plan.
- Master schedule.
- Risk management – Proactively identifying, analyzing, planning and scheduling of risk plans.
- Project status meetings and reports as required.
- Project controls that include, but are not limited to:
    - Communication management.
    - Cost management.
    - Escalation management
    - Change management – Tracking and resolving all scope, schedule, or cost changes and implementing process for obtaining necessary approvals for modifications.
    - Quality – Providing in-progress and final quality audits to ensure customer, industry and FNC requirements are met.

Key Personnel

The listed key personnel below are potential resources for this project. However, due to resource allocation requirements at the time of the actual project start date, the identified personnel are subject to change.

Executive Engagement Leader

Mitch Drake (Fujitsu)

The Executive Engagement Leader will be the liaison between the City, FNC and the ASP throughout the project. The Executive Engagement Leader will meet with the City and the ASP as the project scope is further refined and executed to ensure all parties are in alignment and expeditiously resolve any unforeseen concerns.

Mitch Drake is an executive leader for large scale network projects with over 37 years of experience in the telecommunications sector, including 17 years as an executive leader. He has led nationwide SS7 network deployment projects that included five mated pairs of STPs, as well as teams deploying a nationwide long-distance voice network in all cities with major National Football League teams. His recent projects have focused on middle mile networks connecting anchor institutions in California, with a combined capital cost of over $200 million.

Project Manager

Chris Bourland (Fujitsu)

The Project Manager will be responsible for the execution of all design-build components of the Project. The Project Manager will oversee all outside plant construction and inside plant installation, ensuring that FairlawnGig is completed on time and within budget.

Chris Bourland has over 17 years of Telecom management experience including ILEC, CLEC and wireless environments. He has extensive experience with OSP, ISP, Copper, Fiber FTTx and wireless construction management.

Technical Lead (Wireline)

Hakki Cankaya, PhD (Fujitsu)

The Technical Lead will oversee all network Wireline technical aspects of the Project and support the Project Manager in driving the FairlawnGig to its successful completion. The Technical Lead will provide a single point of contact to provide wireline solutions to technical challenges encountered during project delivery.

Hakki Cankaya is an engineering professional with over 18 years of experience deploying optical transport networks in North America. Hakki specializes in network reliability and availability planning and architectures development for optical networks. He has extensive experience across multiple technical solutions, including DWDM, ROADM, Lightpaths and GMPLS.

Technical Lead (OSP Engineering)

Michael Koenig (Fujitsu)

The Technical Lead will oversee all Outside Plant technical aspects of the Project and support the Project Manager in driving the project to its successful completion. The Technical Lead will provide a single point of contact to provide OSP solutions to technical challenges encountered during project delivery.

Mike Koenig is an Outside Plant Engineer with over 25 years of experience in both copper and fiber design for dozens of ILEC and CLEC customers. He has extensive experience in the OSP planning, design and construction techniques required for FTTx projects.

Technical Lead (Wireless)

Reid Chang, PhD (Fujitsu)

The Technical Lead will oversee all network Wireless technical aspects of the Project and support the Project Manager in driving the FairlawnGig to its successful completion. The Technical Lead will provide a single point of contact to provide solutions to technical challenges encountered during project delivery.

Reid Chang is a Senior Wireless Technical Advisor with over 20 years of practical experience. He is a Subject Matter Expert in multiple areas of Wireless Technology including Product Design, RF Engineering, Product Marketing, System Architect, Network Planning, Performance, Simulation, Deployment and Optimization. Reid holds a Ph.D. in electrical engineering as well as 9 Patents (4 Pending LTE, 5 Awarded), 3 IEEE Publications (1 LTE). He has years of experience in LTE, WiMax and CDMA based systems.

Project Field Director (TBD)

The Project Field Director will be responsible for managing the turnkey design, permitting, procurement and construction of the outside plant network.

6 Competitive Intelligence and Marketing

Competitive Intelligence (CI) Report on Service Providers

The Internet is becoming ever more mobile, pervasive and deeply embedded in personal and business networks. With the advent of the Internet of Things (IoT), Smart Cities and wearable devices, the Internet continues to derive revenue from broadband networks.

Carrier Data marks - The age of Gigabit Internet has arrived

The much publicized Google Fiber initiative sparked a rush by carriers to advance their Gigabit Internet plans. Competing carriers responded with their own offerings; states and cities, likewise, are initiating their own efforts to build, own and/or operate fiber-based Gigabit (GB) systems. Current observations of this rush include:

Residential Gigabit services have established a 1GB competitive price of $60-$70 per month[2]. Reviews of regional carriers as noted in Figure 8 below, show the market pricing spectrum for nine (9) Internet providers. Google set the price with its $70/month service offering. AT&T sells GigaPower 1GB service for $110 per month and Comcast has released its 2GB service at $140 per month in selected markets. Time Warner does not provide a 1GB service; it tops out at 300MB for $70 month, but is planning to roll out Gigabit service by 2017[3]. Pricing noted here excludes promotions, installation, equipment or set up charges. Companies reviewed include: AT&T, Comcast, Frontier, Google, CenturyLink, US Internet, Time Warner and Chattanooga EBP.

Figure 8: Speed to Price Distribution

Commercial 1GB services have established $100+ per month competitive pricing. Google has positioned a $100 per month commercial service. AT&T provides it 1GB GigaPower to commercial clients at its standard $110 per month rate. Comcast has restricted its 2GB service to residential customers only, preferring to leave businesses on slower, but higher margin, business class services for the time being. Comcast continues to individually price Gigabit Ethernet services for its business clients as does Time Warner. Demand-based pricing allows carriers to have a wide variety of price points for individual service, but increases the ability for the City to sway customers with market-based pricing.

---

[2] Fujitsu Network Communications, "FairlawnGig, Engineering and Design Study," 2015

[3] http://www.dslreports.com/shownews/Time-Warner-Cable-CEO-Hints-At-Gigabit-Speeds-by-2017-133833

Wholesale Ethernet demand grows as carriers replace T1/T3/SONET circuits. Carrier pricing for wholesale Ethernet can vary greatly based on geography and type of service need. Carriers tend to price their wholesale Ethernet on an Individual Case Basis (ICB), meaning customers do not normally have the same pricing structure. Service costs to buyers though can easily exceed $1,000 per month for 1GB service. The wholesale market "is largely dominated by a handful of providers, led by Verizon, AT&T, CenturyLink and Level 3, in that order, based on market revenue[4]." Wholesale service revenues are forecasted to reach $6.9 billion by 2018, growing annually at just under 20 percent[5]. The market opportunity to sell in the wholesale space shows great prospect.

Trending in Broadband

Growth in Broadband Utilization

The Cisco Visual Networking Index (VNI) provides the most widely noted tracking on the growth in Internet bandwidth demand. Currently, the VNI 2014-2019 forecast predicts that, "global IP traffic in 2014 stands at 59.9 Exabytes (EB) per month and will nearly triple by 2019, to reach 168.4 Exabytes per month[6]. The US share of this bandwidth should account for approximately 17 percent or approximately 28.6 Exabytes per month by 2019. Bandwidth consumption is increasing exponentially and wireless Internet will claim two-thirds of available bandwidth.

Wireless Services Trends

- Carriers bundle their Wi-Fi service with their Internet service offerings. Hotspot access is "free" to paying customers with access granted wherever that carrier has the operating capacity. This "added value" service is a table stakes play for the City to compete with carriers.
- A high level of network agility in Internet access is required by wireless operators. Customers must be able to move seamlessly between wired and wireless networks. Video applications already account for over half of the total wireless data traffic, agility in network scaling will be a critical element for network uptime. The Wireless Broadband Alliance notes that the strongest drivers of hotspot usage, in order, are: instant logon, seamless roaming, Wi-Fi calling and quality of service[7].
- Wi-Fi offloading to account for the majority of wireless traffic. "By 2019, wired devices will account for 33 percent of IP traffic, while Wi-Fi and mobile devices will account for 66 percent of IP traffic[8]. Smartphone, TVs, tablets and machine to machine (M2M) devices in the IoT space will account for this traffic. The net effect of this transition is that carriers are predicted to drop up to 85% of their wired Internet traffic to Wi-Fi[9] Carriers view this as a potential cost

[4] Frost & Sullivan, "Wholesale Carrier Ethernet Service Market Update, 2014"
[5] Frost & Sullivan, "Wholesale Carrier Ethernet Service Market Update, 2014"
[6] Cisco VNI, 2015
[7] Wireless Broadband Alliance, "Carrier Wi-Fi, The State of the Market 2014"
[8] Cisco VNI, 2015
[9] Cisco VNI, 2015

of servicing reduction under the Next Generation Hotspot program[10], but it is only valid if they can hold the customer to their Wi-Fi network.

- Next Gen Hotspots (NGH) are coming. The NGH is an industry initiative to define new standards for Wi-Fi access such as authentication and network interoperability. The NGH's key driver has been carriers seeking to offload traffic, but that offload represents a revenue opportunity as well. Transient cellular customers moving through the City could potentially be grabbed from the cellular network, not easily though as carrier Wi-Fi networks are pervasive. Targeting this user base with additional services such as free Wi-Fi calling.
- The Internet of Things (IoT) is real. Billions of devices will be connected via the NGH in the near future. Chip makers supporting these devices are already integrating Wi-Fi into their chipsets to enable seamless M2M connectivity. The main business models to date have circulated around smart cities, meter monitoring and vehicle applications. This opens up new opportunities to partner with utilities, medical providers and freight operations as they seek real-time patient, electrical usage, or vehicular location and operating metrics. The ability to monetize such Wi-Fi access would support future the City's broadband revenue growth.

Marketing

Market Survey Results

The City conducted a resident survey at the compactor facility to gauge interest in the FairlawnGig project.

A total of 434 responses were received to the following three questions:

- When this service becomes available, would you have an interest in such a service?
- If this service delivers faster speeds than is currently available in Fairlawn, with local customer service at a competitive price, would you have an interest in such a service?
- The City of Fairlawn may be able to deliver phone service including enhanced 911 with the FairlawnGig. Would you have an interest in this additional service?

[10] See. Wireless Broadband Alliance, www.wballiance.com

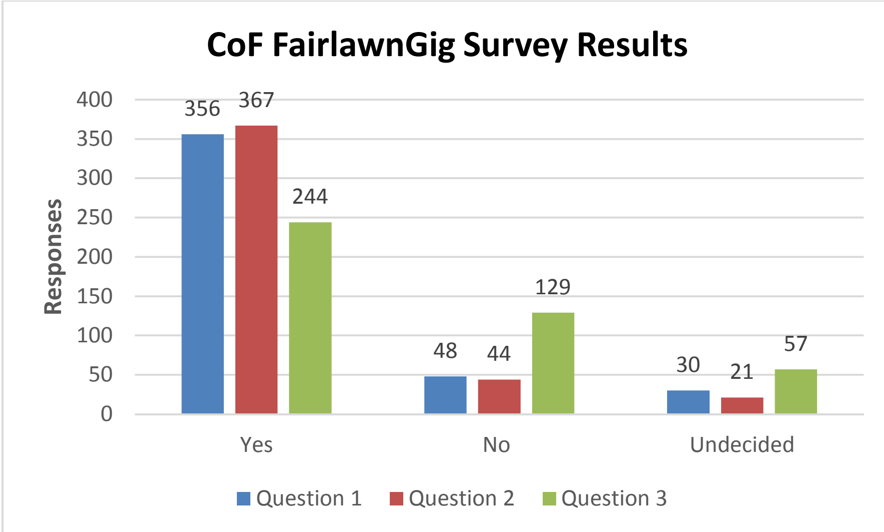


Figure 9: FairlawnGig Survey Results

Summary of Results

- Eight-two percent (82%) of respondents expressed strong interest in the potential availability of a GB Internet service.
- Eighty-five percent (85%) of respondents expressed strong interest in the availability of a faster service than is currently available, competitively priced and supported by local customer service.
- Fifty-six percent (56%) of respondents expressed interested in an E911 service.

Of note in the results is the high correlation (82% to 85%) of interest in Gigabit service combined with competitive pricing and local customer service. The lower result (56%) regarding interest in E911 may be a reflection of less knowledge of the service and how it works, as No and Undecided responses accounted for 44% of answers. Please see Appendix titled **Survey Results 11-30-15**.

The validity/reliability of the survey results is based primarily on the method of collection. The first person verbal responses method tends to provide highly accurate viewpoints of respondents, but can be limited by a respondent's knowledge of the question. Additionally, the count of how many people refused to answer the questions is unknown, therefore, statistical correlation to the whole of the City population is not possible with this method. However, if we assume that all questions where completely understood, then the survey results should be considered highly reliable and actionable by the City.

Marketing Requirements

The retail paradigm has changed. Consumers are technologically savvy, price sensitive, socially connected and better informed on competing products. They use their mobile devices to instantly access pricing and competitive offers[11]. The City needs to meet this paradigm with a value equation customer view as valid both to attract and retain their patronage.

The value equation is not a static formulation. It takes a variety of simultaneous offers and touch points, single contact resolutions all timed to meet customers' individual needs. This requires the City to have flexible offers for customer attraction and retention available across all channels being used.

The Marketing Challenge: The City challenge is how FairlawnGig can sway customers away from existing providers. The main targets of marketing activity include residential, commercial and transient Internet users. Meeting this challenge includes considerations such as:

- Price: The City of Seattle during its due diligence broadband network survey found that 8 in 10 current Internet users would switch from their current carrier to a 1GB provider if the price point did not exceed $75 per month[12].
- Quality of Service: Speed and reliability of service connections routinely top considerations in Internet choice. Other quality items include fast network discovery, authentication and added value applications.
- Customer Service: The Seattle study also found that just 6.1% of Internet customers are "very satisfied" with the customer service from their provider[13]. "Customers today are used to providing personal information to companies in a variety of media, including online profiles and usage data. In return, they expect firms to have the right information on hand in order to respond to and anticipate their needs[14]." Customer expect providers to "know them", the service provider that does that well has a competitive advantage.
- Contact Channels: The City is expected to employ traditional contact channels: call center, retail office, business consultants (wholesale and commercial). Online and/or mobile presence should be considered, with contacts routed back through the call center operations and/or customer relationship management (CRM) systems to coordinate with all customer service channel reps. Meeting the customer need on their channel of choice with offers consistent across channels builds trust and ultimately loyalty.
- Contact Tactics: Tactics in the chosen contact channels should include where feasible: email marketing, search ads, display banners, print ad, direct mail, radio/TV, affiliate relations, social media, blogging, public relations and community events. Perhaps the strongest channel and tactic, however, that the City of Fairlawn is already aware of is the use of the city waste disposal site. As leveraged for the survey, the site provides an in person opportunity to connect with customers.

[11] Robert Worden, Frost & Sullivan, "Smart Retailers are Unifying Channels", 2013
[12] City of Seattle Fiber-to-the-Premises Feasibility Study, 2015
[13] City of Seattle Fiber-to-the-Premises Feasibility Study, 2015
[14] Robert Worden, Frost & Sullivan/IBM, "A Smarter Approach to CRM", 2011

Marketing Recommendations:

- Consumer and commercial customer broadband value is founded on three principal pillars. Quality of Service (QoS) rendered (network uptime, reliability and functionality), price of the service and responsive customer service. Marketing efforts should always feedback to these elements of the equation.

- A sub-$75 dollar service point for residential customers supported by the business case will present a strong lure for customers currently paying similar prices for less bandwidth speed.

- Create a standard commercial monthly GB service rate. This creates a strong differentiator to carrier plans (see Comcast and Time Warner) which would incent business to switch service providers. Google is at $100, AT&T at $110 per month. A $99 dollar commercial rate might be considered.

- Uptime, reliability and scaling should be paramount. Wireless connections should be seamless for FairlawnGig customers and paywalls for transient should be made easy. Regarding functionality, Wi-Fi calling as a potential future application use of the City broadband network should be explored, to securely anchor local customers to the network and attract transient customers.

- Unify customer contact channels. This includes marketing efforts for attraction and retention as well as customer service. A CRM application that provides customer profile data should be available to reps across the marketing channels. Customer needs should be met on a single contact with a FairlawnGig representative.

- Tactical Marketing. Least cost tactics and channels should always be utilized to maximize return on outreach investment; but channel choice should be balanced against effectiveness. The waste facility drop off is a least cost and potentially highly effective marketing point. This should be supported by call center and electronic outreach. Advertising should focus on door hangers (engage local clubs, boy scouts to assist), along with selected print advertising. Radio and TV are expensive channels that will bleed into adjacent areas not serviced by FairlawnGig and thus should be avoided. A dedicated outreach to potential transient Wi-Fi users based on subscription services may be worthwhile.

Future Considerations**:**
The wave of Smart City initiatives should be explored as a future service and revenue generation aspect of the City broadband initiative.

7 Potential Direction Forward and Next Steps

The proposed FairlawnGig municipal service will include both a high speed, carrier-grade Wi-Fi access network and an underground fiber optic network that will be constructed in the City-owned right-of-way to allow ubiquitous internet service available to each and every parcel of property within the City of Fairlawn and the JEDD.

The FairlawnGig project represents the Mayor's vision of a new, high-tech broadband infrastructure in the City of Fairlawn. The Project will deliver to the City a platform to grow and diversify the economy through the commercialization of new service offerings, increase of broadband speeds consistent with the FCC's National Broadband Plan and improve service levels to constituents while providing greater diversity of those services.

FNC will assemble industry leading partners, many who are located in the state of Ohio to lead this effort. These partners will finalize negotiations with the City over the next few days; upon successful completion FNC will add/update this EDC to reflect the entire undertaking.

At this point FNC is satisfied with the goal of the EDC of determining what the FairlawnGig network would cost, which is $10M. FNC is looking forward to working with the City with finalizing who the ASP is, and then work collectively to finalize all budgets. FNC believes the construction and operating details can be worked in concurrent paths, each with reaching conclusion on or near mid-March, just in time to begin construction.

FairlawnGiG Responsibility Matrix

Table Key	
Symbol	Description
-	N/A
X	Exclusive
S	Secondary
P	Primary

Network Design and Construction

	City	Fujitsu	ASP	Notes
Permitting				
Provide Public Rights of Way/Easements	X	-	-	Project contribution
Provide Tower and Structures	X	-	-	Project contribution
Submit Applications	-	X	-	
Approve Permitting Applications	X	X	-	
OSP Deployment				
Fiber Cable Construction	-	X	-	
Fiber Cable Splicing	-	X	-	
Pole Attachments (Construction)	-	X	-	
Cable Locates (Construction)	-	X	-	
Cable Records Maintenance and Retention	-	X	-	
Asset/Inventory Management	S	P	S	FNC to Administer; City to retain all property/assets records
Network Deployment				
Equipment Installation	-	X	-	
Test and turn-up	-	X	-	
QA Acceptance	-	X	-	
Records Retention	-	P	S	Will use Horizon Tel MapCom system
Circuit Assignment	-	X	-	
Provisioning	-	X	-	
Wireless Deployment				
Equipment Installation (Base Station/AP's)	-	X	-	
Test and turn-up	-	X	-	
QA Acceptance	-	X	-	
Records Retention	-	P	S	Joint responsibility
Circuit Assignment	-	X	-	
Provisioning	-	X	-	
Network Change Orders and Growth				
Change Order Requests	S	P	-	FNC to Administer; City to approve
Change Order Scope/Pricing	-	X	-	
Calculating Business Impact	S	P	-	FNC to Administer; City to approve
Change Order Approval	X	-	-	
Road Moves	-	X	-	
Data Center				
Provide Data Center Space, Power, Backup Power (Generator), and Environmental Systems	X	-	-	

Network Operations

	City	Fujitsu	ASP	Notes
Service Assurance				
Network Monitoring	-	X	-	
Capacity Management	-	X	-	
Fault Isolation	-	X	-	
SLA Performance Tracking/Reporting	-	X	-	
Network Dispatch	-	X	-	
Network Repair	-	X	-	
End-user Repair (Home/MDU/Commercial)	-	-	X	Customer side of ONT
Service Activation (Residential and Commercial)				
Service Requests (FTTx and Wireless)	-	-	X	
Call Center	-	-	X	
Retail Center	-	-	X	
Tier 1 Help Desk	-	-	X	
First Point of Contact for Ancillary User's (VPN)	-	X	-	
Help Desk for ISPs Servicing Ancillary User's (VPN)	-	X	-	
Network Management				
Utility Joint Pole Attachments	P	S	-	FNC will administer program on behalf of City
Cable Locating Association Admin	P	S	-	FNC will administer program on behalf of City
Outside Plant Break / fix	P	S	-	FNC Administer; City provides equipment to expose cable
Break / fix splicing	-	X	-	
Tower Structure Attachments	S	P	-	FNC Administer; City negotiate rates
Network Refresh				
Equipment Replacement (8 yr. increments)	-	X	-	
Marketing & Sales (Retail and Wholesale)				
Marketing and Awareness Campaigns	-	-	X	
Branding			X	
Collateral			X	
800 Contact Number			X	
Website Admin			X	
Attracting Service Providers (Open Access)	-	-	X	
Connecting New Users				
Funding Drops for New User's	P	S	S	Customer requests comes to FNC from HT; City reimburses FNC (process attention)
Customer Contract Management	-	-	X	HT responsible for customer contract

General & Administration

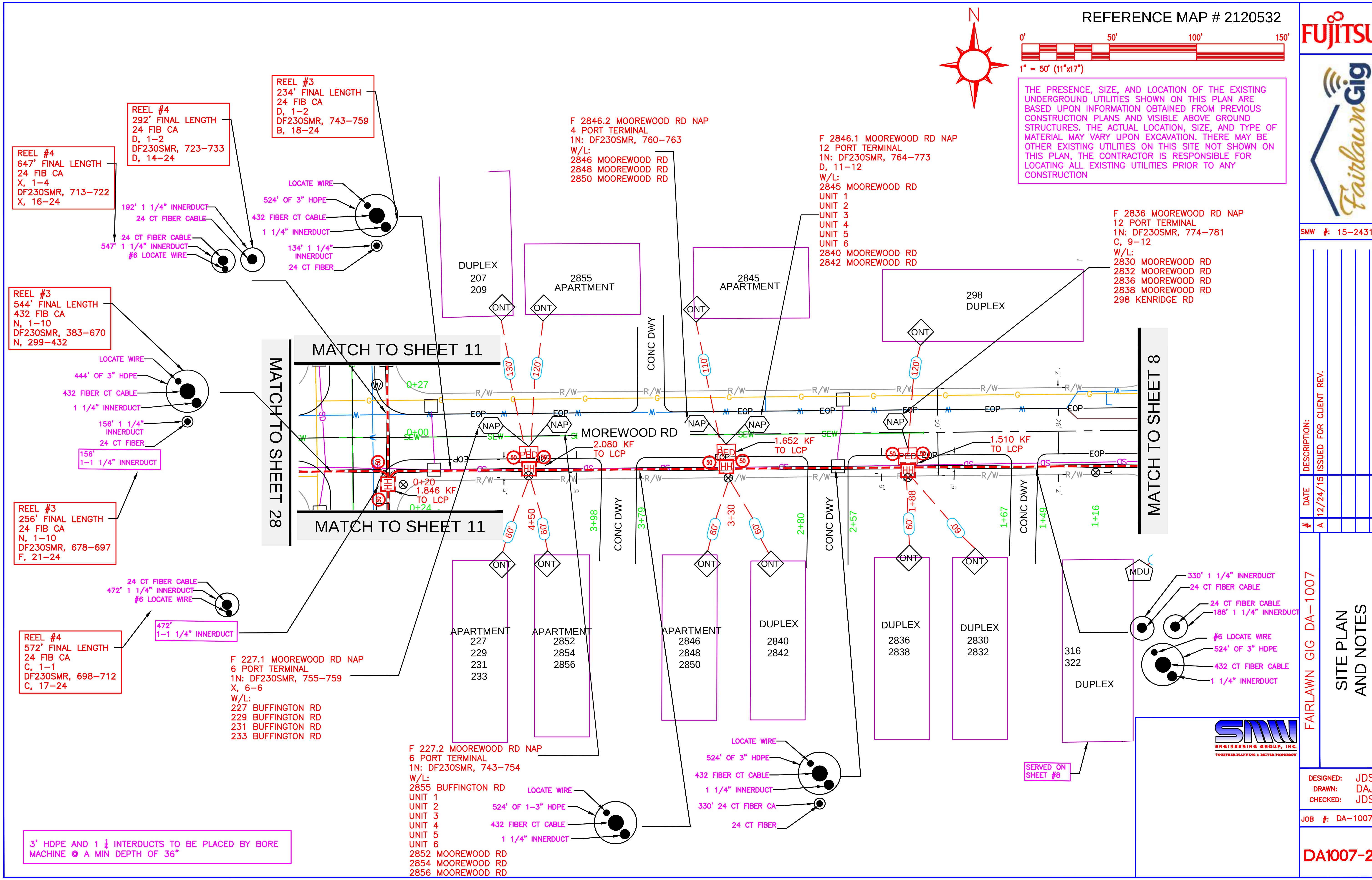
	City	Fujitsu	ASP	Notes
G&A				
Data Center and Retail Office Facilities & Maintenance	X	-	-	
Utilities and Communications	X	-	-	
Insurance	X	-	-	
Backup Power	X	-	-	
Network Operator Administration	-	X	-	
Infrastructure Accounting				
Accounts Payable	X	-	-	
Accounts Receivable	X	-	-	
Asset Accounting	X	-	-	
Tax Compliance	X	-	-	
Budget /Finance	X	-	-	
Regulatory Compliance	X	-	-	

FUJITSU

FairlawnGiG Responsibility Matrix

Materials Management	City	Fujitsu	ASP	Notes
Spare Fiber Cable Storage	P	S	-	
Spare Misc. Material Storage	P	S	-	
ONT's	P	S	-	
Wireless CPE	P	S	-	

Network ASP Operator Administration	City	Fujitsu	ASP	Notes
P&L Review	-	S	P	HT provides monthly operation reports to be reviewed by FNC and City
Performance Reporting/Review	-	S	P	HT provides monthly operation reports to be reviewed by FNC and City
Capital Requests	-	S	P	HT provides monthly operation reports to be reviewed by FNC and City
Customer Escalations	S	-	P	High value customer escalations



REFERENCE MAP # 2120532
N
0' 50' 100' 150'
1" = 50' (11"x17")
THE PRESENCE, SIZE, AND LOCATION OF THE EXISTING UNDERGROUND UTILITIES SHOWN ON THIS PLAN ARE BASED UPON INFORMATION OBTAINED FROM PREVIOUS CONSTRUCTION PLANS AND VISIBLE ABOVE GROUND STRUCTURES. THE ACTUAL LOCATION, SIZE, AND TYPE OF MATERIAL MAY VARY UPON EXCAVATION. THERE MAY BE OTHER EXISTING UTILITIES ON THIS SITE NOT SHOWN ON THIS PLAN, THE CONTRACTOR IS RESPONSIBLE FOR LOCATING ALL EXISTING UTILITIES PRIOR TO ANY CONSTRUCTION
REEL #4
647' FINAL LENGTH
24 FIB CA
X, 1-4
DF230SMR, 713-722
X, 16-24
REEL #4
292' FINAL LENGTH
24 FIB CA
D, 1-2
DF230SMR, 723-733
D, 14-24
REEL #3
234' FINAL LENGTH
24 FIB CA
D, 1-2
DF230SMR, 743-759
B, 18-24
F 2846.2 MOOREWOOD RD NAP
4 PORT TERMINAL
1N: DF230SMR, 760-763
W/L:
2846 MOOREWOOD RD
2848 MOOREWOOD RD
2850 MOOREWOOD RD
F 2846.1 MOOREWOOD RD NAP
12 PORT TERMINAL
1N: DF230SMR, 764-773
D, 11-12
W/L:
2845 MOOREWOOD RD
UNIT 1
UNIT 2
UNIT 3
UNIT 4
UNIT 5
UNIT 6
2840 MOOREWOOD RD
2842 MOOREWOOD RD
F 2836 MOOREWOOD RD NAP
12 PORT TERMINAL
1N: DF230SMR, 774-781
C, 9-12
W/L:
2830 MOOREWOOD RD
2832 MOOREWOOD RD
2836 MOOREWOOD RD
2838 MOOREWOOD RD
298 KENRIDGE RD
LOCATE WIRE
524' OF 3" HDPE
432 FIBER CT CABLE
1 1/4" INNERDUCT
134' 1 1/4" INNERDUCT
24 CT FIBER
192' 1 1/4" INNERDUCT
24 CT FIBER CABLE
24 CT FIBER CABLE
547' 1 1/4" INNERDUCT
#6 LOCATE WIRE
REEL #3
544' FINAL LENGTH
432 FIB CA
N, 1-10
DF230SMR, 383-670
N, 299-432
LOCATE WIRE
444' OF 3" HDPE
432 FIBER CT CABLE
1 1/4" INNERDUCT
156' 1 1/4" INNERDUCT
24 CT FIBER
156' 1-1 1/4" INNERDUCT
REEL #3
256' FINAL LENGTH
24 FIB CA
N, 1-10
DF230SMR, 678-697
F, 21-24
24 CT FIBER CABLE
472' 1 1/4" INNERDUCT
#6 LOCATE WIRE
472' 1-1 1/4" INNERDUCT
REEL #4
572' FINAL LENGTH
24 FIB CA
C, 1-1
DF230SMR, 698-712
C, 17-24
DUPLEX 207 209
2855 APARTMENT
2845 APARTMENT
298 DUPLEX
MATCH TO SHEET 11
MATCH TO SHEET 28
MATCH TO SHEET 8
MOREWOOD RD
CONC DWY
2.080 KF TO LCP
1.652 KF TO LCP
1.510 KF TO LCP
1.846 KF TO LCP
0+27
0+00
0+20
0+24
4+50
3+98
3+79
3+30
2+80
2+57
1+88
1+67
1+49
1+16
APARTMENT 227 229 231 233
APARTMENT 2852 2854 2856
APARTMENT 2846 2848 2850
DUPLEX 2840 2842
DUPLEX 2836 2838
DUPLEX 2830 2832
316 322 DUPLEX
MDU
330' 1 1/4" INNERDUCT
24 CT FIBER CABLE
24 CT FIBER CABLE
188' 1 1/4" INNERDUCT
#6 LOCATE WIRE
524' OF 3" HDPE
432 FIBER CT CABLE
1 1/4" INNERDUCT
F 227.1 MOOREWOOD RD NAP
6 PORT TERMINAL
1N: DF230SMR, 755-759
X, 6-6
W/L:
227 BUFFINGTON RD
229 BUFFINGTON RD
231 BUFFINGTON RD
233 BUFFINGTON RD
F 227.2 MOOREWOOD RD NAP
6 PORT TERMINAL
1N: DF230SMR, 743-754
W/L:
2855 BUFFINGTON RD
UNIT 1
UNIT 2
UNIT 3
UNIT 4
UNIT 5
UNIT 6
2852 MOOREWOOD RD
2854 MOOREWOOD RD
2856 MOOREWOOD RD
LOCATE WIRE
524' OF 1-3" HDPE
432 FIBER CT CABLE
1 1/4" INNERDUCT
LOCATE WIRE
524' OF 3" HDPE
432 FIBER CT CABLE
1 1/4" INNERDUCT
330' 24 CT FIBER CA
24 CT FIBER
SERVED ON SHEET #8
3' HDPE AND 1 ¼ INTERDUCTS TO BE PLACED BY BORE MACHINE @ A MIN DEPTH OF 36"
FUJITSU
FairlawnGig
SMW #: 15-2431
DESCRIPTION: ISSUED FOR CLIENT REV.
DATE 12/24/15
A
FAIRLAWN GIG DA-1007
SITE PLAN AND NOTES
SMW ENGINEERING GROUP, INC.
DESIGNED: JDS
DRAWN: DAJ
CHECKED: JDS
JOB #: DA-1007
DA1007-27

)SP Bill of Materials for Project

CLASSIFICATION		Construction BOM Measurement	Construction BOM Units
	ENGINEERING:		
Engineering Design	Pole Survey, Make Ready Work Report, Route Design, Engineering, Permitting & Construction / As-Built Drawings	FT	0
Engineering Design	Environmental Engineering	FT	0
	CONSTRUCTION:		
	AERIAL: Tree Trimming	FT	700
Poles	Place anchor	Anchor	57
Poles	Make Ready Construction_FOREIGN	Pole	**92**
Cables	Aerial FOC/strand Placement	FT	19,772
	UNDERGROUND:		
Conduits	Trenching **(% of new UG path)**	FT	0
	Hand Trenching		
	Machine Trenching		
	Trenching - Rock Adder		
	Cut and Restore:		
	Asphalt		
	Concrete		
	Brick pavers		
	Sod	FT	24,000
Conduits	Direction Drilling includes Pullback of one Conduit and Tracer Wire	FT	201,860
Conduits	Direction Drilling w/ Rock Railhead Adder **(% of directional drilling)**	FT	0
Conduits	Direction Drilling w/ Rock Mud-Motor Adder **(% of directional drilling)**	FT	0
Conduits	Handhole Installation	EA	401
	10" x 15" HH or Flower Pot Installation		162
Conduits	Underground FOC/Innerduct Placement in Conduit	FT	491,597
	D-Bore Conduit Pullback	FT	109,551
Other	NAP (Terminal) Installation	EA	731
Other	LCP Cabinet Installation	EA	12
	SERVICE DROPS:		
	Drop/ONT Installation	FT	243,700
	SPLICING:		
	Closure Prep, Fusion Splicing, Closure Attachment/Placement	FT	357,879
	FEES:		
Other Upfront Costs - Other	Right-of-Way Acquisition	FT	0
Other Upfront Costs - Other	Right-of-Way Clearance	FT	0
Outside Plant -Other	Quality Control, OTDR/Power Testing, Turn-Up	FT	357,879
Outside Plant - Other	ODOT **(% of route requiring traffic control planning and set-up)**	FT	0

)SP Bill of Materials for Project

		Construction BOM	
		Measurement	Units
	MATERIALS:		
	OSP:		
	AERIAL:		
Outside Plant - Poles	Attach Hardware, Guys, Anchors, U-Guard	Pole	92
Outside Plant - Poles	Dielectric Sno-shoes w/ Hardware	Pair	18
	UNDERGROUND:		
	1.25" Innerduct	FT	160,070
Outside Plant - Conduit	1.25" HDPE SDR 13.5 **(number of conduits to be installed)**	FT	121,833
	2" HDPE	FT	14,856
	3" HDPE	FT	160,340
	4" HDPE	FT	7,760
Outside Plant - Conduit	1.25" Compression Couplers	EA	0
Outside Plant - Conduit	30"x48"x36" Tier 22 HH w/ Lid	EA	160
	24" x 36" Tier 22 HH w/ Lid	EA	242
	10" x 15" HH or Flower Pot	EA	162
Outside Plant - Conduit	96" x 5/8" Copper Ground Rod	EA	435
Outside Plant - Conduit	NEPTCO - Trace Safe Tracer Wire	FT	215,227
Outside Plant - Conduit	Marker Post **(marker separation in feet)**	EA	460
Outside Plant - Conduit	Terminal Post (Test Station)	EA	60
	FOC:		
	432 dielectric FOC	FT	16,370
Outside Plant - Cables	**288 dielectric FOC**	FT	15,047
Outside Plant - Cables	**216 dielectric FOC**	FT	18,635
Outside Plant - Cables	**144 dielectric FOC**	FT	34,151
Outside Plant - Cables	**96 dielectric FOC**	FT	32,821
	72 dielectric FOC	FT	8,217
	48 dielectric FOC	FT	47,783
	24 dielectric FOC	FT	120,031
Outside Plant - Cables	2 fiber drop	FT	216,900
Outside Plant - Cables	4 fiber drop	FT	12,900
	6 fiber drop	FT	2,400
	8 fiber drop	FT	4,300
	12 fiber drop	FT	7,200
Outside Plant - Cables	Splitters	EA	127
Outside Plant - Cables	LCP Cabinet (various sizes) Fully Configured	EA	12
Outside Plant - Cables	Splice Closure w/ trays	EA	327
	LCP & NAP		
	10" Pedestal	EA	288
	10" Pedestal with HH mounting kit	EA	287
Outside Plant - Other	NAP (Terminal) with tail	EA	347
Outside Plant - Other	NAP (Terminal)	EA	403

OSP Bill of Materials for Project

CLASSIFICATION	ENGINEERING:	Construction BOM Measurement	Construction BOM Units
Engineering Design	Pole Survey, Make Ready Work Report, Route Design, Engineering, Permitting & Construction / As-Built Drawings	FT	0
Engineering Design	Environmental Engineering	FT	0
	CONSTRUCTION:		
	AERIAL: Tree Trimming	FT	700
Poles	Place anchor	Anchor	57
Poles	Make Ready Construction_FOREIGN	Pole	**92**
Cables	Aerial FOC/strand Placement	FT	19,772
	UNDERGROUND:		
Conduits	Trenching (% of new UG path)	FT	0
	Hand Trenching		
	Machine Trenching		
	Trenching - Rock Adder		
	Cut and Restore:		
	Asphalt		
	Concrete		
	Brick pavers		
	Sod	FT	24,000
Conduits	Direction Drilling includes Pullback of one Conduit and Tracer Wire	FT	201,860
Conduits	Direction Drilling w/ Rock Railhead Adder (% of directional drilling)	FT	0
Conduits	Direction Drilling w/ Rock Mud-Motor Adder (% of directional drilling)	FT	0
Conduits	Handhole Installation	EA	401
	10" x 15" HH or Flower Pot Installation		162
Conduits	Underground FOC/Innerduct Placement in Conduit	FT	491,597
	D-Bore Conduit Pullback	FT	109,551
Other	NAP (Terminal) Installation	EA	731
Other	LCP Cabinet Installation	EA	12
	SERVICE DROPS:		
	Drop/ONT Installation	FT	85,296
	SPLICING:		
	Closure Prep, Fusion Splicing, Closure Attachment/Placement	FT	357,879
	FEES:		
Other Upfront Costs - Other	Right-of-Way Acquisition	FT	0
Other Upfront Costs - Other	Right-of-Way Clearance	FT	0
Outside Plant -Other	Quality Control, OTDR/Power Testing, Turn-Up	FT	357,879
Outside Plant - Other	ODOT (% of route requiring traffic control planning and set-up)	FT	0

OSP Bill of Materials for Project

		Construction BOM	
		Measurement	Units
	MATERIALS:		
	OSP:		
	AERIAL:		
Outside Plant - Poles	Attach Hardware, Guys, Anchors, U-Guard	Pole	92
Outside Plant - Poles	Dielectric Sno-shoes w/ Hardware	Pair	18
	UNDERGROUND:		
	1.25" Innerduct	FT	160,070
Outside Plant - Conduit	1.25" HDPE SDR 13.5 **(number of conduits to be installed)**	FT	121,833
	2" HDPE	FT	14,856
	3" HDPE	FT	160,340
	4" HDPE	FT	7,760
Outside Plant - Conduit	1.25" Compression Couplers	EA	0
Outside Plant - Conduit	30"x48"x36" Tier 22 HH w/ Lid	EA	160
	24" x 36" Tier 22 HH w/ Lid	EA	242
	10" x 15" HH or Flower Pot	EA	162
Outside Plant - Conduit	96" x 5/8" Copper Ground Rod	EA	435
Outside Plant - Conduit	NEPTCO - Trace Safe Tracer Wire	FT	215,227
Outside Plant - Conduit	Marker Post **(marker separation in feet)**	EA	460
Outside Plant - Conduit	Terminal Post (Test Station)	EA	60
	FOC:		
	432 dielectric FOC	FT	16,370
Outside Plant - Cables	**288 dielectric FOC**	FT	15,047
Outside Plant - Cables	**216 dielectric FOC**	FT	18,635
Outside Plant - Cables	**144 dielectric FOC**	FT	34,151
Outside Plant - Cables	**96 dielectric FOC**	FT	32,821
	72 dielectric FOC	FT	8,217
	48 dielectric FOC	FT	47,783
	24 dielectric FOC	FT	120,031
Outside Plant - Cables	2 fiber drop	FT	75,915
Outside Plant - Cables	4 fiber drop	FT	4,515
	6 fiber drop	FT	840
	8 fiber drop	FT	1,505
	12 fiber drop	FT	2,520
Outside Plant - Cables	Splitters	EA	45
Outside Plant - Cables	LCP Cabinet (various sizes) Fully Configured	EA	12
Outside Plant - Cables	Splice Closure w/ trays	EA	327
	LCP & NAP		
	10" Pedestal	EA	288
	10" Pedestal with HH mounting kit	EA	287
Outside Plant - Other	NAP (Terminal) with tail	EA	347
Outside Plant - Other	NAP (Terminal)	EA	403

OptiTect® Local Convergence Cabinet, LS Series

Features and Benefits

Multiple pad- and pole-mount configurations
Provide operator with maximum deployment flexibility

Unique grounding system
Provides a single point outside the cabinet to isolate and tone cables in the cabinet

Field-replaceable shell
Allows operator to replace outer hardware without interrupting services

Factory-installed, removable brush guard
Provides additional back plane protection

Corning OptiTect® Local Convergence Cabinet, LS Series provides everything necessary to manage up to 864 fibers for an outside plant FTTx application. The OptiTect Local Convergence Cabinet, LS Series is an innovative solution that is the optimal balance between size, density and access. All cabinets share the same intuitive and efficient cable routing and splitter storage. Each cabinet provides superior ergonomics with full front access, resulting in minimal installation time, quick connections and ultimately increased profits.

The OptiTect LS Cabinet was developed with the field craft in mind. In this unique cabinet design, splitter parking and cable toning are simple, providing customers more flexibility and deployment options. All five cabinet sizes (144, 288, 432, 576, 864) offer "pass-through" capabilities for commercial services or other high-bandwidth applications, as well as multiple mounting options to accommodate exclusive below ground and aerial plant installations.

The OptiTect LS Cabinet utilizes quick field placement and parking of splitter modules for a 32-port connector parking clip. Splitters are also easily installed in front-access sliding trays. The best-in-class fiber routing design allows for quick subscriber turn-up and error-free long-term maintenance as the cabinet is loaded to capacity. The labeling scheme is also helpful in providing easy identification of connectors and modules.

One of the many features that the OptiTect Local Convergence Cabinet, LS Series offers is the field–re-

OptiTect Local Convergence Cabinet, 432-Fiber | Photo HWPSS1794

OptiTect Local Convergence Cabinet, 864-Fiber | Photo HWPSS1791

CORNING

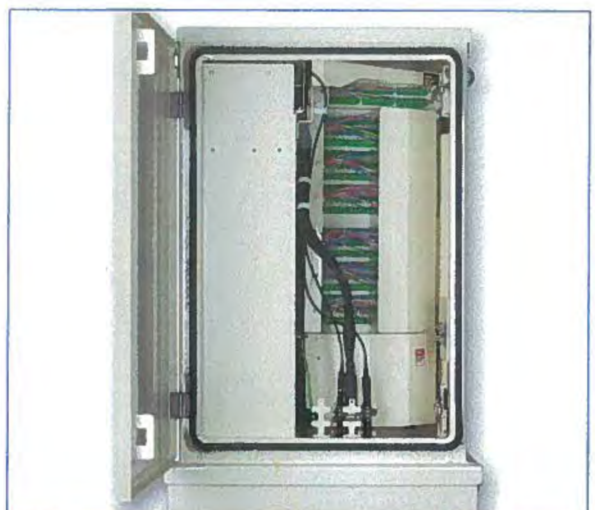
OptiTect® Local Convergence Cabinet, LS Series

Standards

Design and Test Criteria	Cabinets meet applicable sections of Telcordia GR-3125-CORE, GR-63-CORE, GR-449-CORE
	Modular splitters meet applicable sections of GR-1209-CORE, GR-1221-CORE
	Connectors meet applicable sections of Telcordia GR-326-CORE
Approvals and Listings	UL Listed
	RDUP (RUS) Listed

placeable shell. This feature allows operators the ability to avoid interrupting service while installing a new cabinet should the shell become damaged or vandalized.

OptiTect Local Convergence Cabinet (swing-out panel and isolated grounding) | Photo FOH353



OptiTect Local Convergence Cabinet, LS Series, 432-Fiber (rear door removed) | Photo FOH354

CORNING

OptiTect® Local Convergence Cabinet, LS Series

CORNING

Specifications

Design

	Configuration	Number of Doors Pad	Number of Doors Pole	Color
144 Fiber	Pole or Pad	2 (Front + Back)	1 (Front only)	Almond (Standard)
288 Fiber	Pole or Pad	2 (Front + Back)	1 (Front only)	Almond (Standard)
432 Fiber	Pole or Pad	2 (Front + Back)	1 (Front only)	Almond (Standard)
576 Fiber, Small	Pole or Pad	2 (Front + Back)	1 (Front only)	Almond (Standard)
576 Fiber, Large	Pad only	3 (Front + Back)	N/A	Almond (Standard)
864 Fiber	Pad only	3 (Front + Back)	N/A	Almond (Standard)

Also available in green and brown

Mechanical Characteristics

	Pole-Mount Height	Pad-Mount Height Includes 6-in Skirt	Width	Depth	Empty Weight (Pole)	Empty Weight (Pad)	Cabinet Skin Weight
144 Fiber	64.8 cm (25.5 in)	80.01 cm (31.5 in)	63.5 cm (25.0 in)	50.5 cm (19.9 in)	29.5 kg (65 lb)	36.3 kg (80.0 lb)	18.0 kg (40.0 lb)
288 Fiber	64.8 cm (25.5 in)	80.01 cm (31.5 in)	63.5 cm (25.0 in)	50.5 cm (19.9 in)	29.5 kg (65.0 lb)	36.3 kg (80.0 lb)	18.0 kg (40.0 lb)
432 Fiber	87.6 cm (34.5 in)	102.87 cm (40.5 in)	63.5 cm (25.0 in)	50.5 cm (19.9 in)	43.1 kg (95.0 lb)	49.9 kg (110.0 lb)	22.6 kg (50.0 lb)
576 Fiber, Small	87.6 cm (34.5 in)	102.87 cm (40.5 in)	63.5 cm (25.0 in)	50.5 cm (19.9 in)	43.1 kg (95.0 lb)	49.9 kg (110.0 lb)	22.6 kg (50.0 lb)
576 Fiber, Large	N/A	102.87 cm (40.5 in)	108.6 cm (42.8 in)	50.5 cm (19.9 in)	N/A	86.6 kg (191.0 lb)	27.2 kg (60.0 lb)
864 Fiber	N/A	102.87 cm (40.5 in)	108.6 cm (42.8 in)	50.5 cm (19.9 in)	N/A	86.6 kg (191.0 lb)	27.2 kg (60.0 lb)

Splitter Configurations

	Connector Type	Maximum Number of Splitter Modules, 1x64	Maximum Number of Splitter Modules, 1x32 or Dual 1x16	Maximum Number of Splitter Modules, 1x8	Maximum Number of Splitter Inputs	Splitter Output Parking Capacity	Pass Through Capacity
144 Fiber	SC APC or SC UPC	3	5	9	24	128	12
288 Fiber	SC APC or SC UPC	5	9	18	24	128	12

OptiTect® Local Convergence Cabinet, LS Series

CORNING

Splitter Configurations

	Connector Type	Maximum Number of Splitter Modules, 1x64	Maximum Number of Splitter Modules, 1x32 or Dual 1x16	Maximum Number of Splitter Modules, 1x8	Maximum Number of Splitter Inputs	Splitter Output Parking Capacity	Pass Through Capacity
432 Fiber	SC APC or SC UPC	7	14	27	48	192	36
576 Fiber, Small	SC APC or SC UPC	9	18	36	72	192	N/A
576 Fiber, Large	SC APC or SC UPC	9	18	36	72	384	72
864 Fiber	SC APC or SC UPC	14	27	36	72	384	72

OptiTect® Local Convergence Cabinet, LS Series

CORNING

Ordering Information

☐	☐	☐	P	S	☐	☐	☐	1	☐	☐	☐	☐	☐	☐	☐	☐	☐
1	2	3		4	5	6	7		8		9	10		11		12	13

1 Select cabinet color.
- V = Almond (standard)
- W = Green (special color – call a customer care representative for lead time)
- X = Brown (special color)

2 Select cabinet size.
- D = 144 fiber
- C = 288 fiber
- A = 432 fiber
- E = 576 fiber (large housing)
- F = 864 fiber
- U = 576 fiber (small housing)

3 Select mounting.
- P = Pole (144, 288, 432 and small 576 only)
- A = Pad with 6-in skirt (standard)
- B = Pad with 12-in skirt

See Note 1.

4 Defines connector type.
- S = SC APC (standard)

5 Select input cable size.
- 1 = 12 fiber (144 cabinet)
- 2 = 24 fiber (standard for 144 and 288)
- 4 = 48 fiber (standard for 432)
- 7 = 72 fiber (standard for small 576 and 864)

6 Select pass-through cable size.
- 0 = No pass-through fiber
- 1 = 12 pass-through fibers (144 and 288 only)
- 3 = 36 pass-through fibers (432, 576 and 864 only)
- 7 = 72 pass-through fibers (large 576 and 864 only)

See Note 2.

7 Select external toning option.
- \- = No toning (standard)
- T = Toning box

8 Select feeder/pass-through cable type.
- C4 = SST-Ribbon Dielectric Cable
- U4 = ALTOS Loose Tube Dielectric Cable
- UC = ALTOS Loose Tube Single-Jacket, Single-Armored Cable

9 Select distribution cable configuration.
- 1 = One cable (standard)
- 2 = Two cables (must be same fiber count, standard for 576 and 864 cabinets)

10 Select feeder and distribution cable length.
- 16 = 16 m (50 ft)
- 31 = 31 m (100 ft, standard)
- 50 = 50 m (164 ft)

11 Select distribution cable type.
- C4 = SST-Ribbon Cable (fiber count up to 216 F)
- U4 = ALTOS Loose Tube Cable (fiber count up to 432 F)
- Q4 = ALTOS Ribbon Dielectric Cable (fiber count 288-432 F)
- UC = ALTOS Loose Tube Single-Jacket, Single-Armored Cable (fiber count up to 432 F)
- Q5 = ALTOS Ribbon Loose Tube Armored Cable

12 Select splitter module quantity.
- 0 = None (standard)
- 1 = One
- 2 = Two

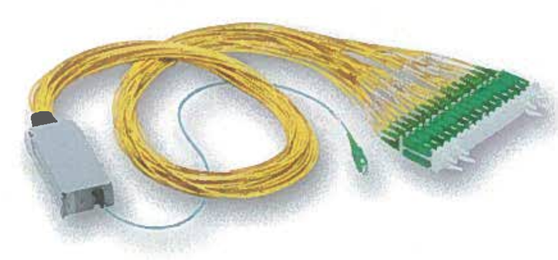
13 Select module type.
- 0 = No module (standard)
- A = 1x32
- D = Dual 1x16

OptiTect® Local Convergence Cabinet, LS Series

CORNING

LS Splitter Modules

The compact yet robust LS Series splitters are available in multiple configurations (1x32, dual 1x16). Each splitter module features small form connectorized inputs and outputs with simple one-step parking.



LS Splitter Module
| Photo HWPSS1800

Features

- First with bend-improved fiber on input and output legs (ITU-T G.657.A compliant)
- Field-proven performance
- Robust housing protects module during installation and throughout product life
- Integrated parking clips installed on connectors
- GR-1209 and GR-1221 qualified
- GR-326 certified connectors

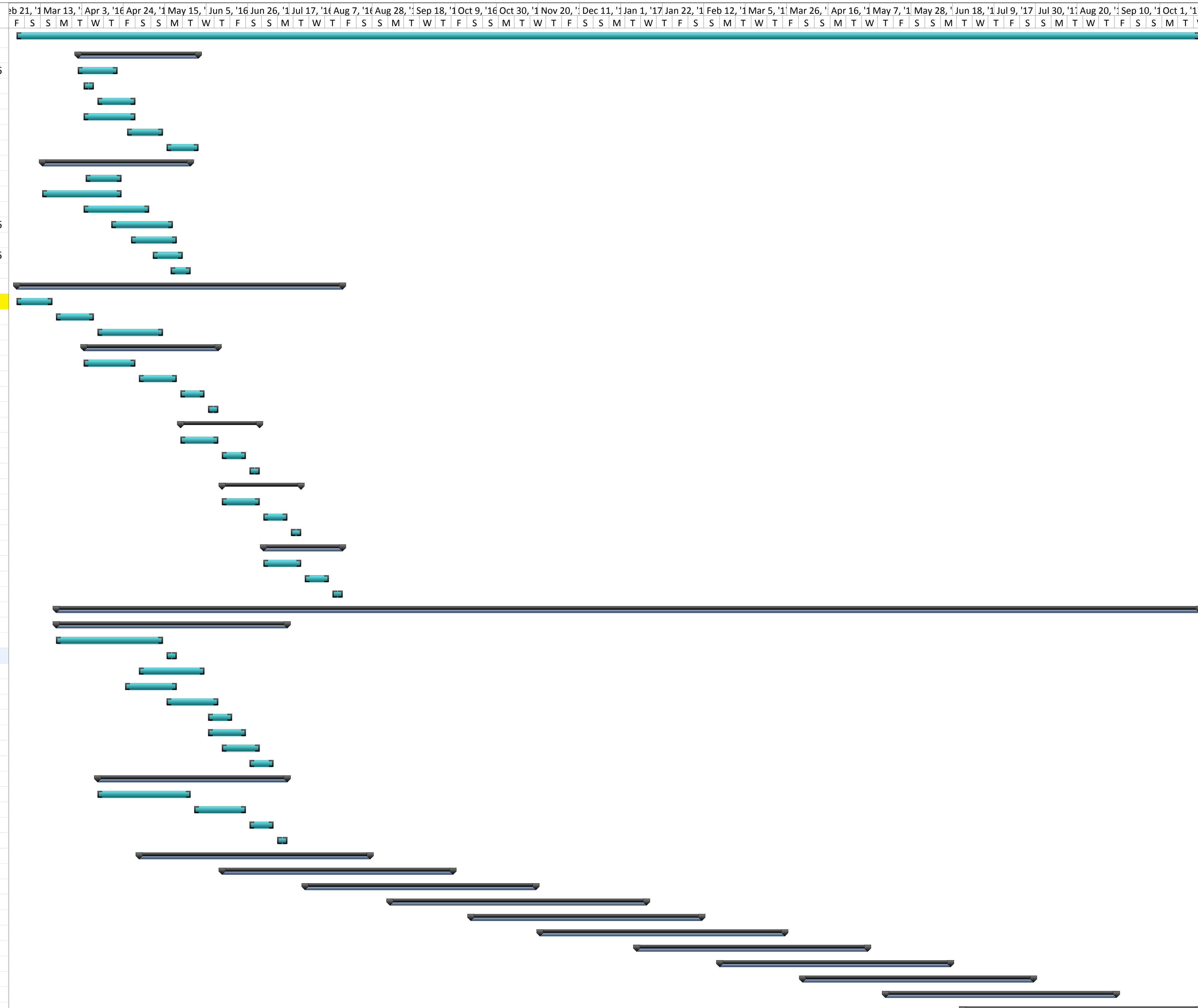
Standard-Performance Devices							
Part Number	Dimensions (HxWxD)	Insertion Loss, Typical	Insertion Loss, Maximum	Uniformity	Return Loss	Directivity	PDL
1x32-Splitter-Module-LS	43 mm x 23 mm x 107 mm (1.7 in x 0.9 in x 4.2 in)	15.7 dB	16.7 dB	1.3	≥ 55 dB	≥ 55 dB	0.3
Dual 1x16 Splitter Modules	43 mm x 23 mm x 107 mm (1.7 in x 0.9 in x 4.2 in)	12.8 dB	13.4 dB	1.0	≥ 55 dB	≥ 55 dB	0.3

Insertion loss values provided do not include connectors.

CORNING

Fairlawn Gig Project Schedule

ID	Task Mode	Task Name	Duration	Start	Finish
1		**Fairlawn Gig Project**	**429 days**	**Tue 3/1/16**	**Fri 10/20/17**
2		**CoF Data Center**	**43 days**	**Fri 4/1/16**	**Tue 5/31/16**
3		Bidding process and award (all ISP)	14 days	Fri 4/1/16	Wed 4/20/16
4		Rack and power engineering design	5 days	Mon 4/4/16	Fri 4/8/16
5		Permitting approval	15 days	Mon 4/11/16	Fri 4/29/16
6		Equipment and LCP cabinet acquisition	20 days	Mon 4/4/16	Fri 4/29/16
7		Equipment installation	14 days	Tue 4/26/16	Fri 5/13/16
8		Turn up and testing	12 days	Mon 5/16/16	Tue 5/31/16
9		**Feeder Ring**	**55 days**	**Mon 3/14/16**	**Fri 5/27/16**
10		Bidding process and award (all OSP)	14 days	Tue 4/5/16	Fri 4/22/16
11		Permitting approval	30 days	Mon 3/14/16	Fri 4/22/16
12		Material acquisition	25 days	Mon 4/4/16	Fri 5/6/16
13		Conduit / infrastructure construction	23 days	Mon 4/18/16	Wed 5/18/16
14		Fiber placement	17 days	Thu 4/28/16	Fri 5/20/16
15		Fiber splicing	11 days	Mon 5/9/16	Mon 5/23/16
16		Fiber testing	8 days	Wed 5/18/16	Fri 5/27/16
17		**Main Wireless Base Stations (4)**	**119 days**	**Tue 3/1/16**	**Fri 8/12/16**
18		Bidding process and award (all wireless)	14 days	Tue 3/1/16	Fri 3/18/16
19		Engineering Design	15 days	Mon 3/21/16	Fri 4/8/16
20		Equipment acquisition	25 days	Mon 4/11/16	Fri 5/13/16
21		**Crown Castle Tower**	**50 days**	**Mon 4/4/16**	**Fri 6/10/16**
22		CCI Engineering drawings approval	20 days	Mon 4/4/16	Fri 4/29/16
23		CCI NTP Approval	15 days	Mon 5/2/16	Fri 5/20/16
24		Construction	10 days	Mon 5/23/16	Fri 6/3/16
25		Testing	5 days	Mon 6/6/16	Fri 6/10/16
26		**Buckingham Doolittle Building**	**30 days**	**Mon 5/23/16**	**Fri 7/1/16**
27		Building approval	15 days	Mon 5/23/16	Fri 6/10/16
28		Construction	10 days	Mon 6/13/16	Fri 6/24/16
29		Testing	5 days	Mon 6/27/16	Fri 7/1/16
30		**Akron Water Tower**	**30 days**	**Mon 6/13/16**	**Fri 7/22/16**
31		City of Akron approval	15 days	Mon 6/13/16	Fri 7/1/16
32		Construction	10 days	Mon 7/4/16	Fri 7/15/16
33		Testing	5 days	Mon 7/18/16	Fri 7/22/16
34		**Stark Knoll Building**	**30 days**	**Mon 7/4/16**	**Fri 8/12/16**
35		Building approval	15 days	Mon 7/4/16	Fri 7/22/16
36		Construction	10 days	Mon 7/25/16	Fri 8/5/16
37		Testing	5 days	Mon 8/8/16	Fri 8/12/16
38		**Distribution Areas (12)**	**415 days**	**Mon 3/21/16**	**Fri 10/20/17**
39		**DA1012 OSP**	**85 days**	**Mon 3/21/16**	**Fri 7/15/16**
40		Permitting approval	40 days	Mon 3/21/16	Fri 5/13/16
41		LCP cabinet placement	5 days	Mon 5/16/16	Fri 5/20/16
42		Pre service order process	25 days	Mon 5/2/16	Fri 6/3/16
43		Material acquisition	20 days	Mon 4/25/16	Fri 5/20/16
44		Conduit / infrastructure construction	20 days	Mon 5/16/16	Fri 6/10/16
45		Fiber placement	10 days	Mon 6/6/16	Fri 6/17/16
46		Terminal placement	15 days	Mon 6/6/16	Fri 6/24/16
47		Fiber splicing	15 days	Mon 6/13/16	Fri 7/1/16
48		Fiber testing	10 days	Mon 6/27/16	Fri 7/8/16
49		**DA1012 Wireless Distribution Access Poin**	**70 days**	**Mon 4/11/16**	**Fri 7/15/16**
50		Attachment Approvals	35 days	Mon 4/11/16	Fri 5/27/16
51		Node Placement	20 days	Mon 5/30/16	Fri 6/24/16
52		Fiber Connectivity	10 days	Mon 6/27/16	Fri 7/8/16
53		Testing	5 days	Mon 7/11/16	Fri 7/15/16
54		**DA1001 OSP**	**85 days**	**Mon 5/2/16**	**Fri 8/26/16**
69		**DA1002 OSP**	**85 days**	**Mon 6/13/16**	**Fri 10/7/16**
84		**DA1003 OSP**	**85 days**	**Mon 7/25/16**	**Fri 11/18/16**
99		**DA1004 OSP**	**94 days**	**Tue 9/6/16**	**Fri 1/13/17**
114		**DA1005 OSP**	**85 days**	**Mon 10/17/16**	**Fri 2/10/17**
129		**DA1006 OSP**	**90 days**	**Mon 11/21/16**	**Fri 3/24/17**
144		**DA1007 OSP**	**85 days**	**Mon 1/9/17**	**Fri 5/5/17**
159		**DA1008 OSP**	**85 days**	**Mon 2/20/17**	**Fri 6/16/17**
174		**DA1009 OSP**	**85 days**	**Mon 4/3/17**	**Fri 7/28/17**
189		**DA1010 OSP**	**85 days**	**Mon 5/15/17**	**Fri 9/8/17**
204		**DA1011 OSP**	**86 days**	**Fri 6/23/17**	**Fri 10/20/17**



RF Measurement and Design for Fairlawn Wi-Fi Network

Executive Summary

Preliminary design and measurement efforts for the proposed wireless network have been completed. Based on the field measurement and computer modeling, Wi-Fi coverage can be provided to the entire city of Fairlawn using fewer than 200 Wi-Fi access points (APs).

However, existing utility poles in the city cannot provide sufficient vertical infrastructure to provide coverage to the entire City and JEDD. Additional rooftop deployments are necessary.

There are two options for providing backhaul capacity to Wi-Fi access points: fiber and fixed wireless.

- Fiber backhaul provides high bandwidth and high reliability. Thus, Fujitsu recommends that Wi-Fi access points be connected via fiber for backhaul whenever and wherever possible. The primary drawback is that the time-to-deployment for fiber will be much longer.
- Wireless backhaul, with the advantages of fast deployment and low cost, should serve as an option where fiber backhaul is not available. The following three points should be taken into consideration:
    1. The license-exempt frequency band specified for this purpose allows for sufficient network performance only when there exists line-of-sight (LOS) between the access point and the serving base station. Sufficient service quality will not be possible in areas where a LOS condition cannot be achieved, for example, when an access point location is shrouded by heavy foliage.
    2. License-free spectra are available for use by the general public as well as by any commercial or governmental organization. As such, devices operating in these frequency bands are vulnerable to external interference. Wireless backhaul links are of particular concern, since an outage of a backhaul link will affect all AP units under that base station sector's coverage footprint. This is obviously a more critical outage than would be the case if only a single AP were to be in outage.
    3. Wireless backhaul is the traffic bottleneck and will limit the overall network throughput performance. Consequently, APs using wireless backhaul will experience lower throughput compared to APs with fiber backhaul.

Fujitsu's fiber planning team has designed a ubiquitous fiber footprint, allowing a sufficient amount of fiber infrastructure to accommodate the backhaul needs for the vast majority of Wi-Fi access points. Since it takes time to deploy the fiber, it is recommended that areas with heavy foliage be given priority in the fiber build schedule, since they cannot be effectively reached wirelessly. The primarily open commercial areas and parks can be served quickly via fixed wireless backhaul. As fiber infrastructure is deployed in more and more locations, the number of Wi-Fi APs that will use wireless backhaul will dwindle, which will have the effect of relieving (or at least not exacerbating) capacity utilization in wireless backhaul portion of the network.

Areas with fiber infrastructure or areas with heavy foliage will use fiber infrastructure for backhaul of Wi-Fi access points. Public areas where Wi-Fi access is desired and areas not expected to receive fiber for some time can be serviced wirelessly, so long as line-of-sight to a serving base station location can be achieved.

1. Background

1.1 Service Requirements

The Basic FairlawnGig service requirement is that "every service address in Fairlawn must have fiber available at the street, or they must be able to receive wireless service from the fixed wireless network, or they must be able to receive wireless service from Wi-Fi at a sufficient level to meet the SLA." That means the communication service can be delivered either by direct fiber connection, or fixed wireless, or standard Wi-Fi. In each case, the subscriber will have a box installed at their premise that enables network connectivity and connects to their home or office network.

It is not necessary to have 100% wireless coverage in year 1. The wireless service requirement has been relaxed to provide the mobile Wi-Fi service at some key areas around Fairlawn that have heavy visitor traffic. Within the first year, the City would like to enable the mobile Wi-Fi service at a few key areas as shown in the map below.

Figure 1 Key areas that must have Wi-Fi service at year 1

Areas 1, 2, 3 and 4 are commercial areas along Market Street. An effort conducted prior to the this engineering study confirmed that there exists line-of-sight (LOS) condition from the Fairlawn Tower to desired Wi-Fi access point (AP) locations around these areas. Areas 5 and 6 are public parks. These could be covered by one AP each on the main building of each park or on the nearby tornado siren that Fairlawn also controls.

One important engineering constraint is that only license-free spectrum at 2.4 GHz and 5 GHz Wi-Fi bands may be used. No licensed band may be considered. The 2.4 GHz channels will be available to guest users and other non-premium end users. 5 GHz channels will be allocated to premier / business users, in addition to supporting wireless network backhaul requirements for APs without access to fiber backhaul. Another notable design specification is that a Wi-Fi product supporting 802.11ac must be used for 5 GHz.

The wireless performance targets are:

- Fixed wireless services:
  (1) Residential: 30 Mbps fixed symmetrical, fixed, secure network.
  (2) Business: 50 Mbps fixed symmetrical, fixed, secure network.

- Mobile Wi-Fi services:
  (1) Mobile Guest Access: 4 Mbps symmetrical, open internet access
  (2) Mobile Premium Access: 25 Mbps symmetrical, secure access

1.2 Wi-Fi Network Architecture

In order to cover the entire city, a very large number (hundreds) of access points are needed. These APs must be distributed across the city in order to provide ubiquitous coverage. A small percentage of areas (usually the buildings in business areas) will have access to fibers, but most of locations currently do not have fiber access. In this situation, providing backhaul to the APs without fiber access becomes a challenge.

The currently proposed wireless network architecture is to use a cascaded approach (Figure 2). This architecture makes use of Wi-Fi access points to provide service to the end users (access link) and uses point-to-multi-point (Pt-to-MP) fixed base stations (BS) to provide wireless backhaul to the APs (backhaul link).

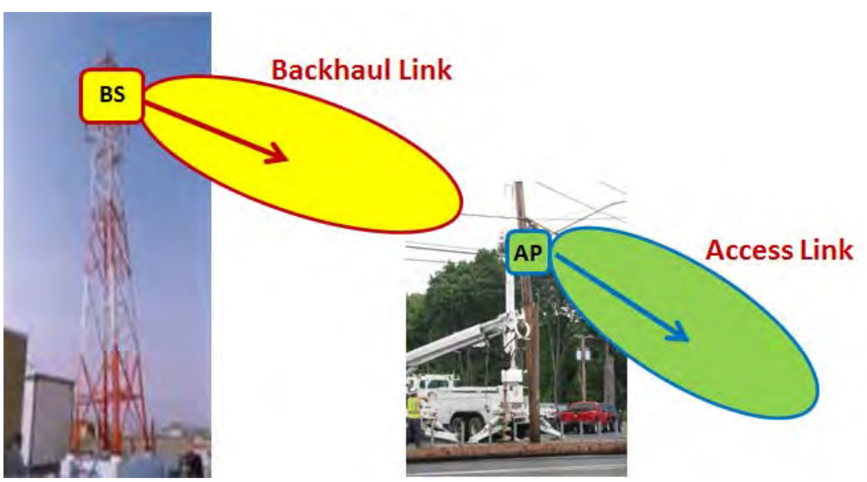


Figure 2. A cascaded network with wireless backhaul and Wi-Fi access network

The access points are operating on dual band, so they will use both 5 GHz and 2.4 GHz for the access links. The 2.4 GHz band will only be used for end-user access. However, the channels in the 5 GHz band are split between the backhaul and access links: a certain bandwidth will be allocated to the base stations for the backhaul link, while the remaining channels are allocated to the APs for the access link.

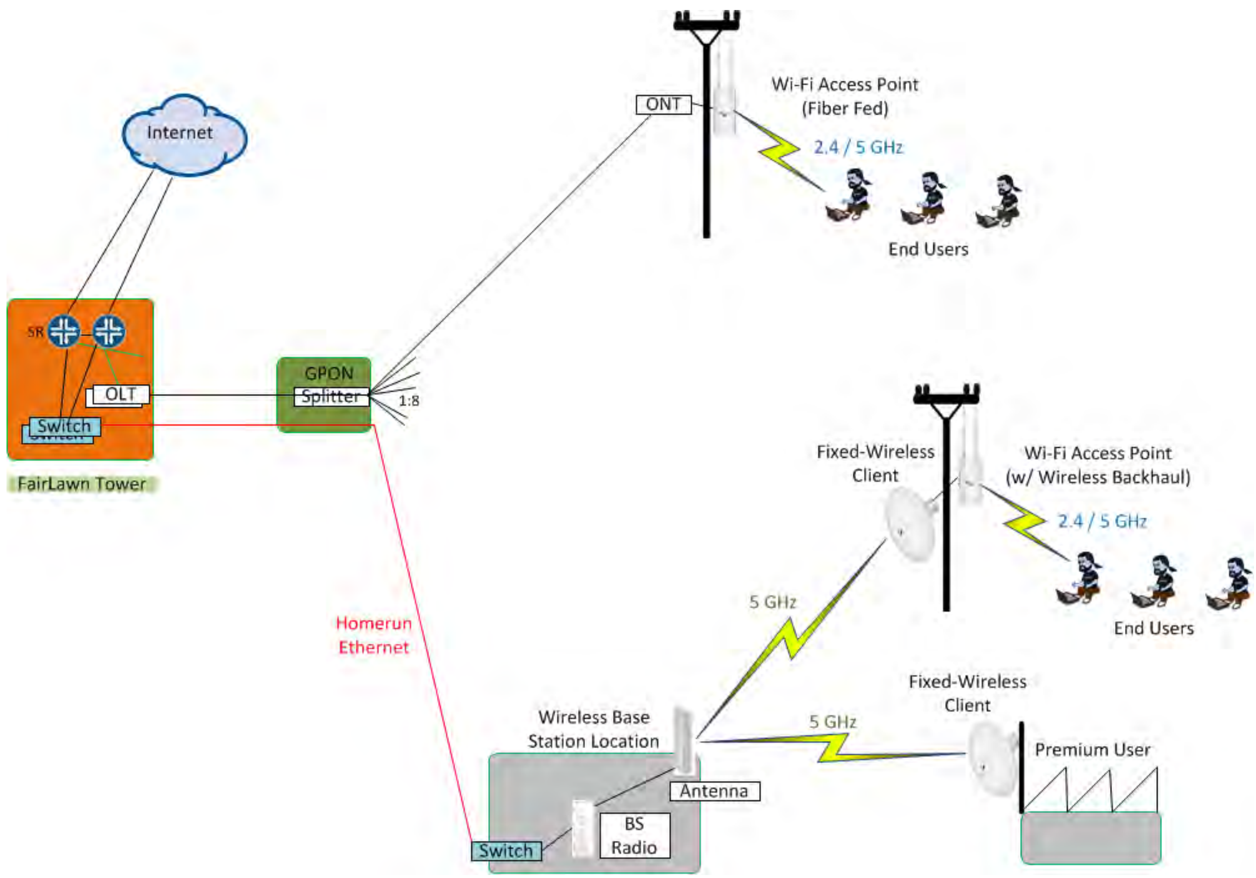


Figure 3. Conceptual view of the Fairlawn Wireless Network

The above graphic (Figure 3) illustrates the wireless connectivity methods to be used. End users connect their devices such as phones, laptops, and tablet computers to Wi-Fi access points using either 2.4 GHz (primarily) or 5 GHz (increasingly) spectrum. User data traffic is backhauled from the Wi-Fi access points either via fiber through the GPON network or wirelessly using a fixed-wireless client, which is connected to a serving base station radio.

Additionally, there exists the option to serve premium wireless clients such as small or medium-sized businesses by installing a fixed-wireless client on their premise and backhauling their traffic through the base station in the same manner as a Wi-Fi access point. However, it should be noted that this will require the fixed-wireless client have clear line of sight to a base station and will contribute to congestion of the 5 GHz wireless spectrum available to the Wi-Fi access points.

In terms of the base station RF coverage, there is a 250-ft tower (Fairlawn Tower) near the center of the city. The city already purchased and installed four AirMax base stations (made by Ubiquiti Networks) on the Fairlawn Tower. They are configured in 4 sectors, two with 60-degree antennas and two with 45-degree antennas (Figure 4).

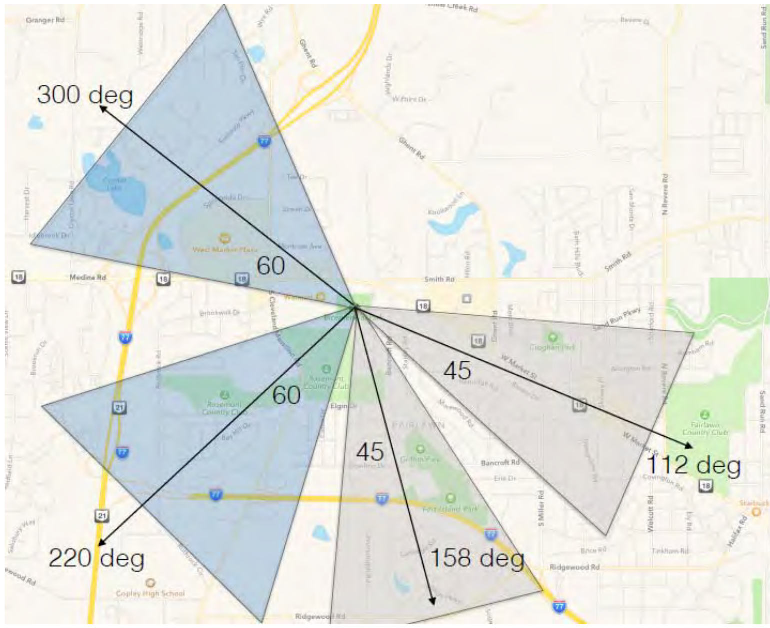


Figure 4. Four sector antennas and their orientations from the center Fairlawn Tower

The City of Fairlawn is relatively small with an area of approximately five square miles. If the entire area were flat with no trees, then several base stations installed on the top of the Fairlawn tower would be able to cover the entire city. However, some areas, particularly in and around residential neighborhoods have very heavy foliage, with trees two to three times taller than the utility posts or houses. Thus, in these areas LOS conditions are almost impossible to achieve for access points installed on utility poles. It should also be noted that installing all APs at one centralized location will not allow for sufficient backhaul capacity for all APs due to the limited frequency available for wireless backhaul.

Therefore, four additional locations have been preliminarily identified.

Preliminary Base Station Locations

#	Area Coverage	Approximate Address
1	Center Tower	3300 Fairlawn Service Dr, Fairlawn, OH 44333
2	Northwest	Dellagnese Building (4000 Embassy Pkwy, Fairlawn, OH 44333)
3	East	Fairlawn Town Center (2775 W Market St, Fairlawn, OH 44333)
4	Southeast	(Akron) Water Tower (41 06 32.98N, 81 35 24.97W)
5	Southwest	Stark Knoll Building (3475 Ridgewood Rd, Fairlawn, OH 44333)

One is a water tower owned by the City of Akron, while the other three are commercial buildings. The heights on these four locations are not as tall as the Fairlawn tower, but it is advantageous to distribute additional base stations throughout the coverage area. Additional base stations may be installed on these five locations in order to provide wireless backhaul to the access points; however, field testing indicated that the eastern base station candidate at Fairlawn Town Center would not provide as much benefit as was hoped. Thus, we elected to remove it from the preliminary design.

Figure 5

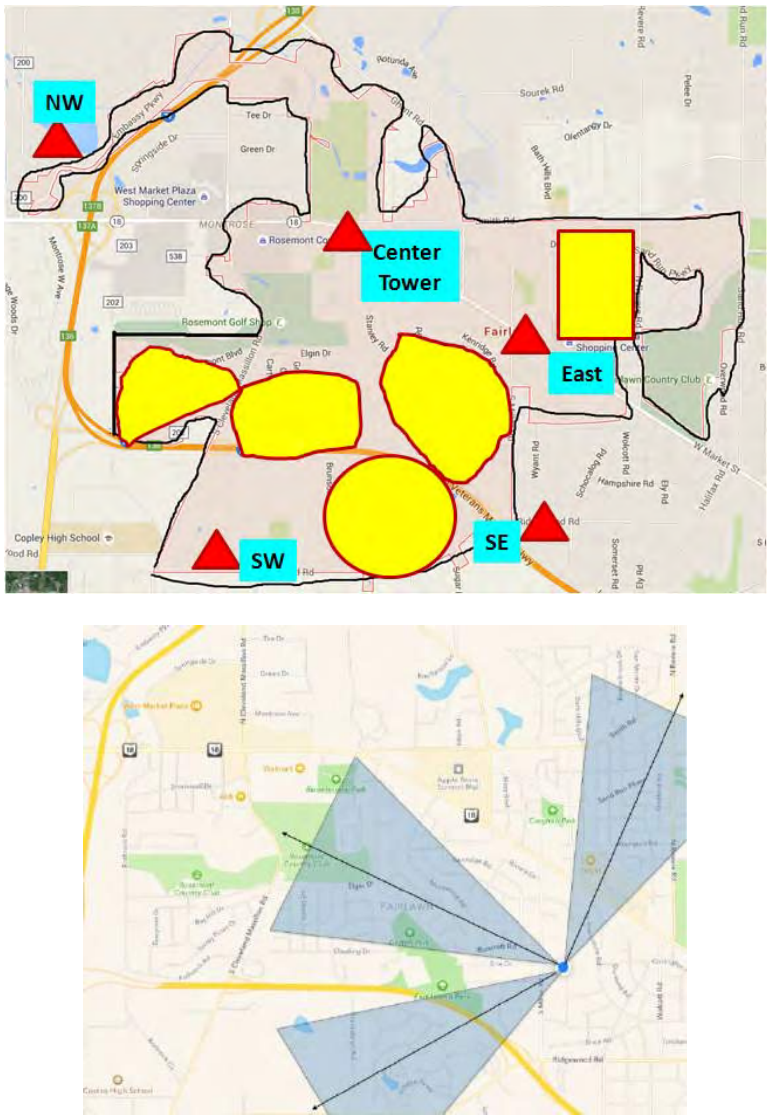
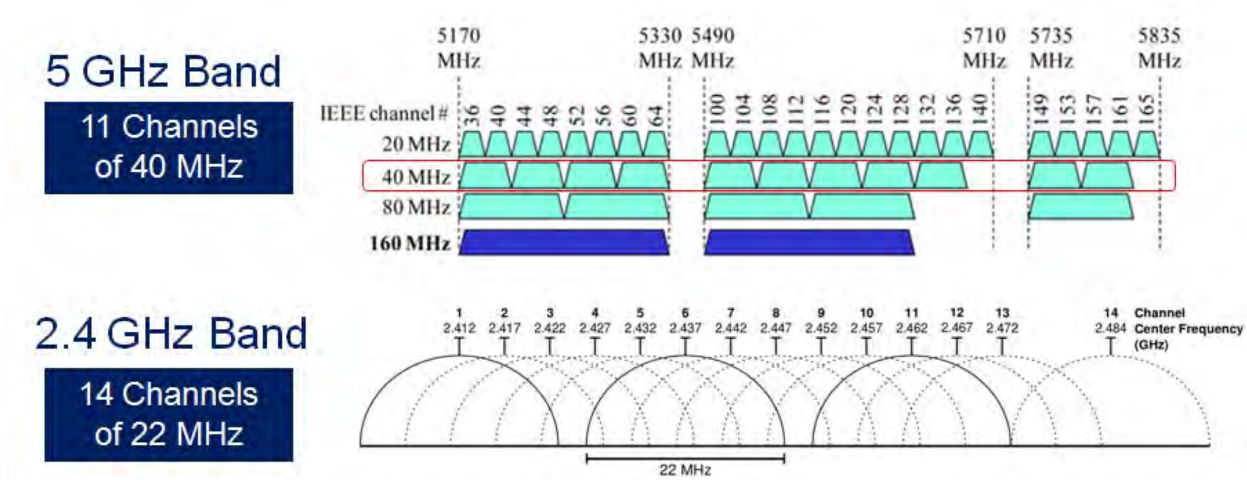


Figure 5. (Top) The approximate locations the fixed wireless BSs will be installed. Areas marked yellow are areas with foliage. (Bottom) Three sector-antennas are installed on Akron Water Tower (SE).

1.3 System Capacity Capabilities

It is worth noting that a variety of connection and backhaul speeds are possible depending on a variety of factors, including the end-user equipment, the backhaul link from the access point fiber or wireless, and the characteristics of that wireless connection. There are two license-exempt frequency bands available for use by the Fairlawn wireless network.

Figure 6



The 5 GHz frequency band has 11 channels of 40 MHz apiece, which must be allocated between end-user access connections and access point backhaul. The 14, mostly overlapping, 22 MHz channels of the 2.4 GHz band will be used exclusively for end-user access.

Figure 7

Figure 7 illustrates that more frequency spectrum will be available for end-user connections than will be available for the wireless backhaul from a Wi-Fi Access Point. Additionally, the end-user connections are likely to be of higher total capacity, since there may be many end users with relatively strong connections. Thus, this wireless backhaul connection represents a point of congestion for the network.

Figure 8

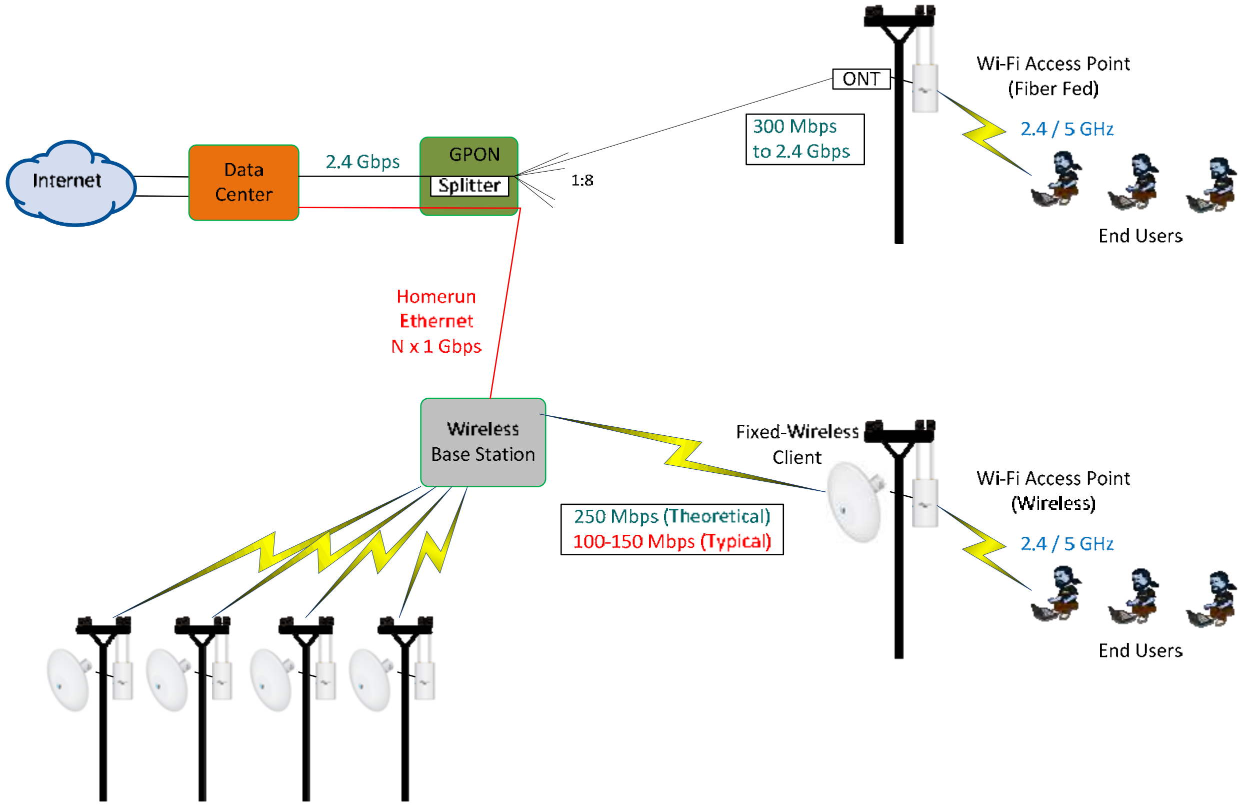


Figure 8 illustrates the capacity difference between wireless and wireline access points. In the wireless scenario, end users are served from a Wi-Fi access point that is connected to a base station through a fixed-wireless device. Using 40 MHz channels, that connection has a theoretical capacity of about 250 Mbps under ideal conditions. A more typical value for engineering purposes would be between 100 Mbps and 150 Mbps. This range was also validated by field measurements conducted as part of this engineering effort.

The other scenario illustrates a fiber-fed access point, which is connected to an Optical Network Terminal (ONT) that feeds into the GPON network. The approximately 2.5 Gbps downstream and 1.24 Gbps upstream capacity is shared amongst connected access points. An 8:1 split would guarantee that at least 300 Mbps would be available to each AP. Again, that the total capacity is shared, so more than 300 Mbps would be available to a given AP in the case that fewer than eight APs are connected to the same splitter of if some APs were to experience a lower bandwidth demand.

The tables below describe bandwidth that could be made available, if equally divided, amongst varying numbers of end users for expected backhaul capacities from fiber and wirelessly-connected access points. It should be noted that Internet traffic is very "bursty", and not all users will place equal demands all the time, so the actual user experience will be generally better than would be indicated by the "fair share" allocation shown below. This concept, called statistical multiplexing, is commonly applied to commercial and residential broadband service offerings.

Fiber-Fed Access Point

Backhaul Capacity	Users	Minimum Capacity Available / User
300-2400 Mbps	6	50-400 Mbps
	12	25-200 Mbps
	24	12.5-100 Mbps

Wirelessly-Backhauled Access Point

Backhaul Capacity	Users	Minimum Capacity Available / User
100-150 Mbps	6	17-25 Mbps
	12	8-13 Mbps
	24	4-6 Mbps

The speeds of user connections will vary depending on factors such as the capabilities of the user's device, proximity to the access point, and external interference conditions. The table below describes commonly used Wi-Fi protocols and the throughput speeds they might achieve.

Wi-Fi Standard	Frequency Band	Theoretical Speed	Typical Speed
802.11a/g	2.4 GHz (a) & 5 GHz (g)	54 Mbps	20 Mbps
802.11n	2.4 GHz & 5 GHz	600 Mbps	40-50 Mbps
802.11ac	5 GHz	1300+ Mbps	70-100 Mbps

Many end users might connect to the same Wi-Fi access point, and the backhaul link will determine total capacity available to all of those users. Therefore, the backhaul link will be a significant contributor to the overall user experience. Since the backhaul capacity from a fiber-fed access point is expected to be at least twice that of a wirelessly backhauled access point, Fujitsu recommends using fiber to serve the Wi-Fi APs wherever possible.

1.4 RF Propagation Characteristics of the City

The city contains areas with quite different propagation characteristics. They can be divided into the following few categories:

(1) Shopping Centers / Strip Malls: These areas are characterized by having very few trees and plenty of open spaces. The heights of the trees are below the utility posts. Figure 9 provides an example.

Figure 9. Example of Strip Mall / Shopping Center.

(2) Business Areas: Offices, hospitals, hotels, etc. The buildings are much larger and taller, which can create some RF shadows. There are trees, which sometimes are quite tall, but the foliage density is not very heavy. Figure 10 gives an example.

Figure 10. Example of a business area with larger buildings

(3) Residential areas with light foliage: There are trees, but the densities of the trees are not high. Line of Sight condition can be achieved via some angles but not everywhere. Figure 11 gives an example.

Figure 11. Example of a residential area with light foliage.

(4) Residential areas with somewhat heavy foliage: The trees are much taller and the densities are much heavier. LOS condition is not available in most cases but may be available at some angles. Figure 12 gives an example.

Figure 12. Example of a residential area with relative heavy foliage.

(5) Residential areas with very heavy foliage. The trees are much taller – typically two to three times taller than the utility posts. Also the tree densities are so heavy that LOS condition is not possible at any angle. Figure 13 gives an example.

Figure 13.Example of a residential area with very heavy foliage.

1.5 Technical Concerns, Caveats

There are some technical concerns that must be stated here as words of caution.

(1) **Interference Concern**: It is generally considered risky to use unlicensed frequency bands for the wireless backhaul. While unlicensed frequency may be acceptable for access links, backhaul links are more critical to the network infrastructure. Each sector of the fixed wireless base station will provide backhaul service for a large number of access points under its coverage footprint. If interference is experienced and the backhaul link is lost, then all of the APs under the back haul's coverage footprint will be out. On the other hand, if interference is experienced in one of the access link, the worst case will be that one AP is out, this is not as bad as the entire group of APs are all out.

The existing noise floor was measured as part of Fujitsu's design evaluation and was found to be relatively low. However, the conditions in license-exempt bands are subject to change at any time, and we would expect the noise floor to rise as more and more APs are deployed and begin radiating in these frequency bands. More ambient noise in the bands will reduce the radio signal to interference plus noise ratio (SINR), which can in turn reduce effective throughput of backhaul links and reduce the cell radius of access points.

Because of the risk of interference and the lack of recourse to remediate it when it occurs, license-exempt frequency bands are most often used to provide service on a best effort basis. This is also effectively why wireless service operators have collectively spent tens of billions of dollars at FCC frequency auctions for exclusive rights to use particular frequency bands in specific geographic areas.

(2) **Coverage Concern**: It was emphasized in the conclusions of many field measurement papers that 5 GHz signal will not work well under non-line of sight (NLOS) conditions. They

work great under LOS, but the coverage reliability degrades severely under NLOS. Fairlawn has some areas with very heavy foliage. Coverage reliability from the wireless backhaul will be very unreliable in these areas. This is a conclusion that has been confirmed by field measurements presented herein.

(3) **Capacity Concern**: In this cascaded network architecture, wireless backhaul is the traffic bottleneck. Assuming all network components perform perfectly, the backhaul capacity will choke the overall network performance. In other words, a congested backhaul link can cause an end user to suffer poor network performance despite having a very strong connection to the serving access point.

The newest 802.11ac is used because of its ultra-high data rate. (Use of the 802.11ac standard is actually a requirement from the City RFP.) However, it should be noted that so long as the APs are using the wireless backhaul, they are not going to get the high data rate 802.11ac technology promises. In fact, it should be expected to fall well short of that measure. This may be illustrated by way of example:

By installing four sectors on the Fairlawn Tower, those four sectors will have very large coverage footprint. It will effectively be capable of providing coverage just about everywhere there is LOS condition. That means a large number of APs will be visible to these four sectors.

We can evaluate how much bandwidth each sector can offer. The peak data rate offered by one sector of AirMax Base station is 250 Mbps for a 40 MHz channel, but that is the peak data rate which can only be achieved under very favorable RF conditions. For planning purpose, the overall average throughput is about one third to half as much as the peak throughput, depending on the RF conditions at the access point locations. So that average throughput number drops to 100 to 150 Mbps. This bandwidth is, in turn, shared by a large number of access points, each of which may have a large number of end users. Also, some homes or businesses with premium services may have direct access to the fixed wireless base station, which further reduces bandwidth available to be shared between the APs.

This overall picture does not look pretty. Additional base stations on different sites would help to further distribute the bandwidth load, but the base stations installed on the center Fairlawn Tower will still be overloaded because of their large coverage footprints due to the favorable propagation conditions.

2. Wireless Equipment Selection

Since this network architecture is a cascaded network with (a) fixed wireless base stations serving as wireless backhaul and (b) Wi-Fi APs, two types of devices are needed: base station and AP. It is preferred (although not required) that both devices are manufactured by the same vendor. This will reduce the risk of interoperability issues and may simplify device management.

Almost all Wi-Fi device vendors make 802.11ac access points. However, not many vendors offer fixed base stations. Fujitsu first researched the vendors that offer both base station and AP products. We also considered AP products that offer mesh capability. Meshing is the ability for one access point to connect to another rather than directly to a base station. This can be advantageous if serving a location that does not have LOS to a base station by backhauling traffic through another AP to the base station. The disadvantage of this approach is that the network can become capacity constrained, and this can create points of failure that affect multiple APs. The AP vendors we studied are:

(1) Ubiquiti (Offers both Wi-Fi AP and Base Station)
(2) Cambium (Offers both Wi-Fi AP and Base Station)
(3) Aruba (Wi-Fi AP has mesh capability)
(4) Zebra (Wi-Fi AP has mesh capability)

The base station products we studied are:

(1) Ubiquiti
(2) Cambium
(3) Aruba
(4) RAD
(5) Proxim

Ubiquiti's products have been recommended because (a) the far lower cost of their products and (b) they offer 802.11ac on both their base stations and APs, providing the highest throughput with the lowest cost. Part of the way that Ubiquiti is able to achieve these lower prices is by selling exclusively through distribution and without a direct sales force. They also provide very limited technical support, so the user community must be more self-reliant.

2.1 Wireless Base Station: Point-to-Multi-Point

Ubiquiti's AirMax Prism Rocket5 AC is the top choice.

Cambium and Aruba both offer base station products, but their products can only support 802.11n, not 802.11ac.

RAD offers a base station product that can cover a very large area with a maximum cell radius of up to 40 km. This is very useful for rural coverage, but the large footprint is not needed for Fairlawn. The cost is much higher than the AirMax base station.

Proxim offers a base station product that can handle high mobility. The product can be deployed on trains or buses with maximum vehicle speed of around 100 km/hr. Because of this capability, the product is very expensive. High mobility is not needed for Fairlawn.

The following table summarizes the findings.

Table 1: Comparison of Pt-t-MP Base Station Products

Company	Product	MSRP	Maximum Throughput	Comments
Ubiquiti	AirMax Prism Rocket5 AC	$229	250 Mbps	Ubiquiti Base station is the only one who can support 802.11 ac, with minimum cost (about $200 per unit)
Cambium	ePMP1000	$449	200 Mbps	ePMP1000 can only support 802.11n. It cannot support 802.11ac
Aruba Networks	AirMesh Mesh Router	$3,295	300 Mbps	AirMesh Router can only support 802.11n. It cannot support 802.11ac. However, the peak data rate is higher than Ubiquiti's product
RAD	Airmux-5000	$4,480	250 Mbps	The RAD's product can support a much larger range (~40 km) so it is good for covering large areas like rural environments. But the cost is much higher than Ubiquiti's product
Proxim	Tsunami Multipoint 8200	$3,499	300 Mbps	Proxim's product can support high mobility so can be implemented to vehicles like train or bus. However, the cost is very high, around $7000 per unit.

2.2 Wireless Access Point

There are many more choices in terms of 802.11ac APs. Just about every Wi-Fi vendor makes an 802.11ac APs. Since Ubiquiti's AirMax base station is the top choice, the 802.11ac Wi-Fi AP from Ubiquiti is also the easiest choice, as it has been proven to work with the Ubiquiti base stations.

Fujitsu additionally evaluated two Wi-Fi AP products due to their special mesh capability. It was mentioned that in areas without LOS condition with the base stations, mesh capability from another AP will be a big plus, since it can potentially enhance the backhaul reliability. Two vendors offer AP products with mesh capability:

(1) Aruba's 270-Series Outdoor AP

The AP contains two radio units, one for 2.4 GHz and one for 5 GHz. The main issue is that if 5GHz is configured for the mesh link, it can no longer be used for the access link. Therefore, the only option is to use 5 GHz for mesh and 2.4 GHz for access. This is not acceptable, because the 5 GHz band will be needed to serve premium business users. It is not desirable to use only the 2.4 GHz band for the access link.

(2) Zebra AP 7652 Outdoor AP

Zebra's AP does allow the 5 GHz to be split between the access-link and mesh-link; however, it is very awkward and difficult to deploy this way. They still strongly recommend to give the entire 5 GHz for the mesh link and only use 2.4 GHz for access link, which we cannot do. If we have to split the 5 GHz band, here is what they recommend:

"Typically we dedicate a radio for backhauling. If client connections go to the backhaul radio, it will congest air space and cause issues for everyone. A second AP will be required at each location to act as a backhaul and the other AP can be used for delivery. It is suggested to have minimum 10 feet separation between AP's to reduce interference. The second radio on the Backhaul AP might be set up to turn on via CRM if the first radio has issues. No use cases here in Canada for that. "

Since most of our APs will be installed on utility poles, there is no practical way to install two access points with 10 feet of separation. One would have to build some type of structure to ensure that the two APs are 10 feet apart. Since each AP costs about $1500, two APs will cost about $3000 as compared to the price of an Ubiquiti AP at around $489.

In summary, the mesh network option is not very attractive, due to the current product limitations. With today's products, either the entire 5 GHz band must be given to the mesh link, or a very expensive and awkward deployment method is needed. Neither option is very attractive.

The following table summarizes the situation:

Table 2 Wi-Fi AP Products that offer Mesh Option

Product	**Company**	**Split 5 GHz for Mesh and Access Link?**	**Comments**
Aruba 270Outdoor AP	Aruba	NO	Aruba's AP contains two radio units: one for 5 GHz and one for 2.4 GHz. If the 5 GHz is used for mesh, then it cannot be used for the access link. Thus, in mesh mode, the access link only has 2.4 GHz. It cannot support mesh mode if both 2.4 GHz and 5 GHz are used for the access link.
AP 7562	Zebra	Yes	It allows the use of partial 5 GHz band for mesh and partial band for access, but a very strange deployment method is needed. They recommend use of two APs: one for backhaul and one for access, separated 10 feet apart. This is very difficult to install and very expensive. Zebra AP is about $1500 per unit.

The least expensive path is still the cascade approach of using Wi-Fi base station as wireless backhaul and Wi-Fi APs without the mesh mode. If some access point locations cannot be sufficiently served by a base station, fiber must be used for backhaul.

3. RF Field Measurement

3.1 Measurement for Wi-Fi Access Link

RF planning is needed to determine the number of APs needed (AP cell count) to cover the whole city and the best locations of APs. However, different propagation conditions will result in differently sized coverage footprints from each access point. For example, APs installed in open areas will have large coverage footprints (due to favorable propagation conditions) compared to APs installed in areas with heavy foliage (due to un-favorable propagation conditions). The heavier the foliage, the higher the loss, and the faster the signal attenuates with distance, resulting in a smaller coverage footprint from an AP.

The purpose of RF measurement for access link is to determine the values of propagation parameters (K1 and K2, used in the RF planning tool) for different types of environments (figure 9 through figure 13).

The RF prediction was conducted using a library of measurement results for different types of RF propagation conditions in different areas in the US. Good results have been observed in real-world deployments using the values from the library. Because of this and the fact that the leafless trees would provide a best-case result, no field measurements for the access link were taken for purposes of model tuning.

3.2 RF Measurement for Fixed Wireless Backhaul Link

3.2.1 Purpose

The purpose of measuring the Pt-to-MP backhaul network is different from the purpose of measuring the AP access network.

- For the AP access network, the goal is to measure the K1 and K2 values for different propagation environments, so an RF planning tool can be used to optimize the AP cell count and determine the optimum AP locations.

- However, for the Pt-to-MP backhaul network, the cell count and their locations are already pre-determined. There are five pre-determined locations available for use, and base stations will be installed on four of these five locations. So the question becomes: given the fact that base stations are installed on these four locations, to what percentage of the service area will these base stations provide good service quality? This becomes a question of determining the “Area Availability” (aka. “Area Reliability”).

    - Area Availability of X% is defined as: X% of a service area will have wireless service quality that is better than the “minimum quality threshold”. “Outage” means the wireless service quality is below the minimum quality threshold.

    - For the cellular industry, “carrier grade of service” is commonly defined as “90% of area reliability”, which means, for a given service area, about 90% of the area will have a wireless service quality that is better than the “minimum quality threshold”. In other words, no more than 10% of area will be in outage. So even “carrier grade of service” does not mean 100% of an area will have good service quality. Up to 10% of area is allowed to be in outage.

- How is the area availability measured? The standard measurement method in cellular industry is to divide the service area into a very large number of bins (not necessarily 5000 as is shown in Figure 14), and use sampling theory to select an adequate number of sampling bins to perform the measurements. The area reliability is estimated from the measurement results from these sampling bins.

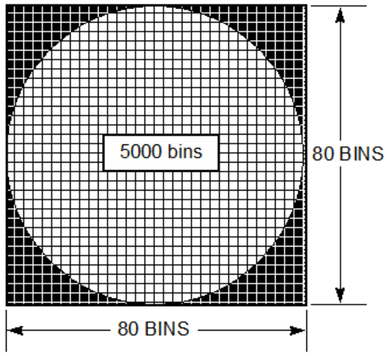


Figure 14. The service area is divided into a large number of bins (not necessarily 5000). Measurement from a small sample of bins is used to estimate the area availability.

Because the size of the bin must be small enough (~ 1/25 = 4% of the cell radius), so the total number of bins will be very large. It is desirable to measure only a small sample of bins while still keeping the sampling error within a tolerable limit.

For a given error limit (=*e*) and confidence level (=*Z*), the number of samples need is (=*n*):

$$\text{Required Sample Number } n = \frac{Z^2 P(1-P)}{e^2} \leq N = \text{Total Number of Bins}$$

Where *P* is the estimated area reliability (*P*=0.9 for 90% area reliability), and *Z* = 1.645 for a 90% confidence interval.

- If the maximum tolerable error is 5% (*e* = 0.05), the minimum number of required samples *n* =97.
- Even if the error bar is relaxed to 10% (*e* = 0.1), the minimum number of required samples is still *n* = 24.

The worst case happens when the estimated area availability *P* = 0.5 (50% availability). In this case,

- If the maximum tolerable error is 5% (*e* = 0.05), the minimum number of required samples *n* =270.
- Even if the error bar is relaxed to 10% (*e* = 0.1), the minimum number of required samples is still *n* = 68.

Because the city has several different types of environments, if such a large number of samples were used for each environment, it would be too time consuming to complete the measurement. For the purpose of reducing time, the number of samples is reduce to a round number, ***n* ~15 to 20**. This will result a relatively large sampling error, so it can only serve as a rough first order approximation.

Furthermore, only areas with heavy foliage will be tested. Areas with plenty of open space, thus have LOS condition, will not be tested. Initially, the following five areas were recommended for testing. Later, only Area #2, #4 and #5 were measured due to lack of vertical assets in areas #1 and #3.

- Area #1 has a good deal of open space. Most locations should have LOS condition to a base station location.
- Area #3 has no utility poles or other vertical structures on which to install APs. These areas may be targeted for early deployment of fiber in order to obviate the requirement for wireless backhaul.

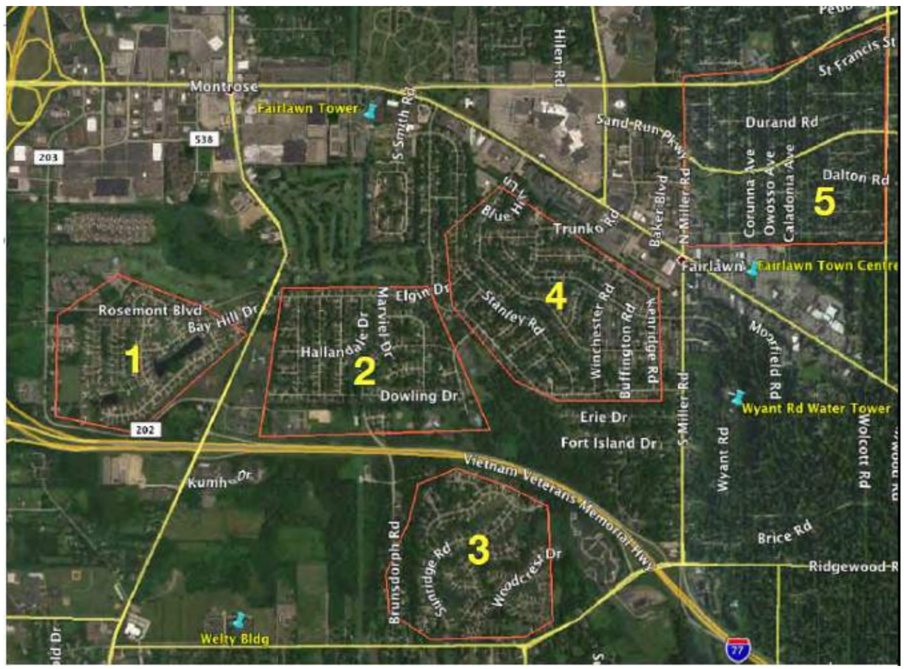


Figure 15. Initially five areas were recommended for measurement. The actual measurements were carried out in Area #2, #4 and #5 only.

To measure an area reliability, one divides the area into a large number of bins, some bins may cover "areas with no interest" (e.g., bodies of water, mountains, or areas with no population). As a result, in real cellular networks, the measurement is always performed via drive test. That means only the bins on drive routes are actually measured. The drive route must be chosen to "evenly" cover the whole area. The receiver antenna is usually installed on top of a drive test vehicle, about 6 ft. above the ground.

Figure 16 (Left) Drive routes; (right) Rx antenna installed on top of drive test van

For the case of fixed wireless measurement, we are only interested in measuring the locations where the APs will be installed. These can either be from the utility poles or building rooftops, and the receive (Rx) antenna height should be where the APs are to be installed (i.e. about 20 ft. above the ground). A bucket truck was used with Rx antenna in the bucket, and the bucket was raised to the appropriate height.

Figure 17. Bucket truck used to measure the Rx signal level at the approximate AP location.

Just as the drive route must be chosen to evenly cover a cellular network area, the measurement locations in Fairlawn must also evenly spread out in the area so as to achieve a representative sample and not leave large areas unexamined.

Because the areas of interest are either located in the south or east side of the city, not all base stations need to be turned on for measurement (Figure 18).

- The base stations on the Fairlawn tower will always be turned on, because base stations on this 250-foot tower can cover the entire city.

- However, base stations in the northwest do not need to be turned on. That location is too far from all of the areas to be measured.

- When measuring the areas near the south, only one or two additional base stations located near the south need to be turned on. In this case, the BS on the water tower will always be on. (It is in a southeastern location.) Additionally, one more base station will be operating on the 45' bucket truck positioned in the southwest.

- When measuring the areas near the east, only one or two additional BSs located near the east need to be turned on. Again, the BS on the water tower will always be on, the BS on the 45' bucket truck, used to be located on the (SW), now moves to the East.

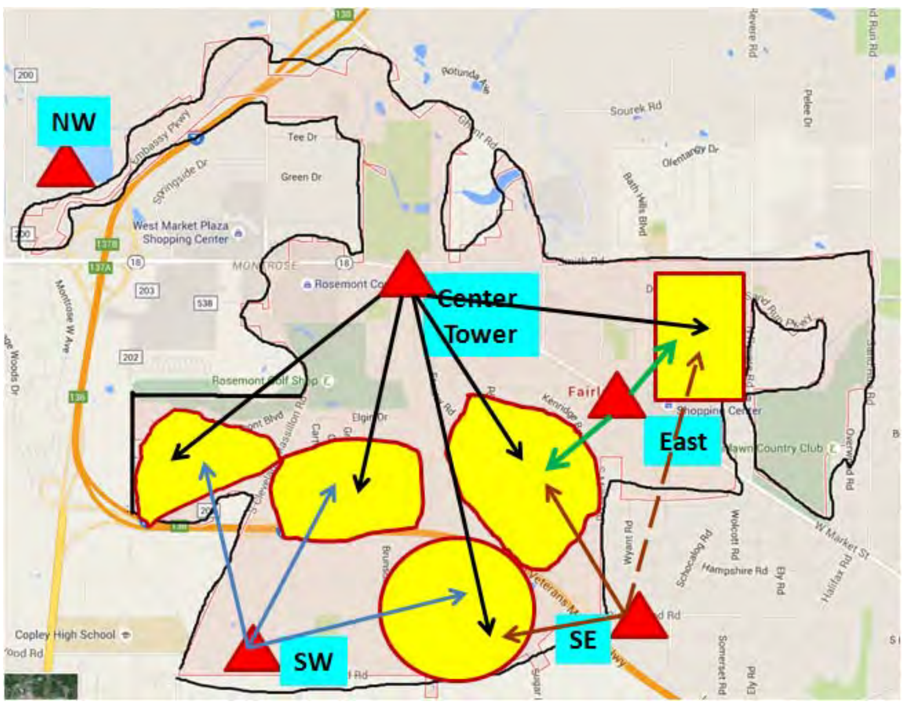


Figure 18. The base stations on the Fairlawn tower and on the water tower (SE) will always be on. The other BS installed on the 45' bucket truck can move between SW and East locations. Yellow areas show where the areas under measurements are located.

3.2.2 Measurement Procedure

The baseline product for Pt-to-MP base station will be Rocket AirMax ac Base Station (and the corresponding CPE) from Ubiquiti. Other products can also be used in a real deployment, but this product is used for measurement. Had the AirMax base station not been available, continuous wave (CW) transmitters could have served the same purpose, though the Tx power level, Tx frequency, antenna gain, and other parameters would have to be set to the same values as the AirMax Base Station.

First, one must make sure that there is no interference (i.e. if the base stations are off, there should be no power measured on the channel frequency).

To save time, it is best to use three sets of base stations transmitting simultaneously, from three different locations, using three different frequencies. This way, the measurement location can potentially be served by three base stations from three different locations.

- One base station is installed on the Fairlawn tower
- One base station is installed on the water tower (SE)
- The 3rd base station can be installed on the 45-ft bucket truck.

The receiver is installed on the 35-ft bucket truck.

1) Drive the 35-ft bucket truck to one of the measurement points (defined in Fig. 10), which is usually next to a utility pole or next to a building if a rooftop installation is expected.
2) Raise the bucket to the same height as the location where the AP is expected to be installed.
3) Measure the received signal level from all of the frequency channels the base stations are transmitting. There can be at most three frequencies from three different base stations that are transmitting simultaneously.
4) Each location should be measured for at least 3 minutes, and the average value for measured signal level should be recorded.
5) Drive to a different location and repeat the above steps.

When the measurements for one area are completed, the crew will relocate to a different area. The base station location and/or orientation may also need to be changed so that the antennas point to the area to be measured. Repeat the above steps until all points are measured.

From the measurement results from these 60+ points, one can give a first-order estimation regarding what are the area availability values for access points being served by these Pt-to-MP base stations.

3.3 The Foliage Loss with and without Leaves

When RF measurements were performed, the leaves on most trees were already gone (Figure 19). Since the measured results are without leaves, how should they be expected to change when the leaves grow back?

The trees without leaves still produce foliage losses due to the branches and twigs; however, the loss will be less compared to the case with leaves. As leaves grow back, the foliage loss will increase, and the highest level of foliage loss will occur during summer.

Figure 19. The current situation near Fairlawn. Most trees have no leaves, but branches and twigs still produce foliage losses

The question is, because currently the foliage losses are lower, therefore the measured receive signal levels will be higher. How should one estimate the received signal levels when leaves have grown back?

Dr. Adegoke did a Ph.D thesis on measurement of different foliage losses with different degrees of leaves on various tree types (Figure 20) for 3.9 GHz and 5.4 GHz signals. The results for 5.4 GHz are very useful to us.

Figure 20. Foliage losses from trees with different levels of leaves were measured for 5.4 GHz.

The following figure shows the additional foliage loss that can be observed as trees grow more and more leaves. The maximum difference can be up to 16 dB. This, of course, will depend on how thick the canopies are. In case of very large canopies, up to 20 dB difference was measured.

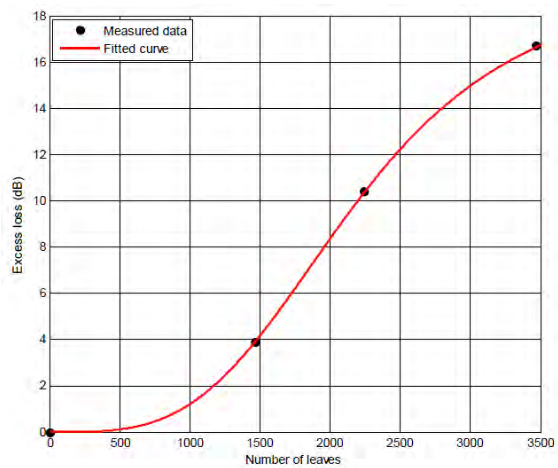


Figure 21. Excess foliage loss as a function of leaf density from the tree.

A large number of empirical formulas are produced based on field measurements. The following figure shows the comparison of in-leaf and out-of-leaf foliage losses for fitted ITU-R model (FUTU-R) at 5.4 GHz. For most cases, the difference is about 10 ~ 15 dB.

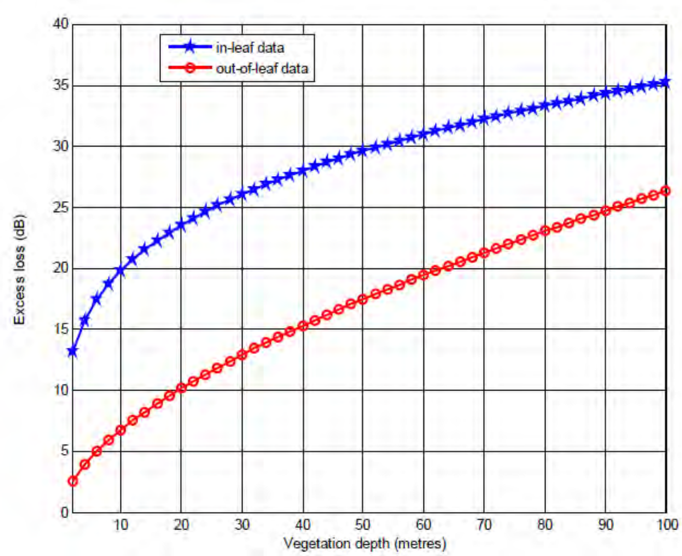


Figure 22. Comparison of foliage losses based on FITU-R for trees with and without leaves (@5.4 GHz).

Different researchers did similar measurements and produced different empirical formulas to predict the foliage loss. The following figure shows a comparison of foliage losses from different empirical formulas.

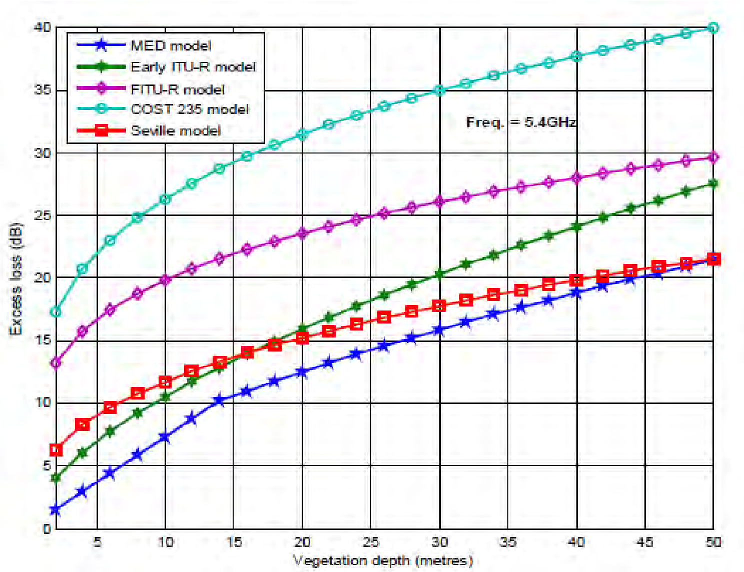


Figure 23. Foliage losses predicted by different empirical formulas

Different empirical formulas produce different curves for foliage losses. While this may appear confusing, the data are actually useful.

For example, the MED (Modified Exponential Decay) model produced the blue curve with foliage losses much lower than other curves. The MED model gives the best fit for the situation that the tree canopies are much higher than the Tx and Rx antennas. As a result, it is really the tree trunks that produced the foliage losses. Tree trunks produce much less obstructions, so the level of foliage loss is lower.

Figure 24. When tree canopies are higher than the antenna heights, it is really tree trunks that produce foliage loss. MED produces good fit for this case.

COST-235 model produces the light-blue-green curve with foliage losses much higher than other curves. This curve gives a good fit for measurement data where both transmit and receive antennas are both obstructed by tree canopies. As a result, maximum foliage loss is experienced.

Figure 25. If both Tx and Rx antennas are obstructed by the tree canopies, the foliage loss will be maximum. COST-235 is the best fit.

The following figure shows measurement results from Dr. Adegoke compared with curves generated from COST-235, FITU-R and MED. It can be seen that COST-235 generally gives an upper bound, MED generally gives a lower bound, and FITU-R generally gives results somewhere in between. So results from FITU-R can be considered as an "average case".

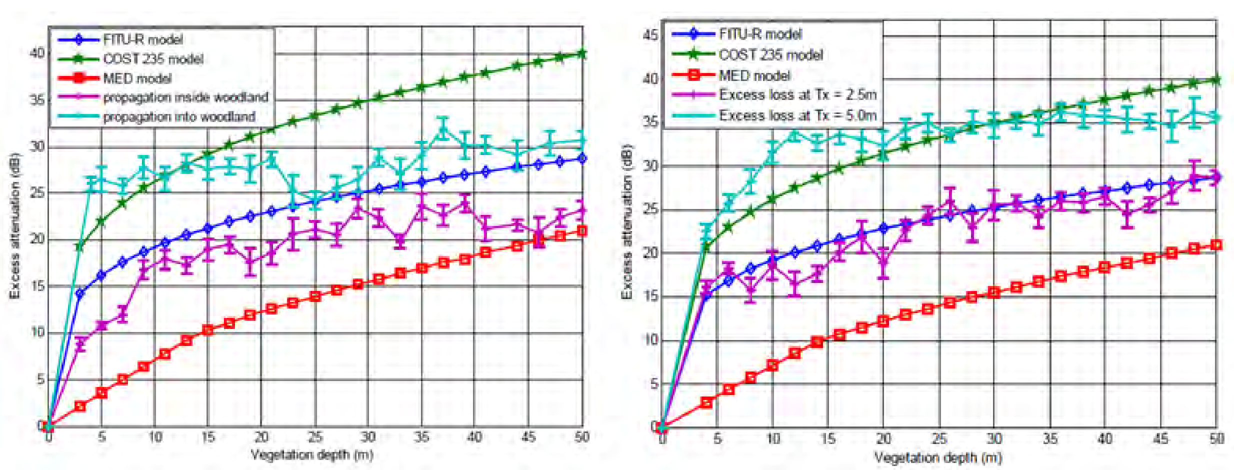


Figure 26. Measurement results compared with upper bound (COST-235), lower bound (MED) and average (FITR-R)

Conclusion:

When received signal level measurements were performed in areas with leafless trees, the received signal levels will be attenuated further by delta dB once the leaves have grown back. The magnitude of this delta value will be a function of locations of transmitter, receiver and the thickness of the tree canopies.

- Very thick canopy: Delta can be up to 20 dB
- Thin canopy: Delta can be 7 dB or less
- Average case: Most delta values are around 10 ~ 15 dB

3.4 Measurement Results

Figure 27 shows the measurement results for Area #2, #4 and #5.

Figure 27. Measurement results with no leaves on trees

Because there are no leaves on the trees, during the summer when leaves are back, the actual signal level can be 10 to 15 dB lower than measured values. As a result, only the locations with measured Rx signal levels marked “green” (> -65 dBm) are acceptable. All other colors are considered “outage”. For example, if the measured signal level = -70 dBm, it is acceptable for now. But when leaves have grown back and an extra 10 to 15 dB of foliage loss is applied, it is reduced to -80 to -85 dBm, which is no longer acceptable.

Area #2:

The measurement locations were not "evenly" distributed across the whole area. All measurements were performed on the east side. No measurements were performed on the west side.

From the measurement result, the Area #2 cannot reach 90% of area reliability. The estimated area reliability in this area is about 50% (about half of the measurement results are "green"), meaning that about half of the utility poles in this area should be expected to be suitable base station locations.

Area #4

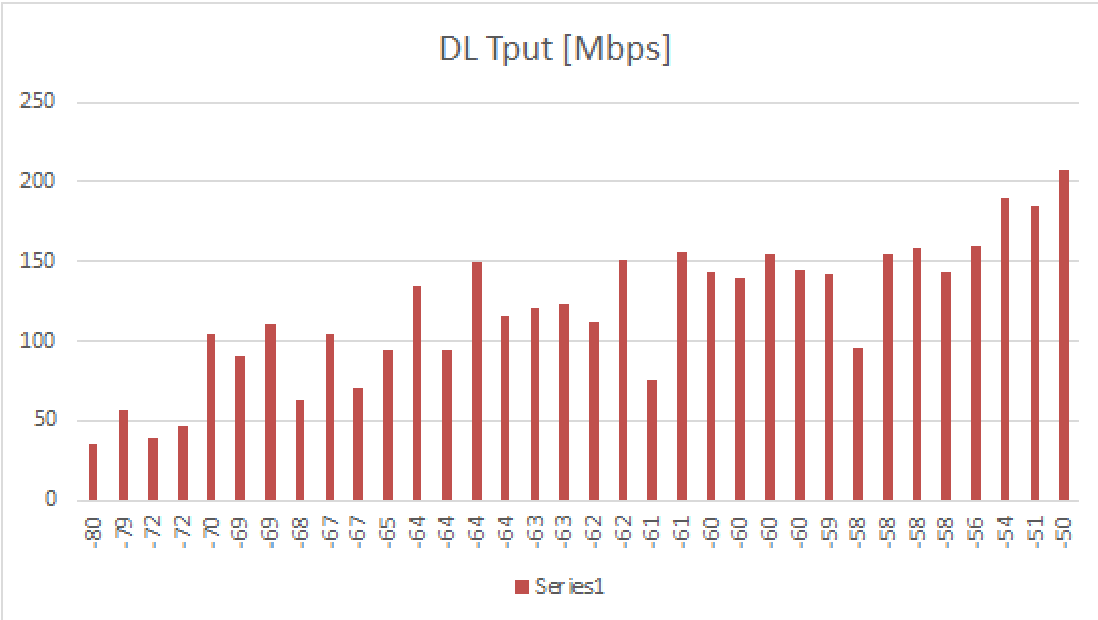
The measurement locations cover the area more evenly. The overall measured Rx signals are much higher in this area.

The northern part of the area has better coverage due to the fact that it is very close to the Fairlawn Tower. The area reliability can almost reach 90% (within the error bar). However, the coverage in south and south east parts are worse. The overall area reliability still cannot reach 90%. It is around 65% to 70%. It is difficult to have a more accurate prediction due to the large error bar.

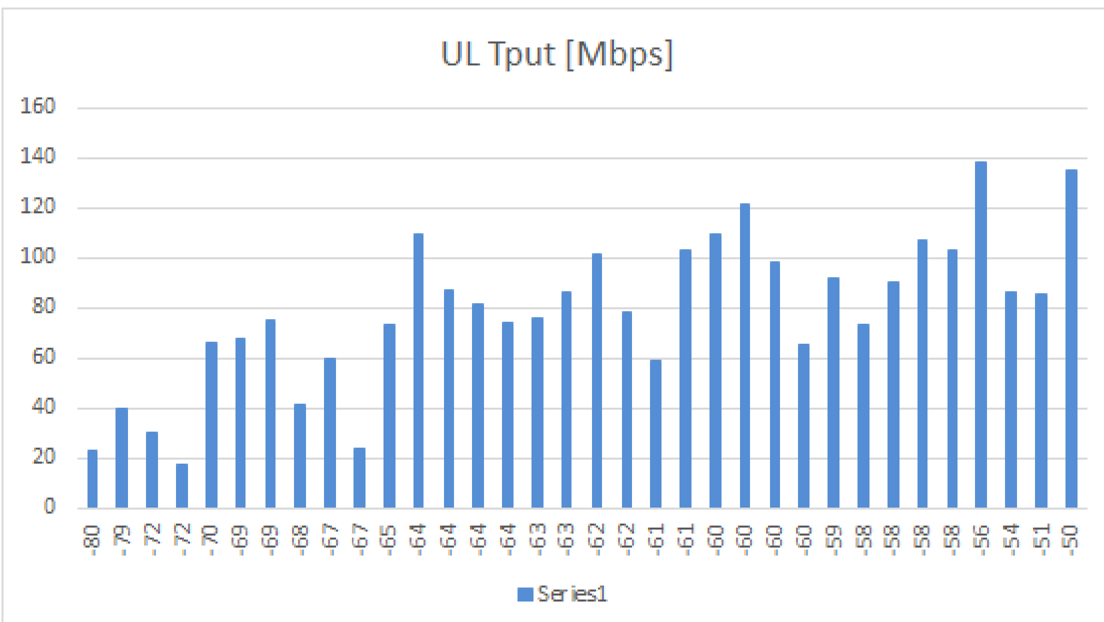
Area #5

This area has very heavy foliage. Most houses are "deep in the woods". Indeed, the measurement results are very poor. Most locations have no service or very poor service. Only one location, near the edge, has good Rx signal level (-58 dBm). The estimated area reliability is below 5%.

Figure 28 shows the actual achieved down link (DL) and up (UL) link throughput as a function of received signal level (RSSI). It can be seen from the results that only in areas with received signal level > -60 dBm, can DL throughput be 150 Mbps or better (UL throughput values are around 80~ 120 Mbps).



(A)



(B)

Figure 28. Measured throughput as a function of received signal level (A) DL throughput (B) UL throughput.

Conclusion and Recommendation

Field measurement results verified that the wireless backhaul can only deliver reasonable throughput at areas with received signal levels above -65 dBm (green color in Fig. 22). In fact, above -60 dBm is highly preferred. From a deployment point of view, it means that the area must have LOS condition with at least one of the fixed wireless base stations. This requirement essentially eliminates all areas with heavy foliage.

Fiber backhaul should be used for Area #5, Area #2, Area #3, and southern part of Area #4. Area #1 and the northern part of Area #4 may be suitable for fixed wireless backhaul.

4. RF Predictions for Wi-Fi Access Networks

A preliminary RF design was performed by assuming availability of vertical assets, which consist of City of Fairlawn traffic lights, tornado sirens, and Ohio Edison utility poles. This resulted in the placement of a total of 114 dual-mode Unifi AC APs. Figure 29 shows the 5 GHz coverage footprints from these APs. Coverage footprints from 2.4 GHz signal will be larger than the coverage footprints from 5 GHz.

It can be seen that 114 APs will not provide sufficient coverage for the entire city. The areas with no vertical assets are not properly covered, which means additional access point locations will be required to further extend the Wi-Fi coverage footprint.

For areas with utility poles and traffic lights, the APs installed on these assets will provide adequate coverage.

By looking at the sizes of the coverage holes, one can conclude that the total number of APs needed to coverage the entire city should be less than 200.

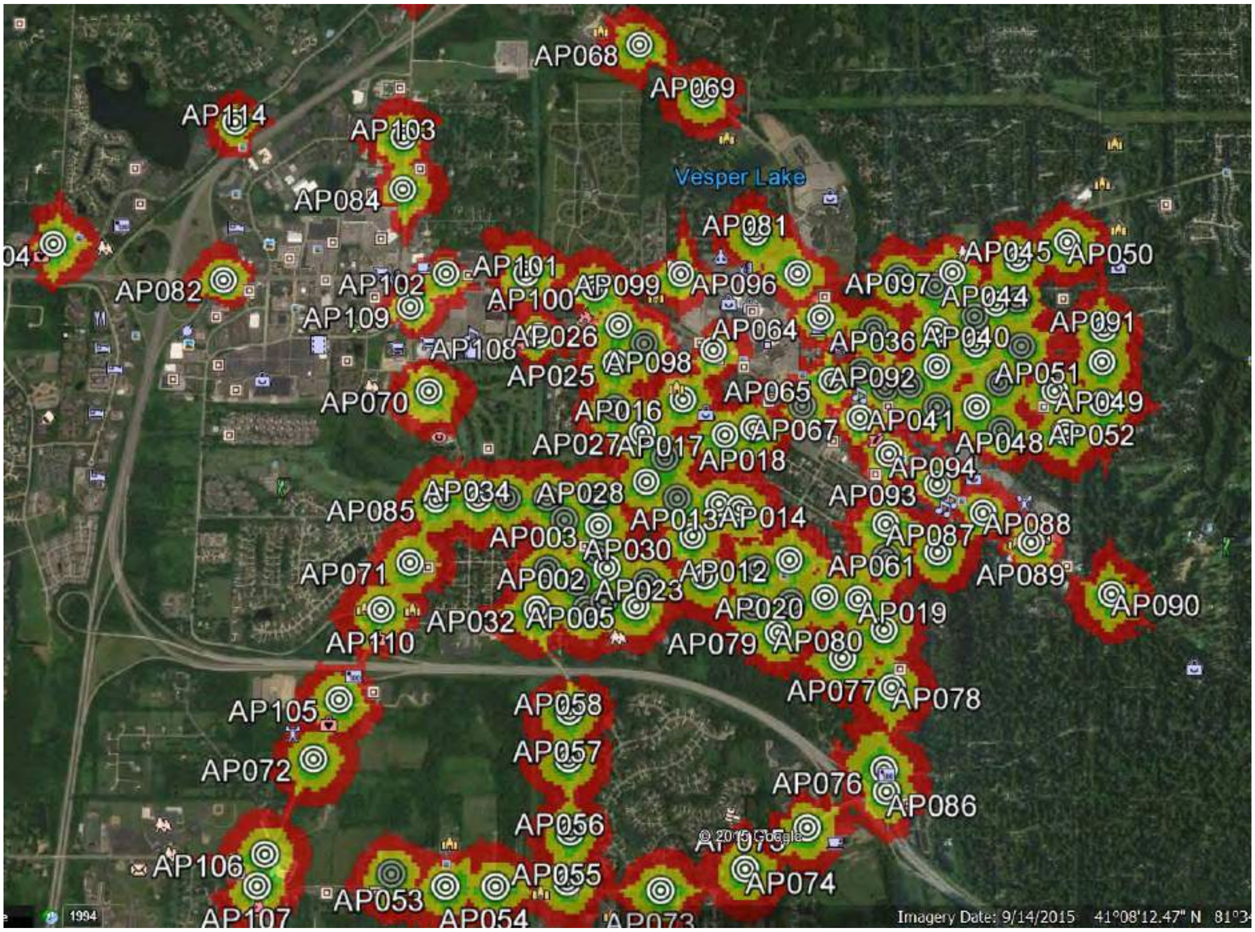


Figure 29. Coverage footprints from 114 APs located on utility poles. Green (>= -65 dBm), Yellow (>= -70 dBm), Red (>= -75 dBm)

A revised RF prediction may be performed making use of additional APs to be placed on yet-to-be-identified vertical assets (e.g. rooftops or poles).

The figure below is a preliminary point-to-multipoint design illustrating how 55 of the Access Point locations can be linked back to the base station locations. This design can be refined as AP locations are added or removed.

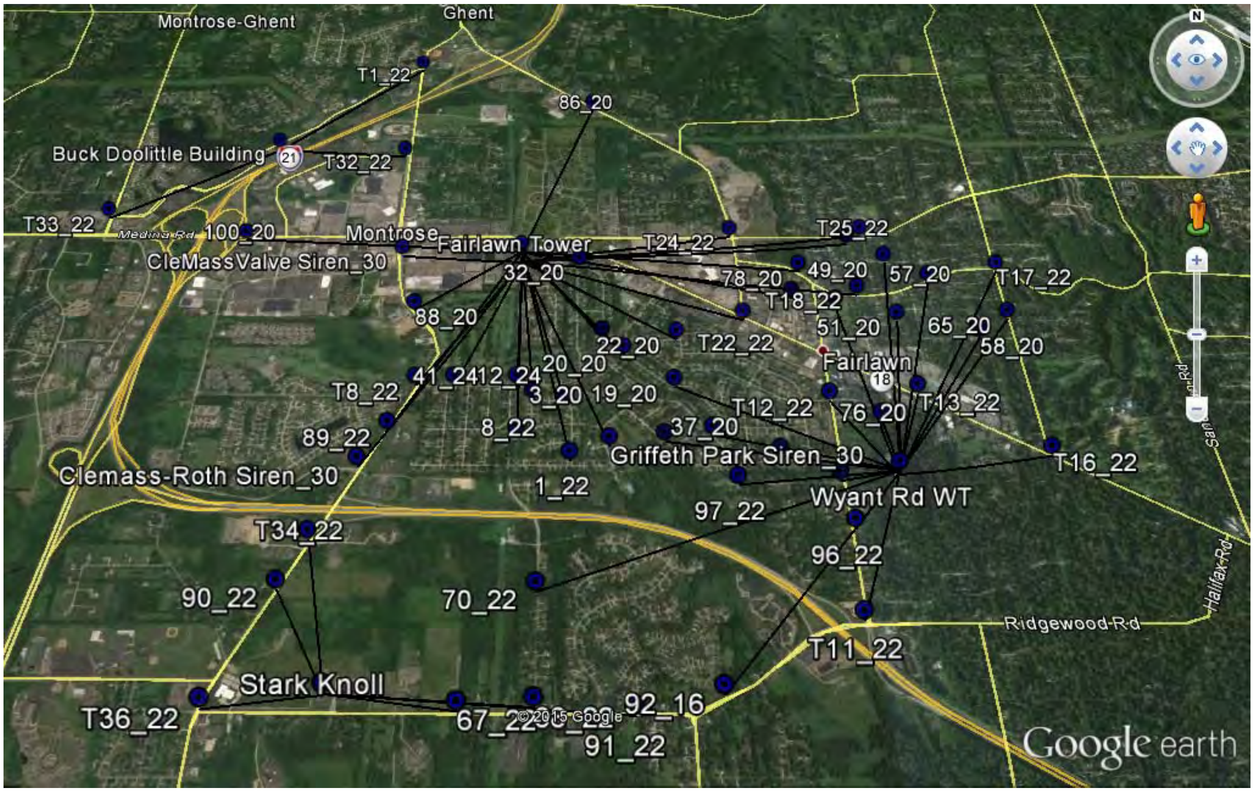


Figure 30. Point-to-Multipoint Link Topology

Point-to-Multipoint Path Analysis

AP Index #	Lat	Long	Path Length (mile)	CPE Height (ft)	Predicted Receive Signal Level at CPE (dBm)	Service Base Station Location
T32	41.14200	-81.63750	0.48	28	-52.52	Buck Doolittle
T1	41.14981	-81.63700	0.70	28	-56.86	Buck Doolittle
T33	41.13726	-81.65741	0.67	28	-56.86	Buck Doolittle
32	41.13368	-81.62496	0.20	20	-50.06	Fairlawn Tower
88	41.13084	-81.63569	0.42	20	-51.4	Fairlawn Tower
CleMass–Valve Siren	41.13450	-81.63686	0.42	36	-51.42	Fairlawn Tower
40	41.12534	-81.62791	0.60	20	-54.48	Fairlawn Tower
T8	41.12620	-81.63514	0.63	28	-54.92	Fairlawn Tower
3	41.12509	-81.62598	0.63	20	-54.94	Fairlawn Tower
41	41.12624	-81.63277	0.57	20	-55.23	Fairlawn Tower
T24	41.13600	-81.61476	0.75	28	-56.37	Fairlawn Tower
T22	41.13021	-81.61452	0.79	28	-56.86	Fairlawn Tower
89	41.12354	-81.63650	0.83	20	-57.24	Fairlawn Tower
78	41.13354	-81.61044	0.96	20	-58.54	Fairlawn Tower
Clemass-Roth Siren	41.12156	-81.63803	0.98	36	-58.75	Fairlawn Tower
100	41.13568	-81.64760	0.99	20	-58.78	Fairlawn Tower
T18	41.13193	-81.60686	1.15	20	-60.15	Fairlawn Tower
81	41.13173	-81.61117	0.93	20	-60.26	Fairlawn Tower
T25	41.13601	-81.60590	1.20	26	-60.51	Fairlawn Tower
22	41.12895	-81.61890	0.62	20	-62.24	Fairlawn Tower
12	41.12627	-81.62890	0.53	20	-63.39	Fairlawn Tower
20	41.12798	-81.62228	0.54	20	-64.96	Fairlawn Tower
Griffeth Park Siren	41.12271	-81.62329	0.83	36	-65.8	Fairlawn Tower
86	41.14626	-81.62394	0.88	20	-67.22	Fairlawn Tower
1	41.12192	-81.62564	0.85	20	-69.11	Fairlawn Tower
33	41.12903	-81.62358	0.44	20	-69.74	Fairlawn Tower
8	41.12325	-81.62881	0.74	20	-69.81	Fairlawn Tower
46	41.13542	-81.60688	1.15	20	-74.19	Fairlawn Tower
T36	41.11031	-81.64429	0.32	20	-48.96	Stark Knoll
67	41.11026	-81.63136	0.36	20	-57.81	Stark Knoll
91	41.11010	-81.62236	0.83	20	-63.14	Stark Knoll
68	41.11043	-81.62746	0.56	20	-70.57	Stark Knoll
T34	41.11784	-81.64021	0.49	28	-75.75	Stark Knoll
90	41.11542	-81.64148	0.35	20	-88.78	Stark Knoll
98	41.12073	-81.61005	0.18	20	-43.86	Wyant Road Water Tank
96	41.11835	-81.60965	0.24	20	-46.46	Wyant Road Water Tank
T13	41.12563	-81.60442	0.34	28	-49.61	Wyant Road Water Tank
T12	41.12516	-81.60989	0.33	28	-57.12	Wyant Road Water Tank
26	41.12209	-81.61331	0.35	20	-59.66	Wyant Road Water Tank
51	41.13017	-81.60466	0.64	20	-63.39	Wyant Road Water Tank
Croghan Park Siren	41.13112	-81.60843	0.71	36	-63.55	Wyant Road Water Tank
49	41.13410	-81.60466	0.91	20	-64.72	Wyant Road Water Tank
T16	41.12222	-81.59731	0.50	28	-64.93	Wyant Road Water Tank
76	41.12397	-81.60701	0.21	20	-65.47	Wyant Road Water Tank
37	41.12329	-81.61713	0.57	20	-66.7	Wyant Road Water Tank
97	41.12062	-81.61593	0.48	20	-67.07	Wyant Road Water Tank
T11	41.11408	-81.60999	0.51	28	-68.15	Wyant Road Water Tank
58	41.12911	-81.59965	0.67	20	-68.69	Wyant Road Water Tank
29	41.12296	-81.62002	0.71	20	-69.3	Wyant Road Water Tank
19	41.12603	-81.61924	0.74	20	-69.69	Wyant Road Water Tank
65	41.13034	-81.59750	0.81	20	-71.87	Wyant Road Water Tank
T17	41.13356	-81.59730	1.00	20	-73.35	Wyant Road Water Tank
92	41.11095	-81.61775	0.90	20	-73.56	Wyant Road Water Tank
70	41.11540	-81.62748	1.15	20	-74.99	Wyant Road Water Tank
57	41.13280	-81.60203	0.85	20	-83.79	Wyant Road Water Tank

Appendix Required Receive (Rx) Signal Levels

If the AirMax base station is used, the following table provides the required Rx signal level in order to get a certain modulation and coding scheme (MCS). Of course, this is assuming there is no interference.

R5AC-PTMP Operating Frequency							
Operating Frequency							Worldwide: 5470 - 5875 MHz USA: 5725 - 5850 MHz
Output Power							27 dBm
TX Power Specifications				RX Power Specifications			
Modulation	Data Rate	Avg. TX	Tolerance	Modulation	Data Rate	Sensitivity	Tolerance
airMAX ac	1x BPSK (½)	27 dBm	± 2 dB	airMAX ac	1x BPSK (½)	-96 dBm	± 2 dB
	2x QPSK (½)	27 dBm	± 2 dB		2x QPSK (½)	-95 dBm	± 2 dB
	2x QPSK (¾)	27 dBm	± 2 dB		2x QPSK (¾)	-92 dBm	± 2 dB
	4x 16QAM (½)	27 dBm	± 2 dB		4x 16QAM (½)	-90 dBm	± 2 dB
	4x 16QAM (¾)	27 dBm	± 2 dB		4x 16QAM (¾)	-86 dBm	± 2 dB
	6x 64QAM (⅔)	27 dBm	± 2 dB		6x 64QAM (⅔)	-83 dBm	± 2 dB
	6x 64QAM (¾)	26 dBm	± 2 dB		6x 64QAM (¾)	-77 dBm	± 2 dB
	6x 64QAM (⅚)	25 dBm	± 2 dB		6x 64QAM (⅚)	-74 dBm	± 2 dB
	8x 256QAM (¾)	23 dBm	± 2 dB		8x 256QAM (¾)	-69 dBm	± 2 dB
	8x 256QAM (⅚)	22 dBm	± 2 dB		8x 256QAM (⅚)	-65 dBm	± 2 dB

The data rate for a given MCS is given by:

Data Rate = (# of OFDM data subcarriers per channel)*(# of MIMO Streams)*(MCS) / (Symbol Duration)

- For a 40 MHz channel, # of OFDM data subcarriers per channel is 108.
- For 802.11ac, symbol duration = 3.6 x $10^{(-6)}$ sec.
- # of MIMO Streams =1 for SISO, = N for NxN MIMO.

From the above formula, one can estimate the expected channel throughput from received signal level.

Managed Network Services and Maintenance Services Descriptions

This document describes the Managed Network Services and Maintenance Services (Services) to be performed by Fujitsu Network Communications, Inc. ("FNC") for the City of Fairlawn (the "City") for the Wireless and Fiber Optic Network. This document is subject to the General Terms and Conditions of Sale between FNC and the City as well as a signed Statement of Work (SOW).

1. Scope of Work

A. Managed Network Services

The FNC Network Operations Center (NOC) provides a 7x24x365 remote monitoring and troubleshooting service with carrier class visibility into the customer's infrastructure. Utilizing the NOC monitoring tools as the platform, the service is scalable and provides multi-tenant support for multiple networking products. At a high level, the Managed Network Service provides the following:

- 7x24 Fault Management for network core and business customers
  - Monitor, Notify and Troubleshoot
- 7x24 Event Management for residential customers
  - 7x24 Monitor and Notify

Service Package Overview

Managed Network Service Component	Exhibit
Fault Management for network core and business customers	
Incident Monitoring	1
Incident Notification	
Incident Restoration	2
Problem Management	3
Configuration Management	4
Inventory/Asset Tracking	5
Circuit Resource Tracking	6
Third party Management	7
Event Management for residential customers	
Incident Monitoring	8
Incident Notification	
Performance Management	9
Reporting	10
Provisioning Management (Move, Adds, Change, Delete) optional	11

i. Fault Management Service Package

Fault Management encompasses detecting, isolating and restoring incidents for the managed devices. It is the process of locating problems on the managed device or external to the managed device. This could include discovering the existence of the problem, identifying the source, and possibly repairing (or at least isolating the device from) the incident through traffic restoration.

o Incident and Alarm Monitoring

The NOC will provide near real time remote monitoring of the supported devices for vendor defined fault-related incidents through its device management software tools, 24x7x365.

Device monitoring is achieved utilizing Simple Network Management Protocol (SNMP) or Transaction Language (TL1). FNC will monitor one designated Target Identification (TID) or Hostname associated with each managed device listed in Appendix 3.

- **Incident and Alarm Notification**

Incidents will be identified automatically by the FNC device management software tools. Incidents may also be reported by the City network management personnel to the FNC service desk by telephone or email.

FNC will correlate and filter incoming alarms and incident information shall be provided to the City personnel.

- **Incident Restoration**

Incident Restoration includes the remote means of restoring network traffic or devices in the event of an outage to operational productivity. Incident restoration does not include resolution due to potential long-term Original Equipment Manufacturers (OEM) engineering or development for final resolution. (FNC can provide next business day advanced hardware replacement services supporting traffic restorations.)

- **Problem Management**

Problem Management is the process of identifying incidents and problems caused by the end-user, network infrastructure or equipment issues, and recommended actions to prevent reoccurrences.

NOTE: An incident is an isolated event that disrupts normal operation. A problem is an underlying issue that could lead to multiple incidents.

- **Configuration Management**

FNC will provide minimal configuration management as required to support our Incident Restoration obligations as part of the Fault Management Service Package. This will include configuration information maintenance.

- **Inventory/Asset Tracking**

Inventory/Device Tracking is the detailed recording and updating of information that captures hardware and software configuration details.

- **Circuit Resource Tracking**

Circuit Resource Tracking is the recording and updating of information which captures circuit configuration details. Such information typically includes the design, configurations and setup of circuits or routing tables within the network or devices. All details are captured from the device, management application, or engineering documentation.

- **Third Party Management**

Third Party Management provides dispatching, guidance and alerts to the City third party providers in the event of Incident restoration or notifications.

ii. Event Management Service Package

For residential customers, FNC provides 24x7x365 coverage of the manage devices for real-time remote Incident monitoring to ensure that detection and notification of Incidents. The NOC's responsibility is to monitor, acknowledge and notify the customer of an Incident or clearance of the Incident.

o Incident Monitoring

Device monitoring is achieved utilizing simple network management protocol (SNMP), transaction language (TL1) or other native protocols as determined. FNC will monitor one designated target identifier (TID) or hostname associated with each device listed in Appendix 3.

o Incident Notification

Incidents are identified automatically and reported by the City network management personnel as defined in the Operational Level Agreement (OLA).

FNC will filter incoming incidents and information is provided to the City personnel.

NOTE: Troubleshooting, as well as parts and personnel dispatch for onsite support, shall be completed by the City personnel if Fault Management Services are not contracted.

iii. Performance Management

Performance management provides monitoring, evaluation, and reporting of managed devices and network status and activity. Performance management aids in the maintenance and operations of the managed devices and network.

iv. Reporting

Numerous periodic management reports are available.

v. Provisioning Service (Optional)

FNC will implement the City's pre-engineered logical requests for Move, Add, and Change (MAC) to the managed network. All MAC's are characterized by the complexity of the requests and are performed remotely from the NOC. All MAC requests will be for currently managed network devices, circuits or termination points. Any requests for adding new devices to the managed network will be supported as a Change Control Request and processed.

B. Maintenance Services

With FNC MSP to protect Fujitsu and selected third-party equipment, you can protect your network assets with technical assistance, software upgrades, preventative maintenance, spares management and on-site maintenance

Maintenance Services	Exhibit
Multi-vendor integrated TAC	12
Advance Hardware Replacement (AHR)	13
Repair and Return	14
Routine Preventative Maintenance	15
Outside Plant Break Fix	16
Software Subscription	17

i. Multi-vendor, Integrated Technical Support (TAC)

The FNC Technical Assistance Center (TAC) is our 24 x 7 x 365 customer solutions center. This facility is staffed by experienced telecom and data engineers, who have an average of more than ten years of experience in troubleshooting not only Fujitsu optical equipment, but are also certified to support various other 3rd party equipment providers. TAC is the central point of contact for resolving network issues related to the operations, performance, reliability, and maintenance of new installations and online operational systems.

ii. Advance Hardware Replacement (AHR)

The Advance Hardware Replacement (AHR) service ensures the City network is continually supported with spares for the Products identified in Appendix 3. Advanced Hardware Replacement entitles the City to the delivery of spared products for replacement of failed units during troubleshooting efforts.

iii. Repair and Return (R&R)

FNC will repair or replace the Fujitsu procured equipment, component, or hardware (individually or collectively “equipment”), identified by the City, that does not materially conform to manufacturer’s specifications.

iv. Routine Preventative Maintenance

FNC’s experienced technicians perform onsite inspections of equipment to ensure ongoing network efficiency. A periodic maintenance program is developed for non-service affecting tasks including test, clean and backup critical network data as well as replacement of hardware filters.

v. Outside Plant Break Fix

Outside Plant (OSP) Break Fix dispatches of experienced field technician with appropriate test equipment to determine where the break is located. The City is responsible for fixing the break (dig up the fiber and fixes the break). FNC will test to ensure that the fix is complete.

vi. Software Subscription

FNC will make available to the City, software updates and upgrades that are available for licensed Network software. The Software Subscription grants the City the right to receive all major, minor, and maintenance release level software that becomes generally available for the Fujitsu procured products.

This service describes Software Subscriptions that are available from FNC for software Products licensed to Customer and identified by an FNC-designated part number. The subscriptions below must be purchased at the time Customer pays the applicable RTU license fee for the applicable software Product.

2. Service Review

FNC provides Managed Network Service Reviews on a quarterly basis. Each Managed Network Service Review includes a review of the data gathered from the Fault Management system including exception details for any incidents failing to meet established metrics. The FNC Service Delivery Manager is responsible for scheduling and conducting reviews.

3. Managed Device Discovery

FNC will perform a discovery of the City's managed devices to verify:

- The list of managed devices
- The City network topology
- managed device's configuration

Audits are performed using network-based tools for the managed devices connected to the network and not via physical audits or onsite visits.

If during the discovery phase, devices are found that are not on FNC's list of managed devices, FNC identify the additional devices and notify the City. New devices may be added through the Change Control Request process and could result in additional charges. Acceptance of new devices may involve a commercially reasonable time frame to expand the tool set(s), or to work with vendors through Letters-of-Agency (LOA) and partners to enable the monitoring and management functionality desired.

4. Connectivity

FNC utilizes a secure VPN connection(s) to access and monitor/manage any device or network remotely. FNC utilizes dedicated and redundant Secure VPN connections to the two (2) geographically diverse NOC data networks to two (2) geographically diverse the City gateway elements into the managed network.

5. Web Portal

FNC provides the City two portals designed to enable easy access to service information collected by FNC's ticketing system and for Service Requests and Change Control notifications. Following are examples for some of the functionality of the portals:

Portal 1 – Partners: https://partners.fnc.fujitsu.com/

- Review, update, escalate and check the status of service incidents (tickets)
- Download entitled FNC software releases
- Download entitled FNC product documentation

Portal 2 – NOC with two Factor Authentication

- Submit Service Requests for new order deployments
- Submit Change Control and Maintenance notifications

- Request a move, add, change or cancellation of asset information
- Access NOC management tools granted per contract (Remote User)

6. Network Operations Center (NOC)

FNC maintains a fully redundant network in geographically diverse locations within the continental US. FNC ensures that only authorized personnel have access to the NOC. FNC is responsible for ensuring that the NOC staff has the necessary product training, knowledge articles, and technical communication bulletins to monitor and manage the supported devices.

7. New Customer Activation

FNC's standard methodology for on-boarding new customers is detailed in the New Customer Activation process Managed-Take-Over plan (MTO) in Appendix 1. The FNC methodology may be modified as agreed between the City and FNC.

Typically, a new customer can be on-boarded within 90 days from receipt of a purchase orders. The addition of a new service, geographic scope, connectivity constraints, number of devices, or the completeness of on-boarding information related to the development of the Operational Level Agreement (OLA) may affect the length of the on-boarding process.

8. Change Control Process

Changes (including additions, deletions, or modifications) to the managed network or supported devices requested by the City after a SOW is signed will be subject to a Change Control Process as defined in the OLA.

9. Prerequisites

In addition to the details specified elsewhere the SOW, the City will adhere to the following responsibilities so that FNC may meet its obligations under an agreed SOW:

- The City will provide FNC with the necessary network addresses, network identification codes, and passwords for FNC to manage and operate its Managed Network Service for the City. In addition, during OLA development, the City agrees to allow FNC to contact its employees, the City employees, contractors and other applicable persons under the City's control, as reasonably required by FNC, to support reasonable activities related to the reasonable operation of the Managed Network Services. All contacts will be pre-approved and arranged by the City.

- With the prior agreement of the City, certain unattended diagnostic equipment, software, and supplies may be placed at the City locations. In addition, FNC may require target systems and other components to be operational at the time of Managed Network Service delivery. The City is responsible for ensuring that all necessary devices that are not under the control of FNC are operational.

- If certain equipment, software or supplies must be installed on the City's premises for diagnostics or fault resolution purposes, these cases will be reviewed and mutually agreed upon between FNC and the City prior to FNC's utilization.

- The City agrees to provide FNC with information concerning third party service providers which FNC on-boards for the Managed Network Service. FNC is not responsible for delays or inability to provide services attributable to FNC's lack of information from the City or failures by such third parties to carry out their respective obligations.

- The City shall provide FNC with Letters-of-Agency (LOA) suitable for FNC to present to each of the City's providers, if required. The LOA's will serve as the City authorization to its providers that FNC will act on the City's behalf with regard to implementing the Managed Network Services hereunder. The LOA's shall state, at a minimum: (i) the name and location of the managed network and (ii) contact name(s) and phone number(s) of the City personnel who can be reached during the hours of operation. A template of an LOA will be provided.

10. Term

The SOW will be effective upon receipt of a signed copy of a SOW and receipt of a purchase order. The initial term is 3 years and will automatically renew unless written notice is provided 120 days prior to the end of the term. Service will begin 45 – 60 days after the effective date.

11. Appendices

Appendix	Description
1	New Customer Activation
2	Service Request Process
3	Supported Devices and Locations
4	Letter of Authorization Template
5	Service Level Objectives
6	Service Delivery Manager
7	Glossary of Terms

EXHIBIT 1 – FAULT MANAGEMENT

1. Service Description

For core and business customers, FNC will provide 24x7x365 coverage of the manage devices for real-time remote Fault Management to ensure that detection, notification; escalation and restoration of Incidents on supported devices can be executed. The FNC Fault Management Service implements proven tools, automated routines, documented processes and technically skilled resources to accomplish this service deliverable.

2. Deliverables

2.1. FNC is responsible for receiving, tracking, management, notification, escalation and restoration of device generated Incidents or the City notifications of an Incident of the managed devices. FNC shall implement and maintain processes that are defined within the Managed Network Services OLA developed for each specific customer.

2.2. FNC utilizes the specific vendor Element Management Systems (EMS) that is integrated into FNC's Operational Support System (OSS). When an Incident is detected the FNC OSS will create a new ticket or update a current ticket.

2.3. Notifications are dependent on the level of service contracted. Most notifications are automated through emails and/or text messages sent to pre-identified the City personnel. In specific cases, FNC may follow up the email or text notification with a phone call to a pre-identified the City contact. FNC also offers a Value Added Service for eBonding of the FNC and the City ticketing systems for immediate and automated ticket linking.

- The OSS used by FNC for the Fault Management Service supports multiple interfaces to multiple element management systems in order to collect the data required. These include SNMP, TL1, EMS/NMS, and programmatic APIs. The managed devices use these mechanisms and do not require customization or integration. FNC manages all managed devices provided such devices are not down due to administrative factors, device shut down or network access restriction periods.

2.4. In cases where a FNC trouble ticket, also known as a Customer Service notification of the Incident, the NOC will commence Incident Restoration.

2.5. FNC's OSS reacts to possible fault scenarios including, but not limited to:

- No response to a poll,
- Unsolicited event is received from a managed device,
- An error log (textual based) message is received from a managed device,
- Alarms and/or conditions are received from a managed device.

2.6. Dispatching of the City Third Party providers

3. Prerequisites

3.1. Network Connectivity

3.2. Development of the OLA

- Supported Location(s)
- The City Contacts
- Network Topology maps with details
- Letters-of-Agency for Third Party and OEM escalations (Appendix 4)
- OEM provider contact information

- Third Party provider contact information

3.3. New Customer Activation (Appendix 1)

4. Exclusions

4.1. Telecommunications Services

In cases where problems are sectionalized to the Carriers network, Incidents will be escalated to the City for escalation to the appropriate Carrier (when applicable) for restoration.

4.2. Demarcation

The demarcation point for a circuit is determined by the equipment owned by the City and managed by FNC versus the equipment owned by the Carrier. If the City owns all network equipment on the customer premises and FNC is managing the device, the demarcation point is at the Carrier termination block in the premise for support purposes but at the ingress port of the router for management purposes. If the Carrier or some other service provider owns the onsite router and has not authorized FNC to monitor its ports, the management demarcation is at the customer switch or router port that connects to the Carrier router port. Demarcation can also be defined as the first connection or termination point away from the FNC managed device.

4.3. Customer Equipment

If a network problem is diagnosed and caused by equipment other than that included in the equipment Appendix 3; FNC will notify the City point-of-contact. The responsibility for the resolution of problems with such equipment rests with the City.

4.4. Site Environment

If a problem is diagnosed and caused by site environment such as power, building damage, schedule labor works, floods, storms or conditions covered by the City-affecting force majeure events, FNC will notify the City. The responsibility for the resolution of problems with such site issues rests with the City.

FUJITSU

EXHIBIT 2 – INCIDENT RESTORATION

1. Service Description

As a deliverable of Fault Management, FNC is responsible for Incident Restoration by receiving, tracking, management, notification; escalation and restoration of network generated Incidents or the City notifications of an Incident. FNC shall implement and maintain processes that are defined within the Managed Network Service OLA developed for each specific customer.

2. Deliverables

2.1 Upon receiving the Incident notification, the NOC personnel will acknowledge the Incident and access the automatically created trouble ticket and reference any associated tickets to the Incident.

2.2 After identifying the troubled network or device, the NOC personnel performs required steps to isolate the issue(s) causing the Incident. Once the issues are identified, the NOC personnel will update the trouble ticket.

2.3 The NOC personnel will follow the OLA developed with the City for the next steps in the process. Next steps could include FNC or the City escalations, FNC or OEM parts or personnel dispatch, or follow up notifications to the City or Third Parties. The trouble ticket will be updated with the specific details.

2.4 The NOC personnel may require onsite assistance or spare units to restore services in specific locations. When necessary and contracted, NOC personnel will dispatch personnel and/or parts to site.

2.5 Once Incident is restored, the NOC personnel updates the trouble ticket and changes the status to Restored.

2.6 As necessary or contracted, if the trouble involves OEM software or hardware engineering to Resolve the trouble, it will be FNC's responsibility to work with the OEM to ensure the OEM provides the software or hardware solution in the agreed timeframe.

2.7 When the long-term solution is available (software or hardware) to Resolve the restored Incident, FNC will notify the City and schedule a maintenance window for implementation.

3. Prerequisites

3.1 Development of the OLA

- Supported Location(s) identified
- The City Contacts information
- Network Topology maps with details
- Third Party provider contact information

3.2 New Customer Activation (Appendix 1)

EXHIBIT 3 – PROBLEM MANAGEMENT

1. Service Description

Problem Management methodology is used to capture systemic issues that generate repeat Incidents, identify and isolate their root causes; define workarounds or temporary solutions and work with the City to implement permanent solutions.

2. Deliverables

2.1 On a regular basis, FNC gathers Incident information and performs analysis in order to identify recurring Incidents. Information sources include:

- Standardized reporting
- Managed Network Service/service delivery team reporting
- Fault (chronic site and exception reporting)
- Trouble ticket reporting
- Any other relevant data source

2.2 FNC works to identify any problems that are generating multiple Incidents or adversely affecting service delivery, these include but are not limited to:

- Known vendor problems
- Site conditions (power interruptions, UPS, environmental conditions)
- The City induced events or exceptions

2.3 When a problem is identified, FNC creates a Customer Service Record (CSR). The problem will be rated based on the severity of impact to the business. A CSR will be assigned to NOC personnel for further investigation.

2.4 When the root cause to a problem is identified and validated the CSR is updated.

2.5 A temporary resolution, workaround or upgrade will be sought to minimize the impact of the problem. When a workaround is not possible, FNC will escalate the problem to Product support to resolution.

2.6 Problem Reports are prepared from data gathered in the CSRs and shared with all concerned parties. The Problem Management system will measure Incidents and the impact of the solution for continuous improvement.

3. Prerequisites

3.1 If required to do so, the NOC may engage the City or the Third Party technical support provider in order to receive reasonable assistance in identifying root causes.

EXHIBIT 4 – CONFIGURATION MANAGEMENT

1. Service Description

Configuration Management is the detailed recording and updating of information that captures hardware and software configuration details. Such information typically includes the configurations of the network, devices and circuit routing information. All details may be captured automatically or manually by database backups from the device or software.

2. Deliverables

Configuration Management is the detailed recording and updating of information that captures hardware and software configuration details. Such information typically includes the configurations of the network, devices and circuit routing information. All details may be captured automatically or manually by database backups from the device or software.

2.1 FNC will utilize a Configuration Management Database ("CMDB") for the Managed Services for the supported devices.

2.2 The NOC performs Remote Memory Backups (RMBU) to allow network restoration of managed devices in the event of a failure from loss of database or provisioning loss.

2.3 Within the NOC, information will be held relating to each Configuration Item. Configuration Items ("CI"s) are divided into three main categories:

- Hardware
- Software
- Database

2.4 The information held within Configuration Management Database is used for the following activities:

- Identification – selecting, describing and labeling each CI (Configuration Item) and recording their attributes within the Configuration Management Database.
- Control – only authorized configuration items are added, removed or changed within the supported environment
- Life Cycle Monitoring – As a device reaches "end of life" FNC will notify the customer of the termination date in order that the City takes appropriate action. As software reaches "end of life" FNC will notify the City of the termination date in order that the City takes appropriate action.
- Verification - regular audits of the information held within the CMDB to maintain its accuracy.
- Changes – the CMDB is audited both before and after major changes to the supported infrastructure (i.e. a new City Implementation).
- Disaster recovery – the CMDB is duplicated for disaster recovery purposes and has a disaster recovery location.

2.5 The following services will be provided for managed devices connected. FNC will provide ongoing support of the managed devices for configuration, including the following:

- Network device Moves, Additions and Changes
- Backup
- System parameters
- Interface configuration
- Protocol configuration
- Password management
- SNMP parameter configuration
- Remote installation of software upgrades

2.6 City Implemented Changes:

- Configuration changes to all supported devices will be performed by the City, unless otherwise agreed upon by all parties. Examples include, but not limited to, setting SNMP parameters, SYSLOG, as well as user names and password. The City will work with FNC to ensure all changes are submitted to FNC within a defined timeframe defined in the OLA.

- The City will adhere to the change management processes (see Appendix 2).

3. Prerequisites

3.1 Minimum 10Mb of bandwidth capacity for connectivity backup purposes

.

EXHIBIT 5 – INVENTORY/DEVICE TRACKING

1. Service Description

Inventory/Device Tracking is the detailed recording and updating of information that captures hardware and software inventory details. Details are typically used for replenishment, carrying costs of inventory, device management, inventory forecasting, inventory evaluation, inventory visibility, physical inventory, available physical space for inventory, quality management, returns and defective goods, and demand forecasting assistance.

2. Deliverables

A report which lists the Inventory/Device within the managed network, (detailed in Appendix 3). Not all details may be applicable for each managed device or location.

2.1 Details captured are: Device type, vendor, serial numbers, date-of-manufacture, release or version numbers, quantity, device TID/Hostname/System address, physical locations including site address, GPS coordinates, floor, aisle, rack and shelf

3. Prerequisites

3.1 Network and device connectivity

3.2 The City provided details which are not remotely accessible

3.3 Details within the reports are limited to the details provided by the City, details which are remotely accessible or details limited by the device and/or management applications

EXHIBIT 6 – CIRCUIT RESOURCE TRACKING

1. Service Description

Circuit Resource Tracking is the recording and updating of information which captures circuit resource details. Details are typically used for network and circuit engineering, customer capacity and bandwidth management, growth forecasting and troubleshooting efforts. Such information typically includes the design, configurations and setup of circuits or routing tables within the network or devices.

2. Deliverables

Report which lists the circuit details within the managed network, (detailed in Appendix 3). Not all details may be available for each managed device or location.

2.1 Details captured are circuit IDs, routing labels, network adjacencies, unique circuit or device identifiers, external termination/ demark point, circuit routes, circuit configuration settings, ports, slots, Access Identifiers (AIDs)

3. Prerequisites

3.1 Network and device connectivity

3.2 Detailed network diagrams for physical, logical, and virtual circuits

3.3 The City provided details which are not remotely accessible

3.4 Details within the reports are limited to the details provided by the City, details which are remotely accessible or details limited by the device and/or management applications

EXHIBIT 7 – THIRD PARTY MANAGEMENT

1. Service Description

Third Party Management provides dispatching, guidance and alerts to the City third party providers in the event of Incident restoration or notifications.

2. Deliverables

2.1 FNC will provide details to the City on all third party notifications, dispatch or contacts. All third party points-of-contact and processes will be established prior to network takeover and management operations begin. All details will be in the form of the Incident report.

3. Prerequisites

3.1 FNC and third party providers require a Letter of Agency (LOA) for FNC to act as the City representative. LOA example in Appendix 4.

3.2 Third Party contact information and contact processes identified and established.

EXHIBIT 8 – EVENT MANAGEMENT

1. Service Description

For residential customers, FNC provides 24x7x365 coverage of the manage devices for real-time remote Incident monitoring to ensure that detection and notification of Incidents.

2. Deliverables

2.1 FNC is responsible for receiving, tracking and notification of network generated Incidents or the City notifications of an Incident. FNC shall implement and maintain processes that are defined within the Managed Network Service Operational Level Agreement (OLA) developed for each specific customer.

2.2 FNC utilizes the specific vendor Element Management Systems (EMS) and are fully integrated into a FNC's Operational Support System (OSS). When an Incident is detected it will be processed through the OSS infrastructure.

2.3 Notifications are automated through emails and/or text messages sent to pre-identified the City personnel.

2.4 FNC will monitor the supported devices for Incidents on a 7x24x365 basis. This service is based on the simple network management protocol (SNMP) standard, transaction language (TL1) or native protocols.

3. Prerequisites

3.1 Network Connectivity

3.2 Development of the OLA

- Supported Location(s)
- The City Contacts
- Network Topology maps with details

3.3 New Customer Activation (Appendix 1)

4. Exclusions

4.1 Onsite or remote troubleshooting

4.2 Network or device configuration backups

4.3 Third Party dispatches

EXHIBIT 9 – PERFORMANCE MANAGEMENT

1. Service Description

Performance management provides monitoring, evaluation, and reporting of managed devices and network status and activity. Performance management aids in the maintenance and operations of the managed devices and network.

2. Deliverables

2.1 Performance monitoring - Performance monitoring entails providing a near real-time view of the managed devices and network utilization. E.g. Proactive optical performance data such as circuit bit error rate, error seconds for path and other performance data will be reported.

2.2 Trend analysis –reporting on long-term performance trends based on historical reporting from archived data. Archived data consists of incidents, alarms and performance data collected from managed devices.

2.3 Proactive monitoring –early notification of potential network problems based on archived performance data. Archived data consists of incidents, alarms and performance data collected from managed devices.

2.4 Dashboards and reports – provide analysis and near real-time snapshots of the managed devices and network. A web-based interface is available to access dashboards and reports.

3. Prerequisites

3.1 Network and device connectivity

EXHIBIT 10 – REPORTING

1. Service Description

Periodic management reports electronically available.

2. Deliverables

2.1 Incident Reports

Report Type	Description	Event Mgmt	Fault Mgmt	Frequency
Incident Ticket Summary Report	Provides a high-level summarized listing of monthly trouble tickets.	Included	Included	Monthly
Incident Classification Summary	Provides a summary of all Incident / problem types encountered for the prior thirty (30) day period	Not Included	Included	Monthly

2.2 Problem analysis report

Report Type	Description	Event Mgmt	Fault Mgmt	Frequency
Problem classification analysis “Root Cause Analysis”	Customized analysis by network and systems technicians, interpreting the fault data, trends, and correlations	Not Included	Included	Monthly

2.3 Configuration Reports

Configuration reports are provided to identify the configuration changes to the infrastructure. FNC may generate one or more of the following reports as per the table below:

Report Type	Description	Event Mgmt	Fault Mgmt	Frequency
Inventory List (Managed Device Listing)	Report showing a detailed list of all devices covered under terms of this Service Description.	Not Included	Included	Annually
Service Request Summary	Report showing all requested changes for the managed infrastructure.	Not Included	Not Included	Monthly
Change Report	Report showing all planned and unscheduled changes to your infrastructure	Not Included	Not Included	Monthly

2.4 Network Diagram

Report Type	Description	Event Mgmt	Fault Mgmt	Frequency
Network Diagram	Shows a conceptual view of device network connections for key devices covered under the terms of this Service Description	Not Included	Included	Bi-Annually

2.5 Network Management Report

Report Type	Description	Event Mgmt	Fault Mgmt	Frequency
Circuit Resource Tracking	Report of circuits within the managed network.	Not Included	Included	Quarterly
Inventory/Device Tracking	Report that describes the Inventory/Devices within the managed network. Information such as the device/unit name, serial numbers, date-of-manufacture, release or version numbers.	Not Included	Included	Quarterly

2.6 Additional Ad Hoc Reports

Some additional options ad hoc reports are available, but may involve additional charges. One-time, special requests will be considered individually, and where possible provided, as time allows.

EXHIBIT 11 – PROVISIONING SERVICES

MOVE, ADD, CHANGE & DELETES

1. Service Description

Move, add, change, deletions (MACD) requests are the City, pre-engineered logical changes implemented remotely by FNC and characterized by simple and complex requirements regarding the request. All MACD requests are for currently managed Network devices which may include one or more of the following:

Examples:

- Circuits
- Ports
- Termination points
- Routing tables
- Access lists
- Passwords

Requests for device additions, deletions, or complex requests with onsite Services for installation or testing are not considered as standard MACD requests and will be supported as a project.

2. Deliverables

2.1 All MACDs are performed remotely by FNC and pre-engineered by the City.

- Move: The function of remotely moving an existing circuit from one termination point to another in the currently managed Network.
- Add: The function of remotely adding a new circuit, activating new groups/slots/ports, IP route, routing tables or users within an existing Network, device or group within the currently managed Network.
- Change: The function of remotely changing a group configuration, user level settings, circuit parameters for operations, IP routing in a switched Network or DNS Proxy block/unblocks.
- Delete: The function of remotely removing a circuit, deactivating groups/slots/ports, IP route, routing tables or users within an existing Network, device or group within the currently managed Network.
- Simple Remote Change –Change affects a single supported device or circuit and can be performed remotely by a NOC provisioning technician.
- Complex Remote Change –Change affecting multiple supported devices, circuits, routing tables or users and can be performed remotely by a NOC provisioning technician. These changes involve an element of risk, and require a back out plan in the event problems are encountered and precautionary measures such as device backups are performed. Each device accessed for MACD changes will be calculated as a single MACD per specific device, i.e. provisioning a complete circuit(s) in a network.
- Circuit – Defined as the access point or section between two or multiple terminals over which one-way or two-way communications may be provided. A complete path may terminate between an access point "A" and a destination point "Z" and transverse over multiple access points. Each transition point or, section, between access points which the path is required to be configured is determined as a circuit. A circuit number is also assigned a unique identifier between each termination point and section.

2.2 All MACDs will be conducted during pre-arranged timeframes after confirmation of request and FNC personnel assignments have been established. Partial, incorrect and / or incomplete requests are excluded from these timeframes and will be returned for resubmission.

2.3 All requests for MACDs must be submitted and processed through the service request process outlined in Appendix 2 of this document.

2.4 The FNC administrators will work with the City for scheduling MACD implementations.

2.5 An onsite change may be necessary with either the simple or complex request. When onsite Services are required for the specific request, a business partner may be necessary at the Customer location performing hands and eyes tasks under direction of the NOC. The business partner may be the City, third party or contracted with FNC.

2.6 FNC will monitor the Network 7x24, but requires the following timeframes for Network change requests allowing FNC time to process and confirm request(s), assign personnel and schedule maintenance time(s):

- Simple Change Scheduling – Scheduled with a firm order commitment (FOC) date three (3) business days (CT) after all specific details are received and verified and accepted for the change requested.

- Complex Change Scheduling – Scheduled with a FOC date five (5) business days (CT) after all specific details are received and verified and accepted for the change requested.

KPI	Definition	Unit	SLO
Simple Change	% Remote Change – Simple MACD on time delivery by Commitment Date	%	95% delivered by the Commitment Date
Complex Change	% Remote Change – Complex MACD on time delivery by Commitment Date	%	95% delivered by the Commitment Date

2.7 Expedited interval requests – Expedited requests can be either Simple or Complex type changes.

- Expedited requests scheduling – Scheduled with a Commitment Date of one (1) business day after all specific details are received verified and accepted for the change requested.

- Number of expedited requests cannot exceed more than **10%** of the total number of requests in base offer.

2.8 Incomplete requests will be returned to the requestor to complete and return prior to scheduling the Service Request. Once the request is accepted, the SLO times will begin.

3. Assumptions and Exceptions

3.1 Requests for device additions, deletions, or complex requests with onsite Services for installation or testing are not considered as standard MACD requests and will be supported as a project.

3.2 All configuration and provisioning requirements included in a project implementation will decrement annual MACD quantities.

3.3 Service request orders are processed during business hours Monday-Friday Central time excluding FNC observed holidays.

3.4 MACDs with any maintenance requiring after-hours or weekend work will require special scheduling.

3.5 All unused MACDs from a previous period are forfeited at the beginning of the following monthly period.

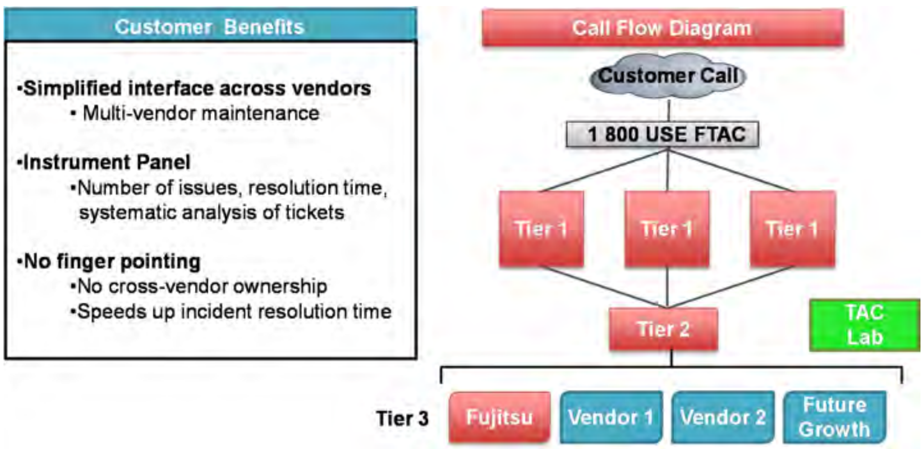
3.6 Requested MACDs from one monthly period implemented in the following monthly period will be calculated against the implemented period's MACD quantity.

EXHIBIT 12 – Multi-vendor, Integrated Technical Support (TAC)

1. Service Description

The FNC Technical Assistance Center (TAC) is our 24 x 7 x 365 customer solutions center. This facility is staffed by experienced telecom and data engineers, who have an average of more than ten years of experience in troubleshooting not only Fujitsu optical equipment, but are also certified to support various other 3rd party equipment providers. TAC is the central point of contact for resolving network issues related to the operations, performance, reliability, and maintenance of new installations and online operational systems.

The diagram below illustrates the call flow for our Multi-Vendor TAC, as well as the associated City benefits.



2. Deliverables

- 7 x 24 x 365 phone access to an FNC TSE (technical support engineer)
- Escalation to higher levels of expertise after reasonable investigation time
- Automated escalation notifications to management (via e-mail)
  - Overdue CSR (Customer Service Request) state
  - Outage CSR logged
  - Outage CSR change of state
  - Others
  - Engineering Investigation Request (EIR)
  - Unit Investigation Request (UIR)
  - Automatic monthly call statistic reports
  - Access to knowledge base and tools for online technical information and customer service request management
  - Customized reports based on customer requirements
    - CSR Reporting
      - Volume
      - Status
      - Duration (Open, Addressed, Restored and Closed)

EXHIBIT 13 – Advance Hardware Replacement (AHR)

1. Service Description

The Advance Hardware Replacement (AHR) service ensures the City network is continually supported with spares for the Products identified in Appendix 3. Advanced Hardware Replacement entitles the City to the delivery of spared products for replacement of failed units during troubleshooting efforts.

2. Deliverables

2.1 FNC provides a 10 business day advance replacement service level objective (SLO) to the location designated by the City for Products identified in Appendix 3.

2.2 Only active equipment (e.g. circuit packs and shelves) are included in this service. Passive equipment (e.g. cables, fibers, filters, attenuators, batteries, passive units, and other miscellaneous hardware) is not supported. A "day" or "business day" is defined as the customary working hours, Monday through Friday, at the stated location, excluding mutually agreed holidays.

2.3 When the City encounters a network failure condition that the City believes is caused by equipment failure that is covered under the SOW, the City should immediately contact FNC's TAC to log a CSR.

If FNC concurs that active Product has caused a network-affecting problem, FNC will, at FNC's expense, ship advance replacement equipment to the City to arrive per the SLO. A SLO response is subject to (a) if FNC received the City's request and confirms the problem before 4:00 PM (central time) on the business day the request was received the advance replacement equipment will be shipped to arrive the next business day; (b) if FNC received the City's request and confirms the problem after 4:00 PM (central time) on the business day the request was received the advance replacement equipment will be shipped to arrive within the SLO after the beginning of the next business day.

2.4 If, upon receipt of the replaced equipment, FNC determines it (a) has not been installed, operated, or maintained, in accordance with the applicable specifications, documentation, and instructions provided by FNC (b) has been subjected to accident, disaster, neglect, abuse, misuse, or damage (e.g. burned, cracked, etc.); (c) has been repaired or modified in any respect by anyone other than FNC or its authorized service representatives without FNC's prior consent; or (d) has been adversely affected by materials, equipment, software or services provided by an entity other than FNC without the City having first received approval from FNC in writing; the returned equipment will not qualify for repair or replacement "at no additional charge" under this Service and the City agrees to be billed and pay FNC as set forth below.

2.5 Title to the advance replacement equipment FNC ships to the City will pass to the City the earlier of (a) the date FNC receives the equipment that was replaced; or (b) the date FNC receives payment for the advance replacement equipment pursuant to FNC invoicing the City as set forth above.

EXHIBIT 14 – Repair and Return (R&R)

1. Service Description

FNC will repair or replace the Fujitsu procured equipment, component, or hardware (individually or collectively "equipment"), identified by the City, that does not materially conform to manufacturer's specifications.

2. Deliverables

2.1 Acting under a Letter of Agency (LOA) where required, FNC will obtain Return Material Authorizations (RMAs) and ship units to vendor repair facilities in-country or to the City's logistics management company / broker for return to the vendor for repair.

2.2 FNC's single action repair service objectives exclude the following:

- Any power failures, fiber cuts or other failures in the fiber connected to the equipment not caused by FNC
- Any failure in air conditioning (HVAC) supporting the equipment not caused by FNC.
- Any Force Majeure event

EXHIBIT 15 – Routine Preventative Maintenance

1. Service Description

FNC's experienced technicians perform onsite inspections of equipment to ensure ongoing network efficiency. A periodic maintenance program is developed for non-service affecting tasks including test, clean and backup critical network data as well as replacement of hardware filters.

2. Deliverables

2.1 FNC and the City develop a periodic maintenance program for non-service affecting tasks. Example tasks include including test, clean and backup critical network data as well as replacement of hardware filters.

2.2 FNC performs the non-service affecting tasks. Correction of minor discrepancies can be scheduled and addressed during a site visit.

FUJITSU

EXHIBIT 16 – Outside Plant Break Fix

1. Service Description

Outside Plant (OSP) Break Fix dispatches of experienced field technician with appropriate test equipment to determine where the break is located. The City is responsible for fixing the break (dig up the fiber and fixes the break). FNC will test to ensure that the fix is complete.

2. Deliverables

2.1 When there is a need for on-site maintenance the City should contact FNC's TAC to log a CSR ticket.

2.2 When FNC concurs that outside plant maintenance is necessary to resolve the City issue, FNC will dispatch technical support personnel to arrive at Customer's site within the mutually agreed upon response time after FNC receives the City's request.

2.3 FNC technical support personnel will determine where the break is located.

2.4 The City provides qualified and experienced on-site field technicians and construction crews for OSP fiber break/fix support including tools, trucks, equipment, test equipment, major materials, minor materials and the other items required to successfully complete the OSP maintenance and repair and available 24 hours a day, 7 days a week, 365 days a year. The field technicians & construction crews will work closely with FNC NOC personnel to coordinate the field technicians' actions during their time on-site.

2.5 Once at the site, the dispatched field technicians will report arrival time to the FNC TAC and they will contact gain access to the affected location so event resolution can be performed with the TAC as directed by FNC.

2.6 FNC will test to ensure that the fix is complete.

2.7 The City will pay for any pole rearrangements or associated costs with Moves, Adds, and Changes as required by utility owners, ROW owners or on private lands.

2.8 Excludes major events where damage repair of aerial plant in excess of 15 pole spans or 3000 aerial feet of fiber or underground plant in excess of 500 feet.

EXHIBIT 17 – Software Subscription

1. Service Description

FNC will make available to the City, software updates and upgrades that are available for licensed Network software. The Software Subscription grants the City the right to receive all major, minor, and maintenance release level software that becomes generally available for the Fujitsu procured products.

This service describes Software Subscriptions that are available from FNC for software Products licensed to Customer and identified by an FNC-designated part number. The subscriptions below must be purchased at the time Customer pays the applicable RTU license fee for the applicable software Product.

2. Deliverables

2.1 If the City is not on the most recent Release of software the City may be required to update to that Release before being eligible for subsequent software updates. The software updates may be made available to the City to download from an FNC website.

2.2 Customer is responsible for implementing any software update or upgrade provided by FNC under this subscription, or may schedule with FNC for on-site support either as part of an On-Site Maintenance Service or as a Software upgrade service.

APPENDIX 1 – NEW CUSTOMER ACTVATION

1. Service Description

This Appendix defines the scope of responsibility for FNC to conduct a Managed-Take-Over (MTO) of the customer's network.

FNC will provide the City with a Project Manager to schedule and kick-off MTO meeting within 5 working days after receipt of a valid purchase order.

The City will provide FNC a Point of Contacts (POCs) to work with the assigned FNC's Project Manager.

New customer due diligence will be 25 business days based on discovery, gap analysis and complexity. The City on-boarding timeline will be mutually agreed based on the City requirements and scope documentation provided by the City.

The City MTO process will require no more than 90 business days lead time based on geographic and connectivity constraints, the number of devices, and size of the new customer's environment and specific details required to develop the Managed Network Service OLA.

1.1 FNC is responsible for the definition and execution of the following:

- MTO kickoff meeting
- MTO Plan

1.2 The Project Plan will contain the main milestones which are as follows:

- Purchase Order
- Implementation time line
- Connectivity Establishment and Functionality
- OLA Development
- Operational Readiness Testing (ORT)

2. Deliverables

2.1 MTO project plan

3. Prerequisites

3.1 Purchase Order

3.2 The City list of contacts, devices to be supported by site locations with postal codes including county, the customer name, the business partners, carriers, and service providers involved with the City.

3.3 The City will provide documenting and identifying the hosting sites for the City/multivendor network equipment with equipment IP addresses, node names, and serial numbers where available and if relevant.

3.4 The City will designate a project manager who will be the single point of contact with the FNC project manager. The City project manager will procure, manage and direct the City resources related to the MTO process.

3.5 The City will be responsible for the implementation of the LAN/WAN infrastructure and security access (such as customer firewalls).

3.6 The City will identify the interconnection methodology and access point. If notification is provided less than 60 calendar days prior to the requested service start date, the service start date may be affected.

3.7 The City will notify FNC in writing of the acceptance or non-acceptance of the Deliverables (according to an acceptance process jointly agreed).

3.8 The City will participate in the necessary briefings, workshops, meetings and/or interviews that will be conducted to allow FNC and the City to finalize the City order.

APPENDIX 2 – Service Request Process

1. Service Description

All changes to the managed network or equipment requested by the City will be subject to the Service Request Process.

The City will be responsible for the pre-engineering of the network. FNC requires notification of requested changes in advance of the required date. Prior notice enables FNC to properly process the request, assign resources, confirm ability to satisfy need, evaluate and identify any issues that may adversely affect the network based on submitted request.

When the City requires Move/Add/Change/Delete (MACD) (e.g. configuration change to managed nodes, new addition, circuit removal) or has scheduled maintenance within the network, the City is required to fill out a request template (provided at new customer activation kickoff meeting) and submit to the Service Request Team and resources will respond as outlined in OLA. Once the change request is confirmed, the Service Request Team will work up a schedule with the City for implementation.

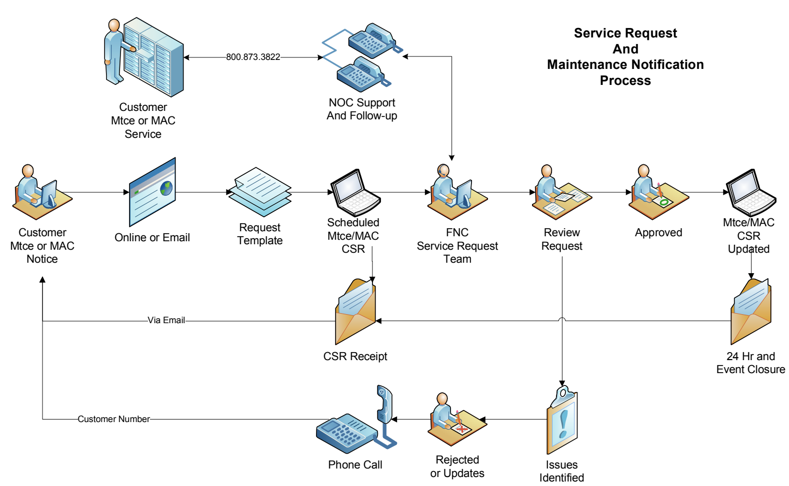
2. Deliverables

If FNC determines that changes are required within the network, FNC will contact the City to explain the requirement and seek approval to schedule and implement the change.

All Class A and Class AC type changes will be implemented at no additional charge. If onsite assistance is required to implement the Class A and Class AC type PCNs, FNC will dispatch onsite personnel if the Onsite Service is contracted with FNC. If Onsite Services are not contracted with FNC, FNC will contact the point-of-contact assigned by the City.

3. Prerequisites

Initial implementation and large quantities of MACD changes are considered a project. A project will have a FNC Program Manager assigned to be the single point-of-contact responsible to schedule planning, configuration, testing and activation/deactivation into the NOC operational network. The City may submit a service request for these requests, and the Service Request Team will inform the FNC PM organization of the requirement. The purpose of assigning a PM, rather than implementing through the normal service request process, is for appropriate scheduling of resources, testing and validation prior to activating the new device(s) in the NOC network.



Service Request & Maintenance Notification

APPENDIX 3 - SUPPORTED DEVICES & LOCATIONS

The list below identifies the key information that must be gathered relative to each of the managed devices and locations to be supported under this Service Description.

This list refers to all managed products placed in (enter product list and location)

- Device Name and Description
- Vendor
- Quantity
- Maintenance vendor / service provider
- Product ID # (if applicable)
- Serial # - Note: For Managed IT Domain Service Supported Devices that are SNMP compliant, serial numbers will be retrieved via electronic means by FNC.
- Managed third party service provider service description
- Managed third- party service provider agreement number/identifier
- Managed third- party service provider contract contact details
- Site Specific Name
- Site Street Address, City, State, Zip, County, Country
- Site Access Requirements
- Site Contacts – Both Primary and Secondary
- Equipment List
- Circuit Mapping
- Timing Source(s)
- Physical Port Mapping which should include:
    - Detailed connection information from the cards in the shelf to connection points showing Rack numbers, Shelf numbers, Jack & Port numbers, etc.
    - FDP / LGX / DSX Panels
    - Timing Connections
    - Alarm Connections
    - Any other direct connections to the equipment being monitored

- Connections from the cards in the shelf going directly to customer equipment without a patch panel
- Connections between cards in the same shelf
- Power Distribution Unit and Fuse Panel Assignments – BDFB
- Rack Drawing (Front View)
- Shelf Drawings

- Onsite Restoration (OSR) Service Level Objective (SLO)
- OSR Vendor
- OSR Vendor contact information and instructions
- Advanced Hardware Replacement (AHR) Service Level Objective (SLO)
- AHR Vendor
- AHR Vendor contact information and instructions
- Parts List of items supported by AHR agreement
- Complete Addresses including Floor/Room/Rack
- GPS Coordinates

NOTE: Online retrievals for equipment revisions, software releases, equipment specifics and other details maybe limited.

APPENDIX 4 - LETTER OF AUTHORIZATION TEMPLATE

To be on customer letterhead and addressed to the Carrier or Service Provider with a copy to Fujitsu [ADDRESS].

Date:

To: Appropriate service provider

From: IT Manager Name

Dear Sir/Madam,

Re: Remote Monitoring and Management Services

The City has recently entered into a contract with Fujitsu to provide remote monitoring and management services to our locations being served by your company. As such Fujitsu will be acting on our behalf when liaising with ____ for maintenance of _____ services or equipment at these locations.

We, [The City] hereby authorize Fujitsu to act on our behalf with regard to support and delivering the Remote Network Management Services under the Agreement between Fujitsu and ourselves.

Such authorization extends only to the provision of Network Management Services and any services provided by _____ directly related to the provision of such Services by Fujitsu.

Instructions issued by Fujitsu shall be accepted by you as if they were our instructions.

Fujitsu has advised that they will contact you shortly to confirm this arrangement. On all future Network Management service related issues please contact Fujitsu as detailed below. All correspondence sent to Fujitsu which relates to these Services should also be copied to myself.

Fujitsu contact details are: -

Regards

APPENDIX 5 – SERVICE LEVEL OBJECTIVES

1. Service Description

1.1 Priority level of device indicates the role of the device in the sub-customer network. Incident severity is defined as device condition and the degree of immediacy for diagnostics and restoration. The following tables describe the severity of Incident level descriptions and SLO.

1.2 FNC uses an Incident tracking system to log all Incident reports per the Severity Listings (Critical/Severity 1, Major/Severity 2, and Minor/Severity 3).

- **Critical/Severity 1 Incident** - All or any combination of the following: (i) Fiber cut or loss of optical path which results in a total loss of traffic, (ii) a system condition that results in a total loss of traffic (1-DS0 to xWDM, IP routing services, server failure, loss of firewall), (iii) if FNC or the City have to reroute all traffic to establish service due to environment, weather or interconnections to other service providers outside of this network, or (iv) failure of communication with the EMS server where visibility to the entire network is lost, or (v) complete loss of routing capabilities, or (vi) security issues (DoS Attack, network breach, etc…)

- **Major/Severity 2 Incident** - All or any combination of the following: (i) fiber cut or loss of optical path and the system engages the automatic protection switch with a loss of redundancy or protection switching capabilities, but no loss of traffic, (ii) equipment failure on a redundancy path which will inhibit any protection switching capabilities and no traffic loss occurs, or (iii) partial failure of communication with the EMS server where a portion of the network still has visibility, or (iv) partial loss of routing capabilities, or (v) security issues (virus encounters, etc…).

- **Minor/Severity 3 Incident** - All errors, warnings, conditions and general information not otherwise included in, or defined as, Critical/ Severity 1 Errors or Major/ Severity 2 Errors where all services and system integrity are maintained. Examples may include air filter notifications to change the air filter, threshold crossings, packet retransmits, etc... All network trouble tickets will remain open until restoration is complete or the City requests closure.

1.3 Times set forth in this Exhibit constitute targeted goals of the FNC Network Operations Center and it is understood that FNC shall use all reasonable efforts to attempt to restore any Incident within the targeted times listed for the specific severity levels. FNC and the City understand the unique nature of any Incident and agree that any sporadic failure to meet the targeted goals shall not constitute a breach of obligations for this deliverable.

2. Incident Notification SLO

Severity	Typical Customer Impact	Internal Notification	NOC Customer Communication	SLO
Critical/Severity 1	Complete loss or critical failure of a customer impacting service, with no available work-around	Within 15 minutes	Within 30 minutes of event initiation At each escalation point and/or status change Within 15 minutes after restoration	>95%
Major/Severity 2	Intermittent loss, degraded performance or simplex mode of a customer impacting service	Within 30 minutes	Within 1 hour of event initiation At each escalation point and/or status change Within 15 minutes after restoration	>95%

3. Incident restoration SLO

Severity	Typical Customer Impact	Description	SLO
Critical/Severity 1	Complete loss or critical failure of a customer impacting service, with no available work-around	The loss of System Service or Network Administration attributable to the device, assuming that external resources, if required, are provided. Loss of Network administrative functions caused by an external fault (i.e., external device management system, physical, link, power, etc.) are excluded.	100% of the problems restored within 24 hours
Major/Severity 2	Intermittent loss, degraded performance or simplex mode of a customer impacting service	The loss of part, but not all, of the functionality of a device or Network. This includes the loss of traffic or services provided by the device. The definition of a Partial Outage is specific to a device type.	90% of the problems restored within 30 days
Minor/Severity 3	No immediate customer impact and/or administration requests affecting a group of users	Network or device informational notices, autonomous messaging, condition notices (i.e. Threshold Crossings, Fan Filter Replacement notices, Retransmits, etc...) or Customer questions. Non device or Network affecting.	90% of the problems restored within 180 days

4. SLO Definitions

4.1 An **Incident Restoration** is a permanent correction to a service affecting Incident.

4.2 A **Temporary Restoration** is a fix that is delivered to a limited number of systems in the field for the purposes of verification or to solve system problems requiring immediate attention. A temporary restoration is usually followed by a Resolution provided by the OEM.

4.3 A **Resolution** is an approved fix available for general distribution, typically a software or hardware release provided by the OEM.

4.4 The **Restoration Time** is the interval from the receipt of the original Incident reported by the managed device, to the time of the service restoration.

5. SLO Exclusions

5.1 Any power failures, fiber cuts or other failures in the fiber connected to the Supported Equipment.

5.2 Any failure in air conditioning (HVAC) supporting the Supported Equipment.

5.3 Any scheduled maintenance action performed on the Supported Equipment in a scheduled maintenance window.

5.4 Any situation where the problem requiring attention is caused by equipment or issues outside the Supported Equipment or portion thereof and FNC's control. This may include but is not limited to powering down equipment connected to the network, unplugging or re-arrangement of cables supporting the network or fiber maintenance (both inside and outside plant).

5.5 Any Force Majeure event.

APPENDIX 6 – Service Delivery Manager

1. Service Description

The Service Delivery Manager (SDM) is an assigned role to be the single point of contact for the City when issues with the service deliverables are identified, distributor of scheduled reports and champion for quarterly meetings. Service Delivery Manager is accountable for the delivery of contractual obligations promoting continuous service quality and high customer satisfaction.

2. Responsibilities

- Accountable for managing service delivery per SLOs.
- Provides a focus for customer advocacy into FNC operations.
- Ensures the information systems and the review structure for SLO and client satisfaction are in place and effectively used.
- Ensures and monitors that processes are in place to pro-actively deliver consistent service quality through rigorous management of service requests and acceptance into service procedures in line with operational quality.
- Provides problem management support to customer issues and ensures root-cause analysis is conducted and a corrective action plan is followed through with any learning applied for future benefits.
- Develops strong relationships and teams.

3. Deliverables

- Ensure the services provided meet the SLO(s) with high customer satisfaction.
- Schedules and conducts quarterly business and operational reviews.
- Provides complete reports timely and consistently.

APPENDIX 7 - GLOSSARY of TERMS

Advanced Hardware Replacement

FNC managed sparing services to provide spares hardware to support network restorations. Assets are either FNC owned, or the City provided and warehoused in secure facilities.

Alarm

An Alarm means an electronic message received from the equipment that usually indicates there is an abnormal condition. The severity of the condition is determined by the NOC and classified based on the definitions in Service Level Objectives.

API

Application programming interface, and is a source code-based specification intended to be used as an interface by software components to communicate with each other.

Circuit Layout Record (CLR)

Used in the telecommunication industry and synonymous with Design Layout Record (DLR) to describe the detailed design path of a completed circuit, including all equipment and network components from one end of the circuit to the other.

It may be detailed enough to include location, floor, row, rack, panel and port for each circuit component or it may simply refer to another previously engineered circuit. A CLR or DLR may describe an end-to-end circuit that comprises physical or virtual circuits. As an example, a physical facility would include a panel, rack and port, while a virtual facility may be a channel on a channelized circuit, such as a T1 on a previously engineered DS3.

Data Communications Network (DCN)

The DCN consists of the DCC (defined below) and associated telemetry interfaces, equipment and circuits that are required to connect the City telecommunication network to FNC's NOC for the purposes of monitoring the City network.

Data Communications Channel (DCC)

The DCC consists of the data channel within the Synchronous Optical Network (SONET) used for the monitoring of NEs operating in a network configuration. The equivalent DCC in Dense Wavelength Division Multiplexing networks is the optical service channel (OSC). FNC assumes that SONET and OSC DCC are available and can be used to monitor Supported Equipment with a limited number of gateway nodes.

Design Layout Record (DLR)

Used in the telecommunication industry and synonymous with Circuit Layout Record (CLR) to describe the detailed design path of a completed circuit, including all equipment and network components from one end of the circuit to the other.

It may be detailed enough to include location, floor, row, rack, panel and port for each circuit component or it may simply refer to another previously engineered circuit. A DLR or CLR may describe an end-to-end circuit that comprises physical or virtual circuits. As an example, a physical facility would include a panel, rack and port, while a virtual facility may be a channel on a channelized circuit, such as a T1 on a previously engineered DS3.

Element Management System (EMS)

EMS consists of software and supporting systems used to monitor and manage the NEs composing a network.

Event Management

Event Management encompasses the assessment, definition, direction and analysis of any reported trouble by the EMS monitoring the device or circuit operations, or from customer notification. The purpose of the NOC is to monitor, acknowledge, and notify the City of an Alarm or clearance of an Alarm.

Hostname

A label that is assigned to a device connected to a computer network and that is used to identify the device in various forms of electronic communication such as the World Wide Web, e-mail or Usenet. Hostnames may be simple names consisting of a single word or phrase, or they may have appended a domain name, which is a name in a Domain Name System (DNS), separated from the host specific label by a period (dot). In the latter form, the hostname is also called a domain name. If the domain name is completely specified including a top-level domain of the Internet, then the hostname is said to be a fully qualified domain name

Implementation Plan

FNC's schedule and plan for moving the City's network under the NOCs responsibility. This plan will support and be coordinated with the City and furthermore be subject to the City's review and approval which will not be unreasonably withheld or delayed.

Incident

An event which is not part of the standard operation of a service and which causes or may cause disruption to or a reduction in the quality of services and/or customer productivity.

Incident Management

The act or acts taken to notify and/or restore normal service operations as quickly as possible with the least possible impact on either the business or the user, at a cost-effective price.

Letter-of-Agency (LOA)

A letter provided by the City to Third Party Providers and/or Original Equipment Manufacturers granting FNC access to act on the City's behalf for escalated support services, dispatches, documentation and any required training as covered in the support agreements with the Third Party Providers or Original Equipment Manufacturers.

Method of Procedure (MOP)

MOPs mean a detailed written procedure for completing complex equipment, network, circuit reconfigurations and similar services. A MOP is typically employed where live traffic is moved, migrated or reconfigured. MOPs are normally written by Tier III (highest level) technicians or engineers.

Move, Add, Change (MAC)

Logical requests changes to the managed network. All MAC's are characterized by the complexity of the requests and are performed remotely from the NOC. All MAC requests will be for currently managed network devices, circuits or termination points.

Initial network activation, device additions or deletions to a network, adding or removing plug-in units or any changes requiring onsite testing and scheduling will be supported as a Service Request.

MPLS

"Multiprotocol Label Switching" is a mechanism in high-performance telecommunications networks that directs data from one network node to the next based on short path labels rather than long network addresses, avoiding complex lookups in a routing table.

Network

A Network consists of a collection of devices and interconnection transmission facilities.

Network Element (NE)

NEs consist of telecommunication hardware equipment and associated software that can be monitored and managed through an EMS. An NE may have multiple shelves as long as they operate as a single addressable manageable unit.

Network Node

A Node consists of a physical location with one or more NEs connected to and functioning in a relationship with other NEs at different physical locations to and from a network for the delivery of telecommunications services.

Network Operations Center (NOC)

The NOC consists of one or more facilities equipped with software and hardware tools, skilled technicians, telemetry circuits and supporting management systems for the control and management of a telecommunications networks. The NOC is responsible for monitoring the network for Alarms or certain conditions which may require special attention to avoid impact on the network's performance.

Network Management System (NMS)

A Network Management System is an application in the NOCs Operational Support System (OSS) used to manage the City networks and/or the Element Management Systems (EMS) used to manage the City networks.

Operational Level Agreement (OLA)

A document created between FNC and supported customer outlining the working relationship and processes how issues are addressed, restored and escalated.

Original Equipment Manufacturer (OEM)

The specific vendor that designed, manufactured and distributed the vendor specific products, applications or devices.

Onsite Restoration (OSR)

A FNC Service offering to provide personnel onsite to assist with trouble restorations. Site response times are variable specific to the requirement and contract.

Portal

A web-based tool designed to enable easy access to service information collected by FNC's Managed IT Domain Service tools.

Problem Management

An underlying issue that could lead to an Incident(s).

Resolved

When the network traffic, device or service is back to the original operational status after the traffic or services have been Restored or repaired.

Restored

When the network traffic, device or services are operational after the event of an Incident. Restoration may involve a temporary fix to bring traffic and services back online where the network or device may require additional work to get it back to original status or Resolved.

Routine Preventative Maintenance (RPM)

A FNC Service offering which provides a routine onsite visit to perform a physical inspection of the facility, managed devices, potential upgrade identifications and fan filter replacements.

Service Request

The Service Request is a type of change control when network equipment is required to be added or removed from a network or onsite services are required for any installation work or testing services are necessary to establish new services or termination of services. Service Requests are treated as a Project with a Program Manager assigned to direct, schedule and ensure all aspects of the project are in order and completed in an agreed timeframe.

Simple Network Management Protocol (SNMP)

An Internet-standard protocol for managing devices on IP networks, including routers, switches, servers, modem racks, and more.

Target Identifier (TID)

Similar to a Hostname for optical products within a managed network. The TID provides a unique identifier for the NOC to access and manage the device.

Transaction Language 1 (TL1)

A widely used management protocol in optical telecommunications networks

VPN

A network that uses primarily public telecommunication infrastructure, such as the Internet, to provide remote offices or traveling users an access to a central organizational network

As you know, the City of Fairlawn conducted a survey on Saturday November 28th and Sunday November 29th at our compactor facility to find out the interest in the FairlawnGig project. Below are the results for the three questions that were asked. The survey count for the two days was 434. We are extremely pleased with the success of the survey and we feel that we are moving in the right direction with this project.

If you notice, everyone answered the first question. A couple of people did not provide an answer for questions #2 and #3 which is why they don't add up to the 434 surveys received.

Question #1 – When this service becomes available, would you have an interest in such a service?
356 Yes **48 No** **30 Undecided**

Question #2 – If this service delivers faster speeds than is currently available in Fairlawn, with local customer service at a competitive price, would you have an interest in such a service?
367 Yes **44 No** **21 Undecided**

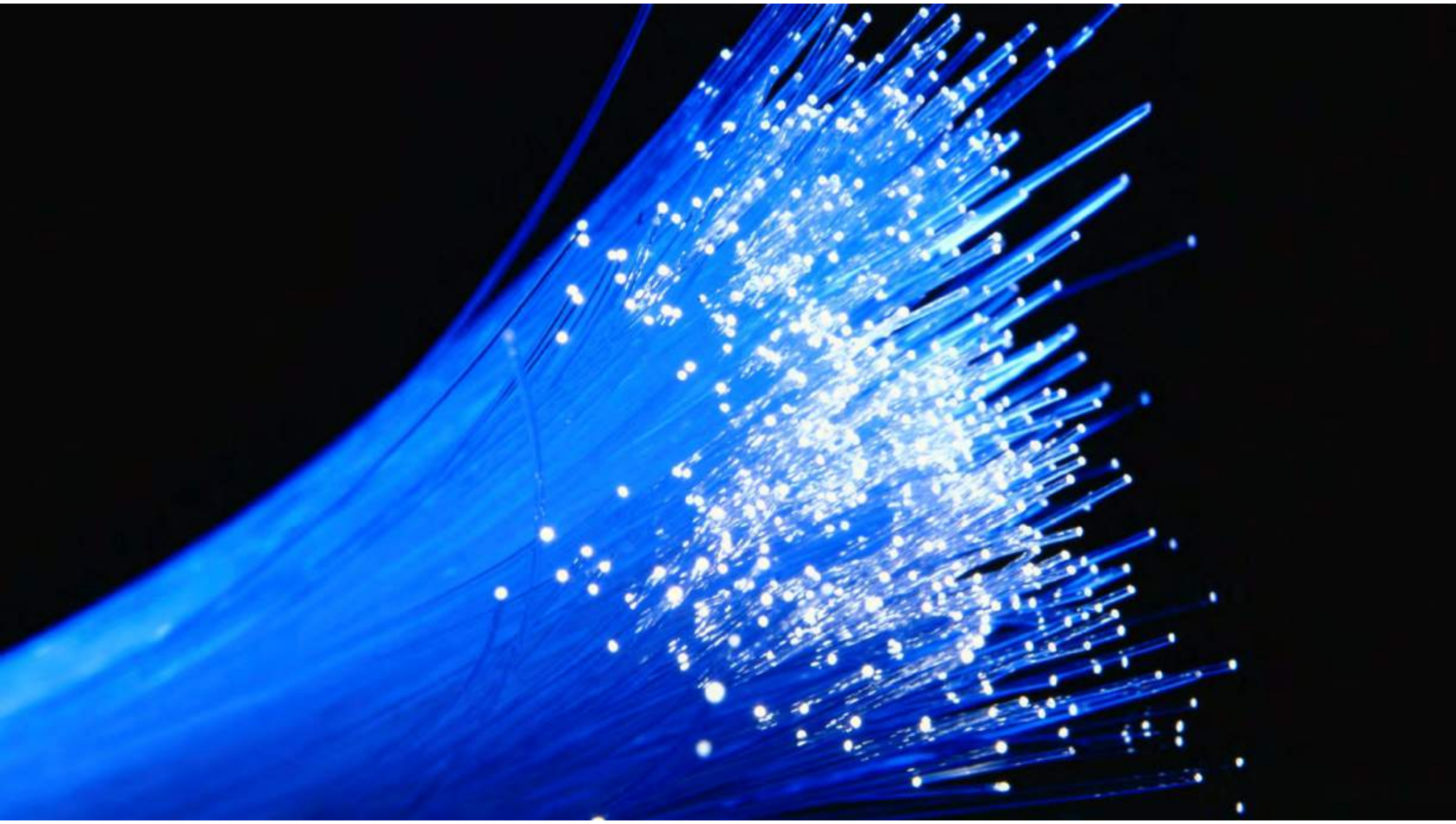
Question #3 – The City of Fairlawn may be able to deliver phone service including enhanced 911 with the FairlawnGig. Would you have an interest in this additional service?
244 Yes **129 No** **57 Undecided**

Our interns also asked for comments from our residents. We received a wide range of responses such as:

Very Excited
Interested in more information
Interested if the price is right
Very interested – loves the idea of Fairlawn Broadband Utility
Looking forward to it
Wants to know if cable will be available?
Will you provide a bundle package?
Interested in switching from Time Warner
Not happy with AT&T
Will it be cheaper than T-W?
Unaware but interested

ctc technology & energy

engineering & business consulting



City of Madison Fiber-to-the-Premises Feasibility Analysis

Prepared for City of Madison
August 2016

Columbia Telecommunications Corporation

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

Contents

Figures

Tables

1 Executive Summary

1.1 Project Background

The City of Madison is among the localities that seek to bring ultra-high-speed broadband connectivity to their communities. The City recognizes fiber-based connectivity—particularly fiber-to-the-premises (FTTP) deployment designed to serve every business and resident in the community—as an important foundation for taking full advantage of the power of broadband. A ubiquitous FTTP buildout ensures that, no matter who the retail service provider is, every resident and business has the opportunity to access the power of a fiber-based network infrastructure. This is especially true if the City prioritizes some form of open access, which is a common goal for many localities.

There are several possible approaches to deploying broadband in a community; the City aims to determine which of these options—if any—makes sense for Madison's residents and businesses. Accordingly, the City engaged CTC Technology & Energy (CTC) to explore whether the City can feasibly[1] pursue deployment of a citywide ultra-high-speed fiber-based broadband network, either directly or through a public–private partnership. This report also aims to assist the City in distilling its goals and focusing on realistic solutions to meet the community's connectivity needs.[2]

This report and the supplemental market research described in Section 1.2 represent the City's compliance with Wisconsin state law, which requires any municipality that seeks to offer broadband services to conduct a cost-benefit analysis.[3]

1.2 Methodology

This report was researched and prepared in early 2016 by CTC, with ongoing input from City staff. In addition to drawing on our extensive industry experience, our analysis is guided by our conversations and interviews with a range of City staff and stakeholders about the City's objectives and desired outcomes.

Over the course of the engagement, CTC performed the following general tasks:

1. Reviewed and inventoried the City's key physical infrastructure, including the Metropolitan Unified Fiber Network (MUFN);

[1] While CTC cannot provide legal counsel and this report does not contain legal guidance, the City has engaged legal counsel to expand on CTC's findings from a legal standpoint.
[2] Appendix A outlines common community goals and objectives to help guide the City's decision-making.
[3] David L. Lovell, "Statutory Limitation on Municipal Offering of Broadband Service," *Wisconsin Legislative Council*, last modified October 3, 2014, https://c.ymcdn.com/sites/www.weda.org/resource/resmgr/Fall_PP/Lovell_Outline_10-3.pdf.

2. Conducted interviews with representatives of City departments, stakeholders, and utility owners;

3. Researched the region's available broadband services and costs (see Section 3);

4. Conducted onsite and desk surveys of City infrastructure;

5. Evaluated potential public–private partnership business models based on current developments in the broadband industry; and

6. Developed pro forma financial statements for the City based on a dark fiber lease model, where the City would own and operate a fiber network, and grant access to it through dark fiber leasing.

In addition to those tasks, at the City's request, CTC prepared a high-level network design and cost estimate for deploying a gigabit FTTP network. The cost estimate (Section 7) provides data relevant to assessing the financial viability of network deployment, and offers guidance in developing business models for a potential City construction effort (including the full range of models for public–private partnerships). This estimate also provides key inputs to financial modeling to determine the approximate revenue levels necessary for the City to service any debt incurred in building the network.

1.3 Residential Market Research Identified Unmet Demand

The City also commissioned CTC to carry out residential market research to supplement the findings of this report, and to help gauge the community's interest in broadband. The City was prudent to reach out directly to the community in order to cast the widest net possible in understanding citizens' needs and desires, and to give residents a voice.

To develop a set of questions tailored for Madison residents, CTC sought feedback from City staff and stakeholders on the survey questionnaire. We adjusted question language and placement consistent with City recommendations, while being mindful of best practices for conducting market research. The resulting questionnaire is attached to this report as Appendix C.

The survey, which was mailed to approximately 3,700 randomly selected Madison residents in early May 2016, was designed to identify issues related to residential demand, and to identify differences among users based on income level, education level, and other differentiating factors.[4]

[4] Individual information about respondents is not reported separately; rather, it helps ensure that the responses are a representative sample of the citizens of the City of Madison.

The survey found that Madison residents are highly connected: 95 percent of respondents have some form of Internet connection (89 percent of residents have home Internet service and 77 percent have a cellular telephone with Internet access). However, the survey also points to service gaps and unmet needs in the residential market. For example, survey responses indicate that:

- Older, low-income, and less-educated respondents are less likely than their counterparts to have some form of Internet access at their home.
- Reliability of respondents' Internet connections ranks as the most important aspect of their Internet service, followed by connection speed and price paid. Residents are generally satisfied with the speed and reliability of their Internet service.
- Respondents would be willing to switch to a very high-speed Internet connection, especially at monthly prices lower than $50 or for a one-time hookup fee at or below $250.
- More than one-half of respondents' employers allow telework, and more than one-fourth of responding households have a member who already teleworks.
- About six in 10 respondents believe that the City should install a state-of-the-art communications network and either offer services or allow private companies to offer services to the public.

We also conclude that small and medium businesses in Madison are not being served at the level they need. Small businesses often buy residential services as an affordable, if not wholly sufficient, solution; if robust broadband is not available throughout the City for residents, there are likely even more gaps for small businesses. And residential services are not sufficient for many small businesses—meaning that there likely are businesses that need more than residential service, but cannot afford enterprise-grade broadband.

1.4 The City's Core Objectives Are Equity, Ubiquity, Competition, Consumer Choice, and Control

The City has been engaged in the issue of broadband access for some time. In 2013, the City created the "Digital Technology Committee" to advise the Mayor and Common Council on how the City currently uses and can improve upon its use of digital technology.[5] One of the Committee's focuses is the "digital divide," which is the disparity between those who have access to modern information and communications technology and those who do not. "Access" encompasses not only the presence of service in an existing area, but also whether it is affordable to potential subscribers. The City is sensitive to the need for a wide range of options

[5] https://www.cityofmadison.com/cityhall/legislativeinformation/roster/102250.cfm, accessed March 2016.

that can serve its diverse population, including those who may have traditionally been unable to purchase service.

Bringing access to traditionally underserved populations is only one key driver for the City's broadband initiative. The City also understands that filling broadband service gaps is important to support robust economic development efforts, particularly for small and medium-sized businesses whose needs are not met with residential-grade service offerings but that cannot afford traditional business-class service.

Based on our discussions with City staff and our understanding of community goals, we recognize the following objectives as the baseline for the City's broadband initiative:

- Equity – Alignment with Racial Equity and Social Justice (RESJ) and digital divide goals
- Ubiquity – Service is deployed to the entire City
- Competition in the marketplace – Enabling multiple providers to compete
- Consumer choice – Citizens can purchase service from various providers
- Control – The City has a long-term stake in the asset

In our view, the benefits of equity, ubiquity, competition, and consumer choice are likely to arise from this initiative, as are additional benefits (such as City control) depending on the model the City adopts. Some of these benefits are summarized below.

1.4.1 Ubiquitous FTTP Deployment Will Create Consumer Choice and Competition

When a new, high-speed Internet service provider (ISP) enters a market, consumers tend to experience an increase in available services and a decrease in the cost of some services. As the new entrant begins to offer services, incumbent providers typically respond by upgrading their infrastructure to enable higher tiers of service and decreasing the price that customers pay. The impact is especially pronounced when the new entrant, or a public sector partner, builds a new FTTP network, capable of delivering speeds beyond what most incumbent cable and telecommunication networks currently provide.

For instance, in most of the markets where Google has announced plans to launch Google Fiber service, consumers benefit from Google's additional service offerings, as well as from upgraded service and significant price reductions from incumbent telecom and cable carriers. A recent *Consumerist* report notes that in markets where Google has announced plans to build fiber, AT&T offers customers 1 Gigabit per second (Gbps) service starting at $70 per month. In markets without competition from Google, AT&T charges customers $80 per month for 300 Mbps service.[6]

The threat of a new entrant is often enough to spur incumbents to make new investment or lower prices. Where competition emerges, the competitive reaction intensifies, and incumbent companies lower prices and improve services. Indeed, in the various markets where Google Fiber has announced that it will—or may—build new fiber networks, the incumbent phone and cable companies have responded by upgrading their own facilities, increasing speeds, and reducing pricing. This reaction frequently emerges in cities that build municipal networks also. For example, in Chattanooga, Tennessee, Comcast fought hard to prevent the public electric utility from offering Internet service. Unable to block the new entrant, Comcast has been forced to compete. The cable company last year announced that Chattanooga would be one of the first cities to receive its 2 Gbps FTTP service.[7]

1.4.2 New Broadband Competition Will Create Benefits for Equity

Residents who do not use broadband are typically confronted with one or more of the following issues:

1. Lack of access to service
2. Inability to afford service
3. Lack of knowledge of how to use computers, devices, or broadband

With those causes in mind, new broadband competition can have a significant positive impact on efforts to close the digital divide. The City's initiative to bring a competitive FTTP provider to Madison addresses the second, and often most pressing concern—affordability—by introducing robust competition into the market.

Broadband competition will serve to lower some prices. We believe that a new provider (whether a public or private entity) will offer some low-cost products. Even if the new provider does not offer low-cost products, incumbents are likely to lower their pricing on some products in response to the new competition. We have seen this in other markets, and have no reason to doubt that the same scenario will play out in Madison.

To be clear, this does not mean that the high-end symmetrical Gigabit products will necessarily be available at low prices, or affordable to every resident. It may be that only lower bandwidth

[6] Chris Morran, "ATT Touts Lower Prices for Gigabit Internet," *Consumerist*, last modified September 15, 2015, http://consumerist.com/2015/09/30/att-touts-lower-prices-for-gigabit-internet-still-charges-40-more-if-google-fiber-isnt-around/.

[7] Jon Brodkin, "Comcast brings fiber to city that it sued 7 years ago to stop fiber roll out," *ArsTechnica,* last modified April 30, 2015, http://arstechnica.com/business/2015/04/comcast-brings-fiber-to-city-that-it-sued-7-years-ago-to-stop-fiber-rollout/.

products are available at low prices. For example, in some markets we have seen the incumbent telephone companies compete for price-sensitive customers by offering low-price, low-bandwidth services.

But a more robust market environment will lead to competitive pricing that benefits low-income consumers in ways that simply do not happen in monopoly and duopoly environments.

We expect this FTTP initiative, regardless of the partner that the City selects or the partnership approach that the City takes, to result in real benefits for low-income residents of Madison. Further, we note that in any partnership arrangement, the City would have the option to subsidize service for low-income residents.

1.4.3 Meeting the Need for Broadband Services to Small and Medium Businesses in Madison Will Promote Economic Vitality and Innovation

Based on our market analysis (Section 3), our knowledge of local broadband markets in general, and our conversations with City staff, we believe that there is likely a significant gap with respect to very high-end competitive broadband services for small and medium-sized businesses. Larger business and institutions appear relatively well served by the incumbents and the competitive providers that are already present in the market—but as is the case in many markets, small and medium-sized businesses likely struggle to get affordable high-end services.

There likely is a gap, too, when it comes to home-based businesses and teleworkers. Many teleworkers are sophisticated telecommunications users—and they need services that have greater reliability and capacity than the consumer-based broadband connections they have from the phone and cable companies that currently serve Madison.

These gaps represent both a real need in the community, and a significant business opportunity for private sector retail service providers. A growing body of evidence demonstrates that high-speed fiber connections facilitate an innovation ecosystem and enable small businesses and start-ups to thrive.

Blazing fast Internet connections provide entrepreneurs, freelancers and small-business owners with a variety of new tools that allow them to compete as never before. A growing portion of the US workforce can do much of their work from wherever they find a robust Internet connection. While a basic broadband connection is sufficient for certain tasks, gigabit speeds enable richer collaboration tools, such as vivid telepresence.[8] As bandwidth-hungry collaboration tools continue to improve, the physical location of people becomes less

[8] http://www.pewinternet.org/2014/10/09/killer-apps-in-the-gigabit-age/

important.[9] Small business owners and entrepreneurs with access to abundant bandwidth can draw on talent from across the globe, forming short-lived teams that complete specific tasks without ever needing to meet in person. Although contractors and freelancers are generally free to roam as they please, they will gravitate to areas with abundant bandwidth that can provide a quality connection to their clients.

Higher speed connections have the potential to improve the flow of goods and services in every sector of the economy. Many entrepreneurs with a desire to create new services based on high capacity connections have flocked to the first few Gig Cities to build and test their products.[10] Although a robust two-way connection has the potential to improve everything from how we exercise[11] to how we react to weather emergencies,[12] there are a number of emerging fields that are entirely dependent on extremely high speed connections. Virtual and augmented reality and precise 3D modeling require data flows far beyond the average home or small business connection speed today. The new businesses that emerge in these sectors will undoubtedly be based in localities that have abundant, affordable bandwidth.

Big bandwidth will be particularly important for the entrepreneurs that seek to create value through the analysis of large data sets. As sensors proliferate and the cost of memory plummets, more data is being collected than ever before in history. In the past, only large companies would be able to afford the computing power necessary to make sense of such huge data sets, but now any savvy statistician with a laptop and a gigabit internet connection can run an analysis in minutes. Big data stands to improve productivity and efficiency in every sector of the economy,[13] but the companies and individuals that will conduct the analysis will be located in areas with abundant bandwidth.

Innovation is possible everywhere, but individuals living in a place with affordable high speed connections have a natural advantage coming up with a new idea or when trying to turn a prototype into a product. Abundant bandwidth gives people the freedom to tinker and figure out how symmetrical high-speed connections can improve our daily lives. As William Gibson once said, "The future is already here, it's just not evenly distributed." People living in the first

[9] According to the New Jersey Institute of Technology, 45 percent of U.S. employees already work from home at least part of the time. http://betanews.com/2015/09/11/the-rise-of-telecommuting-45-percent-of-us-employees-work-from-home/

[10] http://www.nlc.org/Documents/Find%20City%20Solutions/City-Solutions-and-Applied-Research/Innovation%20Districts%20Report.pdf
http://siliconprairienews.com/2014/04/three-years-after-announcement-kansas-city-is-still-figuring-out-fiber/

[11] https://www.nsf.gov/mobile/discoveries/disc_summ.jsp?cntn_id=134550&org=NSF

[12] https://www.us-ignite.org/globalcityteams/actioncluster/zJiQHYzzoXrZJthAHwcN5F/

[13] http://www.mckinsey.com/business-functions/business-technology/our-insights/big-data-the-next-frontier-for-innovation

few cities with super high speed broadband have the chance to create the future for everyone else.

1.5 Building Ubiquitous FTTP in Madison Would Cost at Least $143.5 Million

We developed a conceptual, high-level FTTP design that reflects the City's goals and is open to a variety of architecture options. From this design, we present two cost estimate examples:

1. The cost to deploy *only* the FTTP outside plant (OSP) infrastructure.[14] This is the total capital cost for the City to build a dark FTTP network for lease to a private partner. This is the City's projected OSP cost in a "dark FTTP partnership."[15]

2. The cost to deploy FTTP OSP infrastructure, network electronics, service drops to the consumer, and CPEs.

We provide two versions for each of these estimates: all-underground construction, and a combination of underground and aerial construction (Table 1).

Table 1: Projected Cost Estimates Summary

FTTP Cost Estimates		
	Dark FTTP (No Electronics, Service Drops, or CPEs)	**Fiber, Network Electronics, Service Drops, and CPEs[16]**
Aerial and Underground Construction	$143.5 million	$194 million
All Underground Construction	$149.1 million	$212 million

These estimates represent the total capital costs—which would be incurred by the City, or the City and its partner(s)—to build an FTTP network to support a ubiquitous 1 Gigabit per second (Gbps) data-only service.

1.5.1 Dark FTTP Cost Estimate – No Network Electronics, Service Drops, or CPEs

The dark FTTP partnership cost estimate assumes that the City constructs and owns the FTTP infrastructure up to a demarcation point at the optical tap near each residence and business, and leases the dark fiber backbone and distribution fiber (the fiber in an FTTP network that

---

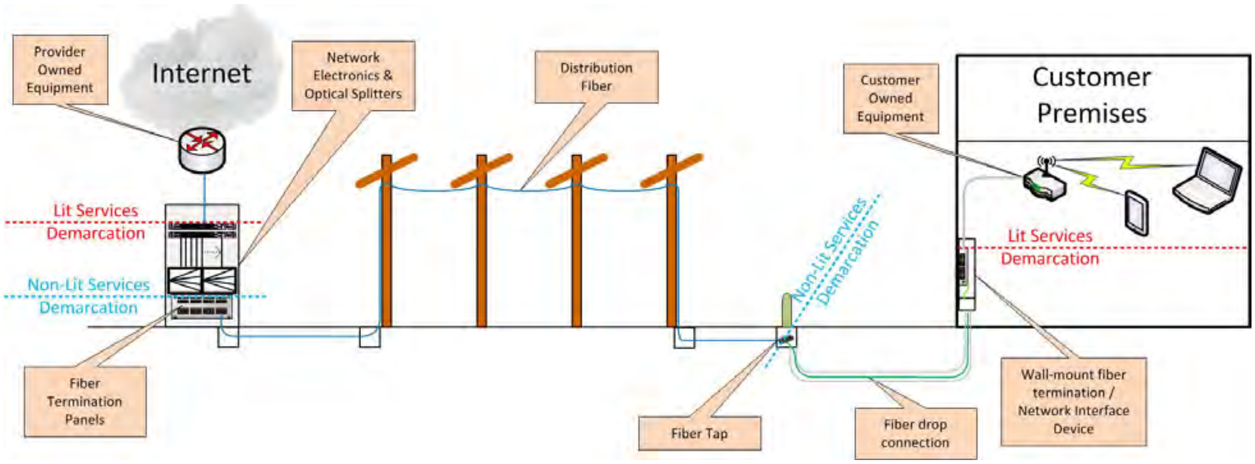
[14] This is the physical portion of a network (also called "layer 1") that is constructed on utility poles (aerial) or in conduit (underground).

[15] See Section 6.4 for more information about the dark FTTP partnership model, where the City would construct, own, operate, and maintain the dark fiber network, and provide access to its partner(s) to "light" the network and offer service over it.

[16] The estimated total cost assumes a 35 percent penetration rate or "take rate," meaning that 35 percent of the residents and businesses passed by the fiber would subscribe to the service.

connects the hub sites to the fiber distribution cabinets)[17] to a private partner. The private partner would be responsible for all network electronics, fiber drops to subscribers, and CPEs—as well as network sales, marketing, and operations.

Figure 1: Demarcation Between City and Partner Network Elements



1.5.1.1 Combination of Aerial and Underground Construction (Dark FTTP Partnership)

Assuming a combination of aerial and underground construction, the citywide dark FTTP network deployment will cost more than $143 million, inclusive of OSP construction labor, materials, engineering, permitting, and pole attachment licensing. Again, this estimate *does not* include any electronics, subscriber equipment, drops, or CPEs. Section 1.5.2 and Section 7 show estimated costs for fiber, network electronics, drops, and CPES, and include all underground construction, as well as a combination of aerial and underground.

[17] The FDC houses the fiber connections between the distribution fiber and the access fiber. FDCs, which can also house network electronics and optical splitters, can sit on a curb, be mounted on a pole, or reside in a building. Access fiber is the fiber in an FTTP network that goes from the FDCs to the optical taps that are located outside of homes and businesses in the ROW.

Table 2: Breakdown of Estimated Dark FTTP Cost – Combination of Aerial and Underground Construction

Cost Component	Total Estimated Cost
OSP Engineering	$14.7 million
Quality Control/Quality Assurance	5.4 million
General OSP Construction Cost	99.3 million
Special Crossings	0
Backbone and Distribution Plant Splicing	5 million
Backbone Hub, Termination, and Testing	11.4 million
FTTP Lateral Installations	7.7 million
Total Estimated Cost:	$143.5 million

1.5.1.2 All Underground Construction (Dark FTTP Partnership)

Assuming that all construction is underground, the citywide dark FTTP network deployment will cost more than $149 million, inclusive of outside plant (OSP) construction labor, materials, engineering, permitting, and pole attachment licensing. Again, this estimate *does not* include any electronics, subscriber equipment, or drops—and it includes no aerial fiber.

The projected cost to construct all underground is only about $5.6 million more than the cost for a combination of aerial and underground fiber. This difference is notably minimal; underground construction costs can sometimes be much higher than aerial, but our projections indicate that it would not add a major financial burden if the City opts to construct the dark FTTP network entirely underground.

Table 3: Breakdown of Estimated Dark FTTP Cost – All Underground Construction

Cost Component	Total Estimated Cost
OSP Engineering	$14.7 million
Quality Control/Quality Assurance	5.4 million
General OSP Construction Cost	104.9 million
Special Crossings	0
Backbone and Distribution Plant Splicing	5 million
Backbone Hub, Termination, and Testing	11.4 million
FTTP Lateral Installations	7.7 million
Total Estimated Cost:	$149.1 million

1.5.2 FTTP Cost Estimate for Fiber, Network Electronics, Service Drops, and CPEs

This variation of the cost estimate assumes that the City constructs and owns the FTTP infrastructure, all network electronics, service drops, and CPEs. This is typical of a retail service model, where the locality is the network owner, the network operator, and the retail service provider.

1.5.2.1 Combination of Aerial and Underground Construction (Fiber, Network Electronics, Drops, and CPEs)

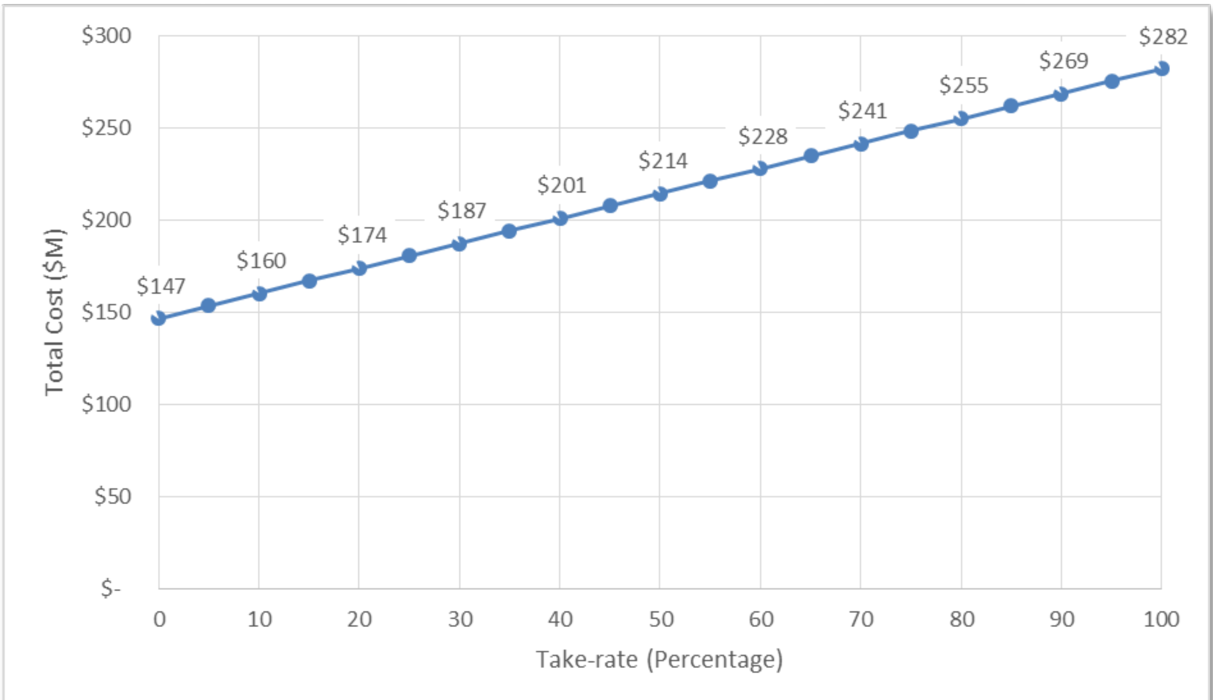
Assuming a combination of aerial and underground construction, the citywide FTTP network deployment will cost more than $194 million. This estimate includes OSP construction labor, materials, engineering, permitting, pole attachment licensing, network electronics, drop installation, CPEs, and testing. The estimated total cost assumes a 35 percent penetration rate or "take rate," meaning that 35 percent of the residents and businesses passed by the fiber would subscribe to the service.

Table 4: Breakdown of Estimated Total Cost

Cost Component	Total Estimated Cost
OSP	$136 million
Central Network Electronics	8 million
FTTP Service Drop and Lateral Installations	28 million
CPE	22 million
Total Estimated Cost:	$194 million

The total cost will vary based in part on the actual take rate because adding subscribers adds costs, to connect the subscribers' home or business to the network at the curb. Figure 2 shows the change in total estimated cost as the take rate increases.

Figure 2: Total Estimated Cost versus Take Rate



1.5.2.2 All Underground Construction (Fiber, Network Electronics, Drops, and CPEs)

The City's existing middle mile fiber that supports the Metropolitan Unified Fiber Network (MUFN) is constructed entirely underground for reliability reasons and to avoid negotiating pole access with the utility owners.[18] As part of our FTTP analysis, we developed a cost estimate assuming that the entire FTTP network were to be constructed underground. An all-underground network would cost more than $212 million. The following is a breakdown of the all-underground cost estimate.

Table 5: Breakdown of Estimated Total Cost with Electronics for an All Underground Network

Cost Component	Total Estimated Cost
OSP	$141 million
Central Network Electronics	8 million
FTTP Service Drop and Lateral Installations	41 million
CPE	22 million
Total Estimated Cost:	$212 million

[18] We note that Madison Gas and Electric (MG&E) is a local pole owner that has so far been collaborative with the City and CTC during the preparation of this analysis.

The cost increase is due to the added cost of constructing the outside plant as well as the increased costs for underground fiber drops, which are significantly more expensive than aerial drops.

1.5.3 MUFN Decreases FTTP Construction Costs

The cost estimate assumes the use of MUFN to provide:

1. Fiber optic connectivity between hub sites and distribution hub sites;
2. Space at existing City facilities to be used as core and distribution sites; and
3. Access to multiple Internet points of presence (POPs) for network connectivity.

The use of MUFN as a backbone would significantly reduce the cost and complexity of deploying an FTTP network because the network already extends to all areas of the City. A detailed engineering design may determine that enhancements to MUFN are necessary to support citywide FTTP; however, the estimate presented in this report assumes that no additional costs are required to enable MUFN to support the FTTP network.

Our FTTP cost estimates assume that the use of MUFN may reduce the total cost of OSP construction by approximately 10 percent, which is reflected in our projections.

Additional savings may also be available through the use of existing conduit in the downtown areas. While this conduit was generally designed to support a middle mile network, it may provide cost savings by eliminating or reducing underground construction along certain routes. A more detailed cost savings would be determined during the engineering of the network.

1.6 Madison Would Require Lease Payments of at Least $15 per Passing per Month to Cover Its Costs

Our financial analysis assumes that the City will construct, own, and maintain the dark fiber network over which one or more private partners will provide lit retail service to end users. In this dark FTTP partnership model,[19] the financial responsibility for deploying core electronics to "light" the network falls to the private partner.

The financial analysis represents a minimum requirement for the City of Madison to break even each year, excluding any potential revenue from other dark fiber lease opportunities that may be available to the City.

Using the $149.1 million all-underground cost estimate for the fiber outside plant (OSP), and in order for the City to maintain positive cash flow, the City's private partner will need to pay a

[19] We also assume the partner is responsible for CPEs, and installing the drop cable to the customer. This model assumes that maintenance and replenishments for electronics are the partner's responsibility.

minimum fee of $15 per passing per month. This payment assumes there are no upfront or balloon payments. Based on an assumption that the City will deploy a ubiquitous FTTP network, the financial model applies the fee to all residential and business premises in the City. The model keeps the $15 per passing fee constant, although the City and its partner should negotiate periodic increases on the portion of the fee covering operational and maintenance costs.

The financial analysis for the base case scenario is as follows:

Table 6: Base Case Financial Analysis

Income Statement	1	5	10	15	20
Total Revenues	$ 88,550	$ 17,710,020	$ 17,710,020	$ 17,710,020	$ 17,710,020
Total Cash Expenses	(856,190)	(2,316,120)	(2,316,120)	(2,316,120)	(2,316,120)
Depreciation	(2,274,200)	(7,494,600)	(7,494,600)	(7,494,600)	(7,494,600)
Interest Expense	(2,430,000)	(7,754,950)	(6,023,970)	(3,866,860)	(1,178,750)
Taxes	-	-	-	-	-
Net Income	$ (5,471,840)	$ 144,350	$ 1,875,330	$ 4,032,440	$ 6,720,550
Cash Flow Statement	**1**	**5**	**10**	**15**	**20**
Unrestricted Cash Balance	$ 209,360	$ 613,770	$ 3,410,190	$ 6,207,970	$ 9,006,860
Depreciation Reserve	-	146,130	196,680	246,990	297,300
Interest Reserve	2,430,000	-	-	-	-
Debt Service Reserve	2,700,000	9,325,000	9,325,000	9,325,000	9,325,000
Total Cash Balance	$ 5,339,360	$ 10,084,900	$ 12,931,870	$ 15,779,960	$ 18,629,160

We have provided the City with a complete financial model in Excel format. Because the Excel spreadsheets can be manipulated to show the impact of changing assumptions (much as we have done in the scenarios in Section 8.6 below), it will be an important tool for the City to use as it negotiates with a private partner.

1.7 Recommendations

We outline here several recommendations for the City as it moves forward in consideration of an FTTP deployment.

1.7.1 Consider Adopting a Partnership Model in Which the City Owns the Dark Fiber Network

There are three basic types of partnerships emerging today:

- **Private investment, public facilitation**: The model focuses not on a public sector investment, but on modest measures the public sector can take to enable or encourage greater private sector investment.

- **Private execution, public investment:** This model, which involves a substantial amount of public investment, is a variation on the traditional municipal ownership model for broadband infrastructure—but with private rather than public sector execution.

- **Shared investment and risk:** In this model, localities and private partners find creative ways to share the capital, operating, and maintenance costs of a broadband network. The evolving structure of this model, referred to as a "Dark FTTP Partnership" is described further below.

We believe that the model most applicable to the City is the "dark FTTP partnership" which is a "shared investment and risk" approach. In the "dark FTTP partnership," the City constructs and owns the fiber network, the private partner "lights" the fiber with electronics, and the private partner directly serves the end user. This is the model currently underway in the City of Westminster, MD with its private partner Ting Internet;[20] a similar model was recently announced by the City of Huntsville, AL with its private partner, Google Fiber.[21]

Retaining ownership of the fiber OSP assets is important to mitigate risk; owning assets is a way for communities to retain some control of the network, and to have some say in when, where, and how it is built. This includes a scenario where a community pursues a partnership with a private provider; a good way to balance risk and reward is for the City to maintain ownership and control of the assets while it assigns operational responsibilities, including the capital investment for network and consumer electronics, to a private partner. This enables both parties to perform functions that highlight their strengths while not having to expend resources and energy attempting to carry out tasks for which they are ill-equipped.

There is risk to the City in this model because it requires a substantial capital investment to build (or expand) and maintain the fiber network, but it also gives the City a degree of control because the City owns the network. In the event that the partnership fails for any reason, the City owns its assets and can take over control of the network directly or by engaging a different partner. Especially given the likelihood that the City-owned MUFN will be used as backbone fiber in the overall FTTP deployment, the City can pursue a partnership model where it retains ownership of the fiber assets. Such a model will enable the City to make use of its existing fiber assets, and retain some degree of control.

1.7.2 At the Appropriate Time, Publish a Dark Fiber Rate Card to Promote Fiber Leasing

If the City enters into a dark FTTP partnership, its private partner(s) will likely want access to significant dark fiber via an IRU or lease agreement, which means the City will need to establish dark fiber lease rates. There will likely be lease rates for access to MUFN fiber (because the

[20] Wiley Hayes, "Westminster, Md. Partners with Private Sector to Broaden Fiber-Optic Network," *GovTech*, last modified October 26, 2015, http://www.govtech.com/dc/articles/Westminster-Md-Partners-with-Private-Sector-to-Broaden-Fiber-Optic-Network.html.

[21] Frederic Lardinois, "Google Fiber Is Coming To Huntsville, Alabama," *Tech Crunch*, last modified February 22, 2016, http://techcrunch.com/2016/02/22/google-fiber-is-coming-to-huntsville-alabama/.

existing rates for access to MUFN fiber may not be applicable to a partnership) and separate rates for access to any new fiber that is constructed as part of the FTTP deployment.[22]

The City currently does not directly lease fiber to any commercial partners. A commercial entity that seeks to lease dark fiber does so through the City's agreements with the Wisconsin Independent Network (WIN) and SupraNet. As part of these agreements, commercial partners are charged for access to dark fiber per the rate sheet shown below. (These rates are only an example, and may not apply as the City moves forward with FTTP deployment.)

Table 7: Current MUFN Dark Fiber Lease Fees

Zone	Topology	Monthly Fee per Pair
1 to 1	Point-to-Point	$350
1 to 2	Point-to-Point	$350
1 to 3	Point-to-Point	$350
2 to 2	Point-to-Point	$350
3 to 3	Point-to-Point	$350
2 to 3	Point-to-Point	$700
1 to 1	Ring	$700
1 to 2	Ring	$700
1 to 3	Ring	$700
2 to 2	Ring	$700
3 to 3	Ring	$700
2 to 3	Ring	$1,100

The numbers in this rate sheet apply only to commercial entities that seek to access the City's dark fiber network, and not to the City's "partners" in the MUFN consortium. The City charges MUFN members the operations costs that the City incurs to perform locates and general maintenance of the fiber network.

By publishing dark fiber lease rates and entering into a partnership arrangement that makes use of City-owned dark fiber at competitive rates, the City will not be competing with the private sector, but enabling it. The City will be reducing barriers to market entry for private providers so that they can offer innovative and new services to Madison residents and businesses, consistent with the City's vision for its community.

1.7.3 Target a 1 Gigabit Per Second (Gbps) Service Offering to Meet the Emerging Broadband Benchmark

The Federal Communications Commission's (FCC) definition of broadband has evolved, especially in recent years. The unchanged core definition is that broadband is high-speed

[22] The City should determine with its counsel the legality of separate lease rates under Wisconsin law.

Internet access that is always on. It is faster than traditional dial-up access, and was most recently defined in early 2015 as being at least 25 Megabits per second (Mbps) download speed and 3 Mbps upload speed. What this means is that when a user receives (downloads) data, the speed must be at least 25 Mbps; and when a user sends (uploads) data, the speed must be at least 3 Mbps.

It is important to note that the FCC's minimum broadband speeds are much slower than the evolving industry standard. The industry began to shift when Google Fiber began offering 1 Gigabit per second (Gbps) service for $70 per month in Kansas City in 2012,[23] lending a household name to a concept select localities and utilities were also working to bring to fruition. Since then, Comcast has begun offering 2 Gbps service in select markets[24]—and in late 2015, the City of Salisbury, NC and Chattanooga's Electric Power Board (EPB) each announced that they will offer 10 Gbps service.[25,26]

In stark contrast to the FCC's most recent definition of broadband, the industry benchmark is 1 Gbps to all homes and businesses as cities throughout the nation find ways to deploy gigabit-capable networks and offer affordable 1 Gbps service. Symmetry between upload and download speeds also sets networks apart. Traditionally, download speeds are emphasized when selling services to consumers, as download speeds typically exceed upload speeds. A symmetrical service offers upload speeds that match or are very close to download speeds. Further, there is an expectation of unfettered access and no caps or restrictions.

In light of the practical definition of broadband within the industry, and the likelihood that Madison's residents and businesses will desire access to 1 Gbps service, we encourage the City to prioritize offering a simple, straightforward 1 Gbps service.

However, we caution the City that offering 1 Gbps service as it rolls out its FTTP initiative can actually serve to *further* the digital divide. If much of the community has the means to purchase 1 Gbps service, but low-income customers are only able to afford 10 Mbps service, this effectively creates the same divide that the City is attempting to bridge with its pilot program. This is not an impossible hurdle—the City might subsidize access to 1 Gbps for its most vulnerable populations, such as those who are part of the City's broadband pilot program (see

[23] Cyrus Farivar, "Google Fiber to arrive this fall; $70 for gigabit service," *ArsTechnica*, last modified July 26, 2012, http://arstechnica.com/business/2012/07/google-fiber-launches-in-kansas-city/.
[24] Fergal Gallagher, "Why Comcast's New 2-Gigabit Broadband Service Won't Worry Google Much," *Tech Times,* last modified April 2 2015, http://www.techtimes.com/articles/43818/20150402/comcasts-new-2gb-broadband-service-twice-fast-google-fiber.htm.
[25] Klint Finley, "Chattanooga Is Offering Internet Faster Than Google Fiber," *Wired*, last modified October 15, 2015, http://www.wired.com/2015/10/chattanooga-is-offering-internet-faster-than-google-fiber/.
[26] Claire Zillman, "Want 10 Gbps Internet? Move to this city," *Fortune*, last modified September 3, 2015, http://fortune.com/2015/09/03/gigabit-internet-municipal/.

Section 2.2.2). But the City should be mindful of this unintended consequence of deploying a citywide ultra-high speed network that seeks to provide 1 Gbps service to all its residents.

1.7.4 Continue to Coordinate and Collaborate with Madison Gas and Electric

In some cases, there is little room for collaboration or even cooperation between the locality and the regional investor-owned utility (IOU). Collaboration with a local utility might mean obtaining access to its utility poles or underground conduit, or any existing fiber infrastructure it may have. It can also mean sharing the cost to deploy new infrastructure that may benefit both the locality and the utility.

As part of this analysis, CTC engineers and City staff met with representatives from Madison Gas and Electric (MG&E) to determine the degree to which the utility may be willing to work with the City toward the goal of deploying an FTTP network. It was our experience that MG&E is amenable to the City's initiative, and is willing to collaborate with the City. If the City aims to construct its network entirely underground, it may be especially beneficial to coordinate with MG&E for access to any conduit the utility may own in areas where deploying fiber will be especially difficult, such as areas with a great deal of concrete or right-of-way (ROW) [27] congestion.

We encourage the City to continue open communication and collaboration with MG&E, and to explore any opportunities for symbiosis. The City may be able to assist MG&E in meeting some of its own connectivity goals, and the two entities may be able to enter a partnership of sorts where the two potentially can jointly build some infrastructure as opportunities arise. There are other utilities in the area that may be helpful from a part

1.7.5 Consider Exploring a Procurement Process to Further Evaluate Partnership Opportunities

If the City moves forward with deploying a network, it may be prudent to conduct a procurement process to gauge private sector interest in partnering with Madison.

After review of the City's needs and discussion with the Mayor and staff, we believe the model that best meets the City's objectives is a partnership in which the City owns and maintains the fiber, while the private entity lights the network and offers service over it. There are a handful of private companies in the industry today that are willing to work with localities to deploy this model, and we encourage the City to open discussions with one or more of these vendors, depending on what it is legally able to do.

It may be that the City can directly enter exclusive negotiations with a private partner based on the release of an updated dark fiber leasing rate sheet. That is, the City may be able to publish

[27] The ROW is land reserved for the public good such as utility construction; it typically abuts public roadways.

its dark fiber lease rates and then execute a contract with a partner based on the partner's acceptance of those rates. Alternatively, the City may need to go through a publicized procurement process, such as a request for information (RFI) or request for proposals (RFP), that allows multiple vendors to respond to the City's articulated needs, and enables negotiation with a partner through a process of elimination. The exact avenue the City takes will be driven by the procurement rules to which the City is bound; these should be reviewed by the City's legal counsel.

1.7.6 Prioritize the Continuation of Service to Customers in Pilot Service Areas if Feasible

As we note in Section 2.2.2, the City is in the process of carrying out a pilot program aimed at bringing affordable broadband service to low-income neighborhoods. The pilot is in its infancy, and is expected to last two years. The City will likely want to find a way to continue providing service to pilot customers beyond the pilot period, whether through a temporary partnership (such as an extension of the City's contract with ResTech) or as part of the overall FTTP deployment.

Some incumbent providers often "cherry pick" in communities by upgrading their infrastructure only in areas where they are certain they will be able to recover their cost of infrastructure investment. This typically means that affluent or middle-class neighborhoods have a greater likelihood of being served by incumbent providers than low-income areas. If the City is covering a portion of the cost to bring last-mile service to these areas, this could reduce the overall cost of an eventual citywide FTTP deployment, which may be attractive to a private sector partner.

2 The City's Goals and Priorities

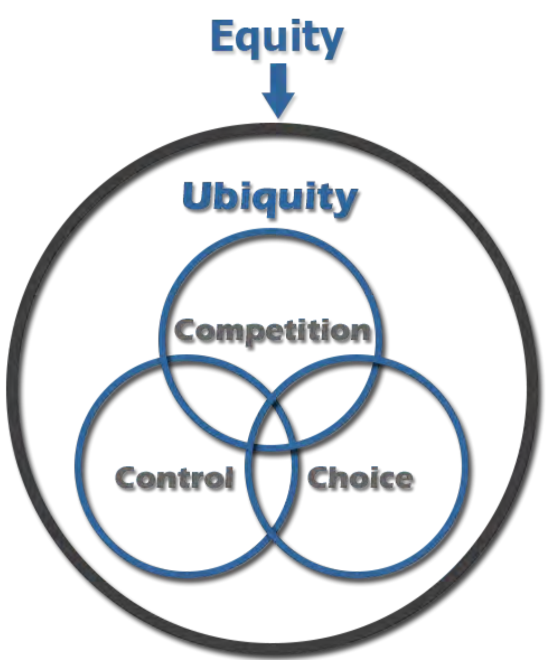
2.1 The City's Core Objectives

Based on our discussions with City staff and our understanding of community goals, we recognize the following objectives as the baseline for the City's broadband initiative:

- Equity – Alignment with Racial Equity and Social Justice (RESJ) and digital divide goals
- Ubiquity – Service is deployed to the entire City
- Competition in the marketplace – Enabling multiple providers to compete
- Consumer choice – Citizens can purchase service from various providers
- Control – The City has a long-term stake in the asset

As we note in Appendix A, ubiquity—which refers to designing and building the network so that it connects every residence, business, and institution in the community—is consistent with and upholds the City's equity initiatives. Incumbent providers have often built only to the most affluent areas of a community where they are sure to see a return on investment (ROI), a practice known as "cherry picking," and the City aims to ensure that none of its residents, businesses, or community anchor institutions (CAIs) is excluded from access to broadband service. Prioritizing ubiquity aligns with the City's other core goals. Ubiquity is a means to achieve equity, and is foundational to the City's broadband initiative.

Figure 3: Equity Informs Ubiquity, Which Aligns with Choice, Competition, and Control



Competition in the marketplace and consumer choice are complementary objectives, and are often sought through a pursuit for open access. That is, many communities prioritize open access as an essential, nonnegotiable objective—but at the core of the pursuit for open access is a desire for competition and consumer choice. We have noted that it may not be necessary to focus on open access in the traditional sense, and by seeking creative ways to foster competition in the marketplace, the City potentially increase consumer choice.

Control of the assets is another important City objective, and one that will be a fundamental aspect of any partnership agreement. It is important for the City to understand what "ownership" really looks like, and what it considers important assets over which it would like to retain control. For example, we believe the City is well-suited to pursue a dark FTTP partnership model where it owns the dark fiber assets but not the network electronics.

2.2 Promoting Equity

2.2.1 Addressing Areas of Need

The City is committed to ensuring that all of its residents have access to the information and services necessary to enjoy a high quality of life, and it is enacting programs to reach vulnerable populations. For example, the City implemented the Racial Equity and Social Justice (RESJ) initiative in 2013 to prioritize inclusion throughout the City for people of color. The RESJ initiative focuses on equity in municipal operations, policies, procedures, and spending—as well as within the community. Its goal is to minimize racial and economic exclusion from important municipal decision-making processes by facilitating change within the City at a fundamental level.

The Neighborhood Resource Teams (NRT) program is another important City initiative. The NRT program, which builds on the RESJ initiative, fosters communication between the City and the community it serves; different teams of City staff serve portions of the community ranging from 500 to 2,000 citizens. The NRTs work with other public, private, and governmental organizations within the community to meet the needs of the populations they serve, and to work collaboratively toward bettering a wide range of aspects of citizens' lives. Everything from public health issues to access to educational resources might be addressed by the NRTs and partnering organizations within the community, based on input from citizens about the needs they perceive in their neighborhoods.

It is beyond the scope of this report to provide extensive guidance on addressing the City's unique digital divide. However, we note that the City's broadband pilot project (see Section 2.2.2) works in conjunction with other City programs to addresses technical, legislative, and social issues. Broadband supports a range of programs and issues, and touches nearly every facet of modern living—and lack of access to it can severely hinder citizens' ability to participate in many aspects of contemporary life.

2.2.2 Bridging the Digital Divide with Pilot Fiber Project

The Common Council approved funds in late 2014 during its annual budget process for a two-year pilot program aimed at bringing broadband Internet service to residential customers in four low-income areas in the City.[28] The following spring, the City issued a request for proposal (RFP), which led to an eventual contract with ResTech Services, LLC.[29]

The pilot is an initiative of Mayor Soglin designed to serve vulnerable populations who may never previously have had access to broadband service—either because there was no service available in their area, or because they could not afford it. The pilot program will offer 10 Megabits per second (Mbps) service at $9.99 per month. The four pilot areas are:

- Allied
- Brentwood
- Darbo-Worthington
- Kennedy Heights

Three of the four areas (Allied, Brentwood, and Darbo-Worthington) are designated NRT neighborhoods. Each of these neighborhoods include multi-dwelling units (MDUs) ranging in size from two units to over 100 units.

While the pilot program was initially envisioned as a wireless deployment, the City broadened its RFP to allow for alternative technologies. ResTech proposed an FTTP approach that would enable it to offer retail services to pilot customers by expanding the City's MUFN network infrastructure into the pilot areas. The contract with ResTech was finalized in early 2016 with the expectation that construction would be underway once weather permitted in the spring.

The pilot was originally intended to produce data to inform a cost-benefit analysis, which could potentially be used to pursue citywide broadband deployment. The initial plans would have produced a cost-benefit analysis at the end of the two-year pilot program, which may be late 2018. After the initial stages of the pilot program were underway, Mayor Soglin determined that the City may want to take on a citywide FTTP initiative sooner than originally anticipated, and tasked the Digital Technology Committee with exploring this possibility. The Digital

---

[28] "City of Madison - File #40237," *City of Madison*, accessed February 16, 2016, https://madison.legistar.com/LegislationDetail.aspx?ID=2473855&GUID=356DEBE5-18B0-44BC-835A-381CCED09BFE.

[29] CTC provided Appendix B, "Best Practices for FTTP Deployment in Underserved Areas," to the City to help shape some portions of its contract with ResTech; that appendix is based on experience with the BTOP project in Champaign-Urbana, Illinois, which brought last-mile service to some underserved portions of the cities.

Technology Committee formed the Citywide Broadband Subcommittee, which engaged CTC to develop a cost-benefit analysis for ubiquitous FTTP deployment.

There is little data from the pilot program at this stage, and we believe that even final data may not be useful to extrapolate to a citywide deployment to shed light on issues like market demand. However, the pilot is a microcosm of an overall citywide FTTP deployment, and can potentially allow small-scale testing of engineering specifications by using a similar financial model where a private vendor provides lit services over City-owned infrastructure.

Further, the pilot can provide helpful word-of-mouth marketing for the City's "brand." Although the City will not be the retail provider, any partnership will likely be perceived as a City project. (This also means that the City will likely be held accountable for any perceived shortcomings or failures.) Through the pilot, the City has an opportunity to create a stable foundation as a trustworthy and competent steward, which may be helpful to get community buy-in for a larger project.

2.3 Understanding Competition and Open Access

A desire for increased competition in the marketplace is often at the root of the goals that drive a public entity to seek ways to expand access to ultra-high speed broadband connectivity. This can potentially be achieved through "open access," which has traditionally meant one infrastructure that is available to multiple providers to offer service. Open access networks are meant to enable numerous providers to deliver service over the network—thus fostering competition—and to give consumers greater choice and flexibility in picking a provider.

Open access is most easily achieved if a community builds and owns a network itself, because it is then in a position to set terms for private lessees of its fiber that could include open access. But some forms of open access may be possible even under the pure private investment model.

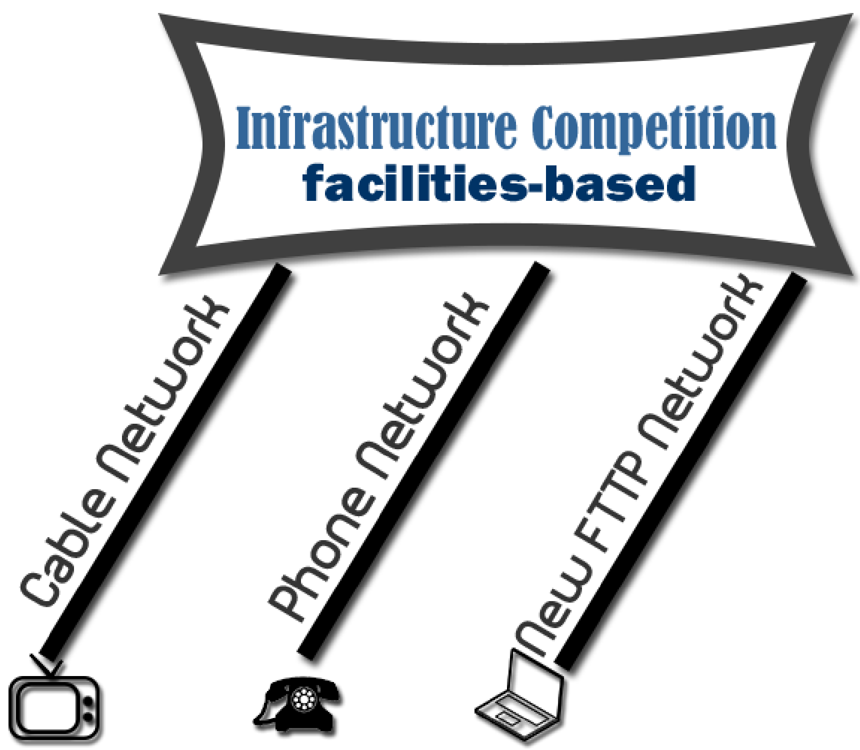
It's essential to note that creating the *potential* for open access does not mean that actual competition will emerge over that platform, particularly over the short to medium term, given the economics of broadband competition—but the potential exists.

There may be other ways for the City to achieve its open access goals, too. That is, the City may find that it can concede on providing infrastructure-based open access if it can ensure that the community's goals with respect to *competition* are met. Indeed, the primary goal of developing an open access network is to level the provider playing field to reduce monopolistic and oligopolistic practices by incumbents, and to give consumers greater choice in service providers. Pursuit of a traditional open access model may not be necessary for to achieve better competition. Rather, competition over the data pipe (known as Over the Top competition) and over multiple network infrastructures (known as facilities-based competition) can serve to enable real competition, thus reducing the need to provide access to physical infrastructure in order to promote and support competition.

2.3.1 Facilities-Based Competition

While it is frequently derided by open access advocates and is not economically efficient, we suggest that the City not discount the benefits of achieving competition through facilities-based competition. In this scenario, competition is achieved when multiple separate entities develop their own separate networks and physical pathways to reach the customer. Most private providers are usually not interested in granting access to their expensive infrastructure for companies that will then compete with them over it, so each of these networks is likely to host only one Internet Service Provider—the network owner.

Figure 4: Facilities-based Infrastructure Competition



This approach is not efficient because it requires a large capital expenditure by each network owner and, frankly, robust competition over separate facilities has not emerged for the most part in the United States, unless one considers the modest duopoly-competition between phone and cable companies to constitute “competition.”

But the past five years have brought new competitive networks and new competitors into the broadband market, led by a range of municipalities and by Google Fiber. For cities that have had the benefit of a third provider in the market (whether public or private), facilities-based competition has begun to work, particularly as the incumbents have started to react to competition by investing, upgrading, and improving services and prices.

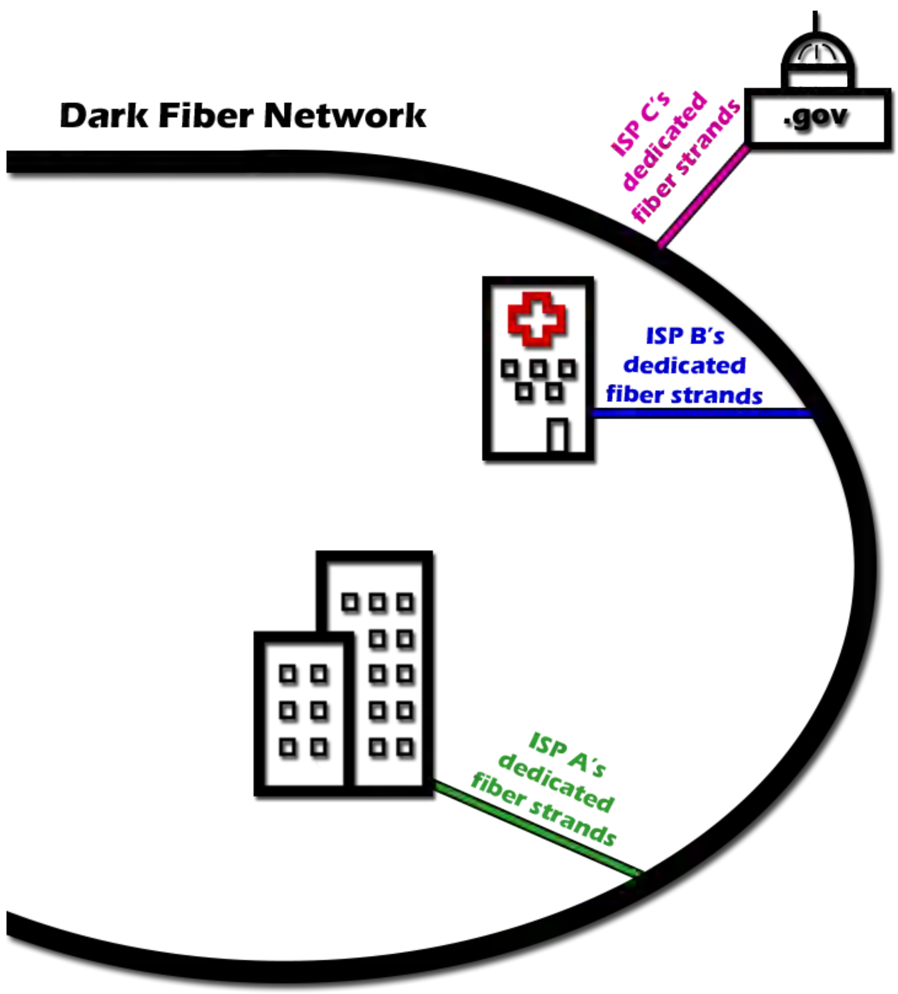
As a result, we believe that Madison is likely to see the substantial benefits of competition from the development of a FTTP network, even if open access over that network does not emerge.

2.3.2 Competition at the Dark Fiber Level

Dark fiber open access enables private providers to offer services without having to construct their own infrastructure. Instead, ISPs can enter into dark fiber lease or indefeasible right of use (IRU) agreements with the network owner, and the ISPs can then offer retail data, video, and voice services over the network.

In a dark fiber model, there is one fiber network infrastructure, and one or more ISPs pay the network owner for access to dedicated fiber strands that the ISPs can use at their discretion (Figure 5).

Figure 5: Competition Over a Dark Fiber Network



This model requires each ISP to "light" the dark fiber by investing in network electronics to provide service over the network. While the cost to install electronics is a lower upfront capital investment than paying to deploy and maintain fiber, electronics costs are still a significant expense for an ISP. This is especially true given that the equipment the ISP owns must be replaced, multiple times over the lifetime of the dark fiber. Equipment may be refreshed every five, seven, or 10 years—and possibly more frequently, depending on advances in technology.

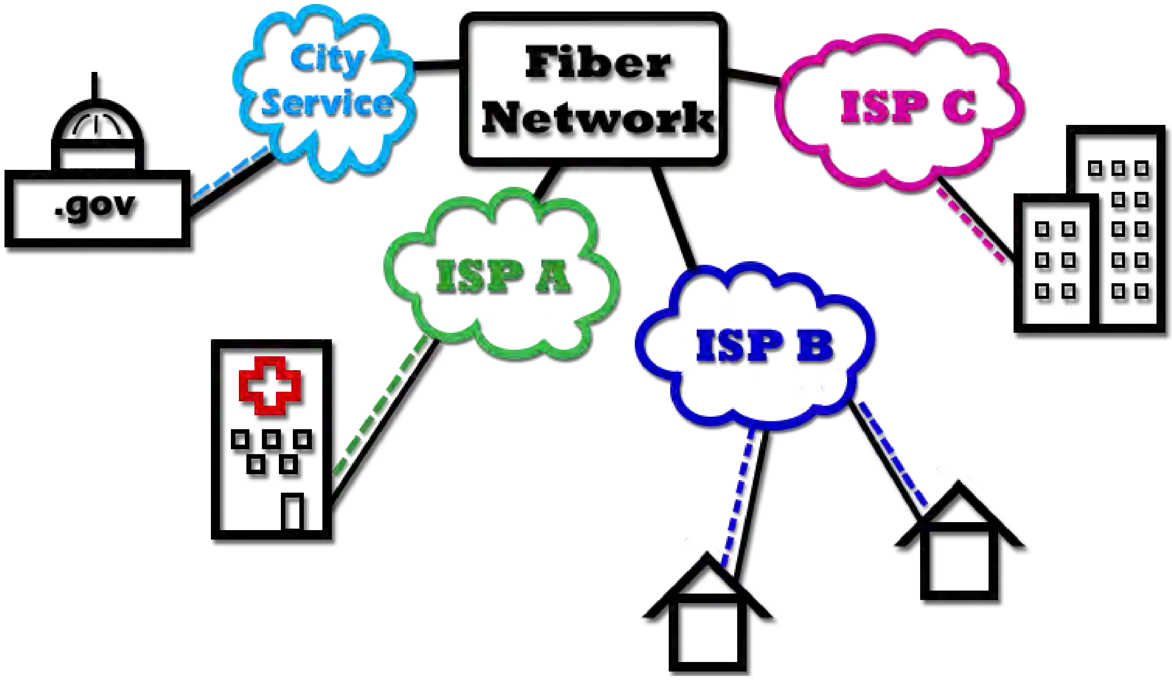
And the ISPs will face many other significant costs to compete in the market, even with access to ubiquitous dark fiber. For example, none of the traditional costs for billing, collections, marketing, and sales are removed by dark fiber access. Nor are costs for customer service. Further, this model may also require the ISP to pay some portion of the cost to install a fiber drop from the dark fiber network at the curb to the home or business of a potential customer it wishes to serve.

As a result, the ISP still has considerable costs to enter the market, thus making multiple-ISP competition at the dark fiber layer more challenging, particularly given that the market has a finite size and that each additional competitor is competing for the same set of customers currently served by the existing providers. For these reasons, we are not optimistic about the potential for multiple-ISP competition over dark fiber, at least in the short- to medium-term. In the long run, the market is likely to change dramatically, however, and dark fiber open access could enable all kinds of new innovators to offer competitive services.

2.3.3 Competition at the "Lit" Services Level

Another option to enable competition is to allow ISPs to compete over a "lit" fiber network—this lowers the barriers to market entry by removing the cost of fiber, electronics, and maintenance, thus allowing more ISPs to compete in the marketplace. In this scenario, the network owner lights the fiber and ISPs compete at the virtual network layer instead of at the physical layer (Figure 6).

Figure 6: Competition Over a Lit Network



In this model, consumers could hypothetically choose which service provider they want to engage by simply clicking a button on a Web interface from the comfort of their homes. The idea is that many ISPs will be able to compete to be a consumer's chosen service provider, and the ISPs can enter the market without having to make large investments in fiber infrastructure or network electronics.

The underpinnings of the traditional open access model are a desire for competition and consumer choice. A lit services model can support both.

That said, it's important to note that even if the barriers to entry are reduced through this model, there is no guarantee that many new competitors will emerge in the near-term. Indeed, it may not make sense for smaller ISPs to operate in a market where there are several other competitors and where customer acquisition and retention costs are correspondingly high.

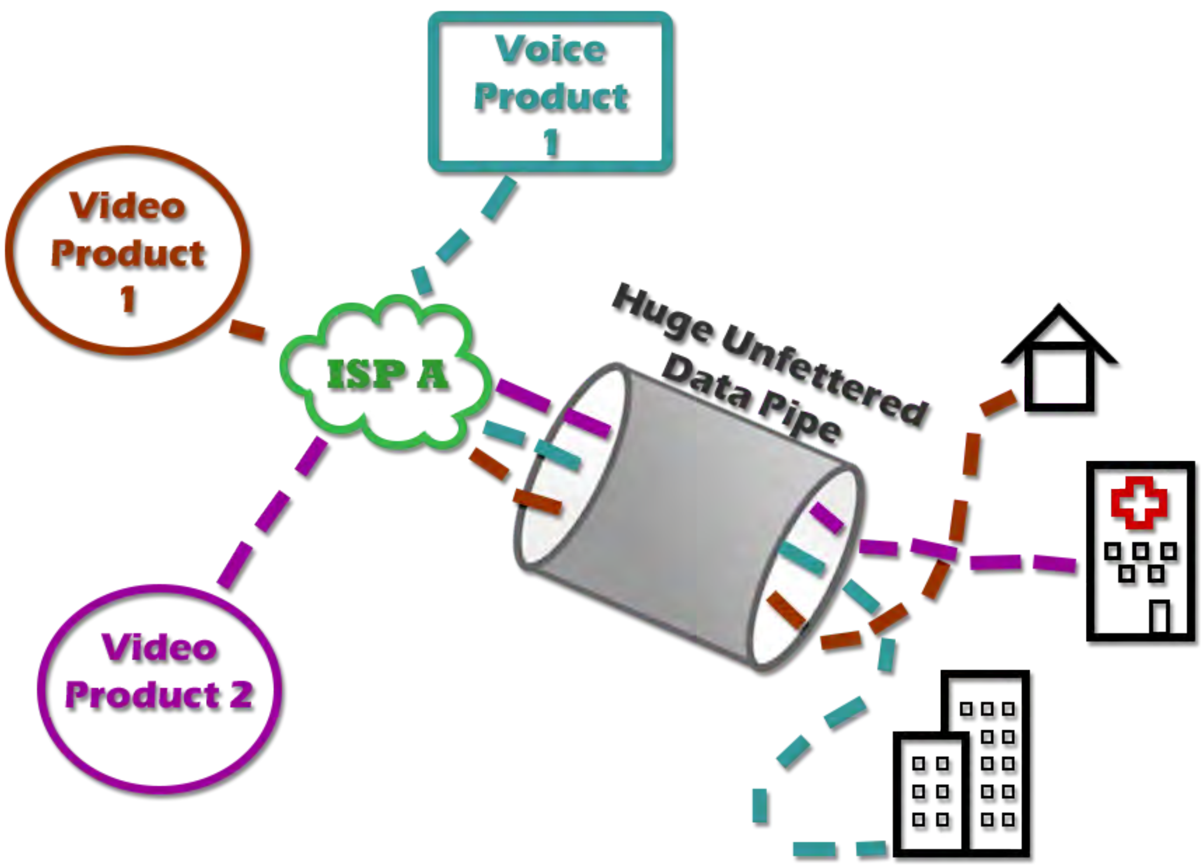
2.3.4 Over-the-Top Content Offers Service-Level Competition and a Variation on Open Access

Another way to potentially achieve the City's open access goals is to enable multiple over-the-top (OTT) providers to offer various services over a high-capacity data network. OTT content (typically video and voice) is delivered over the Internet by a third-party application or service that utilizes a robust, (ideally unfettered) data connection.

OTT content delivery is particularly effective over ultra-high-speed fiber optic broadband networks that are provisioned for affordable data service at 1 Gbps speeds and beyond, operated by service providers that do not put constraints on consumers' access to data. Such high-capacity networks can support a variety of OTT applications to meet consumers' needs. Consumers are likely to pursue alternatives to conventional video and voice services as additional and increasingly varied content becomes available OTT, and as access to high-speed data connections becomes more prominent and affordable.

A large, unfettered data connection can thus serve to meet the competition goals typically associated with open access networks.

Figure 7: Over-the-top Competition



As OTT programming and applications become increasingly prevalent, the need for traditional open access, which relies on access to infrastructure—and all the operational details and costs associated with it—is reduced. The City may find that it can achieve its open access goals of promoting competition and consumer choice through alternative means. If the City builds a ubiquitous network, and then partners with a private entity to manage operations and provide an unfettered data service, this introduces a new competitor into the market and drives competition at the applications layer.

2.3.5 Evolving Over-the-Top Providers

The concept of OTT or "value added" services took hold in the voice market first, as consumers sought alternatives to traditional landline service without being locked into long cell phone contracts—Voice over Internet Protocol (VoIP) providers offered a middle ground. VoIP providers like Vonage emerged in the early 2000s and continued to increase in popularity along with consumers' desire for greater choice. Prior to becoming the videoconferencing-focused service it is today, Skype started with voice service that allowed consumers to make inexpensive or free calls domestically and internationally with their computer, a data connection, and a headset.[30]

Different OTT services have begun to emerge and evolve rapidly in the video market as consumers increasingly ditch cable service in favor of streaming video,[31] and providers clamor to compete with each other in response.[32] There are numerous established services and applications that will likely continue to promote change in the cable industry and drive an increase in consumers' desire for greater choice and control over how they access content. Standalone media-streaming boxes like Apple TV and Roku have enabled consumers to stream content with applications such as YouTube, Netflix, and Hulu without a cable subscription since 2008.[33,34] These "cord-cutters" cancel their cable subscriptions in favor of accessing their favorite content via applications and services streamed over the Internet—OTT content.

Since the debut of Apple TV and Roku, similar devices like the Amazon Fire TV stick and Google Chromecast have entered the market, allowing consumers greater choice. Further, consumers can now purchase smart TVs, which come with preinstalled platforms that support streaming applications and require no additional hardware. With only an Internet connection, consumers can stream movies, music, news, TV shows, movies, and even play games.

Some streaming video services strive to emulate cable television—without the hefty price tag, long contracts, and notoriously subpar customer service that traditional cable providers are

---

[30] Doug Aamoth, "A Brief History of Skype," *Time*, last modified May 10, 2011, http://techland.time.com/2011/05/10/a-brief-history-of-skype/.

[3131] http://www.consumerreports.org/cro/tvservices/more-people-are-cutting-the-pay-tv-cord, accessed April 2016.

[32] http://techcrunch.com/2016/05/02/hulu-to-compete-with-sling-tv-via-new-cable-tv-like-service/, accessed May 2016.

[33] http://www.apple.com/pr/library/2008/01/15Apple-Introduces-New-Apple-TV-Software-Lowers-Price-to-229.html, accessed January 2016.

[34] http://rokumodels.com/roku-models/first-generation-roku/, accessed January 2016.

known for.[35] Other services specialize in one type of content, like only offering documentaries or movies. The OTT video market has exploded in recent years as consumers continue to seek alternatives to traditional video services, and content providers nimbly adapt to consumer demand. Providers like Amazon, Hulu, and Netflix have continued to tailor their approach through efforts like creating original content to supplement traditional content offerings.[36] Such content easily rivals traditional television programming; some OTT provider original series have been nominated or won Critics' Choice, Emmy, Golden Globe, People's Choice, Screen Actors Guild, and other awards. Even tech giant Apple may begin producing original content.[37]

In 2015 alone, several companies began offering standalone streaming or providing access to content through new streaming services. HBO and Showtime both began offering access to their content through directly streaming via subscription service in 2015.[38,39] In addition to an ability to easily access sports programming, a desire for premium programming like HBO and Showtime has been a stubborn barrier to customers who want to eliminate their cable subscriptions (and to competitors that want to disrupt the market). Often, consumers would happily give up enormous cable bills in favor of more streamlined, inexpensive services—but they do not take the leap because they want specific programming that is only available with a cable subscription. It is significant when content powerhouses like HBO and Showtime take such an industry-disrupting leap.

Also in 2015, Verizon FiOS announced an "a la carte" offering called Custom TV, which allows consumers to choose from bundled packages that more appropriately reflect their programming desires and include less unwanted channels.[40] While this is not a true OTT application, it demonstrates a recognition within the incumbent market that consumers are dissatisfied with traditional content delivery and are seeking alternate choices.

As we noted, sports programming is a major barrier for many consumers who wish to cancel their cable subscription. DISH Network launched an OTT service in early 2015 called Sling TV that offers sports programming on channels such as ESPN, as well as other programming and popular TV channels. The service, called Sling TV, is streamed over the Internet.[41] Like other

---

[35] http://www.fool.com/investing/general/2015/06/03/comcast-time-warner-cable-still-rank-worst-in-cust.aspx, accessed January 2016.
[36] http://www.huffingtonpost.com/2014/01/18/netflix-hulu-amazon-prime-originals_n_4591418.html, accessed January 2016.
[37] http://gizmodo.com/the-apple-original-content-rumor-is-back-1727863339, accessed January 2016.
[38] http://www.pcworld.com/article/2894534/hbo-announces-hbo-now-standalone-streaming-service-with-discounted-apple-tv.html, accessed January 2016.
[39] http://money.cnn.com/2015/07/07/media/showtime-streaming/, accessed January 2016.
[40] http://arstechnica.com/business/2015/04/verizons-new-custom-tv-is-small-step-toward-a-la-carte-pricing/, accessed January 2016.
[41] http://www.nytimes.com/2015/01/06/business/media/dish-network-announces-web-based-pay-tv-offering.html, accessed January 2016.

streaming services, Sling TV does not require additional hardware to access OTT content, including sports programming. Sling TV currently is priced at $20 per month with no time commitments, but it has experienced hiccups as its offerings are subject to limitations and restrictions that are reminiscent of traditional cable.[42] Traditional cable content providers' attempts at OTT service have seen varying degrees of success, but it is significant in the industry for these providers to even acknowledge the need for these services.

Companies that hope to compete in the video market will likely find that they must adjust their business models, marketing strategies, and understanding of consumer demands and desires. Perhaps one of the most significant illustrations of this is that, for the first time ever, Comcast's broadband subscribers outnumbered its cable subscribers in 2015—an unprecedented and major shift in the industry.[43] The City can essentially "court" OTT providers and promote these applications by requiring a public–private partnership's data-only offering to provide unfettered access. The City has already laid out unfettered access to data as a base requirement for any partnership agreement it enters. This can help the City achieve its goals of consumer choice and competition in the market without the need for traditional infrastructure-based open access.

[42] http://www.pcworld.com/article/2909572/sling-tv-channel-guide-all-the-programming-and-all-the-restrictions-all-in-one-chart.html, accessed February 2016.

[43] Emily Steel, "Internet Customers Surpass Cable Subscribers at Comcast," *The New York Times,* last modified May 4, 2015, http://www.nytimes.com/2015/05/05/business/media/comcasts-earnings-rise-10-driven-by-high-speed-internet.html?_r=0.

3 Market Analysis: Assessment of the Local Broadband Marketplace

As part of our analysis for the City of Madison, CTC assessed the current market for enterprise and residential or small business services.[44] This analysis outlines various types of service in the City, and corresponding pricing and contract terms where applicable.

Not every service described here is available in every part of the City to all potential customers—especially small and medium businesses. This competitive assessment is intended to outline the breadth of services that may be available to users in the City, but it does not identify specific service boundaries for each provider.

For enterprise users, the analysis summarizes dark fiber and lit services availability and pricing. For the residential and small business market, this analysis describes available cable, digital subscriber line (DSL), satellite, and wireless services.

3.1 Enterprise Market

In this section, we provide an overview of competitive providers for dark fiber and lit services for enterprise customers in the City.

During the course of our research, we identified 10 service providers in the Madison area that offer a range of services, from dark fiber connectivity to data transport services, with speeds that range from 1 Megabit per second (Mbps) to 100 Gigabits per second (Gbps). Individual providers tailor these services to customers' requirements like speed or class of service. Greater proximity to the provider's existing network infrastructure results in lower service pricing. Providers prefer to offer transport services between locations on their network (on-net). For off-net locations, providers provision Multiprotocol Label Switching (MPLS) based services.

A current trend that we expect to continue is the consolidation of competitors through mergers and acquisitions. Madison-area competitors are discussed in detail in the following sections.

3.1.1 Dark Fiber Services

There are two service providers in the City with dark fiber availability: Level 3 Communications and Zayo Group.

Level 3 has dark fiber routes in Madison, as depicted in Figure 8. Services are offered only to select customers based on the provider's application requirements. Dark fiber pricing varies individually, based on distance from the provider's fiber ring. Even a few tenths of a mile distance from Level 3's fiber ring can result in significant price differences for dark fiber connectivity, due to additional construction costs.

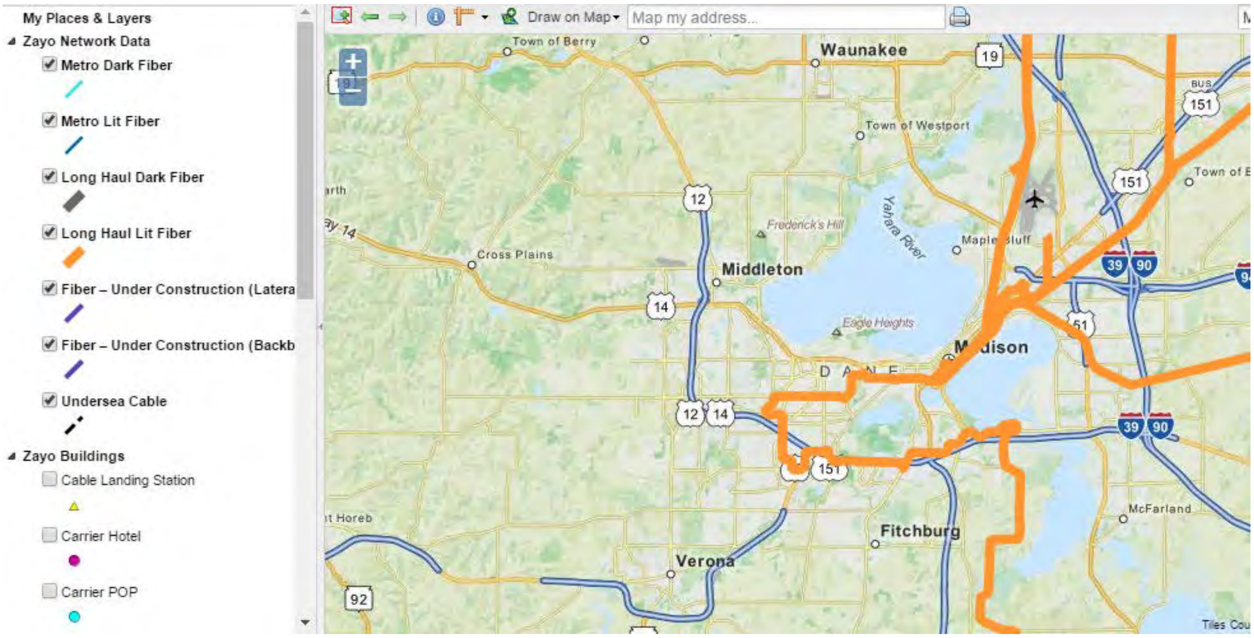
[44] Small business customers often subscribe to the same or comparable service as residential customers because the service meets the needs of the business at an affordable price point.

Figure 8: Level 3 Dark Fiber Routes[45]

Zayo provides dark fiber connectivity over its national network of metro and intercity fiber. The company claims to have proven expertise in deploying major new dark fiber networks and offers multiple financing options, including leases and indefeasible right of use (IRU) agreements. Pricing varies significantly depending on whether the building is on-net. If the location is off-net, construction and splicing costs would apply.[46]

[45] http://maps.level3.com/default/, accessed March 2016.
[46] http://zayofibersolutions.com/why-dark-fiber, accessed March 2016.

Figure 9: Zayo Fiber Map[47]



3.1.2 Lit Services

Almost all existing service providers offer enterprise-grade, Ethernet-based services. Bandwidths range from 1 Mbps to 100 Gbps. Ethernet service can be classified into three types: Ethernet Private Line (EPL or E-Line), Ethernet Virtual Private Line (EVPL), and Ethernet Local Area Network (ELAN). These may be known by different names among providers. EPL is a dedicated, point-to-point high bandwidth Layer 2 private line between two customer locations. The EVPL service is similar to EPL but is not dedicated between two locations. Instead, it provides the ability to multiplex multiple services from different customer locations onto one point on the provider's network (multiple virtual connections) to another point on the network. ELAN is a multipoint to multipoint connectivity service that enables customers to connect physically distributed locations across a Metropolitan Area Network (MAN) as if they are on the same Local Area Network (LAN).

The internet services over Ethernet are typically classified under two categories: Dedicated Internet Access (DIA) and MPLS Internet Protocol (IP) Virtual Private Networks (VPN), or "IP-VPN". Providers prefer to offer MPLS based IP-VPN services when the service locations are off-net, thus avoiding construction and installation costs. MPLS-based networks provide high performance for real-time applications such as voice and video, and are typically priced higher.

The carriers who provide these services in the Madison area are:

- AT&T

[47] http://www.zayo.com/network/interactive-map, accessed March 2016.

- CenturyLink
- Charter
- Level 3 Communications
- TDS Telecom
- US Signal
- Verizon
- Windstream Communications
- XO Communications
- Zayo Group

Prices depend on the bandwidth, location, and network configuration; whether the service is protected or unprotected; and whether the service has a switched or mesh structure.

AT&T has four different types of Ethernet products—GigaMAN, DecaMAN, Opt-E-MAN, and Metro Ethernet. GigaMAN provides a native-rate interconnection of 1 Gbps between customer end points. It is a dedicated point-to-point, fiber optic-based service between customer locations, which includes the supply of the GigE Network Terminating Equipment (NTE) at the customer premises. DecaMAN connects the end points at 10 Gbps and is transmitted in native Ethernet format similar to GigaMAN—only 10 times faster. Opt-E-MAN service provides a switched Ethernet service within a metropolitan area. It supports bandwidths ranging from 1 Mbps to 1,000 Mbps, and configurations such as point-to-point, point-to-multipoint, and multipoint-to-multipoint. Metro Ethernet service provides various transport capabilities ranging from 2 Mbps through 1 Gbps, while meeting IEEE 802.3 standards.[48] A 1 Gbps fiber-based internet service at an off-net location in Madison is priced at $4,135 per month.

CenturyLink provides point-to-point inter-city and intra-city configurations for full-duplex data transmission in the Madison vicinity, as depicted in Figure 10.The company typically offers speeds of 100 Mbps to 10 Gbps.[49]

---

48 http://www.business.att.com/service_overview.jsp?repoid=Product&repoitem=w_ethernet&serv=w_ethernet&serv_port=w_data&serv_fam=w_local_data&state=California&segment=whole accessed March 2016.

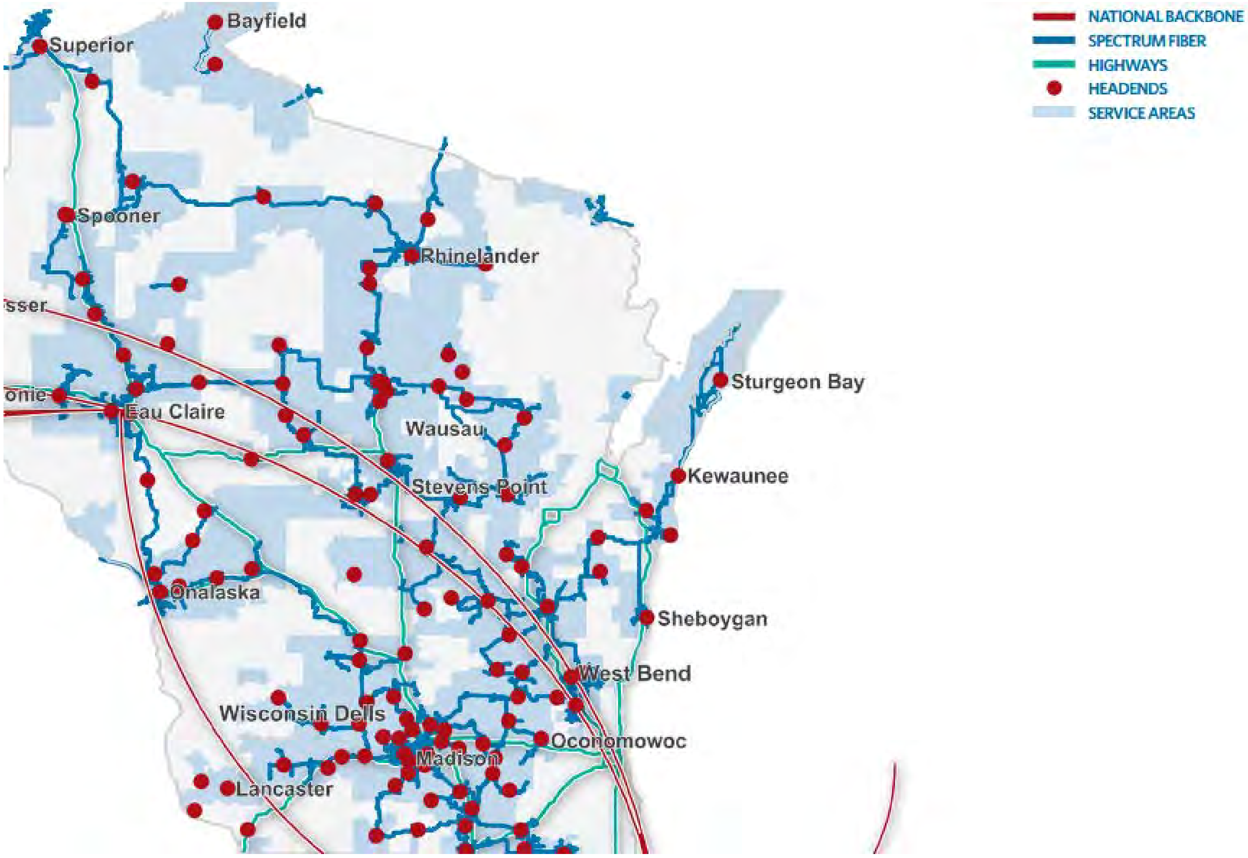
49 http://www.centurylink.com/business/asset/network-map/fiber-network-nm090928.pdf, accessed March 2016.

Figure 10: CenturyLink Network Map

Charter Communications offers Metro Ethernet services and direct Internet access (DIA) in Madison. Metro Ethernet services offer metro and long-haul connectivity and point-to-point, point-to-multipoint or multipoint-to-multipoint configurations. These include EPL, EVPL, and E-LAN services. A point-to-point EPL configuration offers a committed information rate (CIR) connection to connect both metro and long haul optical locations. It provides the customer full control of their network with the simplicity of a point-to-point connection. An EVPL service provides multiple point-to-point connections from the same customer Ethernet port, such as for connecting multiple remote offices to a central headquarters location. The E-LAN service connects all desired locations to create a secure, shared-data network. These services are offered with speeds from 10 Mbps to 10 Gbps with the ability to scale your bandwidth in 10 Mb or 100 Mb increments.[50] In Madison, on-net locations (already connected to their fiber network) can get 1 Gbps DIA service for $1,200 per month with a 36-month contract. Locations that are not already connected to their fiber can get a 1 Gbps DIA service for $7,000 per month with a 36-month contract. For an EPL service, a 1 Gbps connection costs $1,600 per month—but additional construction fees apply for locations not currently connected to its fiber. The Charter network in Madison is depicted in Figure 11.

[50] https://www.charterbusiness.com/mediacontent/pdfs/Charter_Business_Optical_Ethernet.pdf, accessed March 2016.

Figure 11: Charter Network[51]



Level 3 Communications' Metro Ethernet dedicated service is available in bandwidth options of 3 Mbps to 1 Gbps and its EVPL offers speeds ranging from 3 Mbps to 10 Gbps.[52] It is an end-to-end, Layer 2, switched Ethernet service delivered via an MPLS backbone. Internet services are available in a range of 14 speeds, up to 10 Gbps.[53]

TDS Telecom offers Metro Ethernet services in speeds scalable from 1.5 Mbps to 10Gbps in Madison.[54] Pricing is not publicly available for TDS Telecom's enterprise services.

US Signal offers Ethernet services from 100 Mbps to 1 Gbps. They also offer DIA services up to 1 Gbps speeds or higher.[55,56] Pricing for US Signal's enterprise services is not publicly available.

---

[51] https://business.spectrum.com/mediacontent/pdfs/spectrum-business-wisconsin-KMA.pdf, accessed March 2016.

[52] http://www.level3.com/en/products-and-services/data-and-internet/vpn-virtual-private-network/evpl/, accessed March 2016.

[53] http://www.level3.com/~/media/files/factsheets/en_ethernet_fs_ethernetmatrix.pdf, accessed March 2016.

[54] http://www.tdsbusiness.com/products/data-networking/ethernet.aspx, accessed March 2016

[55] https://ussignal.com/network/carrier-services , accessed March 2016.

Verizon offers Ethernet services in certain locations in Madison under three different product categories:

- ELAN
- EPL
- EVPL

The ELAN service is a multipoint-to-multipoint bridging service at native LAN speeds. It is configured by connecting customer User-to-Network Interfaces (UNIs) to one multipoint-to-multipoint Ethernet Virtual Connection or Virtual LAN (VLAN), and provides two Class of Service options (CoS): standard and real time. The EPL is a managed, point-to-point transport service for Ethernet frames. It is provisioned as Ethernet over SONET (EoS) and speeds of 10 Mbps to 10 Gbps are available. EVPL is an all-fiber optic network service that connects subscriber locations at native LAN speeds; EVPL uses point-to-point Ethernet virtual connections (EVCs) to define site-to-site connections. It can be configured to support multiple EVCs to enable a hub-and-spoke configuration, and supports bandwidths from 1 Mbps to 10 Gbps.[57]

Windstream Communications has a nationwide presence serving major metropolitan areas, including the City. It offers DIA services in Madison with speeds up to 1 Gbps.[58],[59]

XO Communications offers carrier Ethernet and DIA services at multiple bandwidth options, ranging from 3 Mbps to 100 Gbps, over its Tier 1 IP network.[60]

Zayo delivers Ethernet in three service types, with bandwidth ranging from 100 Mbps to 10 Gbps, and options like Quality of Service (QoS) guarantees and route protection based on customer needs. The different types of services offered are: Ethernet-Line, which provides point-to-point and point-to-multipoint configurations with reserved bandwidth availability; ELAN, with multipoint configurations having a guaranteed service level; and Ethernet Private Dedicated Network (E-PDN) with a completely private, managed network operated by Zayo, with dedicated fiber and equipment.[61]

3.2 Residential and Small Business Services

Residential and small business customers in the Madison area have access to a range of services, though individual service options are dependent on location. Table 8 lists the service

---

[56] https://ussignal.com/network/dedicated-internet-access accessed March 2016.
[57] http://www.verizonenterprise.com/products/networking/ethernet/, accessed March 2016.
[58] http://carrier.windstreambusiness.com/wordpress/wp-content/uploads/2014/10/Carrier-Ethernet-Ordering-Guide-10.8.14.pdf, accessed March 2016.
[59] http://www.windstreambusiness.com/shop/products/wi/Madison, accessed March 2016.
[60] http://www.xo.com/carrier/transport/ethernet/, accessed March 2016.
[61] http://www.zayo.com/ethernet, accessed March 2016.

providers and minimum price for each type of service that is available in at least some part of the City.

Table 8: Overview of Residential and Small Business Data Services in Madison

Service Type	Provider	Minimum Price (per month)
Cable	Charter	$39.99
DSL	AT&T	$35
	TDS Telecom	$80
Satellite	HughesNet	$49.99
3G/4G/Wireless Internet Service Provider	Verizon	$60
	T-Mobile	$20
	Sprint	$35
	AT&T	$50
	Netwurx	$47.45

3.2.1 Cable

Charter Communications offers Internet services via cable modem in standalone and bundled service packages in Madison. The Internet-only package offered by Charter is 60 Mbps download and 4 Mbps upload for $39.99 per month with a 12-month commitment. A promotion on a bundled service package with TV, Internet, and voice from Charter is being offered at $29.99 per month for each service for new customers.

Internet services for small businesses are offered in two tiers. A service offering for 100 Mbps download and 7 Mbps upload is available at $99 per month for the first 12 months. A 60 Mbps download and 4 Mbps upload is offered at $59.99 per month for the first 12 months. Discounted prices are available if bundled with another service like TV or voice.

3.2.2 Digital Subscriber Line (DSL)

AT&T offers DSL service for residential customers in Madison, starting at $35 per month for unbundled or standalone DSL service at 3 Mbps with a 12-month commitment. Additional options up to 45 Mbps are also available, as indicated in Table 9.

Table 9: AT&T Residential Internet—Internet Only

Internet Speed	Monthly Price (Regular)	Monthly Price (Promo Rate)
Up to 3 Mbps download	$47	$35
Up to 6 Mbps download	$52	$40
Up to 18 Mbps download	$62	$45
Up to 45 Mbps download	$82	$65

AT&T offers DSL-based small business services starting at $80 per month for 18 Mbps download and 1.5 Mbps upload speeds.

TDS Telecom is an Internet service provider that offers DSL speeds from 1 Mbps to up to 25 Mbps download (and 5 Mbps upload) for residential customers in Madison.[62]

TDS Telecom also offers fiber-based Internet services at certain locations in Wisconsin, including Madison suburb Verona.[63,64] It offers download speeds at 25 Mbps, 50 Mbps, 100 Mbps, 300 Mbps and 1 Gbps.

TDS Telecom offers business Internet speeds from 1.5 Mbps (512 Kbps upload) up to 100 Mbps (40 Mbps upload) in Madison.[65] Pricing ranges from $39 per month to $229 per month.

3.2.3 Satellite

Satellite Internet access is available in the area as well. **HughesNet** has four packages available for residential users: 1) Hughesnet Choice with speeds up to 5 Mbps download/1 Mbps upload, a monthly data cap of 5 GB, and 50 GB of "bonus" data (55 GB total) for $49.99 per month 2) HughesNet Prime Plus with speeds up to 10 Mbps download/1 Mbps upload, a 10 GB monthly data cap, and 50 GB of bonus data (60 GB total) for $59.99 per month; and 3) HughesNet ProPlus with speeds up to 10 Mbps/2 Mbps, a monthly data cap of 15 GB, and 50 GB bonus bytes (65 GB total) for $79.99 per month; and 4) HughesNet Max with speeds up to 15 Mbps/2 Mbps, a monthly data cap of 20 GB, and 50 GB of bonus data (70 GB total) for $129.99 per month.

---

[62] http://tdstelecom.com/shop/internet-services/high-speed-internet-plans.html, accessed March 2016.
[63] http://info.tdstelecom.com/MediaRoom/Article.aspx?id=47ac4957-357f-410c-8fed-ea366f3e232c, accessed March 2016.
[64] https://www.tdsfiber.com/where/, accessed March 2016.
[65] http://www.tdsbusiness.com/Libraries/TDS_Resources/High-Speed-Internet-Rate-Sheet.sflb.ashx, accessed March 2016.

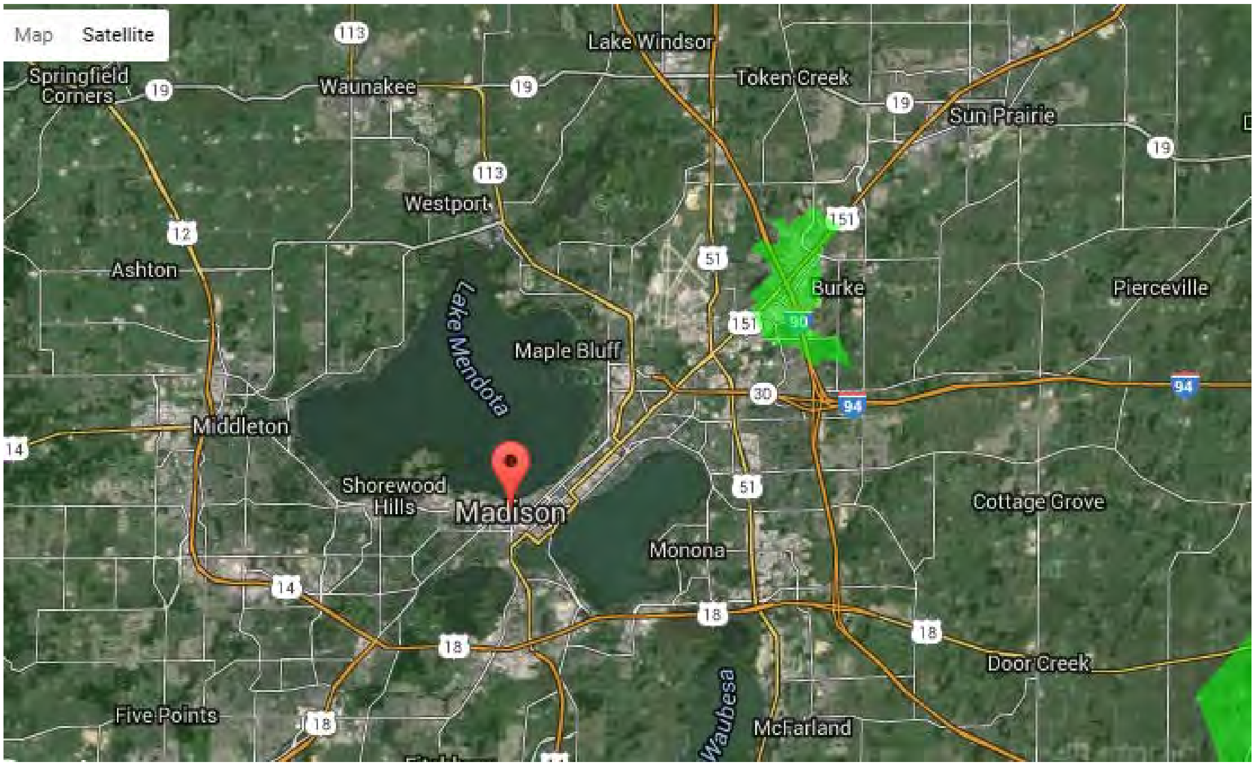
HughesNet has four business internet packages available, of which two packages are for Internet services to small businesses. The Business 50 package provides speeds of up to 5 Mbps download and 1 Mbps upload for $69.99 per month, with a 5 GB per month anytime allowance and 10 GB “bonus bytes” from 2:00 a.m. to 10:00 a.m., for a total monthly data allowance of 15 GB. This package requires a two-year agreement and only supports up to five users. The Business 100 package for $79.99 provides the 10 Mbps download and 1 Mbps upload speeds and offers a higher data allowance threshold of 20 GB per month anytime and 10 GB “bonus bytes” from 2 a.m. to 10 a.m., for a monthly data allowance of 30 GB. This package also requires a two-year agreement and is best for five to just over 10 users.

3.2.4 Wireless

AT&T provides 4G LTE wireless data service in the area, but only offers one package type with a 5 GB per month download allowance for $50 per month. There is an overage fee of $10 per 1 GB over the limit. There are also equipment charges, with or without a contract, and an activation fee.

Netwurx is a wireless Internet service provider (WISP) that provides services in certain parts of Madison for speeds up to 30 Mbps. The coverage map is depicted in Figure 12 (below).

Figure 12: Netwurx Wireless Coverage Map[66]



Netwurx's range of standard speeds and pricing available are indicated in Table 10.

Table 10: Netwurx Internet Services

Package	Internet Speed(Download/Upload)	Monthly Price
Basic	1 Mbps/512 kbps	$47.45
Basic+	1 Mbps to 6 Mbps/ 512 kbps to 2 Mbps	$47.45
Essential Home	5 Mbps/2.5 Mbps	$62.45
Enhanced Home	20 Mbps/10 Mbps	$84.95
Extreme Home	30 Mbps/15 Mbps	$129.95

Sprint also offers 4G LTE wireless data in Madison. The three data packages offered range from 100 MB per month data allowance for $15 per month, to 6 GB per month data allowance for

[66] http://www.netwurx.net/wireless-high-speed, accessed March 2016.

$50 per month, to 12 GB per month data allowance for $80 per month. Each MB over the limit is billed at a cost of $.05. A two-year contract is required, as well as an activation fee of $36 and equipment charges for three different types of devices. There is an early termination fee of $200.

Of the cellular wireless providers in the area, the least expensive wireless data option offered is from **T-Mobile**, for $20 per month with a limit of 1 GB per month. T-Mobile offers additional capabilities and increasing data limits at incremental costs in a total of six packages, up to $70 per month for up to 11 GB of data. Depending upon current promotions, the $35 activation fee is sometimes waived.

Verizon offers two 4G LTE data packages with multiple choices for data allowances and pricing, depending on the desired mobility and equipment chosen. The HomeFusion Broadband Package (LTE-Installed) is a data-only 4G LTE service with WiFi connectivity and wired Ethernet for up to four devices. Available download speeds are 5 Mbps to 12 Mbps, and upload speeds are 2 Mbps to 5 Mbps. Monthly prices range from $60 for a 10 GB data allowance, to $120 for a 30 GB data cap. Overages are charged at $10 per additional GB. A two-year contract is required, with a $350 early termination fee. Verizon offers a $10 monthly deduction for every month completed in the contract. The Ellipsis JetPack provides a mobile solution, with download speeds of 5 Mbps to 12 Mbps and upload speeds of 2 Mbps to 5 Mbps. Prices for the 12 options of data allowances range from $30 per month for a 4 GB data allowance, to $335 per month for 50 GB of data, in addition to a monthly line access charge of $20. The device is $0.99 with a two-year contract. There is a $35 activation fee.

4 Residential Market Research

Madison has a diverse and resilient economy, driven by an educated population, innovative workforce, embrace of technology, and its connections with the University of Wisconsin and state government. A foundation for Madison's successful business climate and quality of life is its use of technology, including reliable and robust access to the Internet.

As part of its efforts to evaluate and improve Internet access and quality for its residents, the City of Madison conducted a survey of residents in Spring 2016. Key findings include:

- Madison residents are highly connected, with 95 percent of respondents having some form of Internet connection. Specifically, 89 percent of residents have home Internet service and 77 percent have a cellular telephone with Internet.
- Older, low-income, and less-educated respondents are less likely than their counterparts to have some form of Internet access at their home.
- Approximately two-thirds of households use a cable modem Internet connection, while much smaller shares have DSL, satellite, fixed wireless, and other connections. The most frequent uses of home Internet are streaming movies, videos, or music, buying products online, and connecting to a work computer. Seven in 10 respondents occasionally use the Internet to access City of Madison information or services.
- Reliability of respondents' Internet connections ranks as the most important aspect of their Internet service, followed by connection speed and price paid. Residents are generally satisfied with the speed and reliability of their Internet service.
- Respondents indicated a willingness to switch to a very high-speed Internet connection, especially at monthly prices lower than $50 or for a one-time hookup fee at or below $250.
- More than one-half of respondents' employers allow telework, and more than one-fourth of responding households have a member who already teleworks.
- An equal share of respondents has antenna (over-the-air) television service, cable television, or television service through the Internet. Those under age 45 are less likely than older respondents to have cable television but are more likely to use the Internet. The most important television programming features are local programming and news programming.
- About six in 10 respondents said that the City should install a state-of-the-art communications network and either offer services or allow private companies to offer services to the public.

This section documents the survey process, discusses methodologies, presents results, and provides key findings that will help the City assess the current state and ongoing needs of its residents regarding high-speed communications services.

4.1 Survey Process

4.1.1 Overview

The City of Madison has a diverse and robust urban climate, and embraces new trends and technologies to improve its economy and quality of life. Supporting its innovative culture is use of the Internet and the myriad of applications and services that are enabled by robust Internet access and services.

As part of a broader effort to evaluate and improve high-speed communications services, the City of Madison conducted a mail survey of randomly selected residences in May 2016. The survey captured information about residents' current communications services, satisfaction with those services, desire for improved services, willingness to pay for faster Internet speeds, and opinions regarding the role of the City in enabling Internet access and service. A copy of the survey instrument is included in Appendix A.

The City acquired the services of Columbia Telecommunications Corporation (CTC) to help assess communications services within the City. CTC and its partner market research firm, Clearspring Research (together, the "Consultant"), coordinated and managed the survey project, including development of the draft questionnaire, sample selection, mailing and data entry coordination, survey data analysis, and reporting of results. CTC and Clearspring have substantial experience conducting similar surveys for municipalities nationwide.

4.1.2 Coordination and Responsibilities

A project of this magnitude requires close coordination between the City and the Consultant managing the project. This section briefly describes the project coordination and responsibilities.

In the project planning phase, the City and the Consultant discussed the primary survey objectives, the timing of the survey and data needs, and options for survey processes. The project scope, timeline, and responsibilities were developed based on those discussions.

The Consultant developed the draft survey instrument based on the project objectives and provided it to City staff for review and comment. The City provided revisions and approved the final questionnaire. The Consultant purchased a mailing list of randomly selected City households to receive the survey packet. The Consultant also coordinated all printing, mailing, and data entry efforts and provided regular updates to City staff. The Consultant performed all data coding and cleaning, statistical analyses, response summaries, and reporting of results.

The primary responsible party at the City was the Chief Information Officer. The Consultant's primary responsible parties were the Principal Analyst, the Principal Research Consultant, and the Research Director.

4.1.3 Survey Mailing and Response

A total of 3,750 survey packets were mailed first-class in May 2016 with a goal of receiving 600 valid responses. Recipients were provided with a postage-paid business reply envelope in which to return the completed questionnaire. A total of 930 useable surveys were received by the date of analysis,[67] providing a gross[68] response rate of 24.8 percent. The margin of error for aggregate results at the 95 percent confidence level for 930 responses is ±3.2 percent, within the initial sample design criteria. That is, for questions with valid responses from all survey respondents, one would be 95 percent confident (19 times in 20) that the survey responses lie within ±3.2 percent of the population as a whole (roughly 90,500 households in the City).

4.1.4 Data Analysis

The survey responses were entered into SPSS[69] software and the entries were coded and labeled. SPSS databases were formatted, cleaned, and verified prior to the data analysis. Address information was merged with the survey results using the unique survey identifiers printed on each survey. The survey data was evaluated using techniques in SPSS including frequency tables, cross-tabulations, and means functions. Statistically significant differences between subgroups of response categories are highlighted and discussed where relevant.

The survey responses were weighted based on the age of the respondent. Since older persons are more likely to respond to surveys than younger persons, the age-weighting corrects for the potential bias based on the age of the respondent. In this manner, the results more closely reflect the opinions of the Madison adult population as a whole.

Table 11 and Figure 13 summarize the weighting used for survey analysis.

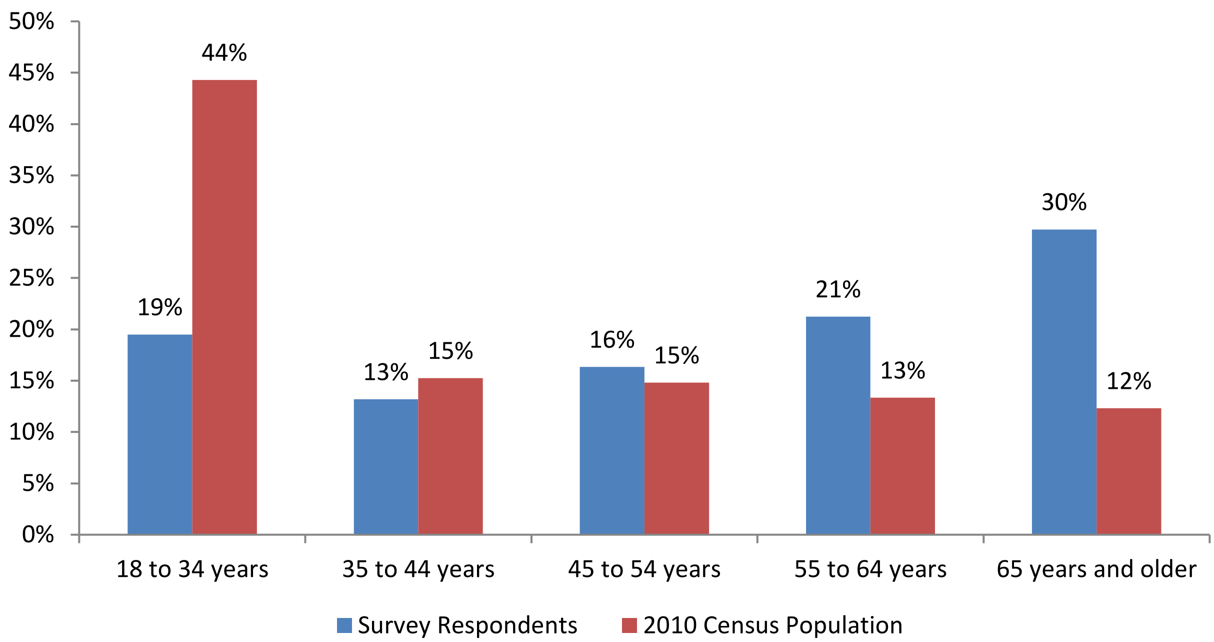
[67] At least 25 responses were received after analysis had begun, and are not included in these results.
[68] 90 surveys were undeliverable, mostly to vacant residences. The "net" response rate is 930/(3,750-90) = 25.4%.
[69] Statistical Package for the Social Sciences (http://www-01.ibm.com/software/analytics/spss/)

Table 11: Age Weighting

Age Cohort	Census Population	Survey Responses**	Weight
18-34*	80,552	179	2.272
35-44	27,731	121	1.157
45-54	26,926	150	0.906
55-64	24,250	195	0.628
65+	22,383	273	0.414
Total	181,842	918	

*For Census data, the 20-34 age cohort was used since many younger adults will not live in separate households.
**Not all respondents provided their age.

Figure 13: Age of Respondents and Madison Adult Population



The following sections summarize the survey findings.

4.2 Survey Results

The results presented in this report are based on analysis of information provided by 930 sample respondents from an estimated 90,500 households in Madison. Results are representative of the set of City households with a confidence interval of ±3.2 percent at the aggregate level.

Unless otherwise indicated, the percentages reported are based on the "valid" responses from those who provided a definite answer and do not reflect individuals who said "don't know" or otherwise did not supply an answer because the question did not apply to them. Key statistically-significant results ($p \leq 0.05$) are noted where appropriate.

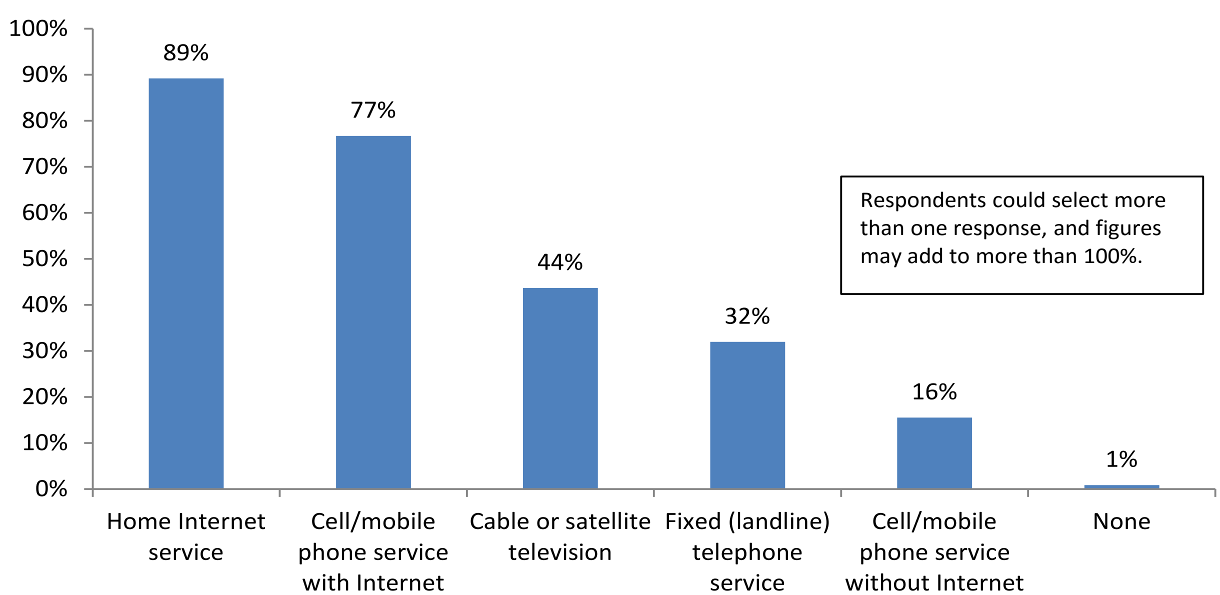
4.2.1 Home Internet Connection and Use

Respondents were asked about their home Internet connection types and providers, use of the Internet for various activities, and satisfaction and importance of features related to Internet service. This information provides valuable insight into residents' need for various Internet and related communications services.

4.2.1.1 Communications Services

Respondents provided information about the communication services currently purchased for their household. As illustrated in Figure 14, 89 percent of respondents purchase home Internet service, and 77 percent purchase cellular/mobile telephone service with Internet; 95 percent have some Internet access—either a home connection or via smartphone. Nearly one-third have fixed (landline) telephone service. Additionally, 44 percent of respondents have cable or satellite television (consistent with cable/satellite saturation reported later in the survey).

Figure 14: Communications Services Purchased



Use of communication services is correlated with the age of the respondent. In particular, those ages 65 and older are less likely to have Internet service in the home or to have cellular/mobile telephone service with Internet. They are more likely than younger respondents to have a fixed (landline) telephone service or cellular/mobile telephone service without Internet. Purchase of cable or satellite television services tends to increase with age, as shown in Figure 15.

Similarly, use of cellular/mobile telephone service with Internet and use of Internet service at home are higher for those with children ages 18 and younger at home, compared with those with no children in the household. Respondents with children at home are more likely than those without children at home to be ages 35 to 54 years of age, while those without children at home are more likely to be ages 18 to 34 years or 55 years or older (See Figure 16).

Figure 15: Services Purchased by Age of Respondent

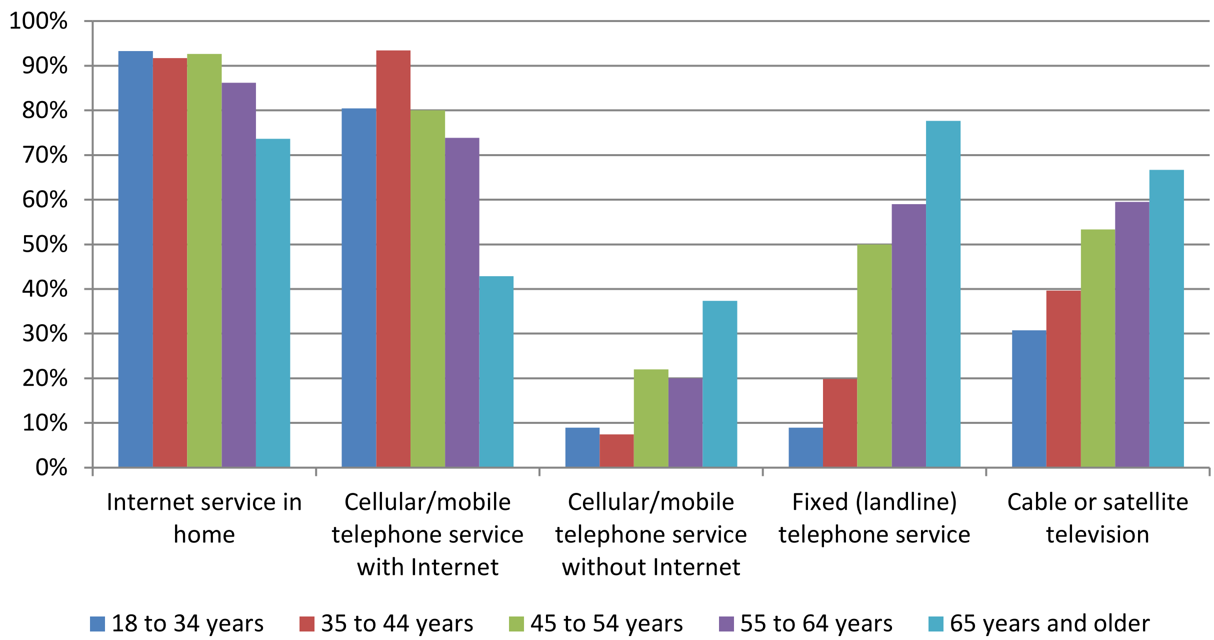
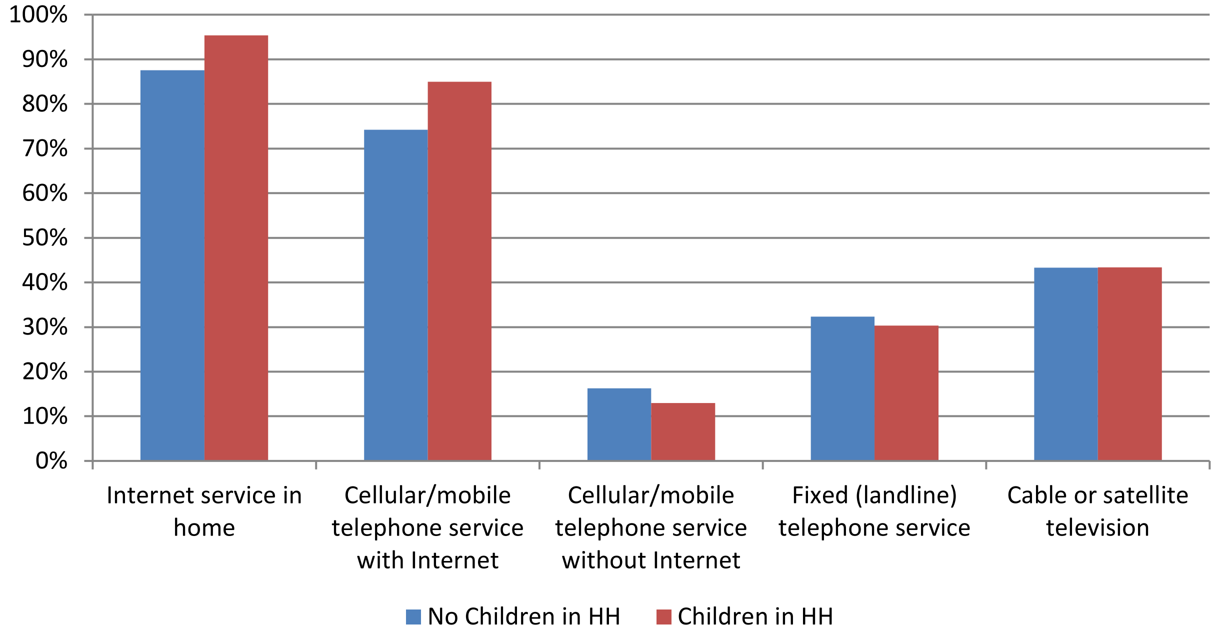
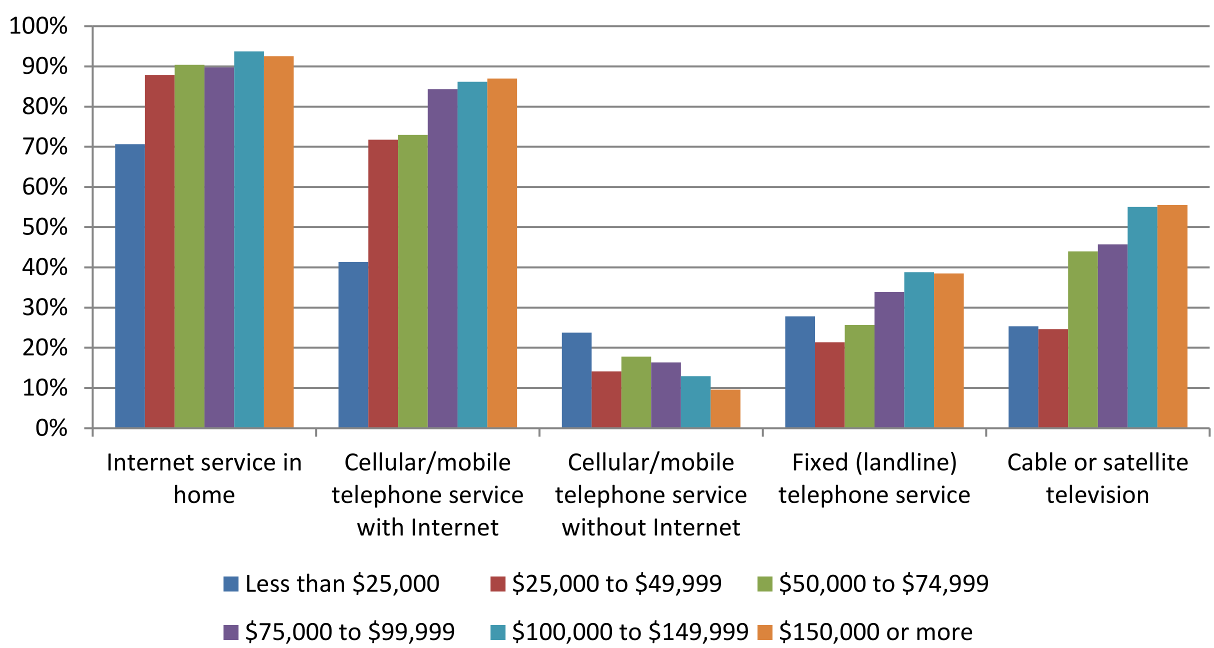


Figure 16: Services Purchased by Presence of Children in Household



The use of some communication services is also associated with household income. In particular, those earning under $25,000 per year are less likely to purchase Internet service in the home or to purchase cellular/mobile telephone service with Internet (see Figure 17).

Figure 17: Services Purchased by Household Income



As discussed previously, the majority of respondents have some Internet access, including 71 percent who have both home Internet service and a cellular/mobile telephone service with Internet (smartphone). Just 18 percent of respondents have a home connection only (no smartphone), and just 5 percent have a smartphone only (no home Internet).

When controlling for age of respondent, Internet usage is lower for households earning less than $25,000 per year for and respondents with a high school education or less. This holds true within all age groups, except for the 18 to 34 cohort for which Internet saturation is universally high.

Table 12: Internet Access by Key Demographics

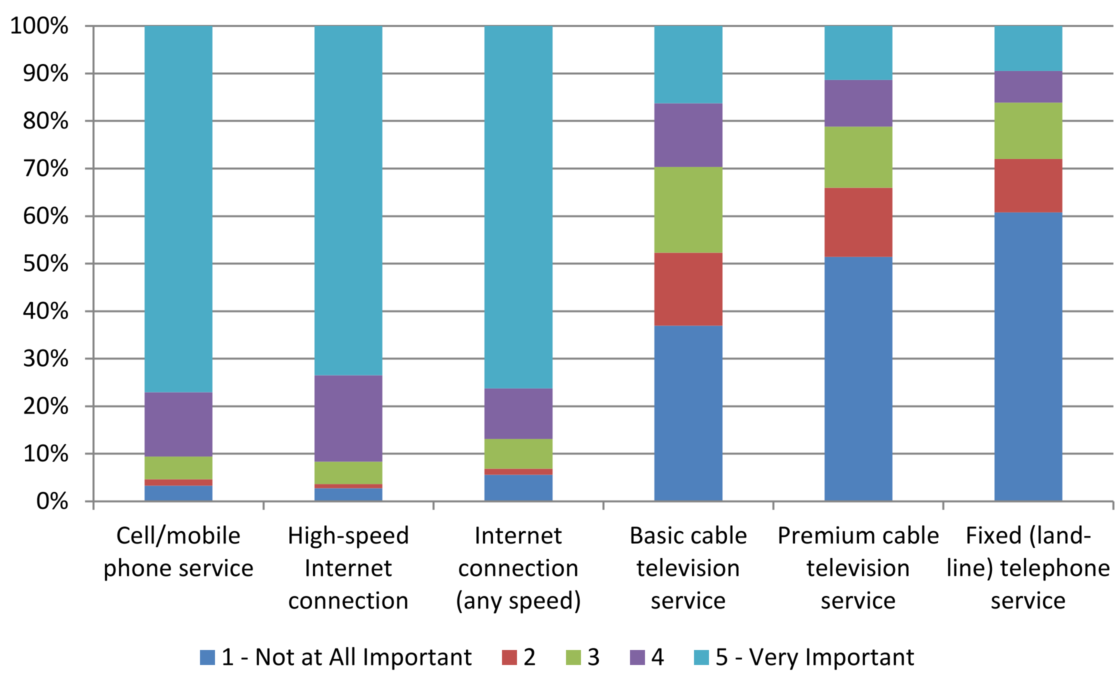
		Home Internet Connection Only	Smartphone Only	Both Home/ Smartphone	Total Internet Access	No Internet Access	*Count*
Gender	Female	20%	5%	70%	94%	**6%**	*427*
	Male	16%	6%	73%	95%	**5%**	*488*
Age Group	18 to 34 years	17%	4%	77%	97%	**3%**	*407*
	35 to 44 years	6%	7%	86%	99%	**1%**	*140*
	45 to 54 years	17%	4%	76%	97%	**3%**	*136*
	55 to 64 years	19%	7%	67%	93%	**7%**	*122*
	65 years and older	37%	7%	36%	80%	**20%**	*113*
Race/ Ethnicity	Other race/ethnicity	20%	6%	66%	93%	**7%**	*90*
	White/Caucasian only	18%	5%	72%	95%	**5%**	*814*
Education Level	HS education or less	25%	9%	47%	81%	**19%**	*80*
	Two-year college or technical degree	20%	6%	67%	94%	**6%**	*116*
	Four-year college degree	17%	4%	76%	97%	**3%**	*407*
	Graduate degree	16%	6%	74%	96%	**4%**	*314*
Household Income	Less than $25,000	35%	6%	36%	76%	**24%**	*61*
	$25,000 to $49,999	23%	7%	65%	94%	**6%**	*188*
	$50,000 to $74,999	22%	5%	68%	95%	**5%**	*174*
	$75,000 to $99,999	12%	7%	77%	97%	**3%**	*165*
	$100,000 to $149,999	10%	3%	83%	97%	**3%**	*190*
	$150,000 or more	11%	5%	82%	98%	**2%**	*111*
Number of Children in Household	No Children in HH	19%	6%	68%	93%	**7%**	*697*
	Children in HH	14%	3%	82%	99%	**1%**	*221*
Total Household Size (Adults + Children)	1	22%	6%	59%	87%	**13%**	*230*
	2	18%	5%	73%	97%	**3%**	*395*
	3	21%	8%	67%	96%	**4%**	*135*
	4 or more	8%	2%	89%	99%	**1%**	*157*
Own or Rent Residence	Own	15%	4%	76%	95%	**5%**	*596*
	Rent	23%	7%	63%	93%	**7%**	*320*
Year at Current Address	Less than 1 year	16%	5%	72%	94%	**6%**	*99*
	1 to 2 years	16%	2%	77%	95%	**5%**	*197*
	3 to 4 years	17%	8%	73%	99%	**1%**	*158*
	Five or more years	19%	6%	68%	93%	**7%**	*467*

4.2.1.2 Importance of Communication Services

Respondents were asked about the importance of various communications services to their household. Internet and cell/mobile phone services were by far the most important, with roughly three-fourths saying cell/mobile phone service, High-speed Internet service, or Internet connection of any speed are "very important," as shown in Figure 18.

Just a small segment of respondents placed moderate or high importance on basic cable television service, premium cable television service, or fixed (landline) telephone service. Although 30 percent of respondents indicated that basic cable television service is of some importance, 37 percent said it is "not at all important." Furthermore, one-half said premium cable television service is "not at all important," and six in 10 said fixed (landline) telephone service is "not at all important." As noted previously, only 32 percent of Madison homes have landline telephone service.

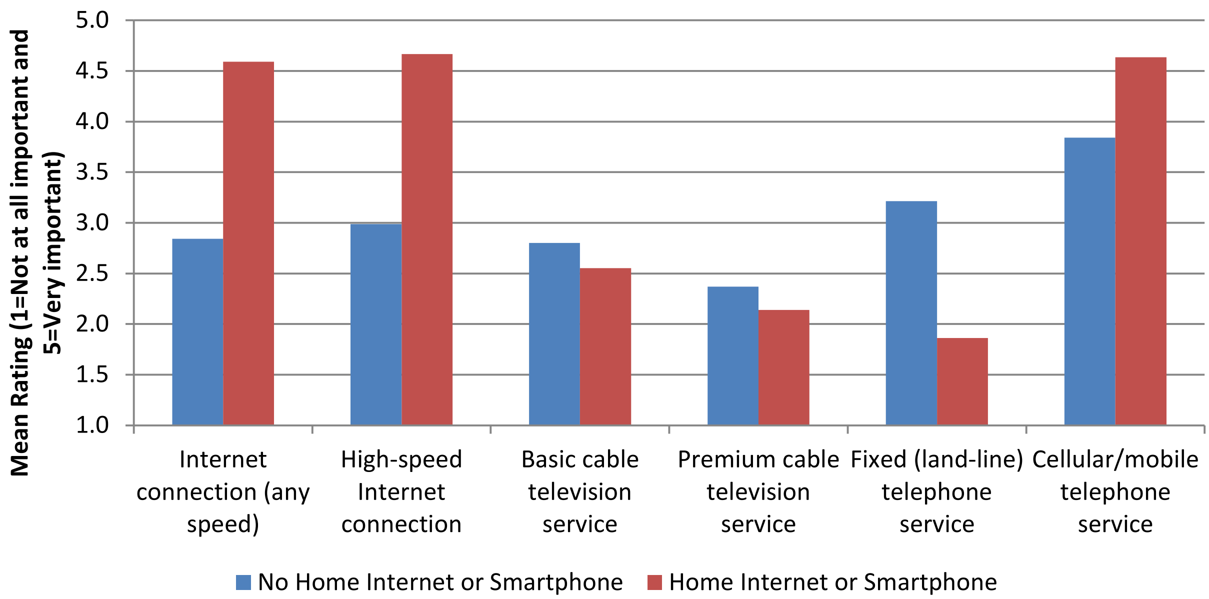
Figure 18: Importance of Communications Service Aspects



As noted previously, only a small share of respondents does not have any Internet connection in their home. Therefore, conclusions regarding this segment of respondents are generally not considered statistically significant, but rather viewed as indicative for those not having home Internet but answering questions regarding the importance of Internet and other metrics.

For households without home Internet service, the importance placed on cell/mobile telephone service, High-speed Internet service, or Internet connection of any speed is much lower than for those with some form of Internet access. Just a small segment of respondents with no Internet access said these features are "very important" (see Figure 19).

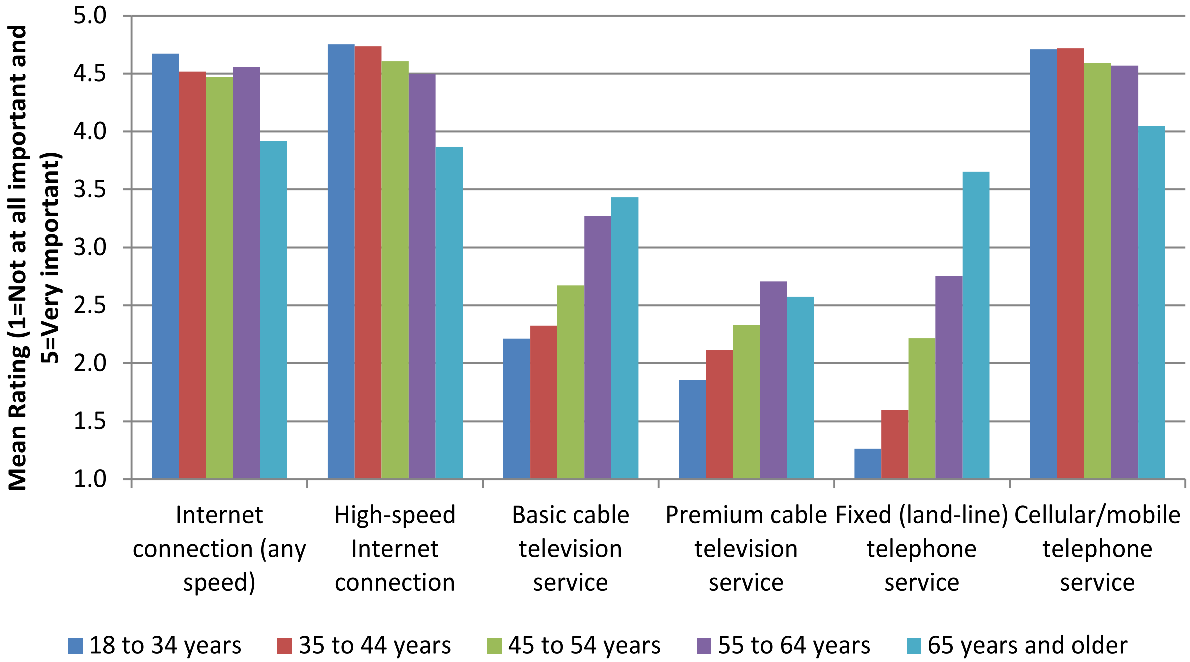
Figure 19: Importance of Communications Services by Home Internet Service



Although more than one-third (35 percent) of those without Internet said these services are "very important," this represents less than 2 percent of the total survey sample. This implies that there is not a sizeable gap between desire for Internet services and access to these services. As noted previously, those ages 65+, less-educated, and lower-income respondents are less likely to have home Internet or a smartphone. Only for the 18 to 34 age group did respondents without Internet place high importance on Internet-related services (suggesting there may be issues with access to Internet for this sub-group), but this is based on a small number of respondents and may not be statistically reliable.

Figure 20 illustrates the importance of communications services by the age of the respondent. The importance of an Internet connection and cellular telephone service is lower for those ages 65 and older. Conversely, the importance of cable television and landline telephone services tends to increase with the age of the respondent.

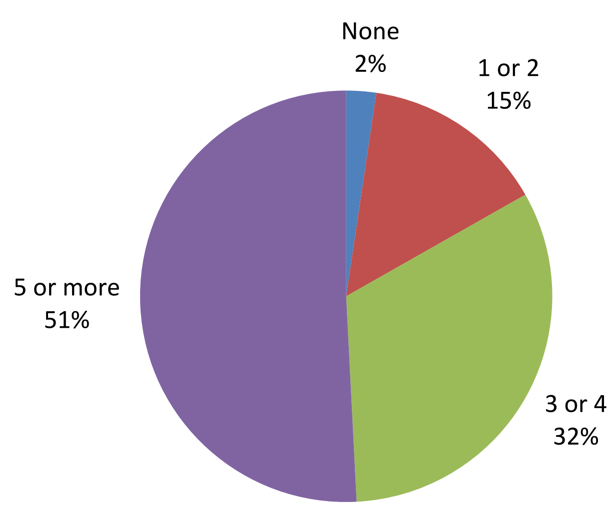
Figure 20: Importance of Communications Services by Age of Respondent



4.2.1.3 Personal Computing Devices

Respondents were asked to indicate the number of personal computing device they have in the home. As might be expected, all respondents with Internet access (either home connection or smartphone) have at least one personal computing device. Six in 10 respondents without Internet access also have a personal computing device.

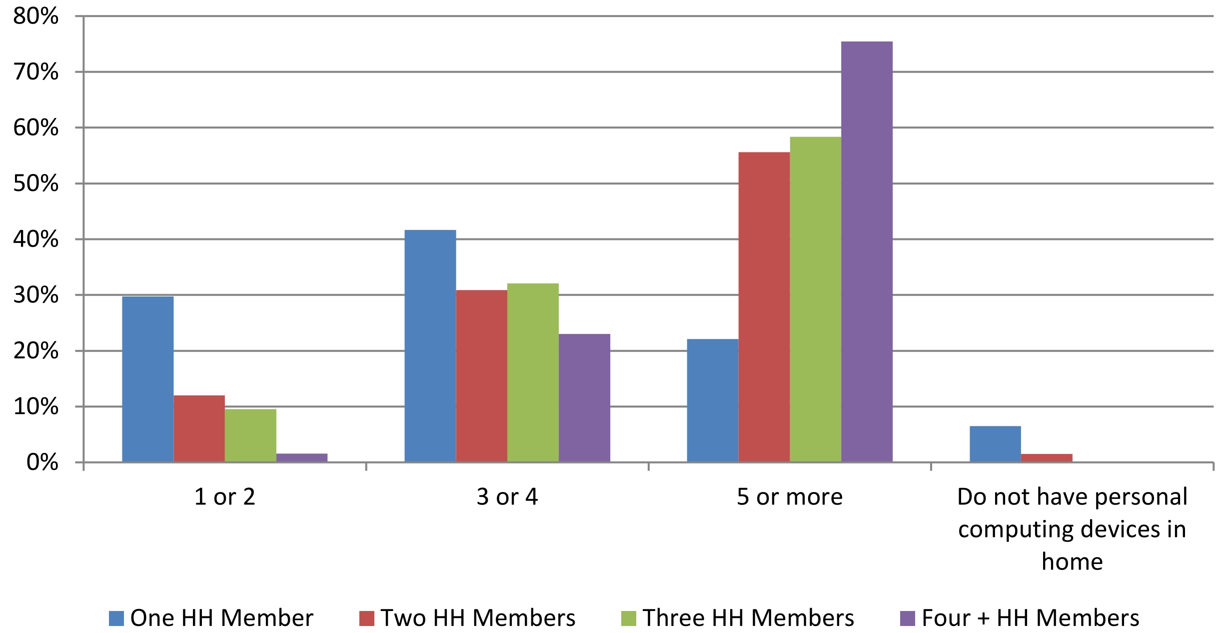
Figure 21: Number of Personal Computing Devices



One-half of respondents have five or more personal computing devices. Another 32 percent have three or four devices, and 15 percent have one or two devices (see Figure 21).

The number of personal computing devices in the home correlates with household size. Three-fourths of households with four or more residents have at least five personal computing devices (see Figure 22).

Figure 22: Number of Personal Computing Devices in Home by Household Size



Similar to respondents ages 65 and older, those with household earning under $25,000 per year, and those with a high school education or less are less likely to have home Internet or personal computing devices, although saturations are still relatively high. (See Figures 23 to 25.)

Figure 23: Have Computing Device(s) and Internet in Home by Age of Respondent

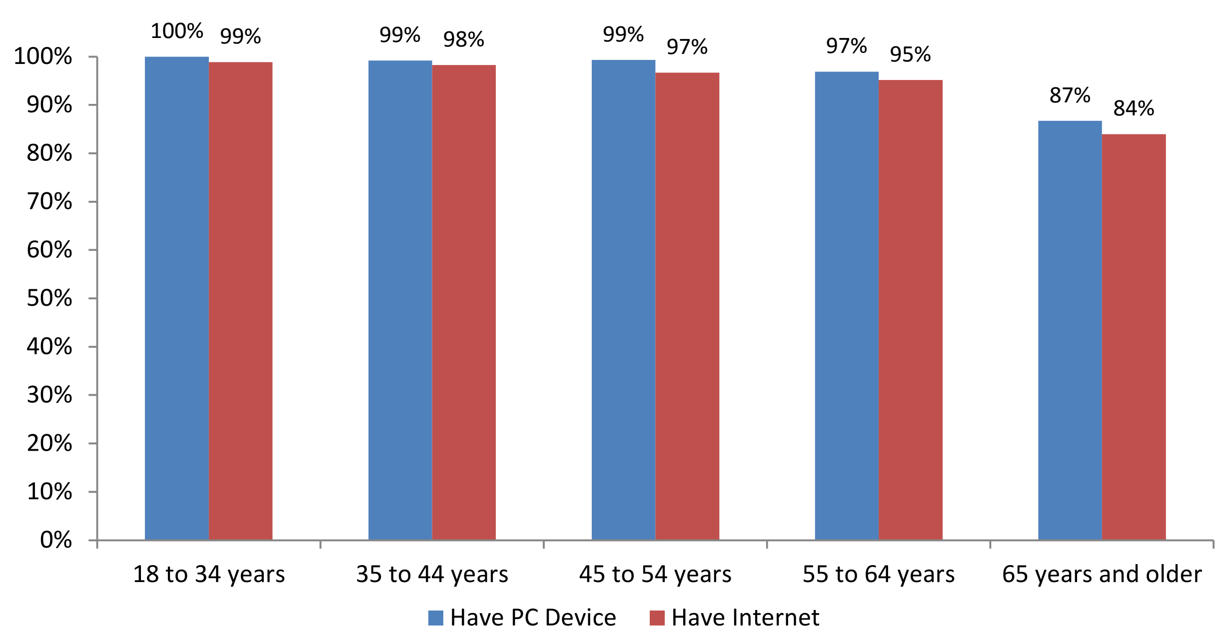


Figure 24: Have Computing Device(s) and Internet in Home by Level of Education

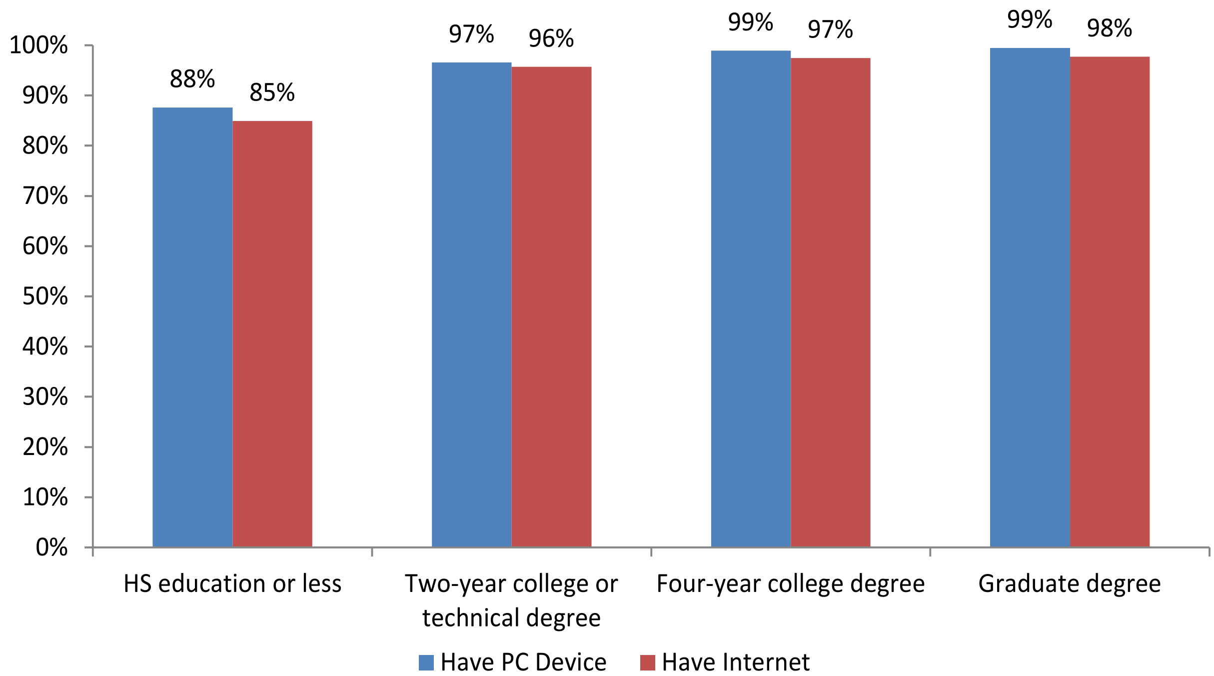
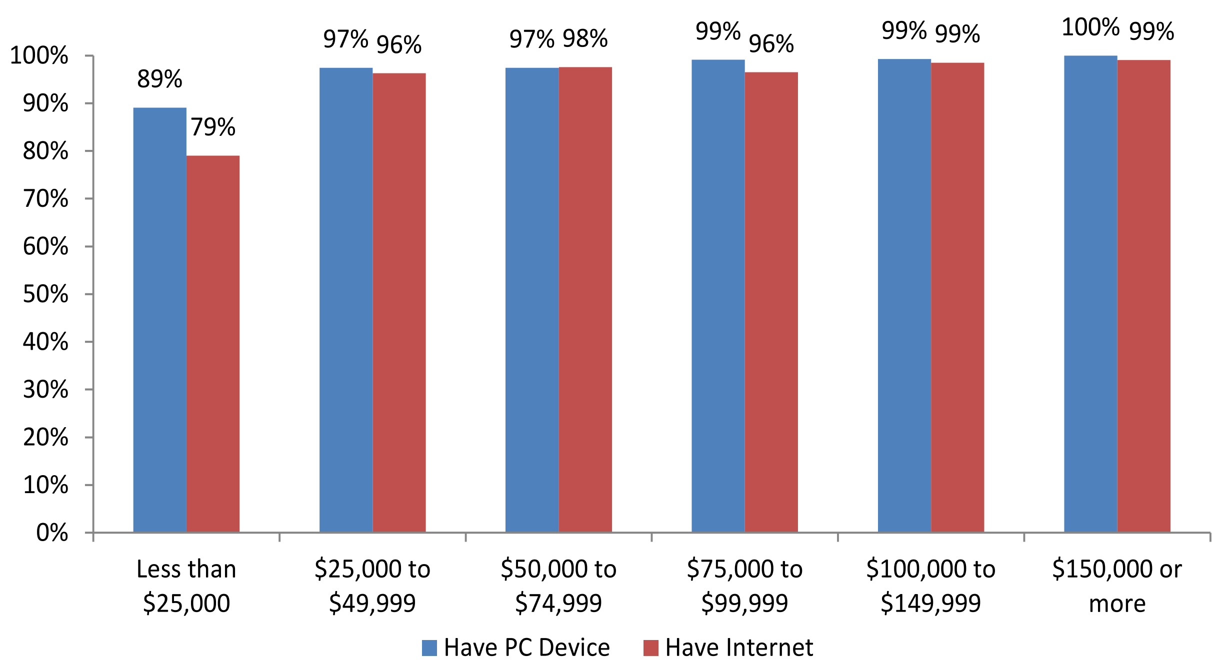


Figure 25: Have Computing Device(s) and Internet in Home by Household Income

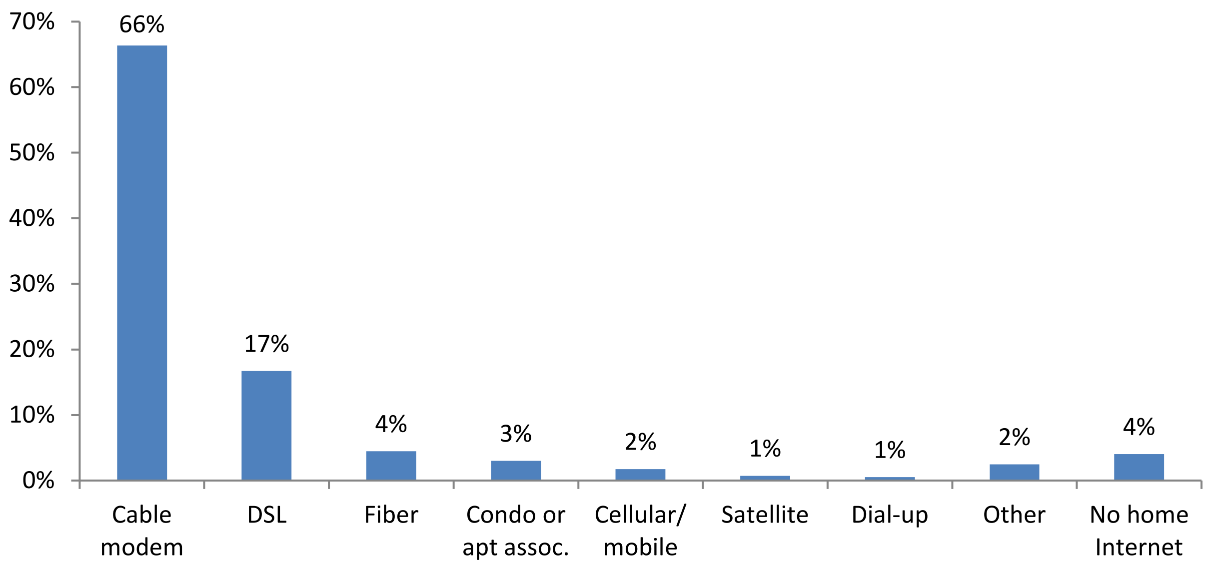


4.2.1.4 Internet Services Purchased

Respondents were asked about their purchase of Internet services for their home, as well as the cost and speed of services purchased.

As shown in Figure 26, the majority of homes (96 percent) reported having home Internet service, consistent with 95 percent reporting Internet access via a home connection or via a smartphone in Question 1. Two-thirds of respondents have a cable modem connection as their primary connection, and 17 percent have a Digital Subscriber Line (DSL). Only 2 percent indicated that they use a cellular/mobile device as their primary Internet connection.

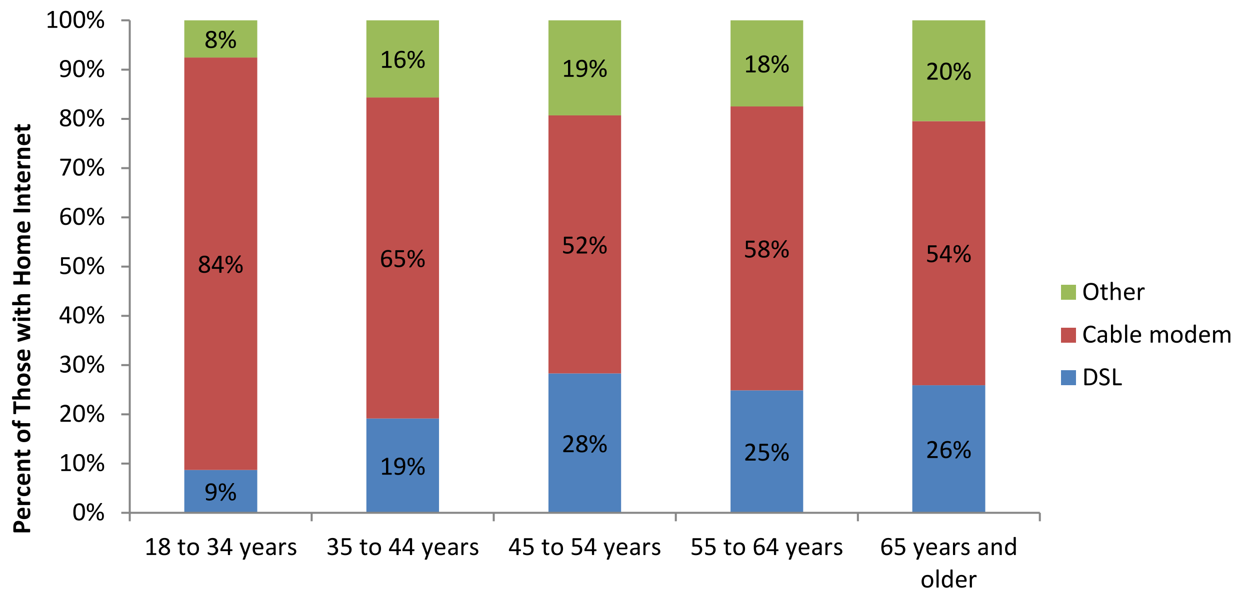
Figure 26: Primary Home Internet Service



Eighteen of 34 responding households without Internet access (and who provided a response) said that the expensive cost is the main reason for not purchasing home Internet service.

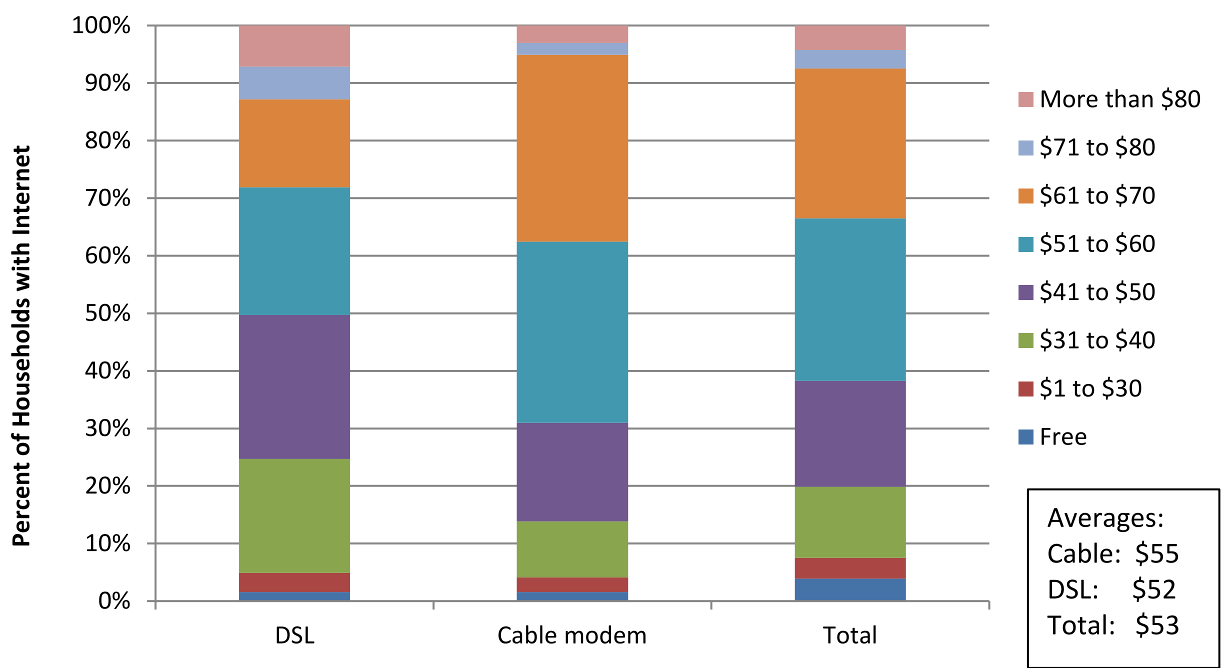
Purchase of home Internet connection or a smartphone was discussed in detail in the previous section. But, among those with home Internet, the connection type also varies significantly by age of respondent. Specifically, those ages 18 to 34 are more likely than older respondents to have a cable modem connection, and they are less likely to have DSL or another type of Internet connection, as shown in Figure 27.

Figure 27: Primary Home Internet Service by Age of Respondent



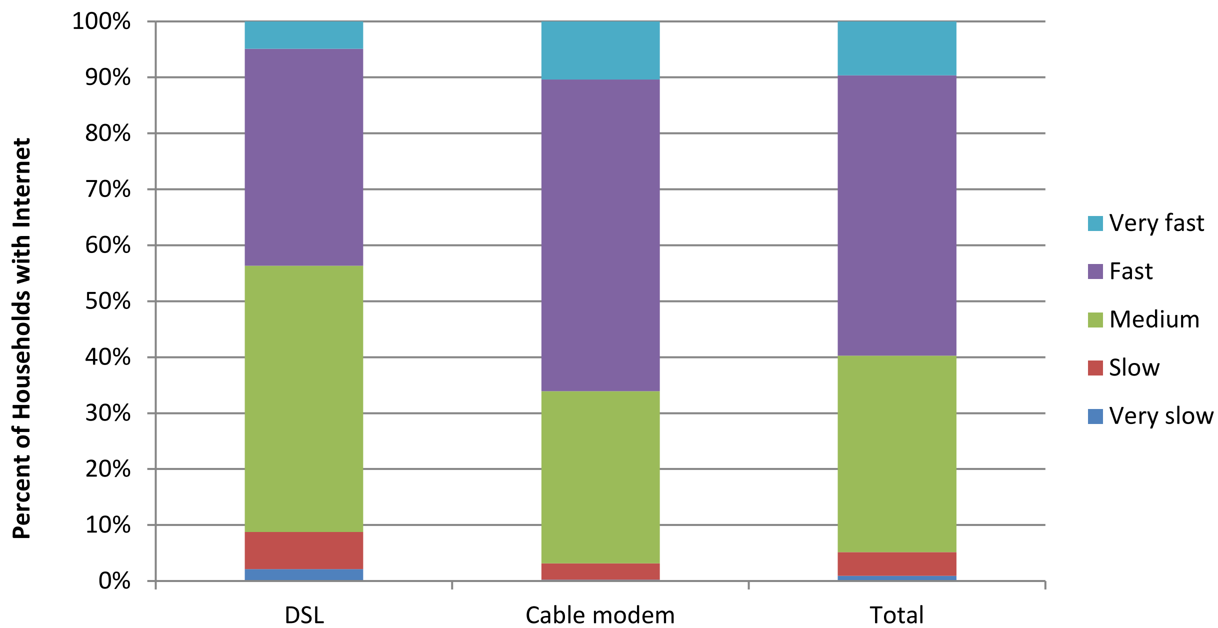
Madison households pay approximately $53 per month for Internet service, on average. The average monthly price is slightly higher for cable than for DSL, as illustrated in Figure 16. More than two-thirds (69 percent) of those with a cable modem pay more than $50 per month, compared with 50 percent of those with DSL. More than one-half of all respondents with Internet pay between $51 and $70 per month.

Figure 28: Estimated Average Monthly Price for Internet Service



Most Internet subscribers described their Internet speed as “medium” (35 percent) or “fast” (50 percent), while only 5 percent said it was “slow” or “very slow.” Cable Internet subscribers tended to rate their connection speed as somewhat faster than DSL, as illustrated in Figure 29.

Figure 29: Internet Speed (Respondent Opinion)



4.2.1.5 Internet Service Aspects

Respondents were asked to rate their levels of importance and satisfaction with various Internet service aspects. Respondents rated connection reliability as the most important aspect, followed by the connection speed and price, as shown in Table 13.

Table 13: Importance of Internet Service Aspects

Service Aspect	Mean	Top-Two Box Percentages
Speed of Connection	4.5	30% 62%
Reliability of Connection	4.8	9% 89%
Price of Services	4.4	29% 58%
Overall Customer Service	4.2	35% 37%
Ability to Bundle with TV service	2.4	9% 10%
Somewhat Important / Very Important		0% 20% 40% 60% 80% 100%

Respondents also rated the speed and reliability of their connection as the aspects with which they are most satisfied, as shown in Table 14. The lowest satisfaction aspect was for the price of service, which is typical in satisfaction surveys.

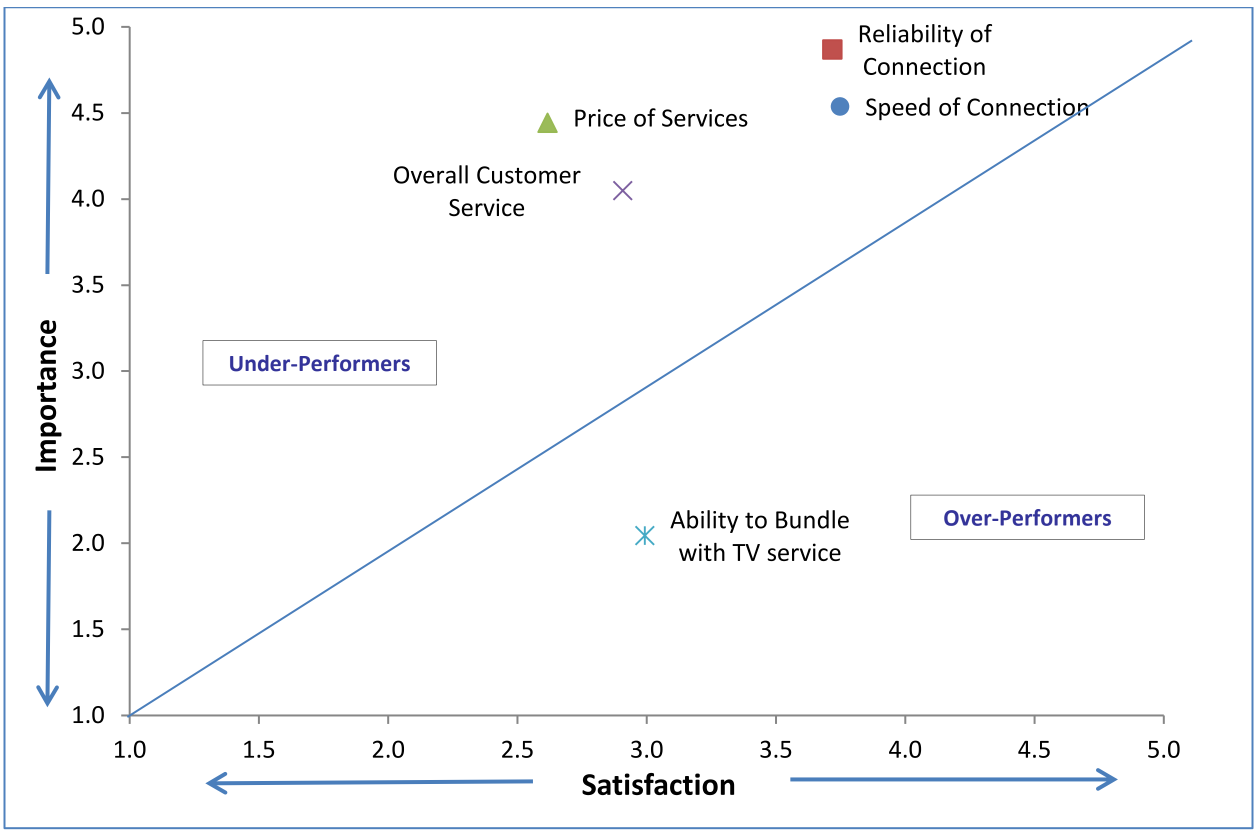
Table 14: Satisfaction with Service Aspects

Service Aspect	Mean	Top-Two Box Percentages
Speed of Connection	3.7	45% 21%
Reliability of Connection	3.7	41% 23%
Price of Services	2.6	13% 6%
Overall Customer Service	2.9	23% 6%
Ability to Bundle with TV service	3.0	16% 12%

Somewhat Satisfied Very Satisfied 0% 20% 40% 60% 80% 100%

A comparison of the importance placed upon Internet service aspects and satisfaction levels provides insight into aspects that are meeting consumers' needs and aspects where satisfaction falls short of importance levels. The importance scores and performance scores were plotted to help visually determine areas in which Internet service providers are doing well and areas that might need improvement. The "upper quadrant" of this "quadrant analysis" indicates that the price, reliability, and overall customer service are the largest "underperforming" aspects (that is, they are farthest from the equilibrium line), as illustrated in Figure 30.

Figure 30: Internet Service Aspect "Quadrant" Analysis



The difference between importance and satisfaction of home Internet aspects is also presented in the "gap" analysis table below. Again, the largest gaps between importance and performance are for price, reliability, and overall customer. Note that reliability has one of the highest satisfaction rankings, but the importance of reliability is extremely high. The only aspect with higher satisfaction than importance is the ability to bundle Internet with TV service.

Table 15: Internet Service Aspect "Gap" Analysis

	Mean Satisfaction	Mean Importance	GAP < = >	Customer Expectations
Ability to Bundle with TV service	3.0	2.0	0.9	Exceeded
Speed of Connection	3.7	4.5	-0.8	Not Met
Overall Customer Service	2.9	4.0	-1.1	Not Met
Reliability of Connection	3.7	4.9	-1.2	Not Met
Price of Services	2.6	4.4	-1.8	Not Met

4.2.1.6 Willingness to Pay for Faster Internet

Respondents were asked if they would be willing to switch to very fast Internet service (1 Gbps) for various price levels. The mean willingness to switch across this array of questions is illustrated in Figure 31, while detailed responses are illustrated in Figure 32.

Figure 31: Mean Willingness to Switch to 1 Gbps Internet at Price Levels

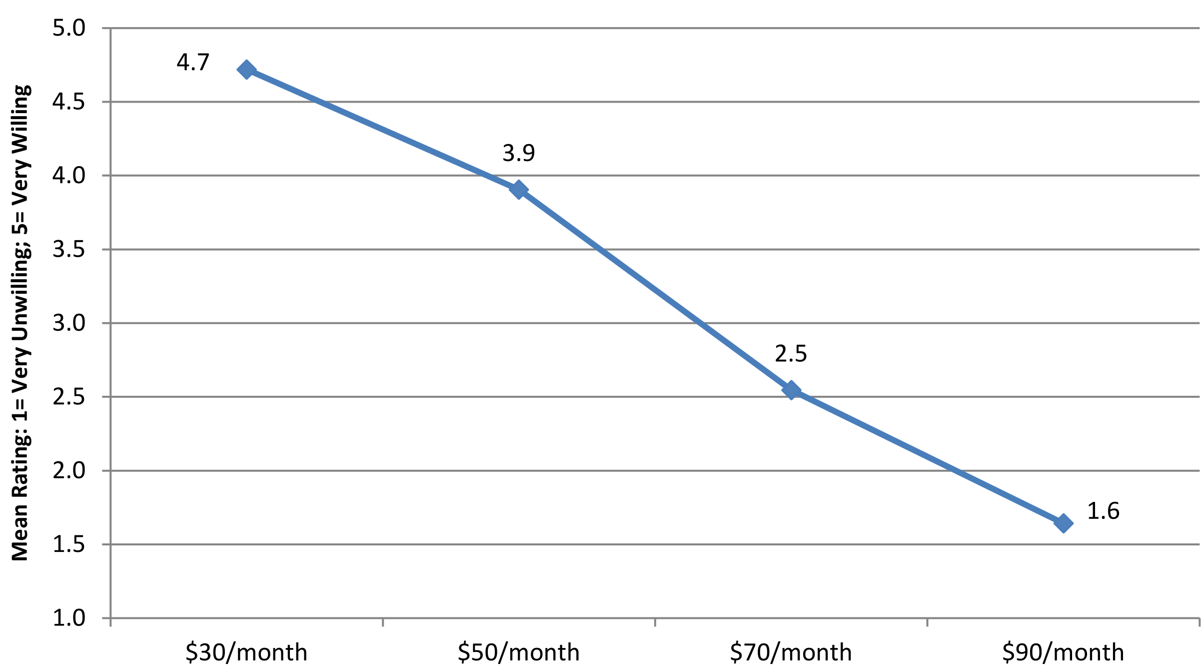
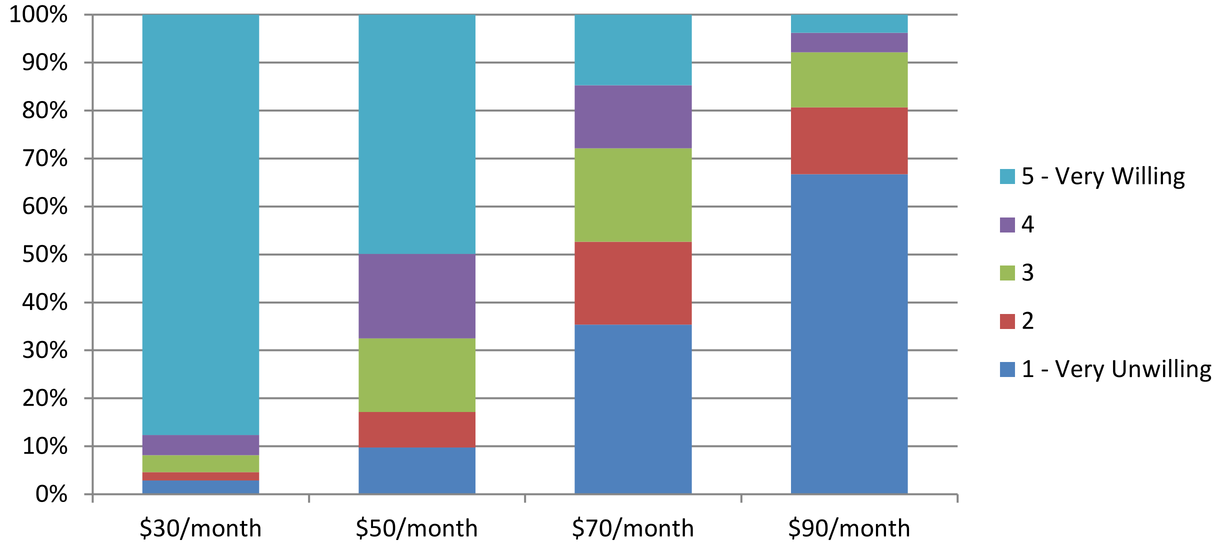
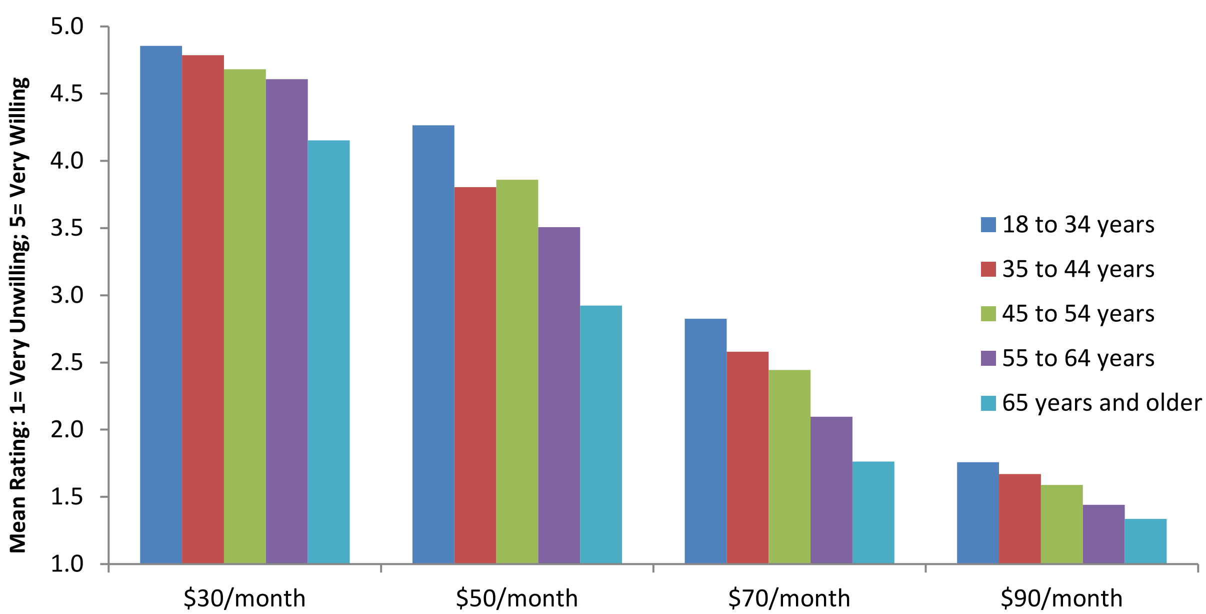


Figure 32: Willingness to Switch to 1 Gbps Internet at Various Price Levels



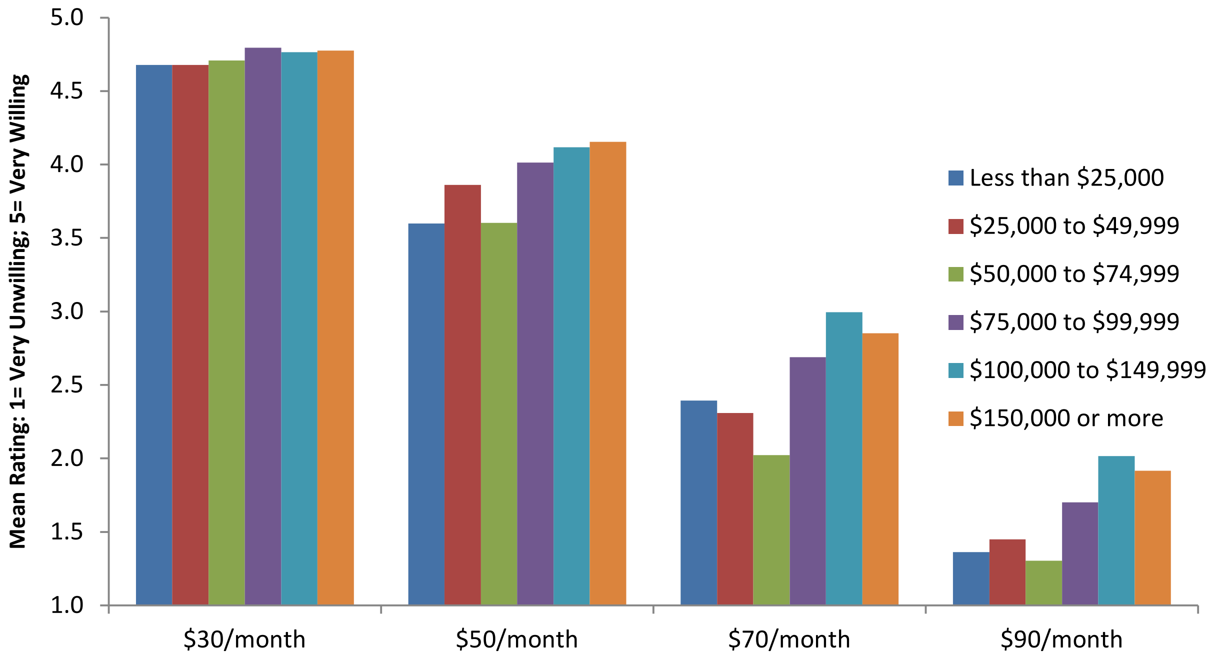
As is evident in Figure 31 and in Figure 32, respondents' willingness to switch to very fast Internet service (defined at 1 Gbps service in the survey) is very high at $30 per month, but drops considerably as the price increases. At a price of approximately $70 per month, the mean rating falls below 3.0 (neither willing nor unwilling). From another perspective, 92 percent are somewhat or very willing to switch to 1 Gbps Internet for $30 per month, dropping to 68 percent at $50 per month, 28 percent at $70 per month, and 8 percent at $90 per month.

Figure 33: Willingness to Switch to 1 Gbps Internet by Age of Respondent



The willingness to switch to very fast Internet service tends to decrease as age increases, and it increases as household income increases (particularly at the higher price points).

Figure 34: Willingness to Switch to 1 Gbps Internet by Price and Household Income



4.2.1.7 Internet Uses and Importance

Respondents were asked about their use of the Internet for various activities, as illustrated in Figure 35. The most common use of the Internet (among those listed) is watching movies, videos, or TV. Nearly three-fourths (72 percent) frequently use the Internet for this purpose. Approximately one-half frequently use the Internet for shopping online, listening to music, or connecting to a work computer. Use of the Internet for running a home business or playing online games is less frequent. Seven in 10 occasionally use the Internet to access City of Madison information or services; just 9 percent access the site frequently.

The use of the Internet for some activities varies by age, as illustrated in Figure 35. Younger respondents are much more likely to use the Internet for many applications, especially listening to music and watching videos or movies. With the exception of accessing the City of Madison website, Internet subscribers ages 65+ are less likely to ever use the Internet for the various activities evaluated.

Figure 35: Home Internet Activities

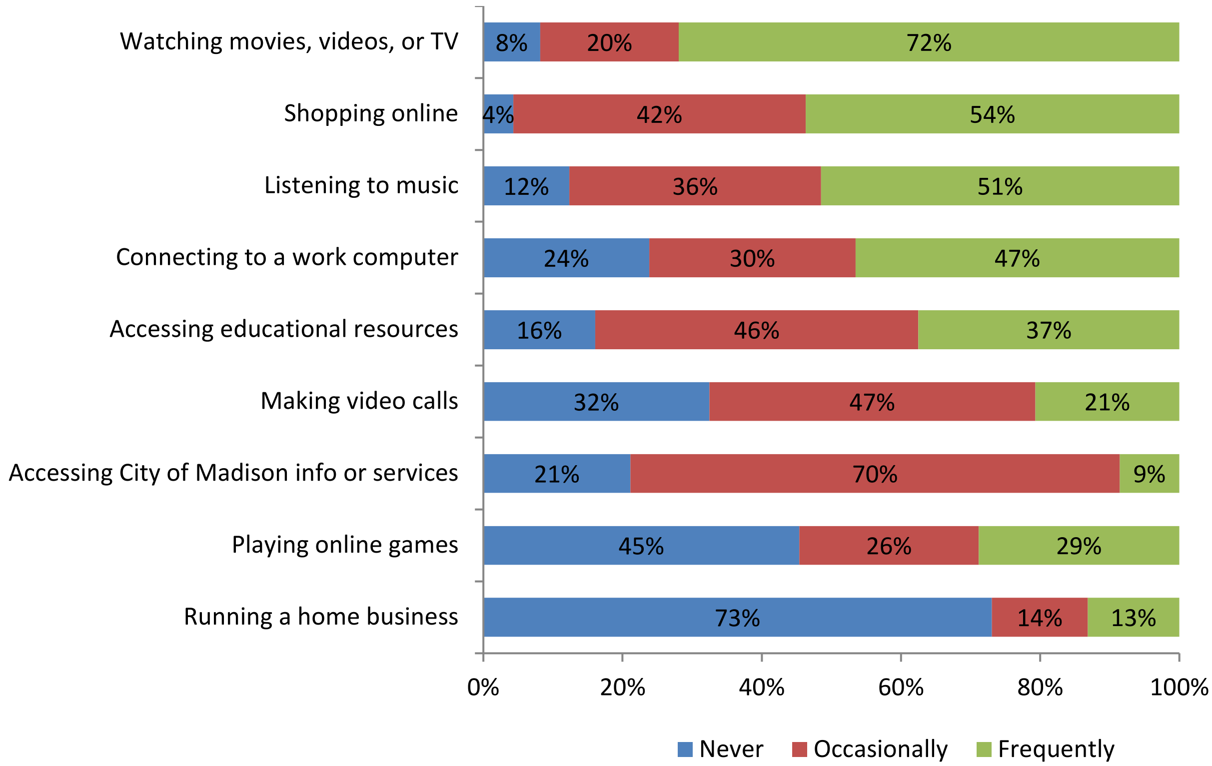
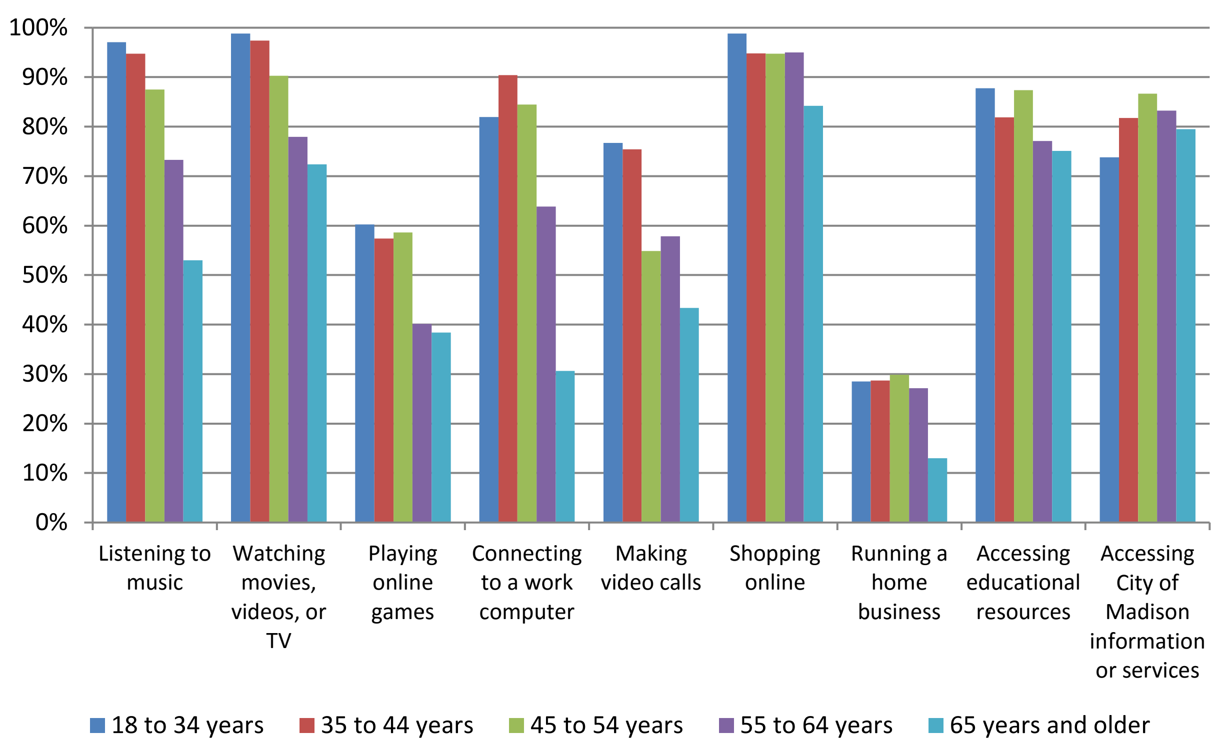


Figure 36: Home Internet Activity by Age of Respondent (Percent Ever Using)



Respondents were asked to rate the importance of aspects when selecting a home Internet provider. The most important aspect is the service provider not placing "caps" on total data use. Six in 10 respondents with Internet said this aspect is "very important." One-half said that buying Internet service with very high connection speeds is "very important." The least important aspect of home Internet service is paying for service based on usage. Just one-fourth of respondents gave this aspect a rating of "4" or "5" (see Figure 37).

Figure 37: Importance of Aspects When Selecting a Home Internet Provider

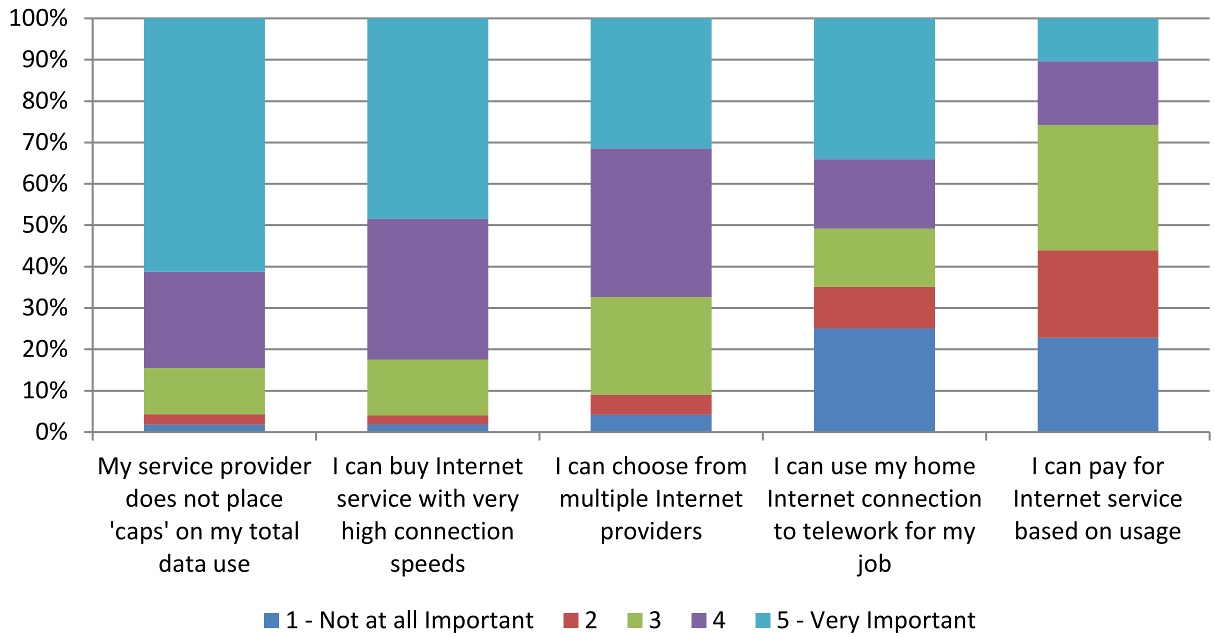
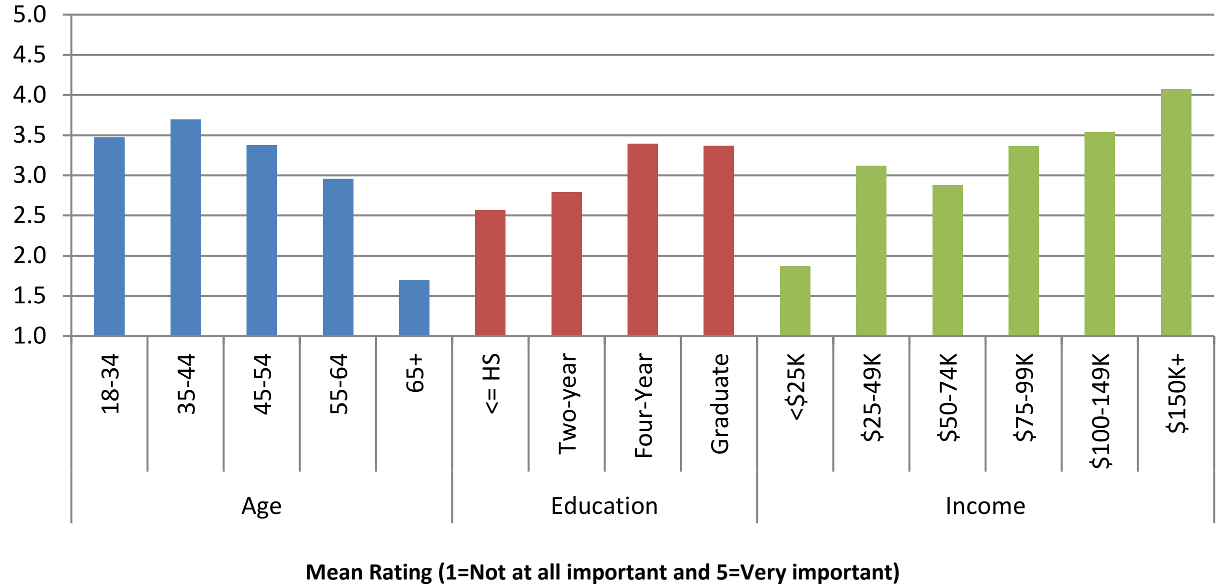


Figure 38: Importance of Home Internet Service to Telework by Demographics

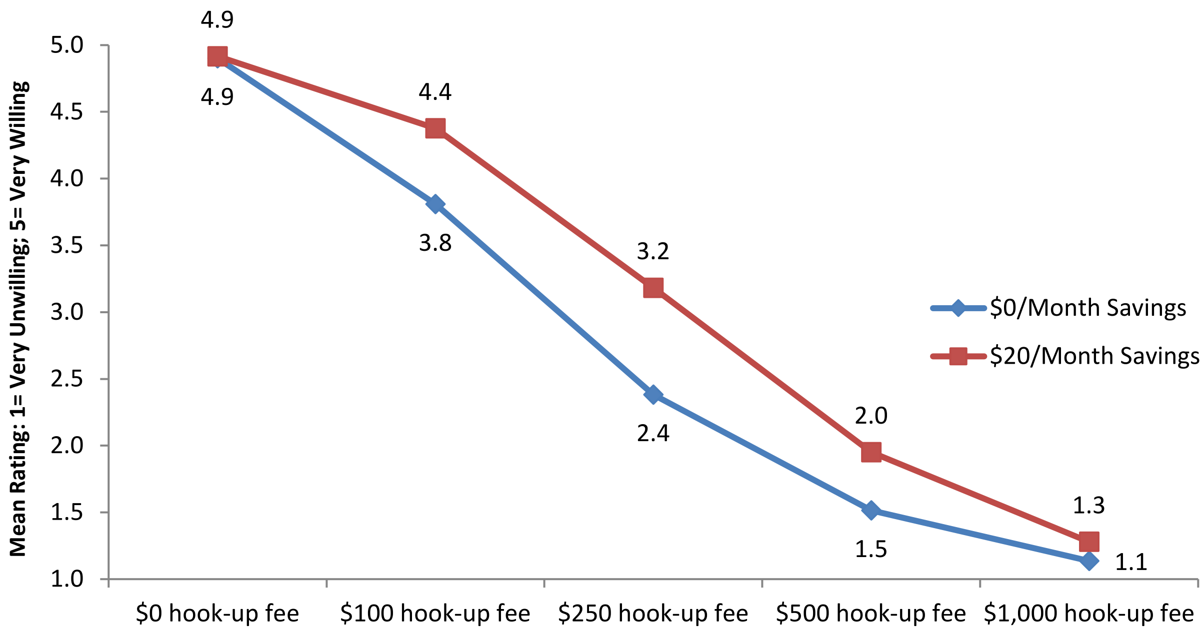


The importance of using a home Internet connection to telework varies by key demographic groups. As might be expected, those ages 65 and older (who are more likely to be retired) gave a lower mean rating to this aspect. The average importance rating also increases as household income increases, and those with at least a four-year college degree placed more importance on this aspect than did those with less education, as illustrated in Figure 38.

4.2.1.8 Willingness to Pay Hook-Up Fee for Fiber-Optic Network

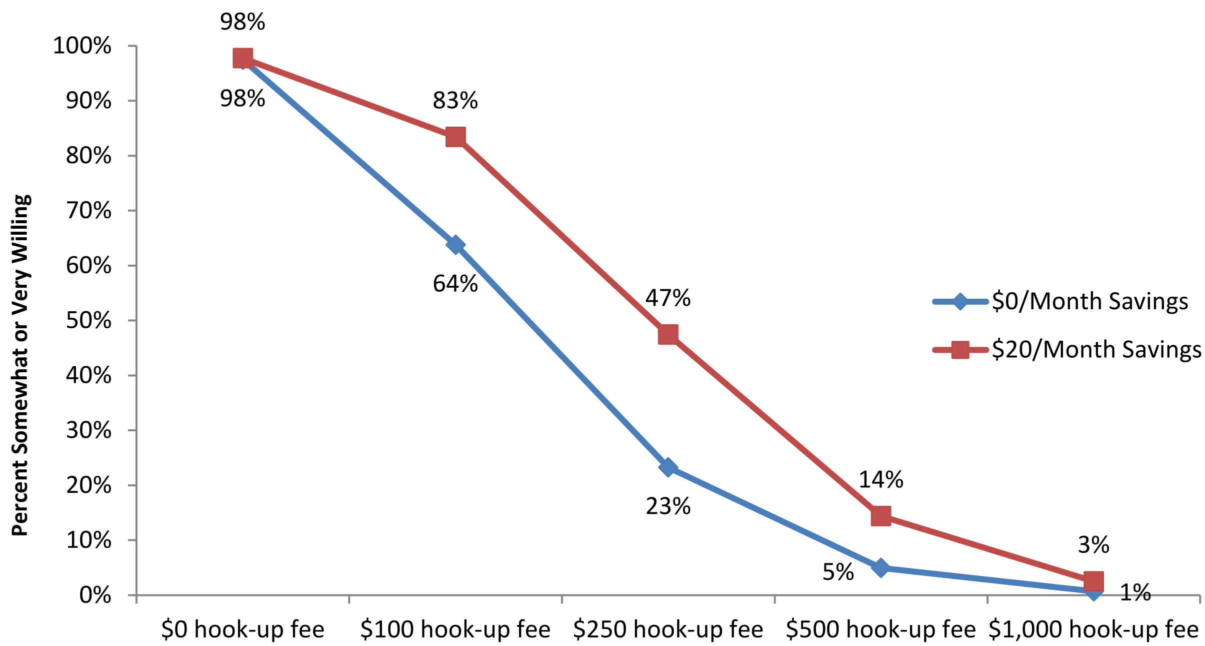
Respondents were asked if they would be willing to pay an upfront hook-up fee to connect to a fiber-optic communications network with very fast Internet (1 Gbps) for: no savings per month and for $20 savings per month on their communications bill. Almost all respondents would be very willing to switch to the network (for $0 savings and for $20 savings) for no hook-up fee. Additionally, they would be more willing to pay the fee for some savings on their monthly communications bill. Respondents are somewhat willing to pay a $100 hook-up fee, particularly for $20 per month savings, but willingness to pay a hook-up fee falls sharply at higher price points, as shown in Figure 39.

Figure 39: Average Willingness to Pay Upfront Hook-Up Fee for Fiber Optic Network



Almost all respondents (98 percent) are somewhat or very willing to pay no fee to connect to the network. The majority would pay a $100 hook-up fee for no savings (64 percent) or a $20 savings per month (83 percent). Although nearly one-half would be at least somewhat willing to pay a $250 hook-up fee for a $20 per month savings, this falls to 23 percent if there were no monthly savings on their bill, as illustrated in Figure 40.

Figure 40: Willingness to Pay Upfront Hook-Up Fee for Fiber Optic Network



The willingness to pay an upfront hook-up fee tends to increase as household income increases, for either no monthly savings or for a $20 per month savings (see Figure 41 and Figure 42).

Figure 41: Willingness to Pay Upfront Hook-Up Fee by Household Income

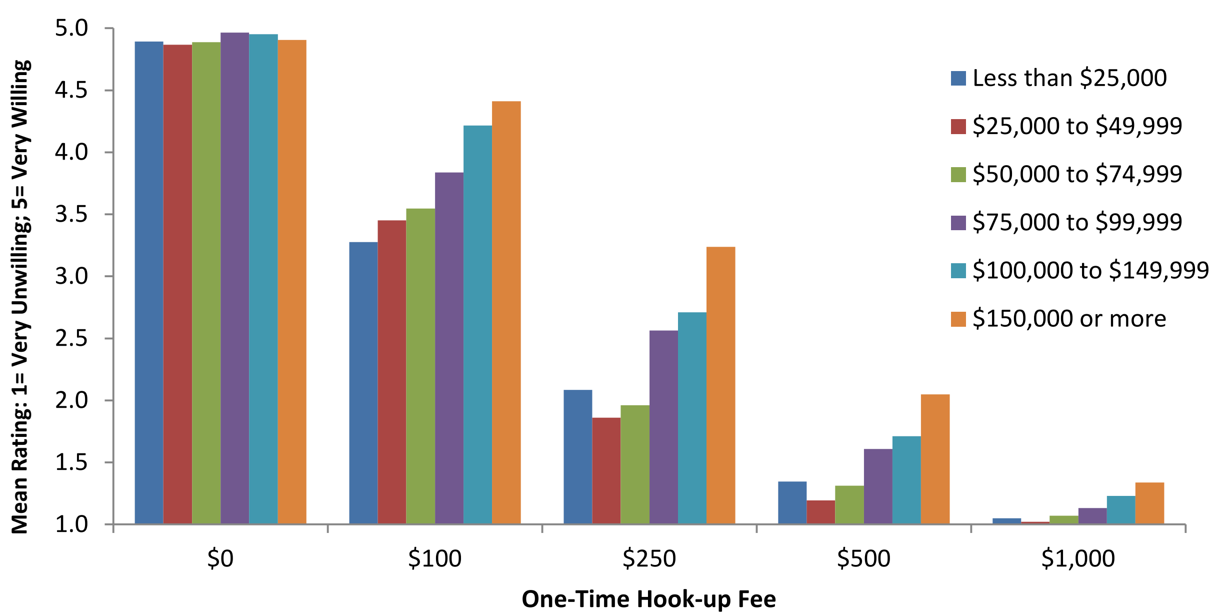
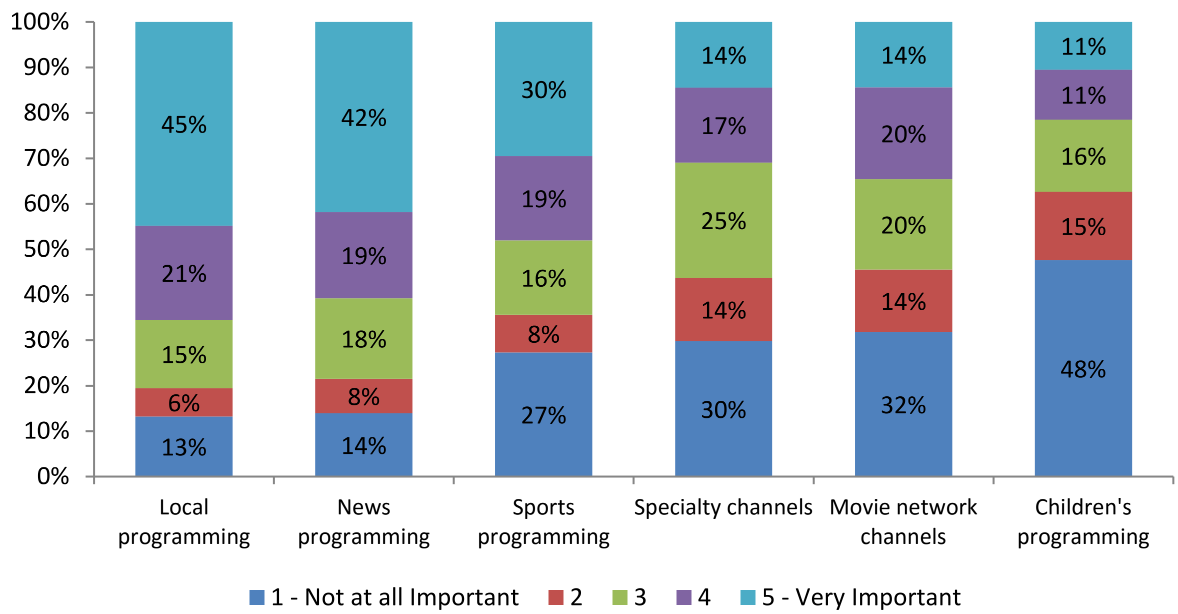


Figure 42: Willingness to Pay Upfront Hook-Up Fee for $20/Month Savings by Income

4.2.2 Television and Telephone Service

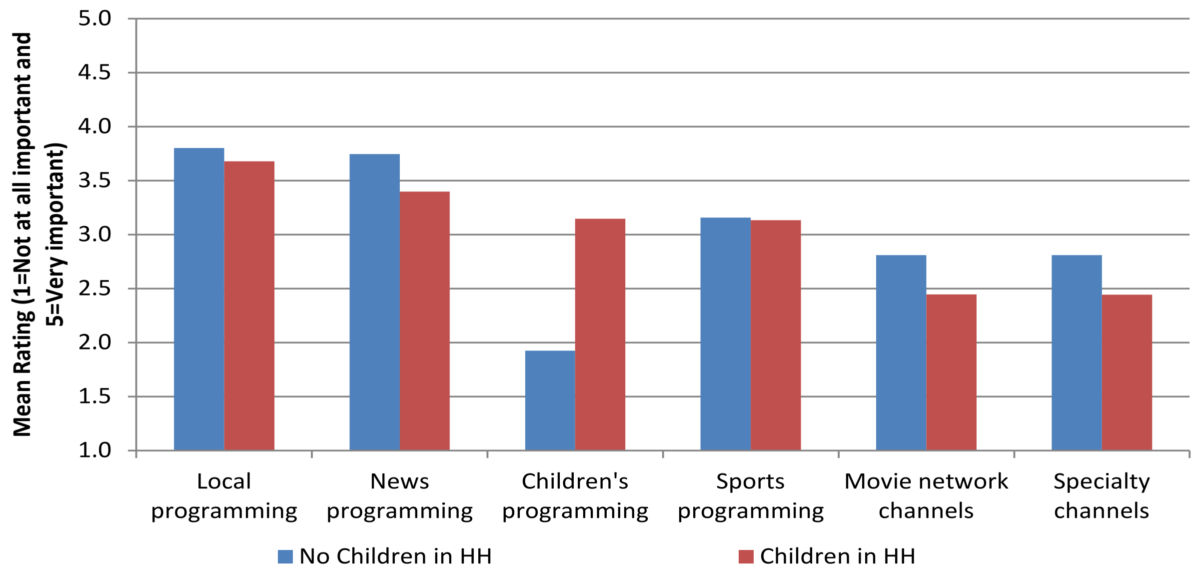
Respondents were asked to evaluate the importance of television programming features, as well as what television and telephone services they receive at home. The most important television programming aspects are local programming and news programming, while the least important is children's programming, as illustrated in Figure 43.

Figure 43: Importance of Television Programming Features



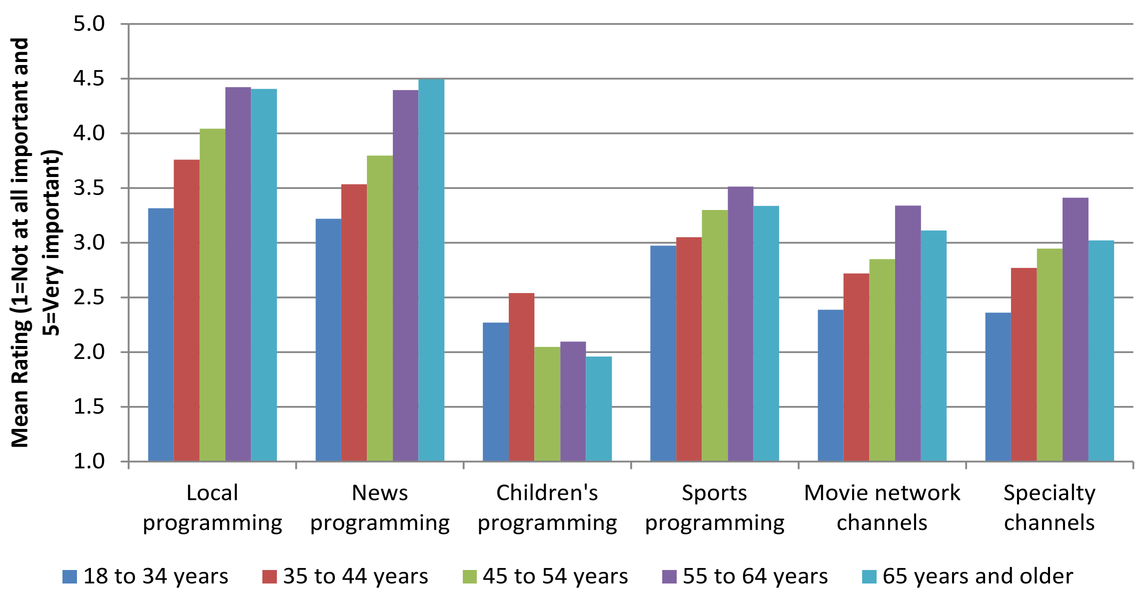
Specifically, about six in 10 gave a rating of "somewhat" or "very important" to local programming and news programming. Nearly one-half (48 percent) of respondents said that children's programming is "not at all important." Although those with children at home gave a higher importance rating to this aspect than did those without children in the household, it is still of only moderate importance overall, as shown in Figure 44.

Figure 44: Importance of Television Programming Aspects by Children in Household



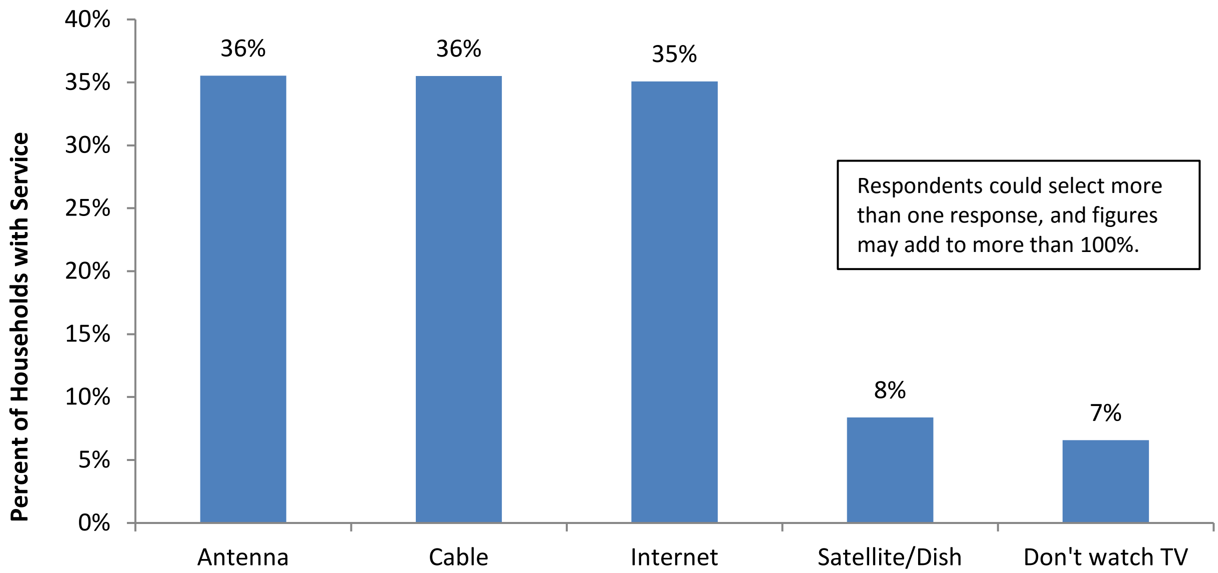
Additionally, the importance placed on local programming and news programming is higher for those ages 65 and older, compared with younger respondents (see Figure 45).

Figure 45: Importance of Television Programming Aspects by Age of Respondent



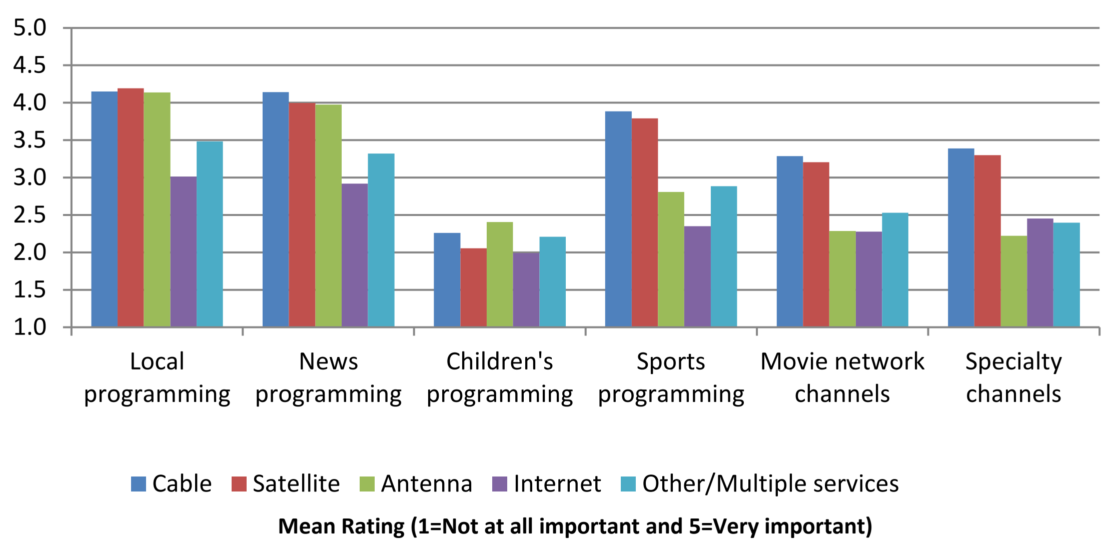
Equal shares of respondents have antenna (over-the-air) television service, cable television, or television service through the Internet. Just 8 percent have satellite/dish, and 7 percent do not watch television (see Figure 46).

Figure 46: Types of Television Service in Home



More than one-fourth of respondents have cable television service only, 20 percent have antenna only, 15 percent use the Internet only, and 7 percent have satellite TV service only. Another 28 percent use more than one type of television service, mainly antenna and Internet. Those who use the Internet as their primary television service placed less importance on key programming features, such as local programming and news programming (see Figure 47).

Figure 47: Importance of Television Programming Features by Types of Television Service



Subscription to television services varies significantly by key demographics. Specifically, those under age 45 are less likely than older respondents to have cable television but are more likely to use the Internet. Similarly, renters (of whom 72 percent are ages 18 to 34) are less likely than homeowners to have cable or satellite television, and they are more likely to use the Internet or not watch TV (see Figure 48 and Figure 49).

Figure 48: Types of Television Service in Home by Age of Respondent

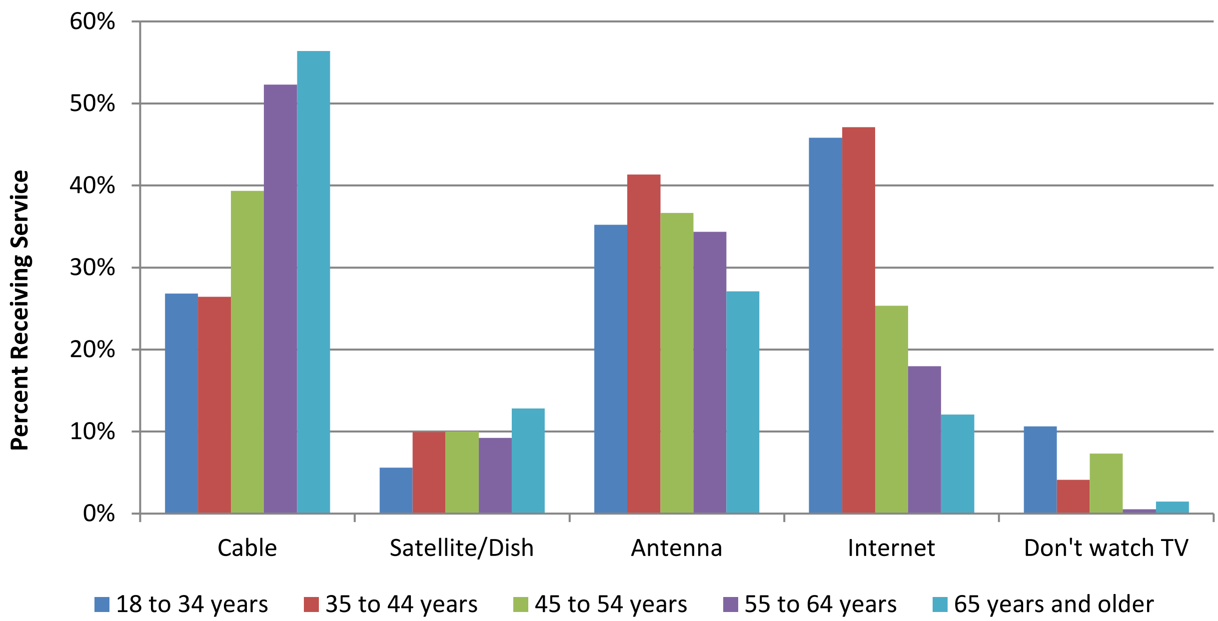
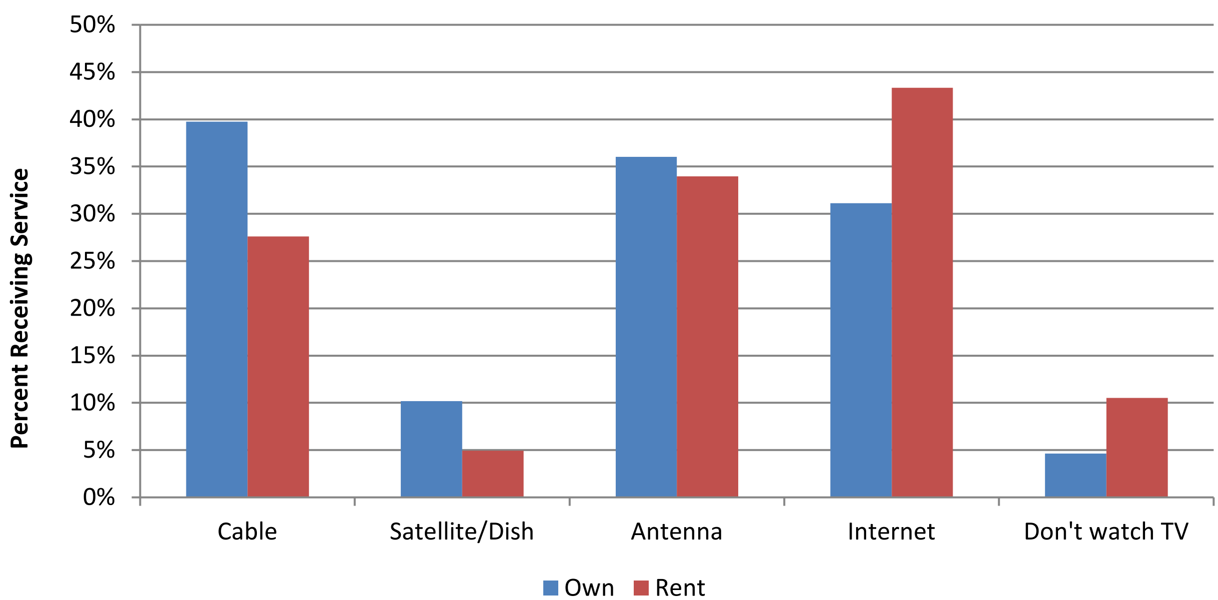
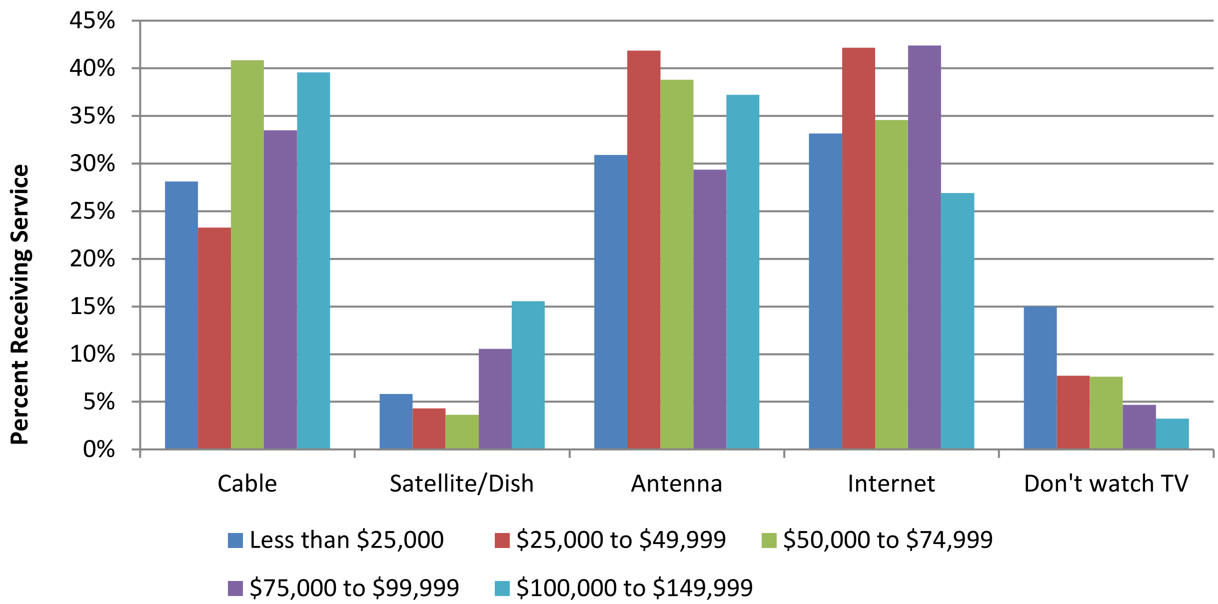


Figure 49: Types of Television Service in Home by Home Ownership



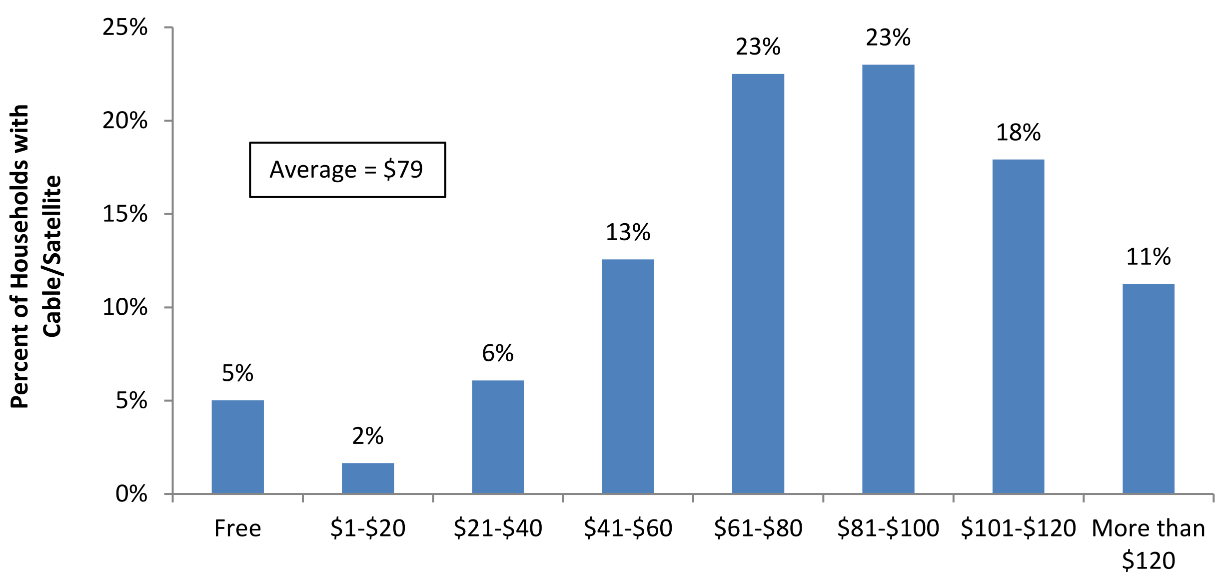
Additionally, respondents earning less than $50,000 were less likely to reporting having cable television (see Figure 50).

Figure 50: Types of Television Service in Home by Household Income



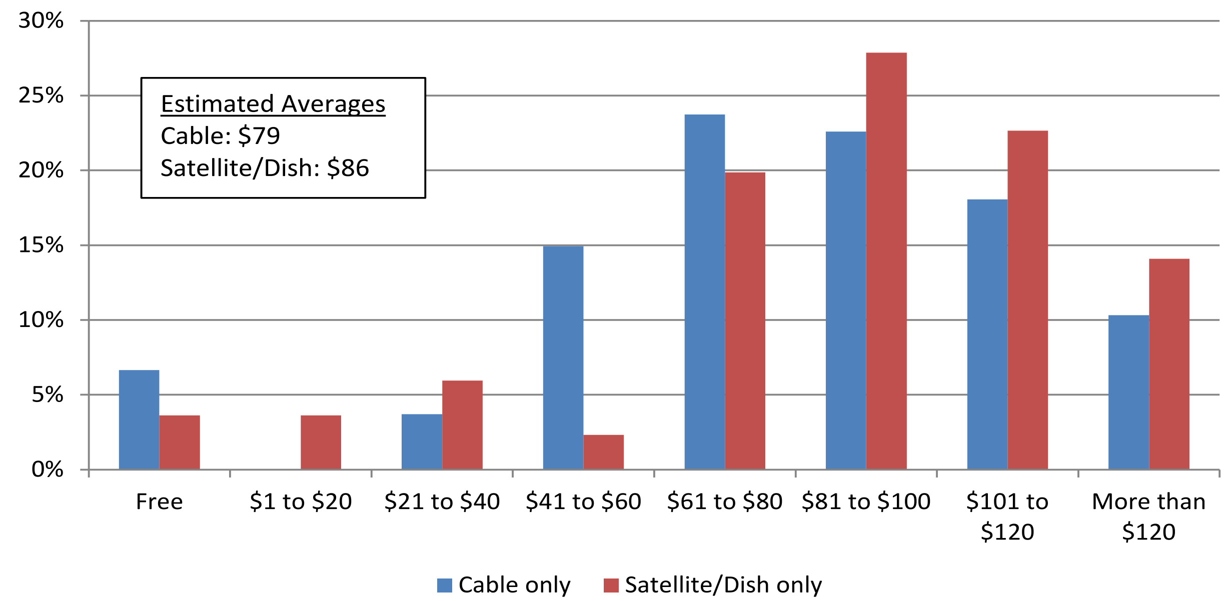
The estimated average monthly price for cable or satellite television service is $79, with 29 percent paying over $100 per month, as illustrated in Figure 51. Nearly one-half of those receiving cable or satellite pays between $61 and $100 per month.

Figure 51: Monthly Price of Cable or Satellite TV Service



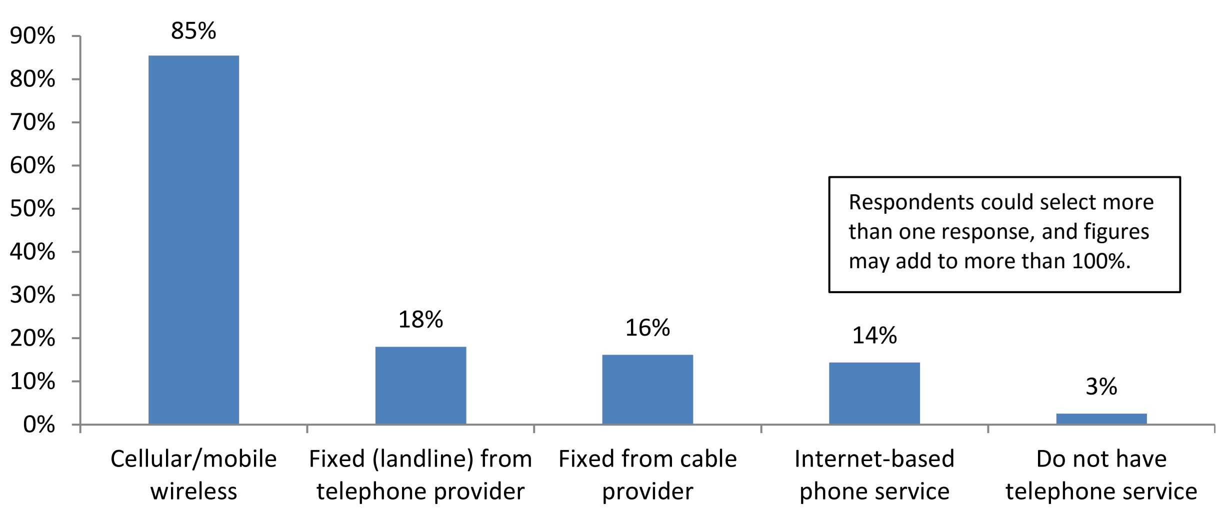
The cost per month for cable is slightly higher than the cost of satellite TV, as illustrated in Figure 52. The estimated monthly cost of cable is $79, and the estimated monthly cost of satellite television is $86.

Figure 52: Monthly Price of TV Service by Service Type



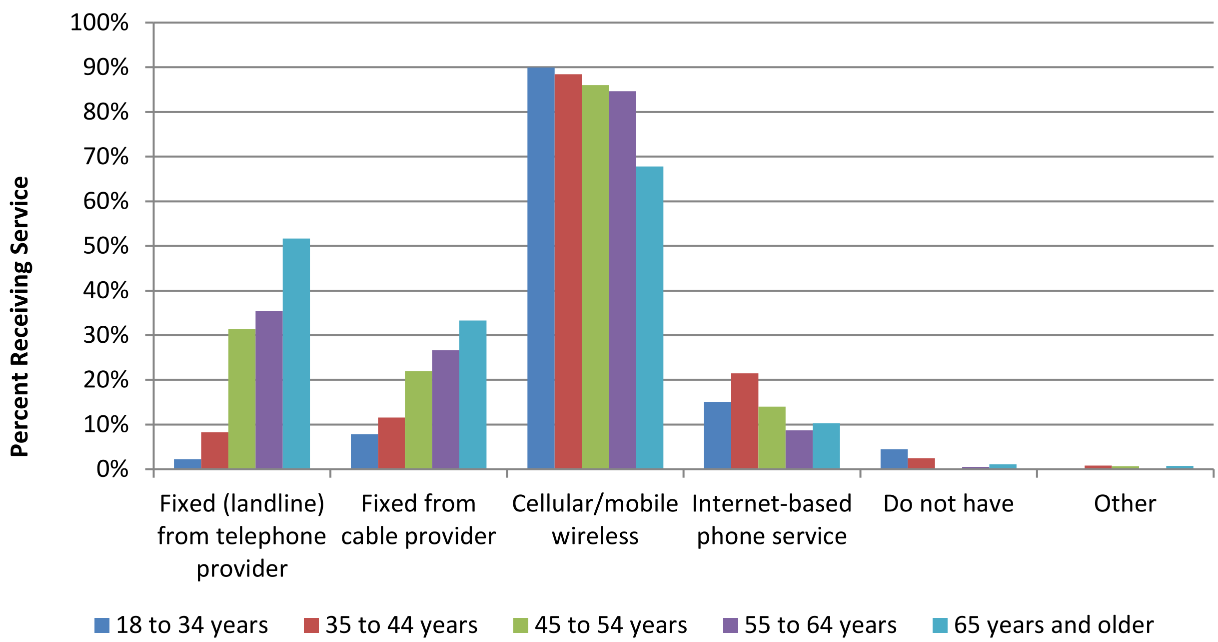
Respondents were asked about their telephone services, both at their home and cellular/ mobile. As illustrated in Figure 53, 85 percent of respondents have a wireless telephone. About one-third have a landline, including 18 percent from a traditional provider and 16 percent from their cable provider. In addition, 14 percent use some form of an Internet-based phone service.

Figure 53: Home Telephone Service(s)



As illustrated in Figure 54, respondents ages 65+ are more likely than younger respondents to have landline telephone service, either from a traditional provider or their cable provider, and they are less likely to have cellular/mobile wireless telephone service.

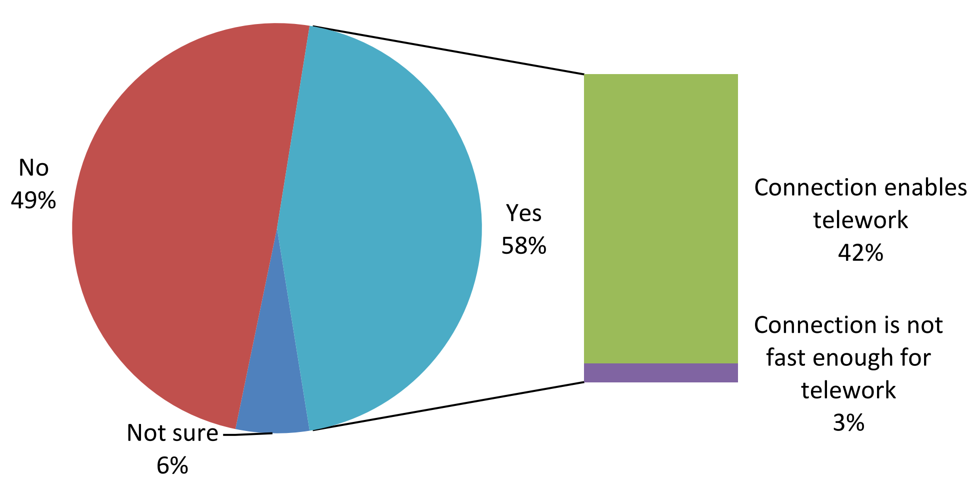
Figure 54: Home Telephone Service(s) by Age of Respondent



4.2.3 Telework and Home Businesses

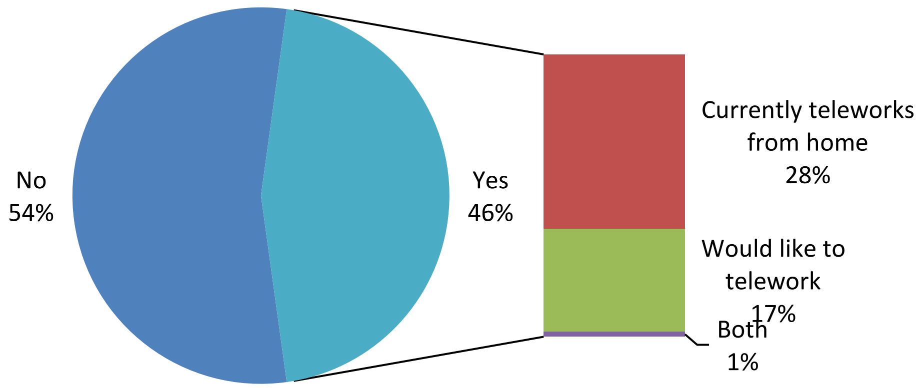
Over one-half of respondents indicated that a member of their family is allowed by their employer to telework. While 58 percent are allowed to telework, only 3 percent indicated that their Internet connection was not fast enough to allow telework (see Figure 55).

Figure 55: Employer Allows Telework



As shown in Figure 56, approximately 28 percent of respondents indicated that someone in their family already teleworks from home and another 17 percent would like to telework. (One percent stated both).

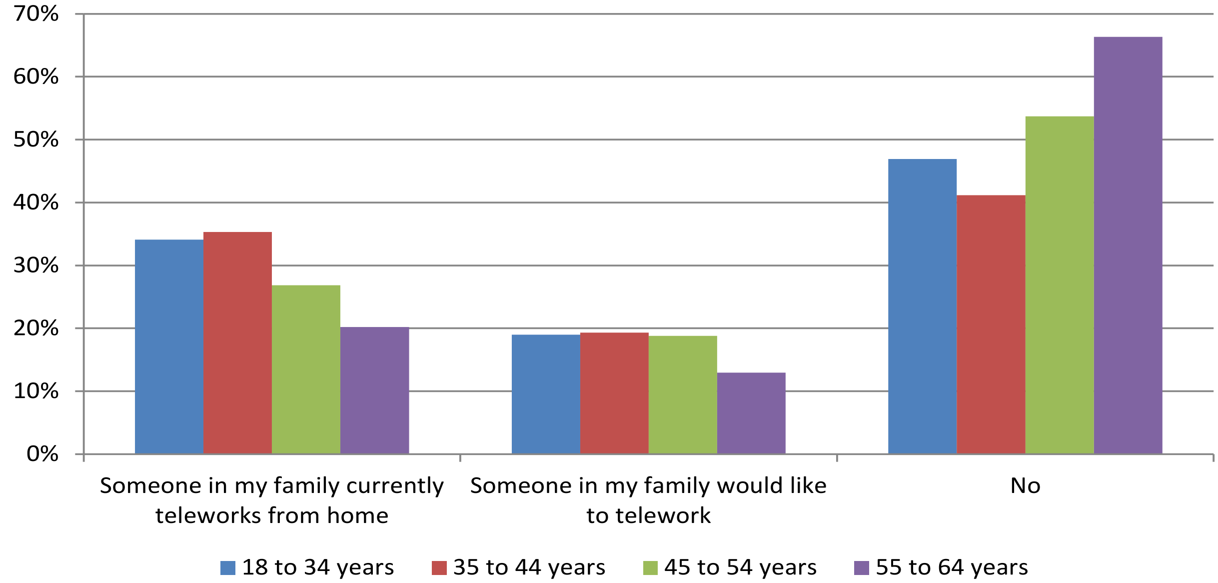
Figure 56: Household Member Teleworks



The majority (64 percent) of household members who are allowed to telework and who have a fast enough home Internet connection do indeed telework from home. This indicates that a substantial additional share may telework if feasible, allowed by their employer, and if their connection were fast enough to enable telework.

Respondents ages 65 and older are less likely than younger respondents to have a household member who teleworks, as may be expected since it is assumed that a larger share of respondents in this age cohort may be retired (see Figure 57).

Figure 57: Current Teleworking and Interest by Age of Respondent



In addition, those with a higher education and those with a higher estimated household income are more likely to have a household member who teleworks, as shown in Figure 58 and Figure 59, respectively.

Figure 58: Current Teleworking and Interest by Level of Education

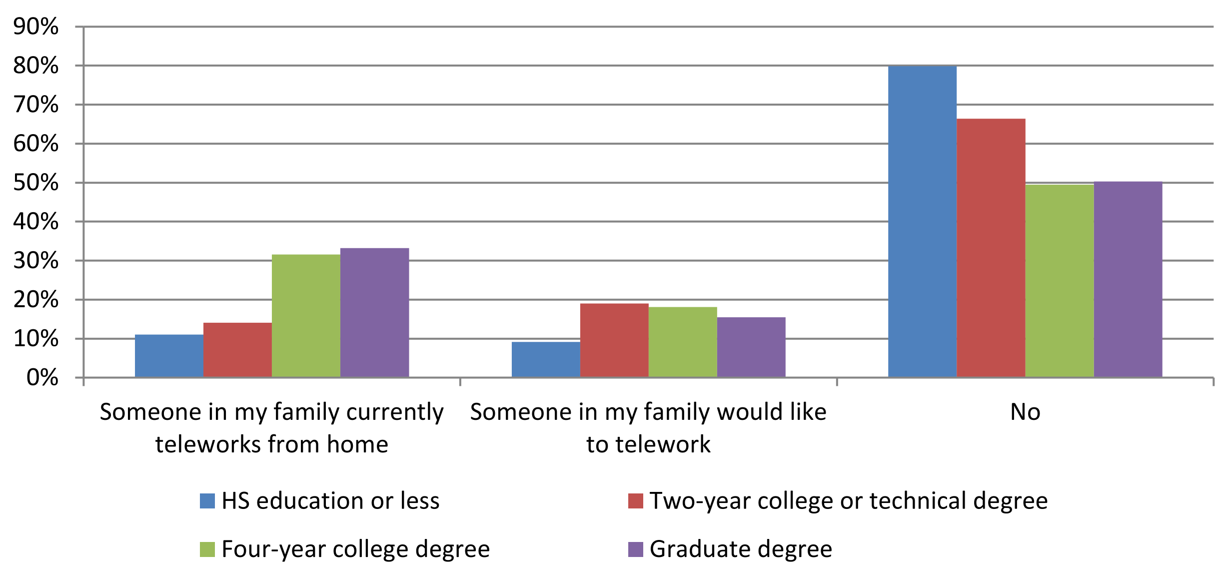
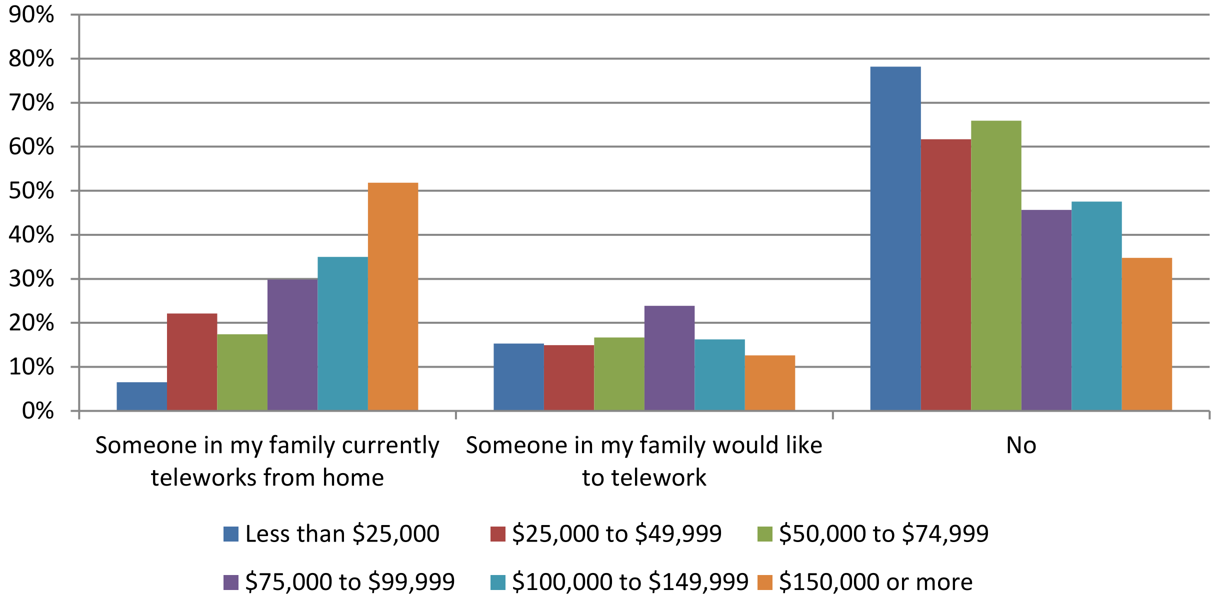


Figure 59: Current Teleworking and Interest by Household Income



More than one-fifth (22 percent) of respondents either has a home-based business or is planning to start one within the next three years, as illustrated in Figure 60. Of those who operate or are planning to start a home-based business, 79 percent indicated that a high-speed Internet connection is (or would be) very important to this business, as indicated in Figure 61.

Figure 60: Own or Plan to Start a Home-Based Business

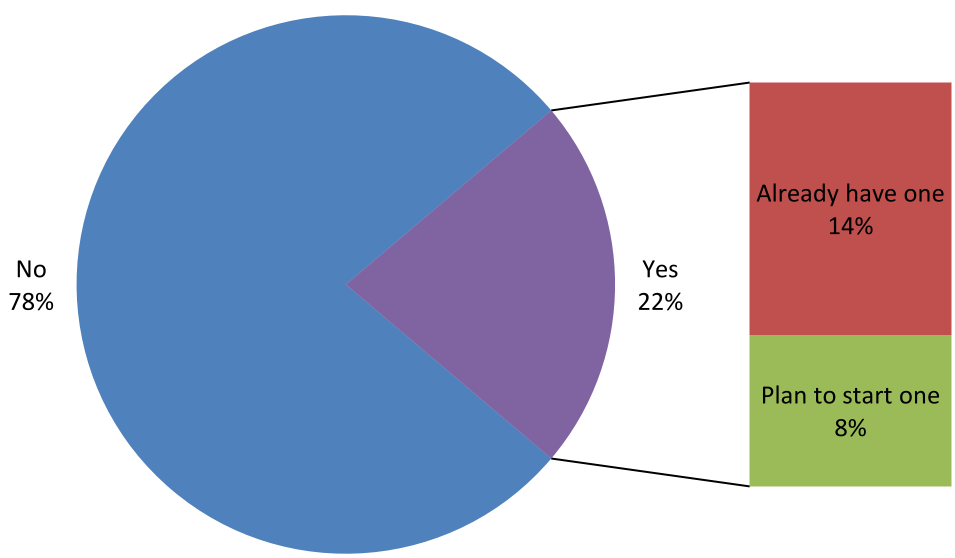
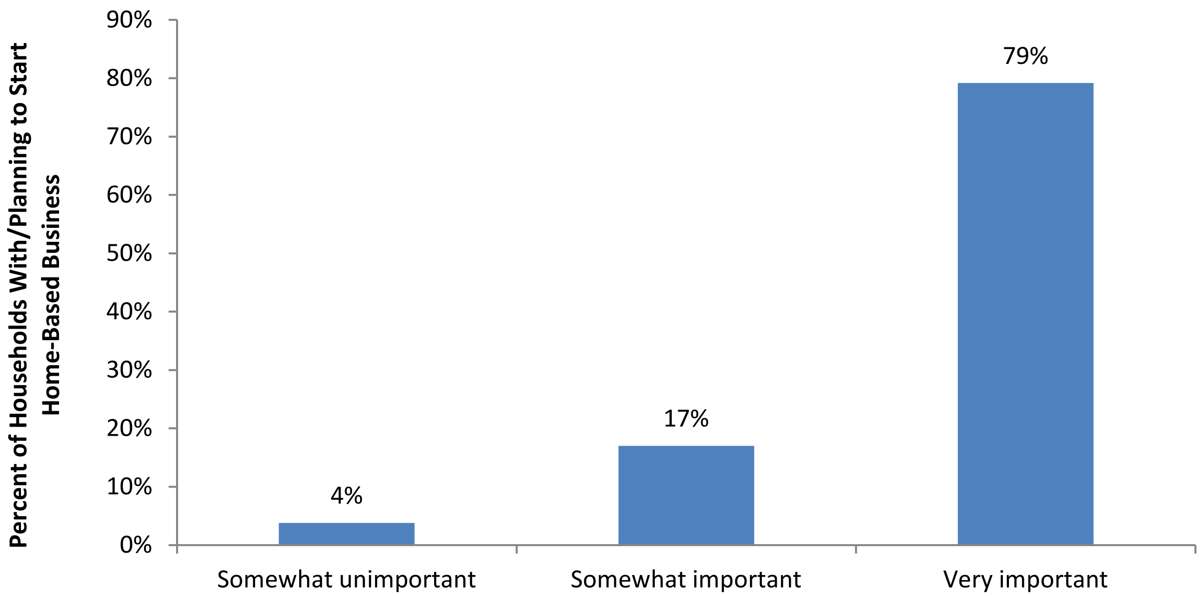


Figure 61: Importance of High-Speed Internet to Home Business



4.2.4 Respondent Opinions

Respondents were asked their opinions about the City's role in providing or promoting broadband communications services within the City. The most favorable opinions were that the City should help ensure that all residents, students, and teachers have access to competitively-priced broadband services. Figure 62 illustrates the mean ratings, while Figure 63 provides detailed responses to each portion of the question.

There is not a strong level of agreement that the City should build a publicly-financed network (to either offer services to the public or to allow private sector companies to offer services on the network); however, respondents were more likely to agree than disagree with these statements.

Figure 62: Opinions About the City's Role(s) (Mean Ratings)

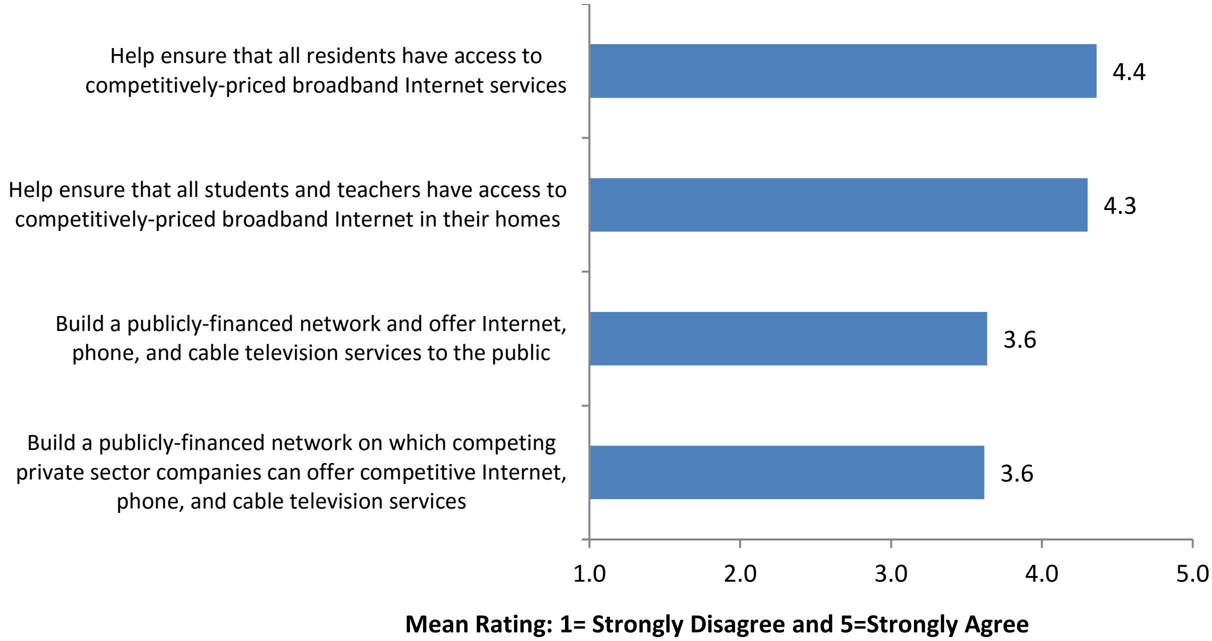
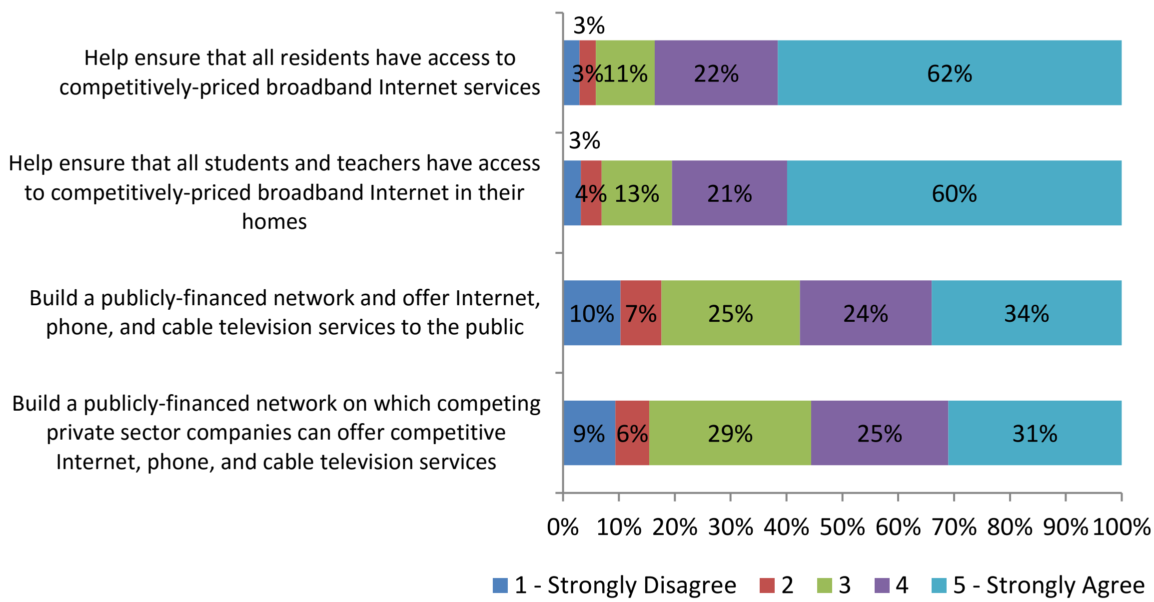
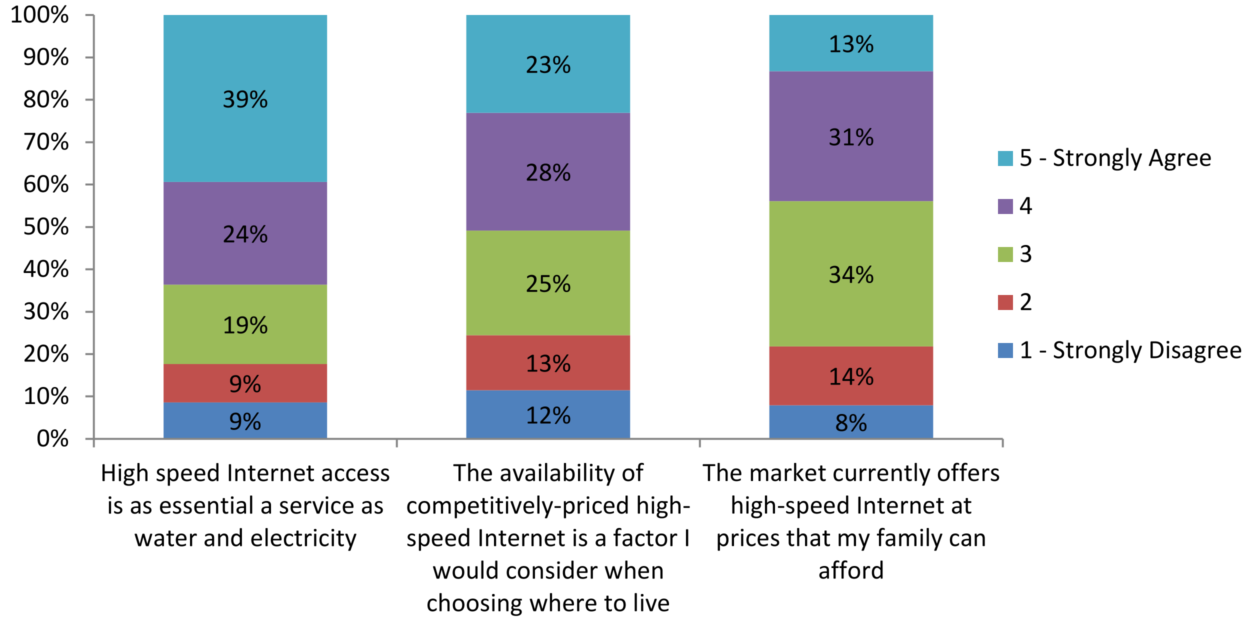


Figure 63: Opinions About the City's Role(s)



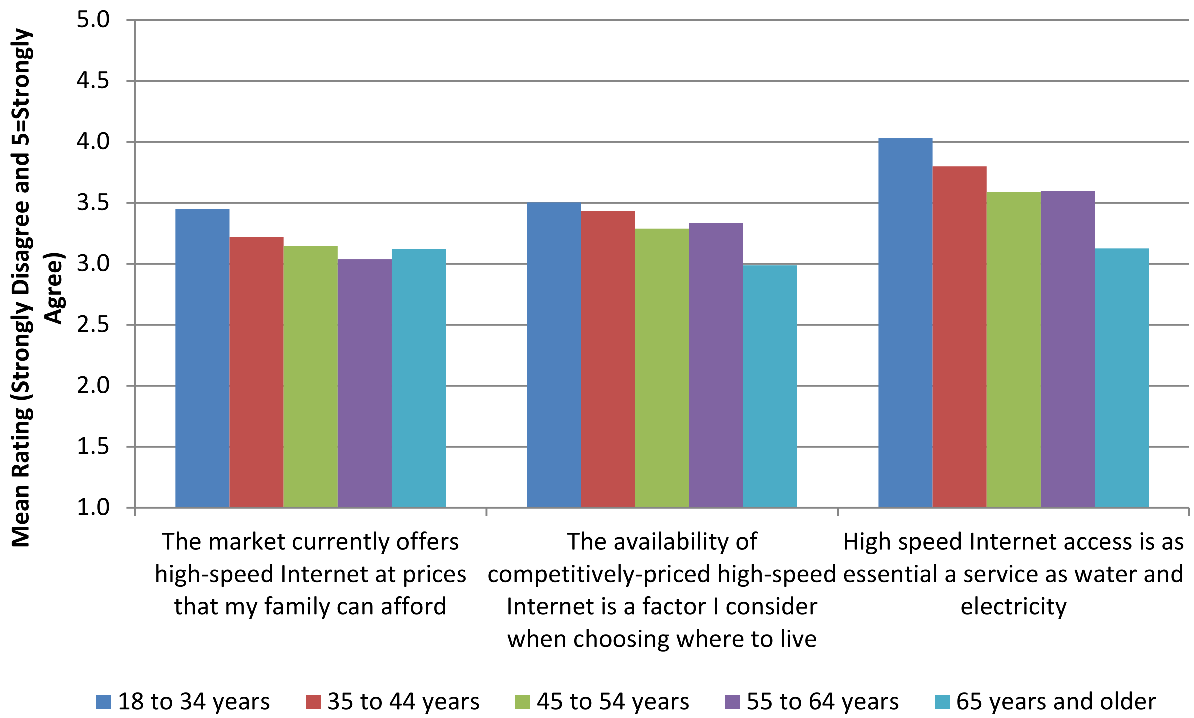
Respondents were also asked their opinion of the current broadband market. Four in 10 strongly agreed that high-speed Internet is an essential service. Much smaller shares thought that the market currently provides high-speed Internet at prices they can afford or that the availability of high-speed Internet is a factor they consider when choosing where to live, as illustrated in Figure 64.

Figure 64: Opinions About Broadband Internet



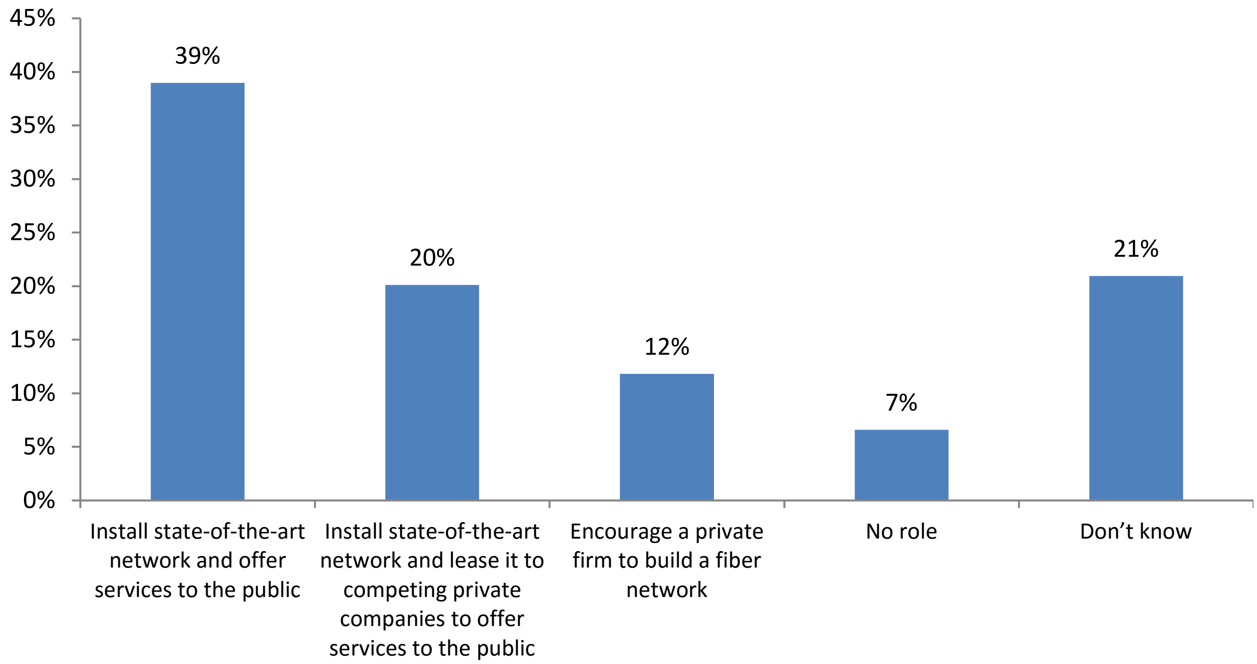
The opinions of the broadband market varied somewhat by the age of the respondent. As Figure 65 illustrates, younger respondents were more likely to agree that high-speed Internet is an essential service.

Figure 65: Opinions About Broadband Internet by Age of Respondent



Respondents were asked what the ***main*** role of the City should be with regards to Internet infrastructure and services. About six in 10 respondents indicated that the City should install a state-of-the-art communications network. About four in 10 respondents thought the City should install a network and offer services to the public. An additional 20 percent said that the City should build the communications network and lease it to competing companies to offer services to the public. Twelve percent thought the City should encourage a private firm to build a communications network. Only 7 percent thought the City should play no role, and 21 percent were unsure, as illustrated in Figure 66.

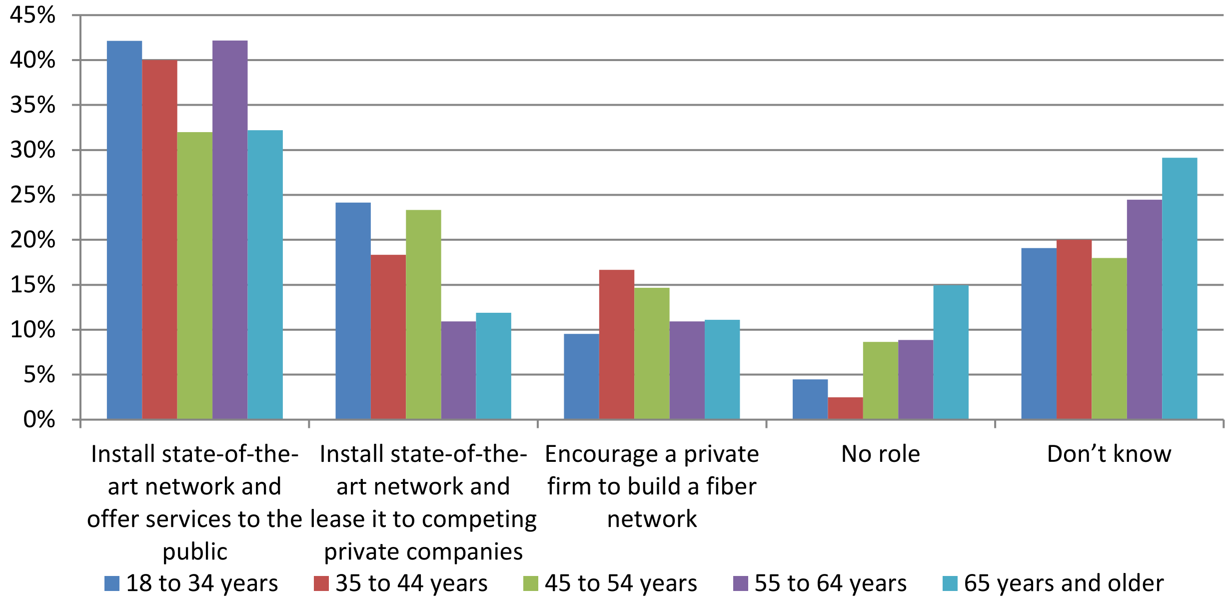
Figure 66: Main Role of the City with Respect to Broadband Access



Support for installation of a state-of-the-art network tends to decline somewhat as age increases. Two-thirds of those ages 18 to 34 would support the installation (either to offer services to the public or to lease to competing private companies), compared with 44 percent of those ages 65 and older (see Figure 67).

These responses indicate a relatively clear signal about residents' desire to have a state-of-the-art communications network and for the City to play some role in its installation. It should be noted that this question did not specifically ask about how that network should be financed or funded. Questions regarding consumers' willingness to pay monthly fees or hook-up costs for access to that network were presented previously.

Figure 67: Main Role of the City with Respect to Broadband Access by Age of Respondent



4.2.5 Respondent Information

Basic demographic information was gathered from survey respondents and is summarized in this section. Several comparisons of respondent information and other survey questions were provided previously in this report.

As indicated previously regarding age-weighting, disproportionate shares of survey respondents were in the older age cohorts relative to the City's adult population as a whole. Approximately 30 percent of survey respondents are ages 65 an older, compared with only 12 percent of the population. Conversely, only 19 percent of survey respondents are under age 35, compared with 44 percent of Madison's population. The survey results have been adjusted to account for these differences, as discussed earlier in this report.

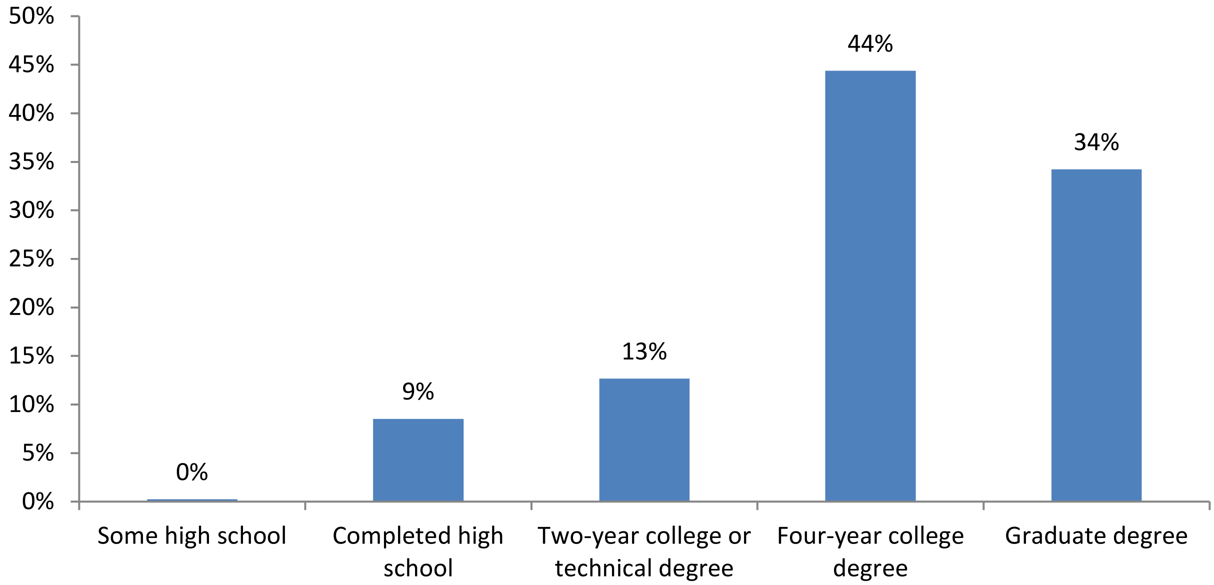
Respondents ages 35 to 54 are more likely than older and younger respondents to have children in the household. They are more likely to earn over $50,000 per year, compared with older and younger respondents. Those ages 65 and older are somewhat more likely to have just one resident in their household. Those ages 18 to 34 are more likely than older respondents to be renters, and they have lived in their home for fewer years on average. (See Table 16: Demographic Profile by Age of Respondent.)

Table 16: Demographic Profile by Age of Respondent

		18-34	35-44	45-54	55-64	65+	Total
Gender	Female	45%	45%	46%	51%	51%	47%
	Male	55%	55%	54%	49%	49%	53%
	Weighted Count	*402*	*140*	*136*	*122*	*113*	*914*
Race/Ethnicity	Other race/ethnicity	12%	12%	9%	7%	6%	10%
	White/Caucasian only	88%	88%	91%	93%	94%	90%
	Weighted Count	*398*	*138*	*134*	*121*	*112*	*904*
Highest level of education	Some high school	0%	0%	1%	0%	1%	0%
	Completed high school	5%	8%	11%	11%	15%	9%
	Two-year college or technical degree	9%	13%	9%	18%	21%	13%
	Four-year college degree	54%	42%	38%	42%	24%	44%
	Graduate degree	32%	37%	41%	28%	39%	34%
	Weighted Count	*407*	*139*	*135*	*122*	*112*	*917*
Approximate 2015 household income	Less than $25,000	7%	4%	3%	7%	14%	7%
	$25,000 to $49,999	28%	17%	12%	11%	24%	21%
	$50,000 to $74,999	20%	13%	20%	25%	19%	20%
	$75,000 to $99,999	16%	25%	17%	19%	19%	19%
	$100,000 to $149,999	17%	28%	27%	24%	17%	21%
	$150,000 to $199,999	7%	6%	10%	7%	4%	7%
	$200,000 or more	4%	7%	11%	6%	3%	6%
	Weighted Count	*404*	*137*	*133*	*111*	*98*	*889*
Total Household Size (Adults + Children)	1	24%	23%	22%	25%	37%	25%
	2	45%	26%	33%	55%	58%	43%
	3	17%	15%	16%	13%	5%	15%
	4 or more	14%	36%	29%	7%	0%	17%
	Weighted Count	*407*	*138*	*136*	*122*	*110*	*917*
Number of children in household	No Children in HH	79%	54%	60%	89%	98%	76%
	Children in HH	21%	46%	40%	11%	2%	24%
	Weighted Count	*407*	*138*	*136*	*122*	*110*	*917*
Own/rent residence	Own	44%	75%	83%	86%	85%	65%
	Rent	56%	25%	17%	14%	15%	35%
	Weighted Count	*407*	*139*	*136*	*119*	*110*	*916*
Number of years lived at current address	Less than 1 year	19%	7%	5%	3%	3%	11%
	1 to 2 years	39%	15%	3%	7%	4%	21%
	3 to 4 years	23%	27%	9%	8%	5%	17%
	Five or more years	19%	52%	83%	83%	88%	51%
	Weighted Count	*407*	*139*	*136*	*122*	*110*	*921*

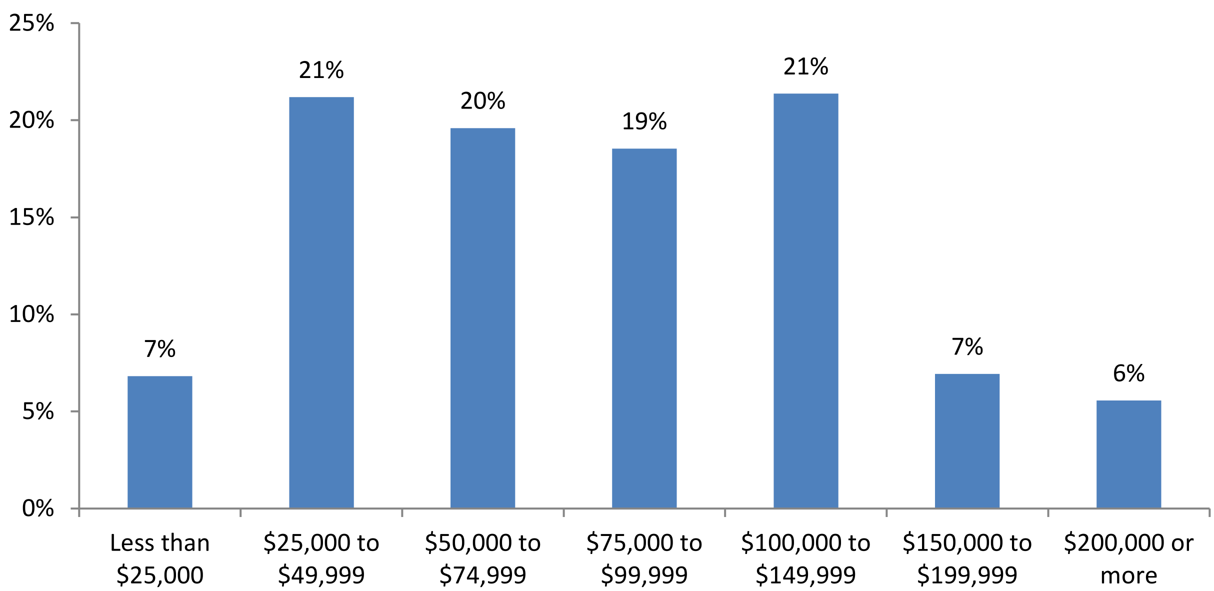
The respondents' highest level of education attained is summarized in Figure 68. More than three-fourths of respondents have a four-year college degree or a graduate degree.

Figure 68: Education of Respondent



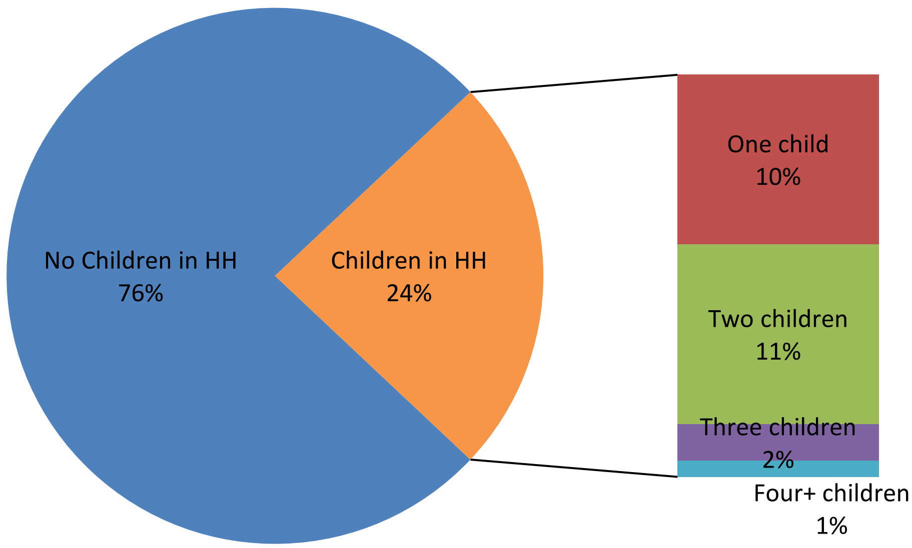
Just 7 percent of respondents are in the lowest income bracket with 2015 household income of less than $25,000. Another 21 percent of respondents earned $25,000 but less than $50,000. About 45 percent of respondents had household incomes of $100,000 or more, as illustrated in Figure 69.

Figure 69: 2015 Household Income



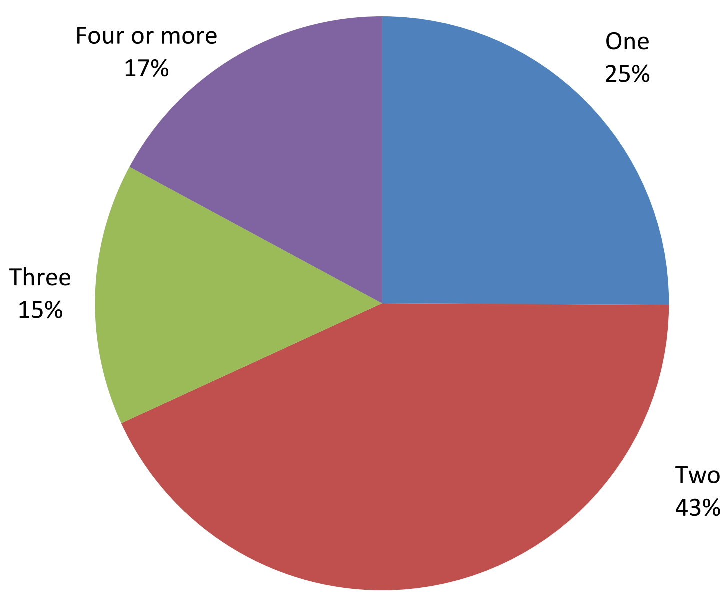
Respondents were asked to indicate the number of adults and children in their household. About one-fourth of respondents have at least one child under age 18 living at home, as shown in Figure 70.

Figure 70: Number of Children in the Household



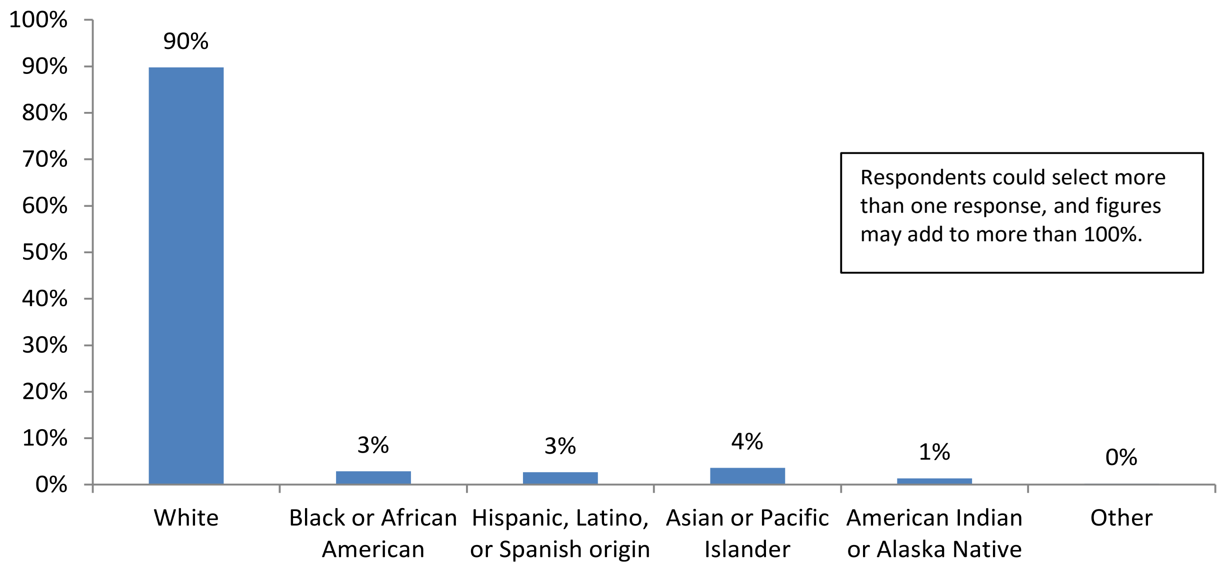
One-fourth of respondents have just one person living in the household, and 43 percent have two household members (including both adults and children). One-third have three or more household members (see Figure 71).

Figure 71: Total Household Size



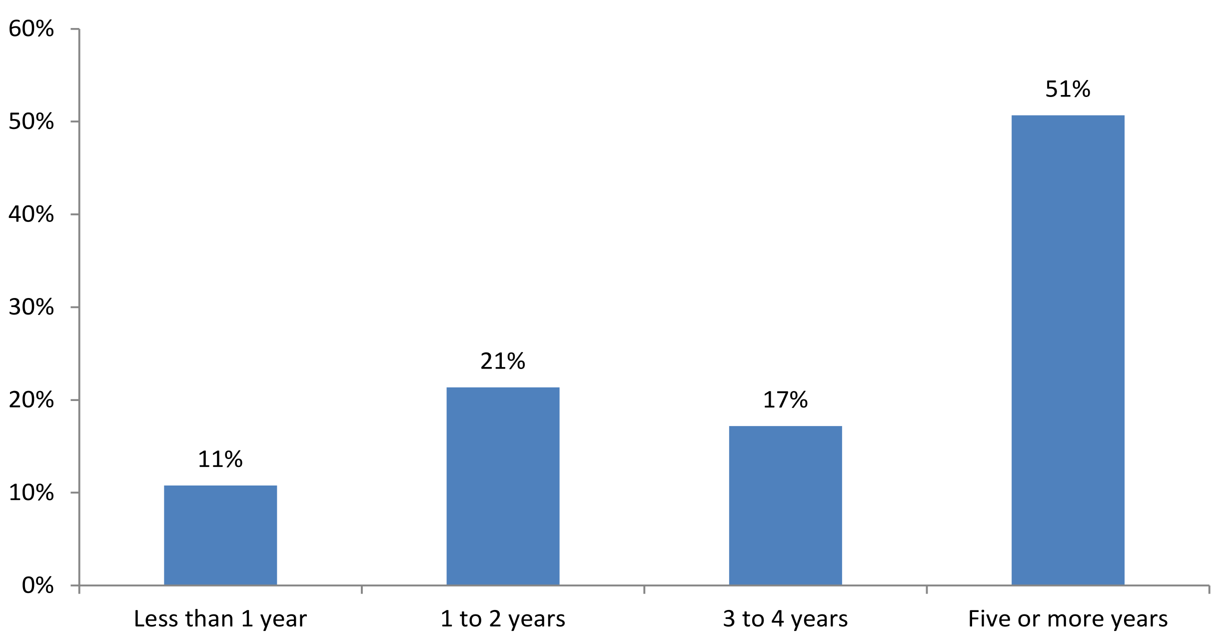
Additionally, the survey sample is split 47 percent women, and 53 percent. Nine in 10 are White only, and one in 10 represent other races/ethnicities, as shown in Figure 72.

Figure 72: Race/Ethnicity of Respondent



Nearly two-thirds of respondents (65 percent) are homeowners. More than half of respondents have lived at their residence for five or more years, as shown in Figure 73.

Figure 73: Length of Residence at Current Address



5 Framework for Options to Meet City's Goals: Public–Private Partnership Models

5.1 Overview of Partnership Frameworks

Public–private partnerships are generally unique to the communities that develop them and entail specific parameters that directly benefit both the community and the chosen private partner. As the City evaluates broadband public–private partnerships, it should consider both the opportunities and potential pitfalls, and pay particular attention to three interwoven issues:

1. Risk
2. Benefit
3. Control

These factors are key considerations for both the City and its potential partner(s). A successful partnership must balance each partner's needs, and there will inevitably be some tradeoff within this framework for each model.

5.1.1 Risk

It is not possible to entirely avoid risk if the City opts be involved at any level in broadband deployment. But calculated risk often yields benefits that would otherwise have been unattainable. One of the most enticing components of a public–private partnership is that it can considerably reduce the City's risk while helping achieve a community's broadband goals.

Public financing (directly with bond issuance or indirect with payment guarantees) to support the partnership will likely be one of the City's greatest risks, though we believe this is a worthwhile investment to enable the City to retain some ownership and control of the assets in a dark FTTP partnership model. Although it will entail some financial and political risk because it will likely require public financing—either through municipal bonds or leveraging tax funds—the long-term dividends will likely be advantageous. This is especially true if the City is able to execute a meaningful partnership with a private entity that will share in the risk.

The City may enter into an agreement that requires it to directly seek bonding for capital investment, or it may find a partner that is willing to use its own capital. It is important to note that even if the City does not directly seek bonds, and the City must commit to a guaranteed payment the City's credit rating and bonding ability may still be impacted if a private partner obtains the financing.

Operations tend to be unpredictable and costly and often represent a great risk for municipal fiber networks. Cities that try to enter the retail market directly are often targeted by hostile incumbent providers that make it very challenging for the City to compete. Part of the attraction to the public–private partnership model is that private entities tend to be equipped to understand the retail business and to help the City mitigate its risk in this area. Given this, the dark FTTP partnership model is most likely to offset the City's risk.

5.1.2 Benefit

As the City considers this endeavor, it should continually weigh the benefits it might expect to receive as part of a public–private partnership against its potential risk. One positive component of emerging partnerships nationwide is that there is potential for a great degree of flexibility. That is, the City is in a position to consider its priorities and pursue those benefits on the frontend of a partnership arrangement.

Conversely, although public–private partnership models are relatively new and evolving all the time, there are several recent examples that the City can look to as guidance on how it might want to proceed. It is too soon to fully map what long-term benefits of partnership might look like, but there are some lessons that can be picked up from some communities that have sought various degrees of partnership.

Although benefits cannot be reliably calculated at this stage, the City can potentially look to other communities to get a sense of the goals other partnerships prioritized for the public entity's benefit. This may help the City determine how to balance its risks, and which areas to focus on in its pursuit of a partner. Madison is a desirable market with much to offer a private partner, especially if the City is willing to directly invest in the dark fiber network.

5.1.3 Control

Because this is the start of the City's broadband initiative, it can choose in the negotiation process its desired level of involvement in infrastructure deployment, network maintenance, and operations. That is, the City can essentially determine from the outset what level of involvement it would like to have at every stage and in every arena of the public–private partnership process.

There are numerous ways that the City can retain some control within the public–private partnership, and perhaps the most important is through retaining ownership of the physical assets. Again, this must be balanced with risk, as it is likely that the City will be required to fund at least part of the capital investment in assets if it hopes to retain control.

The more ownership the City has, the greater degree of control it can maintain. This enables the City to make decisions about placement of the assets, rate of deployment, and the network's overall footprint. Further, it ensures that if the partnership does not succeed, the City still has a physical asset that it can use to deliver services directly or to negotiate a new partnership.

5.2 Public–Private Partnership Models

In this section, we outline the emerging public–private partnership models in the industry today. Although we believe that Model 3—the shared investment and risk model which entails a dark FTTP partnership—will be most beneficial for the City, it is valuable to understand other models that may be available to the City.

5.2.1 Model 1: Private Investment, Public Facilitation

In this approach to public–private partnership, the public sector's cost is significantly reduced. The model focuses not on a public sector investment, but on modest measures the public sector can take to enable or encourage greater private sector investment. The most prominent example of this model is Google Fiber's deployments, including its networks in Austin, Kansas City, Nashville, and elsewhere. Ting Internet[70] is taking a similar approach in smaller markets, including Holly Springs, North Carolina.

This model is seen as the ideal for many communities that wish to minimize public cost. At least in Google Fiber's deployments, the private sector partner's requirements have largely focused on making local government processes more efficient. In return for these relatively low-cost public sector commitments, the communities that are partnering with Google Fiber or Ting Internet benefit from the company's deployment of FTTP infrastructure (and, in many cases, competitive upgrades by the incumbent cable and telephone companies).

This model relies on the private companies to make the investment, while partner communities take certain steps to enable them to build in an expeditious, efficient, low-cost manner. Though Google Fiber is the most prominent example, there is also significant interest among smaller companies—which have fewer resources than Google but can deliver next-generation broadband to businesses and institutions on a targeted basis.

While this model reduces the public sector's cost and risk compared to other models, there is a potential public relations risk. Public expectations can get very high with the announcement of new fiber deployment. If a local government is strongly identified as a partner, it may be held accountable by the community if something goes wrong with the private sector partner's business plan or deployment.

5.2.1.1 Strategies for Encouraging Private Investment

There are a number of strategies the City can take to encourage new private investment and reduce some of the costs and time for private sector entities to deploy advanced broadband services. These can, for example, take the form of specific economic development incentives such as tax benefits to encourage providers to build new infrastructure. MetroNet, a small Midwest ISP, developed a partnership with the City of Crawfordsville, Indiana, to purchase the

[70] Ting, https://ting.com/.

municipal utility's fiber network.[71] The city is assisting MetroNet with financing the purchase and expanding the footprint of the fiber network.

Communities typically offer this type of benefits to new entrants in a market that are willing to invest in next-generation infrastructure, but they can offer those benefits to incumbents if the incumbents will also invest in the same kind of infrastructure.

Another key strategy is for the community to develop and strengthen the local infrastructure assets that enable the deployment of broadband.[72] These include public assets such as fiber, conduit, and real estate. For example, new network deployments can benefit enormously from access to existing government fiber strands, underground communications conduit in which fiber is placed, or real estate where equipment or exterior huts can be located.

Communities can further facilitate the underground construction of conduit and fiber by implementing a "dig-once" policy for all road and related transportation projects, and facilitating in-building access through construction specifications for new buildings.[73]

Building and expanding community infrastructure over time is a low-cost, low-risk strategy that will have real impact and expand options down the road. For example, the City of Mesa, Arizona, began a dig-once initiative in the early 2000s; the city intended to install its own rings of conduit during private sector construction projects, then sell access back to the private sector. Any time the city opened up a street, such as to install water or sewer utilities, it put in conduit.[74] In some instances, the city also added fiber to empty conduit for city purposes or to potentially lease to private providers. In total, the city installed as much as 200 miles of conduit. Mesa targeted four economic development areas in particular, with redundant conduit, fiber, and electric infrastructure. Among those areas was the land around the Phoenix-Mesa Gateway Airport, where Apple announced in early 2015 that it would build a $2 billion data center.

A third important strategy is to improve access to information—an asset that communities might not have considered.[75] Sharing information demonstrates a willingness to engage with the private sector to spur investment. Communities should seek to make data available wherever possible both for public and private uses.

---

[71] "MetroNet plans to expand current fiber optic system," *The Paper of Montgomery County Online,* Mar. 18, 2014, http://goo.gl/5eHuJt.
[72] "Gigabit Communities: Technical Strategies for Facilitating Public or Private Broadband Construction in Your Community," CTC Technology & Energy, Jan. 2014, p. 6–12, http://www.ctcnet.us/gigabit/.
[73] For more discussion of "dig once" policies and related collaborative strategies, see "Gigabit Communities."
[74] "Transcript: Community Broadband Bits Episode 139," Institute for Local Self-Reliance, Feb. 26. 2015, http://goo.gl/pFzN6k.
[75] "Gigabit Communities," p. 13–16.

Geographic information systems (GIS) or similar databases that hold information such as street centerlines, home and business locations, demographics, and details on existing utilities, public infrastructure, ROW, and available easements can be extremely helpful for a locality's own broadband planning, potential public–private partnerships, or a network service provider that is evaluating the deployment of new infrastructure in a community.

Access to this information may attract and speed new construction by private partners, while enabling the community to meet its goals for new, better broadband networks—and potentially to realize revenues for use of the assets.

Finally, the City can take steps to enable broadband construction by making government processes around permitting, ROW access, and inspections more efficient and smooth.[76] In some communities, for example, permitting processes have been moved online, alleviating the need for wasteful and time-consuming paper-based processes. These actions can signal to private partners that there is an investment opportunity in the jurisdiction and that the City will not be a bottleneck or create additional costs.

These steps should take into consideration the needs of the community, balance public interest and public safety, and account for local resources and capacity. For example, the City can choose to be fully transparent about its permitting and ROW processes—including timelines—to enable the communications industry to expeditiously plan and deploy networks.

5.2.1.2 Potential Benefits and Pitfalls

The above strategies can make a difference in the economics of buildout for a private partner. However, they will not dramatically change the underlying economics of broadband network construction and operation. In a best-case scenario, the public sector can reduce the cost of outside plant construction for a broadband network by up to an estimated 8 percent.[77]

Thus these measures can be substantial, but not transformative. Indeed, many incumbent providers overstate the extent to which local government and regulation are hurdles for developing next-generation broadband infrastructure.

Communities should be wary, then, of private sector entities seeking benefits without offering concrete investment proposals. From a business standpoint, for example, incumbents do not need additional support from the City to keep maintaining (or even upgrading) their existing broadband networks and services.

[76] *Id.*, p. 14.
[77] "Gigabit Communities."

5.2.1.3 Case Study: Holly Springs, NC

Over the course of many years, the Town of Holly Springs designed, engineered, and constructed a backbone fiber network to connect municipal buildings. To their great credit, Holly Springs' visionary elected officials chose to build a fiber network with dramatically higher capabilities than the need apparent at the time—knowing that a robust fiber backbone might attract interest from private ISPs that recognize the potential to leverage that backbone to more efficiently build their own FTTP infrastructure.

But a robust backbone network was not enough. The town's government also developed policies and strategies to attract private broadband investment. As a result, Ting Internet announced in mid-2015 that it will bring "crazy fast fiber internet" to the homes and businesses of Holly Springs. Ting plans to expand on Holly Spring's existing fiber pathways and offer symmetrical gigabit Internet access to homes and businesses.

A key factor in Ting's decision to invest in Holly Springs was the fact that the town not only was willing to lease excess fiber in its backbone, but that it also brought best practices to bear in its willingness to work with Ting and facilitate Ting's efforts. Among other things, the town offered efficient government processes, access to information and facilities, and facilitation and support—all of which boosted Ting's confidence about this community as an investment opportunity.

5.2.2 Model 2: Private Execution, Public Funding

This model, which involves a substantial amount of public investment, is a variation on the traditional municipal ownership model for broadband infrastructure—but with private rather than public sector execution. In this model, a selected private partner takes responsibility for some combination of design, construction, financing, operations, and maintenance,[78] funded by the public partner over some period of time.

While this public–private partnership structure is new to broadband, it is used in Europe and increasingly in the U.S. for traditional infrastructure projects such as highways, toll roads, and bridges. The model seeks to leverage the strengths of the private sector to deliver turnkey services and solutions over an extended time of 20 to 40 years.

Unlike transportation or utility infrastructure, however, broadband does represent a somewhat competitive marketplace. Thus, applying the model to broadband in the U.S. creates political and financial risk for the public sector because public funding is used to fund an infrastructure that some residents may not want or choose to use. Indeed, if the broadband network is unsuccessful at generating revenue to cover all public sector costs, the public sector often

---

[78] "Financial Structuring of Public–Private Partnerships (P3s)," U.S. Department of Transportation, 2013, http://goo.gl/gCJIZK.

remains on the hook for those payments. At its core, this model thus involves the public sector essentially becoming the guarantor in the event that the partnership does not secure sufficient revenue to cover all costs, including the profit margins required by the private partners.

And for communities that think this is a way to get financing without bonding, that is only partially true. The public sector partner does not have to bond, but the partnership financing will most likely be considered by auditors, state authorities, and the bond markets as counting against the public sector entity's borrowing capacity.

Despite these risks, the model offers benefits to the public sector by removing significant logistical barriers from large-scale public broadband projects and offering a comprehensive solution (including extensive turnkey private execution and private capital) for the entire community.

One of the most fascinating aspects of the huge escalation in interest in this space over the past few years (catalyzed significantly by Google Fiber) is the emergence of a group of companies that are working with traditional public–private partnership models to develop strategies for enabling local governments to get FTTP networks built.

While the field is very fast developing and constantly changing, at least three companies have emerged so far with fully articulated business models and business propositions for localities: Macquarie Capital, SiFi Networks, and Symmetrical Networks.

All three companies are proposing interesting and innovative approaches—each with the same core concept (though with considerably different detail): The public sector's willingness to contract in the long term is what will enable and secure construction of the network. To date we are not aware of any commitments that these entities have reached with a public entity to deploy a FTTP network.

These variations on the private execution, public funding model are as of yet untested; we urge caution for that reason. But we note that this model is a promising means by which to develop a network that can serve the entirety of the community, not just the parts selected by a private investor.

5.2.2.1 Macquarie Capital

Macquarie Capital and its partner companies, which have pioneered this model in the broadband market in the U.S.,[79] will provide financing, construction, operations, and service delivery over the network. To fund all this activity and investment, the locality will pay Macquarie on an ongoing basis by placing a monthly fee on all local property owners' utility

[79] "Macquarie Capital," Macquarie Group, http://goo.gl/uvUEjv.

bills. Macquarie intends that multiple ISPs will compete over the network, giving consumers a choice of providers and the benefits of price competition (and creating a revenue stream for ISPs, who will pay Macquarie). Macquarie projects that network revenues will grow substantially over time; as service revenues generated by the ISPs increase, Macquarie commits to sharing some of its revenues with the locality.

Macquarie is an experienced and sophisticated entity, and offers a comprehensive solution. We note, however, that its open access business model is not tested and that the utility fee is likely to prove a heavy lift politically in most American communities.

5.2.2.2 SiFi Networks

In the SiFi Networks approach to this model, a local FTTP network is built and operated by SiFi and its partners at public sector expense. SiFi will provide financing and, with its partners, turnkey construction and operations—all of which will be compensated by lease payments from the public sector partner. SiFi will then bring to the community one or more ISP partners, with which the locality will contract to provide open access services over the network.

In SiFi's vision, the ISPs will make minimum payment guarantees to the locality in return for the opportunity to provide services over the network; those amounts will be negotiated and based on the public sector partner's actual costs. If multiple competing ISPs or even a single ISP is willing to make such commitments on a long-term basis, and if those ISPs are viable entities—with commitments backed by real resources—then the model will reduce the public sector partner's risk in terms of the ongoing payments to SiFi and its partners.

The viability of the model thus hinges on the willingness of ISPs to make such commitments, and the ISPs' confidence that they can realize sufficient revenues and margins to justify the commitments.

As with the Macquarie model, the SiFi model is interesting, but, so far, untested.

5.2.2.3 Symmetrical Networks

In Symmetrical Networks' version of this model, Symmetrical and its partners will build the network, which will be operated by an ISP chosen by the public sector partner. That operator may be an ISP that is a partner to Symmetrical, it may be the public sector entity itself, or it may be any other qualified network operator.

Symmetrical does not follow the multiple-ISP open-access approach anticipated by SiFi and Macquarie; rather, it intends that open access will happen "over the top" (OTT), when consumers select their own application providers over an unfettered data connection with no data cap.

Symmetrical will build, finance, and provide turnkey construction for an FTTP network, and the public sector partner will make a lease payment to Symmetrical that will cover the company's debt service, operating costs, and margin. The public sector entity will, in turn, be paid by the ISP; in Symmetrical's modeling, the ISP will pay the locality an amount equal to the locality's obligations to Symmetrical.

Symmetrical believes that this model is viable based on a minimum community-wide take rate of 35 percent. To reduce the public sector partner's risk, Symmetrical will not undertake a project unless city-wide, aggregated commitments at this level have been secured in advance.

As with the SiFi and Macquarie models, the viability of this model hinges on the selected ISP's ability to generate sufficient revenues to cover its required payment to the public sector entity (which equals the locality's required payment to Symmetrical), its costs, and, presumably, an acceptable operating margin. While Symmetrical is confident that this model is viable, it is also quite frank that the public sector entity bears the risk in the event that network revenues fall short of the obligated levels.

5.2.3 Model 3: Shared Investment and Risk (Dark FTTP Partnership)

A public–private partnership model based on shared investment and risk plays to the strengths of both the public and private sector partners. Most localities consider FTTP deployment not as a moneymaker, but as a powerful tool for education and economic development. Thus in a shared investment model, the risk is shared but the community still receives 100 percent of the benefits it seeks—recognizing that the benefits do not all appear on the project's financial statements. For the private partner, a shared investment means less upfront capital (risk), with an opportunity for future revenues.

Among other enormous benefits to this model, cities can not only provide fiber to the private sector—for compensation and to get gigabit and beyond service to the public—but can also secure extensive fiber throughout their communities for internal uses, including municipal and municipal utility operations, public safety, and emerging Smart City and Internet of Things (IoT) applications.

This model will provide an institutional or public sector network of the future—more extensive than any network that served city or county needs in the past, because the fiber will go everywhere in the community. It will have the potential to serve every conceivable application, from traffic signal control to air quality monitoring, from robust and secure public safety communications to high-end videoconferencing between universities and schools.

This benefit is ancillary to the core benefit of enabling a competitive gigabit (and beyond) product over fiber to every home and business in the community—but, in the long run, it has the potential to enable transformative public sector use and services. And indeed, local governments' track record of securing considerable savings and enormous operational capabilities over fiber is already demonstrated.[80]

We note, however, that while this model offers an extraordinary opportunity for innovation, it is in no way a sure thing for communities. We do not have the data points to develop the best practices necessary for success. At the moment, early actors are developing new and exciting partnerships to bring next-generation broadband to their communities. We describe some of those projects in the brief case studies below.

5.2.3.1 Case Study: Westminster, MD

The City of Westminster, Maryland, is a bedroom community of both Baltimore and Washington, D.C. where 60 percent of the working population leaves in the morning to work elsewhere.[81] The area has no major highways and thus, from an economic development perspective, has limited options for creating new jobs. Incumbents have also traditionally underserved the area with broadband.

The city began an initiative 12 years ago to bring better fiber connectivity to community anchor institutions through a middle-mile fiber network. In 2010, the State of Maryland received a large award from the federal government to deploy a regional fiber network called the Inter-County Broadband Network (ICBN) that included infrastructure in Westminster.[82]

Westminster saw an opportunity to expand the last mile of the network to serve residents. At the time, though, it did not have any clear paths to accomplish this goal. City leaders looked around at other communities and quickly realized that they were going to have to do something unique. Unlike FTTP success stories such as Chattanooga, Tennessee, they did not have a municipal electric utility to tackle the challenge. They also did not have the resources, expertise, or political will to develop from scratch a municipal fiber service provider to compete with the incumbents. As a result, they needed to find a hybrid model.

As the community evaluated its options, it became clear that the fiber infrastructure itself was the city's most significant asset. All local governments spend money on durable assets with long lifespans, such as roads, water and sewer lines, and other infrastructure that is used for the public good. The leaders asked, "Why not think of fiber in the same way?" The challenge then

[80] *See, for example:* "Community Broadband Creates Public Savings," Fact Sheet, Institute for Local Self-Reliance, https://goo.gl/kCEZeC.
[81] Case study is based in part on a presentation by Dr. Robert Wack, President, Westminster (Maryland) City Council, during a webinar hosted by the Fiber to the Home Council and facilitated by CTC Technology & Energy. *See*: http://goo.gl/x82Ro7 (password required). See also: Robert Wack, "The Westminster P3 Model," *Broadband Communities Magazine* (Nov./Dec. 2015), http://goo.gl/op1XpH.
[82] "The Project," Inter-County Broadband Network, http://goo.gl/GjBC26.

was to determine what part of the network implementation and operations the private sector partner would handle and what part could be the city's responsibility.

The hybrid model that made the most sense required the city to build, own, and maintain dark fiber, and to look to partners that would light the fiber, deliver service, and handle the customer relationships with residents and businesses. The model would keep the city out of network operations, where a considerable amount of the risk lies in terms of managing technological and customer service aspects of the network.

The city solicited responses from potential private partners through a request for proposals (RFP). Its goal was to determine which potential partners were both interested in the project and shared the city's vision.

The city eventually selected Ting Internet, an upstart ISP with a strong track record of customer service as a mobile operator. Ting shared Westminster's vision of a true public–private partnership and of maintaining an open access network. Ting has committed that within two years it will open its operations up to competitors and make available wholesale services that other ISPs can then resell to consumers.

Under the terms of the partnership, the city is building and financing all of the fiber (including drops to customers' premises) through a bond offering. Ting is leasing fiber with a two-tiered lease payment. One monthly fee is based on the number of premises the fiber passes; the second fee is based on the number of subscribers Ting enrolls.

Based on very preliminary information, given that this is a market in development as we write, we believe this is a highly replicable model.

What is so innovative about the Westminster model is how the risk profile is shared between the city and Ting. The city will bond and take on the risk around the outside plant infrastructure, but the payment mechanism negotiated is such that Ting is truly invested in the network's success.

Because Ting will pay Westminster a small monthly fee for every home and business passed, Ting is financially obligated to the city from day one, even if it has no customers. This structure gives the city confidence that Ting will not be a passive partner, because Ting is highly incented to sell services to cover its costs.

Ting will also pay the city based on how many customers it serves. Initially, this payment will be a flat fee—but in later years, when Ting's revenue hits certain thresholds, Ting will pay the city a small fraction of its revenue per user. That mechanism is designed to allow the city to share in some of the upside of the network's success. In other words, the city will receive a bit of entrepreneurial reward based on the entrepreneurial risk the city is taking.

Perhaps most significantly, there is also a mechanism built into the contract that ensures that the two parties are truly sharing risk around the financing of the outside plant infrastructure. In any quarter in which Ting's financial obligations to the city are insufficient to meet the city's debt service, Ting will pay the city 50 percent of the shortfall. In subsequent quarters, if Ting's fees to the city exceed the debt service requirements, Ting will be reimbursed an equivalent amount. This element of the financial relationship made the deal much more attractive to the city because it is a clear demonstration of the fact that its private partner is invested with it.

5.2.3.2 Case Study: Santa Cruz, CA

In what we believe is the first of many similar projects to come nationwide, the City of Santa Cruz has adopted a variation on the Westminster model (see Section 5.2.3.1 above). In December 2015, the City Council in Santa Cruz signed an agreement that potentially delivers tremendous value to local residents while sharing risk between the public and private sector.

The Santa Cruz City Council approved an agreement between the city and a local ISP, Cruzio. The city will build, own, and maintain a fiber network; Cruzio, which is a DSL reseller, will migrate many of its DSL customers over to the city's fiber network—and will actively pursue additional new customers to buy broadband services over the fiber. As in the Westminster agreement, Cruzio will pay the city both a per-passing and a per-subscriber fee for its use of the city's fiber.

Cruzio is a small company, which creates a certain amount of partnership risk for the city. But from the city's standpoint, it is a very attractive partner—a locally based, locally owned company that employs Santa Cruz residents. In fact, the name of the company incorporates the city's name.

For Santa Cruz, identifying a local partner was a key factor in its negotiations. Cruzio's localism was so important to the city that in early 2015, the Council directed city staff to negotiate exclusively with Cruzio.

Cruzio has operated in the city since the early days of the Internet when it was a dialup ISP. In the broadband era, it migrated to some wireless service and to reselling phone company DSL. The logical next step is for Cruzio to migrate to fiber—which is what the relationship with the city will enable it to do.

The benefits of the partnership to the city include not only owning a next-generation network—and all the positive externalities that come with such a network—but also supporting and enabling an important local employer and longtime partner in the community.

5.2.3.3 Case Study: Garrett County, MD

The case studies presented above are incredibly promising, but those projects may be more challenging to replicate in rural communities, where the cost of fiber deployment, even in a shared-investment scenario, may still be prohibitive. The shared investment and shared risk strategy, however, is still applicable to rural communities—perhaps using other technologies that secure the benefits of broadband even if they do not result in the kinds of speeds that fiber enables.

For example, Garrett County, in far western Maryland, is a relatively remote Appalachian community bordered by West Virginia and Pennsylvania. The county has struggled to get broadband in a number of its remote, mountainous areas. Where broadband is available, it is inadequate DSL service that does not meet the Federal Communications Commission's (FCC) new speed benchmark for broadband service, let alone the requirements for home-based businesses or home schooling. The incumbent provider has not made any plans to expand or upgrade service offerings.

Though mobile broadband is available in some parts of the county, data caps mean that it is not viable for economic or educational activities. (Parents who home-school their children can run through their monthly bandwidth allotment in one day of downloading educational videos.) Beyond these challenges for residents, the county has struggled to attract and retain businesses and teleworkers.

In response, the county has gradually and incrementally built out fiber in some areas, with a focus on connecting specific institutions. And in September 2015, the County Council approved a contract with a private partner to leverage some of that fiber and additional public funding to support the deployment of a fixed-wireless broadband network that will serve up to 3,000 currently unserved homes in the most remote parts of the county. The private partner, Declaration Networks Group (DNG), will also put its own capital toward the construction of the network, and will apply its technical and operational capabilities to managing the network.

The partnership involves cost to the county, but also massive benefit for residents and businesses in the newly served areas.

The county's outlay of funds will be $750,000, which will be matched by a grant from the Appalachian Regional Commission (ARC)—and which will be more than matched by DNG's commitment of both capital and operating funds. That relatively modest county contribution (which was then leveraged for the ARC economic development funding) made the economics of this opportunity very attractive to DNG, and secured a broadband buildout for an area that would otherwise not be attractive for private sector broadband investment.

From an economic development perspective, the county's investment represents enormous value for the dollar. This investment will enable residents in 3,000 homes to buy cost-effective broadband service that they cannot access now, and that will make possible telework, home-based businesses, and home schooling. This investment will also enable the county to close the homework gap for many students in the county schools who do not currently have broadband in their homes—an increasingly critical lack of service.

As the network is deployed over the next few years, the county will reduce to nearly zero the number of homes in the county that do not have access to some kind of broadband communications options. These options may be modest—not the robust speeds available in metro markets—but they are significantly better than nothing, and a huge economic development achievement from the county's standpoint.

5.3 Additional Strategic Considerations for Public–Private Partnerships

As public sector entities of all sizes and capabilities evaluate potential models for public–private partnerships, it is important to approach each proposal with a healthy dose of common sense. Next-generation fiber deployment, particularly on a large scale to reach all residences and businesses in a community, is a valuable and future-proof investment. But it will not be cheap or easy. If anyone tells you otherwise, or claims that they will deliver enormous benefits at little or no cost or risk, ask for examples of projects where they have accomplished what they are promising. If it were easy, we would already have seen enormous private investment in FTTP across the country. Communities should be skeptical of rosy projections.

It is also critical to look for private sector partners that are interested in developing meaningful partnerships to deploy next-generation infrastructure. A significant risk around economic development incentives and other measures to facilitate investment is that private companies will request that localities take on additional costs as a condition of the private investment. For example, a private partner might ask the local government to hire dedicated inspectors and provide free access to real estate—and provide in return only tacit commitments for new services or technological upgrades. The goal of these partnerships is not simply to shift private sector costs to the public sector. If a company is a true partner, it will be willing to make firm commitments to invest in the community in return for the actions the locality takes to lower the cost of deploying infrastructure.

In addition, partners and partnerships will differ in different parts of the country, and with the size of a community. A primary challenge for localities seeking buildout to every residence and business is that the larger the community, the more difficult it may be for a private partner to deploy its service universally. By taking on the risk of fiber construction and finding a partner to light the network and provide service, a locality can increase the potential for a universal fiber buildout to every location.

Finally, do not underestimate the importance of the political element in tackling these challenges. Political concerns will play a huge role in finding solutions. Community and political leaders must jointly decide to pursue a project of this scope, to solve the problems that may arise along the way, and to bring fiber and its benefits to the community.

6 Engineering Analysis: FTTP Network Requirements and Design

The City of Madison recognizes the importance of deploying a robust, scalable FTTP[83] network infrastructure that can support a wide range of applications and services. This section describes many of the applications and services that the City's proposed FTTP network will need to support, as well as the general requirements of the FTTP network design. We present high-level cost estimates for a potential deployment of a gigabit FTTP network in Section 7.

6.1 Field Survey Methodology for Network Design and Cost Estimate

A CTC OSP engineer performed a preliminary survey of Madison via Google Earth Street View to develop estimates of per-mile cost for aerial construction in the power space and communications space, and per-mile costs for underground construction in areas where poles are not available.

A CTC engineer then conducted a brief on-site field study of representative portions of the City. The engineer reviewed available green space, necessary make-ready on poles, and pole replacement—all of which have been factored in to our design and cost estimate.

Figure 74 illustrates the areas reviewed during the field survey, while Table 17 summarizes each. Both the map and the table refer to the four types of population densities and existing utilities we used in our cost estimation model—high, medium aerial, medium underground, and low. (See Section 7.1 for more details.)

[83] FTTP is a network architecture in which fiber optics are used to provide broadband services all the way to each subscriber's premises.

Figure 74: Map of Field Survey Areas

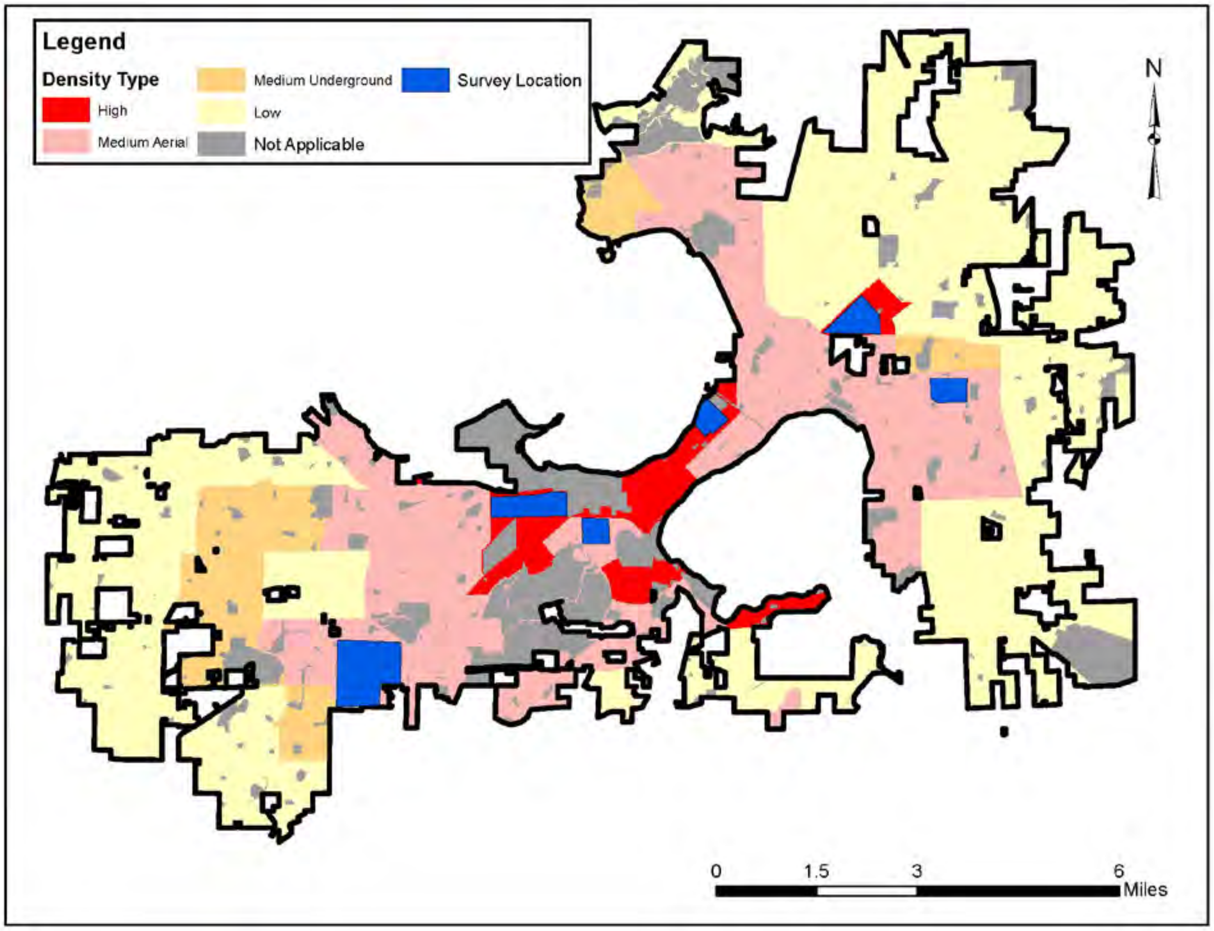


Table 17: Field Survey Findings[84]

	High Density	Medium Density Aerial	Medium Density Underground	Low Density
Aerial Construction	70%	70%	0%	0%
Poles per Mile	35	35	NA	NA
Moves per Pole	2.5	2.5	NA	NA
Poles Requiring Make-Ready	30%	30%	NA	NA
Poles Requiring Replacement	6%	5%	NA	NA
Intermediate Rock[85]	10%	5%	5%	5%
Hard Rock	2%	1%	1%	1%

[84] NA fields corresponds to underground areas, where utility poles are not part of the analysis.
[85] Higher percentages of intermediate and hard rock were used to simulate the tougher underground construction in the high-density downtown areas.

CTC's OSP engineer noted that the quality of the poles and pole attachments in Madison varied, as they do in many cities—but that overall, many poles would be capable of supporting an additional communications attachment with moderate make-ready.

6.2 FTTP Network Requirements

To explain why our analysis focuses on FTTP technology, we describe in this section the services and applications that the City's network must be able to support, the nature of the technologies we chose for the network, and the user groups we anticipate will use the network or subscribe to services.

6.2.1 User Applications and Services

The City's network must be able to support "triple play" services—high-quality data, video, and voice—that residential customers have grown accustomed to having in their homes, although this does not mean that the City or a given partner will be the entity that *directly* provides telephone or cable television services. As Internet technology has improved and network speeds have increased, voice and video services have become available as applications delivered by hundreds of providers over an Internet Protocol (IP)[86] data network connection.

The City and a potential partner can enable residential and small business customers to purchase voice, video, and other over-the-top (OTT)[87] services by providing them with unfettered,[88] reliable, high-speed Internet access with connections at a minimum of 1 Gbps.[89] In other words, the City and its partner would become an IP data network provider, either directly or through partnership(s), and would enable its citizens to purchase services—without the City acting as a gatekeeper.

6.2.1.1 Internet Access

Internet access is the fundamental service that most residents and small business owners will expect from a fiber connection, and is the prerequisite service for all of the applications described below. The retail provider on the FTTP network will also need one or more peering connections with upstream Internet service providers (ISP), reducing wholesale Internet costs and improving service delivery.

As described in detail below, the FTTP network will support a baseline service level (e.g., 1 Gbps) suitable for residential and small business customers. It will also be capable of supporting

[86] Internet Protocol, or "IP," is the method by which computers share data on the Internet.
[87] "Over-the-top" (OTT) content is delivered over the Internet by a third-party application or service. The ISP does not provide the content (typically video and voice) but provides the Internet connection over which the content is delivered.
[88] Meaning that access to websites offering OTT services is not blocked, restricted, or rate-limited.
[89] Rate is a best-effort basis, not a guaranteed speed. Further, it is important to note that with the proposed architecture the retail provider(s) would provide a 1 Gbps baseline service and 10 Gbps and beyond on a case-by-case basis. The baseline can be increased to 10 Gbps and beyond by upgrading the network electronics

higher residential speeds—10 Gbps and beyond—and a range of business and enterprise services.[90]

6.2.1.2 IP Telephony (VoIP) and Video Conferencing

Voice over IP (VoIP) is a voice telephony service delivered over an IP data network.[91] In the context of an FTTP access network, VoIP generally refers to an IP-based alternative to Plain Old Telephone Service (POTS) over copper wiring from a Local Exchange Carrier (LEC).[92] With VoIP, both the live audio (voice) and the call control (signaling) portions of the call are provided through the IP network. Numerous third parties offer this type of full-service VoIP, which includes a transparent gateway to and from the Public Switched Telephone Network (PSTN).[93]

Because VoIP runs over a shared IP network instead of a dedicated pair of copper wires from the LEC, extra design and engineering are necessary to ensure consistent performance. This is how the VoIP services delivered by Comcast (which provides Quality of Service, or QoS,[94] on its network underneath the VoIP services) typically have the same sound and feel as traditional wireline voice calls. In contrast, VoIP services without QoS (such as Skype) will have varied performance, depending on the consistency of the Internet connection. For voice and other real-time services such as video conferencing, network QoS essentially guarantees the perceivable quality of the audio or video transmission.

From a networking perspective, IP-based video conferencing services are fundamentally similar to VoIP. While IP video conferencing is currently less common as a residential application, small and medium-sized businesses in the FTTP domain can be assured that QoS for IP-video conferencing can also be supported, as with VoIP.

6.2.1.3 Streaming Video

The variety of online video available through service providers like Amazon, HBO Go, Hulu, Netflix, YouTube, and others continues to attract users and challenge cable providers' traditional business models. These are all examples of OTT[95] video available over the Internet to users at home or on mobile devices like a smartphone or tablet.

Traditional cable television providers (also known as linear multi-channel video services) can also deliver content over a fiber connection rather than through a separate coaxial cable connection to users' homes.

---

[90] Network can support faster connection speeds and other guaranteed service levels to a portion of end users.
[91] In this context, voice services are delivered over a data connection.
[92] A LEC is a public telephone company that provides service to a local or regional area.
[93] The PSTN is the copper-wire telephone networks that connect landline phones.
[94] QOS is a network's performance as measured on a number of attributes.
[95] OTT refers to voice, video, and other services provided by a third-party over the Internet rather than through a service provider's own dedicated network. OTT is also known as "value added" service.

All of these video services can be supported by the proposed FTTP network—as will be locally produced content from a Media Center and public service videos or documentaries filmed by students, community groups, or others which can be streamed to residents directly from a school, library, or government building that is on the network. The avenues through which consumers can access content are broadening while the process becomes simpler.

Because of the migration of video to IP format, we do not see a need for the FTTP network to support the Radio Frequency (RF) based video cable television service, an earlier technology used by some providers to carry analog and digital television in native form on a fiber system.

Early municipal providers like Lafayette Utilities System (LUS) and Chattanooga's Electric Power Board (EPB) found that a data product alone was not strong enough to obtain the necessary market share to make the endeavor viable. Even when Google Fiber entered the Kansas City market in 2011, it found that if it wanted to get people to switch providers, it *had* to offer cable, deviating from its original plan and introducing more cost and complexity than the simple data service it had anticipated. If an OTT cable offering were available when early municipal providers began offering service and when Google entered the Kansas City market, they may have found that offering traditional cable television was unnecessary. More recent municipal FTTP efforts, like Longmont, Colorado, are successfully gaining market share without providing video services.

6.2.1.4 Cloud Access

"Cloud services" refers to information technology services, such as software, virtualized computing environments, and storage, available "in the cloud" over a user's Internet connection. Enterprise and residential customers alike increasingly use cloud services. With their mobile devices like smartphones and tablets, consumers want access to their photos, videos, and music from anywhere. And businesses want employees to have access to important information to keep operations running smoothly, even when they are away from the office.

The business drivers behind cloud computing are ease of use and, in theory, lower operating costs. For example, if you are a business owner, the "cloud" theoretically allows you to use large-scale information services and technologies—without needing hardware or staff of your own to support it.

Cloud services eliminate the need to maintain local server infrastructure and software, and instead allow the user to log into a subscription-based cloud service through a Web browser or software client. The cloud is essentially a shift of workload from local computers in the network to servers managed by a provider (and that essentially make up the cloud). This, in turn, decreases the end user's administrative burden for Information Technology (IT) services.

Typically, cable modem and DSL services are not symmetrical—thus incumbent network transfer rates to upload to the cloud are significantly slower than download rates. This can cause significant delays uploading to cloud services.

There are also numerous other cloud services that customers frequently use for non-business purposes. These include photo storage services like Flickr and Shutterfly, e-mail services like Gmail and Hotmail, social media sites like Facebook and Twitter, and music storage services like iTunes and Amazon Prime.

By enabling retail ISP(s) to reliably serve residents and small businesses with high-speed services, the City's FTTP network will increase their options to use the cloud. Improving on less robust connections (e.g., cellular broadband or cable modem services), the City's network will also enable teleworkers and home-based knowledge workers in Madison to access cloud-based development environments, interact with application developers (both local and remote), and access content delivery network (CDN) development and distribution channels.[96]

6.2.1.5 Over-the-Top (OTT) Programming

As we noted, OTT programming typically refers to streaming content delivered via a consumer's Internet connection on a compatible device. Consumers' ubiquitous access to broadband networks and their increasing use of multiple Internet-connected devices has led to OTT being considered a disruptive technology for video-based entertainment. The OTT market, which includes providers like Netflix, Hulu, Amazon Instant Video, and iTunes, was expected to grow from about $3 billion in 2011 to $15 billion, by 2016.[97] New projections anticipate that the industry could grow to $17 billion by 2017[98] and $19 billion by 2019.[99]

In order to provision content, OTT services obtain the rights to distribute TV and movie content, and then transform it into IP data packets that are transmitted over the Internet to a display platform such as a TV, tablet, or smartphone. Consumers view the content through a Web-based portal (i.e., a browser) or an IP streaming device (e.g., Google Chromecast, Roku, Apple TV, Xbox 360, or Internet-enabled TV/Smart TV).

One potential difference in the delivery of OTT video content to consumers compared to other data traffic is OTT video's high QoS requirement. QoS prioritizes the delivery of video packets

---

[96] See, for example: "Amazon CloudFront," *Amazon Web Services,* accessed May 3, 2016, http://aws.amazon.com/cloudfront/.

[97] Dr. Karim Taga and Clemens Schwaiger, "Over-the-Top-Video – "First to Scale Wins," *Arthur D Little*, accessed May 3, 2016, http://www.adlittle.com/downloads/tx_adlreports/TIME_2012_OTT_Video_v2.pdf.

[98] "Over-the-top content revenue worldwide from 2008 to 2017," *Statista*, accessed May 3, 2016, http://www.statista.com/statistics/260179/over-the-top-revenue-worldwide/.

[99] Wayne Friedman, "Over-the-Top TV Revenues Forecast to hit $19B In 2019," *Media Post,* last modified June 11, 2015, http://www.mediapost.com/publications/article/251798/over-the-top-tv-revenues-forecast-to-hit-19b-in-2.html.

over other data where uninterrupted delivery is not as critical, which ultimately translates to a high quality viewing experience for customers. Content buffering and caching for streamed content reduces the need for QoS. Network QoS is designed for and driven by the need to support real-time services such as VoIP and video conferencing.

OTT providers typically have to use the operators' IP bandwidth to reach many of their end users. At the same time, they are a major threat to cable television programming, often provided by the very same cable operators, due to their low-cost video offerings. As a result, many cable operators have introduced their own OTT video services to reach beyond the constraints of their TV-oriented platforms and to facilitate multi-screen delivery.[100]

Even Comcast seemed to embrace OTT by launching its "Streampix" in 2012,[101] though that service was less than successful and was ultimately removed as a standalone offering. In 2015, Comcast announced another attempt at providing OTT content in the form of its "Stream" package,[102] however subscribers must also sign up for Xfinity Internet to access "Stream" content.

While the nature of OTT video lends itself nicely to video-on-demand (VoD), time-shifted programming, and sleek user interfaces, OTT providers have limited control over the IP transport of content to users, which can cause strains on network bandwidth due to the unpredictable nature of video demand. Cable operators have experimented with rate limiting and bandwidth caps,[103] which would reduce subscribers' ability to access streaming video content. It is also technically possible for cable operators to prioritize their own traffic over OTT video streams, dial down capacity used by OTT on the system, or stop individual OTT streams or downloads.

Some cable operators have attempted to manage OTT on their networks by incorporating the caching of OTT video content from third-party providers (e.g., Netflix) in their data centers in order to improve QoS and reduce congestion on the cable provider's backbone network. This serves as a means for improving the quality of OTT video for video hosted in the data center.

---

[100] "Cable operators embrace over-the-top video, but studios thwart Netflix, Hulu options," *FierceCable*, last modified July 2, 2013, http://www.fiercecable.com/special-reports/cable-operators-embrace-over-top-video-studios-thwart-netflix-hulu-options.

[101] John Cook, "Comcast unveils $4.99 per month Streampix service, taking aim at Netflix," *GeekWire,* last modified February 21, 2012, http://www.geekwire.com/2012/comcast-unveils-499-month-streampix-service-aim-netflix-hulu/.

[102] Heather Newman, "Why Comcast Is Still Betting On Bundles with Stream," *Forbes,* last modified July 27, 2015, http://www.forbes.com/sites/hnewman/2015/07/27/why-comcast-is-still-betting-on-bundles-with-stream/#2416cfcb72e6.

[103] Jeff Baumgartner, "Comcast tests new usage based internet tier in Fresno," *Multichannel News*, last modified August 1, 2013, http://www.multichannel.com/distribution/comcast-test-new-usage-based-internet-tier-fresno/144718.

6.2.2 Network Design Considerations

This section provides a high-level overview of certain functional requirements used to prepare the conceptual FTTP design and cost estimate. It also presents the technical details of an FTTP network in terms of performance, reliability, and consumer perceptions based on providers' marketing.

Google changed the industry discussions and customer perceptions of data access when it introduced its plans to deploy an FTTP network and offer a 1 Gbps data connection for $70 per month in Kansas City, beginning in 2012.[104] Until Google entered the FTTP market, cable operators such as Comcast questioned the need for 1 Gbps speeds and typically indicated that 10 Mbps was sufficient for residential and small business users. (Gigabit speeds were available in a few localities, such as Chattanooga, Tennessee, but Google's brand name meant that Google Fiber had a bigger impact on national awareness around this type of connection.) Since Google's entry, Comcast and other providers have slowly increased their data offering speeds—moving to 25 Mbps, 50 Mbps, and finally gigabit fiber services in selected markets.

Charter has not indicated plans to offer a 1 Gbps service in Madison; however, it has indicated plans for a demonstration of a 1 Gbps service in Louisville, Kentucky as part of a franchise agreement transfer in that city.[105]

Other cable operators have been more aggressive. For example, Comcast already advertises its 2 Gbps "Gigabit Pro" service in several markets—though that service is only available in locations that are less than one-third of a mile from its existing fiber infrastructure, and requires users to pay at least $1,000 in activation and installation fees. Comcast has also announced plans to upgrade its existing hybrid fiber-coaxial (HFC) network to DOCSIS 3.1 across its entire service area by 2018. Initially, it will offer 1 Gbps service, but DOCSIS 3.1 is capable of offering as much as 10 Gbps service. Comcast has not yet released pricing for DOCSIS 3.1-based services.[106]

It is important to note that Internet access speed represents only one portion of the overall Internet experience, and measuring a network's overall performance on one metric is incomplete. Further, "advertised speed" for residential services is a best-effort commitment, not a guarantee, and does not necessarily reflect actual performance. For example, the

---

[104] "Plans and Pricing," *Google Fiber,* accessed May 3, 2016, https://fiber.google.com/cities/kansascity/plans/.

[105] Daniel Frankel, "Charter takes over TWC's Louisville charter, agrees to free Wi-Fi, 1 Gbps conditions," *FierceCable*, last modified October 23, 2015, http://www.fiercecable.com/story/charter-takes-over-twcs-louisville-charter-agrees-free-wi-fi-1-gbps-conditi/2015-10-23.

[106] Mike Dano, "Comcast: We'll cover our entire network with 10 Gbps-capable DOCSIS 3.1 tech as soon as 2018," *FierceCable*, last modified August 21, 2015, http://www.fiercecable.com/story/comcast-well-cover-our-entire-footprint-10-gpbs-capable-docsis-31-tech-soon/2015-08-21.

advertised speed does not delineate a minimum speed or a guarantee that any given application, such as Netflix, will work all the time.

6.2.2.1 Why Fiber Optics

For several decades, fiber optic networks have consistently outpaced and outperformed other commercially available physical layer technologies, including countless variants of copper cabling and wireless technologies. The ranges of current topologies and technologies all have a place and play important roles in modern internetworking.[107] The evolution of Passive Optical Network (PON) technology has made FTTP architecture extremely cost-effective for dense (and, more recently, even lower and medium-density) population areas.

The specifications and the performance metrics for FTTP networks continue to improve and outperform competing access technologies. In fact, from the access layer up through all segments of the network (the distribution layer and the core, packet-, and circuit-switched transports, and even into the data center), and for almost all wireless "backhaul" communications, optical networking is the standard wireline technology.

Compared to other topologies, fiber-based optical networks will continue to provide the greatest overall capacity, speed, reliability, and resiliency. Fiber optics are not subject to outside signal interference, can carry signals for longer distances, and do not require amplifiers to boost signals in a metropolitan area broadband network.[108]

If an ISP were to build new with no constraints based on existing infrastructure, it would likely begin with an FTTP access model for delivery of all current services; compared to other infrastructure, an FTTP investment provides the highest level of risk protection against unforeseen future capacity demands. In cases where a provider does not deploy fiber for a new route, the decision is often due to the provider's long-term investment in copper OSP infrastructure, which is expensive to replace and may be needed to support legacy technologies.

6.2.2.2 Fiber Routes and Network Topology

FTTP architecture must be able to support a phased approach to service deployment. Phased deployments can help support strategic or tactical business decisions of where to deploy first, second, or even last. Phasing also allows for well-coordinated marketing campaigns to specific geographic areas or market segments, which is often a significant factor in driving initial acceptance rates and deeper penetration. This is the "fiberhood" approach used by Google and others.

[107] An internetwork is a network of interconnected networks.
[108] Maximum distances depend on specific electronics—10 to 40 km is typical for fiber optic access networks.

A fiber backbone brings the fiber near each neighborhood, and fiber can be extended as service areas are added in later phases of deployment. This allows for the fiber in individual neighborhoods to be lit incrementally,[109] with each new neighborhood generating incremental revenue.

The proposed Gigabit passive optical network (GPON) FTTP architecture supports this capability once the core network electronics are deployed and network interconnections are made. GPON is the most commonly provisioned FTTP service—used, for example, by Verizon (in its FiOS systems), Google Fiber, and Chattanooga Electric Power Board (EPB). GPON uses passive optical splitting, which is performed inside fiber distribution cabinets (FDCs), to connect fiber from the optical line terminals (OLTs)[110] to multiple customer premises over a single GPON port. The GPON architecture is discussed further in Section 6.2.2.3 and Section 6.3 below.

In addition to these core considerations, we note that designing the network to support mobile backhaul may allow the City or its partners to generate additional revenue from mobile carriers, as well as improve mobile broadband service in the city. Given that this is a longer-term consideration our financial model does not currently include revenue earned from leasing excess network capacity to cellular providers for mobile backhaul use.

6.2.2.3 Passive Optical Network—Specifications and Technology Roadmap

The first PON specification to enjoy major commercial success in the U.S. is Gigabit-capable Passive Optical Network (GPON). This is the standard commonly deployed in today's commercial FTTP networks and it is inherently asymmetrical. Providers from Google Fiber to Chattanooga's EPB offer 1 Gbps asymmetrical GPON service with relatively high oversubscription rates (albeit far less than non-FTTP competitors). Our suggested network design allows for provision of symmetrical services ranging from typical levels of oversubscription to dedicated symmetrical capacity per subscriber.

The GPON standard (defined by ITU-T G.984.1) was first established and released in 2004, and while it has since been updated, the functional specification has remained unchanged. There are network speed variants within the specification, but the one embraced by equipment manufacturers and now widely deployed in the U.S. provides asymmetrical network speeds of 1.24 Gbps upstream and 2.49 Gbps downstream.

Since the release of the ITU-T G.984.1 GPON specification, research and testing toward faster PON technologies has continued. The first significant standard after GPON is known by several names: XG-PON, 10GPON, or NG-PON1. The NG-PON1 specification offers a four-fold performance increase over the older GPON standard. Although NG-PON1 has been available

[109] As the name implies, "lit fiber" is no longer dark—it is in use on a network, transmitting data.

[110] The OLT is the upstream connection point (to the provider core network) for subscribers.

since 2009, it was not adopted by equipment manufacturers and has not been deployed in provider networks. We expect the version released in 2015, NG-PON2, to evolve as the de facto next-generation PON standard.

These new standards can be implemented through hardware or software (electronics) upgrades, and are "backward compatible" with the current generation, so all variants can continue to operate on the same network.

The optical layer of the NG-PON2 standard is quite different from GPON. The specification uses a hybrid system of new optical techniques, time division multiplexing (TDM) / wave division multiplexing (WDM) PON (TWDM-PON), that basically multiplexes four 10 Gbps PONs onto one fiber, to provide 40 Gbps downstream. This is a 16-fold performance increase over the current GPON standard.

While efforts continue on an ongoing basis by the standards-development community and hardware manufacturers to deliver a WDM-based solution leveraging wavelength-tunable optics to significantly surpass the 10 Gbps barrier, the more recently announced XGS-PON represents an interim solution to facilitate true symmetrical 10 Gbps services (the "S" in "XGS"). The ITU-T announced simultaneously on March 1, 2016 the approval of an amendment to the NG-PON2 standards with the first-stage approval the "XGS-PON" standard.

The XGS-PON physical layer is based on XG-PON specifications (and likely eliminates any potential demand there might have been for XG-PON), operating within the same windows using fixed wavelength optics. Final approval of the standard is expected later in 2016, and some manufacturers expect widespread commercial deployments to begin in 2017—well before NG-PON2 hardware will be widely available or affordable—enabling providers to deliver symmetrical 10 Gbps services over their PON infrastructure while operating in parallel with existing GPON services.

At minimum, the upgrade pathway for existing GPON deployments will require new enhanced small form-factor pluggable (SFP+) modules on the OLT side within the hub building or equipment cabinet, and a new optical network terminal (ONT) device at the customer premises, with software and firmware upgrades on the FTTP electronics. The migration to WDM-based technologies, like NG-PON2, also require the addition of coexistence elements ("CEx") between the OLT and the PON splitters, which can consist of a range of configurations of passive wavelength filters and couplers. Final details are yet to be announced and will vary by manufacturer, but the NG-PON2 specification requires a migration path and backward compatibility with GPON, facilitated by a coordinated wavelength plan that allows each of these standards to operate over common fiber strands without interfering. FTTP equipment manufacturers are actively testing upgrade steps and strategies for migrating from GPON to NG-PON2.

Table 18: PON Standards

Year	Standard
1994	pi-PON. 50 Mb/s, 1310nm bidirectional, circuit switched
1999	A/B-PON. 622/155 Mb/s, 1550nm down, 1310nm up, ATM-based
2004	G-PON. 2.4/1/2Gb/s, 1490nm down, 1310nm up, packet-based G-PON (2.5)
2009	NG-PON1. 10/2.5Gb/s, 1577nm down, 1270nm up, packet-based XG-PON (10)
2015	NG-PON2. 40G+ capacity XLG-PON (40)
2016	XGS-PON. 10/10 Gb/s, 1577nm down, 1270 up

6.2.2.4 Managing Network Demand

Perhaps the most fundamental problem solved by IP packet data networking is how to cost-effectively design, build, and operate a network to manage unpredictable demands and bursts of network traffic.

The earliest transport networks (and many of the major Internet backbone segments today) are circuit switched. This means that each network leg is a fixed circuit, running at a fixed speed all the time. Fixed-circuit networks are less flexible and scalable, and utilize capacity far less efficiently than packet-switched networks; they must be precisely designed and planned in advance, because there are fewer mechanisms to deal with unplanned traffic surges or unexpected growth in demand.

"Dial-up" modems provide an example of circuit-switched technology. Copper POTS lines were in huge demand as residential and business customers purchased fax machines and accessed the Internet over modems. Because the POTS technologies could not support all of these uses at the same time, and were limited to slower speeds, phone companies were only able to serve that demand by installing more copper lines.

The packet-switched DSL, cable modem, fiber, and wireless technologies that replaced POTS addressed the limitations of fixed-circuit technologies because the flow of network traffic is determined on a per packet basis, and the network provides robust mechanisms for dealing with unexpected bursts of traffic. The trade-off for flexibility, resiliency, and ease of use is that network speed will vary, depending mainly on the amount of traffic congestion.

6.2.2.4.1 Oversubscription

An important balancing act in packet networks is between network performance (speed) and network utilization (efficiency). The primary method of achieving this balance is *oversubscription*. Because the vast majority of network users are not actually transmitting data at any given moment, the network can be designed to deliver a certain level of performance based on assumptions around actual use.

Oversubscription is necessary in all packet-switched network environments and is generally beneficial—by enabling the network operator to build only as much capacity as necessary for most scenarios. By way of comparison, the electric industry uses a demand factor to estimate generation requirements. Similarly, a road that has enough capacity to keep most traffic moving at the speed limit most of the time will get congested during peak travel times—but building a road large enough to handle all of the traffic at peak times would be too expensive. Most drivers most of the time have enough room to go the speed limit, but when a lot of users want to be on the road at the same time, everyone has to slow down.

The retail provider(s) using the City FTTP network will need to evaluate and manage its subscription levels to deliver the optimal balance of performance and efficiency. Although the goal of providing symmetrical *dedicated*[111] 1 Gbps data to all subscribers is admirable and technically possible, it may not be very practical or affordable. By comparison, Google's 1 Gbps offering is technically neither symmetrical nor dedicated.

Services may be burstable, meaning that users may experience the advertised data rates at times, but the average speed will vary greatly based on the traffic being generated over the provider's distribution network. Performance parameters on a burstable service are rarely publicized or realized. Often a network operator cannot change this parameter without changing the network's physical connections.

When looking at FTTP requirements, it is important to understand that the speeds and performance stated in marketing material for consumer services are not the same as a network's actual technical specifications. Actual speeds and performance will depend on the activity of other users on the network. Generally, all residential and small business Internet services are delivered on a best-effort basis and have oversubscription both on the network and in the network's connection to the Internet.

First, let's look at network oversubscription. Today's GPON standard supports FTTP network speeds of up to 2.4 Gbps downstream (to the consumers) and 1.2 Gbps upstream (from the consumers) from a given OLT. Each OLT interface is typically connected to passive optical splitters configured to support up to 32 premises.[112] That is, up to 32 users will share the 2.4 Gbps downstream and 1.2 Gbps upstream.[113] Given that not all users will demand capacity at

[111] As its name implies, service is "dedicated" when the link runs directly from the ISP to the user.
[112] Can be deployed in 8 to 1, 16 to 1, and 32 to 1 configurations. Lower rations reduce the number of subscribers sharing the capacity, but increases the number of FDCs and fiber strands.
[113] In an HFC network as used by Comcast, the network capacity is shared among 250 to 500 users.

the same time and that very few applications today actually use 1 Gbps, a provider can reasonably advertise delivery of a symmetrical 1 Gbps service on a best-effort basis and most consumers will have a positive experience. This level of oversubscription at the GPON "access" layer is quite low compared to most modern cable modem networks, which typically share 150 Mbps – 300 Mbps among several hundred users, even while offering service tiers that "burst" to 150 Mbps.

NG-PON2 (described above) will likely enable support of 40 Gbps downstream. In four or so years, the NG-PON2 platform should become standard, and although it will initially be somewhat more expensive, pricing will likely quickly match levels similar to today's 2.4 Gbps platform.

Even with today's 2.4 Gbps GPON platform, the network can be designed to support 10 Gbps, 100 Gbps, or other symmetrical speeds. This can be accomplished with a hybrid approach using Active Ethernet (AE)[114] and GPON, or by deploying a full AE network, which would require placing active electronics inside FDCs in the field.

The next level of oversubscription is generally in the distribution network between the OLT and the service provider's core network. This portion of the network varies drastically between networks of different size, and is specific to the architecture of a particular network. Most OLT hardware provides 10 Gigabit Ethernet (10 GE) interfaces for uplinks to aggregation switches, frequently with multiple 10 GE interfaces supporting dozens of GPON interfaces (each supporting 16 or 32 customers)—perhaps on the order of 500 or 1,000 customers supported over a pair of redundant 10 GE links. While substantially more oversubscription than at the access layer in a GPON network, most OLT hardware is modularly scalable so that oversubscription can be managed by augmenting uplink capacity as demands grow. Moreover, this layer of the network can generally be upgraded less expensively and, indeed over-engineered in the initial deployment without significantly impacting costs in a relative sense, as the number of network devices and interfaces are far fewer than at the access layer.

The next level of oversubscription is with the network's access to the Internet. Again, since not all users demand capacity at the same time, there is no need to supply dedicated Internet bandwidth to each residential or small business customer. In fact, it would be cost prohibitive to do so: Assuming a DIA cost of $0.50 per Mbps per month, the network operator would pay $500 per month for 1 Gbps of DIA. But an operator with a residential and small business 1 Gbps service could easily use an oversubscription of 500 to 1,000 on DIA today. Then, as users

[114] This is a technology that provides a symmetrical (upload/download) Ethernet service and does not share optical wavelengths with other users. For subscribers that receive AE service—typically business customers that request a premium service or require greater bandwidth—a single dedicated fiber goes directly to the subscriber premises with no optical splitting.

require more bandwidth, the operator simply subscribes to more bandwidth. The preferential approach is to reduce the traffic over the Internet, which is accomplished by peering to other networks, placing servers (such as Netflix) on the City's FTTP network (referred to as on-net), and caching.[115]

All of the applications that the City has identified are possible with 1:32 GPON architecture and reasonable oversubscription. If a bottleneck occurs at the Internet access point, the retail provider(s) can simply increase the amount of commodity bandwidth (DIA) it is purchasing or bring servers such as Netflix on-net. Customers looking for greater than 1 Gbps or who require Committed Interface Rates (CIR) can be served via a higher priced Ethernet service rather than the GPON-based 1 Gbps service.

6.2.2.4.2 Rate Limiting

In some networks, unexpected bursts of network traffic slow things down to unacceptable speeds for everyone using the network. Thus there needs to be a mechanism in place to manage these events for the greater good of everyone sharing the network.

One technique for controlling this is called rate-limiting. It can be implemented in many different ways, but the net result is that it prevents over-congestion on a network during the busiest usage times.

Most consumer Internet services today provide subscribers with a "soft" rate for their data connections. This may allow for some extra speed and capacity during times when the network is uncongested, but it may also mean that the "soft" rate may not be achievable during times when the network is the most congested. Providers need to have this flexibility to cost effectively manage the networks overall performance and efficiency and they do this with subscription levels and rate limiting.

6.2.2.5 Internet Protocol (IP) Based Applications

The FTTP design will be an all-IP platform that provides a scalable and cost-effective network in the long run. This will allow the City and its partners to minimize ongoing costs; increase economies of scale with other network, communications, and media industries; and operate a uniform and scalable network. For example, with an IP-based data network, there would not need to be a separate set of video transport equipment in the headend or hubs, nor a set of dedicated video channels. The transport equipment and the spectrum would become uniform and converge to a single IP platform. Thereafter, network upgrades could be carried out solely based on the evolution of high-speed networking architecture, independent of video processing capabilities often inherent in incumbent provider networks.

---

[115] Network server or service that saves Web pages or other Internet content locally.

6.2.2.6 Migration from IPv4 to IPv6 Protocol

The Internet is in the process of migrating from the IPv4 to the IPv6 protocol. This upgrade will include several improvements in the operation of the Internet. One of the most notable is the increase in available device addresses, from approximately four billion to $3x10^{38}$ addresses. IPv6 also incorporates other enhancements to IP networking, such as better support for mobility, multicasting, security, and greater network efficiency; it is being adopted across all elements of the Internet, such as equipment vendors, ISPs, and websites.

Support of IPv6 is not unique to the proposed City FTTP network. Many cable operators have begun migrating their services to IPv6.

Customers with access to IPv6 can connect IPv6-aware devices and applications through their data connection and no longer need to use network address translation (NAT) software and hardware to share the single IP address from the ISP among multiple devices and applications. Each device can have its own address, be fully connected, and (if desired) be visible to outside networks.

One way to think of removing NAT is that it is the IP equivalent of moving from a world of cumbersome telephone systems with a main number and switchboard extension (e.g., 608-555-0000 extension 4422) to one where each individual has a unique direct number (e.g., 608-555-4422). Devices and applications that will particularly benefit from IPv6 include interactive video, gaming, and home automation, because NAT (and other IPv4 workarounds to share limited address space) makes connecting multiple devices and users more complex to configure, and IPv6 will eliminate that complexity and improve performance. With IPv6, each device and user can potentially be easily found, similar to how a phone is reached by dialing its phone number from anywhere in the world.

6.2.2.7 Multicasting—IP Transport of Video Channels

Traditional Internet video can waste capacity, especially in a “channel” video environment, because it sets up a new stream from the source to each viewer. Even if many people are watching the same program at the same time, a separate copy is streamed all the way from the server (or source) to the user. *Multicasting* is a method of transmitting data to multiple destinations by a single transmission operation in an IP network.

Using multicasting, a cable operator (leveraging the proposed FTTP network) can send a program to multiple viewers in a more efficient way. A multicast-aware network sends only a single copy of any given video stream from its source through the various network routers and switches within the network. When a viewer selects the program, the viewer’s device (set-top converter or computer) requests the multicast stream, a copy of which is then provided to that customer by the underlying network—rather than the originating video server or encoder sending a dedicated unicast stream to that customer, as is the case with OTT video services and other Internet-based video applications. Thus, the stream exists only once over any given segment of the network upstream from the access layer, so even if many neighbors are viewing the same stream, multicast video services can never occupy more capacity than the sum of one copy of each video stream (see Figure 75 and Figure 76).

Figure 75: Unicast IP Network Carries Multiple Copies of Single Video Channel

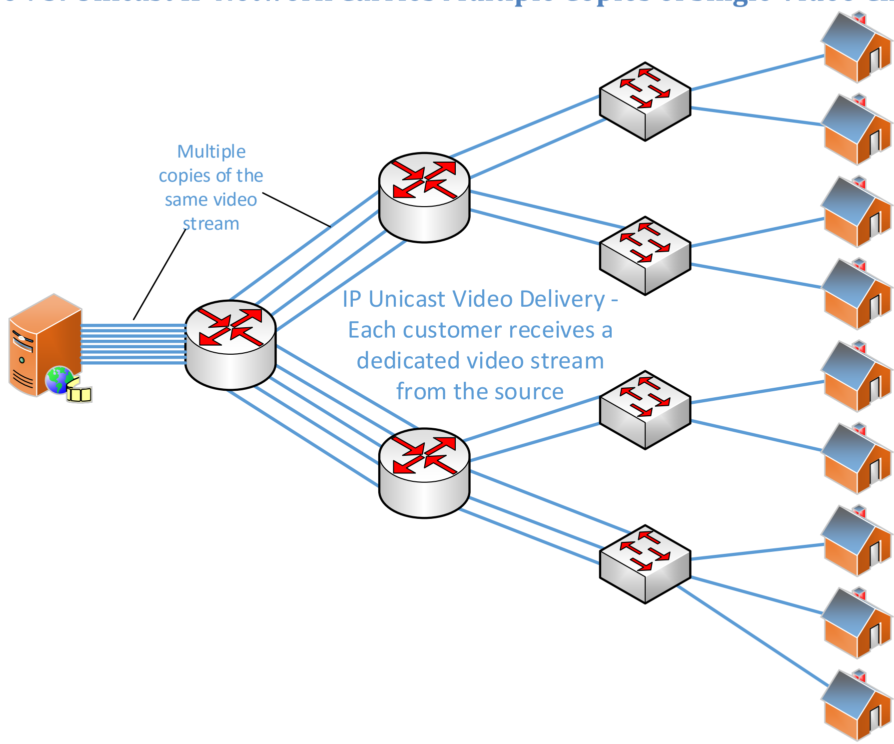
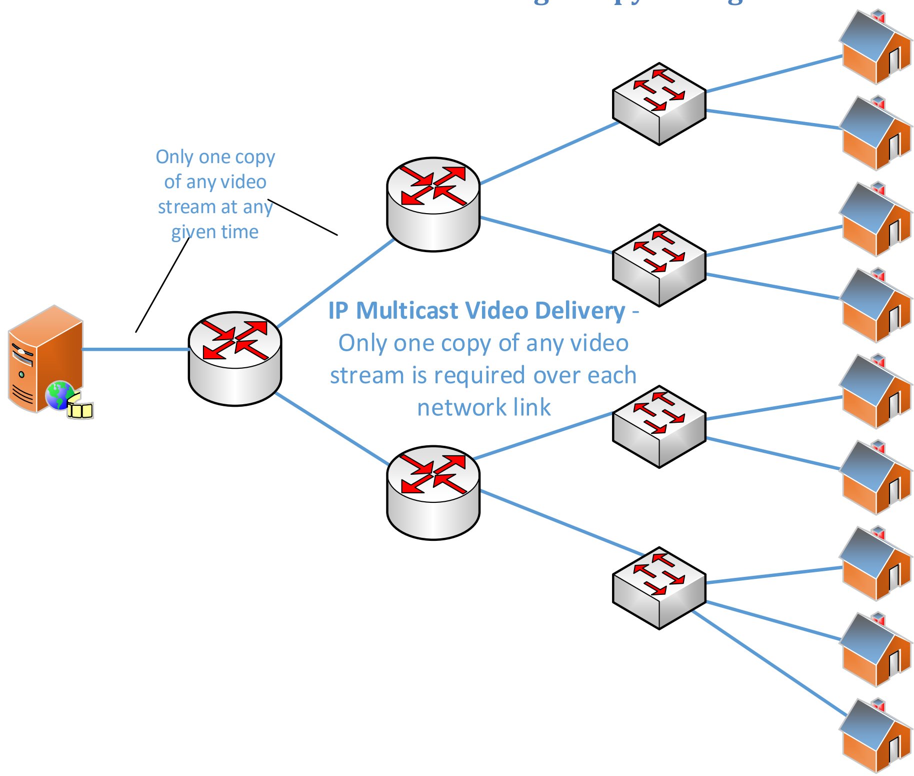


Figure 76: Multicast IP Network Carries Single Copy of Single Video Channel



Multicast is a feature that was optional in IPv4 but standard (and better executed) in IPv6. As multicast-capable and multicast-aware routers and set-top converters become standard, a cable operator and OTT video providers leveraging the City's FTTP network could consider an all-IP video programming offering, and not just VoD, as multicast provides a means to carry traditional channels over IP without wasting the backbone capacity.

6.2.3 Target User Groups

Based on our discussions with City staff, we identified two primary categories of potential network users (in addition to the City):

- Residents
- Small businesses and enterprise users

To analyze the user groups, we first estimated the possible number of "passings"—the number of households and businesses the fiber could potentially pass (potential customers). Based on data provided by the City, there are a total of 61,000 land parcels (structures) in the City and a total of 915 street miles.

The City's property database, PLGEO—which is used for assessments and to generate property tax bills—estimates that there are 114,680 residential households in the City of Madison. See Table 19 below.

Table 19: Total Potential Residential Customers Passed

Dwellings in Structures on Property	Dwelling Units
1-unit, detached	46,320
2 units	6,849
3 or 4 units	6,032
5 to 9 units	4,278
10 to 19 units	2,830
20 or more units[116]	48,371
Residential Total	**114,680**

We typically treat MDUs with 20 or more units on a case-by-case basis because the potential customers there may not be accessible to the City. For example, many large building owners are locked into long-term contracts with a single provider to offer services to all the units in the building. For this analysis, we included 50 percent of households in MDUs with 20 or more units—thus, we estimate that there are 90,494 residential households in Madison.

Table 20: Total Residential Passings

Residential Total	114,680
Less 50% of households in 20 or more units	24,186
Total residential household market base	**90,494**

To determine the number of total businesses, we used data from InfoUSA,[117] which has records for 10,331 businesses in Madison. See Table 21 below.

[116] The 20-or-more unit category is the total dwellings in all structures on the property vs. the census data category is for the total units in a given structure. With census data, CTC treats larger MDUs on a case-by-case basis and the households in these units are not considered in the market potential. The OSP fiber estimate includes a connection to the building, but does not include costs for internal wiring. All other MDUs are treated as a single family unit for the OSP, drop, and CPE estimates. For the PLGEO data we recommend treating 50 percent of units in the 20-plus category on a case-by-case basis and the remaining units as single family units.

[117] See www.InfoUSA.com.

Table 21: Total Potential Business Customers Passed

Total Employees	Total Businesses
1 to 4	5,356
5 to 9	1,896
10 to 19	1,417
20 to 49	1,014
50 to 99	373
100 to 249	191
250 to 499	59
500 to 999	15
1,000 to 4,999	9
5,000 to 9,999	-
10,000 or more	1
Business Total	**10,331**

To estimate potential business passings, we assume that businesses with 100 or more employees are likely to purchase a high-end service such as Metro Ethernet, thus excluding them from the total business market base. Of the 10,331 for which InfoUSA has data, we identified 275 businesses with 100 or more employees.

For the remaining 10,056 businesses, we assume the ratio of businesses that are likely located in office complexes is similar to that of residential units located in large MDUs. Like residential MDUs with 20 or more units, office complexes are treated on a case-by-case business and are excluded from the potential passings we derive and use in our analysis. We use residential census data to produce assumptions about what percentage of businesses are likely located in office complexes. While we used the City's tax database to derive residential passings, we relied on census data to project potential business passings. According to census, just over 21 percent of residential units are in MDUs with 20 or more units. Using this number, we estimate that there are 7,895 businesses in complexes of under 20 units across the City. See Table 22 below.

Table 22: Total Business Passings

Business Total	10,331
Less businesses with 100 or more employees	275
Net Business Total	10,056
Less estimated businesses in office complexes	2,161
Total business GPON market base	**7,895**

Given this, we assume that the City's total passings, or market base, is 98,389 (Table 23).

Table 23: Total Residential and Business Passings

Total residential household market base	90,494
Total business GPON market base	7,895
Total residential and business passings	**98,389**

6.2.3.1 Residents

The largest potential user group for a City FTTP network is the residential market. Residents will require a diverse range of speeds and capabilities—from simple, reliable connectivity at low cost, to extremely-high-speed, symmetrical services that can support hosting and research and development applications. The fiber network will provide the capability to offer a range of services through the same physical medium, requiring only an upgrade of electronics or software at user premises, rather than custom physical connections, to deliver higher-capacity services.

6.2.3.2 Small Businesses and Enterprise Users

In terms of their broadband needs, small businesses are often more similar to high-capacity residential users than to large enterprise customers. They may need more than just a basic connection, but do not typically require the speeds, capacity, or guaranteed service levels that a large organization or high-end data user needs.

The FTTP network must support small businesses and be capable of supporting select institutions and enterprise users. It is important to emphasize that the suggested network design will have enough fiber capacity to provide either AE service or PON service to any business or resident. Our design and cost estimates provide for a conservative business analysis with sufficient fiber strands and network electronics capacity to meet near-term demands at nearly any take rate, and includes AE (dedicated symmetrical gigabit) hardware support for approximately 10 percent of all business passings. With the recommended network in place, the City or another ISP will be able to sell customized service to enterprise customers on a case-by-case basis.

6.3 FTTP Network Design

6.3.1 Network Architecture

OSP (layer 1, also referred to as the physical layer) is both the most expensive part of the network and the longest lasting. The architecture of the physical plant determines the network's scalability for future uses and how the plant will need to be operated and maintained; the architecture is also the main determinant of the total cost of the deployment.

Figure 77 (below) shows a logical representation of the high-level FTTP network architecture we recommend. This design is open to a variety of architecture options. The figure illustrates the primary functional components in the FTTP network, their relative position to one another, and the flexibility of the architecture to support multiple subscriber models and classes of service.

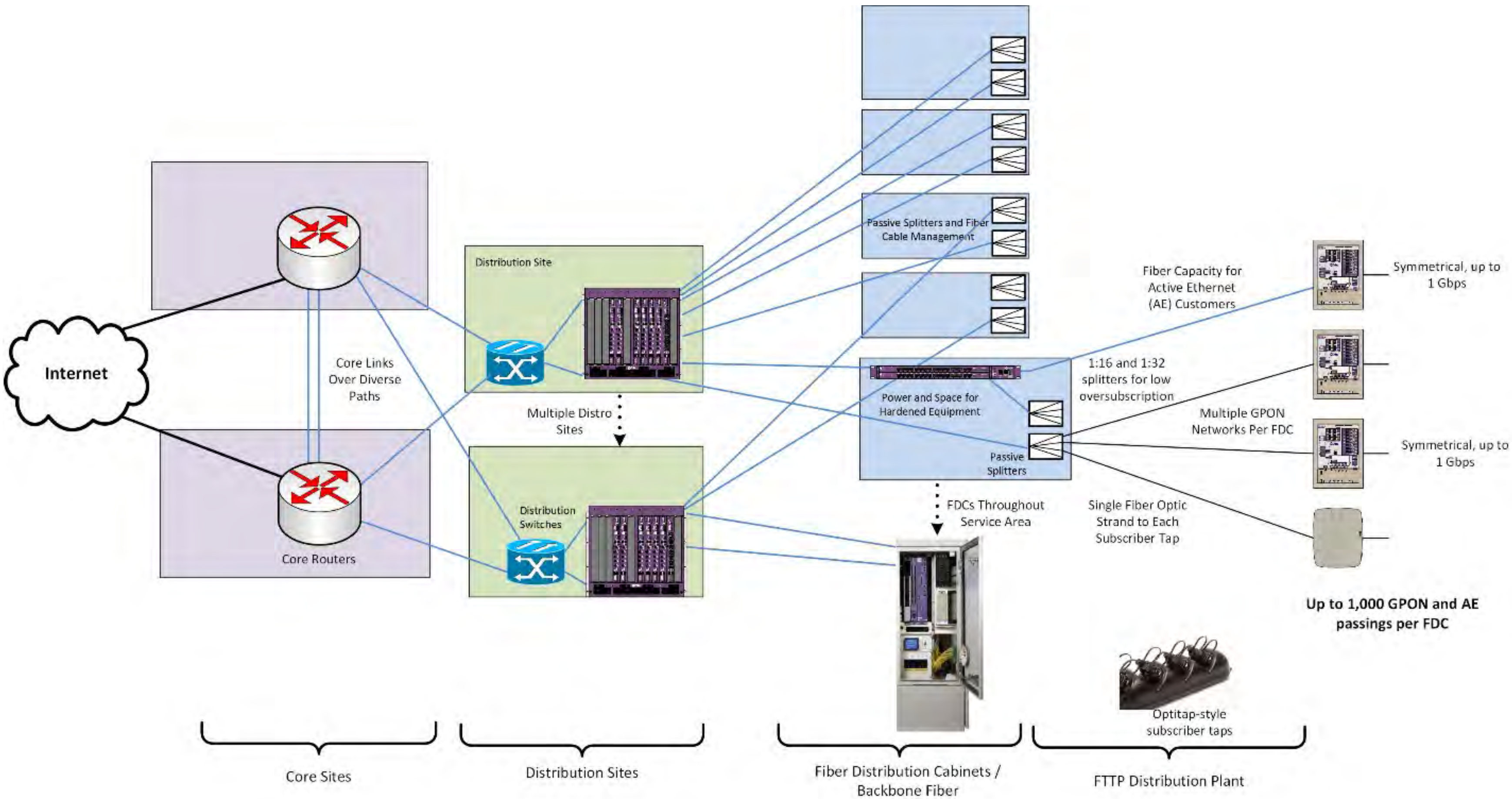
The recommended architecture is a hierarchical data network that provides critical scalability and flexibility, both in terms of initial network deployment and accommodating the increased demands of future applications and technologies. The network characteristics are:

- Capacity – ability to provide efficient transport for subscriber data, even at peak levels
- Availability – high levels of redundancy, reliability, and resiliency; ability to quickly detect faults and re-route traffic
- Diversity – physical path diversity to minimize operational impact resulting from fiber or equipment failure
- Efficiency – no traffic bottlenecks; efficient use of resources
- Scalability – ability to grow in terms of physical service area and increased data capacity, and to integrate newer technologies
- Manageability – simplified provisioning and management of subscribers and services
- Flexibility – ability to provide different levels and classes of service to different customers; can support an open access or single-provider network; can provide separation between service providers on the physical layer (separate fibers) or logical layer (separate virtual local area network (VLAN or VPN)
- Security – controlled physical access to all equipment and facilities, plus network access control to devices

This architecture offers scalability to meet long-term needs. It is consistent with best practices for an open access network model that might potentially be required to support multiple network operators, or at least multiple retail service providers requiring dedicated connections to certain customers. This design would support a combination of GPON and direct AE services (with the addition of electronics at the FDCs), which would enable the network to scale by migrating to direct connections to each customer, or reducing splitter ratios, on an as-needed basis.

The design assumes placement of manufacturer-terminated fiber tap enclosures within the ROW or easements. This provides water-tight fiber connectors for customer drop cables and eliminates the need for service installers to perform splices in the field. This is an industry-standard approach to reducing the customer activation times and the potential for damage to distribution cables and splices. The model also assumes the termination of standard lateral fiber connections within larger multi-tenant business locations and MDUs.

Figure 77: High-Level FTTP Architecture



6.3.2 The Role of the Metropolitan Unified Fiber Network (MUFN)

The Metropolitan Unified Fiber Network (MUFN) is a quasi-public consortium of public and private partners that collaboratively sought a federal grant in 2009 to construct a dark fiber network in the Madison area. Through the MUFN consortium, a robust backbone network was funded with approximately $5.1 million through the Broadband Technology Opportunities Program (BTOP), a federal grant program administered by the National Telecommunications and Information Administration (NTIA).

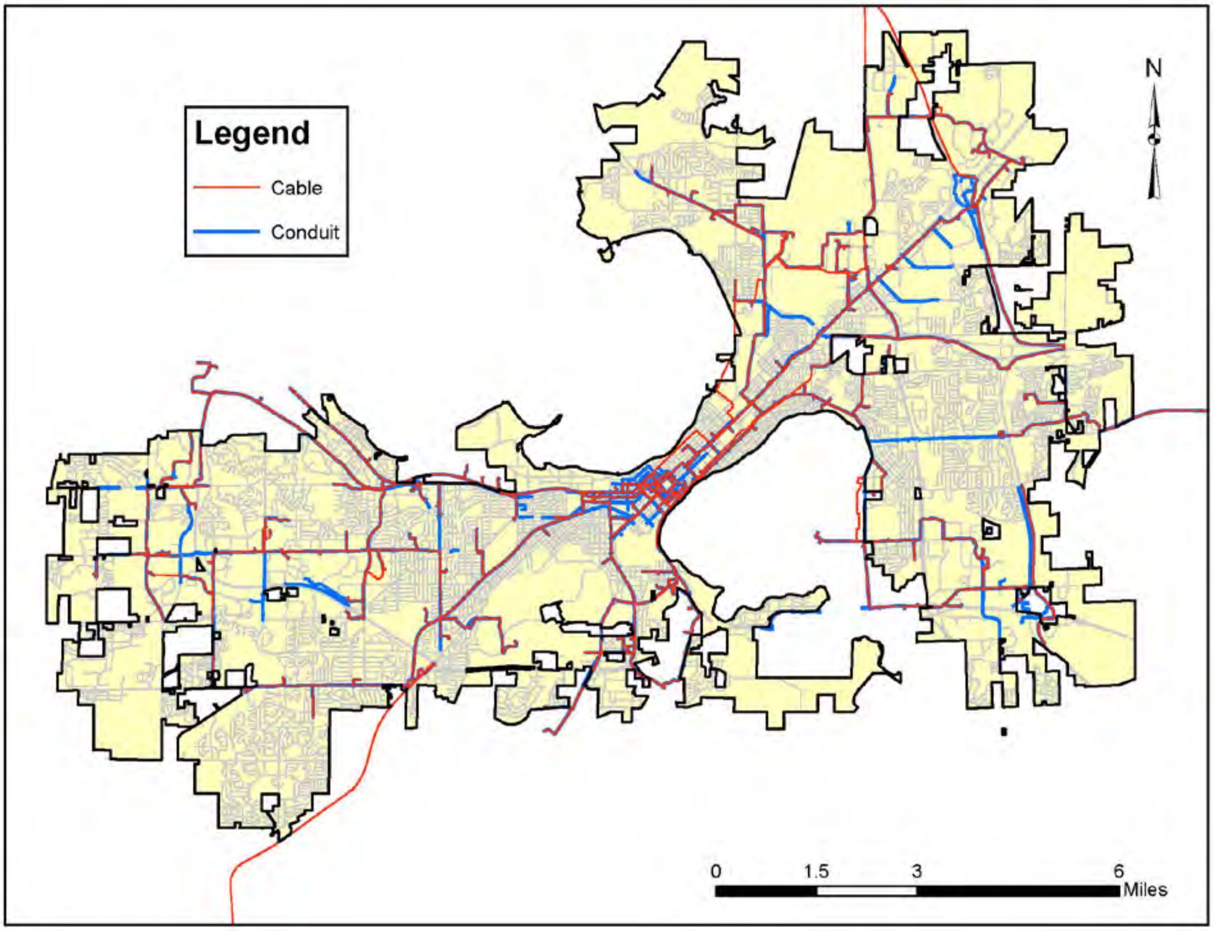
At the end of the grant period, a sub-recipient agreement allowed the City to take ownership of the MUFN fiber and conduit within Madison's corporate limits. As the cost estimate in Section 7 notes, use of MUFN to support an FTTP network in the City would likely decrease the project's overall cost. The MUFN fiber extends to all areas of the City and can provide connectivity into many of the City's neighborhoods.

Though there would be BTOP requirements to satisfy, and the NTIA would likely have to grant permission, the City might be able to give control of the existing MUFN to a private partner through a lease or indefeasible right of use (IRU). The City will have to take into consideration any requirements to which MUFN is beholden as a BTOP recipient, and how to navigate those.[118]

For example, one condition of its BTOP funding is that the MUFN consortium is required to offer commercial service in addition to dark fiber leasing, so the consortium took on two partners to provide commercial service: SupraNet and the Wisconsin Independent Network (WIN).[119,120] This particular stipulation benefits the City—one component of the City's facilities use agreement with WIN is that the City can take ownership of any conduit placed by the private entity. This means that the City's access to conduit for its own use expands as the WIN network grows, which could mean that the City has greater opportunities to leverage existing facilities and infrastructure for FTTP deployment, whether directly or through a partnership. But this also means that there are contractual relationships for the City to consider, and these may impact the terms of a public–private partnership.

[118] This analysis does not anticipate or provide guidance about all that is required of BTOP recipients. The City should work with its legal counsel and the NTIA to determine how best to manage these requirements.
[119] http://www.supranet.net/, accessed April 2016.
[120] https://wins.net/, accessed April 2016.

Figure 78: Map of MUFN Showing Its Suitability as an FTTP Backbone Network



Alternatively, the City could maintain ownership of the MUFN and expand it to meet the needs of a citywide FTTP deployment and to satisfy its portion of a partnership. As we outline below, we believe that retaining ownership of the fiber assets—both the existing network and any potential expansion—is likely to be in the City's best interest as it moves forward with considering an FTTP build-out. Assuming the City can legally retain ownership of its assets, we believe this structure would help mitigate the City's risk and create a good balance between the City and a potential partner.

MUFN fiber also extends to nearby suburbs, including three municipalities that are within the City. Although in-depth analysis about localities outside the City is beyond the scope of this report, these locations could potentially be eventual targets for the City's private partner(s). It may be prudent for the City to work collaboratively with nearby local governments to the greatest extent possible under the state law to facilitate the greatest use of the MUFN fiber in the area.

6.3.3 Network Design Assumptions

The network design and cost estimates assume the City will:

- Identify and procure space at two core facilities to house network electronics and provide backhaul to the Internet;
- Use existing MUFN locations for eight distribution hub facilities with adequate environmental and backup power systems to house network electronics;
- Use the existing MUFN fiber optics to connect core sites to distribution hubs
- Use the existing MUFN fiber and construct additional fiber to connect the distribution hubs to FDCs;
- Construct fiber optics from the FDCs to each residence and business (i.e., from termination panels in the FDC to tap locations in the ROW or on City easements); and
- Construct fiber laterals into large, multi-tenant business facilities and/or residential MDUs.

Leveraging MUFN would decrease the costs associated with both constructing a backbone and identifying locations to house electronics that are attached to the backbone ring. The use of MUFN would also allow the City to conduct FTTP pilot programs or begin deployment in neighborhoods where demand is greatest.

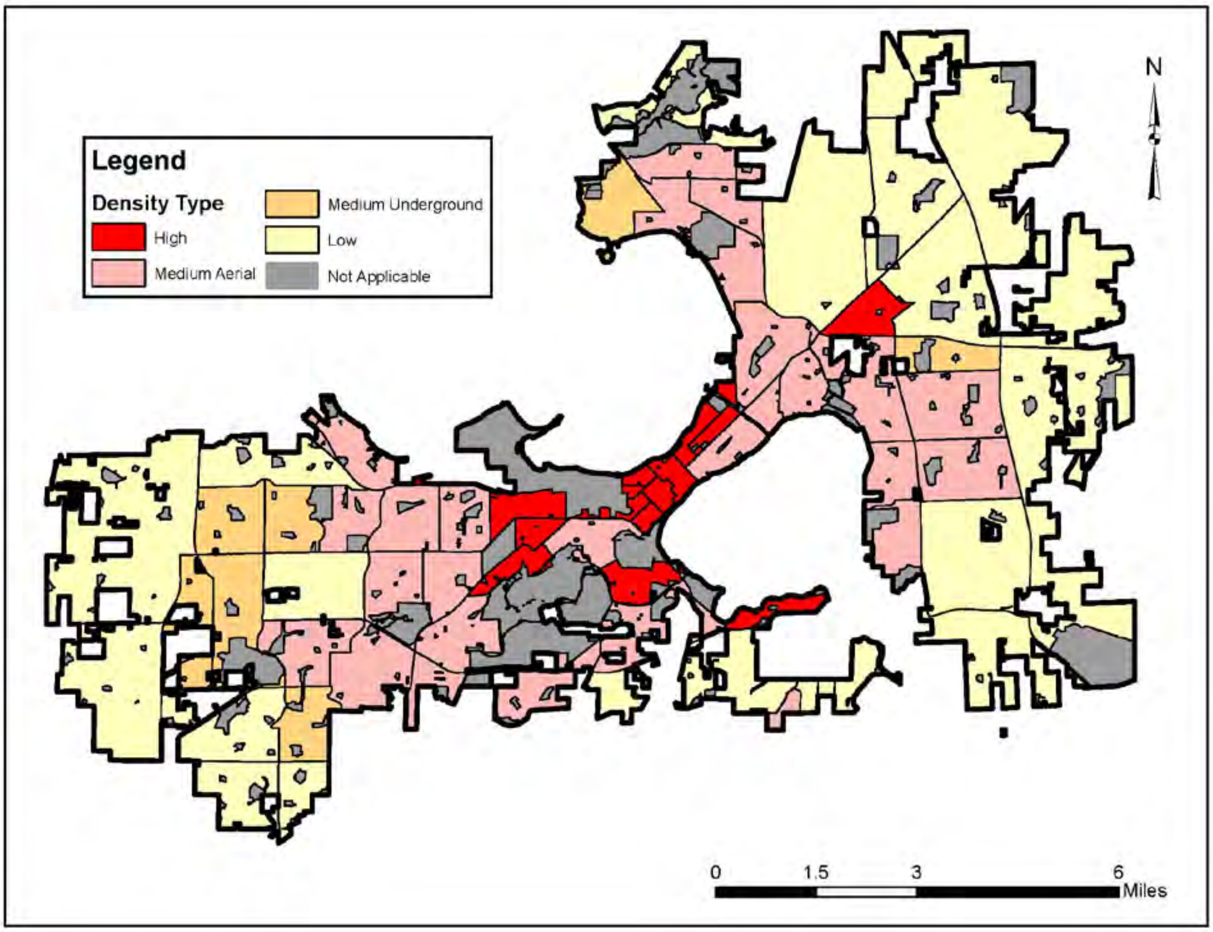
The FTTP network and service areas were defined based on the following criteria:

- Targeting 256 to 512 passings per FDC;
- Service areas defined by passing density and existing utilities, and are broken into the categories of high, medium aerial, medium underground, and low densities;
- Service areas served by multiple FDCs;
- FDCs suitable to support hardened network electronics, providing backup power and an active heat exchange;[121] and
- Avoiding the need for distribution plant to cross major roadways and railways.

[121] These hardened FDCs reflect an assumption that the City's operational and business model will require the installation of provider electronics in the FDCs that are capable of supporting open access among multiple providers. We note that the overall FTTP cost estimate would decrease if the hardened FDCs were replaced with passive FDCs (which would house only optical splitters) and the providers' electronics were housed only at hub locations.

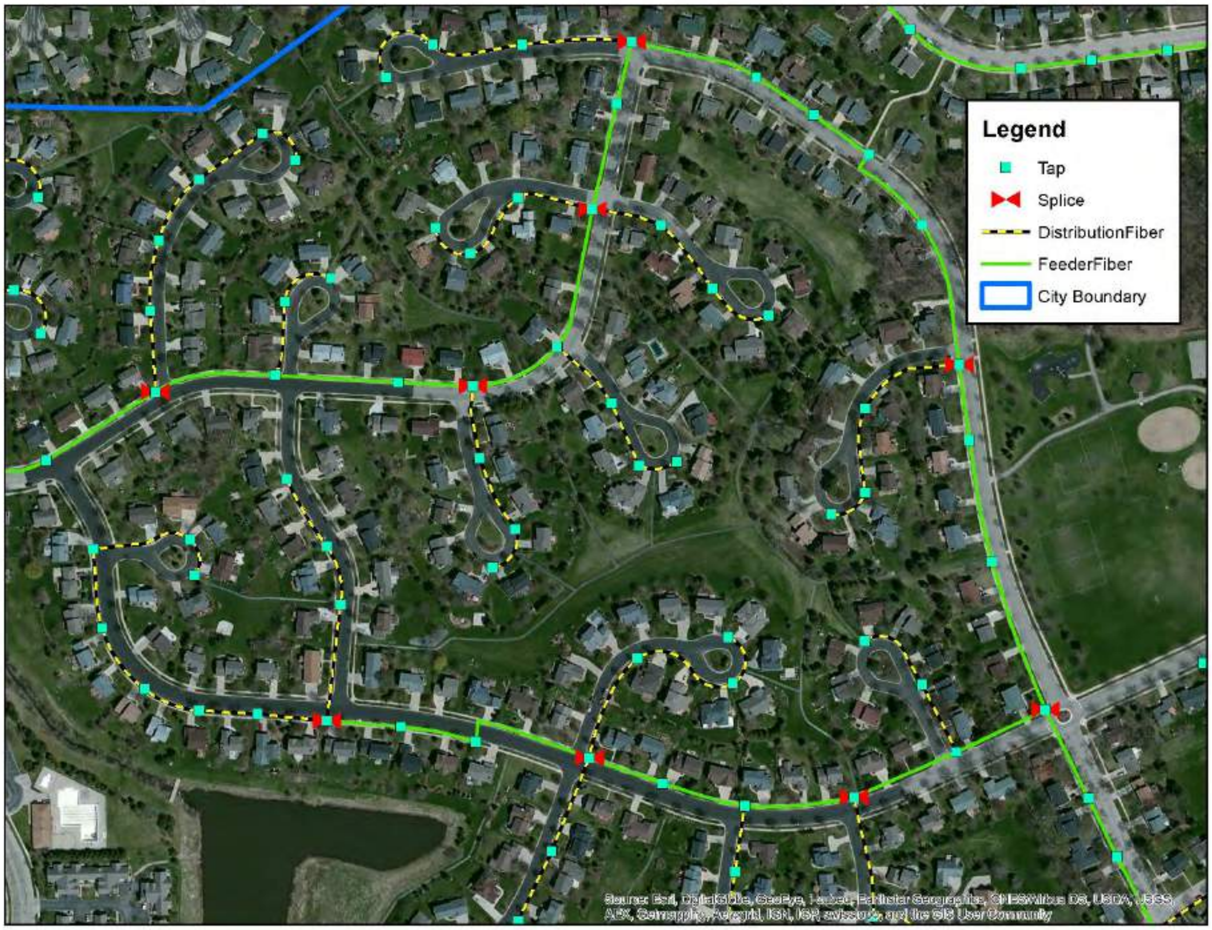
Coupled with an appropriate network electronics configuration, this fiber design serves to greatly increase the reliability of services provided to customers as compared to that of more traditional cable and telephone networks. The backbone design minimizes the average length of non-diverse distribution plant between the network electronics and each customer, thereby reducing the probability of service outages caused by a fiber break.

Figure 79: FTTP Service Areas



The access layer of the network, encompassing the fiber plant from the FDCs to the customers, dedicates a single fiber strand from the FDC to each passing (i.e., potential customer address). This traditional FTTP design allows either network electronics or optical splitters in the FDCs. See Figure 80 below for a sample design.

Figure 80: Sample FTTP Access Layer Design



This architecture offers scalability to meet long-term needs. It is consistent with best practices for an open access network model that might potentially be required to support multiple network operators, or at least multiple retail service providers requiring dedicated connections to certain customers.

6.3.4 Network Core and Hub Sites

The core sites are the bridges that link the FTTP network to the public Internet and deliver all services to end users. The proposed network design includes two core locations, based on the network's projected capacity requirements and the need for geographical redundancy (i.e., if one core site were to fail, the second core site would continue to operate the network).

The location of core network facilities also provides physical path diversity for subscribers and all upstream service and content providers. For our design and cost estimates, we assume that the Madison core sites will be housed in secure locations with diverse connectivity to the Internet and MUFN.

The core locations in this plan will house providers' Operational Support Systems (OSS)[122] such as provisioning platforms, fault and performance management systems, remote access, and other OSS for FTTP operations. The core locations are also where any business partner or content / service providers will gain access to the subscriber network with their own point-of-presence. This may be via remote connection, but collocation is recommended.

The core locations are typically run in a High Availability (HA) configuration, with fully meshed and redundant uplinks to the public Internet and/or all other content and service providers. It is imperative that core network locations are physically secure and allow unencumbered access 24x7x365 to authorized engineering and operational staff.

The operational environment of the network core and hub locations is similar to that of a data center. This includes clean power sources, UPS batteries, and diesel power generation for survival through sustained commercial outages. The facility must provide strong physical security, limited/controlled access, and environmental controls for humidity and temperature. Fire suppression is highly recommended.

Equipment is to be mounted securely in racks and cabinets, in compliance with national, state, and local codes. Equipment power requirements and specification may include 48-volt DC and/or 120/240 volts AC. All equipment is to be connected to conditioned / protected clean power with uninterrupted cutover to battery and generation.

For the cost estimate, we assumed that the core and distribution hubs will be located within existing City facilities connected to MUFN.

6.3.5 Distribution and Access Network Design

The distribution network is the layer between the hubs and the FDCs, which provide the access links to the taps. The distribution network aggregates traffic from the FDCs to the core. Fiber cuts and equipment failures have progressively greater operational impact as they happen closer to the network core, so it is critical to build in redundancies and physical path diversities in the distribution network, and to seamlessly re-route traffic when necessary.

The distribution and access network design proposed in this report is flexible and scalable enough to support two different architectures:

1. Housing both the distribution and access network electronics at the hubs, and using only passive devices (optical splitters and patches) at the FDCs; or

[122] The OSS includes a provider's provisioning platforms, fault and performance management systems, remote access, and other OSS for FTTP operations. The network's core locations house the OSS.

2. Housing the distribution network electronics at the hubs and pushing the access network electronics further into the network by housing them at the FDCs.

By housing all electronics at the hubs, the network will not require power at the FDCs. Choosing a network design that only supports this architecture may reduce costs by allowing smaller, passive FDCs in the field. However, this architecture will limit the redundancy capability from the FDCs to the hubs.

By pushing the network electronics further into the field, the network gains added redundancy by allowing the access electronics to connect to two hub sites. In the event one hub has an outage the subscribers connected to the FDC would still have network access. Choosing a network design that only supports this architecture may reduce costs by reducing the size of the hubs.

Selecting a design that supports both of these models would allow the City to accommodate many different service operators and their network designs. This design would also allow service providers to start with a small deployment (i.e., placing electronics only at the hub sites) and grow by pushing electronics closer to their subscribers.

6.3.5.1 Access Network Technologies

FDCs can sit on a curb, be mounted on a pole, or reside in a building. Our model recommends installing sufficient FDCs to support higher than anticipated levels of subscriber penetration. This approach will accommodate future subscriber growth with minimal re-engineering. Passive optical splitters are modular and can be added to an existing FDC as required to support subscriber growth, or to accommodate unanticipated changes to the fiber distribution network with potential future technologies.

Our FTTP design also includes the placement of indoor FDCs and splitters to support MDUs. This would require obtaining the right to access the equipment for repairs and installation in whatever timeframe is required by the service agreements with the customers. Lack of access would potentially limit the ability to perform repairs after normal business hours, which could be problematic for both commercial and residential services.

In this model we assume the use of GPON electronics for the majority of subscribers and AE for a small percentage of subscribers (typically business customers) that request a premium service or require greater bandwidth. GPON is the most commonly provisioned FTTP service—used, for example, by Verizon (in its FiOS systems), Google Fiber, and Chattanooga EPB.

Furthermore, providers of gigabit services typically provide these services on GPON platforms. Even though the GPON platform is limited to 1.2 Gbps upstream and 2.4 Gbps downstream for the subscribers connected to a single PON, operators have found that the variations in actual subscriber usage generally means that all subscribers can obtain 1 Gbps on demand (without provisioned rate-limiting), even if the capacity is aggregated at the PON. Furthermore, many GPON manufacturers have a development roadmap to 10 Gbps and faster speeds as user demand increases.

GPON supports high-speed broadband data, and is easily leveraged by triple-play carriers for voice, video, and data services. The GPON OLT uses single-fiber (bi-directional) SFP modules to support multiple (most commonly less than 32) subscribers.

GPON uses passive optical splitting, which is performed inside FDC, to connect fiber from the OLTs to the customer premises. The FDCs house multiple optical splitters, each of which splits the fiber link to the OLT between 16 to 32 customers (in the case of GPON service).

AE provides a symmetrical (up/down) service that is commonly referred to as Symmetrical Gigabit Ethernet. AE can be provisioned to run at sub-gigabit speeds, and like GPON easily supports legacy voice, voice over IP, and video. AE is typically deployed for customers who require specific service level agreements that are easier to manage and maintain on a dedicated service.

For subscribers receiving AE service, a single dedicated fiber goes directly to the subscriber premises with no splitting. Because AE requires dedicated fiber (home run) from the OLT to the CPE, and because each subscriber uses a dedicated SFP on the OLT, there is significant cost differential in provisioning an AE subscriber versus a GPON subscriber.

Our fiber plant is designed to provide AE service or PON service to all passings. The network operator selects electronics based on the mix of services it plans to offer and can modify or upgrade electronics to change the mix of services.

6.3.5.2 Expanding the Access Network Bandwidth

GPON is currently the most commonly provisioned FTTP technology, due to inherent economies when compared with technologies delivered over home-run fiber[123] such as AE. The cost differential between constructing an entire network using GPON and AE is 40 percent to 50 percent.[124] GPON is used to provide services up to 1 Gbps per subscriber and is part of an evolution path to higher-speed technologies that use higher-speed optics and wave-division multiplexing.

This model provides many options for scaling capacity, which can be done separately or in parallel:

[123] Home run fiber is a fiber optic architecture where individual fiber strands are extended from the distribution sites to the premises. Home run fiber does not use any intermediary aggregation points in the field.
[124] "Enhanced Communications in San Francisco: Phase II Feasibility Study," CTC report, October 2009, at p. 205.

1. Reducing the number of premises in a PON segment by modifying the splitter assignment and adding optics. For example, by reducing the split from 16:1 to 4:1, the per-user capacity in the access portion of the network is quadrupled.

2. Adding higher speed PON protocols can be accomplished by adding electronics at the FDC or hub locations. Since these use different frequencies than the GPON electronics, none of the other CPE would need to be replaced.

3. Adding WDM-PON electronics as they become widely available. This will enable each user to have the same capacity as an entire PON. Again, these use different frequencies than GPON and are not expected to require replacement of legacy CPE equipment.

4. Option 1 could be taken to the maximum, and PON replaced by a 1:1 connection to electronics—an AE configuration.

These upgrades would all require complementary upgrades in the backbone and distribution Ethernet electronics, as well as in the upstream Internet connections and peering—but they would not require increased fiber construction.

6.3.5.3 Customer Premises Equipment (CPE) and Subscriber Services

In the final segment of the FTTP network, fiber runs from the FDC to customers' homes, apartments, and office buildings, where it terminates at the subscriber tap—a fiber optic housing located in the ROW closest to the premises. The service installer uses a pre-connectorized drop cable to connect the tap to the subscriber premises without the need for fiber optic splicing.

The drop cable extends from the subscriber tap (either on the pole or underground) to the building, enters the building, and connects to CPEs.

7 FTTP Cost Estimates

The cost estimates presented here are highly conservative projections based on a City-funded, ubiquitous FTTP deployment. These estimates include costs the City is likely to incur if it opts to construct and own the fiber network; these costs include outside plant (OSP) construction labor, materials, engineering, permitting, and pole attachment licensing. This analysis shows what we anticipate the City might have to spend on an FTTP deployment with no partnership with the private sector to help share the financial burden.

7.1 OSP Cost Estimation Methodology

As with any utility, the design and associated costs for construction vary with the unique physical layout of the service area—no two streets are likely to have the exact same configuration of fiber optic cables, communications conduit, underground vaults, and utility pole attachments. Costs are further varied by soil conditions, such as the prevalence of subsurface hard rock; the condition of utility poles and feasibility of "aerial" construction involving the attachment of fiber infrastructure to utility poles; and crossings of bridges, railways, and highways.

To estimate costs for a citywide network, we extrapolated the costs for strategically selected sample designs on the basis of street mileage and passings. Specifically, we developed sample FTTP designs to generate costs per passing for four types of population densities and existing utilities—high, medium aerial, medium underground, and low.[125]

Our observations determined that for the medium underground and low-density areas, utilities are primarily underground, but the low-density areas require more construction of fiber to reach a smaller number of homes in an area.

High- and medium-density urban areas tend to have underground utilities; utilities are predominantly aerial in urban residential areas (although the poles there tend to require more make-ready). Medium-density areas tend to have the greatest variation in the percentages of aerial versus underground construction. Generally, the newest subdivisions and developments tend to be entirely underground (medium underground areas), whereas older neighborhoods have a mixture of aerial and underground construction (medium aerial areas). Many areas also tend to have rear easements for utilities, which can increase the cost of construction due to restricted access to the utility poles.

The assumptions, sample designs, and cost estimates were used to extrapolate a cost per passing for the OSP. This number was then multiplied by the number of households in each area based on the City's GIS data. The actual cost to construct FTTP to every premises in the

[125] The sample design was 13 percent of the total City street mileage.

City could differ from the estimate due to changes in the assumptions underlying the model. For example, if access to the utility poles is not granted or make-ready and pole replacement costs are too high, the network would have to be constructed underground—which could significantly increase the cost of construction. Alternatively, if the City were able to partner with a local telecommunications provider and overlash to existing pole attachments, the cost of the build could be significantly lower. Further and more extensive analysis would be required to develop a more accurate cost estimate across the entire City.

7.2 FTTP Cost Estimate Components

Actual costs may vary due to unknown factors, including: 1) costs of private easements, 2) utility pole replacement and make-ready costs, 3) variations in labor and material costs, 4) subsurface hard rock, and 5) the City's operational and business model (including the percentage of residents and businesses who subscribe to the service, otherwise known as the penetration rate or the "take rate"). We have incorporated suitable assumptions to address these items based on our experiences in similar markets.

The technical operating costs for this model are outlined in Section 7.3.4 (not including non-technical operating costs such as marketing, legal services, and financing costs). The total cost of operations will vary with the business model chosen and the level of existing resources that can be leveraged by the City and any potential business partners.

The cost components for OSP construction include the following tasks:

- ***Engineering*** – includes system level architecture planning, preliminary designs and field walk-outs to determine candidate fiber routing; development of detailed engineering prints and preparation of permit applications; and post-construction "as-built" revisions to engineering design materials.

- ***Quality Control / Quality Assurance*** – includes expert quality assurance field review of final construction for acceptance.

- ***General Outside Plant Construction*** – consists of all labor and materials related to "typical" underground or aerial outside plant construction, including conduit placement, utility pole make-ready construction, aerial strand installation, fiber installation, and surface restoration; includes all work area protection and traffic control measures inherent to all roadway construction activities.

- ***Special Crossings*** – consists of specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate / controlled access highways.

- ***Backbone and Distribution Plant Splicing*** – includes all labor related to fiber splicing of outdoor fiber optic cables.
- ***Backbone Hub, Termination, and Testing*** – consists of the material and labor costs of placing hub shelters and enclosures, terminating backbone fiber cables within the hubs, and testing backbone cables.
- ***FTTP Service Drop and Lateral Installations*** **–** consists of all costs related to fiber service drop installation, including outside plant construction on private property, building penetration, and inside plant construction to a typical backbone network service "demarcation" point; also includes all materials and labor related to the termination of fiber cables at the demarcation point. A take-rate of 35 percent was assumed for standard fiber service drops.

7.3 Cost Estimate for Fiber, Network Electronics, Service Drops, and CPEs

This section provides a summary of cost estimates for construction of a citywide FTTP network to all City residents and businesses. This estimate encompasses some costs that we anticipate the City will likely share with a partner—such as network electronics,[126] service drop installation,[127] customer premises equipment (CPE),[128] and testing.

With a retail model, assuming a 35 percent take rate, this deployment will cost more than $194 million—inclusive of OSP construction labor, materials, engineering, permitting, pole attachment licensing, network electronics, drop installation, CPEs, and testing.

Table 24: Breakdown of Estimated Total Cost with Electronics (combination aerial and underground construction)

Cost Component	Total Estimated Cost
OSP	$136 million
Central Network Electronics	8 million
CPE	22 million
FTTP Service Drop and Lateral Installations	28 million
Total Estimated Cost:	$194 million

[126] These is the electronic equipment that "lights" the dark fiber network.
[127] A service drop, or "drop," is the fiber connection from an optical tap in the ROW to the customer premises.
[128] This is the electronic equipment installed at a subscriber's home or business.

7.3.1 OSP

7.3.1.1 Cost of Constructing the Network – Aerial and Underground

In terms of OSP, the estimated cost to construct the proposed FTTP network is $136 million, or $1,380 per passing.[129] As discussed above, our model assumes a mixture of aerial and underground fiber construction, depending on the construction of existing utilities in the area as well as the state of any utility poles and existing infrastructure. Table 25 provides a breakdown of the estimated OSP costs by type of area. (Note, the costs have been rounded.)

Table 25: Estimated OSP Costs for FTTP

Area	Distribution Plant Mileage	Total Cost	Passings	Cost per Passing	Cost Per Plant Mile
High Density	100	$18.7 million	19,400	$960	$184,000
Medium Density Aerial	425	$54.3 million	43,400	$1,250	$128,000
Medium Density Underground	80	$12.1 million	9,300	$1,300	$146,000
Low Density	350	$50.8 million	26,300	$1,935	$143,000

Costs for aerial and underground placement were estimated using available unit cost data for materials and estimates on the labor costs for placing, pulling, and boring fiber based on construction in comparable markets.

The material costs were generally known with the exception of unknown economies of scale and inflation rates, and barring any sort of phenomenon restricting material availability and costs. The labor costs associated with the placement of fiber were estimated based on similar construction projects.

Aerial construction entails the attachment of fiber infrastructure to existing utility poles, which could offer significant savings compared to all-underground construction, but increases

[129] The passing count includes individual single-unit buildings and units in small multi-dwelling and multi-business buildings as single passings. It treats larger buildings as single passings.

uncertainty around cost and timeline. The utility pole owners can impose costs related to pole remediation and "make-ready" construction that can make aerial construction cost-prohibitive in comparison to underground construction.

While generally allowing for greater control over timelines and more predictable costs, underground construction is subject to uncertainty related to congestion of utilities in the public ROW and the prevalence of subsurface hard rock—neither of which can be fully mitigated without physical excavation and/or testing. While anomalies and unique challenges will arise regardless of the design or construction methodology, the relatively large scale of this project is likely to provide ample opportunity for variations in construction difficulty to yield relatively predictable results on average.

We assume underground construction will consist primarily of horizontal, directional drilling to minimize ROW impact and to provide greater flexibility to navigate around other utilities. The design model assumes a single two-inch, High-Density Polyethylene (HDPE) flexible conduit over underground distribution paths, and dual two-inch conduits over underground backbone paths to provide scalability for future network growth.

Underground construction costs may potentially be reduced in some high-density corridors, primarily downtown, by using Madison Gas & Electric conduit in conduit bank, although there would be lease costs for use of the conduit. Conduit is not available in all bank areas and more detailed survey work is required to determine how much is feasible to use, and the degree of cost savings.

7.3.1.2 Cost of Constructing the Network Entirely Underground

The City's existing middle mile fiber that supports MUFN is constructed entirely underground for reliability reasons and to avoid negotiating pole access with the utility owners. As part of our FTTP analysis, we developed a cost estimate assuming that the entire FTTP network were to be constructed underground. An all-underground network would cost more than $212 million. The following is a breakdown of the all-underground cost estimate.

Table 26: Breakdown of Estimated Total Cost with Electronics for an All Underground Network

Cost Component	Total Estimated Cost
OSP	$141 million
Central Network Electronics	8 million
FTTP Service Drop and Lateral Installations	41 million
CPE	22 million
Total Estimated Cost:	$212 million

The cost increase is due to the added cost of constructing the outside plant as well as the increased costs for fiber optic drops, which are significantly more expensive than aerial drops.

7.3.2 Central Network Electronics Costs

Central network electronics will cost an estimated $8 million, or $80 per passing, based on an assumed take rate of 35 percent.[130] (These costs may increase or decrease depending on take rate, and the costs may be phased in as subscribers are added to the network.) The central network electronics consists of the electronics to connect subscribers to the FTTP network at the core, hubs, and cabinets. Table 27 below lists the estimated costs for each segment.

Table 27: Estimated Central Network Electronics Costs

Network Segment	Subtotal	Passings	Cost per Passing
Core and Distribution Electronics	$3 million	98,000	$30
FTTP Access Electronics	$5 million	98,000	$50
Central Network Electronics Total	**$8 million**	**98,000**	**$80**

7.3.2.1 Core Electronics

The core electronics connect the hub sites and connect the network to the Internet. The core electronics consist of high performance routers, which handle all of the routing on both the FTTP network and to the Internet. The core routers should have modular chassis to provide high availability in terms of redundant components and the ability to be "hot swappable"[131] line cards and modular in the event of an outage. Modular routers also provide the ability to expand the routers as demand for additional bandwidth increases.

[130] The take rate affects the electronics and drop costs, but also may affect other parts of the network, as the city may make different design choices based on the expected take rate. A 35 percent take rate is typical of environments where a new provider joins the telephone and cable provider in a city.

[131] Hot swappable means that the line cards or modular can be removed and reinserted without the entire device being powered down or rebooted. The control cards in the router should maintain all configurations and push them to a replaced line card without the need for reconfirmation.

The cost estimate design envisions redundant rings between the core sites running networking protocols such as hot standby routing protocol (HSRP) to ensure redundancy in the event of a core failure. Additional rings can be added as network bandwidth on the network increases. The core sites would also tie to both hubs using 10 Gbps links. The links to the hubs can also be increased with additional 10 Gbps and 40 Gbps line cards and optics as demand grows on the network. The core networks will also have 40 Gbps to ISPs that connect the FTTP network to the Internet.

The cost of the core routing equipment for the two core sites is $1.5 million. These costs do not include the service provider's OSS such as provisioning platforms, fault and performance management systems, remote access, and other OSS for FTTP operations. The services providers and/or their content providers may already have these systems in place.

7.3.2.2 Distribution Electronics

The distribution network electronics at the two hub sites aggregate the traffic from the FDCs and send it to the core sites to access the Internet. The core sites consist of high performance aggregation switches, which consolidate from the traffic from the many access electronics and send it to the core for route processing. The distribution switches typically are large modular switch chassis that can accommodate many line cards for aggregation. The switches should also be modular to provide redundancy in the same manner as the core switches.

The cost estimate assumes that the aggregation switches connect to the access network electronics with 10 Gbps links to each distribution switch. The aggregation switches would then connect to the core switches over single or multiple 10 Gbps links as needed to meet the demand of the FTTP users in each service area.

The cost of the distribution switching equipment for the distribution hubs is $1.5 million. These costs do not include any of the service provider's OSS or other management equipment.

7.3.2.3 Access Electronics

The access network electronics at the FDCs connect the subscribers' CPEs to the FTTP network. We recommend deploying access network electronics that can support both GPON and AE subscribers to provide flexibility within the FDC service area. We also recommend deploying modular access network electronics for reliability and the ability at add line cards as more subscribers join in the service area. Modularity also helps reduce initials capital costs while the network is under construction or during the roll out of the network.

The cost of the access network electronics for the network is $5 million. These costs are based on a take rate of 35 percent and include optical splitters at the FDCs for that take rate.

7.3.3 Customer Premises Equipment and Service Drop Installation (Per Subscriber Costs)

CPEs are the subscriber's interface to the FTTP network. For this cost estimate, we selected CPEs that provide only Ethernet data services (however, there are a wide variety of CPEs offering other data, voice, and video services). Using the estimated take rate of 35 percent, we estimated the CPE for residential and business customers will be $22 million.

Each activated subscriber would also require a fiber drop installation and related electronics, which would cost roughly $1,240 per subscriber, or $50 million total (assuming a 35 percent take rate).

The drop installation cost is the biggest variable in the total cost of adding a subscriber. A short aerial drop can cost as little as $250 to install, whereas a long underground drop installation can cost upward of $2,000. (We estimate an average of $610 per drop installation for the City's deployment.)

The other per subscriber expenses include the cost of the optical network terminal (ONT) at the premises, a portion of the optical line termination (OLT) costs at the hub, the labor to install and configure the electronics, and the incidental materials needed to perform the installation. The numbers provided in the table below are averages and will vary depending on the type of premises and the internal wiring available at each premises.

Table 28: Per Subscriber Cost Estimates

Construction and Electronics Required to Activate a Subscriber	Estimated Average Cost
Drop Installation and Materials	$610
Subscriber Electronics (ONT and OLT)	330
Electronics Installation	200
Installation Materials	100
Total	**$1,240**

7.3.4 Operating Cost Considerations

This section outlines some of the key technical operating expenditures that a citywide FTTP network would incur. Costs for technical operations of the FTTP network include staffing (technicians, program manager), OSP maintenance, electronics maintenance, and customer support.

The costs discussed in this section are not meant to be inclusive of all operating costs such as marketing, legal, and financial costs. Further the magnitude of total cost of operations will vary with the business model chosen, balance of added new staff versus using contractors, the level of existing resources that can be leveraged by the City, and any potential business partners.

In the Financial Analysis we outline the estimated costs for the dark FTTP lease model. This model does not require electronic costs, vendor maintenance fees, or other costs associated beyond maintaining a dark fiber network.

7.3.4.1 Technical Operational Expenditures

If the City were to offer a retail data service, we estimate that the City would likely initially purchase 10 Gbps of Internet capacity. This is an estimated number for the beginning of the network deployment and can be expected to grow as, video streaming and other cloud applications grow in importance. Depending upon the contract terms Internet bandwidth we would estimate costs in the $0.50 per Mbps per month to $1.00 per Mbps per month range in Madison. We recommend that the Internet access be purchased from multiple Internet providers and be load balanced to ensure continuity during an outage.

The operating costs also include maintenance contracts on the core network electronics. These contracts ensure that the City has access to software support and replacement of critical network electronics that would be cost-prohibitive to store as spares. Where cost effective such as the distribution aggregation switches and the FTTP electronics, we recommend storing spares to reduce the total costs of maintenance contracts. We estimate hardware maintenance contracts and sparing at 15 percent of the total electronics cost.

In addition, we recommend planning for an annual payment into a depreciation operating reserve account based on the equipment replacement cost to help limit risk. This reserve fund should never go negative; the balance that accrues in this account will fund the capital needs for ongoing capital replenishments.

7.3.4.1.1 Fiber Maintenance Costs

The City would need to augment its current fiber staff or contractors with the necessary expertise and equipment available to maintain the fiber optic cable in a citywide FTTP network. Typical maintenance costs can exceed 1 percent of the total fiber OSP construction cost per year and includes a mix of City staff and contracted services.

Fiber optic cable is resilient compared to copper telephone lines and cable TV coaxial cable. The fiber itself does not corrode, and fiber cable installed over 20 years ago is still in good condition. However, fiber can be vulnerable to accidental cuts by other construction, traffic accidents, and severe weather. In other networks of this size, we have seen approximately 80 outages per 1,000 miles of plant per year.

The fiber optic redundancy from the hubs to the FDCs in the backbone network will facilitate restoring network outages while repair of the fiber optic plant is taking place.

Depending on the operational and business models established between the City and service providers, the City may be responsible for adds, moves, and changes associated with the network as well as standard plant maintenance. These items may include:

- Adding and/or changing patching and optical splitter configurations at FDCs and hubs;
- Extending optical taps and laterals to new buildings or developments;
- Extending access to the FTTP network to other service providers;
- Relocating fiber paths due to changes such as the widening of roadways;
- Participating in the moving of utilities due to pole replacement projects; and
- Tree trimming along the aerial fiber optic path.

The City would need to obtain contracts with fiber optic contractors that have the necessary expertise and equipment available to maintain a citywide FTTP network. These contracts should specify the service level agreements the City needs from the fiber optic contractors in order to ensure that the City can meet the service level agreements it has with the network service providers. The City should also ensure that it has access to multiple fiber optic contractors in the event that one contractor is unable to meet the City's needs. The fiber optic contractors should be available 24x7 and have a process in place for activating emergency service requests.

7.3.4.1.2 Fiber Locating

The City will be responsible for locating and marking all underground conduit for excavation projects according to Wisconsin's One-Call System statutes. Locating involves receiving and reviewing excavation tickets to determine whether the area of excavation may impact the City's underground FTTP infrastructure. If the system is impacted, the City must mark its utilities in the manner and within the allotted timeframe provided by the statute.

Locating is either done in-house or by contractors who specialize in utility locating. The City may be able to leverage its existing utility locating personnel, processes, or contractors to reduce the cost of utility locating for the FTTP network.

7.3.4.1.3 Pole Attachment Fees

The City will need to pay utility pole owners an annual fee per pole to attach its fiber optic cables to the poles. Pole attachment fees can be thought of a rent for using the pole. Pole attachment fees are set by the pole owner and would be outlined in the City's pole attachment agreement with the owner, which will be negotiated with MGE.

7.3.4.2 Technical Staffing Requirements

Additional staffing will be required to perform the maintenance and operation responsibilities of a Citywide FTTP network. The staffing levels and the responsibility for that staffing will vary greatly with the various potential business models. The following sections outline the technical groups that will be required maintain and operate the network.

7.3.4.2.1 Outside Plant

The OSP group will be responsible for the maintenance, operations, and expansion of the City's telecommunications infrastructure including conduit, fiber, pole attachments, and splice enclosures. During construction, the OSP group will be responsible for tracking and overseeing the construction of new infrastructure. Once the network is constructed, the OSP group will oversee any future adds, moves, or changes to the network.

The OSP group may use contractors to perform activities such as construction, repair, and locating. Management of contractors will be a responsibility of an OSP manager with OSP technicians assisting with project oversight and quality assurance and quality control. The OSP manager will also assist with engineering and design of any adds, moves, and changes that occur on the network.

The OSP group will have responsibility for general field operations. This group will include OSP technicians to perform locates, and contracted support to provide repair services. Tasks will include management of the One Call process, fiber locates, response and troubleshooting of Layer 1 troubleshooting, and fleet management. Additionally, it is critical that while many of OSP jobs may be outsourced, that the OSP group be equipped with the proper locate and testing equipment.

Our estimate includes one OSP manager and up to two OSP technicians to operate the network, depending on what roles are contracted and what capabilities already exist within the City for locates.

7.3.4.2.2 Network Engineering

The network engineering group develops and maintains the network architecture, responds to high-level troubleshooting requests, manages network electronics and makes sure the network delivers to the end user a reliable service.

The network engineering group is responsible for making architecture decisions that will determine how the network is capable of delivering services to users. The network engineering group will also be responsible for change management and architectural review to ensure that network continuity is ensured after changes.

The network engineering group will also be responsible for vendor selections when new hardware, technologies, or contractor support is needed to support the network. The network engineering team will perform regular maintenance of the network as well as provision, deploy, test, and accept any electronics to support new sites or services.

Network technicians will be responsible for troubleshooting issues with network electronics and responding to customer complaints.

To operate network electronics (if required by the business model) we estimate a staffing requirement of two network managers, six network engineers, and seven network technicians that could be a combination of personnel as well as contracted support.

7.3.4.2.3 Network Operations Center and Customer Service

The network will require individuals to perform monitoring and oversight of the network electronics. The group will be responsible for handling technical calls from users, actively monitoring the health of the network, and escalating issues to the proper operations groups. The group is also required to develop and monitor network performance parameters to ensure that the network is meeting its obligations to its user's as defined in the network service level agreements (SLAs).

Often network operations require a 24x7 customer service helpdesk and tools for network monitoring, alerting, and provisioning.

7.4 Cost Estimate for Dark FTTP

The cost estimate is based on a ubiquitous fiber deployment, in which the network is constructed to every building in the community. The estimate provides a breakdown of costs that enables inputs to a range of business models—from a City overbuild,[132] to various public–private partnerships. To illustrate the broad range of potential costs, we present a complete FTTP estimate (fiber and electronics) assuming a 35 percent take rate, which is the percentage of subscribers who purchase broadband service from the FTTP enterprise. We also present a graphic that shows how take rate impacts the total cost.

Any FTTP deployment will require significant capital investment—whether by the City, a private partner, or some combination. It makes sense to think of the cost estimate, which includes everything from dark fiber to network electronics to customer premises equipment (CPE), as a "worst-case scenario." It is unlikely that the City will construct, operate, and maintain the fiber,

[132] In a City overbuild model, the City would construct, own, and maintain the dark fiber; purchase and maintain the network electronics required to "light" the fiber; and purchase and maintain the CPEs.

and offer retail services over the network. However, this feasibility study aims to consider a range of ownership possibilities, as well as risk and reward tradeoffs.

We recommend a dark FTTP partnership model. In this model, the City constructs and owns the fiber network, and the private partner leases the fiber from the City; purchases and maintains network electronics required to "light" the fiber; purchases and maintains CPEs; and directly serves the end user. Unlike the public overbuild model, which includes the substantial capital and operating expense for network electronics, a dark FTTP partnership requires the City to invest in only the fiber outside plant (OSP) capital and operating costs.

The financial analysis below is based on a dark FTTP partnership where the City would construct, own, and operate *only* the fiber assets, not including the drop cable that connects the customer's home to the network.[133] In this model, the cost to own, maintain, and replenish network electronics and CPEs, and to install the drop cable, is passed on to the City's private partner.

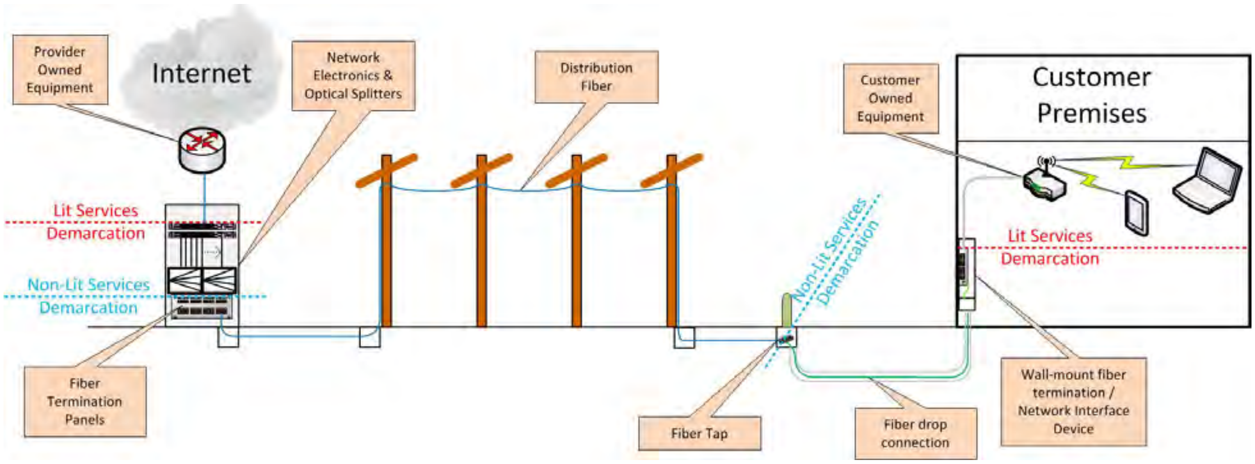
7.4.1 Cost Implications of Dark FTTP Partnership

Many of the assumptions in our analysis could change through negotiation with a private partner—for example, the City may elect to install and retain ownership of drop cables. We have chosen the assumptions in the financial analysis for the base case scenario because we believe this approach presents a reasonable balance of costs, control, and risk for the City. (City ownership of the drops, for example, would increase the City's control, but also significantly increase the City's costs.)

The financial analysis in Section 8 assumes that the City constructs and owns the dark FTTP infrastructure up to a demarcation point at the optical tap near each residence and business, and leases the dark fiber backbone and distribution fiber to a private partner. As we noted, this means the private partner would be responsible for all network electronics, fiber drops to subscribers, and CPEs—as well as network sales, marketing, and operations.

[133] The City can potentially negotiate with its chosen partner(s) about ownership of the customer drop cable.

Figure 81: Demarcation Between City and Partner Network Elements



The precise demarcation point that makes sense for the City and its partner is negotiable, and will have to be determined through discussions between the City and its potential partner(s). For example, some network operators suggest that the network's optical splitters should be a part of the Layer 1 or dark fiber assets. We caution against this approach. The network operator (i.e., the City's partner) should maintain the splitters because, as operator of the electronics, it must determine and control the GPON network split ratio to meet the network's performance standards. This may involve moving power users to GPON ports with lower split ratios, or moving users to different splitters to manage the capacity of the GPON ports. The City should not be involved in this level of network management. Also, the City should not have to inventory various sized splitters or swap them as the network operator makes changes. Even if the City were to decide to purchase some of the optical splitters for the network, we believe it should be the network operator's responsibility to manage and maintain the splitters.

7.4.2 Dark FTTP Cost Estimate – No Network Electronics, Service Drops, or CPEs

While the cost estimate in Section 7.1 anticipates the full range of potential City costs, this section shows the project cost to deploy *only* the FTTP OSP infrastructure.[134] This is the total capital cost for the City to build a dark FTTP network for lease to a private partner—it is the City's projected OSP cost in a dark FTTP partnership.

The City has historically avoided aerial construction when deploying new fiber because of concerns about ice storms and other weather-related incidents that could cause mass outages due to downed aerial lines. In light of this, we estimated costs to place all fiber underground. We based these estimates on two potential construction scenarios: all-underground and a combination of underground and aerial.

[134] This is the physical portion of a network (also called "layer 1") that is constructed on utility poles (aerial) or in conduit (underground).

7.4.2.1 Combination of Aerial and Underground Construction

Assuming a combination of aerial and underground construction, the citywide dark FTTP network deployment will cost more than $143 million—including OSP construction labor, materials, engineering, permitting, and pole attachment licensing. Again, this estimate does not include any electronics, subscriber equipment, drops, or CPEs. Section 7.1 shows estimated costs for fiber, network electronics, drops, and CPES, and include all underground construction, as well as a combination of aerial and underground.

Table 29: Breakdown of Estimated Dark FTTP Cost – Combination of Aerial and Underground Construction

Cost Component	Total Estimated Cost
OSP Engineering	$14.7 million
Quality Control/Quality Assurance	5.4 million
General OSP Construction Cost	99.3 million
Special Crossings	0
Backbone and Distribution Plant Splicing	5 million
Backbone Hub, Termination, and Testing	11.4 million
FTTP Lateral Installations	7.7 million
Total Estimated Cost (aerial and underground):	**$143.5 million**

7.4.2.2 All Underground Construction

Assuming that all construction is underground, the citywide dark FTTP network deployment will cost more than $149 million, inclusive of outside plant (OSP) construction labor, materials, engineering, permitting, and pole attachment licensing. Again, this estimate *does not* include any electronics, subscriber equipment, or drops—and it includes no aerial fiber.

The projected cost to construct all underground is only about $5.6 million more than the cost for a combination of aerial and underground fiber. This difference is notably minimal; underground construction costs can sometimes be much higher than aerial, but our projections indicate that it would not add a major financial burden if the City opts to construct the dark FTTP network entirely underground.

Table 30: OSP Cost Estimate Summary (Underground Construction)

Cost Component	Total Estimated Cost
OSP Engineering	$14,706,000
Quality Control/Quality Assurance	5,429,000
General OSP Construction Cost	104,883,000
Special Crossings	-
Backbone and Distribution Plant Splicing	4,955,000
Backbone Hub, Termination, and Testing	11,406,000
FTTP Lateral Installations	7,741,000
Total Estimated OSP Cost (all underground)	**$149,120,000**

8 Financial Analysis of Dark FTTP Network

The financial analysis for all scenarios presented here represents a minimum requirement for the City of Madison to break even each year, excluding any potential revenue from other dark fiber lease opportunities that may be available to the City.

This analysis assumes that the City will construct, own, and maintain the dark fiber network over which one or more private partners will provide lit retail service to end users. In this dark FTTP partnership model, the financial responsibility for deploying core electronics to "light" the network falls to the private partner. We also assume the partner is responsible for CPEs, and installing the drop cable to the customer. This model assumes that maintenance and replenishments for electronics are the partner's responsibility.

The base case financial analysis assumes all-underground construction. An all-underground network would increase the ongoing costs for fiber locates and ticketing, while eliminating the pole maintenance costs. Using the all-underground cost estimate for the fiber outside plant (OSP), and in order for the City to maintain positive cash flow, the City's private partner will need to pay a minimum fee of $15 per passing per month. This payment assumes there are no upfront or balloon payments. Based on an assumption that the City will deploy a ubiquitous FTTP network, the financial model applies the fee to all residential and business premises in the City. The current model keeps the $15 per passing fee constant, although the City and its partner should negotiate periodic increases on the portion of the fee covering operational and maintenance costs.

The financial analysis for the base case scenario is as follows:

Table 31: Base Case Financial Analysis

Income Statement	1	5	10	15	20
Total Revenues	$ 88,550	$ 17,710,020	$ 17,710,020	$ 17,710,020	$ 17,710,020
Total Cash Expenses	(856,190)	(2,316,120)	(2,316,120)	(2,316,120)	(2,316,120)
Depreciation	(2,274,200)	(7,494,600)	(7,494,600)	(7,494,600)	(7,494,600)
Interest Expense	(2,430,000)	(7,754,950)	(6,023,970)	(3,866,860)	(1,178,750)
Taxes	-	-	-	-	-
Net Income	$ (5,471,840)	$ 144,350	$ 1,875,330	$ 4,032,440	$ 6,720,550

Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 209,360	$ 613,770	$ 3,410,190	$ 6,207,970	$ 9,006,860
Depreciation Reserve	-	146,130	196,680	246,990	297,300
Interest Reserve	2,430,000	-	-	-	-
Debt Service Reserve	2,700,000	9,325,000	9,325,000	9,325,000	9,325,000
Total Cash Balance	$ 5,339,360	$ 10,084,900	$ 12,931,870	$ 15,779,960	$ 18,629,160

Please note that we used a "flat-model" in the analysis. In a "flat-model," inflation and operating cost increases (including salaries) are not used in the analysis because it is assumed that operating cost increases will be offset by increases in operator lease payments over time (and likely passed on to subscribers in the form of increased prices). We anticipate that the City will apply an inflation factor, typically based on a Consumer Price Index (CPI), to the portion of the per subscriber fee covering projected operating expenses during negotiations with a private partner. Please note that it is not appropriate to apply a CPI to the entire passing fee because the majority of the fee is to support the principal and interest on the debt service. This is discussed further in Section 8.5.

This section presents an overview of the financial analysis; we have provided the City with a complete financial model in Excel format. Because the Excel spreadsheets can be manipulated to show the impact of changing assumptions (much as we have done in the scenarios in Section 8.6 below), it will be an important tool for the City to use as it negotiates with a private partner.

8.1 FTTP Financing Options

A key consideration for any FTTP network deployment is how to finance upfront capital construction costs. These costs represent a large expenditure that is generally slow to yield a return; the lack of a quick return on investment (ROI) sheds some light on why the private sector is not clamoring to upgrade existing legacy networks with fiber infrastructure, or to build new FTTP networks.

The City can seek bonding, or borrow funds, to cover construction costs to expand its fiber network, and in consideration of operations and maintenance (O&M) costs. Municipal bonds may also factor into a public–private partnership. While not every partnership will require the City to pursue bonding, all potential private partners will likely request some contribution from the City. One partnership structure that may be particularly desirable to the City entails the City owning and operating the infrastructure while a private partner lights the fiber and offers retail services over it. In this scenario, the likelihood of bonding is much greater because the City would likely be responsible for funding the construction of the network.

The City will likely be required to finance[135] some portion of an FTTP network, even if it engages a partner, and especially if it opts to retain ownership and control of the network, which is a desirable approach for the City. The City of Madison has a great credit rating and a low cost for bond financing, which gives it an advantage and makes it attractive to potential partners. There are also a variety of bonding avenues the City may be able to explore, such as working through the Community Development Authority (CDA) to secure bond financing.

[135] The term "financing" generally refers to any borrowing required or investments provided. The amount financed requires repayment, typically with interest—such as through a bond or loan. By comparison, "funding" means resources that can include subscriber revenues, taxes, or other sources of capital that are used to cover operation, maintenance, debt service, and other expenses. Federal or state grants, such as the BTOP grant that was used to construct the MUFN, are an example of funding. Funding does not require repayment.

We discuss here some of the common types of bonds that municipalities typically rely on for capital projects, and the advantages and disadvantages of each. Please note that the following is a summary, does not include every financing mechanism available to the City, and does not offer any legal or tax advice.

8.1.1 General Obligation Bonds

General obligation bonds are directly tied to the City's credit rating and ability to tax its citizens. This type of bond is not tied to revenues from any specific municipal projects, but is connected instead to citywide taxes and revenues can be used to repay this debt.

City leadership is likely very familiar with this type of bonding, as general obligation bonds are commonly sought in municipal organizations to fund capital improvement projects. Based on conversations with staff, the City is at approximately one-third of its borrowing capacity, as borrowing has increased in recent years due to infrastructure investments.

General obligation bonds can be politically challenging because they generally require a public approval process. These bonds are usually issued for projects that will clearly serve the needs of the entire community, such as roadway improvements. While it is our opinion that a fiber enterprise serving the public clearly meets this condition, incumbent opposition is likely. The City will need to develop a clear vision for its messaging to clearly convey to the community that it intends for the fiber network to serve all members of the community, and to serve all citizens' needs. The pilot project may factor in to demonstrating the City's commitment to serving the entire community, and help with public approval.

Further, a clearly and publicly stated goal of network ubiquity may help ease the process of general obligation bond approval. That is, if the City is willing and able to commit to expanding the network to serve *all* members of the community, it may be politically palatable to request approval of general obligation bonds. In addition, a model which opens fiber access to multiple providers enables new and existing providers to offer new service and give Madison consumers a choice and alternatives. Given the City's dedication to deploying a ubiquitous network, general obligation bonds could be a reasonable option for Madison.

It may be especially helpful if the City can work within existing initiatives and with other public, quasi-public, and private institutions to demonstrate how the fiber network can effectively benefit the entire community. For example, the City may want to consider tapping into the knowledge and resources of its Community Development and Economic Development Divisions to show a fiber network's role in economic development. This, coupled with a concerted effort to ensure the network passes every potential customer in the City so that anyone may potentially access service, could illustrate fiber's potential as a community resource.

8.1.2 Revenue Bonds

Revenue bonds are directly tied to a specific revenue source to secure the bond and guarantee repayment of the debt. For example, the revenue stream from a municipality's electric, natural gas, or water utility may be used to secure a revenue bond.

Theoretically, any municipal service that generates some sort of revenue that could be used to pay back the debt might potentially be used to secure a revenue bond—municipally owned public transportation or hospitals, for example. In light of this, it might make sense that the revenues generated from owning a fiber optic network and leasing it to providers could be used to guarantee a revenue bond, but this is typically not an accepted practice within the bonding community. Municipal broadband projects without a proven revenue stream are usually viewed as high-risk in the bonding community, and the projected revenues from the network will likely be viewed as too uncertain to support repayment of the loan.

If the City wishes to pursue revenue bonds, it may find that other utilities departments' revenues are more likely to be approved as an acceptable stream to support a revenue bond. These bonds are less politically challenging than general obligation bonds, but the City will still need to be prepared to explain why it must pursue this form of bond to help support FTTP network deployment.

8.2 Cost Implications of FTTP Technical Model

The financial analysis in this section assumes that the City constructs and owns the FTTP infrastructure up to a demarcation point at the optical tap near each residence and business, and leases the dark fiber backbone and distribution fiber to a private partner. The private partner would be responsible for all network electronics, fiber drops to subscribers, and customer premises equipment (CPE)—as well as network sales, marketing, and operations.

Using a mix of 38 percent aerial and 62 percent underground construction the citywide dark FTTP network deployment will cost more than $143 million, inclusive of outside plant (OSP) construction labor, materials, engineering, permitting, and pole attachment licensing. This estimate does not include and electronics, subscriber equipment, or drops. The average drop cost with the above mix of aerial and underground construction is $607.

Table 32: Breakdown of Estimated Dark FTTP Cost – Combination of Aerial and Underground Construction

Cost Component	Total Estimated Cost
OSP Engineering	$14.7 million
Quality Control/Quality Assurance	5.4 million
General OSP Construction Cost	99.3 million
Special Crossings	0
Backbone and Distribution Plant Splicing	5 million
Backbone Hub, Termination, and Testing	11.4 million
FTTP Lateral Installations	7.7 million
Total Estimated Cost:	$143.5 million

The City or its partner(s) may aim to place all newly constructed fiber underground to avoid weather-related concerns (e.g., ice storms and other weather incidents that could cause outages due to downed aerial lines), and challenges with obtaining pole attachments. Because all-underground construction is a possibility, we estimated costs to place all fiber underground. We estimate that it will cost more than $149 million to construct an all-underground dark FTTP network, inclusive of outside plant (OSP) construction labor, materials, engineering, permitting, and pole attachment licensing. This estimate does not include and electronics, subscriber equipment, or drops. For the cost estimate in this section we used the all-underground construction estimate.

The all-underground model also increases the average drop cost from $607 to $972—though this is potentially the private provider's cost.

Table 33: Breakdown of Estimated Dark FTTP Cost – All Underground Construction

Cost Component	Total Estimated Cost
OSP Engineering	$14.7 million
Quality Control/Quality Assurance	5.4 million
General OSP Construction Cost	104.9 million
Special Crossings	0
Backbone and Distribution Plant Splicing	5 million
Backbone Hub, Termination, and Testing	11.4 million
FTTP Lateral Installations	7.7 million
Total Estimated Cost:	$149.1 million

The ownership of the drops is an assumption that could be changed through negotiation with a private partner—as, indeed, could many of the assumptions underpinning this analysis. We have chosen this key parameter for the base case scenario because we believe this approach presents a reasonable balance of costs, control, and risk for the City. (City ownership of the drops, for example, would increase the City's control, but also increase the City's costs.)

In a related vein, we note that some network operators suggest that the network's optical splitters should be a part of the Layer 1 or dark fiber assets. We caution against this approach. The network operator (i.e., the City's partner) should maintain the splitters because, as operator of the electronics, it must determine and control the GPON network split ratio to meet the network's performance standards. This may involve moving power users to GPON ports with lower split ratios, or moving users to different splitters to manage the capacity of the GPON ports. The City should not be involved in this level of network management. Also, the City should not have to inventory various sized splitters or swap them as the network operator makes changes. Even if the City decides to purchase some of the optical splitters for the network, we believe it should be the network operator's responsibility to manage and maintain the splitters.

8.3 Financing Costs and Operating Expenses

This financial analysis assumes that the City will cover all of its capital requirements with general obligation (GO) bonds to maximize the benefits of the City's strong bond rating. We assume that the City's bond rate will be 4.5 percent, which represents a two-percentage-point premium over current non-taxable rates. (Because the network will have private users, the City will not be able to bond at a non-taxable rate.)

We expect that the City will take three 20-year bonds—one each in years one, two, and three—for a total of $186.5 million in financing. (The difference between the financed amount and the total capital costs—$149.3 million—represents the amount needed to maintain positive cash flow in the early years of network deployment.) The resulting principal and interest (P&I) payments will be the major factor in determining the City's long-term financial requirements; P&I accounts for about 86.5 percent of the City's annual costs in our base case model after the construction period.

We project that the bond issuance costs will be equal to 1.0 percent of the principal borrowed. For the bond, a debt service reserve account is maintained at 5.0 percent of the total issuance amount. An interest reserve account will be maintained for the first two years. Principal repayment on the bonds will start in year two.

The model assumes a straight-line depreciation of assets, and that the outside plant and materials will have a 20-year life span. Because we assume the City's partner will be responsible for network electronics and CPE, we have not included depreciation or replacement costs for that equipment (although we note that, typically, network equipment would be replaced after 10 years, while CPE and last-mile infrastructure would be depreciated over five years). The model plans for a depreciation reserve account starting in year three to fund future replacements and upgrades.

Table 34 shows the income statement for years one, five, 10, 15, and 20.

Table 34: Income Statement

		Year 1		Year 5		Year 10		Year 15		Year 20
Income Statement										
a. Revenues										
Per Passing	$	88,550	$	17,710,020	$	17,710,020	$	17,710,020	$	17,710,020
Total	$	88,550	$	17,710,020	$	17,710,020	$	17,710,020	$	17,710,020
c. Operating Costs										
Operation Costs	$	705,690	$	1,770,120	$	1,770,120	$	1,770,120	$	1,770,120
Labor Costs		150,500		546,000		546,000		546,000		546,000
Total	$	856,190	$	2,316,120	$	2,316,120	$	2,316,120	$	2,316,120
d. EBITDA	$	(767,640)	$	15,393,900	$	15,393,900	$	15,393,900	$	15,393,900
e. Depreciation		2,274,200		7,494,600		7,494,600		7,494,600		7,494,600
f. Operating Income (EBITDA less Depreciation)	$	(3,041,840)	$	7,899,300	$	7,899,300	$	7,899,300	$	7,899,300
g. Non-Operating Income										
Interest Income	$	-	$	23,800	$	23,800	$	23,930	$	24,060
Interest Expense (10 Year Bond)		-		-		-		-		-
Interest Expense (20 Year Bond)		(2,430,000)		(6,047,770)		(6,047,770)		(3,890,790)		(1,202,810)
Interest Expense (Loan)		-		-		-		-		-
Total	$	(2,430,000)	$	(6,023,970)	$	(6,023,970)	$	(3,866,860)	$	(1,178,750)
h. Net Income (before taxes)	$	(5,471,840)	$	144,350	$	1,875,330	$	4,032,440	$	6,720,550
i. Facility Taxes	$	-	$	-	$	-	$	-	$	-
j. Net Income	$	(5,471,840)	$	144,350	$	1,875,330	$	4,032,440	$	6,720,550

Table 35 shows the cash flow statement for years one, five, 10, 15, and 20. The unrestricted cash balance is approximately $209,000 in year one and $3.4 million in year 10. By year 15, the unrestricted cash balance is approximately $6.2 million and it is $9 million by year 20.

Table 35: Cash Flow Statement

		Year 1	Year 5	Year 10	Year 15	Year 20
Cash Flow Statement						
a. Net Income		$ (5,471,840)	$ 144,350	$ 1,875,330	$ 4,032,440	$ 6,720,550
b. Cash Outflows						
Debt Service Reserve		$ (2,700,000)	$ -	$ -	$ -	$ -
Interest Reserve		(4,860,000)	-	-	-	-
Depreciation Reserve		-	(48,710)	(48,710)	(48,710)	(48,710)
Financing		(540,000)	-	-	-	-
Capital Expenditures		(44,923,000)	-	-	-	(3,000)
	Total	$ (53,023,000)	$ (48,710)	$ (48,710)	$ (48,710)	$ (51,710)
c. Cash Inflows						
Interest Reserve		$ 2,430,000	$ -	$ -	$ -	$ -
Depreciation Reserve		-	-	-	-	3,000
Grants (infrastructure)		-	-	-	-	-
10-Year Bond/Loan Proceeds		-	-	-	-	-
20-Year Bond Proceeds		54,000,000	-	-	-	-
Loan Proceeds		-	-	-	-	-
	Total	$ 56,430,000	$ -	$ -	$ -	$ 3,000
d. Total Cash Outflows and Inflows		$ 3,407,000	$ (48,710)	$ (48,710)	$ (48,710)	$ (48,710)
e. Non-Cash Expenses - Depreciation		$ 2,274,200	$ 7,494,600	$ 7,494,600	$ 7,494,600	$ 7,494,600
f. Adjustments						
Proceeds from Additional Cash Flows (10 Year Bond)		$ -	$ -	$ -	$ -	$ -
Proceeds from Additional Cash Flows (20 Year Bond)		$ (54,000,000)	$ -	$ -	$ -	$ -
Proceeds from Additional Cash Flows (Loan)		$ -	$ -	$ -	$ -	$ -
g. Adjusted Available Net Revenue		$ (53,790,640)	$ 7,590,240	$ 9,321,220	$ 11,478,330	$ 14,166,440
h. Principal Payments on Debt						
10 Year Bond Principal		$ -	$ -	$ -	$ -	$ -
20 Year Bond Principal		-	7,030,840	8,761,700	10,918,680	13,606,660
Loan Principal		-	-	-	-	-
	Total	$ -	$ 7,030,840	$ 8,761,700	$ 10,918,680	$ 13,606,660
j. Cash Balance						
Unrestricted Cash Balance		$ 209,360	$ 613,770	$ 3,410,190	$ 6,207,970	$ 9,006,860
Depreciation Reserve		-	146,130	196,680	246,990	297,300
Interest Reserve		2,430,000	-	-	-	-
Debt Service Reserve		2,700,000	9,325,000	9,325,000	9,325,000	9,325,000
Total Cash Balance		$ 5,339,360	$ 10,084,900	$ 12,931,870	$ 15,779,960	$ 18,629,160

Significant network expenses—known as “capital additions”—are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building a fiber network. (Again, because the City’s responsibility will be limited to OSP, we have not included any costs for core network equipment, drops, or CPE.) This analysis projects that capital additions in year one will total approximately $44.9 million. These costs will total approximately $74.6 million in year two, and $29.8 million in year three. This totals just over $149.3 million in capital additions[136] for years one through three.

8.4 Operating and Maintenance Expenses

The cost to deploy an FTTP network goes far beyond fiber implementation. Network deployment requires sales and marketing, network maintenance and technical operations, and

[136] Includes the FTTP OSP plus vehicles, computers, and test equipment required to maintain the OSP.

other functions. In this model, we assume that the City's partner will be responsible for lighting the fiber and selling services, so the City's financial requirements are limited to expenses related to OSP infrastructure and network administration.

These expanded responsibilities will require the addition of new staff. We assume the City will add a total of four full-time-equivalent (FTE) positions within the first three years, and will then maintain that level of staffing. Our assumptions include one FTE for OSP management and HR/administrative support, and two FTEs for fiber plant maintenance and operations. Salaries and benefits are based on estimated market wages, and benefits are estimated at 40 percent of base salaries.

Locates and ticket processing will be significant ongoing operational expenses for the City. Based on our experience in other cities, we estimate that a contract for locates will cost $133,600 in year one, increase to $267,200 in year two, and increase to $546,000 from year three on. (If the City decides to perform this work in-house, the contract expense would be eliminated—but staffing expenses would increase.)

Additional key operating and maintenance assumptions include the following:

- Insurance is estimated to be $50,000 in year one and $75,000 from year two on.
- Office expenses are estimated to be $2,400 annually.
- Contingency expenses are estimated at $10,000 in year one and $25,000 in subsequent years.
- Legal fees are estimated to be $100,000 in year one, $50,000 in year two, and $25,000 from year three on.
- Consulting fees are estimated at $100,000 in year one and $20,000 from year two on.

Fiber network maintenance costs are calculated at 0.5 percent of the total construction cost, per year. This is estimated based on a typical rate of occurrence in an urban environment, and the cost of individual repairs. This is in addition to staffing costs to maintain fiber.

Table 36 lists the City's projected operating expenses for years one, five, 10, 15, and 20.

Table 36: Operating Expenses

	Year 1	Year 5	Year 10	Year 15	Year 20
Operating Expenses					
Insurance	$ 50,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000
Office Expenses	2,400	2,400	2,400	2,400	2,400
Locates & Ticket Processing	216,600	866,200	866,200	866,200	866,200
Contingency	10,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance	223,680	745,600	745,600	745,600	745,600
Legal and Lobby Fees	100,000	25,000	25,000	25,000	25,000
Consulting	100,000	20,000	20,000	20,000	20,000
Education and Training	3,010	10,920	10,920	10,920	10,920
Pole Attachment Expense	-	-	-	-	-
Sub-Total	$ 705,690	$ 1,770,120	$ 1,770,120	$ 1,770,120	$ 1,770,120
Labor Expenses	$ 150,500	$ 546,000	$ 546,000	$ 546,000	$ 546,000
Sub-Total	$ 150,500	$ 546,000	$ 546,000	$ 546,000	$ 546,000
Total Expenses	$ 856,190	$ 2,316,120	$ 2,316,120	$ 2,316,120	$ 2,316,120
Principal and Interest	$ (4,860,000)	$ -	$ -	$ -	$ -
Facility Taxes	-	-	-	-	-
Sub-Total	$ (4,860,000)	$ -	$ -	$ -	$ -
Total Expenses, P&I, and Taxes	$ (4,003,810)	$ 2,316,120	$ 2,316,120	$ 2,316,120	$ 2,316,120

8.5 Revenue

The base case scenario assumes that the City's private partner will pay a fee of $15 per passing per month, with no upfront or balloon payments. Based on an assumption that the City will deploy a ubiquitous FTTP network, the financial model applies the fee to all residential and business premises in the City. The current model keeps that $15 per passing fee constant, although the City and its partner could negotiate periodic increases.

Operating and maintenance expenses account for approximately 13.5 percent of the City's total annual costs. (P&I payment on debt is the remaining amount.) At a minimum, then, 13.5 percent of the per-passing fee should be increased by a CPI each year.

In the scenarios below, we show how changing certain assumptions related to financing will affect that fee. (We note, too, that the fee will be just one element of the City's negotiations with a private partner.)

8.6 Sensitivity Scenarios

This section demonstrates the sensitivity of the financial projections to changes in various assumptions. For comparison, we repeat the base case scenario—with a per-passing fee of $15 per month—here:

Table 37: Base Case Financial Analysis

Income Statement	1	5	10	15	20
Total Revenues	$ 88,550	$ 17,710,020	$ 17,710,020	$ 17,710,020	$ 17,710,020
Total Cash Expenses	(856,190)	(2,316,120)	(2,316,120)	(2,316,120)	(2,316,120)
Depreciation	(2,274,200)	(7,494,600)	(7,494,600)	(7,494,600)	(7,494,600)
Interest Expense	(2,430,000)	(7,754,950)	(6,023,970)	(3,866,860)	(1,178,750)
Taxes	-	-	-	-	-
Net Income	$ (5,471,840)	$ 144,350	$ 1,875,330	$ 4,032,440	$ 6,720,550

Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 209,360	$ 613,770	$ 3,410,190	$ 6,207,970	$ 9,006,860
Depreciation Reserve	-	146,130	196,680	246,990	297,300
Interest Reserve	2,430,000	-	-	-	-
Debt Service Reserve	2,700,000	9,325,000	9,325,000	9,325,000	9,325,000
Total Cash Balance	$ 5,339,360	$ 10,084,900	$ 12,931,870	$ 15,779,960	$ 18,629,160

8.6.1 Adding a One-Time, $10 Million Payment from the City's Partner

In this section, we demonstrate the impact of a one-time payment from the City's partner on the financial model. A $10 million upfront payment from the private partner would enable the City to reduce its bond requirement by $12.5 million—which, in turn would lower the required per-passing fee to $14.10.

Table 38: A $10 Million Upfront Payment Reduces the City's Borrowing by $12.5 Million

Income Statement	1	5	10	15	20
Total Revenues	$ 10,083,240	$ 16,647,420	$ 16,647,420	$ 16,647,420	$ 16,647,420
Total Cash Expenses	(856,190)	(2,316,120)	(2,316,120)	(2,316,120)	(2,316,120)
Depreciation	(2,274,200)	(7,494,600)	(7,494,600)	(7,494,600)	(7,494,600)
Interest Expense	(2,115,000)	(7,244,610)	(5,631,970)	(3,622,350)	(1,118,010)
Taxes	-	-	-	-	-
Net Income	$ 4,837,850	$ (407,910)	$ 1,204,730	$ 3,214,350	$ 5,718,690

Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 4,254,050	$ 644,730	$ 3,083,290	$ 5,523,210	$ 7,964,230
Depreciation Reserve	-	146,130	196,680	246,990	297,300
Interest Reserve	2,115,000	-	-	-	-
Debt Service Reserve	2,350,000	8,700,000	8,700,000	8,700,000	8,700,000
Total Cash Balance	$ 8,719,050	$ 9,490,860	$ 11,979,970	$ 14,470,200	$ 16,961,530

8.6.2 Increasing the City's Interest Rate

Because the City will be building and maintaining the OSP, but not lighting the fiber or selling retail services, the City's capital investment and financing are the key sensitivities in the model. As we noted above, about 86.5 percent of the City's annual cash outflow will cover P&I; only 13.5 percent of cash outflow will be for network operations and maintenance. If the City's interest rate were to increase by two percentage points, to 6.5 percent, the City would need to increase its borrowing by $7.5 million to cover the increased interest payments in early years, as well as to keep cash flow positive. The increased borrowing would, in turn, increase the required per-passing payment from $15 to $17.75 (a roughly 18 percent increase in that fee).

Table 39: Increasing the City's Interest Rate by 2 Percentage Points Increases Required Borrowing by $7.5 Million

Income Statement	1	5	10	15	20
Total Revenues	$ 104,790	$ 20,956,860	$ 20,956,860	$ 20,956,860	$ 20,956,860
Total Cash Expenses	(856,190)	(2,316,120)	(2,316,120)	(2,316,120)	(2,316,120)
Depreciation	(2,274,200)	(7,494,600)	(7,494,600)	(7,494,600)	(7,494,600)
Interest Expense	(3,672,500)	(11,818,740)	(9,513,410)	(6,354,930)	(2,027,600)
Taxes	-	-	-	-	-
Net Income	$ (6,698,100)	$ (672,600)	$ 1,632,730	$ 4,791,210	$ 9,118,540
Cash Flow Statement	**1**	**5**	**10**	**15**	**20**
Unrestricted Cash Balance	$ 90,600	$ 296,370	$ 3,017,930	$ 5,740,850	$ 8,464,870
Depreciation Reserve	-	146,130	196,680	246,990	297,300
Interest Reserve	3,672,500	-	-	-	-
Debt Service Reserve	2,825,000	9,700,000	9,700,000	9,700,000	9,700,000
Total Cash Balance	$ 6,588,100	$ 10,142,500	$ 12,914,610	$ 15,687,840	$ 18,462,170

In contrast to the scenario above, if the City were able to decrease its interest rate by two percentage points, to 2.5 percent, it would be able to reduce its borrowing by 6.5 million and the required per-passing cost to $12.50.

Table 40: Reducing the City's Interest Rate by 2 Percentage Points Reduces Required Borrowing

Income Statement	1	5	10	15	20
Total Revenues	$ 73,790	$ 14,758,350	$ 14,758,350	$ 14,758,350	$ 14,758,350
Total Cash Expenses	(856,190)	(2,316,120)	(2,316,120)	(2,316,120)	(2,316,120)
Depreciation	(2,274,200)	(7,494,600)	(7,494,600)	(7,494,600)	(7,494,600)
Interest Expense	(1,287,500)	(4,084,500)	(3,045,010)	(1,868,920)	(538,310)
Taxes	-	-	-	-	-
Net Income	$ (4,344,100)	$ 863,130	$ 1,902,620	$ 3,078,710	$ 4,409,320
Cash Flow Statement	**1**	**5**	**10**	**15**	**20**
Unrestricted Cash Balance	$ 129,600	$ 747,370	$ 2,744,180	$ 4,742,350	$ 6,741,620
Depreciation Reserve	-	146,130	196,680	246,990	297,300
Interest Reserve	1,287,500	-	-	-	-
Debt Service Reserve	2,575,000	9,000,000	9,000,000	9,000,000	9,000,000
Total Cash Balance	$ 3,992,100	$ 9,893,500	$ 11,940,860	$ 13,989,340	$ 16,038,920

8.6.3 Increasing the City's Bond Term to 30 Years

The illustrate the sensitivity of the City's financial model to bonding and borrowing terms, we increased the City's bond term from 20 years to 30 years. The per-passing fee required to maintain cash flow decreases from $15.00 to $12.15. However, the longer bond term increases the city's risk and increases the City's interest rate. Further, a longer bond term would require a longer contract with the private partner; given both the pace of change in the broadband industry, and the average lifespan of telecommunications companies.

Table 41: Increasing the City's Bond Term to 30 Years Decreases the Per-Passing Fee

Income Statement		1		5		10		15		20
Total Revenues	$	71,730	$	14,345,120	$	14,345,120	$	14,345,120	$	14,345,120
Total Cash Expenses		(856,190)		(2,316,120)		(2,316,120)		(2,316,120)		(2,316,120)
Depreciation		(2,274,200)		(7,494,600)		(7,494,600)		(7,494,600)		(7,494,600)
Interest Expense		(2,430,000)		(7,926,270)		(7,063,630)		(5,988,670)		(4,649,100)
Taxes		-		-		-		-		-
Net Income	$	(5,488,660)	$	(3,391,870)	$	(2,529,230)	$	(1,454,270)	$	(114,700)

Cash Flow Statement		1		5		10		15		20
Unrestricted Cash Balance	$	192,540	$	860,210	$	3,612,170	$	6,365,460	$	9,119,880
Depreciation Reserve		-		146,130		196,680		246,990		297,300
Interest Reserve		2,430,000		-		-		-		-
Debt Service Reserve		2,700,000		9,175,000		9,175,000		9,175,000		9,175,000
Total Cash Balance	$	5,322,540	$	10,181,340	$	12,983,850	$	15,787,450	$	18,592,180

8.6.4 Reducing Operating Expenses by 25 Percent

Because the City will be borrowing to cover not only all of its capital requirements, but also a portion of its operating costs in the early years, decreasing the City's expenses would have a corresponding effect on the required per-passing fee. However, the impact is not linear. Decreasing operating expenses by 25 percent would only decrease the per-passing cost by 60 cents, to $14.40.

Table 42: Decreasing the City's Operating Expenses by 25 Percent Only Slightly Reduces the Per Passing Fee

Income Statement		1		5		10		15		20
Total Revenues	$	85,010	$	17,001,620	$	17,001,620	$	17,001,620	$	17,001,620
Total Cash Expenses		(642,140)		(1,737,090)		(1,737,090)		(1,737,090)		(1,737,090)
Depreciation		(2,274,200)		(7,494,600)		(7,494,600)		(7,494,600)		(7,494,600)
Interest Expense		(2,430,000)		(7,712,430)		(5,990,490)		(3,844,680)		(1,170,620)
Taxes		-		-		-		-		-
Net Income	$	(5,261,330)	$	57,500	$	1,779,440	$	3,925,250	$	6,599,310

Cash Flow Statement		1		5		10		15		20
Unrestricted Cash Balance	$	419,870	$	748,770	$	3,294,780	$	5,842,120	$	8,390,590
Depreciation Reserve		-		146,130		196,680		246,990		297,300
Interest Reserve		2,430,000		-		-		-		-
Debt Service Reserve		2,700,000		9,275,000		9,275,000		9,275,000		9,275,000
Total Cash Balance	$	5,549,870	$	10,169,900	$	12,766,460	$	15,364,110	$	17,962,890

8.6.5 Construct Network with a Mix of Aerial and Underground Construction

The scenario below assumes a split of roughly 62 percent underground and 38 percent aerial fiber for construction of the City's network (as opposed to the base case and other scenarios, which assume all-underground construction). The mixed construction model also decreases the average drop cost from $972 to $607—though this would be the private provider's cost. In this scenario, the required per-passing fee would increase slightly, to $14.50.

Table 43: Mix of Aerial and Underground Construction Slightly Decreases Per-Passing Fee

Income Statement	1	5	10	15	20
Total Revenues	$ 85,600	$ 17,119,690	$ 17,119,690	$ 17,119,690	$ 17,119,690
Total Cash Expenses	(814,560)	(2,288,200)	(2,288,200)	(2,288,200)	(2,288,200)
Depreciation	(2,190,320)	(7,215,000)	(7,215,000)	(7,215,000)	(7,215,000)
Interest Expense	(2,340,000)	(7,484,820)	(5,814,200)	(3,732,350)	(1,138,000)
Taxes	-	-	-	-	-
Net Income	$ (5,259,280)	$ 131,670	$ 1,802,290	$ 3,884,140	$ 6,478,490

Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 225,640	$ 882,260	$ 3,452,240	$ 6,023,480	$ 8,595,720
Depreciation Reserve	-	140,700	182,200	223,430	264,660
Interest Reserve	2,340,000	-	-	-	-
Debt Service Reserve	2,600,000	9,000,000	9,000,000	9,000,000	9,000,000
Total Cash Balance	$ 5,165,640	$ 10,022,960	$ 12,634,440	$ 15,246,910	$ 17,860,380

Appendix A – Common Community Objectives

This appendix is attached as a separate PDF file.

Appendix B – Best Practices for FTTP Deployment in Underserved Areas

This appendix is attached as a separate PDF file.

Appendix C – Residential Market Research Instrument

This appendix is attached as a separate PDF file.

Appendix D – Glossary of Terms

Access Fiber – The fiber in an FTTP network that goes from the FDCs to the optical taps that are located outside of homes and businesses in the ROW.

AE – Active Ethernet; a technology that provides a symmetrical (upload/download) Ethernet service and does not share optical wavelengths with other users. For subscribers that receive AE service—typically business customers that request a premium service or require greater bandwidth—a single dedicated fiber goes directly to the subscriber premises with no optical splitting.

CPE – Customer premises equipment; the electronic equipment installed at a subscriber's home or business.

Distribution Fiber – The fiber in an FTTP network that connects the hub sites to the fiber distribution cabinets.

Drop – The fiber connection from an optical tap in the ROW to the customer premises.

FDC – Fiber distribution cabinet; houses the fiber connections between the distribution fiber and the access fiber. FDCs, which can also house network electronics and optical splitters, can sit on a curb, be mounted on a pole, or reside in a building.

FTTP – Fiber-to-the-premises; a network architecture in which fiber optics are used to provide broadband services all the way to each subscriber's premises.

GPON – Gigabit passive optical network; the most commonly provisioned FTTP service—used, for example, by Verizon (in its FiOS systems), Google Fiber, and Chattanooga Electric Power Board (EPB). GPON uses passive optical splitting, which is performed inside FDCs, to connect fiber from the Optical Line Terminals (OLTs) to multiple customer premises over a single GPON port.

IP – Internet Protocol; the method by which computers share data on the Internet.

LEC – Local Exchange Carrier; a public telephone company that provides service to a local or regional area.

MDU – Multi-dwelling unit; a large building with multiple units, such as an apartment or office building.

OLT – Optical line terminal; the upstream connection point (to the provider core network) for subscribers. The choice of an optical interface installed in the OLT determines whether the network provisions shared access (one fiber split among multiple subscribers in a GPON architecture) or dedicated AE access (one port for one subscriber).

OSP – Outside plant; the physical portion of a network (also called "layer 1") that is constructed on utility poles (aerial) or in conduit (underground).

OSS – Operational Support Systems (OSS); includes a provider's provisioning platforms, fault and performance management systems, remote access, and other OSS for FTTP operations. The network's core locations house the OSS.

OTT – Over-the-top; content, such as voice or video service, that is delivered over a data connection.

Passing – A potential customer address (e.g., an individual home or business).

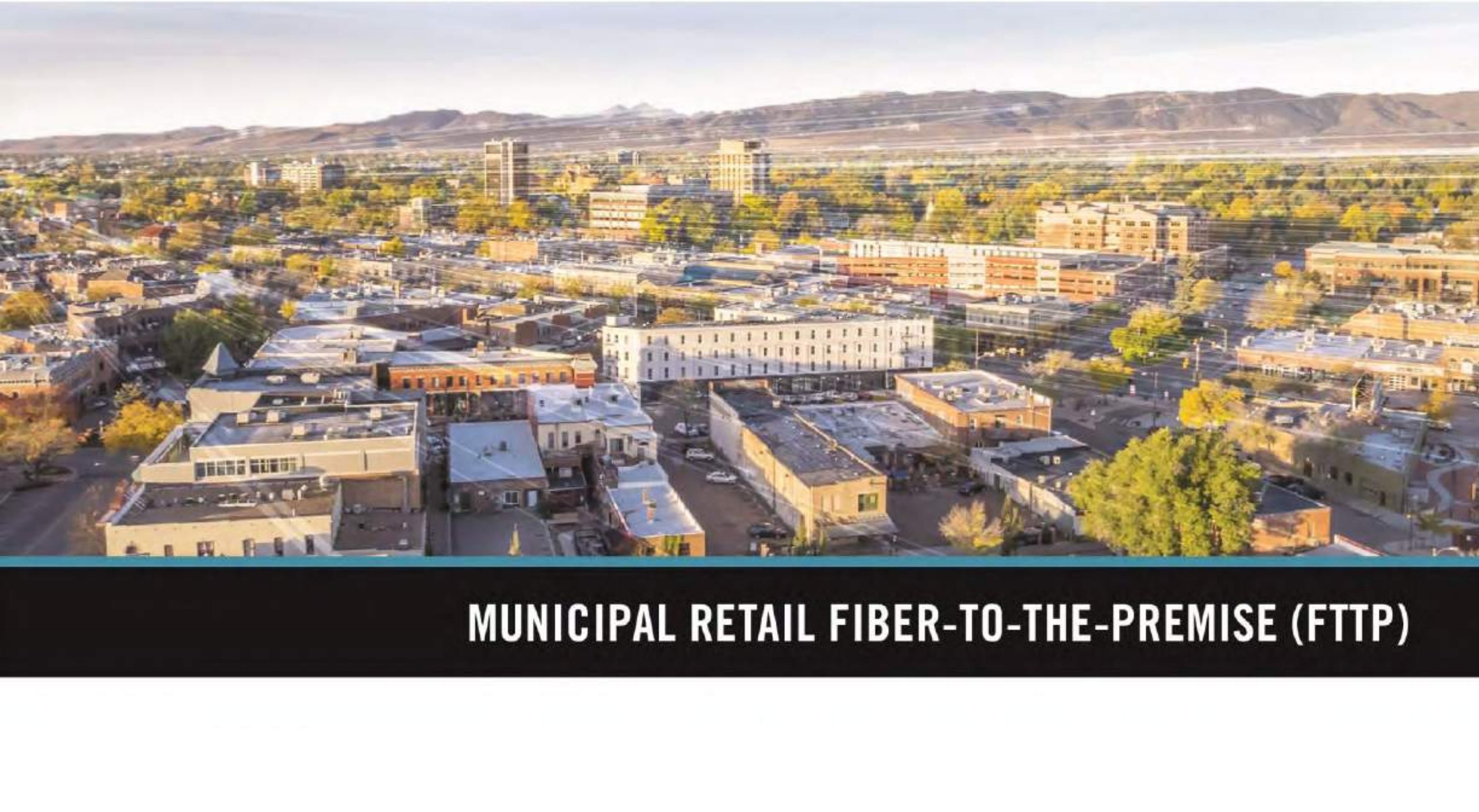
POTS – "Plain old telephone service;" delivered over the PSTN.

PSTN – Public switched telephone network; the copper-wire telephone networks that connect landline phones.

QoS – Quality of service; a network's performance as measured on a number of attributes.

ROW – Right-of-way; land reserved for the public good such as utility construction. ROW typically abuts public roadways.

VoIP – Voice over Internet Protocol; telephone service that is delivered over a data connection.



MUNICIPAL RETAIL FIBER-TO-THE-PREMISE (FTTP)

BROADBAND BUSINESS PLAN

Version III; August 31, 2017

Contents

I. Executive Summary

This document offers a high-level business plan for initiating and operating the City of Fort Collins' Retail fiber-to-the-premise (FTTP) broadband network. After extensive research and due diligence, municipal deployment of a FTTP network is a viable alternative to produce meaningful sustainable benefits for the City of Fort Collins. Fiber's a proven technology with a stable history, capable of meeting current performance standards. It is the most promising alternative to meet future needs.

The business plan (Plan) addresses the broadband status quo in the City of Fort Collins, market profile and opportunity, operating plan, proposed network architecture and financial requirements of the retail model. In addition, the competitive environment will be investigated, possible operating scenarios examined, and frequently asked questions answered.

The Plan was written with data provided by Uptown Services in the 2016 Financial Feasibility Analysis and with data available to staff at the date of publication and may not reflect current conditions. The Plan will be updated as new information becomes available.

II. Mission

Status Quo

The City of Fort Collins began exploring the benefits and need for a high speed fiber network in 2010 when Google announced the launch of the "Think big with a gig: Our experimental fiber network" competition. The City was among the estimated 1,100 communities that applied. After Google announced Kansas City as their first Google Fiber community, the City, along with Colorado State University (CSU) joined an effort called GigU. Thirteen communities and their land-grant universities partnered to explore the benefits to the University and City of Fort Collins by creating a future-proof "Connected City."

Why Fiber-to-the-Premise ("FTTP")? Why Now?

The term "future proofing" is used to describe a city that is connected to the internet for commerce and quality of life services. Fort Collins is home to CSU and an outstanding public school system that uses the internet for world-class research and business. Fort Collins has a tech-savvy culture and a strong economic base with diverse employment opportunities that could benefit from enhanced broadband services. High speed broadband is the nervous system of innovation, entrepreneurship, education and quality of life. The ability to connect quickly and reliably (both upload and download) has proven to be a differentiator.

For the next 30-50 years, fiber is the anticipated required infrastructure. With upgrades to the electronics, a fiber network can handle significantly greater speeds in the future. In contrast, existing coax and copper cable systems are at the end of their technological life and will not support speeds that will be needed throughout the next 20 years. Conversation with the two major incumbents providing internet service in the community indicated both believed their existing speeds were adequate to meet existing consumer needs and their business plan was to upgrade the system speed as the consumer needed it. Neither would commit to when a full fiber network system to all premises may be implemented.

Questions frequently arise as to why the City would enter a market that traditionally has been dominated by private companies. According to the Federal Communications Commission (FCC) the real underlying cause of slow, expensive internet in the U.S. is the lack of competition among providers. New broadband entrants into the market have a substantial impact on price reductions, increased customer service and accelerated infrastructure upgrades. Incumbents typically try to maximize use of the existing infrastructure, such as copper, wireless or a hybrid approach. Non-fiber infrastructure can create dependability concerns due to the life and reliability of copper. Fiber, which the City's exploring in its broadband plan, is not susceptible to weather or electromagnetic interferences and can have a lifespan of 25–40 years or beyond. Currently, wireless technology is a complement to wired connections, not a substitute.

The City realized a fiber-connected city created advantages over a disconnected city. With the growing importance of high speed internet within the economy and citizen's daily lives, a plan for securing gigabit-speed internet across the City's growth management area (GMA) is crucial. It was also apparent that the existing networks within the City's GMA would require significant technology upgrades before they were able to offer reliable gigabit speeds to the general public at a reasonable price. It would seem a municipal network was the obvious option. However, Senate Bill 05-152 (SB152) prohibited the City from being engaged in providing internet services; that is until 2015. In November 2015, 83 percent of Fort Collins voters chose to overturn SB152, thus removing the legal barriers to the City of Fort Collins from providing high speed internet.

Staff created this high-level business plan to document the assumptions, data, estimates, challenges and details associated with creating a municipal retail fiber-to-the-premise (FTTP) network that would offer broadband service to the Fort Collins GMA.

City of Fort Collins Retail Broadband Solution

During the Budgeting for Outcomes (BFO) community outreach in 2014, the community prioritized and identified a need to address the lack of reliable, universal and affordable broadband services. The City of Fort Collins addressed the broadband situation by identifying the following strategic objective in the 2015/2016 Strategic Plan.

"Strategic Objective 3.9 – Encourage the development of reliable high speed internet services throughout the community."

The overall objective is to bring reliable, high speed internet to the city of Fort Collins, while making an informed decision through evaluation of risk and opportunities. The FCC formally defines broadband as internet download speed of 25 megabits per second (Mbps) and upload of 3Mbps or faster. However, a popular benchmark of high-speed broadband is commonly known as gigabit speed (Gbps), and is seen in many cities across the country including Longmont, CO.

One possible option for accomplishing Strategic Objective 3.9 is the City of Fort Collins Municipal Retail FTTP Broadband Network in which the City will design, build, own, operate and market internet services to all premises within the City's GMA. Initial build-out of the network would be within existing city limits and service would be added to the GMA as those areas were annexed into the City. In summary, the City would:

- Design a fiber grid network to ensure infrastructure is available on a community-wide basis
- Borrow between $130M and $150M to fund the network construction and systems implementation to all businesses and residences

- Design a fiber grid system to ensure infrastructure is available on a community wide basis
- Manage construction of the fiber network build, provide quality assurance and comprehensive testing to ensure a high quality network
- Design and install fiber drops to each premise when a customer orders internet service from the City
- Provide internet services to all premises requesting service
- Lease Dark Fiber as requested by businesses
- Develop sales and marketing programs to effectively compete in this competitive market
- Develop appropriate back-office systems required to support customer service and maintain and monitor the network
- Target Residential Pricing of $50/month for 50Mbps service, and $70/month for 1Gbps while also offering an “Affordable Internet” tier program

Fort Collins plans symmetrical (same speed for both downloads and uploads) speed offerings of both 50Mbps and 1Gbps residential offerings. Symmetrical service would also be an option for commercial subscribers.

Additional benefits sought by the City include:

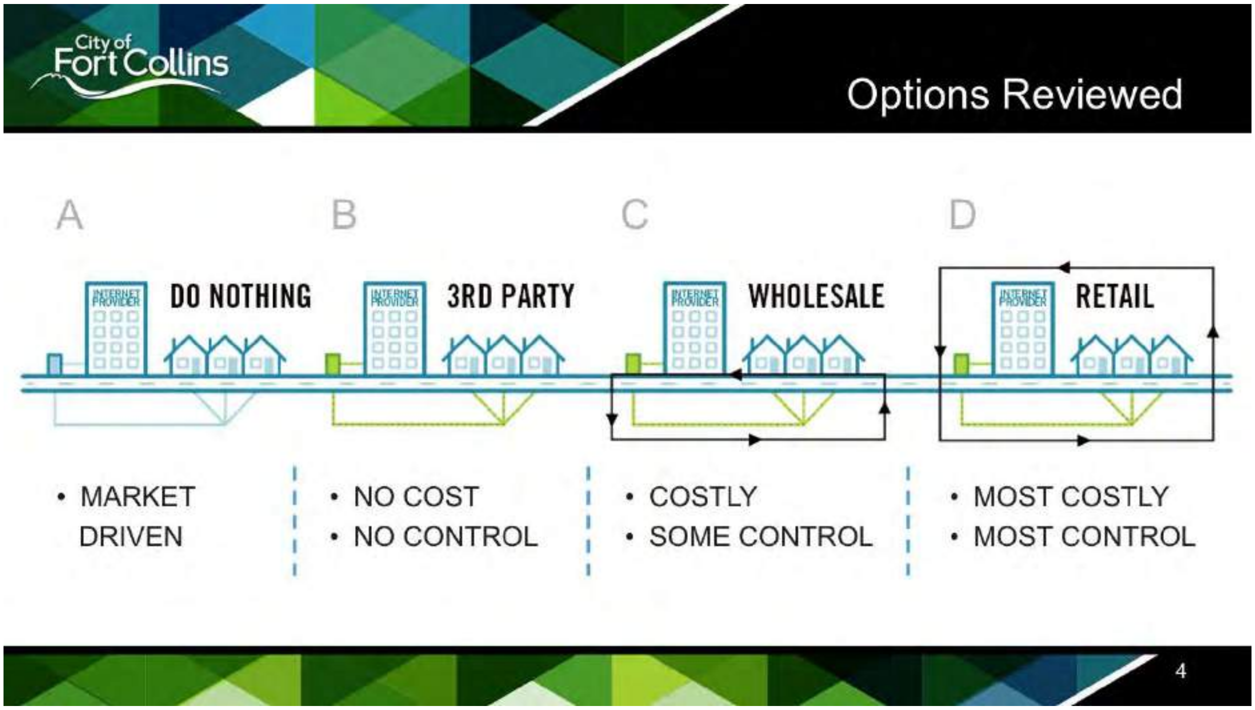
- Competitive pricing
- Universal coverage across the GMA
- Underground service for improved reliability
- Timely implementation to providing services within a reasonable timeframe

History of Investigation

The City held discussions with each of the Fort Collins major incumbents. Each described their strategic commitments and timing to upgrade their existing systems to a high speed fiber-based system. While the incumbents have plans to upgrade their systems over time, no specifics or promises were provided, such as:

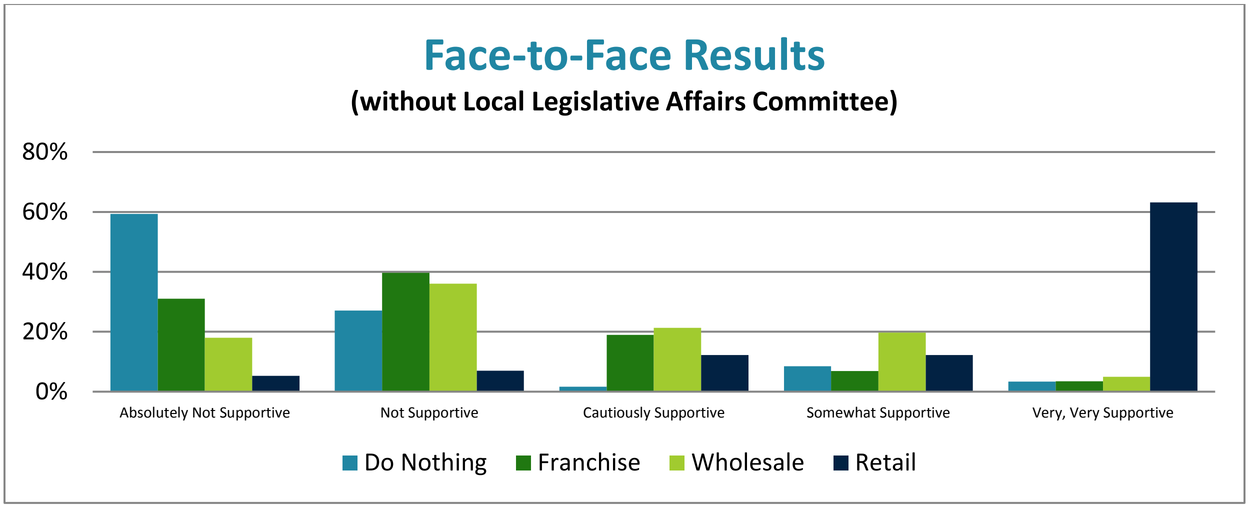
1) What percentage of customers will have FTTP connectivity by year-end 2017/2018?
2) When they will have a network that is fully fiber-based across the entire growth management area?
3) How they will help the City ensure that all neighborhoods benefit from connectivity?

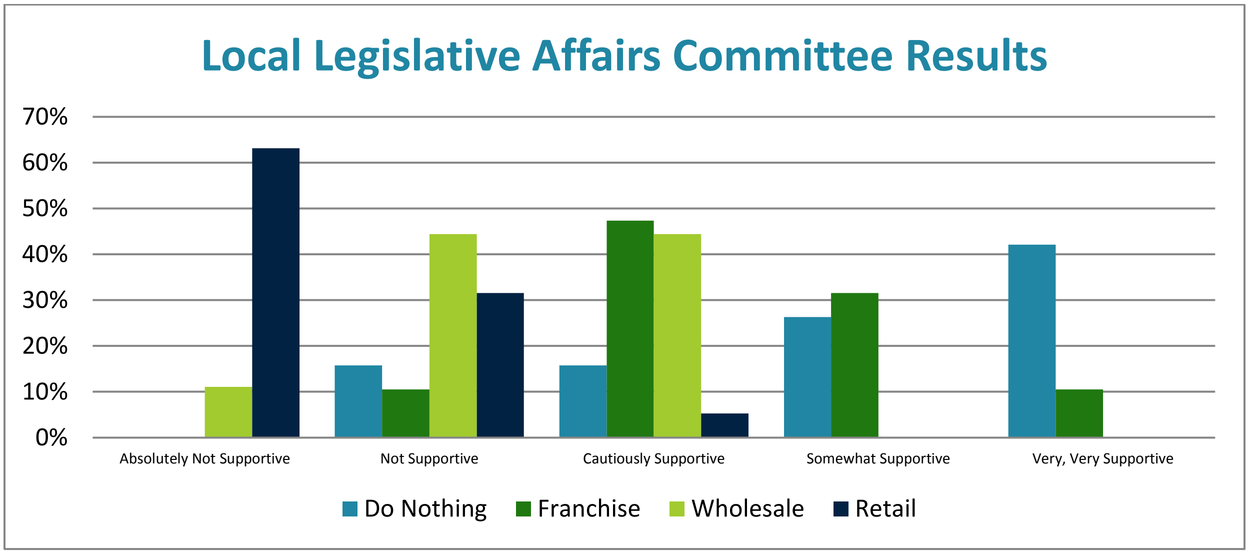
Staff explored a number of solutions in addition to the retail model to achieve the City’s Strategic Objective 3.9 and developed the following four alternatives:

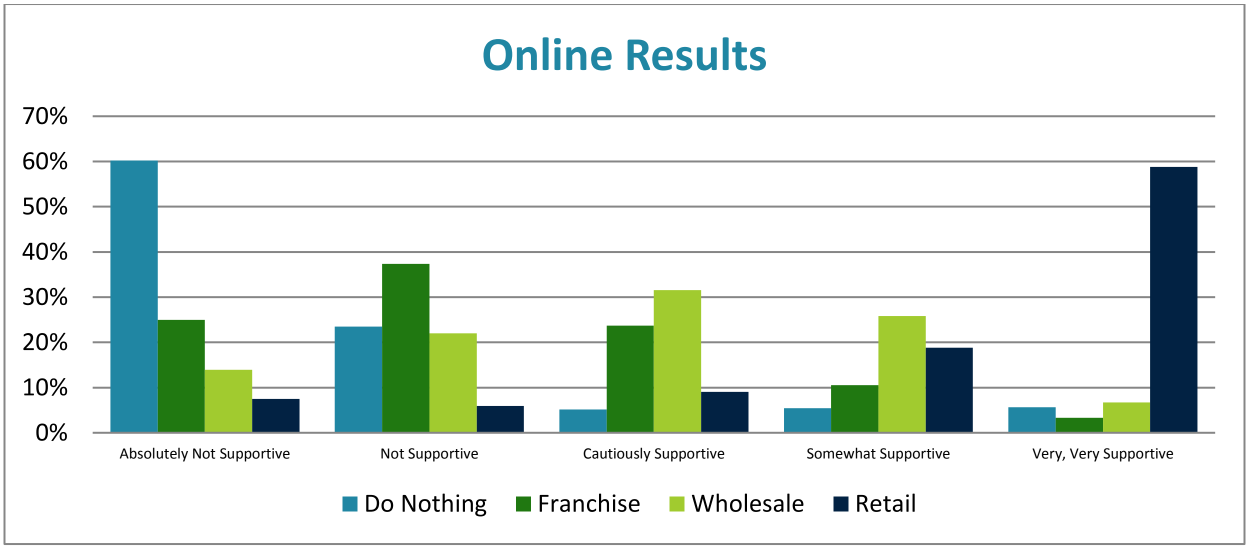


A. **Do Nothing** – Rely on the current incumbents to upgrade their systems and provide improved speed and reliability per their capital improvement plans
B. **3rd Party or Partnership** – Develop a partnership with an existing internet service provider that leverages their expertise and experience combined with the City's brand and reputation to develop and deliver high speed internet within the community
C. **Wholesale Model** – where the City builds out a fiber network and attracts other service providers to market and operate the system
D. **Retail Model** – where the City enters the business of building out, operating and providing internet and other services across a City-owned fiber infrastructure

Extensive community engagement was conducted in 2016 to determine citizen preference among the four options. The graphs below summarize the citizen "in-person" results, Local Legislative Affairs Committee preference and input from the online survey.







NOTE: At the time of the outreach, the third-party alternative was called "franchise." Colorado statute does not allow telecommunication franchises and therefore is now referred to as third-party.

As part of the investigation, staff has had phone discussions and visited with several communities that have launched a broadband effort. In addition, a consultant, Magellan, was engaged in late 2015 to provide case study analysis of the various business models communities have used. Attachment 1 provides the detail of Magellan's analysis. The City of Fort Collins also evaluated how 25 peer communities are working to stay connected. Twenty out of 25 peer cities have state legislation that restricts municipalities' ability to operate in the telecommunications industry. The appendix summarizes how Fort Collins peer cities are approaching broadband.

In summary, the "Do Nothing" alternative did not achieve Strategic Objective 3.9. The Wholesale model requires the City to make a significant investment in building out the fiber network (approximately $90M) and the success of that network and the City's ability to repay the debt for the build-out is dependent on the success of these external service providers. The risks identified with the Wholesale model are similar to what has occurred in Utah and Tacoma Washington. Staff determined neither of these alternatives met the objectives of the project.

From 2016 through early 2017, staff explored both the 3rd Party/Partnership model and the Retail model. This business plan is specific to the exploration of a City owned and operated FTTP internet service business.

The City hired Uptown Services, consultants who have evaluated broadband service offerings in more than 40 different communities, to support a feasibility evaluation of both retail and wholesale models. Working with staff, Uptown conducted market surveys, evaluated and estimated construction costs, estimated market take rates (the market share the City would have after five years) and developed a financial model for a full build-out of a fiber network in Fort Collins. The resulting business plan relies heavily on the work of Uptown Services.

Platte River Power Authority

Platte River Power Authority (PRPA) maintains the local fiber loops for the Cities of Fort Collins, Loveland and the Town of Estes Park. The backbone fiber ring began in 1998 as an electric substation communication upgrade. It replaced unreliable radio and telephone line connectivity for an important supervisory control and data acquisition (SCADA) network. A quality SCADA system provides utilities (both power and water) with valuable knowledge and capabilities that are key to running a reliable and safe business. PRPA and the City of Fort Collins partnered to connect all of the substations in the community with a 144-fiber backbone cable (12 buffer tubes). PRPA, needing only one buffer tube (12 fibers), offered buffer tubes to City Traffic, Utilities and IT departments. The remaining fibers were presented as leasable to public and private local institutions.

PRPA's role continues to include:

- Managing all fiber splices on the substation backbone
- Providing location services for the substation backbone
- Actively leasing dark fiber not used by the host municipality to public and private lessees (potential additional revenue for the new system)
- Provide solution design services to lessees
- Performing ongoing maintenance, troubleshooting, and customer support for lessees
- Maintaining fiber documentation and fiber management database
- Implementing capital improvement
- Administering billing and collections of fiber lease revenue and returning the collected revenue to the municipalities

The current agreement between the City of Fort Collins and PRPA expires on Dec. 15, 2018. Currently, the City utilizes 36 of the 144 fiber strands for existing City use (fire, police, IT, Utility, Traffic, etc.). Of the 144 strands, only 25 are not being utilized. It is also estimated that the City receives $270k in revenue annually from PRPA due to dark fiber leasing agreements.

Given the limited number of unused strands and the expected future need to utilize the existing PRPA fiber infrastructure to support municipal operations, very limited excess capacity has been identified that could be used for the retail model. As a result, the infrastructure needed to support the retail model will require new fiber installation, and will not be able to leverage the existing PRPA fiber ring.

III. Broadband Market Profile

Residential

Currently, the majority of computers and applications do not require gig speed to operate effectively. Studies indicate speeds of 75Mbps will largely handle the average consumers' requirement. However, the City's goal is to "future-proof" with fiber infrastructure for three reasons:

1) As more and more devices are used within a single household, the simultaneous use will begin to exceed the current speed offerings.
2) As speed becomes more readily available, new applications will be developed that require a higher speed.
3) With the growing use of cloud services, a more symmetrical service will be required.

Residential broadband subscribers are utilizing more online applications that require more bandwidth, quality and reliability out of internet connections. The impact of simultaneous applications and devices accessing a single home broadband connection creates a situation where most residential broadband connections are unable to handle the amount of bandwidth needed to support all applications simultaneously. In addition, the myriad of cloud services is driving the need for more symmetrical broadband services, as real-time applications require additional bandwidth, in terms of both download and upload speed. Many times, these applications synchronize in real time, meaning that they are always consuming bandwidth at a constant rate rather than only when the user is actively engaged through their computers, tablets and smartphones. As more of these applications are deployed, broadband connections will need to accommodate the increased bandwidth load.

The proliferation of devices, commonly referred to as the Internet of Things (IOT), is also driving the need for more bandwidth. As more devices in homes, businesses and public places all access existing broadband connections, these demands also extend to many devices inside the home that are now connecting to the internet using residential broadband connections. Many video/audio systems, thermostats, irrigation and security systems are now connected to the internet, consuming more home broadband bandwidth. The increase in the number of devices using internet-based applications continues to drive additional broadband demand in the home.

Commercial

Accessible, affordable and reliable broadband services are a key productivity and efficiency driver for businesses of varying sizes. In many cases, bandwidth consumption outpaces the broadband speeds local businesses are able to purchase. Upgrading is often times not an option due to the prices businesses are able to afford and service availability, as well as other IT-related factors. When local broadband services cannot "keep up" with business needs, businesses lose productivity and efficiency, which affects their bottom line and makes them less competitive with regions that have more affordable broadband services.

Taken in aggregate, this lack of online access will eventually result in a less competitive business market, from an economic perspective, as growth from the digital economy will be realized by other communities. Solid economic studies have not been completed that support this presumption; however, more and more businesses acknowledge that reliable, high speed internet is a requirement as they look at relocation opportunities. Communities also risk retention issues as businesses that are not able to gain efficiencies with their existing broadband services will, in many cases, move operations to communities that have more availability of these services.

Broadband is a fundamental utility asset that businesses require, as they rely on broadband to maintain connectedness to the electronic world. The majority of these types of businesses rely on online services to maintain their daily operations. Through promotion of a community's leading-edge broadband services, current businesses can be assured that they can remain in the region and have robust access to the rest of the digital world. Accessible and affordable high speed broadband has also gone beyond being a differentiator to being a key part of the "minimum ante" for attracting and retaining desirable businesses and facilities. Cities that realize this take steps to ensure their environments are favorable and the "cost of doing business" is not increased due to expensive broadband services.

City of Fort Collins

Fort Collins is nestled against the foothills of the Rocky Mountains and alongside the banks of the Cache La Poudre River. With an estimated population of 167,500, Fort Collins is among the nation's fastest growing metropolitan areas. The City includes many assets and amenities that provide a competitive advantage including: CSU, abundant natural resources and agricultural land, a highly educated and creative workforce, a historic downtown, and many miles of trails, parks and bike paths. Fort Collins is known as an innovative community and has one of the highest rates of patents per capita in the world with a major research institution – CSU – a cluster of federal laboratories and such high-tech companies as Hewlett-Packard, AMD, Intel and Broadcom.

DEMOGRAPHIC FACTS	FORT COLLINS	COLORADO	UNITED STATES
Est. Population, 2017	167,500	5,540,500	323,127,513*
Persons under 5 years old*	5.7%	6.2%	6.2%
Persons under 18 years old*	19.9%	23%	22.9%
Persons 65 years and over*	8.8%	13%	14.9%
Female persons*	50.1%	49.7%	50.8%
Employment[†]	74,498	2,181,455	121,079,879
Median Household Income*	$55,647	$60,629	$53,889
Median Age*	29.3	34.3	37.7
Approx. % of Pop. w/ completion of 4+ years of college education*	52.5%	38.1%	29.8%
White person*	89%	87.5%	77.1%
Persons of Hispanic or Latino origin	10.1%	21.3%	17.6%

*Data provided by ACS 2011-2015 [†]Source: Colorado State Demography Office

Factors that influence local internet adoption include cost, availability and a city's demographics, including income levels. Brookings Institute noted in 2015 that 92.1percent of households earning $75,000 or more annually had a broadband subscription. Using this benchmark to evaluate the Fort Collins market indicates that roughly 36.3 percent of Fort Collins residents earn $75,000 or more per year.

Surveys and market studies performed by Uptown Services LLC, consultants engaged by the City of Fort Collins, found the following issues prevalent:

- The two incumbents have the vast majority of market share for both Internet and voice services in Fort Collins.
- Satisfaction for Internet and voice service benchmarks low; video is average.
- Top residential market needs are: lower prices, increased Internet speed, and improved reliability.
- Top small- to medium-size business market needs are: lower prices and carrier-grade reliability.
- Residential market purchase intent is very high and exceeds Longmont survey metrics.
- Small- to medium-size business market needs are being met, but price levels are high up to 200Mbps.
- Strong provider preference for the City within the residential market.
- Small- to medium-size business market is open to considering the City FTTP network as a provider option.
- The project appeal and purchase intent is strongest among younger households.

IV. Fort Collins Customer Profile

Market Segmentation

Uptown Services LLC were engaged to investigate the Fort Collins market and produce a market demand study based on survey results and expertise.

Uptown segments and methodologies:

Market Segment	Research Methodology	Research Parameters
Residential Consumers	Quantitative Phone Surveys	• Sample size of 400 with 95% Confidence Interval with a ± 4.9 sample error • Weighted by age decile to Fort Collins actual age distribution from 2010 Census data • Screened for telecom/broadband decision maker and employment bias
Small and Medium Sized Businesses		• Sample size of 50 with 95% Confidence Interval with a ± 4.9 sample error • Screened for telecom/broadband decision maker and employment bias • Located within the city limits and not home-based • Has internet
Large Employers and Institutional Partners	Qualitative Depth Interview	• Responses aggregated for confidentiality • Evaluate the current and future demand and need of the commercial and institutional segment • Qualify interest and level of support for the development and implementation of fiber broadband infrastructure

Residential Market

According to Governing.com's "America's Most Connected Cities," 91.4% of Fort Collins residents have at least one wired connection.

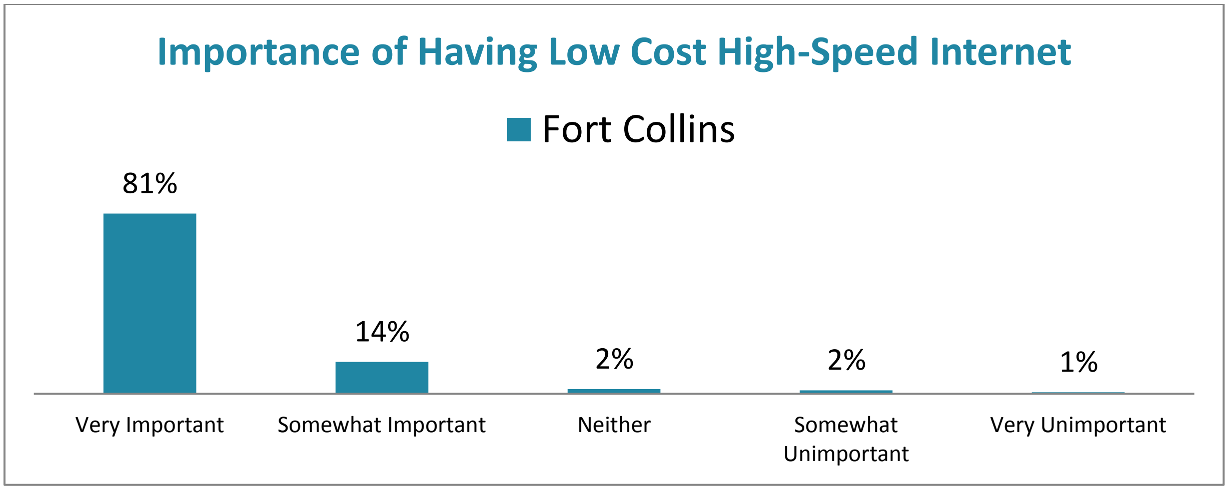
Top 20 cities with the Highest Internet Subscribership Rates per Governing.com 2013:

Ranking	City	Households With Broadband	Households Without Broadband	Population	Median Household Income	College or University?
1	Centennial, CO	96%	1,530	106,000	$96,677	No
2	Cary, NC	95.5%	2,568	151,088	$100,081	Yes
3	Irvine, CA	95.3%	3,944	236,716	$98,923	Yes
4	Frisco, TX	94.7%	2,416	136,791	$108,428	Yes
5	Bellevue, WA	93.6%	3,363	133,992	$48,719	Yes
6	Gilbert, AZ	93.4%	4,733	229,972	$80,121	Yes
7	Boulder, CO	92.7%	3,080	103,166	$57,112	Yes
8	Pearland, TX	92.6%	2,595	100,065	$89,149	Yes
9	Plano, TX	92.3%	8,184	274,409	$79,234	Yes
10	Scottsdale, AZ	92.1%	7,900	226,916	$57,484	Yes
11	College Station, TX	92%	2,785	100,050	$39,479	Yes
12	Coral Springs, FL	92%	3,231	126,604	$69,808	Yes
13	Surprise, AZ	92%	3,835	123,546	$55,857	No
14	Sunnyvale, CA	92%	4,507	147,559	$65,165	Yes
15	Lewisville, TX	91.6%	3,086	101,074	$57,457	Yes
16	Round Rock, TX	91.6%	3,122	109,821	$65,731	Yes
17	Arlington, VA	91.5%	8,452	224,906	$103,010	Yes
18	Fort Collins, CO	91.4%	4,957	152,061	$53,359	Yes
19	Naperville, IL	91.3%	4,329	144,864	$107,306	Yes
20	Torrance, CA	91.2%	5,010	147,478	$76,082	Yes

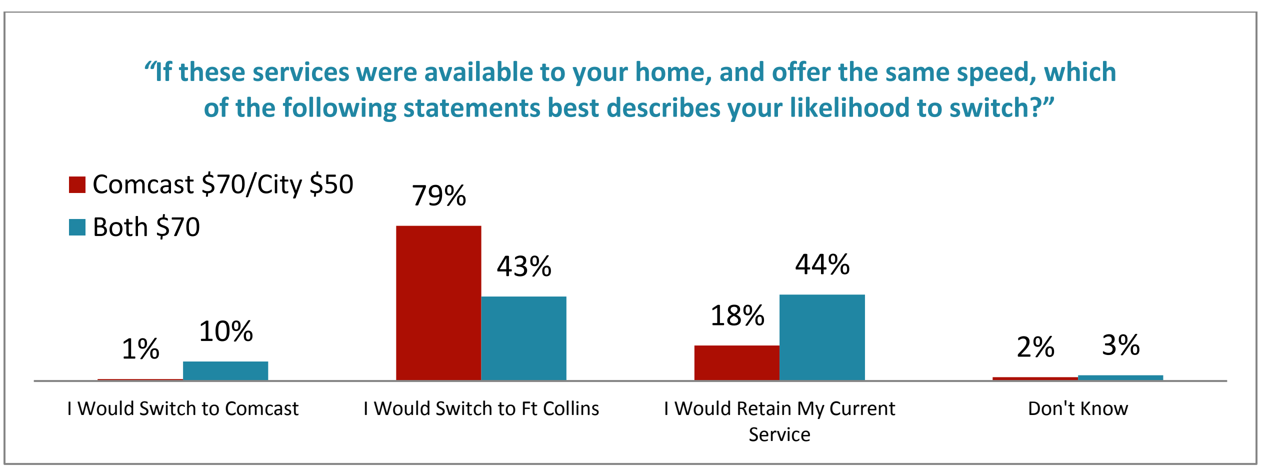
A statistically valid phone residential market demand survey conducted by Uptown Services in March 2016 asked questions around the internet, voice and video services as part of the overall inputs for the financial feasibility analysis. The study focused on high speed internet service, but the appeal of bundling services at a minimal cost was also investigated. The study confirmed that almost all Fort Collins households use the internet. Of Fort Collins households surveyed, 99 percent use the internet at home. Of these connected homes, cable modem and digital subscriber lines (DSL) represent the vast majority of the market share at 94 percent. Additionally, the study indicated that internet usage is prevalent across all income and age groups.

The survey also touched on customer service satisfaction levels, which plays a role in the market demand for alternative broadband services. Respondents were asked to rank customer satisfaction of various services (cable television, satellite television, non-pay television – antenna and basic channels, DSL, cable modem, telephone and electric utility) on a scale of 1-10 (with 10 being "totally satisfied" and 1 being "not at all satisfied"). The average customer satisfaction ranged from a high for electric utility at a mean rating of 8.7, to 6.8 for DSL and 6.6

for cable modem. Sixty-four percent of the respondents rated the City's Utility brand a 9 or 10 rating while other incumbent internet services had significantly lower ratings. Lower prices, increased internet speed, and reliability dominate the wish list of service improvements respondents identified for broadband. Branding and bundling were of secondary importance. Additionally, 81 percent of respondents acknowledged the importance of having low cost, high speed internet.



In addition to questions about current broadband services, market share and customer service satisfaction, the broadband market demand survey asked respondents about their interest and purchase intent (willingness to switch) for broadband services if offered by an alternative fiber network provider. Assuming the competition at a $70 per month price and a City-owned network at $50 per month price, seventy percent of respondents would definitely or probably switch to a City-owned fiber network for internet services. Furthermore, if respondents answered they would 'definitely' or 'probably' switch to the fiber network for internet services, they were asked the reason for the switch. The top three reasons given by respondents for a switch were: need for higher capacity, lower prices and the City as a preferred provider. If both the City and competitive offering were priced at $70 per month, only 45 percent of respondents indicated they would definitely or probably switch to the City-owned network.



Online Residential Broadband Survey

Due to wide-spread community interest, staff made an edited version of the residential market demand phone survey available online to anyone who wanted to participate. This was not intended to be statistically valid, but rather to allow more residents to engage in the conversation. More than 1,800 responses were received and the results were consistent with the original, statistically valid, residential phone survey; the exception being that the online questionnaire saw a higher response from younger demographics.

Top Attributes Relative to Importance Comparable Results

Online Questionnaire Participants	Statistically Valid Phone Survey Participants
Speed	Reliability
Price	Price
Reliability	Speed
Customer Service	Customer Service

Low Income

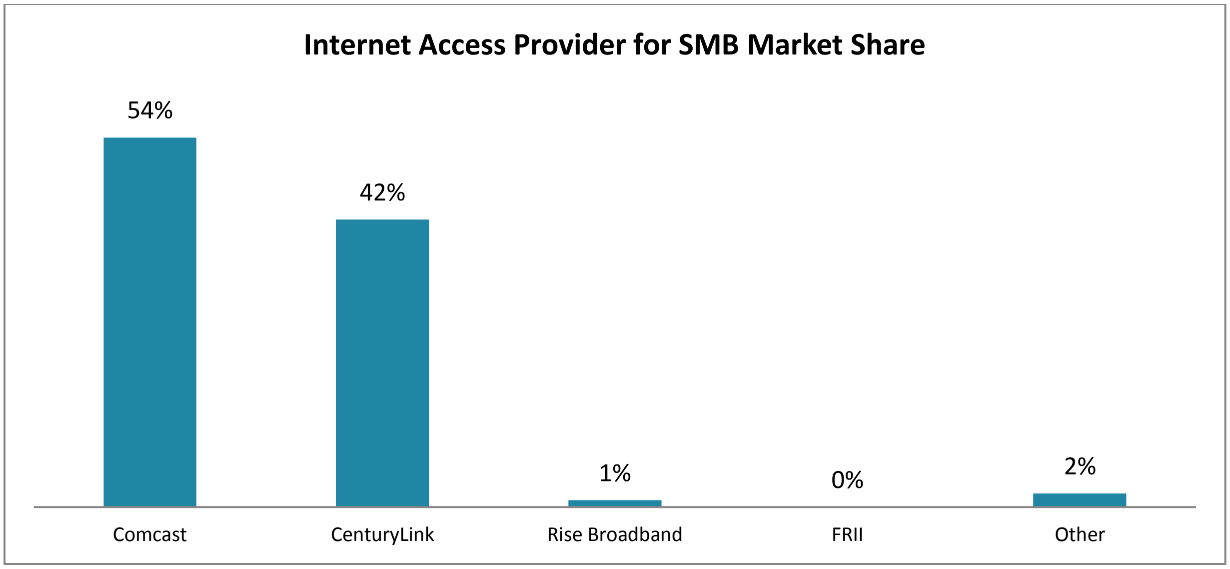
In October 2015, 33 percent (or ~8,744) of Poudre School District (PSD) students participated in the free or reduced lunch program. This program provides subsidized meals for those households that meet the 185 percent of poverty level qualification. The data provided by PSD was then compared to the census data for Fort Collins to verify that 5.4 percent of all households are eligible for the free meals participation program. The low income, affordable tier program will be available to those households at the 1.3 income: poverty ratio to match the free meal participation requirements, and calculates to be approximately 3,332 households.

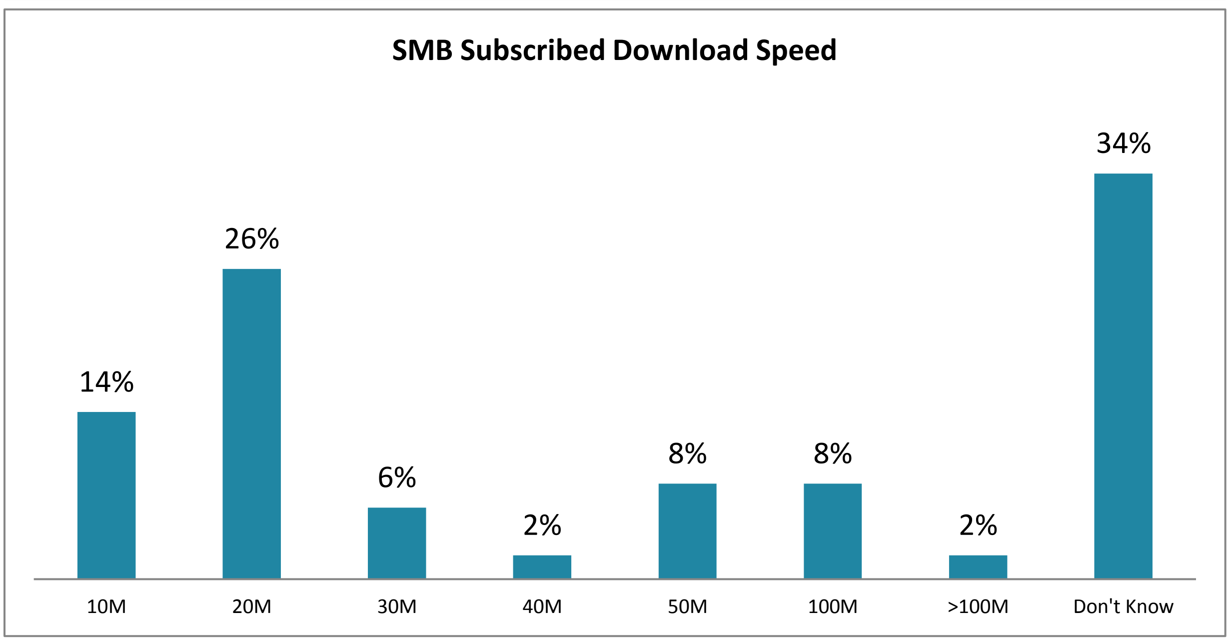
The “Affordable Internet” tier program is not been fully defined. Staff anticipates this will occur during the initial operational planning stage if the retail model is pursued.

Small- to Mid-Size Business

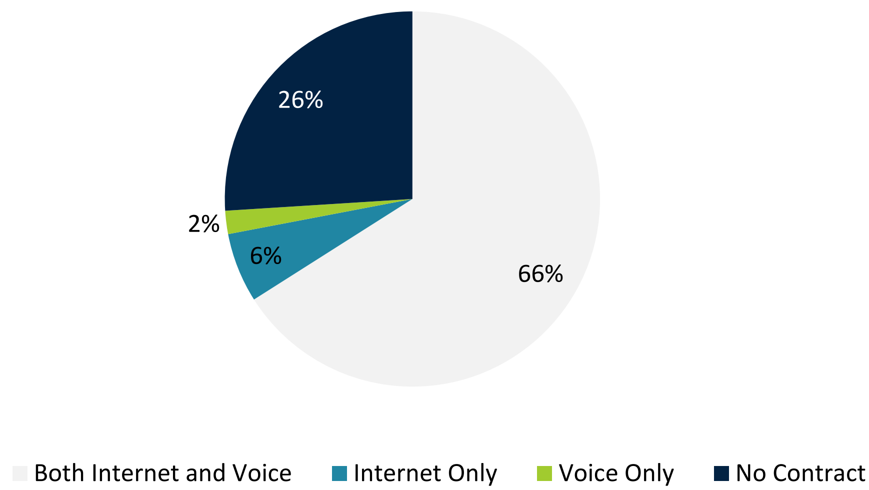
As of 2016, the City of Fort Collins has approximately 8,000 small- to mid-size businesses (SMB). Eighty-eight percent of all Fort Collins businesses are defined as small businesses (less than 50 employees), which is similar to the national average. Nationally, SMBs are responsible for 64 percent of new jobs and 50 percent of non-farm gross domestic product (GDP).

Uptown prepared a separate quantitative, statistically valid phone survey that was deployed to the small- to mid-size business segment in March 2016. The survey found that Comcast and CenturyLink are the only two Internet Service Providers (ISPs) with significant SMB market share in Fort Collins (about 96 percent of respondents). Two-thirds of SMB respondents in Fort Collins are under contract for internet and voice services. Additionally, SMB respondents had similar responses to the residential respondents in regard to customer satisfaction by service and customer needs. Reliability, increased speed and lower internet prices dominated the wish list for service improvements for SMBs. One item to note is that SMBs put a larger emphasis on the need for improved reliability (48 percent of SMBs identified this on their wish list), due to reliance on technology and the internet for business operations (merchant service transactions, ecommerce, cloud-based storage, etc.).

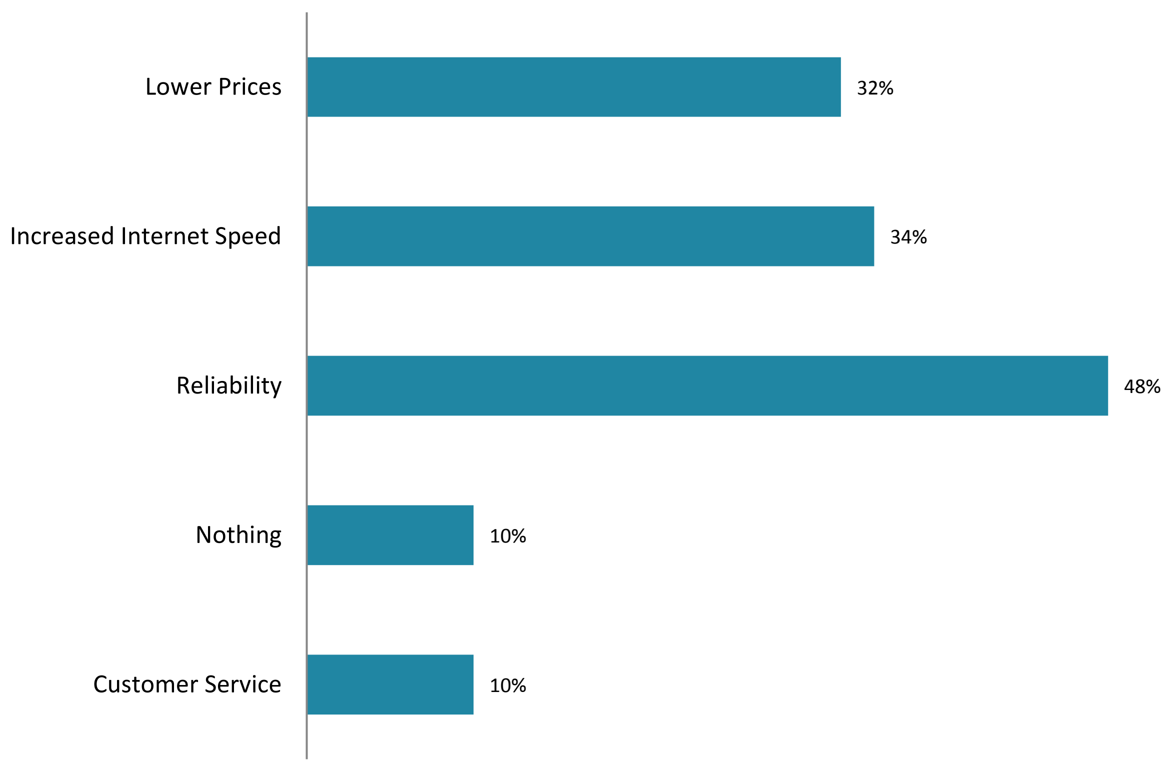


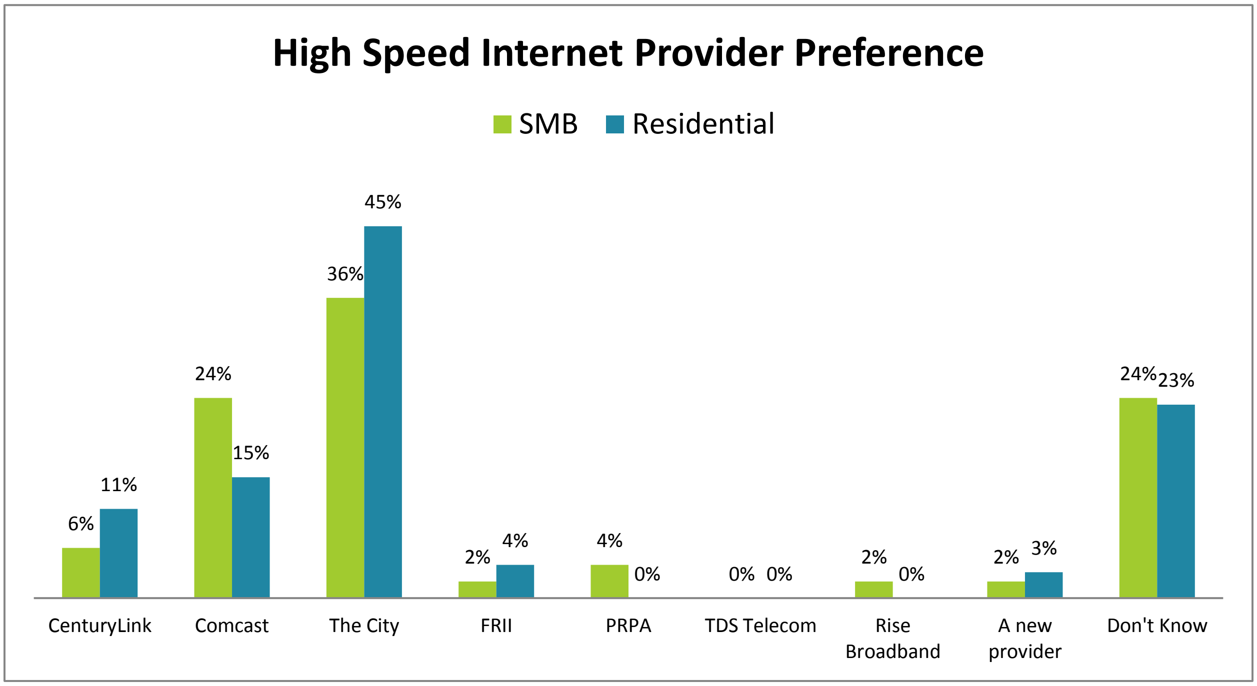


SMB Incidence of Provider Contracts



SMB Wish List for Improved Broadband Services



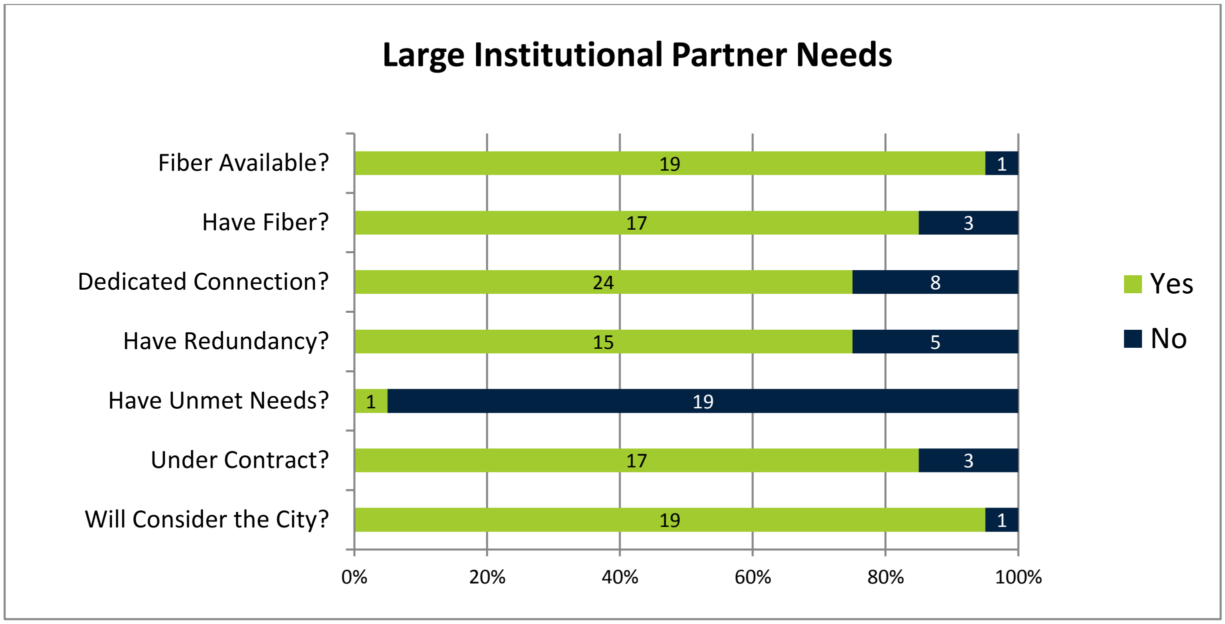


Large Business / Institution

The objective of the large business / institution qualitative survey was to identify the current capacity needs, future capacity needs, unmet needs and level of support for a fiber broadband network. Those interviewed could be major commercial account customers, and/or influencers in the community. A total of 24 interviews were conducted and the responses aggregated for confidentiality.

Findings from large business/institution qualitative surveys:

- Fiber is widely available and there is high incidence of dedicated access via fiber
- The survey found that due to multiple incumbent providers competing in the large business/institution segment
- Advance data needs are being met with dedicated connections for the business/institutions sole usage
- Most firms currently have sufficient bandwidth, but the City FTTP network would be considered as an option for redundancy and potential cost savings



Subscribership ("Take Rate")

Uptown consultants utilized a conservative research technique from the Packaged Goods sector to estimate potential subscribership rate, or take rate. This technique has been utilized for more than 30 years. It was developed as firms realized research respondents, for various reasons, overstate purchase intentions during research as compared to the eventual penetration of a product that was commercially launched. One measure of success for municipal broadband projects is by its "take rate," defined as the number actual number of subscribers divided by the total potential subscribers.

In March of 2016 the Uptown consultants estimated the take rate for City-provided internet service in Fort Collins at 38.8 percent for residential and 45 percent for small business. This assumed no other gig speed internet offering in the City of Fort Collins at the time.

In April 2016 with the potential launch of DOCSIS3.1 by Comcast, a competing internet service that provides 1Gbps down and 30Mbps up, Uptown revised the City's residential take rate to 30.2 percent.

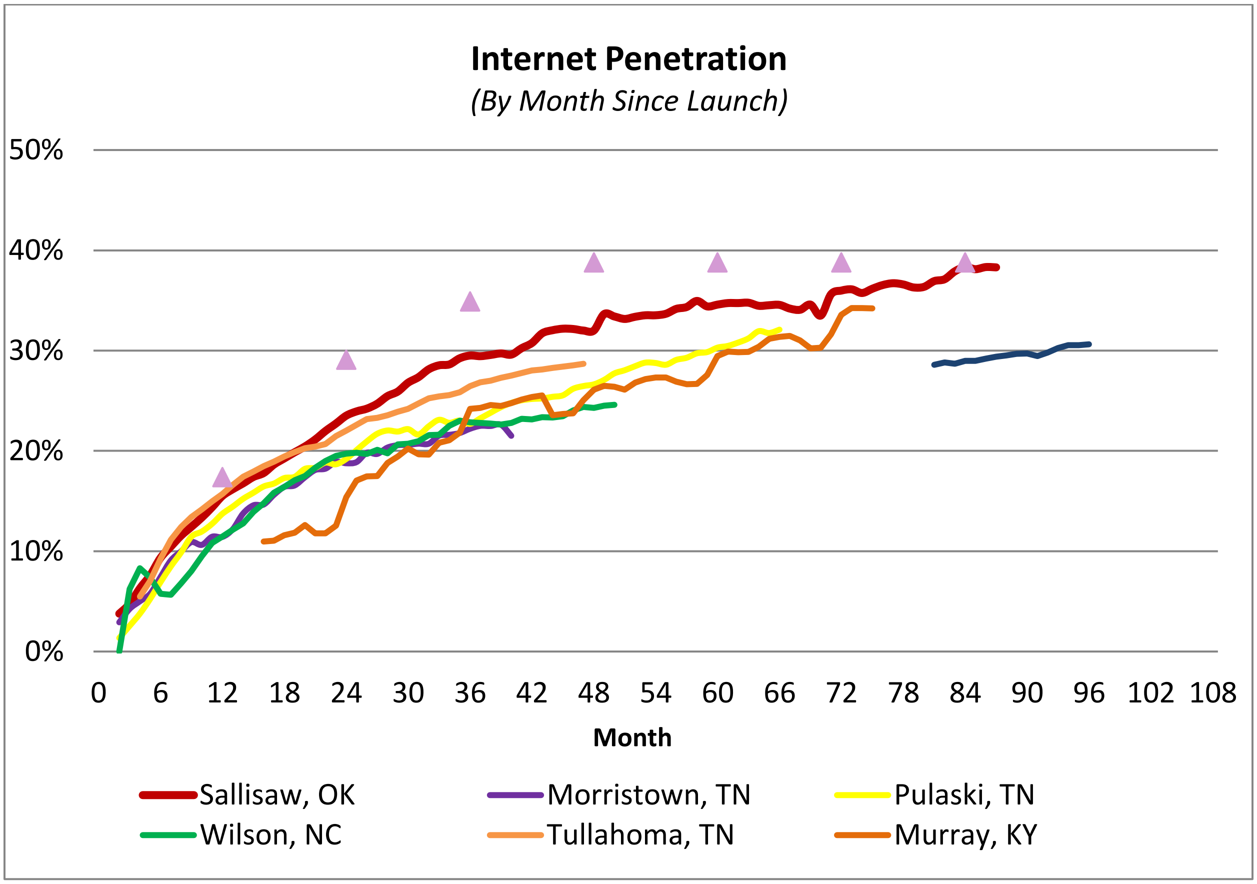
During the recent development of the retail model business plan, staff re-evaluated the pricing model based on industry standards and long-term sustainability. Additionally, during this time of approximately June 2017, Comcast announced the deployment of DOCSIS 3.1 to the Colorado market. This technology utilizes Comcast's existing coaxial cables and can provide 1 Gbps download and 35 Mbps upload speeds.

Due to these changes (listed below), Uptown Services recommended re-surveying the community to confirm the take rate:

1. City of Fort Collins revised the Tier 1 (50 Mbps) internet price from $40 to $50 per month
2. City of Fort Collins revised the Tier 2 (1 Gbps) internet price from $50 to $70 per month
3. Comcast's DOCSIS 3.1 pricing is $159.95 per month without a contract, and $110 per month with a one-year contract.
4. Comcast is testing a $70 per month promotional offer in Longmont, where NextLight 1 Gbps is offered.

Based on the survey responses, Uptown Services has estimated the City's retail model take rate to be 28.2 percent.

The following data shows that the estimated take rate is comparable to similar municipal benchmarks at the 5-year milestone. Five years signifies the completion of the construction period.



Estimated take rates based on the statistically valid phone surveys conducted March 2016, April 2016 and June 2017. The following graph depicts take rates in the 3 distinctly different environments in which the surveys were conducted.

	Pre-DOCSIS 3.1	Post-DOCSIS 3.1 Estimates	Post-DOCSIS 3.1 Announcement*
Residential Internet	38.8%	30.2%	28.2%
SMB Internet	45%		
Residential Voice	28.6%	8.4%	
SMB Voice	41%		

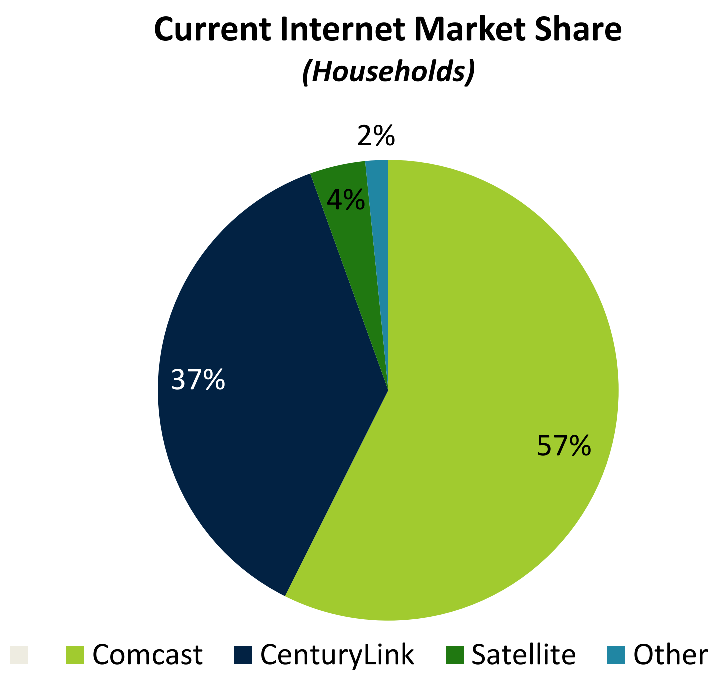
*assuming $70 gig pricing for incumbents and City retail

Residential subscribed premises would reach approximately 18,000 in year 5 and grow with the population at 0.4 percent thereafter. Commercial subscribed premises would reach 3700 premises in year 5 and grow at 1.5 percent while staying at a constant take rate of 45 percent. Voice services take rate would erode throughout time from a high of 8.4 percent in year 4, to 4.7 percent in year 15, as this technology reaches end-of-life and citizens transition from land lines to cellular service.

V. Competitive Environment

Incumbents

The Fort Collins market is dominated by two major incumbents, Comcast and Century Link.



Each of these incumbents operated within the City for several decades and provides all three services generally included in a bundled offering – internet, phone and video content.

Century Link™ (CL) has a significant fiber presence within the community to support their existing network with plans to extend further into new construction neighborhoods at some time in the future. The majority of new residential construction supported by CL is FTTP. CL stated the current average consumer does not need 1 Gbps service. CL shared data with City staff that indicates the maximum consumer need, accounting for multiple devices, is estimated at 75 Mbps with today's applications. CL's not committed to when, or if, they will serve all Fort Collins premises with a fiber connection. CL also shared they face a challenge of meeting their ROI requirements if they were to build out to the entire City with a fiber network.

Comcast also has an extensive fiber presence within the community that primarily extends to the node within a neighborhood. Newly constructed neighborhoods are served by a combination of fiber and/or coax. Comcast also has not committed to a timeline for servicing all Fort Collins households with fiber.

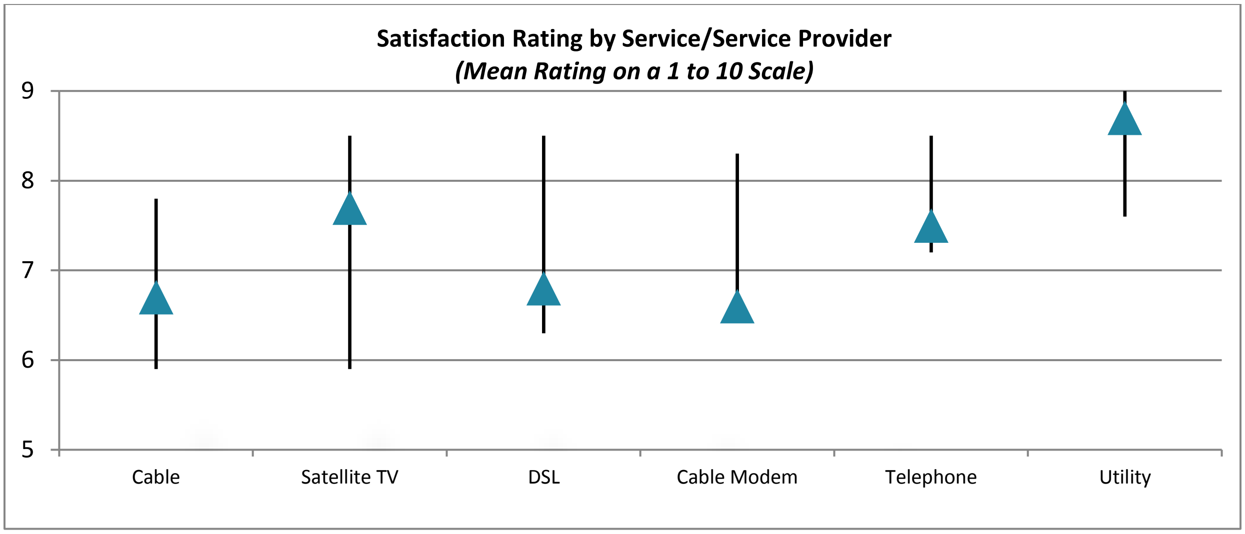
During the community engagement visits, many communities communicated significant challenges from their local incumbents, which illustrate the highly competitive market the City would enter with a retail model offering. The City's anticipated 28.2 percent take rate would largely come from the market share of the two incumbents.

INCUMBENT RESIDENTIAL INTERNET PRICING

	Download	Upload	Price	Technology
Comcast	10M 25M 75M 150M* 250M*	2M 5M 5M 10M 25M	$49.95 $59.95 $74.95 $89.95 $149.95	Cable Modem (DOCSIS 3.0)
	2G* (limited availability within 1/3 mile of fiber network)	2G	MRC: $299.95 NRC: $1,000 (2 Year Term Contract w/ Penalty)	Fiber
	1G	1G	Monthly: $140 3 Year Term: $70	Cable Modem (DOCSIS 3.1)
CenturyLink	1.5M 7M 12M 20M 40M*	896k 896k 896k 896k 5M	$44.00 $49.00 $54.00 $64.00 $74.00	DSL

Prices reflect subscription to Internet service at non-promotional rate as of March 2016.
*Not available in all areas of Fort Collins

The pricing above reflects published prices as of March 2016. Pricing is very dynamic within the market and can change frequently. Bundled services that include video and phone and additional charges are also utilized, making it difficult to develop price-to-price comparisons. Furthermore, citizen satisfaction with their DSL and cable modem broadband service is among the lowest of the 24 markets surveyed by the broadband consultant group Uptown Services.



Competitive Response

Both incumbents have extensive resources, marketing teams and advertising budgets that can create a significant competitive issue for a retail model offering by the City. Comcast is a corporation that had $8B of after-tax profits in 2016, and CL is in the process of acquiring Level3 for approximately $34B. In addition, each incumbent also has legislative lobbyists that can influence future legislation and could impair the City's ability to fund and launch a retail model. Wilson, NC spent approximately two years with legal and legislative hurdles before being able to launch their internet service. UTOPIA, a consortium of sixteen towns in Utah, started out as a retail model before legislation changed, which prevented municipalities from providing retail service. The network was in construction and had to switch to a wholesale or open access model. Various factors influenced the lack of success of UTOPIA, but they were ultimately unable to attract sufficient service providers to make the network economically viable. iProvo, Provo, UT's municipal network also faced the same challenge as UTOPIA sold a $40M network to Google for $1, and UTOPIA is in conversation with a third party who is asking each premise within the service area pay an $18 per month utility fee to support the debt service and network operations. This scenario is intended to illustrate the potential risks and influence large incumbents can have within a local market.

Comcast recently announced the DOCSIS 3.1 technology roll out that utilizes their existing coaxial network infrastructure. DOCSIS 3.1 offers 1 Gbps download speeds and 35 Mbps upload speeds. The retail price of Comcast's 1Gbps service with no contract would be $159.95 per month. A promotional price of $109.99 per month with a one-year agreement will be offered in Fort Collins and Larimer County. The technology upgrade does require customers to perform a cable modem and router replacement, and a firmware upgrade. Comcast believes this new technology will meet the near-term needs of the community, and with future upgrades the existing copper cable is capable of multi-gigabit speeds.

Municipal Retail Implications

Recently, the City Manager, Deputy City Manager and Chief Financial Officer visited several municipal-run broadband providers. The communities visited included: Wilson, NC; Chattanooga, TN; Cedar Falls, IA and Longmont, CO. The site visits allowed the attendees to openly discuss the challenges and opportunities that a municipal-owned retail ISP can have on the local community. Particular emphasis was placed on the governance of their municipal-owned broadband.

	Cedar Falls, IA	Wilson, NC	Chattanooga, TN
Start Date	1995/2013	2008	2013
Market Share	85%	40%	55%
Price – 50/100 Mbps	$58/mth	$35/mth	$60/mth
Price – 1G	$117/mth	$100/mth	$70/Mth
Households Served	12,000	8,300	84,000
1G Customers	36	100	5,000
Governance	Board of Trustees	Council Self-Executing Memo	Board of Trustees L&P CEO decision

Additional lessons learned from the site visits include:

- Broadband is complex and very different from Light & Power – business mindset, market, etc.
- Broadband is a part of the community brand and sense of place
- Broadband creates economic advantage over those without connectivity
- Each of the communities would do it again

The recent market demand study conducted by Uptown Services indicates that given a choice, the majority of respondents prefer to receive high-speed internet from the City (see graph in section IV). In addition, 78 percent of those surveyed ranked Fort Collins Utilities a 9 or 10 out of 10 in terms of satisfaction. The citizens of Fort Collins have trust and brand recognition in the City organization. There's a strong preference for the City within the mass market, both residential and SMBs.

VI. Operating Plan

The following sections highlight the basic operating components needed to successfully conduct the retail model. However, it should be noted these same components would need to be addressed regardless of the operating model.

Retail Model Summary

The retail model assumes the City builds out a fiber network across the entire city limits and ultimately across the entire GMA. The City also operates the network, provides internet and possibly offers other services to subscribers. Marketing, customer acquisition, repair and maintenance to the network, customer service representatives inside of call centers, and administrative and management oversight functions will also need to be created and managed by the City.

The City needs to issue bonds in the range of $130M to $150M to support the construction and infrastructure needed to provide these services. Critical success factors within the financial model include: 1) cost of network build, 2) take rate of the services from Fort Collins premises and 3) the price for the service. Critical operational success factors include: 1) successfully operating within a competitive environment vs. a traditional monopolistic utility environment, 2) gaining expertise and experience within a fast-changing technology business and 3) establishing appropriate governance and oversight structures that allow the broadband business to operate in a competitive market.

Critical Operational Success Factors

The City is focused on service. That will be a strong asset within a broadband launch. Staff's commitment to serving the community and reputation for providing outstanding customer service will be a considerable asset. A shift from an order-taking mindset, current utility operations don't require marketing and selling as they are the only source for citizens to acquire these services, to customer acquisition through marketing and selling will be required. Agility, nimbleness, market analysis, and closing-the-sale are essential attributes.

While the City has experience installing fiber in the ground and utilizing that fiber to monitor and maintain various systems around the city, operating and marketing a network providing retail service in competition with large corporations will require a different expertise and focus from management and staff. Technology will shift, consumer preferences will change, and the organization will need to be adaptable and responsive to these changes.

A governance structure different from the current Utility Enterprise governance will need to be established; one that provides the ability to have private discussion with City Council on matters of strategy, pricing, implementation, service plan changes, etc. All communities visited stressed the need for a governance model that is different from the traditional municipal utility given the competitive nature of the broadband market.

Operations management will be required to make timely business decisions. In order for a retail business to succeed, operational decisions must be made as needed to compete in a time-sensitive, competitive environment. These decisions may have significant material, financial, operational, or personnel impact. Higher level discussions that are less time-sensitive and more focused on overall strategy, vision, or mission can be driven by a council or a board of directors.

Capital Requirement

Capital requirements will be in the range of $130M-$150M depending on the final architecture and subscriber adoption. Capital expenses include: network construction, network start-up costs, issuance fees, capitalized bond interest, debt service, working capital, early installations, etc. The estimated range of investment accommodates some possible contingencies which could include construction cost overruns, higher than anticipated demand, and market competition factors. Other currently unplanned cost implications such as Active Ethernet installation or additional annexations thus increasing Fort Collins GMA, are not included.

The largest cost component of the capital requirement will be the network construction, currently estimated at more than $80M. Network construction amount estimates rest largely on the “passing cost” (explained below). The final passing cost used in the retail model includes a contingency to assist in managing total required capital.

Other significant network start-up related expenses of approximately $30M include: facility equipment and systems, vehicles, engineering design, working capital, and electronic equipment within the network. Bond issuance fees, capitalized interest and working capital also account for an estimated $22-$23M.

Capital Requirements	Amount
Network Construction	$80M
Bond Issuance Fees, Capitalized interest, Financing Misc	$13M
Contract Installation	$7M
Facility & Vehicles	$6M
Fiber Drop, Powering, ONTs	$6M
Fixed Equipment	$5M
Engineering, Design, Inspection	$4M
Back Office Systems and Capital	$1M
Subtotal	**$122M**
Working Capital	$10M
Contingency	$18M
Total	**$150M**

Passing Cost

Fort Collins will require more than 800 miles of fiber to reach the 62,000 premises and 8,000 commercial meters within the GMA. "Passing Cost" is a key variable in modeling the construction cost of the network and conveys the cost of installing fiber to pass each premise.

A key characteristic of Fort Collins that increases the passing cost is the fact that all fiber will need to be installed underground. Ninety-nine percent of all Fort Collins utilities are underground and, per City Code, all new installations are required to be underground as well. Compared to aerial network installations, this dramatically increases the cost of installation but would also increase reliability and reduce maintenance costs overall.

To estimate the cost of installing fiber throughout the Fort Collins network, sample neighborhoods were analyzed. Density, described as number of premises passed per mile, is a key driving variable determining the cost of network installation. Initially, seven sample design representative neighborhoods were analyzed (listed below). The "passing per mile" metric was calculated along with material and labor costs to arrive at a "Total per Passing" cost for each neighborhood. The neighborhood was then given a weight that describes the percentage of Fort Collins GMA that particular neighborhood represented. Multi-Development Units (MDU), such as apartment complexes, were analyzed separately due to their unique characteristics. MDUs were estimated at 50 percent of the average cost of a single-family home installation. The final weighted average cost per passing for Fort Collins was estimated at $855. Due to the varying nature of Fort Collins neighborhoods, the uncertainty of conduit availability, and potential issues with underground installation, a 15 percent contingency factor was added. The final modeled passing cost equated to $984/premise.

NEIGHBORHOOD SAMPLE DESIGN

Sample Design Area	UG Miles	Passings	Passings per Mile	Weight	Matl per Passing	Labor per Passing	Total per Passing
Quail Hollow	3.2	243	75	30.1%	$140	$980	$1,120
English Ranch	2.5	243	96	22.6%	$132	$781	$913
Alta Vista	0.7	63	95	6.4%	$128	$792	$920
Old Town	2.2	235	98	5.7%	$126	$699	$825
Hearthfire	2.6	174	66	2.1%	$165	$1,097	$1,262
Taft Canyon	3.8	235	62	1.8%	$170	$1,187	$1,356
Willow Brook	0.6	81	143	0.0%	$98	$530	$628
MDUs*	0.0	0	0	31.3%	$73	$424	$497
Weighted Average / Total	15.6	1,274	82	100%	$116	$739	$855
15% Contingency							$984

Outside Plant Costs	Weighted Average Per Passing
Materials	$116
Labor	$739
Total	$855
Contingency @ 15%*	$128
Total	$984

Drop Cost

Included in the total capital requirement is the "drop cost." Passing a premise does not connect the premise to the network or enable internet access; it simply means the fiber is in close proximity to the premise. The fiber connection must still go through the "drop" phase before a premise is actually connected to the network. The "drop cost" is the expense incurred to connect the fiber in the street to the premise.

There are two components to the drop cost: pre-install and premise installation. Pre-install includes trenching and installing the fiber underground on the premise property. Premise installation costs primarily consists of the equipment (ONT, power cable, connectors, etc.) needed at the premise to connect the fiber.

Total cost of a drop to a premise will average approximately $591 per premise with the highest cost variable being the contract labor component. During the five years of construction, contract labor is used to avoid the need to hire full-time employees on a long-term basis. Contract labor is needed temporarily during construction to subsidize employee labor capacity to complete pre-installs in a timely manner, and occasionally needed for premise installs during high activity periods.

Drop Components	Average Cost
Contract Labor	$295.79
ONT Expenditures	$172.57
Fiber cable, UPS, Power	$123.42
Total	$591.78

Pricing Assumptions

City retail residential pricing has been determined to be $70/month for gig service, $50/month for 50Mbps service, and $25/mo for voice (phone) service.

City Retail Model	Residential Pricing
Affordable Internet	TBD
50 Mbps Symmetrical	$50/month
1 Gbps Symmetrical	$70/month
Voice	$25/month

This pricing compares favorably to other municipal offerings around the country, as well as incumbent offerings, and accomplishes the additional benefit sought by the City, namely competitive pricing.

Comparative Municipal Offerings around the Country

Area	30 Mbps	50 Mbps	60 Mbps	100 Mbps	1 Gbps
RS Fiber - Minnesota		$50		$70	$130
Arrowhead Electric - MN	$60	$70		$100	
Reedsburg, WI				$45	$75
Sandy, Oregon					$60
Sebewaing, MI	$35	$55		$105	$160
Chatanooga, TN				$58	$70
Lafayette, LA			$53	$63	$110
Longmont, CO	$40				$50
Cedar Rapids, IA				$46	$105
Co-Mo Connect - MO					$100
Ozarks Electric - AR				$50	$80
Average	$45	$58	$53	$67	$94

Commercial service will have a full range of possibilities that includes various speeds and symmetrical options. Residential service is symmetrical by default. The range of the commercial data offering would be:

- Standard Internet Access
  - Shared capacity connection over GPON
  - No contract requirement and no Service Level Agreement (SLA) guarantees
  - Can upgrade to symmetrical bandwidth and add premium BGP Routing (some tiers)
- Dedicated Internet Access
  - Dedicated capacity via Active E connection (same ONT)
  - Requires dedicated fiber strand; practical option for pure commercial service areas
  - Contract agreement with SLA and term requirement
- High Capacity Direct Fiber Access

- Multiple connection options:
  - Direct routed connection
  - Customer CPE connection (either non-protected media converter or protected)
- Protected connection is optional
- Contract agreement with SLA and term requirement
- Resale rights may be included

- Point-to-Point (Transport Circuit): Dedicated pathway of defined capacity without access
- MAN: Customized access and transport solution for multi-site business or institution

City Commercial Download/Upload	City Commercial Price
25 Mbps/5 Mbps Add Symmetrical	$59.95/month + $10
50 Mbps/10 Mbps Add Symmetrical	$69.95/month + $30
100 Mbps/20 Mbps Add Symmetrical	$89.95/month + $50
1 Gbps/500 Mbps Add Symmetrical	$599.95/month $200

Given the wide range of commercial possibilities, the practicality of modeling each option is not feasible and produces diminishing returns with false precision. The retail model therefore focuses on the three lowest material revenue streams shown above and accounts for the majority of commercial revenue streams.

City Commercial Retail Model	City Commercial Price
25Mbps / 5Mbps	$59.95/month
50Mbps / 10Mbps	$69.95/month
100Mbps / 20Mbps	$89.95/month

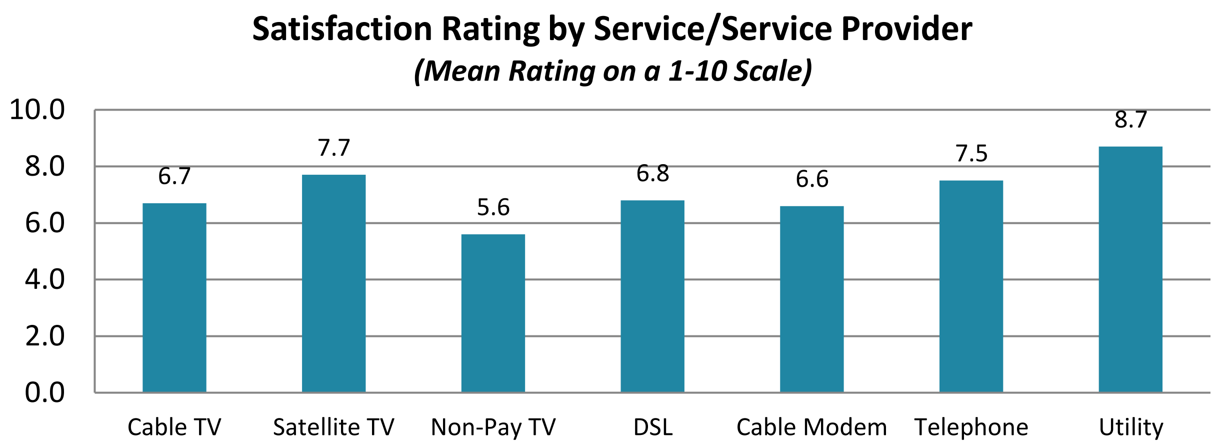
High capacity options refer to dedicated bandwidth. This type of installation requires a custom quote for both the recurring and non-recurring fees ($4,500/month for transport and access on average) and term contract (typically 3 years). Commercial custom install fee to cover unique costs per individual installation. Unlike the standard internet service offerings, the high capacity installs should be reviewed on a case-by-case basis to establish pricing.

Marketing Plan

Objectives

The objectives of the marketing and customer service strategy are to secure and maintain a minimum of 30 percent market share of all premises passed by installing one or more services per premise. The long-term goal will be to secure and maintain a 45 percent to 50 percent market share. Three distinct principles guide the product design, promotion, delivery and support:

- Provide excellent service with high quality technology
- Educate customers on how an FTTP product improves their quality of life
- Capitalize on the strengths and stability of City of Fort Collins brand and high quality customer service



The survey completed by Uptown highlighted that Fort Collins Utilities has the highest customer service satisfaction ratings among service providers. A cornerstone to the marketing and customer service strategy is positioning the image of Fort Collins Utilities as stable, reliable and efficient.

An equally important point to be communicated in the marketing message and reinforced by customer service is the strength of the fiber technology platform. It offers customers increased bandwidth, content and speed, along with more options for interactive services. Fiber has no bandwidth limitation. The fiber network architecture will provide symmetric bandwidth or equal speed for information uploads and downloads. That message will be translated by educating customers about the ways this technology will improve their daily lives. Additionally, fiber can be a platform to other technologies that could create additional opportunities for the City to provide additional services such as wireless, Smart Cities capabilities, etc.

Budget

Marketing budget (not including Marketing Coordinator) in year 1 is $150,000 or one half of a full year's budget due to operations still being in startup mode without a full-year of activity. The budget in year 2-5 budget is $300,000/annually. Year 6+ with on-going operations has a budget of 1 percent of revenue, which equates to an average of approximately $250,000 per year.

Promotion & Advertising

Brand Positioning: Fort Collins Utilities has built a solid reputation for customer service. Additionally, creating excitement as one of the first FTTP communities reinforces that the City of Fort Collins is an innovative and progressive community. For the FTTP project, it will be key to capitalize on this image and reinforce favorable brand reputation by extending its performance in offering broadband services.

Awareness Advertising: The City will implement local ads and promotions. These include print advertising, social media, sponsorships and event marketing (booths at local events).

Direct Marketing and Promotion: The direct marketing program will benefit from a community-level scale of the Utilities brand. These tactics involve targeted marketing as the network is rolled out within specific areas with specific messages and promotional offers. The objective is to get the recipient to respond with information or purchase inquiry (either online or over the phone). The most important direct marketing tactic is direct mail and door hangers, as well as other viable tactics such as bill inserts and marketing events.

Customer Service Plan

Customer Service Strategy

A key component to gaining customers, and more importantly, retaining customers is the service and support they receive. The overriding goals of customer service are to resolve customer issues with the initial call and remain accessible to customers at all times. An important marketing message can focus on the legacy of excellent customer service already provided by the City of Fort Collins.

In an effort to achieve those goals, customers will enjoy multiple points of entry to the customer service department. Representatives will be available to handle both call-in and walk-in inquires.

Additionally, the Utilities website will offer options to review product and service availability, order services, view billing statements and process bill payments.

Option 1: Customer service associates will be managed and integrated as part of the existing Utilities Customer Connection Department ("Customer Connections").

Option 2: Outsource first tier customer call center to a third party provider that runs 24-hours a day. A local presence will be a priority.

Customer Service Planning

The customer service teams' primary focus is customer satisfaction, to maintain customer trust and loyalty, to sell the customer products based on their needs and interests, and to ensure each customer values our products and services. Important performance metrics and indicators include:

- Availability – monthly availability of 99.925 percent
- Mean Time to Repair – monthly average not to exceed two hours Monday - Friday
- Customer Call Wait Time –will not exceed a monthly average of two minutes

Customer Service Staff

Customer Connections success relies on the ability to recruit, hire, train, motivate and retain a team of talented and knowledgeable professionals. Commitment to provide superior customer service is implicit in all job descriptions and it is important that all customer service representatives (CSR) share our commitment to make each customer experience value added and build a lasting customer relationship.

The team of training CSRs will respond to incoming customer calls, handle customer contact in retail locations, up-sell customers (when additional products are available), and make outbound calls to customers for follow-up. They will consider every call taken as a sales opportunity to respond to customer orders to:

- Process new sales and up-sell orders (when additional products are available)
- Process transfer service and move orders
- Process downgrade and disconnect order
- Process equipment-related orders
- Categorize and process order types
- Ask open-ended questions to determine which product offerings best suit the customer's household needs

Uptown estimated that Fort Collins Utilities would need to add four CSRs in year two of the network development and an additional two full-time equivalents (FTE) by year five.

Additionally, Customer Connections will need to hire two FTEs dedicated to Commercial Accounts.

Personnel Requirements

Position Title	Base Salary	Year 1	Year 2	Year 3	Year 4	Year 5
General Manager (GM)	$135,000	1	1	1	1	1
Data Technician	$105,000	1	2	2	2	2
Commercial Account Representative	$80,000	1	2	2	2	2
Sales Engineer	$80,000	1	1	1	1	1
Field Operations Supervisor	$80,000			1	1	1
Marketing Coordinator	$75,000	0.5	1	1	1	1
MDU Account Manager	$75,000	1	2	2	2	2
Contingency	$70,000	5	5	5	5	5
Maintenance Technicians	$65,000		1	1	2	2
Technical Service Representatives (TSR)	$60,000		4	4	5	6
Service Technicians	$60,000		1	3	4	4
Installation Technicians	$55,000		3	7	6	5
Customer Service Representatives (CSR)	$50,000		4	4	5	6
Total		10.5	27	34	37	38

The model assumes the base salary and headcount reported above plus 30 percent for benefits and 2.5 percent annual increase. Management including the General Manager, Data Technician, Commercial Account Representative, Sales Engineer, Marketing Coordinator and Multi-dwelling Unit (MDU) Account Manager will be hired in year one with growths through year three to reach steady state. Front-line hiring will start in year two. Headcount will vary during the five year build out to align with start-up activity with the following numbers representing steady state. Five contingency headcount have been added to the model to account for unforeseen issues or productivity concerns.

- 6 Customer Service Representatives - inbound/office sales, order entry and first tier support
- 6 Technical Service Representatives - second tier customer support, dispatch and service provisioning
- CSR/TSR staffed at 1 FTE per 2,000 accounts growing to 4,000 by Year 5, but with a minimum of 3 FTE for CSR/TSR to ensure phone coverage.
- 5 Install Technicians

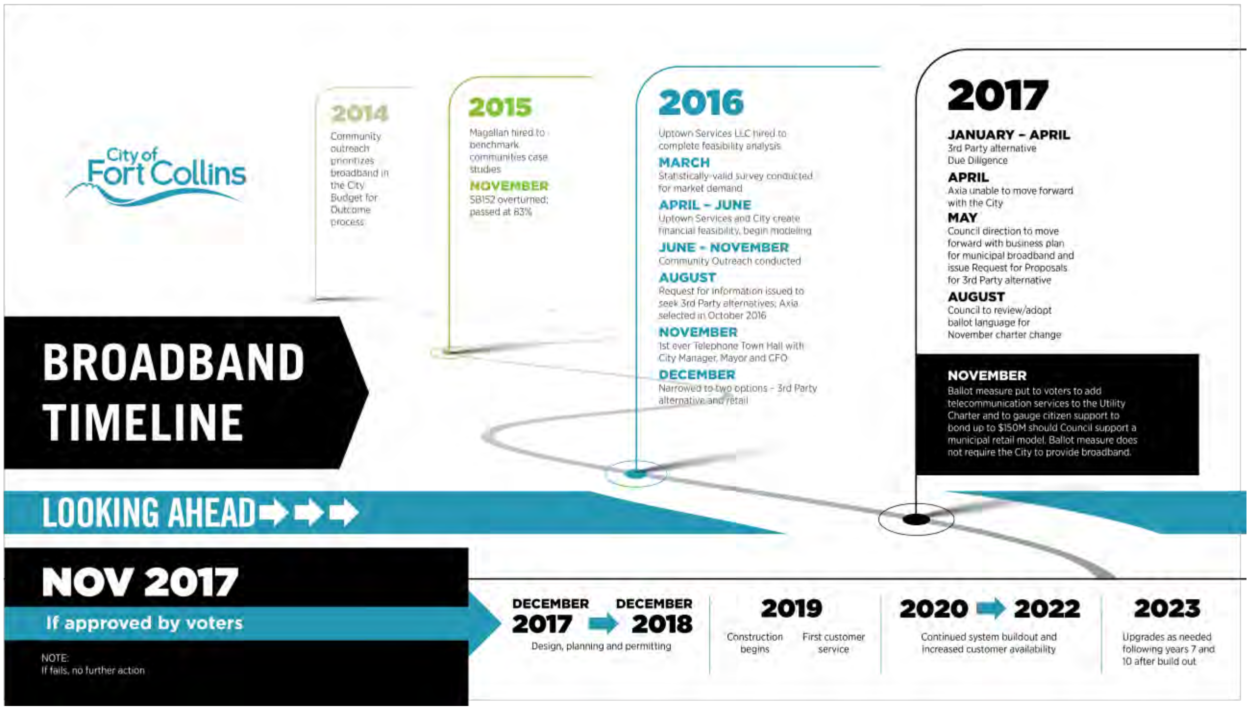
    - Installs are two-phases, with a pre-install followed by a separate premise install. All pre-installs are completed by a contractor at a fixed rate ($200) for Years 1-5, and then insourced. Premise installs are completed by internal FTE, except in Year 4 (25%) and Year 5 (50%) by a contractor at a fixed rate ($250) to maintain Install Tech headcount at long-term levels. Each Install Tech can complete three installs per day, growing to four per day by Year 5.
- 2 Maintenance Technicians – maintain fiber system from backbone to network access point, 1 per 1,000 plant miles of fiber
- 4 Service Technicians – fix subscriber problems
    - Service call volume equals 50 percent of all subscribers/year dropping to 25 percent by Year 5. Each Service Tech can complete four per day growing to 6 per day by Year 5

Compensation is based on the City's wage scale with 30% benefits assumed and 2.5 percent annual salary increases. Annual salary increases may need to be evaluated due to industry standards.

Facilities

A Broadband Office and Shop Facility will be required with approximately 17,000 square feet of both office and shop space. Financial assumptions assume a facility would be built on existing City-owned land and 2017 cost estimates are $5.6M. Leased space will be evaluated during detailed business planning. From the start of design, the time to build appropriate facilities is estimated to take 19 months, and will require interim facilities for operations during the first 1.5 years.

Milestone Timeline



VII. Network Architecture

Network Technologies Overview

Cisco's latest Virtual Networking Index shows the average North American home has seven Internet-capable devices and by the year 2020, that number will swell more than 12 devices per person in a household. This has significant implications for our broadband networks. While our appetite for bandwidth is increasing, new and evolving applications will stimulate this demand even more. A few examples are:

- 4K and 8K High Definition televisions
- Automated homes, where consumers control appliances through phones or tablets
- Fully-integrated security systems, where consumers can protect their homes through sensors and video
- Smart thermostats to reduce energy usage
- eHealth applications and other video or data intensive services
- Smart City and other Internet of Things (IOT) applications

The demand for widespread deployments of high speed broadband is accelerating. Existing service providers are at a crossroad on how to best meet this demand while leveraging existing investments and maximizing limited capital resources.

Existing service providers face different situations based on the type network they manage today and on whether they serve urban areas or more rural communities. Given fiber optic cable has virtually unlimited capacity, it forms the backbone of the Internet, cable TV networks, telephone (including cellular) networks, private business networks and even data center networks. As customers, we expect wireless access be available for convenience. Wireless access is primarily available via Wi-Fi and supplemented with cellular data plans.

The communications community generally agrees that fiber will meet the world's needs today and into the foreseeable future. The only debates involve the speed of the transition. The reason for this is simple: FTTP offers far more bandwidth, reliability, flexibility and security and a longer economic life than alternative technologies, even though its deployment price is comparable. It's less expensive to operate and maintain than copper.

Networks are composed of two parts – the transport medium and the technology that provides services or bandwidth. Copper, fiber and wireless are examples of transport mediums. Various technologies are used to provide services over these medium. Networks today are composed of at least two transport mediums and many use all three. The technology employed for services is discussed later.

Transport medium configurations:

1) Fiber to the Node/Curb (FTTN) – used by Telephone Companies (telcos)
    a) Fiber is deployed to the neighborhood outdoor telco cabinets housing VDSL2 Terminals

b) Leverages copper telephone twisted pair lines using VDSL2 and ,in the future, G.fast

2) Hybrid Fiber Coax (HFC) – Used by cable companies
   a) Fiber is deployed to a node in a neighborhood
   b) Coax (copper) cable is used from the node to the home or business.
   c) The number of amplifiers and other devices required is dependent on distance and condition of the copper
   d) Uses Data Over Cable Service Interface Specification, or DOCSIS
   e) Bandwidth is shared at the node

3) Fiber to the Premise (FTTP) – Used by all types of service providers, mostly in greenfield applications. Fiber is deployed all the way to the premise

4) Wireless - almost a customer expectation
   a) Uses radio frequencies to carry data
   b) Limited by distance, electrical and radio interference
   c) There is an inverse relationship between the radio frequency used and the ability to penetrate physical objects (including leaves and moisture in the air) and the amount of data-carrying capacity

Fiber optic cable is made up of strands of hair-thin glass that carry information by transmitting pulses of light. The pulses are turned on and off very quickly. A single fiber can carry multiple streams of information at the same time over different wavelengths, or colors of light. Fiber has many advantages over copper wire or coaxial cable. It can transmit high bandwidth over long distances, it is rugged and weather proof, resistant to electrical and radio interference, and requires lower operating expenditures.

Copper cable, by contrast, carries low voltage electrical signals. Distance and state of the physical plant greatly impact copper's ability to transmit data. It can support high bandwidth for short distances. The longer a signal travels on copper, the lower the bandwidth. Distance isn't the only constraint for copper. Copper plants are subject to interference from electrical and radio sources. This interference can quickly degrade the Signal to Noise ratio. These limitations as well as the active nature require a very skilled technical staff and power to run the devices through the power distribution. These are just a few of the factors that drive a higher operating expense as compared to fiber.

The above is also true for wireless networks. Tweaking more bandwidth from either wireless or copper plants becomes increasingly difficult and expensive as time goes on. This isn't true of optical fiber, whose capacity is effectively unlimited.

As mentioned above, there are different technologies used to deliver services to bandwidth over the communications networks.

Fiber Technologies

Fiber technologies used for a Fiber-to-the-Premise (FTTP) deployment are lumped into one of two categories: Active or Passive. The primary differences are whether active devices are used in the distribution network and effective distance to a customer. Active systems have powered devices in the field and can drive a signal for longer distances. The power requirements and operating expense is less for an active system than a copper plant. Active systems are used primarily in more dense applications such as corporate networks, campus environments or data centers.

Most operators are deploying passive systems known as Passive Optical Networks (PON). A PON system has an Optical Line Terminal (OLT) as an originating point, usually in a central office. The terminating point is an Optical Network Terminal (ONT), which is located at the customers premise. Passive splitters, based on customer density, are placed in the network between the OTL and ONT. The passive splitter is usually a 1:32 split and reduces fiber required in the networks.

Most of us have heard of the Verizon FIOS and Google Fiber networks, but all of the large telcos and cable operators have deployed PON networks for some of their footprint. Cable operators are leaning toward an Ethernet PON (EPON) system as it is has a migration path that uses the existing DOCSIS element management systems. Gigabit PON (GPON) is being deployed by most other providers. Currently GPON provides higher bandwidth options but EPON is moving quickly toward higher bandwidth options.

GPON is an ITU standard (G.984) that delivers 2.5 gigabits downstream and 1.25 gigabits upstream using multiple Layer 2 networks giving the ability to separately transport services. Standard distance is 20 km with an option to use long range optics extending the reach to 40 or 60 km, and can use a split ratio of up to 128 customers. Most deployments use a 1:32 customer split. Lower splits can increase range.

NG-PON2 is ITU standard and the next evolutionary phase of GPON. It provides for 10 gigabits symmetrical with fixed optics and allows for 40 gigabits using tunable optics. It is currently being deployed primarily with fixed optics. Most equipment sold today is available with an option to upgrade to the new standard.

EPON is an IEEE standard (IEEE802.ah) that delivers 1 gigabit symmetrical bandwidth using a single Layer 2 network to transport all services. An amendment, IEEE 802.3av, provides for 10 gigabits down and 1 gigabit up. Most deployments use a 1:32 split. No upper range is defined.

Copper Technologies

As mentioned earlier, copper and wireless transport medium are subject to many of the same limitations: distance, electric and radio interface, signal cross talk, etc. As such, the technical solutions leverage many of the same features including vectoring, Forward Error Correction, Signal to Noise improvements, etc. They are pulling out every trick in the book to wring out as much bandwidth as possible from these networks. This requires the physical plants be well maintained and continually swept, and requires a very accomplished technical staff to run, thus driving higher operating cost.

Cable plants or HFC plants use DOCSIS for providing bandwidth or services. The most widely deployed generation of DOCSIS technology, known as 3.0, is capable of providing a gigabit per second (Gbps) of broadband capacity downstream and 100 Megabit per second (Mbps) upstream. The newest generation of DOCSIS broadband, known as 3.1, provides a near-term path toward continued improvement of cable broadband performance, with network capacity up to 10 gigabits per second downstream and 1 Gbps upstream. These are asymmetrical products and share this bandwidth across a node. Bandwidth available is determined by number of free channels available for bonding. Each channel can provide roughly 38 Mbps of throughput for DOCSIS 3.0 and between 50 Mbps and 63 Mbps for DOCSIS 3.1.

CableLabs is working on a technology that will enable fully symmetrical speeds, bringing upstream capacity on par with the 10 gigabit per second downstream capacity of DOCSIS 3.1 broadband. This is known as Full Duplex DOCSIS 3.1.

One of the main changes to DOCSIS 3.1 is orthogonal frequency domain multiplexing (OFDM). OFDM makes quantum leaps in the amount of data capacity and speed available – sometimes as much as 50 percent more capacity over the same spectrum. Where DOCSIS 3.0 was able to achieve 6.3 max bits/Hz, DOCSIS 3.1 is able to achieve 10.5 max bit/Hz at 4096 QAM. In a more typical situation where multiple QAMs are being used at the same time, DOCSIS 3.1 is still able to achieve 8.5 bits/Hz, making it 35 percent more efficient.

Most cable plants run over 870 MHz of available spectrum. This is broken down into 6 MHz channels. Several of these are reserved leaving about 132 useable channels. These channels provide both video and data. Different channels must be dedicated for upstream and downstream bandwidth. This is one reason for the asymmetrical nature of DOCSIS. Due to new video compression technologies, you can get about three High Definition video channels per 6 MHz channel. Given cable companies are deploying hundreds of channels, you can see why they are struggling to provide the high speeds customer are expecting. With DOCSIS 3.0, 1 gig of bandwidth uses roughly 27 channels of capacity for the downstream path alone. That is why most systems provide speeds significantly less than 1 Gbps. DOCSIS 3.1 provides for 35 to 50 percent higher data throughput per channel, but even this isn’t enough to meet future needs. Therefore, DOCSIS 3.1 also does away with the 6 MHz channel size and allows for sub-carrier bonding to more efficiently use of the available spectrum. But in order to maximize bandwidth throughput, the coax loops must be shortened, with amplifiers and other devices removed. This helps mitigate two of the limitations of a copper plant: distance and interference.

For fiber-to-the-node (FTTN) deployments, the most prevalent technology is a version of DSL – VDSL2. This is ITU standard G.933.2. As this is a copper technology, it is subject to the same issues as coax and wireless. The bandwidth provided is very limited to between 50 and 100 Mbps. To maximize the bandwidth available, the distance sweet spot is between 500 and 1000 feet.

A new standard, G.fast, under ideal conditions and with vectoring (crosstalk cancellation) and bonding (simultaneous use of more than one pair of copper wires), can provide 500 Mbps symmetrical bandwidth up to 300 feet from a fiber node. G.fast may prove to be an excellent solution for retrofitting apartment buildings with fiber to the basement (as long as those buildings already have good internal copper wiring), but it requires bringing fiber very close to customer premises and is still limited in comparison with true fiber to the home. Using the 2.4 spectrum provides lower bandwidth but a greater distance. Conversely the 5GHz spectrum provides higher data throughput with limited distances.

Wireless Technologies

The two most widely deployed wireless technologies are Wi-Fi and 4G cellular. Wi-Fi is an IEEE standard- 802.11. The most current version is 802.11a wave 2. It uses both the 2.4 and 5 GHz unlicensed spectrum. This is the technology that most of us have in our home and are very familiar with the user experience obstacles such as: distances are very limited, cross talk is rampant and internal walls and other obstructions are a real problem. The primary methodology to drive higher bandwidth is through the utilization of more antennas and bonding the antennas. Unfortunately, while routers are making good progress on this front, very few end devices (PCs, laptops, tablets, etc.) are leveraging the multiple antenna bond feature.

The cellular industry has deployed its fourth generation network known as 4G or LTE. The original specification was for 100 Mbps, with the latest versions supporting up to 1Gbps shared across the entire cell site which is the potential bandwidth shared by all users connected to a cellular antenna. Therefore, a wireless user might get high speeds for a moment or two, if no one else is around. Cell sites vary in size generally covering around five or six miles. Unfortunately, bandwidth drops off very quickly. To illustrate, if you move a quarter of the way from the cell tower to the edge of the cell service area, you can see a 50 percent drop off in bandwidth. Most cell sites utilize fiber backhaul with a target of 300 Mbps of backhaul capacity.

Large companies and the media are already hyping “5G,” despite the fact that we are years away from a 5G standard and nobody actually knows how fast 5G will be. Today, 5G is primarily a marketing term, and often a misleading one. When the average person hears “5G,” they most likely assume it means that gigabit cell phones are around the corner. “5G” today is being used to describe not only the upcoming 5G standard but also for small cell 4G technology being used to fill gaps or relieve congestion, in existing 4G cell sites. It also often confused with wireless connections using millimeter wave spectrum for point-to-point connections.

5G technology will utilize spectrum bands that are higher in frequency than has been typical for mobile services to date. Higher-range frequencies offer the potential of greater bandwidth for improved network capacity, but they do so while limiting effective distance. These characteristics lead to a fiber deep, small cell approach, as the most likely deployment for 5G. These 5G sites will cover hundreds of feet, instead of miles, as in today's 4G deployments. This makes for an excellent urban deployment, but in rural areas where customer concentration is less, this can be an issue. Thus it is highly unlikely 5G will replace 4G for coverage "out of town," and thus will not be a solution for the "digital divide" affecting those areas.

To be clear, in the short run, there may be situations in which the use of 5G connections with fixed wireless backhaul may enable service to certain locations. These locations may be so remote that they are unlikely to ever receive wireline service, and therefore 5G may make sense.

When compared to a 5G network that can deliver significant bandwidth using very high, very short-haul frequencies, FTTP is often less expensive and will have lower operational costs. This is particularly true when one considers how much fiber deployment will be needed to enable 5G.

Implications

All broadband providers today, wired and wireless alike, realize the way to increase broadband capability is to increase the amount of fiber in their network. Landline providers are replacing their copper cable with fiber, cable operators are replacing their coax cable with fiber, and even wireless providers are actually replacing their wireless networks with fiber by placing their towers, or small cells, closer to the customer.

On the other hand, point-to-point wireless links, typically using so-called "millimeter wave" antennas, can be very useful to extend a fiber network to serve a specific neighborhood or building. This type of wireless is not cellular as each user gets much of the total bandwidth potential of the transmission link. Once bandwidth needs require an upgrade to fiber, the wireless link can often remain in place as a backup.

Wireless services are important public amenities, but they are not substitutes or replacements for FTTP. Rather, they complement and extend existing fixed-fiber networks. Many wireless access points and cell sites are already fiber-connected, and the majority of them will be soon. Wireless service can thus be considered an application on a fiber network rather than a separate type of network.

For a cost comparison consider a standard city block. A rule of thumb for the cost of a fiber drop is typically $5 per foot (for buried or aerial). If you use an average fiber drop length in a town environment of 160 feet, the cost is typically $800 per customer. Therefore, the cost to install fiber drops to all 8-12 customers on a city block would range from $6,000 to $10,000. A small tower and 5G cell site would cost $30,000-$50,000. The cell site would also require commercial power and batteries if the wireless network were expected to work during a power outage. For 5G wireless, it appears that the customer premise electronics are at least as much as the FTTP electronics, and likely more expensive. The drop cost for the FTTP network is likely 25 percent of the cost of the 5G wireless drop. Also, considering that the FTTP network can deliver more than 100 times the speed and capacity of the 5G wireless network, it appears that the FTTP is a considerably better value if fixed broadband is the goal with the assumptions above.

As mentioned earlier, the communications community generally agrees that fiber will meet the world's needs today and into the foreseeable future with the only debate involving the speed of the transition.

Net Neutrality

Net Neutrality or Open Internet means there are no restrictions of any kind on access to content on the Web, no limit on downloads and uploads, or no restrictions on delivery methods or providers(email, Video, Skype, Netflix, Chat, etc.). The key principle is access to the internet is not blocked, slowed down, or sped up depending on who or where that access occurs. In essence, Net Neutrality means the internet is open to everyone. Internet providers should not be allowed to charge different companies more or less for their data or to slow down, or block, access to Web sites and services they do not like.

Advocates for an Open Internet believe neutrality has been a core democratizing principle of the Internet since the day it was born. They also believe the Internet is similar to subways, buses, telephone companies, etc., which cannot discriminate, restrict, or differentiate access. Many Fiber providers are embracing Net Neutrality as a market differentiator. Their premise is the fiber networks are not bandwidth constrained as many competitors' networks are so why limit usage. This is a potential market differentiator for the City.

Privacy

The City is fully committed to protecting Personally Identifiable Information (PII) and Customer Privacy (CP) in accordance with applicable law. PII is information about a person that is readily identifiable to that specific individual. Personal information includes such things as an individual's name, address, phone number or email address. Some activities related to CP are website browsing, specific Internet usage history, email, phone records, video viewing habits or other electronic data generated using broadband and other communication services.

As a provider of utility services, the City is sensitive to customers concern for the protection of PII and Customer Privacy. As such, there are policies and procedures are in place that restrict the access and use of utility customers' information. The City will review existing policies and laws related to broadband services to find the appropriate balance between customer's expectation for privacy and applicable state and federal laws. Protecting customer's privacy can be a market differentiator for the City.

A few of the laws or regulation related to PII and CP communications companies are required to include:

1. Colorado Open Records Act (CORA)
2. Electronic Communications Privacy Act
3. The Communications Assistance for Law Enforcement Act (CALEA)
4. Cable Act 1984
5. Consumer Protection Act 1992
6. Telecommunications Act 1996

The City will provide the protection of PII and CP while complying with lawful request, warrants or subpoenas routed to the appropriate, designated city office.

The level of Fort Collin's access and control of Personally Identifiable Information and Customer Privacy will be determined by the business model deployed. The city will work with potential third party vendors to preserve customer's privacy.

Security

Establishing and maintaining a secure computing environment is challenging as networks are increasingly interconnected and data flows ever more freely. Therefore, it is critical the design, implementation and day-to-day practices of the entire operating environment integrate appropriate security measures. Detailed security measures are dependent on the business model, core network equipment, access network equipment, operating systems and services provided.

Developing security strategies that can protect all parts of a complicated network while having a limited effect on ease of use and performance is one of the most important and difficult tasks related to network design. The City will work with third parties and vendors to achieve a reliable and secure network. For each part of the network, the security mechanisms required will focus on but not be limited to the following:

1. Access control
2. Authentication
3. Network Flows/Firewalls
4. Service Design
5. Denial of service controls (Anti-Spoofing Filters)
6. Privacy for users (Split Horizon)

7. Physical security
8. Auditing and monitoring

The design philosophy is to block everything and then allow access as warranted. Firewalls will protect security zones/regions. Up to date, documented network flows and Access Control List (ACL) are required. Service design will segment and restrict the potential for cross talk. Services will be removed when no longer needed. Required during implementation is network validation and testing against the network design.

The system will be monitored to ensure proper operation and to verify the functioning of applicable security features. This includes monitoring access, insuring all security patches are applied, verifying required services are configured securely and no passwords are left set to the factory defaults. All failed login attempts and ACL violations will be alerted. The monitoring and removal of inactive services is required. Denial of Service (DDOS) attacks are increasing. The design will address this risk and at a minimum provide monitoring and the ability to black hole the offending traffic

While the network architecture is a key component of a secure network, physical security of the network equipment maybe the biggest risk. To mitigate this risk, facility security and access to the equipment will be addressed. Best practices for secured, hardened sites include monitored access controls, monitored environmental controls, diverse, redundant power and internet access. Equipment in the field must be also be secured and monitored.

Assessing the risk to the network is ongoing effort and not just limited to deployment. Building a team that can identify common vulnerabilities and threats, and develop mitigation strategies in a responsive manner is a key success factor.

Other security related topics such as anti-virus, parental controls, privacy, encryption and data integrity are not discussed here, as these are primarily associated with applications and end users or customer systems. These security risks are a market opportunity to provide additional services to customers.

City of Fort Collins Assets

Fiber Inventory Assessment

- Fiber Network Characteristics
  - 144 fiber cable routed throughout the City in conduit
  - 112 fibers in use; 32 fibers "available"
- Network Users
  - City Departments – Traffic, IT, Utilities (electric and water)
  - Third-party governmental entities – CSU, Larimer County, Schools
  - Private sector dark fiber leases – Level 3, FRII, i-cubed, "Yipes"
- Fiber capacity

  - 32 fibers are likely not available throughout the network
  - City should reserve at least one spare buffer tube for maintenance
  - Capacity could be characterized as “scarce”
- Applicability to Future Broadband Efforts
  - Backbone – could be used to connect network hub sites
  - Feeder – not sufficient capacity to provide capacity beyond hub sites

Underground Infrastructure

- Significant Fiber Conduit in place
  - Available maps show pervasive deployment of two-inch conduit
  - Feeder – not sufficient capacity to provide capacity beyond hub sites
- Applicability to broadband effort
  - Additional microducts can be blown in with existing fiber cable
  - Spare conduit could support multiple fiber and/or microducts
  - Reduces feeder network construction requirements
  - Limits costly hard surface construction and new railroad crossings
  - Not appropriate for distribution network
- Implications of joint use with Electric Utility
  - Electric staff desires to route around structures with energized facilities
  - Would require creating path around manholes
  - Would avoid safety issues with non-qualified personnel
  - Would limit fiber damage in case of fire or explosion in manhole
  - Budget affected with creation of alternate paths

Other Assets

- Substations
  - Substation not equipped to handle telecom equipment
  - Most substations do have space for new telecom hut (~8’ x 12’)
  - Fiber conduit would need to be routed to new hut
- Existing Fiber Network Equipment
  - Existing City network does not appear useful for FTTP
  - IT Department would prefer to be a customer of network
  - CSU Manages the Fort Collins network
  - No overlap beyond the use of 12-24 fibers for backbone systems
- Tropos Wireless Network
  - System currently used for meter reading only – not wi-fi
  - Sized for collection of meter reading data – 10 routers per square mile
  - Consumer broadband would require 5x – 7x number of routers (>$5M)
  - Tropos 7320 routers do not support 802.11ac (limited to 802.11n)
  - Expanding Tropos system for broadband = expensive distraction that cannot perform at the same level as FTTP

GPON in Model

Gigabit Passive Optical Network (GPON)

- 2 backbone providers
- 2.4G downstream, 1.2G upstream
- Single fiber delivery to subscriber optical network terminal (ONT)
- Majority of FTTP deployments have been GPON
- In GPON 1:32 @ 50%, utilization is 10-15% of 2.4Gbps available
- Consumption tied to subscriber behavior not their provisioned bandwidth on fiber (high breakage on 1Gig service)

Network Electronics
GPON cards and ports = $50 per subscriber

Outside Plant Materials
GPON splitters = $15 more per passing

Technical Services
GPON splitters require four splices / eight passings = $20 per passing

Outside World – Content
Two physically diverse Internet backbone connections desired

GPON and Active Ethernet Summary

GPON – Low Cost and Flexible

- 2.5G of shared downstream bandwidth
- Flexible splitter placement and less demand for fiber strands
- High port density – 5210 subs in one chassis (10 rank units)
- Consumes less space in rack and 33 percent as much power required
- Supports path to 10G GPON

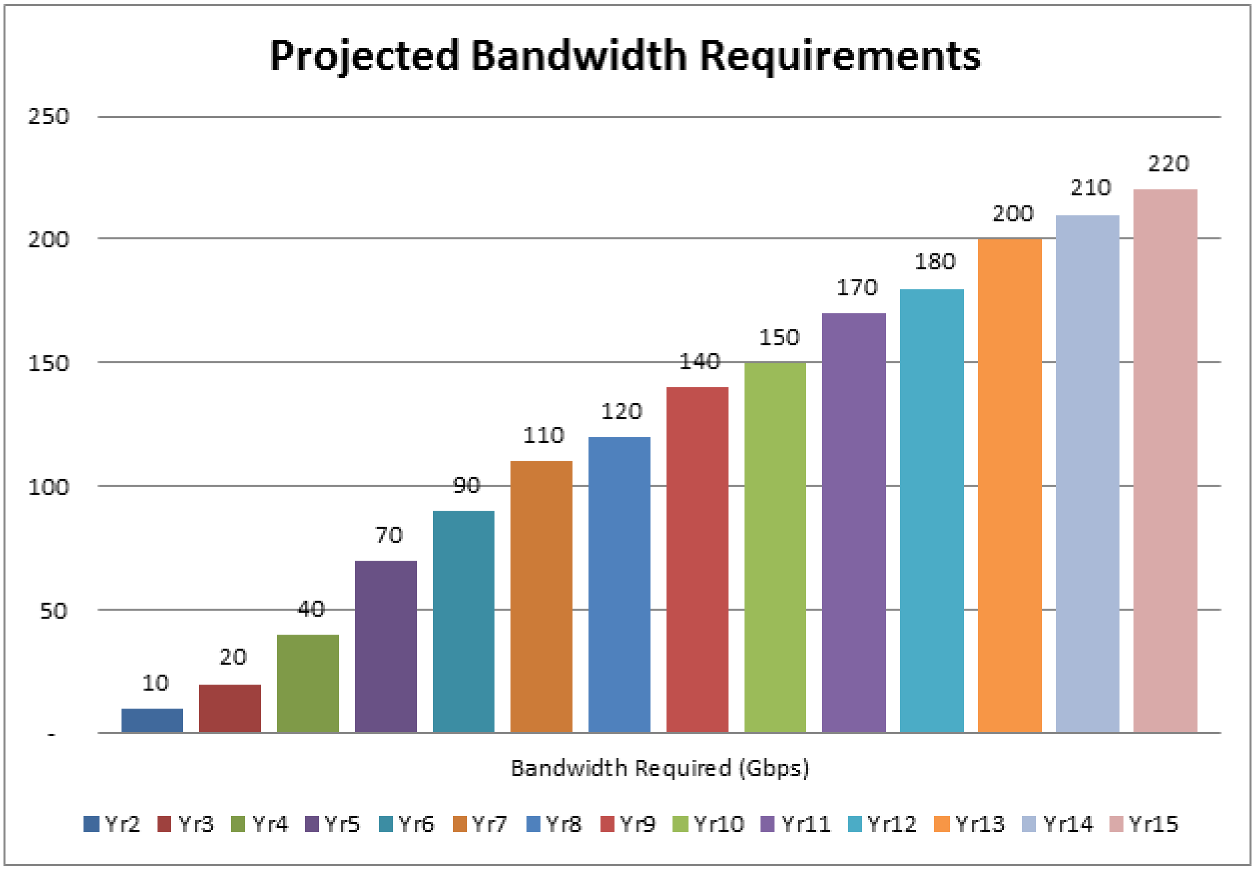
Active Ethernet – Futureproof

- Dedicated GigE from serving switch to each subscriber
- One strand from subscriber to serving switch location
- Better suited for high capacity transport services
- Longer reach – 60 km
- Extreme fiber strand counts required without active field cabinets
- Requires more fiber, space, power, cabinets, electronics and capital

VIII. Financial Model

Base Case Assumptions

- Majority of network will be GPON deployment
- Costs based on similar municipal FTTP deployments
  - o Headcount
  - o Contractor costs
  - o Equipment
  - o Construction labor bids
  - o Software proposals
  - o CLEC partner terms
- Assumes Comcast deployment of DOCSIS3.1 at $70 price point for gig services and resulting impact on take rate
- Capital budget is based on sample design calculated “passing cost” plus 15 percent contingency $984/premise (see section VI Passing Cost)
- Debt interest rates 4 percent Series A and 5 percent Series B include 75 basis point contingency
- Total Premises Assumed:
  - o Residential: 62,000
  - o Commercial: 8,000
  - o High Capacity: 400
- Take Rate: (see section IV Subscribership)
  - o Residential Internet: 28.2 percent
  - o Commercial Internet: 45 percent
  - o Voice: 8.4% high point in year 4 (0.3 percent erosion assumed yearly post year 4)
- Pricing (see section VI Pricing Assumptions)
  - o Residential $70/month for 1Gbps, $50/month for 50Mbps
  - o Affordable Internet tier to be determined
  - o Commercial & High Capacity various options starting at $59.95/month for 25Mbps/5Mbps asymmetrical, up to custom dedicated symmetrical gig speed bandwidth
- Personnel at 38 headcount in year 5 with 30% benefits and 2.5 percent annual increase (see section VI Personnel Requirements)
- Total bandwidth requirements are a function of take rate and data demand. Total demand grows with subscribership and bandwidth usage per subscriber. – please see following graph



Construction Phase Years 1-5

Funding

Base case modeling shows $130-150M will be needed (exact amount depends on contingency) to fund the operations, construction costs of the new network, capitalized interest, issuance costs, and other expenses associated with the new start up. A substantial portion of the funding will be in the form of bonds. The bonds will be issued in the form of an A Series and B Series at the beginning of the project. Series A is anticipated to be tax exempt at 4 percent and Series B non-tax exempt at 5 percent.

	Amount	Interest Rate	Issuance	Tax
Series A	$64M	4%	Year 1	Tax Exempt
Series B	$58M	5%	Year 1	Taxable

Due to interest rate risk and possible delay in timing, the Series A is estimated at 4 percent (per guidance from finance council which includes 75 basis pts contingency) with Series B estimated at 1 percent more than the Series A to account for the taxability of the bond. Series A will be primarily used in the first 3 years to fund construction costs. Due to taxability of Series B, it can be used to fund working capital and operational needs, and additional construction beyond the 3 year time window. Total bond amount also includes issuance fees of 2 percent and 2 years of capitalized interest.

Debt Service	Year1	Year2	Year3	Year4	Year5	Year10	Year15
Bond Issuance Cost	($2,439,533)	$0	$0	$0	$0	$0	$0
Bond Series 1 Interest	($2,566,000)	($2,566,000)	($2,566,000)	($2,395,227)	($2,217,624)	($1,217,186)	$0
Bond Series 2 Interest	($2,891,332)	($2,891,332)	($2,891,332)	($2,891,332)	($2,709,683)	($1,655,770)	($310,682)
Short Term Interest	$0	$0	$0	$0	$0	($107,650)	($2,557)
Short Term Loan Principal Payment	$0	$0	$0	$0	$0	($2,012,310)	$0
Bond Principal Payment - Series 1	$0	$0	$0	($4,269,322)	($4,440,095)	($5,402,055)	($6,572,426)
Bond Principal Payment - Series 2	$0	$0	$0	$0	($3,632,982)	($4,636,708)	($5,917,745)
Total	**($7,896,865)**	**($5,457,332)**	**($5,457,332)**	**($9,555,882)**	**($13,000,384)**	**($15,031,679)**	**($12,803,410)**

Short term debt of approximately $10M (without contingency) is also assumed to be needed for non-capital expenditures and working capital provided that the City does not fund via other sources. The assumed short term interest rate is 5.0 percent and withdrawals are estimated to be taken as needed in the first 5 years. Short term debt will be paid back by fiber utility cash flows starting in year 6.

Total debt amounts in excess of the $122M in bonds and $10M in short term debt have been discussed to account for unforeseen risk, possible construction overruns, higher than anticipated demand, and general uncertainty. The contingency amount is estimated at approximately 10%-15% for a total of $130M-$150M.

Expenses Year 1

Capital Expenditures	Year1	Year2	Year3	Year4	Year5
Network Construction	$0	$19,857,262	$20,254,819	$20,661,335	$19,211,856
Contract Installation	$0	$438,171	$1,137,085	$1,971,454	$3,085,613
Facility & Vehicles	$5,600,000	$335,400	$360,908	$95,509	$0
Fiber Drop, Powering, ONTs	$0	$601,550	$1,495,156	$1,872,583	$2,307,130
Fixed Equipment	$967,500	$878,663	$896,246	$914,225	$932,612
Engineering, Design, Inspection	$2,713,442	$250,217	$251,233	$252,273	$278,337
Back Office Systems and Capital	$790,000	$240,000	$24,000	$24,000	$24,000
Total	**$10,070,942**	**$22,601,263**	**$24,419,448**	**$25,791,379**	**$25,839,547**
				Cumulative Total	**$108,722,580**

Construction expense will focus on priority start-up costs such as:

1) $5.6M Facility – 17,300 square-feet (sf) building with 8,800 sf office space and 9,500 sf shop

2) $2.7M Engineering - Network Design, backbone services and GPS mapping

3) $968K Fixed Network Equipment – Backbone electronics, core head end switch/router, test equipment, internet services back office platforms

4) $790K Back Office Systems, Other Capital – Broadband billing system, network and fiber management systems

Expenses Year 2 - 5

1) Construction begins on the network in year two and finishes in year five with a total cost of $80M. Cost is a combination of plant miles installed (200 miles per year x $4000 per mile) and passing cost of $984 per meter and passing approximately 18,000 meters per year.

2) Network related fixed equipment and capital of approximately $9.9M total in years 2-5 includes ONTs and fiber drop materials.

3) Contract installation costs of $6.6M. Third party installers are hired on a temporary basis to assist with the surge of installs in years 2-5. Estimated at a flat rate of $200 per pre-install, and $250 per premise install.

4) $800K installation and service vehicles purchased include; service vans, bucket trucks and heavy service install rigs. Vehicles are replaced on a 6 year cycle and purchases begin in year two with ramp up costs continuing in years three and four.

Revenue

	Year1	Year2	Year3	Year4	Year5
Active Residential Premises	0	1,982	6,655	12,069	18,014
Total Revenue	**$0**	**$916,653**	**$4,879,311**	**$10,888,757**	**$18,211,765**

Year two is the first year of subscriber revenue. Although by the end of year 2 roughly 25 percent of the network has been installed, not all of those initial subscribers have received service for the full year, and therefore cannot account for a full year of revenue. Network installation will continue at 25 percent per year through year 5, and estimated number of subscribers will increase by approximately 5000 per year through year 4 and another 6000 in year five.

	Year1	Year2	Year3	Year4	Year5
Residential Internet	$0	$609,243	$3,193,006	$6,938,680	$11,176,790
Commercial Internet	$0	$69,093	$426,334	$1,091,238	$2,228,246
High Capacity Services	$0	$78,629	$435,359	$1,094,400	$2,099,183
Total	**$0**	**$756,966**	**$4,054,699**	**$9,124,318**	**$15,504,219**

Approximately 55 percent of revenue will be generated by active residential internet premises. The number of homes passed per year increases by approximately 15,000/year from years 2-5. Subscriber take rate is estimated at 28.2 percent with the number of eligible premise passings growing conservatively at 0.8 percent in years 2-5 and then 0.4 percent in years 6-15. It is estimated 56 percent of residential subscribers will choose the 50Mbps option at $50 per month and roughly 44 percent the 1Gbps option at $70 per month.

Approximately 30 percent of revenue will come from commercial and high-capacity internet services split evenly between the two groups. Ramp up will be delayed in comparison to the residential segment per survey data and Uptown experience. It is generally known that commercial business tends to adopt slower, but ultimately the take rate will be higher. Commercial revenue derived from 45 percent take rate of approximately 8,000 premises assumed. Uptown experience has shown that the bulk of commercial subscribers take advantage of the lowest two tiers of service. The high-capacity market is highly varied and conservatively modeled at five percent of commercial premises.

The remaining 15 percent of revenue is provided by residential and commercial phone service penetration of 8.4 percent. Phone revenue decreases both in amount and in proportion to the internet services revenue over time. Residential phone pricing is $25 per month. Commercial phone pricing is $14 per line per month.

Operations Phase Years 6+

	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Revenue										
Total	$22,783,408	$23,777,179	$24,703,513	$25,202,613	$25,383,653	$25,548,804	$25,697,621	$25,848,046	$26,000,098	$26,153,798
Operating Expenses										
Total Operating Expense	$4,826,271	$4,874,048	$5,217,769	$5,431,482	$5,305,943	$5,617,558	$5,817,263	$5,695,110	$5,977,152	$6,165,445
SG&A										
Total SG&A	$1,055,856	$1,084,269	$1,112,355	$1,136,518	$1,157,853	$1,177,155	$1,196,501	$1,216,064	$1,235,838	$1,255,816
Total Expense	$5,882,128	$5,958,318	$6,330,124	$6,567,999	$6,463,795	$6,794,714	$7,013,765	$6,911,174	$7,212,990	$7,421,261
Operating Income	$16,901,280	$17,818,862	$18,373,390	$18,634,613	$18,919,857	$18,754,090	$18,683,857	$18,936,872	$18,787,108	$18,732,537
Operating Margin	74%	75%	74%	74%	75%	73%	73%	73%	72%	72%

Total revenue past year five will range between $23M to $26M per year with conservative growth estimated to level out at 0.6 percent for total revenue. All revenue streams are expected to experience moderate population growth impacts except voice service which will erode over the same time period.

Expenses during operations will range from $6M in year 5 to $7.4M in year 15. Three main drivers of the operational expense are; overhead staffing at approximately 50 percent of expenses, internet backbone expenses at 22 percent of expense, and marketing/customer service at 18 percent of expenses.

Operating margin fluctuates between 70 to 75 percent in years 5-15, but remains healthy. Operating income is therefore between $17 to 19M per year and is capable of servicing the debt payments that are expected to reach a maximum of $15M.

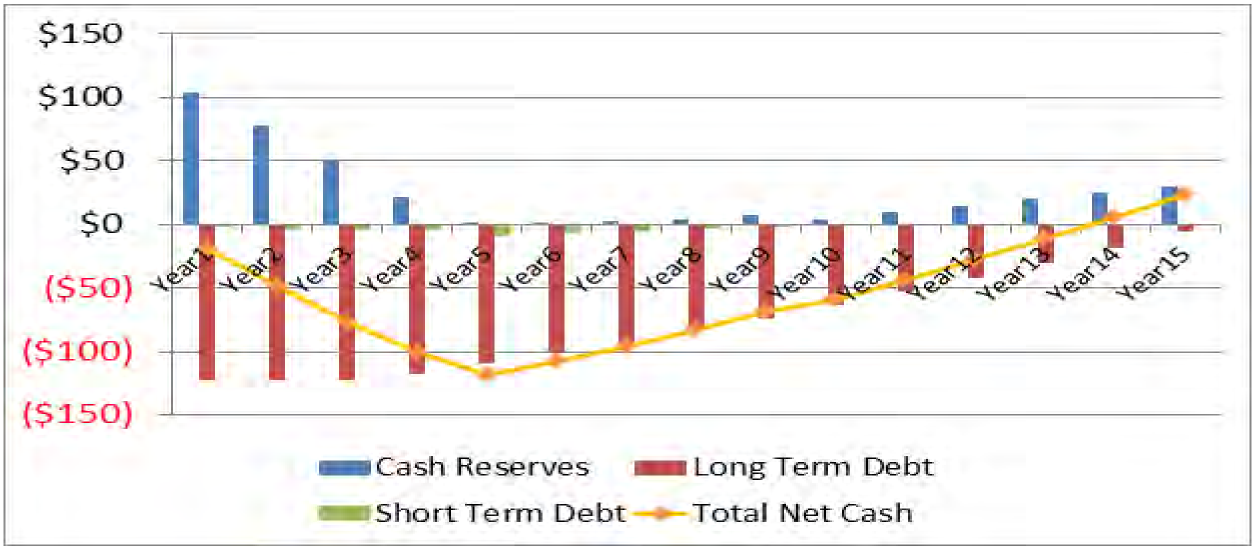
	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Total Capital	$644,553	$1,521,603	$941,828	$937,307	$6,294,844	$611,662	$608,719	$605,751	$952,031	$955,997

Capital expenditures will continue past the construction phase. Subscriber churn will force continued investment in drop fiber, power and install equipment. Gradual growth and changes in GMA will also require marginal continued construction cost in the operational phase years. While most revenue and expense items are conservatively forecasted with moderate growth assumptions and fairly steady estimates in years 6-15, capital refresh is the exception with periodic vehicle replacement needed, a $1M ONT technology upgrade anticipated in year 7, and an electronics refresh of $6M expected in year 10.

Net Cash

	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Total Net Cash	($109,078,481)	($97,606,777)	($84,492,360)	($70,550,920)	($61,084,938)	($45,684,709)	($29,766,588)	($12,984,210)	$3,941,006	$21,463,362

Net Cash is the metric by which Uptown evaluates success of broadband initiatives. It is a form of payback metric that expresses the year that operations of the network has generated enough funds to pay off all the debt (although the network may choose not to pay off the debt at that time for any number of reasons). The general rule to follow is a network is successful if it is able to pay off all debt incurred by year 15, with the earlier payoff the better. The City retail model currently is expected to hit this milestone in year 14 with $3.9M net positive cash flow. This is not to be confused with operational cash flow as the network generates positive operational cash flow (operations revenue exceeds expenses) as early as year 3, however, that excess cash is mostly consumed by debt service until the bond balance has been paid.


$150
$100
$50
$0
($50)
($100)
($150)
Year1
Year2
Year3
Year4
Year5
Year6
Year7
Year8
Year9
Year10
Year11
Year12
Year13
Year14
Year15
Cash Reserves
Long Term Debt
Short Term Debt
Total Net Cash

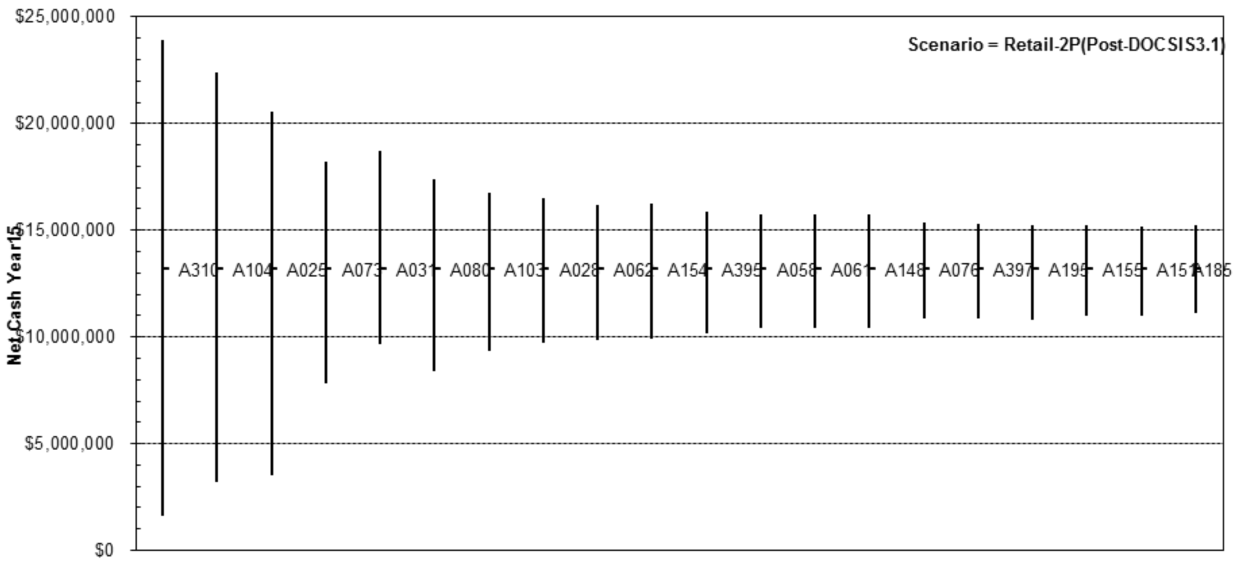
Financial Statements

	Year 1	Year 2	Year 3	Year 4	Year 5
Revenue					
Residential Phone	$0	$109,504	$517,542	$986,360	$1,346,796
Commercial Phone	$0	$50,183	$307,070	$778,079	$1,360,749
Residential Internet	$0	$609,243	$3,193,006	$6,938,680	$11,176,790
Commercial Internet	$0	$69,093	$426,334	$1,091,238	$2,228,246
High Capacity Services	$0	$78,629	$435,359	$1,094,400	$2,099,183
Other Retail Revenue	$0	$0	$0	$0	$0
Total	$0	$916,653	$4,879,311	$10,888,757	$18,211,765
Operating Expenses					
Internet Backbone/IPAddres	$0	$203,238	$400,342	$611,490	$914,321
Professional Services	$30,000	$10,000	$10,000	$10,000	$10,000
Locates & Right of Way Fee	$482,619	$266,269	$266,269	$266,269	$266,269
Staffing Expenses	$968,500	$1,938,788	$2,560,898	$2,638,920	$2,884,263
Vehicle maintenance	$0	$57,656	$130,015	$145,380	$149,015
Vendor Maintenance	$0	$55,000	$55,000	$55,000	$55,000
Rents and Utilities	$20,000	$20,000	$20,000	$20,000	$20,000
Total Operating Expense	$1,501,119	$2,550,951	$3,442,524	$3,747,059	$4,298,867
SG&A					
Marketing Expenses	$198,750	$399,938	$402,436	$404,997	$407,622
Customer Service Expenses	$104,000	$479,700	$491,693	$503,985	$660,080
Billing Expenses	$0	$4,365	$14,823	$27,078	$42,188
Total SG&A	$302,750	$884,003	$908,951	$936,060	$1,109,890
Total Expense	$1,803,869	$3,434,953	$4,351,475	$4,683,120	$5,408,758
Operating Income	-$1,803,869	-$2,518,301	$527,836	$6,205,637	$12,803,007
Operating Margin	NM	-275%	11%	57%	70%

	Year 6	Year 7	Year 8	Year 9	Year 10
Revenue					
Residential Phone	$1,465,971	$1,411,407	$1,356,412	$1,300,985	$1,245,123
Commercial Phone	$1,771,873	$1,999,637	$2,124,870	$2,145,539	$2,166,350
Residential Internet	$13,436,728	$13,510,268	$13,584,171	$13,658,437	$13,733,070
Commercial Internet	$2,982,146	$3,047,076	$3,113,284	$3,180,792	$3,249,625
High Capacity Services	$3,027,550	$3,709,280	$4,410,780	$4,802,276	$4,874,310
Other Retail Revenue	$99,139	$99,511	$113,997	$114,584	$115,174
Total	$22,783,408	$23,777,179	$24,703,513	$25,202,613	$25,383,653
Operating Expenses					
Internet Backbone/IPAddres	$1,365,893	$1,335,942	$1,599,992	$1,732,042	$1,612,092
Professional Services	$10,000	$10,000	$10,000	$10,000	$10,000
Locates & Right of Way Fee	$266,269	$266,269	$266,269	$266,269	$266,269
Staffing Expenses	$2,956,370	$3,030,279	$3,106,036	$3,183,687	$3,173,985
Vehicle maintenance	$152,740	$156,559	$160,473	$164,484	$168,597
Vendor Maintenance	$55,000	$55,000	$55,000	$55,000	$55,000
Rents and Utilities	$20,000	$20,000	$20,000	$20,000	$20,000
Total Operating Expense	$4,826,271	$4,874,048	$5,217,769	$5,431,482	$5,305,943
SG&A					
Marketing Expenses	$338,146	$350,842	$362,932	$370,820	$375,601
Customer Service Expenses	$676,582	$693,497	$710,834	$728,605	$746,820
Billing Expenses	$41,128	$39,931	$38,589	$37,092	$35,432
Total SG&A	$1,055,856	$1,084,269	$1,112,355	$1,136,518	$1,157,853
Total Expense	$5,882,128	$5,958,318	$6,330,124	$6,567,999	$6,463,795
Operating Income	$16,901,280	$17,818,862	$18,373,390	$18,634,613	$18,919,857
Operating Margin	74%	75%	74%	74%	75%

	Year 11	Year 12	Year 13	Year 14	Year 15
Revenue					
Residential Phone	$1,188,824	$1,132,085	$1,074,904	$1,017,278	$959,205
Commercial Phone	$2,181,488	$2,190,778	$2,199,857	$2,208,715	$2,217,344
Residential Internet	$13,805,086	$13,874,464	$13,944,168	$14,014,200	$14,084,562
Commercial Internet	$3,310,211	$3,362,287	$3,415,181	$3,468,905	$3,523,472
High Capacity Services	$4,947,425	$5,021,636	$5,096,961	$5,173,415	$5,251,016
Other Retail Revenue	$115,770	$116,370	$116,975	$117,585	$118,199
Total	$25,548,804	$25,697,621	$25,848,046	$26,000,098	$26,153,798
Operating Expenses					
Internet Backbone/IPAddres	$1,840,143	$1,954,195	$1,744,247	$1,936,299	$2,032,352
Professional Services	$10,000	$10,000	$10,000	$10,000	$10,000
Locates & Right of Way Fee	$266,269	$266,269	$266,269	$266,269	$266,269
Staffing Expenses	$3,253,335	$3,334,668	$3,418,035	$3,503,486	$3,591,073
Vehicle maintenance	$172,811	$177,132	$181,560	$186,099	$190,751
Vendor Maintenance	$55,000	$55,000	$55,000	$55,000	$55,000
Rents and Utilities	$20,000	$20,000	$20,000	$20,000	$20,000
Total Operating Expense	$5,617,558	$5,817,263	$5,695,110	$5,977,152	$6,165,445
SG&A					
Marketing Expenses	$380,296	$384,905	$389,607	$394,406	$399,303
Customer Service Expenses	$765,491	$784,628	$804,244	$824,350	$844,958
Billing Expenses	$31,369	$26,969	$22,213	$17,082	$11,555
Total SG&A	$1,177,155	$1,196,501	$1,216,064	$1,235,838	$1,255,816
Total Expense	$6,794,714	$7,013,765	$6,911,174	$7,212,990	$7,421,261
Operating Income	$18,754,090	$18,683,857	$18,936,872	$18,787,108	$18,732,537
Operating Margin	73%	73%	73%	72%	72%

Sensitivity



ID	Title	Best	Worst	ID	Title	Best	Worst
A31	Blended Cost per Meter Passed - During Build	$1,082	$885	A39	Bond Rate - Series 1	4.1%	3.4%
A10	Residential Internet Tier2 - Year1	$54.95	$44.96	A05	Business Package 1	110.0%	90.0%
A02	Residential Internet Access Penetration	33.2%	27.2%	A06	Lines per Business Package	4.2	3.4
A07	High Capacity Services Penetration of Med-Large	49.5%	40.5%	A14	Business Package 1 Per Line - Year 1	$15.40	$12.60
A03	Tier2 Year 10 - Res	66.0%	54.0%	A07	DIA Year 10 - Bus	82.5%	67.5%
A08	Percentage of all Businesses	5.5%	4.5%	A39	Bond Rate - Series 2	5.2%	4.3%
A10	Residential Internet Tier 1 - Year 1	$43.95	$35.96	A19	Bandwidth Minimum Capcity Trigger	88.0%	72.0%
A02	Tier 1 Year 10 - Res	33.0%	27.0%	A15	Direct Fiber High Cap ARPU	$3,300	$2,700
A06	Commercial Internet Access Penetration	49.5%	40.5%	A15	Tier 1 Bus Price	$65.95	$53.96
A15	DIA ARPU	$1,650	$1,350	A18	Residential Average Bandwidth - Year 1	1,650	1,350

The Uptown model utilizes over 450 variables to mimic the City fiber network and generate 15 years of proforma financial activity. While all variables are important and can affect the City broadband simulation, not all variables are within the City's control, some variables are dictated by market factors, or still other variables may have very little significant impact on total results. In the end, only a few material variables drive the model results, and even fewer may be within the City management's control. The example tornado graph above indicates that three core variables in particular heavily influence the model's results:

1) Passing cost
2) Residential internet pricing
3) Take rate

While other factors will influence the end result, it would take a combination of other issues to affect the model as much as any one of these 3 core variables.

Scenarios

A number of scenarios (adjusted variables, or combination or variables) were tested to determine impact of possible future states.

Base Case scenario:

- Penetration take rate 28.2 percent
- Passing cost $984
- Revenue during operations phase $23M - $26M/yr
- Construction phase capital cost $109M
- Estimated bond and short term debt total $132M
- Net Cash turns positive in year 14

Active Ethernet installation scenario:

- Penetration take rate 28.2 percent
- Passing cost $1135
- Revenue during operations phase $23M - $26M/yr
- Construction phase capital cost $129M
- Estimated bond need of $145M, short term not available
- Net Cash estimated to turn positive in year 17

Take Rate reduction scenario:

- Penetration take rate 22.5 percent
- Passing cost $984
- Revenue during operations phase $20M - $23M/yr
- Construction phase capital cost $106M
- Estimated bond and short term debt total $134M
- Net Cash estimated to turn positive in year 16

Take Rate increase scenario:

- Penetration take rate 45 percent
- Passing cost $984
- Revenue during operations phase $31M - $35M/yr
- Construction phase capital cost $115M
- Estimated bond and short term debt total $135M
- Net Cash estimated to turn positive in year 12

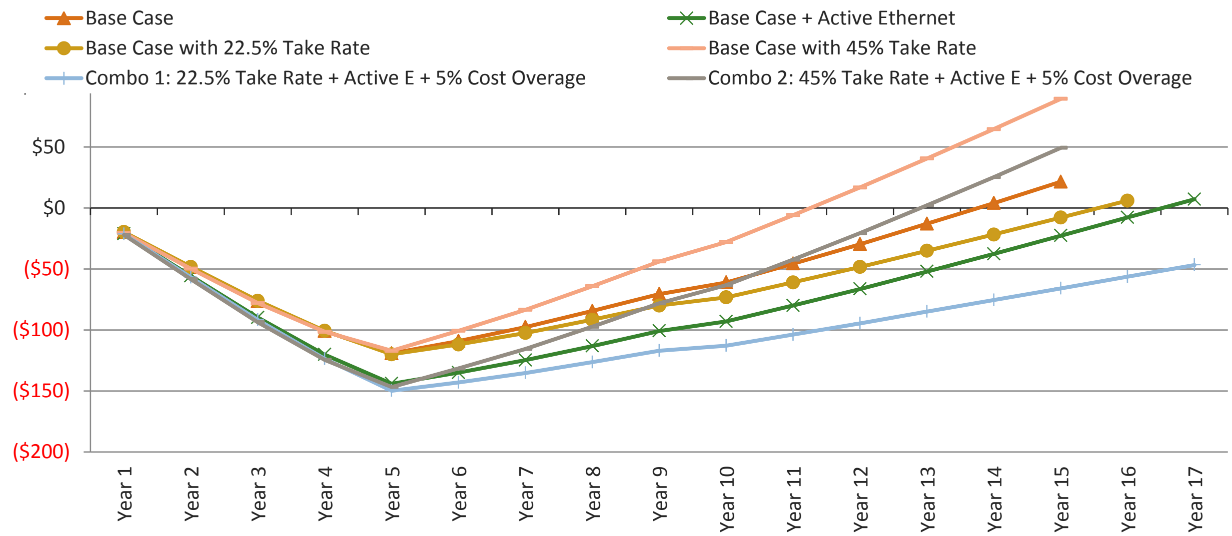
Combination 1 Scenario:
22.5 percent take rate, Active Ethernet installation, 5 percent cost overrun

- Penetration take rate 22.5 percent
- Passing cost $1192
- Revenue during operations phase $20M - $23M/yr
- Construction phase capital cost $131M

- Estimated bond need $147M, short term not available
- Net Cash does not turn positive in first 20 years

Combination 2 Scenario:
45 percent take rate, Active Ethernet installation, 5 percent cost overrun

- Penetration take rate 45 percent
- Passing cost $1192
- Revenue during operations phase $31M - $35M/yr
- Construction phase capital cost $131M
- Estimated bond and short term debt total $162M
- Net Cash estimated to turn positive in year 13



Mitigation

Scenario planning is useful to give management insight into potential outcomes; however, risk mitigation should be built into the business operations of the network to properly mitigate the potential for heavy losses. It must be acknowledged that these strategies have varying levels of success, and some may not be feasible in a network situation:

1) Pilot testing and sequential spending – move forward with large expenses only after smaller tests have proved successful

2) Timing – extension of construction timing may help financials as the network generates sufficient cash to fund growth, if given enough time

3) Variable vs. Fixed cost structure – variable cost structure can be a safer business model in which expenses are only incurred after revenue is assured, but it usually employs outsourced activities, longer lead time for customers, and potential loss of margin

4) Construction roll-out only after securing tenant anchors and stable revenue stream in strategic locations

Risk and Worst Case

As currently envisioned, the broadband service would be provided through the City's Light & Power utility. To fund the network construction, the City would issue Light & Power revenue bonds, which would be repaid by the network's users. These bonds would be backed by the revenues and rate payers of the Light & Power Utility. All business startups incur risk and not all risks can be mitigated. Risks associated with the municipal retail business plan include, but are not limited to: competition, startup, governance, technology and financial risk. If the City Retail FTTP network is successful, only households that subscribe for the service will pay for the network.

As modeled for this analysis, in the event insufficient revenue was generated by network subscribers, Light & Power rate payers would be responsible for covering any shortfall revenue necessary to cover debt service and operating expenditures. Staff also identified a worst case scenario (all of the debt is spent, the network fails and no revenue is realized from the network) to cover the $130 of debt to build the City Retail FTTP network. In the worst case scenario, a monthly fee estimated at $17 per month would be charged to each Light & Power account. The $17 per month is equivalent to $2,420 per premise over the life of the debt but would be reduced the later in time such a worst case scenario occurred.

IX. Opportunities and Threats

A number of potential opportunities and threats exist within this type of venture. The following highlight some of the possibilities.

Opportunities:

1) Possible additional revenue streams
   a. Lease of dark fiber
   b. Over the top internet service provider if open access

2) Market share greater than assumed
   a. Additional capital costs required but additional cash flow could payback debt faster
   b. Higher satisfaction, confidence in City brand and citizen confidence

Threats:

1) Marketing reaction of large incumbents
   a. Aggressive pricing
   b. Signing up multiple dwelling units with multi-year revenue sharing agreements with property owners
   c. Locking up customers during planning year with multi-year contracts at discounted prices

2) Possible legislative/political changes sponsored by large incumbents
   a. Restrict municipality's ability to add telecom into L&P Utility forcing need to create 5th utility
   b. Impact on financing could force General Obligation debt vs. lower interest revenue bonds
   c. Change in municipality's ability to provide retail internet service as occurred in Utah this forced a Wholesale model alternative that ultimately failed to generate enough revenue to support debt service

3) Governance
   a. City's ability to modify governance and run a municipal broadband utility as a private enterprise would be run.
      i. Private executive sessions to discuss strategy, pricing, marketing competitive reactions
      ii. Maintain a level playing field with competition by not adding social costs to the cost structure – i.e. low income rate subsidies should be borne by the municipality and not by the broadband utility

4) Business Risk
    a. Take rate of less than assumed by year five will impact ability of the broadband utility to support debt requirements (see Scenarios section VIII.G)
    b. Construction cost greater than expected (see Scenarios section VIII.G)
    c. Price reductions if needed to meet competition given price elasticity identified in survey results
    d. Rate risk in financing
    e. Municipal organization needs to develop expertise and experience in staff and culture to successfully compete with incumbents – business plan and execution management

X. Appendix

Peer Cities

PEER CITIES UPDATE

ATTACHMENT 1

State	City	State with Restriction	Next Century Cities Member	Model Exploring	Other
California		California Government Code 61100(af)			Community service districts may provide broadband services if a private person or entity is unwilling to deploy broadband services. If a city builds its own network and then a private company shows up "ready, willing, and able to acquire, construct, improve, maintain, and or operate broadband," the city has to turn it over or lease it to the company at FMV.
	Santa Rosa		No	-	Residential fiber service is only available to 2% of people living in Santa Rosa.
	Santa Barbara		No	-	Cox, Frontier and Windstream Communications provide wired services, but does not offer 1G.
	Anaheim		No	-	For $44.99/month, Time Warner provides 100 Mbps upload, 10 Mbps download service.
	Palo Alto		Yes	P3	Leases Dark Fiber Optic Backbone Network; Developed a FTTP Master Plan and Wireless Network Plan.
	Burbank		Yes	N/A	ONE Burbank offers business services - dark fiber leasing, dedicated internet access (DIA), Virtual Private LAN services, Wave Lambda Services, Communication Transport Services. Offers free Wi-Fi throughout the city using a "best efforts/as-is" basis utilizing existing network from smart meters.
Florida		FL.Stat.350-81, FL.Stat.166.047			Municipalities must hold public meetings that allow providers to comment on served and unserved areas. Florida requires a feasibility study or proof of profitability within four years or shut down, merge with a private company or seek an extension from municipal council or authority to continue providing services. State statute prohibits the use of taxpayer dollars to fund the network build
	Gainesville		Yes		Gainesville Regional Utilities built an Innovation Zone Network that serves businesses, multi-dwelling units (MDUs) and greenfield development.
	Coral Springs		No		AT&T GigaPower Network serves the Coral Springs area.
Michigan		MI Laws Ann.484.2252			A public entity may provide telecommunication services within its boundaries if the following requirements are met: a request for competitive bids to provide telecommunication services is issued, less than three bids are received, and 60-days pass from the date the request for bids was issued. The Michigan Broadband Development Authority (MBDA) is a state agency that assist in attracting private sector investments in Internet infrastructure.
	Ann Arbor		No		AT&T GigaPower Network serves the Ann Arbor area with FTTP 1G service at $80/month symmetrical.
Nebraska		Neb.Rev.Stat 86-575, Neb.Rev.Stat 86-594			Statutory language prohibits retail municipal broadband, telecom, or cable services.
	Lincoln/Lancaster County		Yes	3rd Party	Partner with Allo, 3rd Party, by leasing conduit. 1G service is $80/month symmetrical.