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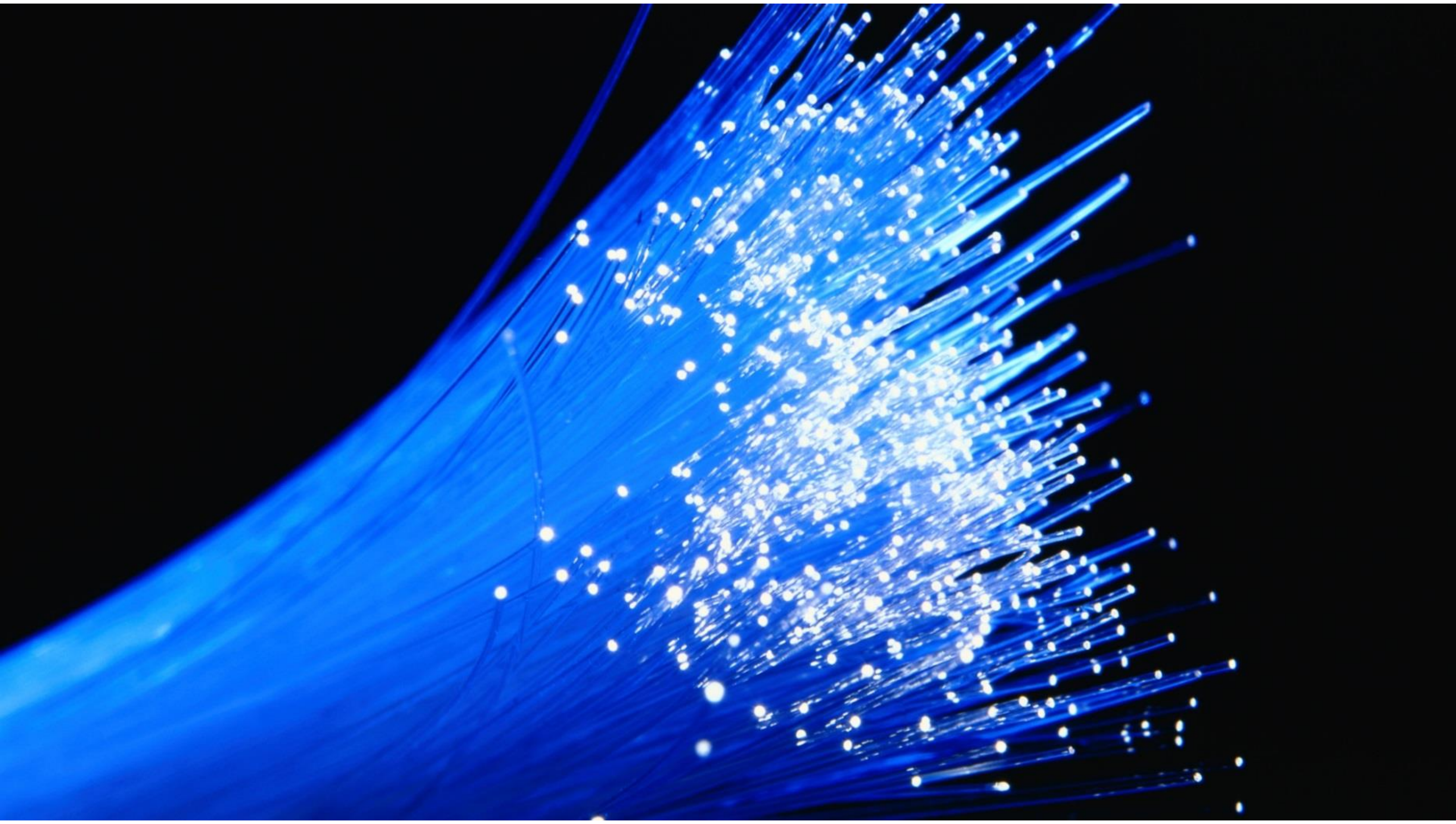

Broadband Feasibility Study

Prepared for City of Newark, Delaware
July 2016

Columbia Telecommunications Corporation

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1 Executive Summary

The City of Newark hired CTC Technology & Energy (CTC) in early 2016 to assess the feasibility of investing public funds in fiber-to-the-premises (FTTP) broadband infrastructure and in fiber and wireless infrastructure to provide wireless service to the public. This project follows an initial engagement in which CTC facilitated a workshop for City staff and the community to begin exploring a broadband project.[1] This report represents CTC's analysis and recommendations to the City.

This report concludes that constructing an FTTP network is not financially feasible. It recommends the City instead consider constructing middle-mile (backbone) fiber infrastructure and new wireless access points to enable free, "best effort" outdoor Wi-Fi service along the Main Street corridor, in public parks, and along the roadways in many neighborhoods in proximity to those locations. This report also recommends the City seek to collaborate on future fiber planning and construction with the University of Delaware (UD) and the Delaware Department of Transportation (DelDOT).

1.1 Project Overview

Over the course of the engagement, CTC engineers and analysts performed a range of tasks, including:

- Conducting field surveys to develop insight and data on the City's roads, buildings, and other aspects of the physical environment that might effect a fiber network deployment
- Facilitating discussions with City staff on broadband needs
- Facilitating a public "town hall" meeting to hear residents' opinions on broadband issues
- Seeking input on broadband issues from large businesses in Newark
- Conducting an online survey of Newark residents to gather anecdotal insights[2]
- Creating high-level candidate network models to meet the City's primary goals
- Developing cost estimates and financial models

The City and stakeholder groups opted to pursue two candidate technical network approaches:

1) Construction of a citywide FTTP network

[1] Our workshop presentation is attached as Appendix A.

[2] This survey was conducted at the City's request. As we discussed with the City's project team prior to initiating this survey, the results are not statistically valid and can only be taken as anecdotal evidence of public opinion.

2) Expansion of the City's middle-mile (backbone) fiber and wireless infrastructure to support free outdoor Wi-Fi and, potentially, dark fiber leases for institutions and businesses

1.2 Recommendations

1.2.1 Consider Pursuing a Middle-Mile Fiber and Wi-Fi Expansion

We recommend the City consider pursuing a middle-mile fiber and wireless expansion project to offer free outdoor public Wi-Fi along Main Street and in public parks. In order to provide the necessary capacity and performance, we determined the City would need to install a new network of approximately 27 wireless access points directly connected to fiber along the Main Street corridor, and would need to build fiber to provide more capacity to existing wireless access points in others parts of the City.

In order to provide the required capacity, we developed a system-level design for middle-mile fiber to serve the new Main Street wireless access points, as well as middle-mile fiber rings to connect existing access points throughout the City. Because the City's parks are spread across the jurisdiction, the incremental cost to construct rings rather than just designing laterals to individual parks was relatively low; the ring design is thus a cost-effective way for the City to achieve far greater broadband coverage.

This model would require the City to subsidize the network's operations or earn an equivalent amount of revenue to maintain positive cash flow over time. Including operating expenses, the City will need about $671,200 annually to sustain the network (see Section 5.2).

If such an initiative is within the City's budget (both in terms of upfront capital expenses and ongoing operating expenses), the fiber and wireless infrastructure could deliver wide-ranging additional benefits, including improved public safety communications and the ability to support "smart city" innovations. (We describe some of these benefits in Section 6.)

In addition, we note the City has potential partners for fiber construction in the University of Delaware (UD) and the Delaware Department of Transportation (DelDOT); those partnerships may reduce the City's costs.

1.2.2 Seek Collaboration with University of Delaware and the Delaware Department of Transportation

We encourage the City to work with UD and DelDOT on collaborative fiber planning and construction. UD has indicated it is satisfied with its current on-campus services, and does not need connectivity to its off-campus sites—but given the number of off-campus UD locations, and the university's interest in ensuring connectivity for the thousands of students who live off-campus, there might be an opportunity for a mutually beneficial collaboration in the future.

DelDOT has existing fiber in the Newark area, and has plans (and funding) to build more fiber through the City as part of its five-year statewide fiber network expansion. Based on CTC's discussions with DelDOT intelligent transportation management systems (ITMS) leadership, DelDOT is a willing partner and will share its fiber assets with the City (see Section 2.3).

1.2.3 Recommending Against an FTTP Deployment

We have explored the City's interest in, and ability to execute on, an FTTP network. We do not believe this is in the City's best interest.

We evaluated three construction scenarios to determine the most cost-effective approach:

1. Build the network entirely in the power space on utility poles—an option open to the City as an electric utility
2. Build the network in the power space on utility poles in more congested areas, but build in the communications space on the utility poles in less-congested areas where it would be cost-effective
3. Build the network entirely underground

Building primarily in the power space, but using the communications space where feasible (Scenario 2 above), is the most cost-effective of the three FTTP options, and therefore the approach we took as the basis for our financial analysis. (See Section 3 for more details).

Even using this comparatively cost-effective approach, however, the FTTP network would be extremely expensive to construct—due in part to the City's relatively low average density of passings per mile of fiber, combined with higher-than-average per-mile construction costs. Assuming a private partner leases the City's FTTP network and sells services to residents,[3] the network would have a deficit of $40.8 million by year 20. Even with a 100 percent "take rate"[4] (i.e., with the highest potential subscriber revenue), the City would still need an additional $2.5 million in annual revenue or subsidy to maintain a positive cash flow[5] (See Section 5.1).

A retail FTTP offering would also increase the City's risks. Although the City has experience providing customer service through its utility operations, providing customer service for a broadband enterprise would require a substantial increase in the City's customer service

[3] Based on the contract terms established in the broadband public–private partnership between the City of Westminster, Maryland, and its private partner, Ting.
[4] The take rate is the percentage of households or businesses that purchase service, out of the total number of households or businesses passed by the fiber infrastructure.
[5] This analysis is based on assumptions around a potential public–private partnership, and the payments that the partner would make to the City. See Section 5 for more details.

resources. This would create an ongoing operational cost for the City's fiber enterprise in addition to the annual subsidy.

Finally, since most of the City currently is served by Verizon FiOS and cable broadband, the City's potential take rate is likely limited. That is not to say that there are no gaps in availability; for example, the City reports that some businesses in the City's commercial areas are unable to purchase the level of broadband connectivity they need. And the existing services do not deliver the level of performance (i.e., 1 Gbps) that state-of-the-art fiber networks now deliver. But in our experience, it is difficult to make a business case for a public sector broadband initiative in a community that has Newark's level of existing broadband services. A public sector initiative would not likely achieve the take rate it needs to be financially sustainable.

2 Current State and Future Needs

2.1 City of Newark

The City is interested in exploring the feasibility of a public–private partnership to develop a fiber-to-the-premises (FTTP) network. To that end, in addition to asking CTC to develop a high-level design and cost estimate, the City held its own, independent discussion with representatives of Ting, the company that is partnering with the City of Westminster, Maryland, to deliver broadband services over the City's FTTP network.

In CTC's meetings and discussions with City staff, we also confirmed the City seeks to understand the feasibility of an alternative project in which it would expand broadband service to the Main Street commercial corridor (including buildings used by UD for offices and classrooms), offer free Wi-Fi in public parks, connect public safety cameras, and potentially lease dark fiber to enterprise customers and off-campus UD facilities.

Accordingly, we developed two candidate approaches: FTTP and a middle-mile fiber/wireless expansion. (See Sections 3 and 3.1 below.) Following on the development of the middle-mile fiber/wireless expansion model, we also explored potential benefits of that approach related to "smart city" innovations (see Section 6 below).

2.2 University of Delaware

CTC facilitated a meeting among UD leaders, UD IT and network leadership, and the City Manager. While the UD representatives expressed enthusiasm about the City's planning efforts, they stated the university is in a holding pattern on initiatives such as this until a new university president is appointed. UD does not currently seek any fiber connections from the City.

The City and UD have two separate fiber interconnections—one for connecting Smart Grid AMI concentrators on campus to the City and one for UD to have access to City resources. UD has an agreement with the Newark utility to attach its fiber to City utility poles.

Both on and off campus, UD's students represent a large stakeholder group for the City's broadband planning. According to data compiled in the "Urban Partners" housing study, more than half of the City's population of roughly 35,000 are students—about 15,800 undergraduates (7,200 of whom live in dorms on campus) and 3,600 graduate students.

On campus, students have free access to Wi-Fi and Comcast cable television. UD is interested in exploring how to provide off-campus students with Internet access, making the broadband service available to on-campus students "portable," and minimizing or eliminating the costs students incur to connect and disconnect their service when they move.

For its internal uses, too, UD would like to see "seamless" connections to off-campus UD office and classroom locations. UD identified more than 20 off-campus university locations that could be connected by City fiber; see Section 3.1.

2.3 Delaware Department of Transportation (DelDOT)

In discussions with DelDOT director of ITMS, we found considerable DelDOT backbone could potentially be available to the City. These include four miles that DelDOT has already built in Newark and 3.5 miles it is planning to build in Newark as part of its network expansion. The routes, if the City can get access, are along the same routes as the prospective City middle-mile build scenario (Figure 18) and can offset approximately one-fourth of the City's potential construction costs.

DelDOT has its fiber build funded, so it will not necessarily be asking Newark for financial contributions, although it may ask for help with access to poles and the rights-of-way (ROW).

DelDOT may also be interested in the City's additional fiber in the future. There are also routes that DelDOT is considering building, apart from the City middle-mile routes, that may be of value to the City's future initiatives.

2.4 Business Community

To gather insight on the local business community's potential interest in communications services, CTC attempted to contact representatives of the five largest businesses (by number of employees) in Newark[6] to discuss their current broadband use and their interest in dark fiber connections. (This needs assessment effort was anecdotal only; a full survey of the enterprise market was outside the scope of this engagement.)

Because the incremental cost of adding strands to a fiber route is minimal, the City could potentially connect those businesses (and other large customers) at the cost of constructing lateral fiber from its backbone to the business.

Of the five companies the City requested we contact, we were able to discuss the City's broadband plans with two of the five companies. (Representatives of the other companies did not respond to our repeated attempts to contact them.)

We discussed dark fiber connectivity with the assistant regional director of operations and an IT department staff member at one company. While both indicated that the company is satisfied with its current connectivity and has no immediate need for service from the City, they expressed interest in being kept apprised as the City's plans progress. (The company does not have diverse,

[6] The City's Planning and Development Department provided the list of companies, including telephone numbers.

redundant connections, for example, and it has a mild preference for having service choices and cost competition available in case the company develops problems with its current service.)

The representative we spoke to at the second company indicated that the Newark location has service through Verizon that is centrally managed by the company, which is headquartered elsewhere. The location has a Web-based inventory system and often uses streaming videos for staff training and product information. The company representative indicated the service is reliable and fast enough for their uses, with occasional delays in viewing media and video content.

In our middle-mile candidate approach, we prepared a system-level design of fiber laterals to each of these five business locations so that the City can price typical fiber connectivity, in order to illustrate the likely range of costs for connecting corporate and other sites over lateral fiber; see Section 3.1.

2.5 Residents

The City had initially planned to work with the University of Delaware Center for Applied Demography and Survey Research (CADSR) to perform a statistically valid survey of City residents. Because of the transition within UD leadership, however, CADSR was unable to participate in this project. The City's project budget precluded the development and execution of a statistically valid survey without CADSR's involvement, so the City worked with CTC to develop a non-scientific survey that was distributed in utility bills and made available through a Web interface as a means of gathering anecdotal information. Appendix C includes an overview of the survey responses.

3 Candidate Approach: Fiber-to-the-Premises

At the City's request, CTC prepared a high-level network design and cost estimate for deploying a citywide gigabit FTTP network to every home, business, and institution in Newark. This deployment would cost almost $26 million, inclusive of outside plant (OSP) construction labor, materials, engineering, permitting, pole attachment licensing, network electronics, drop and lateral installations, customer premises equipment (CPE), and testing.

Table 1: Breakdown of Estimated Total Cost[7]

Cost Component	Total Estimated Cost
OSP	$20.9 million
Central Network Electronics	1.1 million
CPE	2.1 million
FTTP Service Drop and Lateral Installations	1.8 million
Total Estimated Cost:	$25.9 million

This cost estimate provides data relevant to assessing the financial viability of network deployment, and to developing a business model for a potential City construction effort (including the full range of models for public–private partnerships). This estimate will also enable financial modeling to determine the approximate revenue levels necessary for the City to service any debt incurred in building the network.

Our system-level design and cost estimate are underpinned by data and insight gathered by CTC engineers through a number of related steps, including discussions with City stakeholders and an extensive desk survey of candidate fiber routes.

We have included a glossary of FTTP terms in Appendix C.

3.1 Field Survey

A CTC OSP engineer performed an in-person survey of representative portions of Newark, then supplemented those findings with a desk survey via Google Earth Street View. With those inputs, the engineer developed estimates of per mile cost for aerial construction on utility poles, and per mile costs for underground construction (where poles are not available). The engineer reviewed available green space, necessary make ready on poles, and required pole replacement—all of which have been factored in to our design and cost estimate.

[7] Cost have been rounded in the table.

CTC's OSP engineer noted the quality of the poles and pole attachments varied, as they do in many cities—but that overall, many poles would not be capable of supporting an additional communications attachment without significant make ready. In most cases, we found the poles lacked the height required to add additional attachments. And in many areas, especially the high-density areas, there are already three or more attachers in the communications space.

Because the City is the utility pole owner—and is thus able to construct in the power space—we explored the ability of the poles to support the FTTP deployment in the power space (i.e., the top portion of a utility pole, reserved for electric lines) as well as the communications space (i.e., the lower portion of the pole, reserved for cable, telephone, and fiber optic lines). Our survey results (see the table below) indicated the utility poles will require significantly less make ready if the FTTP plant is installed within the power space.

While constructing fiber in the power space would incur additional costs for running fiber down to the poles, installing taps, and splicing the fiber, the make ready in the power space is only 8 percent with an average of two moves and 3 percent pole replacement. In contrast, make ready requirements in the communications space are quite high:

- In high-density areas, make ready is about 65 percent with an average of five moves and 18 percent pole replacement
- In lower-density areas, make ready is 50 to 55 percent with an average of three moves and 8 percent pole replacement

Figure 1 and Figure 2 illustrate the areas reviewed during the field survey and the density areas of the City, while Table 2 summarizes the OSP engineer's findings and estimates for the survey areas. Both the map and the table refer to the three types of population densities utilities conditions we used in our cost estimation model—high, medium, and low.

Figure 1: Map of Field Survey Areas

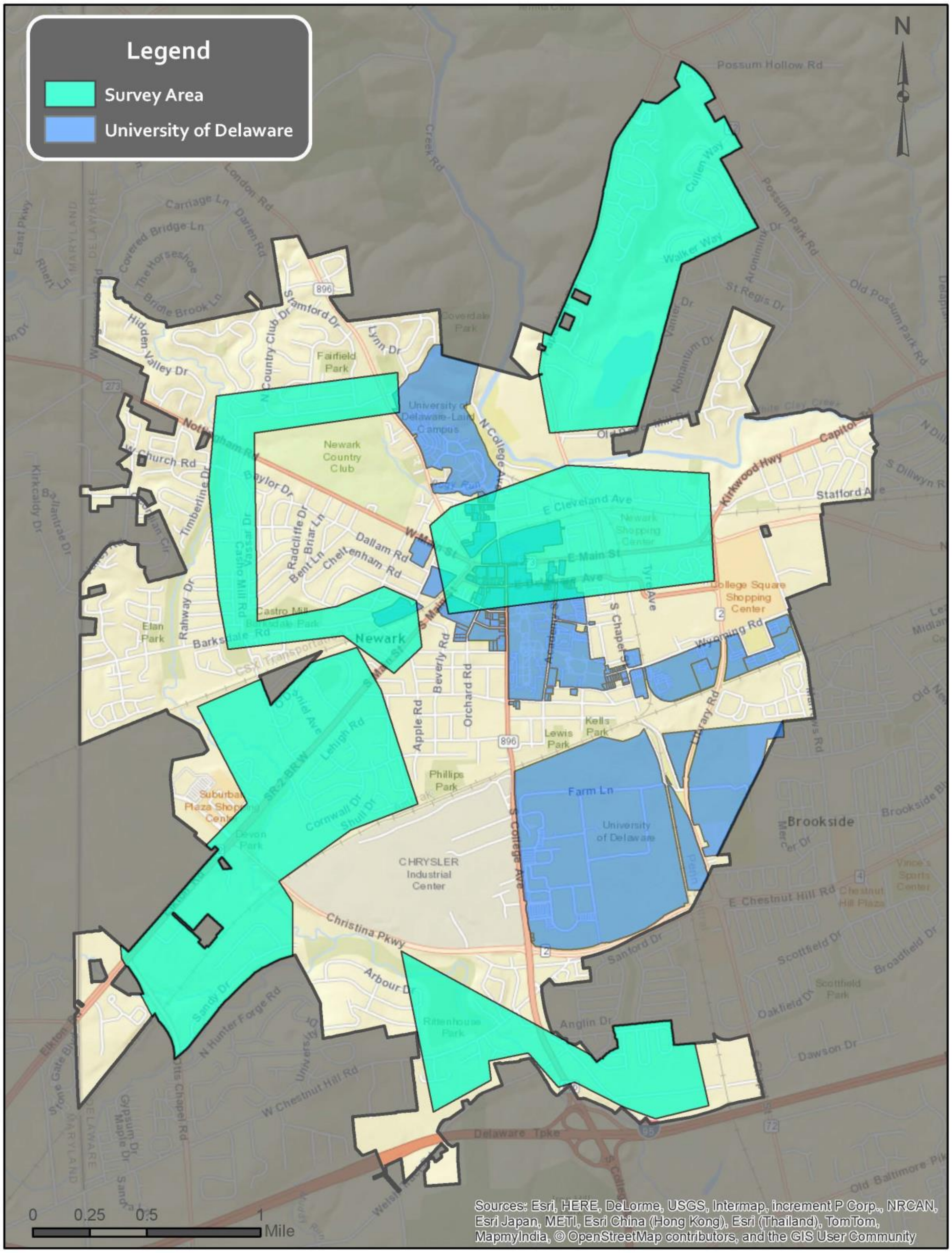


Figure 2: Map of Density Areas

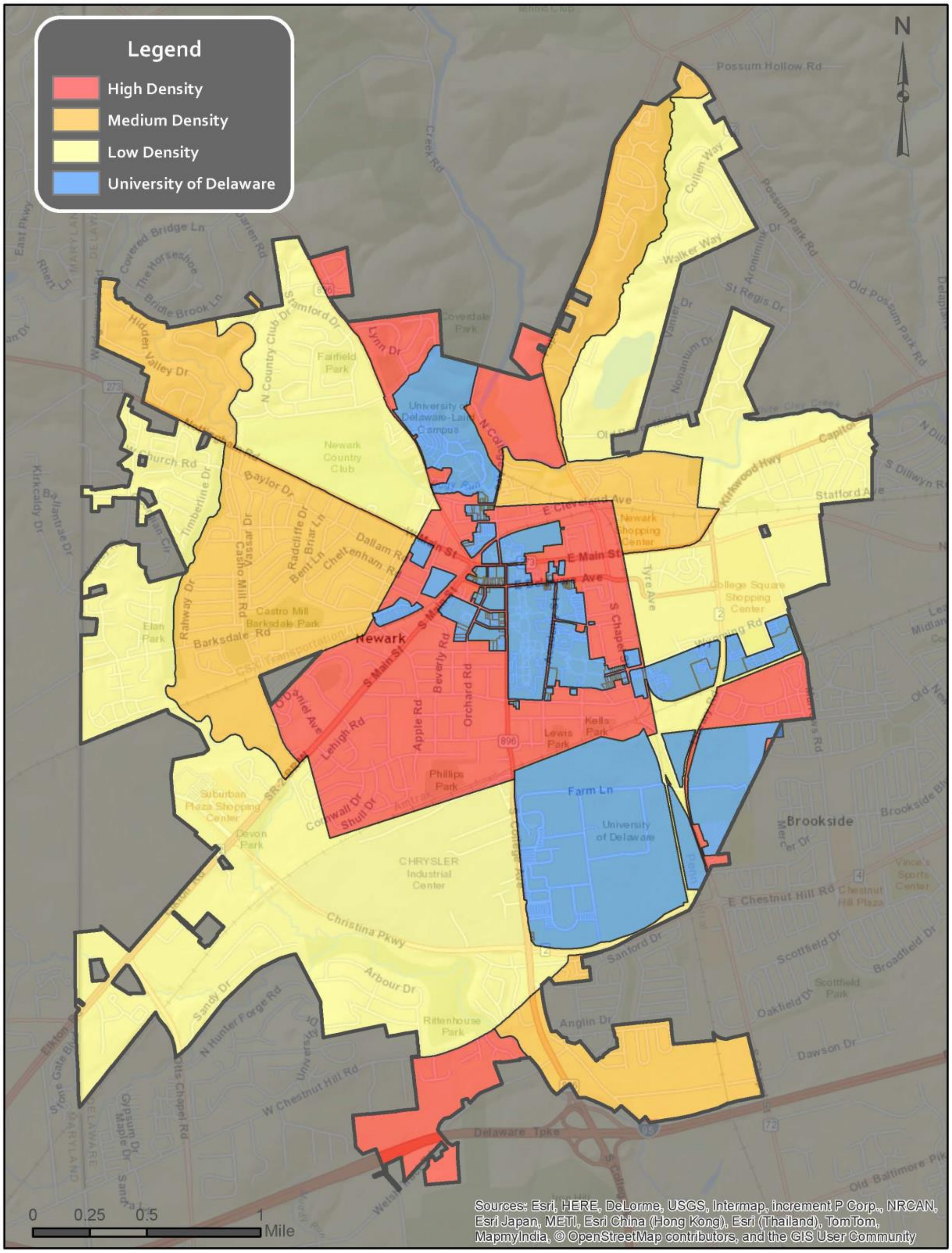


Table 2: Field Survey Findings

Assumptions	**High Density in Communications Space**	**High Density in Power Space**
Viable Aerial Routes	80%	
Poles Per Mile	39.5	
Percentage of Poles Requiring Make Ready	65%	8%
Percentage of Poles Requiring Replacement	18%	3%
Average Moves Per Pole	5	3
Intermediate Rock Percentage	2%	
Hard Rock Percentage	1%	
Assumptions	**Medium and Low Density in Communications Space**	**Medium and Low Density in Power Space**
Viable Aerial Routes	58%	
Poles Per Mile	40.4	
Percentage of Poles Requiring Make Ready	52.5%	4%
Percentage of Poles Requiring Replacement	8%	3%
Average Moves Per Pole	3	2
Intermediate Rock Percentage	2%	
Hard Rock Percentage	1%	

3.2 FTTP Network Design

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 3 (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 drawing 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 its ability to accommodate the increased demands of future applications and technologies. The characteristics of this hierarchical FTTP data network are:

- Capacity – ability to provide efficient transport for subscriber data, even at peak levels

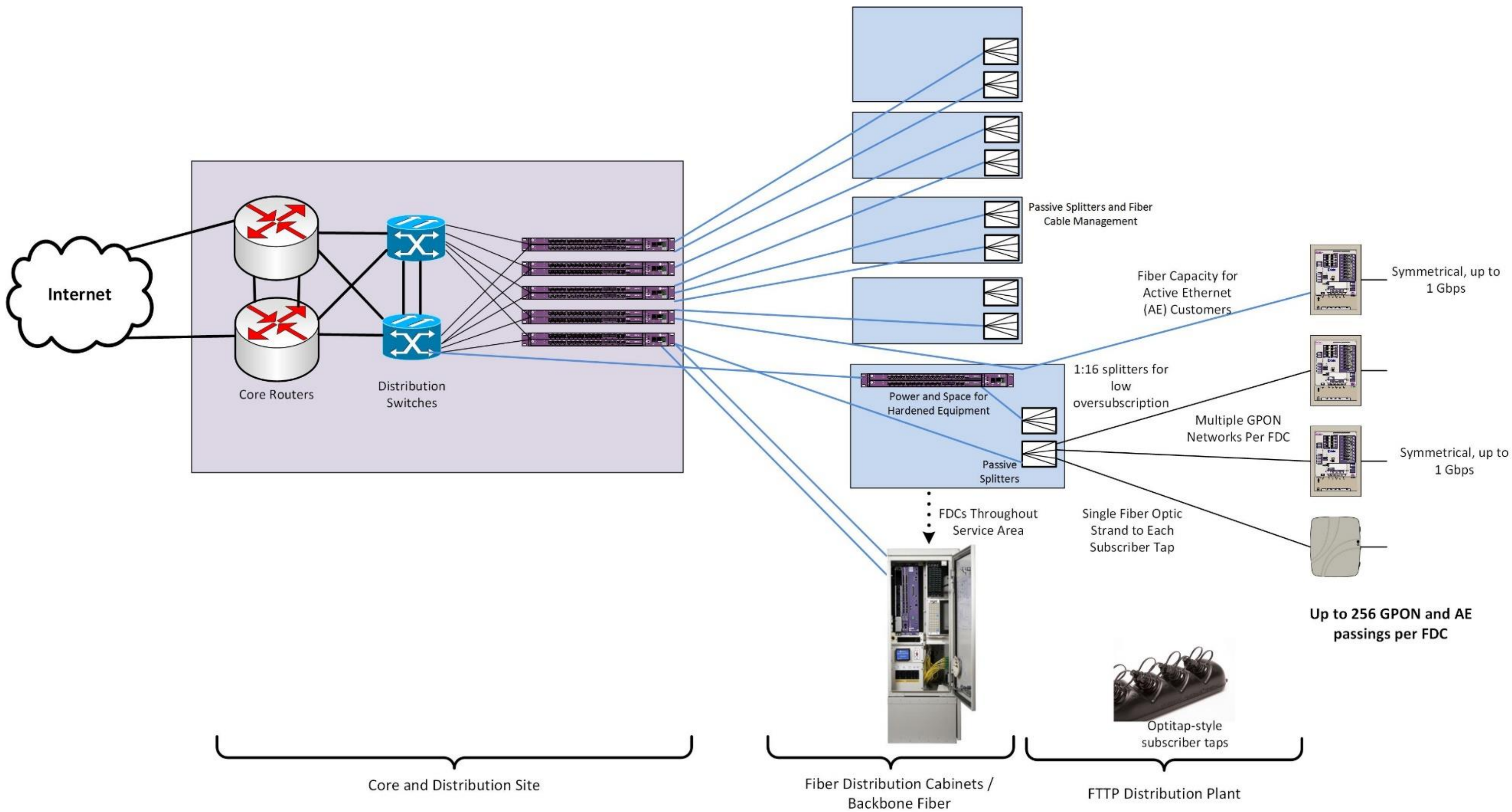
- Availability – high levels of redundancy, reliability, and resiliency; ability to quickly detect faults and re-route traffic
- Diversity – physical path diversity to minimize operational impact resulting from fiber or equipment failure
- Efficiency – no traffic bottlenecks; efficient use of resources
- 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 customer environments; can support an open access network or a single-provider network; can provide separation between service providers on the physical layer (separate fibers) or logical layer (separate 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 Gigabit Passive Optical Network (GPON)[8] and direct Active Ethernet services (with the addition of electronics at the fiber distribution cabinets), 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 right-of-way or easements, providing water-tight fiber connectors for customer service drop cables and eliminating the need for service installers to perform splices in the field. This is an industry-standard approach to reducing both 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 multi-dwelling units.

[8] GPON is the most widely-used FTTP architecture globally, common to Google Fiber, Verizon FiOS, and Chattanooga EPB.

Figure 3: High-Level FTTP Architecture



3.2.1 Network Design

The network design and cost estimates assume the City will:

- Identify space for the core and distribution facility to house network electronics and provide backhaul to the Internet;
- Construct fiber to connect the core and distribution facility to the fiber distribution cabinets (FDC);
- Construct fiber optics from the FDCs to each residence and business (i.e., from termination panels in the FDC to tap locations in the right-of-way or on City easements); and
- Construct fiber laterals into large, multi-tenant business facilities and/or multi-dwelling units.

The FTTP network and service areas were defined based on the following criteria:

- Targeting 512 passings per FDC;
- FDCs suitable to support hardened network electronics, providing backup power and an active heat exchange;[9] and
- Avoiding the need for distribution plant to cross major roadways and railways.

Coupled with an appropriate network electronics configuration, this design serves to greatly increase the reliability of fiber services provided to the customers 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.

The fiber plant from the FDCs to the customers dedicates a single fiber strand from the FDC to each passing (potential customer address). This traditional FTTP design allows either network electronics or optical splitters in the FDCs. See Figure 4 below for a sample design in Newark.

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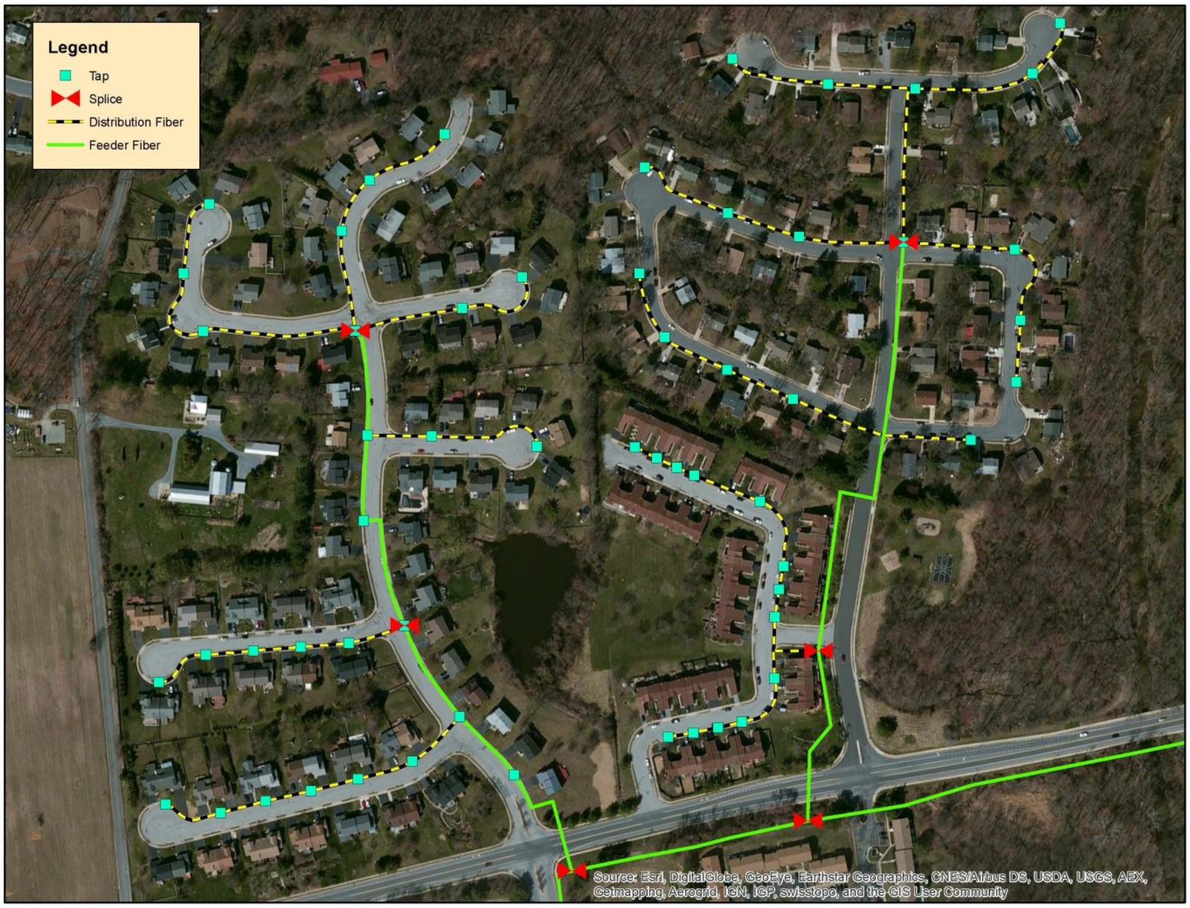
[9] These hardened FDCs reflect an assumption that the City's operational and business model will require the installation of provider electronics in the FDCs that are capable of supporting open access among multiple providers. We note that the overall FTTP cost estimate would decrease if the hardened FDCs were replaced with passive fiber distribution cabinets (which would house only optical splitters) and the providers' electronics were housed only at hub locations.

Figure 4: Sample FTTP Access Layer Design in Newark



This architecture offers scalability to meet long-term needs, and 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.

3.2.2 Network Core and Distribution Facility

The core and distribution facility links the FTTP network to the public Internet and delivers all services to end users. The proposed network design includes one core and distribution location, based on the network's projected capacity requirements.

The facility also provides physical path diversity for subscribers and all upstream service and content providers. For our design and cost estimates, we assume that the Newark core site will be housed in a secure telecommunications shelter that has access to fiber optic carriers for Internet connectivity.

The core location in this plan will house the providers' Operational Support Systems (OSS) such as provisioning platforms, fault and performance management systems, remote access, and other operational support systems for FTTP operations. The core location is also where any business partners or content / service providers will gain access to the subscriber network with their own points-of-presence. This may be via remote connection, but collocation is recommended.

The core location should 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 the core network location be physically secure and allow unencumbered access 24x7x365 to authorized engineering and operational staff.

The operational environment of the network core is similar to that of a server hosting facility. This includes clean power sources, uninterruptible power source (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 assume the core facility will be a secure telecommunications shelter located on existing City property connected to the fiber optic network and to Internet service provider (ISP) fiber.

Figure 5: Example of a Core Site Facility

3.2.3 Distribution and Access Network Design

The distribution network is the layer between the core and distribution facility and the fiber distribution cabinets (FDCs, which provide the access links to the taps). The distribution network aggregates traffic from the FDCs to the core. Because fiber cuts and equipment failures have progressively greater operational impact as they happen closer to the network core, 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 and supports two different architectures:

1. Housing both the distribution and access network electronics at the core, and using only passive devices (optical splitters and patches) at the FDCs; or

2. Housing the distribution network electronics at the core and pushing the access network electronics further into the network by housing them at the FDCs.

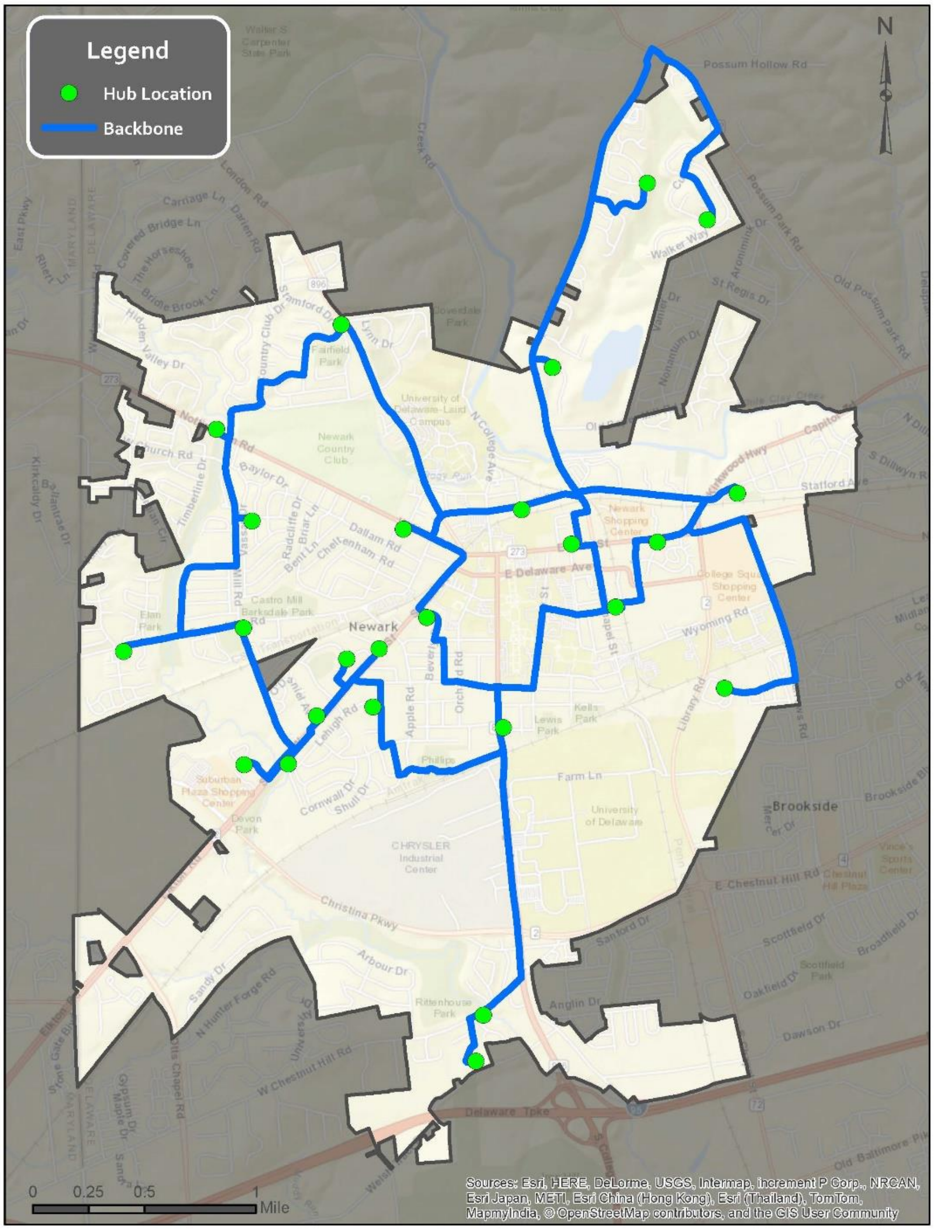
By housing all electronics at the core, the network will not require power at the FDCs. Choosing a network design that only supports this architecture may reduce costs by allowing smaller, passive FDCs in the field. However, this architecture will limit the redundancy capability from the FDCs to the core.

Pushing the access network electronics further into the field provides the network with added redundancy, by allowing the access electronics to connect to the core over redundant connections. In the event one fiber link has an outage, the subscribers connected to that FDC would still have network access. Choosing a network design that only supports this architecture may reduce costs by reducing the size of the core.

Selecting a design that supports both of these models enables 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 core) and grow by pushing electronics closer to their subscribers.

Figure 6 is a map of a simulated backbone design and FDC locations based on population densities. An actual backbone design and cabinet placement location would be developed during the detailed engineering phase.

Figure 6: Simulated Backbone and FDC Location Map



3.2.3.1 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.

Figure 7: Fiber Distribution Cabinet

Our FTTP design also includes the placement of indoor FDCs and splitters to support larger 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 Active Ethernet 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 deliver 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 mean 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) Small Form-factor Pluggable (SFP) modules to support multiple (most commonly less than 32) subscribers.

GPON uses passive optical splitting, which is performed inside FDCs, to connect fiber from the OLTs to the customer premises. The FDCs house multiple optical splitters, each of which splits the fiber link from the OLT to between 16 and 32 customers (in the case of GPON service).

Active Ethernet (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 (SLA) that are easier to manage and maintain on a dedicated service.

For subscribers receiving Active Ethernet service, a single dedicated fiber goes directly to the subscriber premises with no splitting. Because AE requires dedicated fiber (also known as "home run" fiber) from the OLT to the CPE, and because each subscriber uses a dedicated SFP on the OLT, there is a significant cost differential in provisioning an AE subscriber versus a GPON subscriber.

Our fiber plant is designed to provide Active Ethernet 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.

3.2.3.2 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[10] such as Active Ethernet. (The cost differential between constructing an entire network using GPON and Active Ethernet is 40 percent to 50 percent.[11]) 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 wavelength-division multiplexing (WDM).

This model provides many options for scaling capacity, which can be done separately or in parallel:

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.

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[10] 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.

[11] "Enhanced Communications in San Francisco: Phase II Feasibility Study," CTC report, October 2009, at p. 205.

2. Adding higher speed PON protocols by adding electronics at the FDC or hub locations. Since these use different frequencies than the GPON electronics, none of the 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 Active Ethernet 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.

3.2.3.3 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 right-of-way 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. Fiber laterals also connect from the FDC to larger MDUs and businesses. The drop cable extends from the subscriber tap (either on the pole or underground) to the building, enters the building, and connects to customer premises equipment (CPE).

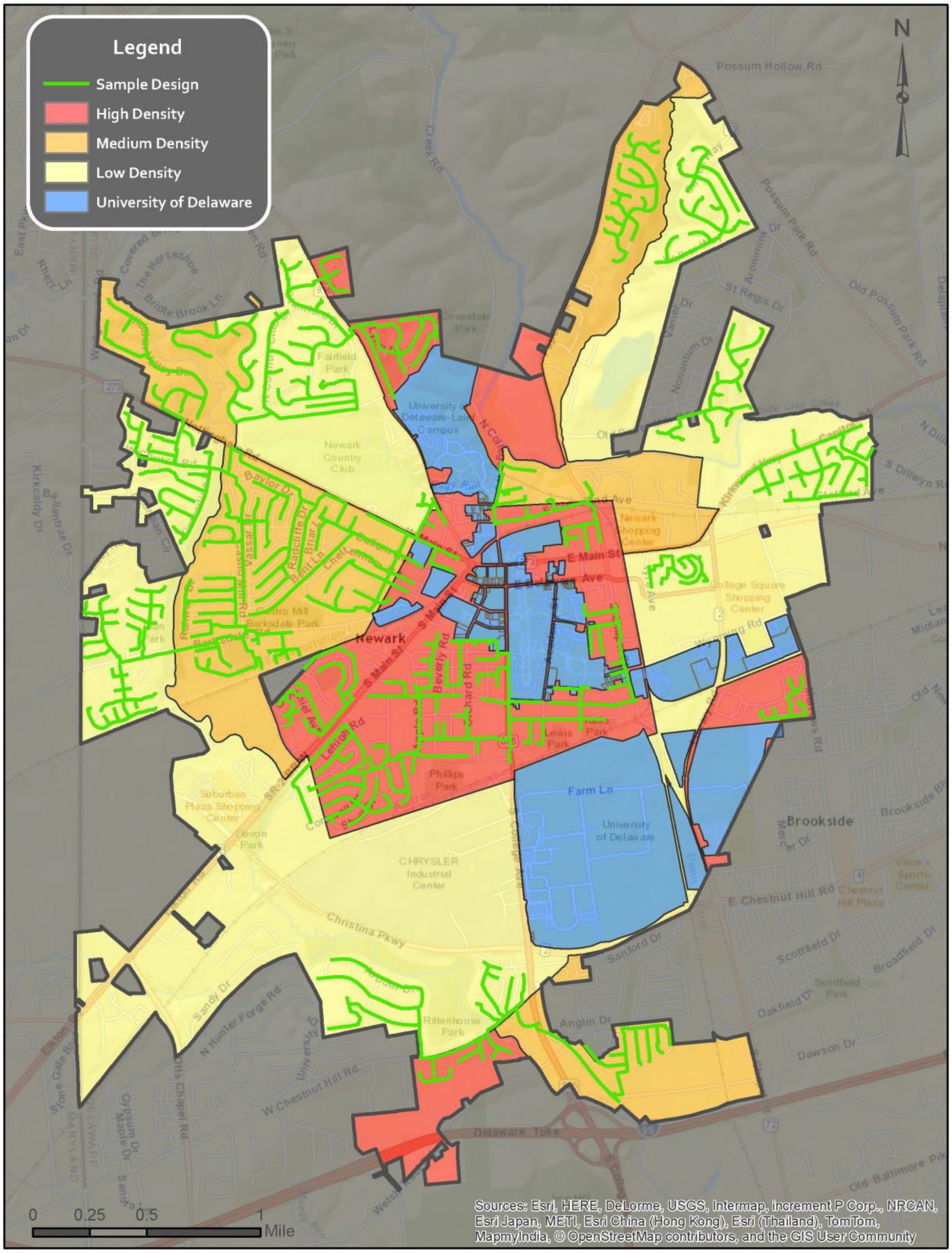
3.3 OSP Cost Estimation Methodology

3.3.1 Overview

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 three types of population densities and existing utilities—high, medium, and low. [12] Figure 8 shows the locations where sample designs were developed.

[12] The sample design was 38 percent of the total City street mileage.

Figure 8: Map Showing Sample Design Locations



The majority of communications utilities in Newark are aerial, except for newer housing developments, which tend to have underground utilities.

We used these assumptions, sample designs, and cost estimates to extrapolate a cost per passing for the OSP. This number was then multiplied by the number of passings based on Census and City data. The actual cost to construct FTTP to every premises in the City could differ from the estimate due to changes in the assumptions underlying the model. For example, if 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.

3.3.2 OSP Cost Estimate Breakdowns

The cost components for OSP construction include the following scope of 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 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 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.

3.3.3 Issues Related to Constructing the FTTP in the Power Space

Given the amount of make ready and pole replacement required to add an attachment in the communications space on the poles—and the fact that the City is the power company and pole owner—CTC explored the cost of constructing the FTTP network within the power space above the communications space.

Constructing the FTTP network within the power space reduces the make ready required on the utility poles because existing space reserved as the safety zone between the communications space and the power space may be used to construct fiber. The downside of constructing the network in the power space is that the cost of constructing the fiber increases because installation must be performed by certified electric line engineers. Another negative is the requirement to install All Dielectric Self-Supporting (ADSS) cable in the power space.[13]

The requirement to use ADSS limits the ability to overlash feeder and distribution fiber as well as drop cables to subscribers. In addition, the optical taps should be attached to the utility poles in the communications space to limit the need to have certified power technicians install the drops to each subscriber. These constraints require that the feeder fiber be spliced at each tap location and the optical tap dropped into the communications space. This increases the number of splices required along the feeder fiber. An alternative is to purchase customized feeder and optical taps based on the detailed engineering design so preconnectorized splice ports are installed at the factory at each location where taps are required. Optical taps would then be installed at the corresponding splice ports. These construction methods increase the cost of the FTTP build compared to constructing a traditional FTTP network in the communications space.

The following table outlines our cost estimates based on either constructing in the communications space or power space.

[13] ADSS fiber contains no metallic components that require grounding. A plastic strength member replaces the metallic strand typically installed in the communications space. Because ADSS fiber is non-metallic, it can be placed either directly below the lowest conductor in the power space or above the highest cable in the communications space.

Table 3: Cost of Construction in Communications Space and Power Space

Assumptions	**High Density in Communications Space**	**High Density in Power Space**
Cost of Constructing Aerial Fiber per foot	$3	$5
Percentage of Poles Requiring Make Ready	65%	8%
Percentage of Poles Requiring Replacement	18%	3%
Average Moves Per Pole	5	3
Total Splices Required	132	1,440
Total Construction Cost Per Mile	**$204,000**	**$147,000**
Assumptions	**Medium Density in Communications Space**	**Medium Density in Power Space**
Cost of Constructing Aerial Fiber per Foot	$3	$5
Percentage of Poles Requiring Make Ready	52.5%	4%
Percentage of Poles Requiring Replacement	6%	3%
Average Moves Per Pole	4	2
Total Splices Required	108	981
Total Construction Cost Per Mile	**$142,000**	**$137,000**
Assumptions	**Low Density in Communications Space**	**Low Density in Power Space**
Cost of Constructing Aerial Fiber per Foot	$3	$5
Percentage of Poles Requiring Make Ready	50%	4%
Percentage of Poles Requiring Replacement	6%	3%
Average Moves Per Pole	2.5	2
Total Splices Required	192	1,864
Total Construction Cost Per Mile	**$119,000**	**$129,000**

Based on these finding and cost assumptions, the FTTP cost estimate in this report is based on constructing the FTTP network in the power space in the City's high- and medium-density areas, and in the communications space in the low-density areas.

3.4 FTTP Cost Estimate

This section provides a summary of cost estimates for construction of an FTTP network to all City residents and businesses.

3.4.1 Comparative FTTP Cost Estimates

Based on the conceptual, high-level FTTP design that reflects the City's goals and is open to a variety of architecture options, we developed two cost estimates.

The first estimate shows 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. This estimate includes the cost to deploy FTTP outside plant (OSP) infrastructure, all required networked electronics, service drops to consumers, and customer premises equipment (CPE).

The second estimate is the cost to deploy *only* the FTTP OSP infrastructure. This is the total capital cost for the City to build a "dark" FTTP network for lease to a private partner.

3.4.1.1 Total FTTP Cost Estimate (Fiber and Electronics)

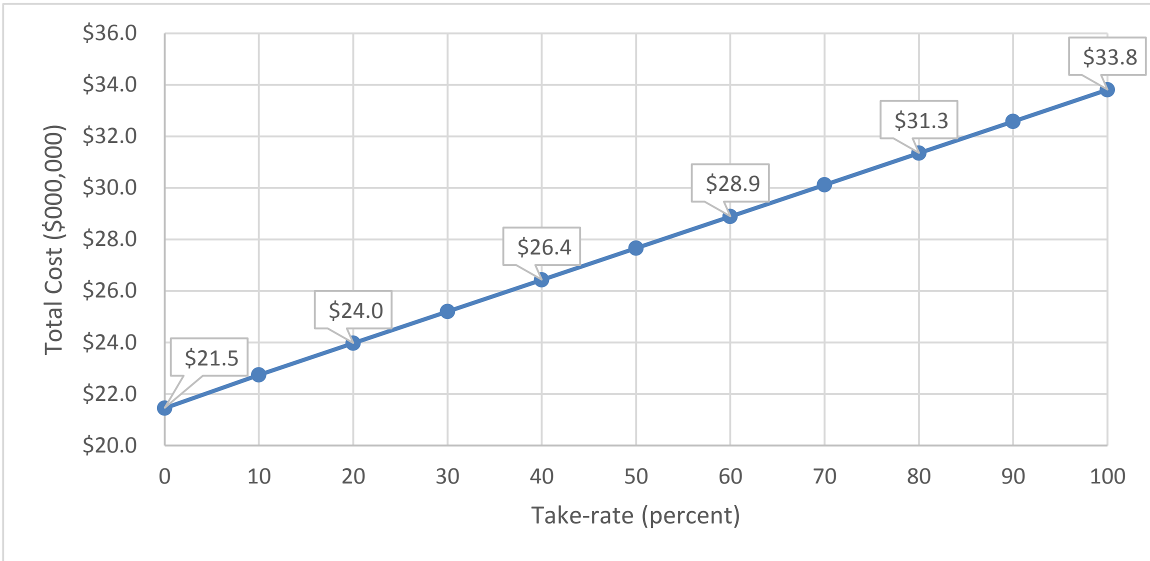
This citywide FTTP network deployment will cost almost $26 million, inclusive of outside plant (OSP) construction labor, materials, engineering, permitting, pole attachment licensing, network electronics, drop and lateral installations, customer premises equipment (CPE), and testing. (See Section 3.4 for details.) 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 data service. The total cost is $2,650 per passing on average with higher density areas having a lower cost per passing and lower density areas having a higher cost per passing.

Table 4: Breakdown of Estimated Total Cost

Cost Component	Total Estimated Cost
OSP	$20.9 million
Central Network Electronics	1.1 million
CPE	2.1 million
FTTP Service Drop and Lateral Installations	1.8 million
Total Estimated Cost:	$25.9 million

Total costs will vary as the take rate increases or decreases; Figure 9 shows the total estimated cost at various take rates.

Figure 9: Total Estimated Cost versus Take Rate



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 (not including non-technical operating costs such as marketing, legal services, and financing costs) are outlined in Section 3.5. 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.

3.4.1.2 Dark FTTP Cost Estimate (No Electronics, Drops, or CPEs)

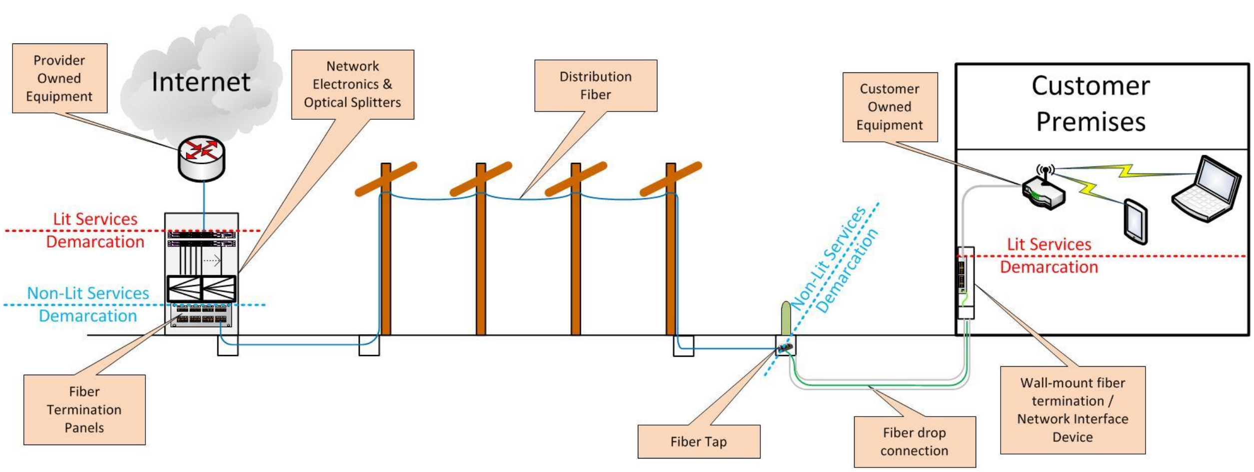
This citywide FTTP network deployment will approximately $21 million, inclusive of outside plant (OSP) construction labor, materials, engineering, permitting, and pole attachment licensing. Because this estimate *does not* include any electronics, subscriber equipment, or drops, it is referred to as the "dark" FTTP cost estimate. It is especially relevant if the City opts for a partnership model in which it is responsible for constructing the physical network, and a partner "lights" the network (operating electronics and selling services to the public).

Table 5: Breakdown of Estimated Dark FTTP Cost

Cost Component	Total Estimated Cost
OSP Engineering	$2.6 million
Quality Control/Quality Assurance	$.9 million
General OSP Construction Cost	$13.4 million
Special Crossings	–
Backbone and Distribution Plant Splicing	$2.7 million
Backbone Hub, Termination, and Testing	$1.2 million
FTTP Lateral Installations	$.2 million
Total Estimated Cost:	$21.0 million

This estimate assumes 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 CPEs—as well as network sales, marketing, and operations.

Figure 10: Demarcation Between City and Partner Network Elements



A variation of the above demarcation is to have the City pay for the drops and include this cost in the lease price. Including the drop cost would increase the estimated fiber cost by approximately $700 per subscriber. This variation on the ownership and demarcation was done in Westminster, Maryland.

In a related vein, we note that some network operators suggest 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. If the City is strictly a dark fiber partner, 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.

3.4.2 OSP

In terms of OSP, the estimated cost to construct the proposed FTTP network is $21 million, or $2,650 per passing.[14] As discussed above, our model assumes an optimized 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. The model also assumes that the high and medium density areas will be constructed in the power space and the low density areas will be constructed in the communications space. Table 6 provides a breakdown of the estimated OSP costs (note the costs have been rounded).

Table 6: Estimated OSP Costs for FTTP

Area	Distribution Plant Mileage	Total Cost	Passings	Cost per Passing	Cost per Plant Mile
Backbone	21	$1,200,000	NA	NA	$58,000
High Density (Power Space)	46	$6,800,000	3,160	$2,135	$147,000
Medium Density (Power Space)	35	$4,800,000	2,060	$2,350	$137,000
Low Density (Comms Space)	68	$8,000,000	2,670	$3,020	$120,000

[14] For this calculation, single-unit buildings and individual units in small multi-dwelling and multi-business buildings are counted as single passings. Larger buildings are treated as single passings.

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 based on current known item costs, not including potential additional economies of scale through bulk purchases and unanticipated price inflation, and barring any sort of phenomenon restricting material availability. 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, yet even on City-owned poles, increases uncertainty around cost and timeline. In some circumstances, costs related to pole remediation and make ready 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 rights-of-way 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 right-of-way 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.

The choice to construct in the power space or the communications space for aerial construction was determined by the overall cost of construction. We determined that for all areas except the low density areas, it was more cost-effective to construct in the power space than the communications space.

3.4.3 Central Network Electronics Costs

Central network electronics will cost an estimated $1 million, or $135 per passing, based on an assumed take rate of 35 percent.[15] These costs may increase or decrease depending on the actual

[15] 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.

take rate, and the costs may be phased in as subscribers are added to the network. The central network electronics consist of the electronics to connect subscribers to the FTTP network at the core, hubs (distribution electronics), and cabinets (access electronics). Table 7 below lists the estimated costs for each segment.

Table 7: Estimated Central Network Electronics Costs

Network Segment	Subtotal	Passings	Cost per Passing
Core and Distribution Electronics	$400,000	7,900	$60
Access Electronics	600,000	7,900	75
Central Network Electronics Total	*$1,000,000*	*7,900*	*$135*

3.4.3.1 Core Electronics

The core electronics connect to the network's distribution electronics on one side, and to the Internet on the other. 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 hot swappable[16] line cards (which improve performance in the event of an outage). Modular routers also provide the ability to expand the routers as demand for additional bandwidth increases.

The core sites would also redundantly tie to the distribution electronics 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 routers will also have 10 Gbps links to Internet service providers (ISP) that connect the FTTP network to the Internet.

The cost of the core routing equipment is $250,000. These costs do not include the service provider's Operational Support Systems (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.

3.4.3.2 Distribution Electronics

The network's distribution electronics aggregate the traffic from the fiber distribution cabinets (FDC) and forward it to the core routers to access the Internet. The distribution electronics consist of high-performance aggregation switches that consolidate the traffic from the many access electronics and send it to the core for route processing. The distribution switches typically are

[16] Hot swappable means that the line cards 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 the configurations to a replaced line card without the need for reconfiguration.

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 access device. 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 is $150,000. These costs do not include any of the service provider's OSS or other management equipment.

3.4.3.3 Access Electronics

The access electronics at the core or FDCs connect the subscribers' customer premises equipment (CPE) to the FTTP network. We recommend deploying access electronics that can support both GPON and Active Ethernet 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 initial capital costs while the network is under construction or during the rollout of the network.

The cost of the network access electronics is $600,000. These costs are based on a take rate of 35 percent and include optical splitters at the FDCs to support that take rate.

3.4.4 Customer Premises Equipment and Service Drop Installation (per Subscriber Costs)

The drop installation cost is the most significant variable in the total cost of adding a subscriber. While a short aerial drop can cost as little as $250 to install, a long underground drop installation can cost upward of $2,500. Therefore, we estimate an average of $765 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 ONT, which is the customer premises equipment (CPE) on an FTTP network, is the subscriber's interface to the FTTP network. For this cost estimate, we selected CPEs that provide only Ethernet data services. (There is a wide variety of CPEs offering other data, voice, and video services.) Estimating a 35 percent take rate, we estimated that the CPE for residential and business customers will cost $2 million (including the electronics and 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 8: Per Subscriber Cost Estimates

Construction and Electronics Required to Activate a Subscriber	Estimated Average Cost
Drop Installation and Materials	$765
Subscriber Electronics (ONT)	345
Electronics Installation	200
Installation Materials	100
Total	*$1,410*

3.5 Operating Cost Considerations

This section outlines some of the key technical operating expenditures that a citywide FTTP network would require. Costs for technical operations of the FTTP network include staffing (technicians, program managers), OSP maintenance, electronics maintenance, and customer support.

The costs discussed in this section are not inclusive of all operating costs such as marketing, legal, and financial costs. Further, the City's total cost of operations will vary with the business model chosen, the balance it strikes between adding new staff and using contractors, the level of existing resources that can be leveraged by the City, and the roles of any potential business partners.

In CTC's financial and business analysis (Section 5.1) we outline the estimated costs for the dark FTTP lease model. This model does not require electronics costs, vendor maintenance fees, or other costs beyond those associated with maintaining a dark fiber network.

3.5.1 Technical Operational Expenditures

If the City were to offer a retail data service, we estimate, based on comparable markets and the size of the population, that the City would likely initially purchase 4 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 on the contract terms, we would estimate that Internet bandwidth would cost in the $0.75 to $1.25 per Mbps per month range. We also 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 it is cost-effective to do so, 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.

3.5.1.1 Fiber Maintenance Costs

The City would need to augment its current fiber staff or hire contractors with the necessary expertise and equipment to maintain the fiber optic cable in a citywide FTTP network. Maintenance costs typically approximate 1 percent of the total OSP fiber construction cost per year, based on a mix of City staff and contracted services.

Relative to copper telephone lines and cable TV coaxial cable, fiber optic cable is significantly more resilient. 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 on average 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’s contracts with fiber optic contractors should specify the SLAs the City needs in order to ensure that the City, in turn, can meet the SLAs 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.

3.5.1.2 Fiber Locating

As with its power network, the City will be responsible for locating and marking all underground conduit for excavation projects according to state utility locating requirements. 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.

3.5.1.3 Pole Attachment Fees

Although there is a history of reciprocal arrangements between the City and Verizon, the City may need to pay Verizon an annual fee per pole to attach its fiber optic cables to Verizon 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. Depending on policies and other regulations, the electric utility may have to charge the FTTP network pole attachments fees on City-owned electric utility poles.

3.5.2 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 to maintain and operate the network.

3.5.2.1 Outside Plant

A City OSP group will need to 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; OSP technicians will assist with project oversight, 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 utility locating process, fiber locates, Layer 1 troubleshooting and response, and fleet management. Additionally, while many OSP jobs may be outsourced, it is critical the OSP group (whether comprised of staff or contractors) be equipped with the proper locate and testing equipment.

Our estimate includes one OSP manager and up to one OSP technician to operate the network, depending on what roles are contracted and what capabilities already exist within the City.

3.5.2.2 Network Engineering

A City network engineering group would need to develop and maintain the network architecture, respond to high-level troubleshooting requests, manage network electronics, and make sure the network delivers a reliable service to the end user.

The network engineering group would be 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 would 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 one network manager, a part-time network engineer, and two network technicians that could be a combination of in-house personnel and contracted support.

3.5.2.3 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 users as defined in the network SLAs.

Often network operations require a 24x7 customer service helpdesk and tools for network monitoring, alerting, and provisioning.

4 Candidate Approach: Middle-Mile Fiber and Wi-Fi

In the second model requested by the City, the City would extend its existing fiber backbone and install additional wireless equipment to increase the capacity of its existing Wi-Fi network. This approach would provide "best effort" outdoor Wi-Fi coverage over most of the City with greatly increased speeds, making possible both public Wi-Fi service and wireless communications for the City's internal uses—such as public safety and "smart city" innovation.

The model is designed to optimize the performance at target areas along Main Street and in public parks. In addition to supporting Wi-Fi (the City's stated goal), the fiber expansion would create additional benefits; it would potentially:

- Support dark fiber connections to almost two dozen off-campus UD locations, and
- Enable the City to construct laterals to lease dark fiber to enterprise customers and institutions.

4.1 Expanding Wi-Fi Access to Parks and Main Street Corridor

The City's existing Wi-Fi network is primarily used for low-bandwidth, machine-to-machine communications. It is set up to collect data from the utility's Automatic Meter Reading system collectors (which in turn read utility meters)—an application that uses only a small fraction of the network's capacity.

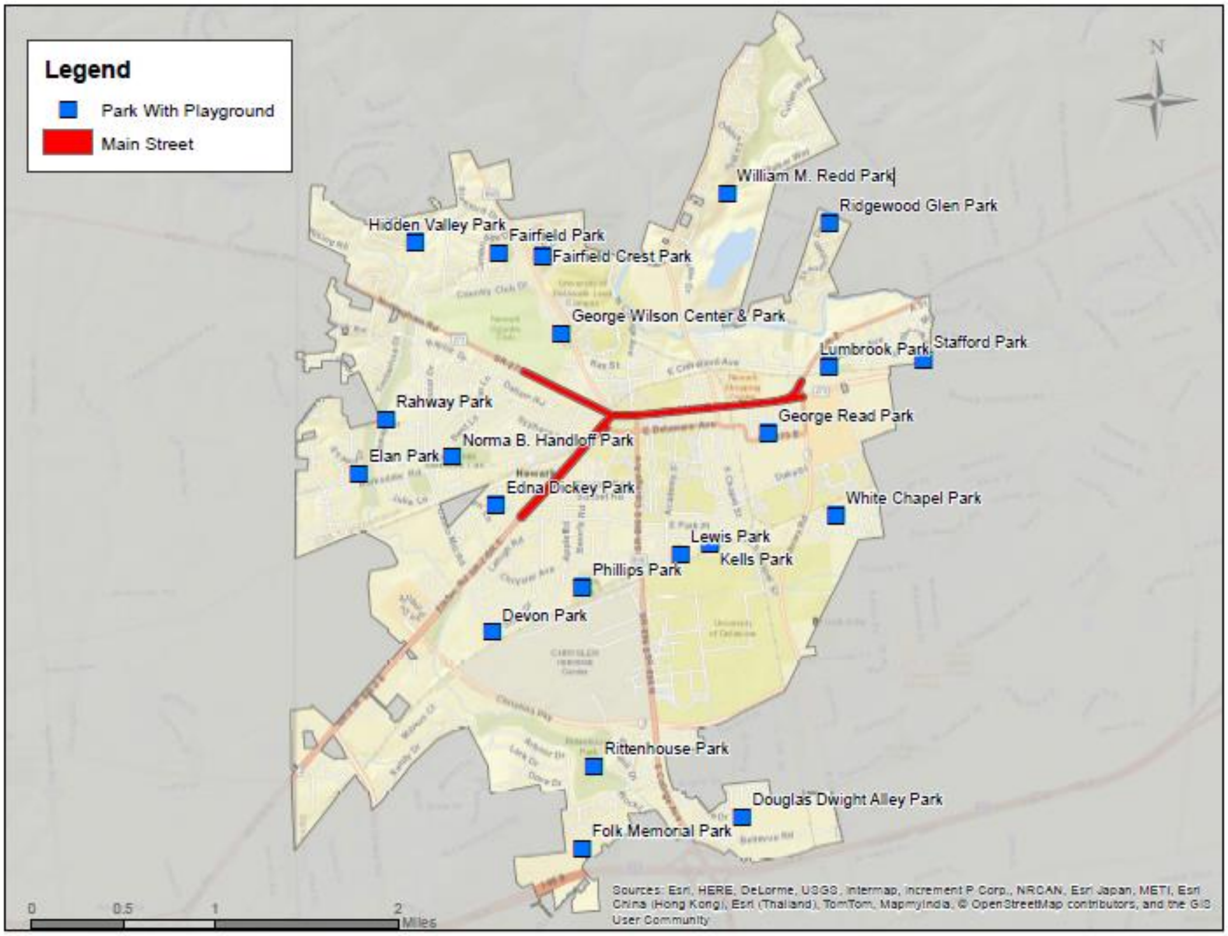
The City's stated goal is to provide free Wi-Fi access along the Main Street corridor and in public parks across the City. To determine whether the existing infrastructure could be used to provide that outdoor wireless coverage, CTC engineers completed a range of analytical tasks:

1. Identified the targeted coverage areas, as determined by the City
2. Reviewed the City's documentation on its existing Wi-Fi system, including closeout documentation for the system installation
3. Interviewed representatives of the Wi-Fi system's OEM vendor (ABB/Tropos)
4. Analyzed existing Wi-Fi coverage
5. Performed a throughput analysis

4.1.1 Proximity of Existing Wireless Network to Target Coverage Areas

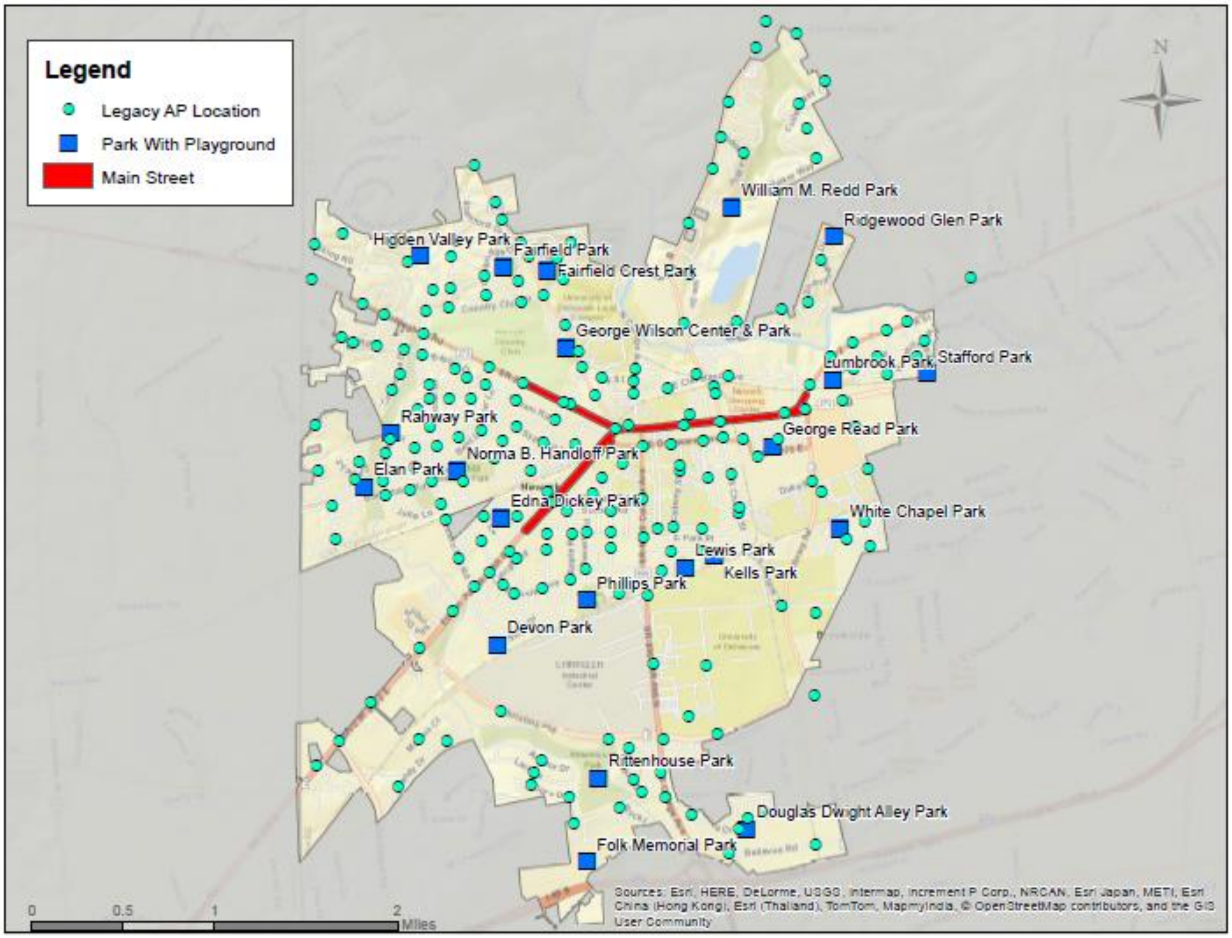
Using the City's GIS database, we identified the City's candidate parks and the target Main Street coverage area. Figure 11 shows these areas.

Figure 11: Target Coverage Areas (Parks and Main Street)



The City's existing Wi-Fi system is a "mesh" network that includes 219 Tropos wireless access points (AP) installed throughout the City. As the map in Figure 12 illustrates, the City's current wireless infrastructure already covers a significant portion of the community.

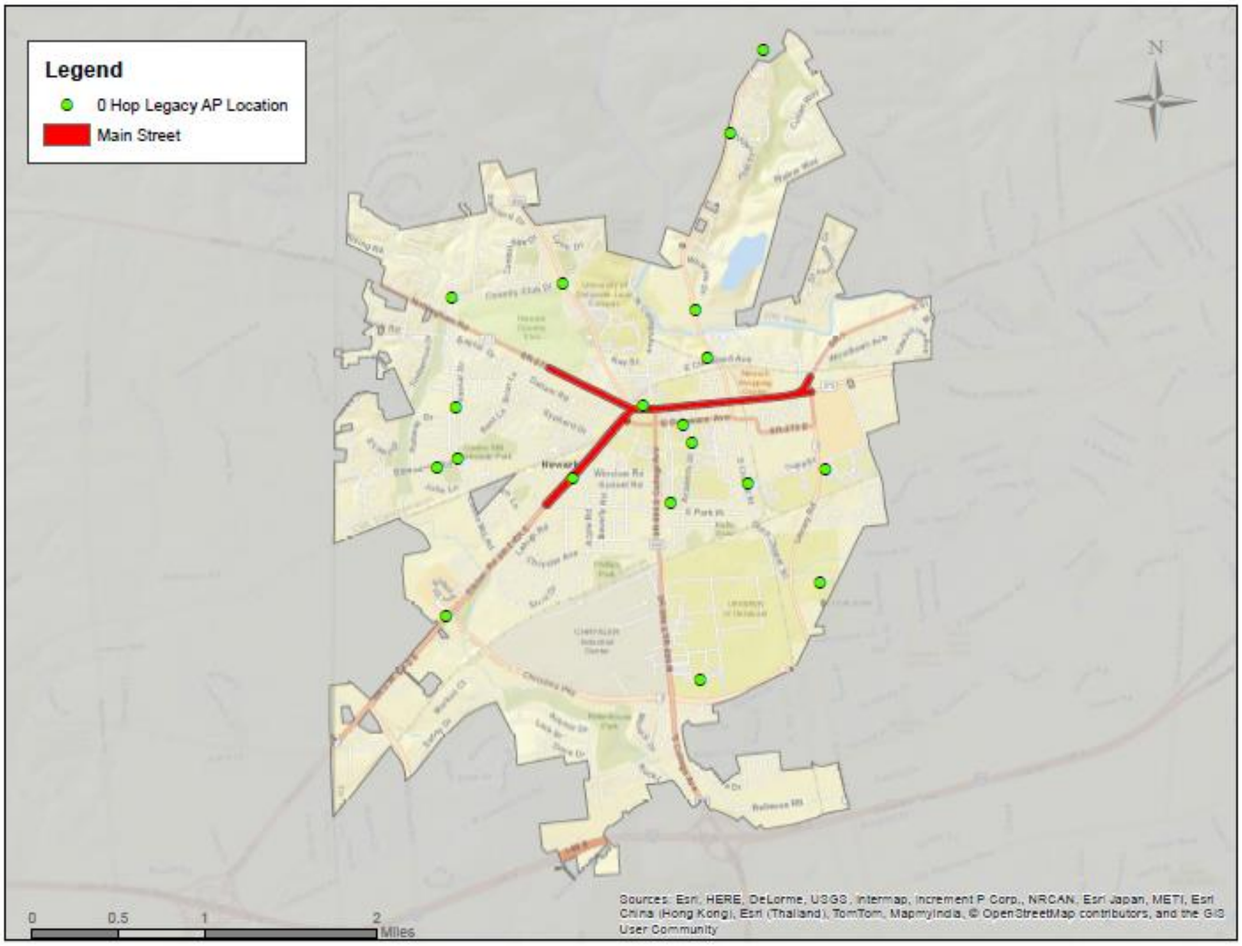
Figure 12: Location of Wireless Access Points Relative to Target Coverage Areas



However, of the City's 219 existing AP locations, we found that only 19 are connected by City fiber. The fact that fewer than 10 percent of AP locations are directly connected means the majority of wireless locations connect to the network through multiple wireless "hops" before they reach a fiber connection, and therefore the performance of the network is much less than a network with more fiber connections and fewer hops. (The greater the number of hops, the slower the network.)

We have labeled the fiber-connected APs as "0 hop legacy AP locations" in the map in Figure 13.

Figure 13: Wireless Access Points Connected by City Fiber



4.1.2 Requirements for Providing Target Wireless Coverage

In comparing the target coverage area to the locations of existing infrastructure, we found that, by and large, the areas are already receiving adequate coverage from the existing Wi-Fi system.[17] The larger issue to address, then, is not coverage but capacity—the fact that many Wi-Fi access points share few fiber connection points to the network and to the Internet.

[17] The City should review the parks and determine whether it wants to add access points to any outliers that do not currently have coverage. We have included in our Bill of Materials (BOM) five extra access points that will likely be needed to cover all of the parks once the final selection is made.

CTC conducted a capacity analysis on the existing Wi-Fi system and determined the system is adequate for its designed purpose of meter reading and monitoring. However, if the network is open to wider public use, it will need to accommodate higher-bandwidth devices such as Internet browsing and music and video streaming over users' laptops, tablets, and smartphones. In order to meet these objectives, the City will need to install additional infrastructure to be able to handle that greater bandwidth.

Our analysis revealed two ways in which the network would need improvement—physically adding APs along Main Street, and constructing new middle-mile fiber to connect APs (thus reducing the number of hops between APs to improve capacity).

4.1.2.1 Adding a New Network of Wireless Access Points Along Main Street

The City identified Main Street as the main target corridor for public Wi-Fi. This area of the City will likely have a higher density of people using the Wi-Fi system as they shop, eat at restaurants, and conduct their business.[18] Because of the greater number of people, there needs to be both a higher density of APs, and more points of fiber backhaul for those APs.

In order to provide the necessary capacity and performance, we determined that the City would need to install a new network of approximately 27 outdoor APs directly connected to fiber. The new, fiber-ready APs would use the latest Wi-Fi technology standard, called 802.11ac, which offers the highest data rates currently available on the market.[19]

Because the City's current AP vendor, Tropos, does not provide an AP that supports 802.11ac technology, the City would need to operate the 802.11ac devices in tandem with its existing Tropos mesh network (i.e., the 219 existing APs throughout the City). In order to do so, the City would need to install and operate a new wireless controller for the new type of AP, while the legacy Tropos APs would remain on their existing controller.

The design for the new AP network along the Main Street corridor uses omni-directional antennas that are directly connected to the APs to provide coverage to users in proximity to each AP (up to 500 feet). The APs are backward compatible to older versions of the Wi-Fi standard (such as 802.11 a/b/g/n). A wireless LAN controller is required managing the new, integrated network. The customer access management (such as authentication and security) will be managed by a network access management device.

[18] This will be a free, "best effort" service that will generally provide strong outdoor coverage, but that will not reliably provide indoor signal strength.
[19] The theoretical maximum speed of 802.11ac is in the order of Gbps. However, real-world speeds are dependent on multiple factors such as distance from customer, obstructions in the path and RF interference. Also, the network will be provisioned to ensure that the data rates are shared across all users.

Figure 14 (below) depicts the possible locations of the new APs along the Main Street corridor, based on overlapping 500-foot radii. We recommend using fiber optic backbone to connect these new APs back to the network operations center, so that backhaul is not a limiting factor in the performance of the network. The network design balances capital cost against the need for adequate future capacity.

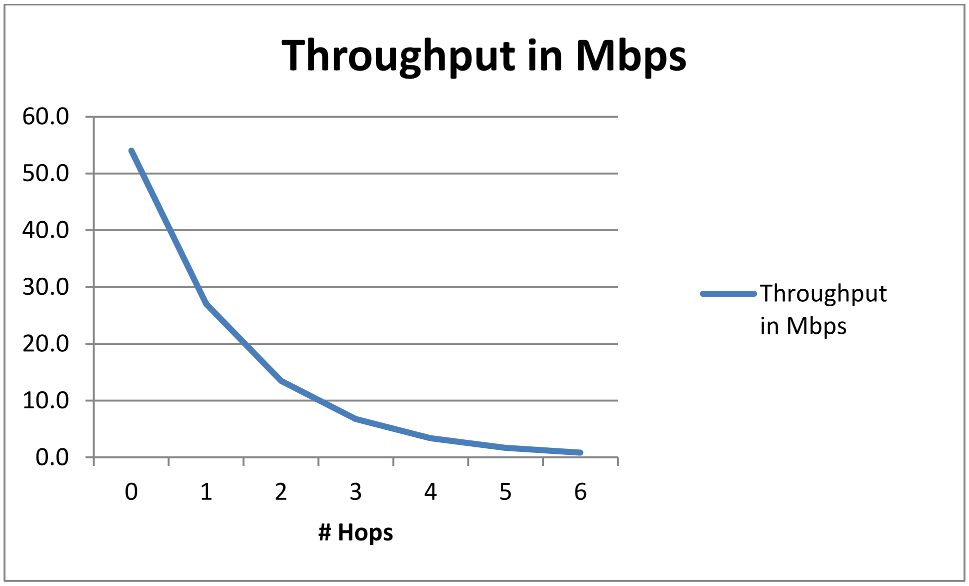
Figure 14: Potential Wireless Access Points Along Main Street

4.1.2.2 Adding Fiber Backhaul to Reduce Hops Between Existing Access Points

The City's current Wi-Fi network is a meshed design, in which data "hops" from one Tropos AP to another. In the existing configuration, data from a given AP may need to hop up to six times before reaching an AP that is connected to the fiber backhaul.

However, with each hop, the network's throughput and latency is dramatically degraded. In fact, each hop can reduce the available throughput by up to 50 percent—meaning that the existing network will be less capable of supporting end users' bandwidth requirements. Figure 15 depicts the throughput reduction as the number of hops is increased.

Figure 15: Reduction in Wireless AP Throughput as Hops Increase



While the current design suffices for machine-to-machine communications, APs with three or greater hops make the network unsuitable for public Wi-Fi and other City uses. Accordingly, we suggest constructing middle-mile fiber to connect additional existing APs to ensure than no AP requires more than two hops before being backhauled. To do this, CTC has identified 48 locations where adding fiber backhaul to the system would connect current three-hop and five-hop APs. (The current four- and six-hop APs would all be reduced to one hop with the addition of these new backhaul points.)

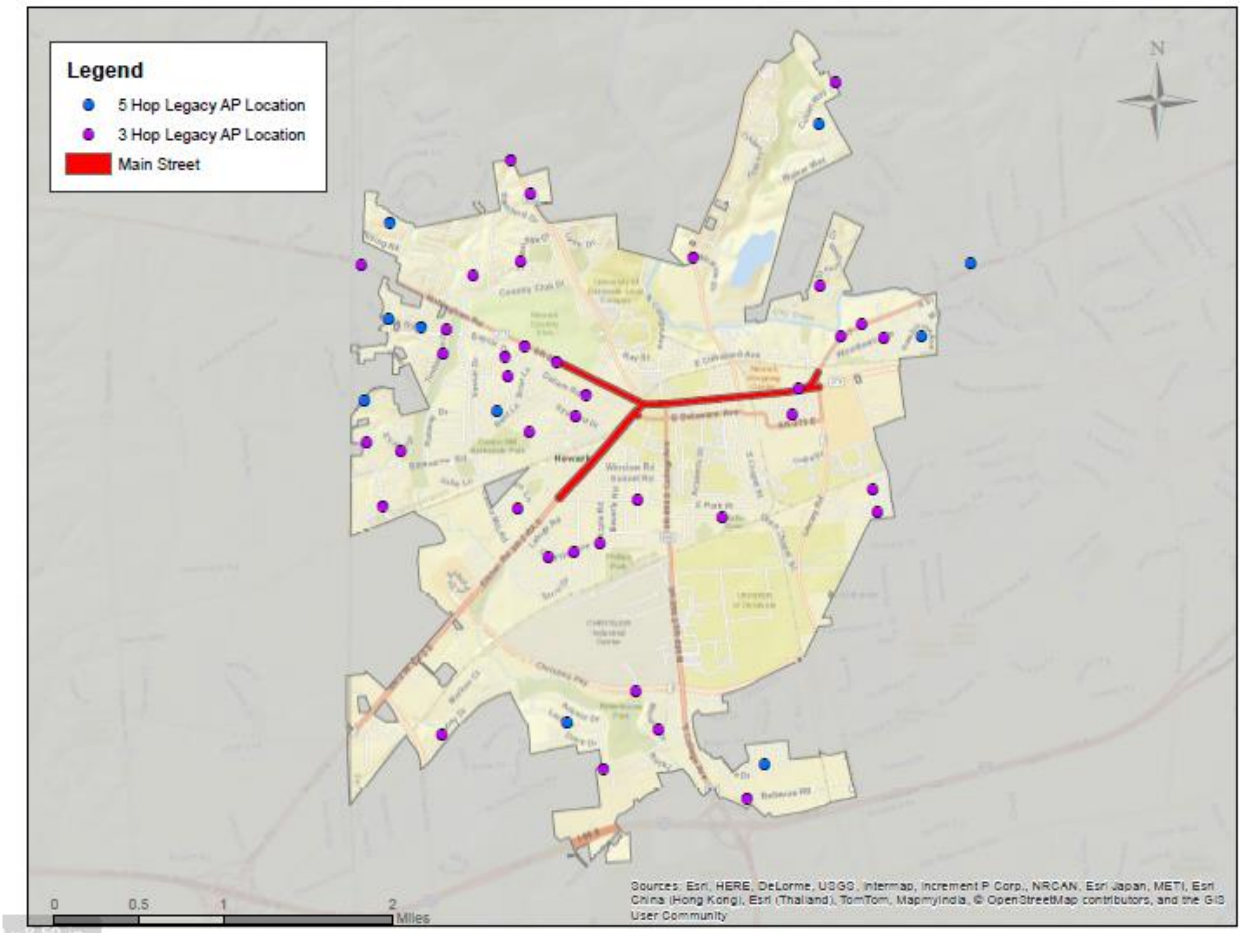
Table 9 identifies the number of APs requiring each number of hops in the current network and as proposed.

Table 9: Number of Hops Needed per Access Point (Current and Proposed)

# Hops	Current # APs	Proposed # APs
0	19	67
1	63	152
2	61	
3	38	
4	24	
5	10	
6	4	
Total	219	219

This approach will significantly improve the performance of any access points that are not directly connected by fiber and add nearly 4 Gbps of aggregate Internet capacity to the system. Figure 16 shows the locations of three- and five-hop APs that would be connected to fiber.

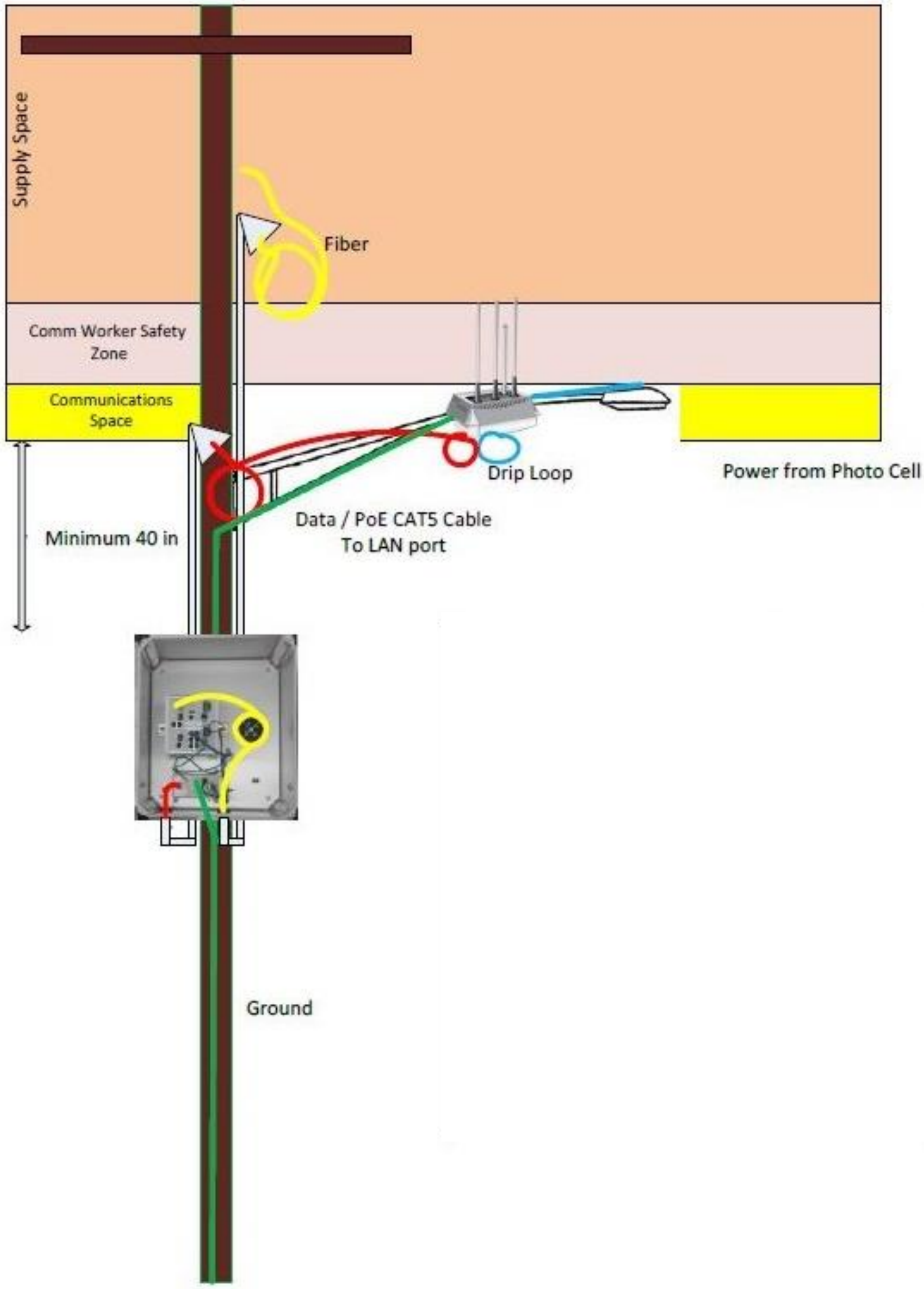
Figure 16: Access Point Locations that Require Additional Fiber Backhaul



4.1.3 Sample Wireless Installation

Although the new APs will not be Tropos equipment (see Section 4.1.2.1), the APs will be mounted in essentially the same way as the City's existing APs. Tropos prepared the following diagram to illustrate a typical installation.

Figure 17: Sample Wi-Fi AP Installation



Source: Tropos

4.2 Expanding Middle-Mile Fiber to Enable Wi-Fi and Serve UD Sites and Business Customers

In addition to supporting expanded public Wi-Fi access, constructing middle-mile fiber would enable the City to directly connect UD and business locations along the Main Street Corridor and elsewhere with fiber.

In order to provide the required capacity, we designed middle-mile fiber to serve the new Main Street wireless APs, as well as middle-mile fiber rings to connect existing APs in other parts of the City. Because the City's parks are spread out across the jurisdiction, the incremental cost to construct rings rather than just designing laterals to individual parks was quite low; the ring design is thus a cost-effective way for the City to achieve far greater broadband coverage.[20]

The backbone comprises 29.5 miles of 288-count fiber—23.7 miles of aerial construction and 5.8 miles of underground construction. Strands are assigned to the APs and to the substation interconnection, but other strands are not allocated and would be available for other uses.

This candidate design maximizes the availability of existing and planned DelDOT fiber in the middle mile (see Section 2.3); it would encompass 3.99 miles of existing DelDOT fiber and 3.5 miles of planned DelDOT fiber in the middle mile. The UD and corporate laterals would not overlap, and thus would require all new construction.

For the aerial portions of the construction, the average span length would be 138.5 feet (assuming an average of 40 pole spans around the City).

The maps below illustrate two phases of construction:

- Middle-mile fiber to connect wireless APs and UD sites
- Lateral fiber to connect UD and corporate sites

[20] In addition, unlike in an FTTP deployment, building middle-mile fiber for businesses, institutions, and wireless connections can be done cost-effectively in the power space in all density areas. This is because the user connections are less numerous, and fiber continues for longer distances without needing to be spliced.

Figure 18: Proposed Middle-Mile Fiber to Connect APs

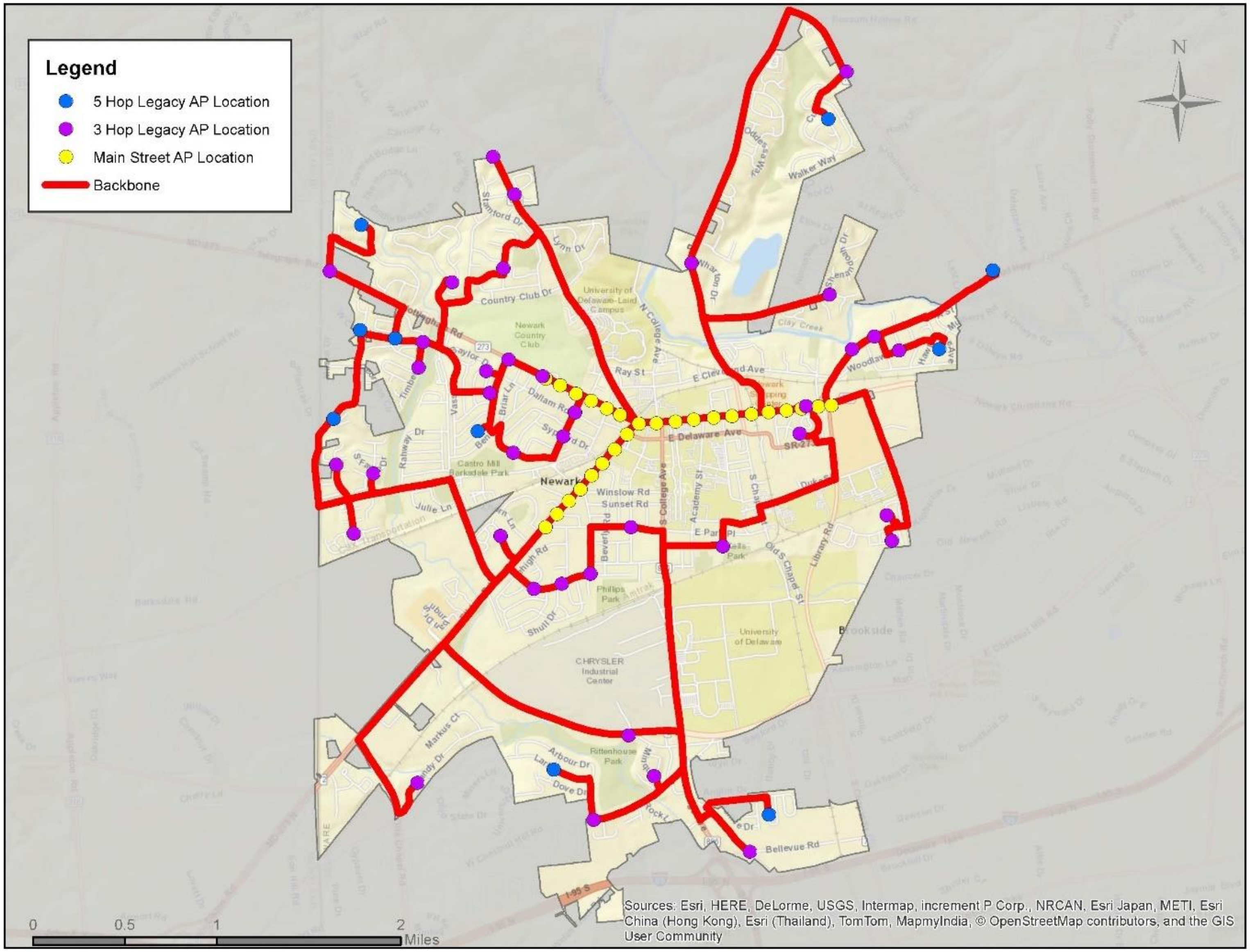
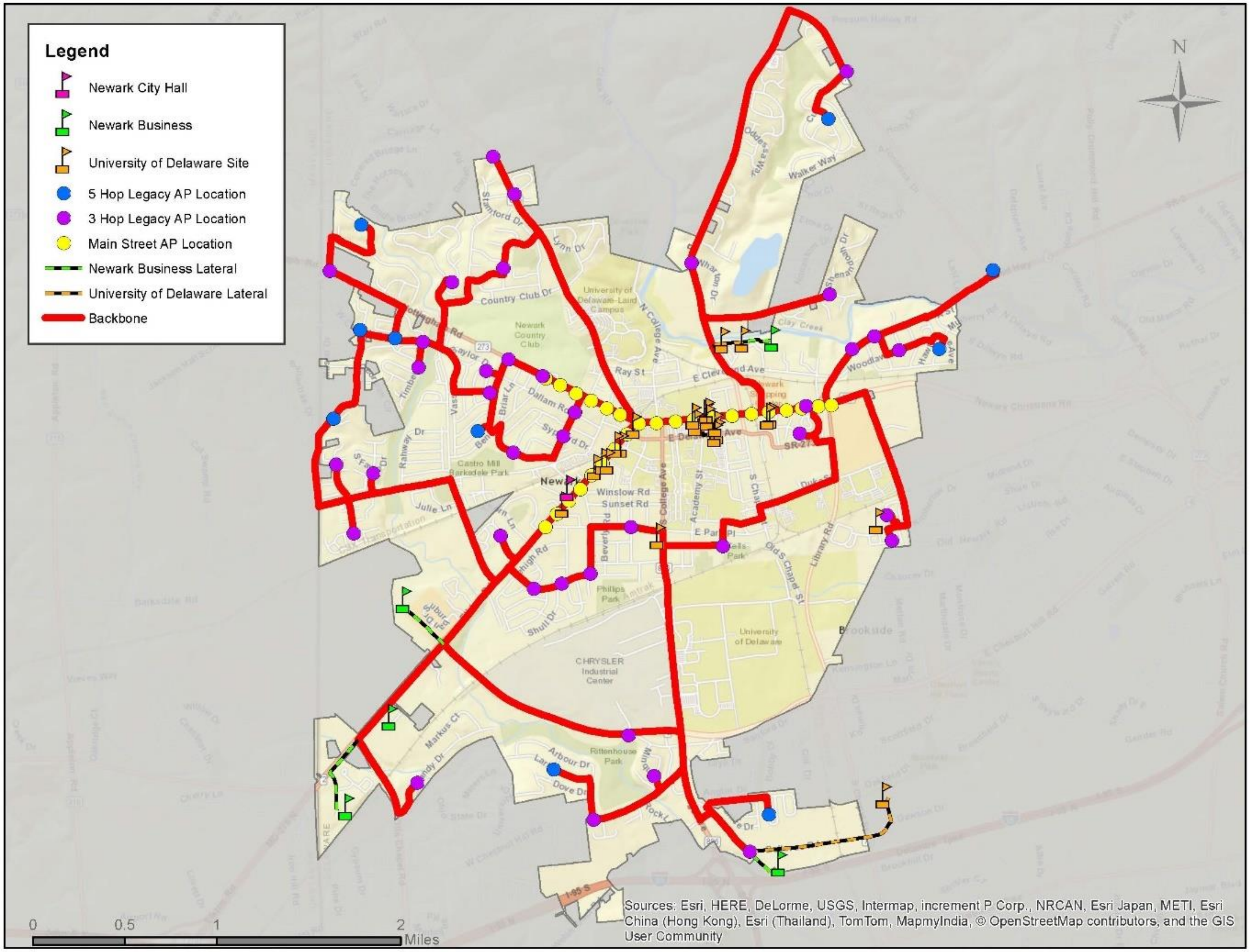


Figure 19: Proposed Middle-Mile Fiber with UD and Corporate Laterals



4.3 Cost Estimate

Based on our analysis, the City would need to install 27 new APs along Main Street, and connect both those APs and 48 other existing APs (three- and five-hop legacy APs) with middle-mile fiber.

The new APs and related equipment are listed in the Bill of Materials in Table 10. Each new AP would comprise four antennas. As noted in Section 4.1.2, we have included five extra APs (for a total of 32) as a contingency, in case the network deployment requires additional coverage (e.g., in the vicinity of a park that does not currently have adequate coverage).

Table 10: Bill of Materials for Wireless Hardware

Description	Quantity	Material	Material Total
Directional antenna and mounting hardware	-	$ 1,000	$ -
Omnidirectional access antenna	128	$ 240	$ 30,720
Power supply	32	$ 300	$ 9,600
Outdoor Wi-Fi APs	32	$ 3,100	$ 99,200
WLAN controller	1	$ 12,000	$ 12,000
Wi-Fi Direct	1	$ 4,000	$ 4,000
AP mounting hardware	32	$ 400	$ 12,800
Fiber to Ethernet media converter/switch	48	$ 400	$ 19,200
Total			$ 187,520

The majority of the project cost is the cost of middle-mile fiber, to connect the APs and for potential government, institutional, and business uses. The estimated total cost to construct 32 miles of fiber backbone and laterals to 22 UD locations and five candidate corporate locations is $3.4 million; of that total, $3.1 million is the backbone fiber, and the remainder is the fiber to connect that backbone to the UD and corporate locations. As noted, collaboration with DelDOT, in obtaining use of both four miles of existing fiber and 3.5 miles of planned fiber, could save the City approximately $750,000 to $1 million out of the $3.1 million backbone cost.

In Table 11, below, we have itemized the fiber construction costs in three phases—the middle-mile “backbone” construction (phase 1), the addition of laterals to connect the few UD sites that were not directly connected by the backbone fiber along Main Street (phase 2), and the addition of laterals to connect the five candidate businesses described in Section 2.4 (phase 3).

Table 11: Estimated Cost for Middle-Mile and Lateral Fiber Construction

Cost Component	Phase 1 Backbone	Phase 2 University Sites	Phase 3 Corporate Sites	Total Estimated Cost
OSP Engineering	$451,000	$20,000	$16,000	$487,000
Quality Control/Quality Assurance	166,000	7,000	6,000	179,000
Standalone General OSP Construction	1,953,706	85,326	71,494	2,110,000
General OSP Construction Cost	1,954,000	85,000	71,000	2,111,000
Special Crossings	440,000	34,000	–	474,000
Backbone and Distribution Plant Splicing	58,000	24,000	5,000	87,000
Backbone Hub, Termination, and Testing	33,000	32,000	7,000	72,000
Total Estimated Cost:	**$3,102,000**	**$202,000**	**$105,000**	**$3,409,000**

5 Financial Analysis

This section presents a financial analysis of the two candidate approaches—an FTTP network deployment, and a middle-mile fiber and Wi-Fi model. Both approaches would require the City to finance upfront capital costs, to make annual principal and interest (P&I) payments, and to cover ongoing operating and equipment replacement expenses.

We found that to maintain a positive cash balance, the FTTP enterprise would require extensive funding by the City (or some other revenue source) on the order of $2.5 million per year, over and above a private partner's likely payments. Absent that annual subsidy, the network would run a large deficit and would not be sustainable. Accordingly, we believe there is considerable risk in that approach. Our analysis is described in Section 5.1.

Our analysis of a free, outdoor citywide Wi-Fi network and the middle-mile fiber needed to support it would require about $671,000 in annual City subsidy (or some other revenue source). Based on our discussions with the City and stakeholders we have not found extensive demand for middle-mile fiber leasing or enterprise services, beyond the current collaboration with UD, so we believe the City cannot count primarily on revenues to offset these costs. Thus, while the annual cost for the Wi-Fi and middle-mile fiber model is considerably lower than the FTTP scenario, the cost would still likely need to be covered by the City—and thus needs to be weighed against the network's benefits to the public and UD, and to meeting the current and future communications needs of the City. Our analysis is provided in Section 5.2.

5.1 FTTP

Potential business models for an FTTP deployment range from a retail model in which the City directly provides fiber service, to a wholesale model in which the City builds an open access network and invites private partners to deliver services over the network, to a model in which the City builds the fiber and enters a partnership with an anchor service provider (the model adopted by Ting and the City of Westminster, Maryland).

Of the various models, the City's staff expressed the most interest in the Westminster model, because it leverages the City's abilities as a utility, while offsetting some of the risk the City would have in implementing a new broadband enterprise.[21] Accordingly, we developed our financial analysis based on that model—including the two-tier fee structure (a fee per passing and a fee per subscriber) incorporated in that partnership.

[21] We note, too, that the City held its own, independent meeting with representatives of Ting, the company that is partnering with the City of Westminster to deliver broadband services over the City's FTTP network.

As we explain in detail below, **building an FTTP network and following the Westminster model in Newark would result in an estimated annual deficit of $2.5 million**[22]—meaning that the City would need to dramatically increase its lessee fee, earn dark fiber lease revenue, or provide an ongoing subsidy to maintain a positive cash flow. We have chosen a subsidy as a placeholder for the annual operating shortfall.

This section presents an overview of the FTTP financial model. We have provided the City with a complete financial model in Excel format; because the Excel spreadsheet can be modified to show the impact of changing assumptions (much as we have done in the scenarios in Section 5.1.4 below), it will be an important tool for the City to use if it negotiates with a private partner.

5.1.1 Revenue

Our analysis assumes the City's private partner will pay two monthly fees, as in the Westminster model: $6 per passing per month and $11 per subscriber per month.[23] 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.

However, **those fees are not sufficient to enable the FTTP enterprise to maintain a positive cash flow. To create a model that maintains positive cash flow, we need to assume the City will subsidize the network—making a $1 million payment in year three and $2.5 million in year four and all subsequent years.** This annual revenue is a critical element in maintaining positive cash flow.

5.1.2 Financing Costs and Operating Expenses

This financial analysis assumes the City will cover all of its capital requirements with general obligation (GO) bonds to maximize the benefits of the City's bond rating. We assume the City's bond rate will be 6 percent, which represents a premium over current non-taxable rates. Because the network will have private users (i.e., the projected corporate customers), the City will not be able to bond at a non-taxable rate.

We expect the City will take four 20-year bonds—one each in years one, two, three, and four—for a total of $30 million in financing. (This is 130 percent of projected capital expenses; the difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment.) The resulting

[22] The key factors influencing this shortfall are Newark's low density of passings per mile and high make-ready costs.

[23] Because operating and maintenance expenses account for approximately 18.8 percent of the City's total annual costs, 18.8 percent of the per-passing and per-subscriber fees should be increased by a CPI each year. It is not appropriate to apply a CPI to the entire per-passing fee because the majority of that fee supports the principal and interest on the debt service (which are fixed costs).

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 81 percent of the City's annual costs in our base case model after the construction period.

We project 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 four 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. 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 12 shows the income statement for years one, five, 10, 15, and 20—again, assuming a $2.5 million annual subsidy from the City.

Table 12: Income Statement

Income Statement	**Year 1**	**Year 5**	**Year 10**	**Year 15**	**Year 20**
a. Revenues					
Connection Fee (net)	$ -	$ -	$ -	$ -	$ -
Per Passing	2,840	568,080	568,080	568,080	568,080
Per Customer (incremental)	1,190	364,720	364,720	364,720	364,720
Upfront Payment	-	-	-	-	-
Backbone Completion Payment	-	-	-	-	-
Hub Completion Payment	-	-	-	-	-
Dark Fiber and Other Leases (net)	-	2,500,000	2,500,000	2,500,000	2,500,000
Avoided Costs (net)	-	-	-	-	-
Total	$ 4,030	$ 3,432,800	$ 3,432,800	$ 3,432,800	$ 3,432,800
c. Operating Costs					
Operation Costs	$ 198,000	$ 355,200	$ 355,200	$ 355,200	$ 355,200
Labor Costs	150,500	336,000	336,000	336,000	336,000
Total	$ 348,500	$ 691,200	$ 691,200	$ 691,200	$ 691,200
d. EBITDA	$ (344,470)	$ 2,741,600	$ 2,741,600	$ 2,741,600	$ 2,741,600
e. Depreciation	345,250	1,468,220	1,080,850	1,080,850	1,080,850
f. Operating Income (EBITDA less Depreciation)	$ (689,720)	$ 1,273,380	$ 1,660,750	$ 1,660,750	$ 1,660,750
g. Non-Operating Income					
Interest Income	$ -	$ 4,050	$ 4,050	$ 4,020	$ 4,000
Interest Expense (10 Year Bond)	-	-	-	-	-
Interest Expense (20 Year Bond)	(504,000)	(1,352,500)	(1,352,500)	(900,590)	(295,840)
Interest Expense (Loan)	-	-	-	-	-
Total	$ (504,000)	$ (1,348,450)	$ (1,348,450)	$ (896,570)	$ (291,840)
h. Net Income (before taxes)	$ (1,193,720)	$ (412,800)	$ 312,300	$ 764,180	$ 1,368,910
i. Facility Taxes	$ -	$ -	$ -	$ -	$ -
j. Net Income	$ (1,193,720)	$ (412,800)	$ 312,300	$ 764,180	$ 1,368,910

Table 13 shows the cash flow statement for years one, five, 10, 15, and 20, including the City's subsidy. The unrestricted cash balance is approximately $83,500 in year one, $811,900 in year 10, and $962,00 in year 15. By year 20, it is approximately $1.1 million.

Table 13: Cash Flow Statement

	Year 1	Year 5	Year 10	Year 15	Year 20
Cash Flow Statement					
a. Net Income	$ (1,193,720)	$ (412,800)	$ 312,300	$ 764,180	$ 1,368,910
b. Cash Outflows					
Debt Service Reserve	$ (420,000)	$ -	$ -	$ -	$ -
Interest Reserve	(1,008,000)	-	-	-	-
Depreciation Reserve	-	(36,710)	(27,020)	(27,020)	(27,020)
Financing	(84,000)	-	-	-	-
Capital Expenditures	(6,460,010)	-	-	-	-
Total	$ (7,972,010)	$ (36,710)	$ (27,020)	$ (27,020)	$ (27,020)
c. Cash Inflows					
Interest Reserve	$ 504,000	$ 84,000	$ -	$ -	$ -
Depreciation Reserve	-	-	-	-	-
Grants (infrastructure)	-	-	-	-	-
10-Year Bond/Loan Proceeds	-	-	-	-	-
20-Year Bond Proceeds	8,400,000	-	-	-	-
Loan Proceeds	-	-	-	-	-
Total	$ 8,904,000	$ 84,000	$ -	$ -	$ -
d. Total Cash Outflows and Inflows	$ 931,990	$ 47,290	$ (27,020)	$ (27,020)	$ (27,020)
e. Non-Cash Expenses - Depreciation	$ 345,250	$ 1,468,220	$ 1,080,850	$ 1,080,850	$ 1,080,850
f. Adjustments					
Proceeds from Additional Cash Flows (10 Year Bond)	$ -	$ -	$ -	$ -	$ -
Proceeds from Additional Cash Flows (20 Year Bond)	$ (8,400,000)	$ -	$ -	$ -	$ -
Proceeds from Additional Cash Flows (Loan)	$ -	$ -	$ -	$ -	$ -
g. Adjusted Available Net Revenue	$ (8,316,480)	$ 1,102,710	$ 1,366,130	$ 1,818,010	$ 2,422,740
h. Principal Payments on Debt					
10 Year Bond Principal	$ -	$ -	$ -	$ -	$ -
20 Year Bond Principal	-	998,440	1,336,130	1,788,040	2,392,790
Loan Principal	-	-	-	-	-
Total	$ -	$ 998,440	$ 1,336,130	$ 1,788,040	$ 2,392,790
j. Cash Balance					
Unrestricted Cash Balance	$ 83,520	$ 686,130	$ 811,920	$ 962,180	$ 1,112,690
Depreciation Reserve	-	104,590	118,670	108,550	98,430
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,500,000	1,500,000	1,500,000	1,500,000
Total Cash Balance	$ 1,007,520	$ 2,290,720	$ 2,430,590	$ 2,570,730	$ 2,711,120

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. This analysis projects that capital additions in year one will total approximately $6.3 million. These costs will total approximately $10.5 million in year two, and $4.2 million in year three. This totals just over $21 million in capital additions for years one through three.

5.1.3 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 other functions. In this model, we assume the City's partner will be responsible for selling services, so the City's financial requirements are limited to expenses related to OSP operations and maintenance, and network administration.

These expanded responsibilities will require the addition of new staff. We assume the City will add a total of two and one-quarter 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, one FTE for fiber plant maintenance and operations, and one-quarter FTE for HR/administrative support. Salaries and benefits are based on estimated market wages, and benefits are estimated at 40 percent of base salary.

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 $12,300 in year one, increase to $24,700 in year two, and increase to $49,400 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:

- Pole attachment fees are $25 per year per pole.
- Insurance is estimated to be $25,000 in year one and $50,000 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 $50,000 in year one, $25,000 in year two, and $15,000 from year three on.
- Consulting fees are estimated at $50,000 in year one and $10,000 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 14 lists the City's projected operating expenses for years one, five, 10, 15, and 20.

Table 14: Operating Expenses

	Year 1	Year 5	Year 10	Year 15	Year 20
Operating Expenses					
Insurance	$ 25,000	$ 50,000	$ 50,000	$ 50,000	$ 50,000
Office Expenses	2,400	2,400	2,400	2,400	2,400
Locates & Ticket Processing	12,300	49,400	49,400	49,400	49,400
Contingency	10,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance	31,600	105,200	105,200	105,200	105,200
Legal and Lobby Fees	50,000	15,000	15,000	15,000	15,000
Consulting	50,000	10,000	10,000	10,000	10,000
Education and Training	3,000	6,700	6,700	6,700	6,700
Pole Attachment Expense	13,700	91,500	91,500	91,500	91,500
Sub-Total	$ 198,000	$ 355,200	$ 355,200	$ 355,200	$ 355,200
Labor Expenses	$ 150,500	$ 336,000	$ 336,000	$ 336,000	$ 336,000
Sub-Total	$ 150,500	$ 336,000	$ 336,000	$ 336,000	$ 336,000
Total Expenses	$ 348,500	$ 691,200	$ 691,200	$ 691,200	$ 691,200
Principal and Interest	$ -	$ (36,710)	$ (27,020)	$ (27,020)	$ (27,020)
Facility Taxes	-	-	-	-	-
Sub-Total	$ -	$ (36,710)	$ (27,020)	$ (27,020)	$ (27,020)
Total Expenses, P&I, and Taxes	$ 348,500	$ 654,490	$ 664,180	$ 664,180	$ 664,180

Our “flat-model” analysis does not include inflation and salary cost increases 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 the City will apply an inflation factor, typically based on a Consumer Price Index (CPI), to its projected operating expenses during negotiations with a private partner.

5.1.4 Sensitivity Scenarios

This section demonstrates the sensitivity of the financial projections to changes in various assumptions. For comparison, the financial analysis for the “base case” scenario (i.e., the scenario established by our basic set of assumptions, including a private partner achieving a 35 percent take rate[24] and paying the City a per-passing fee of $6 per month, and a per-subscriber fee of $11 per month), is as follows:

[24] A 35 percent take rate is typical of environments where a new provider joins the telephone and cable provider in a city.

Table 15: Base Case Financial Analysis with 35 Percent Take Rate

Income Statement	1	5	10	15	20
Total Revenues	$ 4,030	$ 3,432,800	$ 3,432,800	$ 3,432,800	$ 3,432,800
Total Cash Expenses	(348,500)	(691,200)	(691,200)	(691,200)	(691,200)
Depreciation	(345,250)	(1,468,220)	(1,080,850)	(1,080,850)	(1,080,850)
Interest Expense	(504,000)	(1,686,180)	(1,348,450)	(896,570)	(291,840)
Taxes	-	-	-	-	-
Net Income	$ (1,193,720)	$ (412,800)	$ 312,300	$ 764,180	$ 1,368,910
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 83,520	$ 686,130	$ 811,920	$ 962,180	$ 1,112,690
Depreciation Reserve	-	104,590	118,670	108,550	98,430
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,500,000	1,500,000	1,500,000	1,500,000
Total Cash Balance	$ 1,007,520	$ 2,290,720	$ 2,430,590	$ 2,570,730	$ 2,711,120

As we note in Section 5.1.1, this analysis indicates a financially sustainable enterprise only with the City's $2.5 million annual subsidy; absent that subsidy, the network would have a large deficit.

5.1.4.1 Eliminating the City's Annual Subsidy

Eliminating the City's subsidy would create a large deficit. Within five years, the network's deficit would be $3.7 million; by year 20, the deficit would be $40.8 million.

Table 16: Eliminating Dark Fiber Revenue Creates a Large Deficit

Income Statement	1	5	10	15	20
Total Revenues	$ 4,030	$ 932,800	$ 932,800	$ 932,800	$ 932,800
Total Cash Expenses	(348,500)	(691,200)	(691,200)	(691,200)	(691,200)
Depreciation	(345,250)	(1,468,220)	(1,080,850)	(1,080,850)	(1,080,850)
Interest Expense	(504,000)	(1,686,180)	(1,348,450)	(896,570)	(291,840)
Taxes	-	-	-	-	-
Net Income	$ (1,193,720)	$ (2,912,800)	$ (2,187,700)	$ (1,735,820)	$ (1,131,090)
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 83,520	$ (5,313,870)	$ (17,688,080)	$ (30,037,820)	$ (42,387,310)
Depreciation Reserve	-	104,590	118,670	108,550	98,430
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,500,000	1,500,000	1,500,000	1,500,000
Total Cash Balance	$ 1,007,520	$ (3,709,280)	$ (16,069,410)	$ (28,429,270)	$ (40,788,880)

5.1.4.2 Make Drop Costs the Responsibility of a Private Partner

Our financial analysis assumes the City constructs and owns the FTTP infrastructure up to a demarcation point at the optical tap near each residence and business, and installs fiber drops to subscribers. The City's partner would then add network electronics and supply customer premises equipment (CPE)—as well as taking responsibility for network sales, marketing, and operations.[25]

[25] 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 our analysis. We have chosen this key parameter because this approach represents the City's stated preference for a potential partnership model. City ownership of the drops increases the City's control, although it also significantly increase the City's costs.

Because the expense of constructing fiber drops to subscribers is such a significant portion of network deployment costs, transferring that responsibility to the private partner that serves end users would reduce the City's borrowing requirements. Assuming the base case's per-passing and per-subscriber fees—and the City's $2.5 million subsidy—this scenario results in a positive cash flow with $27.6 million in borrowing.

Table 17: Requiring Partner to Pay for Drop Costs Decreases City's Required Borrowing

Income Statement	1	5	10	15	20
Total Revenues	$ 4,030	$ 3,432,800	$ 3,432,800	$ 3,432,800	$ 3,432,800
Total Cash Expenses	(348,500)	(691,200)	(691,200)	(691,200)	(691,200)
Depreciation	(343,990)	(1,080,850)	(1,080,850)	(1,080,850)	(1,080,850)
Interest Expense	(504,000)	(1,544,890)	(1,232,050)	(813,400)	(253,140)
Taxes	-	-	-	-	-
Net Income	$ (1,192,460)	$ 115,860	$ 428,700	$ 847,350	$ 1,407,610
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 89,830	$ 864,900	$ 2,087,580	$ 3,311,210	$ 4,535,080
Depreciation Reserve	-	81,060	71,660	61,540	51,420
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,380,000	1,380,000	1,380,000	1,380,000
Total Cash Balance	$ 1,013,830	$ 2,325,960	$ 3,539,240	$ 4,752,750	$ 5,966,500

5.1.4.3 Increasing the Per-Passing and Per-Subscriber Fees

If the City were to negotiate dramatically higher per-passing and per-subscriber fees, it would not need to subsidize the network. The increase would take the per-passing fee to $22 and the per-subscriber fee to $42.

Table 18: Increasing the Per-Passing and Per-Subscriber Fees Eliminates the Need for Subsidy

Income Statement	1	5	10	15	20
Total Revenues	$ 14,950	$ 3,475,510	$ 3,475,510	$ 3,475,510	$ 3,475,510
Total Cash Expenses	(348,500)	(691,200)	(691,200)	(691,200)	(691,200)
Depreciation	(345,250)	(1,468,220)	(1,080,850)	(1,080,850)	(1,080,850)
Interest Expense	(504,000)	(1,686,180)	(1,348,450)	(896,570)	(291,840)
Taxes	-	-	-	-	-
Net Income	$ (1,182,800)	$ (370,090)	$ 355,010	$ 806,890	$ 1,411,620
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 94,440	$ 1,582,500	$ 1,921,840	$ 2,285,650	$ 2,649,710
Depreciation Reserve	-	104,590	118,670	108,550	98,430
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,500,000	1,500,000	1,500,000	1,500,000
Total Cash Balance	$ 1,018,440	$ 3,187,090	$ 3,540,510	$ 3,894,200	$ 4,248,140

The City could achieve the same end result—positive cash flow over time—if it were to raise the fees by slightly less ($18 per passing, $37 per subscriber), but increase its bond term to 30 years.

Table 19: Increasing the Per-Passing and Per-Subscriber Fees Eliminates the Need for Subsidy

Income Statement	1	5	10	15	20
Total Revenues	$ 12,520	$ 2,931,010	$ 2,931,010	$ 2,931,010	$ 2,931,010
Total Cash Expenses	(348,500)	(691,200)	(691,200)	(691,200)	(691,200)
Depreciation	(345,250)	(1,468,220)	(1,080,850)	(1,080,850)	(1,080,850)
Interest Expense	(504,000)	(1,745,650)	(1,590,790)	(1,383,650)	(1,106,420)
Taxes	-	-	-	-	-
Net Income	$ (1,185,230)	$ (974,060)	$ (431,830)	$ (224,690)	$ 52,540
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 92,010	$ 1,527,350	$ 1,550,440	$ 1,598,000	$ 1,645,810
Depreciation Reserve	-	104,590	118,670	108,550	98,430
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,500,000	1,500,000	1,500,000	1,500,000
Total Cash Balance	$ 1,016,010	$ 3,131,940	$ 3,169,110	$ 3,206,550	$ 3,244,240

5.1.4.4 *Reducing Operating Expenses by 25 Percent*

Because the City will be borrowing to cover not just 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 dark fiber lease revenue. However, the impact is not linear. Decreasing operating expenses by 25 percent would only decrease the necessary annual subsidy (starting in year four) by $200,000, to $2.3 million.

Table 20: Decreasing the City's Operating Expenses by 25 Percent Reduces the Necessary Subsidy

Income Statement	1	5	10	15	20
Total Revenues	$ 4,030	$ 3,232,800	$ 3,232,800	$ 3,232,800	$ 3,232,800
Total Cash Expenses	(261,380)	(518,400)	(518,400)	(518,400)	(518,400)
Depreciation	(345,250)	(1,468,220)	(1,080,850)	(1,080,850)	(1,080,850)
Interest Expense	(504,000)	(1,686,180)	(1,348,450)	(896,570)	(291,840)
Taxes	-	-	-	-	-
Net Income	$ (1,106,600)	$ (440,000)	$ 285,100	$ 736,980	$ 1,341,710
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 170,640	$ 1,042,920	$ 1,032,710	$ 1,046,970	$ 1,061,480
Depreciation Reserve	-	104,590	118,670	108,550	98,430
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,500,000	1,500,000	1,500,000	1,500,000
Total Cash Balance	$ 1,094,640	$ 2,647,510	$ 2,651,380	$ 2,655,520	$ 2,659,910

5.1.4.5 *Increasing the Network's Take Rate*

In the scenarios below, we have assumed the City's FTTP infrastructure would achieve a much higher (and generally unrealistic) take rate of either 50 percent or 100 percent of all passings. In both cases, assuming that the per-passing and per-subscriber fees remain constant, the City would require less annual subsidy starting in year four—$75,000 less with a 50 percent take rate, or $275,000 less with a 100 percent take rate. Put another way, though, this means that even with a 100 percent take rate, the City would still need $2.5 million in annual subsidy to maintain a positive cash flow.

Table 21: Increasing Take Rate to 50 Percent Reduces the Necessary Subsidy

Income Statement	1	5	10	15	20
Total Revenues	$ 4,030	$ 3,513,950	$ 3,513,950	$ 3,513,950	$ 3,513,950
Total Cash Expenses	(348,500)	(691,200)	(691,200)	(691,200)	(691,200)
Depreciation	(345,250)	(1,634,080)	(1,080,850)	(1,080,850)	(1,080,850)
Interest Expense	(504,000)	(1,752,020)	(1,403,240)	(936,620)	(312,140)
Taxes	-	-	-	-	-
Net Income	$ (1,193,720)	$ (563,350)	$ 338,660	$ 805,280	$ 1,429,760
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 83,520	$ 880,760	$ 907,880	$ 971,940	$ 1,036,250
Depreciation Reserve	-	112,870	139,390	129,270	119,150
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,555,000	1,555,000	1,555,000	1,555,000
Total Cash Balance	$ 1,007,520	$ 2,548,630	$ 2,602,270	$ 2,656,210	$ 2,710,400

Table 22: Increasing Take Rate to 100 Percent Reduces the Necessary Subsidy

Income Statement	1	5	10	15	20
Total Revenues	$ 4,030	$ 3,834,560	$ 3,834,560	$ 3,834,560	$ 3,834,560
Total Cash Expenses	(348,500)	(691,200)	(691,200)	(691,200)	(691,200)
Depreciation	(345,250)	(2,187,030)	(1,080,850)	(1,080,850)	(1,080,850)
Interest Expense	(504,000)	(1,967,500)	(1,582,560)	(1,067,660)	(378,600)
Taxes	-	-	-	-	-
Net Income	$ (1,193,720)	$ (1,011,170)	$ 479,950	$ 994,850	$ 1,683,910
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$ 83,520	$ 1,576,480	$ 1,554,980	$ 1,612,010	$ 1,669,280
Depreciation Reserve	-	140,530	208,520	198,400	188,280
Interest Reserve	504,000	-	-	-	-
Debt Service Reserve	420,000	1,735,000	1,735,000	1,735,000	1,735,000
Total Cash Balance	$ 1,007,520	$ 3,452,010	$ 3,498,500	$ 3,545,410	$ 3,592,560

5.2 Middle-Mile Fiber and Wi-Fi

Our financial analysis is based on the City creating an enterprise to build and operate the middle-mile fiber and Wi-Fi system. Financing would come from a combination of bond proceeds and an internal loan.

As with our analysis of a potential FTTP deployment, the financial analysis presented here represents a minimum requirement for the City of Newark to maintain positive cash flow each year. This business model does not include revenue from selling wireless service (i.e., if the City decides to offer free public Wi-Fi), but we do include potential dark fiber lease revenue.

Based on the apparent lack of interest in dark fiber among the local business community, we recognize that assumptions about dark fiber lease revenue are optimistic unless UD were to lease a significant portion of the fiber. That said, adding excess fiber during the middle-mile construction would require relatively little incremental investment, so we believe having a fiber count of 288 may be a low-risk strategy that could have benefit for City and City utility use in the future.

We have included the lease revenue required to cover debt service and operational expenses (including a reserve fund for wireless and test equipment refreshes) in order to maintain positive cash flow each year (unrestricted cash balance). That same level of revenue could be replaced with a City subsidy, grant funding, or some other source of funding to achieve the same end result.

This section presents an overview of the financial model; we have provided the City with a complete financial model in Excel format. The Excel spreadsheets can be manipulated to show the impact of changing assumptions.

5.2.1 Financing Costs and Operating Expenses

This financial analysis assumes the City will cover its capital requirements with a combination of a $3.4 million general obligation (GO) bond and a $1 million internal loan. This financing exceeds the projected capital expenses; the difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment.

We assume the City's bond rate will be 4.5 percent over a 20-year term, and the internal loan will be at 3 percent over 10 years. The resulting principal and interest (P&I) payments will be the major factor in determining the City's long-term financial requirements.

We project 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 both the bond and the loan will start in year two.

The model assumes a straight-line depreciation of assets, and that the fiber plant will have a 20-year life span. Wireless APs and the fiber management software would be replaced after seven years, while the test equipment would be depreciated over five years. The model plans for an annual $46,000 contribution to a depreciation reserve account starting in year two to fund future replacements and upgrades.

5.2.2 Operating and Maintenance Expenses

Deploying and maintaining fiber and wireless APs will require the addition of new staff. We assume the City will add a total of slightly more than one full-time-equivalent (FTE) positions within the first three years, and will then maintain that level of staffing. Our assumptions include 0.75 FTE for a network engineer, 0.20 FTE for fiber allocation management, and 0.10 FTE for HR/administrative support. Salaries and benefits are based on estimated market wages, and benefits are estimated at 35 percent of base salary.

Additional key operating and maintenance assumptions include the following:

- DIA is estimated to increase over the City's existing costs by $9,000 in year one, and $18,000 in all subsequent years.
- Fiber locates are estimated at $2,600 in year one and $5,200 in subsequent years.
- Pole attachment fees are $24 per year per pole (i.e., the City would pay Newark Electric).
- Contingency expenses are estimated at $5,000 per year.
- Legal and consulting fees are estimated to be $10,000 in years one and two, decreasing to $4,000 annually from year three on.

5.2.3 Revenue

The model requires a certain amount of annual revenue to maintain positive cash flow over time. Debt service alone will require $399,000 in annual revenue; including operating expenses, the City will need about $671,200 in annual revenues to maintain positive cash flow.

The revenue requirement would be somewhat lower if the City were to identify a no-interest source of funding to replace the $1 million internal loan. If the City's budget were to reflect the value of benefits delivered by the network, that accounting would also enable the City to lower its revenue requirements.

Given its intent to offer free public Wi-Fi service, the primary potential revenue source available to the City would be dark fiber lease fees. We calculated the required dark fiber lease revenue at an average of $75 per month per strand per mile.[26]

Based on that pricing, the City would need to lease 672 strand miles of fiber to sustain the enterprise. (Recognizing that developing this amount of leases would require an extended sales period, we assume that the leases are established over time—with a cumulative total of 280 miles in year 1, 560 miles in year 2, and 672 miles in year 3.)

5.2.4 Financial Projections

The income statement and cash flow projection in the following tables assume all capital, operating, and interest expenses—as well as the offsetting revenue amounts—described above.

[26] We also included projected revenue for network connections and splices over the first four years of network deployment and operations. We estimate that this annual revenue will range from $13,700 to $19,200 in those years.

Table 23: Middle-Mile Fiber and Wi-Fi Income Statement

Year	1	3	5	10
a. Revenues				
Dark Fiber IRU Payments	-	-	-	-
Network Connections and Splices (Dark Fiber)	13,700	19,200	-	-
Dark Fiber Maintenance and Lease Fees - Plus Lateral Fees	-	671,200	671,200	671,200
Total	$ 13,700	$ 690,400	$ 671,200	$ 671,200
b. Operating Expenses - Cash (not including taxes in line h)				
Operating & Maintenance Expenses	$ 40,300	$ 88,100	$ 68,900	$ 68,900
Operating Expenses - Training, Attachments, Utilities	22,300	23,600	23,600	23,600
Economic Development Credits	-	-	-	-
Salaries	59,000	125,000	127,000	133,000
Total	$ 121,600	$ 236,700	$ 219,500	$ 225,500
c. Revenues less Cash Operating Expenses (a-b)	$ (107,900)	$ 453,700	$ 451,700	$ 445,700
d. Operating Expenses - Non-Cash				
Depreciation	$ 162,300	$ 163,300	$ 163,300	$ 164,600
e. Operating Income (d-c)	$ (270,200)	$ 290,400	$ 288,400	$ 281,100
f. Non-Operating Income				
Interest Income	$ -	$ -	$ -	$ -
Investment Income	-	-	-	-
Interest Expense (Short-Term)	-	-	-	-
Interest Expense (Long-Term))	(153,410)	(148,130)	(136,850)	(103,890)
Interest Expense (Internal)	(30,000)	(27,050)	(20,870)	(3,740)
Total	$ (183,410)	$ (175,180)	$ (157,720)	$ (107,630)
g. Net Income	$ (453,610)	$ 115,220	$ 130,680	$ 173,470
h. Taxes	$ -	$ -	$ -	$ -
i. Net Income After Fees & In Lieu Taxes	$ (453,610)	$ 115,220	$ 130,680	$ 173,470

Table 24: Middle-Mile Fiber and Wi-Fi Cash Flow Statement

	1	3	5	10
Total Revenues	$ 13,700	$ 690,400	$ 671,200	$ 671,200
Total Cash Expenses	(121,600)	(236,700)	(219,500)	(225,500)
Depreciation	(162,300)	(163,300)	(163,300)	(164,600)
Interest Expense	(183,410)	(175,180)	(157,720)	(107,630)
Net Income	$ (453,610)	$ 115,220	$ 130,680	$ 173,470
Unrestricted Cash Balance	$ 29,710	$ 88,960	$ 103,100	$ 116,910
Depreciation Operating Reserve	-	92,000	184,000	77,000
Debt Service Reserve	170,450	170,450	170,450	170,450
Total Cash Balance	$ 200,160	$ 351,410	$ 457,550	$ 364,360

6 Potential Benefits of Middle-Mile Fiber and Wi-Fi

If it is within the City's budget (both in terms of upfront capital expenses and ongoing operating expenses), deploying a middle-mile fiber and wireless expansion project would enable the City to consider offering free Wi-Fi along Main Street and in public parks. The candidate citywide Wi-Fi model we describe in Section 3.1 might also be the first step toward delivering wide-ranging additional benefits, including improved public safety communications and the ability to support "smart city" innovations. It is important to note, however, that this infrastructure is only the first step, and there would be capital and operational costs for each smart city system.

The Wi-Fi network is a possible solution for mobile broadband communications to public safety vehicles. Within the coverage area of the system, the public safety vehicles could connect to the network and receive potentially higher speed communications than over the carrier cellular network. The City could use the 4.9 GHz spectrum designed for public safety, Wi-Fi like communications, creating a dedicated secure private wireless network within the Wi-Fi network, decreasing the utilization of the carrier network and providing a wireless network that is end-to-end under the City's control.

Solar-powered "smart" trash-cans already alert City workers when they are full, saving staff-time and resources in public trash collection. In the connected City of the future, sensors will also automatically coordinate traffic lights to shift traffic away from areas of congestion and reduce carbon emissions. And ambulance equipment will automatically share data with emergency room doctors from the field—even as devices in the ambulance communicate with traffic lights to speed and clear traffic between emergency locations and hospitals.

All these innovations will be enabled by the City's own communications network and by the "Internet of Things," the rapidly developing host of innovations designed to change and improve how government operates—resulting in "data-driven systems for transport, waste management, law enforcement, and energy use to make them more efficient and improve the lives of citizens."[27]

With a citywide Wi-Fi network, Newark could potentially position itself for future Smart City innovation—with sensors embedded throughout City infrastructure to enable City agencies to collect and analyze countless streams of data.

Those data streams will range from the mundane—parking meter malfunctions—to the critical—pollution and chemical spill alerts. They will allow the City to make data-driven decisions about

[27] Bernard Marr, "How Big Data And The Internet Of Things Create Smarter Cities," *Forbes*, May 19, 2015, http://www.forbes.com/sites/bernardmarr/2015/05/19/how-big-data-and-the-internet-of-things-create-smarter-cities/

future initiatives—big data sets about traffic patterns, for example, can inform policy on congestion mitigation; big data regarding ambulance delays can enable new technologies that reduce traffic in real time on routes between accident locations and hospitals.

These applications are possible in the near term:

In **traffic management**, broadband-enabled sensors will provide a critical tool to help alleviate traffic. Next-generation systems will adjust timing based on real-time traffic data transmitted to the signals via field sensors, radio frequency ID readers, and cameras—enabling the City to eliminate choke points and reduce congestion and carbon emissions.

In **weather emergencies**, road-weather information systems will enable City officials to anticipate and adapt to changing weather conditions. Monitors will provide data on friction and basic weather details, such as temperature and humidity. Monitors will communicate with plow trucks to help the City make more informed decisions about when to plow or salt the roadways.[28]

In **health care**, communications will further enable hospitals to determine treatment before patients even arrive. First responders and emergency room doctors will access HIPAA releases and begin medical treatment. Ambulances will automatically share data with E.R. doctors during transit. And remote video links will enable doctors to direct treatment by EMTs in the ambulances.

In **environment protection and public works**, data sensors will detect gas and water leaks, allow utility and City workers to react immediately, reducing risk of explosions, reducing waste and costs, and increasing utility reliability.

In **government operations**, City agencies and workers will connect to each other over City-owned wireless connections. Seamless communications among public facilities will enable City workers and first responders to communicate, train, and learn without the costs of extensive travel.

At the beginning of the 20th century, electric infrastructure made possible the basic but essential service of electric light—and a century of City innovation enabled by electricity lay ahead, including innovations from public water fountains to information technology. In the same way, City communications infrastructure today enables the Smart City—smart trash cans, water leak detectors, and ambulances. And a century of innovation enabled by the new communications capabilities lies ahead, with new applications and capabilities we can't imagine now any more than we could imagine the Internet in the early days of electricity.

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[28] Ben Miller, "Smarter Road Weather Sensor Networks Offer Better Safety, Forecasting," *GovTech*, October 15, 2015, http://www.govtech.com/fs/Smarter-Road-Weather-Sensor-Networks-Offer-Better-Safety-Forecasting.html

Appendix A: Broadband Workshop Presentation

This presentation is attached as a separate PDF file.

Appendix B: Online Survey Results

The community survey the City distributed offers some insight into the potential customer base and market in Newark, but the respondents should not be considered truly representative of a random selection of the population for a number of reasons:

1. A majority (64.4 percent) of respondents were over 55 years of age; 13.6 percent were over 74.

2. Only 81 respondents (13.4 percent) were under 40. This heavy skew in age demographics leaves a large and potentially important portion of the population underrepresented by this survey.[29]

3. The responses to other questions on this survey, such as the percentage of respondents who never user their Internet connection to play video games (50.9 percent) or access school resources (70.8 percent), may be more strongly influenced by age demographic than anything else.

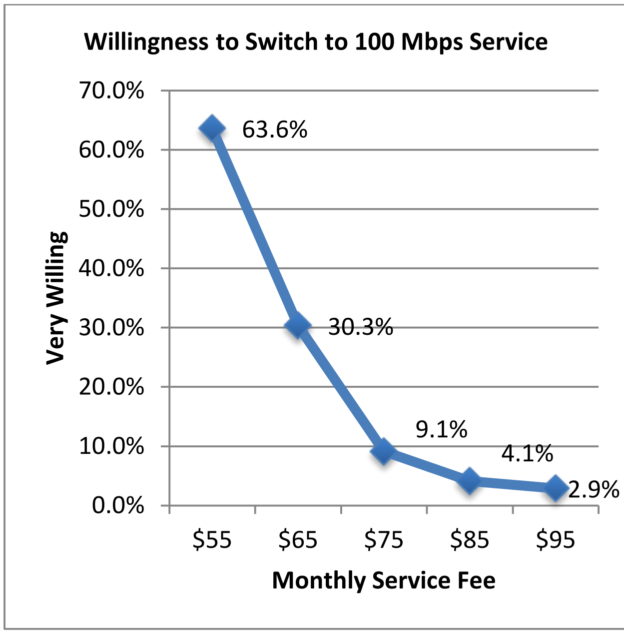
4. Only 17 respondents (2.5 percent) reported that they do not have home Internet service.

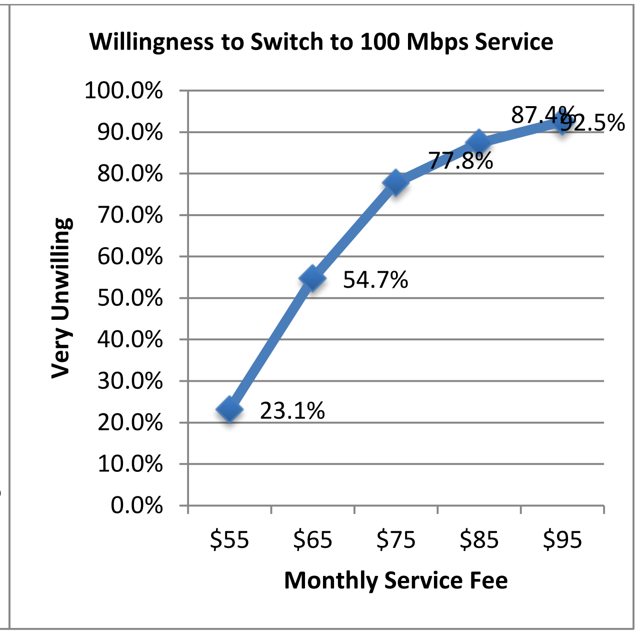
We received 701 survey responses: 546 from the Web survey and 155 from the bill stuffer survey. Of these respondents, 509 (72.6 percent) said they are full-time residents of Newark. Since the survey does not necessarily represent the population, the results have a high margin of error; questions with fewer than 30 responses will have no statistical meaning, as is the case with respondents who do not have home Internet access.

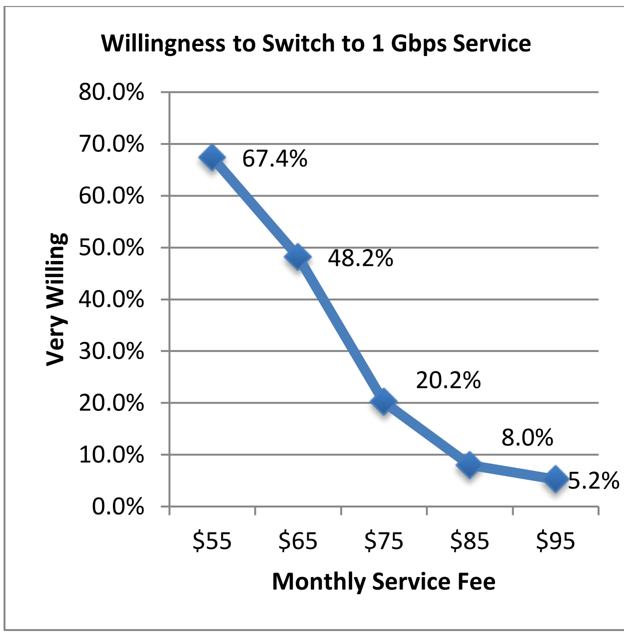
Pricing, Speed, and Satisfaction

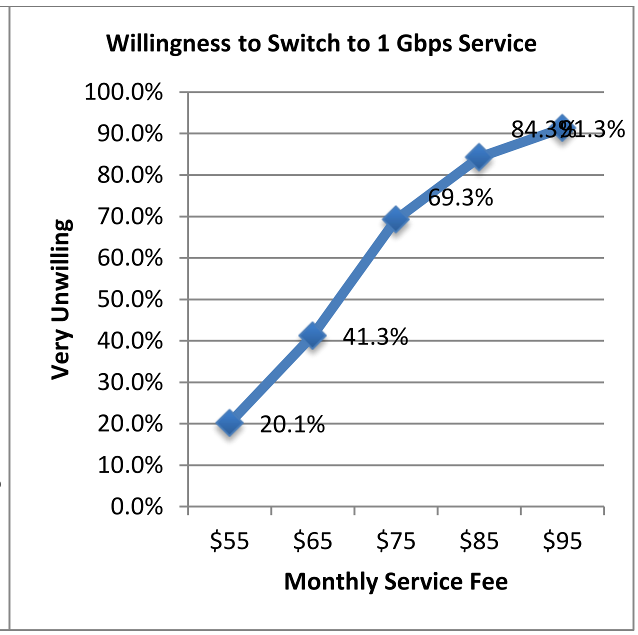
Caveats aside, there are some insights we can take from the survey. 87.6 percent of respondents described the speed of their Internet connection as medium (29.7 percent), fast (46.6 percent), or very fast (11.3 percent). 81.1 percent are either satisfied or very satisfied with the speeds they are getting. This may help explain responses regarding willingness to switch to a 100 Mbps or 1 Gbps service. Although 27.3 percent of respondents said they were already paying over $70 per month for Internet service, only 9.1 percent said they would be willing to switch to 100 Mbps service for $75 per month. 20.1 percent said they would be willing to switch to 1 Gbps service at that price. As seen in the figures below, respondents are more willing to switch to a new service at a lower price and are more willing to switch to a 1 Gbps service then a 100 Mbps service, though not drastically so.

[29] According to U.S. Census data, more than 60 percent of Newark's population is age 34 or under. See: http://www.infoplease.com/us/census/data/delaware/newark/demographic.html

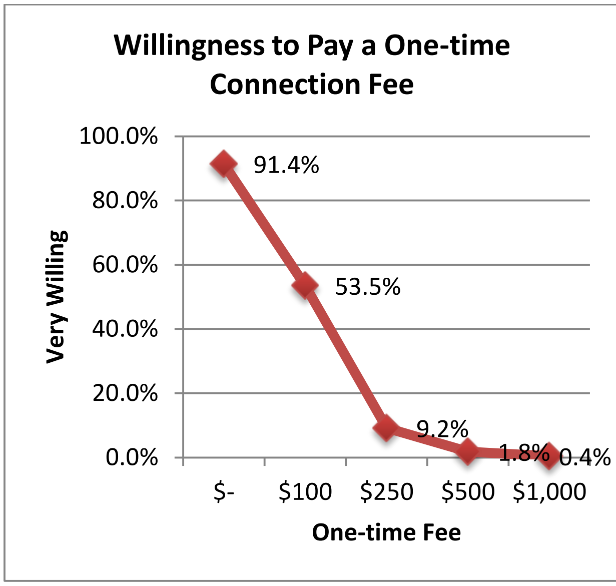


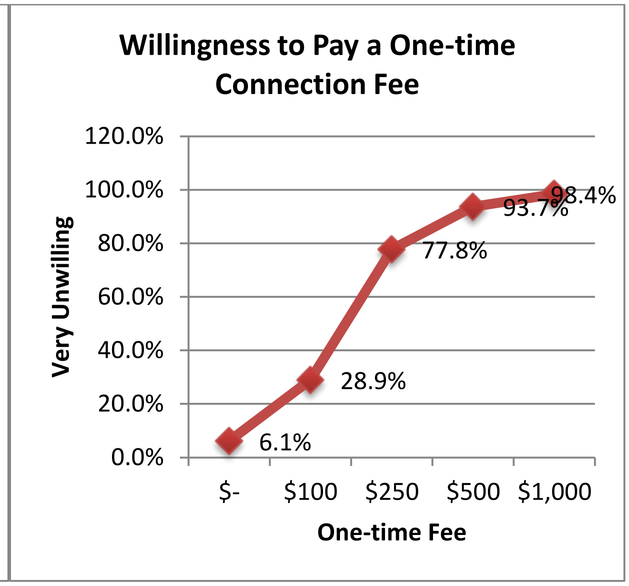






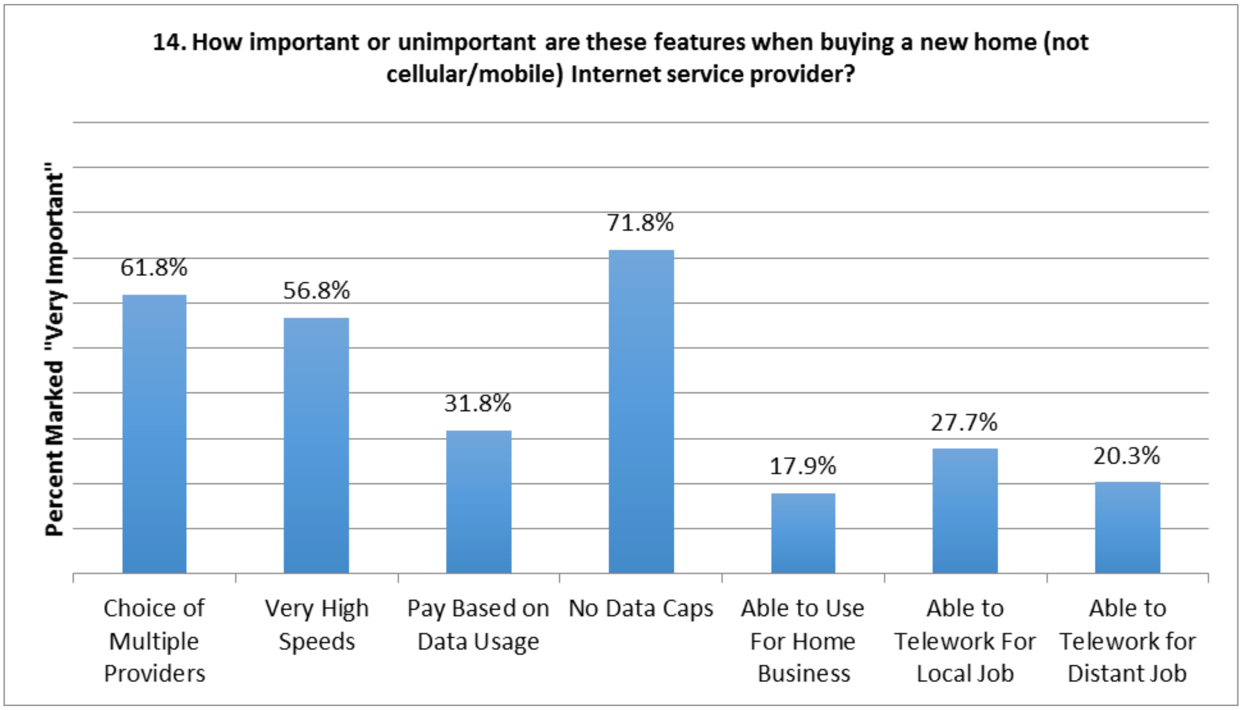
The price of a connection fee also has a major effect on the respondents' willingness to switch services. 53.5 percent said they would be willing to pay a one-time connection fee for 1 Gbps service up to $100. Only 9.2 percent were willing to pay up to $250.



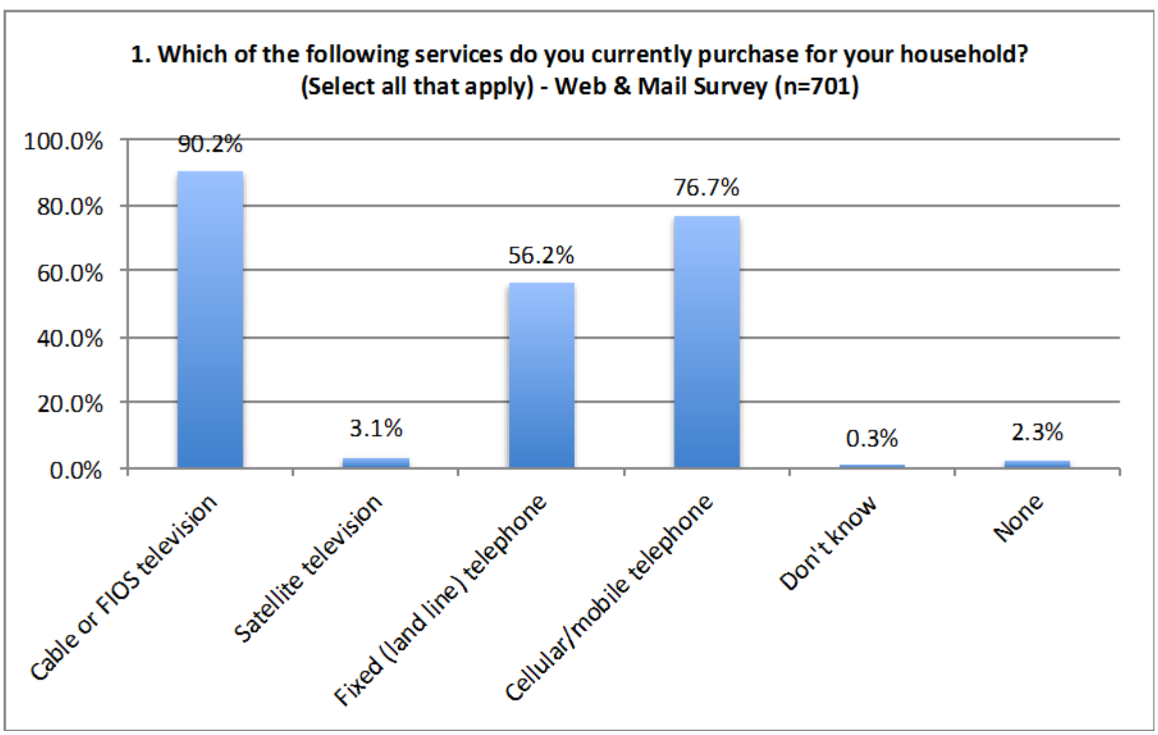


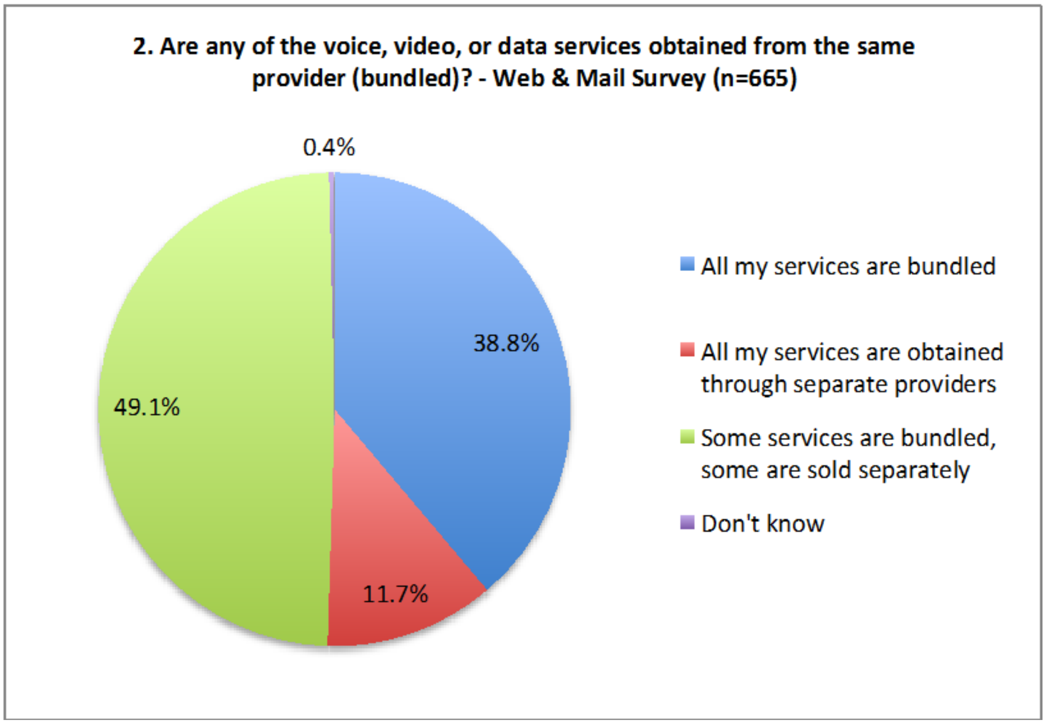
Important Features of Internet Service

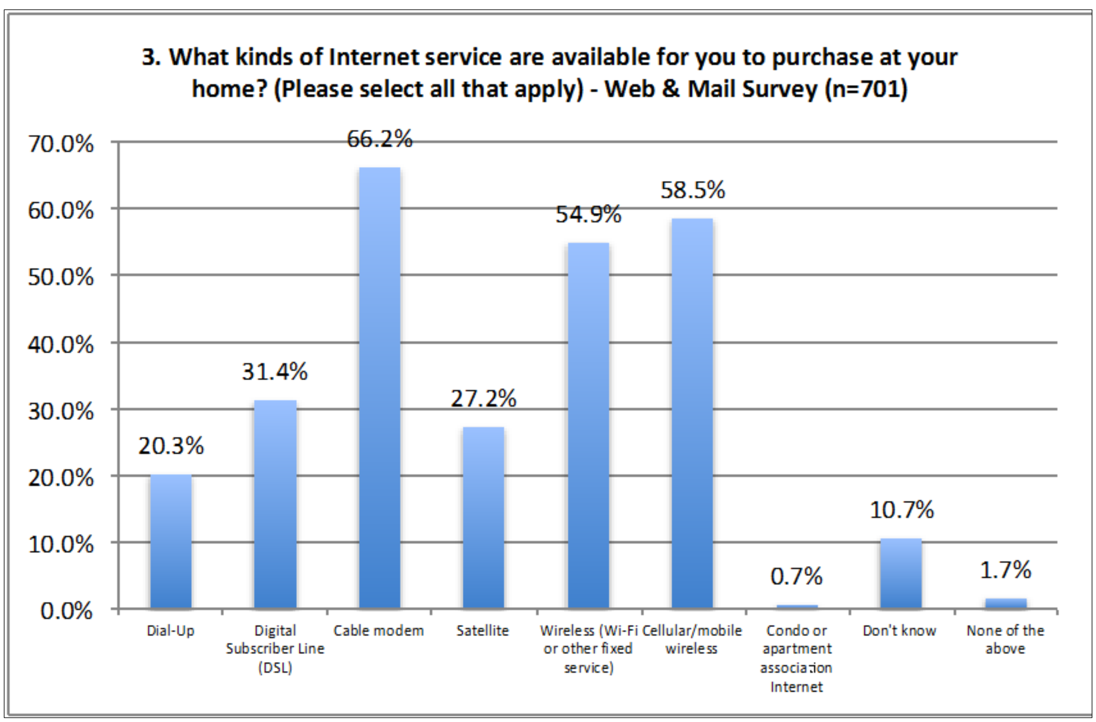
A vast majority of respondents (over 85 percent) indicated that speed, reliability, price, ability to contact their provider, technical support, customer service, and clarity of their bill were all important or very important to them. In contrast, only 45.0 percent said the ability to bundle other services with their Internet service was important. Finally, 71.8 percent of respondents indicated that, when purchasing home Internet service, they considered a lack of data caps very important. Also commonly ranked as very important were the ability to choose between multiple providers and the availability of very high data speeds.

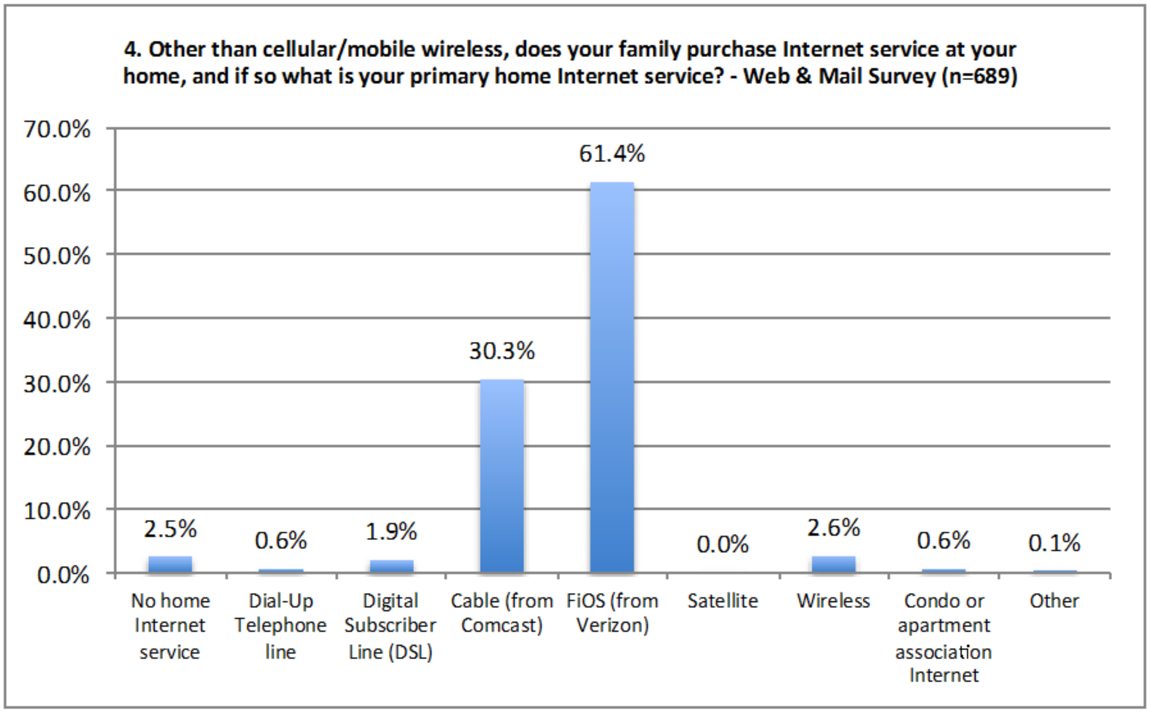


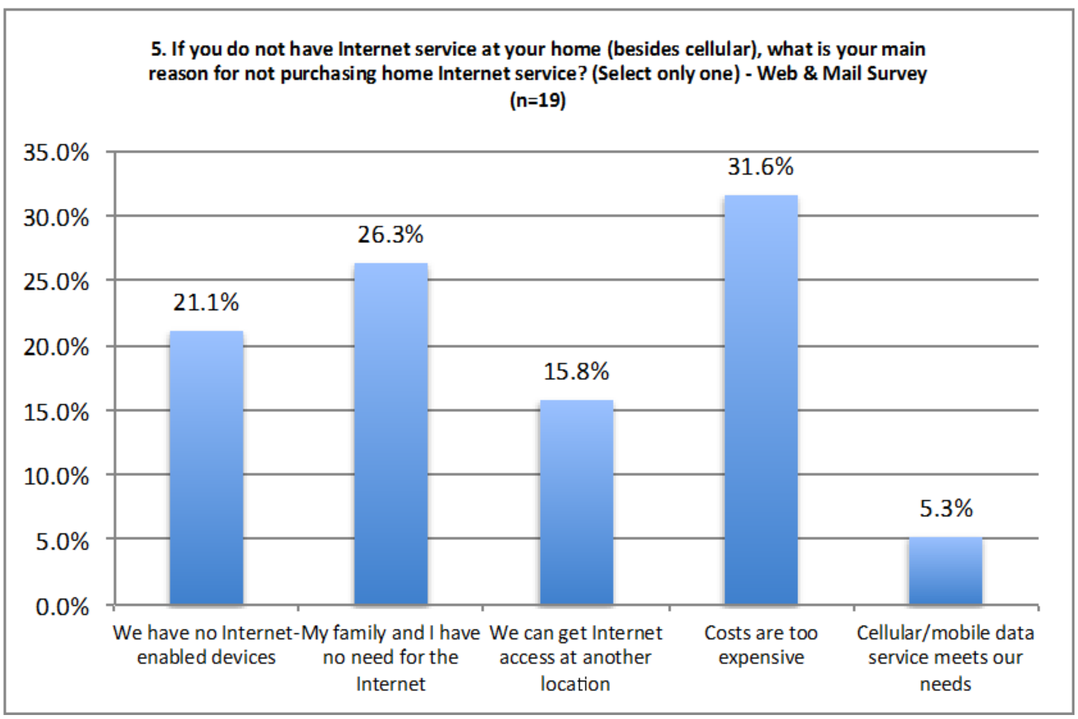
The remaining figures below show the responses to selected survey questions.

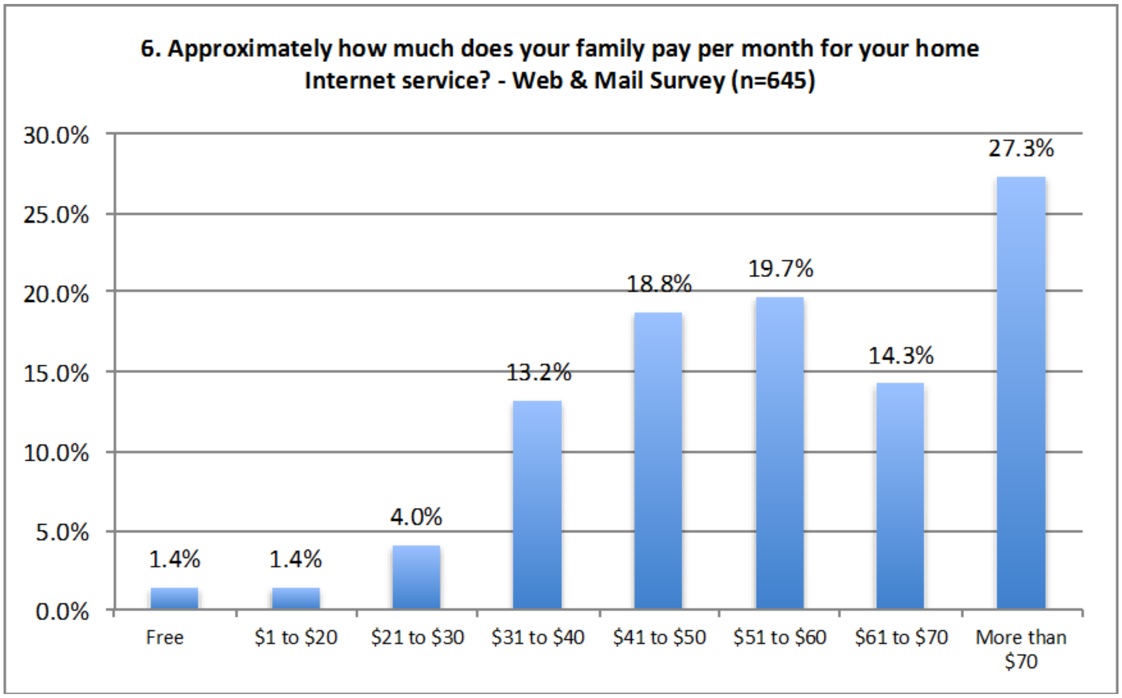


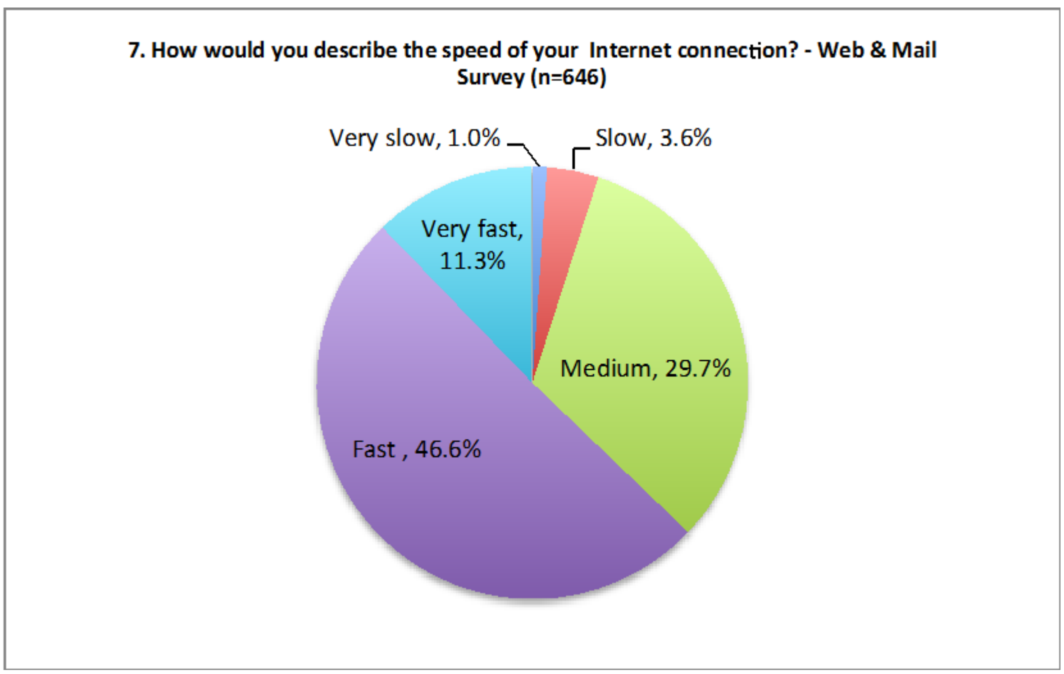

2. Are any of the voice, video, or data services obtained from the same provider (bundled)? - Web & Mail Survey (n=665)
0.4%
38.8%
11.7%
49.1%
All my services are bundled
All my services are obtained through separate providers
Some services are bundled, some are sold separately
Don't know

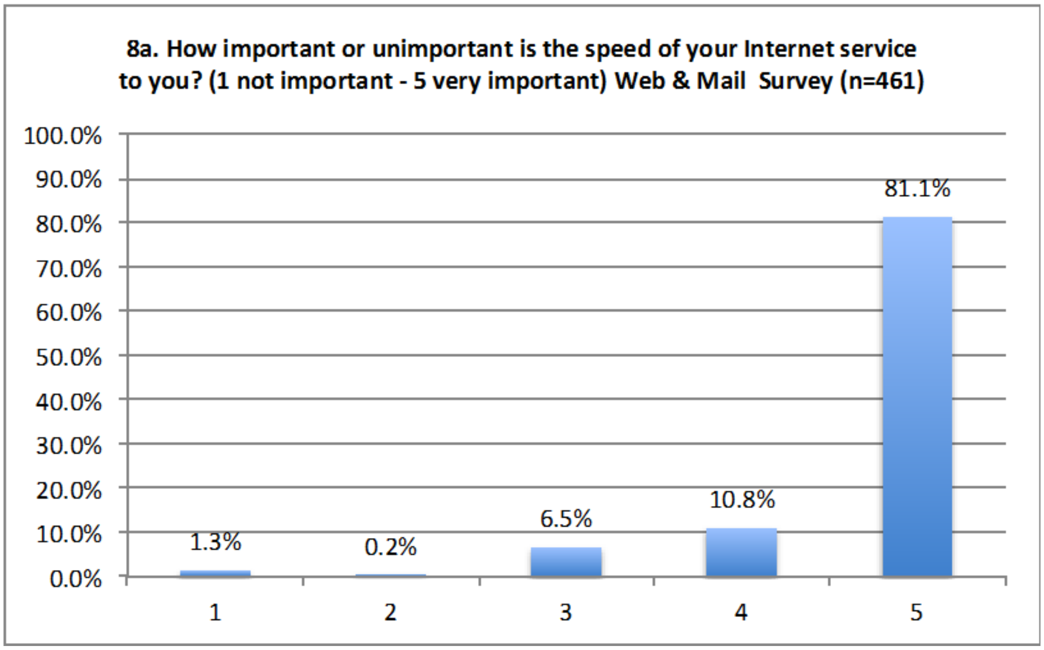

3. What kinds of Internet service are available for you to purchase at your home? (Please select all that apply) - Web & Mail Survey (n=701)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
20.3%
31.4%
66.2%
27.2%
54.9%
58.5%
0.7%
10.7%
1.7%
Dial-Up
Digital Subscriber Line (DSL)
Cable modem
Satellite
Wireless (Wi-Fi or other fixed service)
Cellular/mobile wireless
Condo or apartment association Internet
Don't know
None of the above

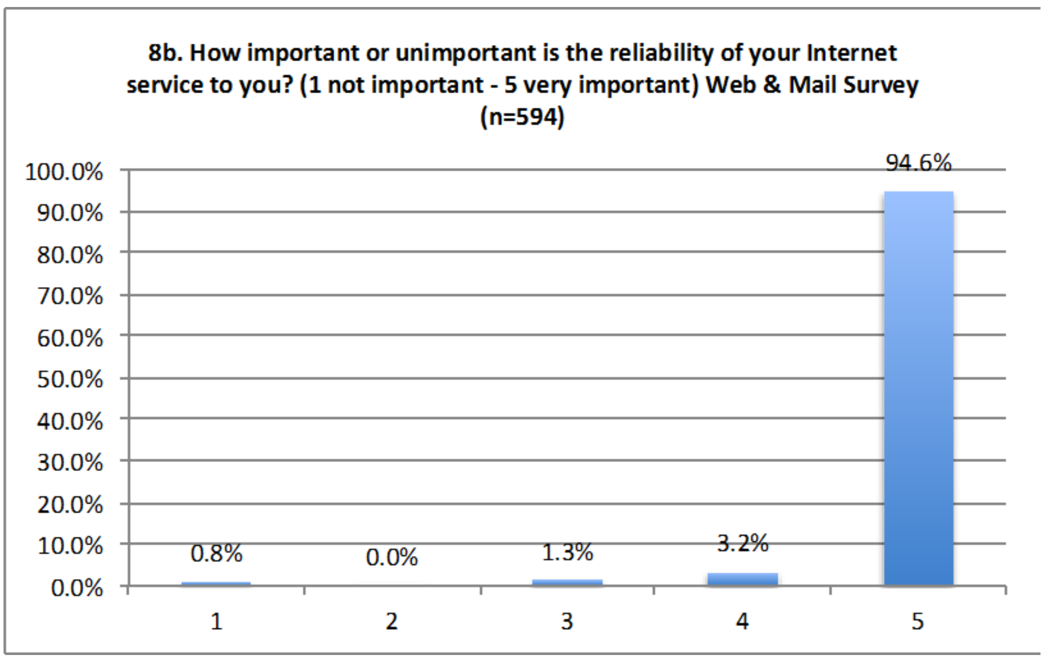

4. Other than cellular/mobile wireless, does your family purchase Internet service at your home, and if so what is your primary home Internet service? - Web & Mail Survey (n=689)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
2.5%
0.6%
1.9%
30.3%
61.4%
0.0%
2.6%
0.6%
0.1%
No home Internet service
Dial-Up Telephone line
Digital Subscriber Line (DSL)
Cable (from Comcast)
FiOS (from Verizon)
Satellite
Wireless
Condo or apartment association Internet
Other

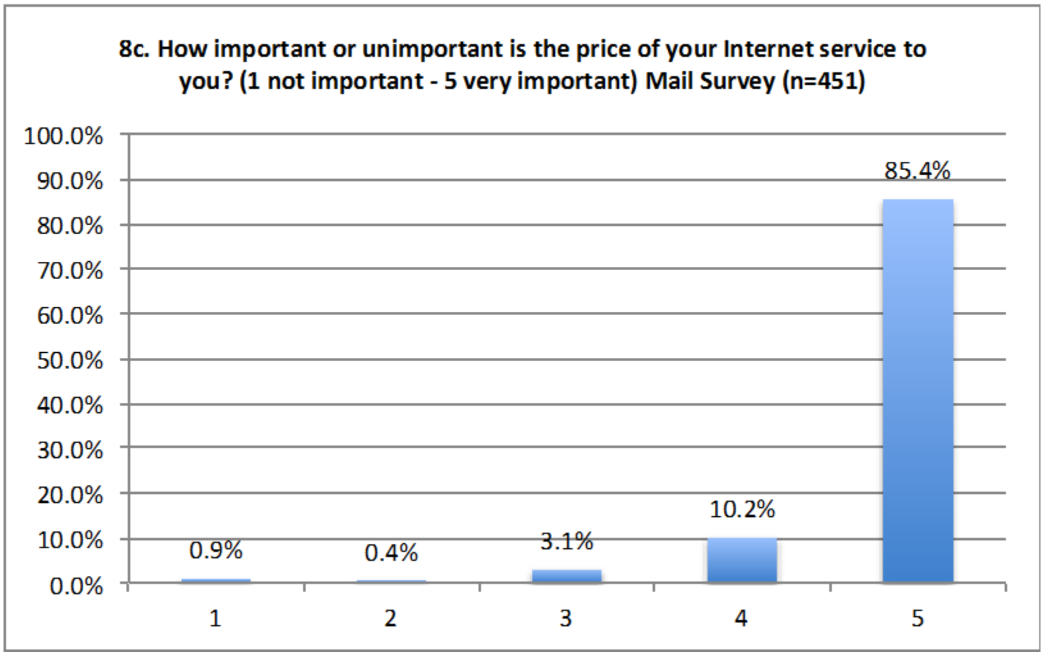

5. If you do not have Internet service at your home (besides cellular), what is your main reason for not purchasing home Internet service? (Select only one) - Web & Mail Survey (n=19)
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
21.1%
26.3%
15.8%
31.6%
5.3%
We have no Internet-enabled devices
My family and I have no need for the Internet
We can get Internet access at another location
Costs are too expensive
Cellular/mobile data service meets our needs

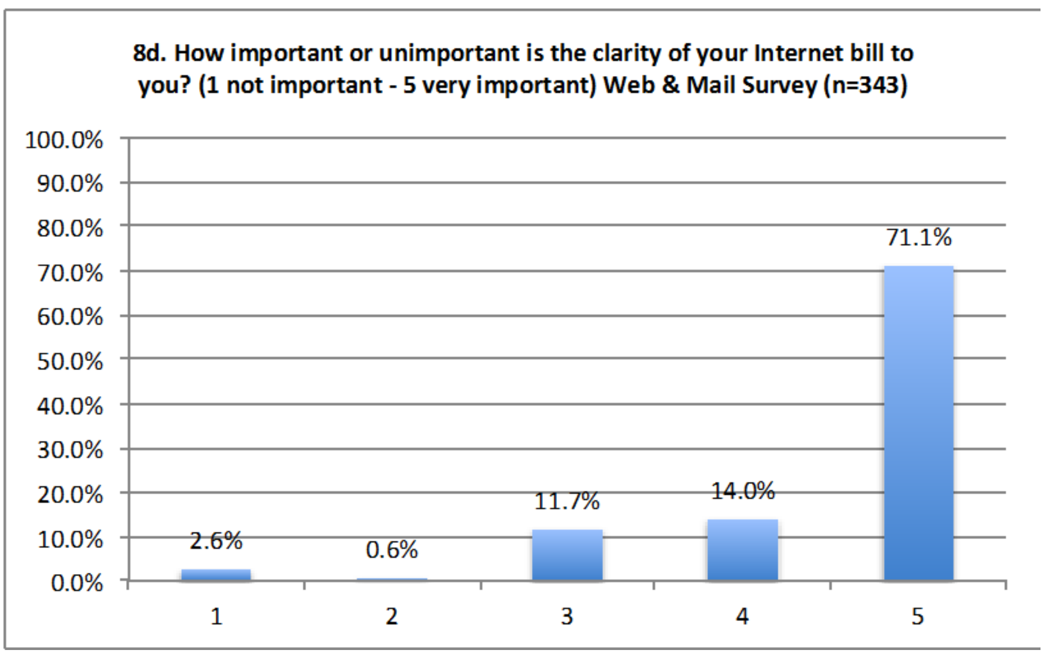

6. Approximately how much does your family pay per month for your home Internet service? - Web & Mail Survey (n=645)
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1.4%
1.4%
4.0%
13.2%
18.8%
19.7%
14.3%
27.3%
Free
$1 to $20
$21 to $30
$31 to $40
$41 to $50
$51 to $60
$61 to $70
More than $70

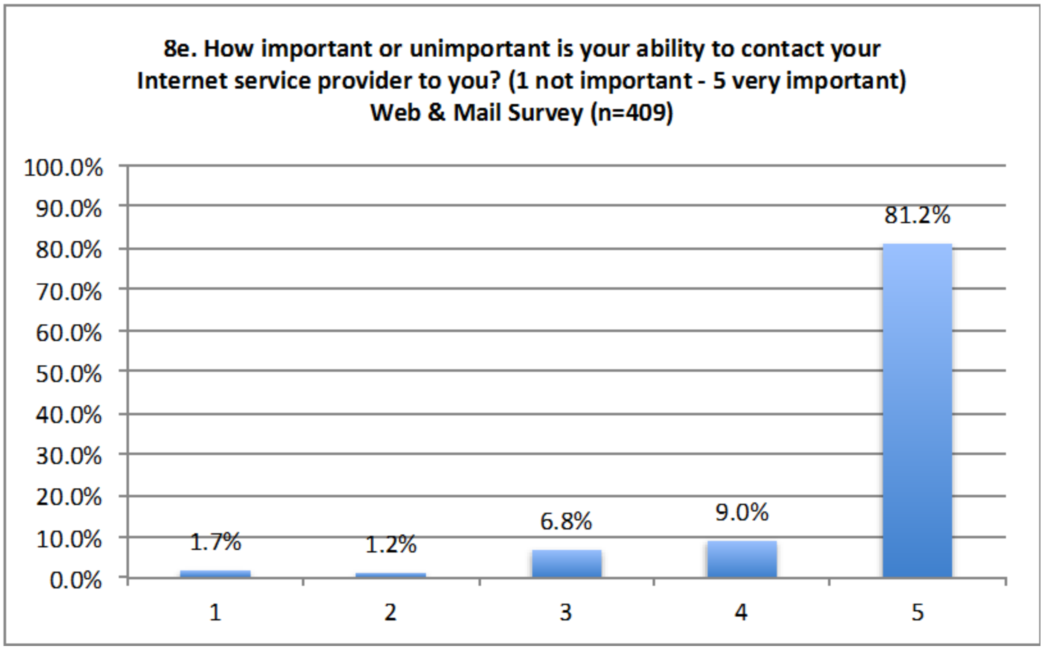

7. How would you describe the speed of your Internet connection? - Web & Mail Survey (n=646)
Very slow, 1.0%
Slow, 3.6%
Very fast, 11.3%
Medium, 29.7%
Fast , 46.6%

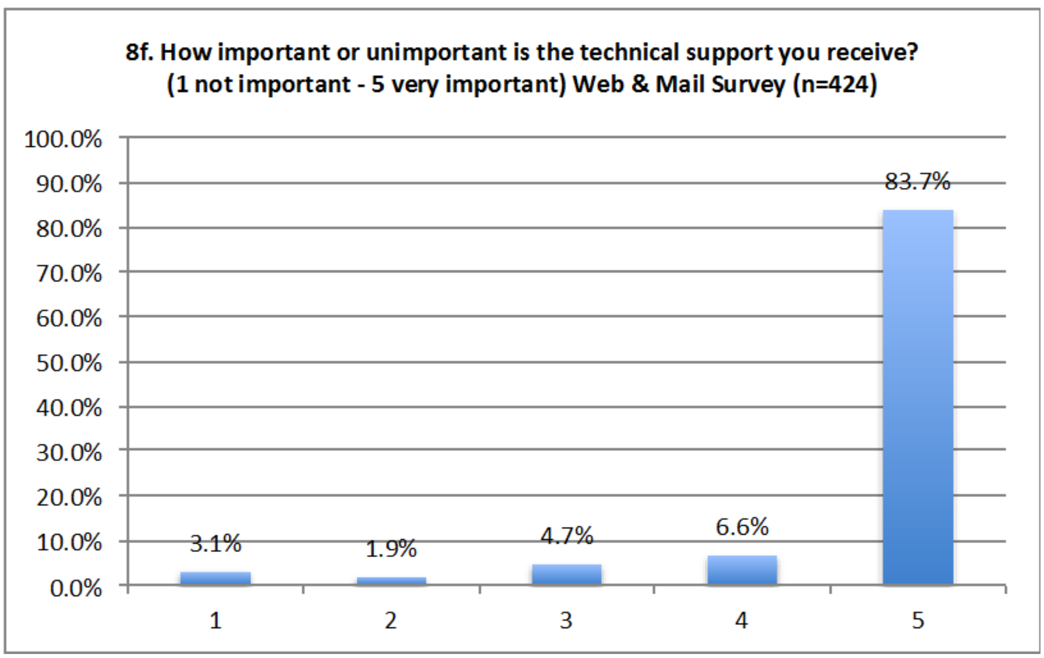

8a. How important or unimportant is the speed of your Internet service to you? (1 not important - 5 very important) Web & Mail Survey (n=461)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1.3%
0.2%
6.5%
10.8%
81.1%
1
2
3
4
5

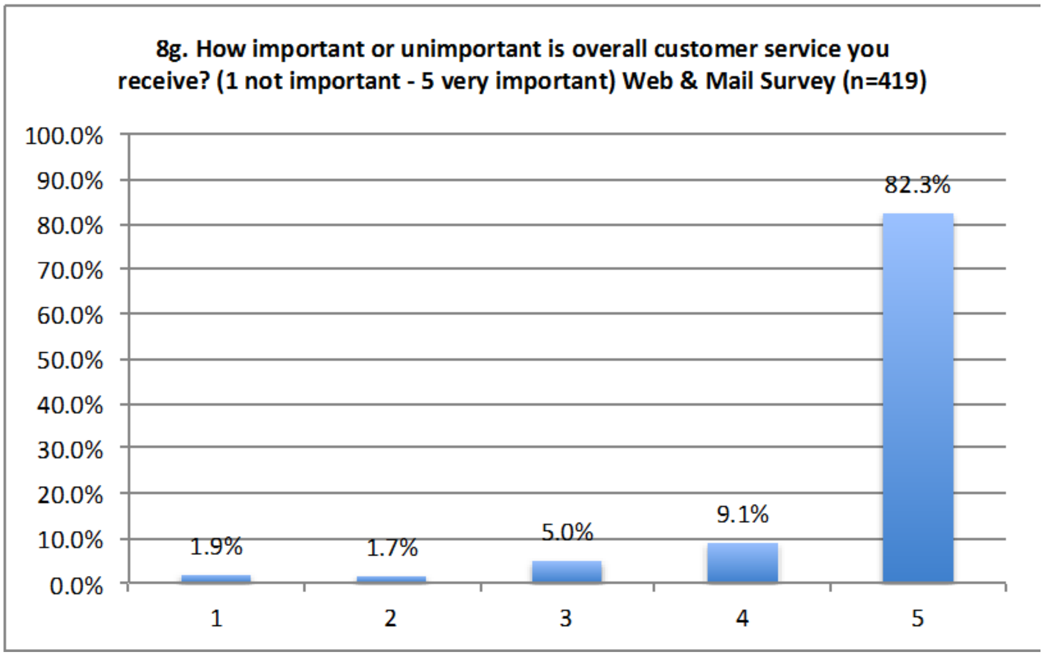

8b. How important or unimportant is the reliability of your Internet service to you? (1 not important - 5 very important) Web & Mail Survey (n=594)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0.8%
0.0%
1.3%
3.2%
94.6%
1
2
3
4
5

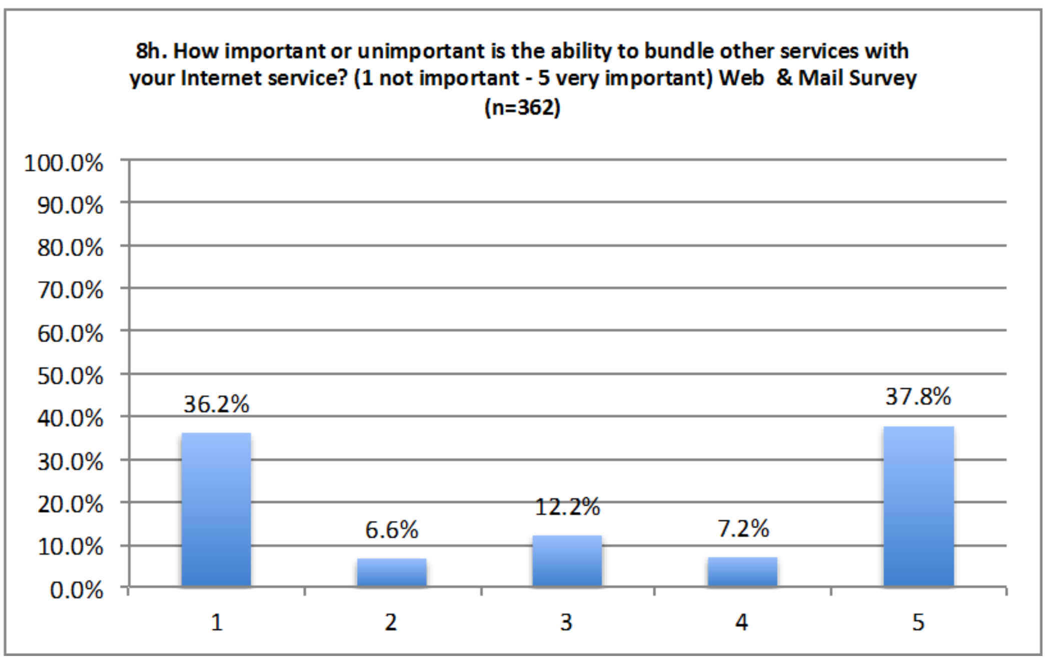

8c. How important or unimportant is the price of your Internet service to you? (1 not important - 5 very important) Mail Survey (n=451)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0.9%
0.4%
3.1%
10.2%
85.4%
1
2
3
4
5

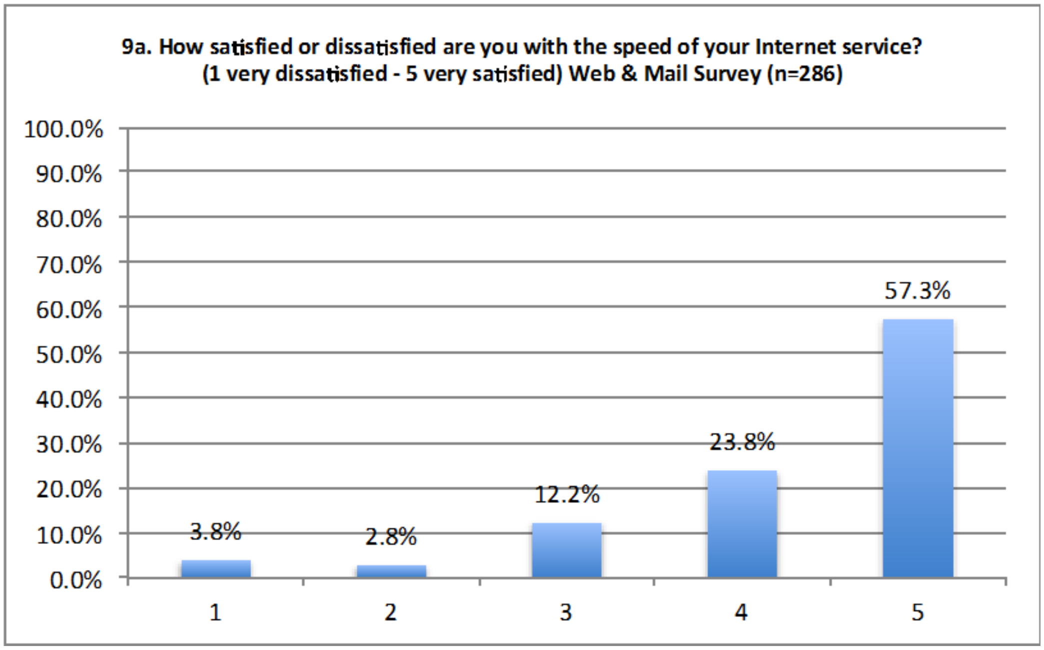

8d. How important or unimportant is the clarity of your Internet bill to you? (1 not important - 5 very important) Web & Mail Survey (n=343)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
2.6%
0.6%
11.7%
14.0%
71.1%
1
2
3
4
5

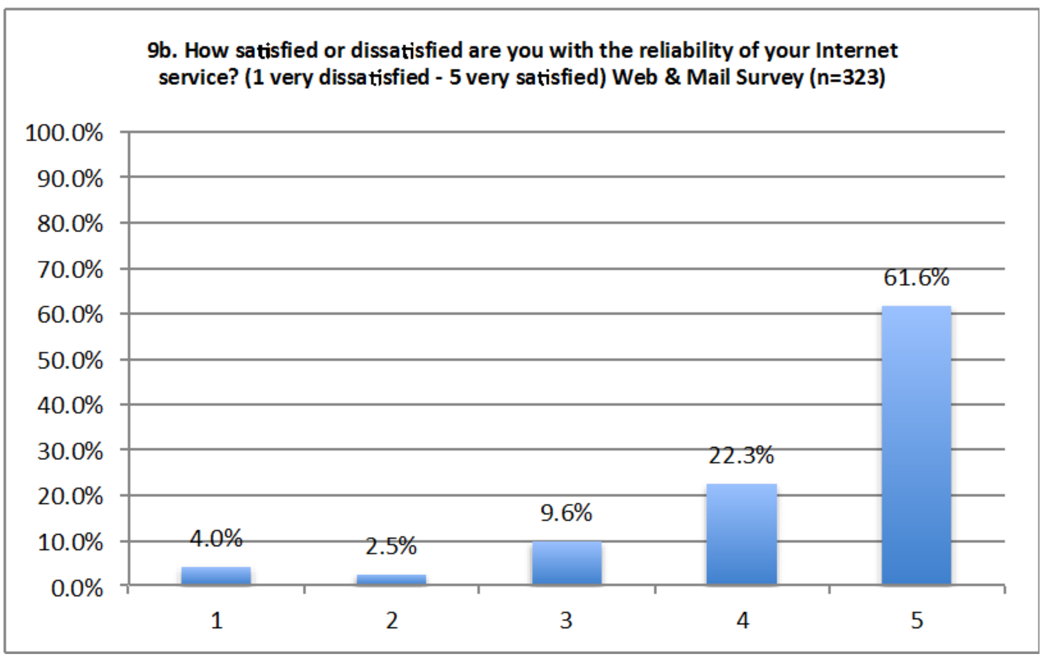

8e. How important or unimportant is your ability to contact your Internet service provider to you? (1 not important - 5 very important) Web & Mail Survey (n=409)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1.7%
1.2%
6.8%
9.0%
81.2%
1
2
3
4
5


8f. How important or unimportant is the technical support you receive? (1 not important - 5 very important) Web & Mail Survey (n=424)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
3.1%
1.9%
4.7%
6.6%
83.7%
1
2
3
4
5


8g. How important or unimportant is overall customer service you receive? (1 not important - 5 very important) Web & Mail Survey (n=419)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1.9%
1.7%
5.0%
9.1%
82.3%
1
2
3
4
5


8h. How important or unimportant is the ability to bundle other services with your Internet service? (1 not important - 5 very important) Web & Mail Survey (n=362)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
36.2%
6.6%
12.2%
7.2%
37.8%
1
2
3
4
5


9a. How satisfied or dissatisfied are you with the speed of your Internet service?
(1 very dissatisfied - 5 very satisfied) Web & Mail Survey (n=286)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
3.8%
2.8%
12.2%
23.8%
57.3%
1
2
3
4
5


9b. How satisfied or dissatisfied are you with the reliability of your Internet service? (1 very dissatisfied - 5 very satisfied) Web & Mail Survey (n=323)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
4.0%
2.5%
9.6%
22.3%
61.6%
1
2
3
4
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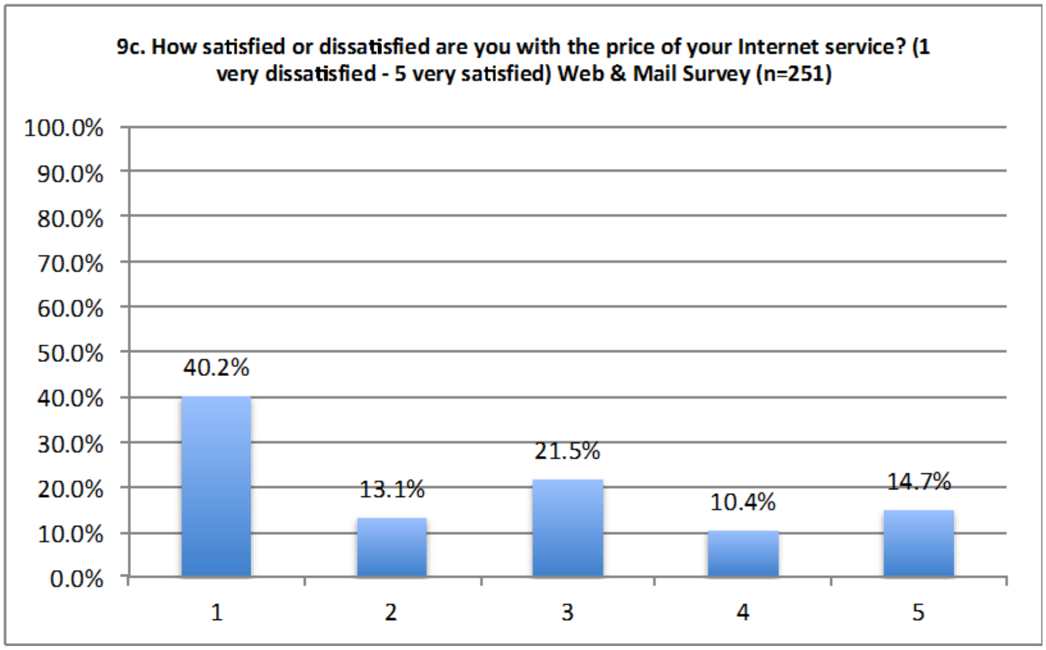
9c. How satisfied or dissatisfied are you with the price of your Internet service? (1 very dissatisfied - 5 very satisfied) Web & Mail Survey (n=251)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
40.2%
13.1%
21.5%
10.4%
14.7%
1
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3
4
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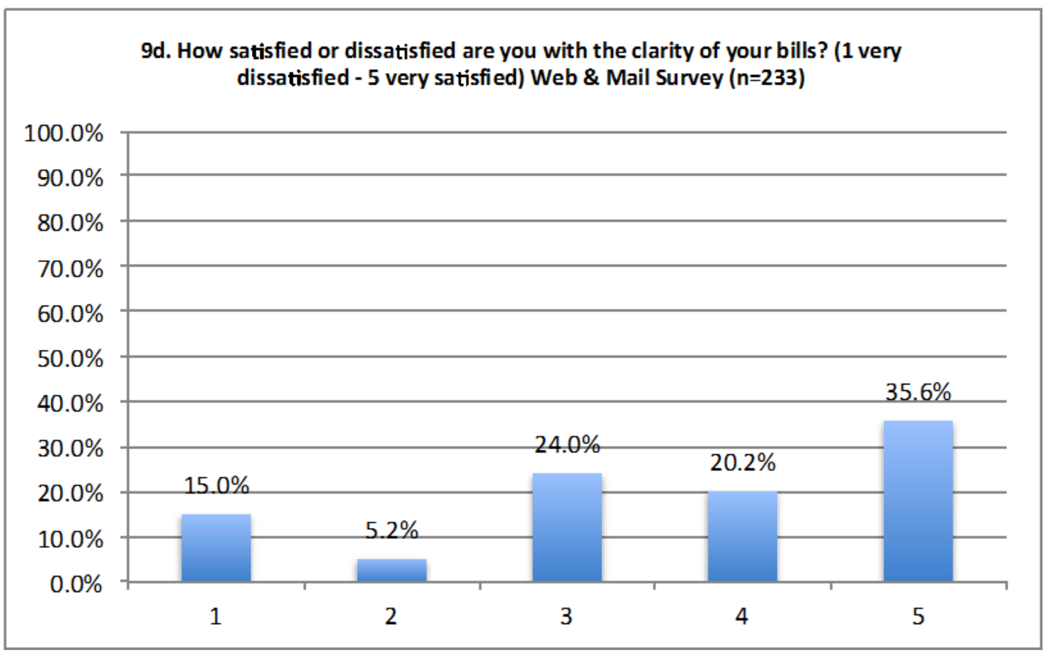
9d. How satisfied or dissatisfied are you with the clarity of your bills? (1 very dissatisfied - 5 very satisfied) Web & Mail Survey (n=233)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
15.0%
5.2%
24.0%
20.2%
35.6%
1
2
3
4
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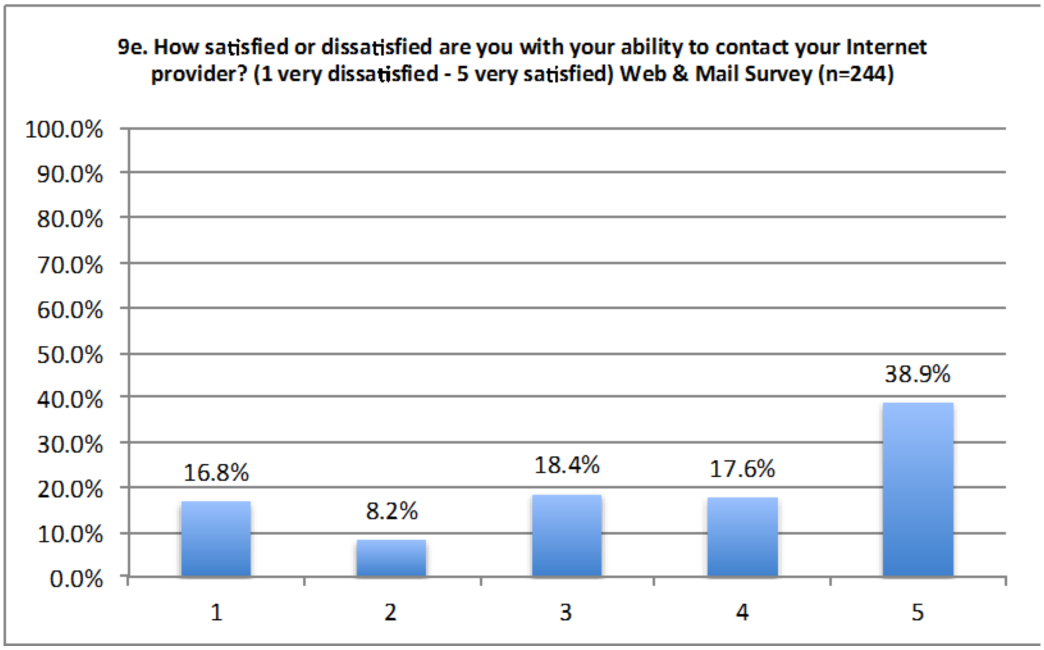
9e. How satisfied or dissatisfied are you with your ability to contact your Internet provider? (1 very dissatisfied - 5 very satisfied) Web & Mail Survey (n=244)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
16.8%
8.2%
18.4%
17.6%
38.9%
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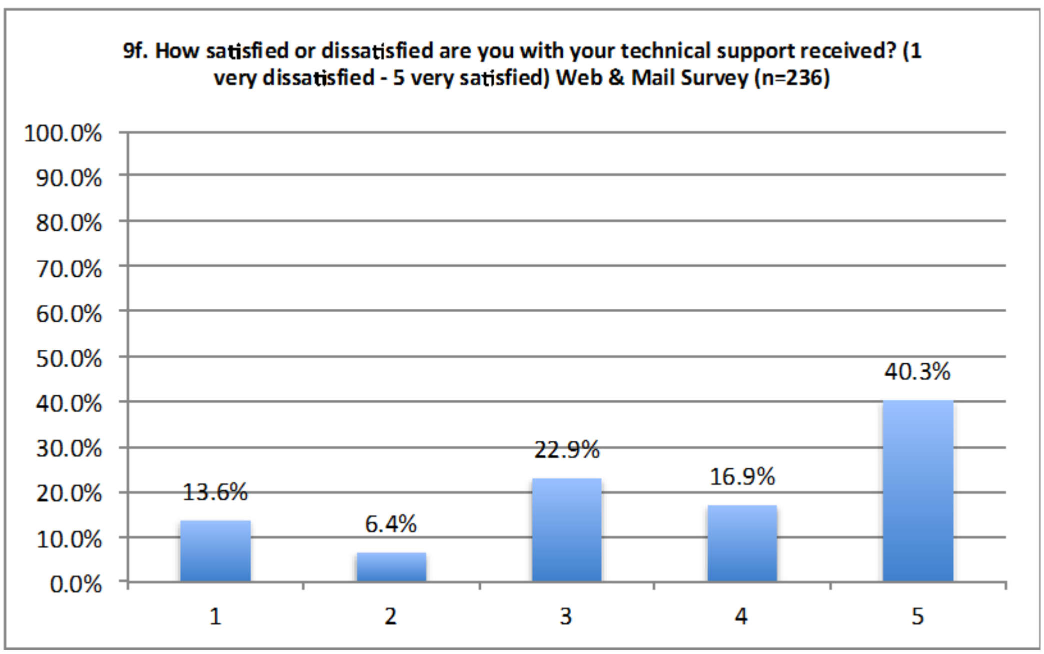
9f. How satisfied or dissatisfied are you with your technical support received? (1 very dissatisfied - 5 very satisfied) Web & Mail Survey (n=236)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
13.6%
6.4%
22.9%
16.9%
40.3%
1
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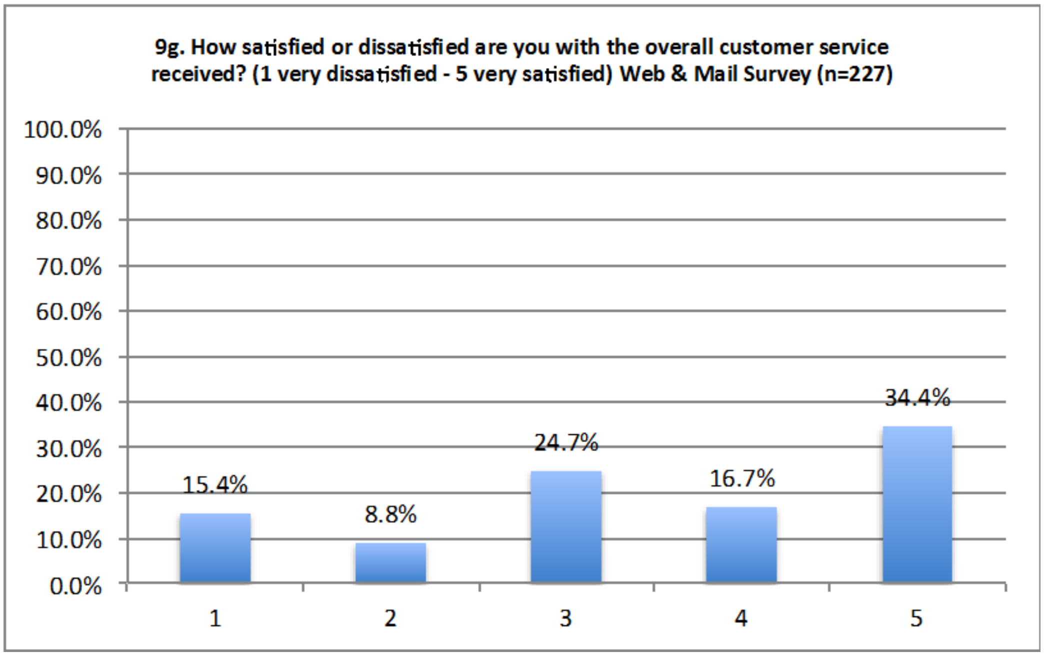
9g. How satisfied or dissatisfied are you with the overall customer service received? (1 very dissatisfied - 5 very satisfied) Web & Mail Survey (n=227)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
15.4%
8.8%
24.7%
16.7%
34.4%
1
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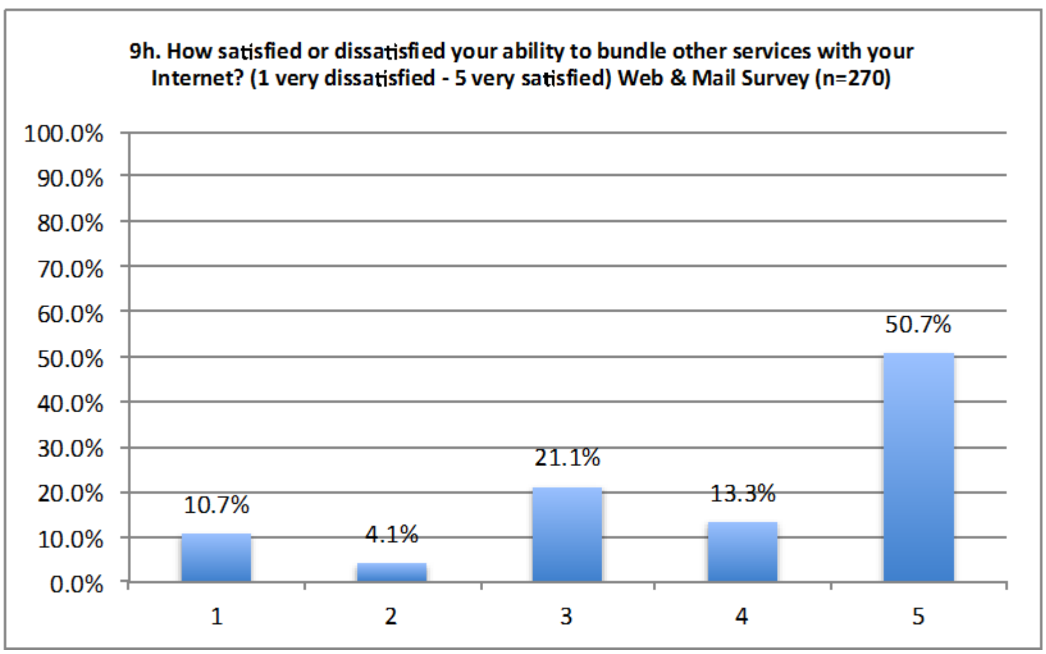
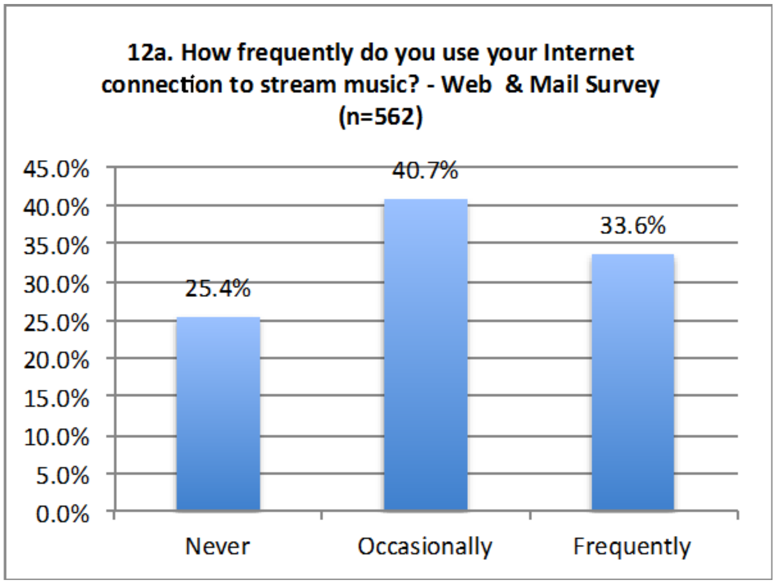
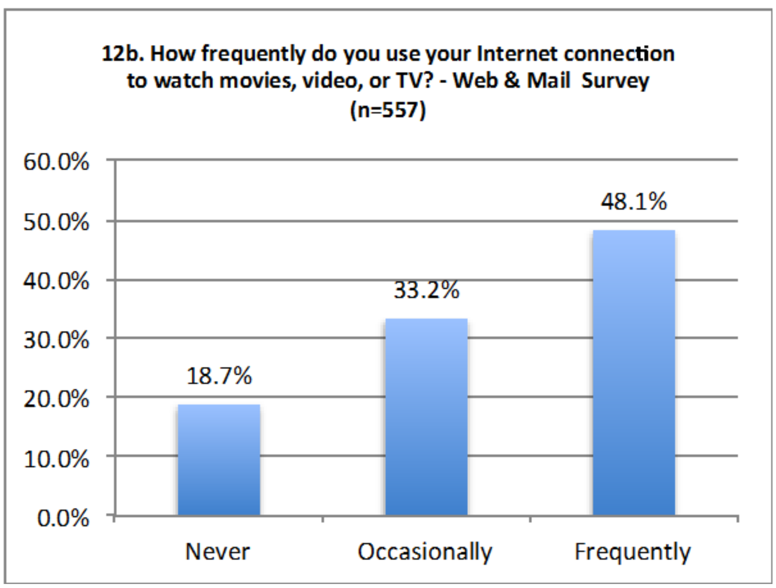
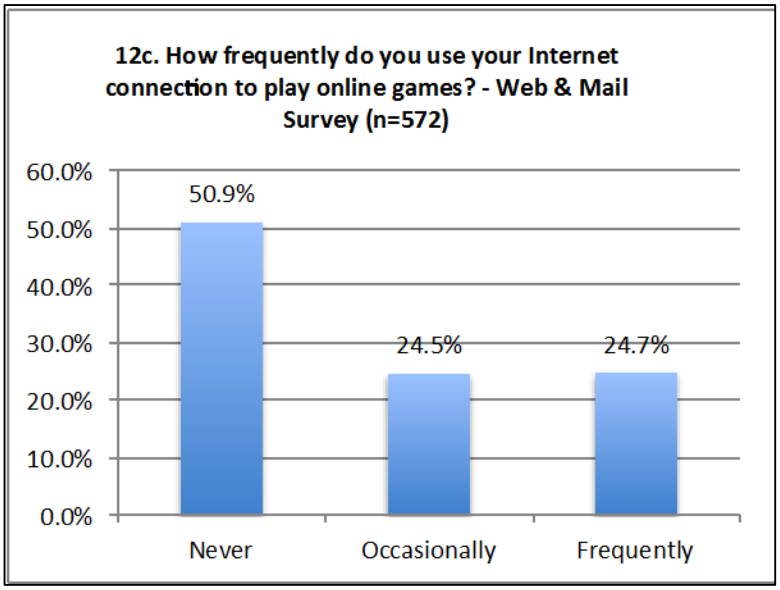
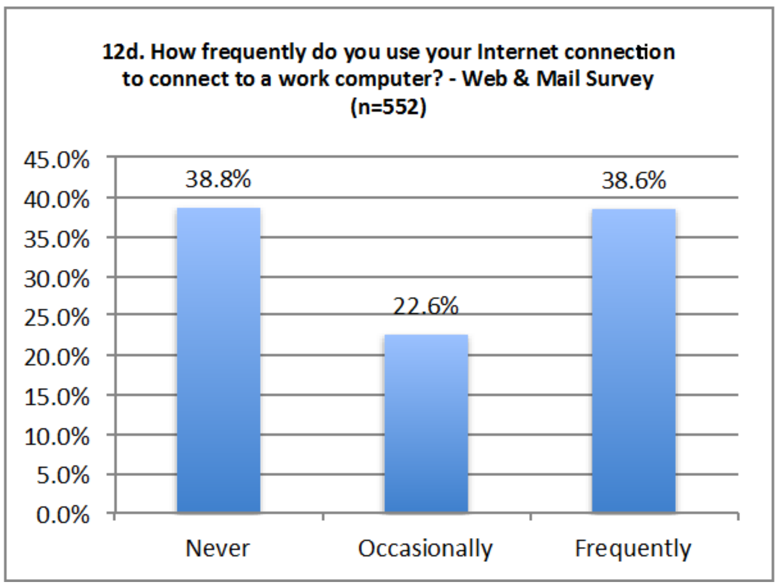
3
4
5

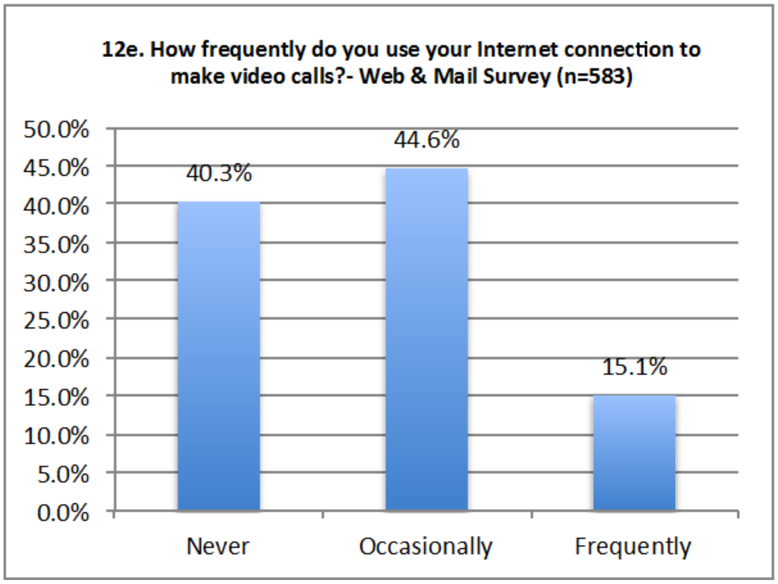

9h. How satisfied or dissatisfied your ability to bundle other services with your Internet? (1 very dissatisfied - 5 very satisfied) Web & Mail Survey (n=270)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
10.7%
4.1%
21.1%
13.3%
50.7%
1
2
3
4
5

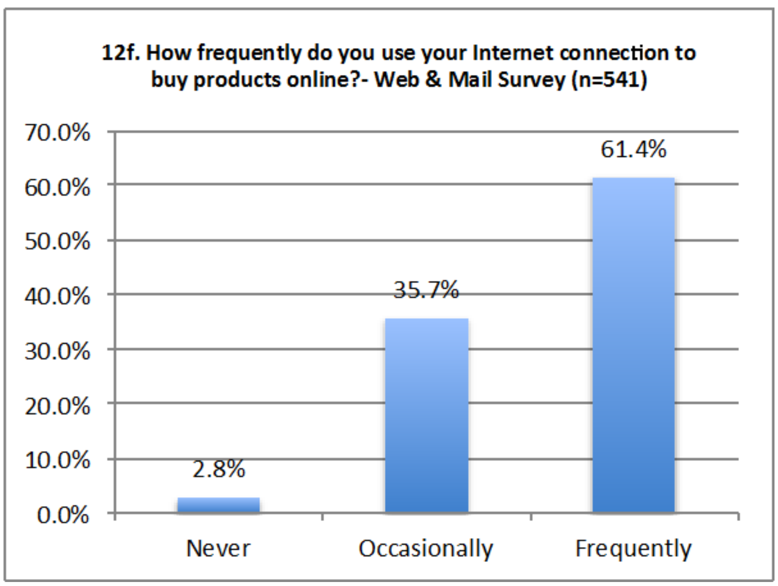

12a. How frequently do you use your Internet connection to stream music? - Web & Mail Survey (n=562)
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
25.4%
40.7%
33.6%
Never
Occasionally
Frequently

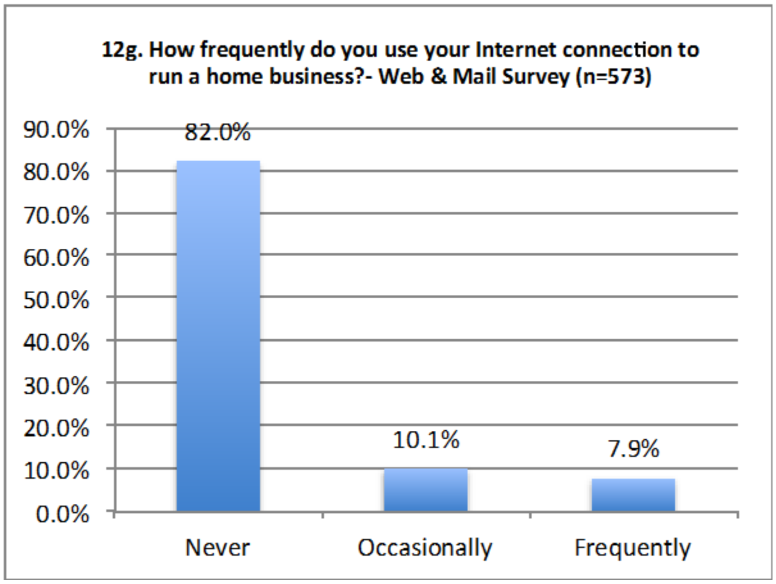

12b. How frequently do you use your Internet connection to watch movies, video, or TV? - Web & Mail Survey (n=557)
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
18.7%
33.2%
48.1%
Never
Occasionally
Frequently

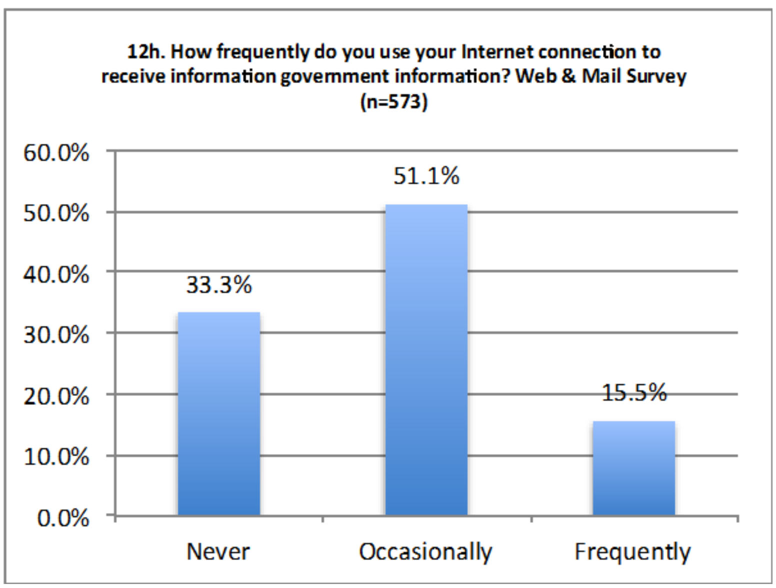

12c. How frequently do you use your Internet connection to play online games? - Web & Mail Survey (n=572)
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
50.9%
24.5%
24.7%
Never
Occasionally
Frequently

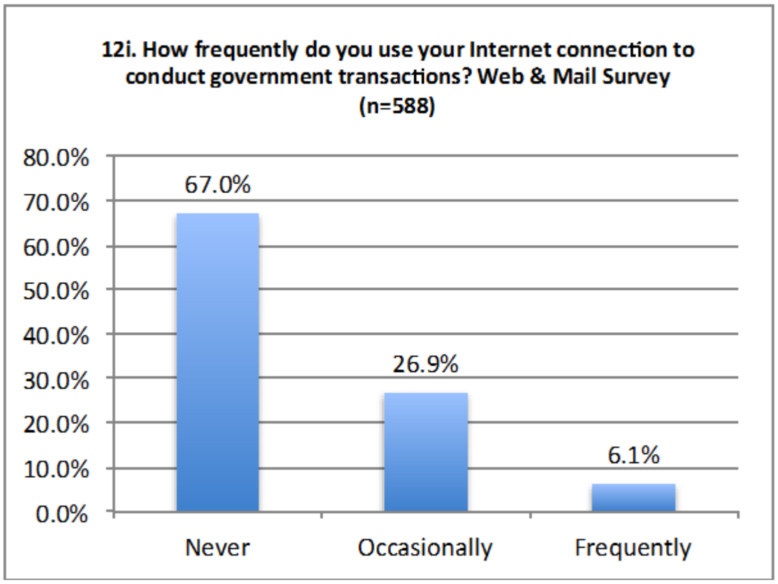

12d. How frequently do you use your Internet connection to connect to a work computer? - Web & Mail Survey (n=552)
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
38.8%
22.6%
38.6%
Never
Occasionally
Frequently

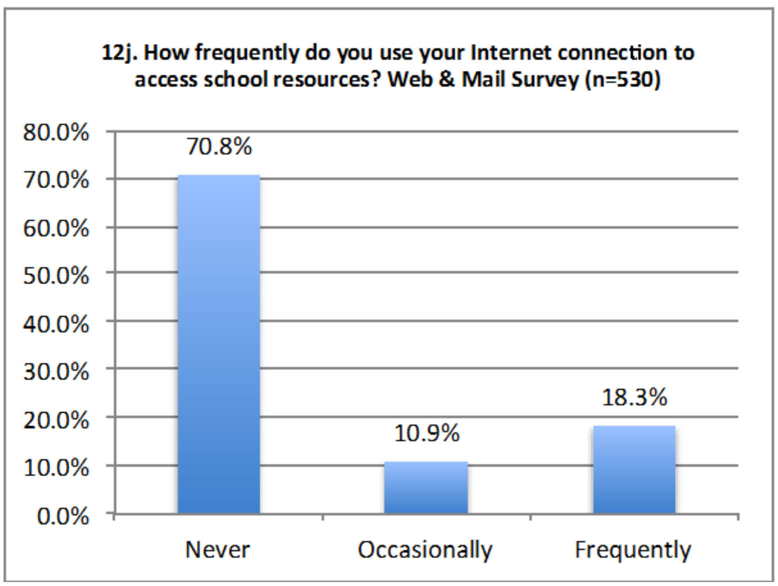

12e. How frequently do you use your Internet connection to make video calls?- Web & Mail Survey (n=583)
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
40.3%
44.6%
15.1%
Never
Occasionally
Frequently

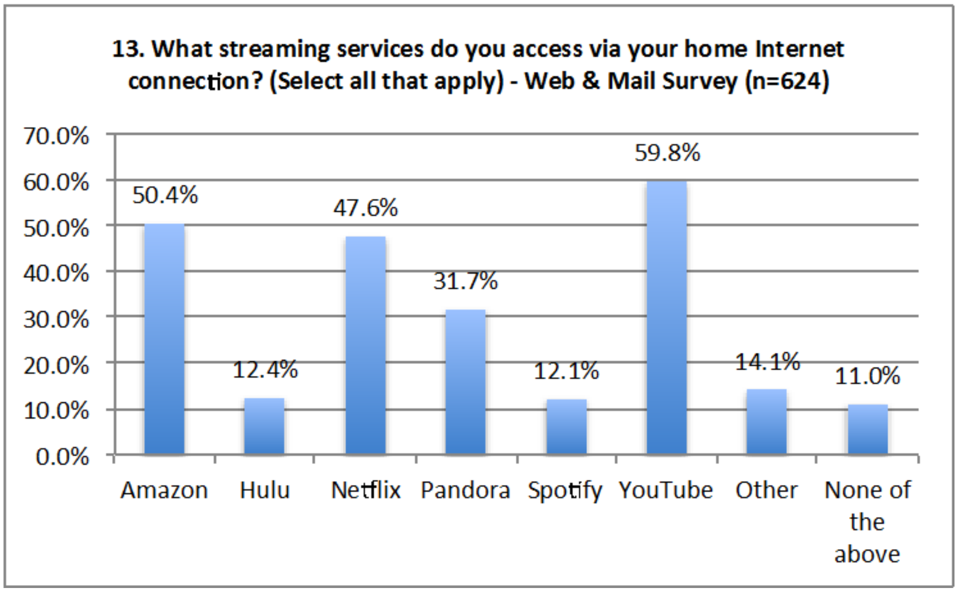

12f. How frequently do you use your Internet connection to buy products online?- Web & Mail Survey (n=541)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
2.8%
35.7%
61.4%
Never
Occasionally
Frequently

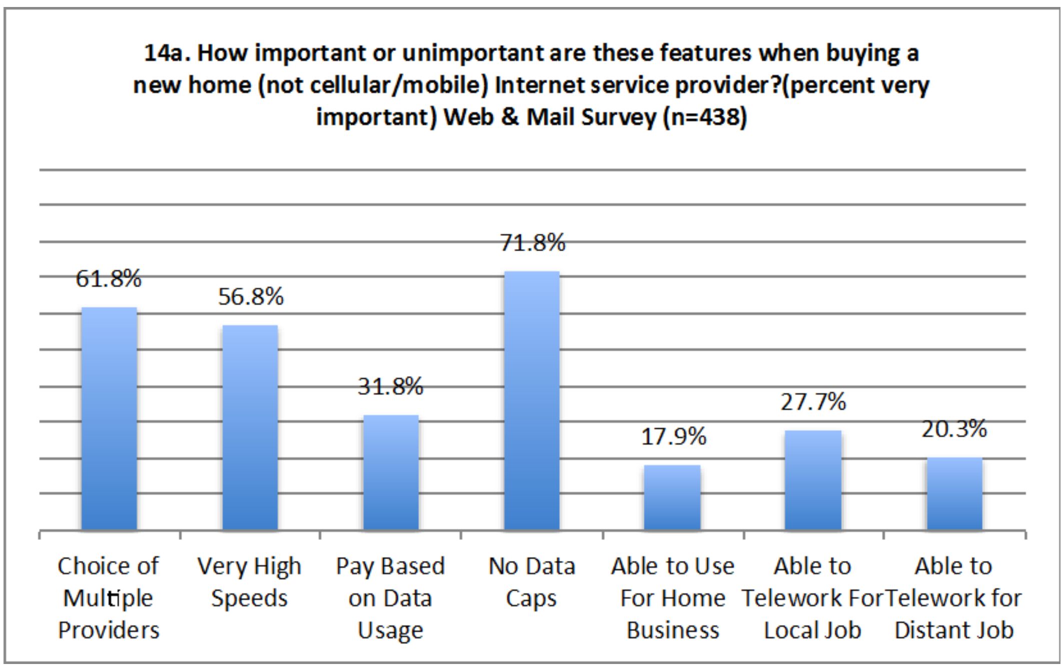

12g. How frequently do you use your Internet connection to run a home business?- Web & Mail Survey (n=573)
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
82.0%
10.1%
7.9%
Never
Occasionally
Frequently

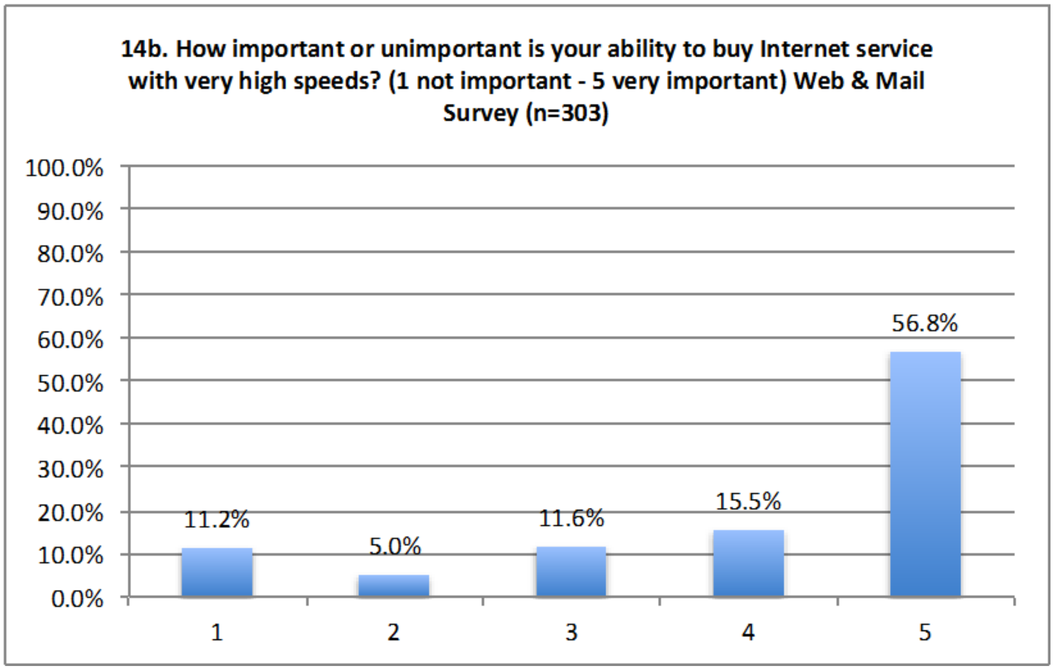

12h. How frequently do you use your Internet connection to receive information government information? Web & Mail Survey (n=573)
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
33.3%
51.1%
15.5%
Never
Occasionally
Frequently

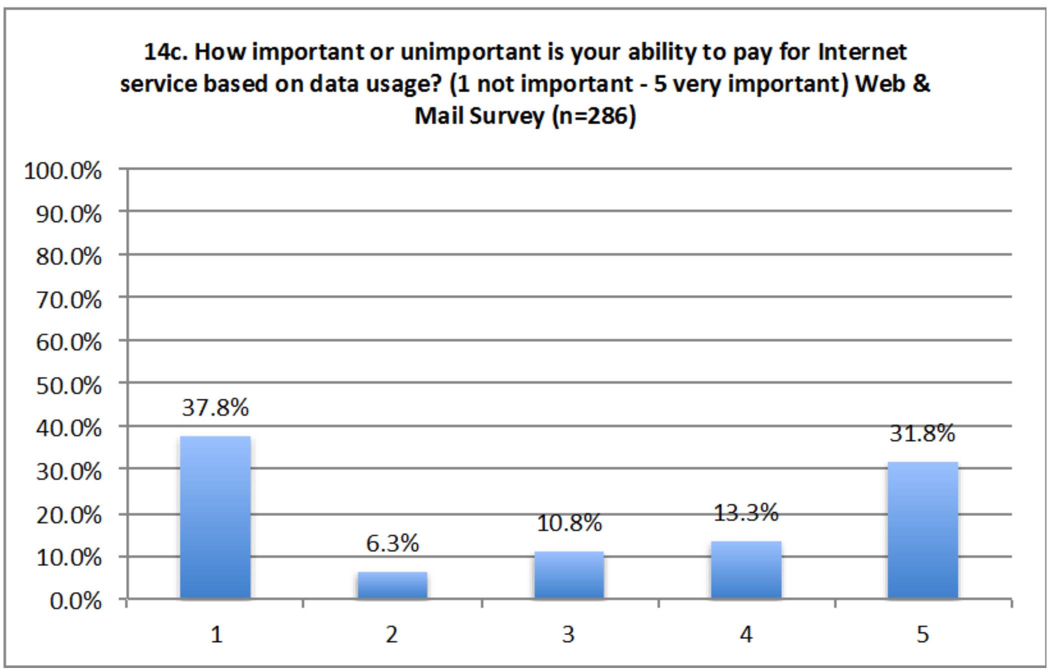

12i. How frequently do you use your Internet connection to conduct government transactions? Web & Mail Survey (n=588)
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
67.0%
26.9%
6.1%
Never
Occasionally
Frequently

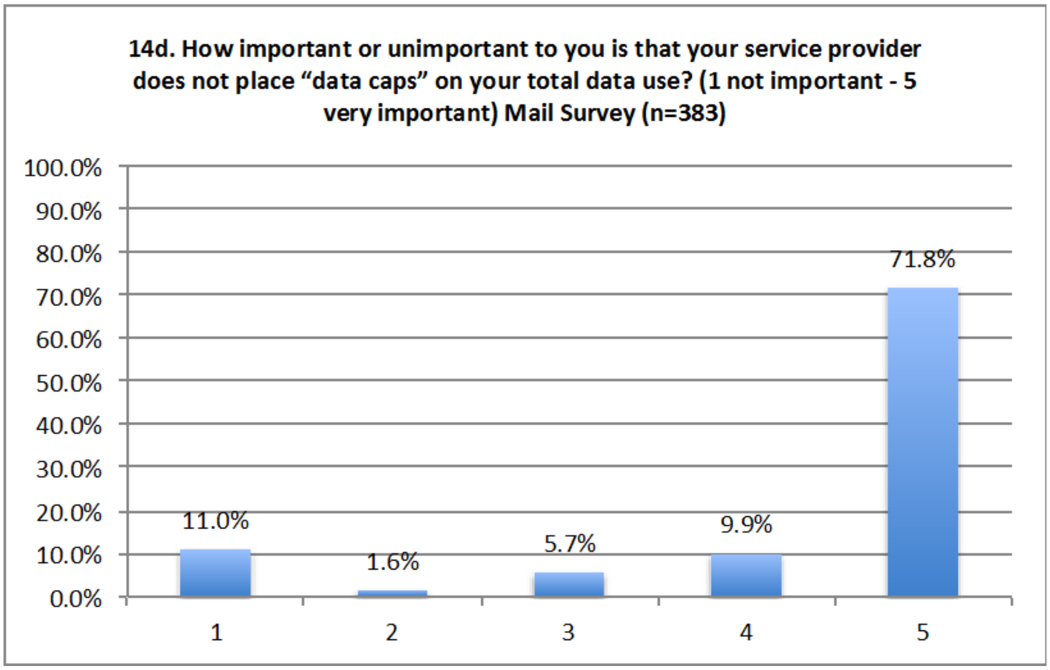

12j. How frequently do you use your Internet connection to access school resources? Web & Mail Survey (n=530)
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
70.8%
10.9%
18.3%
Never
Occasionally
Frequently

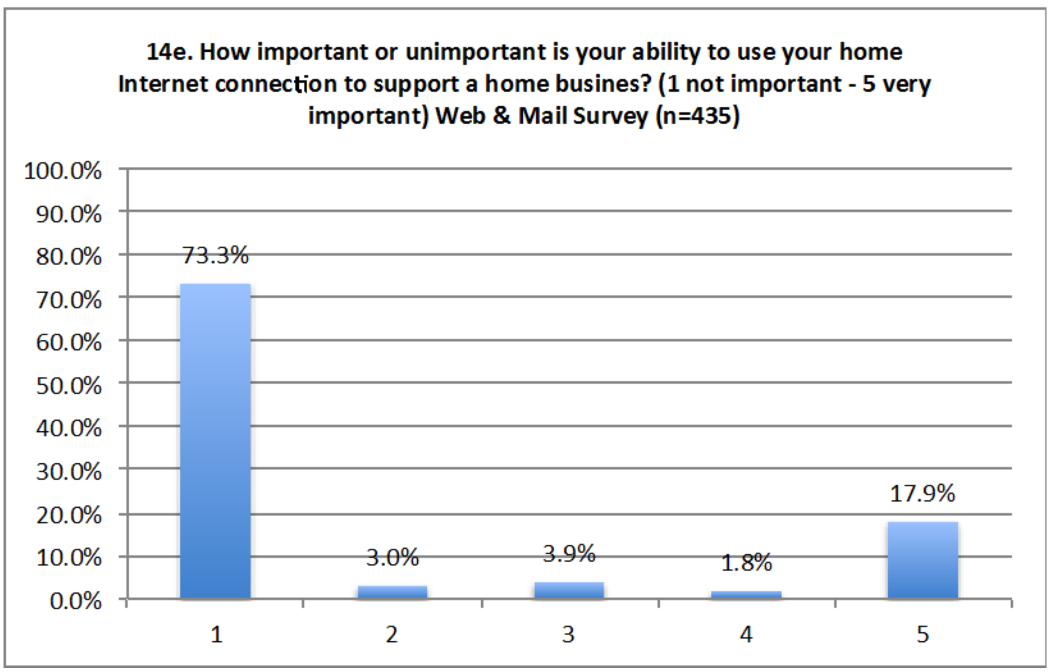

13. What streaming services do you access via your home Internet connection? (Select all that apply) - Web & Mail Survey (n=624)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
50.4%
12.4%
47.6%
31.7%
12.1%
59.8%
14.1%
11.0%
Amazon
Hulu
Netflix
Pandora
Spotify
YouTube
Other
None of the above

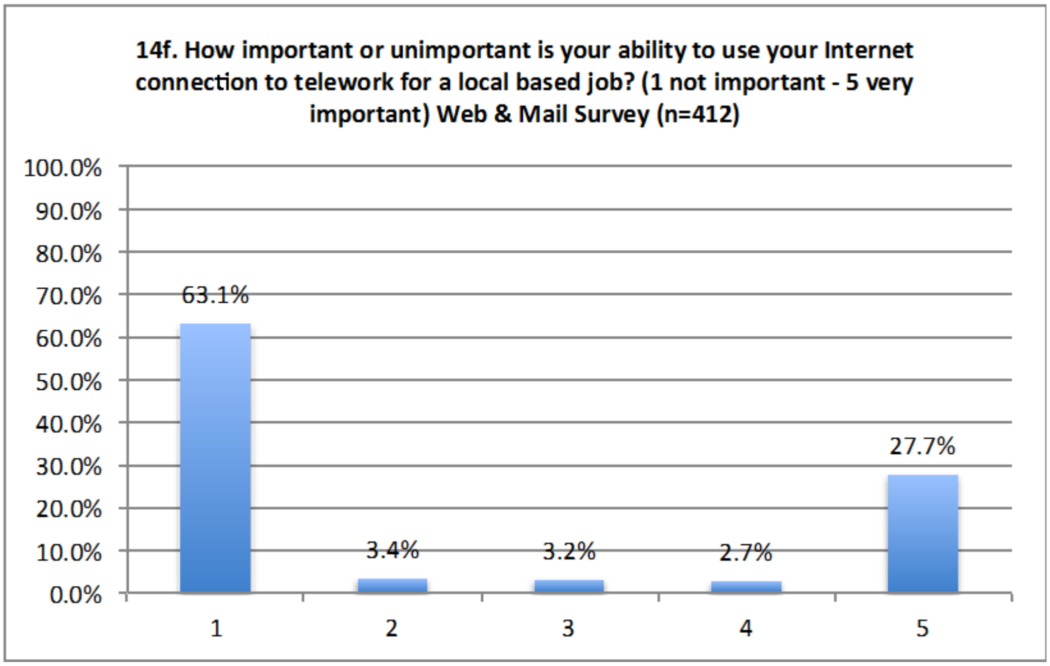

14a. How important or unimportant are these features when buying a new home (not cellular/mobile) Internet service provider?(percent very important) Web & Mail Survey (n=438)
61.8%
56.8%
31.8%
71.8%
17.9%
27.7%
20.3%
Choice of Multiple Providers
Very High Speeds
Pay Based on Data Usage
No Data Caps
Able to Use For Home Business
Able to Telework For Local Job
Able to Telework for Distant Job

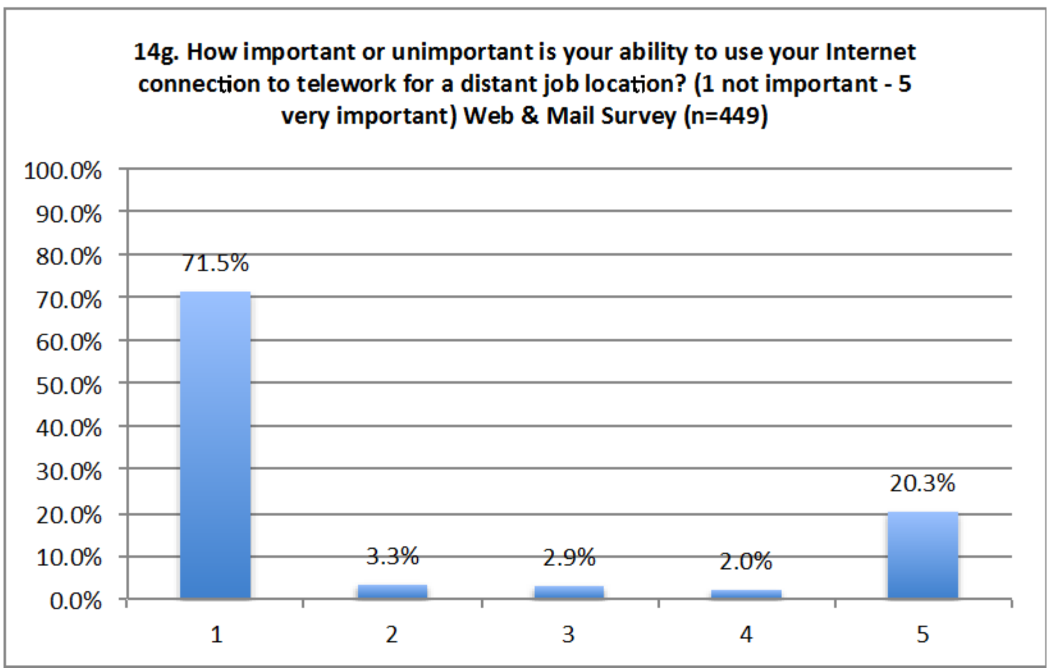

14b. How important or unimportant is your ability to buy Internet service with very high speeds? (1 not important - 5 very important) Web & Mail Survey (n=303)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
11.2%
5.0%
11.6%
15.5%
56.8%
1
2
3
4
5

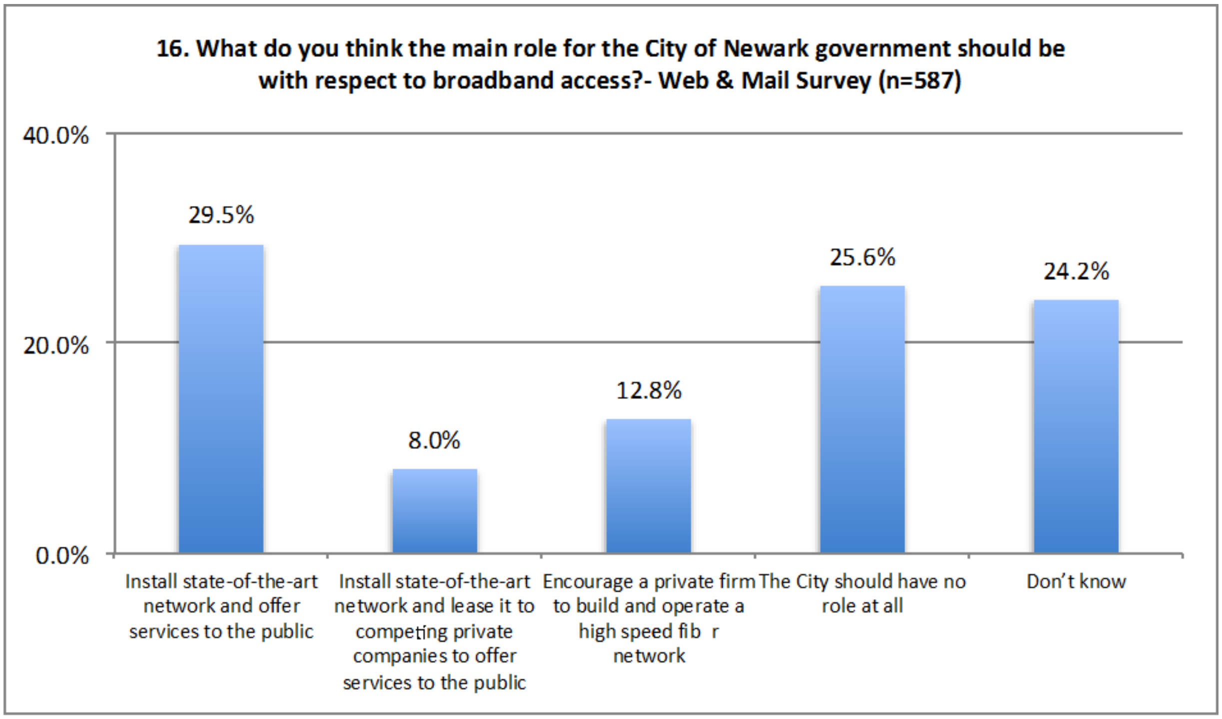

14c. How important or unimportant is your ability to pay for Internet service based on data usage? (1 not important - 5 very important) Web & Mail Survey (n=286)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
37.8%
6.3%
10.8%
13.3%
31.8%
1
2
3
4
5

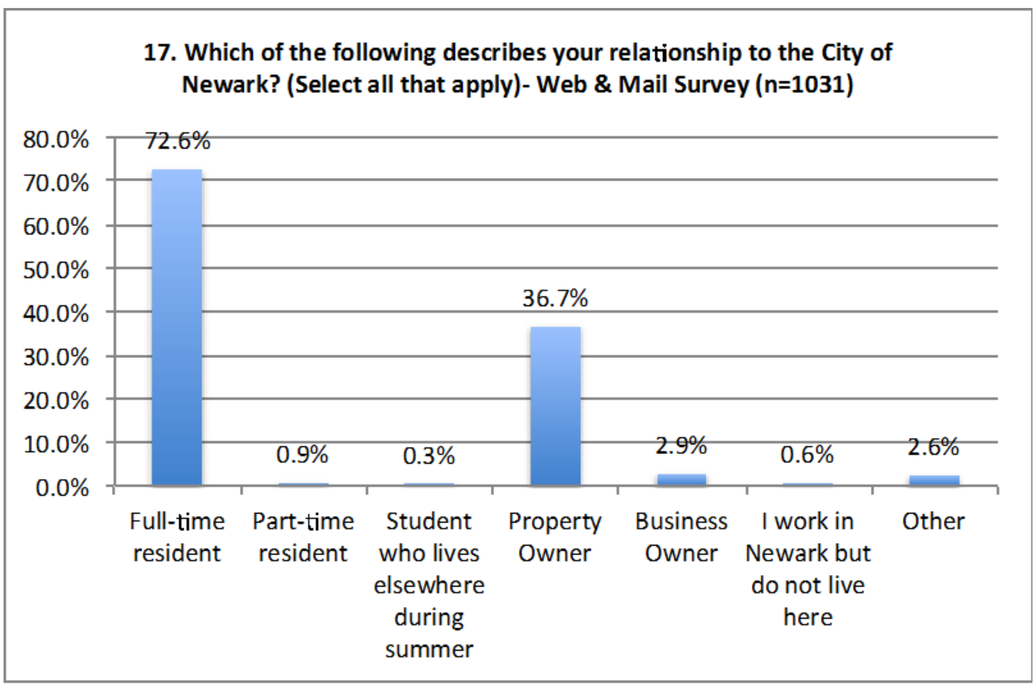

14d. How important or unimportant to you is that your service provider does not place "data caps" on your total data use? (1 not important - 5 very important) Mail Survey (n=383)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
11.0%
1.6%
5.7%
9.9%
71.8%
1
2
3
4
5

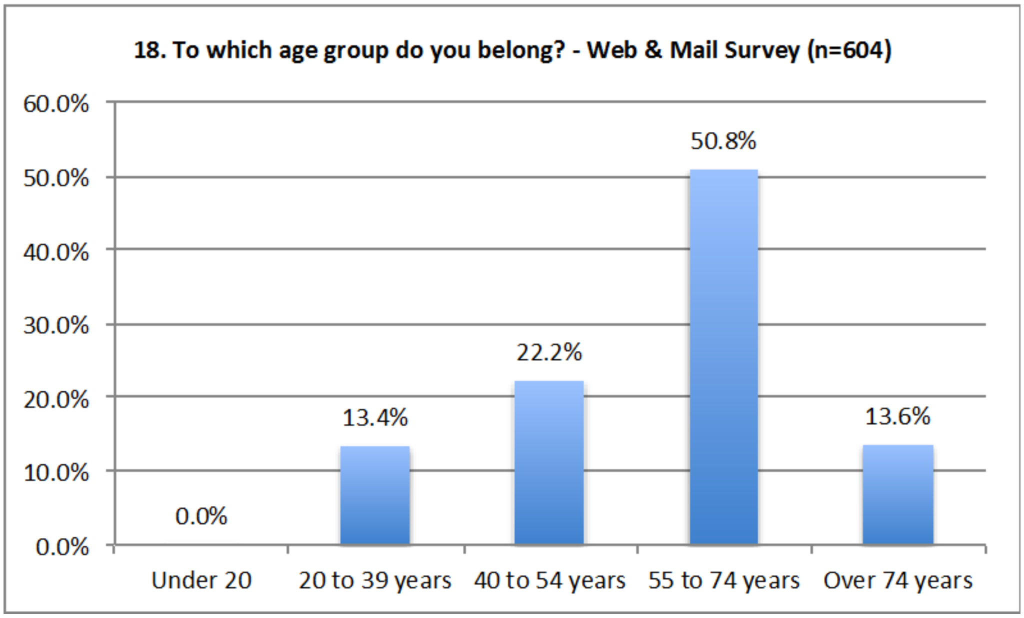

14e. How important or unimportant is your ability to use your home Internet connection to support a home busines? (1 not important - 5 very important) Web & Mail Survey (n=435)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
73.3%
3.0%
3.9%
1.8%
17.9%
1
2
3
4
5


14f. How important or unimportant is your ability to use your Internet connection to telework for a local based job? (1 not important - 5 very important) Web & Mail Survey (n=412)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
63.1%
3.4%
3.2%
2.7%
27.7%
1
2
3
4
5


14g. How important or unimportant is your ability to use your Internet connection to telework for a distant job location? (1 not important - 5 very important) Web & Mail Survey (n=449)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
71.5%
3.3%
2.9%
2.0%
20.3%
1
2
3
4
5


16. What do you think the main role for the City of Newark government should be with respect to broadband access?- Web & Mail Survey (n=587)
40.0%
20.0%
0.0%
29.5%
8.0%
12.8%
25.6%
24.2%
Install state-of-the-art network and offer services to the public
Install state-of-the-art network and lease it to competing private companies to offer services to the public
Encourage a private firm to build and operate a high speed fib r network
The City should have no role at all
Don't know


17. Which of the following describes your relationship to the City of Newark? (Select all that apply)- Web & Mail Survey (n=1031)
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
72.6%
0.9%
0.3%
36.7%
2.9%
0.6%
2.6%
Full-time resident
Part-time resident
Student who lives elsewhere during summer
Property Owner
Business Owner
I work in Newark but do not live here
Other


18. To which age group do you belong? - Web & Mail Survey (n=604)
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0.0%
13.4%
22.2%
50.8%
13.6%
Under 20
20 to 39 years
40 to 54 years
55 to 74 years
Over 74 years

Appendix C: Glossary

AE – Active Ethernet; provides a symmetrical (up/down) Ethernet service that does not share optical wavelengths with other users. For subscribers that receive Active Ethernet 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 FTTP network fiber that connects the backbone hub sites to the FDCs.

Drop – The fiber connection from an optical tap in the right-of-way 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.

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 rights-of-way.

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 EPB. GPON uses passive optical splitting, which is performed inside FDCs, to connect fiber from the OLTs to multiple customer premises using a single GPON port.

MDU – Multi-dwelling unit (i.e., 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 Active Ethernet 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 operational support systems for FTTP operations. OSS is housed in a network's core locations.

Passing – A potential customer address (e.g., an individual home or business).

ROW – Right-of-way; land reserved for the public good such as utility construction (typically abutting public roadways).