



City of Palo Alto City Council Staff Report

(ID # 6104)

Report Type: Action Items

Meeting Date: 9/28/2015

Summary Title: Discussion of Fiber-to-the-Premises and Direction on Next Steps for Fiber and City Wireless Services

Title: Discussion of Fiber-to-the-Premises Master Plan and Direction to Staff on Next Steps for Fiber and City Wireless Services

From: City Manager

Lead Department: IT Department

Staff Recommendation

To meet the strategic goals of the Council priority for the Technology and the Connected City initiative to facilitate citywide fiber-to-the-premises internet access and new wireless capabilities, staff recommends that City Council receive the attached Fiber to the Premises Master Plan and Wireless Network Plan, and direct staff to:

1. Defer issuing a Request for Information (RFI) until after December 31, 2015 to determine interest from the private sector in partnering with the City to build and operate a citywide fiber-to-the-premises (FTTP) network. The intervening time between now and the end of the year should enable emerging gigabit broadband services from the private sector to be settled. During this time staff will further evaluate strengths and weaknesses of public utility options.
2. Issue Request for Proposal(s) (RFP) to add dedicated wireless facilities to improve communications for Public Safety and Utilities departments; with an option for expanding Wi-Fi coverage at City facilities and public areas.

UAC Recommendation

The Utilities Advisory Commission recommends that Council receive the attached Fiber to the Premises Master Plan and Wireless Network Plan, and direct staff to:

1. Defer issuing a Request for Information (RFI) until after December 31, 2015 to determine interest from the private sector in partnering with the City to build and operate a citywide Fiber-to-the-Premises (FTTP) network. The intervening time between now and the end of

the year should enable emerging gigabit broadband services from the private sector to be settled. During the time between now and end of year, direct staff to evaluate the option of offering a city-owned FTTP network to all Palo Alto households and businesses as a public benefit.

2. Issue Request for Proposal(s) (RFP) to add dedicated wireless facilities to improve communications for Public Safety and Utilities departments; with an option for expanding Wi-Fi coverage at City facilities and public areas.

At the September 2, 2015 Utilities Advisory Commission (UAC) meeting, staff provided a report and two recommendations regarding the FTTP Master Plan and Wireless Network Plan. By a vote of 4 to 3, the UAC commissioners amended staff's first recommendation, by requesting staff to evaluate a city-owned FTTP network to all Palo Alto households and businesses as a publicly-funded public benefit. Instead, staff recommends an evaluation of strengths and weaknesses of public utility options rather than only a public benefit option. Staff and the UAC are in agreement on Recommendation #2.

This report also provides an update on the City's ongoing discussions with Google Fiber to build a fiber-optic network in Palo Alto, in addition to AT&T's plan to deploy its gigabit-speed Internet service called "GigaPower" in Palo Alto.

Executive Summary

On February 2, 2015, the Council approved and authorized the City Manager to execute two Professional Services contracts in amounts not-to-exceed \$144,944 and \$131,650 to Columbia Telecommunications, dba CTC Technology & Energy (CTC), for a FTTP Master Plan and a complementary Wireless Network Plan respectively (Reference CMR ID # 5443).

The FTTP Master Plan evaluated the following:

- Maintaining the viability of the existing dark fiber network offerings;
- Evaluation of potential uses of the existing dark fiber network to support citywide FTTP deployment;
- Information for City staff, City Council, Utilities Advisory Commission, Citizen Advisory Committee, and other stakeholders on benefits, risks, and challenges of a network deployment in a competitive business and residential telecommunications market dominated by two large incumbent service providers;
- Outline of the incumbent service providers' likely reactions to a municipal FTTP overbuild;
- Anticipating the influence of public and private FTTP offerings on market structure, including potential business models that may include a public-private partnership;
- Consideration of the use of existing City and Utilities assets to encourage FTTP deployment;
- Outline of the impact FTTP might have on the usability of City and Utilities assets;
- Based on a high-level engineering study, a realistic estimate of the cost to deploy and operate a citywide FTTP network.

The complementary Wireless Network Plan evaluated the following:

- Deployment of public Wi-Fi and secure City enterprise network access at City buildings and other facilities not already served;
- Deployment of a point-to-multipoint network for secure City enterprise access for first responders and Utilities;
- Deployment of a citywide mobile data network for public safety users.

The key recommendations from CTC in the FTTP Master Plan and Wireless Network Plan are as follows:

FTTP Master Plan

1. Recommends the City not directly pursue provision of retail services through FTTP;
2. Recommends exploring a partnership model where the City builds, owns and maintains fiber with services provided by one or more private sector Internet Service Providers (ISPs);
3. Recommends issuing a Request for Information (RFI) to explore private sector interest in a viable partnership and develop a framework and documentation for FTTP deployment and a subsequent competitive solicitation.

Wireless Network Plan

1. Recommends expanding the City's existing Wi-Fi coverage to additional City facilities and adjoining public areas such as parks;
2. Recommends installing dedicated wireless facilities to address the needs of the City's first responders and Utilities;
3. Recommends considering a citywide broadband wireless network for use by the general public.

In its reports, CTC notes the importance of recognizing that wireless technology is not a competitor to FTTP technology in a market such as Palo Alto; rather, they work together and complement each other. Wireless provides a mobility component to the City's fiber-optic backbone. Fiber-optics, in turn, provides the high capacity backhaul¹ extension needed to create a robust, high-capacity, low-latency wireless broadband network.

Background

At the February 2, 2013 City Council retreat, the Council chose "Technology and the Connected City" as one of its three top priorities for 2013. A Council Committee was formed for this initiative and on June 24, 2013, the Council approved a Council Committee recommendation to develop a work plan to evaluate the feasibility of building a citywide FTTP network and requested the City Manager to appoint a Citizen Advisory Committee (Advisory Committee) to assist in the evaluation (Reference CMR ID #3914). On October 28, 2013, the Council approved the Council Committee recommendation (Reference CMR ID #4203) to develop a FTTP Master Plan to build out the City's dark fiber backbone system to provide Fiber-to-the-Premises and

¹ "Backhaul" is a term used in communications to define the medium used (i.e. fiber optics, copper and coaxial cable and microwave) to transmit voice, video and data traffic to a network backbone and then back to a remote or central site.

develop a complementary Wireless Network Plan with a near-term focus on Wi-Fi, and a long-term consideration of other wireless technologies.

In February of 2014, the City Manager appointed nine (9) Palo Alto residents to the Advisory Committee. The committee has met nine times since the committee was established and meets approximately every two months. At this time, there are six active members remaining on the committee. The committee members are: Richard Brand, Bob Harrington, Andrew Kau, Donn Lee, Christine Moe and Andy Poggio. The most recent Advisory Committee meeting occurred on August 20, 2015. At this meeting, the committee members had an opportunity to review and discuss the FTTP Master Plan and Wireless Network Plan with staff and CTC representatives and provide feedback. The Advisory Committee concurred with staff's recommendation to postpone issuing an RFI for FTTP to enable emerging gigabit broadband services from the private sector to be settled.

The City's Chief Information Officer (CIO) is responsible for directing staff activities for the Technology and the Connected City initiative. Under the direction of the CIO, staff developed request for proposals (RFPs) to retain consulting services for the FTTP Master Plan and Wireless Network. Approximately 1.75 FTEs are assigned from the Information Technology and Utilities Departments to develop the plans.

Development of the RFP for each plan was assisted by the Advisory Committee. RFPs were issued in July of 2014. Through a competitive bidding process, four vendors were interviewed by City staff and one member of the Advisory Committee in September 2014. The interview panel selected CTC Technology & Energy to recommend to the Council to provide professional consulting services for the FTTP Master Plan and Wireless Network Plan. CTC is an independent communications and IT engineering consulting firm with more than twenty five years of experience. CTC has provided the City with professional telecommunications consulting services since 2000. CTC's customer base includes federal, state and local government agencies and the firm has been a leader in developing "gigabit-facilitation strategies."²

² CTC is not affiliated with equipment manufacturers or cable operators and has no relationships with firms or individuals who may submit proposals in response to future RFPs that may be developed through this engagement. CTC's responses to the FTTP and Wireless RFPs states that "we can provide independent guidance; we have, as a policy, no financial stake in the strategies you choose and will not bid on any resulting construction work."

At the June 3, 2015 UAC meeting, Chair Foster appointed Commissioners Danaher and Schwartz to the UAC's Fiber-to-the-Premises committee. Staff met with Chair Foster and Commissioners Danaher and Schwartz on July 8, 2015, to provide background for Utilities' commercial dark fiber enterprise, the FTTP Master Plan and Wireless Network Plan and timetable to complete these plans, and also provide an update on Google Fiber and AT&T GigaPower. Staff and CTC representatives met with the committee on August 21, 2015, to review the draft plans. The UAC also concurred with staff's recommendation to postpone issuing an RFI to enable emerging gigabit broadband services from the private sector to be settled.

Discussion

Fiber-to-the-Premises Master Plan

The FTTP Master Plan report prepared by CTC focuses on helping key stakeholders to understand the potential challenges and difficulties of operating a "for-choice" retail broadband service, an open access network model,³ or other variations of these models. The report also assesses the likely reaction from incumbent telecommunication service providers if the City built a citywide FTTP network.

CTC does not recommend offering conventional cable television or landline telephony services. This is due to continuing consumer migration away from traditional cable offerings in favor of "over-the-top" (OTT)⁴ video content (e.g. Netflix, Hulu, Amazon Instant Video, YouTube, Sling TV and iTunes). Another important trend is the estimated 40-50% of U.S. households now without a landline telephone service, relying instead exclusively on cellular phones and other OTT telephony services such as Voice over Internet Protocol (VoIP). These trends will continue as more non-traditional video content and voice services emerge and greater programming variety becomes available via OTT. This trend is commonly known as consumer "cord-cutting" which appears to be happening at a more accelerated pace than most telecom industry analysts anticipated.⁵

The FTTP Master Plan report presents an assessment of existing City infrastructure and assets, evaluation of recommended technologies, detailed financial modeling and cost projections, and additional considerations for the City. The report includes financial considerations, including market variables that may affect market share, cash flow, and other fundamental aspects that might affect the FTTP offering and its long-term financial sustainability. The following outlines the highlights of the key findings and recommendations in the report:

1. Obtaining market share and acquiring new customers is necessary to the FTTP offering's sustainability, as long as this does not interfere with the established revenue stream and

³ An open access network model has historically been defined as one network infrastructure over which multiple, separate providers can offer service.

⁴ OTT refers to delivery of audio, video and other media over the Internet without the involvement of multi-channel pay-TV providers such as cable TV and direct broadcast satellite companies in the control or distribution of the content.

⁵ Reuters, August 7, 2015: U.S. pay TV cord-cutting accelerates in second quarter - analysts
<http://www.reuters.com/article/2015/08/08/television-cable-idUSL1N10J00P20150808>

customer base for the commercial dark fiber enterprise. Maintaining the viability of the existing dark fiber offering is important to Utilities to avoid erosion of the customer base and existing revenues (approximately \$2 million in net revenues each year). Note, however, that the dark fiber enterprise will likely see competition from planned services from AT&T, Comcast and other providers.⁶

2. **Cost and Financial Analysis for FTTP Deployment:** Section 8 of the report provides the anticipated costs and financial analysis associated with an FTTP deployment. All assumed costs used in this analysis were vetted with City staff for accuracy. This analysis is a snapshot projection based on certain assumptions, and represents a range of potential outcomes, which depend on a variety of factors. CTC's analysis shows that, assuming the network achieves the take rate⁷ required to cash flow the enterprise, the City will require an estimated overall capital investment of approximately \$77.6 million⁸ to build the network over a three year period (take rate projections for this report are explained in item #8 below). The components of this capital investment include network equipment, outside plant and facilities, last mile and customer premises equipment and miscellaneous implementation costs. This cost and the anticipated startup costs associated with initial network deployment are subject to change based on real-world variables.
3. **Inventory and Assessment:** In Section 3 of the report, CTC conducted preliminary research into the City's existing infrastructure and assets as an initial step toward planning how best to deploy FTTP infrastructure. CTC notes that existing infrastructure is not always an asset in the pursuit of FTTP; for example, if barriers to the infrastructure are too many or the cost to "ready it" for FTTP is too great. CTC also considered the existing dark fiber optic backbone system, and what role it might have in an FTTP network, if any. Utility poles and conduit were also evaluated. One obstacle to leveraging an asset is getting it "cleaned up" to the point of being usable in the course of a citywide FTTP network build.⁹ A primary example of this is the "make-ready" process that must occur for a utility pole that does not have enough space for the attachment of new facilities for FTTP. In some cases utility poles may need to be replaced entirely if there is not enough space.
4. **Comparison of FTTP Technology:** Section 4 of the report describes the primary types of FTTP technology deployed today. From a purely technical standpoint - independent of a given network's design or goals - each of these technologies has strengths and weaknesses. CTC recommends using Gigabit-capable Passive Optical Network (GPON) technology, which is the most commonly provisioned FTTP technology due to its inherent economies as

⁶ Comcast Ethernet V. Dark Fiber - The Dark Side of Dark Fiber

http://business.comcast.com/docs/default-source/white-papers/cb_ethernetvsdarkfiber_whitepaper_3-14.pdf?sfvrsn=0

⁷ Take rate is the percentage of subscribers who purchase services from an enterprise - and is an important driver in the success of an FTTP retail model. If the required take rate is not met, the enterprise will not be able to sustain itself and its operational costs will have to be offset through an alternative source.

⁸ See FTTP Master Plan Report Table 10, page 133, "Capital Additions."

⁹ The existing fiber infrastructure is approximately 54 percent overhead and 46 percent underground. The majority of the underground infrastructure is placed in commercial areas - only approximately 15 percent of it is underground in residential areas. The majority of new fiber for the FTTP network will be placed in residential areas and will likely follow aerial routes.

compared with other technologies evaluated in the report. The network design and GPON technology proposed by CTC represents the current state of the art within the framework of financial feasibility.

5. The term “overbuild” refers to deploying a network where incumbent telecommunication service providers already serve customers. A new FTTP network competes directly with existing local cable, DSL, and other incumbent ISPs to offer services to customers. Fiber overbuilds generally do not offer a high rate of return, which is why there are not many private sector providers seeking to build fiber networks where customers are already served. Private and public sector entities that opt to overbuild usually consider alternative reasons and benefits for deploying a network and focus on other value drivers that make business sense. Examples of these drivers are communities seeking to enhance economic development by providing access to ultra-high speed Internet to serve businesses and research parks. An example of a private sector overbuilder is Google Fiber, which has the financial resources to disrupt the market and push the other providers to improve their data offerings to remain competitive.
6. The potential reaction from large incumbent telecommunication and ISPs to competition from a municipal FTTP network should not be overlooked. CTC encourages the City to come to internal agreement on its public messaging. Incumbents in Palo Alto would likely respond to the City’s market entry by running pricing promotions and other specials to target consumers and attempt to lock them into long contracts. They may also launch politically slanted campaigns fraught with scare tactics, claiming that the City is already well-served with broadband and has no reason to develop a municipal offering.
7. An alternative to traditional overbuilding is to “cherry pick”, or build to areas of a community where the provider is most likely to obtain a high number of subscribers willing to pay for service with a resulting high rate of return on capital investment. This approach is similar to Google’s “fiberhood” strategy where they only build if a certain percentage of residents sign up. Nevertheless, this approach is often not feasible for a public entity due to the political pressure to provide fiber access to all premises in the community irrespective of future rate of return on capital investment.
8. If the City built and operated a FTTP network and provided for-choice retail services there are inherent challenges that the City would face. These challenges include high costs compared to other metropolitan areas for labor and materials. Moreover, the cost of outside plant (OSP)¹⁰ and drop cables¹¹ will be greater than other metropolitan areas because Bay Area costs, particularly labor and overhead for employees, tend to be higher.¹²
9. As a result of these high build and staffing costs, the required take rate is 72 percent, which is significantly higher than private and public overbuilders have been able to obtain. In

¹⁰ OSP is physical assets like overhead and underground fiber, accompanying ducts and splice cases, and other network components.

¹¹ Drop cables connect the fiber optic backbone to the customer premises.

¹² Labor will be more costly than in other metropolitan areas because salaries in the Bay Area tend to be higher on average, and overhead for City employees is calculated at an extremely high 65 percent. As a comparison, CTC has usually calculated this rate at approximately 35 percent in other recent studies CTC conducted. The model assumes that all debt service and network replenishments would be covered, which factors into the necessary take rate.

comparison, CTC's recent analyses conducted for other municipalities have shown a required take rate in the mid 40 percent range in order to maintain positive cash flow."

10. CTC evaluated using initial funding that does not need to be paid back, such as using the Fiber Optic Fund Rate Stabilization Reserve¹³ to help cover implementation costs to reduce the required take rate. In Section 8.3.2 of the report, Figure 30 shows the impact of funding amounts to \$20 million in \$5 million increments. For each \$5 million in funding, there is approximately a 3.8 percentage point drop in required take rates.¹⁴ Nonetheless, the possibility that an overbuilder can obtain a 57 percent take rate as shown in the graph in Section 8 of the report (Cost and Financial Analysis for FTTP Deployment/page 142/Figure 30) in a competitive telecommunications market with two dominant providers (AT&T and Comcast) and several smaller providers is unlikely.
11. In light of the high cost to build and the extremely high take rate required, it may seem that there is little incentive for any public or private overbuilder to pursue a FTTP deployment in Palo Alto; however, the public and private sectors have unique advantages that may impact their ability to undertake a standalone overbuild. A private and public entity could complement one another by developing a partnership that can take advantage of each entity's strengths, and may significantly reduce risk.
12. Many private providers have certain cost advantages that a public entity simply cannot replicate, like buying power with vendors for decreased electronics costs and the potential to reduce or entirely avoid maintenance fees for electronics. Large private providers will often maintain their own inventory of core electronics and share use of electronics over deployments in multiple markets. This is a cost savings and an advantage with which the City is unable to compete.
13. Many private providers already possess internal technical capabilities, and they may share staffing with other deployments. Technical support, sales, customer service, and other personnel may simply be reallocated to support deployment in a new market, with little to no impact on overhead costs and no need to hire additional staff. As an example, a large provider like Comcast does not necessarily have to hire additional staff to support an influx of 20,000 new customers. It can leverage its existing staff pool, which is already supported by its customer base in other markets.
14. The private sector can also avoid some of the staffing challenges the City faces by locating staff in other regions. As noted, Bay Area salaries are high, and the overhead for City employees is especially costly. If the City wanted to directly provide retail service, it could potentially reduce overhead costs by outsourcing to local firms, but for political reasons it will likely not be in the City's best interest to contract with entities outside Palo Alto. The private sector is at an advantage because it does not have to manage the same political considerations as the City. The operational costs that the City can expect to face are thus greater and more complex than what an established, private-sector entity with economies of scale might incur.

¹³ The Projected Ending Reserve for FY 2016 is \$22.4 million.

¹⁴ Note the individual data points in Figure 30 will vary from the 3.8 percent average since the resulting cash flow balances and projected Internal Rate of Return (IRR) vary from case to case.

15. Absent a private entity building and operating an FTTP network with unfettered data access, CTC recommends that the City consider pursuing a public-private partnership that leverages each party's strengths, shares financial risks, and provides unfettered data access to the community. CTC's report evaluates the numerous advantages and disadvantages of the various public-private partnership models in its report.
16. In light of the high costs the City will face for labor and overhead and the high necessary take rate, CTC does not recommend that the City directly pursue an FTTP model in which it provides retail services. The City simply does not have the same buying power as the private sector, and it is not particularly skilled at operating a for-choice competitive business. However, it may make sense for the City to deploy, own, and maintain the fiber infrastructure, and to engage a private provider to manage the FTTP enterprise's operations. This would allow the City to focus on the long-term fiber investment and to leverage a private partner's operational efficiencies to potentially create a strong enterprise and reduce the take rate necessary to make the enterprise cash flow.
17. As a next step in FTTP planning, CTC recommends the City develop and distribute a Request for Information (RFI): a potential key step toward exploring the interest of the private sector in developing viable partnerships is to develop a framework and documentation for a request for information (RFI) process. This will help the City clearly articulate its goals and inform the private sector of the City's existing assets (e.g. rights-of-way, utility poles, conduit and fiber) and its desire to deploy FTTP. CTC recommends that the City undertake this process to help inform its own needs, and to clearly break down its expectations for itself and a potential partner.
 - a. Note: Staff agrees with CTC's recommendation to issue an RFI, but recommends postponing the issuance until after emerging gigabit broadband services from the private sector are settled.

Wireless Network Plan

The Wireless Network Plan prepared by CTC included a comprehensive analysis of the long-term needs for municipal wireless services within Palo Alto. CTC examined a wide range of applications that could potentially be addressed through the implementation of one or more commercial wireless technologies. CTC also examined various deployment scenarios such as blanket citywide coverage through Wi-Fi technology, expanded targeting of Wi-Fi access at and around City facilities, and dedicated projects focusing on providing priority, high-reliability services to the City's critical infrastructure operated by Utilities and public safety agencies. The process to gather information for this analysis involved a "user needs assessment" which involved in-depth interviews with staff in several City departments (City Manager, Information Technology, Planning/Transportation Division, Office of Emergency Services, Public Works and Utilities).

In addition to the above-noted staff interviews, a community survey was also conducted on Palo Alto Open City Hall to determine the interest in public Wi-Fi potentially provided by the City. The summary for the outcome of the survey shows the following results for 275 respondents:

- Over 85 percent of respondents identified ultra-high speed Wi-Fi Internet access in Palo Alto as important;
- Almost 65 percent of respondents indicated a willingness to pay for the service;
- 46 percent of respondents believe city government should provide Wi-Fi services to the public.

The results of the survey are found here:

<https://www.cityofpaloalto.org/civicax/filebank/documents/48722>

Based on CTC's staff interviews and analysis, the Wireless Network Plan presents an assessment of existing City infrastructure and assets, evaluation of recommended technologies, detailed financial modeling and cost projections, and additional considerations for the City. The report also includes examples of other municipalities that built Wi-Fi and wireless networks for a variety of communication needs and applications, including public access to these networks. The report includes "lessons learned" for each example.

The following provides background for the recommendations noted above and the various factors the City should consider for municipal wireless implementation scenarios that address specific communications needs within the City and the community:

1. Expand the deployment of Wi-Fi coverage to City facilities and adjoining public areas. The City successfully deployed Wi-Fi to thirty (30) City facilities for public and internal City use; CTC recommends that the City continue to deploy Wi-Fi at other City facilities, smaller City buildings, and park and recreational areas.
2. Install dedicated wireless facilities to address the needs of the City's public safety responders and Utilities. To address the City's high-priority internal needs, CTC recommends that the City consider deploying wireless infrastructure to support enterprise applications. For Utilities, these would include real-time monitoring and control of facilities that are not connected to the existing fiber-optic network (e.g., pump stations, electrical line monitoring).¹⁵ For public safety agencies, the wireless infrastructure would support mobile and portable communications for command and patrol vehicles, as well as incident command networks in the areas where existing commercial wireless services are often saturated due to a high concentration of public users (e.g., major events at Stanford University).
3. Consider a citywide broadband wireless network for use by the general public. A citywide public Wi-Fi deployment is technically feasible, however, only in concert with the deployment of a citywide FTTP network. The existing fiber-optic infrastructure operated by Utilities has neither the capacity nor the coverage area to support a citywide wireless deployment without a major expansion. If, on the other hand, a citywide fiber-optic network were in place, it would provide a mechanism for backhauling traffic from the individual wireless access points with transmission speeds measured in gigabits. This type of

¹⁵ Monitoring of electrical lines for voltage amplitude and phase shift. Monitoring provides a means to measure power in real time and adjust the system to achieve higher efficiency.

system would have the capability and coverage area to provide service competitive with existing 4G and future 5G commercial wireless networks.

Based on the above-noted recommendations, CTC has recommended four independent scenarios, which can be implemented singularly or in combination to address a mix of public and internal City services (including municipal operations and public safety applications):

Scenario 1

Deploy Public Wi-Fi and Secure City Enterprise Network Access at City Buildings:

In this scenario, the City would deploy Wi-Fi at all City buildings not currently served, and support both free public access and secure enterprise network access for City employees. This option is basically an expansion of the City's original deployment (thirty City locations are currently being served) to include all City buildings, parks, and recreational areas. The capital amount required for deployment at additional City sites will depend on the number of sites, and will presumably be comparable to the City's costs for its previous deployments at major City buildings. These City buildings, parks and recreational areas are identified and prioritized in Section 7.2.2 of the Wireless Network Plan report.

Scenario 2

Deploy Public Wi-Fi and Secure City Enterprise Network Access Citywide:

Scenario 2 would deploy "blanket" wireless coverage for public and City users. CTC envisions a two-phase deployment approach:

Phase A: Leveraging *existing fiber*, provide public Wi-Fi to core City business and residential areas.¹⁶ CTC estimates the capital cost to construct the infrastructure for this deployment to be approximately \$4.7 million, and the yearly operating expenses to be \$600,000 (assuming operation on a subscription basis at \$20 per month, with a minimum of 2,550 customers).

Phase B: Contingent on the City *upgrading fiber* as part of a Utilities upgrade or FTTP deployment provide public Wi-Fi to core business and residential areas.¹⁷ CTC estimates the capital cost to construct the infrastructure for this deployment to be approximately \$3.3 million, and the yearly operating expenses to be \$433,000 (assuming operation on a subscription basis at \$20 per month, with a minimum of 1,880 customers).

Residents and visitors would be able to access the network with any consumer-grade smartphone, tablet, or computer. The network would deliver Gigabit service at each access point, and would be IEEE 802.11/b/g/n/ac compatible.¹⁸ Nationally, many communities have deployed citywide Wi-Fi either under municipal funding or in partnership with a commercial provider. These services are generally well-received by the public, *but* CTC states it has been

¹⁶ Phase A: 100 Mbps shared among all users, 400+ wireless access points, light pole mounted, wireless mesh technology.

¹⁷ Phase B: 1 Gbps shared among all users, 600+ wireless access points, light pole mounted, fiber connected to each wireless access point, three to five years after Phase A completion.

¹⁸ IEEE 802.11 is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 2.4, 3.6, 5, and 60 GHz frequency bands.

unable to find any municipal implementation projects that represent an economically viable standalone business opportunity. The public will clearly use available free Wi-Fi; however, when asked to pay for the service in a public space, many consumers have little interest. Consumers often will pay for such services in confined/restricted facilities such as an airplane, at an airport, or in a hotel. In contrast, blanket coverage often referred to as “amenity communication services” are generally expected to be provided free of charge.

Scenario 3

Deploy a Point-to-Multipoint Network for Secure City Enterprise Access:

In this scenario, the City would deploy a citywide high-reliability, dedicated, critical-infrastructure broadband wireless network to support public safety, Utilities, Public Works, and Traffic Engineering needs. As in the Police Department’s Mobile Emergency Operations Center (MEOC) incident deployment, City Hall would serve as the core site for a point-to-multipoint deployment.¹⁹ CTC estimates the capital cost to construct the infrastructure for this deployment to be approximately \$370,000. It is anticipated that the annual operational cost to support this scenario will be low. Staffing will be supported by Public Safety and Utilities as a minor add-on to their current operation of radio, fiber-optic, and other communications equipment. Hardware maintenance will likely be outsourced to equipment manufacturers/vendors. For this scenario CTC estimates a maximum annual expenditure of \$10,000.

Scenario 4

Deploy a Citywide Mobile Data Network for Public Safety Users:

In this scenario, the City would create hot spots for public safety mobile data network access to augment existing wireless operations at key facilities and routes (schools, stadiums, business areas). The hot spots would provide radial coverage to first responders and other authorized users. The City would equip its public safety vehicles with exterior mounted antennas and mobile routers capable of acting as access points. As an initial step, access points could be deployed at Utilities’ nine substations to provide coverage to a significant portion of the City. The City has more than 130 locations (including 101 fiber-connected traffic signals) that are suitable access points, so this scenario has great potential for phased deployment. CTC estimates the capital cost to construct the infrastructure for this deployment to be approximately \$337,600. It is anticipated that the annual operational cost to support this scenario will be low. Staffing will be supported primarily by Public Safety as an addition to its operation of land mobile radio and other existing communications equipment. Hardware maintenance will likely be outsourced to equipment manufacturers/vendors. For this scenario CTC estimates a maximum annual expenditure of \$30,000.

Google Fiber and AT&T GigaPower Update

¹⁹ Sites to be served include: mobile public safety command vehicles, all Police/Fire radio sites, Utilities substations, Utilities facilities not connected to fiber-optic network, selected traffic engineering sites, and portable Public Works camera sites.

In January, 2015, Google selected Atlanta, Charlotte, Raleigh/Durham, and Nashville as the next markets that will receive Google Fiber deployments. In March, 2015, Google announced it would be expanding Google Fiber into Salt Lake City and in early August 2015, Google announced they will also build a fiber optic network in San Antonio, Texas. Google is still evaluating expansion plans in Phoenix, Portland and the San Jose Metro area, which includes the cities of Palo Alto, Mountain View, Santa Clara, Sunnyvale and San Jose. Google has already deployed fiber optics in the Kansas City metro area and construction of a Google fiber optic network is underway in Austin, Texas. In 2013, Google bought an existing municipal fiber optic network in Provo, Utah.

City staff continues to meet with Google representatives on a regular basis. These meetings with Google representatives include discussions about the California Environmental Quality Act (CEQA) requirements, permitting processes for use of the public rights-of-way, utility pole attachments, conduit usage and dark fiber licensing. Staff anticipates that Google will make a final decision to build a fiber optic network in the San Jose metro area this fall.

In April 2014, AT&T announced their plan to bring fiber to the Silicon Valley area. Subsequently, in May 2015, AT&T approached the City with intentions to bring its gigabit Internet service to Palo Alto. This service, called “GigaPower”, is an upgrade to AT&T’s existing U-verse services (*Project Lightspeed*) and will be deployed to residents via the installation of twenty seven (27) new cabinets that will be placed next to existing U-verse cabinets. Initially, AT&T will select neighborhoods with high potential for adoption and will use consumer demand levels to determine further deployments in the city. AT&T plans to begin construction in the last quarter of 2015 and begin providing service in 2016.

To begin the process with the City, AT&T has provided a sample permit application to the Department of Public Works for review. Once agreement is reached on the submittal of permit applications and the process for moving the permits through the appropriate City departments, AT&T will submit the required applications for all 27 cabinets.

Resource Impact

Approximately 1.75 FTEs are assigned from the Information Technology and Utilities Departments to work with CTC to complete the FTTP Master Plan and Wireless Network Plan. Future fiscal impacts will be addressed with the Council once the findings and recommendations from the FTTP Master Plan and the Wireless Network Plan are evaluated by the Council and further direction is provided on the City’s level of involvement in the implementation of the plans.

Policy Implications

Development of the Fiber-to-the-Premises Master Plan and Wireless Network Plan is consistent with the Telecommunications Policy adopted by the Council in 1997, to facilitate advanced telecommunications services in Palo Alto in an environmentally sound manner (Reference CMR: 369:97- Proposed Telecommunications Policy Statements).

Environmental Review

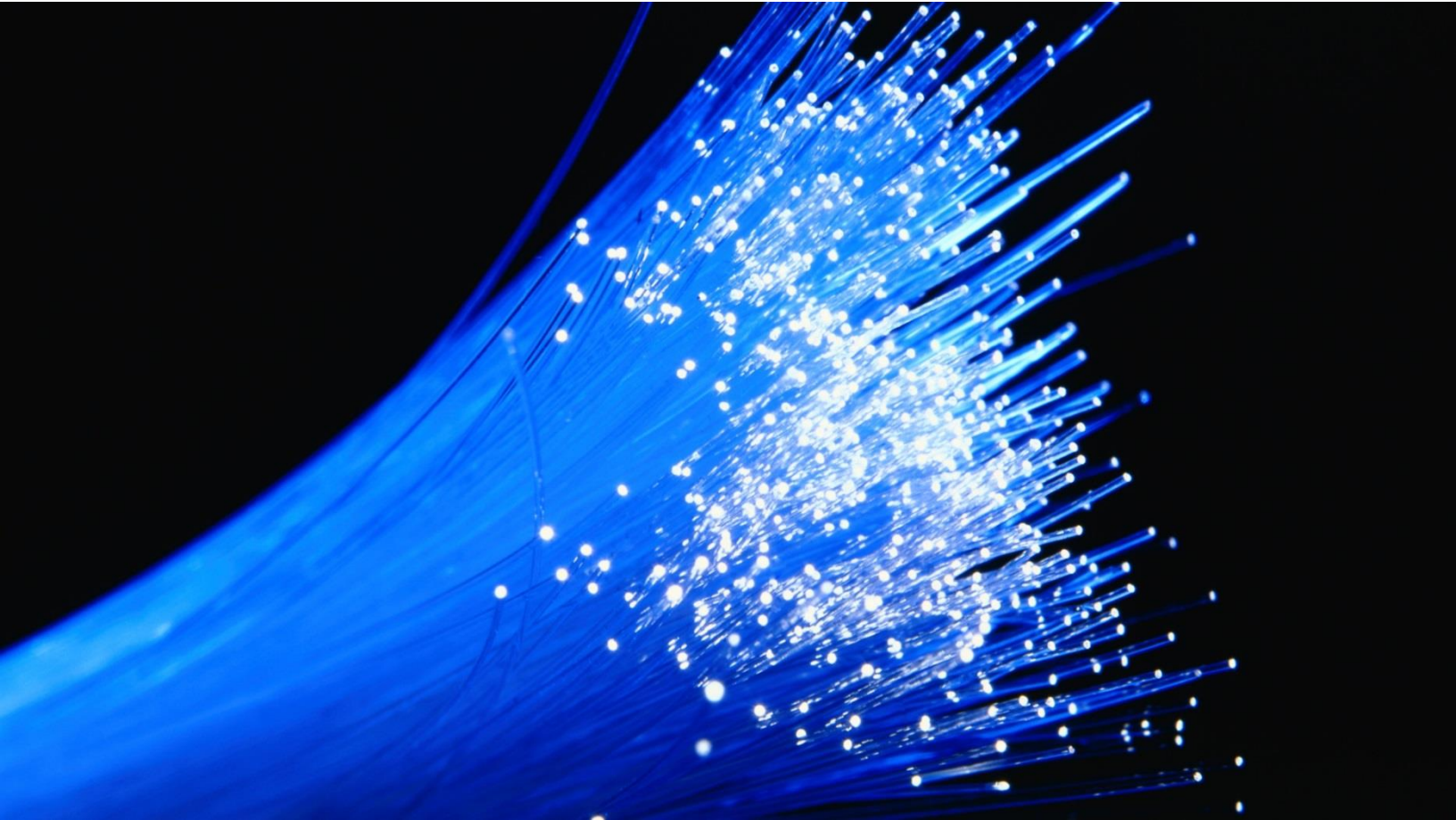
The development of a FTTP Master Plan and Wireless Network Plan are not projects under the California Environmental Quality Act (CEQA) as feasibility and planning studies are exempt under CEQA Guidelines Section 15262.

Attachments:

- **Attachment:** Attachment A: Palo Alto FTTP Master Plan - Final - 20150910 (DOCX)
- Attachment: Attachment B: Appendix A - Palo Alto Existing Market Assessment - Rev 4 - Final - 20150910 (DOCX)
- Attachment: Attachment C: Appendix B - Palo Alto FTTP Financial Models Rev 13 20150715 (PDF)
- Attachment: Attachment D: Palo Alto - Wireless Network Plan - Rev 8a - Final - 20150910 (DOC)
- Attachment: Attachment E: Appendix B - Palo Alto Wireless Option A Financial Rev 1 20150607 (PDF)
- Attachment: Attachment F: Appendix C - Palo Alto Wireless Option B Financial Rev 1 20150607 (PDF)
- Attachment: Attachment G: Excerpted Draft Minutes of the September 2, 2015 UAC Meeting (DOCX)

ctc technology & energy

engineering & business consulting



City of Palo Alto Fiber-to-the Premises Master Plan

**Prepared for City of Palo Alto
September 2015**

Columbia Telecommunications Corporation

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

Contents

1	Executive Summary.....	1
1.1	Background and Objectives.....	1
1.2	Fiber Is an Important Community Asset and Differentiator	5
1.3	FTTP Overbuild Challenges.....	6
1.4	Financial and Other Considerations and Challenges for FTTP in Palo Alto.....	6
1.5	Breakdown of How Capital and Operations Funds Are Allocated	9
1.5.1	Infrastructure Costs	10
1.5.2	Operating Costs.....	10
1.5.3	Public and Private Entity Cost Advantages and Disadvantages.....	13
1.6	Recommendations	13
1.6.1	Establish a Realistic Timeline	13
1.6.2	Explore a Partnership Model Where the City Builds, Owns, and Maintains Fiber .	14
1.6.3	Develop and Distribute a Request for Information	15
2	FTTP Network Requirements.....	18
2.1	User Applications and Services	18
2.1.1	Internet Access.....	19
2.1.2	IP Telephony (VoIP) and Video Conferencing.....	19
2.1.3	Streaming Video.....	20
2.1.4	Cloud Access	20
2.2	User Groups.....	21
2.2.1	Passings.....	22
2.2.2	Residents.....	22
2.2.3	Small Businesses and Enterprise Users.....	23
2.2.4	Public Safety.....	24
2.2.5	Electric Utility.....	25
2.2.6	Health Care	25
2.3	Network Design Requirements	25
2.3.1	Why Fiber Optics.....	27
2.3.2	Fiber Routes and Network Topology	27

2.3.3	Passive Optical Network—Specifications and Technology Roadmap	28
2.3.4	Managing Network Demand.....	29
2.3.5	Internet Protocol (IP) Based Applications.....	32
2.3.6	Migration from IPv4 to IPv6 Protocol	32
2.3.7	Multicasting—IP Transport of Video Channels.....	33
2.3.8	Over-the-Top (OTT) Programming.....	35
2.4	Integration of Wireless Communications	36
2.4.1	Mobile Backhaul.....	37
2.4.2	Partnerships with Wireless Carriers.....	39
2.4.3	Potential Wireless Services by City FTTP Network	39
2.4.4	Residential Wireless Services—Wi-Fi and New Technologies	39
2.4.5	Roaming Wi-Fi Networks	41
3	Inventory and Assessment.....	43
3.1	Existing Dark Fiber Optic Backbone Network	43
3.2	Utility Poles	46
3.3	Existing Conduit.....	47
3.4	Permitting Process	48
3.5	Review of Existing Agreements.....	48
3.5.1	Master License Agreement	48
3.5.2	Joint Pole Agreements	49
4	Comparison of FTTP Technologies.....	50
4.1	Types of FTTP Technologies	50
4.2	Assessment of Recommended FTTP Technologies	54
4.2.1	Network Design Trade-Offs	54
4.2.2	Electronics.....	55
4.2.3	Facilities.....	56
4.2.4	Customer Premises	56
5	FTTP Design and Cost Estimates	58
5.1	Issues Related to Aerial Construction	60

5.2	Cost Estimates	62
5.3	Methodology for Developing OSP Route Assumptions	65
5.4	Backbone Routes.....	67
5.5	Network Architecture and Electronics	67
5.5.1	Core Network Sites	71
5.5.2	Distribution and Access Network Design.....	74
5.6	Operations and Maintenance Cost Estimates.....	82
5.6.1	Subscriber Provisioning.....	83
5.6.2	Maintenance	83
6	FTTP Business Models and Municipal Objectives.....	84
6.1	Defining Broadband	84
6.1.1	Broadband Speed.....	84
6.1.2	Relationship of Service and Infrastructure	85
6.2	Business Models.....	87
6.2.1	Retail Services	87
6.2.2	Wholesale Services	87
6.2.3	Infrastructure Participation and Public–Private Partnerships.....	88
6.3	Redefining Open Access	90
6.3.1	Open Access Goals	91
6.3.2	Evolving Over-the-Top Providers	92
6.4	FTTP Objectives	96
6.4.1	Community Broadband Objectives.....	96
6.4.2	Ubiquity.....	98
6.4.3	Consumer Choice	102
6.4.4	Competition in Market.....	103
6.4.5	Ownership and Control of Assets	104
6.4.6	Performance	105
6.4.7	Affordability	106
6.4.8	Risk Aversion	107

6.4.9	Cash Flow	109
7	Potential for Public–Private Partnership	111
7.1	Broadband Public–Private Partnership Framework.....	112
7.1.1	Risk	113
7.1.2	Benefit	114
7.1.3	Control	114
7.2	Model 1 – Public Investment with Private Partners	115
7.3	Model 2 – Public Sector Incenting Private Investment.....	117
7.4	Model 3 – Shared Investment and Risk	120
7.4.1	Case Study: Champaign–Urbana, Illinois	120
7.4.2	Case Study: Garret County, Maryland	121
7.4.3	Case Study: Westminster, Maryland	122
7.5	Define the City’s Objectives	123
7.6	City and Partner Responsibilities	124
7.7	Develop a Request for Information.....	125
7.8	Additional Considerations for Public–Private Partnerships.....	125
8	Cost and Financial Analysis for FTTP Deployment.....	128
8.1	Financing Costs and Operating Expenses.....	129
8.2	Operating and Maintenance Expenses	133
8.3	Summary of Operating and Maintenance Assumptions.....	135
8.4	Sensitivity Scenarios.....	136
8.4.1	Labor, Vendor Maintenance Fees, and DIA	136
8.4.2	Initial Funding	141
8.4.3	Impact of Take Rate on Cash Flow.....	144
8.4.4	Impact of Service Fees on Cash Flow	147
	Appendix A – Existing Palo Alto Market Assessment	151
	Appendix B – Financial and Cost Analysis.....	152

Figures

Figure 1: Breakdown of How Funds Are Used in Year 7	9
Figure 2: Infrastructure Costs in Year 7	10
Figure 3: Operating Expenses in Year 7	11
Figure 4: Breakdown of Operating Expenses in Year 7	12
Figure 5: Unicast IP Network Carries Multiple Copies of Single Video Channel.....	34
Figure 6: Multicast IP Network Carries Single Copy of Single Video Channel	34
Figure 7: Cable Operator Providing Fiber Backhaul to Cell Sites and Micro/Nanocells	38
Figure 8: Comcast Wi-Fi Hotspots in Palo Alto	41
Figure 9: Examples of Pole Zones	45
Figure 10: Aerial and Underground Utilities in Palo Alto	59
Figure 11: Examples of Pole Lines Requiring Tree Trimming.....	60
Figure 12: OSP Crew Replacing a Pole	62
Figure 13: Sample FTTP Network Design to Determine Quantities per Street Mile	66
Figure 14: Backbone Design.....	68
Figure 15: High-Level FTTP Architecture.....	69
Figure 16: Sample Floorplan for Core Location	73
Figure 17: Sample List of Materials for Core Location.....	73
Figure 18: BNG Facility	76
Figure 19: List of Materials for BNG.....	76
Figure 20: Example Small Outdoor FDC Housing PON Splitters	77
Figure 21: Example Large Outdoor FDC Housing an OLT.....	78
Figure 22: List of Materials for High-Density OLT Site (Up to 2,000 Subscribers)	78
Figure 23: Example Indoor FDC Option for OLTs	78
Figure 24: CPE Kits.....	81
Figure 25: Wholesale Lit Services	88
Figure 26: Infrastructure Participation Role in Partnerships and Turnkey Vendor Relationship .	89
Figure 27: Interactions between Objectives.....	98
Figure 28: Ubiquity Alignments, Conflicts, and Potential Outcomes	102
Figure 29: Risk and Reward Matrix	108
Figure 30: Impact of Initial Funding on Required Take Rate	142

Tables

Table 1: PON Standards	29
Table 2: Poles and Heights.....	47
Table 3: Comparison of FTTP Technologies	50
Table 4: Estimated OSP Costs for FTTP (Assuming a 35 Percent Take Rate)	64
Table 5: Estimated Electronics Costs for FTTP (Assuming a 35 Percent Take Rate).....	64
Table 6: Common Goal Alignment.....	97
Table 7: Operating Expenses in Years 1, 5, 10, 15, and 20	130
Table 8: Income Statement.....	131
Table 9: Cash Flow Statement	132
Table 10: Capital Additions	133
Table 11: Labor Expenses.....	135
Table 12: Base Case Scenario – Residential Service \$70 per Month, Small Commercial Service \$80 per Month, Medium Commercial Service \$220 per Month	137
Table 13: Decrease Overhead to 27 Percent of Salaries (from 65 percent), Financing Reduced by \$5 Million, and Take Rate Decreased to 62.1 Percent	137
Table 14: Eliminate Vendor Maintenance Contracts and Reduce Take Rate to 62.1 Percent ...	138
Table 15: Reduce Labor Expenses by 40 Percent and Reduce Take Rate to 57.6 Percent.....	139
Table 16: Eliminate Vendor Maintenance Contracts, Reduce Labor Expenses by 40 Percent, and Reduce Take Rate to 51.3 Percent.....	139
Table 17: DIA Monthly Price (per Mbps) Increases by \$0.50	140
Table 18: DIA Monthly Price (per Mbps) Decreases by \$0.50	140
Table 19: Eliminate Vendor Maintenance Contracts, Reduce Labor Expenses by 50 Percent, Reduce DIA by 67 Percent, and Reduce Take Rate to 45 Percent.....	141
Table 20: Use \$5 Million in Start-Up Funds (Decrease Amount Bonded by Same), Reduce Take Rate to 65.7 Percent	142
Table 21: Use \$10 Million in Start-Up Funds (Decrease Amount Bonded by Same), Reduce Take Rate to 63 Percent	143
Table 22: Use \$15 Million in Start-Up Funds (Decrease Amount Bonded by Same), Reduce Take Rate to 60.3 Percent	143
Table 23: Use \$20 Million in Start-Up Funds (Decrease Amount Bonded by Same), Reduce Take Rate to 56.7 Percent	144

Table 24: Residential Market Share Increase by 5 Percentage Points (4.5 Percentage Point Take Rate Increase)	144
Table 25: Residential Market Share Increase by 10 Percentage Points (9 Percentage Point Take Rate Increase)	145
Table 26: Residential Market Share Decrease by 5 Percentage Points (4.5 Percentage Point Take Rate Decrease)	145
Table 27: Residential Market Share Decrease by 10 Percentage Points (9 Percentage Point Take Rate Decrease)	146
Table 28: Commercial Market Share Increase by 10 Percentage Points (9 Percentage Point Take Rate Increase)	146
Table 29: Commercial Market Share Decrease by 10 Percentage Points (9 Percentage Point Take Rate Decrease)	147
Table 30: Residential Monthly Service Prices Increase by \$5	147
Table 31: Residential Monthly Service Prices Increase by \$10	148
Table 32: Residential Monthly Service Prices Decrease by \$5	148
Table 33: Residential Monthly Service Prices Decrease by \$10	149
Table 34: Small Commercial Monthly Service Prices Increase by \$10	149
Table 35: Small Commercial Monthly Service Prices Decrease by \$10	150

1 Executive Summary

This analysis was prepared by CTC Technology & Energy (CTC) to provide strategic recommendations for the City of Palo Alto in its effort to ensure that its residents and businesses have competitive, available, and affordable access to fiber-based state-of-the-art connectivity services.¹ This report presents an assessment of existing City infrastructure and assets, an evaluation of recommended technologies, detailed financial modeling and cost projections, and additional considerations for the City.

1.1 Background and Objectives

Located in northern Santa Clara County, California, and nestled in the San Francisco Bay Area, the City of Palo Alto has a resident population of approximately 66,000,² and a daytime population of more than 125,000.³ The City is situated in “Silicon Valley”⁴ and boasts educational levels and income rates well above the national average.⁵

City of Palo Alto Utilities (CPAU) has successfully operated a dark fiber network for almost two decades.⁶ It serves a range of City and other customers with more than 200 dark fiber service connections to commercial users. In light of CPAU’s success with its dark fiber network, and to keep pace with the increasing need for robust connectivity services, the City is exploring the possibility of a municipally owned fiber-to-the-premises (FTTP) network, adding residential customers to the mix. This would not replace the dark fiber network, but would complement it by serving customers that the City is not currently able to reach.

To uphold the City’s primary objective of ensuring that residents and businesses have access to competitively priced and well-managed broadband services, this report prioritizes the following City goals:

- Foster local competition in the telecommunications industry
- Maintain the viability of the existing dark fiber network offerings

¹ The demand for higher-performing services will continue to increase. Given this, it is important for the delivery platform to not just support 1 Gigabit per second (Gbps) service, but also to be able to scale to 10 Gbps and beyond as applications and needs expand.

² <http://quickfacts.census.gov/qfd/states/06/0655282.html>, accessed June 2015.

³ Daytime population estimate is based on input from City and CPAU staff, and City of Palo Alto Fire Department data. <http://www.cityofpaloalto.org/gov/depts/fir/overview/default.asp>, accessed August 2015.

⁴ A colloquial term for the northern portion of the San Francisco Bay Area, where the silicon transistor chip was invented. <http://www.investopedia.com/terms/s/siliconvalley.asp>, accessed May 2015.

⁵ The City’s per capita income was estimated by the 2013 census at \$121,465 while the national average was estimated at approximately \$52,250. In 2014, the national average of those who had obtained a bachelor’s degree or higher was 34 percent, while in Palo Alto that number was 79.8 percent at the 2013 census.

⁶ <http://www.cityofpaloalto.org/gov/depts/utl/about/history.asp>, accessed June 2015.

- Evaluate potential uses of the dark fiber network to support FTTP deployment
- Inform City staff, City Council, Utilities Advisory Commission, Citizen Advisory Committee, and other stakeholders on benefits, risks, and challenges of a network deployment in a competitive business and residential telecommunications market dominated by two large incumbent service providers
- Outline the incumbent service providers' likely reactions to a municipal FTTP overbuild⁷
- Anticipate the influence of public and private FTTP offerings on market structure, including potential business models that may include a public-private partnership
- Consider use of existing City and CPAU assets to encourage FTTP deployment
- Outline the impact FTTP might have on the usability of City and CPAU assets
- Based on a high-level engineering study, provide a realistic estimate of the cost for the City to deploy and operate a citywide FTTP network

Obtaining viable market share and acquiring new customers is necessary to sustain a City FTTP offering. Maintaining the viability of the existing dark fiber offering is important to CPAU to avoid erosion of the customer base and existing revenues (approximately \$2 million in net revenues per year). We note, however, that the dark fiber enterprise will likely see competition from planned services from Comcast and AT&T. These services and their threats are discussed below.

We aim to help the City and other key stakeholders understand the potential challenges and difficulties of operating a for-choice competitive retail service, an open access fiber network model,⁸ or other variations of these models to help prepare for anticipated responses from potential competitors and community stakeholders. Our financial analysis seeks to understand and present potential variables that may affect market share, cash flow, and other fundamental aspects of operating a City FTTP offering.

It is also important to understand the presence of incumbent providers in the region, and the potential for additional competitors to enter the market.

Google Fiber announced in early 2014 that the City is on its short list of communities where the company may expand its FTTP business. (Google Fiber is also considering other California communities, including San Jose, Santa Clara, Sunnyvale, and Mountain View.)⁹ In addition,

⁷ See Section 1.3 for a definition of overbuilding.

⁸ An open access network model has historically been defined as one network infrastructure over which multiple, separate providers can offer service.

⁹ <http://www.multichannel.com/news/technology/google-fiber-sets-18-city-expansion/387338>, accessed July 2015.

AT&T announced in April 2014 that it, too, would bring fiber to Silicon Valley.¹⁰ Although these providers have not currently deployed in the City, they are aware of a market opportunity in a high-profile region.

The potential reaction from large incumbent telecommunications and Internet service providers should not be overlooked, and we encourage the City to come to internal agreement on its public messaging. Incumbents in Palo Alto would likely respond to the City's market entry by running pricing promotions and other specials to target consumers and attempt to lock them in to long contracts. They may also launch politically slanted campaigns fraught with scare tactics, claiming that the City is already well-served with broadband and has no reason to develop a municipal offering.

In essence, these providers may temporarily act like competitors to try to obtain a larger market share, and to deter consumers from buying service from the City. However, the incumbent providers' prices are often high, and their core systems will usually remain unchanged—meaning they will typically provide service over outdated legacy copper infrastructure. This technology often requires significant over-subscription and limits the number of subscribers these providers can support.

Comcast's announcement in spring 2015 that it will roll out 2 gigabit per second (Gbps) symmetrical service in select markets (including Palo Alto) is an indication of potential incumbent reaction to a new competitive provider entering the market. The Comcast 2 Gbps service, "Gigabit Pro," is priced at \$300 per month with combined installation and activation fees of up to \$1,000; the service also requires lengthy contracts with hefty penalties for early cancellation.¹¹ With such high prices, the service is not a significant threat in the residential market. However, it could seriously disrupt the business market by providing a mid-range offering that was not previously available.

In May 2015, AT&T indicated to the City that it is interested in bringing its gigabit Internet service to Palo Alto. This service, called "GigaPower," is an upgrade to AT&T's existing LightSpeed service and can provide up to 1 Gbps of Internet speed to users. Initially, AT&T will select neighborhoods with high potential for adoption and will use consumer demand levels to determine further deployments in the City. It plans to begin providing service as soon as 2016. It is important to note that the pricing AT&T offers in a market depends on what existing competition looks like—particularly whether Google Fiber also offers services there. In Kansas

¹⁰ http://about.att.com/story/att_eyes_100_u_s_cities_and_municipalities_for_its_ultra_fast_fiber_network.html, accessed July 2015.

¹¹ "Experience fast like never before," Comcast website, <http://www.xfinity.com/multi-gig-offers.html>, accessed September 2015.

City, Kansas and Austin, Texas—where it competes directly with Google Fiber—AT&T seems to match Google Fiber’s \$70 per month price.

In markets where it does not have to compete with Google Fiber (such as Cupertino, where it launched GigaPower in March 2015),¹² AT&T charges \$110 per month for its GigaPower service—\$40 per month higher than in Google Fiber markets.

Moreover, in July 2015, AT&T completed its \$49 billion acquisition of satellite television provider DirecTV after the Federal Communications Commission (FCC) ratified the merger deal.¹³ The ratification outlined conditions placed on AT&T in order to achieve the FCC’s approval. AT&T agreed to expand its high-speed gigabit fiber optic broadband access to 12.5 million customers. This target is approximately 10 times the size of AT&T’s present gigabit fiber deployment; it would increase the entire nation’s residential fiber build by more than 40 percent, and would more than triple the number of metropolitan areas that AT&T has announced plans to serve.

In communities where Google has entered the market, the disruption has been more widespread and profound. Google’s price point of \$70 per month for 1 Gbps service is substantially lower than Comcast or AT&T’s pricing, and its deployments are more aggressive—thus, more neighborhoods have access to its services.

Offerings from AT&T, Comcast, and Google may also impact the City’s existing dark fiber service by enticing some business customers to the new lower-cost services. As new services are introduced, it will become more critical for the City and the value-added resellers (VARs) that license its dark fiber to distinguish differences in a range of performance factors beyond cost and speed.¹⁴ Customer service may be one example.

It is also important to establish a clear understanding early-on of potential legal liabilities and any recourse the City may have in the event of aggressive opposition by incumbent providers. This report provides guidance and advice within CTC’s purview,¹⁵ and we encourage the Office of the City Attorney to work with qualified outside legal counsel trained in the nuances of

¹² <http://www.cnet.com/news/at-t-gigapower-aims-to-bring-blazing-fast-internet-to-cupertino/>, accessed July 2015.

¹³ <http://fortune.com/2015/07/24/att-directv-merger-conditions/>, accessed July 2015.

¹⁴ Speed is just one performance attribute. Performance attributes such as symmetry, oversubscription, committed transport rates, capacity constraints, latency, and business practices also influence users’ experience with the service.

¹⁵ CTC staff is not able to provide legal advice or guidance.

telecommunications law.¹⁶ Being prepared at the outset with legal resources can save time, money, and stress as FTTP planning and deployment occurs.

1.2 Fiber Is an Important Community Asset and Differentiator

Palo Alto is a unique hub for technological and business innovation, and is widely known as a premier startup center. Many tech giants got their start in the City—Facebook, Google, Hewlett Packard, and Palantir,¹⁷ to name just a few. Even Yahoo! was started as a project by two Stanford University graduate students.¹⁸ The City is home to a wide variety of research, innovation, and technologically-oriented enterprises and entities. These range from large public institutions like the Stanford Research Park to branches of private companies dedicated to research and development, such as the Ford Motor Research and Innovation Center.

Further, the City has been ranked numerous times as one of the best cities in which to live in America—it was number one in 2014¹⁹ and landed at number five in 2015.²⁰ Although “quality of life” is subjective and difficult to quantify, one of the reasons the City retained its high ranking in 2015 was that it is an especially great place to live for “those blazing the digital frontier,” due to the City’s dark fiber network.²¹

The City is likely to feel competitive pressure from other communities that recognize that affordable and widely available broadband connectivity can help attract and retain tech startups and heavy hitters. Standing out from other communities by offering access to robust connectivity can have enormous economic development benefits,²² and can tremendously impact a community’s livability.²³ The City may discover that it has to make greater efforts than ever before to retain its status as one of the leading technological communities in the U.S.

The City is already well ahead of most other communities in the U.S.—those its own size, and even much larger cities—in a number of ways.

Broadband, and specifically ultra-high speed broadband that can be supported only by fiber optic networks, is fast becoming a differentiating asset for communities, especially as cultural

¹⁶ In anticipation of this, our financial projections allocate funds for legal fees starting in year one.

¹⁷ <http://www.lifewithfive.com/20-tech-companies-with-roots-in-palo-alto/>, accessed July 2015.

¹⁸ <http://www.fundinguniverse.com/company-histories/yahoo-inc-history/>, accessed August 2015.

¹⁹ <http://livability.com/best-places/top-100-best-places-to-live/2014>, accessed July 2015.

²⁰ <http://livability.com/best-places/top-100-best-places-to-live/2015>, accessed July 2015.

²¹ <http://livability.com/best-places/top-100-best-places-to-live/2015>, accessed July 2015.

²² http://www.nytimes.com/2014/02/04/technology/fast-internet-service-speeds-business-development-in-chattanooga.html?_r=0, accessed July 2015.

²³ <http://www.tennessean.com/story/money/tech/2015/02/01/kansas-city-google-fiber-changed-workers-lives/22601915/>, accessed July 2015.

awareness about municipal fiber options increases.²⁴ The City may find that making an investment in broadband assets now will pay significant dividends over decades to come.

1.3 FTTP Overbuild Challenges

The term “overbuild” refers to deploying a network in a market where incumbent providers already serve customers. A new City FTTP network would compete directly with existing local cable, DSL, and other incumbent Internet service providers (ISPs) to offer services to customers.

Generally, fiber overbuilds do not offer a high rate of return, which is why there are not many private sector providers clamoring to build fiber networks in markets where customers are already served. Instead, private and public sector entities that opt to overbuild usually consider alternative reasons and benefits for deploying a new network. These entities focus on other value and drivers that make a business case for overbuilding.

For example, a municipality may choose to enter the market as an overbuilder for economic development purposes, like serving anchor tenant businesses, school districts, and research parks. Alternatively, a private entity may opt to overbuild and offer services to supplement other parts of its business. Google Fiber is an example of this: By disrupting the market and incenting other providers to step up their data offerings, Google’s other business branches (e.g., search, AdWords, Chrome, Gmail, Maps, YouTube, and mobile application development) can potentially thrive. That is, consumers in an environment with greater choice and access to high-speed offerings are more likely to take advantage of Google’s various other services and products that rely on a robust data connection.

An alternative to traditional overbuilding is to “cherry pick,” or build only to areas in a community where the provider is most likely to obtain a high number of subscribers willing to pay for service (and thus where the provider can expect a high return on capital investment). However, this approach is often not practicable for a public entity due to pressure it is likely to receive from citizens—it is not politically palatable for a municipality to deny portions of the community access to a service. Ubiquity is a common municipal goal.²⁵

1.4 Financial and Other Considerations and Challenges for FTTP in Palo Alto

Section 8 details the anticipated costs and financial analysis associated with an FTTP deployment. (All assumed costs used in this analysis were vetted with City staff for accuracy.)

²⁴ <http://www.nydailynews.com/news/politics/obama-municipalities-provide-internet-speed-push-article-1.2078146>, accessed July 2015.

²⁵ Ubiquity is based on the FCC’S definition of “universal service” in the Communications Act of 1934, and the Telecommunications Act of 1996: “all Americans should have access to communications services.” <https://www.fcc.gov/encyclopedia/universal-service>, accessed August 2015.

These projections are a snapshot based on certain assumptions; they represent a range of *potential* outcomes, which depend on a variety of factors.

This analysis shows that, assuming the network achieves the 72 percent take rate required to positively cash flow the enterprise,²⁶ the City will require an estimated overall capital investment of approximately \$77.6 million (see Table 10) to build the network. (This cost and the anticipated startup costs associated with initial network deployment are subject to change based on real-world variables.)

Certain challenges inherent to FTTP deployment are especially pronounced in the City of Palo Alto. The City's primary challenge in its pursuit of an FTTP buildout is that its costs will be high compared to other metropolitan areas for labor and materials. The cost of outside plant (OSP)²⁷ and drop cables²⁸ will be greater than in other metropolitan areas because Bay Area costs tend to be higher, many of the easements where the City must build are privately owned, and every drop cable must be placed in conduit.

Labor will be more costly than in other metropolitan areas because salaries in the Bay Area tend to be higher on average, and overhead for City employees is calculated at an extremely high 65 percent. (As a comparison, we have usually calculated this rate at approximately 35 percent in other recent studies we have conducted.) The model assumes that all debt service and network replenishments would be covered, which factors into the necessary take rate.

The high construction, borrowing, and staffing costs result in a higher necessary take rate for the City's FTTP enterprise to obtain and maintain positive cash flow. Based on the financial projections (and the underlying assumptions), a 72 percent take rate is required to make the enterprise cash flow positive. This is not only much higher than overbuilders have been able to achieve in other communities, but also higher than the required take rates for other potential municipal fiber enterprises. As a comparison, other recent analyses we have conducted for municipalities have shown a required take rate in the mid-40 percent range in order to maintain positive cash flow.

In light of the high cost to build and the extremely high required take rate, it may seem that there is little incentive for any provider (public or private) to pursue an FTTP deployment in Palo

²⁶ Take rate is the percentage of subscribers who purchase services from an enterprise—and is an important driver in the success of an FTTP retail model. If the required take rate is not met, the enterprise will not be able to sustain itself and its operational costs will have to be offset through an alternative source.

²⁷ OSP is physical assets like overhead and underground fiber, accompanying ducts and splice cases, and other network components.

²⁸ Drop cables connect the fiber optic backbone to the customer premises. See Section **Error! Reference source not found..**

Alto. However, the public and private sectors each have unique advantages and disadvantages that may impact their ability to undertake a standalone overbuild. A private entity and a public entity could complement one another by developing a partnership that can take advantage of each entity's strengths, and may significantly reduce cost and risk.

For example, a large private provider has certain cost advantages that a public entity simply cannot replicate, like buying power with experienced vendors to lower installation labor costs, to reduce electronics costs, and the potential to reduce or entirely avoid maintenance fees for electronics. Large private providers will often maintain their own inventory of core electronics and share use of electronics over deployments in multiple markets. This is a cost savings and an advantage with which the City is unable to compete.

Some private sector investors may have such strong balance sheets that their investments can be made from cash on hand, eliminating borrowing costs and lender restrictions. Moreover, when a municipality borrows money to invest in a fiber-based venture, the debt and its servicing costs are public. Any shortfall in meeting project projections can quickly become difficult to manage in a municipal environment.

Additionally, many private providers already possess internal technical capabilities, and they may share staffing with other deployments. Technical support, sales, customer service, and other personnel may simply be reallocated to support deployment in a new market, with little to no impact on overhead costs and no need to hire additional staff. As an example, a large provider like Comcast does not necessarily have to hire additional staff to support an influx of 20,000 new customers. It can leverage its existing staff pool, which is already supported by its customer base in other markets.

The private sector can also avoid some of the staffing challenges the City faces by locating staff in other regions. As we noted, Bay Area salaries are high, and the overhead for City employees is especially costly. If the City wanted to directly provide retail service, it could potentially reduce overhead costs by outsourcing to local firms, but for political reasons it will likely not be in the City's best interest to contract with entities outside Palo Alto. The private sector is at an advantage because it does not have to manage the same political considerations as the City. The operational costs that the City can expect to face are thus greater and more complex than what an established, private-sector entity with economies of scale might incur.

Section 8.4 provides an analysis of the sensitivities of key assumptions on projected cash flow and required take rates. This analysis offers additional insights on how to leverage the City's and potential private partners' strengths and weaknesses.

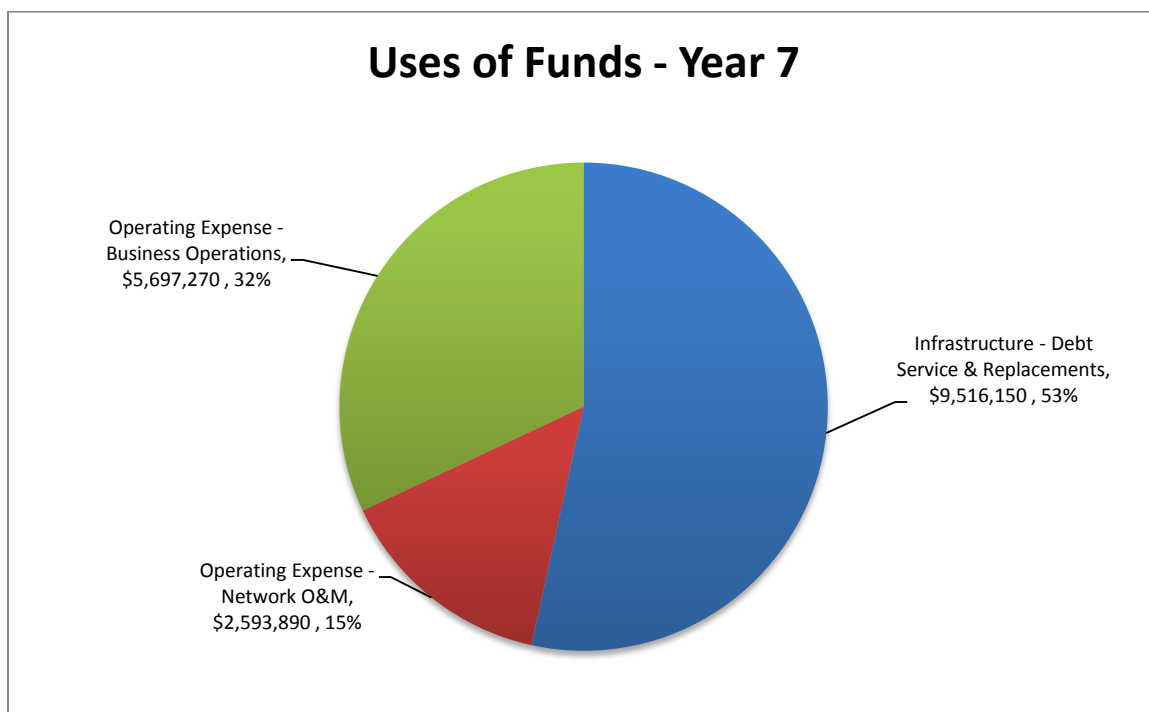
Absent a private entity building and operating an FTTTP network with unfettered data access, we recommend that the City consider pursuing a public–private partnership that leverages each party’s strengths, shares financial risks, and provides unfettered data access to the community. These recommendations are discussed further in Section 1.6 below.

1.5 Breakdown of How Capital and Operations Funds Are Allocated

To further illustrate potential City FTTTP costs, we created a breakdown to show how funds are used. The analysis develops a snapshot of how funds are used in year seven because this is the point at which the business model has stabilized—for example, the required take rate has been met, the FTTTP buildout is complete, and the depreciation reserve fund has started. Some expenses follow take rates, some are fixed, and some are step functions. The examples below assume a 72 percent take rate.

Figure 1 shows that 53 percent of the funds in year seven go toward infrastructure: debt service for the capital investment (fiber, startup funds, and electronics) and asset replenishment (the depreciation reserve fund, which is used to pay for network upgrades and replacements).

Figure 1: Breakdown of How Funds Are Used in Year 7



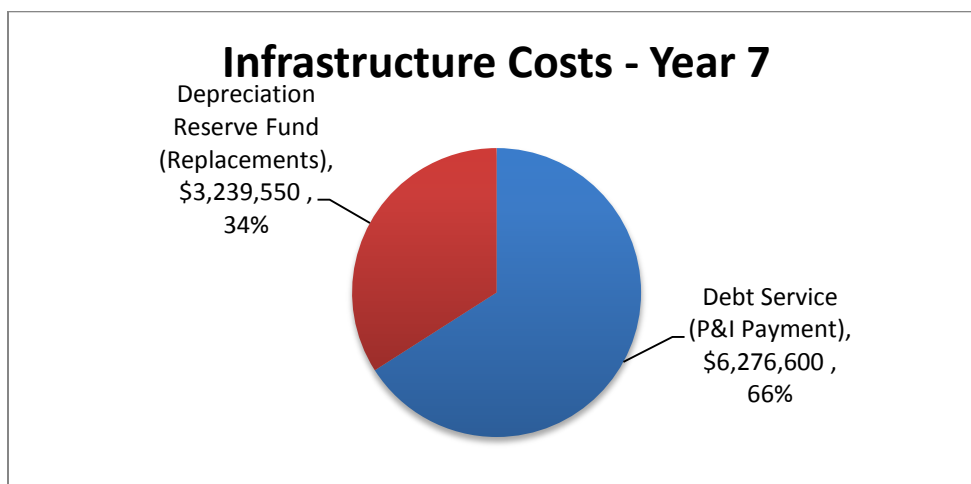
Of the remaining uses of funds, 32 percent is estimated for operating the business and 15 percent is estimated for network maintenance (fiber and electronics).

1.5.1 Infrastructure Costs

Figure 2 shows that debt service, or principal and interest (P&I) payments, account for 66 percent of infrastructure costs (which, as shown in the chart above, represents 53 percent of the *total* uses of funds). The depreciation reserve fund, which is used to pay for the cost of replacing infrastructure and equipment, accounts for 34 percent of infrastructure costs. That is, 66 percent of 53 percent (or 35 percent) of the *total* uses of funds goes toward debt service or P&I payments for the cost of infrastructure. The remaining 34 percent of 53 percent (18 percent) of the *total* uses of funds goes toward the depreciation reserve fund, which covers the cost of network replenishments and electronics replacements.

The public sector has an advantage over the private sector in terms of infrastructure costs because fiber is a long-term investment that is typically best suited for the public sector. Although the private sector has some buying power advantages, the private sector also has to show a 10 percent or higher rate of return on the investment over 20 to 30 years—whereas a public entity simply needs to break even.

Figure 2: Infrastructure Costs in Year 7



1.5.2 Operating Costs

Figure 1 shows that 47 percent of the uses of funds (32 percent and 15 percent) are allocated for operating the business and for network maintenance (fiber and electronics). Figure 3 shows that 31 percent of the operating expenses are for network operations and maintenance (O&M), while 69 percent are for business operations. Please note that of the estimated \$2.59 million in network O&M expenses, \$1.37 million is for vendor maintenance contracts alone.

Figure 3: Operating Expenses in Year 7

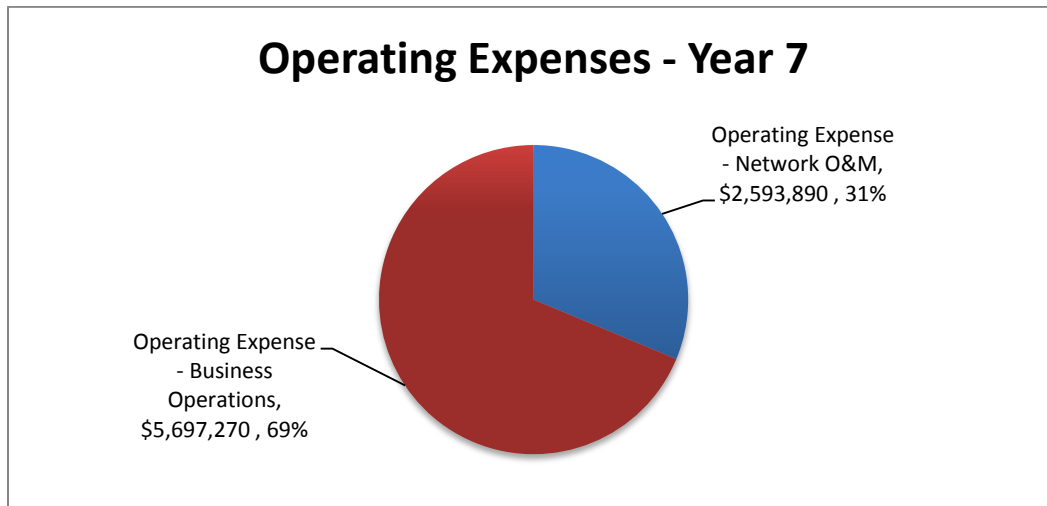
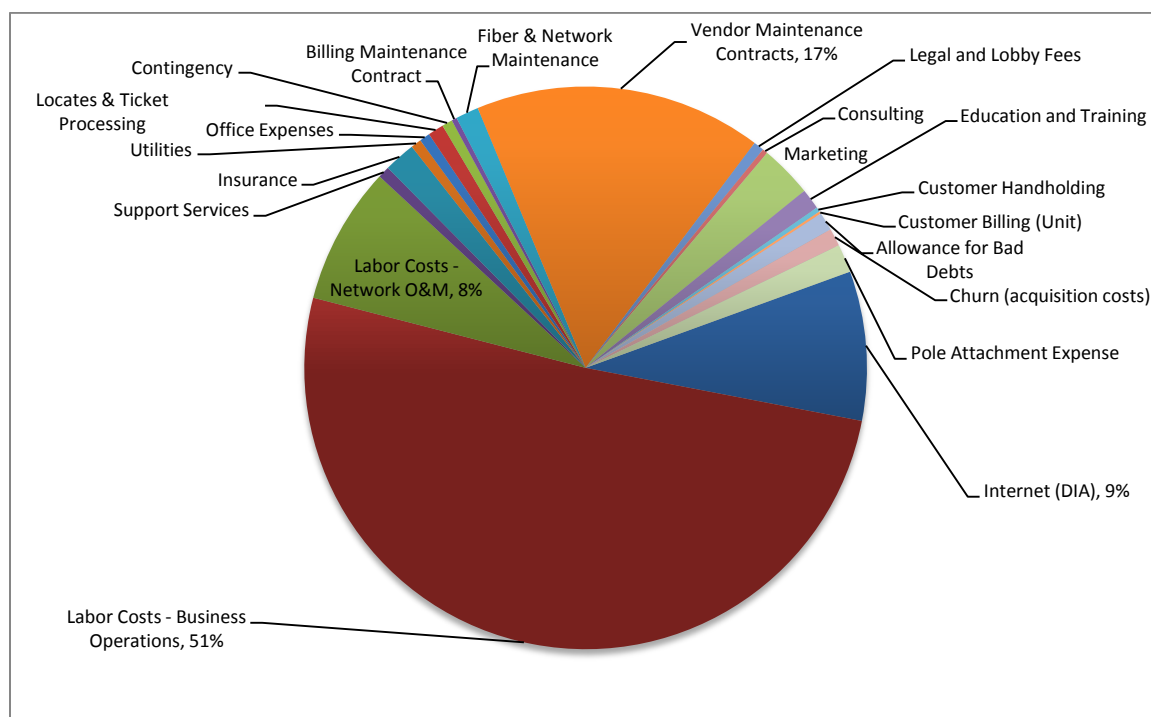


Figure 4 further breaks down the estimated operating expenses. Labor costs for business operations expenses account for 51 percent of all operating expenses, which reflects the high cost of labor in the City. As we noted, private providers are at an advantage because they can generally leverage existing resources and spread their costs over deployments in multiple markets. The public sector will likely need to hire some additional in-house staff and contract out some of its needs, and the City does not have prior experience with this particular type of specialized staffing.

Figure 4: Breakdown of Operating Expenses in Year 7

Similarly, network operations labor accounts for 8 percent of operating expenses, and the City will likely have to hire new staff and potentially contract out some of these tasks. CPAU has experience with some functions (e.g., locates, ticket processing, and OSP fiber maintenance) and may be able to train additional staff for less cost than hiring new staff for other labor functions. Still, the cost of additional City staff is significant, and there may be some network operations functions with which the City is unfamiliar.

Vendor maintenance contracts account for 17 percent of operating costs, and this is an area where the private sector has an advantage. As with other areas, private entities can potentially leverage their own existing resources and disperse costs over multiple deployments—and if the private entity is large enough, it may be able to completely eliminate some of these costs.

Direct Internet Access (DIA)²⁹ accounts for 9 percent of operating costs, and it is calculated at \$0.75 per Megabit per second (Mbps)³⁰ per month. This is a reasonable cost for DIA, and somewhat reduces the potential advantage private providers have based on cost alone. However, larger providers are able to avoid more costs with on-net servers from peering

²⁹ The enterprise must purchase DIA to provide Internet service to its customers.

³⁰ This assumption was made based on input from City and CPAU staff.

partners like Netflix. Further, costs tend to be minimal for private providers (almost nonexistent for some) due to the high volume of DIA that they purchase.

1.5.3 Public and Private Entity Cost Advantages and Disadvantages

Private entities have cost advantages with 85 percent of operating costs (40 percent of uses of funds) and 17 percent of vendor maintenance contracts, such as core network equipment. The public sector has an advantage over the long-term investment—35 percent of the uses of funds (or 66 percent of 53 percent). That is, the private sector has the many advantages we enumerated above that have to do with operational costs for which private entities are typically staffed and prepared. The City has the advantage of being able to make a longer-term investment than most private providers because it does not have to demonstrate a high rate of return.

1.6 Recommendations

In light of the high costs the City will face for labor and overhead and the high necessary take rate, we do not recommend that the City directly pursue an FTTP model in which it provides retail services. The City simply does not have the same buying power and experience as the private sector, and it is not particularly skilled at operating a for-choice competitive business.

However, it may make sense for the City to deploy, own, and maintain the fiber infrastructure, and to engage a private provider to manage the FTTP enterprise's operations. This would allow the City to focus on the long-term fiber investment and to leverage a private partner's operational efficiencies to potentially create a strong enterprise and reduce the take rate necessary to make the enterprise cash flow positive.

1.6.1 Establish a Realistic Timeline

We discuss below the potential of exploring a public-private partnership, and the possibility of issuing a request for information (RFI) to facilitate such a relationship. Note that these steps depend heavily on potential, impending changes in the Palo Alto market in the final months of 2015. Although an RFI process and seeking a partnership may ultimately make sense, we believe it is prudent to take a conservative wait-and-see approach through the end of the year.

As we noted, incumbent providers often react to the *threat* of competition in the market by aggressively marketing and improving customer service. It may be that the simple possibility of Google Fiber entering the market spurs AT&T to more quickly begin upgrading its infrastructure to fiber in the City. One of FCC Chairman Wheeler's recommendations to fellow commissioners

for stipulating approval of AT&T's acquisition of DirecTV was that AT&T increase its fiber build-out.³¹

Further, Comcast has a history of competing based on real and threatened competition in the market, and the notion of both Google and AT&T bringing competition to the City may increase the likelihood that it, too, improves its customer service and widens its offering.

Palo Alto is currently an interesting market, and it may be worth the City waiting to take definitive action until it has a sense of whether it is necessary for the City to directly fill any service gaps with a public-private partnership. That is, if existing private sector providers begin to compete in earnest in the City, there may be few, if any, service gaps to fill.

1.6.2 Explore a Partnership Model Where the City Builds, Owns, and Maintains Fiber

The City could potentially develop a partnership in which the private provider(s) agree to certain service terms and pay fees on a per-passing and/or per-subscriber basis. Meanwhile, the private provider(s) could own and operate the network's electronics layer and manage the relationship with retail customers. This is similar to the model that the City of Westminster, Maryland is currently deploying with its partner, Ting Internet.³² Section 7.4.3 discusses the Ting partnership model in more detail.

A partnership could focus on providing ultra-high-speed 1 Gbps³³ service to consumers at competitive prices—say, \$70 per month for residential and \$80 per month for small business users. This type of arrangement could balance each party's risk, address service gaps in Palo Alto, and meet the City's connectivity goals. We outline here the reasons we believe the City may benefit most from pursuing a partnership in which it retains ownership of the fiber assets and engages a partner to deploy electronics, manage retail relationships, and provide a positive user experience.

The City has an advantage over the private sector in terms of deploying, paying for, and owning fiber assets. Network deployment tends to be capital intensive, and the return on investment often takes much longer than the private sector can sustain without other incentives for building fiber. The financial analysis (see Section 8) considers what it would look like financially if the City were to deploy the network on its own and offer retail services.

³¹ <http://arstechnica.com/business/2015/07/att-reportedly-wins-fcc-chairmans-support-for-directv-merger/>, accessed August 2015.

³² <https://ting.com/blog/next-ting-town-westminster-md/>, accessed July 2015.

³³ This service could be scalable to 10 Gbps through electronics upgrades, and the partnership could serve certain users on a case-by-case basis with this higher offering. The 1 Gbps service offering is meant to be the FTTP enterprise's baseline service, or the target for most of its users.

Another important consideration is the evolution of open access and how it may impact the City's offering. Historically, open access has meant one network infrastructure over which multiple providers can offer service. Often the infrastructure was publicly owned and ISPs entered into an agreement to enable them to provide service over the public, open infrastructure.

If instead an unfettered data product were available over the FTTP enterprise's infrastructure, the City and a private partner might be able to take on responsibilities that play to their strengths while mitigating their risks and avoiding tasks for which they may be ill-equipped. The private entity could potentially avoid making a large capital investment while the City could avoid the unknowns and variability of providing retail service. Such a partnership may foster new ways to achieve the choice that open access has traditionally supported—through applications and services that can be delivered through an unrestricted data offering.

The City may find it beneficial to contract with one provider at the outset for partnership. That partner could operate the City-owned FTTP network, and after a certain number of years, the City may opt to make the network truly open access so that any provider that wishes to offer service over the infrastructure has the option to do so. Such an arrangement could significantly reduce the City's costs—most of which are related to labor.

Further, the partnership model could allow the City to leverage a private entity's buying power for electronics, reduced DIA costs, and other uses of funds. This could result in a much lower take rate necessary to make the enterprise cash-flow positive. For example, if the City could reduce salary expenses by 50 percent, eliminate costly vendor maintenance contracts (by allowing the private partner to manage these relationships), and reduce DIA costs by 67 percent, the necessary take rate could be reduced to 45 percent of passings (i.e., potential users). This take rate could potentially be lowered even further by pursuing a strategic deployment approach that requires a neighborhood to reach a certain take rate threshold before the City builds fiber there.

The enormous cost that the City is likely to incur for labor alone makes a municipal retail FTTP offering challenging. The City will likely see tremendous benefit from working with the private sector to reduce costs and leverage strengths. If it is willing and able to make a long-term investment in fiber infrastructure, it then also has the advantage of a greater degree of control by retaining ownership of the FTTP network.

1.6.3 Develop and Distribute a Request for Information

One potential key step toward exploring the interest of the private sector in developing viable partnerships is to develop a framework and documentation for an RFI process. This will help the

City clearly articulate its goals and inform the private sector of the City's existing assets and its desire to deploy FTTP. We recommend that the City undertake this process to help inform its own needs, and to clearly break down its expectations for itself and a potential partner.

An RFI can help a public entity to evaluate potential vendors or partners with which the City may want to develop a relationship. An RFI also allows the City to gather information to potentially inform an eventual contract negotiation process.

The RFI documents should clearly articulate the City's needs and desires, and invite private companies to respond and outline their unique approaches to solving the City's connectivity needs. Because the documents will lay the foundation for informing the contractual relationship between the City and its partner(s), the operational functions of each party should be clearly articulated. One useful aspect of developing RFI documentation is that it may help the City to flesh out some areas where its own goals are unclear. Further, the RFI could identify to what degree the City may need to be prepared to invest in infrastructure.

The RFI does not have to create strict parameters about how the City expects its objectives to best be met or identify the business plan the City intends to pursue—instead, the RFI can clearly lay out the City's goals and any non-negotiable items (e.g., CPAU must retain ownership of existing fiber, and will own and maintain newly constructed infrastructure in the power space)³⁴ but leave room for a private partner to respond creatively.

Indeed, it may be prudent to use caution in the degree to which the City specifies its requirements of a private partner. An overly detailed RFI may scare off potential respondents that do not believe they possess all the staff, qualifications, or resources to meet a strict list of demands outlined by the City. In contrast, a strategically developed RFI can elicit interest from providers that may not have been aware that the City is considering FTTP deployment and that the City may be willing to make its infrastructure available for use by the private sector.

The RFI process can also help the City understand more clearly the real costs associated with its goals. The City may be able to obtain clear industry pricing for various support services like network operations and maintenance that a private provider may offer.

An important consideration for an RFI process is that not all potential partner companies will respond in writing to the request. This should not discourage the City from developing an RFI—such a document is extremely valuable not only for evaluating the written responses, but also for outlining the City's goals and sparking conversation. If the RFI process does not immediately

³⁴ The “power space” refers to the area on a utility pole reserved for infrastructure for the electric utility. There is also a separate “communications space,” which contains infrastructure that belongs to phone, cable, and Internet providers. Please see Section 3.1.1 for a more detailed description, specific to City of Palo Alto Utilities (CPAU).

elicit a partner, or if for some reason negotiations with a potential partner do not pan out, the City will likely find that the RFI remains useful for attracting and communicating with private companies. It becomes a document that the City can rely on to clearly articulate its objectives—and if an additional means of procurement is ultimately necessary, the RFI can serve as a basis for that process.

Finally, it is important to be realistic about what a partnership may entail on behalf of both parties.³⁵ The City must develop and clearly identify its own desires, goals, and requirements for a network. Once it has defined what it hopes to achieve, it can summarize this in an RFI to allow potential private partners to respond based on their own abilities and willingness to help meet the City's needs.

³⁵ Jon Brodtkin, "Skeptics Say LA's Free Fiber Plan As Plausible As Finding a Unicorn," *Ars Technica*, November 8, 2013, <http://arstechnica.com/information-technology/2013/11/skeptics-say-las-free-fiber-plan-as-plausible-as-finding-a-unicorn/> (Accessed May 2015).

2 FTTP Network Requirements

The City recognizes the importance of robust, scalable infrastructure when designing and deploying an FTTP network. It requires the ability to support a wide range of applications and services, and service delivery to both the community as a whole and specific user groups. Ultimately, this network will promote long-term economic development and community interests.

This section describes many of the City’s required applications and services; the user groups the City aims to serve; and the general requirements of FTTP network design that would support identified and emerging applications and services. We present the proposed design in Section 5.

2.1 User Applications and Services

The City’s FTTP network must be able to support “triple play” services—high-quality data, video, and voice—that residential customers have grown accustomed to having in their homes, although this does not necessarily mean that the City must be the entity that *directly* provides telephone or cable television services. As Internet technology has improved and network speeds have increased, voice and video services have become available as applications delivered by hundreds of providers over an Internet Protocol (IP) data network connection—so the City can enable these services by building a robust IP network.

The City can enable residential and small business customers to purchase voice, video, and other over-the-top (OTT)³⁶ services by providing them with unfettered,³⁷ reliable, high-speed Internet access with connections at a minimum of 1 Gbps.³⁸ In other words, the City would become an IP data network provider, either directly or through partnership(s), and would enable its citizens to purchase services—without the City taking a gatekeeper role.

Additionally, the City could at some point open the network on a wholesale basis to any qualified provider to offer a data service bundled with Voice-over-Internet Protocol (VoIP),³⁹ cloud storage, or other services. The fiber connection will also support customer-selected

³⁶ “Over-the-top” (OTT) content is delivered over the Internet by a third-party application or service. The ISP does not provide the content (typically video and voice) but provides the Internet connection over which the content is delivered.

³⁷ Meaning that access to websites offering OTT services is not blocked, restricted, or rate-limited.

³⁸ Rate is a best-effort basis, not a guaranteed speed. Further, it is important to note that with the proposed architecture the City would provide a 1 Gbps baseline service and 10 Gbps and beyond on a case-by-case basis. The baseline can be increased to 10 Gbps and beyond by upgrading the network electronics

³⁹ Telephony (voice) service delivered over an IP data network

applications such as telemedicine, VoIP, the Internet of Things (IoT), video streaming, home security monitoring, and cloud services.

2.1.1 Internet Access

Internet access is the fundamental service that most residents and small business owners will expect from a fiber connection, and is the prerequisite service for all of the applications described below. The City's FTTP network will also include one or more peering connections with upstream ISPs, reducing wholesale Internet costs and improving service delivery.

As described in detail below, the FTTP network will support a baseline service level (e.g., 1 Gbps) suitable for residential and small business customers. It will also be capable of supporting higher residential speeds—10 Gbps and beyond—and a range of business and enterprise services.⁴⁰

2.1.2 IP Telephony (VoIP) and Video Conferencing

As noted above, VoIP is a voice telephony service delivered over an IP data network.⁴¹ In the context of an FTTP access network, VoIP generally refers to an IP-based alternative to Plain Old Telephone Service (POTS) over dedicated copper wiring from a Local Exchange Carrier (LEC). With VoIP, both the live audio (voice) and the call control (signaling) portions of the call are provided through the IP network. Numerous third parties offer this type of full-service VoIP, which includes a transparent gateway to and from the Public Switched Telephone Network (PSTN).

Because VoIP runs over a shared IP network instead of a dedicated pair of copper wires from the LEC, extra design and engineering are necessary to ensure consistent performance. This is how the VoIP services delivered by Comcast (which provides Quality of Service or QoS on its network underneath the VoIP services) typically have the same sound and feel as traditional wireline voice calls. In contrast, VoIP services without QoS (such as Skype) will have varied performance, depending on the consistency of the Internet connection. For voice and other real-time services such as video conferencing, network QoS essentially guarantees the perceivable quality of the audio or video transmission.

From a networking perspective, IP-based video conferencing services are fundamentally similar to VoIP. While IP video conferencing is currently less common as a residential application, small and medium-sized businesses in the FTTP domain can be assured that QoS for IP-video conferencing can also be supported, as with VoIP.

⁴⁰ Network can support faster connection speeds and other guaranteed service levels to some portion of end users.

⁴¹ In this context, voice services are delivered over a data connection.

2.1.3 Streaming Video

The variety of streaming online video through applications like YouTube, Netflix, Hulu, HBO Go, and others continues to attract users and challenge cable providers' traditional business models. These are all examples of OTT⁴² video available over the Internet to users at home or on mobile devices like a smartphone or tablet.⁴³ Section 6.3.2 discusses OTT in greater detail.

Traditional cable television providers (also known as multi-channel video services) can also deliver content over a fiber connection rather than through a separate coaxial cable connection to users' homes.

All of these video services can be supported by the City's FTTN network—as will be locally produced content from the Media Center and public service videos or documentaries filmed by high school students, which can be streamed to residents directly from a school, library, or government building that is on the network (“on net”). The avenues through which consumers can access content are broadening while the process becomes simpler.

Because of the migration of video to IP format, we do not see a need for the FTTN network to support the Radio Frequency (RF) based video cable television service, an earlier technology used by some providers to carry traditional analog and digital television in native form on a fiber system.

Early municipal providers like Lafayette Utilities System (LUS) and Chattanooga's Electric Power Board (EPB) found that a data product alone was not strong enough to obtain the necessary market share to make the endeavor viable. Even when Google Fiber entered the Kansas City market in 2011, it found that if it wanted to get people to switch providers, it *had* to offer cable, deviating from its original plan and introducing more cost and complexity than the simple data service it had anticipated. If an OTT cable offering were available when early municipal providers began offering service and when Google entered the Kansas City market, it may have found that offering traditional cable television was unnecessary.

2.1.4 Cloud Access

“Cloud services” refers to information technology services, such as software, virtualized computing environments, and storage, available “in the cloud” over a user's Internet connection. Enterprise and residential customers alike increasingly use cloud services. With the continually rising popularity of mobile devices like smartphones and tablets, consumers want access to their photos, videos, and music from anywhere. And businesses want employees to

⁴² OTT refers to voice, video, and other services provided over the Internet rather than with a service provider's own dedicated network.

⁴³ OTT content is delivered over the Internet by a third-party application or service. OTT is also known as “value added” services.

have access to important information to keep operations running smoothly, even when they are away from the office.

The business drivers behind cloud computing are ease of use and, in theory, lower operating costs. For example, if you are a business owner, the “cloud” theoretically allows you to use large-scale information services and technologies—without needing to have hardware or staff of your own to support it.

Cloud services eliminate the need to maintain local server infrastructure and software, and instead allow the user to log into a subscription-based cloud service through a Web browser or software client. The cloud is essentially a shift of workload from local computers in the network to servers managed by a provider (and that essentially make up the cloud). This, in turn, decreases the end user’s administrative burden for IT services.

Typically, cable modem and DSL services are not symmetrical—thus incumbent network transfer rates to upload to the cloud are significantly slower than download rates. This can cause significant delays uploading to cloud services.

There are also numerous other cloud services that customers frequently use for non-business purposes. These include photo storage services like Flickr and Shutterfly, e-mail services like Gmail and Hotmail, social media sites like Facebook and Twitter, and music storage services like iTunes and Amazon Prime.

By enabling ISPs to reliably serve residents and small businesses with high-speed services, the City’s FTTP network will increase their options to use the cloud. Improving on less robust connections (e.g., cellular broadband or cable modem services), the City’s network will also enable telecommuters and home-based knowledge workers in Palo Alto to access cloud-based development environments, interact with application developers (both local and remote), and access content distribution network (CDN) development and distribution channels.⁴⁴

2.2 User Groups

The City has identified categories of users for the network:

- Residents
- Small businesses and enterprise users
- Public safety
- Municipal services, such as Electric Utilities
- Healthcare

⁴⁴ See, for example: “Amazon CloudFront,” <http://aws.amazon.com/cloudfront/>

2.2.1 Passings

Here we explain the possible number of “passings”—homes and businesses the fiber could potentially pass—that this analysis estimated. We estimate there are 22,709 households to pass in the City of Palo Alto. Of these, 17,308 are in single-family residential homes. There are 1,794 residential households in structures with 2 to 4 units,⁴⁵ known as multi-dwelling units (MDUs). There are 3,536 households in residential buildings that contain 5 to 19 units. And there are 71 residential mobile homes. Thus, we assume 22,709 residential passings.

We did not include in the assumed residential passings the 5,226 households that are in buildings with 20 or more units. Typically, large MDUs with 20 or more units are served by existing long-term contracts between building owners and incumbent ISPs. Each of these buildings must be considered on a case-by-case basis.

We estimate that there are 3,926 businesses in Palo Alto, and 734 of these are in a large office complex. Therefore, we assume a total of 3,192 potential businesses.

The estimated 22,709 residential passings and 3,192 business passings results in 25,901 total residential and business passings.

In short, this analysis does not consider the 5,226 households or 734 businesses that are in residential or business buildings with many units. These must be considered on a case-by-case basis.

2.2.2 Residents

The City’s primary focus—and the largest potential user group for a citywide FTTP network—is the residential market. There are approximately 17,308 households in single-family homes, 10,556 households in multi-dwelling units (MDU),⁴⁶ and 71 households in mobile homes or RVs.⁴⁷ As we noted in Section 2.2.1, there are 5,226 households in MDUs with 20 or more units, and these will not be part of the City’s focus.

The City’s residents will require a diverse range of speeds and capabilities—from simple, reliable connectivity at low cost, to extremely high speed, symmetrical services that can support hosting and research and development applications. The fiber network will provide the capability to offer a range of services through the same physical medium, requiring only an

⁴⁵ We assume that each unit in a building holds a unique household.

⁴⁶ Of the 10,556 households in MDUs, 5,226 are in structures with 20 or more households in each building. These buildings are often served under a long-term contract with one of the incumbent providers or a specialty ISP.

⁴⁷ 2015 Official City Data Set for Use by City Staff in Reports and Other City Materials, based on ACS Demographic and Housing Estimates 2011-2013 American Community Survey (ACS) 3-Year Estimates, supplemented with additional data from ACS 3-year estimates.

upgrade of electronics or software at the user premises, and not customized physical connections.

2.2.3 Small Businesses and Enterprise Users

There are approximately 4,000 businesses in Palo Alto, of which more than 3,200 have fewer than 10 employees.^{48, 49}

In terms of their broadband needs, these small businesses are often more similar to high-capacity residential users than to large enterprise customers. They may need more than just a basic connection, but do not typically require the speeds, capacity, or guaranteed service levels that a large organization or high-end data user needs.

The City's FTTP network will support small businesses and will be capable of supporting select institutions and enterprise users. It is important to emphasize that the suggested network design will have enough fiber capacity to provide either Active Ethernet service or Passive Optical Network (PON) service to any business or resident. With that fiber in place, the City or an ISP can then sell customized service to enterprise customers on a case-by-case basis.

The operational plan will also need to address many enterprise users' needs for static IP addresses,⁵⁰ and how the network operations can support this.

The FTTP network will support basic service levels up to services just short of the highest-speed connections required by large enterprise users (a function that has been successfully addressed through the City's dark fiber leasing program, which serves a different market segment). The FTTP network is meant to complement the City's dark fiber licensing program. That is, the FTTP offering will serve users whose connectivity needs are not significant enough to warrant executing a dark fiber agreement. Similarly, the dark fiber licensing program successfully provides service to users whose connectivity needs would likely not be sufficiently met by an FTTP offering. However as noted in Section 1.1, some dark fiber users may find that the FTTP offering, Comcast's Gigabit Pro, or AT&T's GigaPower more appropriately meets their needs.

The City currently licenses dark fiber service connections to approximately 100 commercial customers. There are 230 total active dark fiber service connections serving commercial customers (some customers have multiple connections).⁵¹ Commercial customers generate 91

⁴⁸ Information obtained from www.infoUSA.com using specified business size ranges as search parameters.

⁴⁹ Estimate 3,926 businesses with less than 99 employees. Further estimate that 734 of these businesses are in office complexes and treated on a case-by-cases basis in the FTTP model. The remaining 3,192 businesses are treated as a stand-alone facility in the FTTP design.

⁵⁰ Some residential users will require static IP addresses. These can be offered as an option for a premium service.

⁵¹ These connections are typically provided by value-added resellers that "light the fiber" by bundling the necessary electronics and bandwidth with the City's dark fiber, thus creating a turnkey customer solution.

percent of the dark fiber licensing revenues—more than 40 percent of these revenues come from value-added resellers. The fiber network also serves the following City accounts:⁵²

- IT Infrastructure Services
- Utilities Substations
- Utilities Engineering
- Public Works
- Water Quality Control Plant
- Community Services (Art Center)

The FTTP offering and the dark fiber offering complement each other in that they each provide a specific service to unique user groups. The average community user likely has not been able to directly use the City's dark fiber leasing program to meet their connectivity needs. The FTTP offering could fill gaps in the community not currently met by the dark fiber licensing program.

2.2.4 Public Safety

Public safety users have more stringent requirements for reliability than most other users because of their role as first responders during emergency situations. Given these requirements and potential liabilities, we recommend directly assigning fiber strands to public safety users as opposed to serving them through use of the FTTP electronics that will serve residential and small business customers.

With this approach, the FTTP network for delivering residential services will not be encumbered by the public safety users' more stringent QoS and reliability requirements. The key to serving the public safety departments' needs is to design the fiber routes to meet path diversity requirements and with sufficient fiber strands to dedicate to public safety. The routes should also have sufficient range and reach to ensure that fiber connections are available wherever the public safety agencies might need it.

To that end, we recommend that the City's network design reserve up to 12 strands of fiber to each public safety facility, and 12 strands at each fiber distribution cabinet (FDC) for future use by City and public safety applications such as traffic devices, wireless devices, and CCTV.⁵³ The fiber could support connectivity to mobile command centers and connectivity of portable devices to a dedicated public safety network. The public safety agencies will need to install any electronics and backup power that may be necessary to provide the level of secure service

⁵² As of the end of fiscal year 2015, the fiber optic fund has a reserve of approximately \$20.0 million. There is a separate \$1.0 million Emergency Plant Replacement fund. According to the proposed fiscal year 2016 Budget, the fiber reserve is projected to increase by approximately \$2.3 million.

⁵³ Network can be designed so an FDC serves 128 to 254 premises—see design section for additional details.

capacity, resilience, and prioritization they need for critical communications and lifeline services.

2.2.5 Electric Utility

We have reserved fiber in the network design for the electric utility to implement a “Smart Grid” program for stakeholders and customers. This is a digital technology that allows for two-way communication between the utility and its customers as well as sensing within the utility system. The electric utility could deploy advanced metering infrastructure (AMI) to support its operations and maximize efficiency—for example, it might opt to install smart meters and implement advanced meter reading (AMR).

2.2.6 Health Care

Health care providers have a role similar to public safety users in critical situations and often need guaranteed reliability, prioritization, and dedicated capacity. As long as the fiber network is designed to connect the City’s healthcare facilities, the network will have the capacity to serve the health care sector’s many needs—from enabling a health information exchange with secure media access⁵⁴ to interconnecting facilities to create a community healthcare services network.

Depending on the needs of a particular health care site, it is possible to provide the site with a range of services from dark fiber to GPON-based FTTP services. A medical center may be a candidate for dark fiber or Metro Ethernet. A doctor’s office or small clinic might use the GPON FTTP service to connect to other medical resources—enabling the office to download large files and quickly access research and reference materials, both local and cloud-based.

Telemedicine, which is recognized as one of the broadband applications with the greatest potential to improve citizens’ quality of life, requires end-to-end high-speed access and data transmission between medical facilities. In some cases, this can be a connection between a provider’s facility and a patient’s home, or even a provider’s home. To the extent that the network design connects the necessary facilities, the City’s FTTP network will have the capacity to support telemedicine applications.

2.3 Network Design Requirements

This section provides a high-level overview of the network requirements used to prepare the conceptual FTTP design and cost estimate. It also presents the technical details of an FTTP

⁵⁴ The FTTP network operator does not provide HIPAA security or encryption. These are enabled by the FTTP network, but have to be the responsibility of the subscriber / application owner to implement over the FTTP network.

network in terms of performance, reliability, and consumer perceptions based on providers' marketing.

Google changed the industry discussions and customer perceptions of data access when it introduced its plans to deploy an FTTP network and offer a 1 Gbps data connection for \$70 per month in Kansas City.⁵⁵ Until Google entered the FTTP market, cable operators such as Comcast questioned the need for 1 Gbps speeds and typically indicated that 10 Megabits per second (Mbps) is sufficient for residential and small business users. (Gigabit speeds were available in a few localities, such as Chattanooga, Tennessee, but Google's brand name meant that Google Fiber had a bigger impact on national awareness around this type of connection.) Since Google's entry, Comcast and other providers have slowly increased their data offering speeds—moving to 25 Mbps, 50 Mbps, and finally gigabit fiber services in selected markets.

Comcast announced plans to offer 250 Mbps and 2 Gbps services in selected areas,⁵⁶ including to several California cities and the Bay Area. It indicated that it would begin offering services in June 2015, but has experienced some delays.⁵⁷ It released pricing for the service in July 2015,⁵⁸ though monthly and installation fees are high and wait time for installation can be as long as two months.

Additionally, AT&T announced in August 2014 that it would introduce its fiber-based "GigaPower" gigabit Internet service to select customers in certain areas of Cupertino, California.⁵⁹ The 1 Gbps service is available for \$110 per month, while customers can also opt for a 300 Mbps service for \$80 per month.⁶⁰

It is important to note that Internet access speed represents only one portion of the overall Internet experience, and measuring a network's overall performance on one metric is incomplete. Further, "advertised speed" for residential services is a best-effort commitment, not a guarantee, and does not necessarily reflect actual performance. For example, the advertised speed does not delineate a minimum speed or a guarantee that any given application, such as Netflix, will work all the time.

⁵⁵ <https://fiber.google.com/cities/kansascity/plans/>, accessed May 2015.

⁵⁶ Sean Buckley, "Comcast shakes up California's broadband market with 2 Gig, 250 Mbps broadband plans," *Fierce Telecom*, April 20, 2015.

http://www.fiercetelecom.com/story/comcast-shakes-californias-broadband-market-2-gig-250-mbps-broadband-plans/2015-04-20?utm_medium=nl&utm_source=internal

⁵⁷ <http://arstechnica.com/business/2015/06/comcast-2gbps-fiber-to-launch-in-a-bunch-of-markets-this-month/>, accessed June 2015.

⁵⁸ <http://time.com/money/3957600/comcasts-gigabit-internet-price/>, accessed July 2015.

⁵⁹ <http://www.pcmag.com/article2/0,2817,2463576,00.asp>, accessed May 2015.

⁶⁰ <http://www.cnet.com/news/at-t-gigapower-aims-to-bring-blazing-fast-internet-to-cupertino/>, accessed May 2015.

2.3.1 Why Fiber Optics

For several decades, fiber optic networks have consistently outpaced and outperformed other commercially available physical layer technologies, including countless variants of copper cabling and wireless technologies. The range of current topologies and technologies all have a place and play important roles in modern internetworking.⁶¹ The evolution of Passive Optical Network (PON) technology has made FTTP architecture extremely cost-effective for dense (and, more recently, even lower and medium-density) population areas.

The specifications and the performance metrics for FTTP networks continue to improve and outperform competing access technologies. In fact, from the access layer up through all segments of the network (the distribution layer and the core, packet-, and circuit-switched transports, and even into the data center), and for almost all wireless “backhaul” communications, optical networking is the standard wireline technology.

Compared to other topologies, fiber-based optical networks will continue to provide the greatest overall capacity, speed, reliability, and resiliency. Fiber optics are not subject to outside signal interference, can carry signals for longer distances, and do not require amplifiers to boost signals in a metropolitan area broadband network.⁶²

If an ISP were to build new with no constraints based on existing infrastructure, it would likely begin with an FTTP access model for delivery of all current services; compared to other infrastructure, an FTTP investment provides the highest level of risk protection against unforeseen future capacity demands. In cases where a provider does not deploy fiber for a new route, the decision is often due to the provider’s long-term investment in copper OSP infrastructure, which is expensive to replace and may be needed to support legacy technologies.

2.3.2 Fiber Routes and Network Topology

FTTP architecture must be able to support a phased approach to service deployment. Phased deployments can help support strategic or tactical business decisions of where to deploy first, second, or even last. Phasing also allows for well-coordinated marketing campaigns to specific geographic areas or market segments, which is often a significant factor in driving initial acceptance rates and deeper penetration. This is the “fiberhood” approach used by Google and others.

A fiber backbone brings the fiber near each neighborhood, and fiber can be extended as service areas are added in later phases of deployment. This allows for the fiber in individual

⁶¹ An internetwork is a network of interconnected networks.

⁶² Maximum distances depend on specific electronics—10 to 40 km is typical for fiber optic access networks.

neighborhoods to be lit incrementally,⁶³ with each new neighborhood generating incremental revenue.

The proposed GPON FTTP architecture supports this capability once the core network electronics are deployed and network interconnections are made. The GPON architecture is discussed further in the design report and in Section 2.3.3 below.

2.3.3 Passive Optical Network—Specifications and Technology Roadmap

The first Passive Optical Network (PON) specification to enjoy major commercial success in the U.S. is Gigabit-capable Passive Optical Network (GPON). This is the standard commonly deployed in today's commercial FTTP networks and it is inherently asymmetrical. Providers from Google Fiber to Chattanooga's EPB offer 1 Gbps asymmetrical GPON service with high oversubscription rates. Our suggested network design allows for provision of symmetrical services on a case-by-case basis.

The GPON standard (defined by ITU-T G.984.1) was first established and released in 2004, and while it has since been updated, the functional specification has remained unchanged. There are network speed variants within the specification, but the one embraced by equipment manufacturers and now widely deployed in the U.S. provides asymmetrical network speeds of 1.24 Gbps upstream and 2.48 Gbps downstream.

Since the release of the ITU-T G.984.1 GPON specification, research and testing toward faster PON technologies has continued. The first significant standard after GPON is known by several names: XG-PON, 10GPON, or NG-PON1. The NG-PON1 specification offers a four-fold performance increase over the older GPON standard. Although NG-PON1 has been available since 2009, it was not adopted by equipment manufacturers and has not been deployed in provider networks. We expect the next version under development, NG-PON2, to evolve as the de facto next-generation PON standard. (Many industry sources indicate or anticipate fielding that standard by late 2015.)

These new standards can be implemented through hardware or software (electronics) upgrades, and are "backward compatible" with the current generation, so all variants can continue to operate on the same network.

The optical layer of the NG-PON2 standard is quite different from GPON. The specification uses a hybrid system of new optical techniques, time division multiplexing (TDM) / wave division multiplexing (WDM) PON (TWDM-PON), that basically multiplexes four 10 Gbps PONs onto one

⁶³ As the name implies, "lit fiber" is no longer dark—it is in use on a network, transmitting data.

fiber, to provide 40 Gbps downstream. This is a 16-fold performance increase over the current GPON standard.

At minimum, the upgrade pathway for existing GPON deployments will require new enhanced small form-factor pluggable (SFP+) modules on the OLT side at the hub building or cabinet, and a new optical network terminal (ONT) device at the customer premises, with software and firmware upgrades on the FTTP electronics. Final details are yet to be announced and will vary by manufacturer, but the NG-PON2 specification requires a migration path and backward compatibility with GPON. FTTP equipment manufacturers are believed to be testing upgrade steps and strategies for migrating from GPON to NG-PON2.

Table 1: PON Standards

1994	pi-PON. 50 Mb/s, 1310nm bidirectional, circuit switched
1999	A/B-PON. 622/155 Mb/s, 1550nm down, 1310nm up, ATM-based
2004	G-PON. 2.4/1/2Gb/s, 1490nm down, 1310nm up, packet-based G-PON (2.5)
2009	NG-PON1. 10/2.5Gb/s, 1577nm down, 1270nm up, packet-based XG-PON (10)
2014	NG-PON2. 40G+ capacity XLG-PON (40)

2.3.4 Managing Network Demand

Perhaps the most fundamental problem solved by IP packet data networking is how to cost-effectively design, build, and operate a network to manage unpredictable demands and bursts of network traffic.

The earliest transport networks (and many of the major Internet backbone segments today) are circuit switched. This means that each network leg is a fixed circuit, running at a fixed speed all the time. Fixed-circuit networks are less flexible and scalable; they must be precisely designed and planned in advance, because there are fewer mechanisms to deal with unplanned traffic surges or unexpected growth in demand.

“Dial-up” modems provide an example of circuit-switched technology. Copper POTS lines were in huge demand as residential and business customers purchased fax machines and accessed the Internet over modems. Because the POTS technologies could not support all of these uses at the same time, and were limited to slower speeds, phone companies were only able to serve that demand by installing more copper lines.

The packet-switched DSL, cable modem, fiber, and wireless technologies that replaced POTS addressed the limitations of fixed-circuit technologies because the flow of network traffic is determined on a per packet basis, and the network provides robust mechanisms for dealing

with unexpected bursts of traffic. The trade-off for flexibility, resiliency, and ease of use is that network speed will vary, depending mainly on the amount of traffic congestion.

2.3.4.1 Oversubscription

An important balancing act in packet networks is between network performance (speed) and network utilization (efficiency). The primary method of achieving this balance is *oversubscription*. Because the vast majority of network users are not actually transmitting data at any given moment, the network can be designed to deliver a certain level of performance based on assumptions around actual use.

Oversubscription is necessary in all packet-switched network environments and is generally beneficial—by enabling the network operator to build only as much capacity as necessary for most scenarios. By way of comparison, the electric industry uses a demand factor to estimate generation requirements. Similarly, a road that has enough capacity to keep most traffic moving at the speed limit most of the time will get congested during peak travel times—but building a road large enough to handle all of the traffic at peak times would be too expensive. Most drivers most of the time have enough room to go the speed limit, but when a lot of users want to be on the road at the same time, everyone has to slow down.

The City will need to evaluate and manage its subscription levels to deliver the optimal balance of performance and efficiency. Although the goal of providing symmetrical *dedicated*⁶⁴ 1 Gbps data to all Palo Alto subscribers is admirable and technically possible, it may not be very practical or affordable. By comparison, Google’s 1 Gbps offering is technically neither symmetrical nor dedicated. And while Comcast’s 2 Gbps offering might be symmetrical, it is not dedicated.

Services may be burstable, meaning that users may experience the advertised data rates at times, but the average speed will vary greatly based on the traffic being generated over the provider’s distribution network. Performance parameters on a burstable service are rarely publicized or realized. Often a network operator cannot change this parameter without changing the network’s physical connections.

When looking at FTTP requirements, it is important to understand that the speeds and performance stated in marketing material for consumer services are not the same as a network’s actual technical specifications. Actual speeds and performance will depend on the activity of other users on the network. Generally, all residential and small business Internet services are delivered on a best-effort basis and have oversubscription both on the network and in the network’s connection to the Internet (Direct Internet Access).

⁶⁴ As its name implies, service is “dedicated” when the link runs directly from the ISP to the user.

First, let's look at network oversubscription. Today's GPON standard supports FTTP network speeds of up to 2.4 Gbps downstream (to the consumers) and 1.2 Gbps upstream (from the consumers) from a given FDC. The FDC is typically configured to support up to 32 premises.⁶⁵ That is, up to 32 users will share the 2.4 Gbps downstream and 1.2 Gbps upstream.⁶⁶ Given that not all users will demand capacity at the same time and that very few applications today actually use 1 Gbps, a provider can reasonably advertise delivery of a symmetrical 1 Gbps service on a best-effort basis and most consumers will have a positive experience.

NG-PON2 (described above) will likely enable support of 40 Gbps downstream. In four or so years, the NG-PON2 platform should become standard, and although it will initially be somewhat more expensive, pricing will likely quickly match levels similar to today's 2.4 Gbps platform.

Even with today's 2.4 Gbps GPON platform, the network can be designed to support 10 Gbps, 100 Gbps, or other symmetrical speeds. This can be accomplished with a hybrid approach using active Ethernet (AE) and GPON, or by deploying a full AE network, which would require placing active electronics at the FDC.

The next level of oversubscription is with the network's access to the Internet. Again, since not all users demand capacity at the same time, there is no need to supply dedicated Internet bandwidth to each residential or small business customer. In fact, it would be cost prohibitive to do so: Assuming a DIA cost of \$0.50 per Mbps per month, the network operator would pay \$500 per month for 1 Gbps of DIA. But an operator with a residential and small business 1 Gbps service could easily use an oversubscription of 500 to 1,000 on DIA today. Then, as users require more bandwidth, the operator simply subscribes to more bandwidth. The preferential approach is to reduce the traffic over the Internet, which is accomplished by peering to other networks, placing servers (such as Netflix) on the City's FTTP network (referred to as on-net), and caching.⁶⁷

All of the applications that the City has identified are possible with 32:1 GPON architecture and a reasonable oversubscription. If a bottleneck occurs at the Internet access point, the City can simply increase the amount of commodity bandwidth (DIA) it is purchasing or bring servers such as Netflix on-net. Customers looking for greater than 1 Gbps or who require Committed Interface Rates (CIR) can be served via a higher priced Ethernet service rather than the GPON-based 1 Gbps service.

⁶⁵ Can be deployed in 8 to 1, 16 to 1, and 32 to 1 configurations. Lower ratios reduce the number of subscribers sharing the capacity, but increases the number of FDC's and fiber strands.

⁶⁶ In an HFC network as used by Comcast, the network capacity is shared among 250 to 500 users.

⁶⁷ Network server or service that saves Web pages or other Internet content locally.

2.3.4.2 Rate Limiting

In some networks, unexpected bursts of network traffic slow things down to unacceptable speeds for everyone using the network. Thus there needs to be a mechanism in place to manage these events for the greater good of everyone sharing the network.

One technique for controlling this is called rate-limiting. It can be implemented in many different ways, but the net result is that it prevents over-congestion on a network during the busiest usage times.

Most consumer Internet services today provide subscribers with a “soft” rate for their data connections. This may allow for some extra speed and capacity during times when the network is uncongested, but it may also mean that the “soft” rate may not be achievable during times when the network is the most congested. Providers need to have this flexibility to cost effectively manage the networks overall performance and efficiency and they do this with subscription levels and rate limiting.

2.3.5 Internet Protocol (IP) Based Applications

The FTTP design will be an all-IP platform that provides a scalable and cost-effective network in the long run. This will allow the City to minimize ongoing costs; increase economies of scale with other network, communications, and media industries; and operate a uniform and scalable network. For example, with an IP-based data network, there would not need to be a separate set of video transport equipment in the headend or hubs, nor a set of dedicated video channels. The transport equipment and the spectrum would become uniform and converge to a single IP platform. Thereafter, network upgrades could be carried out solely based on the evolution of high-speed networking architecture, independent of video processing capabilities often inherent in incumbent provider networks.

2.3.6 Migration from IPv4 to IPv6 Protocol

The Internet is in the process of migrating from the IPv4 to the IPv6 protocol. This upgrade will include several improvements in the operation of the Internet. One of the most notable is the increase in available device addresses, from approximately four billion to 3×10^{38} addresses. IPv6 also incorporates other enhancements to IP networking, such as better support for mobility, multicasting, security, and greater network efficiency; it is being adopted across all elements of the Internet, such as equipment vendors, ISPs, and websites.

Support of IPv6 is not unique to the proposed City FTTP network. Comcast has begun migrating all of its services to IPv6.

Customers with access to IPv6 can connect IPv6-aware devices and applications through their data connection and no longer need to use network address translation (NAT) software and

hardware to share the single IP address from the ISP among multiple devices and applications. Each device can have its own address, be fully connected, and (if desired) be visible to outside networks.

One way to think of removing NAT is that it is the IP equivalent of moving from a world of cumbersome telephone systems with a main number and switchboard extension (e.g., 650-555-0000 extension 4422) to one where each individual has a unique direct number (e.g., 650-555-4422). Devices and applications that will particularly benefit from IPv6 include interactive video, gaming, and home automation, because NAT (and other IPv4 workarounds to share limited address space) makes connecting multiple devices and users more complex to configure, and IPv6 will eliminate that complexity and improve performance. With IPv6, each device and user can potentially be easily found, similar to how a phone is reached by dialing its phone number from anywhere in the world.

2.3.7 Multicasting—IP Transport of Video Channels

Traditional Internet video can waste capacity, especially in a “channel” video environment, because it sets up a new stream from the source to each viewer. Even if many people are watching the same program at the same time, a separate copy is streamed all the way from the server (or source) to the user. *Multicasting* is a method of transmitting data to multiple destinations by a single transmission operation in an IP network.

Using multicasting, a cable operator (leveraging the proposed FTTP network) can send a program to multiple viewers in a more efficient way. A multicast-aware network sends only a single copy of the program (known as a multicast stream) from the server or source through the various network routers through the network. When a viewer selects the program, the viewer’s device (set-top converter or computer) connects to the multicast stream. The stream exists only once on the network, so even if the viewer and many neighbors are viewing the same stream, only one copy is being sent through the network (see Figure 5 and Figure 6).

Figure 5: Unicast IP Network Carries Multiple Copies of Single Video Channel

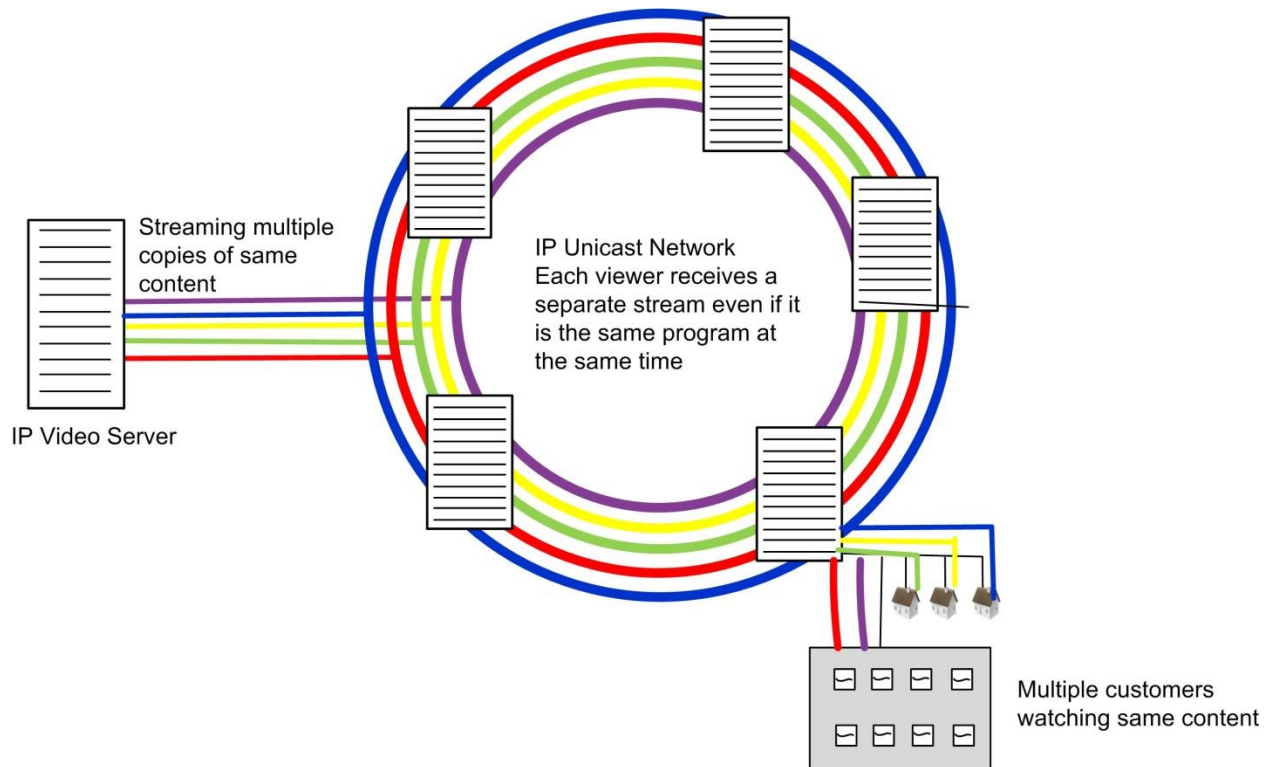
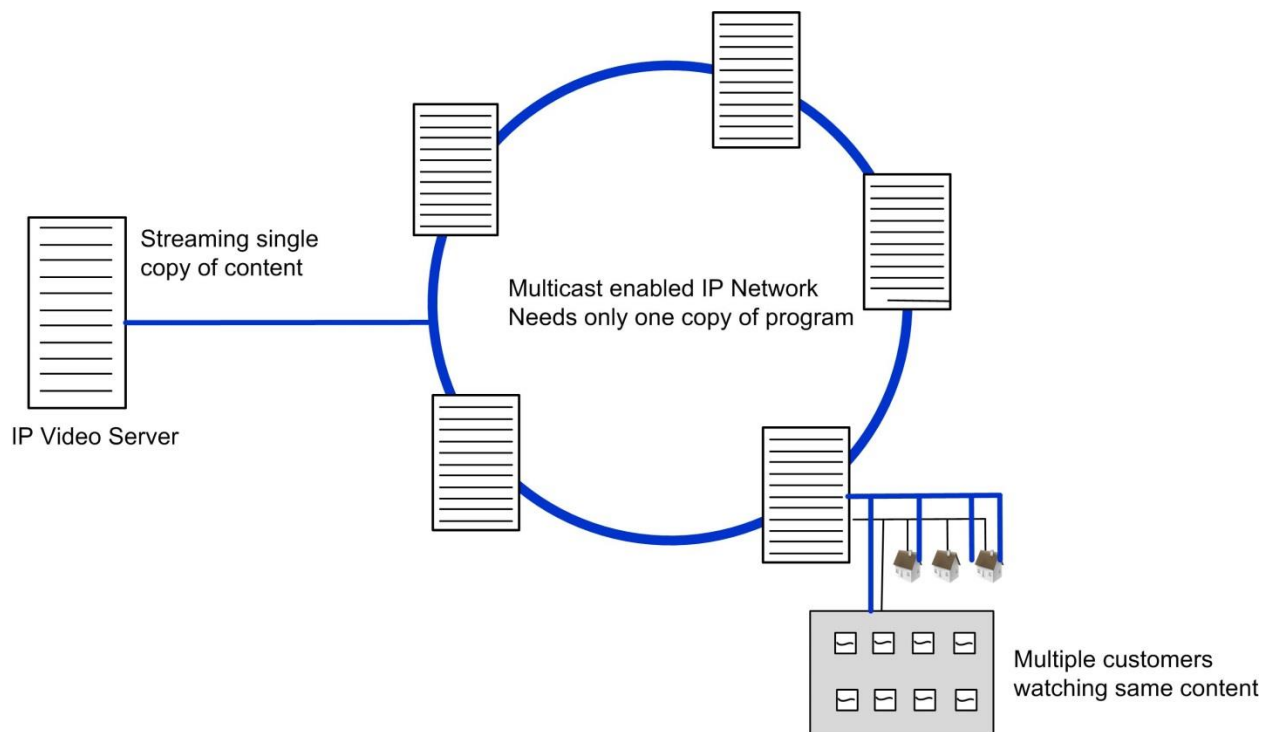


Figure 6: Multicast IP Network Carries Single Copy of Single Video Channel



Multicast is a feature that was optional in IPv4 but standard (and better executed) in IPv6. As multicast-capable and multicast-aware routers and set-top converters become standard, a cable operator leveraging the City FTTP could consider an all-IP video programming offering, and not just video-on-demand (VoD), as multicast provides a means to carry traditional channels over IP without wasting the backbone capacity.

2.3.8 Over-the-Top (OTT) Programming

As we noted, OTT programming typically refers to streaming content delivered via a consumer's Internet connection on a compatible device. Consumers' ubiquitous access to broadband networks and their increasing use of multiple Internet-connected devices has led to OTT being considered a disruptive technology for video-based entertainment. The OTT market, which includes providers like Netflix, Hulu, Amazon Instant Video, and iTunes, is expected to grow from about \$3 billion in 2011 to \$15 billion, by 2016.⁶⁸

In order to provision content, OTT services obtain the rights to distribute TV and movie content, and then transform it into IP data packets that are transmitted over the Internet to a display platform such as a TV, tablet, or smartphone. Consumers view the content through a Web-based portal (i.e., a browser) or an IP streaming device (e.g., Google Chromecast, Roku, Apple TV, Xbox 360, or Internet-enabled TV/Smart TV).

One potential difference in the delivery of OTT video content to consumers compared to other data traffic is OTT video's high QoS requirement. QoS prioritizes the delivery of video packets over other data where uninterrupted delivery is not as critical, which ultimately translates to a high quality viewing experience for customers. Content buffering and caching for streamed content reduces the need for QoS. Network QoS is designed for and driven by the need to support real-time services such as VoIP and video conferencing.

OTT providers typically have to use the operators' IP bandwidth to reach many of their end users. At the same time, they are a major threat to cable television programming, often provided by the very same cable operators, due to their low-cost video offerings. As a result, many cable operators have introduced their own OTT video services to reach beyond the constraints of their TV-oriented platforms and to facilitate multi-screen delivery.⁶⁹

⁶⁸ "Over-the-Top-Video – "First to Scale Wins," Arthur D Little, 2012

http://www.adlittle.com/downloads/tx_adlreports/TIME_2012_OTT_Video_v2.pdf

⁶⁹ "Cable operators embrace over the top," *FierceCable*, July 2, 2013, <http://www.fiercecable.com/special-reports/cable-operators-embrace-over-top-video-studios-thwart-netflix-hulu-options>

Even Comcast seemed to embrace OTT by launching its “Streampix” in 2012,⁷⁰ though that service was less than successful and was ultimately removed as a standalone offering. In 2015, Comcast announced another attempt at providing OTT content in the form of its “Stream” package,⁷¹ however subscribers must also sign up for Xfinity Internet in order to access “Stream” content.

While the nature of OTT video lends itself nicely to VoD, time-shifted programming, and sleek user interfaces, OTT providers have limited control over the IP transport of content to users, which can cause strains on network bandwidth due to the unpredictable nature of video demand. Cable operators have experimented with rate limiting and bandwidth caps,⁷² which would reduce subscribers’ ability to access streaming video content. It is also technically possible for cable operators to prioritize their own traffic over OTT video streams, dial down capacity used by OTT on the system, or stop individual OTT streams or downloads.

Some cable operators have attempted to manage OTT on their networks by incorporating the caching of OTT video content from third-party providers (e.g., Netflix) in their data centers in order to improve QoS and reduce congestion on the cable provider’s backbone network. This serves as a means for improving the quality of OTT video for video hosted in the data center.

2.4 Integration of Wireless Communications

With the improvement of the quality and speed of wireless communications, the public has become accustomed to accessing Internet services over wireless technologies, either on a communications link managed by a wireless service provider (i.e., a cellular data plan), on local infrastructure typically managed at a home or business (i.e., a Wi-Fi hotspot), or through a mixture of those two approaches (e.g., a hotspot operated by a service provider, municipality, landlord, or homeowners association).

The ability to deliver TV content to consumer devices anywhere at any time is highly dependent on the evolution of wireless technologies. Cellular service providers nationwide operate a mixture of third-generation (3G) and emerging fourth-generation (4G) wireless technologies.⁷³

⁷⁰ <http://www.geekwire.com/2012/comcast-unveils-499-month-streampix-service-aim-netflix-hulu/>, accessed May 2015.

⁷¹ http://www.forbes.com/fdc/welcome_mjx.shtml, accessed July 2015.

⁷² “Comcast tests new usage based internet tier in Fresno,” *Multichannel News*, August 1, 2013 <http://www.multichannel.com/distribution/comcast-test-new-usage-based-internet-tier-fresno/144718>

⁷³ The strict definition of 4G from the International Telecommunications Union (ITU) was originally limited to networks capable of peak speeds of 100 Mbps to 1+ Gbps depending on the user environment; according to that definition, 4G technologies are not yet deployed. In practice, a number of existing technologies (e.g., LTE Revision 8, WiMAX) are called 4G by the carriers that provide them and represent a speed increase over 3G technologies as well as a difference of architecture—more like a data cloud than a cellular telephone network overlaid with data services. Furthermore, a transition technology called HSPA+, an outgrowth of 3G GSM technology (previously

As of today, the latest 4G Long Term Evolution (LTE) technologies have been rolled out by every major U.S. carrier, creating an environment for better access to streaming video. In the near term, the challenges for wireless carriers are for greater capacity, extending network coverage, and efficiently utilizing the limited amount of wireless spectrum. FTTP and cable operators are well positioned to mitigate some of these issues with now available Wi-Fi capabilities in premises electronics. As described in the following section, FTTP and cable operators have pursued synergies with wireless carriers by exploring ways to use and extend each other's communication networks.

2.4.1 Mobile Backhaul

One area for greater collaboration between cable, FTTP, and wireless carrier networks is the provision of backhaul from cell sites to core network locations. In a carrier wireless network, cell towers are typically connected (backhauled) to the wired telecommunication network through low-bandwidth circuits. Given the fact that cable and FTTP operators have infrastructure that is spread out in a pattern that can easily reach cell towers, a relatively small investment in upgrading the fiber portion of cable operator networks for robust Metro Ethernet services will equip them with capabilities for mobile backhaul.⁷⁴ The need and demand to access fiber for backhaul will continue to increase as we move toward fifth-generation (5G)⁷⁵ wireless technologies.

As cell coverage continues to evolve the coaxial portion of the cable system (as well as customer premises) and FTTP drops may be suitable for small “picocell” devices—miniature cell sites resembling Wi-Fi hotspots that can connect a handful of wireless users to a carrier, typically for indoor locations with poor wireless coverage.

The trend towards ever decreasing coverage areas of individual mobile broadband base stations, or “cell site” radios, is driven by the need to increase aggregate capacity of the network by reusing the same wireless spectrum to serve smaller groups of customers. Each cell site is generally hardwired or connected via licensed microwave links to the provider's backbone network—so as the coverage area of each decreases, the requirements for this backhaul connectivity increase. More numerous, smaller cell sites offer reduced technical complexity and have less demanding physical requirements, including mounting structures and electrical power.

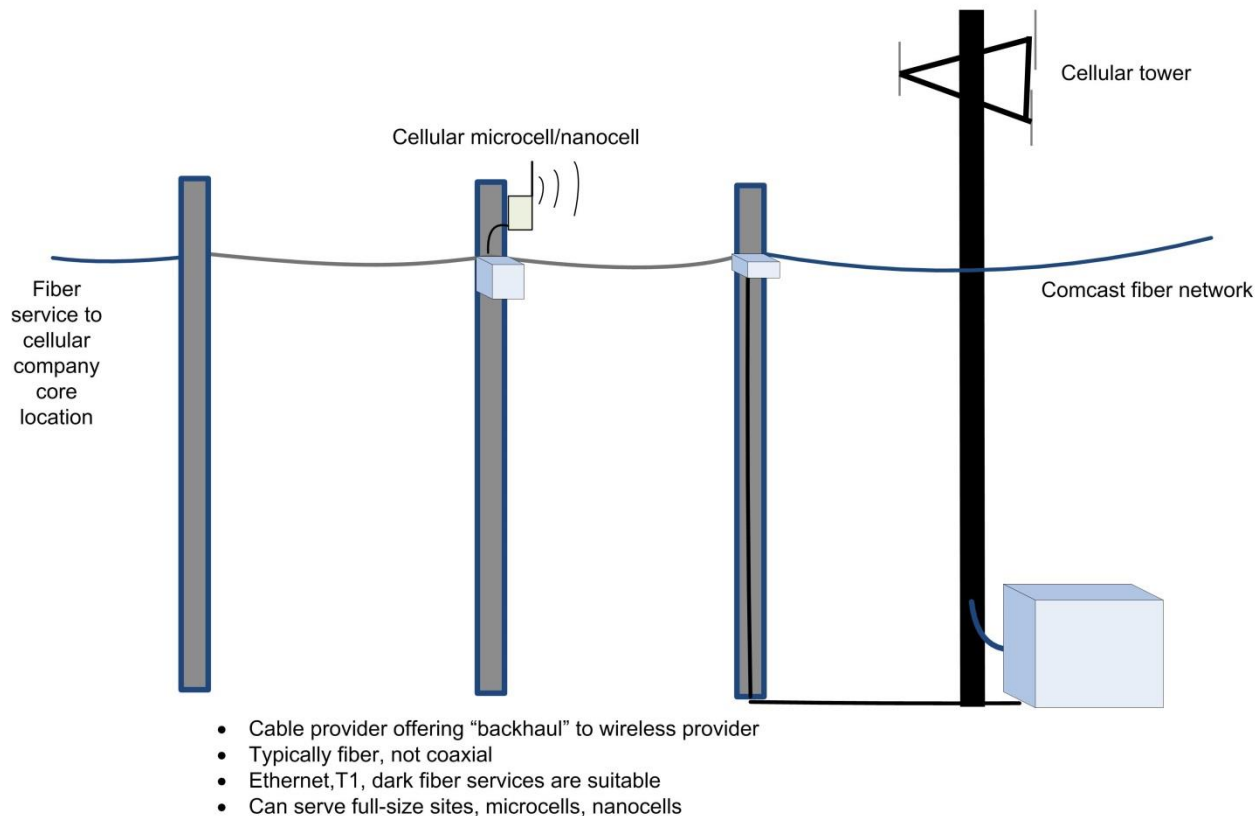
considered a 3G or 3.5G technology, with less capability than LTE or WiMAX), has been marketed as “4G” by certain carriers—so the definition of 4G is now fairly diluted. The ITU and other expert groups have more or less accepted this.

⁷⁴ “Mobile backhaul opportunity knocks for cable operators,” *CED Magazine*, Feb 28, 2011,

<http://www.cedmagazine.com/articles/2011/02/mobile-backhaul%3A-opportunity-knocks-for-cable-operators>

⁷⁵ We anticipate that 5G rollouts will begin in the 2020 timeframe. It features greater capacity, smaller cells, and better traffic prioritization.

Figure 7: Cable Operator Providing Fiber Backhaul to Cell Sites and Micro/Nanocells



A "standard" cell site in a suburban or urban area is likely to have a coverage radius of a few miles, but can extend to more than 20 miles in some cases, with antenna arrays mounted to a large tower or atop a tall building. The radio equipment is likely to be housed in a large weather-proof enclosure or small shelter equipped with climate control systems and backup power generators. Typical electrical power requirements are in the 1 – 4 kilowatt (kW) range per carrier. Due to the cost and physical space requirements, collocation of multiple carriers is common at cell sites.

Although the terminology is not always used consistently, a microcell generally refers to a compact base station targeting a coverage range of less than a mile or two within a specific area of particularly high density usage and/or to fill coverage gaps. Large hotels, airports, and sports venues are often served by one or more microcell to offload capacity demand from adjacent cell sites. As with a standard cell site, microcells are also operated and managed by the wireless provider. The limited coverage area of a microcell does not necessarily require antennas to be located on tall towers, and can often be supported by utility poles, street lights, and rooftops. Microcell equipment can generally be supported in small outdoor equipment enclosures that can be mounted to a utility pole.

As cell sites get even smaller, their terminology and typical configuration become less consistent. Picocells and femtocells represent a breed of based station targeting very small coverage areas of a few hundred feet or less. These base stations may resemble a home Wi-Fi router, and may not be operated or installed by the wireless provider. Femtocells are typically installed indoors by an individual customer, allowing their own Internet connection to provide backhaul for the wireless services.

2.4.2 Partnerships with Wireless Carriers

In addition to the greater speeds available on the latest LTE networks, wireless carriers can also promote the usage of video streaming on mobile devices (such as smartphones and tablets) by implementing functionalities that optimize the broadcast of premium TV content on the wireless network. A technique called Evolved Multimedia Broadcast Multicast Service (eMBMS) along with the implementation of new adaptive streaming protocols (in place of buffering) and High Efficiency Video Coding (HEVC) enable wireless carriers to use the spectrum more efficiently for the provision of TV content and to improve quality.⁷⁶

Some cable companies such as Comcast are also offering customers a “Quad Play” of Internet, voice, cable, and wireless services (by reselling wireless phone services). This strategy also provides another portal for extending the reach of cable television and associated services.

2.4.3 Potential Wireless Services by City FTTP Network

Wi-Fi enables the delivery of content to multiple TVs, tablets, PCs, and smartphones without the limits of cabling and without needing to have licensed wireless spectrum. Cable providers have been offering wireless Internet services for several years through Wi-Fi routers connected to DOCSIS-based cable modems.⁷⁷ Comcast and other video content providers are now increasingly pursuing ways to offer wireless transmission of video content on home networks as well as on large-scale roaming networks. The CPEs proposed with the City FTTP network have the option of supporting Wi-Fi at a nominal cost. Theoretically, Wi-Fi may also enable a provider to offer some of its services from its cable plant to a home or business without installing a cable into the premises.

2.4.4 Residential Wireless Services—Wi-Fi and New Technologies

Wi-Fi or Wireless Local Area Network (WLAN) technology is based on the IEEE 802.11 standard. WLANs have been able to provide greater bandwidth over the course of their evolution and may potentially create a completely wire-free future for connectivity within the home.

⁷⁶ “Verizon’s McAdam Sees Broadcast Video over LTE in 2014,” *Multichannel News*, Jan. 8, 2013, <http://www.multichannel.com/telco-tv/ces-verizons-mcadam-sees-broadcast-video-over-lte-2014/141109>. See also: <http://www.engadget.com/2015/01/14/att-lte-broadcast/>.

⁷⁷ DOCSIS, or “Data Over Cable Service Interface Specifications,” is the standard that enables cable operators to transport data over existing cable architecture.

One of the latest versions of the 802.11 standard, 802.11ac, is now becoming available, and positions WLANs to target the wireless market growth expected over the next few years by offering speeds of up to 1.3 Gbps⁷⁸—doubling that of the current 802.11n standard. The new standard (operating only in the 5 GHz band as opposed to both the 5 GHz and 2.4 GHz bands) has various design enhancements, including:

- Increase in channel sizes up to 160 MHz from a maximum of 40 MHz in 802.11n
- Use of higher modulation and coding schemes such as 256 QAM (an improvement over 64 QAM)
- Greater number of multiple input, multiple output (MIMO) antenna streams (i.e., eight antenna streams instead of four) separated spatially in a manner that improves data rates and performance
- Use of multi-user MIMO, which supports simultaneous transmission to multiple clients, thus more effectively utilizing channel bandwidth

The Wi-Fi Alliance, a trade association that ensures the interoperability of equipment from different vendors, approved 802.11ac technology on various new devices in 2013. The relatively faster adoption of this new technology had become a necessary step in order to support the pervasive bandwidth demanded by mobile applications and the increasing number of devices per user. Backward-compatibility to older standards and 2.4 GHz equipment is a feature that will be present on most devices for the foreseeable future.

Another standard—802.11ad—which will offer functionalities closer to peer-to-peer (P2P) applications has been in development by Samsung and others and uses the 60 GHz band of radio spectrum. It has the capability to transfer up to 7 Gbps.⁷⁹ This technology is more suited for high capacity, line-of-sight links (such as in-room wireless connection) and has the potential to be a highly effective way to communicate between content delivery mediums and user screens—similar to how an HDMI cable or docking station would work, but at greater distances.

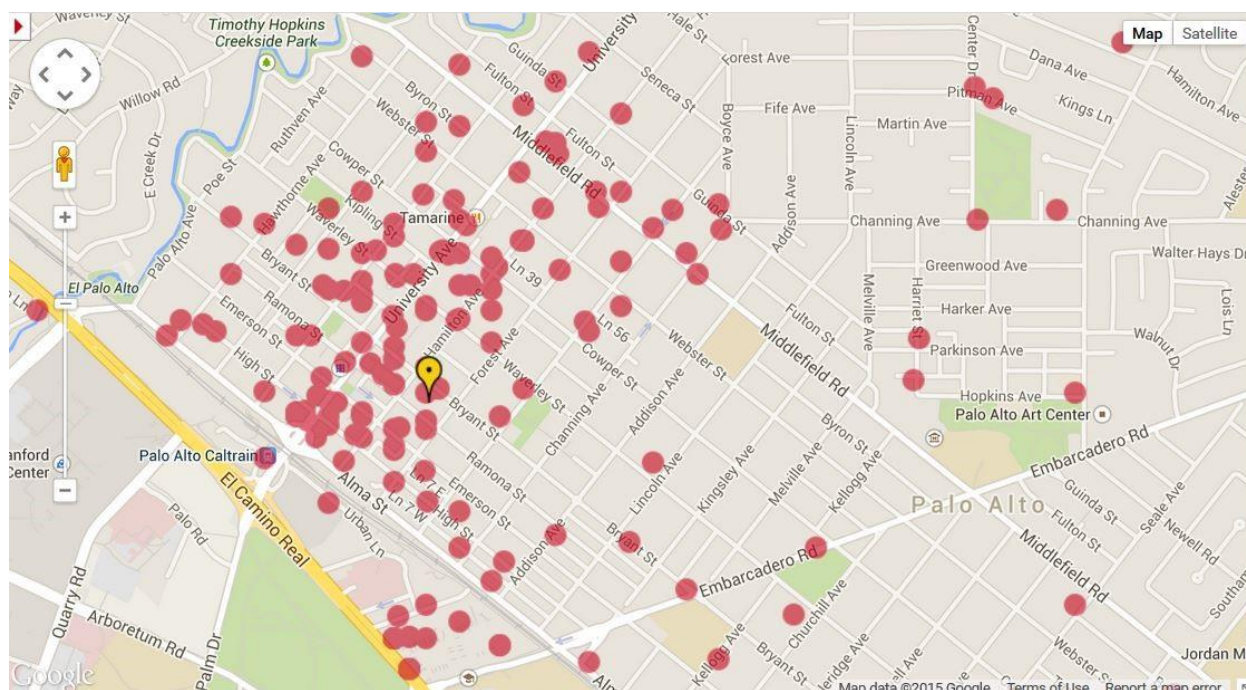
⁷⁸ “802.11ac: The fifth Generation of Wi-Fi Technical White Paper,” Technical White Paper, Cisco Systems, August 2012

⁷⁹ “Amendments in IEEE 802.11ad enable Multi-gigabit throughput and groundbreaking capacity,” IEEE Standards Association, January 8, 2013, <http://standards.ieee.org/news/2013/802.11ad.html>, and “Samsung Develops 802.11 AD Wi-Fi, But Will it be Sunk by Poor Penetration?” *DailyTech*, October 14, 2014, <http://www.dailytech.com/Samsung+Develops+80211+AD+WiFi+But+Will+it+be+Sunk+by+Poor+Penetration/article36707.htm#sthash.9sEhr0rN.dpuf><http://www.dailytech.com/Samsung+Develops+80211+AD+WiFi+But+Will+it+be+Sunk+by+Poor+Penetration/article36707.htm>

2.4.5 Roaming Wi-Fi Networks

This option is difficult for the City to support due to service area (not technical) limitations. Cable providers have been able to broaden their wireless service footprints by creating a nationwide roaming Wi-Fi network. Comcast has expanded its Wi-Fi hotspot network, “Xfinity WiFi,” to several densely populated areas within its service region to provide wireless Internet access to both subscribers (at no additional charge) and non-subscribers (at a pay-per-time-block rate). See Figure 8 below.

Figure 8: Comcast Wi-Fi Hotspots in Palo Alto



Comcast and four other cable companies—Time Warner Cable, Cox Communications, Cablevision, and Bright House Networks—collaborated to create a Wi-Fi roaming network across the United States, named “CableWiFi.” This network allows cable subscribers to access the Internet within the coverage of 300,000 hotspots belonging to any of the cable providers in more than a dozen major cities.⁸⁰

⁸⁰ <http://www.timewarnercable.com/en/support/faqs/faqs-internet/twcwifihot/cablewifi/what-is-cablewifi.html>, accessed April 2015.

In June 2013, Comcast launched a “homespot” network⁸¹ that sets up an additional sub-network on the Wi-Fi gateways deployed in individual customer premises that is accessible to all Comcast subscribers. This model has already been demonstrated in Europe and has the potential to provide millions of hotspots across Comcast’s service footprint, enabling roaming access to video and data content.

The expansion of roaming Wi-Fi networks either collaboratively (e.g., CableWiFi) or by individual cable providers (e.g., Comcast’s homespot) does not appear to create bandwidth bottlenecks on cable operator networks at the moment. Rather, the networks create benefit to cellular wireless carriers, which have a new avenue to relieve their network congestion by offloading their data services to cable operator’s public Wi-Fi networks. At the same time, wireless subscribers can also direct their traffic to Wi-Fi networks whenever possible to avoid the data caps set by cellular providers. In both cases, multiple-system operators (MSOs) benefit by 1) obtaining a greater penetration in the wireless broadband market and 2) the creation of a smooth transition in the TV viewing experience outside of their coverage area.

⁸¹ “Comcast unveils plans for millions of Xfinity WiFi Hotspots,” press release, Comcast Corp., June 10, 2013, <http://corporate.comcast.com/news-information/news-feed/comcast-unveils-plans-for-millions-of-xfinity-wifi-hotspots-through-its-home-based-neighborhood-hotspot-initiative-2>

3 Inventory and Assessment

CTC conducted preliminary research into the City’s existing infrastructure and assets as an initial step toward planning how best to deploy FTTP infrastructure. This section outlines the framework of our understanding.

We note that existing infrastructure is not always an asset in the pursuit of FTTP—for example, if barriers to the infrastructure are too many or the cost to ready it for FTTP is too great. Here we consider the infrastructure and what role it might have in an FTTP network, if any. One obstacle to leveraging an asset is getting it cleaned up to the point of being usable in the course of a citywide FTTP network build.

It is our understanding that the existing fiber infrastructure is approximately 54 percent overhead and 46 percent underground.⁸² The majority of the underground infrastructure is placed in commercial areas—only approximately 15 percent⁸³ of it is underground in residential areas. The majority of new fiber for the FTTP network will be placed in residential areas and will likely follow aerial routes.⁸⁴

3.1 Existing Dark Fiber Optic Backbone Network

The City’s existing dark fiber optic backbone network consists of a combination of underground and overhead (aerial) construction. It primarily serves businesses and rarely extends into residential areas except for routing purposes.

Dark fiber is unused fiber strands within a cable bundle through which no light is transmitted, or strands not carrying a signal. CPAU’s basic business model is to provide dark fiber connectivity to users requiring access to large amounts of bandwidth. Customers are responsible for providing and maintaining the equipment to “light-up” or provision licensed fiber strands. Dark fiber is licensed to a variety of commercial firms, the Palo Alto Unified School District, and other organizations without transmission service. The City also uses the network for its own communication requirements. In contrast, traditional telecommunication service providers only make available certain products within their service options that may not adequately meet the requirements of the specific applications. The CPAU dark fiber network has high market share and brand awareness among commercial enterprises and other organizations that need the quantity and quality of bandwidth provided by direct fiber optic connections.

⁸² The overhead lines for approximately 14,050 homes remain to be undergrounded and the current program undergrounds facilities for approximately 150 to 200 homes per Underground District.

⁸³ CPAU Engineering confirmed percentages on April 3, 2015.

⁸⁴ CPAU has scheduled overhead to underground conversion districts in residential areas.

The first phase of the fiber backbone construction occurred in 1996 and 1997. The initial portions of the network were constructed in a backbone ring architecture in existing utility rights-of-way (ROW). The fiber backbone was routed to pass and provide access to key City facilities and offices. The majority of the City's business parks (e.g., Stanford Research Park) and commercial properties mostly in the downtown area are also passed by the fiber backbone.

The original fiber backbone consisted of 33 route miles with 144 or more strands of single-mode fiber along most routes. The fiber backbone has been expanded to approximately 49 route miles of mostly 144-count or 288-count single-mode fiber.⁸⁵ A budget has been approved to develop a network capital improvement and strategic plan to address congestion in several high fiber-use areas by adding more fiber in anticipation of future customer needs.

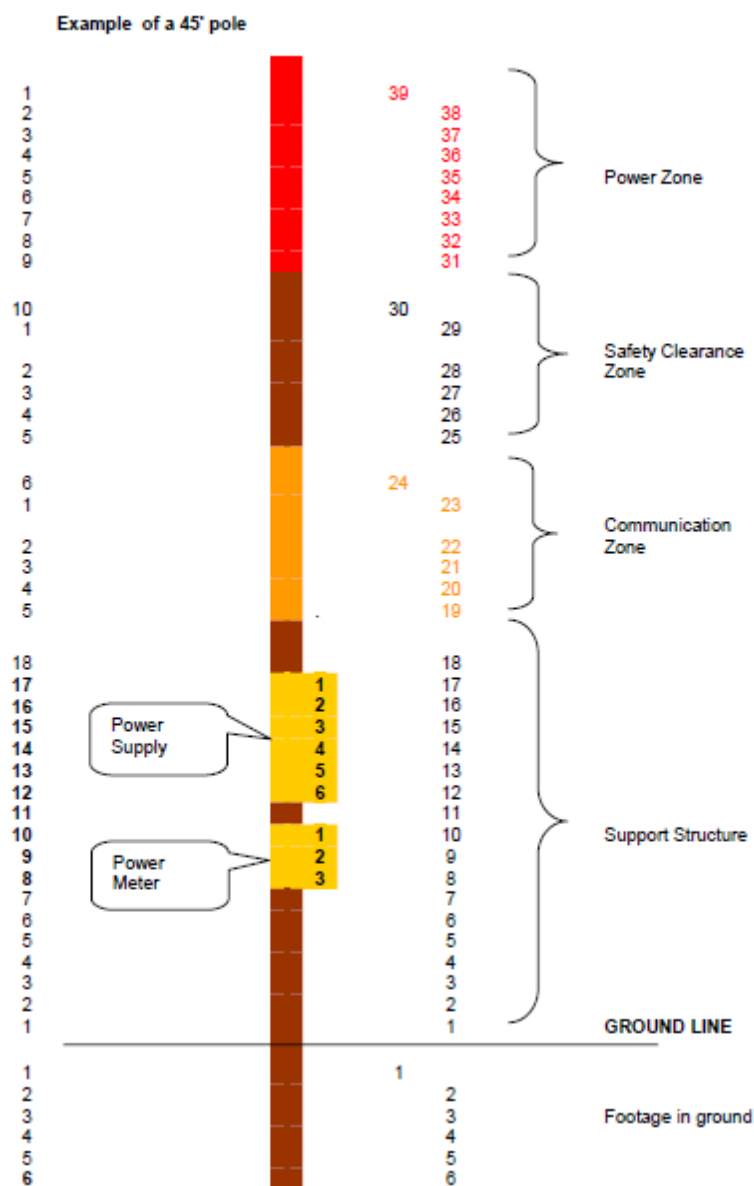
It is important to note that in addition to the backbone there is a considerable presence of fiber optic lateral connections, or "drop cables." Drop cables connect the backbone to the customer premises. Often the drop cables provide additional access to customers as they may provide at least supplemental conduit or aerial paths. For example, a drop cable may be installed extending several blocks from the backbone, thereby providing a less expensive, expedited connection for other customers along that path.

There are also plans to use the fiber capital improvement budget to establish a central connection point in multi-tenant commercial buildings in anticipation of acquiring new dark fiber customers.

The City's overhead fiber is placed in a designated area in the communications space on the utility poles allocated specifically for the City to place its infrastructure. Although this is not the "power space" in the traditional sense, it is referred to as power space or "safety clearance zone" by City and Utility staff. The space on the pole below the power zone and the safety clearance zone is called the "communication zone," which is the space on the pole occupied by AT&T, Comcast and other "attachers" (see Figure 9). As a practice, no communications infrastructure may be placed in the actual power zone or safety clearance zone, which means that as the City considers its FOTP enterprise, it will be necessary to make use of the designated City space in the communications zone (i.e., space in the communication zone not owned by AT&T). If there is no space readily available, it will require either adjusting the position of existing attachments or replacing the pole with a taller one (see Figure 9).

⁸⁵ Results in a total of 5,610 "fiber miles."

Figure 9: Examples of Pole Zones



There is already fiber in the City's designated space and some⁸⁶ of the fiber cable has already been overlashed.⁸⁷ In these cases, there is no possibility of additional overlash. This is the dark fiber infrastructure, an important endeavor and revenue stream for the City. Although there is extensive existing fiber on the dark fiber network, most of it is already allocated for use—thus it may not be an asset in the context of the FTTP network. This infrastructure may be best retained for delivering dark fiber services. The FTTP build may cost slightly more because the

⁸⁶ CPUC is reviewing to determine percent of the fiber cable routes that are overlashed.

⁸⁷ Overlashing is the act of attaching the new fiber cable to the existing fiber cable.

limited ability to leverage the existing fiber infrastructure. Please note even if existing fiber strands were available, the cost reduction impact would be minimal to the overall FTTP deployment cost. The existing backbone routes are a small percentage of the required FTTP routes. The key City assets include the ownership of the utility poles and existing conduit.

3.2 Utility Poles

One of the most valuable assets the City has is the ownership of utility poles.⁸⁸ The City jointly owns with AT&T the majority of the existing poles and controls the access. This simplifies the make-ready process because the City does not have to deal with the complication of an outside private entity.⁸⁹ However, though the make-ready will be less complex on City-owned poles, a fair amount of work is necessary to be able to attach additional cable to most poles and make-ready costs are still likely to be significant.

Additionally, issues like private easement installations mean that not all poles will be readily accessible to the City. For example, an estimated 25 percent of existing poles are located in Public Utility Easements on private property behind homes and businesses.⁹⁰ This can render some of these poles impractical for FTTP purposes while others may require expensive pole replacement with an overhead crane.

Table 2 shows a breakdown of utility pole heights throughout the City, but some will need to be replaced entirely. For example, 35-foot poles will likely have to be replaced simply because there will not be enough space to sustain additional fiber infrastructure necessary for the FTTP build.⁹¹

The poles and pole heights are summarized in Table 2 below.

⁸⁸ City and AT&T jointly own approximately 5,400 of the 6,000 or so utility poles in Palo Alto. See the 100+ year plus agreement, which is included in the *Google Fiber Checklist* response. The joint ownership can impact the make-ready process.

⁸⁹ Pole replacement or significant make-ready does require coordination with Comcast and other “attachers.”

⁹⁰ Information based on email of March 27, 2015 from City representatives.

⁹¹ See CPUC GO-95 for details on overhead construction standards.

Table 2: Poles and Heights

Height (feet)	Count
15	-
20	-
25	8
30	107
35	544
40	1,194
45	2,030
50	1,333
55	295
60	248
65	112
70	45
75	3
80	2
Unknown	<u>10</u>
Total Poles	5,931

3.3 Existing Conduit

There is existing conduit throughout the City and even spare conduit in many areas, but not all of it is accessible or usable at this point without considerable cost, time, and effort to prepare it. It is unclear to what degree supposedly spare conduit is actually free and available for the City's use in the FTTP build, even though it is City-owned conduit.⁹²

It is possible that in some locations (especially the downtown areas) other entities have placed their infrastructure in City conduit. The process of moving another entity's infrastructure from the City's conduit is likely to be time consuming and expensive, and may potentially involve litigation. In some cases, it may be more cost and time effective to simply place new conduit to facilitate the FTTP network build; an exception to this might be in areas where there is little remaining underground space to install additional conduit. A thorough evaluation of City documentation (and perhaps physical assessment of areas where empty conduit is expected to be) is necessary to determine the usability of the existing conduit.⁹³

As we noted above, approximately 15 percent of residential areas have underground infrastructure. In these areas, there are three separate conduits that run into each house:

- Power
- Cable television

⁹² The *Google Fiber Checklist* response includes a list of "available spare conduit."

⁹³ The City anticipates performing a fiber audit in the near future.

- Telephone services

Although the City’s pilot project allowed communications cable to be pulled into the same conduit as power cable, this will not be an ongoing practice; fiber drops will not be allowed in the existing electric conduit. The City’s attorneys are currently investigating whether customers could opt to have cable television or telephone lines removed from existing conduit on their premises to allow fiber to be run in its place.⁹⁴ In light of this possibility, conduit from the curb to the customer premises may be an asset, but it will take time to understand the nuances of this.⁹⁵

3.4 Permitting Process

The City’s permitting processes are well defined and methodical, and we expect that this will not be a significant obstacle in the pursuit of FFTP. Further, permits are likely to be mostly unnecessary for the FFTP enterprise. Only powered devices in the right-of-way (ROW) require permitting and our expectation is that most of the FFTP enterprise’s infrastructure will be non-powered pedestals.

3.5 Review of Existing Agreements

Per the City’s request, CTC reviewed existing agreements to assess the potential impact of current agreements on a citywide FFTP build.

3.5.1 Master License Agreement

The City has developed a Master License Agreement for installation of wireless facilities in Palo Alto and future attachments by third parties. We reviewed the agreement and found that in general it is an acceptable framework for an FFTP license agreement. There are areas where timelines and application rate can be improved, to increase the speed of deployment and reduce the cost and potential risk to a network builder. If necessary, the City should augment its workforce to accommodate a larger scale of pole use applications and make-ready work,⁹⁶ and have a means of being compensated by the network builder to do so:

- Section 5.1 provides timelines for City review and pole work. Subsection A gives the City 20 days to determine whether and where attachments or conduit occupancy are feasible, and to process the request form; Subsection D gives the City 30 days to provide an estimate for costs, including make-ready. While these timetables are appropriate for smaller projects, such as wireless or short fiber runs, or for processing material at the

⁹⁴ CTC cannot provide legal advice or guidance.

⁹⁵ See CPUC GO-128 for underground construction standards.

⁹⁶ “Make ready” refers to the process of readying utility poles for the attachment of additional infrastructure. This can include moving existing utilities or potentially replacing poles entirely if space is severely limited and existing poles cannot accommodate additional infrastructure.

beginning of a large project, it should be possible in a larger project to reduce this period.⁹⁷

- Subsection F provides the City 105 days to complete make ready work—again, in a larger scale project, the City should be able to establish processes to reduce this period or make it possible for a City-approved contractor to perform the work
- Section 5.1.1 limits the application size to 15 poles, effectively one-half mile of pole line (or another number specified by the Utility Director). An FTTP project will require a significantly larger scale of poles—again this should be feasible in a large-scale project.
- Exhibit G requires the use of inner duct and, at the direction of the Utility, “divide a duct,” which is a good practice to make effective use of limited conduit space.

3.5.2 Joint Pole Agreements

We reviewed the joint use and pole attachment agreements with PG&E and Pacific Telephone and Telegraph (now AT&T). These agreements delineate the roles of pole owners jointly using poles. We did not find requirements that would have a technical impact on a new FTTP network operator. Sections (l) and (m) address third-party use of poles, and (n) appears to deny the City the right to operate a telephone or telegraph service on the poles. We recommend the City’s legal counsel review these agreements; we do not provide legal advice, and the agreements are now 97 years old, so it is not clear which portions apply today or have been modified by other laws or agreements.

⁹⁷ The overall approval process for a large-scale project may be longer, but often there are pre-set processes and established protocol for larger projects, which enables expedited timelines for providing estimates.

4 Comparison of FTTP Technologies

As we have explained in detail in Section 2, fiber optics are the state-of-the-art network medium in terms of capacity, speed, reliability, and resiliency. But fiber as a medium is only part of the equation when it comes to designing a network. That fiber must be connected to electronics and deployed in a certain configuration to achieve the network operator’s goals.

In this section, we identify a range of current FTTP technologies and discuss the pros and cons of each one—particularly in light of the City’s goal of providing symmetrical gigabit service.⁹⁸ With that background established, we then explore the FTTP technologies underpinning our proposed network design and discuss the benefits, limitations, and tradeoffs that make those technologies the best fit for Palo Alto.

4.1 Types of FTTP Technologies

The primary types of FTTP technology being deployed today are Active Ethernet, Passive Optical Networking (PON), Gigabit-capable Passive Optical Networking (GPON), and Wave-Division Multiplexing (WDM) PON (WDM/PON). From a purely technical standpoint—independent of a given network’s design or goals—each of these technologies has strengths and weaknesses. We summarize those in the table below.

Table 3: Comparison of FTTP Technologies

Factor	Technology			
	Active Ethernet (AE)	Passive Optical Networking (PON)		
		GPON	10G-PON	WDM-PON
Residential service	Not cost-effective to build for most residential customers; fastest potential symmetrical speeds	Single fiber split among 32 customers; no guaranteed symmetrical speed (upload is generally slower)	Faster potential download and upload speeds than GPON, but symmetrical speeds still not guaranteed	Next-generation architecture (not yet standardized) enables dedicated wavelengths and symmetrical speeds for each

⁹⁸ As we explain below, the City’s stated goal of “symmetrical gigabit service” reflects an admirable and forward-looking commitment to providing state-of-the-art service to local residents and businesses—but the realities of both FTTP network design and network economics mean that the City’s network will, like all FTTP deployments, enable service *up to* gigabit speeds for the majority of consumers most of the time. The network design we propose for the City represents the current state of the art within the framework of financial feasibility.

Factor	Technology			
	Active Ethernet (AE)	Passive Optical Networking (PON)		
		GPON	10G-PON	WDM-PON
				customer
Business/institutional service	Dedicated physical fiber connection (no splitting) to enable symmetrical connections up to 100 Gigabits per second (Gbps) (though still entails oversubscription from the Ethernet switches in the access layer)	Generally only practical for small business customers at connections below 1 Gbps	Can support small and medium sized businesses; symmetrical connections of 1 Gbps and higher possible	Potential to support to large businesses
Active infrastructure	May require electronics in the field; speeds only limited by electronics installed	No electronics required in the field; more efficient use of fiber plant; speeds limited by the technology to 2.4 Gbps downstream and 1.2 Gbps upstream	No electronics required in the field; more efficient use of fiber plant; speeds limited by the technology to 10 Gbps downstream and 2.5 Gbps upstream; electronics more expensive than GPON	No electronics required in the field; more efficient use of fiber plant; potentially unlimited bandwidth using dedicated wavelengths per customer

Factor	Technology			
	Active Ethernet (AE)	Passive Optical Networking (PON)		
		GPON	10G-PON	WDM-PON
Passive infrastructure	Requires either electronics placed in the field or more fiber back to the hubs	Optical splitters in cabinets near customers. No electronics in the field	Optical splitters in cabinets near customers. No electronics in the field; uses same splitters as GPON	Optical splitters in cabinets near customers. No electronics in the field. Requires specialized DWDM ⁹⁹ splitters/filters
Maintenance requirements	Requires more maintenance than PON because AE has either more fiber or electronics in the field	Requires less maintenance than AE because of centralized electronics in hubs	Requires less maintenance than AE because of centralized electronics in hubs	More complex provisioning and stricter fiber performance metrics than other PON technologies

As we mention in Section 5, “FTTP Design and Cost Estimates,” PON technology has made FTTP architecture extremely cost-effective for densely populated areas such as Palo Alto, and even for lower and medium-density population areas.

Fiber optic equipment generally has a range of 12 miles with standard PON electronics¹⁰⁰ and almost 50 miles with higher-powered electronics.¹⁰¹ The range reduces or eliminates the need for electronics or powering in the middle of the network, reducing the network’s required staffing and maintenance and improving availability during storms or mass power outages.¹⁰²

⁹⁹ Dense Wavelength Division Multiplexing, an optical technology used to increase bandwidth over an existing fiber optic backbone.

¹⁰⁰ ITU-T Recommendation G.984.2 Gigabit-capable Passive Optical Networks (GPON): Physical Media Dependent (PMD) layer spec., p. 10, Table 2a, <http://www.itu.int/rec/T-REC-G.984.2-200303-I/en>.

¹⁰¹ Cisco Small Form-Factor Pluggable Modules for Gigabit Ethernet, http://www.cisco.com/en/US/prod/collateral/modules/ps5455/ps6577/product_data_sheet0900aecd8033f885.pdf.

¹⁰² Powering is required at the central office facility (usually equipped with long-running generators) and at the user premises (requiring the user to have backup power, such as a battery or a home generator). In contrast,

Service levels can be continuously upgraded simply by replacing or upgrading the network electronics at the ends.

That said, PON architecture—which is the standard for residential and small business FTTP design—employs passive optical splitters in the field (i.e., in FDCs, installed near customer premises); the splitters reduce the size and cost of the “feeder” cables that need to be installed from the network core to the FDCs. And because there are fewer feeder cables, the network requires fewer expensive electronics at the core. But saving money on electronics and fiber requires a tradeoff: Splitting the fiber at the FDC (typically serving 32 residential customers per strand, or “32:1”) limits the potential bandwidth available for each customer.

In contrast, an Active Ethernet design (also known as “homerun” fiber architecture), deploys one fiber strand from the core or hub all the way to a customer’s premises—meaning that the full capacity of that strand is reserved for that one customer. This architecture is typically reserved for business customers that have greater needs than the average residential customer; a fully Active Ethernet network deployment offers greater scalability to meet the long-term needs of large enterprise users, and is consistent with best practices for an open access network model that might potentially be required to support dedicated connections to certain customers. At the same time, Active Ethernet design requires more core electronics, larger strand counts from the core to the network hubs, and larger (and significantly more expensive) hub facilities capable of terminating a greater quantity of fiber strands.¹⁰³

GPON is currently the most commonly provisioned FTTP technology, due to inherent economies when compared with technologies delivered over home-run fiber¹⁰⁴ such as Active Ethernet. The cost to construct an entire network using GPON is approximately 40 percent to 50 percent less than Active Ethernet.¹⁰⁵ GPON is used to provide services up to 1 Gbps per subscriber and is part an evolution path to higher-speed technologies that use higher-speed optics and wave-division multiplexing. Most GPON networks will support an open access network deployment that supports multiple ISPs

But there is a middle ground in selecting a technology: A hybrid approach. A network architecture organized primarily around GPON technology can also include sufficient fiber and

hybrid fiber-coaxial networks have power supplies in each neighborhood with a few hours of battery backup. Once the batteries are depleted, the cable operator must place a generator at each power supply location.

¹⁰³ Open access was not originally supported over GPON architecture, but GPON standards and vendor features have evolved. Today GPON can support open access—so open access requirements do not drive a decision as to whether an Active Ethernet or GPON is more appropriate.

¹⁰⁴ 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.

¹⁰⁵ “Enhanced Communications in San Francisco: Phase II Feasibility Study,” CTC report, October 2009, at p. 205.

electronics to support Active Ethernet connections to a predetermined percentage of customer passings.¹⁰⁶ This is the approach represented by our recommended FTTP design for Palo Alto, which we describe in the following sections.

4.2 Assessment of Recommended FTTP Technologies

Our proposed FTTP design is a hybrid GPON and Active Ethernet network. As with any citywide network, the architecture represents a balancing act between performance and cost (among other variables). We first describe that balancing act, then delve into the specific network design criteria and expected performance parameters for these technologies.

4.2.1 Network Design Trade-Offs

At a high level, city streets offer an apt analogy to the challenges of designing an FTTP network. A local road has enough capacity for a certain amount of traffic. If fewer drivers are on the road, they can each move more quickly (up to the posted speed limit). If more drivers are on the road, such as during rush hour, everyone slows down.

The planners who designed and built that road considered a number of factors in determining how many lanes to construct (and what materials to use in that construction). They looked at how much space they had in which to build, how much traffic they expected to travel on the road at given times, and how expensive it would be to build and maintain the road.

If the City wanted every resident to be able to drive the speed limit at all times, it could conceivably build an enormous street. Traffic would never slow down. But there are problems with that approach. For starters, the street would cost a lot more to construct and maintain. It would also take up valuable land and might be considered unsightly. And it would be mostly empty for a majority of each day—so all that extra capacity would only be useful during certain peak times.

And what if we were talking instead about a toll road, with electronic toll readers mounted above each lane? All those electronics would not only add to the cost of constructing and maintaining the network—they would also need to be replaced in a number of years (another huge expense) to keep the network up to date.

Now consider an FTTP network. Instead of lanes, think of fiber strands. Instead of toll readers, think of network electronics. Instead of speed limits, think of symmetrical 1 Gbps network speeds.

¹⁰⁶ Or, to fine-tune the balance between cost and capacity even further, the FDCs could house 16:1 or 64:1 splitters rather than 32:1 splitters.

Although fiber as a medium offers tremendous capacity, an FTTP network design includes only a finite number of fiber strands—and those strands are lit with a specified type of electronic equipment, installed at key locations around the City to create an “information highway” with enough capacity for a certain amount of traffic to move at a certain maximum speed.

Could the City build a network that guarantees symmetrical 1 Gbps connectivity to every resident and business? Yes—with an Active Ethernet architecture. But the network would still employ some level of oversubscription to the Internet.¹⁰⁷ The alternative to oversubscription—purchasing 1 gigabit of dedicated Internet access for each subscriber—would cost the network \$750 per subscriber per month, assuming a typical cost of 75 cents per Mbps.

This illustrates why FTTP networks for residential and small business customers are designed with a primarily GPON architecture (and the electronics, fiber count, oversubscription, and other parameters that follow from that approach) to deliver “up to” a certain performance level.¹⁰⁸

As the old joke about engineers goes, the glass is neither half full nor half empty—it is simply twice as big as it needs to be to meet the project’s goal.¹⁰⁹ A hybrid GPON/Active Ethernet network will cost-effectively deliver a level of service that meets most customers’ expectations most of the time.

We note, too, that Google Fiber advertises “a connection that’s up to 1,000 megabits per second”¹¹⁰ but does not commit to symmetrical connections (i.e., same upload and download speeds) and does not guarantee 1 Gbps service. Google Fiber deployments are GPON networks—so Google is providing “up to” speeds, just as the Palo Alto network would, and counts on oversubscription to make the network financially viable.

4.2.2 Electronics

FTTP networks include core electronics (routers, aggregation switches, optical line terminals) and user premises electronics (ONT/Ethernet switch/router). We describe each of these in detail in the Task 2 report.

The electronics specified in our proposed network design illustrate the balance between the proposed network’s fiber count, service levels, and cost. For example, we have designed a

¹⁰⁷ In addition, that guaranteed 1 Gbps would only be on a transport level, not from an Internet connection standpoint; the network traffic would still be aggregated at the hub or core electronics.

¹⁰⁸ For large business customers or other users with high-level or specialized needs, the network is typically designed with higher potential capacity (Active Ethernet).

¹⁰⁹ See, for example: Malcolm Gladwell, “The Engineer’s Lament,” *The New Yorker*, May 4, 2015.

<http://www.newyorker.com/magazine/2015/05/04/the-engineers-lament>

¹¹⁰ Google Fiber, <https://fiber.google.com/about/>

GPON network that enables up to 5 percent of passings to receive Active Ethernet service—reducing the need for costly electronics and limiting the fiber count overall, while still ensuring that the network can meet the anticipated service level needs of local businesses.

Similarly, we chose a 1:32 split at the FDCs, rather than a 1:64 split, to balance the maximum potential service speeds at each residence and cost.¹¹¹ (On the flip side, we did not choose a 1:16 split because that would have dramatically increased the network cost without dramatically improving customers' perceptions of their service performance.)

4.2.3 Facilities

The network headend and distribution hubs located throughout the service area must provide space for network electronics, servers to support a range of network management and service provisioning functions, and collocation space for potential third-party providers. The estimated space requirement for the headend—as well as the cost of the equipment—is largely dependent on the size of the network. It is not uncommon for relatively large deployments to consist of hub sites serving 10,000 to 20,000 subscribers, with cabinets located throughout the service area to house passive and/or electronic equipment for every few hundred passings.

Hub sites are necessary to aggregate fiber connections and to house FTTP transport electronics. The number and size of hub facilities depends on the size and physical distribution of the system and the electronics selected (e.g., Active Ethernet, PON). Hub facilities can be co-located with existing provider facilities, and can also be located in large outdoor cabinets or small prefabricated buildings. The size can range from a cabinet costing approximately \$25,000 to serve as many as about 10,000 subscribers (PON only), to an equipment shelter capable of serving about the same number of Active Ethernet subscribers costing upwards of \$500,000. Task 2 provides further details on the design for Palo Alto.

Generally one or two (redundant) headends will house central networking and application hardware necessary for the operator to maintain and operate an FTTP system. The headend and hubs may also include space for other service providers to collocate their equipment.

We describe the facilities in our proposed design section.

4.2.4 Customer Premises

Each customer needs to be physically connected to the system, and most operators construct a fiber drop and install customer premises equipment (CPE) only to residents who subscribe to the service. Cost depends on a range of factors including the distance of the premises from the right-of-way, and whether the drop is aerial or underground. Installation costs can soar if the

¹¹¹ For reference, Google typically designs for a 16 to 1 split.

house or business is extremely far from the road or requires construction under roads or driveways.

As we detail in the financial analysis, we recommend appropriate CPE for a variety of customer types (e.g., single-family home, multi-dwelling units).

5 FTTP Design and Cost Estimates

In this section we describe a recommended FTTP network design, organized by network layers, that reflects current construction practices. We also estimate the cost of materials and anticipated labor expenses.

We begin our discussion with the physical layer (layer 1, also referred to as OSP). 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 initiative.

To develop the inputs and insights necessary to create this network design, we drew on our experience with a wide range of fiber initiatives; held discussions with City staff; completed an extensive desk survey of the City using the City’s GIS mapping and comprehensive street-level views available in Google Earth; and reviewed the analysis we developed during our previous engagements with the City.¹¹²

We note that the City’s primary focus—and the largest potential user group for a citywide FTTP network—is the residential market, which is comprised of 22,709 residential households (17,308 in single-family; 5,330 in multi-dwelling units,^{113,114} and 71 in mobile homes).¹¹⁵ Adding the City’s 3,192 businesses,¹¹⁶ we estimate that Palo Alto has a total of 25,901 residential and business premises passings (potential users).

The majority of the City has aerial utilities and therefore aerial plant is a key part a citywide fiber network. Aerial plant is typically less expensive to build than underground plant, and in Palo Alto this is especially the case.¹¹⁷ The City has the exclusive right to place fiber in a designated area in the communications space allocated specifically for the City. (Although this is not the “power space” in the traditional sense,¹¹⁸ it is referred to as power space by City and

¹¹² CTC’s previous engagements with the City of Palo Alto have included providing strategic guidance and advice on expanding the City’s dark fiber network to create opportunities for enhanced municipal and commercial services.

¹¹³ Of the 10,556 households in MDUs, 5,226 are in structures with 20 or more households. These buildings are often served under a long-term contract with one of the incumbent providers or a specialty ISP.

¹¹⁴ 256 in duplexes; 1,538 in building with 3 to 4 households; 1,598 in building with 5 to 9 households; 1,938 in buildings with 10 to 19 households

¹¹⁵ http://factfinder.census.gov/bkmk/table/1.0/en/ACS/13_3YR/DP04/1600000US0655282, accessed May 2015.

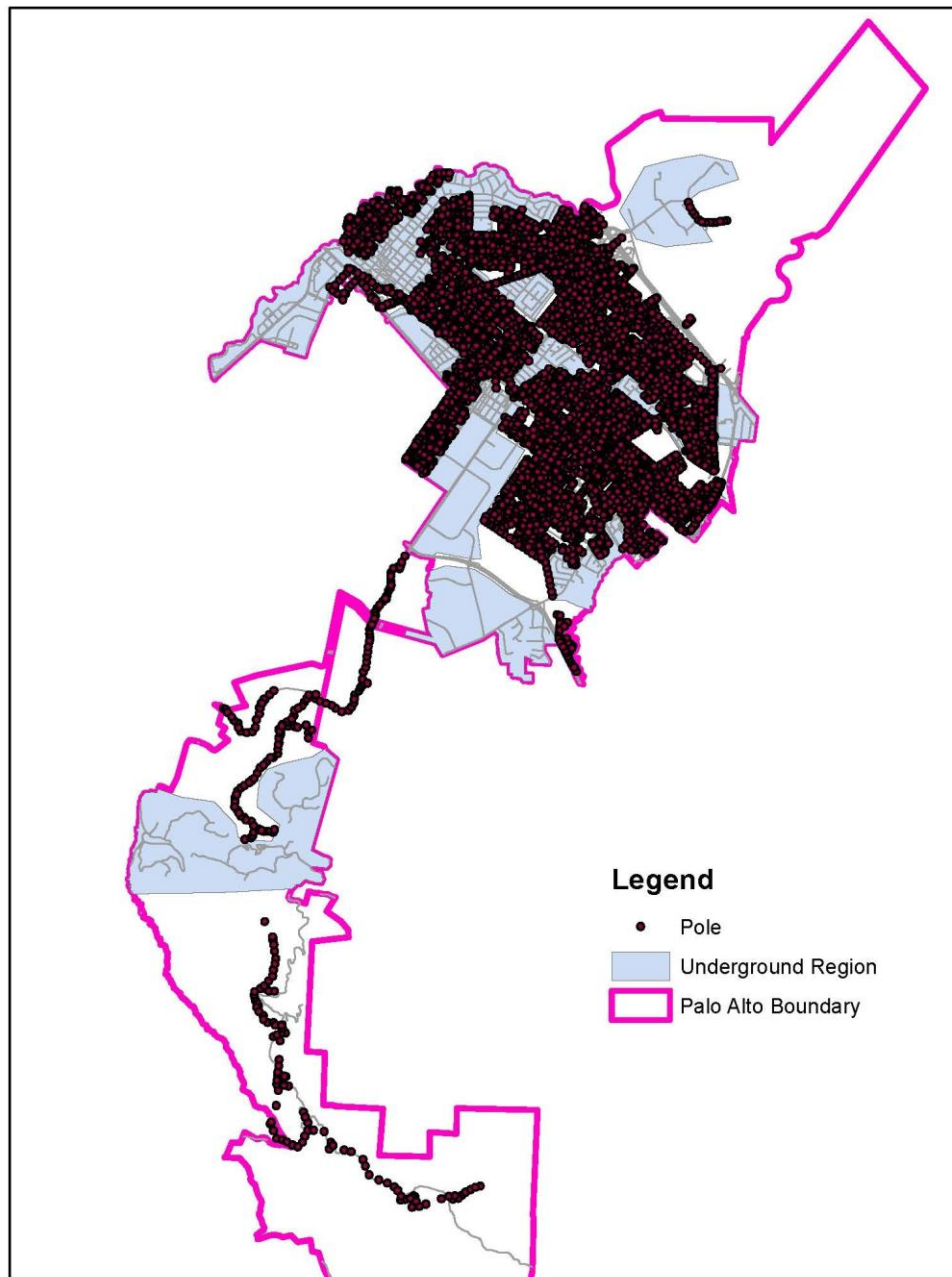
¹¹⁶ Number of businesses is based on data from Infousa.com. We included the total estimated 3,926 businesses with fewer than 100 employees, less the estimated 734 businesses in larger office complexes. The large office complexes, like large residential MDUs, are typically served under a long-term contract.

¹¹⁷ The citywide ratio in Palo Alto is 54 percent overhead and 46 percent underground.

¹¹⁸ A common interpretation of “power space” is the space restricted to high-voltage qualified personnel approved by the power utility. In this case, the “power space” is in the communications space, below the high-voltage

CPAU staff.) Having this exclusive space reduces make-ready costs and pole replacement costs, as the City generally does not need to find space for fiber placement. In the event an FTTP buildout is done by an entity without access to this space, make-ready costs will be higher.

Figure 10: Aerial and Underground Utilities in Palo Alto



restricted space, but reserved for use by the power utility. In the Palo Alto power space, construction and maintenance crews will not need to be certified in high-voltage construction. Cables can be any type, whereas construction in the high-voltage space needs to be non-metallic dielectric cable, which is more expensive to buy and install.

5.1 Issues Related to Aerial Construction

There are some barriers to the use of City poles. First, there are trees along the pole lines that need to be trimmed in order to place fiber (Figure 11). We estimate the cost of tree trimming to be approximately \$3.84 per foot based on costs for similar projects, and that tree trimming will be needed for approximately 40 percent of the aerial fiber plant.¹¹⁹

Figure 11: Examples of Pole Lines Requiring Tree Trimming



¹¹⁹ There are a variety of potential environmental threats to aerial fiber (e.g., squirrels).

Second, approximately 25 percent of the poles are located in Public Utility Easements on private property behind homes and businesses.¹²⁰ The need to access and work on these poles may create delays, complexity, and higher cost in construction.

Finally, the City has already built a 49-mile fiber backbone on the utility poles. We assessed the impact on the City's existing fiber system and commercial dark fiber customer base if an FTTP network builder licenses dark fiber from the City. Based on our review, the existing City fiber is already in use or reserved for dark fiber license and is likely not available for FTTP. In certain cases, the existing dark fiber network may be available for use based on the required fiber strand count and make ready for a given location. To determine the best use of existing dark fiber, we recommend a full inventory of these assets to include the percentage of fiber currently in use, areas of extreme congestion, and locations where some excess capacity may be available.¹²¹

In some cases, the City can increase capacity on aerial fiber infrastructure by "overlashing" a new cable to an existing cable. This strategy is commonly used by telecommunications and cable companies; a significant fraction of Verizon's FiOS FTTP system, for example, is overlashed to copper telephone cables. Cable operators typically expand fiber in their networks by overlashing it to their coaxial cables. Overlash is significantly less costly than creating a new attachment on the poles; it also does not typically require make ready, so it requires significantly less time and coordination with the pole owner. This may be especially attractive in situations where a network operator is using another utility's poles.

However, in many cases, the City fiber is already overlashed with additional fiber. As a result, the City needs to add an additional attachment for FTTP over routes where fiber is already in place. Our cost estimate reflects that need.

Even with the allocation of pole space to the City, when other cables occupy the communications space, they must be moved to allow space for the placement of the new attachment in compliance with *National Electric Safety Code* and *State of California Rules for Overhead Line Construction, General Order No. 95* (GO95) requirements for clearance between power and communication cables, and between communication cables and ground levels. Make ready tasks include moving existing utilities and installing extension arms. We estimate a need for make ready on 20 percent of poles, but do not expect this work to be extensive.

¹²⁰ Information based on email of March 27, 2015 from City representatives.

¹²¹ CPAU will be issuing an RFP to select a consulting firm to perform a fiber audit.

When poles cannot be made ready for an additional attachment simply by moving cables on the existing pole and keeping all clearances from the ground and power space, it may become necessary to place a taller pole that would allow the new attachment with adequate clearances (Figure 12). (The same issue arises for poles that are too old and worn-out to support a new attachment.) All utilities currently on the pole would need to be transferred from the old pole to the new pole. We expect, based on our analysis, that pole replacement will be required in 3 percent of cases. In addition, we understand that 544 (8 percent) of the poles are 35 feet high, which is relatively short and may create issues with clearance with existing utilities. We recommend budgeting for replacement of these poles, as well, for a total replacement of 11 percent of poles. We estimate a cost of \$12,000 per pole replacement.

Figure 12: OSP Crew Replacing a Pole



5.2 Cost Estimates

FTTP construction in Palo Alto will entail costs in two basic categories:

- OSP labor and materials
- Network electronics

Our model assumes a mix of aerial and underground fiber construction, based on the prevailing mix of utilities in the City, and a 35 percent take rate.¹²² Please note this take rate is only used as a placeholder for discussion in this section; as seen in the full financial analysis in Section 8, which shows the impact of take rate on construction cost, cash flow, and net income, a much higher take rate is required to cash flow the enterprise.

In terms of OSP, the estimated cost to construct the proposed FTTP network is approximately \$47 million—which corresponds to a cost of slightly higher than \$1,800 per passing¹²³ including drop cable installation,¹²⁴ or \$1,357 per passing excluding drop installation. Table 4 summarizes the OSP costs.

The OSP cost estimate, excluding drop installation to homes and businesses, is approximately 10 percent higher than the cost previously estimated by Axia NetMedia (a member of the consortium that prepared the City’s 2007 Ultra-High-Speed Broadband System Business Plan).¹²⁵ The drop estimate is approximately three times that estimated by Axia, on a per drop basis. The OSP and drop estimates are in line with comparable density builds, and builds with the same aerial/underground mix. The availability of dedicated pole space for the City reduces the amount of make ready needed, so the estimate is in line with a build where only moderate make ready is needed.

¹²² Take rate is the percentage of subscribers who purchase services from an enterprise, and is a crucial driver in the success of an FTTP retail model. If the take rate is not met, the enterprise will not be able to sustain itself and its operational costs will have to be offset through some funding source to avoid allowing the enterprise to fail.

¹²³ The model counts each potential residential or business customer as a passing, so single-unit buildings count as one passing, while each unit in a multi-dwelling or multi-business building is treated as a single passing.

¹²⁴ Assumes take rate of 35 percent, with only connected homes and businesses receiving drops.

¹²⁵ “Fiber to the Premise for the City of Palo Alto,” June 16, 2008.

<http://www.cityofpaloalto.org/civicax/filebank/documents/12789>

Table 4: Estimated OSP Costs for FTTP (Assuming a 35 Percent Take Rate)

Cost Component	Total Estimated Cost
OSP Engineering	\$3,572,100
Quality Control/Quality Assurance	924,400
General OSP Construction Cost	25,526,800
Special Crossings	145,400
Backbone and Distribution Plant Splicing	762,700
Backbone Hub, Termination, and Testing	4,206,300
FTTP Service Drop and Lateral Installations	11,690,300
Total Estimated Cost:	\$46,828,000
Total Estimated Passings:	25,901

Assuming a 35 percent take rate, the required electronics will cost approximately \$13.6 million. Table 5 summarizes the electronics costs. Please note that the costs in the table are inclusive of an estimated \$1.5 million in core network integration and set-up fees. The total price will vary with different take rates, because of different economies of scale and equipment configurations. We can assume that CPE cost will scale linearly, for example, so a 25 percent take rate would reduce the CPE cost by approximately 28.6 percent or \$1.3 million. The core and aggregation electronics will not scale linearly—primarily because less OLT equipment is needed—so a 25 percent take rate would mean a smaller percentage reduction of approximately 16.8 percent or \$1.3 million in those costs.

Table 5: Estimated Electronics Costs for FTTP (Assuming a 35 Percent Take Rate)

Core Routers	\$1,794,820
Core Network Servers	310,000
Base Aggregation Switches	2,143,610
Base OLT	186,060
Residential CPEs	4,021,320
Business CPEs	514,240
Aggregation Switches	1,716,590
OLTs	2,937,960
	\$13,624,600

Relative to the Axia estimate, the electronics estimate is similar for non-CPE electronics, and approximately 50 percent higher, per user, for CPE electronics.

We estimated costs for aerial and underground placement using available cost data for materials. The material costs were generally known with the exception of unknown economies of scale and inflation rates, and barring any sort of phenomenon restricting material availability and costs.

We estimated labor costs for placing, pulling, and boring fiber based on similar construction projects in comparable markets.

For purposes of design and cost estimates, we identified the small and mid-sized MDU buildings across the City. Based on Census data, we estimate there are 288 MDU buildings¹²⁶ in Palo Alto that comprise five to 19 units (see Section 2.2.1) We estimate that the average drop from the closest existing fiber to these buildings is about 475 feet. (Buildings that have 20 or more units will generally need to be dealt with on a case-by-case basis because those larger buildings may already have bulk provider contracts).¹²⁷ Section 2.2.1 explains estimated numbers.

In the sections below, we describe our methodology and provide more detail on the estimated OSP and CPE costs.¹²⁸ We also discuss assumptions about the average amount of required pole replacements, make ready, and guy and anchor replacements. The percentage of poles meeting each criterion were averaged out to a per-mile cost.

5.3 Methodology for Developing OSP Route Assumptions

We reviewed available green space and evaluated the amount of necessary make ready on poles, pole replacement, and guy replacement. A CTC OSP Engineer performed a preliminary survey via Google Earth Street View to develop estimates of underground versus aerial percentages, per mile cost for aerial construction in the power space and communications space, per mile costs for underground (where poles are not available), and cost estimates for fiber drops to customer premises. The aerial placement of fiber was also determined through surveying in Google Earth Street View.

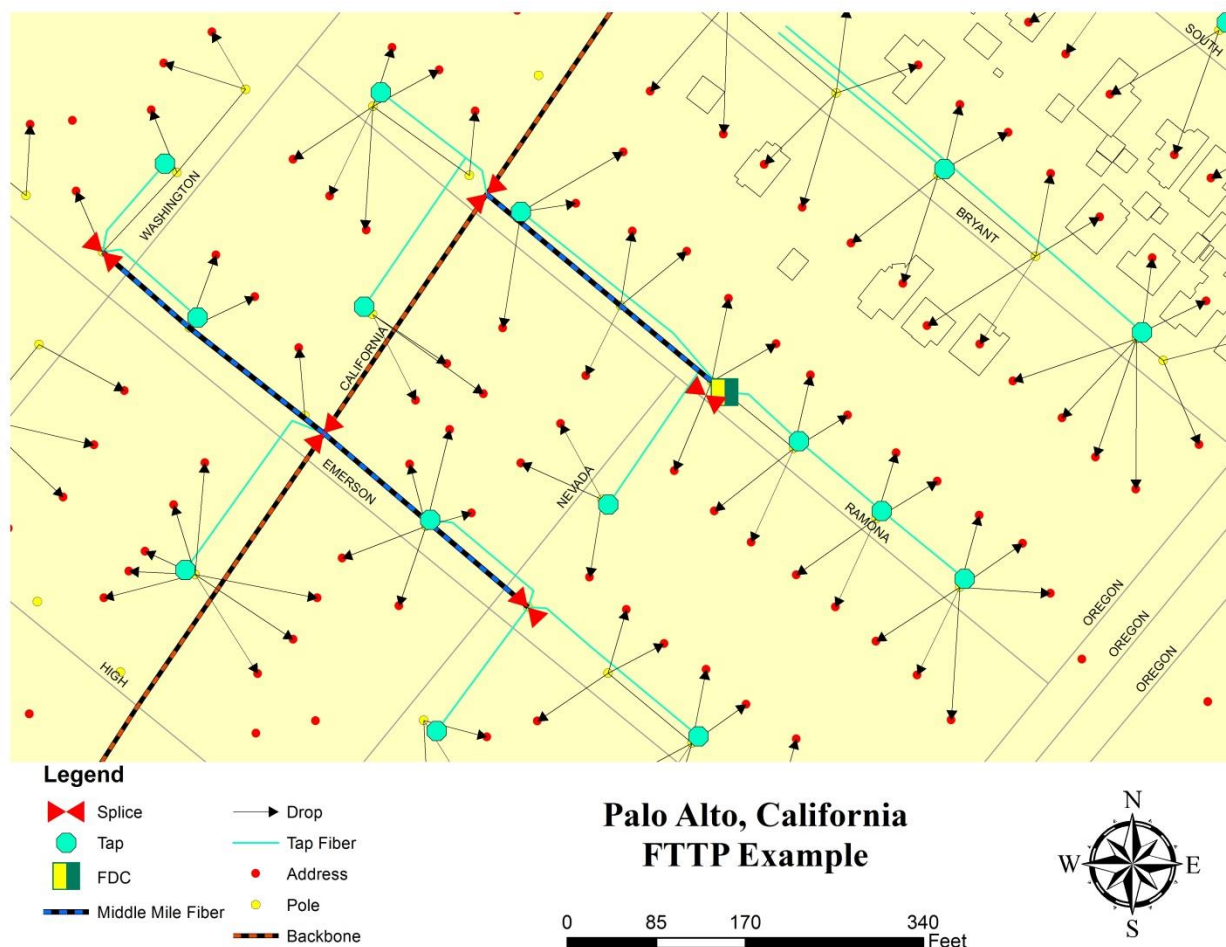
¹²⁶ The Census data indicate the number of households in structures with a range of units. For calculating the number of households, we assumed that a structure with 5 to 9 units has an average of 8 units, a structure with 10 to 19 units has an average of 16 units, and a structure with 20 or more units has an average of 96 units. For households in duplexes and in structures with 3 to 4 units, we treated each household as a single-family unit.

¹²⁷ Some large MDUs have existing, long-term contracts with providers to offer services to all the units in a single building. Often, in such cases, the provider has brought service to the building and performed all the in-building wiring to serve each unit.

¹²⁸ See Section 8 for a discussion and presentation of the total cost of ownership.

CTC engineers then developed an FTTP design in a representative sample area of the City. The engineering was completed to the level of individual drop cables. Figure 13 provides a detail from the sample design.

Figure 13: Sample FTTP Network Design to Determine Quantities per Street Mile



Based on the engineered FTTP sample, we developed labor and materials costs per Palo Alto street mile. We used ESRI's ArcGIS¹²⁹ suite to calculate the total number of street miles and then extrapolated to determine the required materials and the labor associated with the construction.

¹²⁹ Geographic information system (GIS) software enables users to create, analyze, and manipulate complex map data. ESRI's ArcGIS suite is one such collection of software, and the tool CTC used to create map-based projections for this project.

5.4 Backbone Routes

CTC engineers designed backbone routes to be as equidistant as possible to the entire City while also accounting for higher density areas (which will demand more fibers to serve the high number of possible subscribers). The backbone is distinct from the existing CPAU fiber backbone and is composed of 18 miles of aerial and 10 miles of underground fiber (288-count).

The backbone construction and the FTTP build would use the same aerial and underground infrastructure so they would share the same aerial attachments, and no overbuild would take place in the underground portion. Figure 14 below shows the backbone design, with colors indicating the density of homes and businesses.

5.5 Network Architecture and Electronics

Figure 15 below shows a logical representation of the recommended FTTP network. It illustrates the primary functional components in the FTTP network, their relative position to one another, and the flexible nature of the architecture to support multiple subscriber models and classes of service.

Figure 14: Backbone Design

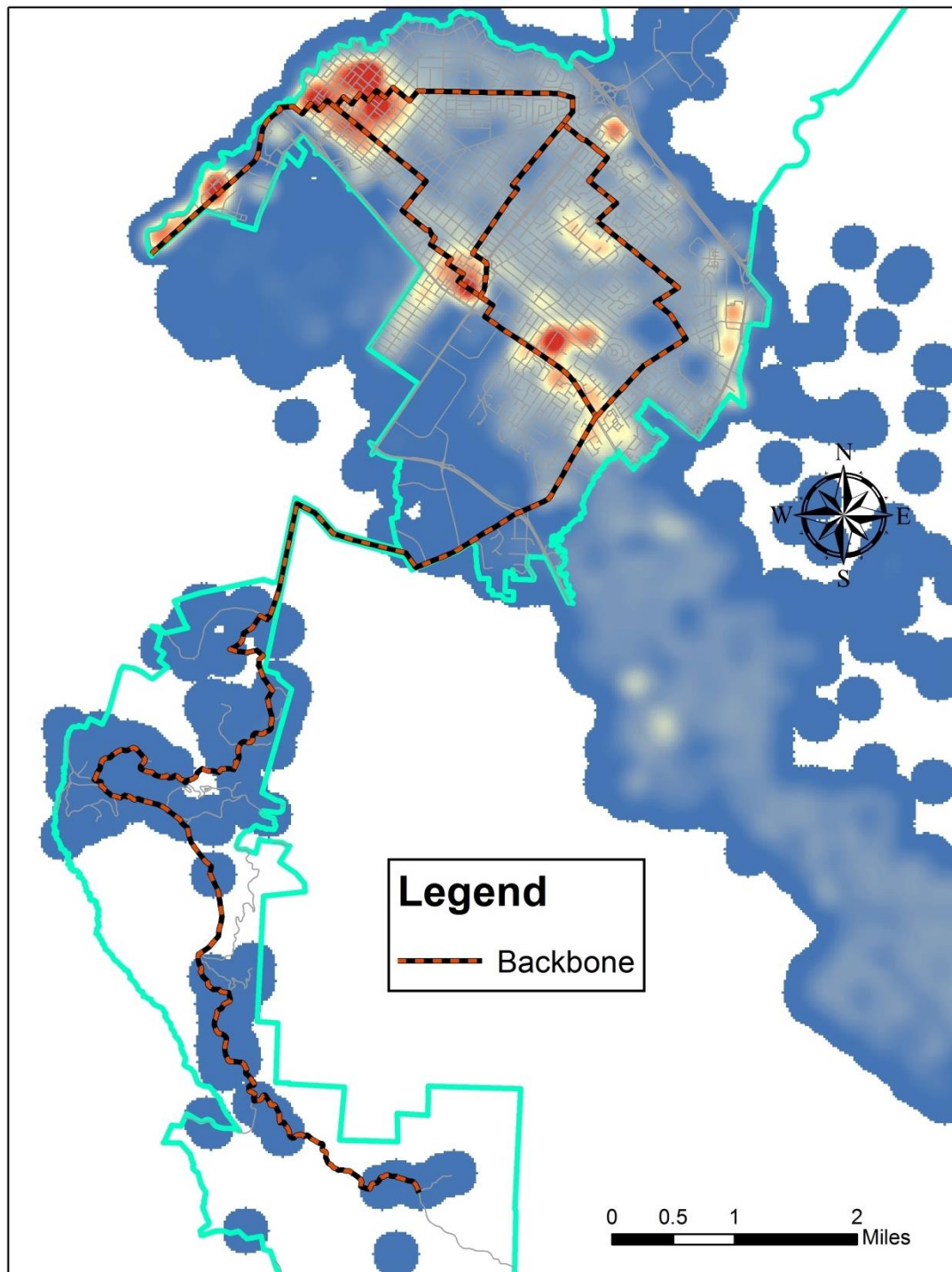
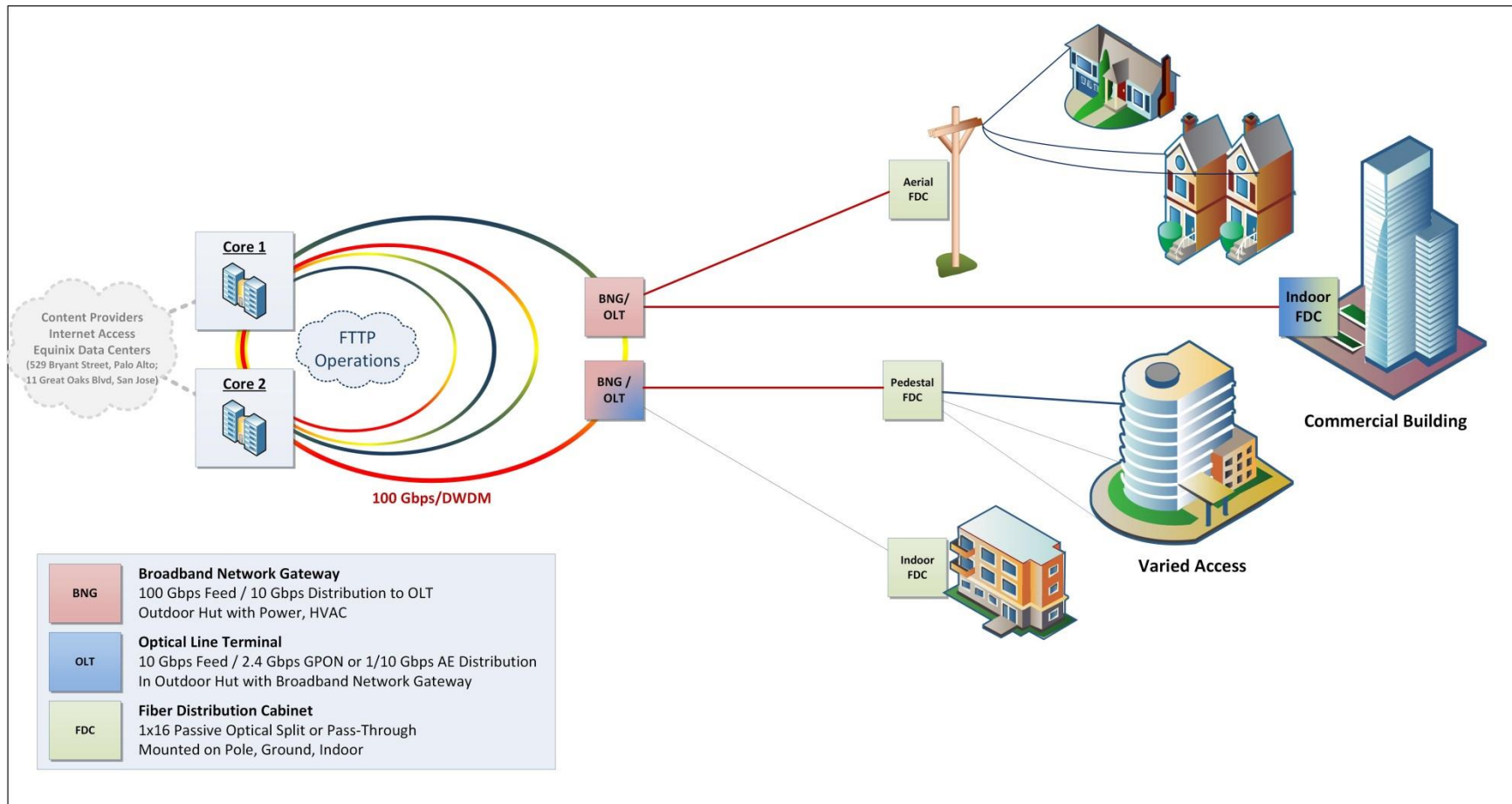


Figure 15: High-Level FTTP Architecture



The recommended FTTP network (Figure 15) is a hierarchical data network that provides critical scalability and flexibility, both in terms of initial network deployment and capability 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 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 or poor 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. Separation between service providers can be provided on the physical layer (separate fibers) or logical layer.
- *Security* – controlled physical access to all equipment and facilities, plus network access control to devices

In order to deliver these characteristics, the fiber count was selected to provide a dedicated fiber from each premises to the FDC, and 48 fibers from each FDC to the broadband network gateway (BNG). This results in a range of fiber counts, but generally six or eight 288-count cables leave each BNG, four 288-count cables leave each FDC, and the count decreases from the FDC toward the premises. The backbone ring covers the same route as the BNG-to-FDC communications, so even though only a few dozen fibers are needed for core-to-BNG or BNG-to-BNG communications, at least 288-count of new fiber will be needed along most of the backbone route.

In the backbone ring routes, almost all of the fiber in the cables are in use, either as part of the Dense Wavelength Division Multiplexing (DWDM)¹³⁰ network or as part of the connectivity from the BNG to the FDCs, with the exception of spare count set aside for future needs or for repairs.

¹³⁰ DWDM is an optical technology used to increase bandwidth over an existing fiber optic backbone.

In the routes to the FDCs, the fibers are again mostly in use with the exception of a spare count. The routes from the FDCs to the passings are less heavily utilized. Because each passing has a dedicated fiber from an FDC, passings that do not subscribe to the service are connected via fibers that are not in use.

The following sections provide an overview of requirements and recommendations for the network's core and distribution layers.

5.5.1 Core Network Sites

The core sites are the bridges that link the FTTP network to the public Internet (via a network access point, or NAP) and deliver all services to end users. The proposed network design includes two core locations, based on the network's projected capacity requirements and the need for geographical redundancy (i.e., if one core site were to fail, the second core site would continue to operate the network).

The location of core network facilities also provides physical path diversity for subscribers and all upstream service and content providers. For our design and cost estimates, we assume that the Palo Alto core sites will be housed in secure locations with diverse connectivity to Internet network access points such as the Equinix Data Center at 529 Bryant Street (formerly known as "PAIX") and to Equinix at 11 Great Oaks Boulevard in San Jose.¹³¹ Few cities have robust network access points, as Palo Alto does with Equinix located downtown. It is the communications hub of everything Internet. Interconnecting at Equinix, coupled with the unique makeup of businesses in Palo Alto, is a reason the City's 49-mile open dark fiber network has become successful in the past two decades.

The core locations in this plan house Operational Support Systems (OSS) such as provisioning platforms, fault and performance management systems, and remote access.¹³² The core locations are also where any business partner 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 locations are typically run in a High Availability (HA) configuration, with fully meshed and redundant uplinks to the public Internet and/or all other content and service providers. It is

¹³¹ Equinix, Inc. is a U.S. public corporation that provides carrier-neutral data centers and Internet exchanges. Equinix provides network-neutral data centers (IBX or "International Business Exchange") and interconnection services. The company offers colocation, traffic exchange and outsourced IT infrastructure solutions to enterprises, content companies, systems integrators and over 950 network service providers worldwide. Equinix currently operates 101 data centers across 32 major metropolitan areas in 15 countries globally.

¹³² OSS were not included as part of the network electronics cost estimate. Network service operators may already have these systems in place on their existing networks. These cost are included in the financial analysis when appropriate.

imperative that core network locations are physically secure and allow unencumbered access 24x7x365 to authorized engineering and operational staff.

For Palo Alto, there is a wide range of options for core locations. One possibility is the use of outdoor enclosures. In a high-cost urban/suburban environment like Palo Alto, however, it may be more cost-effective and secure to use an existing building. Options might include using a secure location in the City Hall building, CPAU central or substation facilities, or other similar City-owned facilities with robust physical security, diverse fiber entry, and reliable backup power.

The operational environment of the core network locations is similar to that of a data center environment. This includes clean power sources, UPS batteries, and diesel power generation for survival through sustained commercial outages. The facility must provide strong physical and seismic security, limited/controlled access, and environmental controls for humidity and temperature. Fire suppression is highly recommended.

We estimate the floor space requirements for each core facility to be approximately 75 square feet. Figure 16 below illustrates a sample floorplan; Figure 17 provides a sample list of materials.

Figure 16: Sample Floorplan for Core Location

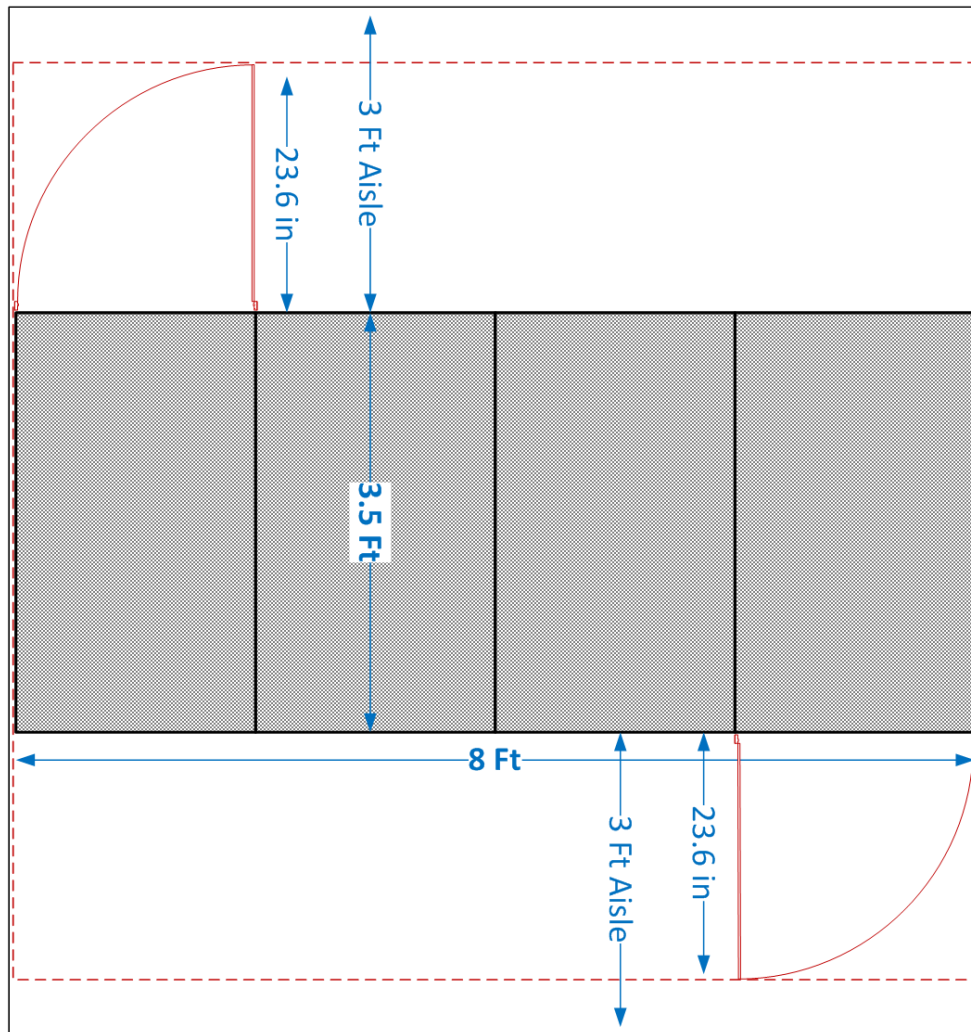


Figure 17: Sample List of Materials for Core Location

4 19-inch Cabinets
1 Core Router
2 Fiber Panels / Cross Connects
4 Cable Ladders and Cable Management
1 Element Management System
Core Network Servers
Service Operator's and Partner's OSS

Equipment is to be mounted securely in racks and cabinets, in compliance with all national, state, and local electrical and seismic 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.

The FTTP architecture includes an integrated Element Management System (EMS) at the core sites. The EMS provides fault, performance, and configuration management for the FTTP electronics, and provides a unified platform for all subscriber and FTTP equipment provisioning activities. The EMS also provides essential data for engineering and operational purposes, including equipment inventory, resource utilization and performance data, Quality-of-Service (QoS) metrics for Service Level Agreements (SLA), and numerous other performance threshold alarms.

The EMS platform for FTTP electronics is integrated with a higher-level fault and performance management platform that supports the entire network from edge to edge. This provides a single top-level platform for all devices in the architecture to be monitored and managed on a 24x7x365 basis.

The top-level fault and performance management platform would be designed to poll various devices and resources at regular intervals, and to record values for performance attributes that are critical to the operational health of each resource. This includes monitoring key resources such as link utilization, interface performance statistics, and so on. In addition, network devices are configured to send asynchronous (event-driven) notifications to the management platform in the event of hardware failure or an unexpected condition such as the loss of a connection to a neighboring device. Such fault and threshold alarms are sent to operational personnel for immediate evaluation and response.

Other important core network services include essential applications such as Domain Name Services (DNS), Network Time Protocol (NTP), and Dynamic Host Configuration Protocol (DHCP), which will be handled by servers and appliances at the core of the network.

5.5.2 Distribution and Access Network Design

The distribution network is the layer between the core locations and the last-mile subscriber connections. The key characteristics and capabilities in the distribution network are capacity, availability, resiliency, and reliability.

The distribution network carries heavily aggregated traffic closer to the core, and extends over long distances to end users. Fiber cuts and equipment failures have progressively greater operational impact as they happen in closer proximity to the network core. For this reason, it is critical to build in redundancies and physical path diversities, to seamlessly re-route traffic when necessary.

Gigabit-Capable Passive Optical Network (GPON) technology uses a completely passive (i.e., without powered electronics) optical fiber distribution network to connect the provider to the customer premises. In a PON FTTP deployment, devices requiring electrical power only exist at

the customer premises and the hub or cabinet location. PON uses a shared optical fiber path consisting of optical splitters.

Active Ethernet access is based on widely deployed and standardized Ethernet technologies, and requires powered Ethernet switching equipment at one or more intermediate points within the fiber distribution network to aggregate network traffic among subscribers.

5.5.2.1 Rings

The simplest way to achieve the design objectives of the City's distribution network is with a 100 Gbps Ethernet ring, which would provide an extremely high level of service availability. The ring in our proposed design cross-connects at multiple points to protect against physical cuts in underground applications, and pole/line damage in aerial applications. Additional rings can be added in the future for more capacity using more fiber strands or DWDM. The ring connects directly to both core network locations, and the ring is designed to provide service to all parts of the City's expected coverage area.

5.5.2.2 Broadband Network Gateway Routers

As illustrated in Figure 15 above, the 100 Gigabit Ethernet ring interconnects the core locations to the two broadband network gateway (BNG) routers. The primary function of the BNG nodes is to distribute/aggregate traffic to/from multiple 10 Gbps ports on the access equipment, which are located in the hubs with the BNGs.

In our model, the two BNG nodes each serve up-to approximately 14,000 passings. This passing count is consistent with Google Fiber deployment and other FTTP architectures. It can be reduced by choosing to deploy more BNG nodes in the City.

BNG nodes require a controlled operational environment similar to core network locations, but they generally contain many more ports in order to aggregate traffic from the access equipment. The BNG is an aggregation point for Ethernet switches and PON electronics. It corresponds to the "hut" in the Google Fiber architecture.

For the two BNG nodes in our model, we recommend outdoor shelters. BNG sites must provide clean power, HVAC, UPS batteries, and diesel power generation for sustained outages. We expect the BNG shelter building footprint to be approximately 12' x 10' (Figure 18).

Figure 18: BNG Facility

As illustrated in Figure 15, the BNG facility also contains the optical line terminals (OLT). The OLTs in the BNG provide flexibility in terms of supporting varying subscriber densities and subscriber services. The choice of an optical interface (small form-factor pluggable, or SFP) installed in the OLT allows the network to provide 2.4 Gbps to 16 subscribers in a GPON architecture, or 1 Gbps or 10 Gbps symmetrical Active Ethernet access (for one subscriber). Furthermore, OLT chassis are typically stackable, which enables multiple OLT chassis to share a backplane (stack ring) with a common uplink to the BNG router. In the recommended design, the uplinks to the BNG routers are 10 Gbps.

The sample list of materials for a BNG location is provided in Figure 19. Please note that the materials needed at the BNG locations varies greatly with the take rate and number of open access providers.

Figure 19: List of Materials for BNG

1 BNG Router
19-inch Racks
Fiber panels / cross connects
Cable Ladders and Cable Management
GPON and AE Access Equipment / OLTs

5.5.2.3 Fiber Distribution Cabinets (FDCs)

In our model, the FDCs house optical splitters, which connect the fiber from the access equipment or OLTs at the BNGs to the fiber that goes to the customer premises. Optical splitters are relatively inexpensive and are not powered, which reduces the size of the FDCs and the complexity of placing FDCs in the community.

Our recommended design limits each FDC to a service area of 1,500 passings, or less. The FDCs can be placed in the public right-of-way, on City property, or on private property where

appropriate to serve MDUs. FDCs can range in configuration from small pedestals or cabinets having a physical footprint of less than 1 foot by 1 foot (Figure 20), containing fiber terminations and optical splitters to serve fewer than 100 subscribers, to large cabinets with a footprint of 4 feet by 8 feet and supporting network electronics, fiber terminations, and splitters for more than 2,000 subscribers. Our proposed architecture is based on the use of larger FDCs (Figure 21) capable of supporting more widespread use of Active Ethernet and/or GPON OLT hardware deployed in the field. FDCs of this type will have larger physical size as compared to traditional telephone cabinets and cable TV pedestals (Figure 21), and locations would need to be selected to both minimize visual impact in residential areas and ensure that power can be provided to the FDC. (Smaller indoor FDCs are also an option; see Figure 23).

A key advantage of using multiple distributed FDCs rather than a more centralized design is the flexibility to place aggregation points at ideal geographic locations to minimize the quantity and length of fiber laterals, and thereby provide ringed fiber paths with increased network availability and greater overall redundancy of the service. Compared to other models, this approach potentially allows the full citywide FTTP deployment to occur at lower cost (supporting short- to mid-term requirements), with an option to potentially place electronics in the FDC and serve all passings with Active Ethernet.

Figure 20: Example Small Outdoor FDC Housing PON Splitters



Figure 21: Example Large Outdoor FDC Housing an OLT¹³³



Figure 22: List of Materials for High-Density OLT Site (Up to 2,000 Subscribers)

QTY	Name	Description
-	OLT; non-hardened 20-Blade AC/DC Chassis	20-Slot Indoor chassis, high cap 20 line cards, multi-terabit backplane
15	OLT; Hardened 2-Blade AC Chassis	Hardened OLT chassis, 2 slots, 2x10Gb Uplink SFPs, stackable
19	OLT; GPON line card, 8-port	8 GPON ports and 2 10GE Ports, needs SFPs
-	OLT; GPON line card, 4-port GPON, 2-port AE	4 GPON ports and 2 GE ports, needs SFPs
11	OLT; AE line card, 24-port	provides 24 AE ports, needs CSFPs
242	OLT; AE SFP, 2-port (duplex)	AE GE duplex SFP for 12-port line cards
30	OLT; Uplink 10GE SFP+ 300M multimode	For 10GE uplinks to local ASR
-	OLT; Uplink 10GE SFP+ 10km 1310nm	For 10GE uplink to remote ASR
152	OLT; GPON OIM, single port	Supports 32x and 64x
152	1x16 Splitter	Optical Splitter and Fiber Patches
15	OLT; Stack ring Cable, 10GE, 1m	Stack Ring Cables - modular - fixed RJ45 ends

Figure 23: Example Indoor FDC Option for OLTs



¹³³ The large ODC would be used in an all-Active Ethernet model. The proposed model would use smaller ODCs that do not require power.

GPON is currently the most commonly provisioned FTTP technology, due to inherent economies when compared with technologies delivered over home-run fiber¹³⁴ such as Active Ethernet. The cost to construct an entire network using GPON is approximately 40 percent to 50 percent less than Active Ethernet.¹³⁵ GPON is used to provide services up to 1 Gbps per subscriber and is part an evolution path to higher-speed technologies that use higher-speed optics and wave-division multiplexing.

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

1. Reducing the number of premises in a PON segment by modifying the splitter assignment and adding optics. For example, by reducing the split from 16:1 to 4:1, the per-user capacity in the access portion of the network is quadrupled.
2. Adding higher speed PON protocols can be accomplished by adding electronics at the FDC locations. Since these use different frequencies than the GPON electronics, none of the other CPE would need to be replaced.
3. Adding WDM-PON electronics, as they become widely available. This will enable each user to have the same capacity as an entire PON. Again, these use different frequencies than GPON and are not expected to require replacement of legacy CPE equipment.
4. Option 1 could be taken to the maximum, and PON replaced by a 1:1 connection to electronics—an Active Ethernet configuration.

All of these upgrades would also require upgrades in the backbone and distribution Ethernet electronics and in the upstream Internet connections and peering, but would not require increased fiber construction.

5.5.2.4 Open Access Considerations

Open access is the ability of a network platform to enable multiple service providers to serve customers over a single architecture. Open access can be achieved at layer 1 (separate fibers for separate providers), layer 2 (separate Ethernet capacity for separate providers), and layer 3 (separate virtual networks for separate providers).

Open access is commonly available on fiber networks in Europe and in the Asia-Pacific region, where it is required by regulators. It is also provided in networks in the State of Washington, where public utility districts (PUDs) are restricted in their ability to offer retail voice, video, and

¹³⁴ 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.

¹³⁵ “Enhanced Communications in San Francisco: Phase II Feasibility Study,” CTC report, October 2009, at p. 205.

data services. There have been some open access networks deployed in the U.S., including UTOPIA and the iProvo deployments in Utah. Both of these deployments have had difficulty in obtaining subscribers. The 2004 iProvo deployment was acquired by Google Fiber in 2013 and UTOPIA is seeking an operational partner. (UTOPIA is further discussed in Section 7.2.)

Different networks have provided open access in different ways. A layer 1 model exists in the Netherlands. Citynet, operated by the City of Amsterdam, operates the fiber, and provides fiber to service providers, which operate all electronics and have the relationship with the customer. In Sweden, the municipal power company owns and operates the physical fiber and contracts with a company that both operates the electronics and provides capacity to the service providers, which in turn have the relationship with the customer. In Singapore, the model is similar to Sweden but regulated and managed by the national government. In New Zealand, the municipal power company owns the fiber and operates the electronics; various service providers purchase Ethernet capacity on the network and have the relationship with the customer.

The architecture proposed here is physically capable of any of these models. The proposed GPON electronics enable the City to offer open access at layers 2 and 3 by apportioning capacity to the different service providers and enabling the providers to connect to the network at core locations or other points, as is done in Singapore, Sweden, and New Zealand. A choice of Active Ethernet or GPON has no impact on open access *per se*, it simply means that the open access will be on an Active Ethernet or GPON platform.

If the City wishes to offer open access at layer 1, as is done in Amsterdam, enabling separate service providers to have separate fibers, it can allocate fiber to those providers and offer space in the BNG and FDC facilities. Those providers could offer either Active Ethernet or GPON service over that fiber, depending on what electronics they use and where they place it. As discussed, the architecture places dedicated fiber from each premises to the FDC, and does not lock the City into either type of electronics.

5.5.2.5 Passive Optical Splitters

GPON uses passive optical splitting, which is performed inside FDCs, to connect fiber from the OLTs to the customer premises. In this model, the splitters are located in the ODC cabinets. The FDCs house multiple optical splitters that each split the fiber link to the OLT between 16 customers (in the case of GPON service); for subscribers receiving Active Ethernet service, a single dedicated fiber goes directly to the subscriber premises with no splitting.

FDCs can sit on a curb, be mounted on a pole, or reside in a building. Our model recommends installing sufficient FDCs to support higher than anticipated levels of subscriber penetration. This approach will accommodate future subscriber growth with minimal re-engineering. Passive

optical splitters are modular and can be added to an existing FDC as required to support subscriber growth, or to accommodate unanticipated changes to the fiber distribution network with potential future technologies.

Our FTTP design also includes the placement of indoor FDCs and splitters to support MDUs. This would require obtaining the right to access the equipment for repairs and installation in whatever timeframe is required by the service agreements with the customers. Lack of access would potentially limit the ability to perform repairs after normal business hours, which could be problematic for both commercial and residential services.

5.5.2.6 Customer Premises Equipment (CPE) and 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.

The drop cable extends from the subscriber tap (either on the pole or underground) to the building, enters the building, and connects CPEs.

We have specified three CPE kits to offer various features and capabilities and to meet subscriber budgets. Figure 24 lists the basic and premium kits for single-family unit (SFU) and multi-dwelling unit (MDU) subscribers, as well as the quantity of each estimated in our model. The primary distinction between the two subscriber classes is the cost of inside plant cabling. The basic CPE kit provides simple Ethernet on the subscriber LAN, whereas the premium CPE includes the fastest Wi-Fi available today (802.11ac).

Figure 24: CPE Kits

Name	Description	Each
ONTKitResidentialSFUBasic	ONT,Enclosure,ONID,BhrUPS,Ethernet	\$395
ONTKitResidentialSFUPremium	ONT,Enclosure,ONID,BhrUPS,Ethernet,AdvancedWi-Fi	\$455
ONTKitResidentialSFUAEAccess	ONT,Enclosure,ONID,BhrUPS,Ethernet,AdvancedWi-Fi,AEAccess	\$555
ONTKitResidentialMDUBasic	ONT,Enclosure,ONID,IndoorCabling,BhrUPS,Ethernet	\$766
ONTKitResidentialMDUPremium	ONT,Enclosure,ONID,IndoorCabling,BhrUPS,Ethernet,AdvancedWi-Fi	\$826
ONTKitResidentialMDUAEAccess	ONT,Enclosure,ONID,IndoorCabling,BhrUPS,Ethernet,AdvancedWi-Fi,AEAccess	\$926
ONTKitBusiness(SFU)Basic	ONT,Enclosure,ONID,BhrUPS,Ethernet	\$366
ONTKitBusiness(SFU)Premium	ONT,Enclosure,ONID,BhrUPS,Ethernet,AdvancedWi-Fi	\$426
ONTKitBusiness(SFU)AEAccess	ONT,Enclosure,ONID,BhrUPS,Ethernet,AdvancedWi-Fi,AEAccess	\$526
ONTKitBusiness(MDU)Basic	ONT,Enclosure,ONID,IndoorCabling,BhrUPS,Ethernet	\$766
ONTKitBusiness(MDU)Premium	ONT,Enclosure,ONID,IndoorCabling,BhrUPS,Ethernet,AdvancedWi-Fi	\$826
ONTKitBusiness(MDU)AEAccess	ONT,Enclosure,ONID,IndoorCabling,BhrUPS,Ethernet,AdvancedWi-Fi,AEAccess	\$926

We recommend indoor CPE devices, which generally do not need to be configured or maintained by the operator after they are installed. Placing CPE devices outdoors unnecessarily increases cost by requiring hardened equipment. In the financial model we will discuss the mix of CPE kits and present the sensitivities of the CPE and take-rate assumptions.

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. GPON is the most commonly provisioned FTTP service—used, for example, by Verizon (in its FiOS systems), Google Fiber, and Chattanooga EPB.

Furthermore, providers of gigabit services typically provide these services on GPON platforms. Even though the GPON platform is limited to 1.2 Gbps upstream and 2.4 Gbps downstream for the subscribers connected to a single PON, operators have found that the variations in actual subscriber usage generally means that all subscribers can obtain 1 Gbps on demand (without provisioned rate-limiting), even if the capacity is aggregated at the PON. Furthermore, many GPON manufacturers have a development roadmap to 10 Gbps and faster speeds as user demand increases.

GPON supports high-speed broadband data, and is easily leveraged by triple-play carriers for voice, video, and data services. The GPON OLT uses single-fiber (bi-directional) SFP modules to support multiple (in this model, 16) subscribers.

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 easily supports legacy voice (GR-303 and TR-008) and Next Gen Voice over IP (SIP and MGCP). AE also supports Video. Service distance (from the OLT) can extend as far as 75 Km (about 46 miles).

Because AE requires dedicated fiber (home run) from the OLT to the CPE, and because each subscriber uses a dedicated SFP on the OLT, there is significant cost differential in provisioning an AE subscriber versus a GPON subscriber. This hardware cost differential is partially reflected in the CPE kit pricing for an AE subscriber, which includes the dedicated SFP module on the OLT. The GPON CPE (\$455) costs less than half the CPE for Active Ethernet service (\$926).

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.

5.6 Operations and Maintenance Cost Estimates

This section provides a brief overview of operations and maintenance (O&M) costs from a technical perspective. An expanded discussion of O&M, including sales, marketing, administration, customer support, and other costs, is included in Section 8.

5.6.1 Subscriber Provisioning

The recommended subscriber provisioning platform will generally be purchased from the selected vendor for FTTP electronics.¹³⁶ The platform facilitates additions, moves, changes, and deletions of subscribers on the system, and tracks all activities. The provisioning platform is accessed by system administrators and customer service representatives in direct support of end subscribers.

5.6.2 Maintenance

5.6.2.1 Sparing

The City will need to manage spare equipment inventory for lower-cost quick-fix items such as line cards, interface modules, and power supplies.

5.6.2.2 Electronic Equipment Support and Maintenance

Network equipment is covered by each vendor's maintenance program, which typically includes extended warranty support, repair and replacement services, remote technical support, on-site technical support, and SLAs for response times to various types of reported issues. Annual support services often vary significantly between vendors; a common level of annual support often falls into the range of 15 percent of initial equipment cost.

5.6.2.3 Fiber Maintenance

Fiber optic cable is resilient compared to copper telephone lines and cable TV coaxial cable. The fiber itself does not corrode, and fiber cable installed more than 20 years ago is still in good condition. However, fiber can be vulnerable to accidental cuts by other construction, traffic accidents, and severe weather. The City would need to augment its current fiber staff or contractors with the necessary expertise and equipment available to maintain a citywide FTTP network.

Conservatively speaking, typical maintenance costs can range from 1 percent to 5 percent of the total construction cost, per year. As Section 8.3 shows, our analysis assumes fiber network maintenance costs are calculated at \$10,000 per year plus 0.25 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.

¹³⁶ The owner of the electronics is typically responsible for the provisioning platform.

6 FTTP Business Models and Municipal Objectives

As the City of Palo Alto evaluates how best to obtain FTTP based services in the community, there are several potential avenues it might pursue. Not all municipal FTTP networks have been deployed using the same model. The core business models that the City might consider include:

- Retail – the City builds and operates the FTTP network and directly offers services
- Wholesale – the City builds and retains ownership of the network and enables multiple ISPs access to the infrastructure
- Infrastructure Participation – the City enables various degrees of participation from providers by making available for use assets like City-owned dark fiber, utility poles, and other properties
- “Turnkey” or Public–Private Partnership – the City enables a private sector partner or a “turnkey vendor” to design, build, and operate the FTTP network

Each approach accomplishes the City’s end goal of offering retail services over an FTTP network slightly differently, and each has potential advantages and drawbacks. As we discuss in Section 6.4, there are numerous objectives that the City may prioritize as it determines what it deems most important in this pursuit. Further, these models can be mixed to best meet the unique objectives the City may pursue.

In this analysis, we consider the various objectives that the City may prioritize in its pursuit of an FTTP network, and how those may impact the City’s choice of business model. For example, the retail model is inherently high risk and may not be the City’s best option if it wants to prioritize risk aversion as a key objective. In the same vein, some turnkey solutions may minimize the City’s control of newly constructed FTTP infrastructure, which could conflict with a City expectation about ownership and control of assets.

It is important for the City to have a clear vision of its own priorities and eventual goals for the FTTP network so that it can determine to what degree it will be involved at every level of network design and deployment.

6.1 Defining Broadband

To adequately consider business models and potential City objectives, we must first briefly define “broadband” and explain the elements of broadband service delivery.

6.1.1 Broadband Speed

The Federal Communications Commission’s (FCC) definition has evolved, and continues to change. The core definition that remains unchanged is that broadband is high-speed Internet access that is always on. It is faster than traditional dial-up access, and was defined in 2000 as

being at least 200 Kbps in at least one direction. What this means is that when a user sends (uploads) or receives (downloads) data, the speed in either the download or upload direction must be at least 200 Kbps.

In 2010, that definition was upgraded to require at least 4 Mbps download and 1 Mbps upload speeds for a connection to be classified broadband. The FCC again updated its standard in 2015 to 25 Mbps download speed and 3 Mbps upload speed.¹³⁷ It made this change to keep pace with a rapidly expanding need for high-capacity connections. The proposed definition would require that any connection defined as broadband offer at least 25 Mbps download and 3 Mbps upload speeds.

It is important to note, however, that the FCC's stance on what constitutes "broadband" does not necessarily reflect the industry's definition. In stark contrast to the most recent definition of 25 Mbps download and 3 Mbps upload, the industry benchmark is 1 Gbps. Further, symmetry between upload and download speeds sets networks apart. Traditionally, download speeds are emphasized when selling services to consumers, as download speeds typically exceed upload speeds. A symmetrical service offers upload speeds that match or are very close to download speeds.

Broadband speed is only one component of its definition, however—especially as it relates to the consumer. We sought to define what broadband means to businesses, residents, and to the Palo Alto community, keeping in mind that the needs of users vary greatly across residential and business connections. Perhaps most important in defining and understanding broadband is to acknowledge that the definition is constantly evolving.

As we noted, the industry benchmark is increasingly accepted as *at least* 1 Gbps—indeed, not to be outdone by competitors, Comcast announced earlier this year its rollout of a 2 Gbps service in select markets.¹³⁸ Further, there is an expectation of unfettered access and no caps or restrictions. However, the Comcast rollout has been delayed, and speculations pointed to an uncertainty about how to price the service,¹³⁹ though it announced pricing in July 2015.¹⁴⁰

6.1.2 Relationship of Service and Infrastructure

The FCC definition of broadband does not address competition or market structure. To fully understand broadband, it is helpful to distinguish between service and infrastructure. Public

¹³⁷ <https://www.fcc.gov/document/fcc-finds-us-broadband-deployment-not-keeping-pace>, accessed May 2015.

¹³⁸ <http://www.pcmag.com/article2/0,2817,2479953,00.asp>, accessed May 2015.

¹³⁹ <http://www.fiercetelecom.com/story/comcast-pushes-back-heralded-2-gbps-fiber-home-rollout/2015-06-02>, accessed June 2015.

¹⁴⁰ <http://arstechnica.com/business/2015/07/comcasts-2gbps-internet-costs-300-a-month-with-1000-startup-fees/>, accessed July 2015.

roads offer an apt comparison to the broadband environment, as this analogy helps illustrate what the competitive environment looks like.

Consider public roadways in the context of package delivery. Companies like FedEx, UPS, the U.S. Postal Service, and many small businesses compete in the package-delivery market using public roads. Use of the roadways is a critical part of the business model for all package-delivery services, but none of them actually *owns* the roads. This fosters competition.

With broadband, the “roads” and the “delivery service” are controlled by the same entity. Imagine if each package delivery service was forced to build its own roadway in order to deliver packages. This would likely eliminate, or at least severely hinder, competition. Only the wealthiest companies that were able to finance large capital costs toward roadway construction would be able to sustain their expensive package-delivery businesses. The roads would be tailored to businesses that are willing and able to pay the price, and would exclude others.

Small businesses would not stand a chance at competing, and consumer choice would be severely limited. Users would be able to choose only from a handful of large businesses to meet their package-delivery needs. In this kind of environment, there is no incentive for package delivery services to keep prices low or to provide quality customer service—because the consumer has no alternative.

High customer satisfaction is an important goal in the telecommunications industry. While Internet access speeds get the headlines, user-friendly customer service within a pricing structure the average consumer can easily understand and work with is what consumers most desire. Palo Alto is no exception.

A ubiquitous open-access communications infrastructure would be a platform for enabling competitive commerce. But, to refer back to the package-delivery comparison, the “packages” would be “packets” of the virtual variety, arriving at computers and other devices rather than curbside mailboxes.

The City may find that its best option is to build the “roads” over which service is delivered and act as the deliverer itself (the retail model). Alternatively, it may find that it should build and maintain the service delivery infrastructure while enabling various providers to deliver service (the wholesale model).

Or, it may find that building the “roads” is too costly and risky, and it will instead find ways to smoothly enable one or more private entities to do this—such as promoting ease of access to rights-of-way to facilitate construction (infrastructure participation). Finally, the City may find

that it is best to entice a private entity to invest in infrastructure and deliver service (“turnkey” model or public–private partnership).

6.2 Business Models

As we noted, there are four main business models that the City may opt to pursue for the FTTP network. It is also possible to pursue some combination of these, or to pull attractive elements from each to create the best potential chance for success. The overarching goal is to maximize reward and minimize risk.

6.2.1 Retail Services

In the retail model, the City would build the infrastructure and act as the sole ISP delivering services. This model carries the greatest risk to the City because it includes operational costs, including sales and marketing. Further, the City has minimal experience operating a for-choice business, including expensive marketing and advertising efforts, and time-consuming customer service requirements.

Although the City does offer a range of standard municipal services, it is unfamiliar with the nuances and difficulties of administering a for-choice always-on service like an FTTP network. Because of its inherently round-the-clock nature, network management can be exceptionally challenging. The City has experience maintaining a fiber network that serves dark fiber customers, but retail subscribers are a much different group. The time and money spent on customer “hand-holding” alone are significant, and the technical support and customer service staff necessary to manage retail subscribers is much greater than administering dark fiber agreements.

Often there is a steep learning curve for municipalities that enter the retail market because they must learn to navigate a unique business world that bears little resemblance to a typical government environment. We anticipate the City will struggle with adjusting to market conditions and remaining responsive. The details of providing service at any level are many, and can be especially tedious during startup.

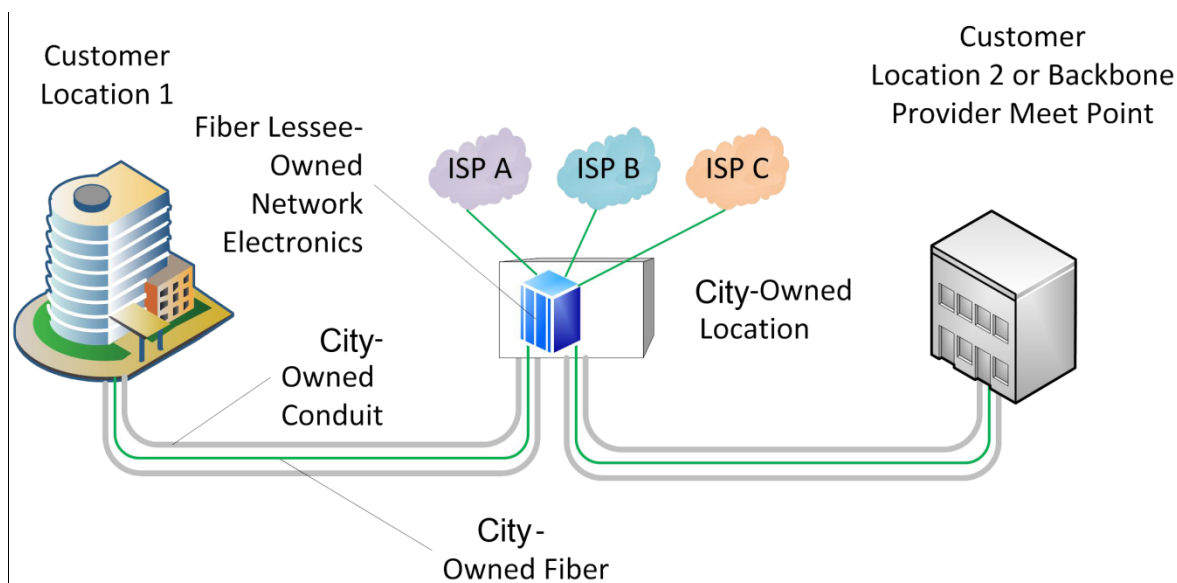
6.2.2 Wholesale Services

A wholesale or open access model separates the “infrastructure” from the “retail” services. In a perfect market, consumers would have access to any service provider they desire. Separating the infrastructure from the service is a step in that direction. In the City’s case, licensing fiber to wholesale providers, who in turn would light the fiber and sell wholesale lit services,¹⁴¹ will have the added benefit of achieving the City’s policy goals (i.e., promoting economic development and competition) without requiring the City to take on the burden of operations and management.

¹⁴¹ Lambdas can also fit into this model.

Figure 25 below illustrates a wholesale lit service scenario, in which the wholesale provider lights the fiber and the ISPs deliver retail service over the City’s fiber to consumers. Wholesale-lit services can be priced in various ways—and the provider, not the City, will determine actual pricing.

Figure 25: Wholesale Lit Services

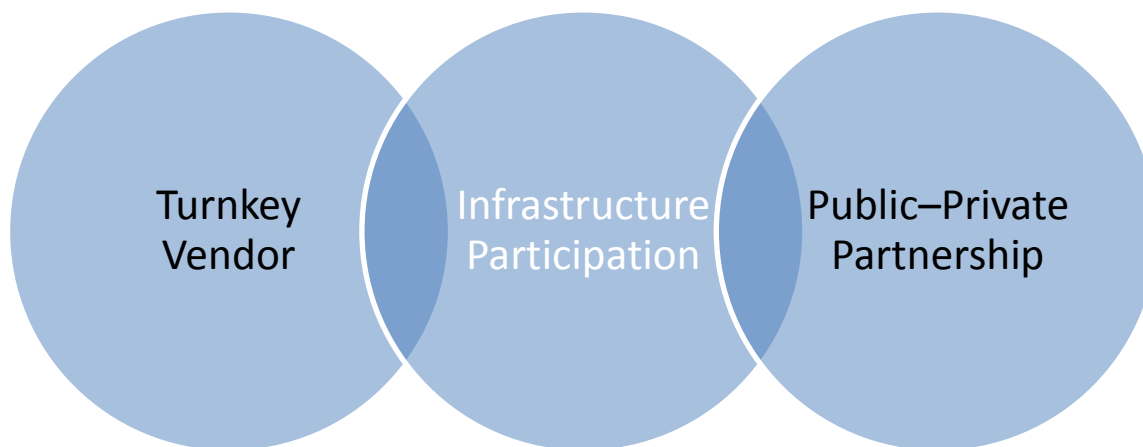


As we noted, an in-depth evaluation of the City’s fiber is necessary to determine to what degree (if any) existing assets are valuable and able to be used for the FTTP endeavor.

6.2.3 Infrastructure Participation and Public-Private Partnerships

Although the City identified “infrastructure participation” as a standalone model, this could be incorporated with the possibility of attracting a “turnkey” vendor or entering into a public-private partnership (see Figure 26). A partnership could essentially encompass infrastructure participation, and both represent the varying degrees to which the City may choose to become involved in service delivery over the FTTP network.

Figure 26: Infrastructure Participation Role in Partnerships and Turnkey Vendor Relationship



The subtle distinction between a turnkey vendor and partner is the City's level of involvement in the relationship. A turnkey vendor would design, build, and operate the FTTP network using its own capital, taking on most or all of the risk, and reaping most or all of the reward.

The City could make itself attractive to a partner like this by removing barriers to access like challenging and costly permitting processes. It may be able to allow access to its utility poles at a discounted rate, or could license dark fiber strands. Again, this illustrates an overlap of infrastructure participation and attraction of a turnkey vendor.

As its name implies, a public-private partnership is a joint relationship in which the City has at least some degree of involvement and investment in the design, deployment, and operation of the FTTP network. In general, we believe that a partnership model is more likely to be successful than attempting to attract a turnkey private vendor. Though it can be difficult for most cities to incite significant private investment without having their own skin in the game, Palo Alto's unique characteristics may allow it to attract a viable partner with minimal public investment.¹⁴²

City-owned infrastructure and processes are key components in attracting a turnkey vendor or developing a public-private partnership. Most communities that decide to pursue some form of network implementation prefer to retain ownership and control of the physical assets. This usually includes at least the fiber in the ground or on poles, and all accompanying ducts, splice cases, and other network components, or the OSP. It often also entails ownership of network electronics such as routers and other equipment at the network core or central office (CO).

¹⁴² The degree to which the City is involved will be based on factors like the City's desired level of involvement, a private partner's experience and expertise, and ultimately the negotiated terms of a partnership.

This is important to mitigate the City's risk; retaining ownership of the assets is a critical way for communities to retain some control of the network. This includes a public-private partnership scenario—a good way to balance risk and reward is for the City to maintain ownership and control of the assets while it assigns operational responsibilities to its private partner(s). This enables both parties to perform functions that highlight their strengths while not having to expend resources and energy attempting to carry out tasks for which they are ill-equipped.

The City may want to determine ahead of time whether it wants to retain ownership of assets and to what degree. It may want complete control, including responsibility for maintaining all the fiber and electronics. In Palo Alto, the City has experience operating and maintaining a fiber network, which gives it an advantage in this area. But the details of maintaining a network change when transitioning from primarily dark-fiber agreements to providing retail service, and the City should take this into consideration as it pursues an FTTP network.

On the other hand, the City may want to retain control only through ownership with no hands-on role of its own. This would shift all the responsibility for network maintenance and repair as well as electronics replenishments and network upgrades to the private partner(s). This would reduce the City's required staffing, but will likely also come with some sort of price tag.

Alternatively, the City may decide that in its pursuit of a public-private partnership, it will allow potential partners' level of experience to drive what degree of ownership the City retains. That is, one potential private partner may be prepared to take over total responsibility for the network while a different potential partner may have no experience with this and might ask that the City continue in this role.¹⁴³

Perhaps the single most important issue to keep in mind regarding ownership of assets to any degree is that the City will likely be responsible for funding network construction and deployment, particularly if it wishes to retain ownership of the assets. Potential partners may be willing to make capital investment, but will likely then retain ownership and control of the infrastructure they build.

6.3 Redefining Open Access

"Open access" traditionally means one network infrastructure over which multiple providers are able to offer service. In an open access municipal network, the locality typically owns the fiber optic network and enters into wholesale transport, dark fiber license, or indefeasible right of use (IRU) agreements with third party providers to offer retail data, video, and voice services over the network.

¹⁴³ If the City is tasked with this in a potential public-private partnership, it may be able to contract out tasks for which it is not equipped.

Often the municipality allows third party providers access to lit services instead of dark fiber to achieve their service goals. Whatever the means (dark or lit services), open access has historically meant that multiple providers offer services over one central infrastructure, which is usually publicly owned. In the case of Palo Alto, the wholesale model is most closely aligned with the traditional definition of open access, but we outline in this section how the goals of open access may be met in new ways.

We previously noted that the City's network must be able to support "triple play" services—high quality data, video, and voice—that residential users have grown accustomed to having in their homes. But what it means to support triple play services has evolved, and the means through which this is accomplished has changed as technologies have improved and network speeds have increased.

Similarly, the definition of open access has shifted recently, just as the broadband landscape has evolved in recent years. While it has traditionally meant that network owners must provide access to their infrastructure, some communities are finding that they can achieve their broadband goals without a traditionally open-access network. Instead of multiple ISPs and other private entities providing service over one network, open access is achievable through multiple OTT providers offering various services.

This is especially effective if the network is provisioned for affordable unfettered 1 Gbps data service—ultra-high speed fiber optic broadband networks offering top tier speeds possess the capacity to provide a variety of different OTT applications to meet consumers' needs. Thus, the City's network can support triple play by enabling OTT applications that effectively provide all these services—while at the same time simplifying the consumer's experience and potentially lowering their overall cost.

As awareness and access increase and prices decrease, consumers are likely to continue pursuing alternatives to conventional voice and video services. A new era of OTT content via 1 Gbps data services is emerging—and with it comes an updated definition of open access, and alternative paths for communities to attain their broadband goals.

6.3.1 Open Access Goals

Localities have traditionally sought to develop open access networks in their pursuit of other community goals. Key among these is competition. The purpose of open access networks is to enable as many providers as possible to deliver service over the network, to give consumers greater choice and flexibility in picking a provider, and ultimately to broaden availability.

Communities are recognizing that competition is key, and that providing a competitive marketplace for consumers may not look like what has traditionally been considered open access. Providing a competitive environment with numerous applications and offerings that

enable consumer choice meets customer needs in a new way—and a data connection enables cloud-based applications and services. A public or public-regulated offering that provides a robust retail data service and competitively priced wholesale transport access brings open-access objectives to the market.

If the City’s FTTP network delivers an unfettered data offering that does not impose caps or usage limits on one use of data over another (i.e., does not limit streaming), it has created an open access network on the applications side. All application providers (data, voice, video, cloud services) are equally able to provide their services, and the consumer’s access to advanced data opens up the marketplace.

The City or its partner as a premium data-only provider fosters access in the near-term to create an open network. This is a building block toward potentially opening the network further in the future as the FTTP enterprise evolves, if this form of open access remains an ongoing goal for the City.

Getting to traditional open access where multiple ISPs offer service has been slow and problematic in the United States. Focusing on other forms of open access provides a viable and attractive substitute in the meantime, and may ultimately eliminate the need for traditional open access. One of the most important elements to successfully redefine open access is the emergence and evolution of OTT providers and next generation applications to support consumers’ needs.

6.3.2 Evolving Over-the-Top Providers

OTT or “value added” services have evolved more quickly in the voice market than in video, though it is not a new concept in either. Recent announcements of expanded OTT video offerings suggest that consumers are seeking alternatives to traditional video services, and the market is responding.

Consider important changes in the landline telephone market over the past decade to illustrate what is likely to happen with video content. Ten years ago, home telephones were still nearly ubiquitous, even in households where all members subscribed to wireless phone service. Yet data from a December, 2013 National Institutes of Health (NIH) report showed that more than a quarter of households in Santa Clara County were wireless only, with no landline telephone.¹⁴⁴

National usage has continued to decline—January through June 2014 was the first six-month period during which a majority of U.S. children lived in households with wireless-only telephone

¹⁴⁴ National Institutes of Health. (2014). Wireless Substitution: State-level Estimates from the National Health Interview Survey, 2012 (Report No. 1250). Retrieved from <http://www.cdc.gov/nchs/data/nhsr/nhsr070.pdf>.

service.¹⁴⁵ This decline was possible due to increasingly accessible and affordable cellular and wireless service along with other alternatives to landline—programs like Skype and Google Voice, services like Vonage and Lingo, and technology like magicJack and Ooma.

The cable industry may be poised to see a similar shift toward nontraditional technologies, applications, and services that allow consumers greater flexibility and choice. An increased desire for OTT offerings could have a significant industry impact,¹⁴⁶ though this will likely be more gradual than changes to the voice industry because of cable content owners' great degree of control. Major industry shifts have been predicted,¹⁴⁷ but major industry changes have been slower to materialize than in the voice industry.

To understand why the shift may be gradual, consider Google Fiber's entry into the Kansas City market just a few years ago as an example of the firmly rooted power of cable. Google Fiber found that a data product alone was not strong enough to obtain the necessary market share to make its endeavor viable. If it wanted to get people to switch providers, Google Fiber *had* to offer cable, deviating from its original plan and introducing more cost and complexity than the simple data service it intended to offer. Google Fiber may have found that offering traditional cable television was unnecessary if OTT cable options with a broad range of content were widely available when it entered the Kansas City market.

In 2011, Google Fiber was forced to set a precedent offering traditional cable services when entering the Kansas City market, and has necessarily continued these offerings in subsequent markets. It will likely eventually phase out its traditional cable offering as more OTT content becomes available and consumers seek other, less costly alternatives to traditional cable.

Smart mobile devices, where content can come from cellular networks or WiFi networks, add network choice to the consumer list. As more non-traditional content providers emerge, greater programming variety becomes available via OTT, network choice grows, and network operators offer a wider variety of pricing plans, the demand for alternative access to content may increase.

Consumer demand and expectation is another potentially key driving factor that may facilitate change in the industry. Due to the always-on and at-your-fingertips nature of applications and services that are supported by access to the Internet, consumers have come to expect “on-

¹⁴⁵ National Institutes of Health. (2014). Wireless Substitution: Early Release of Estimates from the National Health Interview Survey, January-June 2014. Retrieved from <http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201412.pdf>.

¹⁴⁶ This change is not without other risks to the City. Unless legislation changes in accordance with the industry, this market transition to OTT services could have serious adverse consequences to City cable franchise fee and utility tax revenue.

¹⁴⁷ <http://www.businessinsider.com/cord-cutters-and-the-death-of-tv-2013-11>, accessed June 2015.

demand” services and control over their choices in ways that have not previously existed.¹⁴⁸ Consumers who are used to having Internet access—especially digital natives¹⁴⁹—are accustomed to quickly and easily receiving the goods and services they desire. There is an increasing expectation among consumers in the U.S. that services will be readily available on-demand with minimal effort. By simply engaging an App on a smartphone or clicking a mouse on a laptop, consumers expect instant access to goods, services, and content.

Further, in part because of the growth of cloud services, there is an increased consumer desire for simplicity and integration among services and content. And because of technological advancements and “cheap computing power,”¹⁵⁰ the costs associated with what would have been luxuries for the rich only a few years ago are now attainable for the average household.

Since the start of this year, the market has begun to shift more dramatically with the emergence of additional OTT content. Dish Network launched an OTT service in early 2015 that offers sports programming on channels such as ESPN as well as other programming and popular TV channels without a cable subscription. The service, called Sling TV, is streamed over the Internet.¹⁵¹ It does not require any additional hardware and is enabled by installing an application on a device such as a smartphone, tablet, laptop, or Internet-connected television. Sling TV currently is priced at \$20 per month with no time commitments, but it is complex and fraught with limitations and restrictions.¹⁵² Traditional cable content providers’ attempts at OTT have seen varying degrees of success, but it is significant in the industry for these providers to even acknowledge the need for these services.¹⁵³

In addition to recent entrants to the OTT market, there are numerous established services and applications that will likely continue to promote change in the cable industry and drive an increase in consumers’ desire for greater choice and control over how they access content. Standalone media-streaming boxes like Apple TV and Roku have enabled consumers to stream content with applications such as YouTube, Netflix, and Hulu without a cable subscription since 2008. These “cord-cutters” cancel their cable subscriptions in favor of accessing their favorite content via applications and services streamed over the Internet. An ever-increasing percentage of consumers are getting these services using mobile devices.

¹⁴⁸ <http://www.businessinsider.com/the-on-demand-economy-2014-7>, accessed May 2015

¹⁴⁹ <http://www.cnn.com/2012/12/04/business/digital-native-prensky/>, accessed May 2015

¹⁵⁰ <http://www.economist.com/news/leaders/21637393-rise-demand-economy-poses-difficult-questions-workers-companies-and>, accessed May 2015.

¹⁵¹ <https://www.sling.com/>, accessed April 2015

¹⁵² <http://www.pcworld.com/article/2909572/sling-tv-channel-guide-all-the-programming-and-all-the-restrictions-all-in-one-chart.html>, accessed May 2015.

¹⁵³ As we noted in Section 2.3.8, Comcast is poised this year to make its second attempt at an OTT offering.

Since the debut of Apple TV and Roku, similar devices like the Chromecast, Google Nexus, and Amazon Fire TV have entered the market, allowing consumers greater choice. Further, consumers can now purchase smart TVs, which come with preinstalled platforms that support streaming applications. These devices require no additional hardware—with only an Internet connection, consumers can stream music, TV shows, movies, and even play games.

While Comcast’s own attempt at OTT content through its “Streampix” offering was not a huge success,¹⁵⁴ that pursuit illustrates the cable giant’s understanding of streaming as the future of content delivery. The fact that its broadband subscriptions surpassed its cable subscribers this year further puts to rest the notion that the video industry can move forward without embracing new and innovative content delivery mechanisms. Further, Comcast has announced that it will begin offering a new streaming service,¹⁵⁵ and it is reportedly in talks with “nontraditional” content and media providers.¹⁵⁶

Although the video industry has been slow to change, traditional content providers have begun efforts in recent years to provide OTT content to keep up with consumer demand for greater flexibility, and to compete with companies like Netflix and Hulu. Comcast’s own recent developments show that this understanding is beginning to resonate with even the largest providers.

Verizon FiOS announced earlier this year its own “a la carte” offering called Custom TV, which allows consumers to choose from bundled packages that more appropriately reflect their programming desires and include less unwanted channels.¹⁵⁷ While this is not a true OTT application, it demonstrates the recognition within the incumbent market that consumers are dissatisfied with traditional content delivery and are seeking alternate choices.

Further, HBO announced plans last year to offer its own OTT service;¹⁵⁸ it began offering HBO NOW on a variety of platforms and devices in mid-2015.¹⁵⁹ Access to premium programming like sports and HBO has been a stubborn barrier to customers who want to eliminate their cable subscriptions (and to competitors that want to disrupt the market). Often, consumers would happily give up enormous cable bills in favor of more streamlined, inexpensive services—but they do not take the leap because they want specific programming that is only available

¹⁵⁴ <http://www.lightreading.com/video/ott/comcast-turns-off-streampix/d/d-id/711098>, accessed May 2015.

¹⁵⁵ <http://corporate.comcast.com/comcast-voices/a-new-streaming-tv-service-from-comcast>, accessed July 2015.

¹⁵⁶ <http://blogs.wsj.com/cmo/2015/07/24/this-chart-shows-why-comcast-would-be-interested-in-vice-media-and-buzzfeed/>, accessed July 2015.

¹⁵⁷ <http://arstechnica.com/business/2015/04/verizons-new-custom-tv-is-small-step-toward-a-la-carte-pricing/>, accessed May 2015.

¹⁵⁸ HBO to Launch Standalone Over-the-Top Service in U.S. Next Year. 2014 October 15.

<http://variety.com/2014/tv/news/hbo-to-launch-over-the-top-service-in-u-s-next-year-1201330592/>, accessed March 2015.

¹⁵⁹ <https://order.hbonow.com/>, accessed June 2015.

over cable. It is significant when a content powerhouse like HBO acknowledges the importance of change in the industry.

Companies that hope to compete in the video market will likely find that they must adjust their business models, marketing strategies, and understanding of consumer demands and desires. Perhaps one of the most significant illustrations of this is that, for the first time ever, Comcast's broadband subscribers outnumbered its cable subscribers—an unprecedented and major shift in the industry.¹⁶⁰

In light of the high costs associated with providing traditional cable service, the City will likely benefit most from focusing on a data-only offering as it goes through startup. If a data-only offering does not prove to be viable, the City can then readjust its approach and potentially partner with a private provider that can offer IP-based cable. One important goal is for the City to drive the market by showing consumers that a high-capacity data product is sufficient to meet all their content needs, and can lead to overall telecommunications savings.

6.4 FTTP Objectives

As part of our analysis of business models the City might want to pursue, we evaluated certain common broadband objectives that many communities prioritize, and how these may affect the City's decision-making process. Choosing which goals to prioritize can be challenging, and we sought to provide the City with information to empower decisions about its connectivity needs that will have ongoing positive outcomes.

6.4.1 Community Broadband Objectives

Competition and consumer choice are only two of several objectives that may drive a community's pursuit of a publicly owned fiber optic network. Many public entities share certain objectives when it comes to considering investment in a community broadband network:

- Affordability
- Cash Flow
- Competition in Market
- Consumer Choice
- Ownership and Control of Assets
- Performance
- Risk Aversion
- Ubiquity

¹⁶⁰ http://www.nytimes.com/2015/05/05/business/media/comcasts-earnings-rise-10-driven-by-high-speed-internet.html?_r=0, accessed May 2015.

Each of these is understandable in the context of what is best for a community, though they do not necessarily all align with one another. In fact, some common objectives that communities prioritize when planning their networks actually conflict with one another. In light of this, communities benefit from careful consideration of which objectives they deem most important to adequately meet their needs.

As an example, risk aversion is top priority for some communities—it may be politically challenging to build a network, and the only way to complete it is to assure key stakeholders and the public that there is minimal risk involved. As we explain below, risk aversion is in direct conflict with building the network throughout an entire community, and ubiquity may be the most important objective for another community. Each community must find the balance that is most appropriate to its needs so that it can achieve its goals without sacrificing important objectives. Our analysis does not advise the City on which objective(s) it should prioritize; rather, we describe common objectives and their role in communities, how they interact with each other, and potential advantages and disadvantages of each.

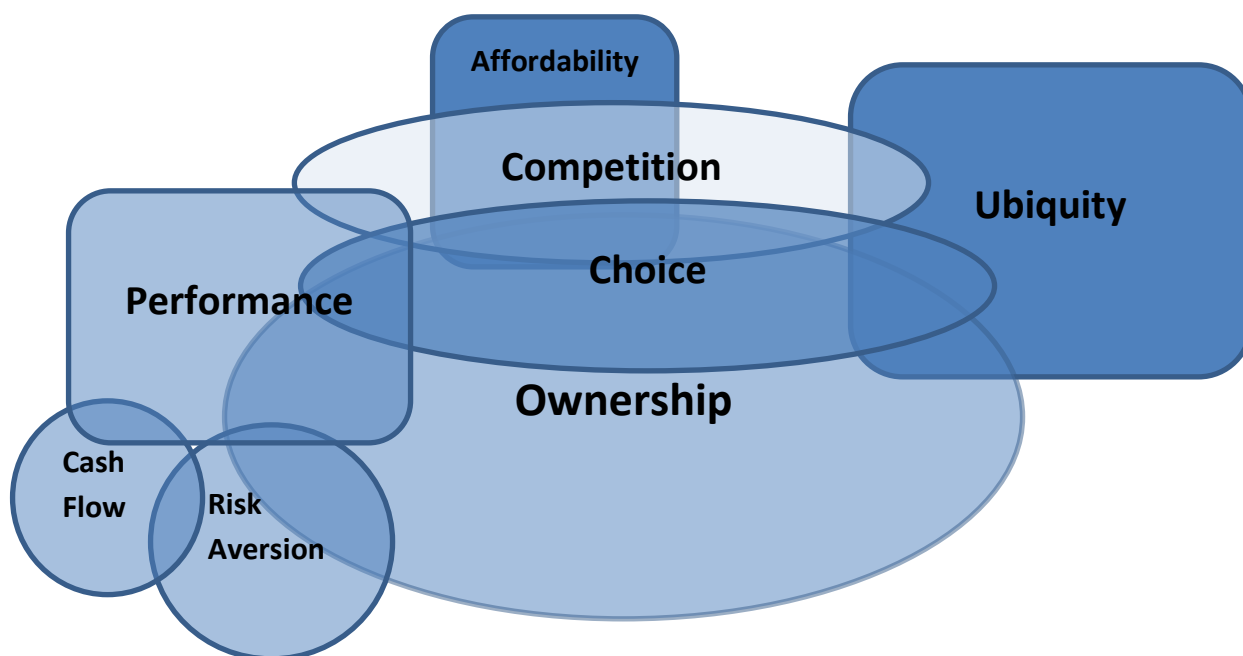
We illustrate in Table 6 below the intersection of common objectives and in the sections that follow we explain these in greater detail as well as how they align and differ. As the key at the top of the following table shows, objectives may have no impact, they may be in alignment, they might conflict, or they may be inapplicable.

Table 6: Common Goal Alignment

	A: Align		C: Conflict		NI: No Impact		NA: Not Applicable	
	Ubiquity	Choice	Competition	Ownership	Performance	Affordability	Risk Aversion	Cash Flow
Ubiquity	NA	A	A	A	NI	C	C	C
Choice	A	NA	A	A	A	A	C	NI
Competition	A	A	NA	A	A	A	C	NI
Ownership	A	A	A	NA	A	A	A	C
Performance	NI	A	A	A	NA	NI	A	A
Affordability	C	A	A	A	NI	NA	C	C
Risk Aversion	C	C	C	A	A	C	NA	A
Cash Flow	C	NI	NI	C	A	C	A	NA

In the sections below, we further explain this table and how the objectives listed here interact with one another.

We detail below the interaction between objectives, and how prioritizing one objective may impact another. Figure 27 below shows a visualization of Table 6 to illustrate the relationship between objectives.

Figure 27: Interactions between Objectives

There are numerous possible outcomes associated with different objectives, and the City has to determine what it believes will best serve its unique needs and have the greatest impact on its community. This analysis does not seek to urge the City in any particular direction, but we do make recommendations about some of the objectives that may well serve any public network.

For example, performance is an objective that either interacts favorably or not at all with other objectives, and prioritizing performance can have a significant positive impact on the FFTP network's viability by setting it apart from incumbent providers. Thus, there are no real disadvantages to making performance a top priority for the FFTP network because doing so does not have to be at the exclusion of any other objectives. Further, some objectives can and should be pursued in parallel.

6.4.2 Ubiquity

For most communities that opt to build and operate a network to any degree, ubiquity—which refers to designing and building the network so that it connects every structure in the community—is a key objective. From Connecticut to Minnesota to Oregon, communities (and

community organizations) large and small prioritize ubiquity as a primary goal in their broadband pursuit.¹⁶¹

This is a respectable objective for any community, and it makes sense that leaders want to bring service to the entire community, but immediate, community wide build-out often entails significant risk and cost. The financial risk alone is significant and in order to make the model sustainable, the service may have to be priced out some consumers' reach.

Overall risk aversion conflicts directly with the notion of a full-scale community build-out, as the City will likely face stringent construction deadlines and much higher capital costs than it would if it were to undergo a phased build-out. The need for outside funding is likely also higher with a ubiquitous network build, which greatly increases the City's risk.

Because the City will likely need to procure financing from an outside source, and due to high capital investment for large-scale construction, it is likely that the City will be forced to raise monthly service fees. This reduces the affordability of the City's FTTP network and to some degree defeats the purpose of ubiquitous build-out. If the service reaches the entire community but it is priced too high for many residents and businesses to afford it, this fails to meet the City's goal of providing access to its citizens—it is essentially inaccessible.¹⁶²

Cash flow is another objective that conflicts with ubiquity. The City likely will not expect to make a profit on the FTTP network, but it is important for the entity to become able to financially sustain itself, including operating costs and any debt service payments. This is often referred to as "cash flow" or "breakeven." The higher cost of building out to every structure in the City means that the point at which the FTTP network is able to cash flow will come much later than if the City slowly built out and began generating subscriber revenue earlier on in the process.

6.4.2.1 Impact on Business Model

A key consideration for network implementation is how to fund both capital construction costs and ongoing operational expenses. The importance of factoring in the ongoing cost of operations cannot be overstated—these expenses fluctuate based on the success of the enterprise, and can vary considerably each year, and even month to month. The capital and operating costs associated with a full-scale communitywide build-out will be significant, and the

¹⁶¹ <http://www.cnet.com/news/connecticut-communities-join-together-for-gigabit-broadband/>, accessed April 2015.

http://broadband.blandinfoundation.org/uls/resources/Vision_Statement_FINAL_0228.pdf, accessed April 2015.

<https://www.portlandoregon.gov/revenue/article/394185>, accessed April 2015.

¹⁶² The City conducted a study in 2012 that sought to understand the possibility of "user financing" in Palo Alto. The results of the study can be found at: <http://www.cityofpaloalto.org/civicax/filebank/documents/30112>, accessed June 2015.

City will likely have to seek outside funding to support construction and the FTTP network's startup costs. It is also possible that outside funding or some internal subsidy will be necessary to support ongoing operations—everything from network equipment license fees to direct customer support.

The City may be able to go out for bond (i.e., borrow funds) to enable construction of an FTTP network. There are two types of bonds that municipalities typically rely on for capital projects.

General obligation (GO) bonds are directly tied to the City's credit rating and ability to tax its citizens. This type of bond is not related to any direct revenues from specific projects, but is connected instead to citywide taxes and revenues that can be used to repay this debt.

GO bonds can be politically challenging because they may require public approval, which can be hard won. Because of the politically polarizing nature of GO bonds, they are generally issued for projects that will clearly serve the needs of the entire community, such as roadway improvements. It is challenging in many communities to make the case for a fiber enterprise serving the public to such a degree that GO bonds are warranted.

Revenue bonds are directly tied to a specific revenue source to secure the bond and guarantee repayment of the debt. The revenue stream from a municipality's electric, natural gas, or water utility may be used to secure a revenue bond.¹⁶³ In fact, in theory, any municipal service that generates some sort of revenue that could be used to pay back the debt might potentially be used to secure a revenue bond—municipally owned public transportation or hospitals, for example. Given this, it stands to reason that the FTTP network's revenues could be used to guarantee a revenue bond, but this is typically not an accepted practice within the bonding community, particularly with FTTP endeavors. Instead, the City would likely need to consider other revenue sources it could tie the enterprise to if it aims to seek revenue bonds.¹⁶⁴

Seeking bonds increases the City's overall risk and it is much more likely to require outside funding if it intends to pursue a ubiquitous build-out. At the same time, the City may find that a clearly stated goal of ubiquity eases the process of GO bond approval, which could be beneficial. If the City anticipates a need for outside funding for any construction and expects that it may be politically complex to seek bonding, ubiquity may be a reasonable conduit through which to achieve that goal.

¹⁶³ Revenue bonds are **not** a consideration for Palo Alto, given that the City attorney has previously advised that using utility electric, gas and water revenues to back a revenue bond is prohibited. In light of the City attorney's legal opinion, the City will need to consider alternative revenue sources.

¹⁶⁴ Revenue bonds are not a consideration for Palo Alto. It is possible that the Fiber Optic Fund Reserve (~\$20M) or annual revenues (~\$3M) from the commercial licensing of dark fiber can be used to secure a revenue bond, though this will require internal City discussion and approval from the City's legal counsel.

Bonding aside, the City's FTTP network is harder to oppose if ubiquity is a primary objective. The City could make a strong case in favor of FTTP implementation by being clear that it would not "cherry pick" or build only to economically desirable neighborhoods where it expects a return on investment. There are few, if any, traditionally low-income areas in the City, but there are still potentially areas in the City where demand is low enough that private providers are unlikely to build there. Income disparity is not the only reason a private provider may cherry pick—these providers typically build based on where they determine they are most likely to recover their cost to build.

The City likely will not have to assist a large number of low-income residents with reduced service fees, but it still may benefit from choosing to invest in infrastructure throughout the community. The FTTP network could serve areas that have been historically underserved, including parts of the community where perhaps no infrastructure previously existed. This would not only bring the FTTP network's offering to those parts of the community, but could also enable local ISPs to provide service over the network's infrastructure and gain market share in areas that had previously been too costly to serve.

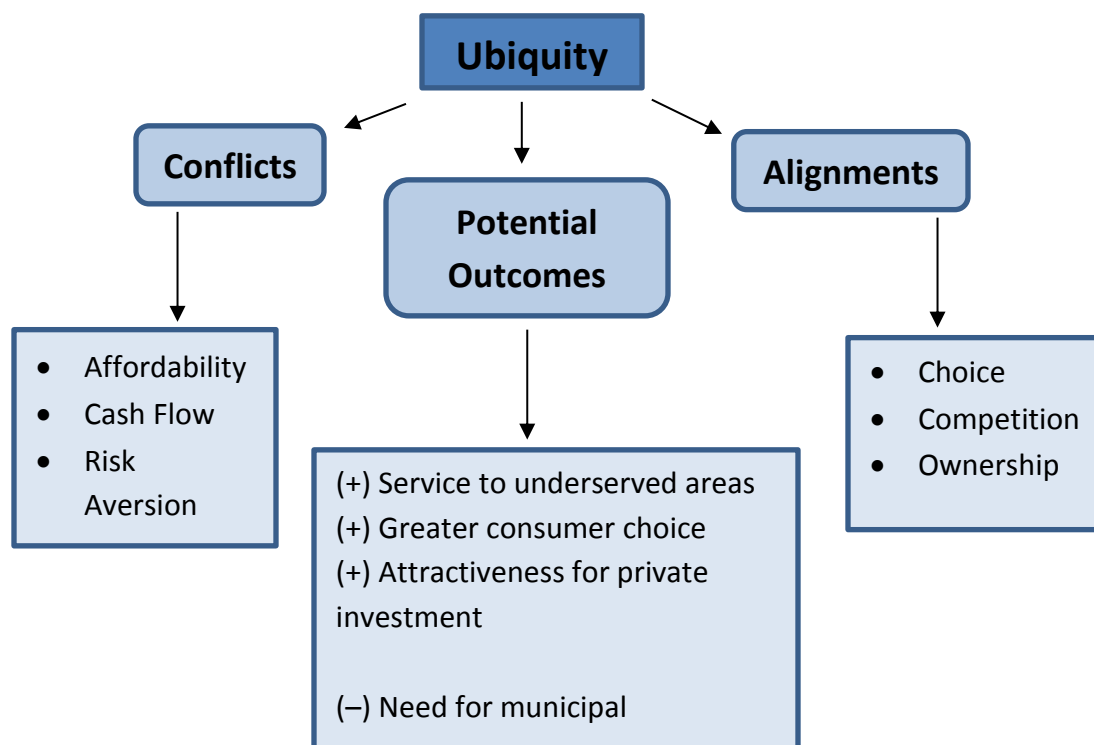
The City may determine that it will be best served by not partnering with multiple ISPs but seeking one partner to manage and operate the network. Whether the City pays for network construction will determine whether a ubiquitous network is attractive to a private partner. If the City requires ubiquity but is not prepared to fund significant portions of the network, it will likely find that private entities have little desire to partner. Conversely, if the City funds significant portions of construction of a ubiquitous network that a private partner can then expand and operate,¹⁶⁵ it may find that it is an attractive community for private investment.¹⁶⁶

Figure 28 shows conflicts, alignments, and potential outcomes associated with prioritizing ubiquity.

¹⁶⁵ For example, the existing fiber optic backbone may be sufficient to attract partnership, or the City may opt to fund network expansion to key economically desirable areas to entice private investment to build to the remainder of the community.

¹⁶⁶ The City has some funds for system capacity improvement allocated in its Fiber Optic System Rebuild project (FO-16000), which will install new aerial duct or substructures (conduit and boxes) and additional fiber backbone cable to increase capacity for sections of the dark fiber ring that are at or near capacity and allows CPAU to meet commercial customer requests for service. However, this reinvestment does not increase the attractiveness of the fiber to encourage a partner to build FTTP. The commercial dark fiber reach is a relatively small portion of the total FTTP investment, and the FTTP endeavor will likely benefit little from commercial dark fiber expansion. The City anticipates the rebuild will be completed with the budget funds requested for Fiscal Year 2016 (\$1.15 million) and Fiscal Year 2017 (\$1.25 million) for a project total of \$2.4 million over two years. The remainder of the \$4.9 million project cost originally shown on the City's budget represents a placeholder for future fiber expansion. The City should prioritize internal discussions regarding which funds are allocated for dark fiber vs FTTP, and what impact they may have on overall cost to deploy FTTP.

Figure 28: Ubiquity Alignments, Conflicts, and Potential Outcomes



6.4.3 Consumer Choice

As we noted, localities often pursue open access as a means to increase consumer choice, and this is an important consideration and a high priority for many communities. Incumbent cable and Internet providers may have little economic incentive to expand to areas of the community where they believe they will not recover significant portions of their cost.

An overarching goal of developing an open access network is to level the provider playing field to reduce monopolistic and oligopolistic practices by incumbents, and to give consumers greater choice in service providers.

Most other objectives that a community decides to pursue will interact favorably with consumer choice. A ubiquitous network that fosters open access, boosts competition, and reaches all parts of the community enhances consumer choice on a number of levels. In addition to gaining access to residential services that may have previously been unavailable, consumers often end up with greater flexibility to access services at various community locations. Ubiquity and competition enable enhanced services at community centers, religious institutions, educational facilities, and other locations that benefit residents.

Affordability of services is an important component in access that ties directly with competition and consumer choice—being able to pay for services is often a major barrier for consumers.

Having affordable access to services with competitive speeds can significantly improve quality of life, make residential areas more desirable, and spur business growth. Access to premium residential services at affordable prices can also incite home-based businesses, support continued education, and enable better access to basic human services like healthcare and education.

Risk aversion could negatively impact consumer choice. If the City decides that it will slowly and organically build out its network and does not take steps to prioritize particularly vulnerable areas, it is possible that only the consumers who have traditionally enjoyed provider choice will be positively affected. The City may find that it can balance risk mitigation with community benefit by deliberately funding service to portions of the community that may be undesirable for a private entity. If the City chooses to seek partnership, this could be negotiated.¹⁶⁷

6.4.4 Competition in Market

Fostering competition in the market is generally the second component of an open access pursuit. That is, communities often seek to develop an open access infrastructure to enable multiple providers to offer service over the network and enhance competition. Like consumer choice, this is generally a major reason communities attempt to pursue a traditional open access infrastructure. Similar to consumer choice, competition in the market can be achieved through open access in the traditional sense as well as through other means.

The key for most objectives is to determine whether they are primary, how they may conflict with others, and how best to pursue whatever a community deems is its most important goal(s). We believe that competition both upholds and is upheld by all other potential primary objectives—it aligns with, does not impact, or is not impacted by other common community objectives.

Choice and competition go hand in hand, and seeking ways to encourage competition will likely only result in greater consumer choice in communities. Similarly, a ubiquitous network build will probably result in greater competition among local providers. This is not only through providers potentially offering services over the City's network, but also in the form of incumbent providers lowering prices and enhancing services in response to improved services by other providers.¹⁶⁸ This also speaks to competition vis-à-vis affordability and network performance: the greater the market competition, the greater the likelihood that other providers will seek to improve their services and lower their prices.

¹⁶⁷ The Urbana-Champaign Big Broadband (UC2B) public network negotiated a similar partnership with a private entity.

¹⁶⁸ <http://www.cnet.com/news/googles-fiber-effect-fuel-for-a-broadband-explosion/>, accessed April 2015.

Competition in the market and consumer choice can be prioritized simultaneously with other objectives without negative consequences, and localities often find that focusing on the overall well-being of their communities and citizens has numerous advantages.

It is important to note, however, that there may be some risk involved with creating competition in the market. The service provider industry can be inhospitable, particularly to a public provider. A major challenge faced by networks built and operated by public institutions is opposition from existing, private-sector providers, as we previously noted. There are a number of reasons for this, some of which are related to perception while others relate to the market itself. Criticisms will range from allegations of cross-subsidization of expenses, using general or other funds for debt service coverage, to questioning the need or demand for public based connectivity services.

An important risk that the City should keep in mind is the potential for litigation from objectors ranging from incumbent providers to watchdog groups. Lafayette's LUS was sued by incumbent providers the same year it proposed creation of a separate utility for fiber-to-the-home-and-business,¹⁶⁹ and the Tennessee Cable Telecommunications Association filed a lawsuit against EPB.¹⁷⁰ These are only two examples of the litigation that public sector entrants to the market have faced from incumbent providers and others.

6.4.5 Ownership and Control of Assets

Retaining ownership of OSP assets is important to mitigate risk; owning assets is an important way for communities to retain some control of the network. This includes a scenario wherein a community pursues partnership with a private provider—a good way to balance risk and reward is for the City to maintain ownership and control of the assets while it assigns operational responsibilities to a private partner. This enables both parties to perform functions that highlight their strengths while not having to expend resources and energy attempting to carry out tasks for which they are ill-equipped.

Cash flow could potentially conflict with ownership and control of assets, depending on to what degree the City chooses to exert control. Maintaining a fiber optic network can be costly, particularly if the City opts to be the retail provider for the service. Operational expenses are a sizable and often unpredictable portion of overall network cost, and it can be difficult to get the take rate necessary to reach cash flow.

Other objectives either interact favorably or not at all with ownership and control of the assets. If the City retains complete control of the assets, it can make determinations about which

¹⁶⁹ <http://lusfiber.com/index.php/about-lus-fiber/historical-timeline>, accessed June 2015.

¹⁷⁰ <http://www.chattanooga.com/2007/9/21/113785/Cable-Group-Files-Suit-To-Try-To-Block.aspx>, accessed June 2015.

provider(s), if any, can offer services over the network. It can regulate which service providers offer services and to what degree, thus allowing for considerable quality control. For example, if a locality offers dark fiber agreements to multiple ISPs, it can determine specific metrics that guide the providers' service.

Similarly, the City may choose to oversee and maintain the network—a function with which it is already well accustomed and for which it is already staffed to some degree—and rely on a private partner to deliver retail services. The City may also be able to govern price points to support consumer affordability and service speeds to enhance performance. And because the City owns the network itself, it is in control of performance at that level.

6.4.6 Performance

Network performance can be a powerful differentiator for a community broadband endeavor. Many communities are already served to some degree by incumbent providers—whether by large national cable or telephone companies or small local ISPs.

Prioritizing performance in a municipal retail offering is not only advantageous, we believe it is necessary to make the offering stand out among existing broadband providers. Market entry is generally a major challenge for municipal retail providers, and even a public–private partnership will likely benefit from focusing on one or two highly specialized offerings to allow it to thrive among incumbents.

The City's FTTP enterprise will likely struggle and has a greater potential for failure if it attempts to compete with incumbent providers by offering services similar to existing packages. Instead, it is important to recognize gaps in the existing broadband market and seek to fill those with a unique service offering that incumbents are not currently able to provide. Our analysis suggests that a 1 Gbps niche service may enable the City to directly serve customers with an exceptional offering, or will enable a private partnership to enter the market and avoid competing with “me too” services.

A 1 Gbps service that is expandable to 10 Gbps and beyond may be the differentiator that the City needs to stand out. By focusing on an extremely powerful data-only offering and communicating with users about the potential advantages of a high-performance, unfettered data product, the City may spark the shift in the market it needs to be successful. The goal is to focus on *unbundling*, and effectively encouraging consumers to leverage the data service to its fullest capacity—by not emulating traditional providers and focusing on television lineup as a selling feature.¹⁷¹

¹⁷¹ It may be challenging to attract users who are accustomed to triple play services, but it will be a far greater challenge to compete with incumbent providers by offering the same packages, or “me too” services.

Performance interacts favorably or not at all with other objectives, which is shown in the visual breakdown in Figure 28. There are no disadvantages to prioritizing performance as a key objective in a community build, and we believe that this should be a main focus of any fiber enterprise.

As we noted, a 1 Gbps service offering can significantly disrupt the market by enabling OTT content and enabling consumers to make more flexible choices about the services they subscribe to, and the providers they select. This enables choice and competition in the market.¹⁷²

As we noted, if the City retains ownership of its assets, it also has better control over performance. The City—whether acting as the retail provider or overseeing a private entity who is serving end user customers—can command the performance that it deems appropriate to best serve the community’s needs.

Risk aversion and cash flow both interact well with performance. We believe that the City minimizes its risk by entering the market with a premium 1 Gbps high performance network. The City can set itself apart from other providers by offering a high-speed data product that incumbents cannot.¹⁷³ Further, it can differentiate itself by having an always-on extremely reliable service that customers can use in new and beneficial ways—like to operate a home-based business or telecommute to their job or pursue an advanced degree.

6.4.7 Affordability

Affordability is important even in communities that are fortunate to have few low-income areas—like Palo Alto. While this objective is certainly more important for vulnerable portions of the community, still affordability is often a necessary objective for localities. For example, the City may prioritize affordability in an effort to ensure that its entrepreneurs and tech startups can afford the robust connectivity necessary to support their business endeavors.

The City of Palo Alto is uniquely positioned with exceptional economic health, and few—if any—traditionally low-income areas. This is not to say, however, that there are not areas in the City where demand is low enough that private providers are unlikely to build there. Even without income disparity as a driving force behind cherry picking, private providers typically cherry pick based on where they determine they are most likely to recover their cost to build.

¹⁷² Note that this analysis recommends an initial offering of 1 Gbps service. Over time, incumbents may work to challenge the City’s FTTP offering, and the City will have to respond by evaluating its offering and potential changes it should make at that time.

¹⁷³ It is important to note that products like AT&T’s GigaPower and Comcast’s Gigabit Pro do not set their advertised 1 Gbps and 2 Gbps service as a baseline, which is what we have suggested to the City. Rather, these products offer a 10 Mbps to 100 Mbps baseline with the potential to offer 1 Gbps to 2 Gbps service as occasional exceptions. The City, on the other hand, may be able to provide service up to 10 Gbps and beyond with 1 Gbps as its baseline.

While the City is fortunate that it may not be faced with the choice to potentially offset service costs for a large number of low-income residents, still it may benefit from choosing to invest in infrastructure throughout the community.

Providing affordable service to the entire community would likely create benefit for the City in forms like enhanced quality of life and economic benefit. Further, the City could work with other local government agencies—for example, the Association of Bay Area Governments (ABAG)¹⁷⁴—to fully leverage benefits that are not monetarily quantifiable. These “benefits beyond the balance sheet” cannot be measured on a financial statement, but their impact communitywide is often profound. Bringing ultra-high speed affordable access to portions of the community that may have previously had little to no access to any connectivity may significantly enhance the quality of life, thus often raising a community’s overall desirability.

As we previously noted, prioritizing ubiquity may come at the exclusion of affordability for some consumers unless the City is able to offset costs in some other way. It could negotiate an agreement with one or more private partners that includes sensitivity to the need for affordable, accessible services in all parts of the community. Similarly, the City may decide that it is politically palatable to subsidize services for certain portions of the community.

Choice, competition, and ownership all interact favorably with affordability. If the City is able to reduce pricing to a level that is attainable to all of its residents, the expansion of choice and the likelihood of increased competition will be notable. And if the City retains ownership of its assets, it can make choices about affordability similar to the control it can exert over performance.

If the City decides to subsidize services, it may find that it becomes more difficult to prioritize risk aversion and cash flow. The more debt and responsibility the City takes on, the higher its risk and the longer it will take for the FTTP network to be cash-flow positive. Similarly, even if the City does not directly subsidize services, prioritizing affordability may mean pricing the product low enough that it is challenging to also prioritize risk aversion and cash flow. It will be important for the City to determine its priorities, and to strike a balance so that one objective is not achieved entirely at the exclusion of another.

6.4.8 Risk Aversion

Risk aversion is important and it is equally important to balance risk and reward. It may take considerably longer to design, build, and deploy a network if risk aversion is the City’s top objective. The “slow and steady” approach is not without merits, but it also does not necessarily give a community a competitive edge. Decreased speed to market—or building out slowly—gives competitors too much time to respond to the City’s approach.

¹⁷⁴ <http://www.abag.ca.gov/>, accessed August 2015.

Figure 29 shows a risk and reward matrix that highlights the City’s most likely low-risk-low-reward, low-risk-high-reward, high-risk-high-reward, and high-risk-low-reward outcomes. The lowest risk with the highest potential reward lies in building the network in a phased approach, specifically based on the Google build-to-demand model.¹⁷⁵ This approach signs up a community by neighborhood (known as “fiberhoods” in the Google Fiber model) and once a neighborhood has reached a certain threshold, fiber will be built there.

Figure 29: Risk and Reward Matrix

		Risk	
		High	Low
Reward	High	○ Deploy a ubiquitous communitywide FTTP build, partner with a private provider to operate the retail component, City maintains ownership and control of assets	○ Prioritize risk aversion to avoid bonding, slowly expand network in a phased approach and engage private partnership for operation and retail services
	Low	○ City attempts to compete with tiered services similar to incumbents – a “me-too” offering.	○ Maintain current network and do not pursue expansion of services

If the City chooses this approach, it must recognize that it necessarily sacrifices certain other objectives like affordability and consumer choice. Risk aversion will generally come at the expense of objectives like these, and is especially in conflict with a ubiquitous build-out.

These objectives do not have to be mutually exclusive; instead, the City has to decide to what degree it wants to prioritize which objective, and be prepared for possible conflicts and how to mitigate those. For example, if the City chooses a phased approach, it may opt to first expand service to a location that can demonstrate the power of the network. This will support marketing, and can potentially help convince consumers to sign up for service, thereby achieving ubiquity in a lower risk fashion.

¹⁷⁵ <http://www.wsj.com/articles/google-fuels-internet-access-plus-debate-1408731700>, accessed April 2015.

Risk aversion conflicts with ubiquity, choice, competition, and affordability. As we previously noted, it will be challenging to obtain a ubiquitous build-out at all, and especially not within a few years if the City prioritizes risk aversion as its key objective. Because the network is unlikely to be built out quickly in this case, it also reduces the likelihood of increased competition and choice. As we previously noted, the City's speed to market is critical to secure its potential competitive edge and take full advantage of its unique niche service offering. Further, affordability becomes more difficult to achieve because the City must align service fees to support self-sustaining operations. This means the monthly service will be priced higher to avoid City subsidy.

If the community chooses to prioritize risk aversion, it will align with ownership, cash flow, and performance. Ownership of the assets usually means lower risk for the City because it has greater control and flexibility.

6.4.9 Cash Flow

Becoming cash flow positive is a common important goal for any business or entity, and it is also a bit complex to define. Net income is often referred to as "cash flow," though this is technically incorrect because depreciation is a non-cash expense.

Earnings before interest, taxes, depreciation, and amortization (EBITDA) is the difference between operating revenues and operating expenses; it is a key metric in designing a viable financial model, along with net income. In a capital intensive business such as an FTTP enterprise, EBITDA must become positive quickly to keep the enterprise afloat. When EBITDA becomes positive, the business can be said to be cash flow positive. Net income then deducts interest, taxes, and depreciation.

Revenues are tied to an enterprise's ability to be sustainable or cash flow positive. Collecting revenues to pay off debt and support business operations bolsters the net income and increases the likelihood that it will become positive.

Several objectives may conflict with cash flow, like affordability, ownership, and ubiquity. As we noted, revenue collection directly impacts cash flow so higher revenues mean a greater likelihood of being cash flow positive. If the service is priced affordably, this may mean lower monthly service fees and a longer path to the enterprise becoming cash flow positive, or self-sustaining.

Ownership may also impact cash flow, especially if the City elects to retain ownership of all network electronics, including CPEs. Depreciation costs are significant, and it is important to reserve funds for equipment and infrastructure replacement. Typically, last mile and CPEs are replaced after approximately five years, core network equipment is replaced after seven years,

and outside fiber and facilities are replaced after 20 to 30 years. Because the useful life of fiber is considered to be 20 years or more, our financial analyses do not account for its replacement.

Another element of ownership in the context of cash flow is the need for network maintenance and locating costs. Because the City already owns a fiber network and has experience with locating, these additional costs will likely be incremental and less significant than a startup enterprise. Yet increased costs associated with serving an increased volume of end users may be significant in terms of both locating and replacing equipment at customer homes and businesses.

7 Potential for Public–Private Partnership

As Section 6 discussed, vendor categories can and should be expanded to explore the potential for public–private partnership, where the City and a private entity work together to achieve mutual goals for the FTTP network. While this model is newly emerging, we believe that engaging a private partner may enable the City to take advantage of opportunities to mitigate risk and maximize opportunity.

Section 6 noted that bringing a fiber connection to every home and business in the community (ubiquitous FTTP deployment) is a primary objective for many localities—this is one of the City’s chief goals. Designing and deploying a network that reaches every area¹⁷⁶ of the community accomplishes this common objective, but at a cost. To achieve this and other goals, the public sector is in the early stages of exploring partnerships with private providers to reduce the risk of deploying and operating next-generation broadband networks. This may prove to be an especially useful way to more quickly deploy the network and increase a municipal provider’s speed to market—thus reducing the time competitors have to react negatively.

Broadband networks support 1 Gbps speeds and beyond, setting them apart from the legacy copper networks favored by incumbent providers. Fiber also supports symmetrical speeds—a key differentiator for Internet service from Google Fiber and other innovators compared to incumbent telephone and cable companies where upload speeds lag far behind download speeds.¹⁷⁷

Many communities and localities are likely aware of Google Fiber and municipal fiber success stories¹⁷⁸ such as Chattanooga, Tennessee’s EPB and Lafayette, Louisiana’s LUS. Yet these are only the highest profile examples of successful FTTP deployment. Many other communities may be unable to allocate other resources or funds to the fiber enterprise, or they may lack the population to attract Google Fiber,¹⁷⁹ or the capital and expertise to deploy and operate a network on their own. Because of these and other factors, many communities are turning to unique public–private partnership models.

¹⁷⁶ Given the scope of construction, the network will be deployed in stages, and some neighborhoods will necessarily be served before others.

¹⁷⁷ As we previously noted, GPON technology is inherently asymmetrical. See our previous discussion of this and oversubscription to the Internet.

¹⁷⁸ In many cases, the FTTP network implementation was funded with reserves or other sources, and the operation of the FTTP network is supported with subscriber revenues.

¹⁷⁹ Please note that all of the City’s objectives might not be reached in partnership. For example, with Google Fiber the ubiquity goal is not necessarily achieved. It is important for the City to determine which objectives are its priority.

These partnerships are often tailored to the communities that develop them and entail specific parameters that directly benefit both the community and the chosen private partner. Some examples are traditional public–private partnerships that resemble highway and toll-road construction projects. In other cases, public entities may encourage new investment through economic development incentives and other measures to reduce costs for infrastructure deployment. Finally, there are hybrid models where a locality and private entity share the capital costs, operation, and maintenance of a broadband network.¹⁸⁰

Here we provide an overview of three models for public–private partnerships, including examples of some that have been recently developed. We further offer a framework for the City to consider as it evaluates potential models and attempts to determine which—if any—are best suited to its needs. A successful partnership must consider tradeoffs in risk, benefit, and control to help maximize benefits for the public and private partners.

7.1 Broadband Public–Private Partnership Framework

As the City evaluates broadband public–private partnership models, it should focus on opportunities and potential pitfalls, and consider the following key factors:

- Risk
- Benefit
- Control

These factors are important considerations for both the City and its potential service provider and/or vendor partner(s). A successful partnership must consider tradeoffs in risk-benefit-control to help maximize benefits for public and private partners, and there will inevitably be some tradeoff within this framework for each model.

For example, the higher the public investment, the higher the City’s risk. Aside from fortunate communities that win the "Google lottery" or attract another private partner willing to invest its own capital, most public–private partnerships will require some public investment, which involves risk for a community. But as public funding increases, so does public control over the project itself, including the ability to focus on specific outcomes.

Contrast this with a private investment model where the public sector may be focused solely on engagement and planning. Such a model entails lower public cost and reduced public risk, but it also means the City’s benefits are more modest and the private sector partner(s) completely control infrastructure deployment.

¹⁸⁰ CTC’s 2011 report to Palo Alto proposed potentially using the Fiber Fund Reserve to build hub sites and neighborhood nodes as an incentive for a private firm to build out the last mile. The staff memorandum containing that report can be found at <http://www.cityofpaloalto.org/civicax/filebank/documents/27421>, accessed June 2015.

Finally, a model designed around shared investment and risk can yield opportunity and benefits both for the City and its partner(s). In such a model, each side of the public–private partnership focuses on its unique strengths while relinquishing other responsibilities and duties to the other partner. For example, the City may opt to fund the construction and deployment of the physical network and preliminary messaging to the public while the partner(s) is tasked with actual deployment and eventual operation overseeing the relationship with end users.

It is important to note that we have only a handful of data points on different models for broadband public–private partnerships. Google has, through its pilot deployments, alerted other companies that there is a business opportunity in community broadband and an increasing number are emerging as potential investors and partners. As a result, there is a range of opportunities for the public sector, but no clear-cut strategy. This is new territory and any community that opts to proceed is necessarily taking on some risk. However, the potential benefits are considerable and the opportunity for public sector innovation and creativity has never been higher.

7.1.1 Risk

There is simply no way to altogether avoid risk if the City chooses to proceed with some level of municipal involvement in deploying a broadband network. But calculated risk can and often does yield benefits that would otherwise have been unattainable. One of the most enticing components of a public–private partnership is that it can considerably reduce a locality’s risk while helping achieve a community’s broadband goals.

Public funding to support the partnership will likely be one of the City’s greatest risks. It will likely entail some risk for the City to retain a level of ownership and control of the assets because it will likely require public funding—either through municipal bonds or leveraging tax or other funds.

The City may enter into an agreement that requires it to directly seek bonding for capital investment, or it may find a partner that is willing to use its own capital, such as in a concessionaire model (see Section 7.2). It is important to note that even if the City does not directly seek bonds, some partnership models may impact the City’s credit rating and bonding ability, depending on how the private partner secures financing.¹⁸¹

Operations tend to be unpredictable and costly and often represent a great risk for municipal fiber networks. Cities that try to enter the retail market directly are often targeted by hostile

¹⁸¹ This potential is highest in the concessionaire model.

incumbent providers that make it challenging for the municipality to compete.¹⁸² This can include difficulties as serious as costly litigation. Part of the attraction to the public–private partnership model is that private entities tend to be equipped to understand the retail business and react to market conditions quicker. This expertise helps the City mitigate its operation risk, though there is no guarantee that either party in a partnership can avoid risk altogether.

7.1.2 Benefit

As the City considers this endeavor, it should continually weigh the benefits it might expect to receive as part of a public–private partnership against its potential risk. One positive component of emerging partnerships nationwide is that there is potential for a great degree of flexibility. That is, the City is in a position to consider its priorities and pursue those benefits on the frontend of a partnership arrangement.

Conversely, although public–private partnership models are relatively new and evolving all the time, there are several recent examples that the City can look to as guidance on how it might want to proceed. Not enough time has elapsed to fully map what long-term benefits of partnership might look like, but there are some lessons that can be picked up from some communities that have sought various degrees of partnership.

Although benefits cannot be adequately calculated at this stage, the City can potentially look to other communities to get a sense of the goals other partnerships prioritized for the public entity’s benefit. This may help the City determine how to balance its risks, and which areas to focus on in its pursuit of a partner.

7.1.3 Control

Because this is the start of the City’s endeavor, it can choose in the negotiation process its desired level of involvement in infrastructure deployment, network maintenance, and operations. That is, the City can essentially determine from the outset what level of involvement it would like to have at every stage and in every arena of the public–private partnership process.

There are numerous ways that the City can retain some control within the public–private partnership, and perhaps the most important is through retaining ownership of the physical assets. Again, there is a balance to be struck with risk—it is likely that the City will be required to fund at least part of the capital investment in assets if it hopes to retain control of these.

The flip side of this is the more ownership the City has, the greater degree of control it can maintain. This enables the City to make decisions about placement of the assets, rate of

¹⁸² While this analysis cannot cover the exhaustive range of all potential threats to the municipal retail offering, a municipality that enters the retail market may be subject to a variety of legal and other threats, and may need to develop contingencies. We encourage the City to consult closely with qualified industry legal counsel.

deployment, and the network's overall footprint. Further, it ensures that if the partnership does not succeed, the City still has a physical asset that it can use to deliver services directly or to negotiate a new partnership.

Ownership of assets is an important way the City can retain control. There are also other potential mechanisms that enable the City to retain some control over the network and enterprise, and to ensure that the partnership consistently works in its favor. For example, the City may negotiate certain contractual provisions that provide it with some amount of control.¹⁸³

7.2 Model 1 – Public Investment with Private Partners

One public–private partnership model involves substantial public investment. It is a variation on the traditional municipal ownership model for broadband infrastructure, in which a public entity takes on all the risk, but also has full control of the project.

The emerging innovation makes use of the traditional public–private partnership structure used in Europe and increasingly in the U.S. for infrastructure projects such as highways, toll roads, and bridges, where a private partner takes responsibility for design, construction, financing, operations, and maintenance.¹⁸⁴ The model seeks to leverage the strengths of the private sector to deliver turnkey services and solutions over an extended time of 20 to 40 years.

For example, the state of Maryland is pursuing private companies to design, build, operate, and help pay for a light-rail project to serve the Washington metro area suburbs.¹⁸⁵ Under the proposed public–private partnership, Maryland and private partners would split the construction costs for the project and the state would later reimburse the private construction costs over five years. The private sector would assume the financial risks of any construction delays or cost overruns. The state would then pay the private partners a concessionaire to operate and maintain the line for 30 to 35 years.

We are now seeing the public–private partnership model applied to broadband in the U.S. market. Though, we have seen it in other construction projects, broadband is new because unlike transportation infrastructure, broadband is to a certain extent a competitive marketplace. Thus, applying it to broadband is new and innovative, but also creates a political

¹⁸³ The City's legal counsel can determine the best contractual mechanisms to consider in the context of a public–private partnership; CTC cannot provide legal guidance.

¹⁸⁴ "Financial Structuring of Public–Private Partnerships (P3s)," U.S. Department of Transportation, 2013, http://www.fhwa.dot.gov/ipd/pdfs/p3/factsheet_04_financialstructuring.pdf (Accessed April, 2015).

¹⁸⁵ Katherine Shave, "Maryland gets approval to seek public–private partnership to build, operate Purple Line," *Washington Post*, Nov. 6, 2013, http://www.washingtonpost.com/local/trafficandcommuting/maryland-transportation-officials-get-approval-to-pursue-private-partners-for-purple-line-deal/2013/11/06/93c1546a-470b-11e3-bf0c-cebf37c6f484_story.html (Accessed April, 2015).

and financial risk for the public sector, given that public–private partnerships often provide a guaranteed revenue stream to a private partner.

If the broadband network is unsuccessful at generating revenues the public sector remains on the hook for those payments. Despite these risks, the model offers considerable benefits to the public sector by removing significant financial and logistical barriers to large-scale public broadband projects.

Macquarie Capital and partner companies have pioneered the model in the U.S. Macquarie is an Australian investment firm that provides advisory and capital raising services to corporate and government clients in areas such as infrastructure, utilities, telecommunications, media, entertainment and technology.¹⁸⁶ They are currently in the midst of a complex process with localities that are members of the UTOPIA Network, an FTTP network in Utah that is owned by 15 member communities.¹⁸⁷ Following a 6–5 split among the 11 member cities, the UTOPIA board voted in 2014 to turn over operation and management of the network to Macquarie.¹⁸⁸ The private company will finish construction of the network and provide Internet service to all residents for 30 years in exchange for a monthly utility fee paid by the residents of the member communities.

The proposal is attractive given the turnkey private financing, deployment, operations, and revenue-sharing solutions that Macquarie can deliver. However, the requirement of guaranteed public funding in the form of a utility fee to all residents is not politically viable for some communities. As a result, a small handful of UTOPIA member communities have dropped out of the proposal. The City may find that because of the strong libertarian presence, it could struggle to gain public approval of any additional utility fees or taxes, and this may make the Macquarie model especially challenging to pursue.

Macquarie is also working with the Commonwealth of Kentucky on a private–public partnership to build an open-access, middle-mile broadband network across the state.¹⁸⁹ Under the partnership, the Commonwealth will own the network and contribute some funding for construction. Macquarie will finance the bulk of construction and have a 30-year contract to

¹⁸⁶ <http://www.macquarie.com/us/about/company/macquarie-capital#> (accessed April 2015).

¹⁸⁷ <http://www.utopianet.org/about-utopia/> (accessed Apr. 24, 2015).

¹⁸⁸ Benjamin Wood, “UTOPIA board votes to move forward with Macquarie deal,” *Desert News*, June 30, 2014, <http://www.deseretnews.com/article/865606086/UTOPIA-board-votes-to-move-forward-with-Macquarie-deal.html?pg=all> (accessed April 2015).

¹⁸⁹ Rachel Aretakis, “Partnership to build high-speed broadband network in Kentucky,” *Louisville Business First*, Dec. 23, 2014, <http://www.bizjournals.com/louisville/news/2014/12/23/artnership-to-build-high-speed-broadband-network.html?page=all> (accessed April 2015).

operate and maintain the network. Revenues generated by leasing the network to Internet providers will be split between the Commonwealth and Macquarie.

The public sector is not dependent solely on private parties like Macquarie to develop similar projects. There are likely other entities that would engage in this type of arrangement that leverages private sectors strengths while recognizing that some public funding is necessary to enable next generation connectivity. Public investment and public–private partnership models that leverage private partners with turnkey solutions are attractive because they remove significant challenges from public sector, but also require a community to take on some risk. As a result, the model will appeal to some communities, but not to others.

7.3 Model 2 – Public Sector Incenting Private Investment

In another model of public–private partnership, the cost to the public sector is significantly reduced. The model focuses on more modest measures by the public sector to enable or encourage greater private sector investment. The most prominent example of the model is Google Fiber, including its deployments in Kansas City and Austin.

The model is seen as the ideal for many communities given that public cost is minimized and Google’s requirements have largely focused on engagement with the company and making local government processes more efficient. In return, communities fortunate enough to attract Google’s investment not only benefit from the company’s own deployment of FTTP infrastructure, but also upgrades from the incumbent cable and telephone companies. The model relies on the private companies to make the investment, while partner communities take certain steps to enable them come into the market to build in an expeditious, efficient, low-cost manner. Though Google Fiber is the most prominent example, there is significant interest by smaller companies as well who may not be able to deploy FTTP but deliver next-generation broadband to businesses and intuitions on a more targeted basis.

Even as the cost/risk for public sector is largely reduced compared to other models, there is a potential public relations risk. Public expectations can get very high with the announcement of new fiber deployment. If the community is strongly identified as a partner, when something goes wrong with private sector business plan or deployment, the public sector may held accountable for the private sector failure.

There are a number of strategies localities can take to encourage new private investment and reduce some of the costs and time for private sector entities to deploy advanced broadband services. They can take the form of specific economic development incentives such as tax benefits to encourage providers to build new infrastructure. For example, MetroNet, a small Midwest Internet provider, developed a partnership with the City of Crawfordsville, Indiana to

purchase the municipal utility's fiber network. The city is assisting MetroNet with financing the purchase and expanding the footprint of the fiber network.¹⁹⁰

MetroNet has entered other communities where they did not purchase existing infrastructure, but where the municipality has provided other tax benefits, and modified permitting process to allow for ease of access. Again, a major consideration for a partner like this is the high likelihood that the private entity will *not* build to all areas of the community. If a private company is not beholden to the City via a clearly articulate partner relationship, it is unlikely that the private company will build to areas of the community where it does not anticipate easily recovering its costs.

Another key strategy is to develop and strengthen the local infrastructure assets that enable the deployment of broadband.¹⁹¹ These include public assets such as fiber, conduit, and real estate. For example, new network deployments can benefit enormously from access to existing government fiber strands, underground communications conduit in which fiber is placed, or real estate where equipment or exterior huts can be located. The City's existing fiber network and infrastructure may be usable to some degree to incent private investment—for example, a private entity may need access to only a small amount of dark fiber to serve certain areas.¹⁹²

Communities can further facilitate the underground construction of conduit and fiber by implementing a “dig-once” policy for all road and related transportation projects, and facilitating in-building access for new providers through construction specifications for new buildings. These policies are generally implemented through revisions to existing municipal codes or by developing new ordinances.

Building and expanding your broadband assets over time is a low-cost, low-risk strategy that will have real impact and expand options down the road. For example, Mesa, Arizona began a dig-once initiative in the early 2000s to install its own rings of conduit during private sector construction projects, and then to sell access back to the private sector. Anytime the city was required to open up a street, such as to install water or sewer utilities, it also put in conduit.¹⁹³ In some instances, the City also added fiber to empty conduit for city purposes or to potentially lease out to private providers. In total, the city installed 150 to 200 miles of conduit. The City in

¹⁹⁰ “MetroNet plans to expand current fiber optic system,” “The Paper of Montgomery County Online, Mar. 18, 2014, <http://thepaper24-7.com/Content/News/Local-News/Article/MetroNet-plans-to-expand-current-fiber-optic-system/23/22/44447> (Accessed May 2015).

¹⁹¹ “Gigabit Communities: Technical Strategies for Facilitating Public or Private Broadband Construction in Your Community,” CTC Technology & Energy, Inc., Jan. 2014, p. 6 – 12, <http://www.ctcnet.us/wp-content/uploads/2014/01/GigabitCommunities.pdf> (Accessed May 2015).

¹⁹² As we previously noted, the City's existing dark fiber infrastructure must be fully evaluated to determine what, if any, portion of it is usable for the FTTP network.

¹⁹³ “Transcript: Community Broadband Bits Episode 139,” Institute for Local Self-Reliance, Feb. 26. 2015, <http://muninetworks.org/content/transcript-community-broadband-bits-episode-139> (Accessed April, 2015).

particular targeted four economic development areas, including developing redundant conduit, fiber, and electric infrastructure. Among those areas was land around the Phoenix-Mesa Gateway Airport, where Apple recently announced that it would invest \$2 billion to build a data center for the company's global networks investment.¹⁹⁴

A second important strategy is to improve access to information—an asset that communities might not have considered. Sharing information demonstrates a willingness to engage with the private sector to spur investment. Communities should seek to make data available wherever possible both for public and private uses.

GIS or similar databases that hold such information as street centerlines, home, and business locations, demographics, existing utilities, locality infrastructure, rights-of-way, and available easements can be extremely helpful for a locality's own broadband planning, potential public-private partnerships, or a network service provider that is evaluating the deployment of new infrastructure into a community.

Access to this information may attract and speed new construction by private partners, while enabling the community to meet its goals for new, better broadband networks—and potentially to realize revenues for use of the assets.

Finally, localities can take steps to make government processes around permitting, rights-of-way access, and inspections more efficient and smooth to help with broadband construction. These actions can signal to private partners that there is an investment opportunity in the jurisdiction and that the locality will not be a bottleneck or create additional costs. These steps should take into consideration the needs of the community, balance public interest and public safety, and account for local resources and capacity. For example, localities should be fully transparent about the range of permitting and rights-of-way processes, including timelines, to enable the communication industry to expeditiously plan and deploy networks.

The above strategies (including assets, data and efficient processes) can make a difference in the economics of build out for a private partner. However, they will not dramatically change the underlying economics of broadband networks construction and service. In a best-case scenario, the public sector can potentially reduce the construction of a broadband network in a way that can be substantial but not transformative for developing next-generation broadband infrastructure.

Indeed, many incumbent providers overstate the extent to which communities and regulation are the problem. If a community is offering the equivalent of economic development or other

¹⁹⁴ <http://azgovernor.gov/governor/news/governor-doug-ducey-announces-major-apple-expansion-arizona> (Accessed April, 2015).

benefits to a company to entice them to invest in next generation infrastructure that is different than the business relationship a community already has with existing providers and incumbents. Communities can and should offer those benefits to incumbents if they will also invest in the same kind of next-generation infrastructure. Communities should be wary of private sector entities seeking benefits without offering concrete investment proposals. From a business standpoint, incumbents do not need additional benefits to keep maintaining their existing broadband networks and services. The City of Palo Alto participated in responding to the Google Fiber City Checklist process in 2014.

7.4 Model 3 – Shared Investment and Risk

A public–private partnership model based upon shared investment and risk plays to the strengths of both the public and private sector partners. Any locality thinking about an FTTP deployment is not doing so because it is a moneymaker or a good strategy for bringing in new revenues. Rather, it is a powerful strategy for education, healthcare, and economic development. Thus in a shared investment model, from the standpoint of a locality, the risk is shared but the community still receives 100 percent of indirect benefits, even if they all do not all appear on the project’s financial statements. For the private partner, it means less upfront investment and capital (risk), with an opportunity for future revenues.

This model offers an extraordinary opportunity for innovation. However, we are in the early stages of what it looks like—and the model is in no way a sure thing for communities. In 10 years, we may be able to look back and have the data points to develop the best practices necessary for success. At the moment though, early actors are developing new and exciting partnerships to bring next-generation broadband to their communities. In the following case studies, we briefly describe some of those projects.

7.4.1 Case Study: Champaign–Urbana, Illinois

The University of Illinois and the two cities of Champaign and Urbana, Illinois have worked together over the past number of years to expand broadband infrastructure and connectivity across the area. Those efforts included the development of the Urbana-Champaign Big Broadband (UC2B) network, which is now owned and operated by a not-for-profit (NFP) corporation.¹⁹⁵ Through a range of different strategies and by leveraging local private capital, state funds, and federal funds, UC2B built fiber rings specifically engineered to enable FTTP deployment in the most cost-effective manner. It also built FTTP in select parts of the community with lowest adoption rates on theory that those parts of the community would be the last place private sector would deploy; so the public sector went there first.

¹⁹⁵ <http://uc2b.net/about/> (Accessed April, 2015).

U2CB leveraged its existing investment to attract a private partner, iTV-3, an Illinois company with FTTP experience. The two partners, entered into an agreement that gives iTV-3 access to U2CB fiber through an indefeasible right of use (IRU) at no cost in return for meeting community's goals of deploying additional FTTP with the following requirements:¹⁹⁶

1. Gigabit service speeds
2. Wholesale access on the network to competing companies
3. No cherry picking – all neighborhoods have equal opportunity to get services if presales reach 50 percent of residents

Under this model, Champaign–Urbana receives 100 percent of economic development and other benefits in return for taking on approximately 30 percent of the (cost) risk. It also means the community can now focus on driving demand and adoption, while relying on an experienced private partner to handle customer service, marketing, and operations.

7.4.2 Case Study: Garret County, Maryland

Garret County, in far western Maryland, is a relatively remote community in Appalachia surrounded on two sides by West Virginia, on one side by Pennsylvania. The County has struggled to get broadband in a number of remote parts of the community. Where broadband is available, it is inadequate DSL service that does not meet the FCC's minimum definition for broadband, let alone the requirements for home-based businesses. The incumbent provider has not made any plans to expand or upgrade service offerings.

Though mobile broadband is available, bandwidth caps mean that it is not viable for economic or educational activities. For example, parents who home-school their children can run through their bandwidth cap in one day of downloading educational videos. Beyond these challenges for residents, the county has struggled to attract and retain businesses.

In response, the County has gradually and incrementally built out fiber in some areas, with a focus on connecting specific institutions. It is now in negotiations with a viable private partner to leverage some of that fiber and additional public funding to support the deployment a fixed wireless broadband network that will serve up to 3,000 homes in the most remote parts of the county. The private partner will also put its own capital toward the construction of the network, along with its technical and operational capabilities to manage the network. The partnership may involve significant cost to the County, but also massive benefit for residents and business in the newly served areas.

¹⁹⁶ <http://uc2b.net/wordpress/wp-content/uploads/2014/05/UC2B-iTV3-Press-Packet.pdf> (Accessed April, 2015).

7.4.3 Case Study: Westminster, Maryland

Westminster is a bedroom community of both Baltimore and Washington, D.C., where currently 60 percent of the working population leaves in the morning to commute to work elsewhere. The area has no major highways and thus, from an economic development perspective, has limited options for creating new jobs. Incumbents have also traditionally underserved the area with broadband.

The City began an initiative 12 years ago to bring better fiber connectivity to community anchor institutions through a middle-mile fiber network. In 2010, the State of Maryland received a large award from the federal government to deploy a regional fiber network called the Inter-County Broadband Network (ICBN) that included infrastructure in Westminster.

Westminster saw an opportunity to finish the goal of the network by expanding the last-mile of the network.

At the time, though, it did not have any clear paths to accomplish the goal. City leaders looked around at other communities and realized quickly that they would have to do something unique. Unlike FTTP success stories such as Chattanooga, Tennessee they did not have a municipal electric utility to tackle the challenge. They also did not have the resources, expertise, or political will to develop from scratch, a municipal fiber service provider to compete with the incumbents. As a result, they needed to find a hybrid model.

As the community evaluated its options, it became clear that the fiber infrastructure itself was the City's most durable asset. All local governments spend money on durable assets with long lifespans, such as roads, water, and sewer lines, and other infrastructure that is used for the public good. The leaders asked, why not think of fiber in the same way? The challenge then was to determine the breakdown of the network: What part would the private sector partner handle and what part could the City take responsibility for?

The hybrid model that made the most sense required the city to build, own, and maintain the dark fiber¹⁹⁷, and to look to partners who would light the fiber and handle the customer service relationship with residents and businesses.

The model would keep the city out of operational aspects where a considerable amount of the risk lies in terms of managing the technological and customer service aspects of a network. The City solicited responses from potential private partners through a request for proposal (RFP). Its goal was to determine who was interested in the project, and who shared the City's vision.

¹⁹⁷ Fiber configured to support a GPON architecture.

It was challenging to find partners who were willing to share infrastructure and operations. Eventually the City selected an upstart ISP called Ting, with a strong track record of customer service as a mobile operator. Ting shared Westminster's vision of a true public-private partnership and of maintaining an open access network.

Under the terms of the partnership, the City is building and financing all of the fiber (including drops to customer premises) through a bond offering and tax dollars from the property tax base. Ting is leasing fiber with a two-tiered lease payment. One fee is based upon the number of premises the fiber passes (as the network grows both in size and customers there is an upside for the community) and the second fee is based on number of subscribers they enroll.

As the network grows, Ting will help fund the network capital expenditures, which will lessen the financial burden on Westminster. In the future, additional operators may become partners on the network as well, opening the door to additional services for the community and revenues for the city.

7.5 Define the City's Objectives

As the City considers its roles and responsibilities in a public-private partnership, it is important for its key goals or objectives to be clearly defined. This will help City officials and staff articulate priorities in advance of a potential partnership negotiation, which should in turn help the City manage its potential risks by identifying strengths and vulnerabilities ahead of time.

Ubiquity is often a top priority for public entities, and one that officials and staff can easily identify—bringing fiber to every resident and business in a community is can significantly increase quality of life and economic development opportunities. It is also politically palatable and can help incite the public to support a locality's FTTP project. This is one of the City's stated goals: it will not cherry pick, but will prioritize building to every area of the community.

Another important objective that may be more difficult to identify and especially challenging to define in the context of a public-private partnership is ownership and control of assets. Precisely what it means to own and control assets may vary from one community to another, and it is important for each locality to determine where on the spectrum its priorities lie.

The City of Palo Alto has experience maintaining an existing dark fiber network and may be comfortable retaining full ownership and control of the physical assets, including routine and emergency fiber maintenance. It is at an advantage over communities that are building fiber for the very first time and may find that responsibility daunting, and could even discourage pursuit of an FTTP deployment. For the City, retaining ownership of OSP is likely a minimum priority—it may be more complex to determine whether owning and maintaining network electronics is attractive.

7.6 City and Partner Responsibilities

The City should determine what role it expects to take on in design, deployment, and operation of the FFTP network before it moves forward with any type of relationship with the private sector. While this can and should be flexible, the City should have some sense of what it is absolutely *not* willing or able to do, and what functions it *must* retain in-house. For example, the City may be unable to turn over some aspects of fiber maintenance to a private provider.

Various partners bring different skillsets and experience to the potential relationship, and the City should remain open to all the potential functions a partner can perform. For example, the City may initially expect that it will perform all network maintenance on the new FFTP network, but ultimately finds that a partner wishes to take on some or all of these duties. The City can expect that each potential partner or vendor will possess its own unique approach to FFTP deployment and operation, and there may be minimal flexibility on some aspects of a partner's business model. Ultimately, whether it opts to pursue a true partnership where it takes on certain roles, or to engage a vendor where the City turns over all responsibility to a private entity, the City is pursuing a relationship, and its parameters should be clearly defined.

The City could consider retaining ownership and control of the fiber assets and engage a private partner to manage the wholesale and retail components of the FFTP network. Because the City has experience maintaining and overseeing a dark fiber network, costs to continue this and add responsibilities for the new FFTP network should be incremental. Further, the City then retains control of the fiber to ensure that it functions to the City's standards.

Even if the FFTP network is separate from the existing dark fiber network (e.g., the existing network does not contain enough spare capacity to support an FFTP expansion), the City may want to retain control of the new asset to ensure its functionality is comparable to the existing network. Further, this ownership allows the City to reclaim the fiber if the partnership does not work out—and it then has a physical asset that it can operate itself, or that it can use to attract new investment and/or partnership.

Effective customer acquisition, marketing, and sales campaigns are generally expensive and require a skill set that public entities may not possess without hiring additional staff and/or contracting services with a third party. Because the City does not have experience with marketing and advertising an FFTP network or a similar undertaking, it may be prudent to consider leaving this task to the private partner. A partnership should allow for both the public and the private entity to capitalize on their strengths and shift other responsibilities to the other partner.

7.7 Develop a Request for Information

Implementing policies that are friendly to the private sector are a good way to indicate that the City wants to incent private investment there, and a more direct way to engage the private sector is to issue a request for information (RFI). Such a document would clearly articulate the City's needs and desires and invite private companies to respond and outline their unique approach to solving the City's connectivity needs.

An RFI process can be a great for localities to garner information from the private sector about companies that may be interested in partnering with the City to some degree. An RFI does not have to stringently outline all of the City's goals or create strict parameters about how its objectives will best be met. Rather, an RFI can express a City's desires and lay out any non-negotiable items (such as no cherry picking) but leave room for a private partner to respond creatively.

Indeed, we encourage any locality that considers issuing an RFI to exercise caution in the degree to which it specifies its requirements of a public partner. An overly detailed RFI may scare off potential respondents who do not believe they possess all the staff or qualifications to meet a strict list of demands outlined by the locality.

One final consideration in the potential for going through an RFI process is that not all potential partner companies will directly respond. This should not discourage the City from issuing an RFI—such a document is extremely valuable not only for getting a sense of who responds, but also for outlining the City's goals. For example, if the time period to respond to the RFI ends and no viable partner has emerged, or if for some reason negotiations with a chosen partner do not pan out, the City will likely find that the RFI remains useful for attracting and communicating with private companies.

Finally, it is important to be realistic about what a partnership for an FTTP network may entail on behalf of both parties.¹⁹⁸ Again, the City must develop its own understanding of its desires, goals, and requirements for an FTTP network. Once it has clearly defined what it hopes to achieve through pursuing FTTP deployment, it can summarize this in an RFI to allow potential private partners to respond based on their own ability and willingness to help meet the City's needs.

7.8 Additional Considerations for Public-Private Partnerships

It is important to approach various models and proposals for public-private partnership with common sense and skepticism as public sector entities of all sizes and capacities evaluate them.

¹⁹⁸ Jon Brodtkin, "Skeptics Say LA's Free Fiber Plan As Plausible As Finding a Unicorn," *Ars Technica*, November 8, 2013, <http://arstechnica.com/information-technology/2013/11/skeptics-say-las-free-fiber-plan-as-plausible-as-finding-a-unicorn/> (Accessed May 2015).

Next-generation fiber deployment, particularly on a large scale to reach all residents and businesses in a community, is a valuable and potentially future-proof investment. But it will not be cheap or easy. The City should ask any private provider that claims otherwise or asserts that it will deliver enormous benefits or revenues at no cost should for examples of projects where it has accomplished what it is promising. If it were easy, there would be enormous private investment in FTTP across the country. Unfortunately, there will always be entities trying to sell snake oil with unrealistic business plans. Communities should be wary of rosy projections.

There are several examples of municipal or public fiber endeavors that may have started strong but have struggled to stay afloat, or have even had to sell assets or otherwise enter into agreements in which they are forced to relinquish a great deal of control. Tacoma Click! is one example of a public network that consistently struggled to become viable, and ultimately entered into discussions with two separate private entities to essentially “take over” network operations.¹⁹⁹

Further, some supposed success stories leave out special circumstances that enabled the enterprise to prosper. For example, a municipal provider that enters a market where there is little or no competition has an advantage that often cannot be replicated. Other fiber endeavors may have been heavily subsidized through funding sources that are not available in all communities. For example the Chattanooga Electric Plant Board (EPB) received federal grants to assist in its FTTP deployment.

It is also critical for the City to seek private sector partners that are interested in developing meaningful partnerships to deploy next-generation infrastructure. For example, a significant risk around economic development incentives and other measures to facilitate private investment is that companies will request that localities take on certain costs; for example, a private partner might ask the local government to hire dedicated inspectors and provide free access to real estate—and provide in return only tacit commitments for new services or technological upgrades. If a company is a true partner, it will be willing to make firm commitments in return for the actions the locality takes to lower infrastructure deployment costs. The goal of these partnerships is not simply to shift private sector costs to the public sector.

In addition, partners and partnerships will differ in different parts of company, and with the size of community. A primary challenge for localities seeking to build to every residence and business is that the larger the community, the more difficult it may be for a private partner to deploy its service universally.²⁰⁰ By taking on the risk of fiber construction and finding a partner

¹⁹⁹ <http://www.thenewstribune.com/2015/04/22/3754054/tacomas-rainier-connect-makes.html>, accessed June 2015.

²⁰⁰ Sonic.net is an example of this.

to light the network and provide service, a locality can increase the potential for ubiquitous build-out to every location.

Finally, do not underestimate the importance of the political element in tackling these challenges. Political concerns will play a huge role in finding solutions, regardless of the size of the community. Community and political leaders must jointly decide to pursue a project of this scope, to solve the problems that may arise along the way, and to bring fiber and its benefits to the community.

8 Cost and Financial Analysis for FTTP Deployment

The financial analysis in this section assumes the City owns, operates, and provides retail services to residents and businesses in the community. This financial analysis is based on a number of assumptions (outlined in Section 8.3 below, and further detailed in Appendix B), and these have been vetted with City staff.

Note that this analysis uses a flat model, using a base assumption that revenues will increase over time to offset increased expenses. The model assumes that subscribership will ramp up over years one through three, and then remain steady. The purpose of the flat financial model is to avoid introducing inflation adders that may incorrectly represent—and overstate—the projections. See Appendix B for the detailed financial and cost analysis.

The financial model is designed to be cash flow positive in year one—this is accomplished through bond and loan financing. Given the cost to construct, maintain, and operate the FTTP network a 72 percent take rate of households and businesses passed is required to maintain positive cash flow.

In the analysis we assume three services are offered:

- A 1 Gbps residential service at \$70 per month,
- A 1 Gbps small commercial service at \$80 per month, and
- A 1 Gbps medium commercial service at \$220 per month (has some service level agreements with service)

A 1 Gbps high-speed data offering for \$70 per month for residential customers and \$80 per month for small business users is a good benchmark for the City to pursue. This is Google's price point, and is lower than some other providers. For example, Ting Internet recently announced that it will be serving Charlottesville, Virginia with a 1 Gbps offering for \$89 per month.²⁰¹

For businesses we assume that 40 percent will obtain the higher-level service.

Please note this analysis does not indicate or review whether that obtaining this required take-rate is realistic. The model does show the breakdown of expenses by function and provides insights on how a public-private partnership might seek to reduce operating expenses to improve the viability of a FTTP deployment in Palo Alto. The complete model is provided in Appendix B.

²⁰¹ <http://www.reuters.com/article/2015/06/15/idUSnGNX1v7Cv8+1c4+GNW20150615>, accessed June 2015.

Please note that we used a “flat-model” in the analysis. With a “flat-model”, inflation and salary cost increases are not used in the analysis because it is assumed that operating cost increases will be offset and passed on to subscribers in the form of increased prices. Models that add an inflation factor to both revenues and expenses can greatly overstate net revenues in the out-years since net revenues would then also increase by the same inflation factor.

8.1 Financing Costs and Operating Expenses

This financial analysis assumes a combination of bonds and loans will be necessary. We expect that the City will seek a 20-year bond and a 10-year loan. Principal repayment on the 20-year bond and on the 10-year loan will start in year four. We project that the bond issuance costs will be equal to 1.0 percent of the principal borrowed. For the bond, a debt service reserve account is maintained at 5.0 percent of the total issuance amount. An interest reserve account equal to years one and two interest expense is maintained for the first two years.

The model assumes a straight-line depreciation of assets, and that the outside plant and materials will have a 20-year life span while network equipment will need to be replaced after 10 years. Last mile and CPEs as well as other miscellaneous implementation costs will need to be accounted for after five years. Network equipment will be replaced or upgraded at 80 percent of its original cost, miscellaneous implementation costs will be at 75 percent, and last mile and CPEs will be at 40 percent.²⁰² The model plans for a depreciation reserve account starting in year four—this funds future electronics replacements and upgrades.

Our analysis estimates total financing requirements to be \$50 million in bonds and a \$25.3 million loan.²⁰³

- We assume a 20-year bond in a total amount of \$50 million to be issued in full in year one.
- This bond is issued at a 4.0 percent finance rate and principal payments start in year four.
- Loans totaling \$25.3 are issued in the amounts of:
 - \$4.3 million in year one
 - \$17 million in year two
 - \$4 million in year three
- Loans are issued at 5.0 percent and principal payments start in year four.

²⁰² In addition, we assume an annual cost of 1 percent of the total accrued CPE value for miscellaneous replacements and upgrades.

²⁰³ The scope of work for this report does not include a review of the City’s bonding capability or review of local or state bonding restrictions. A more detailed review and opinion from the City’s accountants of bonding capability and restrictions is recommended, if bonding is pursued.

Table 7 shows operating expenses for years one, five, 10, 15, and 20. As seen, some expenses will remain constant while others will increase as the network matures and the customer base increases.

Table 7: Operating Expenses in Years 1, 5, 10, 15, and 20

Operating Expenses	Year 1	Year 5	Year 10	Year 15	Year 20
Support Services	\$57,020	\$55,950	\$55,950	\$55,950	\$55,950
Insurance	100,000	150,000	150,000	150,000	150,000
Utilities	25,000	50,000	50,000	50,000	50,000
Office Expenses	36,000	50,000	50,000	50,000	50,000
Locates & Ticket Processing	19,000	75,000	75,000	75,000	75,000
Contingency	25,000	50,000	50,000	50,000	50,000
Billing Maintenance Contract	15,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance	89,920	109,900	109,900	109,900	109,900
Vendor Maintenance Contracts	-	1,369,600	1,369,600	1,369,600	1,369,600
Legal and Lobby Fees	150,000	50,000	50,000	50,000	50,000
Consulting	100,000	25,000	25,000	25,000	25,000
Marketing	500,000	250,000	250,000	250,000	250,000
Education and Training	28,200	97,650	97,650	97,650	97,650
Customer Handholding	2,810	22,380	22,380	22,380	22,380
Customer Billing (Unit)	1,400	11,190	11,190	11,190	11,190
Allowance for Bad Debts	12,730	87,440	87,440	87,440	87,440
Churn (acquisition costs)	10,530	83,930	83,930	83,930	83,930
Pole Attachment Expense	134,340	134,340	134,340	134,340	134,340
Internet	<u>89,230</u>	<u>711,430</u>	<u>711,430</u>	<u>711,430</u>	<u>711,430</u>
Sub-Total	\$1,396,180	\$3,408,810	\$3,408,810	\$3,408,810	\$3,408,810
Labor Expenses	<u>\$1,409,930</u>	<u>\$4,882,350</u>	<u>\$4,882,350</u>	<u>\$4,882,350</u>	<u>\$4,882,350</u>
Sub-Total	<u>\$1,409,930</u>	<u>\$4,882,350</u>	<u>\$4,882,350</u>	<u>\$4,882,350</u>	<u>\$4,882,350</u>
Total Expenses	<u>\$2,806,110</u>	<u>\$8,291,160</u>	<u>\$8,291,160</u>	<u>\$8,291,160</u>	<u>\$8,291,160</u>
Principal and Interest	\$2,215,000	\$6,276,610	\$6,276,610	\$6,276,610	\$6,276,600
Facility Taxes	-	-	-	-	-
Sub-Total	<u>\$2,215,000</u>	<u>\$6,276,610</u>	<u>\$6,276,610</u>	<u>\$6,276,610</u>	<u>\$6,276,600</u>
Total Expenses, P&I, and Taxes	\$5,021,110	\$14,567,770	\$14,567,770	\$14,567,770	\$14,567,760

Table 8 shows the income statement for years one, five, 10, 15, and 20.

Table 8: Income Statement

	Year 1	Year 5	Year 10	Year 15	Year 20
Revenues					
Internet - Residential	\$1,722,000	\$13,735,680	\$13,735,680	\$13,735,680	\$13,735,680
Internet - Business	472,320	3,752,640	3,752,640	3,752,640	3,752,640
Enterprise	-	-	-	-	-
Connection Fee (net)	350,850	-	-	-	-
Provider Fee	-	-	-	-	-
Assessments	-	-	-	-	-
Ancillary Revenues	-	-	-	-	-
Total	\$2,545,170	\$17,488,320	\$17,488,320	\$17,488,320	\$17,488,320
Content Fees					
Internet	<u>\$89,230</u>	<u>\$711,430</u>	<u>\$711,430</u>	<u>\$711,430</u>	<u>\$711,430</u>
Total	\$89,230	\$711,430	\$711,430	\$711,430	\$711,430
Operating Costs					
Operation Costs	\$1,306,950	\$2,697,380	\$2,697,380	\$2,697,380	\$2,697,380
Labor Costs	<u>1,409,930</u>	<u>4,882,350</u>	<u>4,882,350</u>	<u>4,882,350</u>	<u>4,882,350</u>
Total	\$2,716,880	\$7,579,730	\$7,579,730	\$7,579,730	\$7,579,730
EBITDA	\$(260,940)	\$9,197,160	\$9,197,160	\$9,197,160	\$9,197,160
Depreciation	3,434,290	8,270,820	5,562,930	5,292,010	5,292,010
Operating Income (EBITDA less Depreciation)	\$(3,695,230)	\$926,340	\$3,634,230	\$3,905,150	\$3,905,150
Non-Operating Income					
Interest Income	\$ -	\$30,000	\$30,000	\$4,710	\$6,470
Interest Expense (10 Year Bond)	-	-	-	-	-
Interest Expense (20 Year Bond)	(2,000,000)	(1,440,200)	(1,440,200)	(861,790)	(158,070)
Interest Expense (Loan)	<u>(215,000)</u>	<u>(958,350)</u>	<u>(958,350)</u>	<u>(624,510)</u>	<u>(198,430)</u>
Total	\$(2,215,000)	\$(2,368,550)	\$(2,368,550)	\$(1,481,590)	\$(350,030)
Net Income (before taxes)	\$(5,910,230)	\$(2,187,610)	\$1,265,680	\$2,423,560	\$3,555,120
Facility Taxes	\$ -	\$ -	\$ -	\$ -	\$ -
Net Income	\$(5,910,230)	\$(2,187,610)	\$1,265,680	\$2,423,560	\$3,555,120

Table 9 shows the cash flow statement for years one, five, 10, 15, and 20. The unrestricted cash balance is approximately \$44,000 in year one and \$459,000 in year 10. By year 15, the unrestricted cash balance is approximately \$3.3 million and it is \$6.2 million by year 20.

Table 9: Cash Flow Statement

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	\$(5,910,230)	\$(2,187,610)	\$1,265,680	\$2,423,560	\$3,555,120
Cash Flow	\$43,660	\$(366,210)	\$280,340	\$385,100	\$386,870
	Year 1	Year 5	Year 10	Year 15	Year 20
Principal Payments	\$-	\$3,141,090	\$3,878,060	\$4,790,310	\$5,920,100
Interest Payments	<u>2,215,000</u>	<u>3,135,520</u>	<u>2,398,550</u>	<u>1,486,300</u>	<u>356,500</u>
Total Debt Service	\$2,215,000	\$6,276,610	\$6,276,610	\$6,276,610	\$6,276,600
	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	\$43,660	\$161,700	\$459,140	\$3,316,690	\$6,227,400
Funded Depreciation	-	6,128,590	9,500,450	(614,170)	86,170
Restricted Cash Balance (Interest Reserve)	2,000,000	-	-	-	-
Restricted Cash Balance (Debt Service Reserve)	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,543,660	\$8,790,290	\$12,459,590	5,202,520	\$8,813,570

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, implementing, and lighting a fiber network. Table 10 shows the capital additions costs in years one, two, and three, and the total for years one through three, assumes a 72 percent take rate, or about 18,650 subscribers.

This analysis projects that capital additions in year one will total approximately \$46.8 million. These costs will total approximately \$20.6 million in year two, and \$10.3 million in year three. This totals just under \$77.7 million for total capital additions costs for years one through three, assumes a 72 percent take rate, or about 18,650 subscribers.

Table 10: Capital Additions

Capital Additions	Year 1	Year 2	Year 3	Total Years 1 to 3
Network Equipment				
Core & Base Equipment	\$4,434,490	\$ -	\$ -	\$4,434,490
Incremental (Switches & OLTs)	6,833,660	2,277,890	-	9,111,550
Total	\$11,268,150	\$2,277,890	\$ -	\$13,546,040
Outside Plant and Facilities				
Total Backbone and FTTP	\$31,966,480	\$7,991,620	\$ -	\$39,958,100
Additional Annual Capital	-	-	-	-
Total	\$31,966,480	\$7,991,620	\$ -	\$39,958,100
Last Mile and Customer Premises Equipment				
CPE Gbps (medium commercial)	\$61,020	\$210,930	\$211,980	
CPE Residential & Small Commercial	\$1,108,790	\$3,866,040	\$3,869,040	\$8,843,870
Enterprise CPE and Drop	-	-	-	-
Average Drop Cost	<u>1,772,960</u>	<u>6,179,220</u>	<u>6,185,280</u>	<u>14,137,460</u>
Total	\$2,942,770	\$10,256,190	\$10,266,300	\$23,465,260
Miscellaneous Implementation Costs				
Splicing	\$ -	\$ -	\$ -	
Vehicles	150,000	-	-	
Emergency Restoration Kit	50,000	-	-	
Work Station, Computers, and Software	\$18,000	\$32,000	\$22,000	\$72,000
Fiber OTDR and Other Tools	\$85,000	-	-	85,000
Generators & UPS	-	-	-	-
OSS (Operations Support System)	300,000	-	-	300,000
Total	\$603,000	\$32,000	\$22,000	\$657,000
Total Capital Additions	\$46,780,400	\$20,557,700	\$10,288,300	\$77,626,400

8.2 Operating and Maintenance Expenses

The cost to deploy an FTTP network goes far beyond fiber implementation. Network deployment requires additional staffing for sales and marketing, network operations, and other functions new to the City. The addition of new staff and inventory requirements will require office and warehousing space:

- Expand office facilities for management, technical and clerical staff
- Expand retail “storefront” to facilitate customer contact and enhance their experience doing business with the FTTP enterprise
- Provide warehousing for receipt and storage of cable and hardware for the installation and on-going maintenance of the broadband infrastructure
- Establish location to house servers, switches, routers, and other core-network equipment

Training new and existing staff is important to fully realize the economies of starting the FTTN network. The training will be particularly important in the short-term as the new enterprise establishes itself as a unique entity providing services distinct from the dark fiber services provided by CPAU today.

CPAU already has billing software and capabilities, and the enterprise might save money by using these, if possible. The estimated incremental cost of billing for the new FTTN enterprise is five cents per bill. In addition, we have included a \$50,000 set-up fee and \$.25 per bill for support services.

Marketing and Sales is critical, and is a new activity for the City and the Utility. It is important to be proactive in setting customer expectations, addressing security concerns, and educating the customers on how to initiate services.

Staffing with skills in the following disciplines are required:

- Sales/Promotion
- Internet and related technologies
- Staff Management
- Strategic Planning
- Finance
- Vendor Negotiations
- Networking (addressing, segmentation)
- Marketing

The expanded business and increased responsibilities will require the addition of new staff. The initial additional positions, staffing levels and base salaries are shown in Table 11. These numbers assume that two shifts of customer service representative support is provided and one and one-half shifts of customer technicians are available. Changing to full 24x7 will increase staffing costs. Changing the support to 7am to 8pm (or other reduced hours) will decrease the required number of staff.

Note that Table 11 lists only new employees—the model assumes no existing staff will be allocated to the enterprise.

Table 11: Labor Expenses

Service Position Total	Year 1	Year 2	Year 3	Year 4	Year 5+	Year 1 Salary
Business Manager	0.50	1.00	1.00	1.00	1.00	\$150,000
Market & Sales Manager	1.00	1.00	1.00	1.00	1.00	\$126,000
Broadband Service Engineer	1.00	1.00	1.00	1.00	1.00	\$124,000
Internet Technician (staff in field tech support)	0.50	1.00	1.00	1.00	1.00	\$83,000
Customer Service Representative	2.00	10.00	16.00	16.00	16.00	\$65,000
Service Technicians/Installers & IT Support	2.00	7.00	12.00	12.00	12.00	\$90,000
Sales and Marketing Representative	1.00	2.00	2.00	2.00	2.00	\$83,000
Fiber Plant O&M Technicians	1.00	2.00	2.00	2.00	2.00	\$95,000
Total	9.00	25.00	36.00	36.00	36.00	
Total Customers	2,339	10,491	18,651	18,651	18,651	
Customers per Employee	260	420	518	518	518	
Total Salaries	\$854,500	\$2,119,000	\$2,959,000			
Total Salaries (with overhead)	\$1,409,930	\$3,496,350	\$4,882,350			

8.3 Summary of Operating and Maintenance Assumptions

The model assumes direct Internet access costs at \$0.75 per Mbps per month. Additional key operating and maintenance assumptions include:

- Salaries and benefits are based on estimated market wages. See Table 11 for a list of staffing requirements. Benefits are estimated at 65 percent of base salary.
- Insurance is estimated to be \$100,000 in year one and \$150,000 from year two on.
- Utilities are estimated to be \$25,000 in year one and \$50,000 from year two on.
- Office expenses are estimated to be \$36,000 in year one and \$50,000 from year two on.
- Facility lease fees are expected to be \$0—these are accounted for in estimated office expenses.
- Locates and ticket processing are estimated to start in year one at \$19,000, increase to \$38,000 in year two, and increase to \$75,000 from year three on.
- Contingency is estimated to be \$25,000 in year one and \$50,000 from year two on.
- Billing and maintenance contract fees are estimated at \$15,000 in year one, and \$25,000 from year two on.
- Legal fees are estimated to be \$150,000 in year one, \$75,000 in year two, and \$50,000 from year three on.
- Consulting fees are estimated at \$100,000 in year one, \$50,000 in year and two, and \$25,000 from year three on.

- Marketing and promotional expenses are estimated to be \$500,000 in year one, and \$250,000 from year two on.

Vendor maintenance contract fees are expected to start at \$1.37 million in year two and remain steady from year two on. Annual variable and operating expenses not including direct Internet access include:

- Education and training are calculated as 2 percent of direct payroll expense.
- Customer handholding is estimated to be 10¢ per subscriber per month.
- Customer billing (incremental) is estimated to be 5¢ per bill per month.
- Support services are estimated to be \$.25 per bill per month.
- Allowance for bad debts is computed as 0.5 percent of revenues.
- Churn is anticipated to be 1.5 percent annually.

Fiber network maintenance costs are calculated at \$10,000 per year plus 0.25 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.

The Palo Alto Utility User Tax (UUT) is only charged on telephone service (landline, cell & VoIP). The UUT is not assessed on video or Internet services.

8.4 Sensitivity Scenarios

This section shows the large impact that small fluctuations in take rate, subscriber fees, and other key assumptions can have on financial modeling. Note that many of these scenarios may not be realistically attainable. They are meant to demonstrate the sensitivity of these assumptions to the financial projections.

We specifically examine the impact of the three largest operating expense items (staffing, vendor maintenance contracts, and Internet access).

8.4.1 Labor, Vendor Maintenance Fees, and DIA

As we previously noted, the base case shows that a 72 percent take rate is required to maintain cash flow. Table 12 below shows the base case income and cash flow statements.

In this section, we demonstrate how fluctuations in staffing costs, vendor maintenance costs, and DIA can affect the required take rate. These effects are important to understand and consider when reviewing partnership opportunities. It is important that a partner be able to offer savings in these categories as compared to the base case assumptions used in the analysis.

Table 12: Base Case Scenario – Residential Service \$70 per Month, Small Commercial Service \$80 per Month, Medium Commercial Service \$220 per Month

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$17,488,320	\$17,488,320	\$17,488,320	\$17,488,320
Total Cash Expenses	(2,806,110)	(8,291,160)	(8,291,160)	(8,291,160)	(8,291,160)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,030)
Taxes	-	-	-	-	-
Net Income	\$(5,910,230)	\$(2,187,610)	\$1,265,680	\$2,423,560	\$3,555,120
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$43,660	\$161,700	\$459,140	\$3,316,690	\$6,227,400
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,543,660	\$8,790,290	\$12,459,590	\$5,202,520	\$8,813,570
Investment Metric					
Internal Rate of Return (IRR) – 20 year			0.47%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$23,140,050)		
Discount Rate			4.00%		

The impact of salary overhead is one of the important assumptions that we changed to demonstrate the sensitivity to the financial projections. The base case scenario assumed that overhead for personnel will be 65 percent of the base salary. Decreasing overhead to 27 percent allows borrowing to be reduced by \$5 million and required take rate to be reduced by 10 percentage points to maintain cash flow.

Table 13: Decrease Overhead to 27 Percent of Salaries (from 65 percent), Financing Reduced by \$5 Million, and Take Rate Decreased to 62.1 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$15,081,480	\$15,081,480	\$15,081,480	\$15,081,480
Total Cash Expenses	(2,474,900)	(6,489,030)	(6,489,030)	(6,489,030)	(6,489,030)
Depreciation	(3,344,360)	(7,491,010)	(5,151,390)	(4,904,450)	(4,904,450)
Interest Expense	(2,165,000)	(2,874,100)	(2,178,890)	(1,352,810)	(302,450)
Taxes	-	-	-	-	-
Net Income	\$(5,439,090)	\$(1,772,660)	\$1,262,170	\$2,335,190	\$3,385,550
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$324,190	\$(258,860)	\$331,870	\$3,111,930	\$5,947,450
Depreciation Reserve	-	5,571,860	9,207,260	701,540	2,054,370
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,824,190	\$7,813,000	\$12,039,130	\$6,313,470	\$10,501,820
Investment Metric					
Internal Rate of Return (IRR)			0.52%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$21,532,230)		
Discount Rate			4.00%		

To demonstrate the power that a large incumbent provider may have, we show that eliminating vendor maintenance contracts can, in itself, reduce required take rate by 10 percentage points. This sensitivity is an example of the distinct operating advantage held by large providers like Comcast, which can eliminate or greatly reduce the costs associated with maintenance contracts.

Table 14: Eliminate Vendor Maintenance Contracts and Reduce Take Rate to 62.1 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$15,081,480	\$15,081,480	\$15,081,480	\$15,081,480
Total Cash Expenses	(2,806,110)	(6,281,090)	(6,281,090)	(6,281,090)	(6,281,090)
Depreciation	(3,344,360)	(7,491,010)	(5,151,390)	(4,904,450)	(4,904,450)
Interest Expense	(2,215,000)	(3,115,340)	(2,369,280)	(1,478,300)	(345,115)
Taxes	=	=	=	=	=
Net Income	\$(5,820,300)	\$(1,805,960)	\$1,279,720	\$2,417,640	\$3,550,825
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$942,980	\$4,231,820	\$3,735,840	\$5,429,180	\$7,177,980
Depreciation Reserve	-	5,571,860	9,207,260	701,540	2,054,380
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$5,442,980	\$12,303,680	\$15,443,100	\$8,630,720	\$11,732,360
Investment Metric					
Internal Rate of Return (IRR) – 20 year	0.60%				
Net Present Value (NPV) at a 4 percent discount rate – 20 year	\$(21,211,620)				
Discount Rate	4.00%				

Reducing labor costs (salaries and overhead) by 40 percent would enable the FFTP enterprise to cash flow with a greater than 14 percentage point drop in take rate. Providers that are able to leverage existing resources or avoid the higher Bay Area labor costs can realize a portion of this impact.

Table 15: Reduce Labor Expenses by 40 Percent and Reduce Take Rate to 57.6 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$13,989,960	\$13,989,960	\$13,989,960	\$13,989,960
Total Cash Expenses	(2,242,138)	(5,410,930)	(5,410,930)	(5,410,930)	(5,410,930)
Depreciation	(3,291,320)	(7,119,830)	(4,947,740)	(4,714,950)	(4,714,950)
Interest Expense	(2,215,000)	(3,116,010)	(2,369,740)	(1,476,680)	(342,835)
Taxes	-	-	-	-	-
Net Income	\$(5,203,288)	\$(1,656,810)	\$1,261,550	\$2,387,400	\$3,521,245
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$2,037,350	\$6,007,850	\$4,984,420	\$5,976,420	\$7,024,270
Depreciation Reserve	-	5,305,430	9,023,780	1,348,740	2,968,180
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$6,537,350	\$13,813,280	\$16,508,200	\$9,825,160	\$12,492,450
Investment Metric					
Internal Rate of Return (IRR) – 20 year			0.60%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$20,682,070)		
Discount Rate			4.00%		

Table 16 shows the combination of eliminating vendor maintenance contracts and labor expenses.

Table 16: Eliminate Vendor Maintenance Contracts, Reduce Labor Expenses by 40 Percent, and Reduce Take Rate to 51.3 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$12,458,760	\$12,458,760	\$12,458,760	\$12,458,760
Total Cash Expenses	(2,242,140)	(4,069,800)	(4,069,800)	(4,069,800)	(4,069,800)
Depreciation	(3,253,180)	(6,649,990)	(4,711,920)	(4,489,300)	(4,489,300)
Interest Expense	(2,215,000)	(3,116,840)	(2,370,010)	(1,474,780)	(339,775)
Taxes	-	-	-	-	-
Net Income	\$(5,165,150)	\$(1,377,870)	\$1,307,030	\$2,424,880	\$3,559,885
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$2,418,870	\$8,661,930	\$7,385,660	\$7,897,200	\$8,467,130
Depreciation Reserve	-	4,972,220	8,915,860	2,108,700	4,190,250
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$6,918,870	\$16,134,150	\$18,801,520	\$12,505,900	\$15,157,380
Investment Metric					
Internal Rate of Return (IRR) – 20 year			0.79%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$18,943,390)		
Discount Rate			4.00%		

The cost of DIA is estimated at \$0.75 per Mbps per month. Table 17 shows that increasing DIA by \$0.50 quickly drives cash flow negative. Decreasing this cost by \$0.50 per month increases the overall cash by \$10 million.

Table 17: DIA Monthly Price (per Mbps) Increases by \$0.50

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$17,488,320	\$17,488,320	\$17,488,320	\$17,488,320
Total Cash Expenses	(2,865,600)	(8,765,450)	(8,765,450)	(8,765,450)	(8,765,450)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	–	–	–	–	–
Net Income	\$(5,969,720)	\$(2,661,900)	\$791,390	\$1,949,270	\$3,080,825
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$(15,830)	\$(1,587,440)	\$(3,661,450)	\$(3,175,350)	\$(2,636,110)
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,484,170	\$7,041,150	\$8,339,000	\$(1,289,520)	\$(49,940)
Investment Metric					
Internal Rate of Return (IRR) – 20 year			(0.52%)		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$28,995,110)		
Discount Rate			4.00%		

Table 18: DIA Monthly Price (per Mbps) Decreases by \$0.50

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$17,488,320	\$17,488,320	\$17,488,320	\$17,488,320
Total Cash Expenses	(2,746,620)	(7,816,870)	(7,816,870)	(7,816,870)	(7,816,870)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	–	–	–	–	–
Net Income	\$(5,850,740)	\$(1,713,320)	\$1,739,970	\$2,897,850	\$4,029,405
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$103,150	\$1,910,840	\$4,579,730	\$9,808,730	\$15,090,870
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,603,150	\$10,539,430	\$16,580,180	\$11,694,560	\$17,677,040
Investment Metric					
Internal Rate of Return (IRR) – 20 year			1.41%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$17,285,000)		
Discount Rate			4.00%		

By reducing the costs of vendor maintenance contracts, labor expenses, and DIA, the required take rate can be dramatically reduced. In Table 19 we show an example that reduces the required take rate to 45 percent.

Table 19: Eliminate Vendor Maintenance Contracts, Reduce Labor Expenses by 50 Percent, Reduce DIA by 67 Percent, and Reduce Take Rate to 45 Percent

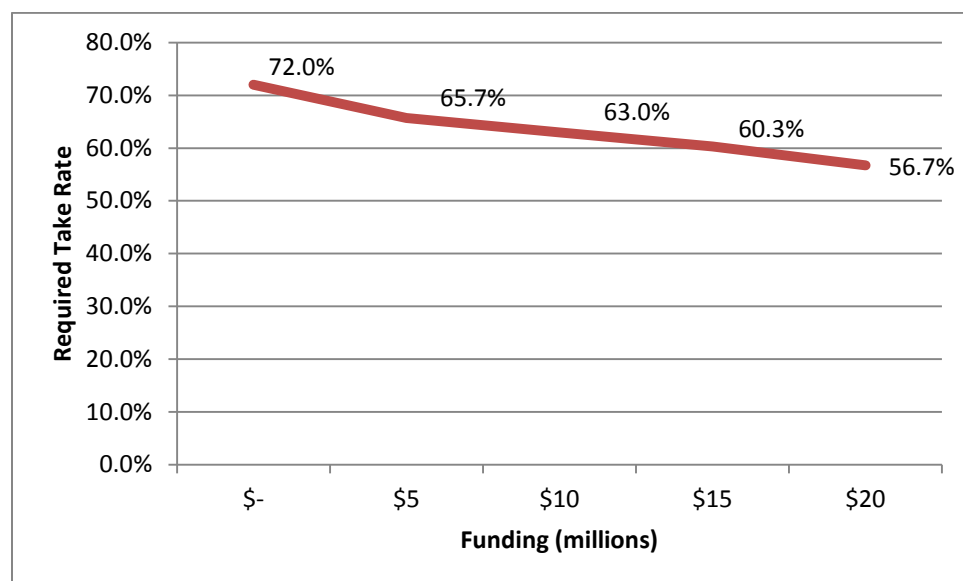
Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$10,930,320	\$10,930,320	\$10,930,320	\$10,930,320
Total Cash Expenses	(2,041,655)	(3,113,615)	(3,113,615)	(3,113,615)	(3,113,615)
Depreciation	(3,187,340)	(6,142,130)	(4,438,430)	(4,233,370)	(4,233,370)
Interest Expense	(2,215,000)	(3,117,750)	(2,370,570)	(1,472,600)	(336,615)
Taxes	–	–	–	–	–
Net Income	\$(4,898,825)	\$(1,443,175)	\$1,007,705	\$2,110,735	\$3,246,720

Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$3,277,645	\$10,107,325	\$6,753,840	\$4,948,700	\$3,202,930
Depreciation Reserve	-	4,608,650	8,693,850	2,980,380	5,455,570
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$7,777,645	\$17,215,975	\$17,947,690	\$10,429,080	\$11,158,500

Investment Metric	
Internal Rate of Return (IRR) – 20 year	0.15%
Net Present Value (NPV) at a 4 percent discount rate – 20 year	(\$21,576,050)
Discount Rate	4.00%

8.4.2 Initial Funding

Using funds that do not need to be paid back to help cover implementation costs can reduce the required take rate. In Figure 30 we show the impact of funding amounts to \$20 million in \$5 million increments. For each \$5 million in funding, we see approximately a 3.8 percentage point drop in required take rates. (Please note the individual data points in Figure 30 below will vary from the 3.8 percent average since the resulting cash flow balances and projected IRR vary from case to case.)

Figure 30: Impact of Initial Funding on Required Take Rate

In Table 20 to Table 23, we show the resulting income and cash flow statements for each \$5 million funding increment.

**Table 20: Use \$5 Million in Start-Up Funds (Decrease Amount Bonded by Same),
Reduce Take Rate to 65.7 Percent**

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$15,956,280	\$15,956,280	\$15,956,280	\$15,956,280
Total Cash Expenses	(2,806,110)	(7,748,000)	(7,748,000)	(7,748,000)	(7,748,000)
Depreciation	(3,368,480)	(7,763,050)	(5,289,500)	(5,036,130)	(5,036,130)
Interest Expense	(2,015,000)	(2,923,920)	(2,225,710)	(1,393,850)	(331,700)
Taxes	-	-	-	-	-
Net Income	\$(5,644,420)	\$(2,478,690)	\$693,070	\$1,778,300	\$2,840,450
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$1,401,880	\$1,747,590	\$(63,470)	\$446,080	\$1,009,740
Depreciation Reserve	-	5,765,070	9,278,290	257,190	1,351,020
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	<u>2,250,000</u>	<u>2,250,000</u>	<u>2,250,000</u>	<u>2,250,000</u>	<u>2,250,000</u>
Total Cash Balance	\$5,451,880	\$9,762,660	\$11,464,820	\$2,953,270	\$4,610,760
Investment Metric					
Internal Rate of Return (IRR)	(0.12%)				
Net Present Value (NPV) at a 4 percent discount rate – 20 year	(\$23,931,230)				
Discount Rate	4.00%				

**Table 21: Use \$10 Million in Start-Up Funds (Decrease Amount Bonded by Same),
Reduce Take Rate to 63 Percent**

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$15,300,000	\$15,300,000	\$15,300,000	\$15,300,000
Total Cash Expenses	(2,806,110)	(7,536,760)	(7,536,760)	(7,536,760)	(7,536,760)
Depreciation	(3,350,950)	(7,559,850)	(5,186,670)	(4,937,980)	(4,937,980)
Interest Expense	(1,815,000)	(2,733,350)	(2,082,440)	(1,307,470)	(315,205)
Taxes	-	-	-	-	-
Net Income	\$(5,426,890)	\$(2,529,960)	\$494,130	\$1,517,790	\$2,510,055
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$2,277,120	\$3,018,010	\$1,336,620	\$1,877,640	\$2,473,800
Depreciation Reserve	-	5,620,790	9,227,370	588,270	1,877,750
Interest Reserve	1,600,000	-	-	-	-
Debt Service Reserve	<u>2,000,000</u>	<u>2,000,000</u>	<u>2,000,000</u>	<u>2,000,000</u>	<u>2,000,000</u>
Total Cash Balance	\$5,877,120	\$10,638,800	\$12,563,990	\$4,465,910	\$6,351,550
Investment Metric					
Internal Rate of Return (IRR)			0.06%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$20,863,300)		
Discount Rate			4.00%		

**Table 22: Use \$15 Million in Start-Up Funds (Decrease Amount Bonded by Same),
Reduce Take Rate to 60.3 Percent**

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$14,645,400	\$14,645,400	\$14,645,400	\$14,645,400
Total Cash Expenses	(2,806,100)	(7,476,960)	(7,476,960)	(7,476,960)	(7,476,960)
Depreciation	(3,333,490)	(7,356,980)	(5,084,140)	(4,840,110)	(4,840,110)
Interest Expense	(1,615,000)	(2,542,770)	(1,939,170)	(1,221,090)	(298,705)
Taxes	-	-	-	-	-
Net Income	\$(5,209,420)	\$(2,731,310)	\$145,130	\$1,107,240	\$2,029,625
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$3,151,820	\$3,837,550	\$1,536,380	\$1,359,490	\$1,238,780
Depreciation Reserve	-	5,476,820	9,176,280	918,090	2,402,640
Interest Reserve	1,400,000	-	-	-	-
Debt Service Reserve	<u>1,750,000</u>	<u>1,750,000</u>	<u>1,750,000</u>	<u>1,750,000</u>	<u>1,750,000</u>
Total Cash Balance	\$6,301,820	\$11,064,370	\$12,462,660	\$4,027,580	\$5,391,420
Investment Metric					
Internal Rate of Return (IRR)			(0.12%)		
Net Present Value (NPV) at a 4 percent discount rate - 20 year			(\$19,550,760)		
Discount Rate			4.00%		

**Table 23: Use \$20 Million in Start-Up Funds (Decrease Amount Bonded by Same),
Reduce Take Rate to 56.7 Percent**

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$13,770,600	\$13,770,600	\$13,770,600	\$13,770,600
Total Cash Expenses	(2,806,110)	(6,996,600)	(6,996,600)	(6,996,600)	(6,996,600)
Depreciation	(3,287,370)	(7,054,760)	(4,916,100)	(4,684,350)	(4,684,350)
Interest Expense	(1,415,000)	(2,352,380)	(1,796,180)	(1,134,210)	(281,675)
Taxes	-	-	-	-	-
Net Income	\$(4,963,310)	\$(2,633,140)	\$61,720	\$955,440	\$1,807,975
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$4,312,860	\$5,917,320	\$4,171,030	\$4,408,330	\$4,701,900
Depreciation Reserve	-	5,259,460	9,014,570	1,451,250	3,140,430
Interest Reserve	1,200,000	-	-	-	-
Debt Service Reserve	<u>1,500,000</u>	<u>1,500,000</u>	<u>1,500,000</u>	<u>1,500,000</u>	<u>1,500,000</u>
Total Cash Balance	\$7,012,860	\$12,676,780	\$14,685,600	\$7,359,580	\$9,342,330
Investment Metric					
Internal Rate of Return (IRR)			0.46%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$15,015,170)		
Discount Rate			4.00%		

8.4.3 Impact of Take Rate on Cash Flow

Realized take rates will have a high impact on the projections. A 4.5 percentage point take rate increase adds approximately \$11 million to the year 20 cash balance. A 9 percentage point increase adds almost \$14 million. Note that the results are not linear because financing was not increased in the model, and a take rate increase drives a higher capital expenditure.

Table 24: Residential Market Share Increase by 5 Percentage Points (4.5 Percentage Point Take Rate Increase)

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$18,346,800	\$18,346,800	\$18,346,800	\$18,346,800
Total Cash Expenses	(2,806,110)	(8,371,660)	(8,371,660)	(8,371,660)	(8,371,660)
Depreciation	(3,456,900)	(8,564,250)	(5,709,100)	(5,432,200)	(5,432,200)
Interest Expense	(2,215,000)	(3,113,430)	(2,368,400)	(1,482,760)	(351,955)
Taxes	-	-	-	-	-
Net Income	\$(5,932,840)	\$(1,702,540)	\$1,897,640	\$3,060,180	\$4,190,985
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$(181,550)	\$1,198,420	\$4,952,000	\$11,408,190	\$17,915,810
Depreciation Reserve	-	6,336,450	9,561,960	(1,085,680)	(679,770)
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,318,450	\$10,034,870	\$17,013,960	\$12,822,510	\$19,736,040
Investment Metric					
Internal Rate of Return (IRR) – 20 year			1.68%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$15,842,870)		
Discount Rate			4.00%		

Table 25: Residential Market Share Increase by 10 Percentage Points (9 Percentage Point Take Rate Increase)

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$19,205,280	\$19,205,280	\$19,205,280	\$19,205,280
Total Cash Expenses	(2,806,110)	(8,858,920)	(8,858,920)	(8,858,920)	(8,858,920)
Depreciation	(3,506,830)	(8,895,330)	(5,892,620)	(5,602,450)	(5,602,450)
Interest Expense	(2,215,000)	(3,112,830)	(2,367,960)	(1,484,220)	(353,975)
Taxes	-	-	-	-	-
Net Income	\$(5,982,770)	\$(1,661,800)	\$2,085,780	\$3,259,690	\$4,389,935
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$(680,060)	\$577,830	\$5,667,810	\$13,614,740	\$21,612,920
Depreciation Reserve	-	6,574,440	9,736,030	(1,668,160)	(1,489,470)
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$3,819,940	\$9,652,270	\$17,903,840	\$14,446,580	\$22,623,450
Investment Metric					
Internal Rate of Return (IRR) – 20 year			2.01%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$13,861,120)		
Discount Rate			4.00%		

As expected, take rate decreases lead to a similar decline in cash balances. Table 26 and Table 27 show this impact.

Table 26: Residential Market Share Decrease by 5 Percentage Points (4.5 Percentage Point Take Rate Decrease)

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$16,629,840	\$16,629,840	\$16,629,840	\$16,629,840
Total Cash Expenses	(2,806,110)	(8,055,610)	(8,055,610)	(8,055,610)	(8,055,610)
Depreciation	(3,409,000)	(7,973,430)	(5,412,910)	(5,148,680)	(5,148,680)
Interest Expense	(2,215,000)	(3,114,480)	(2,368,730)	(1,480,380)	(348,105)
Taxes	-	-	-	-	-
Net Income	\$(5,884,940)	\$(2,513,680)	\$792,590	\$1,945,170	\$3,077,445
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$295,620	\$4,670	\$(2,369,970)	\$(2,328,170)	\$(2,231,680)
Depreciation Reserve	-	5,917,550	9,428,390	(130,750)	858,160
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,795,620	\$8,422,220	\$9,558,420	\$41,080	\$1,126,480
Investment Metric					
Internal Rate of Return (IRR) – 20 year			(0.49%)		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$28,223,660)		
Discount Rate			4.00%		

Table 27: Residential Market Share Decrease by 10 Percentage Points (9 Percentage Point Take Rate Decrease)

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$15,771,360	\$15,771,360	\$15,771,360	\$15,771,360
Total Cash Expenses	(2,806,110)	(7,568,460)	(7,568,460)	(7,568,460)	(7,568,460)
Depreciation	(3,359,040)	(7,642,460)	(5,229,450)	(4,978,490)	(4,978,490)
Interest Expense	(2,215,000)	(3,115,070)	(2,369,160)	(1,478,920)	(346,085)
Taxes	–	–	–	–	–
Net Income	\$(5,834,980)	\$(2,554,630)	\$604,290	\$1,745,490	\$2,878,325
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$794,170	\$624,090	\$(3,087,690)	\$(4,537,280)	\$(5,932,050)
Depreciation Reserve	-	5,679,620	9,254,390	451,510	1,667,590
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$5,294,170	\$8,803,710	\$8,666,700	\$(1,585,770)	\$(1,764,460)
Investment Metric					
Internal Rate of Return (IRR) – 20 year			(0.94%)		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$30,207,740)		
Discount Rate			4.00%		

Increases and decreases in small commercial take rates do have an impact, but not as significant as changes in the residential. This is due to the overall number of business passings compared to residential passings. Table 28 and Table 29 show the impact on income and cash flow statements related to changing take rates for businesses (small and medium).

Table 28: Commercial Market Share Increase by 10 Percentage Points (9 Percentage Point Take Rate Increase)

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$17,954,400	\$17,954,400	\$17,954,400	\$17,954,400
Total Cash Expenses	(2,806,110)	(8,322,740)	(8,322,740)	(8,322,740)	(8,322,740)
Depreciation	(3,442,390)	(8,353,390)	(5,605,660)	(5,332,480)	(5,332,480)
Interest Expense	(2,215,000)	(3,113,800)	(2,368,480)	(1,481,930)	(350,565)
Taxes	–	–	–	–	–
Net Income	\$(5,918,330)	\$(1,835,530)	\$1,657,520	\$2,817,250	\$3,948,615
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$(39,100)	\$1,194,490	\$3,539,680	\$8,484,630	\$13,482,390
Depreciation Reserve	-	6,187,360	9,527,110	(750,990)	(124,220)
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,460,900	\$9,881,850	\$15,566,790	\$10,233,640	\$15,858,170
Investment Metric					
Internal Rate of Return (IRR) – 20 year			1.24%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$18,482,510)		
Discount Rate			4.00%		

Table 29: Commercial Market Share Decrease by 10 Percentage Points (9 Percentage Point Take Rate Decrease)

Income Statement	1	5	10	15	20
Total Revenues	\$2,545,170	\$17,016,960	\$17,016,960	\$17,016,960	\$17,016,960
Total Cash Expenses	(2,806,110)	(8,255,870)	(8,255,870)	(8,255,870)	(8,255,870)
Depreciation	(3,423,500)	(8,184,650)	(5,516,600)	(5,248,660)	(5,248,660)
Interest Expense	(2,215,000)	(3,114,100)	(2,368,640)	(1,481,220)	(349,505)
Taxes	-	-	-	-	-
Net Income	\$(5,899,440)	\$(2,537,660)	\$875,850	\$2,031,210	\$3,162,925
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$153,460	\$(830,600)	\$(2,580,400)	\$(1,810,950)	\$(988,220)
Depreciation Reserve	-	6,066,900	9,462,380	(466,910)	300,060
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,653,460	\$7,736,300	\$9,381,980	\$222,140	\$1,811,840
Investment Metric					
Internal Rate of Return (IRR) – 20 year			(0.34%)		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$27,759,630)		
Discount Rate			4.00%		

8.4.4 Impact of Service Fees on Cash Flow

Service fees can have a large impact on the projections. Assuming no change to take rates, a \$5 per month service fee increase adds approximately \$19 million to the year 20 cash balance. A \$10 increase adds almost \$38 million. Please note, however, there is a correlation between take rates to fee increases.

Table 30: Residential Monthly Service Prices Increase by \$5

Income Statement	1	5	10	15	20
Total Revenues	\$2,668,170	\$18,469,440	\$18,469,440	\$18,469,440	\$18,469,440
Total Cash Expenses	(2,806,720)	(8,296,070)	(8,296,070)	(8,296,070)	(8,296,070)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$(5,787,840)	\$(1,211,400)	\$2,241,890	\$3,399,770	\$4,531,325
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$166,050	\$3,761,840	\$8,940,330	\$16,678,930	\$24,470,670
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,666,050	\$12,390,430	\$20,940,780	\$18,564,760	\$27,056,840
Investment Metric					
Internal Rate of Return (IRR) – 20 year			2.37%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$11,088,890)		
Discount Rate			4.00%		

Table 31: Residential Monthly Service Prices Increase by \$10

Income Statement	1	5	10	15	20
Total Revenues	\$2,791,170	\$19,450,560	\$19,450,560	\$19,450,560	\$19,450,560
Total Cash Expenses	(2,807,340)	(8,300,970)	(8,300,970)	(8,300,970)	(8,300,970)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	=	=	=	=	=
Net Income	\$(5,665,460)	\$(235,180)	\$3,218,110	\$4,375,990	\$5,507,545
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$288,430	\$7,362,000	\$17,421,590	\$30,041,290	\$42,714,130
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,788,430	\$15,990,590	\$29,422,040	\$31,927,120	\$45,300,300
Investment Metric					
Internal Rate of Return (IRR) – 20 year			4.14%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			\$962,380		
Discount Rate			4.00%		

As expected, monthly service fee decreases produce a similar decline in cash balances. This impact is shown in Table 32 and Table 33.

Table 32: Residential Monthly Service Prices Decrease by \$5

Income Statement	1	5	10	15	20
Total Revenues	\$2,422,170	\$16,507,200	\$16,507,200	\$16,507,200	\$16,507,200
Total Cash Expenses	(2,805,490)	(8,286,260)	(8,286,260)	(8,286,260)	(8,286,260)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	=	=	=	=	=
Net Income	\$(6,032,610)	\$(3,163,830)	\$289,460	\$1,447,340	\$2,578,895
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$(78,720)	\$(3,438,470)	\$(8,022,130)	\$(10,045,690)	\$(12,016,090)
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,421,280	\$5,190,120	\$3,978,320	\$(8,159,860)	\$(9,429,920)
Investment Metric					
Internal Rate of Return (IRR) – 20 year			(1.63%)		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$35,191,340)		
Discount Rate			4.00%		

Table 33: Residential Monthly Service Prices Decrease by \$10

Income Statement	1	5	10	15	20
Total Revenues	\$2,299,170	\$15,526,080	\$15,526,080	\$15,526,080	\$15,526,080
Total Cash Expenses	(2,804,880)	(8,281,350)	(8,281,350)	(8,281,350)	(8,281,350)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$(6,155,000)	\$(4,140,040)	\$(686,750)	\$471,130	\$1,602,685
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash					
Balance	\$(201,110)	\$(7,038,610)	\$(16,503,320)	\$(23,407,930)	\$8,080
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,298,890	\$1,589,980	\$(4,502,870)	\$(21,522,100)	\$2,594,250
Investment Metric					
Internal Rate of Return (IRR) – 20 year			(3.99%)		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$47,242,500)		
Discount Rate			4.00%		

Increases and decreases in small commercial prices do have an impact, but not as significant as changes in the residential. This is due to the overall number of business passings compared to residential passings. Table 34 and Table 35 show the impact on the income and cash flow statements caused by changing fees for small businesses.

Table 34: Small Commercial Monthly Service Prices Increase by \$10

Income Statement	1	5	10	15	20
Total Revenues	\$2,565,930	\$17,653,800	\$17,653,800	\$17,653,800	\$17,653,800
Total Cash Expenses	(2,806,210)	(8,291,990)	(8,291,990)	(8,291,990)	(8,291,990)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$(5,889,570)	\$(2,022,960)	\$1,430,330	\$2,588,210	\$3,719,765
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$64,320	\$768,960	\$1,889,650	\$5,570,450	\$9,304,390
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,564,320	\$9,397,550	\$13,890,100	\$7,456,280	\$11,890,560
Investment Metric					
Internal Rate of Return (IRR) – 20 year			0.80%		
Net Present Value (NPV) at a 4 percent discount rate – 20 year			(\$21,107,430)		
Discount Rate			4.00%		

Table 35: Small Commercial Monthly Service Prices Decrease by \$10

Income Statement	1	5	10	15	20
Total Revenues	\$2,524,410	\$17,322,840	\$17,322,840	\$17,322,840	\$17,322,840
Total Cash Expenses	(2,806,000)	(8,290,330)	(8,290,330)	(8,290,330)	(8,290,330)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	=	=	=	=	=
Net Income	\$(5,930,880)	\$(2,352,260)	\$1,101,030	\$2,258,910	\$3,390,465
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$23,010	\$(445,560)	\$(971,370)	\$1,062,930	\$3,150,370
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>	<u>2,500,000</u>
Total Cash Balance	\$4,523,010	\$8,183,030	\$11,029,080	\$2,948,760	\$5,736,540
Investment Metric					
Internal Rate of Return (IRR) – 20 year	0.13%				
Net Present Value (NPV) at a 4 percent discount rate – 20 year	(\$25,172,680)				
Discount Rate	4.00%				

Appendix A – Existing Palo Alto Market Assessment

Appendix B – Financial and Cost Analysis

ctc technology & energy

engineering & business consulting

Appendix A: Existing Market Assessment Final

**Prepared for City of Palo Alto
July 2015**

Columbia Telecommunications Corporation

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

Contents

1	Existing Market Assessment	1
2	Enterprise Market	1
1.1	Dark Fiber Services	1
1.1.1	Integra Telecom	1
1.1.2	Level(3).....	2
1.1.3	Zayo.....	3
1.2	Ethernet Services.....	4
1.2.1	AT&T.....	4
1.2.2	CenturyLink	5
1.2.3	Cogent Communications.....	5
1.2.4	Comcast.....	5
1.2.5	Level(3).....	6
1.2.6	Megapath.....	6
1.2.7	Integra Telecom	6
1.2.8	Verizon	6
1.2.9	Windstream Communications	7
1.2.10	XO Communications	7
1.2.11	Zayo.....	7
2	Residential and Small Business Services	8
2.1	Cable.....	8
2.2	DSL.....	9
2.2.1	AT&T.....	9
2.2.2	EarthLink	10
2.2.3	MegaPath.....	10
2.2.4	Sonic.....	10
2.3	Satellite.....	10
2.3.1	HughesNet	10

2.3.2	Exede.....	11
2.3.3	DishNET	11
2.4	Wireless.....	11
2.4.1	Verizon	11
2.4.2	Sprint.....	12
2.4.3	AT&T.....	12
2.4.4	Cricket Wireless	12
2.4.5	T-Mobile.....	12
2.4.6	Etheric Networks.....	13

Figures

Figure 1: Integra Telecom Network Map.....	2
Figure 2: Level(3) Dark Fiber Routes.....	3
Figure 3: Zayo Fiber Map	4

Tables

Table 1: Overview of Residential and Small Business Data Services in Palo Alto.....	8
Table 2: Comcast Residential Internet – Internet Only	9
Table 3: Comcast Small Business Internet – Internet Only.....	9
Table 4: AT&T Residential Internet – Internet Only	10
Table 5: Etheric Networks Internet Services.....	13

1 Existing Market Assessment

This existing market assessment provides an overview of providers that currently offer services with which the City’s potential new fiber-to-the-premises (FTTP) enterprise might compete. The information provided here is based on what was publicly available—providers often do not publish extensive information about their networks (e.g., capacity and other specific details).

2 Enterprise Market

This section summarizes competitors for dark fiber and Ethernet services with respect to the enterprise customers within the City of Palo Alto.

During the course of our research, we identified 11 service providers in the Palo Alto area that offer a range of services from dark fiber connectivity to data transport services, with speeds that range from 1 Megabit per second (Mbps) to 100 Gigabits per second (Gbps). Individual providers tailor these services to a customer’s requirements, such as speed and class of service. Greater proximity to the provider’s existing network infrastructure results in lower service pricing. Providers prefer to offer transport services between locations on their network (On-Net) and provision Multiprotocol Label Switching (MPLS) based services for connecting locations that are Off-Net.

A trend that we expect to continue is the consolidation of competitors through mergers and acquisitions. Competitors are discussed in detail in the following sections.

1.1 Dark Fiber Services

In addition to the City of Palo Alto Utilities (CPAU) dark fiber offering,¹ our analysis found that three service providers in the City offer dark fiber services²: Integra Telecom, Level (3) and Zayo.³ There may be other providers that offer dark fiber (e.g., on a case-by-case basis), but this analysis yielded information only about the three discussed here.

1.1.1 Integra Telecom

Integra Telecom offers dark fiber services within the city. They provide flexible options in securing dark fiber through bundles, lease, and indefeasible rights of use (IRU). The dark fiber routes are depicted in Figure 1.^{4,5} Dark fiber pricing varies individually, based on distance from

¹ CPAU is engaged in capital improvements for added capacity and to provide additional dark fiber routes.

² An assessment of the potential impact of alternative dark fiber provider offerings to City of Palo Alto’s existing dark fiber enterprise is beyond the scope of this analysis.

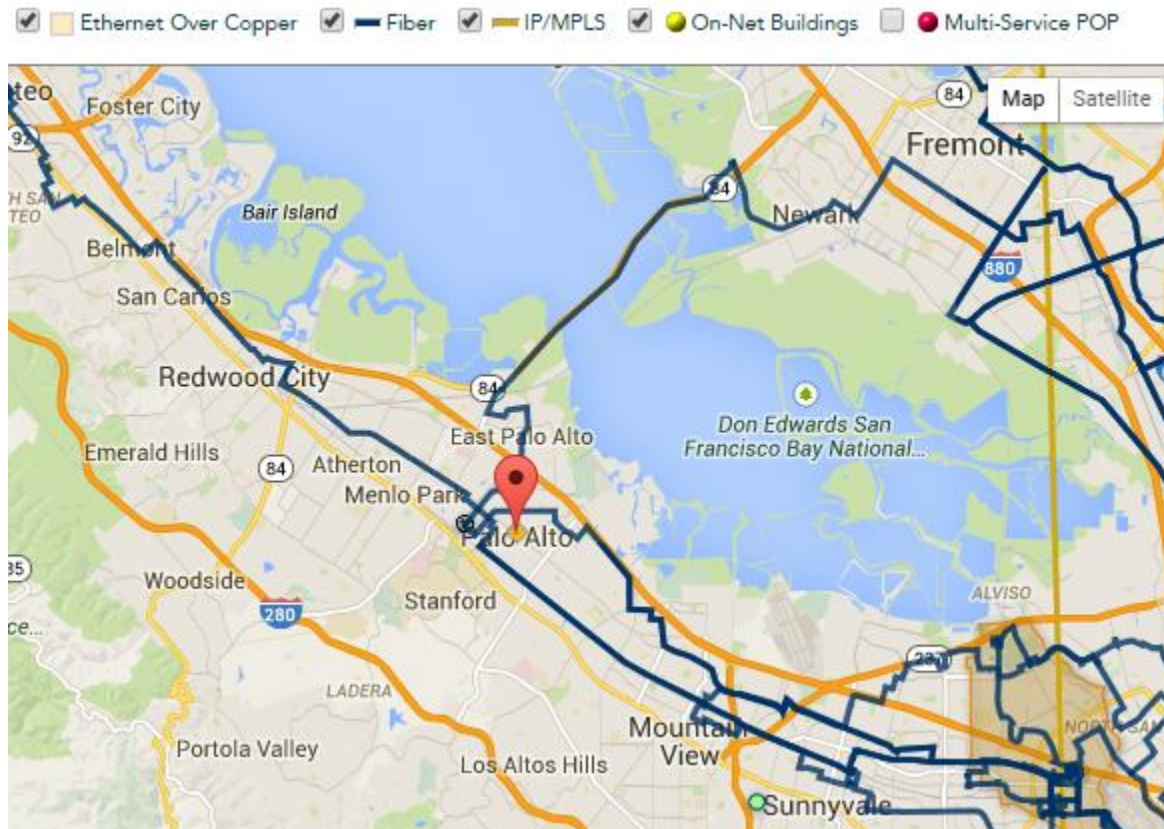
³ While this analysis yielded only these three, there may be other providers offering dark fiber—for example, on a case-by-case basis.

⁴ <http://www.integratelecom.com/pages/network-map.aspx>, accessed March 2015.

⁵ As we noted, carriers typically do not publish details such as whether they directly own the routes depicted on their publicly-available maps.

the provider's fiber ring. A difference in a few tenths of a mile can lead to significant differences in the price of dark fiber connectivity due to additional construction costs.

Figure 1: Integra Telecom Network Map

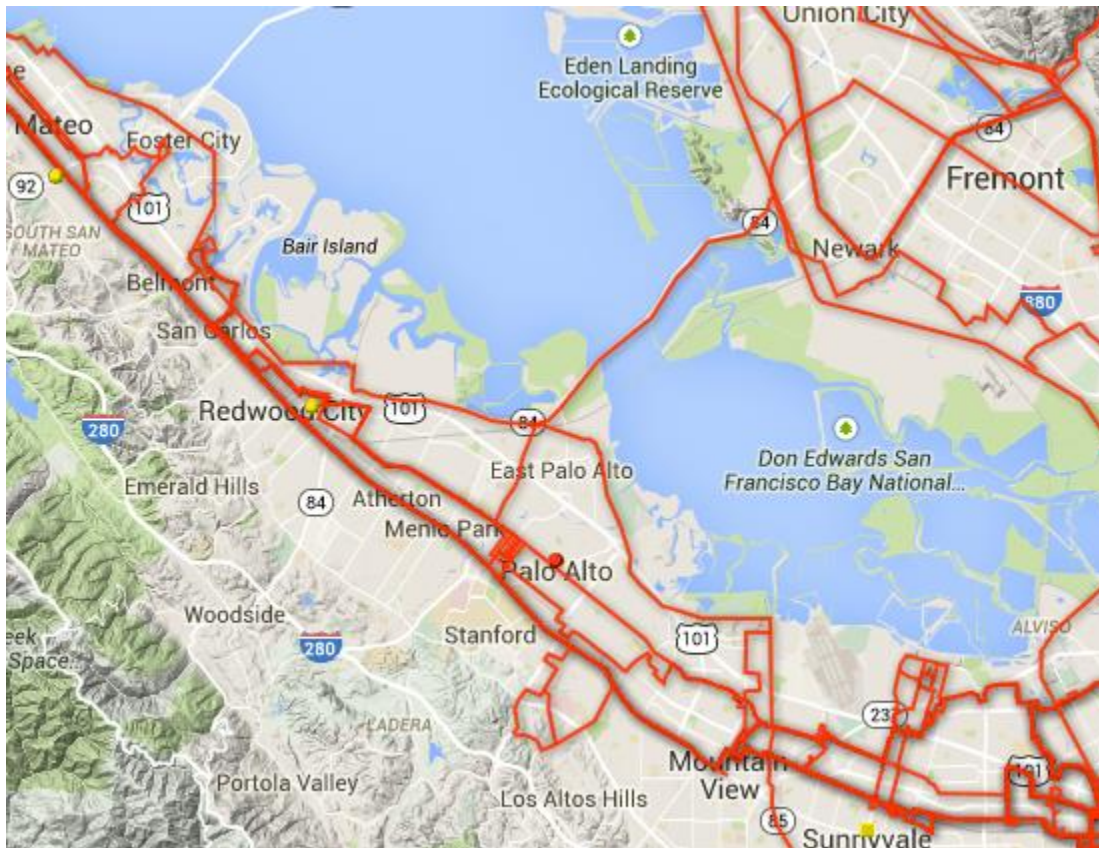


1.1.2 Level(3)

Level(3) has multiple dark fiber routes in Palo Alto as depicted in Figure 2.⁶ Services are offered only to select customers based on their application requirements.

⁶ As we noted, carriers typically do not publish details such as whether they directly own the routes depicted on their publicly-available maps.

Figure 2: Level(3) Dark Fiber Routes⁷



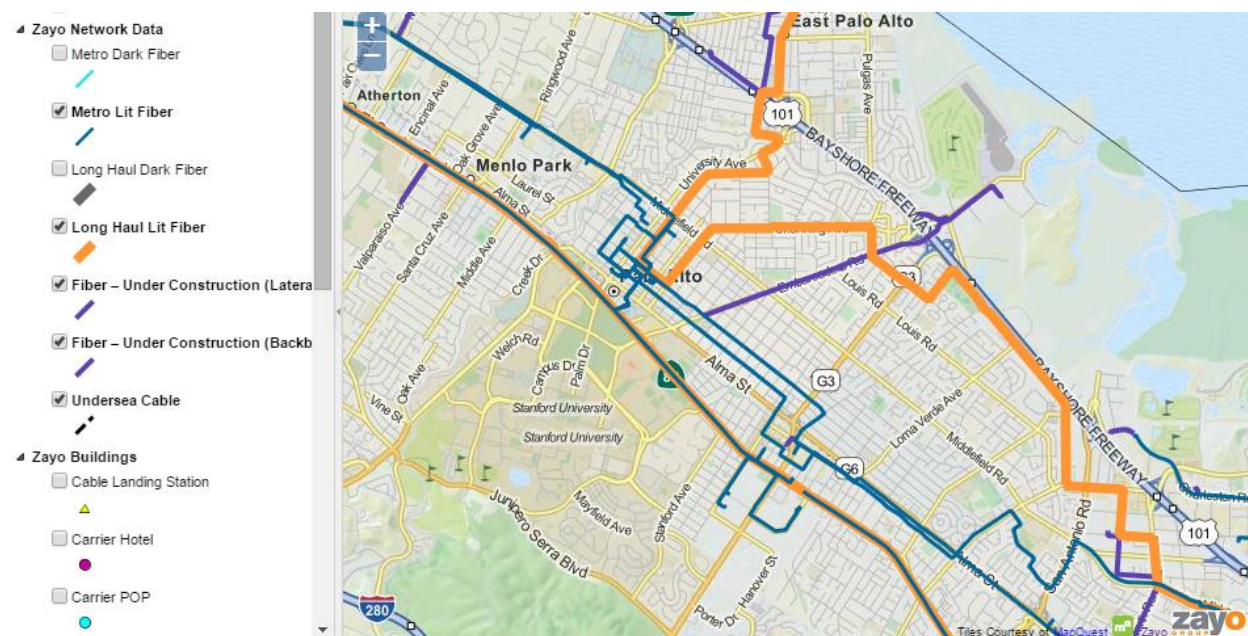
1.1.3 Zayo

Zayo provides dark fiber connectivity over its national network of metro and intercity fiber.⁸ The company claims to have proven expertise in deploying major new dark fiber networks and offers multiple financing options including lease or Indefeasible Rights of Use (IRU). Pricing varies significantly depending on whether the building is On-Net or not; if the location is Off-Net, construction and splicing costs would apply.⁹

⁷ <http://maps.level3.com/default/>, accessed May 2015.

⁸ Zayo is also a CPAU Value Added Reseller (VAR), based on conversations with CPAU staff.

⁹ <http://zayofibersolutions.com/why-dark-fiber>, accessed May 2015.

Figure 3: Zayo Fiber Map¹⁰

1.2 Ethernet Services

Most existing service providers offer enterprise-grade Ethernet based services. These are typically classified under two categories: point-to-point connectivity and access services, such as Dedicated Internet Access (DIA) and IP Virtual Private Networks (IP-VPN). Bandwidths range from 1 Mbps to 100 Gbps. Providers prefer to offer MPLS based IP-VPN services when the service locations are Off-Net to avoid construction and installation costs. MPLS based networks provide high performance for real-time applications like voice and video, and are typically priced higher.

The carriers who provide these services in the Palo Alto region are AT&T, CenturyLink, Cogent Communications, Comcast,¹¹ Integra Telecom, Level (3), Megapath, Verizon, Windstream Communications, XO Communications and Zayo. Prices depend on the bandwidth, location, and network configuration, whether the service is protected or unprotected, and whether the service has a switched or mesh structure.

1.2.1 AT&T

AT&T has four different types of Ethernet products—GigaMAN, DecaMAN, Opt-E-MAN, and Metro Ethernet. GigaMAN provides a native-rate interconnection of 1 Gbps between customer end points. It is a dedicated point-to-point fiber optic based service between customer

¹⁰ <http://www.zayo.com/network/interactive-map>, accessed March 2015.

¹¹ It appears Comcast may be pursuing the enterprise market more aggressively through means like going into wireless backhaul. http://www.fiercetelecom.com/offer/gc_backhaul?sourceform=Organic-GC-Backhaul-FierceTelecom, accessed July 2015.

locations which includes the supply of the GigE Network Terminating Equipment (NTE) at the customer premises. DecaMAN connects the end points at 10 Gbps and is transmitted in native Ethernet format similar to GigaMAN, only 10 times faster. Opt-E-MAN service provides a switched Ethernet service within a metropolitan area. It supports bandwidths ranging from 1 Mbps to 1,000 Mbps, and configurations such as point-to-point, point-to-multipoint, and multipoint-to-multipoint. Metro Ethernet service provides various transport capabilities ranging from 2 Mbps through 1 Gbps while meeting IEEE 802.3 standards.¹²

1.2.2 CenturyLink

CenturyLink provides point-to-point inter-city and intra-city configurations for full-duplex data transmission.¹³ The company offers speeds of 100 Mbps to 10 Gbps.¹⁴

1.2.3 Cogent Communications

Cogent Communications' Ethernet services are available at speeds of 1.5 Mbps to 10 Gbps.¹⁵ The company provides middle mile services with the last mile service provisioned through local exchange carriers (LEC).¹⁶ Often, more competitive pricing and better customer support is available through Cogent even though the company utilizes the LECs' last-mile services. Cogent has two on-net locations (data centers) in the City.

1.2.4 Comcast

Comcast provides Ethernet Private Line (EPL) services. EPL service enables customers to connect their Customer premises equipment (CPE) using a lower cost Ethernet interface, as well as using any Virtual Local Area Networks (VLAN) or Ethernet control protocol across the service without coordination with Comcast. EPL service is offered with 10Mbps, 100Mbps, 1 Gbps or 10 Gbps Ethernet User-to-Network Interfaces (UNI) and is available in speed increments from 1 Mbps to 10 Gbps.¹⁷

It is important to note that Comcast began offering "Gigabit Pro" service in 2015, a 2 Gbps service priced at \$300 per month with installation fees of up to \$1,000.¹⁸ Given the installation and monthly fees, this service is priced out of most residential users' reach. Further, the service

¹²

http://www.business.att.com/service_overview.jsp?repoid=Product&repoitem=w_ethernet&serv=w_ethernet&serv_port=w_data&serv_fam=w_local_data&state=California&segment=whole, accessed March 2015.

¹³ CenturyLink is also a CPAU VAR and typically uses ring configuration for redundancy, based on conversations with CPAU staff.

¹⁴ <http://www.centurylink.com/business/products/products-and-services/data-networking/private.html>, accessed May 2015.

¹⁵ <http://www.cogentco.com/en/products-and-services>, accessed May 2015.

¹⁶ Cogent is also a CPAU VAR, based on conversations with CPAU staff.

¹⁷ <http://business.comcast.com/ethernet/products/ethernet-private-line-technical-specifications>, accessed April 2015.

¹⁸ <http://www.theverge.com/2015/7/13/8949207/comcast-gigabit-pro-price-300>, accessed July 2015.

does not have the bells and whistles that traditional Metro Ethernet has—such as committed interface rates. However, if Gigabit Pro is successful, it could disrupt the Metro Ethernet market by filling a mid-range gap with service and pricing that has not previously existed.

1.2.5 Level(3)

Level (3)'s Metro Ethernet dedicated service is available in bandwidth options of 3 Mbps to 1 Gbps and its Ethernet Virtual Private Line (VPL) offers in speeds ranging from 3 Mbps to 10 Gbps.¹⁹ It is an end-to-end Layer 2 switched Ethernet service delivered via a Multi-protocol Label Switched (MPLS) backbone. Internet services are available in a range of 14 speeds up to 10 Gbps.²⁰

1.2.6 Megapath

Megapath offers business Ethernet services in the Palo Alto area with advertised speeds up to 45 Mbps. Higher speeds are available on a case- by-case basis.²¹

1.2.7 Integra Telecom

Integra Telecom offers Ethernet services from 1.5 Mbps to 10 Gbps. The point-to-point E-Line and multipoint -to -multipoint E-LAN configurations are available.²²

1.2.8 Verizon

Verizon offers Ethernet services under three different product categories—Ethernet Local Area Network (LAN), EPL, and EVPL. The Ethernet LAN is a multipoint-to-multipoint bridging service at native LAN speeds. It is configured by connecting customer User-to- Network Interfaces (UNIs) to one multipoint-to-multipoint Ethernet Virtual Connection or Virtual LAN (VLAN), and provides two Class of Service options—standard and real time. The Ethernet Private Line is a managed, point-to-point transport service for Ethernet frames. It is provisioned as Ethernet over SONET (EoS) and speeds of 10 Mbps to 10 Gbps are available. The EVPL is an all-fiber optic network service that connects subscriber locations at native LAN speeds; EVPL uses point-to-point Ethernet virtual connections (EVCs) to define site-to-site connections. It can be configured to support multiple EVCs to enable a hub and spoke configuration and supports bandwidths from 1 Mbps to 10 Gbps.²³

¹⁹ <http://www.level3.com/en/products-and-services/data-and-internet/vpn-virtual-private-network/evpl/>, accessed March 2015.

²⁰ http://www.level3.com/~media/files/factsheets/en_ethernet_fs_ethernetmatrix.pdf, accessed April 2015.

²¹ <http://www.megapath.com/data/ethernet/>, accessed May 2015.

²² <http://www.integratelecom.com/enterprise/products/pages/carrier-ethernet-services.aspx>, accessed May 2015.

²³ <http://www.verizonenterprise.com/products/networking/ethernet/>, accessed April 2015.

1.2.9 Windstream Communications

Windstream Communications has a nationwide presence serving major metropolitan areas, including the City, with private line and MPLS VPN services with speeds up to 10 Gbps.^{24, 25}

1.2.10 XO Communications

XO Communications offers carrier Ethernet services at multiple bandwidth options from 3 Mbps to 100 Gbps over their Tier 1 IP network.^{26, 27}

1.2.11 Zayo

Zayo delivers Ethernet in three service types with bandwidth ranging from 100 Mbps to 10 Gbps and options like quality of service (QoS) guarantees and route protection based on customer needs. The different types of services offered are: Ethernet-Line, which provides point-to-point and point-to-multipoint configurations with reserved bandwidth availability; Ethernet-LAN, with multipoint configurations having a guaranteed service level; and Ethernet Private Dedicated Network (E-PDN) with a completely private, managed network operated by Zayo with dedicated fiber and equipment.²⁸ As an example of pricing, Zayo charges a monthly recurring cost of \$1,613 to \$2,090 (depending on contract term) for 1 Gbps point-to-point Ethernet service between On-Net sites in the Los Angeles region that are three miles apart.

²⁴ <http://carrier.windstreambusiness.com/wordpress/wp-content/uploads/2014/10/Carrier-Ethernet-Ordering-Guide-10.8.14.pdf>, accessed April 2015.

²⁵ <http://www.windstreambusiness.com/shop/products/ca/palo-alto>, accessed May 2015.

²⁶ <http://www.xo.com/carrier/transport/ethernet/>, accessed May 2015.

²⁷ <http://www.xo.com/network-services/internet-access/ip-transit/100G/>, accessed May 2015.

²⁸ <http://www.zayo.com/ethernet>, accessed April 2015.

2 Residential and Small Business Services

Residential and small business customers in the Palo Alto region have access to a range of services, though individual service options are dependent on location. Table 1 lists the service providers and minimum price for each type of service that is available in at least some part of the City.

Table 1: Overview of Residential and Small Business Data Services in Palo Alto

Service Type	Provider	Minimum Price (per month)
Cable	Comcast	\$29.99
DSL	AT&T	\$29.95
	Earthlink	\$80
	MegaPath	\$45
	Sonic	\$40
Satellite	DishNET	\$49.99
	Exede	\$49.99
	HughesNet	\$49.99
3G/4G/ WISP	AT&T	\$50
	Cricket	\$35
	Sprint	\$35
	Verizon	\$60
	T-Mobile	\$20
	Etheric Networks	\$85

2.1 Cable

Comcast offers internet service from 3 Mbps to 150 Mbps download speeds starting at \$29.99 per month in the City as illustrated in Table 2. Promotional rates are available for the first year after which the rates increase. Discounted prices are available if bundled with another service like voice or TV.²⁹ On the small business side, multiple options are available starting at 16 Mbps download speeds up to 150 Mbps download speeds as illustrated in Table 3.³⁰ Bundling with voice introduces a savings of \$30-\$40.

²⁹ <http://www.comcast.com/internet-service.html>, accessed March 2015.

³⁰ <http://business.comcast.com/internet/business-internet/plans-pricing>, accessed May 2015.

Table 2: Comcast Residential Internet – Internet Only

PACKAGE	INTERNET SPEED	REGULAR PRICE	PROMO RATE
Economy	Up to 3 Mbps download	\$39.95/mo	-
Performance Starter	Up to 6 Mbps download	\$49.95/mo	\$29.99/mo
Performance	Up to 25 Mbps download	\$61.95/mo	\$39.99/mo
Blast!	Blast! Internet - up to 105 Mbps download	\$78.95/mo	-
Extreme	up to 150 Mbps download	\$114.95/mo	-

Table 3: Comcast Small Business Internet – Internet Only

PACKAGE	INTERNET SPEED	PRICE
Starter	16 Mbps download/3 Mbps upload	\$69.95/mo
Deluxe 50	50 Mbps download/ 10 Mbps upload	\$109.95/mo
Deluxe 75	75 Mbps download/15 Mbps upload	\$149.95/mo
Deluxe 100	100 Mbps download/20 Mbps upload	\$199.95/mo
Deluxe 150	150 Mbps download/20 Mbps upload	\$249.95/mo

2.2 DSL

Four providers offer DSL services in Palo Alto: AT&T, EarthLink, MegaPath, and Sonic.

2.2.1 AT&T

AT&T offers DSL service for residential customers in Palo Alto starting at as \$29.95 per month for unbundled or standalone DSL service at 3 Mbps with a 12-month commitment. Additional options up to 45 Mbps are available as indicated in Table 4.

Table 4: AT&T Residential Internet – Internet Only

INTERNET SPEED	REGULAR PRICE	PROMO RATE
Up to 3 Mbps download	\$42/mo	\$29.95/mo
Up to 6 Mbps download	\$52/mo	\$34.95/mo
Up to 18 Mbps download	\$62/mo	\$44.95/mo
up to 45 Mbps download	\$82/mo	\$44.95/mo

2.2.2 EarthLink

EarthLink provides DSL based business services in the region starting at \$80 per month and offering speeds up to 6 Mbps with 99.9% network availability.³¹

2.2.3 MegaPath

MegaPath is an Internet service provider that offers speeds of up to 20 Mbps download and 1 Mbps upload for business customers in certain parts of Palo Alto.³² The lowest plan offered by them is for 1.5 Mbps download speeds at \$45 per month.

2.2.4 Sonic

Sonic offers residential internet services at 20 Mbps and 40 Mbps at a rate of \$40 per month and \$60 per month respectively in Palo Alto. The service also includes a phone connection. The provider is promoting the development of gigabit fiber connectivity on a neighborhood by neighborhood basis depending on the interest shown by consumers.³³ Sonic also offers business internet and phone service in some locations in Palo Alto for \$89.95 per month for speeds of 40 Mbps.

2.3 Satellite

Satellite Internet access is available in the area as well and three providers offer the service: HughesNet, Exede, and DishNET.

2.3.1 HughesNet

HughesNet has four packages available for residential users: 1) Connect Satellite with speeds up to 5 Mbps download/1 Mbps upload, a monthly data cap of 5 GB, and 5 GB of “bonus” data (10 GB total) for \$49.99 per month 2) HughesNet Power with speeds up to 10 Mbps download/1

³¹ <http://www.earthlinkbusiness.com/DSL/>, accessed March 2015.

³² <http://www.megapath.com/services/>, accessed May 2015.

³³ <https://www.sonic.com/availability>, accessed May 2015.

Mbps upload, a 10 GB monthly data cap, and 10 GB of bonus data (20 GB total) for \$59.99 per month; and 3) HughesNet Power Pro with speeds up to 10 Mbps/2 Mbps, a monthly data cap of 15 GB, and 15 GB bonus bytes (30 GB total) for \$79.99 per month; and 4) HughesNet Power Max with speeds up to 15 Mbps/2 Mbps, a monthly data cap of 20 GB, and 20 GB of bonus data (40 GB total) for \$129.99 per month.

HughesNet offers two packages for Internet services to small businesses. The Business 50 package provides speeds of up to 5 Mbps download and 1 Mbps upload for \$69.99 per month with a 5 GB per month anytime allowance and 10 GB bonus bytes from 2am to 10 am for a total monthly data allowance of 15 GB. This package requires a two year agreement and only supports up to five users. The Business 100 package provides the same download and upload speeds of the Business 50 package, but offers a higher data allowance threshold of 10 GB per month anytime and 15 GB bonus bytes from 2 am to 10 am for a monthly data allowance of 25 GB. This package also requires a two year agreement and is best for 5 to just over 10 users.

2.3.2 Exede

Exede offers three Internet packages in the region each with up to 12 Mbps download and 3 Mbps upload speeds. These packages are: 1) Evolution 5 with a monthly 5 GB data cap (excluding emails and web pages) for \$49.99 per month 2) Evolution 20 with a 20 GB monthly data cap for \$69.99 per month and 3) Freedom with unlimited access for \$99.99 per month.

2.3.3 DishNET

DishNET offers three residential Internet packages in the region. These packages are: 1) Up to 5 Mbps download speed with a monthly 5 GB data cap and 5 GB of bonus data for \$49.99 per month with a 24-month commitment; 2) download speeds up to 10 Mbps with a 10 GB monthly data cap and 10 GB of bonus data for \$59.99 per month with a 24-month commitment; and 3) up to 10 Mbps download speed with a 15 GB monthly data cap and 15 GB of bonus data for \$79.99 per month with a 24-month commitment.

2.4 Wireless

There are six providers that offer wireless Internet services in Palo Alto: Verizon, Sprint, AT&T, Cricket Wireless, T-Mobile, and Etheric Networks.

2.4.1 Verizon

Verizon offers two 4G LTE data packages with multiple choices for data allowances and pricing depending on the desired mobility and equipment chosen. The HomeFusion Broadband Package is a data-only 4G LTE service with WiFi connectivity and wired Ethernet for up to four devices. There are download speeds of 5 Mbps to 12 Mbps and upload speeds of 2 Mbps to 5 Mbps. Monthly prices range from \$60 for a 10 GB data allowance to \$120 for a 30 GB data cap. Overages are charged at \$10 per additional GB. A two-year contract is required with a \$350

early termination fee. Verizon offers a \$10 monthly deduction for every month completed in the contract. The Ellipsis JetPack provides a mobile solution with download speeds of 5 Mbps to 12 Mbps and upload speeds of 2 Mbps to 5 Mbps. Prices for the 12 options of data allowances range from \$30 per month for a 4 GB data allowance to \$335 per month for 50 GB of data, in addition to a monthly line access charge of \$20. The device is \$0.99 with a two-year contract. There is a \$35 activation fee.

2.4.2 Sprint

Sprint offers 4G LTE wireless data in Palo Alto. The three data packages offered range from 100 MB per month data allowance for \$15 per month to 6 GB per month data allowance for \$50 per month to 12 GB per month data allowance for \$80 per month. Each MB over the limits is billed at a cost of \$.05. A two-year contract is required as well as an activation fee of \$36, and equipment charges for three different types of devices. There is also an early termination fee of \$200.

2.4.3 AT&T

AT&T also provides 4G LTE wireless data service in the area, but only offers one package type with a 5 GB per month download allowance for \$50 per month. There is an overage fee of \$10 per 1 GB over the limit. There are also equipment charges with or without a contract and an activation fee.

2.4.4 Cricket Wireless

Cricket Wireless, which recently became a subsidiary of AT&T, offers 4G LTE wireless service in Palo Alto with a download speed of up to 8 Mbps with three options for data allowance packages. Starting at \$35 per month for 1 GB of data allowed there are also options for data allowances of 3 GB (\$45) and 10 GB (\$55). Data used beyond allowances are at reduced speeds. There is a \$79.99 modem fee for an additional device. There is a \$15 activation fee, but no contract or early termination fees.

2.4.5 T-Mobile

Of the cellular wireless providers in the area, the least expensive wireless data option offered is from T-Mobile for \$20 per month with a limit of 1 GB per month. T-Mobile offers additional capabilities and increasing data limits at incremental costs in a total of six packages up to \$70 per month for up to 11 GB of data. Depending upon current promotions, the \$35 activation fee may be waived.

2.4.6 Etheric Networks

Etheric Networks is a wireless internet service provider (WISP) that provides services in Palo Alto for speeds up to 30 Mbps.³⁴ The range of speeds and pricing available are indicated in Table 5. A radio and antenna fee of \$299 is also charged during setup and installation.

Table 5: Etheric Networks Internet Services

PACKAGE	INTERNET SPEED	PRICE
Bronze	Up to 5 Mbps download	\$85/mo
Silver	Up to 10 Mbps download	\$99/mo
Gold	Up to 20 Mbps download	\$139/mo
Platinum	up to 25Mbps download	\$179/mo
Diamond	up to 30 Mbps download	\$229/mo

³⁴ <http://ethericnetworks.com/residential/>. accessed May 2015.

**City of Palo Alto
Palo Alto, California
FTTP Network
July 15, 2015**

Appendix B - Retail Data Services - Rev 13

First is to ensure that all assumptions are clearly understood and their impact to the projected results. Second is to present a plausible outcome of the proposed broadband business. Third is to provide a guide to judge the progress of the broadband business as it unfolds. CTC does not warrant the analysis, the assumptions, or the success of the broadband business. CTC only offers this tool as a means of providing consultative advice. There will usually be differences between the projected and actual results, because events and circumstances frequently do not occur as expected, and those differences may be material.

City of Palo Alto
FTTP Network
Appendix B - Retail Data Services - Rev 13
July 15, 2015

Financial Statements	Page
Income Statement	3
Cash Flow Statement	5
Capital Additions	7
Financial Summary Tables	9
Scenarios	13
Expense Charts	21
 FTTP Cost Summary	
OSP Cost Estimate Summary	25
Network Electronics Summary	26
 Other	
Project Assumptions	27

DRAFT

City of Palo Alto
 FFTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Income Statement

	Year	1	2	3	4	5	6	7	8	9	10
a. Revenues											
Internet - Residential	\$	1,722,000	\$ 7,726,320	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680
Internet - Business		472,320	2,109,840	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640
Enterprise		-	-	-	-	-	-	-	-	-	-
Connection Fee (net)		350,850	1,222,800	1,224,000	-	-	-	-	-	-	-
Provider Fee		-	-	-	-	-	-	-	-	-	-
Ancillary Revenues		-	-	-	-	-	-	-	-	-	-
Total	\$	2,545,170	\$ 11,058,960	\$ 18,712,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320
b. Content Fees											
Internet	\$	89,230	\$ 400,170	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430
Enterprise		-	-	-	-	-	-	-	-	-	-
Total	\$	89,230	\$ 400,170	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430
c. Operating Costs											
Labor Costs	\$	1,409,930	\$ 3,496,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350
Support Services		57,020	31,470	55,950	55,950	55,950	55,950	55,950	55,950	55,950	55,950
Insurance		100,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000
Utilities		25,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Office Expenses		36,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Facility Lease		-	-	-	-	-	-	-	-	-	-
Locates & Ticket Processing		19,000	38,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Contingency		25,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Billing Maintenance Contract		15,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance		89,920	109,900	109,900	109,900	109,900	109,900	109,900	109,900	109,900	109,900
Vendor Maintenance Contracts		-	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600
Legal and Lobby Fees		150,000	75,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Consulting		100,000	50,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Marketing		500,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
Education and Training		28,200	69,930	97,650	97,650	97,650	97,650	97,650	97,650	97,650	97,650
Customer Handholding		2,810	12,590	22,380	22,380	22,380	22,380	22,380	22,380	22,380	22,380
Customer Billing (Unit)		1,400	6,290	11,190	11,190	11,190	11,190	11,190	11,190	11,190	11,190
Allowance for Bad Debts		12,730	55,290	93,560	87,440	87,440	87,440	87,440	87,440	87,440	87,440
Churn (acquisition costs)		10,530	47,210	83,930	83,930	83,930	83,930	83,930	83,930	83,930	83,930
Pole Attachment Expense		134,340	134,340	134,340	134,340	134,340	134,340	134,340	134,340	134,340	134,340
Total	\$	2,716,880	\$ 6,070,970	\$ 7,585,850	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730
d. EBITDA	\$	(260,940)	\$ 4,587,820	\$ 10,415,040	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160
e. Depreciation	\$	3,434,290	\$ 6,119,300	\$ 8,176,960	\$ 8,223,890	\$ 8,270,820	\$ 7,934,470	\$ 6,749,060	\$ 5,562,930	\$ 5,562,930	\$ 5,562,930
f. Operating Income (EBITDA less depreciator	\$	(3,695,230)	\$ (1,531,480)	\$ 2,238,080	\$ 973,270	\$ 926,340	\$ 1,262,690	\$ 2,448,100	\$ 3,634,230	\$ 3,634,230	\$ 3,634,230
g. Non-Operating Income											
Interest Income	\$	-	\$ 6,250	\$ 6,250	\$ 13,890	\$ 21,570	\$ 24,850	\$ 22,040	\$ 17,820	\$ 23,910	\$ 30,000
Interest Expense (10 Year Bond)		-	-	-	-	-	-	-	-	-	-
Interest Expense (20 Year Bond)		(2,000,000)	(2,000,000)	(2,000,000)	(2,000,000)	(1,915,600)	(1,827,830)	(1,736,550)	(1,641,610)	(1,542,880)	(1,440,200)
Interest Expense (Loan)		(215,000)	(1,065,000)	(1,265,000)	(1,265,000)	(1,219,920)	(1,172,580)	(1,122,870)	(1,070,680)	(1,015,880)	(958,350)
Total	\$	(2,215,000)	\$ (3,058,750)	\$ (3,258,750)	\$ (3,251,110)	\$ (3,113,950)	\$ (2,975,560)	\$ (2,837,380)	\$ (2,694,470)	\$ (2,534,850)	\$ (2,368,550)
h. Net Income (before taxes)	\$	(5,910,230)	\$ (4,590,230)	\$ (1,020,670)	\$ (2,277,840)	\$ (2,187,610)	\$ (1,712,870)	\$ (389,280)	\$ 939,760	\$ 1,099,380	\$ 1,265,680
i. Facility Taxes	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
j. Net Income	\$	(5,910,230)	\$ (4,590,230)	\$ (1,020,670)	\$ (2,277,840)	\$ (2,187,610)	\$ (1,712,870)	\$ (389,280)	\$ 939,760	\$ 1,099,380	\$ 1,265,680

City of Palo Alto
 FFTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Income Statement

	Year	11	12	13	14	15	16	17	18	19	20
a. Revenues											
Internet - Residential	\$	13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680
Internet - Business		3,752,640	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640	3,752,640
Enterprise		-	-	-	-	-	-	-	-	-	-
Provider Fee		-	-	-	-	-	-	-	-	-	-
Ancillary Revenues		-	-	-	-	-	-	-	-	-	-
Total	\$	17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320
b. Content Fees											
Internet	\$	711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430
Enterprise		-	-	-	-	-	-	-	-	-	-
Total	\$	711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430
c. Operating Costs											
Labor Costs	\$	4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350
Support Services		55,950	55,950	55,950	55,950	55,950	55,950	55,950	55,950	55,950	55,950
Insurance		150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000
Utilities		50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Office Expenses		50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Facility Lease		-	-	-	-	-	-	-	-	-	-
Locates & Ticket Processing		75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Contingency		50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Billing Maintenance Contract		25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance		109,900	109,900	109,900	109,900	109,900	109,900	109,900	109,900	109,900	109,900
Vendor Maintenance Contracts		1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600	1,369,600
Legal and Lobby Fees		50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Consulting		25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Marketing		250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
Education and Training		97,650	97,650	97,650	97,650	97,650	97,650	97,650	97,650	97,650	97,650
Customer Handholding		22,380	22,380	22,380	22,380	22,380	22,380	22,380	22,380	22,380	22,380
Customer Billing (Unit)		11,190	11,190	11,190	11,190	11,190	11,190	11,190	11,190	11,190	11,190
Allowance for Bad Debts		87,440	87,440	87,440	87,440	87,440	87,440	87,440	87,440	87,440	87,440
Churn (acquisition costs)		83,930	83,930	83,930	83,930	83,930	83,930	83,930	83,930	83,930	83,930
Pole Attachment Expense		134,340	134,340	134,340	134,340	134,340	134,340	134,340	134,340	134,340	134,340
Total	\$	7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730
d. EBITDA											
	\$	9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160
e. Depreciation											
	\$	5,011,700	\$ 4,466,710	\$ 4,467,410	\$ 5,292,010	\$ 5,292,010	\$ 5,292,010	\$ 4,966,140	\$ 4,466,710	\$ 4,467,410	\$ 5,292,010
f. Operating Income (EBITDA less depreciatio											
	\$	4,185,460	\$ 4,730,450	\$ 4,729,750	\$ 3,905,150	\$ 3,905,150	\$ 3,905,150	\$ 4,231,020	\$ 4,730,450	\$ 4,729,750	\$ 3,905,150
g. Non-Operating Income											
Interest Income	\$	12,890	\$ 9,040	\$ 3,490	\$ (1,050)	\$ 4,710	\$ 10,480	\$ 15,850	\$ 16,550	\$ 11,010	\$ 6,470
Interest Expense (10 Year Bond)		-	-	-	-	-	-	-	-	-	-
Interest Expense (20 Year Bond)		(1,333,410)	(1,222,350)	(1,106,840)	(986,720)	(861,790)	(731,870)	(596,740)	(456,220)	(310,070)	(158,070)
Interest Expense (Loan)		(897,930)	(834,490)	(767,880)	(697,940)	(624,510)	(547,400)	(466,430)	(381,420)	(292,160)	(198,430)
Total	\$	(2,218,450)	(2,047,800)	(1,871,230)	(1,685,710)	(1,481,590)	(1,268,790)	(1,047,320)	(821,090)	(591,220)	(350,030)
h. Net Income (before taxes)											
	\$	1,967,010	\$ 2,682,650	\$ 2,858,520	\$ 2,219,440	\$ 2,423,560	\$ 2,636,360	\$ 3,183,700	\$ 3,909,360	\$ 4,138,530	\$ 3,555,120
i. Facility Taxes											
	\$	-	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
j. Net Income											
	\$	1,967,010	\$ 2,682,650	\$ 2,858,520	\$ 2,219,440	\$ 2,423,560	\$ 2,636,360	\$ 3,183,700	\$ 3,909,360	\$ 4,138,530	\$ 3,555,120

City of Palo Alto
FTTP Network
Appendix B - Retail Data Services - Rev 13
July 15, 2015

Cash Flow Statement

	1	2	3	4	5	6	7	8	9	10
a. Net Income	\$ (5,910,230)	\$ (4,590,230)	\$ (1,020,670)	\$ (2,277,840)	\$ (2,187,610)	\$ (1,712,870)	\$ (389,280)	\$ 939,760	\$ 1,099,380	\$ 1,265,680
b. Cash Outflows										
Debt Service Reserve	\$ (2,500,000)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Interest Reserve	(4,000,000)	-	-	-	-	-	-	-	-	-
Depreciation Reserve	-	-	-	(3,289,560)	(3,308,330)	(3,173,790)	(3,239,550)	(2,670,210)	(2,670,210)	(2,670,210)
Financing	(500,000)	-	-	-	-	-	-	-	-	-
Capital Expenditures	(46,780,400)	(20,557,700)	(10,288,300)	(234,650)	(234,650)	(1,864,010)	(4,361,130)	(4,357,670)	(234,650)	(234,650)
Total	\$ (53,780,400)	\$ (20,557,700)	\$ (10,288,300)	\$ (3,524,210)	\$ (3,542,980)	\$ (5,037,800)	\$ (7,600,680)	\$ (7,027,880)	\$ (2,904,860)	\$ (2,904,860)
c. Cash Inflows										
Interest Reserve	\$ 2,000,000	\$ 2,000,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Depreciation Reserve	-	-	-	234,650	234,650	1,864,010	4,361,130	4,357,670	234,650	234,650
Investment Capital	-	-	-	-	-	-	-	-	-	-
Start Up Funds	-	-	-	-	-	-	-	-	-	-
Grants (infrastructure)	-	-	-	-	-	-	-	-	-	-
Grants (customer premises)	-	-	-	-	-	-	-	-	-	-
10-Year Bond/Loan Proceeds	-	-	-	-	-	-	-	-	-	-
20-Year Bond Proceeds	50,000,000	-	-	-	-	-	-	-	-	-
Loan Proceeds	4,300,000	17,000,000	4,000,000	-	-	-	-	-	-	-
Total	\$ 56,300,000	\$ 19,000,000	\$ 4,000,000	\$ 234,650	\$ 234,650	\$ 1,864,010	\$ 4,361,130	\$ 4,357,670	\$ 234,650	\$ 234,650
d. Total Cash Outflows and Inflows	\$ 2,519,600	\$ (1,557,700)	\$ (6,288,300)	\$ (3,289,560)	\$ (3,308,330)	\$ (3,173,790)	\$ (3,239,550)	\$ (2,670,210)	\$ (2,670,210)	\$ (2,670,210)
e. Non-Cash Expenses - Depreciation	\$ 3,434,290	\$ 6,119,300	\$ 8,176,960	\$ 8,223,890	\$ 8,270,820	\$ 7,934,470	\$ 6,749,060	\$ 5,562,930	\$ 5,562,930	\$ 5,562,930
f. Adjustments										
Proceeds from Additional Cash Flows (10 Year Bond)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Proceeds from Additional Cash Flows (20 Year Bond)	\$ (50,000,000)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Proceeds from Additional Cash Flows (Loan)	\$ (4,300,000)	\$ (17,000,000)	\$ (4,000,000)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
g. Adjusted Available Net Revenue	\$ (54,256,340)	\$ (17,028,630)	\$ (3,132,010)	\$ 2,656,490	\$ 2,774,880	\$ 3,047,810	\$ 3,120,230	\$ 3,832,480	\$ 3,992,100	\$ 4,158,400
h. Principal Payments on Debt										
10 Year Bond Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
20 Year Bond Principal	-	-	-	2,109,930	2,194,330	2,282,100	2,373,380	2,468,320	2,567,050	2,669,730
Loan Principal	-	-	-	901,670	946,760	994,090	1,043,800	1,095,990	1,150,790	1,208,330
Total	\$ -	\$ -	\$ -	\$ 3,011,600	\$ 3,141,090	\$ 3,276,190	\$ 3,417,180	\$ 3,564,310	\$ 3,717,840	\$ 3,878,060
i. Net Cash	\$ 43,660	\$ (28,630)	\$ 867,990	\$ (355,110)	\$ (366,210)	\$ (228,380)	\$ (296,950)	\$ 268,170	\$ 274,260	\$ 280,340
j. Cash Balance										
Unrestricted Cash Balance	\$ 43,660	\$ 15,030	\$ 883,020	\$ 527,910	\$ 161,700	\$ (66,680)	\$ (363,630)	\$ (95,460)	\$ 178,800	\$ 459,140
Depreciation Reserve	-	-	-	3,054,910	6,128,590	7,438,370	6,316,790	4,629,330	7,064,890	9,500,450
Interest Reserve	2,000,000	-	-	-	-	-	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,543,660	\$ 2,515,030	\$ 3,383,020	\$ 6,082,820	\$ 8,790,290	\$ 9,871,690	\$ 8,453,160	\$ 7,033,870	\$ 9,743,690	\$ 12,459,590
Un-depreciated Value of Capital Assets	\$ 43,346,110	\$ 57,784,510	\$ 59,895,850	\$ 51,906,600	\$ 43,870,430	\$ 37,799,970	\$ 35,412,050	\$ 34,206,790	\$ 28,878,510	\$ 23,550,220
Debt Service Balance (10 Year Bond)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Debt Service Balance (20 Year Bond)	\$ 50,000,000	\$ 50,000,000	\$ 50,000,000	\$ 50,000,000	\$ 47,890,070	\$ 45,695,740	\$ 43,413,640	\$ 41,040,260	\$ 38,571,940	\$ 36,004,890
Debt Service Balance (Internal Loan)	\$ 4,300,000	\$ 17,000,000	\$ 4,000,000	\$ (901,670)	\$ (946,760)	\$ (994,090)	\$ (1,043,800)	\$ (1,095,990)	\$ (1,150,790)	\$ (1,208,330)
Debt Service (P&I)	\$ 2,215,000	\$ 3,065,000	\$ 3,265,000	\$ 6,276,600	\$ 6,276,610	\$ 6,276,600	\$ 6,276,600	\$ 6,276,600	\$ 6,276,600	\$ 6,276,610
Debt Coverage Ratio	-	-	-	1.97	1.88	1.85	1.75	1.84	1.76	1.69
Debt Service Coverage Ratio	-	-	-	0.88	0.88	0.93	0.91	1.08	1.07	1.07

City of Palo Alto
FTTP Network
July 15, 2015

Cash Flow Statement

	11	12	13	14	15	16	17	18	19	20
a. Net Income	\$ 1,967,010	\$ 2,682,650	\$ 2,858,520	\$ 2,219,440	\$ 2,423,560	\$ 2,636,360	\$ 3,183,700	\$ 3,909,360	\$ 4,138,530	\$ 3,555,120
b. Cash Outflows										
Debt Service Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Interest Reserve	-	-	-	-	-	-	-	-	-	-
Depreciation Reserve	(2,405,620)	(2,144,020)	(2,144,360)	(2,540,160)	(2,540,160)	(2,540,160)	(2,383,750)	(2,144,020)	(2,144,360)	(2,540,160)
Financing	-	-	-	-	-	-	-	-	-	-
Capital Expenditures	(9,249,170)	(3,686,320)	(4,361,130)	(4,357,670)	(234,650)	(234,650)	(234,650)	(1,864,010)	(4,361,130)	(4,357,670)
Total	\$ (11,654,790)	\$ (5,830,340)	\$ (6,505,490)	\$ (6,897,830)	\$ (2,774,810)	\$ (2,774,810)	\$ (2,618,400)	\$ (4,008,030)	\$ (6,505,490)	\$ (6,897,830)
c. Cash Inflows										
Interest Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Depreciation Reserve	9,249,170	3,686,320	4,361,130	4,357,670	234,650	234,650	234,650	1,864,010	4,361,130	4,357,670
Investment Capital	-	-	-	-	-	-	-	-	-	-
Start Up Funds	-	-	-	-	-	-	-	-	-	-
Grants (infrastructure)	-	-	-	-	-	-	-	-	-	-
Grants (customer premises)	-	-	-	-	-	-	-	-	-	-
10-Year Bond/Loan Proceeds	-	-	-	-	-	-	-	-	-	-
20-Year Bond Proceeds	-	-	-	-	-	-	-	-	-	-
Loan Proceeds	-	-	-	-	-	-	-	-	-	-
Total	\$ 9,249,170	\$ 3,686,320	\$ 4,361,130	\$ 4,357,670	\$ 234,650	\$ 234,650	\$ 234,650	\$ 1,864,010	\$ 4,361,130	\$ 4,357,670
d. Total Cash Outflows and Inflows	\$ (2,405,620)	\$ (2,144,020)	\$ (2,144,360)	\$ (2,540,160)	\$ (2,540,160)	\$ (2,540,160)	\$ (2,383,750)	\$ (2,144,020)	\$ (2,144,360)	\$ (2,540,160)
e. Non-Cash Expenses - Depreciation	\$ 5,011,700	\$ 4,466,710	\$ 4,467,410	\$ 5,292,010	\$ 5,292,010	\$ 5,292,010	\$ 4,966,140	\$ 4,466,710	\$ 4,467,410	\$ 5,292,010
f. Adjustments										
Proceeds from Additional Cash Flows (10 Year Bond)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Proceeds from Additional Cash Flows (20 Year Bond)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Proceeds from Additional Cash Flows (Loan)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
g. Adjusted Available Net Revenue	\$ 4,573,090	\$ 5,005,340	\$ 5,181,570	\$ 4,971,290	\$ 5,175,410	\$ 5,388,210	\$ 5,766,090	\$ 6,232,050	\$ 6,461,580	\$ 6,306,970
h. Principal Payments on Debt										
10 Year Bond Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
20 Year Bond Principal	2,776,520	2,887,580	3,003,090	3,123,210	3,248,140	3,378,060	3,513,190	3,653,710	3,799,860	3,951,860
Loan Principal	1,268,740	1,332,180	1,398,790	1,468,730	1,542,170	1,619,270	1,700,240	1,785,250	1,874,510	1,968,240
Total	\$ 4,045,260	\$ 4,219,760	\$ 4,401,880	\$ 4,591,940	\$ 4,790,310	\$ 4,997,330	\$ 5,213,430	\$ 5,438,960	\$ 5,674,370	\$ 5,920,100
i. Net Cash	\$ 527,830	\$ 785,580	\$ 779,690	\$ 379,350	\$ 385,100	\$ 390,880	\$ 552,660	\$ 793,090	\$ 787,210	\$ 386,870
j. Cash Balance										
Unrestricted Cash Balance	\$ 986,970	\$ 1,772,550	\$ 2,552,240	\$ 2,931,590	\$ 3,316,690	\$ 3,707,570	\$ 4,260,230	\$ 5,053,320	\$ 5,840,530	\$ 6,227,400
Depreciation Reserve	2,656,900	1,114,600	(1,102,170)	(2,919,680)	(614,170)	1,691,340	3,840,440	4,120,450	1,903,680	86,170
Interest Reserve	-	-	-	-	-	-	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 6,143,870	\$ 5,387,150	\$ 3,950,070	\$ 2,511,910	\$ 5,202,520	\$ 7,898,910	\$ 10,600,670	\$ 11,673,770	\$ 10,244,210	\$ 8,813,570
Un-depreciated Value of Capital Assets	\$ 27,787,700	\$ 27,007,300	\$ 26,901,030	\$ 25,966,690	\$ 20,909,330	\$ 15,851,970	\$ 11,120,480	\$ 8,517,780	\$ 8,411,500	\$ 7,477,160
Debt Service Balance (10 Year Bond)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Debt Service Balance (20 Year Bond)	\$ 33,228,370	\$ 30,340,790	\$ 27,337,700	\$ 24,214,490	\$ 20,966,350	\$ 17,588,290	\$ 14,075,100	\$ 10,421,390	\$ 6,621,530	\$ 2,669,670
Debt Service Balance (Internal Loan)	\$ (2,477,070)	\$ (3,809,250)	\$ (5,208,040)	\$ (6,676,770)	\$ (8,218,940)	\$ (9,838,210)	\$ (11,538,450)	\$ (13,323,700)	\$ (15,198,210)	\$ -
Debt Service (P&I)	\$ 6,276,600	\$ 6,276,600	\$ 6,276,600	\$ 6,276,600	\$ 6,276,610	\$ 6,276,600	\$ 6,276,600	\$ 6,276,600	\$ 6,276,600	\$ 6,276,600
Debt Coverage Ratio	1.68	1.67	1.60	1.45	1.39	1.33	1.31	-	-	-
Debt Service Coverage Ratio	1.13	1.19	1.18	1.08	1.08	1.08	1.11	-	-	-

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Capital Additions

	1	2	3	4	5	6	7	8	9	10
Network Equipment										
Core & Base Equipment	\$ 4,434,490	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Incremental (Switches & OLTs)	6,833,660	2,277,890	-	-	-	-	-	-	-	-
Additional Annual Capital	-	-	-	-	-	-	-	-	-	-
Total	\$ 11,268,150	\$ 2,277,890	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Outside Plant and Facilities										
Total Backbone and FTTP	\$ 31,966,480	\$ 7,991,620	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Additional Annual Capital	-	-	-	-	-	-	-	-	-	-
Total	\$ 31,966,480	\$ 7,991,620	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Last Mile and Customer Premises Equipment										
CPE Gbps (medium commercial)	\$ 61,020	\$ 210,930	\$ 211,980	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
CPE Residential & Small Commercial	1,108,790	3,866,040	3,869,040	-	-	-	-	-	-	-
Enterprise CPE and Drop	-	-	-	-	-	-	-	-	-	-
Average Drop Cost	1,772,960	6,179,220	6,185,280	-	-	-	-	-	-	-
Additional Annual Replacement Capital	-	-	-	234,650	234,650	234,650	234,650	234,650	234,650	234,650
Total	\$ 2,942,770	\$ 10,256,190	\$ 10,266,300	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650
Miscellaneous Implementation Costs										
Splicing	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Vehicles	150,000	-	-	-	-	-	-	-	-	-
Emergency Restoration Kit	50,000	-	-	-	-	-	-	-	-	-
Work Station, Computers, and Software	18,000	32,000	22,000	-	-	-	-	-	-	-
Fiber OTDR and Other Tools	85,000	-	-	-	-	-	-	-	-	-
Generators & UPS	-	-	-	-	-	-	-	-	-	-
OSS	300,000	-	-	-	-	-	-	-	-	-
Additional Annual Capital	-	-	-	-	-	-	-	-	-	-
Total	\$ 603,000	\$ 32,000	\$ 22,000	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Replacement Costs for Depreciation										
Network Equipment	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Last Mile and Customer Premises Equipment	-	-	-	-	-	1,177,110	4,102,480	4,106,520	-	-
Miscellaneous Implementation Costs	-	-	-	-	-	452,250	24,000	16,500	-	-
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 1,629,360	\$ 4,126,480	\$ 4,123,020	\$ -	\$ -
Total Capital Additions	\$ 46,780,400	\$ 20,557,700	\$ 10,288,300	\$ 234,650	\$ 234,650	\$ 1,864,010	\$ 4,361,130	\$ 4,357,670	\$ 234,650	\$ 234,650
		\$ 77,626,400								
Depreciation Reserve Contribution	\$ -	\$ -	\$ -	\$ 3,289,560	\$ 3,308,330	\$ 3,173,790	\$ 3,239,550	\$ 2,670,210	\$ 2,670,210	\$ 2,670,210
Draws from Depreciation Reserve	\$ -	\$ -	\$ -	(234,650)	(234,650)	(1,864,010)	(4,361,130)	(4,357,670)	(234,650)	(234,650)
Net Depreciation Reserve Balance	\$ -	\$ -	\$ -	\$ 3,054,910	\$ 6,128,590	\$ 7,438,370	\$ 6,316,790	\$ 4,629,330	\$ 7,064,890	\$ 9,500,450

City of Palo Alto
FTTP Network
July 15, 2015

Capital Additions

	11	12	13	14	15	16	17	18	19	20
Network Equipment										
Core & Base Equipment	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Incremental (Switches & OLTs)	-	-	-	-	-	-	-	-	-	-
TBD	-	-	-	-	-	-	-	-	-	-
TBD	-	-	-	-	-	-	-	-	-	-
Additional Annual Capital	-	-	-	-	-	-	-	-	-	-
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Outside Plant and Facilities										
Total Backbone and FTTP	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Additional Annual Capital	-	-	-	-	-	-	-	-	-	-
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Last Mile and Customer Premises Equipment										
CPE Gbps (medium commercial)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
CPE Residential & Small Commercial	-	-	-	-	-	-	-	-	-	-
Average Drop Cost	-	-	-	-	-	-	-	-	-	-
Additional Annual Replacement Capital	234,650	234,650	234,650	234,650	234,650	234,650	234,650	234,650	234,650	234,650
Total	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650	\$ 234,650
Miscellaneous Implementation Costs										
Splicing	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Vehicles	-	-	-	-	-	-	-	-	-	-
Emergency Restoration Kit	-	-	-	-	-	-	-	-	-	-
Work Station, Computers, and Software	-	-	-	-	-	-	-	-	-	-
Fiber OTDR and Other Tools	-	-	-	-	-	-	-	-	-	-
Generators & UPS	-	-	-	-	-	-	-	-	-	-
Additional Annual Capital	-	-	-	-	-	-	-	-	-	-
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Replacement Costs for Depreciation										
Network Equipment	\$ 9,014,520	\$ 1,822,310	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Last Mile and Customer Premises Equipment	-	1,177,110	4,102,480	4,106,520	-	-	-	1,177,110	4,102,480	4,106,520
Miscellaneous Implementation Costs	-	452,250	24,000	16,500	-	-	-	452,250	24,000	16,500
Total	\$ 9,014,520	\$ 3,451,670	\$ 4,126,480	\$ 4,123,020	\$ -	\$ -	\$ -	\$ 1,629,360	\$ 4,126,480	\$ 4,123,020
Total Capital Additions	\$ 9,249,170	\$ 3,686,320	\$ 4,361,130	\$ 4,357,670	\$ 234,650	\$ 234,650	\$ 234,650	\$ 1,864,010	\$ 4,361,130	\$ 4,357,670

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Financial Summary Tables

	Year 1	Year 5	Year 10	Year 15	Year 20
Operating Expenses					
Support Services	\$ 57,020	\$ 55,950	\$ 55,950	\$ 55,950	\$ 55,950
Insurance	100,000	150,000	150,000	150,000	150,000
Utilities	25,000	50,000	50,000	50,000	50,000
Office Expenses	36,000	50,000	50,000	50,000	50,000
Locates & Ticket Processing	19,000	75,000	75,000	75,000	75,000
Contingency	25,000	50,000	50,000	50,000	50,000
Billing Maintenance Contract	15,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance	89,920	109,900	109,900	109,900	109,900
Vendor Maintenance Contracts	-	1,369,600	1,369,600	1,369,600	1,369,600
Legal and Lobby Fees	150,000	50,000	50,000	50,000	50,000
Consulting	100,000	25,000	25,000	25,000	25,000
Marketing	500,000	250,000	250,000	250,000	250,000
Education and Training	28,200	97,650	97,650	97,650	97,650
Customer Handholding	2,810	22,380	22,380	22,380	22,380
Customer Billing (Unit)	1,400	11,190	11,190	11,190	11,190
Allowance for Bad Debts	12,730	87,440	87,440	87,440	87,440
Churn (acquisition costs)	10,530	83,930	83,930	83,930	83,930
Pole Attachment Expense	134,340	134,340	134,340	134,340	134,340
Internet	89,230	711,430	711,430	711,430	711,430
Sub-Total	\$ 1,396,180	\$ 3,408,810	\$ 3,408,810	\$ 3,408,810	\$ 3,408,810
Labor Expenses	\$ 1,409,930	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350
Sub-Total	\$ 1,409,930	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350	\$ 4,882,350
Total Expenses	\$ 2,806,110	\$ 8,291,160	\$ 8,291,160	\$ 8,291,160	\$ 8,291,160
Principal and Interest	\$ 2,215,000	\$ 6,276,610	\$ 6,276,610	\$ 6,276,610	\$ 6,276,600
Facility Taxes	-	-	-	-	-
Sub-Total	\$ 2,215,000	\$ 6,276,610	\$ 6,276,610	\$ 6,276,610	\$ 6,276,600
Total Expenses, P&I, and Taxes	\$ 5,021,110	\$ 14,567,770	\$ 14,567,770	\$ 14,567,770	\$ 14,567,760

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Financial Summary Tables

	Year 1	Year 5	Year 10	Year 15	Year 20
a. Revenues					
Internet - Residential	\$ 1,722,000	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680	\$ 13,735,680
Internet - Business	472,320	3,752,640	3,752,640	3,752,640	3,752,640
Enterprise	-	-	-	-	-
Connection Fee (net)	350,850	-	-	-	-
Provider Fee	-	-	-	-	-
Assessments	-	-	-	-	-
Ancillary Revenues	-	-	-	-	-
Total	\$ 2,545,170	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320
b. Content Fees					
Internet	\$ 89,230	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430
Total	\$ 89,230	\$ 711,430	\$ 711,430	\$ 711,430	\$ 711,430
c. Operating Costs					
Operation Costs	\$ 1,306,950	\$ 2,697,380	\$ 2,697,380	\$ 2,697,380	\$ 2,697,380
Labor Costs	1,409,930	4,882,350	4,882,350	4,882,350	4,882,350
Total	\$ 2,716,880	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730	\$ 7,579,730
d. EBITDA	\$ (260,940)	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160	\$ 9,197,160
e. Depreciation	3,434,290	8,270,820	5,562,930	5,292,010	5,292,010
f. Operating Income (EBITDA less Depreciation)	\$ (3,695,230)	\$ 926,340	\$ 3,634,230	\$ 3,905,150	\$ 3,905,150
g. Non-Operating Income					
Interest Income	\$ -	\$ 30,000	\$ 30,000	\$ 4,710	\$ 6,470
Interest Expense (10 Year Bond)	-	-	-	-	-
Interest Expense (20 Year Bond)	(2,000,000)	(1,440,200)	(1,440,200)	(861,790)	(158,070)
Interest Expense (Loan)	(215,000)	(958,350)	(958,350)	(624,510)	(198,430)
Total	\$ (2,215,000)	\$ (2,368,550)	\$ (2,368,550)	\$ (1,481,590)	\$ (350,030)
h. Net Income (before taxes)	\$ (5,910,230)	\$ (2,187,610)	\$ 1,265,680	\$ 2,423,560	\$ 3,555,120
i. Facility Taxes	\$ -	\$ -	\$ -	\$ -	\$ -
j. Net Income	\$ (5,910,230)	\$ (2,187,610)	\$ 1,265,680	\$ 2,423,560	\$ 3,555,120

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Financial Summary Tables

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	\$ (5,910,230)	\$ (2,187,610)	\$ 1,265,680	\$ 2,423,560	\$ 3,555,120
Cash Flow	\$ 43,660	\$ (366,210)	\$ 280,340	\$ 385,100	\$ 386,870

	Year 1	Year 5	Year 10	Year 15	Year 20
Principle Payments	\$ -	\$ 3,141,090	\$ 3,878,060	\$ 4,790,310	\$ 5,920,100
Interest Payments	2,215,000	3,135,520	2,398,550	1,486,300	356,500
Total Debt Service	\$ 2,215,000	\$ 6,276,610	\$ 6,276,610	\$ 6,276,610	\$ 6,276,600

	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	\$ 43,660	\$ 161,700	\$ 459,140	\$ 3,316,690	\$ 6,227,400
Funded Depreciation	-	6,128,590	9,500,450	(614,170)	86,170
Restricted Cash Balance (Interest Reserve)	2,000,000	-	-	-	-
Restricted Cash Balance (Debt Service Reserve)	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,543,660	\$ 8,790,290	\$ 12,459,590	5,202,520	\$ 8,813,570

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Financial Summary Tables

Capital Additions

	Year 1	Year 2	Year 3	Total Years 1 to 3
Network Equipment				
Core & Base Equipment	\$ 4,434,490	\$ -	\$ -	\$ 4,434,490
Incremental (Switches & OLTs)	6,833,660	2,277,890	-	9,111,550
TBD	-	-	-	-
TBD	-	-	-	-
Additional Annual Capital	-	-	-	-
Total	\$ 11,268,150	\$ 2,277,890	\$ -	\$ 13,546,040
Outside Plant and Facilities				
Total Backbone and FTTP	\$ 31,966,480	\$ 7,991,620	\$ -	\$ 39,958,100
Additional Annual Capital	-	-	-	-
Total	\$ 31,966,480	\$ 7,991,620	\$ -	\$ 39,958,100
Last Mile and Customer Premises Equipment				
CPE Gbps (medium commercial)	\$ 61,020	\$ 210,930	\$ 211,980	
CPE Residential & Small Commercial	\$ 1,108,790	\$ 3,866,040	\$ 3,869,040	\$ 8,843,870
Enterprise CPE and Drop	-	-	-	-
Average Drop Cost	1,772,960	6,179,220	6,185,280	14,137,460
Total	\$ 2,942,770	\$ 10,256,190	\$ 10,266,300	\$ 23,465,260
Miscellaneous Implementation Costs				
Splicing	\$ -	\$ -	\$ -	
Vehicles	150,000	-	-	
Emergency Restoration Kit	50,000	-	-	
Work Station, Computers, and Software	\$ 18,000	\$ 32,000	\$ 22,000	\$ 72,000
Fiber OTDR and Other Tools	85,000	-	-	85,000
Generators & UPS	-	-	-	-
OSS	300,000	-	-	300,000
Additional Annual Capital	-	-	-	-
Total	\$ 603,000	\$ 32,000	\$ 22,000	\$ 657,000
Total Capital Additions	\$ 46,780,400	\$ 20,557,700	\$ 10,288,300	\$ 77,626,400

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Scenarios

Base Case

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320
Total Cash Expenses	(2,806,110)	(8,291,160)	(8,291,160)	(8,291,160)	(8,291,160)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,030)
Taxes	-	-	-	-	-
Net Income	\$ (5,910,230)	\$ (2,187,610)	\$ 1,265,680	\$ 2,423,560	\$ 3,555,120
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 43,660	\$ 161,700	\$ 459,140	\$ 3,316,690	\$ 6,227,400
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,543,660	\$ 8,790,290	\$ 12,459,590	\$ 5,202,520	\$ 8,813,570
Investment Metric					
Internal Rate of Return (IRR) - 20 year					0.47%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (23,140,050)
Discount Rate					4.00%

1. Decrease Overhead to 27 Percent of Salaries (from 65 percent), Financing Reduced by \$5 Million, and Take Rate Decreased to 62.1 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 15,081,480	\$ 15,081,480	\$ 15,081,480	\$ 15,081,480
Total Cash Expenses	(2,474,900)	(6,489,030)	(6,489,030)	(6,489,030)	(6,489,030)
Depreciation	(3,344,360)	(7,491,010)	(5,151,390)	(4,904,450)	(4,904,450)
Interest Expense	(2,165,000)	(2,874,100)	(2,178,890)	(1,352,810)	(302,450)
Taxes	-	-	-	-	-
Net Income	\$ (5,439,090)	\$ (1,772,660)	\$ 1,262,170	\$ 2,335,190	\$ 3,385,550
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 324,190	\$ (258,860)	\$ 331,870	\$ 3,111,930	\$ 5,947,450
Depreciation Reserve	-	5,571,860	9,207,260	701,540	2,054,370
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,824,190	\$ 7,813,000	\$ 12,039,130	\$ 6,313,470	\$ 10,501,820
Investment Metric					
Internal Rate of Return (IRR)					0.52%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (21,532,230)
Discount Rate					4.00%

2. Use \$5 Million in Start-Up Funds (decrease amount bonded by same), Reduce Take Rate to 65.7 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 15,956,280	\$ 15,956,280	\$ 15,956,280	\$ 15,956,280
Total Cash Expenses	(2,806,110)	(7,748,000)	(7,748,000)	(7,748,000)	(7,748,000)
Depreciation	(3,368,480)	(7,763,050)	(5,289,500)	(5,036,130)	(5,036,130)
Interest Expense	(2,015,000)	(2,923,920)	(2,225,710)	(1,393,850)	(331,700)
Taxes	-	-	-	-	-
Net Income	\$ (5,644,420)	\$ (2,478,690)	\$ 693,070	\$ 1,778,300	\$ 2,840,450
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 1,401,880	\$ 1,747,590	\$ (63,470)	\$ 446,080	\$ 1,009,740
Depreciation Reserve	-	5,765,070	9,278,290	257,190	1,351,020
Interest Reserve	1,800,000	-	-	-	-
Debt Service Reserve	2,250,000	2,250,000	2,250,000	2,250,000	2,250,000
Total Cash Balance	\$ 5,451,880	\$ 9,762,660	\$ 11,464,820	\$ 2,953,270	\$ 4,610,760
Investment Metric					
Internal Rate of Return (IRR)					-0.12%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (23,931,230)
Discount Rate					4.00%

City of Palo Alto
 FFTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Scenarios

3. Use \$10 Million in Start-Up Funds (decrease amount bonded by same), Reduce Take Rate to 63 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 15,300,000	\$ 15,300,000	\$ 15,300,000	\$ 15,300,000
Total Cash Expenses	(2,806,110)	(7,536,760)	(7,536,760)	(7,536,760)	(7,536,760)
Depreciation	(3,350,950)	(7,559,850)	(5,186,670)	(4,937,980)	(4,937,980)
Interest Expense	(1,815,000)	(2,733,350)	(2,082,440)	(1,307,470)	(315,205)
Taxes	-	-	-	-	-
Net Income	\$ (5,426,890)	\$ (2,529,960)	\$ 494,130	\$ 1,517,790	\$ 2,510,055
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 2,277,120	\$ 3,018,010	\$ 1,336,620	\$ 1,877,640	\$ 2,473,800
Depreciation Reserve	-	5,620,790	9,227,370	588,270	1,877,750
Interest Reserve	1,600,000	-	-	-	-
Debt Service Reserve	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Total Cash Balance	\$ 5,877,120	\$ 10,638,800	\$ 12,563,990	\$ 4,465,910	\$ 6,351,550
Investment Metric					
Internal Rate of Return (IRR)					0.06%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (20,863,300)
Discount Rate					4.00%

4. Use \$15 Million in Start-Up Funds (decrease amount bonded by same), Reduce Take Rate to 60.3 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 14,645,400	\$ 14,645,400	\$ 14,645,400	\$ 14,645,400
Total Cash Expenses	(2,806,100)	(7,476,960)	(7,476,960)	(7,476,960)	(7,476,960)
Depreciation	(3,333,490)	(7,356,980)	(5,084,140)	(4,840,110)	(4,840,110)
Interest Expense	(1,615,000)	(2,542,770)	(1,939,170)	(1,221,090)	(298,705)
Taxes	-	-	-	-	-
Net Income	\$ (5,209,420)	\$ (2,731,310)	\$ 145,130	\$ 1,107,240	\$ 2,029,625
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 3,151,820	\$ 3,837,550	\$ 1,536,380	\$ 1,359,490	\$ 1,238,780
Depreciation Reserve	-	5,476,820	9,176,280	918,090	2,402,640
Interest Reserve	1,400,000	-	-	-	-
Debt Service Reserve	1,750,000	1,750,000	1,750,000	1,750,000	1,750,000
Total Cash Balance	\$ 6,301,820	\$ 11,064,370	\$ 12,462,660	\$ 4,027,580	\$ 5,391,420
Investment Metric					
Internal Rate of Return (IRR)					-0.12%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (19,550,760)
Discount Rate					4.00%

5. Use \$20 Million in Start-Up Funds (decrease amount bonded by same), Reduce Take Rate to 56.7 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 13,770,600	\$ 13,770,600	\$ 13,770,600	\$ 13,770,600
Total Cash Expenses	(2,806,110)	(6,996,600)	(6,996,600)	(6,996,600)	(6,996,600)
Depreciation	(3,287,370)	(7,054,760)	(4,916,100)	(4,684,350)	(4,684,350)
Interest Expense	(1,415,000)	(2,352,380)	(1,796,180)	(1,134,210)	(281,675)
Taxes	-	-	-	-	-
Net Income	\$ (4,963,310)	\$ (2,633,140)	\$ 61,720	\$ 955,440	\$ 1,807,975
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 4,312,860	\$ 5,917,320	\$ 4,171,030	\$ 4,408,330	\$ 4,701,900
Depreciation Reserve	-	5,259,460	9,014,570	1,451,250	3,140,430
Interest Reserve	1,200,000	-	-	-	-
Debt Service Reserve	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Total Cash Balance	\$ 7,012,860	\$ 12,676,780	\$ 14,685,600	\$ 7,359,580	\$ 9,342,330
Investment Metric					
Internal Rate of Return (IRR)					0.46%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (15,015,170)
Discount Rate					4.00%

Scenarios

6. Eliminate Vendor Maintenance Contracts and Reduce Take Rate to 62.1 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 15,081,480	\$ 15,081,480	\$ 15,081,480	\$ 15,081,480
Total Cash Expenses	(2,806,110)	(6,281,090)	(6,281,090)	(6,281,090)	(6,281,090)
Depreciation	(3,344,360)	(7,491,010)	(5,151,390)	(4,904,450)	(4,904,450)
Interest Expense	(2,215,000)	(3,115,340)	(2,369,280)	(1,478,300)	(345,115)
Taxes	-	-	-	-	-
Net Income	\$ (5,820,300)	\$ (1,805,960)	\$ 1,279,720	\$ 2,417,640	\$ 3,550,825
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 942,980	\$ 4,231,820	\$ 3,735,840	\$ 5,429,180	\$ 7,177,980
Depreciation Reserve	-	5,571,860	9,207,260	701,540	2,054,380
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 5,442,980	\$ 12,303,680	\$ 15,443,100	\$ 8,630,720	\$ 11,732,360
Investment Metric					
Internal Rate of Return (IRR) - 20 year					0.60%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (21,211,620)
Discount Rate					4.00%

7. Reduce Salary Expenses by 40 Percent and Reduce Take Rate to 57.6 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 13,989,960	\$ 13,989,960	\$ 13,989,960	\$ 13,989,960
Total Cash Expenses	(2,242,140)	(5,410,930)	(5,410,930)	(5,410,930)	(5,410,930)
Depreciation	(3,291,320)	(7,119,830)	(4,947,740)	(4,714,950)	(4,714,950)
Interest Expense	(2,215,000)	(3,116,010)	(2,369,740)	(1,476,680)	(342,835)
Taxes	-	-	-	-	-
Net Income	\$ (5,203,290)	\$ (1,656,810)	\$ 1,261,550	\$ 2,387,400	\$ 3,521,245
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 2,037,350	\$ 6,007,850	\$ 4,984,420	\$ 5,976,420	\$ 7,024,270
Depreciation Reserve	-	5,305,430	9,023,780	1,348,740	2,968,180
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 6,537,350	\$ 13,813,280	\$ 16,508,200	\$ 9,825,160	\$ 12,492,450
Investment Metric					
Internal Rate of Return (IRR) - 20 year					0.60%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (20,682,070)
Discount Rate					4.00%

8. Eliminate Vendor Maintenance Contracts, Reduce Salary Expenses by 40 Percent, and Reduce Take Rate to 51.3 Percent

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 12,458,760	\$ 12,458,760	\$ 12,458,760	\$ 12,458,760
Total Cash Expenses	(2,242,140)	(4,069,800)	(4,069,800)	(4,069,800)	(4,069,800)
Depreciation	(3,253,180)	(6,649,990)	(4,711,920)	(4,489,300)	(4,489,300)
Interest Expense	(2,215,000)	(3,116,840)	(2,370,010)	(1,474,780)	(339,775)
Taxes	-	-	-	-	-
Net Income	\$ (5,165,150)	\$ (1,377,870)	\$ 1,307,030	\$ 2,424,880	\$ 3,559,885
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 2,418,870	\$ 8,661,930	\$ 7,385,660	\$ 7,897,200	\$ 8,467,130
Depreciation Reserve	-	4,972,220	8,915,860	2,108,700	4,190,250
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 6,918,870	\$ 16,134,150	\$ 18,801,520	\$ 12,505,900	\$ 15,157,380
Investment Metric					
Internal Rate of Return (IRR) - 20 year					0.79%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (18,943,390)
Discount Rate					4.00%

Scenarios

9. Residential Market Share Increase by 5 Percent (4.5 percent take rate increase)

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 18,346,800	\$ 18,346,800	\$ 18,346,800	\$ 18,346,800
Total Cash Expenses	(2,806,110)	(8,371,660)	(8,371,660)	(8,371,660)	(8,371,660)
Depreciation	(3,456,900)	(8,564,250)	(5,709,100)	(5,432,200)	(5,432,200)
Interest Expense	(2,215,000)	(3,113,430)	(2,368,400)	(1,482,760)	(351,955)
Taxes	-	-	-	-	-
Net Income	\$ (5,932,840)	\$ (1,702,540)	\$ 1,897,640	\$ 3,060,180	\$ 4,190,985
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ (181,550)	\$ 1,198,420	\$ 4,952,000	\$ 11,408,190	\$ 17,915,810
Depreciation Reserve	-	6,336,450	9,561,960	(1,085,680)	(679,770)
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,318,450	\$ 10,034,870	\$ 17,013,960	\$ 12,822,510	\$ 19,736,040
Investment Metric					
Internal Rate of Return (IRR) - 20 year					1.68%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (15,842,870)
Discount Rate					4.00%

10. Residential Market Share Increase by 10 Percent (9 percent take rate increase)

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 19,205,280	\$ 19,205,280	\$ 19,205,280	\$ 19,205,280
Total Cash Expenses	(2,806,110)	(8,858,920)	(8,858,920)	(8,858,920)	(8,858,920)
Depreciation	(3,506,830)	(8,895,330)	(5,892,620)	(5,602,450)	(5,602,450)
Interest Expense	(2,215,000)	(3,112,830)	(2,367,960)	(1,484,220)	(353,975)
Taxes	-	-	-	-	-
Net Income	\$ (5,982,770)	\$ (1,661,800)	\$ 2,085,780	\$ 3,259,690	\$ 4,389,935
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ (680,060)	\$ 577,830	\$ 5,667,810	\$ 13,614,740	\$ 21,612,920
Depreciation Reserve	-	6,574,440	9,736,030	(1,668,160)	(1,489,470)
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 3,819,940	\$ 9,652,270	\$ 17,903,840	\$ 14,446,580	\$ 22,623,450
Investment Metric					
Internal Rate of Return (IRR) - 20 year					2.01%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (13,861,120)
Discount Rate					4.00%

11. Residential Market Share Decrease by 5 Percent (4.5 percent take rate decrease)

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 16,629,840	\$ 16,629,840	\$ 16,629,840	\$ 16,629,840
Total Cash Expenses	(2,806,110)	(8,055,610)	(8,055,610)	(8,055,610)	(8,055,610)
Depreciation	(3,409,000)	(7,973,430)	(5,412,910)	(5,148,680)	(5,148,680)
Interest Expense	(2,215,000)	(3,114,480)	(2,368,730)	(1,480,380)	(348,105)
Taxes	-	-	-	-	-
Net Income	\$ (5,884,940)	\$ (2,513,680)	\$ 792,590	\$ 1,945,170	\$ 3,077,445
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 295,620	\$ 4,670	\$ (2,369,970)	\$ (2,328,170)	\$ (2,231,680)
Depreciation Reserve	-	5,917,550	9,428,390	(130,750)	858,160
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,795,620	\$ 8,422,220	\$ 9,558,420	\$ 41,080	\$ 1,126,480
Investment Metric					
Internal Rate of Return (IRR) - 20 year					-0.49%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (28,223,660)
Discount Rate					4.00%

Scenarios

12. Residential Market Share Decrease by 10 Percent (9 percent take rate decrease)

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 15,771,360	\$ 15,771,360	\$ 15,771,360	\$ 15,771,360
Total Cash Expenses	(2,806,110)	(7,568,460)	(7,568,460)	(7,568,460)	(7,568,460)
Depreciation	(3,359,040)	(7,642,460)	(5,229,450)	(4,978,490)	(4,978,490)
Interest Expense	(2,215,000)	(3,115,070)	(2,369,160)	(1,478,920)	(346,085)
Taxes	-	-	-	-	-
Net Income	\$ (5,834,980)	\$ (2,554,630)	\$ 604,290	\$ 1,745,490	\$ 2,878,325
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 794,170	\$ 624,090	\$ (3,087,690)	\$ (4,537,280)	\$ (5,932,050)
Depreciation Reserve	-	5,679,620	9,254,390	451,510	1,667,590
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 5,294,170	\$ 8,803,710	\$ 8,666,700	\$ (1,585,770)	\$ (1,764,460)
Investment Metric					
Internal Rate of Return (IRR) - 20 year					-0.94%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (30,207,740)
Discount Rate					4.00%

13. Commercial Market Share Increase by 10 Percent (9 percent take rate increase)

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 17,954,400	\$ 17,954,400	\$ 17,954,400	\$ 17,954,400
Total Cash Expenses	(2,806,110)	(8,322,740)	(8,322,740)	(8,322,740)	(8,322,740)
Depreciation	(3,442,390)	(8,353,390)	(5,605,660)	(5,332,480)	(5,332,480)
Interest Expense	(2,215,000)	(3,113,800)	(2,368,480)	(1,481,930)	(350,565)
Taxes	-	-	-	-	-
Net Income	\$ (5,918,330)	\$ (1,835,530)	\$ 1,657,520	\$ 2,817,250	\$ 3,948,615
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ (39,100)	\$ 1,194,490	\$ 3,539,680	\$ 8,484,630	\$ 13,482,390
Depreciation Reserve	-	6,187,360	9,527,110	(750,990)	(124,220)
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,460,900	\$ 9,881,850	\$ 15,566,790	\$ 10,233,640	\$ 15,858,170
Investment Metric					
Internal Rate of Return (IRR) - 20 year					1.24%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (18,482,510)
Discount Rate					4.00%

14. Commercial Market Share Decrease by 10 Percent (9 percent take rate decrease)

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 17,016,960	\$ 17,016,960	\$ 17,016,960	\$ 17,016,960
Total Cash Expenses	(2,806,110)	(8,255,870)	(8,255,870)	(8,255,870)	(8,255,870)
Depreciation	(3,423,500)	(8,184,650)	(5,516,600)	(5,248,660)	(5,248,660)
Interest Expense	(2,215,000)	(3,114,100)	(2,368,640)	(1,481,220)	(349,505)
Taxes	-	-	-	-	-
Net Income	\$ (5,899,440)	\$ (2,537,660)	\$ 875,850	\$ 2,031,210	\$ 3,162,925
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 153,460	\$ (830,600)	\$ (2,580,400)	\$ (1,810,950)	\$ (988,220)
Depreciation Reserve	-	6,066,900	9,462,380	(466,910)	300,060
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,653,460	\$ 7,736,300	\$ 9,381,980	\$ 222,140	\$ 1,811,840
Investment Metric					
Internal Rate of Return (IRR) - 20 year					-0.34%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (27,759,630)
Discount Rate					4.00%

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Scenarios

15. Residential Monthly Service Prices Increase by \$5

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,668,170	\$ 18,469,440	\$ 18,469,440	\$ 18,469,440	\$ 18,469,440
Total Cash Expenses	(2,806,720)	(8,296,070)	(8,296,070)	(8,296,070)	(8,296,070)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$ (5,787,840)	\$ (1,211,400)	\$ 2,241,890	\$ 3,399,770	\$ 4,531,325
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 166,050	\$ 3,761,840	\$ 8,940,330	\$ 16,678,930	\$ 24,470,670
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,666,050	\$ 12,390,430	\$ 20,940,780	\$ 18,564,760	\$ 27,056,840
Investment Metric					
Internal Rate of Return (IRR) - 20 year					2.37%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (11,088,890)
Discount Rate					4.00%

16. Residential Monthly Service Prices Increase by \$10

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,791,170	\$ 19,450,560	\$ 19,450,560	\$ 19,450,560	\$ 19,450,560
Total Cash Expenses	(2,807,340)	(8,300,970)	(8,300,970)	(8,300,970)	(8,300,970)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$ (5,665,460)	\$ (235,180)	\$ 3,218,110	\$ 4,375,990	\$ 5,507,545
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 288,430	\$ 7,362,000	\$ 17,421,590	\$ 30,041,290	\$ 42,714,130
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,788,430	\$ 15,990,590	\$ 29,422,040	\$ 31,927,120	\$ 45,300,300
Investment Metric					
Internal Rate of Return (IRR) - 20 year					4.14%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ 962,380
Discount Rate					4.00%

17. Residential Monthly Service Prices Decrease by \$5

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,422,170	\$ 16,507,200	\$ 16,507,200	\$ 16,507,200	\$ 16,507,200
Total Cash Expenses	(2,805,490)	(8,286,260)	(8,286,260)	(8,286,260)	(8,286,260)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$ (6,032,610)	\$ (3,163,830)	\$ 289,460	\$ 1,447,340	\$ 2,578,895
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ (78,720)	\$ (3,438,470)	\$ (8,022,130)	\$ (10,045,690)	\$ (12,016,090)
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,421,280	\$ 5,190,120	\$ 3,978,320	\$ (8,159,860)	\$ (9,429,920)
Investment Metric					
Internal Rate of Return (IRR) - 20 year					-1.63%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (35,191,340)
Discount Rate					4.00%

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Scenarios

18. Residential Monthly Service Prices Decrease by \$10

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,299,170	\$ 15,526,080	\$ 15,526,080	\$ 15,526,080	\$ 15,526,080
Total Cash Expenses	(2,804,880)	(8,281,350)	(8,281,350)	(8,281,350)	(8,281,350)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$ (6,155,000)	\$ (4,140,040)	\$ (686,750)	\$ 471,130	\$ 1,602,685
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ (201,110)	\$ (7,038,610)	\$ (16,503,320)	\$ (23,407,930)	\$ 8,080
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,298,890	\$ 1,589,980	\$ (4,502,870)	\$ (21,522,100)	\$ 2,594,250
Investment Metric					
Internal Rate of Return (IRR) - 20 year					-3.99%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (47,242,500)
Discount Rate					4.00%

19. Small Commercial Monthly Service Prices Increase by \$10

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,565,930	\$ 17,653,800	\$ 17,653,800	\$ 17,653,800	\$ 17,653,800
Total Cash Expenses	(2,806,210)	(8,291,990)	(8,291,990)	(8,291,990)	(8,291,990)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$ (5,889,570)	\$ (2,022,960)	\$ 1,430,330	\$ 2,588,210	\$ 3,719,765
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 64,320	\$ 768,960	\$ 1,889,650	\$ 5,570,450	\$ 9,304,390
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,564,320	\$ 9,397,550	\$ 13,890,100	\$ 7,456,280	\$ 11,890,560
Investment Metric					
Internal Rate of Return (IRR) - 20 year					0.80%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (21,107,430)
Discount Rate					4.00%

20. Small Commercial Monthly Service Prices Decrease by \$10

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,524,410	\$ 17,322,840	\$ 17,322,840	\$ 17,322,840	\$ 17,322,840
Total Cash Expenses	(2,806,000)	(8,290,330)	(8,290,330)	(8,290,330)	(8,290,330)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$ (5,930,880)	\$ (2,352,260)	\$ 1,101,030	\$ 2,258,910	\$ 3,390,465
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 23,010	\$ (445,560)	\$ (971,370)	\$ 1,062,930	\$ 3,150,370
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,523,010	\$ 8,183,030	\$ 11,029,080	\$ 2,948,760	\$ 5,736,540
Investment Metric					
Internal Rate of Return (IRR) - 20 year					0.13%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (25,172,680)
Discount Rate					4.00%

City of Palo Alto
 FFTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Scenarios

21. DIA Monthly Price (per Mbps) Increases by \$0.50

Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320
Total Cash Expenses	(2,865,600)	(8,765,450)	(8,765,450)	(8,765,450)	(8,765,450)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$ (5,969,720)	\$ (2,661,900)	\$ 791,390	\$ 1,949,270	\$ 3,080,825
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ (15,830)	\$ (1,587,440)	\$ (3,661,450)	\$ (3,175,350)	\$ (2,636,110)
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,484,170	\$ 7,041,150	\$ 8,339,000	\$ (1,289,520)	\$ (49,940)
Investment Metric					
Internal Rate of Return (IRR) - 20 year					-0.52%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (28,995,110)
Discount Rate					4.00%

22. DIA Monthly Price (per Mbps) Decreases by \$0.50

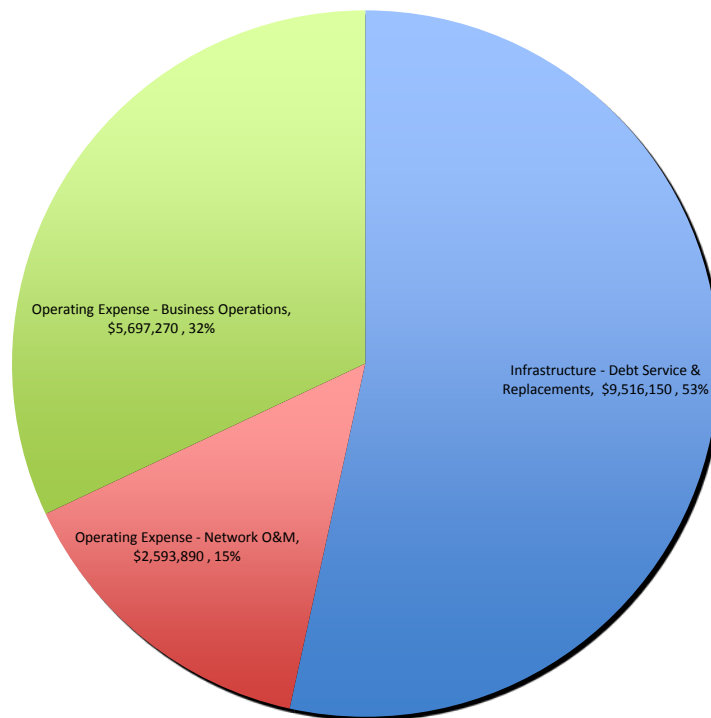
Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320	\$ 17,488,320
Total Cash Expenses	(2,746,620)	(7,816,870)	(7,816,870)	(7,816,870)	(7,816,870)
Depreciation	(3,434,290)	(8,270,820)	(5,562,930)	(5,292,010)	(5,292,010)
Interest Expense	(2,215,000)	(3,113,950)	(2,368,550)	(1,481,590)	(350,035)
Taxes	-	-	-	-	-
Net Income	\$ (5,850,740)	\$ (1,713,320)	\$ 1,739,970	\$ 2,897,850	\$ 4,029,405
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 103,150	\$ 1,910,840	\$ 4,579,730	\$ 9,808,730	\$ 15,090,870
Depreciation Reserve	-	6,128,590	9,500,450	(614,170)	86,170
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 4,603,150	\$ 10,539,430	\$ 16,580,180	\$ 11,694,560	\$ 17,677,040
Investment Metric					
Internal Rate of Return (IRR) - 20 year					1.41%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (17,285,000)
Discount Rate					4.00%

23. Eliminate Vendor Maintenance Contracts, Reduce Salary Expenses by 50 Percent, Reduce DIA by 67%, and Reduce Take Rate

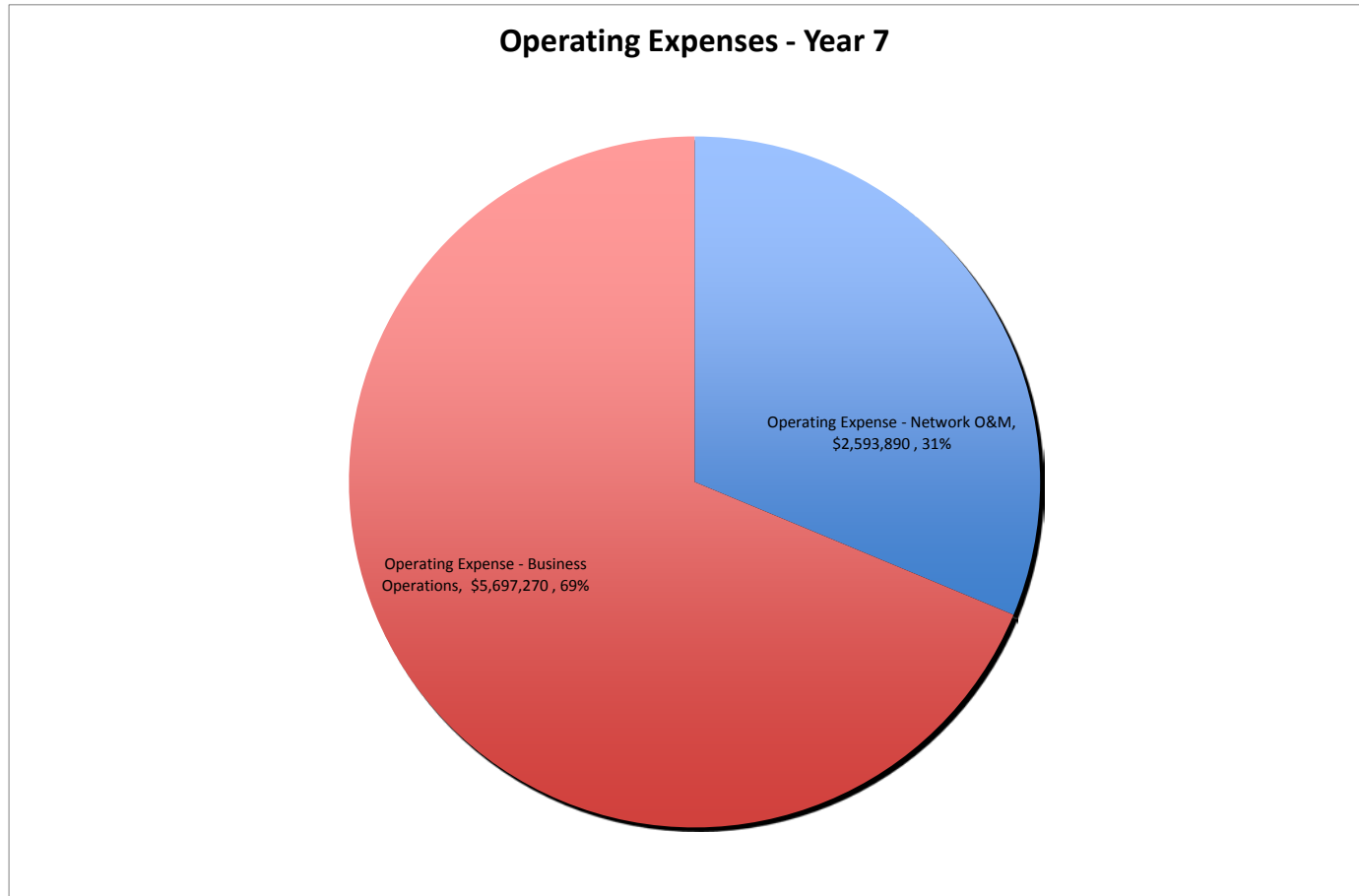
Income Statement	1	5	10	15	20
Total Revenues	\$ 2,545,170	\$ 10,930,320	\$ 10,930,320	\$ 10,930,320	\$ 10,930,320
Total Cash Expenses	(2,041,655)	(3,113,615)	(3,113,615)	(3,113,615)	(3,113,615)
Depreciation	(3,187,340)	(6,142,130)	(4,438,430)	(4,233,370)	(4,233,370)
Interest Expense	(2,215,000)	(3,117,750)	(2,370,570)	(1,472,600)	(336,615)
Taxes	-	-	-	-	-
Net Income	\$ (4,898,825)	\$ (1,443,175)	\$ 1,007,705	\$ 2,110,735	\$ 3,246,720
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	\$ 3,277,645	\$ 10,107,325	\$ 6,753,840	\$ 4,948,700	\$ 3,202,930
Depreciation Reserve	-	4,608,650	8,693,850	2,980,380	5,455,570
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	\$ 7,777,645	\$ 17,215,975	\$ 17,947,690	\$ 10,429,080	\$ 11,158,500
Investment Metric					
Internal Rate of Return (IRR) - 20 year					0.15%
Net Present Value (NPV) at a 4 percent discount rate - 20 year					\$ (21,576,050)
Discount Rate					4.00%

Expense Charts

Uses of Funds - Year 7

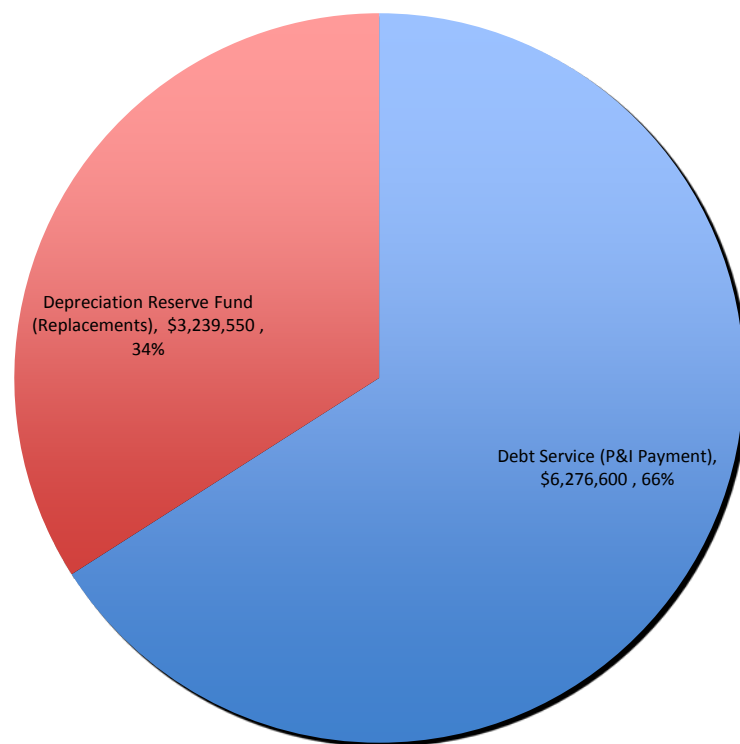


Expense Charts

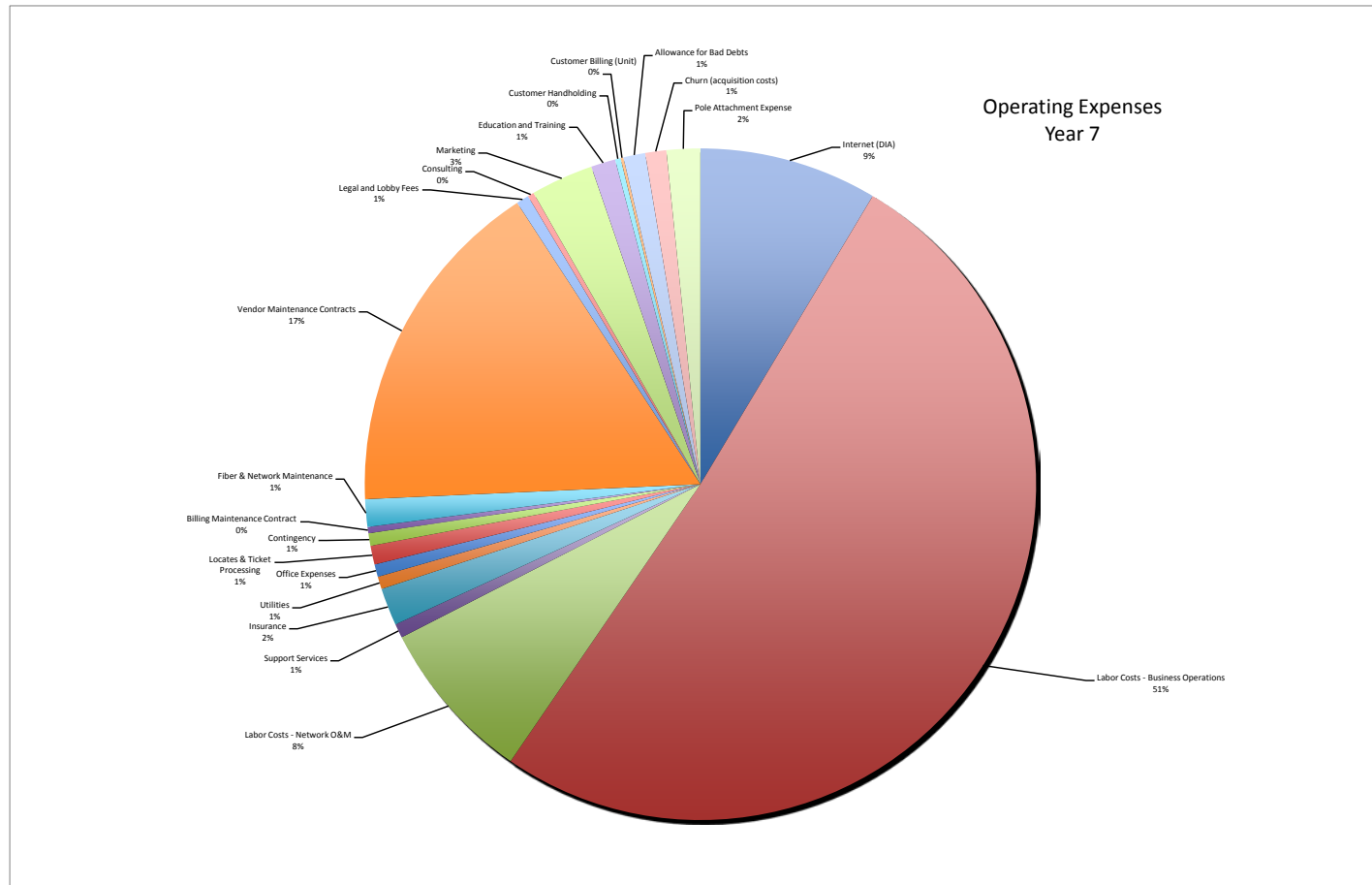


Expense Charts

Infrastructure Costs - Year 7



Expense Charts



City of Palo Alto
FTTP Network
Appendix B - Retail Data Services - Rev 13
July 15, 2015

OSP Cost Estimate Summary

Item	Cost
OSP Engineering	\$ 3,572,100
Quality Control/Quality Assurance	924,400
General OSP Construction Cost	25,526,800
Special Crossings	145,400
Backbone and Distribution Plant Splicing	762,700
Backbone Hub, Termination, and Testing	4,206,300
FTTP Service Drop and Lateral Installations (see note below)	<u>4,820,400</u>
Total Estimated OSP Cost	\$39,958,100

Please note the above estimate does not include the drop costs to individual residences and small businesses. These drop costs are included in the per subscriber costs.

City of Palo Alto
 FTTP Network
 Appendix B - Retail Data Services - Rev 13
 July 15, 2015

Network Electronics Summary

Item	Cost
Core Routers	\$ 1,794,820
Core Network Servers	310,000
Base Aggregation Switches	2,143,610
Base OLT	186,060
CPE Gbps (medium commercial)	483,930
CPE Residential & Small Commerci	8,843,870
Aggregation Switches	3,105,910
OLTs	6,005,640
Total	\$ 22,873,840

Item	Cost	
Core & Base Equipment	\$ 4,434,490	
CPEs	9,327,800	one-to-one relationship with take rate
Incremental (Switches & OLTs)	9,111,550	step function with take rate
Total	\$ 22,873,840	

Project Assumptions

Page Title Information

Organization	City of Palo Alto
Plan Name	Palo Alto, California FTTP Network
Date	Appendix B - Retail Data Services - Rev 13 July 15, 2015

Financial Assumptions

10 Year Bond or Loan									
Finance Rate	4.00%								
Period (Years)	10								
Principal Repayment Period Start	4								
Bond Issuance Cost	1.00%	of issue	0.15	1000	150				
Debt Service Reserve	0.00%								
Interest Reserve	yes								

20 Year Bond									
Finance Rate	4.00%								
Period (Years)	20								
Principal Repayment Period Start	4								
Bond Issuance Cost	1.00%	of issue							
Debt Service Reserve	5.00%								
Interest Reserve	yes								

Loan									
		1	2	3	4	5			
Finance Rate		5.00%	5.00%	5.00%	6.00%	6.00%			
Period (Years)		20	20	20	3	3			
Principal Repayment Start		4	3	2	1	1			

Other									
Interest Earned on Available Cash	0.25%	only applied to reserve funds in calculation							

Source of Funds	Amount Issued	Year																		
Cash flow w/o investment funds and w/startup funds	\$	(54,256,340)	\$	(17,028,630)	\$	(3,132,010)	\$	2,656,490	\$	2,774,880	\$	3,047,810	\$	3,120,230	\$	3,832,480	\$	3,992,100	\$	4,158,400
Cash flow after investment funds	\$	(54,256,340)	\$	(17,028,630)	\$	(3,132,010)	\$	2,656,490	\$	2,774,880	\$	3,047,810	\$	3,120,230	\$	3,832,480	\$	3,992,100	\$	4,158,400
Unrestricted cash balance (years 1 to 10)	\$	43,660	\$	15,030	\$	883,020	\$	527,910	\$	161,700	\$	(66,680)	\$	(363,630)	\$	(95,460)	\$	178,800	\$	459,140
Total cash balance	\$	4,543,660	\$	2,515,030	\$	3,383,020	\$	6,082,820	\$	8,790,290	\$	9,871,690	\$	8,453,160	\$	7,033,870	\$	9,743,690	\$	12,459,590
Unrestricted cash balance (years 11 to 20)	\$	986,970	\$	1,772,550	\$	2,552,240	\$	2,931,590	\$	3,316,690	\$	3,707,570	\$	4,260,230	\$	5,053,320	\$	5,840,530	\$	6,227,400

		1	2	3	4	5														
Use Investment Capital		no	no	no																
Investment Capital	\$	-	\$	-	\$	-	\$	-	\$	-										
Start Up Funds	\$	-	\$	-	\$	-	\$	-	\$	-										
Grants (Infrastructure)	\$	-	\$	-	\$	-	\$	-	\$	-										
Grants (customer premises)	\$	-	\$	-	\$	-	\$	-	\$	-										
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	Weighted rate									
		87.64%	87.68%	87.67%	100.00%	100.00%	Percent Residential													
		12.36%	12.32%	12.33%	0.00%	0.00%	Percent Commercial													
10-Year Bond/Loan Proceeds	\$	-	\$	-	\$	-	\$	-	\$	-										
20-Year Bond Proceeds	\$	50,000,000	\$	50,000,000	\$	-	\$	-	\$	-										
Loan Proceeds	\$	25,300,000	\$	4,300,000	\$	17,000,000	\$	4,000,000	\$	-										
Sub-total	\$	75,300,000																		
Total	\$	75,300,000	\$	4,300,000	\$	17,000,000	\$	4,000,000	Base case	\$	25,300,000	\$	25,300,000							

Depreciation (Straight Line)		Total	15,000,000	10,000,000	5,000,000	2,500,000	1,000,000	500,000	250,000	125,000	62,500
	Years		Annual Rate								
Outside Plant and Facilities	20		5.00%	Sheet D1	If years changed, need to change CA sheet (when replenishments occur)						
Network Equipment	10		10.00%	Sheet D2	If years changed, need to change CA sheet (when replenishments occur)						
Miscellaneous Implementation Costs	5		20.00%	Sheet D3	If years changed, need to change CA sheet (when replenishments occur)						
Last Mile and Customer Premises Equipment	5		20.00%	Sheet D4	If years changed, need to change CA sheet (when replenishments occur)						
Depreciation Reserve (years 1 to 10)	-	-	-	3,054,910	6,128,590	7,438,370	6,316,790	4,629,330	7,064,890	9,500,450	
Depreciation Reserve (years 11 to 20)	2,656,900	1,114,600	(1,102,170)	(2,919,680)	(614,170)	1,691,340	3,840,440	4,120,450	1,903,680	86,170	
Funded Depreciation	1	2	3	4	5	6	7	8	9	10	
	0%	0%	0%	40%	40%	40%	48%	48%	48%	48%	

Replacement/Upgrade Costs (Percent of Total Costs)									
	Replacement								
Network Equipment	80%								
Miscellaneous Implementation Costs	75%								
Last Mile and Customer Premises Equipment	40%								

Project Assumptions

Revenues

Internet Services									
Monthly Retail Price									
R 30 Mbps	\$	-	\$	-	\$	-	100.00%	30	
R 50 Mbps	\$	-	\$	-	\$	-	100.00%	30	
R 100 Mbps	\$	-	\$	-	\$	-	100.00%	30	
R 250 Mbps	\$	-	\$	-	\$	-	100.00%	30	0.47%
R 1 Gbps	\$	70.00	\$	-	\$	70.00	100.00%	250	Allcatel & others repoi
B 100 Mbps	\$	-	\$	-	\$	-	100.00%	250	0.5 to
B 250 Mbps	\$	-	\$	-	\$	-	100.00%	250	2000
B 1 Gbps (small commercial)	\$	80.00	\$	-	\$	80.00	100.00%	250	oversubscription
B 1 Gbps (medium commercial)	\$	220.00	\$	-	\$	220.00	100.00%	250	oversubscription
10 Gbps	\$	-	only used with enterprise customer						
								75	

		1		3		5		7		9										
Unrestricted Cash Balance (yr. 1 to yr. 10)	\$	43,660	\$	15,030	\$	883,020	\$	527,910	\$	161,700	\$	(66,680)	\$	(363,630)	\$	(95,460)	\$	178,800	\$	459,140
Unrestricted Cash Balance (yr. 11 to yr. 20)	\$	986,970	\$	1,772,550	\$	2,552,240	\$	2,931,590	\$	3,316,690	\$	3,707,570	\$	4,260,230	\$	5,053,320	\$	5,840,530	\$	6,227,400

Project Assumptions

Operation and Maintenance Expenses

Annual Fixed Operating Expense										
	Year 1	Year 2	Year 3	Year 4	Year 5 plus					
Insurance	\$ 100,000	\$ 150,000	\$ 150,000	\$ 150,000	\$ 150,000					
Utilities	\$ 25,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000					
Office Expenses	\$ 36,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000					
Locates & Ticket Processing	\$ 19,000	\$ 38,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 3,750	per month per	50 miles	25.00%	50.00%
Contingency	\$ 25,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000					
Billing Maintenance Contract	\$ 15,000	\$ 25,000	\$ 25,000	\$ 25,000	\$ 25,000					
Fiber & Network Maintenance	\$ 10,000									
	\$ 0.250%	Annual + Fiber Implementation Cost								
Vendor Maintenance Contracts	\$ -	\$ 1,369,600	\$ 1,369,600	\$ 1,369,600	\$ 1,369,600	10.00%	Output to "Electronics Totals"			
	Year 1	Year 2	Year 3	Year 4	Year 5 plus					
Legal and Lobby Fees	\$ 150,000	\$ 75,000	\$ 50,000	\$ 50,000	\$ 50,000					
Consulting	\$ 100,000	\$ 50,000	\$ 25,000	\$ 25,000	\$ 25,000					
Marketing	\$ 500,000	\$ 250,000	\$ 250,000	\$ 250,000	\$ 250,000					
Annual Variable Operating Expense (not including DIA)										
Education and Training	2%	percent of direct payroll								
Customer Handholding	\$ 0.10	per subscriber per month								
Customer Billing (Unit)	\$ 0.05	per bill								
Allowance for Bad Debts	0.50%	percentage of revenues								
Customer Churn (annual)	1.50%	Customer Promotions/Acquisition								
			\$ 300							
	Year 1	Year 2	Year 3	Year 4	Year 5+					
Internet Connection Fee	\$ 89,230	\$ 400,170	\$ 711,430	\$ 711,430	\$ 711,430	\$ 0.75	per Mbps per month	0.47%		
Minimum Bandwidth	2,000	Mbps	1,500	per month	0.75	per Mbps per month				
Pole Attachment Expense										
Attachment Fees	4,478 poles at		\$ 30.00	per year	783,552 feet	175	feet per span			
Taxes										
City and State Tax (Utility Fee)	0.0000%	percent of revenue	State	0.0000%	City	0.0000%	Overhead	148.40	63.99%	
Utility Fees Assumed to be a Pass Through to Customer								231.90		

Project Assumptions

Labor Expense

Labor (Direct)

New Employees										
	Year 1	Year 2	Year 3	Year 4	Year 5+	Labor Cost				
Business Manager	0.50	1.00	1.00	1.00	1.00	150,000		247,500		
Market & Sales Manager	1.00	1.00	1.00	1.00	1.00	126,000				
Broadband Service Engineer	1.00	1.00	1.00	1.00	1.00	124,000				
Internet Technician (staff in field tech support)	0.50	1.00	1.00	1.00	1.00	83,000				
Customer Service Representative	2.00	10.00	16.00	16.00	16.00	65,000	2,500	2	Number of Customers per CSR-Number of St Based on Wilson	
Service Technicians/Installers & IT Support	2.00	7.00	12.00	12.00	12.00	90,000	2,500	1.5	Number of Customers per Tech Number of St Based on Wilson 4	
Sales and Marketing Representative	1.00	2.00	2.00	2.00	2.00	83,000	with commissions			
Call Center Support (24x7)	-	-	-	-	-	65,000				
Fiber Plant O&M Technicians	1.00	2.00	2.00	2.00	2.00	95,000	200	Miles of line per technician	1	Ratio for 24x7 Based on Wilson Wilson 750
TBD	-	-	-	-	-	-	232	Miles of line		
Total New Staff	9	25	36	36	36		50.00%	In Year 1		
Existing Employees										
	Year 1	Year 2	Year 3+	Labor Cost						
Broadband Service Manager	-	-	-	\$ 65,000						
Broadband Technician	-	-	-	\$ 90,000						
Switch Technician	-	-	-	\$ 83,000						
Customer Service Representative	-	-	-	\$ 65,000						
Service Technicians	-	-	-	\$ 95,000						
Sales and Marketing Representative	-	-	-	\$ -						
Total Existing Staff	-	-	-	\$ -						
Total Existing Staff	-	-	-	\$ -						
Service Position Total										
	Year 1	Year 2	Year 3	Year 4	Year 5+	Year 1 Salary				
Business Manager	0.50	1.00	1.00	1.00	1.00	\$ 150,000	\$	150,000	Business Operations	
Market & Sales Manager	1.00	1.00	1.00	1.00	1.00	\$ 126,000	\$	126,000	Business Operations	
Broadband Service Engineer	1.00	1.00	1.00	1.00	1.00	\$ 124,000	\$	124,000	Network O&M	
Internet Technician (staff in field tech support)	0.50	1.00	1.00	1.00	1.00	\$ 83,000	\$	83,000	Network O&M	
Customer Service Representative	2.00	10.00	16.00	16.00	16.00	\$ 65,000	\$	1,040,000	Business Operations	
Service Technicians/Installers & IT Support	2.00	7.00	12.00	12.00	12.00	\$ 90,000	\$	1,080,000	Business Operations	
Sales and Marketing Representative	1.00	2.00	2.00	2.00	2.00	\$ 83,000	\$	166,000	Business Operations	
Call Center Support (24x7)	-	-	-	-	-	\$ 85,000	\$	-		
Fiber Plant O&M Technicians	1.00	2.00	2.00	2.00	2.00	\$ 95,000	\$	190,000	Network O&M	
TBD	-	-	-	-	-	\$ -	\$	-		
Total Existing Staff	-	-	-	-	-	\$ -	\$	-		
Total	9.00	25.00	36.00	36.00	36.00		\$	2,959,000		
Total Customers	2,339	10,491	18,651	18,651	18,651					
Customers per Employee	259.89	419.64	518.08	518.08	518.08					
Total Salaries	\$ 854,500	\$ 2,119,000	\$ 2,959,000							
Benefits	65%	of base salary	65							
Total Direct Labor Cost	\$ 1,409,930	\$ 3,496,350	\$ 4,882,350							
Salary Multiplier	0.00%	annual multiplier	(i.e. salaries increase by x percent faster than ability to increase fees)							
Operation Support Services										
Billing & CSR Support Services	\$50,000	set-up fee +								
	\$0.25	per customer per month								

internet
call customers
dedicated 24x7
month
250 calls per month
10 staff
7500
750 customers

Project Assumptions

Unrestricted cash balance (years 1 to 10) \$ 43,660.00 \$ 15,030.00 \$ 883,020.00 \$ 527,910.00 \$ 161,700.00 \$ (66,680.00) \$ (363,630.00) \$ (95,460.00) \$ 178,800.00 \$ 459,140.00

Market Size

Residential

Number of Potential Subscribers 22,709
 Potential Multi-Housing 0 Applies to All Services
 Subscriber Growth Rate 0.00%

City of Palo Alto 22,709 80 MS Ceiling CPE Funding
 tbd - 40.00% MS Ceiling 0.00%
 tbd - 40.00% MS Ceiling 0.00%
 22,709 80.00% MS Weighted 0.00%

Commercial

Number of Potential Subscribers 3,192
 Subscriber Growth Rate 0.00% Applies to All Services

City of Palo Alto 3,192 80.00% MS Ceiling CPE Funding
 tbd - 0.00% MS Ceiling 0.00%
 tbd - 0.00% MS Ceiling 0.00%

Penetration Rates - Data

Residential Internet Services

Existing Dial-up Customers 0
 Number of Potential New Subscribers 22,709

Initial Data Users 96%
 Occupancy Rate 94%

Input to Network Cost Estimate 72.00% Take Rate of all households/businesses passed

Projected Market Size

Year 1 Year 2 Year 3 Year 4 Year 5
 90% 90% 90% 90% 90%
 Year 6 Year 7 Year 8 Year 9 Year 10+
 90% 90% 90% 90% 90%

Residential Business 72.0% 22,709 16,351 Output to "Electron
 72.0% 3,192 2,299 Output to "Electron
 25,901 18,651
 (1) Check Sum

Market Share Percentage of Market

Year 1 Year 2 Year 3 Year 4 Year 5
 10% 45% 80% 80% 80%
 9.0% 40.5% 72.0% 72.0% 72.0%
 Year 6 Year 7 Year 8 Year 9 Year 10+
 80% 80% 80% 80% 80%
 72.00% 72.00% 72.00% 72.00% 72.00%

yr. 1 yr. 2 yr. 3
 1.00 45% 80%
 10%
 Market share multiplier for sensitivity analysis
 72.0% 80.000%

Package Take Rate

R 30 Mbps 0%
 R 50 Mbps 0%
 R 100 Mbps 0%
 R 250 Mbps 0%
 R 1 Gbps 100%
 Year 2 Year 3 Year 4 Year 5
 0% 0% 0% 0%
 0% 0% 0% 0%
 0% 0% 0% 0%
 100% 100% 100% 100%

Project Assumptions

Commercial Internet Services												
Number of Potential Subscribers	3,192											
Initial Data Users	96% Estimate 92%											
Occupancy Rate	94% Estimate											
Projected Market Size	Year 1	Year 2	Year 3	Year 4	Year 5							
	90%	90%	90%	90%	90%	90%						
	Year 6	Year 7	Year 8	Year 9	Year 10+							
	90%	90%	90%	90%	90%	90%						
Market Share	Year 1	Year 2	Year 3	Year 4	Year 5							
	10%	45%	80%	80%	80%	1.00	yr. 1	yr. 2	yr. 3			
	9.0%	40.5%	72.0%	72.0%	72.0%	72.0%	10%	80.000%	45%	80%	0.47%	
Percentage of Market	Year 6	Year 7	Year 8	Year 9	Year 10+							
	80%	80%	80%	80%	80%	80%						
Market Share	72.00%	72.00%	72.00%	72.00%	72.00%	72.00%						
Percentage of Market												
Package Take Rate	Year 1	Year 2	Year 3	Year 4	Year 5							
	B 100 Mbps	0.00%	0%	0%	0%	0%						
	B 250 Mbps	0.00%	0%	0%	0%	0%						
	B 1 Gbps (small commercial)	59.98%	60%	60%	60%	60%						
	B 1 Gbps (medium commercial)	40.00%	40%	40%	40%	40%	linked to businesses with AE CPE					
	10 Gbps	0.02%	0%	0%	0%	0%						

Project Assumptions

Capital Additions

Network Equipment										
see sheet "Electronics Summary"										
Core & Base Equipment	\$	4,434,490	\$	-	\$	-	\$	-	\$	4,434,490
Incremental (Switches & OLTs)	\$	6,833,660	\$	2,277,890	\$	-	\$	-	\$	9,111,550
Additional Annual Capital		0% (% of turn-key cost)			Starts in year			4		
Outside Plant and Facilities										
see sheet "OSP Summary"										
Total Estimated OSP Cost	\$	31,966,480	\$	7,991,620	\$	-	\$	-	\$	39,958,100
		-		-		-		-		-
		-		-		-		-		-
Total Backbone and FTTP	\$	31,966,480	\$	7,991,620	\$	-	\$	-	\$	-
	\$	31,966,480	\$	39,958,100	\$	39,958,100	\$	39,958,100	\$	53,504,140
Additional Annual Capital		0% (% of turn-key cost)			Starts in year			4		
Last Mile and Customer Premises Equipment										
CPE Gbps (medium commercial)	\$	61,020	\$	210,930	\$	211,980	\$	-	\$	-
CPE Residential & Small Commercial	\$	499	per new subscriber (average)							483,930.00
CPE Gbps (medium commercial)	\$	526	per new subscriber (average)							
Average Drop Cost	\$	758	per new residential subscriber							
Average Drop Cost	\$	758	per new commercial subscriber							
Additional Annual Replacement Capital		1.00% (% of CPE's in service ²)			Starts in year			4		\$ 107,492,210
Must be 4 or greater										
Miscellaneous Implementation Costs										
Splicing	\$	-	\$	-	\$	-	\$	-	\$	-
Vehicles	\$	150,000	\$	-	\$	-	\$	-	\$	-
Emergency Restoration Kit	\$	50,000	\$	-	\$	-	\$	-	\$	-
Work Station, Computers, and Software	\$	2,000	per employee							
Fiber OTDR and Other Tools	\$	85,000	\$	-	\$	-	\$	-	\$	-
Generators & UPS	\$	-	\$	-	\$	-	\$	-	\$	-
OSS	\$	300,000	\$	-	\$	-	\$	-	\$	-
Additional Annual Capital		0% (% of Year 1)			Starts in year			4		
ONT Kit - Residential SFU - Basic 20% \$ 395										
ONT Kit - Residential SFU - Premium 75% \$ 455										

²Approximate required additional annual capital to account for damages and early replacements.

ONT Kit - Residential SFU - Basic	20%	\$	395
ONT Kit - Residential SFU - Premium	75%	\$	455
ONT Kit - Residential SFU - AE Access	5%	\$	555
ONT Kit - Residential MDU - Basic	20%	\$	766
ONT Kit - Residential MDU - Premium	75%	\$	826
ONT Kit - Business (SFU) - Basic	10%	\$	366
ONT Kit - Business (SFU) - Premium	50%	\$	426
ONT Kit - Business (SFU) - AE Access	40%	\$	526
ONT Kit - Business (MDU) - Basic	10%	\$	766
ONT Kit - Business (MDU) - Premium	50%	\$	826
ONT Kit - Business (MDU) - AE Access	40%	\$	926

ctc technology & energy

engineering & business consulting



Findings and Recommendations for Wireless Network Plan Final – Revision 8a

**Prepared for City of Palo Alto
August 2015**

Columbia Telecommunications Corporation

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

Contents

1	Summary of Recommendations	1
2	Executive Summary.....	3
3	A Review of the Municipal Wireless Landscape	5
3.1	Town of Brookline, MA.....	5
3.1.1	System Description	5
3.1.2	Lessons Learned	6
3.2	Lompoc, CA.....	6
3.2.1	System Description	6
3.2.2	Lessons Learned	7
3.3	Port Angeles, WA	7
3.3.1	System Description	8
3.3.2	Network Operations	14
3.3.3	Lessons Learned	17
3.4	Ripon, California	18
3.4.1	System Description	18
3.4.2	Lessons Learned	18
3.5	San José, CA.....	18
3.5.1	System Description	19
3.5.2	Lessons Learned	19
3.6	Santa Clara, CA	19
3.6.1	System Description	19
3.6.2	Lessons Learned	20
3.7	Implications to Consider for Palo Alto Wireless Deployment.....	21
4	Wireless Network Architecture	23
4.1	Point-to-Point Communications Links.....	23
4.2	Point-to-Multipoint Communications Links	24
4.3	Blanket Coverage	25
5	Wi-Fi Technology	27

5.1	Transmission Evolution	27
5.1.1	802.11a	27
5.1.2	802.11b	28
5.1.3	802.11g	28
5.1.4	802.11n	28
5.1.5	802.11ac.....	29
5.2	Achievable Network Data Throughput Rates.....	30
5.3	Network Security.....	32
5.4	Signal Propagation and Interference Rejection	32
6	City Resources to Support Wireless Deployment.....	33
6.1	Fiber-Optic Backbone Requirements	33
6.2	Installation Options for Wireless Access Devices.....	36
7	Palo Alto Requirements Analysis and Stakeholder Input	38
7.1	The Need for Wireless Broadband	38
7.2	Stakeholder Input.....	40
7.2.1	Information Technology.....	40
7.2.2	Community Services.....	43
7.2.3	City of Palo Alto Utilities	45
7.2.4	Planning and Community Environment Department – Transportation Division ...	46
7.2.5	Public Works Department – Engineering Services Division.....	47
7.2.6	Public Safety Departments: Police Department, Office of Emergency Services, Fire Department.....	47
8	Potential Palo Alto Wireless Deployment Options	52
8.1	Scenario 1: Deploy Public Wi-Fi and Secure City Enterprise Network Access at City Buildings.....	52
8.2	Scenario 2: Deploy Public Wi-Fi and Secure City Enterprise Network Access	53
8.3	Scenario 3: Deploy a Point-to-Multipoint Network for Secure City Enterprise Access .	58
8.4	Scenario 4: Deploy a Citywide Mobile Data Network for Public Safety Users.....	58
9	System-Level Design and Cost Estimates for Wireless Deployment Scenarios.....	61
9.1	Scenario 1	61

9.2	Scenario 2, Phase A	61
9.2.1	Basic Assumptions	62
9.2.2	Financial Summary.....	62
9.3	Scenario 2, Phase B	63
9.3.1	Basic Assumptions	63
9.3.2	Financial Summary.....	64
9.4	Scenario 3.....	64
9.4.1	Basic Assumptions	65
9.4.2	Financial Summary.....	66
9.5	Scenario 4.....	66
9.5.1	Basic Assumptions	66
9.5.2	Financial Summary.....	67
10	Business Case for Citywide Wireless.....	69
10.1	City-Owned Wholesale Model.....	69
10.2	Privately Owned Managed-Services Model	69
10.3	Hybrid Model (Public–Private Partnership).....	70
11	Future Wireless Technology Innovations	71
11.1	Future 5G Technology Deployment	71
11.2	Integrating Wi-Fi and Cellular	72
	Appendix A: Summary of Potential Stakeholder Needs	74
	Appendix B: Financial Projections for Scenario 2, Phase A	75
	Appendix C: Financial Projections for Scenario 2, Phase B.....	76

Figures

Figure 1: Port Angeles, Washington – BTOP-Funded Wireless Network Project	8
Figure 2: Network Overview of Port Angeles Wireless Network Infrastructure	10
Figure 3: Wireless Access Point Mounted on Street Light.....	11
Figure 4: Wireless Access Point (Detail).....	11
Figure 5: Locations of Wireless Access Points in Port Angeles	12
Figure 6: Backhaul for Wireless Access Points in Port Angeles	13
Figure 7: Functional Diagram of the VLAN Infrastructure	14

Figure 8: Exterior-Mounted Customer Premises Equipment (CPE) Unit	15
Figure 9: Illustration of Public Safety Mobile Router Function	17
Figure 10: SVP MeterConnect Coverage Area	20
Figure 11: Sample Point-to-Point Link Analysis	24
Figure 12: Point-to-Multipoint Example	25
Figure 13: Conceptual Approach to Providing Downtown Palo Alto Coverage	26
Figure 14: Sample Directly Connected Wireless Network.....	34
Figure 15: Sample Wireless Mesh Network.....	35
Figure 16: Typical Wireless Access Point Installation for Mesh System	37
Figure 17: OverAir Wi-Fi Hotspot.....	40
Figure 18: Wi-Fi Access Unit in Palo Alto	41
Figure 19: Private Point-to-Multipoint Wireless.....	49
Figure 20: Command Vehicle as Mobile Access Point	51
Figure 21: Wi-Fi Access in City Buildings – RF Radiation Map	52
Figure 22: Illustration of Targeted Wi-Fi Deployment in Downtown Palo Alto.....	55
Figure 23: Local Businesses Offering Wi-Fi	56
Figure 24: Comcast Wi-Fi Locations.....	56
Figure 25: AT&T Wi-Fi Locations.....	57
Figure 26: Illustration of Public Safety Mobile Network Deployment.....	59
Figure 27: Candidate Access Points for Public Safety Mobile Data Network	60
Figure 28: Point-to-Point Links (Scenario 3)	65
Figure 29: Map of Locations for Scenario 4 Deployment	67

Tables

Table 1: 802.11 Version Summary	31
Table 2: City Sites with Facility-Wide Wi-Fi	42
Table 3: First-Priority Community Services Sites	43
Table 4: Second-Priority Community Services Sites	43
Table 5: Third-Priority Community Services Sites.....	44
Table 6: Scenario 2-A Financial Summary (Capital Costs).....	63
Table 7: Scenario 2-B Financial Summary (Capital Costs).....	64
Table 8: Scenario 3 Financial Summary (Capital Costs)	66
Table 9: Scenario 4 Financial Summary (Capital Costs)	68

1 Summary of Recommendations

Working in partnership with City of Palo Alto (City) staff, CTC Technology & Energy (CTC) conducted a comprehensive analysis of the long-term needs for municipal wireless services within Palo Alto. We examined a wide range of applications that could potentially be addressed through the implementation of one or more commercial wireless technologies.

We also examined various deployment scenarios, such as blanket citywide coverage through Wi-Fi technology; expanded targeting of Wi-Fi access at and around City facilities; and dedicated projects focusing on providing priority, high-reliability services to the City's critical infrastructure operated by the City's utilities (CPAU) and public safety agencies.

We recommend that the City consider focusing on municipal wireless implementation scenarios that address specific communications needs:

- **Expand the deployment of Wi-Fi coverage to City facilities and adjoining public areas.** The City's Information Technology Department successfully deployed Wi-Fi to 30 City facilities for public and internal City use; we recommend that the City continue to deploy Wi-Fi at other City facilities including those operated by the Community Services Department, smaller City buildings, and park and recreational areas.
- **Install dedicated wireless facilities to address the needs of the City's first responders and CPAU.** To address the City's high-priority internal needs, we recommend that the City consider deploying wireless infrastructure to support enterprise applications. For CPAU, these would include real-time monitoring and control of facilities that are not part of the existing fiber-optic network (e.g., pump stations, end of line monitoring). For public safety agencies, the wireless infrastructure would support mobile and portable communications for command and patrol vehicles, as well as incident command networks in the areas where existing commercial wireless services are often saturated due to a high concentration of public users (e.g., during sporting events).
- **Consider a citywide broadband wireless network for use by the general public.** A citywide public Wi-Fi deployment is technically feasible, but *only* in concert with the deployment of a citywide fiber-to-the-premises (FTTP) network. The existing fiber-optic infrastructure operated by CPAU has neither the capacity nor the coverage area to support a citywide wireless deployment without a major expansion.

If, on the other hand, a citywide fiber-optic network were in place, it would provide a mechanism for backhauling traffic from the individual wireless access points with transmission speeds measured in gigabits. This type of system would have the capability and coverage area to provide service competitive with existing 4G and future 5G commercial wireless networks.

It is difficult to predict what technical standards will be employed by consumer devices for wireless communications in the future. The Institute of Electrical and Electronics Engineers (IEEE) Standards organizations continue to move forward on Wi-Fi platforms to support tablets and laptops. Commercial wireless smart devices will be adhering to other standards groups in the definition of the new 5G technology. And efforts are underway to merge, or at least bond, these two initiatives.

What *is* clear is that whatever technologies are deployed for wireless access at the hardware/equipment level will have a relatively short life for each cycle of implementation (based on history, typically from five to seven years *maximum*). On the other hand, investment in core wireless infrastructure—which includes mounting locations (poles, towers), electric power, and high-capacity backhaul links for access devices—will provide a foundation for much greater longevity for supporting the continual migration of wireless technology standards for access devices. That is, access device level technology evolves so rapidly that the City can likely expect that whatever technologies it deploys will become obsolete within a few years; the long-term investment is in core wireless infrastructure.

Wireless technology is not a competitor to FTTP technology in a market such as Palo Alto; rather, they work together in partnership. Wireless provides a mobility component to the fiber-optic backbone. Fiber-optic, in turn, provides the high-capacity backhaul extension needed to create a robust, high-capacity, low-latency wireless broadband network.

2 Executive Summary

This report identifies near-term, low-risk opportunities for the City to implement wireless broadband infrastructure to provide enhanced broadband services to its citizens and to support the City’s internal (enterprise) communications needs.

Working closely with City staff, CTC Technology & Energy (CTC) examined existing municipal infrastructure and resources in detail—including fiber-optic backbone network connectivity, suitable mounting locations for wireless devices, and requisite powering. We also evaluated the City’s maintenance support processes and staffing. This report complements the “Fiber-to-the-Premises Master Plan” report prepared by CTC.

Through our discussions with representatives of various City departments we produced a list of potential applications that might be addressed through wireless technology.

Based on this assessment process, our experience in similar markets nationwide, and our knowledge of wireless broadband technologies, we prepared four viable scenarios for the City’s consideration and potential implementation. These independent scenarios—which can be implemented singularly or in combination—address a mix of public and internal City services (including municipal operations and public safety applications):

Scenario 1: Deploy Public Wi-Fi and Secure City Enterprise Network Access at City Buildings

In this scenario, the City would deploy Wi-Fi at all City buildings, and support free public access and secure enterprise network access for City employees. This option is basically an expansion of the Information Technology Department’s original deployment (30 City locations are currently being served) to include all City buildings, the airport, parks, and recreational areas.

Scenario 2: Deploy Public Wi-Fi and Secure City Enterprise Network Access Citywide

In this scenario, the City would deploy “blanket” wireless coverage for public and City users. We envision a two-phase deployment.

Phase A: Provide public Wi-Fi to core City business and residential areas

- 100 Mbps shared among all users
- 400+ wireless access points
- Light pole mounted
- Leverage existing fiber
- Wireless mesh technology

Phase B: Provide public Wi-Fi to core City business and residential areas

- 1 Gbps shared among all users
- 600+ wireless access points
- Light pole mounted
- Fiber connected to each wireless access point
- Contingent on City upgrading fiber as part of a CPAU upgrade or FTTP deployment
- Three to five years after Phase A completion

Scenario 3: Deploy a Point-to-Multipoint Network for Secure City Enterprise Access

In this scenario, the City would deploy a citywide high-reliability, dedicated, critical-infrastructure broadband wireless network to support public safety, CPAU, Department of Public Works, and Traffic Engineering needs. As in the Police Department's Mobile Emergency Operations Center (MEOC) incident deployment, City Hall would serve as the core site for a point-to-multipoint deployment. Public access would continue to be delivered by local businesses and incumbent service providers.

Scenario 4: Deploy a Citywide Mobile Data Network for Public Safety Users

In this scenario, the City would create hot spots for public safety mobile data network access to augment existing wireless operations at key facilities and routes (schools, stadiums, business areas). The hot spots would provide radial coverage to first responders and other authorized users. The City would equip its public safety vehicles with exterior mounted antennas and mobile routers capable of acting as access points. As an initial step, access points could be deployed at CPAU's nine utilities facilities to provide coverage to a significant portion of the City. The City has more than 130 locations (including traffic signals) that are suitable access points, so this scenario has great potential for phased deployment.

To create a framework for understanding the pros and cons of these four scenarios, we provide background on municipal wireless projects nationwide (Section 3), an overview of wireless network architectures (Section 4), and a discussion of Wi-Fi technology and network operations (Section 5). We then discuss the City resources available to support a wireless network deployment (Section 6) and present a summary of the high-level needs assessment we developed with City representatives (Section 7).

Next, we describe the scenarios in detail (Section 8) and include cost estimates to construct and operate each (Section 9) using currently available equipment, based on preliminary system engineering. (Scenarios selected for implementation will require additional engineering studies and contractual documents in order to proceed to implementation.) In the final section of the report, we offer insight into future wireless innovations (Section 11).

3 A Review of the Municipal Wireless Landscape

This section examines a representative sampling of wireless initiatives that have been undertaken by selected municipal governments over the past decade. In each of these case studies, the municipality has deployed wireless technology to address the public's broadband communications needs and to meet municipal telecommunications requirements.

We selected these examples to illustrate a wide range of relevant implementation strategies and approaches to charting a citywide plan for deploying wireless services.¹

The following wireless deployments were examined:

- Brookline, MA – Citywide wireless network for public access and public safety
- Lompoc, CA – Subscriber-based municipal citywide Wi-Fi network
- Port Angeles, WA – Citywide wireless network for public access and public safety
- Ripon, CA – Citywide mobile public safety network
- San José, CA – Limited area deployment for public access with a separate traffic equipment control network
- Santa Clara, CA – Citywide wireless network for public access and city utility

3.1 Town of Brookline, MA

The Town of Brookline, Massachusetts has a population of approximately 57,700 in a land area of approximately 6.8 square miles. The Town is served by a commercial wireless provider, Galaxy Internet Systems. Under a public/private partnership agreement negotiated with Galaxy, the company built and operated a citywide wireless system to serve the dual function of providing paid Internet subscriber service as well as an independent network to support public safety.

3.1.1 System Description

The Brookline network, installed in 2007, consists of a total of 330 wireless access points and employs mesh connecting network technology. Subscriber access is provided on the 2.4 Gigahertz (GHz) unlicensed wireless band. The backhaul² mesh operates in the 5.8 GHz wireless band. The 4.9 GHz licensed Public Safety spectrum is used by both police and fire. The police have a total of 25 vehicles and the fire department has 12. Each public safety vehicle has mobile routing used to toggle between the 4.9 GHz network and the Verizon commercial wireless network.

¹ Note that CTC's analysis included a national review of municipal subscriber-financed citywide Wi-Fi coverage networks, and did not yield any examples of systems that were fully financed through subscriber revenues.

² Backhaul is the connection between a network end point and a core site.

Wireless access equipment is manufactured by Strix Systems.³ The 330 network access units are mounted on utility poles and other similar Town-owned structures. The mounting leases are a part of the community's contribution to the partnership with Galaxy.

3.1.2 Lessons Learned

Over the approximately five years that this project has been operational the Town's public safety team has been satisfied with the performance. For over a year the system has been operating without necessary maintenance support due to the fact that the system owner (Galaxy) is in the process of closing down its operations. All indications are that the system is working to the technical standards of performance that were anticipated as a part of the design and implementation.

Unfortunately, limitations in network throughput performance based on the now obsolete IEEE 802.11a/b technologies preclude subscriber support at a level currently desired by most of the subscriber base. This is an example of a scenario in which the technology functions to its design expectation, yet fails to address rapidly increasing customer expectations. Rather than invest in an upgrade of the technology, the system owner has chosen to abandon the operation and pursue other more lucrative opportunities.

3.2 Lompoc, CA

The City of Lompoc has a population of approximately 42,000 in a land area of approximately 7.2 square miles. The city constructed its wireless system in 2006 at a capital cost of nearly \$4 million. The primary purpose for constructing the system was to provide fee-based Wi-Fi services to city residents. The system also supports public safety mobile data service and utility smart meter applications.

3.2.1 System Description

The Lompoc network (Lompocnet)⁴ consists of a total of 215 wireless access points and employs mesh technology. Subscriber access is provided on the 2.4 GHz unlicensed wireless band. The backhaul mesh operates in the 5 GHz wireless band. Within the mesh, an additional point-to-point backhaul network provides dedicated links interconnecting core mesh access sites. Data speeds vary based on location in the network and signal strength; speeds are typically in the 700 Kbps to 3 Mbps range. The subscriber base is approximately 1,500 users, with about 80 percent paying \$15 per month and the remainder paying an hourly access fee.⁵

³ See press release at <http://www.strixsystems.com/pr2006massachusetts.aspx>

⁴ <http://www.cityoflompoc.com/lompocnet/Information.htm>

⁵ <http://www.MuniWireless.com/2009/02/05/up-date-on-Lompoc-Network/>

3.2.2 Lessons Learned

The City has moved many of its internal telecommunications services from commercial carriers to the wireless network, and uses the wireless network wherever possible. Also, new services such as video surveillance are being considered. In evaluating performance it was noted that within certain building structures the attenuation of signals from the Wi-Fi access units degraded signal performance, encouraging subscribers to install external receiving/repeater devices with the assistance of system staff.

A subscriber-financed wireless network faces heavy competition from commercial cellular carriers and fixed fiber/wire/cable television providers. The commercial carriers deliver higher-speed services over a much greater area.

Finally, the rapid changes in technology dictate the need for a proactive program to update technology to address customer needs and expectations. Historically, municipal infrastructure projects have been associated with services such as water, power and gas utilities. Telecommunications is an entirely different ball game.

3.3 Port Angeles, WA

The City of Port Angeles is located approximately 100 miles northwest of Seattle. The City is a harbor border crossing with Canada on San Juan Straights, south of Victoria, BC. The population of the city is 20,100. The City of Port Angeles, like Palo Alto, operates its own electrical utility and has a backbone fiber-optic network.

In May of 2013, Port Angeles completed a citywide broadband wireless network funded in part by a grant under the American Recovery and Reinvestment Act of 2009 (ARRA) Broadband Technology Opportunities Program (BTOP). The City received \$2.6 million as a sub-grantee of the Northwest Open Access Network (NoaNet),⁶ which received a total grant of \$54.4 million.⁷

⁶ NoaNet is a statewide broadband fiber optic service provider that provide whole state-wide networking services. NoaNet is owned jointing by participation municipal utilities.

⁷ CTC assisted the city in developing the BTOP grant, prepared the system-level RFP to purchase the system, and provided technical oversight throughout the construction process.

Figure 1: Port Angeles, Washington – BTOP-Funded Wireless Network Project



The primary goal of the Port Angeles project was to provide high capacity, dedicated broadband wireless coverage to the City's public safety staff. A secondary objective was to provide lower-cost citywide Wi-Fi to the public, selected anchor facilities defined under the ARRA grant, and underserved Native American communities. In developing the business plan for the network, the city chose to make the Wi-Fi service available to the public on a subscription basis indirectly through the services of a third-party ISP for marketing, customer support, and Internet access.

The City's wireless network was designed for the purpose of providing mobile coverage to public safety patrol vehicles over approximately 80 percent of the City's 10.7-square-mile land area.

The network provides client (user) access through two independent wireless networks employing both the 4.9 GHz (licensed) and 2.4 GHz (unlicensed, public) wireless bands. The 4.9 GHz spectrum has been reserved by the FCC for the exclusive use of the local public safety entities and other associated agencies with a public safety focus, such as utility infrastructure.

In order to establish reliable network coverage to users throughout the City, the initial network deployment was comprised of 239 wireless access points installed at locations to maximize wireless coverage to targeted areas. Each of the access points is interconnected to the core backbone network either through direct connection to the City's broadband fiber-optic network or through a wireless mesh link.

3.3.1 System Description

The following paragraphs describe the major components used in the City's network.

3.3.1.1 Wireless Access Points

All users access the Port Angeles network through one of its 239 wireless access points. Wireless links in UHF⁸ and SHF⁹ spectrum are used to provide a digital communications path between the user (client) and the access point. This network supports fixed and mobile users.

Dedicated radio frequency spectrum is provided in three separate bands:

1. The 4.9 GHz public safety band supports communications between public safety vehicles (e.g., police cars, fire trucks) and fixed network locations.
2. Access to the public network is in the unlicensed 2.4 GHz wireless band, which is used universally to support both business and home users through commonly available IEEE¹⁰ 802.11n equipment. Nearly all consumer laptop computers, tablet devices and smart phones contain internal hardware and system software to operate in this band.
3. The wireless access points form a wireless mesh using the 5.8 GHz wires band, which serves as backhaul both between access points, and from the access points to the City's fiber-optic network.

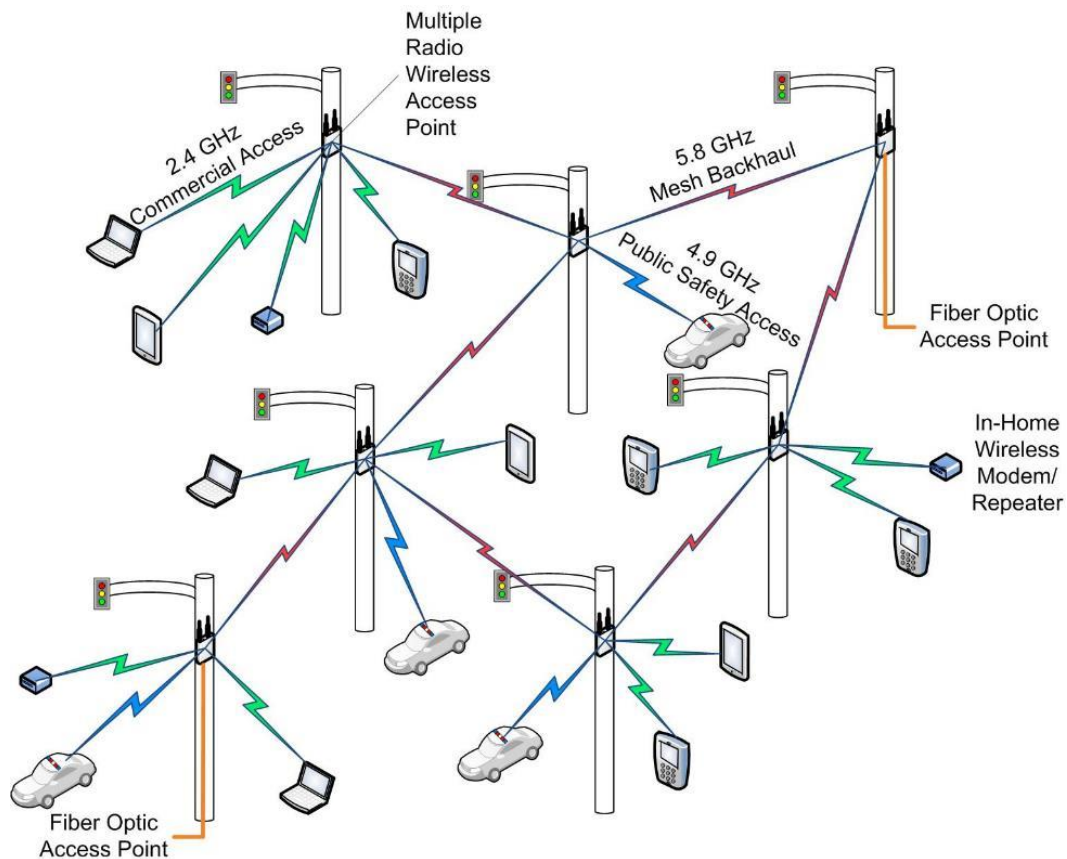
Figure 2 graphically illustrates the network operation and functionality.

⁸ Ultra High Frequency (300 MHz – 3GHz)

⁹ Super High Frequency (3 GHz – 30 GHz)

¹⁰ Institute of Electronic and Electrical Engineers, Inc. is the international professional organization which has spearhead network standardization among manufacturers for more than four decades.

Figure 2: Network Overview of Port Angeles Wireless Network Infrastructure



Low-power wireless equipment available for 4.9 GHz and 2.4 GHz for this type of network deployment exhibit limited range primarily due to radio signal absorption created by structures and foliage that attenuate the direct line-of-sight radiation between network components. In general, the range of most applications is limited to the direct optical line of sight of not more than 250 to 300 feet from the access point.

In addition to the wireless links between the users and the access devices, there is an independent backhaul wireless link between the individual wireless access points and the fiber-optic network.

Figure 3 is a photograph of one of the Port Angeles wireless access points mounted on a streetlight. The majority of the access units are mounted on either streetlights or utility poles. The power to operate the unit is obtained either from the streetlight wiring or an added circuit on the utility pole. The devices are typically mounted at a nominal height of 20 feet above ground. Based on field testing, this mounting position appeared to provide the best compromise between distance coverage and providing sufficient signal in the immediate vicinity of the mounting structure. Placing access points at a higher elevation created additional interference at adjacent sites.

Figure 3: Wireless Access Point Mounted on Street Light



Figure 4 below illustrates a typical Port Angeles wireless access point. The electronic component box, on the extreme right, houses the wireless radio transmission electronics for each of the wireless bands. The vertical elements above and below the housing are antennas used to communicate with public safety vehicles and fixed commercial users. The units employ 802.11n multiple access antennas—referred to in the industry as multiple input, multiple output (MIMO) technology that continuously selects the best transmission path between the user and the access unit. The panel antennas located between the access unit and the pole are directional antennas used to communicate with adjacent access points through the 5.8 GHz wireless mesh.

Figure 4: Wireless Access Point (Detail)



Depending on the access point's physical location within the mesh network, the access unit may be connected directly to the backbone fiber-optic network. For mesh-only connected units, the physical length between hops and the number of hops varies throughout the system based on the placement of the access point and the location of existing fiber-optic interconnection points.

The City's long-term strategy to enhance network performance includes adding access points to expand the coverage area and adding fiber access points to decrease the number of hops within the network to the nearest fiber access point. The current implementation was developed as a balance to minimize construction costs and maximize service area within a constrained capital budget.

Figure 5 below is a City map illustrating the location of the wireless access points. The blue circles indicate the location of the wireless access points; the sites with the outer red circles are fiber network interconnection points.

Figure 5: Locations of Wireless Access Points in Port Angeles



The map in Figure 6 illustrates the backhaul connecting the wireless access points. It should be noted that wireless backhaul mesh is a dynamic, computer-managed infrastructure. Path

routing changes in real time to maximize throughput, so Figure 6 illustrates the backhaul routing taken at a particular moment in time.

Figure 6: Backhaul for Wireless Access Points in Port Angeles



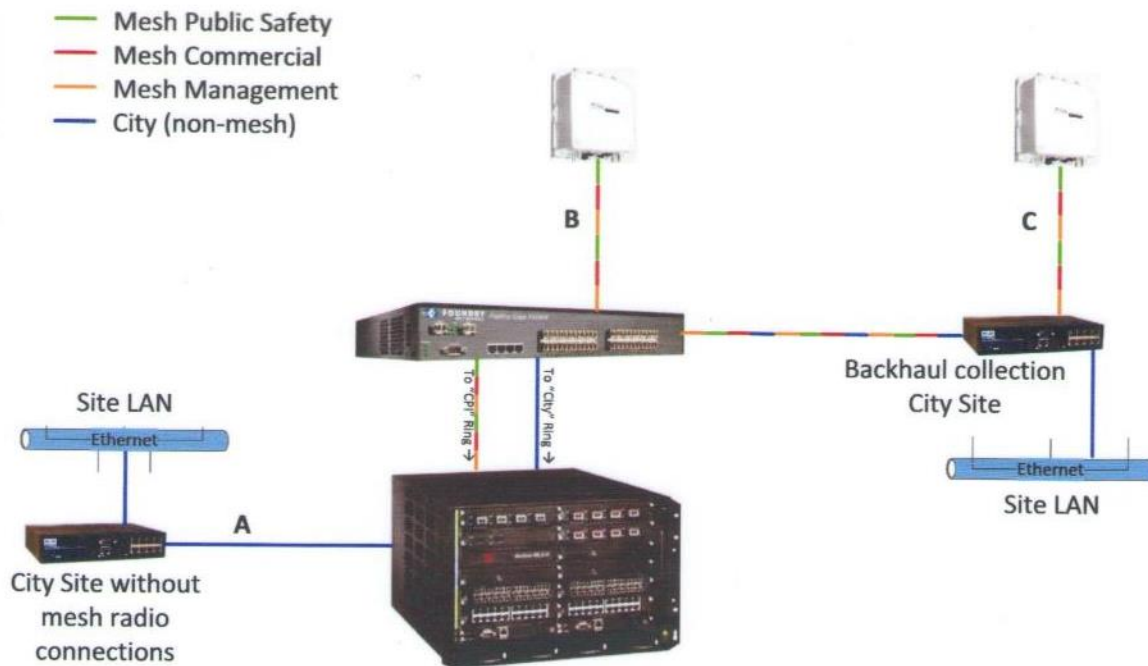
3.3.1.2 Virtual LANs and Interconnection

The individual Port Angeles wireless access points are connected to the network control center through a fiber-optic network owned and operated by the local system integrator, Capacity Provisioning Inc. (CPI). Traffic from each of the devices travels back to the facility through virtual local area network pathways, called VLANs or virtual LANs. These individual segments separate traffic between the various applications, such as public safety, public subscriber service, and network monitoring and control. This permits both the segmentation and separation of services and at the same time provides the necessary security between the individual networks. The VLAN capability will permit the public access network to provide "open access" to multiple Internet service providers (ISPs)—a requirement of the BTOP funding.

Figure 7 illustrates the VLAN concept and how it is used in the Port Angeles network. As can be seen in the figure, the green lines represent the transmission of public safety data, the red line

indicates the commercial network, the yellow line identifies network management, and the blue line shows dedicated City services within the existing CPI fiber-optic network. The virtual LAN concept provides a mechanism for clearly separating individual services while multiplexing or combining on a common transmission line.

Figure 7: Functional Diagram of the VLAN Infrastructure



The CPI monitor software oversight of the instantaneous performance of any wireless system varies due to changes in path loss, traffic loading within any particular segment, and interference from other RF-emitting devices.

A real-time performance tool created by the City's contractor provides a valuable oversight mechanism for weeding out specific network problems associated with one or more of the access points; it provides network managers with the tools to tune and align components to maximize network performance. It also provides network planners with quantitative measurement for determining which locations need to be addressed with direct fiber access points as the network expands.

3.3.2 Network Operations

The public safety network is managed jointly by the City and its vendor, CPI. The public 2.4 GHz network is operated as a commercial venture with network support from CPI. The network as designed and built has the capability to support additional ISPs.

3.3.2.1 Public Access Network Specifics

The Port Angeles public network is designed to provide efficient low-cost services to the general public and commercial users. It is intended primarily as a service for home and small business applications, and is targeted toward the general public on the move.

At the time the network project was completed, only one Internet service provider, OlyPen, had entered into an agreement with the City to provide public Internet access over the network. OlyPen is an established local ISP that has provided other forms of Internet access on the Olympic Peninsula since 1996.

OlyPen's Metro-Net Mobile Service uses the network's 239 wireless access points; it is a Wi-Fi service over most of the City that is similar to the wireless hotspots available to the public in many airports, coffee shops, restaurants, and hotels.

OlyPen's Metro-Net Fixed-Point Internet service is similar to cable, DSL, and other forms of fixed broadband Internet services, in that a device commonly referred to as customer premises equipment (CPE)—in this case, an externally mounted wireless transceiver—is installed by the company at the customer's residence or business. (See Figure 8.) There is no need for a cable TV connection or telephone line to obtain a service.

Figure 8: Exterior-Mounted Customer Premises Equipment (CPE) Unit



3.3.2.2 Public Safety Network Specifics

The public safety network is focused on providing high-speed, low-cost network services to vehicles. While the wireless network provides services throughout most of the pertinent areas in Port Angeles, the high priority and on-demand service requirements of the public safety community require additional facilities to augment the wireless service.

Installed in each of the City’s public safety vehicles is a mobile routing device that continuously examines signal quality from both the City’s wireless network and the available commercial wireless services. The router dynamically provides the most cost-effective and reliable service by switching between the City network and the pay-as-you-go commercial network as needed.¹¹ (See Figure 9.)

The mobile router is an important component in the network because public safety vehicles are regularly operated outside of the City of Port Angeles. Public safety service obligations to the public do not stop at the City line—and, in fact, many of the staff are constantly traversing City boundaries.

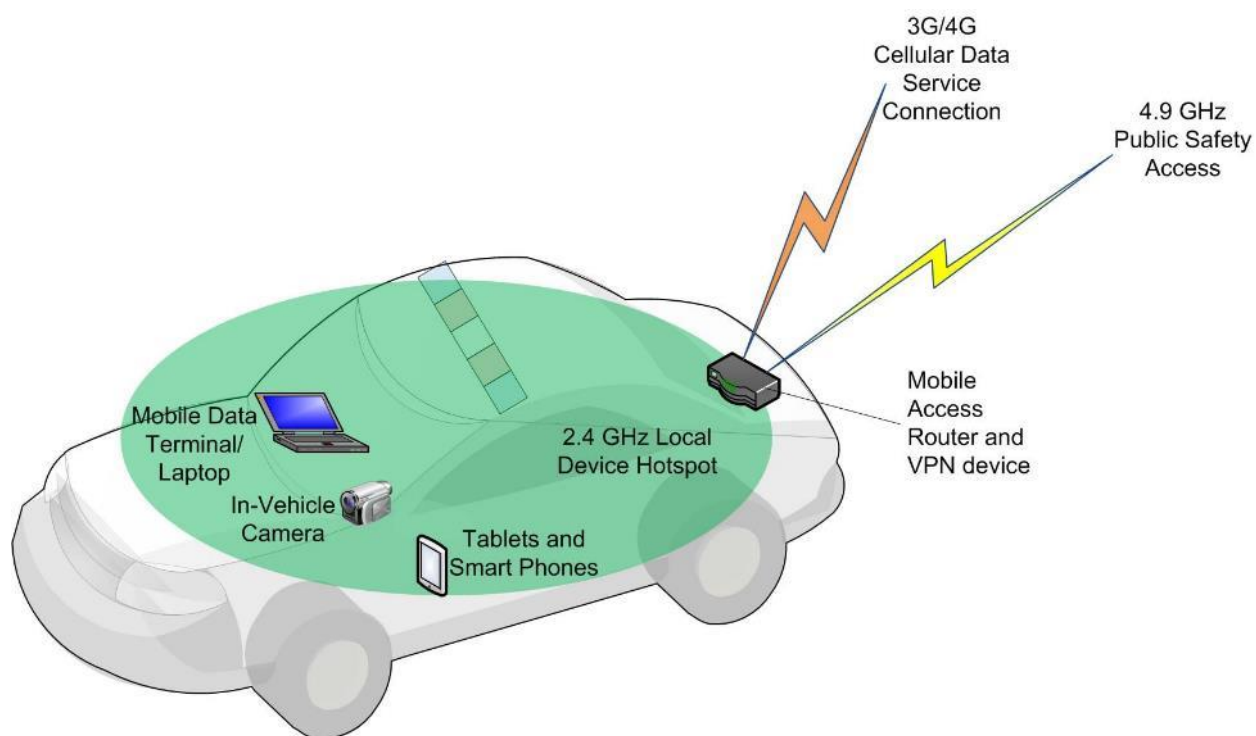
Further, there are also areas within the City where wireless coverage is not always reliable. The long-term goal for the project is to isolate and reduce the dead spot areas, through repositioning the access points or adding access points as funding permits.

Commercial 4G services are available to all public safety vehicles, patrol vehicles have a very high probability of accessing either or both the commercial services and the City wireless network. Ongoing work is focused on refining and expanding this network to improve coverage in critical areas, while the network management team’s ongoing adjustment and tweaking of the internal vehicular routers aims to provide more or less continuous wireless coverage with the 4.9 GHz service to minimize access to pay-as-you-go services within the City limits.

Public safety vehicles are also equipped with a mobile router device that provides connectivity back into the Port Angeles network. The router ensures that all data between the public safety vehicle and the Port Angeles network is transmitted securely via built-in VPN.

¹¹ Typically wireless users on commercial networks pay a fixed fee for a defined amount of data service. Beyond that point services are paid for on a metered basis.

Figure 9: Illustration of Public Safety Mobile Router Function



Within the public safety vehicle and 100 to 200 feet from the vehicle, a secure 2.4 GHz hotspot provides connectivity to other Wi-Fi enabled devices. This hotspot can provide connectivity for mobile data terminals, laptops, in-vehicle cameras, and other network-connectable devices.

3.3.3 Lessons Learned

The Port Angeles network performance has clearly addressed the public safety users' requirements. Patrol officers routinely use the in-vehicle real-time video surveillance capability to assist officers on patrol.

The City's Information Technology department was not an active participant in the wireless project. Staff concluded that because of the manner in which the system was configured to support the public Wi-Fi implementation, the network did not provide adequate security to support critical City applications. This precludes the use of the network to support any City enterprise network and Utility SCADA requirements.

Finally, the revenues received from retail Wi-Fi users have fallen short of expectations.¹² There is a daily "free" offering that is popular and draws users. Experience to date is that the third-party commercial ISP did not aggressively pursue the retail market for consumer services. This Wi-Fi service directly competes with DSL services provided by the ISP.

¹² A specific dollar amount is not publicly available.

3.4 Ripon, California

The City of Ripon, California has a population of approximately 14,200 over a land area of approximately 5.5 square miles.

3.4.1 System Description

This Ripon system was installed to support public safety applications within the city. It was constructed in 2005 and operates in the 2.4 GHz unlicensed band. It employs proprietary Motorola Mesh electronics (a product that has been discontinued). There are a total of 52 wireless access points providing coverage over most of the city. There are a total of 81 client devices comprising a mix of mobile vehicles, video cameras, and SCADA devices. The system has been in operation for approximately 10 years.¹³

The Ripon Police Department's IT department operates the system and can support the limited maintenance that it requires. It has proved to be a valuable tool to support day-to-day public safety applications. The system relies totally on the mesh infrastructure to interconnect all the wireless access points.

3.4.2 Lessons Learned

This Ripon system was designed to serve a specific application and is maintained and operated by the user group. Public safety staff seems to be very satisfied with the overall operation. They are proposing to upgrade the system to new technology since the original system hardware vendor Motorola no longer supports this product. The 10-year lifespan goes well beyond expectations in wireless technology. This particular product represented a good mix for a relatively small community focusing on specific requirements and goals.

This an example of a successful, standalone wireless project targeted to a single user group (public safety) that is managed and operated by the user group. The equipment selected appears to have met all the design performance requirements of the users. As in many technology-based projects, simple is good.

3.5 San José, CA

The City of San José has two interesting, ongoing wireless initiatives. Recent deployment of public wireless has been installed in limited areas of the city's downtown business center for both public access and enhancements to parking.¹⁴ Public access is also available at the convention center and the airport. This installation uses high-performance 802.11n technology

¹³ Information provided by Ripon PD IT department staff

¹⁴ Joint press release City of San José, Lenka Wright & Mark Riscaro Ruckus Wireless June 4, 2014 City expands service to SJC Airport and convention center.

A separate system is being installed for communications and control purposes with the city traffic signals.¹⁵ This is a standalone telemetry system independent of the public access network.

3.5.1 System Description

The San Jose Wi-Fi system provides free Wi-Fi public services in limited multi-block areas in the downtown core business areas. The vendor has installed and maintains equipment serving the targeted outdoor areas, the city convention center, and the airport. The equipment used for traffic signal control is independent of the wireless network and is operated and maintained by the City's traffic engineering organization.

3.5.2 Lessons Learned

As a part of this recent downtown San Jose wireless network deployment, high-capacity IEEE 802.11n technology was installed to increase throughput performance up to 200 Mbps and expanded coverage. Wireless is a rapidly developing technology; typically new generations of equipment have a practical maximum useful life of five to seven years. This is particularly true for the access point hardware which is installed in the field. Other elements of the system such as broadband backhaul to interconnect to control centers and the physical mounting structures used for the access points have practical lives of 20 to 30 years. As has been demonstrated by the cellular industry, there is a constant need to redeploy new in-field electronic equipment to capitalize on ever-expanding throughput capacity requirements for users and address changes in communications technologies (e.g., enhanced signaling and encoding) and expanded spectrum resources resulting from FCC efforts to reclaim SHF spectrum.

Deploying separate wireless networks for public wireless access and for the traffic signal application has merit. The design for each network can be tailored to meet the specific operating requirements and performance specifications for each of these services. A single universal wireless network generally may not cost-effectively address all of the specific requirements of various user groups within the municipality. A generic area-wide backbone wireless network may have merit for certain deployments. In many cases, it unfortunately may not address all users adequately.

3.6 Santa Clara, CA

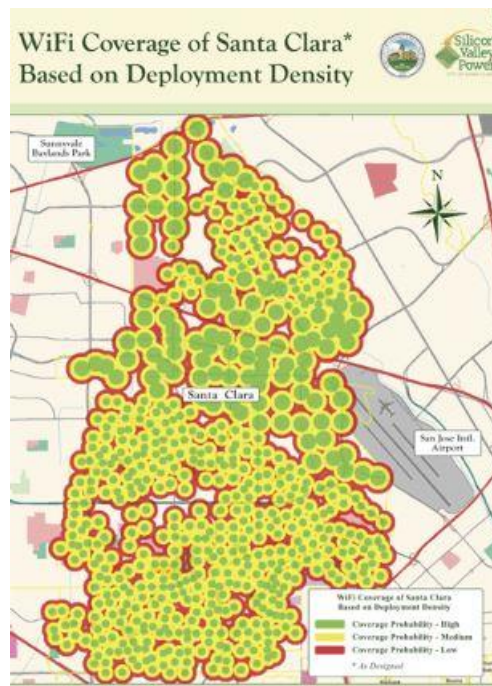
3.6.1 System Description

The Santa Clara system is a general-purpose citywide system that provides free Wi-Fi coverage to citizens and supports control monitoring functions for the city's utility. The system operated by Silicon Valley Power (SVP MeterConnect) provides coverage within the city limits over approximately 19 square miles. There are a total of 600 access points in a mesh network to

¹⁵ Public release, Proxim wireless, Reducing congestion on the streets of San José with Wireless Traffic Control

extend the coverage of existing fiber-optic deployment. Figure 10 is a map posted on the City website showing the areas of coverage.¹⁶ Portions of the infrastructure of the system were purchased through a distressed sale of installed assets by the city utility from a defunct commercial provider for approximately \$200,000. It was upgraded and expanded in 2013 at a cost of approximately \$2 million. Separate SSID accesses are available to the public, government, and public institutions. The City estimates there are approximately 5,000 unique public users. Public access is provided up to 3 Mbps.

Figure 10: SVP MeterConnect Coverage Area



3.6.2 Lessons Learned

As noted in so many systems, the public will use free Wi-Fi service on a regular basis. Santa Clara does not have a fee-based service; all public access is free. Traffic depends on a variety of factors which include speed, reliability, and other available services. The network is operated by the City municipal utility. Estimated annual operating costs, in addition to the capital cost, are approximately \$200,000 per year. A substantial portion of this is mesh radio software licenses and maintenance.

For the longer term, future upgrading of the system to support newer, higher-capacity services will require a substantial investment in fiber-optic transmission plant.

¹⁶ Santalarafreewifi.com

3.7 Implications to Consider for Palo Alto Wireless Deployment

Our review of the selected municipal wireless projects provides some insight on deployment issues that might be addressed in formulating a Palo Alto wireless plan. In this review of municipal projects we focused on projects targeted to support public safety, cities with an existing fiber-optic infrastructure, and in some cases cities that operate their own electrical utility.

We note that, in the projects described above, there are several recurring findings—specifically a set of common findings within the municipal wireless community. Our industry review, while clearly limited in scope, reveals that there is a core thread that supports some rather practical, common-sense guidelines for wireless deployment:

- None of the municipal or commercial projects that we examined were able to develop a sufficient revenue stream to make the undertaking a viable business proposition. The public appears to appreciate the availability of free high-speed Wi-Fi; if you build it and give it visibility, the public will use it. For example, logins in Port Angeles increase substantially during periodic free periods. On the other hand, when the public is asked to pay for service on an ongoing or subscription basis, there appears to be a very small customer base.

Should the City elect to move forward on deploying a subscriber-financed citywide Wi-Fi coverage model, we strongly recommend that the City first undertake a systematic consumer demand study to determine the interest in a Wi-Fi product, the performance parameters anticipated by users, and the subscription rates that users are willing to pay for the service. (We note that the City invited residents to participate in an online survey about wireless service options in July 2015.) In our nationwide review of municipal subscriber-financed citywide Wi-Fi coverage networks, we did not find any systems that were fully financed through subscriber revenues.

- The practical deployment of Wi-Fi services requires a high-capacity connection between the access points through an expansive, dedicated high-capacity broadband backhaul network.¹⁷ This backhaul network can use either wireless or fiber-optic technologies (and in many cases, a mix of both technologies). In Palo Alto, the existing CPAU fiber-optic infrastructure does not have sufficient citywide points of presence or the requisite capacity to support citywide implementation of a public Wi-Fi network.
- Should the City choose to move forward on implementing citywide Wi-Fi coverage, the most cost-effective and efficient manner for deployment would be to do so in concert

¹⁷ Backhaul networks connect wireless access points to the core network management system.

with an aggressive citywide fiber-optic expansion project, as set out in the city's FTTP deployment study.¹⁸

- Finally, a word of caution: Consumer-targeted wireless technology continues to evolve rapidly; wireless electronic equipment generally incorporates significant performance upgrades in three to five year intervals. It is difficult to predict what technical standards will be employed by consumer devices for wireless communications in the future. Any practical deployment for wireless technologies associated with consumer devices needs to take this into account. That said, investment in core wireless infrastructure—which includes mounting locations (poles, towers), electric power, and high-capacity backhaul links for access devices—will provide a foundation for much greater longevity for supporting the continual migration of wireless technology standards for consumer access devices.

For each wireless deployment scenario, a comprehensive business plan needs to be developed for upgrading access equipment at regular intervals. In contrast, much of the core infrastructure such as the mounting structures (e.g., utility poles and streetlight poles) for the access devices, power equipment, and backhaul networks, typically will be operational for 20 to 30 years.

¹⁸ This would entail with an estimated capital investment of approximately \$77.6 million.

4 Wireless Network Architecture

Three general types of wireless topology are commonly employed in the system-level architecture of network design: (1) point-to-point communications, (2) point-to-multipoint communications, and (3) blanket (area-wide) coverage. Generally each of these technologies is used to construct wide-area municipal networks. This section examines the fundamentals of each topology and how they are implemented in practical networks.

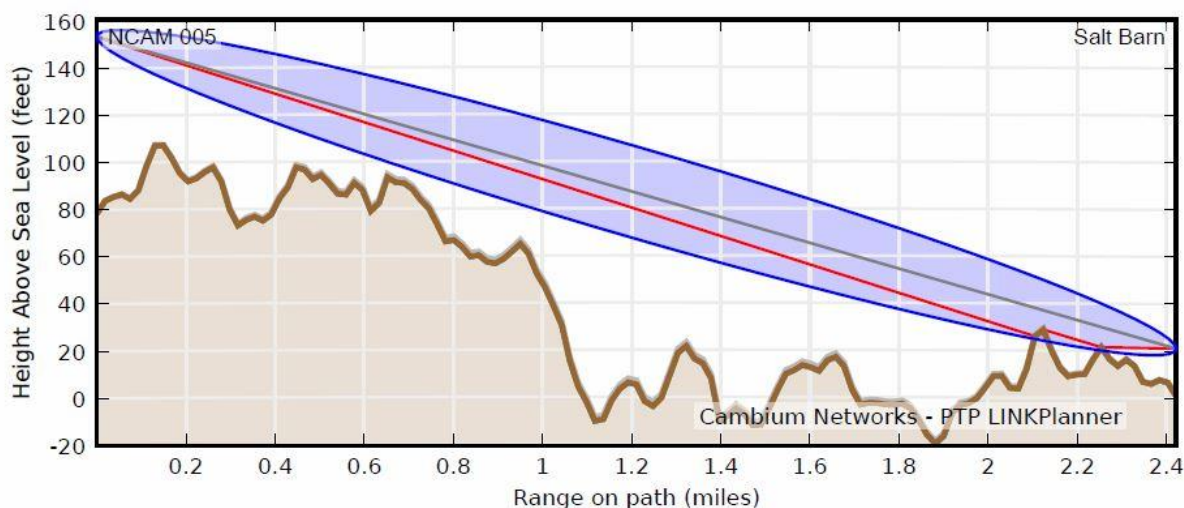
4.1 Point-to-Point Communications Links

The point-to-point topology supports a communication link between two points. Typically this is bidirectional and is configured to support data rates, availability, and security levels required for the specific application. For wireless communications, equipment is mounted at an elevation such that there is a line-of-sight path between the two points in the network. The height of the emitting and receiving antennas needs to be at a level above ground and generally clear of trees, buildings, and other objects that might absorb or reflect radio signals along the path. Lower frequency systems operating in the 700 Megahertz (MHz) UHF range not only provide a direct signal but also can support reliable extended coverage beyond clear line of sight. New technologies such as MIMO supporting multiple antennas permit extended range through the use of multiple input and output antennas.

A wide variety of point-to-point products available from various manufacturers operate in both licensed and unlicensed spectrum in the 2.4 GHz to 5 GHz range; these products can support bidirectional point-to-point IP-based links and data rates in excess of 100 Mbps. These devices support full error detection and data encryption algorithms. Typically the devices include an integrated radio and antenna as a single package for mounting on buildings and towers. Many are small and can be comfortably mounted on existing urban hardware such as traffic signals, utility poles, and streetlights.

In order to support a reliable, point-to-point wireless link it is common to mount devices at elevations of 20 to 75 feet¹⁹ above ground, positioned to avoid nearby obstructions. Depending on terrain, foliage, and other obstructions, point-to-point infrastructure will provide reliable communications links at distances up to 2.5 miles operating in spectrum from 2.4 GHz to 5 GHz. Figure 1 illustrates a simple point-to-point link connecting one fixed antenna located 70 feet above ground to a second site 20 feet above ground. This terrain profile analysis does not include amounts for clearance of buildings and vegetation; rather, it represents a starting point for an infield walkout evaluation to determine the existence of site-specific path coverage issues.

¹⁹ Subject to local zoning ordinances containing restrictions and requirements on heights and mounting structures.

Figure 11: Sample Point-to-Point Link Analysis

4.2 Point-to-Multipoint Communications Links

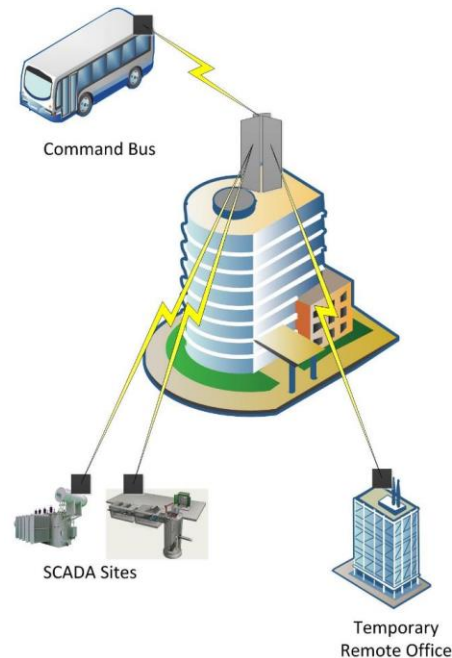
Point-to-multipoint deployments build on the point-to-point topology by adding additional sites to the network. One or more sites serve as the core site. The core or hub site is located in a position where it is able to communicate with all of the sites within the point-to-point network. All of the individual service points must be able to support a reliable point-to-point link between the hub site and the service point. This generally requires a detailed investigation to determine the most suitable location for the core hub site. Generally this is located in an elevated area, typically an existing tower, building, or other such structure that provides for the highest suitable height above the average terrain of the area encompassing all of the individual service points.

Since the hub site represents a single point of failure for the entire network, it generally includes hot standby backup core communications equipment that automatically switches an operation in the event of failure of the primary equipment. Individual site equipment installations may or may not be backed up based on network priorities. Figure 12 illustrates a typical point-to-multipoint network. Here, practical applications include communications to a parked public safety command van, links for temporary work sites or offices, and Utility SCADA sites.

The point-to-multipoint network is generally the basis for wide-area deployment. For example, if the point-to-point range between any two devices is two miles or less, the area served by a hub site would be limited to a radius of two miles from the hub site. In order to expand coverage, in areas where there exists a robust fiber-optic network infrastructure, wireless hub sites are interconnected by fiber. In Palo Alto given the existing fiber-optic infrastructure, direct fiber-optic interconnection would be the preferred option.

In situations where fiber-optic interconnection is not available the options include extended point-to-point wireless links utilizing narrow beam antennas at higher elevations or so-called mesh technologies that repeat and forward data traffic between hub sites.

Figure 12: Point-to-Multipoint Example



4.3 Blanket Coverage

Blanket coverage addresses the requirement to provide a minimum level of interference-free wireless service throughout a defined coverage area. This coverage is typical of the type of service being provided by commercial wireless carriers such as Verizon, AT&T, Sprint, and T-Mobile. The service providers place base station facilities that communicate directly with user devices (often handheld or mobile devices, in locations that vary with the time of day).

In order to provide this coverage, the commercial carriers have invested large sums of money in acquiring spectrum resources from the FCC, building towers, and developing an extensive backhaul system to integrate each of the transmission tower facilities into an area-wide network. Generally the towers are shared by the various commercial cellular providers and distributed antenna system (DAS) operators, and are often leased from companies that focus on tower facilities as revenue-producing investments.

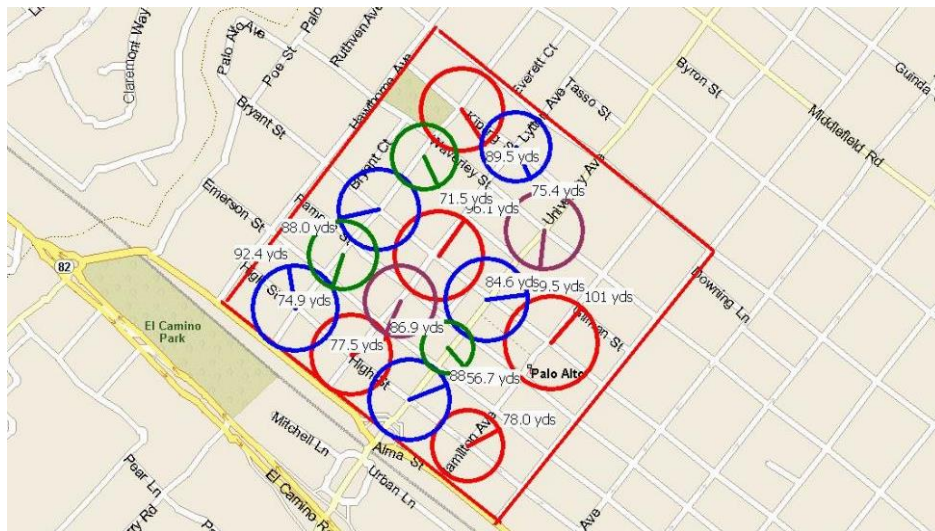
There are alternatives to the traditional commercial wireless carriers for providing localized blanket wireless coverage. Blanket coverage networks can be installed in targeted areas and provide services within the specified areas that can rival traditional carrier 4G services in both cost and performance. This type of implementation would no doubt focus on short-range high-capacity wireless access devices located within the target service area. Most consumer devices

such as tablets, smartphones, and PCs include Wi-Fi capability. Newer devices support both 2.4 GHz and 5 GHz technologies. They support data transmission rates in excess of 50 Mbps. The range of modern Wi-Fi wireless access points is typically 200 to 300 feet.

Figure 13 illustrates a conceptual approach to providing coverage within a defined area of Palo Alto's central business district. As can be seen in the figure, access devices located at intersections might be mounted either on traffic signals or on utility or light poles in the area.²⁰ Each access point serves a limited area and provides sufficient signal intensity to communicate with low-power mobile devices such as tablets and smartphones. Different colors for the coverage areas for each of the access points indicate differing channels for communication to minimize interference between adjacent sites and to enhance the overall capacity of the system.

In this illustration, the wireless access point provides point to multipoint infrastructure to communicate with the subscriber unit. Backhaul of information from the wireless access point would be provided via individual point-to-point fiber-optic links to a core management center. To minimize fiber deployment, optical multiplexing technologies²¹ might be employed to permit the integration of the backhaul link onto individual shared fiber lines with each site utilizing differing optical wavelength.

Figure 13: Conceptual Approach to Providing Downtown Palo Alto Coverage



²⁰ It should be noted that while on the surface it might be a simple matter to add equipment to the traffic signal infrastructure, there are numerous, unique challenges associated with each potential access site. Planning will need to be coordinated with traffic engineers and in some cases specific locations may prove to be unusable.

²¹ For this type of application, optical splitters are used to separate individual optical channels much like the travel lanes on a highway. By employing optical multiplexing the same fiber can carry the backhaul of a dozen or more sites.

5 Wi-Fi Technology

5.1 Transmission Evolution

Since its introduction in 1997, Wi-Fi technology has become synonymous with wireless Internet. The technology is based on protocols and techniques from the IEEE 802.11 standard. Standards-based technology ensures the interoperability of equipment from different vendors. The introduction of various improvements or versions of the 802.11 standard has resulted in the improvement of speeds from 2 Mbps to the 100 Mbps+ speeds that are available today in Palo Alto.

The two main unlicensed frequency bands used for municipal wireless applications are the 2.4 GHz and 5 GHz bands permitted under §15 of the FCC rules. The 5 GHz band contains three separate sub-bands (5.1 GHz, 5.3 GHz, and 5.8 GHz). There is also a separate 50 MHz allocation in the 4.9 GHz band which is reserved for licensed public safety applications. The 2.4 GHz frequency band is the most widely used, and is therefore most susceptible to interference from other devices that use the same frequency—such as Bluetooth, microwave ovens, and cordless phones. The 5 GHz band generally can support transmission rates of greater than twice as fast as 2.4 GHz, primarily due to additional spectrum bandwidth and lower interference levels employing 802.11 based network equipment. However, as distance increases, signal strength falls off more rapidly at 5 GHz than 2.4 GHz.

The original version of the 802.11 standard (802.11-1997) is now obsolete. The versions of the standard that are still in use (listed in order of evolution) include 802.11a, 802.11b, 802.11g, 802.11n, and, most recently, 802.11ac. Wi-Fi devices are certified by the Wi-Fi Alliance to operate according to one or more of these versions. Individual manufacturers often support products that in general adhere to 802.11 standards and also have proprietary aspects.

The following is a summary of the 801.11 versions used in open architecture deployment.

5.1.1 802.11a

The 802.11a version of Wi-Fi operates in the 5 GHz spectrum with a channel size (bandwidth) of 20 MHz. It was first defined in 1999 and later redefined in 2012. It uses a technique called the Orthogonal Frequency Division Multiplexing (OFDM)²² scheme, which is also used by other technologies such as digital subscriber line (DSL), long-term evolution (LTE), and Data over Cable Service Interface Specifications (DOCSIS). It has physical layer data rates of up to 54 Mbps

²² The OFDM scheme spreads aggregated IP traffic over a number of much smaller “channels,” or subcarriers, these small channels are “orthogonal” to each other in the sense that they can be efficiently placed into much larger spectrum blocks without interfering with each other in spite of less guard spacing between them.

utilizing modulation²³ techniques such as 16 QAM²⁴ and Forward Error Correction (FEC) coding.²⁵

5.1.2 802.11b

This version operates in the 2.4 GHz spectrum and was introduced in 2000. It uses Direct Sequence Spread Spectrum (DSSS) techniques that were previously deployed in 802.11-1997. It has a signaling data rate of up to 11 Mbps using different modulation schemes. The Complementary Code Keying (CCK) modulation is used for the 11 Mbps data rates. In the 2.4 GHz spectrum in North America there are only three standard 20 MHz channels that do not overlap with one another.

5.1.3 802.11g

Introduced in 2003, this version operates in the 2.4 GHz spectrum using OFDM, which results in higher physical layer data signaling rates of up to 54 Mbps (with 16 QAM). It uses 20 MHz channel allocation. The 802.11g standard is dynamically compatible with 802.11b. In a mixed standard environment where an 802.11b/g access point serves a client device with only 802.11b capabilities, creating compatibility could effectively lower the speed of the 802.11g network to that of the 802.11b.

5.1.4 802.11n

The 802.11n version, which was approved in 2009, operates in both the 5 GHz and 2.4 GHz bands and is able to obtain much higher data rates due to multiple factors:

- Increased channel sizes by bonding two 20 MHz channels, which nearly double the data (bps) available
- Implementing higher-order data encoding rates to 64 QAM
- Advanced antenna techniques such as multiple input, multiple output (MIMO) and beamforming. MIMO involves the splitting of data into multiples spatial streams that are

²³ A modulation scheme spreads data on a carrier signal by using different combinations of the amplitude and/or phase of the carrier signal.

²⁴ The number “X” in the X-QAM modulation refers to the number of possible combinations in the modulation scheme—the combinations of distinct types of changes in amplitude and/or phase in a signal. More speed requires higher-order modulation schemes, but higher-order schemes are more sophisticated to design and build and more sensitive to noise and imperfections in the signal. In a 256-QAM, there are 256 combinations changes in amplitude or phase. 256 is also 2^8 , and 256 combinations can be depicted mathematically in the full range of combinations of eight digits of “0” or “1.” In a 256-QAM (2^8 -QAM) channel of a given bandwidth, the theoretical capacity is [channel width in bps] x 8.

²⁵ A coding scheme determines the number of data bits versus error correction bits being transmitted within a packet.

transmitted from multiple antennas at the same time on the same frequency channel (up to four streams in the case of 802.11n).²⁶

- Use of packet aggregation to improve the efficiency of the MAC layer packet transmission
- Better error correction techniques such as Low Density Parity Check (LDPC), which in turn make data transmission more spectrally efficient—that is, allows more data (bps) within the limited amount of spectrum (Hz)
- Shorter guard interval resulting in a 10 percent speed improvement

In the 5 GHz band implementation, there are nine standard 20 MHz channels in North America. 802.11n is downward compatible with other versions of the 802.11 standard and is generally the level of network implementation found in existing commercial and government enterprise networks.

5.1.5 802.11ac

The 802.11ac version was published in December 2013. It operates only in the 5 GHz spectrum band, which has greater spectrum availability (and therefore a greater number of channels) and is less susceptible to RF noise than 2.4 GHz. Physical layer data rates of up to 1.3 Gbps are possible through 802.11ac.

This throughput is achieved through the following methods, which build on 802.11n:

- Larger channel sizes by greater channel bonding up to 80 or even 160 MHz²⁷
- Denser encoding schemes such as 256 QAM up from 64QAM in 802.11n
- Implementation of higher-order MIMO antennas with the availability of up to eight spatial streams
- Enhanced low-density parity check (LDPC) error-correcting codes
- Implementation of Multiuser MIMO (MU-MIMO) where a Wi-Fi access point is able to use its antennas to transmit multiple frames to different client devices, at the same time and over the same frequency channels. In contrast, 802.11n only had Single User MIMO (SU-MIMO)

²⁶ The MIMO streams travel to the receiving antennas following multiple paths. Multiple copies of the signals arrive at each antenna with slightly different timing which can be used to reinforce each other. This improves the signal to noise ratio, reliability and range.

²⁷ The use of 160 MHz in the United States is still under review.

- Optionally, shorter guard interval (for a 10 percent increase in speed)
- Optionally, enhanced beamforming techniques

Theoretically, a 1,300 Gbps physical layer data rate can be achieved by employing an 80 MHz bandwidth data transmission stream using 256 QAM encoding and three spatial streams at 5/6 coding.

802.11ac devices are now being introduced into the market. These are compatible with existing 802.11a/n deployments. For the 2.4 GHz band, 802.11n will continue to provide the maximum throughput.

5.2 Achievable Network Data Throughput Rates

While the standard addresses the physical layer (Layer 1) data rates for each of the versions of the 802.11 standard, the actual, practical data transmission are substantially lower than the bit transfer rates. A major part of the modifications in each version affected the physical layer while the same Media Access Control or MAC layer (Layer 2) protocol, called Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), was in place. The MAC also uses messages called request-to-send/clear-to-send (RTS/CTS) to help avoid collisions with clients connecting with the same access point. Because of these types of overheads and the error correction required, the efficiency of the MAC layer ranges between 60 percent and 70 percent. The actual throughput available on each of these technologies is therefore 70 percent or less than of the physical layer (Layer1) data signaling rate.

As with many radio-based technologies, the external conditions (such as the line of sight and interference) greatly affect the operation of wireless devices. The effective data rates available on a wireless network are also a function of many other factors such as:

- Signal strength over noise (S/N) at the receiver or the network interface device²⁸
- Signal to interference (signals in the pass-band over the internal receiver noise)²⁹
- Availability of multiple channels or channel bandwidth for channel bonding

Increasing the channel bandwidth results in a reduction of the range of the system as the same transmission power is split across a larger number of subcarriers. Also, in high noise environments, a 40 MHz channel bandwidth adapts to use 20 MHz bandwidth. Higher-order modulations and coding schemes are dependent on greater signal strength for operation. This

²⁸ Devices employing adaptive modulation technology may operate with low S/N levels of 10 dB but to achieve full advantage of 256 QAM encoding throughput requires an additional 22 dB of signal for a 32 dB S/N (over 100 times the receiver signal level to obtain full data rate throughput).

²⁹ Interference from other RF energy devices (e.g., wireless access units, radar, microwaves and consumer devices).

means that the highest data rates are usually available only at close proximity to the access point where signal strength is the highest. This is considered to be adaptive modulation and coding to ensure that most optimum mode of transmission is used.

The improvement of data speeds due to MIMO is directly proportional to the number of spatial streams. But, more spatial streams require more antennas and consume additional power. Therefore, it may not be possible to implement this fully on mobile devices with limitations on hardware and power. For instance, an 802.11n radio provider may advertise 300 Mbps speed. When we examine this:

- The channel size has to be 40 MHz
- This is the data rate at the highest modulation rate; with a MAC efficiency of 60 percent of the actual throughput, the data rate will be 170 Mbps
- MIMO operation is required

Table 1 provides a simplified overview of pertinent operational parameters associated with the evolution of the 802.11 equipment used in the deployment of municipal wireless technology. The 802.11 standards are the product of more than a decade of planning, drafting, and negotiation among network architects, equipment designers, manufacturers, and government radio frequency regulators.

Table 1: 802.11 Version Summary³⁰

Version	Frequency	Max Modulation Rates (Mbps)	Typical Data Rates (Mbps) ³¹	Modulation	
802.11a	5 GHz	54	20	OFDM	16QAM
802.11b	2.4 GHz	11	5	DSSS	CCK
802.11g	2.4 GHz	54	20	DSSS, OFDM	16QAM
802.11n	5 or 2.4 GHz	600	170	OFDM	64QAM
802.11ac	5 GHz	1300	TBD	OFDM	256QAM

³⁰ IEEE Std 802.11 for wireless local area networks (WLANs) as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions. IEEE Standards 2008-2011.

³¹ Half duplex transmission rates, typical only one device is transmitting at a time using a common spectrum.

5.3 Network Security

Security is an integral component of any networking technology, including Wi-Fi. The oldest security protocol for Wi-Fi is the Wired Equivalent Privacy or WEP. It is no longer considered sufficient, but 64 bit and 128 bit WEP are still in use. The WPA protocol was introduced in 2003 with an encryption technique called TKIP. Currently, the latest version of WPA (called WPA2) is the recommended technique for Wi-Fi security along with an encryption technique called Advanced Encryption Standard (AES). There are other methods that can be used to improve Wi-Fi security such as MAC Filtering and Wireless Intrusion Protection Systems (WIPS).

5.4 Signal Propagation and Interference Rejection

The physics of radio frequency propagation results in unavoidable wireless propagation loss that is a function of distance. This ultimately results in lower speeds at the edge of an access point's coverage area due to the reduction in signal strength.

For example, 2.4 GHz UHF and particularly 5 GHz SHF networks have very limited ability to penetrate the walls of buildings and other dense objects like tree limbs, and even dense leaves. In the case of an outdoor deployment, certain types of construction such as stucco and high-efficiency windows, in particular, block signal penetration into and out of buildings. The performance of outdoor networks is impacted by vegetation, hills, buildings, building materials, and other obstructions because the UHF and SHF devices require close to line-of-sight transmission for optimum operation. A technically savvy user will tend to use and install devices in locations that minimize loss, have lower interference levels, and have multipath signals. For the casual user, reliability issues can be frustrating. (This is one good reason that a citywide Wi-Fi deployment would not be a substitute for wired Internet service in most residents' homes.)

With the ubiquity of unlicensed RF-emitting devices in homes and businesses, the environmental RF interference levels in 2.4 GHz and 5.8 GHz bands is very high. Unfortunately, the common technique used to improve the performance is increasing the number of access units, which only exacerbate the problem by increasing interference.

In the planning phase of any wireless network for a controlled area, RF spectrum analysis equipment enables the designer to discover the sources of existing interference. Interference mitigation techniques (including channel planning allocation and smart access devices that support on-the-fly, dynamic channel assignment) can be utilized to improve performance. The current 802.11n standard supports advanced techniques of mitigating interference such as antenna arrays with beamforming which enable wireless device with advanced technology to automatically detect and steer transmissions to the clearest signal path.

6 City Resources to Support Wireless Deployment

As a part of this study, we examined key elements of the existing City infrastructure to determine the feasibility of using existing City assets in whole or in part to construct wireless infrastructure. As an example, the City has more than 100 traffic signals that are connected by fiber-optics; these have the potential to form a practical foundation for mounting, powering, and interconnecting wireless access points to create a targeted blanket network in the core central business area.

In this section we examine the City's existing resources and the suitability to support wireless deployment. Resources examined include:

- Fiber-optic infrastructure
- Suitable municipal building mounts
- Street lights and traffic signal mounts
- Utility facilities (substations, towers, and similar structures)

As with any infrastructure deployment, mounting access points would require an evaluation of the impacts on City infrastructure and an awareness of potential public concerns. This includes security of facilities like electric substations; potential complications related to mounting on traffic signals; and the visual impact of new equipment on street lights and municipal buildings. It would also require sensitivity to consumers' apprehension about issues such as radiofrequency (RF) radiation in public spaces like parks.

6.1 Fiber-Optic Backbone Requirements

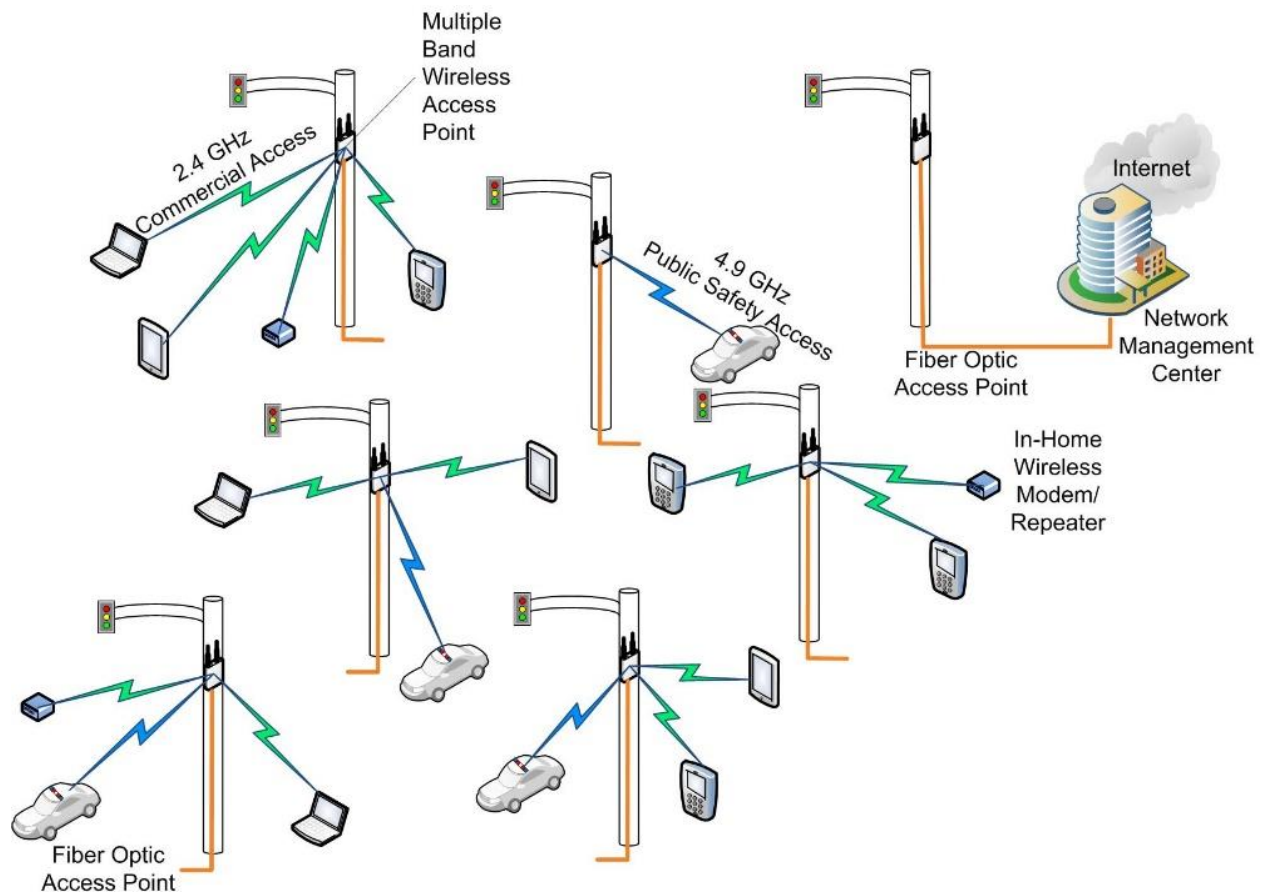
In order to implement a citywide open access Wi-Fi network, the City's wireless system will require an extensive backbone network to interconnect each of the individual access points to a central control and distribution center. Assuming that the client or user devices are typical smartphones, tablets, and laptops, the consumer access units will need to communicate with the user devices in either the 2.4 GHz or 5 GHz bands. A practical network will need to support the IEEE 802.11 standards, which encompass several iterations of changes in security, throughput, and coverage.

A typical consumer expects that a device will interconnect to the network with a minimal amount of changes in the configuration of the user device. The technology employed in Wi-Fi generally supports coverage in an outdoor environment of up to 300 feet from the wireless access point. This distance can be reduced based on a variety of factors such as foliage, interference, number of users, and the overall sensitivity and power level of the user device.

This limitation in coverage creates the need for a large number of wireless access points to cover a relatively small area. For example, a rule of thumb might be a requirement for 40 to 50 access points per square mile. Palo Alto’s core residential area and commercial business zone—the area in which the majority of residents would be served—is approximately 11.5 square miles. (This excludes industrial parks and the larger Foothills preserve areas.)

Each of the wireless access points requires connectivity back to the control or management center. There are generally two alternatives to support this so-called backhaul link. The first is to directly connect each of the hundreds of access points directly back to the center through an extensive fiber-optic network. Figure 14 illustrates a directly connected wireless network.

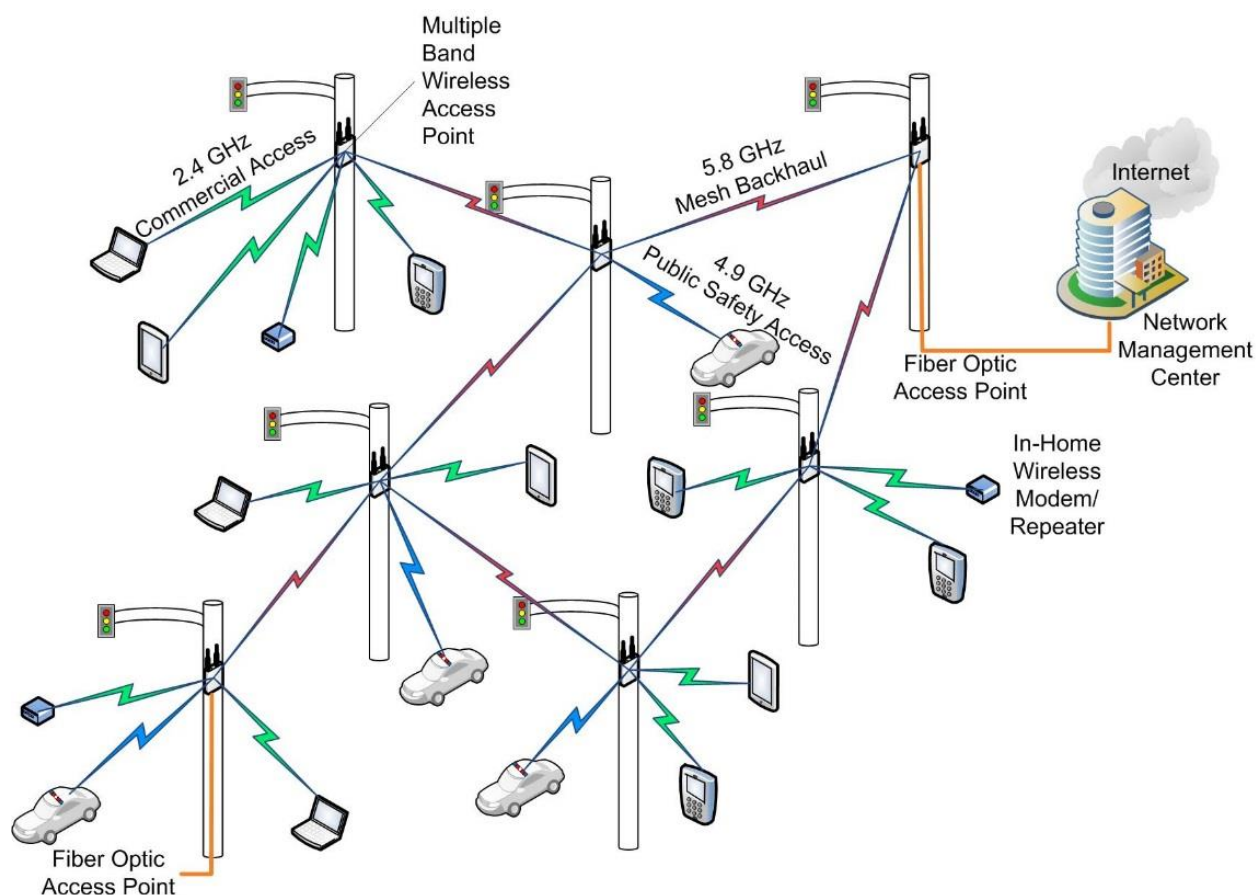
Figure 14: Sample Directly Connected Wireless Network



Alternatively, a hybrid connection can be developed using a mix of a limited number of fiber-optic links interconnecting a so-called mesh network that provides a wireless link between adjacent access points (Figure 15). This approach requires fewer fiber-optic links and reduces the overall capacity of the network, because the total wireless capacity is divided between

services provided to the end-user and supporting the backhaul link to the control management center.

Figure 15: Sample Wireless Mesh Network



In addition, each backhaul link, often referred to as a “hop,” introduces a delay in transmitting the signal from one point on the network to another. The delay, referred to as latency in the industry, reduces the overall suitability of the network to support certain key functions such as voice over IP (VoIP) and video. One other factor to consider is the fact that the equipment employing mesh technology is generally proprietary in nature, which means that the user or service provider is limited to one source for hardware and software support.

We examined the fiber backbone in the existing Palo Alto network and determined that the existing fiber infrastructure is suitable to support the deployment of the citywide fiber-optic network using mesh technology. Our review of the existing fiber infrastructure confirms that there is sufficient fiber in place that, with the addition of short fiber extensions for existing splice points, the existing fiber could enable rapid deployment of sufficient fiber-connected nodes to support mesh technology requirements established by equipment vendors. The fiber

strand count is nominal and should not affect existing capacity within the fiber network to impact the Utility's dark fiber leasing business.

Our review of the fiber-optic maps indicates that in general, within one mile of any location in the City south of the Foothill Expressway, there is a fiber-optic cable suitable for interconnecting the access points with the mesh technology. Naturally, practical design would focus on strategically locating the fiber-connected nodes or access points to existing fiber-optic splice locations. For example, there is a significant availability of fiber-optic cabling along Middlefield Road that could be used to interconnect access points along this road and also to extend fiber from Middlefield Road to other parallel streets.

The capacity of wireless technology will continue to grow as more sophisticated encoding technology is brought into the open 802.11 standards or, potentially, into future standards for commercial user equipment. The FCC continues to work with the industry to expand available spectrum in both the 4 GHz and 5 GHz bands. This increase in spectrum and enhanced technology will continue to enable higher-capacity services to end-users—and in turn will necessitate construction of high-capacity fiber-optic backhaul networks to provide capacity between wireless access points and the core management system.

Should the City move forward with the FTTP initiative, consideration should be given to integrating the backhaul requirements for a modern high-capacity wireless network into the design and construction of the FTTP network. The cost to install drop connections to a wireless access point will be far lower than for the City to construct a dedicated fiber-optic backhaul network for the purposes of supporting a high-capacity wireless network.

6.2 Installation Options for Wireless Access Devices

The reliable coverage area for wireless access points operating in the unlicensed 2.4 GHz and 5 GHz bands is limited to distances of less than 300 feet when communicating with consumer-grade electronics in devices such as smartphones, tablets, and laptops. The attenuation³² caused by buildings, trees, foliage, and weather conditions further limits service areas. There is, however, a beneficial aspect of the small service footprint. Because fewer users occupy a given service area, the access points can provide a generally high level of throughput to each user. In fact, a growing trend in the commercial wireless industry is to reduce the service size for each antenna site, because the carriers are restricted to a specific amount of RF spectrum at the user location.

In Palo Alto there is a ready supply of mounting structures suitable for mounting wireless access points. The most obvious are streetlights and traffic signals. These locations fall within the public right-of-way, generally are substantial enough to mount the small radio transceivers that communicate with the user, and have a primary power source with uninterruptable power

³² Attenuation is a reduction of signal strength.

supply (UPS) backup for the access point equipment (usually 25 W or less). Typically, wireless access devices are mounted at an elevation of 18 to 20 feet above ground, to provide a good compromise between the users located near the device and those at the periphery (typically 300 feet from the device).

The current generation of outside wireless access units that would be used to provide blanket City coverage include integrated, weather- and environmentally protected housings and are intended to be bolted or banded to a wide range of light poles, traffic signals, and building exteriors with minimal visual clutter. Access units designed to be used for fiber backhaul applications typically have integrated antennas and are available in a form factor less than 9×9×10 inches. The weight for the entire package is less than five pounds.

Access units for mesh deployment are larger due to the additional radios within each housing. These devices have a somewhat larger form factor—typically in the 12×8×5-inch range without antennas—and weigh less than 20 pounds. Figure 16 is a photograph illustrating a typical wireless access point installation for a mesh system. (As with any installation on a pole, the City would need to calculate the acceptable load for each pole prior to installing an access point.)

Figure 16: Typical Wireless Access Point Installation for Mesh System



7 Palo Alto Requirements Analysis and Stakeholder Input

The following sections of this report analyzes and presents recommendations on the City’s requirements and options for deploying wireless technology to support specific broadband communications needs identified by the project team. This analysis represents a continuation of the City’s commitment to providing services to citizens and local businesses, and enhancing the communications resources supporting first responders and other City employees.

7.1 The Need for Wireless Broadband

This requirements study for wireless broadband within Palo Alto not only addresses the needs of residents, businesses, and government employees, but also examines the ever-expanding communications systems requirements of our modern society.

In general, most people are familiar with wireless networks; they connect our devices to the Internet service within our residences, and connect our voice calls to the public telephone network. In addition to these very basic functional networking services, there are an ever-expanding variety of electronic devices that require so-called machine-to-machine communications links³³ to control centers and to other equipment associated with the devices. City of Palo Alto Utilities (CPAU) is very familiar with this technology—the department long ago installed fiber-optic cabling to interconnect its command and control centers to devices that monitor and control external facilities such as power substations and water treatment plants (i.e., supervisory control and data acquisition, or “SCADA”).

Typically, machine-to-machine links interconnect distributed equipment that monitor status such as temperature, water level, intrusion, or possibly fire. Alarms are detected either locally or at a core facility; supervisory personnel are alerted to the malfunction via the network. Often, the machine-to-machine links will provide sufficient information that the problem or issue can be addressed or at least mediated remotely. This saves time, staff resources, and the potential expense of dealing with major repairs caused by an inability to sense or detect abnormal operation.

As part of the requirements analysis, we examined the City’s potential needs to expand wireless infrastructure—or the utilization of existing wireless communications resources—for the purpose of providing additional services to citizens, delivering public services in a more cost-effective manner, and leveraging the City’s existing broadband assets. To do this, we met with representatives of departments and divisions that provide a wide range of services to City residents, including the City Manager’s Office, the City’s Public Safety departments (Police Department, Office of Emergency Services, and Fire Department), the Transportation Division,

³³ Often referred to as the “Internet of things.”

and the Community Services, Information Technology, Utilities, Planning and Community Environment, and Public Works departments.

We also examined opportunities for providing enhanced consumer wireless services to the general public, both citywide and within targeted areas. We note that the City's Information Technology department has already taken the initiative to install modern high-capacity wireless networks within most of the City's major buildings. Modern wireless networks provide secure, user-friendly communications links to support a wide variety of smartphones, tablets, laptops, and computer peripheral devices.³⁴ Technologies deployed by the City's Information Technology department provide users with network transmission speeds in excess of 100 fold over earlier wireless networks.

Our findings and recommendations cover a wide range of applications and services that will advance the deployment of technology, particularly to enhance citizen services and to support the City's first responders.

In light of the City's complementary ongoing study of FTTP network deployment options, we note that the wireless broadband technology we explore in this report does not compete with fiber-optic broadband networks in complex urban environments such as Palo Alto. Rather, wireless technology supplements the City's backbone fiber assets and the services delivered over that fiber. Should the City elect to move forward on citywide deployment of a high capacity Wi-Fi service, ***a mandatory requirement will be that a citywide FTTP network*** be in place to provide backhaul links from hundreds of wireless access points to a network management and control center with eventual linking to the Internet.

By its nature, fiber-optics requires rigid or physically fixed points of attachment to a network—and transports information point-to-point. In contrast, wireless technology enables mobile networking. Mobility might involve communications with devices in motion (such as for public safety applications) or devices that need to be moved to different locations within a defined area (such as in business, or in a home where residents are using tablets or laptops).

We are increasingly becoming a mobile society when it comes to communications. Early communications systems such as the telegraph and telephone were confined to fixed points of access and termination. It is hard to believe that it has only been a few decades since consumers first had the ability to take their communications systems on the move. No doubt the traditional landline will eventually disappear from the home or office and be replaced by personal communications equipment.

³⁴ Consumer equipment interfaces with the City's wireless network over 2.4 GHz and 5 GHz unlicensed spectrum using the international standard IEEE 802.11 protocols. These protocols have been developed over the past two decades and continue to provide upward mobility in terms of performance, security, and overall reliability.

The requirement for portability and ability to access network resources from any location in the City is the driving force for implementing broadband wireless services. Indeed, while most Palo Alto residents acquire broadband services to their home through a physical cable (e.g., from a cable modem or fiber-optic provider), they also generally employ wireless networking technology within their premises to link all of their individual devices to the network. The same requirements noted in the consumer electronics world are also quite prevalent in both business and government work environments.

7.2 Stakeholder Input

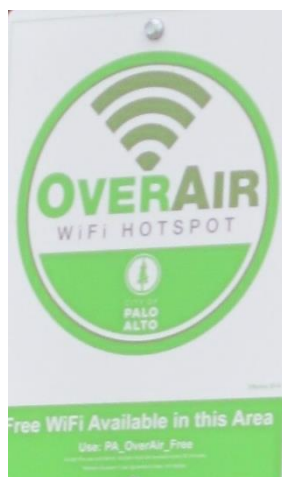
As previously noted, we gathered insight and input from a wide range of City departments and divisions. The following sections detail the City’s current uses of wireless technology and its short- and long-term needs for additional wireless infrastructure and applications. These needs (which are listed in Appendix A) inform the deployment options described in Section 8 below.

7.2.1 Information Technology

The City’s Information Technology Department has completed the installation of enhanced wireless networking access equipment in 30 of the major City buildings that provides public access to citizens; the wireless access is generally available in the adjoining property areas, as well. This network supports both public access and access for authorized City staff to the City’s enterprise network. Table 2 provides a list of City sites that currently have facility-wide Wi-Fi service. A total of \$180,000 has been invested in constructing the 30 buildings’ networks. The yearly operating cost for the service is approximately \$13,500.

The buildings that currently have service display the “OverAir Wi-Fi Hotspot” emblem throughout the facility (see Figure 17). The equipment used to provide this service is consistent with the current level of technology for providing high-capacity, secure, and reliable services.

Figure 17: OverAir Wi-Fi Hotspot



As is the case with much of the equipment associated with Information Technology, there is a relatively short user technology timeframe for this wireless equipment. In other words, while the equipment may still be operational and fully functional over possibly a decade, the combination of the movement of technology to new generations of hardware, the development of new software, and the lack of cost-effective long-term support from equipment manufacturers requires fairly frequent equipment replacement cycles—typically at five- to seven-year intervals. Fortunately, this type of upgrade generally only involves the wireless access devices—hardware that is typically located in the false ceilings of buildings or other locations that are accessible to the technical support team.

The Information Technology Department also provides public Wi-Fi service on community properties associated with the City. For example, Figure 18 is a photograph of an access point located in the City Hall Plaza area. An outdoor access point device typically provides service to an area several hundred feet in diameter from the unit. Distances vary based on the equipment used, the number of other access units in the vicinity, and the end-users' devices. (Consumers' smartphones, tablets, and laptops are generally restricted in power and overall sensitivity, and hence tend to be the limiting factor with regard to overall service area associated with wireless access points.)

Figure 18: Wi-Fi Access Unit in Palo Alto



Table 2: City Sites with Facility-Wide Wi-Fi

Site Name	Address
Cogswell Plaza (outdoor)	264 Lytton Av
City Hall	250 Hamilton Av
Fire Station 1	301 Alma St
Fire Station 2	2675 Hanover St
Fire Station 3	799 Embarcadero Rd
Fire Station 4	3600 Middlefield Rd
Fire Station 5	600 Arastradero Rd
Fire Station 6	711 Serra St (Stanford)
Children’s Theater	1305 Middlefield
Art Center	1313 Newell Rd
Lucie Stern Community Center	1305 Middlefield
Junior Museum & Zoo	1451 Middlefield
Cubberley Comm Center (partial)	4000 Middlefield
Baylands Interpretive Center	2775 Embarcadero Rd
Children's Library	1275 Harriet St
Municipal Service Center - Bldg. A	3201 East Bayshore Rd
City Hall - King Plaza (outdoor)	250 Hamilton Av
Municipal Service Center - Bldg. B	3201 East Bayshore Rd
Development Center	285 Hamilton Av
Downtown Library	270 Forest Av
College Terrace Library	2300 Wellesley St
Municipal Service Center – Bldg. C	3201 East Bayshore Rd
Utilities	3241 E. Bayshore
Foothill Interpretive Center	3300 Page Mill Rd
Utilities	1005 Elwell Ct
Utilities	1007 Elwell Ct
Water Quality Control Plant	2501 Embarcadero Way

Site Name	Address
Animal Services	3281 East Bayshore Rd
Mitchell Park Library and Community Center	3800 Middlefield Rd
Main Library	1213 Newell Rd

7.2.2 Community Services

Palo Alto's Department of Community Services operates the City's community centers, parks, sports fields, and numerous specialized centers citywide. Not all of the facilities operated by Community Services have modern high-capacity wireless services like the sites listed in Table 2, which have service provided by the Information Technology Department. The Community Services staff have requested that free, open public access be installed at all of the facilities operated by the department to provide the level of services that citizens expect from Community Services.

Many of the Community Services facilities are on or near the City's existing fiber-optic network and therefore could be connected to equipment similar to that deployed in City Hall. The department staff requested that a multi-year capital program be established for implementing broadband services at all department facilities. The tables below identify the department staff's priorities for implementation.

Table 3: First-Priority Community Services Sites

Facility	Ownership	Address
Rinconada Pool	City	777 Embarcadero Road
Pearson-Arastradero Interpretive Center	City	1530 Arastradero Road
Cubberley Fields	City & PAUSD ³⁵	4000 Middlefield Road, T-2

Table 4: Second-Priority Community Services Sites

Facility	Ownership	Address
Municipal Golf Course	City	1875 Embarcadero Road
Baylands Athletic Center	City	1900 Geng Road, off Embarcadero
El Camino Park	City	1 El Camino Real
Greer Park	City	1098 Amarillo Street
Lytton Plaza	City	202 University Avenue
Mitchell Park	City	6 East Meadow Avenue
Rinconada Park	City	777 Embarcadero Road

³⁵ Joint shared use with Palo Alto Unified School District (PAUSD)

Facility	Ownership	Address
Stanford – Palo Alto Playing Fields	Stanford University	El Camino at Page Mill Road
Ventura Community Center	City	3990 Ventura Court
Baylands Nature Preserve (incl. Byxbee)	City	2775 Embarcadero Road
Esther Clark Preserve	City	Old Trace Road
Foothills Park	City	33 Page Mill Road
Pearson-Arastradero Preserve	City	Arastradero Road at Page Mill Road

Table 5: Third-Priority Community Services Sites

Facility	Ownership	Address
Bol Park	City	Laguna between Barron and Matadero avenues
Boulware Park	City	39 Fernando Avenue
Bowden Park	City	Alma Street at California Avenue
Bowling Green Park	City	474 Embarcadero Road
(Juana) Briones Park	City	Arastradero at Clemo Street
Cameron Park	City	211 Wellesley Street
Eleanor Pardee Park	City	851 Center Drive
El Palo Alto Park	City	El Camino Real at Alma Street
Heritage Park	City	Homer at Waverley
Hoover Park	City	2901 Cowper Street
Hopkins Creekside	City	Palo Alto Avenue from Emerson to Marlowe streets
Johnson Park	City	Everett and Waverley
Kellogg Park	City	Waverly at Embarcadero Road
Mayfield Park	City	23 Wellesley Street
Monroe Park	City	Monroe and Miller Avenue
Peers Park	City	1899 Park Boulevard
Ramos Park	City	8 East Meadow Avenue
Robles Park	City	4116 Park Boulevard
Scott Park	City	Scott Street at Channing Avenue
Seale Park	City	31 Stockton
Terman Park	City & PAUSD ³⁶	655 Arastradero Road
Wallis Park	City	Grant Avenue at Ash Street
Weisshaar Park	City	2298 Dartmouth Street
Werry Park	City	23 Dartmouth Street

³⁶ Joint shared use with PAUSD

7.2.3 City of Palo Alto Utilities

Palo Alto operates its own utilities, including electric, gas, water, wastewater, and fiber-optic services. City of Palo Alto Utilities (CPAU) has been a nationally recognized leader providing quality utility services to citizens and businesses since 1896.

With regard to telecommunications, the utility-deployed fiber-optic technology is a backbone transmission medium used to control and monitor critical utility infrastructure on a citywide basis. Wireless technology enables the utility to expand the reach of its fiber footprint to support a wide range of monitoring devices citywide. Wireless technology can be installed more rapidly and at a lower cost than fiber-optic technology, particularly for applications to address temporary locations or sites that are currently being supported by underperforming technology such as leased copper lines and antiquated point-to-point radio systems. It can also be used to support emerging customer monitoring and control systems associated with smart grid technology.

CPAU previously commissioned EnerNex Corporation to conduct a study of requirements for the utility to capitalize on emerging smart grid technologies.³⁷ One of the areas of analysis in that report focused on the need for backhaul communications capability to monitor and control field devices. Wireless technology is one of the options for backhauling information from customer premises equipment in real time to determine and control operation. In addition, in applications where the utility chooses to install equipment supporting open telecommunications architecture, a broadband wireless system might prove to be an attractive alternative.

Future planning for both wireless and fiber-optic deployment should be performed in concert because they are dependent on each other. To be effective, wireless access points need cost-effective connection points to the fiber-optic backhaul. Fiber technology can leverage the quick, low-cost deployment attributes of wireless to provide seamless network connections to support many City and commercial applications.

The utility is currently piloting several projects associated with smart grid deployment. Our review of the pilot projects indicates that the existing implementations employ proprietary telecommunications technology developed by the vendors and integrated as a part of the service packages. The systems currently under evaluation link to the pilot test area through commercial wireless services.

With regard to near-term requirements, CPAU needs to upgrade certain existing links from

³⁷ "Assessment of Smart Grid Applications in Palo Alto and Two-Year Smart Grid Related Work Plan for 2012 and 2013," City Council Staff Report, City of Palo Alto, Feb. 13, 2012. <http://www.cityofpaloalto.org/civicax/filebank/documents/41569>

legacy radio equipment and dial-up (telephone line) monitor and control equipment. The links in question include:

- Existing radio links (Foothills sites)
 - Power line monitor/closure control
 - Water utility facilities
- Four existing dial-up lines to water storage/control sites outside of fiber coverage footprint
- New SCADA telemetry monitoring and control for electrical distribution equipment (monitor end-of-line voltages, open/closure control)
 - College Avenue
 - Emerson Street
 - Other applications for future deployment include remote cameras to monitor construction areas, water levels, and general security requirements at key facilities

7.2.4 Planning and Community Environment Department – Transportation Division

The City's Transportation Division "enhances safety and mobility in Palo Alto's transportation system while protecting environmental resources and preserving the community's quality of life."³⁸ The Transportation Division's responsibilities range from traffic operations and parking management to public transit services and regional transportation activities.

Our discussion with Transportation Division staff indicated the need for communications network facilities beyond the areas served through fiber to connect monitoring devices associated with the deployment of new services targeted toward monitoring traffic flow, enhancing bicycle safety, and improving central city parking. Specifically, the division needs an ability to transfer information in real time from selected sites for both bicycle traffic and parking status. The communications infrastructure should enable communications from sensors located along bike paths and within designated parking areas such as city parking lots and buildings. The division's overall goals are to provide citizens with real-time information on parking status and to gather long-term data focused on enhancements to both bike paths and parking areas.

Other applications for the network are to expand the locations where traditional automobile traffic monitoring equipment can be cost-effectively installed outside the footprint of the

³⁸ "Transportation," City of Palo Alto website, <http://www.cityofpaloalto.org/gov/depts/pln/transit/>

existing fiber-optic network. These devices support the real-time monitoring of traffic counting and turning-vehicle backups, and measuring travel times and vehicle densities on given routes.

7.2.5 Public Works Department – Engineering Services Division

Public Works oversees diverse responsibilities that range from construction and maintenance of public facilities, streets, sidewalks, and storm drains to the oversight of construction work done within the City. To assist the department and this work, the ability to place video cameras for remote construction observation can facilitate oversight of both construction and project status. Strategically placed monitoring equipment will improve the efficiency of the department's inspection staff by enabling real-time status monitoring and enabling inspection staff to deal with issues as they developed. The goal here is to improve the overall efficiency of construction oversight and minimize disruption.

7.2.6 Public Safety Departments: Police Department, Office of Emergency Services, Fire Department

The City's public safety departments have requirements for citywide and adjacent jurisdictional voice and data communications services. For example, the Police Department operates the Public Safety Answering Point (PSAP) for law enforcement, Fire/ambulance, Public Works, Utilities, and Stanford University. By the very nature of public safety communications, these systems must have a high degree of availability, have a defined quality of service, be highly reliable, and function independently of commercial service demands.

In addition to traditional voice radio systems, there is an ever-growing demand (in Palo Alto and nationwide) for data communications to support first responders. This is a key driver of any wireless deployment in the City. The use of commercial cellular providers has greatly improved public safety operations for day-to-day operation. Unfortunately, during critical demand periods, the availability of such networks and overall throughput becomes limited.

While existing commercial services continue to provide new capabilities, commercial providers are not able to simultaneously meet first responder and public user demand during emergencies. When too many users (first responders and citizens) are attempting to use the same commercial communications services, those networks can become overloaded. This can also happen as a result of sheer overloading by the high density of users in a given geographical area, such as during a major sporting event or public demonstration. (During an interview, City staff provided examples of the network overload phenomena often associated with Stanford University activities.)

Congress has taken action to address public safety's unique mobile communications needs nationwide. The federal First Responder Network Authority (FirstNet), which was created by the Middle Class Tax Relief and Job Creation Act in 2012, is working with state and local

governments to develop a national network to “build, operate and maintain the first high-speed, nationwide wireless broadband network dedicated to public safety.”³⁹ We note that FirstNet is a long-term solution that will complement the City’s efforts, but not replace the need to meet its own local communications requirements.

Palo Alto’s first responders have taken positive steps to address deficiencies within the departments’ data communications network. The Police Department is taking steps to improve overall services through the implementation of two separate initiatives.

7.2.6.1 Wireless Point-to-Multipoint Prototype

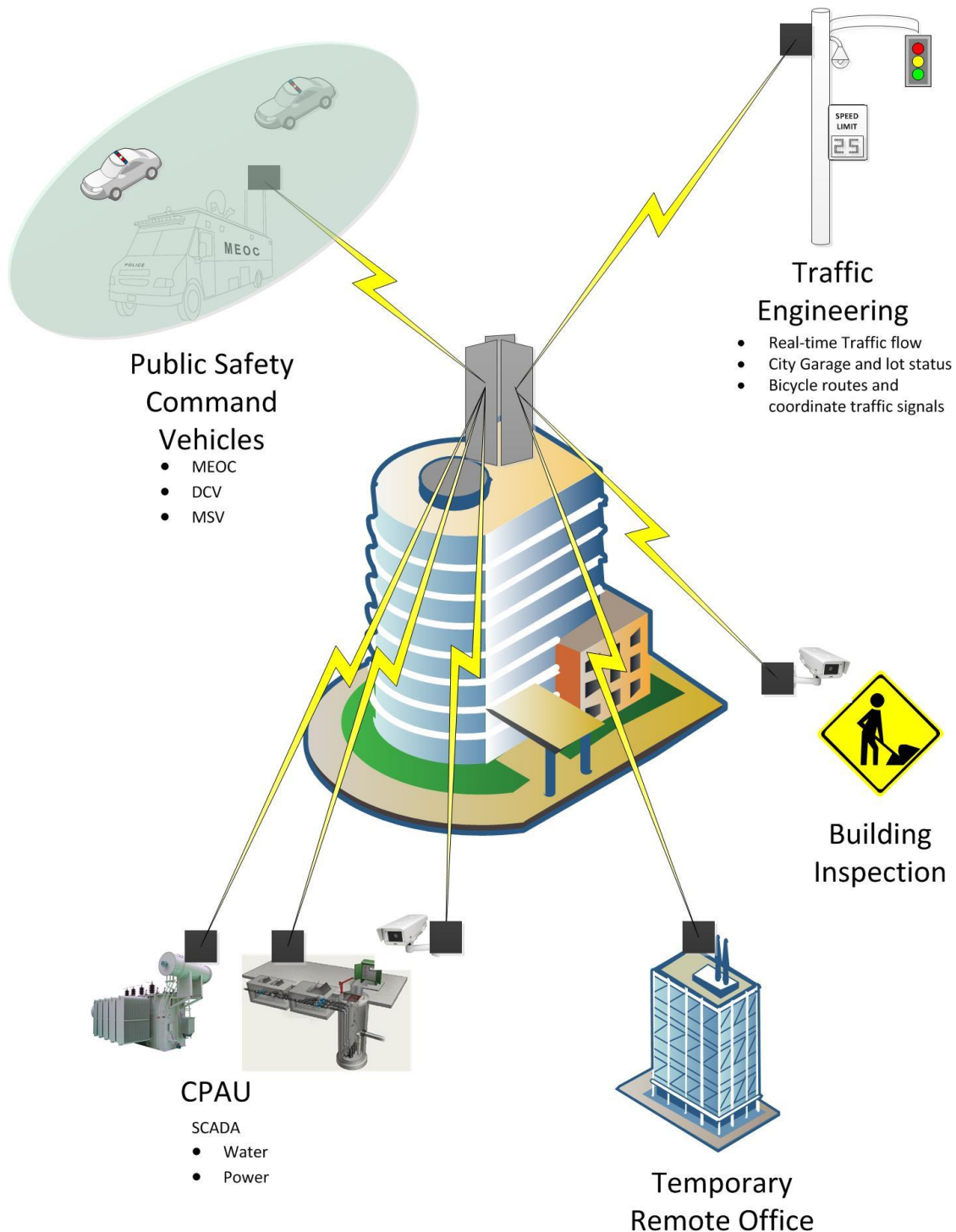
The first initiative involves the use of the public safety Mobile Emergency Operations Center (MEOC), a state-of-the-art standalone command vehicle, and several other command vehicles that are linked by a high-capacity broadband wireless network for mobile command post operation. This prototype system maintains a base station (access facility) on the City Hall rooftop, which communicates through a point-to-multipoint link to the remote vehicles within a defined arc of the city. The system, which has now been validated through field testing in operational deployment, will need to be expanded to provide 360-degree citywide coverage.

This same service can be expanded to address the point-to-multi-point requirements presented in the preceding paragraphs for CPAU, the Planning and Community Environment Department–Transportation Division, and the Public Works Department–Engineering Services Division.

Figure 19 below illustrates the operation of a core-based point-to-multipoint high-capacity broadband wireless system like the one being implemented by the Police Department.

³⁹ “About FirstNet,” First Responder Network Authority, <http://www.firstnet.gov/about>

Figure 19: Private Point-to-Multipoint Wireless



This illustration includes the concept of adding other core infrastructure users to the network to expand the overall usefulness of the project to other critical service providers within the City government. For example, some of the requirements elicited from CPAU, Transportation, and Public Works can be addressed by expanding the existing network without impacting overall

system capacity. Further, expansion of the existing Police network through the addition of equipment at the core City Hall site to provide solid 360-degree coverage from this location will enhance the operation not only for public safety, but additionally for other critical infrastructure operation applications.

Under the current architecture all of the core equipment is located at a single facility, which is potentially subject to failure through a building structure failure or major fire. For this type of deployment, consideration should be given to a backup or auxiliary site in the Foothills to backup or augment the single core site.

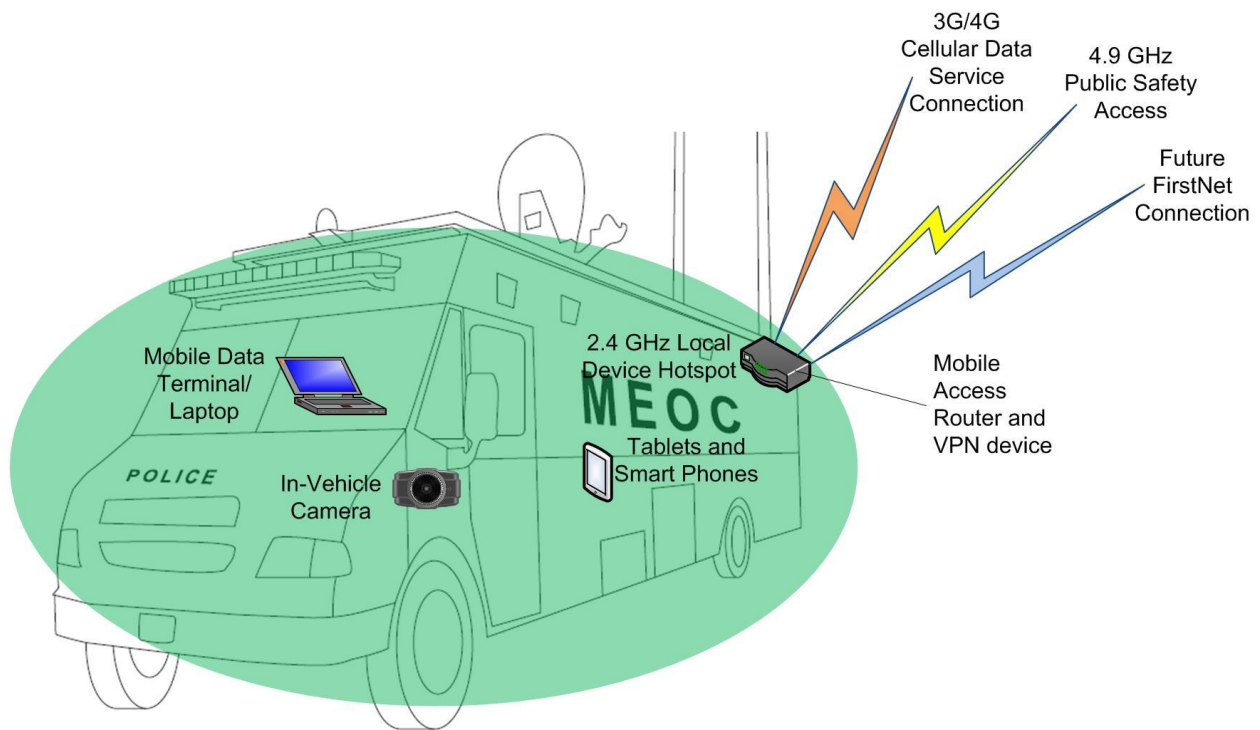
7.2.6.2 Public Safety Mobile Data Network

The City's first responders have an ever-increasing demand for information in the field, including timely access to information while traveling to an incident. Expanding requirements for video communications can and often does overload commercial networks, particularly with multiple vehicles operating on site.

In certain situations, such as parades, sporting events, and other pre-planned activities, the command vehicles can serve as an access point for interconnection to a vast array of networking resources. The Police Department has been deploying smart mobile router devices that permit the vehicles to interconnect to the most desirable network connection. Figure 20 below illustrates the overall concept.

The router can continuously monitor available networks and resources—which might include leased services from AT&T or another provider, public Wi-Fi, and other services such as the 4.9 GHz broadband services used to support the command vehicle. In the future the same device will be able to communicate with FirstNet.

Figure 20: Command Vehicle as Mobile Access Point



Over the two decades that the City’s fiber network has been operating in Palo Alto, a large number of access points have been provided to support various municipal functions such as control equipment for utility operations and traffic signaling, links to public buildings, and other similar applications. These sites offer the potential for locating wireless access points to communicate exclusively with public safety vehicles supporting both Police and Fire department operations.

Another implementation scenario to consider involves deployment of access points at either critical locations within the City or along pertinent transportation routes. We anticipate that initial deployment will leverage to the maximum degree possible existing network access points. Generally we found as a part of our evaluation that existing fiber-optic broadband services for City use are located near or coincide with the areas where there is potentially the highest need for public safety support (e.g., the downtown University Avenue business area, Stanford University, and major thoroughfares).

8 Potential Palo Alto Wireless Deployment Options

Based on our research and analysis, we have developed four general options for addressing the City's communications needs with wireless broadband deployment. The scenarios are generally independent of each other and targeted to address specific needs uncovered in the requirements analysis. They are targeted toward specific user groups and areas of deployment, and offer a range of coverage opportunities (distinguishing between public and governmental access). These scenarios could be deployed singularly or in combination.

We present a system-level overview of each scenario below. We address the potential capital and operating costs for these deployment scenarios in Section 9.

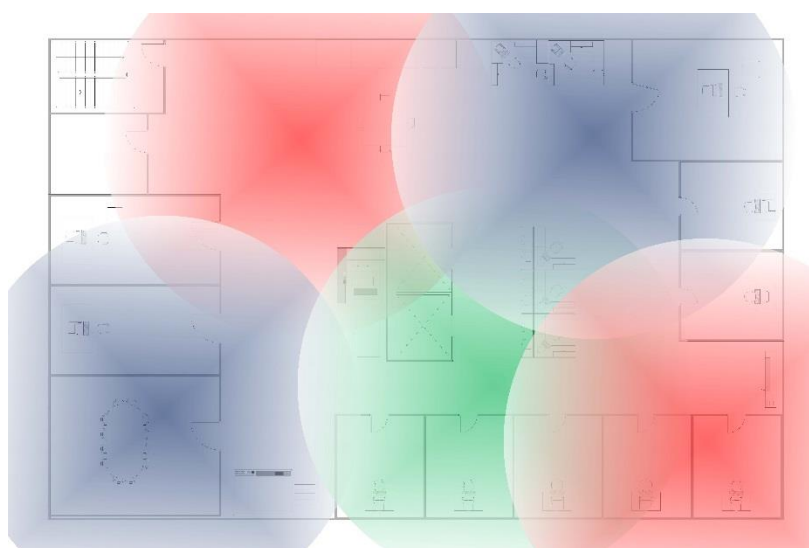
8.1 Scenario 1: Deploy Public Wi-Fi and Secure City Enterprise Network Access at City Buildings

In this scenario, the City would deploy Wi-Fi at all City buildings and support both free public access and secure enterprise network access for City employees. This option is basically a continuation of the Information Technology department's ongoing efforts at the 30 locations which are currently being served.

Residents and visitors would be able to access the network with any consumer-grade smartphone, tablet, or computer. The network would deliver state-of-the-art Gigabit service (1 Gbps) at each access point, and would be 802.11a/b/g/n/ac compatible.

The access points would be installed to serve a defined target area with a minimum signal level of -65 dBm and sufficient capacity to simultaneously serve a number of users equivalent to 70 percent of the facility's maximum capacity.

Figure 21: Wi-Fi Access in City Buildings – RF Radiation Map



8.2 Scenario 2: Deploy Public Wi-Fi and Secure City Enterprise Network Access

As in Scenario 1, the City would deploy Wi-Fi and support both free public access and secure enterprise network access for City employees. Rather than only blanketing City buildings, however, the City would make the service available either citywide or in targeted areas. This option would be more expensive to deploy, operate, and maintain than Scenario 1.

We envision a two-phase approach:

Phase A: Provide 100 Mbps blanketed public Wi-Fi to core City business and residential areas

- 400+ wireless access points
- Light pole mounted
- Leverage existing fiber
- Wireless mesh technology

Phase B: Provide 1 Gbps blanketed public Wi-Fi to core City business and residential areas

- 600+ wireless access points
- Light pole mounted
- Fiber connected to each wireless access point
- Contingent on City upgrading fiber as part of a CPAU upgrade or FTTP deployment
- Three to five years after Phase A completion

Residents and visitors would be able to access the network with any consumer-grade smartphone, tablet, or computer. The network would deliver Gigabit service at each access point, and would be 802.11a/b/g/n/ac compatible.

The access point would be installed to serve a defined target area with a minimum signal level of -85 dBm. In order to provide modern high-speed service, the access points would need to be installed at intervals of 500 feet or less within the defined coverage area. The access points would be installed to minimize visual clutter and would have backup power.

In this scenario, Palo Alto would be matching or exceeding the level of service available in many public locations nationwide. The nearby cities of Mountain View,⁴⁰ Santa Clara, and San José have implemented Wi-Fi coverage within designated areas to support access to both the public Internet and municipal communications activities. Nationally, many communities have deployed citywide Wi-Fi either under municipal funding or in partnership with a commercial provider.

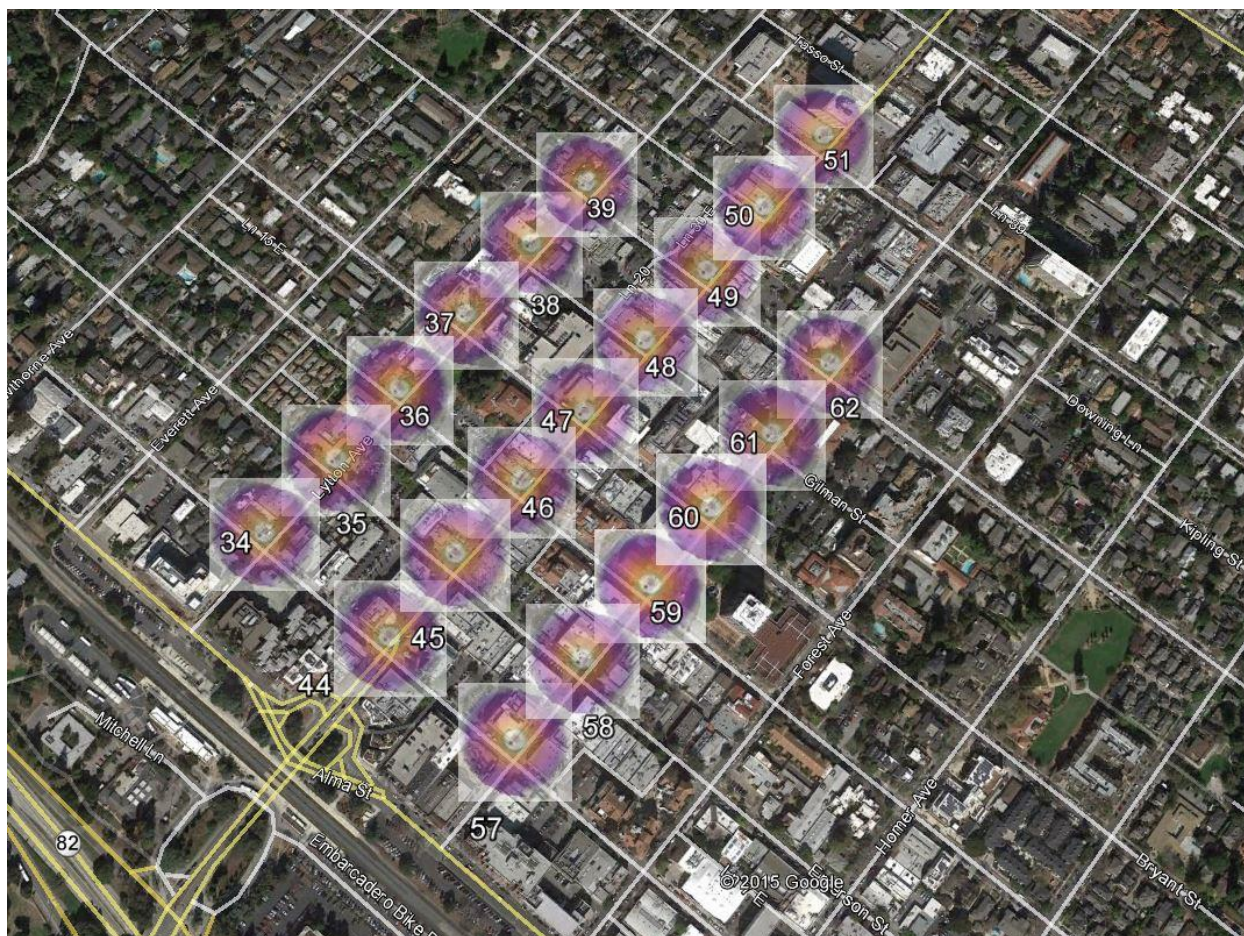
These services have generally been well received by the public—but we have been unable to find any municipal implementation projects that represent an economically viable standalone business opportunity. The public clearly will use available free Wi-Fi. However, when asked to pay for the service in a public space, many consumers have little interest. Consumers often will pay for such services in confined/restricted facilities such as on an airplane, at an airport, or in a hotel. In contrast, the blanket services often referred to as “amenity communication services” are expected to be provided free of charge.

Figure 22 illustrates how a blanket Wi-Fi network might be operated in a target location such as the central business district along University Avenue. This particular exhibit assumes placement of the wireless access points coincident with traffic signals; the City’s traffic signals are connected to the backbone fiber-optic network and these locations are suitable for mounting wireless devices and interconnecting through the City’s existing power/communications infrastructure. (See Section 6 for details on potential issues related to deploying access points on existing public infrastructure.)

In order to provide proper signal levels to consumer smartphones and tablets, and additionally to provide signal penetration into nearby buildings, a substantial number of access points will be required. Based on our experience in other similar communities, we estimate that the City would need 35 to 40 access points per square mile to provide adequate signal levels.

⁴⁰ For more details on Wi-Fi in Mountain View, see <http://mountainview.gov/depts/it/wi-fi.asp>

Figure 22: Illustration of Targeted Wi-Fi Deployment in Downtown Palo Alto



As a part of our requirements assessment, we discussed the desirability of a universal broadband wireless service with the City’s Manager of Economic Development in the City Manager’s office. Based on this meeting there have been no specific requests from the business community or the general public for wireless services. We note that a significant number of Palo Alto businesses offer free Wi-Fi service to patrons (see Figure 23). Additionally, broadband carriers such as Comcast and AT&T have installed and operate Wi-Fi access points for their customers in many areas of the City. (Figure 24 and Figure 25 are maps showing the locations of Comcast and AT&T Wi-Fi services in the downtown University Avenue business corridor.)

Given the availability of these services, it appears that commercial businesses are at least partially addressing the public’s need for Wi-Fi access (though the City’s need for wireless enterprise access remains unmet).

Figure 23: Local Businesses Offering Wi-Fi⁴¹

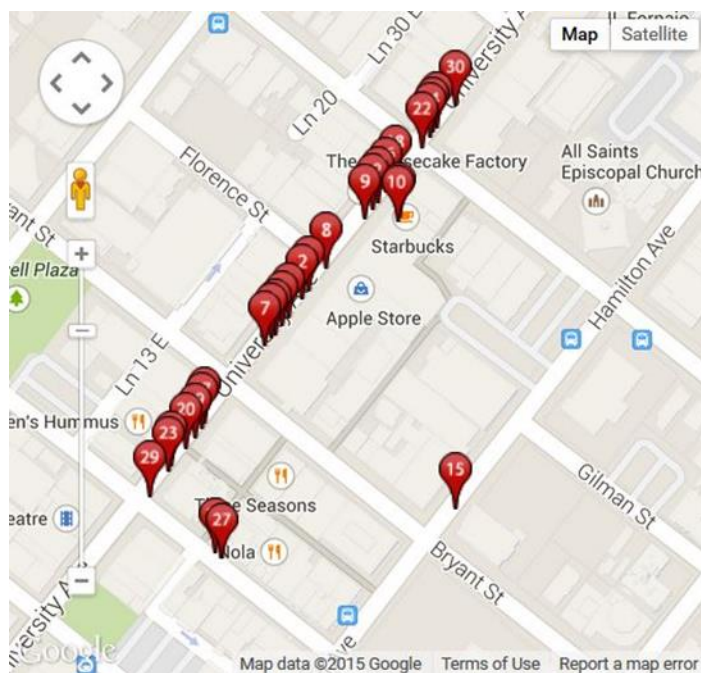
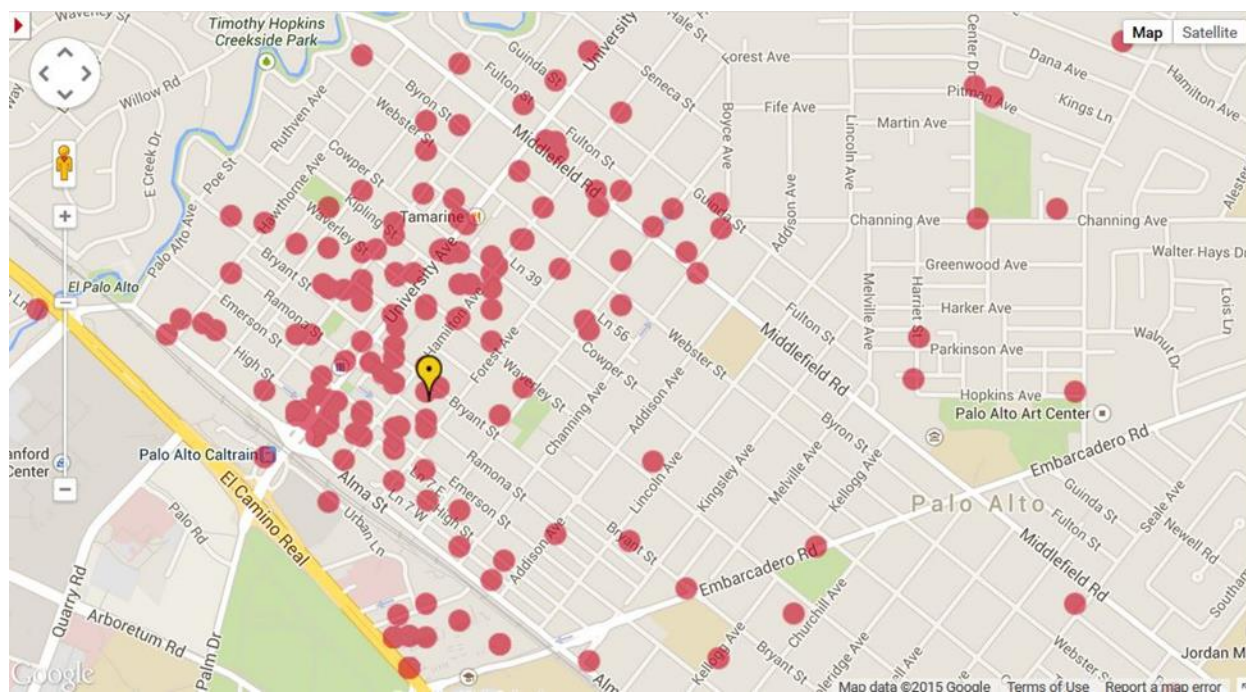
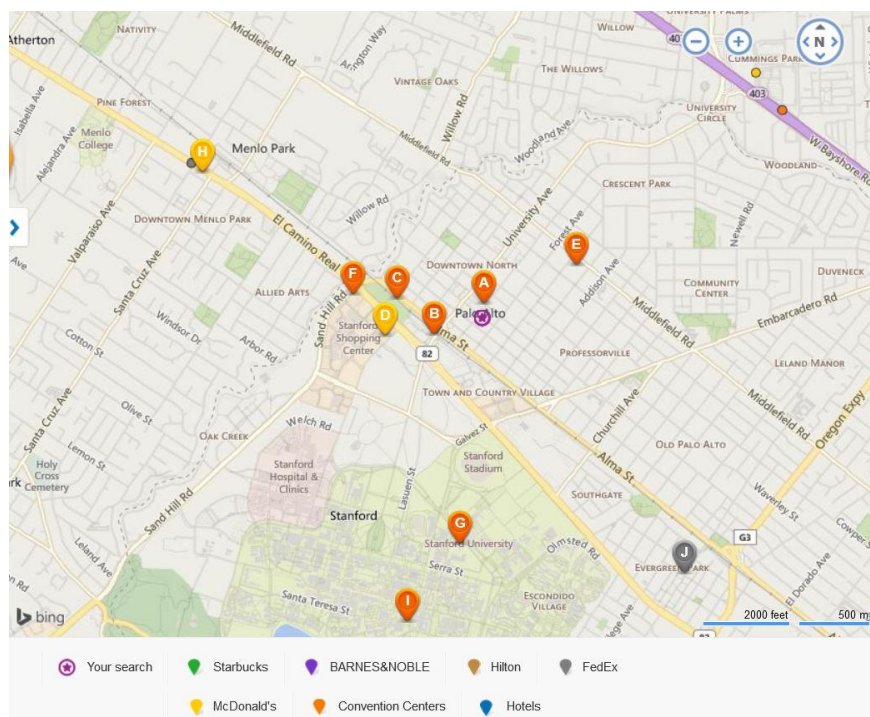


Figure 24: Comcast Wi-Fi Locations



⁴¹ Source: www.openwifispots.com

Figure 25: AT&T Wi-Fi Locations



It should be noted, too, that other cities' implementations of municipal Wi-Fi services generally did not develop the anticipated level of acceptance. Part of the problem with those deployments related to the speed and reliability of earlier Wi-Fi technology compared to commercial wireless options. In the same timeframe that those cities implemented municipal Wi-Fi, the commercial wireless carriers successfully deployed 3G and 4G data access technologies that have developed a high degree of consumer acceptance based on cost, performance, and the convenience of essentially universal service. In contrast, many municipal Wi-Fi deployments served only a limited area—and performance in many cases fell short of user expectations as discussed earlier in the case studies in Section 2.

For the public in general, the simplicity of using a single network for voice and data has proved to be very appealing. However, with the wide deployment of smartphones and tablets, and particularly the emphasis on video and multimedia presentations, requirements for cellular capacity and bandwidth have become significant issues for users and service providers. Most cellular service providers limit the amount of data available through a basic smartphone contract. Customers that exceed the capacity limit are forced to pay extra fees for service.

Recently companies like Republic Wireless and Google have arrived at an innovative solution to address the demand issue and, at the same time, potentially reduce consumer costs.⁴² The

⁴² Ryan Knutson, "The Race over Wi-Fi Phones: Google learns from Republic Wireless, which is trying to turn the business on its head," *Wall Street Journal*, May 6, 2015.

concept, which is rather simple, involves using a smartphone that senses available Wi-Fi services and automatically switches away from the consumer wireless service provider networks (e.g., AT&T, Verizon, Sprint, T-Mobile) to take advantage of the free Wi-Fi connectivity. (See Section 11.2 for more details on this technology.)

Assuming this device is accepted by consumers and can move into the existing environment, it will create demand for access to high-capacity, low-latency Wi-Fi network connectivity. Indeed, Wi-Fi phones in the hands of millions of users might create a demand for a level of Wi-Fi service both in capacity and reliability that far exceeds the type of infrastructure that currently exists within the primary business areas of cities nationwide.

8.3 Scenario 3: Deploy a Point-to-Multipoint Network for Secure City Enterprise Access

In this scenario, the City would deploy limited wireless technology to meet only its internal needs; public access would continue to be delivered by local businesses and incumbent service providers (see Section 8.2).

In this scenario, as in the Police Department's current prototype, City Hall would serve as the core site for a point-to-multipoint deployment. The line-of-sight range for the wireless access would be 20 or more miles, operating on 4.9 GHz licensed public safety spectrum (see Figure 19).

Client access devices would be carrier-grade, proprietary fixed/portable equipment capable of throughput at 5 Mbps, 10, Mbps and 100 Mbps. Typical performance characteristics for a point-to-multipoint deployment would include:

- Vendor proprietary MIMO protocol
- Adaptive modulation
- Maximum latency of 5 msec.
- Four to six sector antennas and core
- 125 Mbps /sector
- 5/10/20 MHz channel
- GPS synchronization
- Guaranteed Quality of Service

8.4 Scenario 4: Deploy a Citywide Mobile Data Network for Public Safety Users

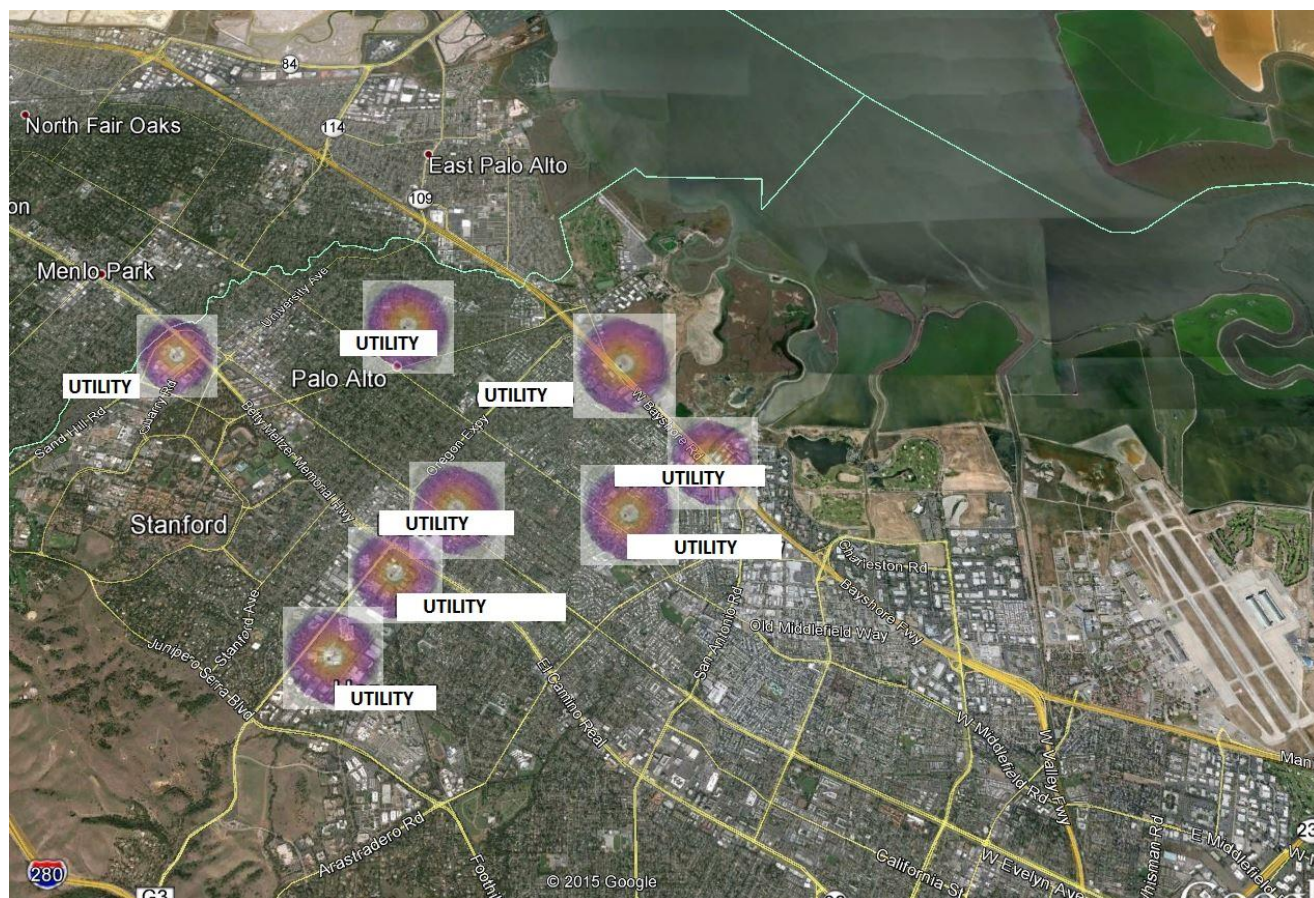
In this scenario, the City would create hot spots for public safety mobile data network access. The hot spots would provide radial coverage to first responders and other authorized users over a distance of 1,000 to 1,500 feet. As an initial step, access points could be deployed at

CPAU's facilities (see Figure 26 below) to create eight hot spots and provide coverage to a significant portion of the City.

These access points would operate on 4.9 GHz licensed public safety spectrum using 802.11a technology. The targeted performance levels would be a minimum 54 Mbps @ -84 dBm and a minimum 6 Mbps @ -94 dBm. Mesh functionality would be an option.

The City would equip its public safety vehicles with exterior mounted antennas and mobile routers capable of acting as access points with a minimum 27 dBm signal.

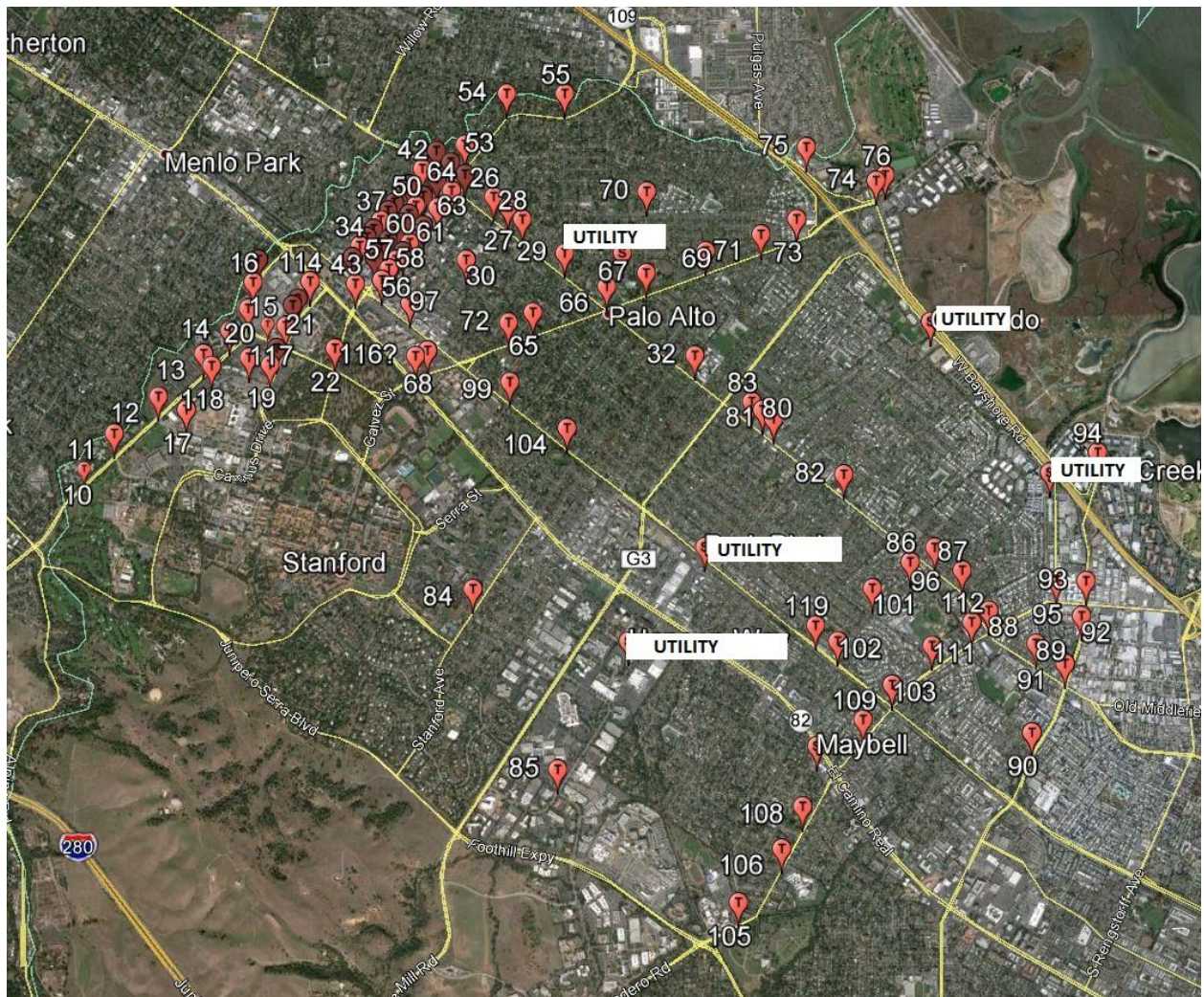
Figure 26: Illustration of Public Safety Mobile Network Deployment



In addition to the CPAU facilities, however, the City has more than 130 locations (including traffic signals) that currently have fiber network access, power, and mounting structures—and that are suitable access points for supporting connectivity to mobile public safety vehicles (see Figure 27 below). This scenario, then, has great potential for phased deployment. Depending on the City's needs and budget, the next phases of deployment could be either at fixed points (e.g., Stanford Stadium) or along priority routes (e.g., University Avenue).

This option for wireless deployment would directly address the Police Department’s needs for reliable communications citywide, and would eliminate the conflict between first responder communications and public communications during emergencies or large events. This deployment would also help cover areas of Palo Alto where the incumbent cellular provider has insufficient coverage.

Figure 27: Candidate Access Points for Public Safety Mobile Data Network



9 System-Level Design and Cost Estimates for Wireless Deployment Scenarios

In this section we review the user requirements determined as a part of our user assessment and present a preliminary system-level engineering design and cost estimate for implementing each of the four scenarios developed. We assume that these representative designs will undergo a detailed final review as a part of the City's evaluation of this report by participating departments. These designs were developed to provide decision-makers with a baseline of potential costs, a definition of services provided in each scenario, and a list of anticipated benefits from the implementation.

In preparing these estimates we have worked closely with City staff to draw from internal databases and the expertise of the staff. Once a decision has been made regarding which projects or scenarios are to be implemented, a more detailed study or review of the basic data will be required, along with the preparation of a bid request to identify a qualified system integrator to construct the selected systems.

9.1 Scenario 1

This scenario presents a strategy to implement both public wireless access and secure enterprise network access for City employees at City facilities. This option represents a continuation of the Information Technology department's ongoing efforts at many City locations. The capital amount required for deployment at additional City sites will depend on the number of sites, and will presumably be comparable to the City's costs for its previous deployments at major City buildings.

This model assumes that the City would systematically deploy Wi-Fi at all City buildings, and would provide both free public access and secure enterprise network access for City employees. The access points would be installed to serve a defined target area with a minimum signal level of -65 dBm and sufficient capacity to simultaneously serve a number of users, equivalent to 70 percent of the facility's maximum capacity. The wireless access would also extend outside of buildings to a limited area in the vicinity.

9.2 Scenario 2, Phase A

This scenario presents a strategy to implement public wireless coverage citywide or in defined areas using 802.11g/n technology. This is a near-term implementation scenario, utilizing to the maximum extent existing fiber infrastructure. It can be deployed as an initial implementation strategy to meet citywide coverage goals. The subsequent upgrade (defined in Scenario 2, Phase B) can be implemented to increase throughput and be integrated into future FTTP deployments.

9.2.1 Basic Assumptions

This model assumes that the existing City infrastructure will be used to deploy this network to the maximum extent possible. Specifically, fiber-optic backbone cable will be connected at strategic locations using existing fiber splice points. The number of connections to the fiber backbone will be determined on a cost basis. Mesh technology will be employed to interconnect access points that are not directly fiber connected. There will be a ratio of greater than or equal to 9 to 1 of unconnected to connected access points.

All access points will be mounted on existing city-owned light poles, traffic signals, or other similar structures that permit mounting at a level of approximately 20 feet above ground and have existing AC power.

The system will be constructed to meet performance specifications under IEEE 802.11 g/n. The estimated useful life for this technology is five years.

For the purpose of equipment replacement it is assumed that the useful life for any electronic equipment is seven years or less. Fiber-optic cabling, access points mounting equipment, and hardware has a useful life of 30 years.

For purposes of this estimate we assume a coverage area of 11.5 square miles. This is our estimate of the area containing most of the City's contiguous residential neighborhoods and commercial business areas. It excludes park and preserve areas west of the City proper in the foothills and the large commercial corporate office parks. Coverage signal intensity is targeted to support smartphones, tablets, and laptops within the 11.5-square-mile service area. Due to the high density of large trees in residential areas, reliable in-building service may require users to install external receiving equipment with regeneration capability within the structure.

This network will support client equipment operating in the 2.4 GHz and 5 GHz unlicensed Wi-Fi bands.

9.2.2 Financial Summary

We estimate the capital cost to construct the infrastructure for this deployment to be approximately \$4.7 million, and the yearly operating expenses to be \$600,000 (assuming operation on a subscription basis at \$20 per month, with a minimum of 2,550 customers).⁴³ Full financial projections for this scenario are included in Appendix B.

The table below provides a summary of projected capital costs for this scenario.

⁴³ Note that in our review of the Wi-Fi industry, we have found no systems in any similar markets that have achieved this level of subscriber penetration.

Table 6: Scenario 2-A Financial Summary (Capital Costs)

Item	Cost
Fiber Access Points	\$2,645,000
Backup power	\$345,000
Fiber Core Electronics	\$55,500
Fiber to splice (new)	\$502,500
Installation	\$728,750
Engineering & Oversight	\$384,910
<i>Total</i>	<i>\$4,661,660</i>

9.3 Scenario 2, Phase B

This scenario presents an implementation strategy to implement public wireless coverage citywide or in defined areas using 802.11ac technology. This is a longer-term implementation scenario, utilizing a new fiber-optic-based backhaul network to link each access point to the core network, capable of supporting gigabit throughput to each access point.

In Palo Alto, the existing CPAU fiber-optic infrastructure does not have sufficient citywide area coverage, points of presence, or capacity to support citywide implementation of a public Wi-Fi network. A backhaul network to support this topology would be required to connect to wireless access points with a spacing between sites of 1,000 feet or less. This scenario is feasible only with the complementary deployment of a citywide fiber network, which has a projected cost of approximately \$77.6 million.

9.3.1 Basic Assumptions

We assume a new backhaul infrastructure will be used to deploy this network to the maximum extent possible. Specifically, fiber-optic backbone cable will be connected to each access point. This cost estimate assumes that the fiber attachment (drop) cost will be the same as attaching a residential subscriber to an FTTP network.

As in the case of Phase A, all access points will be mounted on existing City-owned light poles, traffic signals, or other similar structures that permit mounting at a level of approximately 20 feet above ground and have existing AC power.⁴⁴

The system will be constructed to meet performance specifications under IEEE 802.11 ac. The estimated useful life for this technology is five years.

⁴⁴ As we note in Section 5, mounting access points would require an evaluation of the impacts on City infrastructure—including potential complications related to mounting on traffic signals and the visual impact of new equipment on street lights and municipal buildings.

For the purpose of equipment replacement it is assumed that the useful life for any electronic equipment is seven years or less. Fiber-optic cabling, access points mounting equipment and hardware all have a useful life of 30 years.

For purposes of this estimate we assume the coverage area to be 11.5 square miles. This is our estimate of the area containing most of the City’s contiguous residential neighborhoods and commercial business areas. It excludes park and preserve areas west of the City proper in the foothills and the large commercial corporate office parks. Coverage signal intensity is targeted to support smartphones, tablets, and laptops within the 11.5-square-mile service area. Due to the high density of large trees in residential areas, reliable in-building service may require users to install external receiving equipment with regeneration capability within the structure.

This network will support client equipment operating in the 2.4 GHz and 5 GHz unlicensed Wi-Fi bands.

9.3.2 Financial Summary

We estimate the capital cost to construct the infrastructure for this deployment to be approximately \$3.3 million, and the yearly operating expenses to be \$433,000 (assuming operation on a subscription basis at \$20 per month, with a minimum of 1,880 customers). Full financial projections for this scenario are included in Appendix C. The table below provides a summary of projected capital costs for this scenario.

Table 7: Scenario 2-B Financial Summary (Capital Costs)

Item	Cost
Fiber Access drops	\$1,495,000
Backup power	\$345,000
Fiber Core Electronics	\$155,500
Fiber drops	\$287,500
Installation	\$743,750
Engineering & Oversight	\$272,410
<i>Total</i>	<i>\$3,299,160</i>

9.4 Scenario 3

This scenario presents an implementation strategy to create high-capacity point-to-multipoint broadband wireless coverage citywide for Public Safety, Utilities, Public Works, and Traffic engineering users. This scenario would use a primary core site at City Hall and a new backup core site to support the most critical sites (redundantly) at a to-be-determined site in the Foothills preserve area.

9.4.1 Basic Assumptions

This model assumes that services will be obtained through a line-of-sight path between the core sites (City Hall and Foothills site). Multi-sector antennas will be installed all at all core sites with 90-degree sectors providing a minimum throughput of 100 Mbps/ sector.

Sites to be served include:

- Mobile public safety command vehicles
- All Police/Fire radio sites
- Utilities facilities
- Utilities facilities not connected to fiber-optic network
- Selected Traffic engineering sites
- Portable Public Works camera sites

Figure 28 shows the locations of some key fixed sites assumed for the network to prepare this estimate. The map will be expanded if the scenario is proposed for implementation and the backup site location is selected.

Figure 28: Point-to-Point Links (Scenario 3)



9.4.2 Financial Summary

Table 8 provides a summary of parameters and projected capital costs for this scenario. It is anticipated that the annual operational cost to support this scenario will be low. Staffing will be supported by Public Safety and Utilities as a minor add-on to their current operation of radio, fiber-optic, and other communications equipment. Hardware maintenance will likely be outsourced to equipment manufacturers/vendors. For this scenario we estimate a maximum annual expenditure of \$10,000 with a useful equipment life of seven to 10 years.

Table 8: Scenario 3 Financial Summary (Capital Costs)

Parameters	
Core Sites	2
Client sites	30
Capital Costs	
Base Stations (2)	\$190,000
Client Access Units	\$45,000
Installation	\$25,000
Engineering and Oversight	\$25,000
Core Site Network Integration	\$85,000
<i>Total</i>	<i>\$370,000</i>

9.5 Scenario 4

This scenario presents an implementation strategy to create wireless coverage citywide for public safety vehicles at key City locations and along predefined routes. The initial deployment includes vehicle router equipment to interface with commercial cellular networks, 4.9 GHz equipment, and future FirstNet deployments. For planning purposes, a fleet deployment of 50 vehicles is assumed.

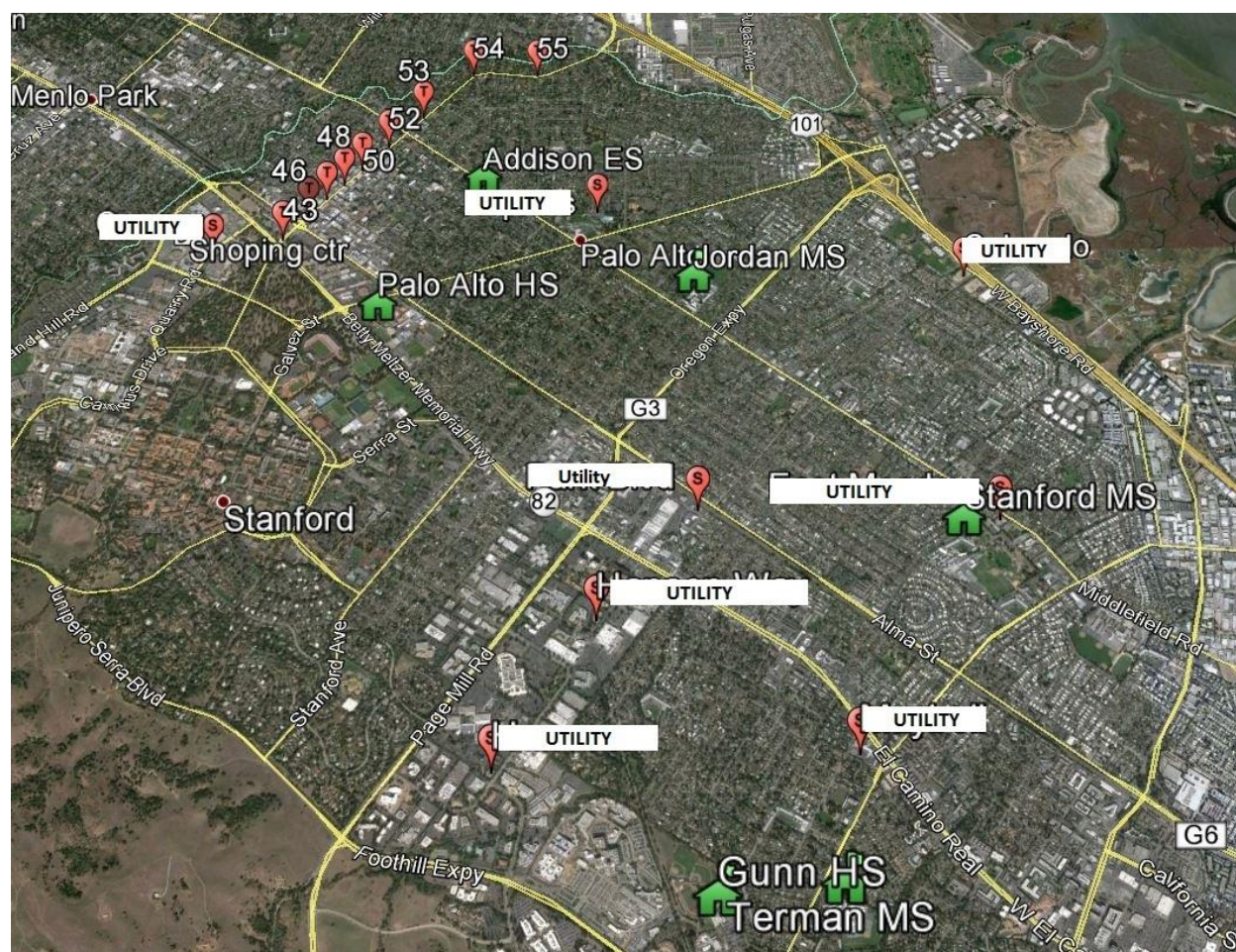
9.5.1 Basic Assumptions

This model assumes that all network backhaul infrastructure is in place and will be used to deploy this network to the maximum extent possible. Specifically, the access point will be located at traffic signals (9), public schools (5), and utility facilities (9). All selected facilities have IP network connectivity and all have available AC primary power.

The system will be constructed to meet performance specifications under IEEE 802.11a. The estimated useful life for this technology is five years. For purpose of equipment replacement, it is assumed that the useful life for any electronic equipment is seven years or less. Fiber-optic cabling, access points mounting equipment, and hardware all have a useful life of 30 years.

Figure 29 is a map showing the locations of traffic lights (T), public schools, and utility facilities that have been selected to establish this pricing model.

Figure 29: Map of Locations for Scenario 4 Deployment



9.5.2 Financial Summary

Table 9 provides the details for our projections, and assumes a six-month construction timeframe using existing IP fiber network connected backhaul.

It is anticipated that the annual operational cost to support this scenario will be low. Staffing will be supported primarily by Public Safety as an addition to its operation of land mobile radio and other existing communications equipment.

Hardware maintenance no doubt will be outsourced to equipment manufacturers/vendors. For this scenario we estimate a maximum annual expenditure of \$30,000 with a useful equipment life of five to seven years.

Table 9: Scenario 4 Financial Summary (Capital Costs)

Parameters	
Access Points (En Route)	9
Hot Spot Access Points	23
Vehicle Routers	50
Capital Costs (Unit)	
Wireless AP Hardware	\$2,100
Battery Backup	\$600
Mobile Routers	\$2,500
Installation Cost (Unit)⁴⁵	
AP Router and Power	\$1,250
Fiber Hub Integration	\$25,000
Vehicle routers	\$1,500
Capital Costs (Total)	
Access points	\$67,200
Mobile Routers	\$125,000
Fiber Core Electronics	\$30,000
Installation	\$87,500
Engineering & Oversight	\$27,900
<i>Total:</i>	<i>\$337,600</i>

⁴⁵ Per unit costs used to develop total capital cost for installation.

10 Business Case for Citywide Wireless

In our development of Scenario 2, we examined the advantages and disadvantages of the various business models used in other communities to deploy municipal wireless networks. Our analysis included a review of networks deployed in other cities. The business models examined included the following:

1. City-owned wholesale model: the wireless network is owned and operated by the City
2. Privately owned managed-services model: the wireless network is owned and operated by a service provider, but the City is an “anchor tenant” for the network
3. Hybrid model (public-private partnership): the City owns the network, but outsources operation and maintenance to a service provider

10.1 City-Owned Wholesale Model

We examined this option in the context of either the City’s Information Technology department or the Utility providing this service. Currently the City does not have staff with the capability of supporting a major telecommunications deployment citywide. The recent deployment of wireless technology throughout major City facilities required the services of an outside contractor to support day-to-day operations. Moving from a platform of several dozen buildings to an entire citywide system consisting of more than 600 access points and possibly thousands of subscribers would represent a major departure from the way the City currently operates. Further, based on all of the available information, the revenue requirements to support such an operation greatly exceed service fees and costs for penetrations observed in other markets that do not have the wide variety of wireless availability that exists in Palo Alto.

10.2 Privately Owned Managed-Services Model

As part of our analysis we examined in detail the wireless requirements for City agencies. Scenarios 3 and 4 as defined in this report are targeted to address City government needs. (For reasons of security, network capacity, or availability, the use of a common citywide municipal wireless network was dismissed for supporting City government applications.)

It should be noted that most of the citywide government-related telecommunications applications are currently addressed by the existing fiber-optic network. Further, the broadband needs met by the existing network generally fall under the nature of supporting critical infrastructure and are more appropriately served by an independent wireless network with highly refined user requirements.

We did not uncover any significant need or revenues that might be directed to a partnership with a private operator whereby the operator would receive payment for City use. We note that in other communities where this approach has been used, the communities do not appear to have resources like the high-capacity fiber-optic network, as is the case in Palo Alto.

10.3 Hybrid Model (Public-Private Partnership)

As noted in this report, there is a significant opportunity for an outside vendor to partner with the City and the use much of the existing infrastructure to facilitate citywide deployment of a broadband wireless system. Scenario 2 examines the cost to construct and operate a citywide network leveraging a segment of the City's infrastructure.

The City could consider issuing an RFP to solicit the interest of prospective commercial organizations for such deployment. As discussed in the next section of this report, there are opportunities for integrating or blending Wi-Fi and wireless services in the urban environment. Wi-Fi deployment would increase capacity while also possibly making available to commercial wireless service providers additional sites citywide for their small-scale antenna deployment.

If the City were to move forward on this model, it would clearly need to examine the feasibility of obtaining sufficient revenue from the deployment to address the long-term cost of operation. Experience nationwide indicates that the public will use free Wi-Fi services where available; the issue here is obtaining revenue from the service.

Most consumers associate access to Wi-Fi with restaurants, coffee shops, and institutional waiting rooms. For the consumer on the move, network access is normally provided through smartphones. And while residential service is feasible for Wi-Fi, specific environmental issues in Palo Alto (such as foliage, restrictions on antenna placement for access equipment, and in many cases the need for an externally mounted access units for consumers) represent impediments not just to commercial deployment, but to the use of City Wi-Fi as a replacement for wired Internet service in many residents' homes.

11 Future Wireless Technology Innovations

This report presents a pragmatic examination of current requirements for broadband wireless services within the City of Palo Alto and alternatives for using existing infrastructure to address needs in the near-term. The recommendations contained herein focus on leveraging existing assets and using off-the-shelf technology available from major vendors. All of the scenarios presented in this document represents technologically and financially viable undertakings.

We note, however, that investments in physical infrastructure relating to wireless—such as mounting location for access devices, powering (either through commercial sources or renewable energy), and backhaul from access locations to network control centers over high-capacity fiber-optic technology links—represent a prudent investment to support long-term wireless deployment by either municipal entities or commercial wireless vendors. Much of the infrastructure has the potential for multiple uses—in the same way that operators often share cell towers, meaning that the same infrastructure supports competing commercial service providers.

11.1 Future 5G Technology Deployment

The Next Generation Mobile Networks (NGMN) Alliance,⁴⁶ an international consortium of wireless service providers and equipment manufacturers, is currently formulating the system-level requirements for “5G” next-generation public wireless networks targeted for deployment in 2020. The Alliance’s white paper published in February 2015 set out the system-level performance specifications for this new technology.⁴⁷ It also addresses requirements for various categories of user access equipment such as smartphones and office technology, as well as new areas of focus such as the Internet of Things (telemetry and appliance devices) and broadcast services and emergency communications in times of natural disaster.

A few of the key points addressed in this comprehensive, visionary document include:

- Data transfer speed baselining at 1 Gbps. with a peak throughput up to 10 Gbps
- Several hundreds of thousands of simultaneous connections to be supported for massive sensor deployments (Internet of Things).
- Enhanced spectral efficiency (more throughput per segment of radio bandwidth)
- Improved coverage

⁴⁶ <https://www.ngmn.org/home.html>

⁴⁷ NGMN 5G White Paper, NGMA Alliance, Frankfurt, Germany Feb 2015

- Significantly reduced latency (i.e., ≤ 10 msec. for all applications and ≤ 1 msec. for critical applications)

The rapid growth of the Internet of Things (“IoT”)⁴⁸ will require bits of information from sensors embedded in our devices; at the other end of the scale, the increase in enhanced high-definition video traffic, high-resolution photos, and terabit file transfers will require enormous amounts of bandwidth. Users will require portable equipment that can operate for long periods of time with very limited power sources. Other users’ requirements are focused on rapid access anticipating network latency of 1 msec. or less.

The City of Palo Alto will need to take into account the sweeping upgrade in technology proposed by the move to 5G, because that new technology will set the benchmark for consumer expectations for any City services. Any deployment by the City of Palo Alto needs to be compatible with the community’s expectations—and specifically with competitive services that will be offered by commercial wireless providers. (As a point of comparison, consider that wireless systems implemented by commercial organizations and municipal governments prior to the deployment of 4G technology by commercial operators were essentially obsolete once the new commercial technology was deployed.) That said, investment in core wireless infrastructure will provide a foundation for supporting the continual migration of wireless technology standards for access devices.

11.2 Integrating Wi-Fi and Cellular

One option for increasing the availability of wireless spectrum and increasing throughput to user devices is to bond or integrate Wi-Fi services with cellular service. Although Wi-Fi and LTE cellular technologies use different transmission, encoding, and radio spectrum, they can be linked by enhanced user access equipment that communicates simultaneously with both networks.

Generally, cellular technology provides the most robust means for communicating from the user to the wireless access point. Further, in most practical applications the communications traffic is heavily weighted toward downloads to user devices. Smartphones and other devices can be preprogrammed to take advantage of the presence of both Wi-Fi and cellular service so that upstream traffic from the user can be targeted toward the cellular link (which generally exhibits greater range and reliability than a similar link to a Wi-Fi access point).

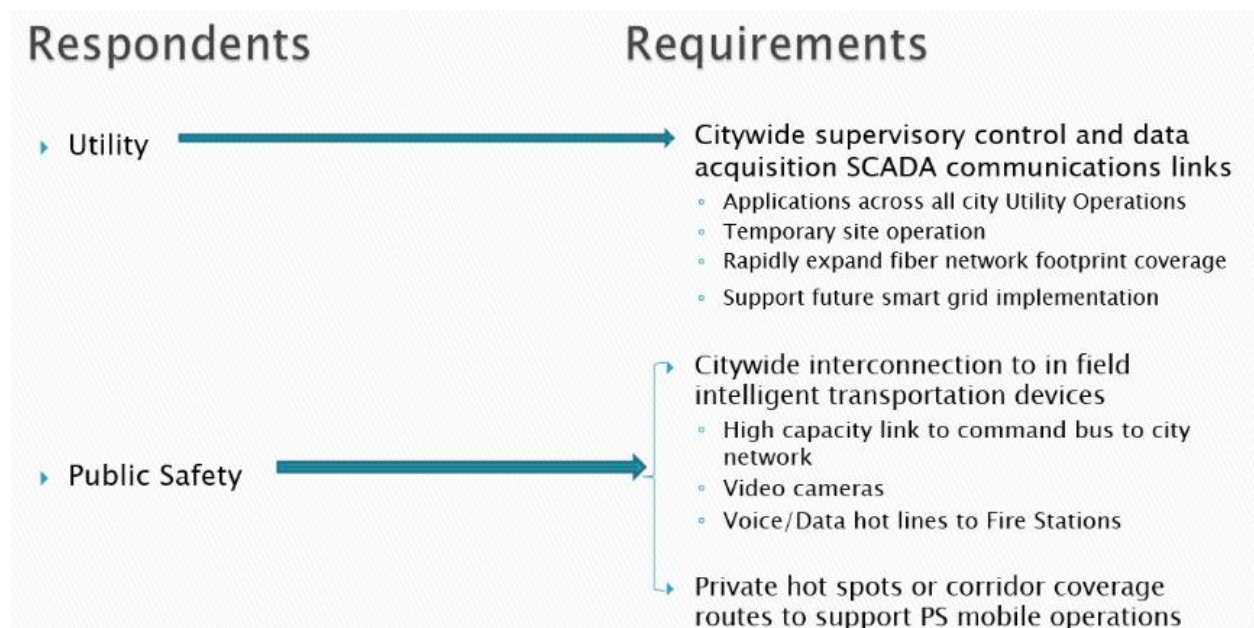
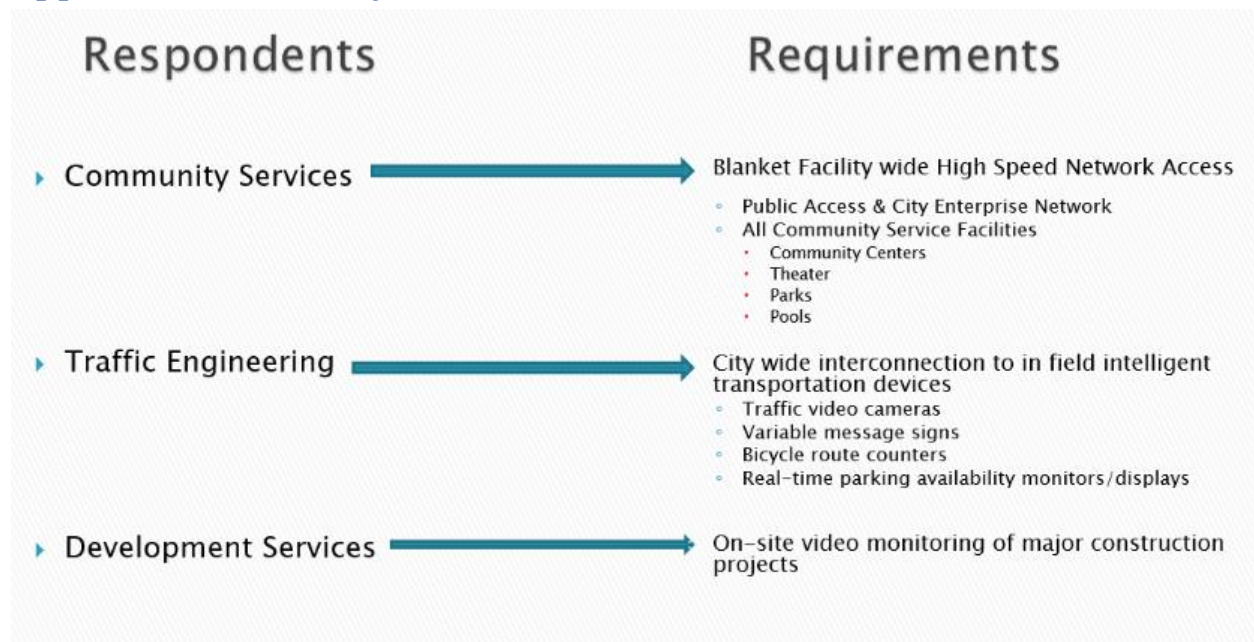
⁴⁸ The “Internet of Things” is the popular name for the growing number of consumer devices like appliances and thermostats that are “Web-enabled” and can be accessed and controlled by a user over an Internet connection. See, for example: <http://www.wired.com/2015/04/google-says-internet-things-will-save-electricity/>.

Alcatel-Lucent is one of the organizations examining this concept and looking into integrating Wi-Fi into the existing 4G cellular infrastructure.⁴⁹ This represents a stopgap measure to increase the overall download capability of existing cellular services.

We recommend that the City monitor this blending technology along with other approaches to integrating cellular and Wi-Fi technology. Assuming such technologies are successful, they may create a demand for a consistent level of high-quality Wi-Fi service throughout the community and possibly create an economic justification for deploying a citywide Wi-Fi blanket.

⁴⁹ Blending Wi-Fi and Cellular, Alcatel-Lucent Strategical White Paper, June 2015.

Appendix A: Summary of Potential Stakeholder Needs



Appendix B: Financial Projections for Scenario 2, Phase A

Appendix C: Financial Projections for Scenario 2, Phase B

City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
Palo Alto, CA
June 7, 2015

Wireless Financial Analysis - Scenario II a

The projections used in this analysis were prepared to assist in the assessment of the financial feasibility of establishing a enterprise to offer connectivity services in the identified service area. Where appropriate, the analysis includes projected operating revenues, expenses, and cash flows for the life of the system based on estimated construction costs and various market penetration rates. This analysis should not be used for any other purpose. There will be differences between the projected and actual results, because events and circumstances frequently do not occur as expected, and those differences may be material. CTC has no responsibility to update or certify this projection for events and circumstances occurring after the date of this projection.

Table of Contents
City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
June 7, 2015

Description	Page
Income Statement	3
Cash Flow Statement	4
Capital Additions	5
Depreciation	9
Expenses	10
Revenues - Site Based	11
Breakeven Analysis	12
Assumptions	13

City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
June 7, 2015

Income Statement

Year	1	2	3	4	5	6	7
a. Revenues							
Wireless Connection	\$ 492,000	\$ 612,000	\$ 612,000	\$ 612,000	\$ 612,000	\$ 612,000	\$ 612,000
Wireless Equipment and Connection Fees (non-recurring)	-	-	-	-	-	-	-
Total	\$ 492,000	\$ 612,000	\$ 612,000	\$ 612,000	\$ 612,000	\$ 612,000	\$ 612,000
b. Operating Expenses - Cash (not including taxes in line h)							
Operating Expenses	\$ 171,510	\$ 383,160	\$ 395,730	\$ 395,730	\$ 395,730	\$ 395,730	\$ 395,730
Operating Expenses - Misc.	256,700	185,200	160,200	160,200	160,200	160,200	160,200
Support Allocations	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Total	\$ 478,210	\$ 618,360	\$ 605,930	\$ 605,930	\$ 605,930	\$ 605,930	\$ 605,930
c. Revenues less Cash Operating Expenses (a-b)	\$ 13,790	\$ (6,360)	\$ 6,070	\$ 6,070	\$ 6,070	\$ 6,070	\$ 6,070
d. Operating Expenses - Non-Cash							
Depreciation	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500
e. Operating Income (d-c)	\$ (600,710)	\$ (620,860)	\$ (608,430)	\$ (608,430)	\$ (608,430)	\$ (608,430)	\$ (608,430)
f. Non-Operating Income							
Interest Income	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Investment Income	-	-	-	-	-	-	-
Interest Expense (Short-Term)	-	-	-	-	-	-	-
Interest Expense (Long-Term))	-	-	-	-	-	-	-
Interest Expense (Internal)	-	-	-	-	-	-	-
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
g. Net Income	\$ (600,710)	\$ (620,860)	\$ (608,430)	\$ (608,430)	\$ (608,430)	\$ (608,430)	\$ (608,430)
h. Taxes	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
i. Net Income After Fees & In Lieu Taxes	\$ (600,710)	\$ (620,860)	\$ (608,430)	\$ (608,430)	\$ (608,430)	\$ (608,430)	\$ (608,430)

City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
June 7, 2015

Cash Flow Statement

Year	1	2	3	4	5	6	7
a. Net Income (From Income Statement)	\$ (600,710)	\$ (620,860)	\$ (608,430)	\$ (608,430)	\$ (608,430)	\$ (608,430)	\$ (608,430)
b. Cash Outflows							
Debt Service Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Interest Reserve	-	-	-	-	-	-	-
Depreciation Operating Reserve	-	-	-	-	-	-	-
Financing	-	-	-	-	-	-	-
Capital Expenditures	\$ (4,686,660)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total	\$ (4,686,660)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c. Cash Inflows							
Interest Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Depreciation Operating Reserve	-	-	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-	-	-
Short Term Financing	-	-	-	-	-	-	-
Long Term Financing (Bond)	-	-	-	-	-	-	-
Cash Start	-	-	-	-	-	-	-
Internal Loan	-	-	-	-	-	-	-
Internal Funding (non-loan)	4,686,660	-	-	-	-	-	-
Total	\$ 4,686,660	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d. Total Cash Outflows and Inflows (b+c)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
e. Non-Cash Expenses - Depreciation	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500
f. Adjustments (Proceeds from)							
Short Term Financing	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Long Term Financing (Bond)	-	-	-	-	-	-	-
Internal Loan	-	-	-	-	-	-	-
Internal Funding (non-loan)	(4,686,660)	-	-	-	-	-	-
Total	\$ (4,686,660)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
g. Adjusted Available Net Revenue	\$ (4,672,870)	\$ (6,360)	\$ 6,070	\$ 6,070	\$ 6,070	\$ 6,070	\$ 6,070
h. Principal Payments on Debt							
Short Term Bond/Loan Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Long Term Bond Principal	-	-	-	-	-	-	-
Internal Loan Principal	-	-	-	-	-	-	-
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
i. Net Cash	\$ 13,790	\$ (6,360)	\$ 6,070	\$ 6,070	\$ 6,070	\$ 6,070	\$ 6,070
Avoided Costs (see j and k below)	-	-	-	-	-	-	-
Adjusted Net Cash	\$ 13,790	\$ (6,360)	\$ 6,070	\$ 6,070	\$ 6,070	\$ 6,070	\$ 6,070
Cash Balance (Enterprise)							
Unrestricted Cash Balance	\$ 13,790	\$ 7,430	\$ 13,500	\$ 19,570	\$ 25,640	\$ 31,710	\$ 37,780
Depreciation Operating Reserve	-	-	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-	-	-
Total Cash Balance	\$ 13,790	\$ 7,430	\$ 13,500	\$ 19,570	\$ 25,640	\$ 31,710	\$ 37,780

City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
June 7, 2015

Capital Additions

Year	1	2	3	4	5	6	7
a. Fiber Implementation Costs							
Fiber (30 year depreciation)	\$ 502,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Expansion Fiber (30 year depreciation)	-	-	-	-	-	-	-
Headend and Hub Equipment (10 year depreciation)	-	-	-	-	-	-	-
Headend and Hub Equipment (7 year depreciation)	-	-	-	-	-	-	-
Network Equipment (6 year depreciation)	-	-	-	-	-	-	-
CAI Customer Equipment (6 year depreciation)	-	-	-	-	-	-	-
Total	\$ 502,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
e. Wireless Network Costs (7 year depreciation)							
Microwave (10 year)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Structures (20 year)	-	-	-	-	-	-	-
Access (10 year)	-	-	-	-	-	-	-
Network Equipment (7 year)	3,045,500	-	-	-	-	-	-
Spare Equipment (7 year)	25,000	-	-	-	-	-	-
Installation & Engineering (7 year)	1,113,660	-	-	-	-	-	-
Total	\$ 4,184,160	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
f. Wireless Customer Connection Cost (5 year depreciation)							
CPE	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total Capital	\$ 4,686,660	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
June 7, 2015

Principal and Interest Payments (Year 1 Financing)

	Payment Year	1	2	3	4	5	6	7	Total
Short Term Financing									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Payment	\$ -							
	Loan Amount/Balance (beginning of year)	\$ -							
	Loan Amount/Balance (end of year)	\$ -	-	-	-	-	-	-	
	Payment Start	2							
	Term (years)	7							
	Interest	4.00%							
Long Term Financing (Bond)									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Payment	\$ -							
	Loan Amount/Balance (beginning of year)	\$ -	-	-	-	-	-	-	
	Loan Amount/Balance (end of year)	\$ -	-	-	-	-	-	-	
	Payment Start	2							
	Term (years)	20							
	Interest	4.50%							
Internal Loan									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Payment	\$ -							
	Loan Amount/Balance (beginning of year)	\$ -	-	-	-	-	-	-	
	Loan Amount/Balance (end of year)	\$ -	-	-	-	-	-	-	
	Payment Start	2							
	Term (years)	3							
	Interest	2.00%							
Total									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total (all years)									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
June 7, 2015

Depreciation

	Year	1	2	3	4	5	6	7
30 Year Capital Expenditures	\$	502,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
20 Year Capital Expenditures		-	-	-	-	-	-	-
10 Year Capital Expenditures		-	-	-	-	-	-	-
7 Year Capital Expenditures		4,184,160	-	-	-	-	-	-
6 Year Capital Expenditures		-	-	-	-	-	-	-
5 Year Capital Expenditures		-	-	-	-	-	-	-
Total	\$	4,686,660	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

	Year	1	2	3	4	5	6	7
Depreciation Total	\$	614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500	\$ 614,500

City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
June 7, 2015

Expenses

Year	1	2	3	4	5	6	7
Expenses							
<i>Operating Expenses</i>							
tbd	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
tbd	-	-	-	-	-	-	-
Marketing	10,000	7,500	7,500	7,500	7,500	7,500	7,500
Legal	10,000	2,500	2,500	2,500	2,500	2,500	2,500
Fiber Lease	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Site Lease	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Maintenance & Monitor	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Equipment Maintenance	-	211,600	211,600	211,600	211,600	211,600	211,600
Fiber Maintenance Fees	\$ 2,510	\$ 12,560	\$ 25,130	\$ 25,130	\$ 25,130	\$ 25,130	\$ 25,130
Contingency	-	-	-	-	-	-	-
Total	\$ 171,510	\$ 383,160	\$ 395,730	\$ 395,730	\$ 395,730	\$ 395,730	\$ 395,730
<i>Operating Expenses - Misc.</i>							
Attachment & Power Fees	\$ 124,200	\$ 124,200	\$ 124,200	\$ 124,200	\$ 124,200	\$ 124,200	\$ 124,200
Education and Training	-	-	-	-	-	-	-
Allowance for Bad Debts	15,000	18,000	18,000	18,000	18,000	18,000	18,000
Customer Acquisition Costs	102,500	25,000	-	-	-	-	-
Internet Connection Fee	15,000	18,000	18,000	18,000	18,000	18,000	18,000
Utilities	-	-	-	-	-	-	-
Total	\$ 256,700	\$ 185,200	\$ 160,200	\$ 160,200	\$ 160,200	\$ 160,200	\$ 160,200
<i>Taxes</i>							
Dark Fiber & IRU Taxes	-	-	-	-	-	-	-
City and State Taxes	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-
<i>Salary Allocations</i>							
Staff Allocations (Administration & Support)	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000
Total	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000
Grand Total	\$ 478,210	\$ 618,360	\$ 605,930	\$ 605,930	\$ 605,930	\$ 605,930	\$ 605,930

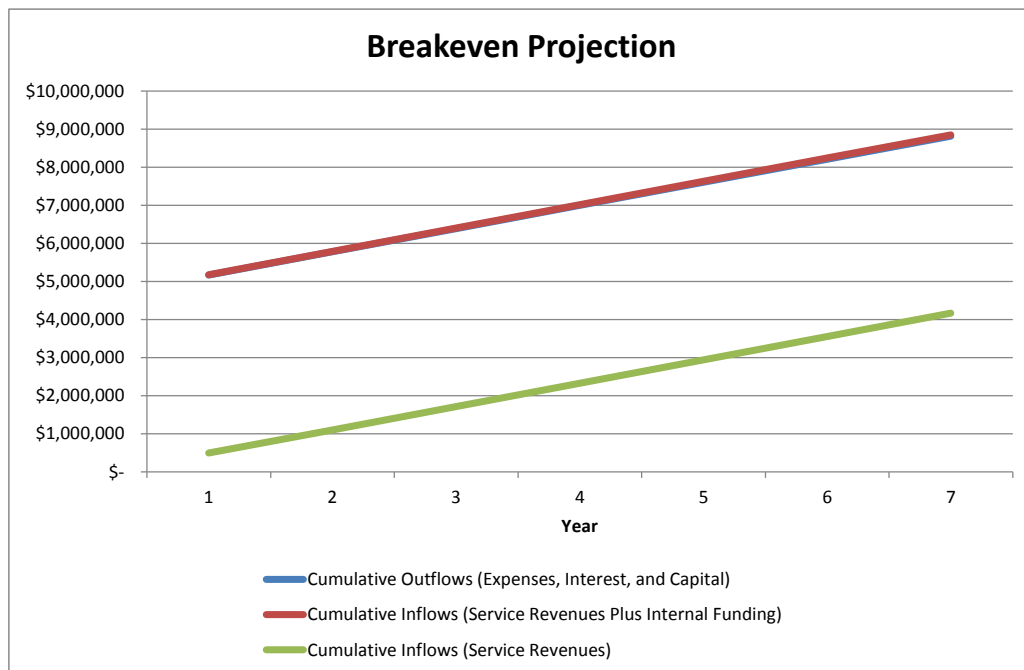
City of Palo Alto
Scenario II a - Blanket Wi-Fi 802.11 g/n
Financial Projections Rev 1
June 7, 2015

Revenues - Site Based

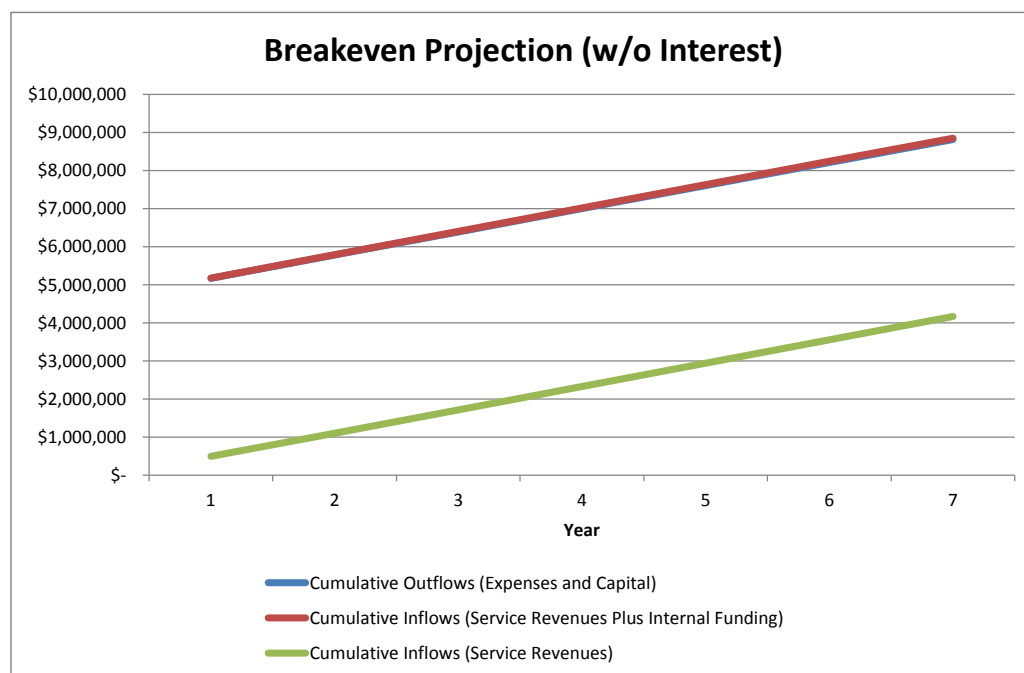
	Year	1	2	3	4	5	6	7
Wireless Connection								
Mobile	\$	492,000	\$	612,000	\$	612,000	\$	612,000
tbd		-		-		-		-
Total	\$	492,000	\$	612,000	\$	612,000	\$	612,000

Breakeven Analysis

Including interest, operating expenses, and capital in cash outflows



Including operating expenses, and capital in cash outflows (interest not included)



Assumptions

Page Title Information

Organization	City of Palo Alto
Plan Name	Scenario II a - Blanket Wi-Fi 802.11 g/n
	Financial Projections Rev 1
Location	Palo Alto, CA
Date	June 7, 2015
	Wireless Financial Analysis - Scenario II a

Financial Assumptions

Finance Requirements

Beginning Cash	\$ -									
	Year									
	1	2	3	4	5					
Short Term Financing	\$ -	\$ -	\$ -	\$ -	\$ -					
Long Term Financing (Bond)	-	-	-	-	-					
Internal Loan	-	-	-	-	-					
Internal Funding (non-loan)	4,686,660	-	-	-	-	-	-	-	-	-
Total	\$ 4,686,660	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Year									
	1	2	3	4	5	6	7	8	9	10
Depreciation Operating Reserve	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Year									
	1	2	3	4	5	6	7	8	9	10
Capital Expenditure Funded by Depreciation Reserve	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Unrestricted Cash Balance	\$ 13,790	\$ 7,430	\$ 13,500	\$ 19,570	\$ 25,640	\$ 31,710	\$ 37,780	\$ (550,150)	\$ (1,138,080)	\$ (1,726,010)
Depreciation Operating Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Debt Service Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total Cash Balance	\$ 13,790	\$ 7,430	\$ 13,500	\$ 19,570	\$ 25,640	\$ 31,710	\$ 37,780	\$ (550,150)	\$ (1,138,080)	\$ (1,726,010)

Short Term Financing										
Bonding Finance Rate	4.00%	4.00%	4.00%	4.00%	4.00%					
Period (Years)	7	10	10	7	7					
Principal Repayment Period Start	2	2	2	1	1					
Bond/Loan Issuance Cost	1.00%	1.00%	1.00%	1.00%	1.00%					
Debt Service Reserve	0.00%	0.00%	0.00%	0.00%	0.00%					
Interest Reserve	no	no	no	no	no					
Interest Reserve Year 1 Financing	\$ -	\$ -								
Interest Reserve Year 2 Financing		\$ -	\$ -							
Interest Reserve Year 3 Financing			\$ -	\$ -						
Interest Reserve Year 4 Financing				\$ -	\$ -					
Interest Reserve Year 5 Financing					\$ -	\$ -				
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Long Term Financing (Bond)										
	4.50%	4.50%	4.50%	4.50%	4.50%					
Principal Repayment Period Start	20	20	20	20	20					
Bond Issuance Cost	1.00%	1.00%	1.00%	1.00%	1.00%					
Debt Service Reserve	5.00%	5.00%	5.00%	5.00%	5.00%					
Interest Reserve	yes	yes	yes	yes	yes					
Interest Reserve Year 1 Financing	\$ -	\$ -								
Interest Reserve Year 2 Financing		\$ -	\$ -							
Interest Reserve Year 3 Financing			\$ -	\$ -						
Interest Reserve Year 4 Financing				\$ -	\$ -					
Interest Reserve Year 5 Financing					\$ -	\$ -				
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Internal Loan										
Finance Rate	2.00%	2.00%	2.00%	2.00%	2.00%					
Period (Years)	3	3	3	3	3					
Principal Repayment Period Start	2	2	2	1	1					
Other										
Investment Income	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Interest Earned on Available Cash	0.00%	Linked to previous year cash balance				Use one or the other, but not both				
	0.00%	Linked to depreciation and debt service reserve funds								

Wireless Customers											
		Year									
Wireless Connection		1	2	3	4	5	6	7			
Mobile		2,050	2,550	2,550	2,550	2,550	2,550	2,550			
tbd		-	-	-	-	-	-	-			
Total		2,050	2,550	2,550	2,550	2,550	2,550	2,550			
Incremental		2,050	500	-	-	-	-	-			
		Calculation of Average Speed per Customer									
Enter in speed (Mbps) of each service under year one		1	2	3	4	5	6	7	8	9	10
Wireless - Residential		10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Wireless - Business		10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Average Mbps		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Total Mbps		20,500	25,500	25,500	25,500	25,500	25,500.00	25,500.00	25,500.00	25,500.00	25,500.00
		13,790	7,430	13,500	19,570	25,640	31,710	37,780			

Wireless Customers												
		Year										
Wireless Connection		1	2	3	4	5	6	7				
Mobile		\$ 20.00	\$ 20.00	\$ 20.00	\$ 20.00	\$ 20.00	\$ 20.00	\$ 20.00				
tbd		\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -				

Operation & Maintenance Expense Assumptions

Taxes										
Dark Fiber & IRU Taxes	0.00%									
City and State Taxes	0.0000%		State	0.0000%		County	0.0000%		City	0.0000%
Sales tax is a pass through expense										
#DIV/0!										
Operating Expenses										
	1	2	3	4	5	6	7	8	9	10
tbd	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
tbd	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Marketing	\$ 10,000	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500
Legal	\$ 10,000	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500
Fiber Lease	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000
Site Lease	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000
Maintenance & Monitor	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000
Equipment Maintenance	\$ -	\$ 211,600	\$ 211,600	\$ 211,600	\$ 211,600	\$ 211,600	\$ 211,600	\$ 211,600	\$ 211,600	\$ 211,600
Fiber Maintenance Fees	\$ 2,510	\$ 12,560	\$ 25,130	\$ 25,130	\$ 25,130	\$ 25,130	\$ 25,130	\$ 25,130	\$ 25,130	\$ 25,130
Fiber Maintenance Fees (percentage of cumulative cost)	0.50%	2.50%	5.00%							
Contingency	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Operating Expenses - Misc.										
Allowance for Bad Debts	3.00%	of GPON, MetroE, and wireless services								
Customer Acquisition Costs	\$ 50.00	per Wireless Customer								
	1	2	3	4	5	6	7	8	9	10
DIA Sales (Mbps) (for MAN customers)	0	0	0	0	0	0	0	0	0	0
DIA Sell price	\$ 20.00	per Mbps per month								
	1	2	3	4	5	6	7	8	9	10
Internet Connection Fee	\$ 15,000	\$ 18,000	\$ 18,000	\$ 18,000	\$ 18,000	\$ 18,000	\$ 18,000	\$ 18,000	\$ 18,000	\$ 18,000
DIA for Services										
per Mbps per month	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50
oversubscription ratio	25	25	25	25	25	25	25	25	25	25
Internal Use										
Mbps Available for Internal (total)	-	-	-	-	-	-	-	-	-	-
per Mbps per month	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50
Total Cost Annual	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	1	2	3	4	5	6	7	8	9	10
Total BW used internally (Mbps)	-	-	-	-	-	-	-	-	-	-
Available BW to apply to other users	-	-	-	-	-	-	-	-	-	-
Needed for Wireless users	820	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
Net required for other users	820	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
Attachment & Power Fees										
	575	attachments at \$ 216.00 per year								
	\$ 18.00	per month								
	1	2	3	4	5	6	7	8	9	10
Utilities	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

Salaries (Calculation Base 4)Annual escalation **0.00%** Above what rate increases are (applied to the FTE's only - first five rows of table below)

	1	2	3	4	5	6	7	8	9	10
Staff Allocations (Administration & Support)	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000
FTE (2)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
FTE (3)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
FTE (4)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
FTE (5)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
TBD	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
TBD	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
TBD	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000

Capital Requirement Assumptions**Miscellaneous Costs**

Misc. Equipment	\$ -	\$ -	\$ -		100%	year 6
tbd 1	\$ -	\$ -	\$ -		100%	year 6
tbd 2	\$ -	\$ -	\$ -		100%	year 6
tbd 3	\$ -	\$ -	\$ -		100%	year 6
tbd 4	\$ -	\$ -	\$ -		100%	year 6
tbd 5	\$ -	\$ -	\$ -		100%	year 6
tbd 6	\$ -	\$ -	\$ -		100%	year 8

Additional Annual Capital Costs **0.00%** Percent of Year 1 to Year 3 fiber implementation costs Starts in year **4****Implementation Costs**

Base Network	1	2	3	4	5	Year 1 Build	Year 2 Build	Total
Fiber (30 year depreciation)	\$ 502,500	\$ -	\$ -			100%	0%	\$ 502,500
Headend and Hub Equipment (10 year depreciation)	\$ -	\$ -	\$ -			100%	0%	\$ -
Headend and Hub Equipment (7 year depreciation)	\$ -	\$ -	\$ -			100%	0%	\$ -
Network Equipment (6 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -			
CAI Customer Equipment (6 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -			
Customer pay?						Yes	For Years 1 to 5	Yes For Replenishments
Incremental A								
Fiber (30 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
Headend and Hub Equipment (10 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
Headend and Hub Equipment (7 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
Network Equipment (6 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
CAI Customer Equipment (6 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
Incremental B								
Fiber (30 year depreciation)	\$ -	\$ -	\$ -			\$ -		\$ -
Headend and Hub Equipment (10 year depreciation)	\$ -	\$ -	\$ -			\$ -		\$ -
Headend and Hub Equipment (7 year depreciation)	\$ -	\$ -	\$ -			\$ -		\$ -
Network Equipment (6 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		\$ -
CAI Customer Equipment (6 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		\$ -
Total Network							Replacement	
Fiber (30 year depreciation)	\$ 502,500	\$ -	\$ -					
Headend and Hub Equipment (10 year depreciation)	-	-	-				100%	Year 11
Headend and Hub Equipment (7 year depreciation)	-	-	-				100%	year 8
Network Equipment (6 year depreciation)	-	-	-	-	-		100%	year 8
CAI Customer Equipment (6 year depreciation)	-	-	-	-	-		100%	year 8
Business Development & Support Engineering	\$ -	\$ -	\$ -					
	\$ 502,500	\$ -	\$ -	\$ -	\$ -			
Other Misc.								
Administration	\$ -	\$ -	\$ -	na	na	na	na	na
Operation and Network Equipment	\$ -	\$ -	\$ -	na	na	na	na	na
Expansion Fiber (30 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Fiber (Accrued)	\$ 502,500	\$ 502,500	\$ 502,500					
Network Equipment (Accrued)	\$ -	\$ -	\$ -					
Business Development & Support (Accrued)	\$ -	\$ -	\$ -					
			\$ 502,500					

Wireless

Microwave (10 year)	\$ -	\$ -	\$ -	
Structures (20 year)	\$ -	\$ -	\$ -	
Access (10 year)	\$ -	\$ -	\$ -	

Network Equipment (7 year)	\$ 3,045,500	\$ -	\$ -	0% year 8
Spare Equipment (7 year)	\$ 25,000	\$ -	\$ -	0% year 8
Installation & Engineering (7 year)	\$ 1,113,660	\$ -	\$ -	0% year 8
Total	\$ 4,184,160	\$ -	\$ -	
Accrued	\$ 4,184,160	\$ 4,184,160	\$ 4,184,160	
				3774250 \$ 409,910

Scenario II a - Blanket Wi-Fi 802.11 g/n

18 month construction timeframe

Parameters 802.11 g/n

Total Areas Sq. Mi.	11.5
Access Points/Sq. Mi.	50
Fiber connection (splice)	67
Outdoor Routers	575

Capital Costs

Fiber Access Points	\$	2,645,000	7 year	x	
Backup power	\$	345,000	7 year	x	
Fiber Core Electronics	\$	55,500	7 year	x	
Fiber to splice (new)	\$	502,500	20 to 30 year	x	
Installation	\$	728,750	7 year	x	
Engineering & Oversight	\$	384,910	7 year	x	
Capital Cost	\$	4,276,750			\$ 3,774,250
	\$	4,661,660			

Capital Cost (Unit)

Wireless AP Hardware Cost	\$	4,100	x	
Battery Backup Cost	\$	600	x	
Fiber plant Extension (drop)	\$	7,500	x	
Fiber Core Electronics	\$	55,500	x	
AC Power	\$	500	check with lee	

Installation Cost (Unit)

AP - Router & Power	1250	x
Fiber Hub Electronics	10000	x

Operating Expenses (yr.)

Site Lease	24000	check with PA
Equipment Maintenance	\$ 211,600	x
Fiber Lease	50000	check with PA
Site Power \$18/mo./site	\$ 124,200	x
Maintenance & Monitor	\$ 75,000	\$ 130.43 per AP

City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
Palo Alto, CA
June 7, 2015

Wireless Financial Analysis - Scenario II b

The projections used in this analysis were prepared to assist in the assessment of the financial feasibility of establishing a enterprise to offer connectivity services in the identified service area. Where appropriate, the analysis includes projected operating revenues, expenses, and cash flows for the life of the system based on estimated construction costs and various market penetration rates. This analysis should not be used for any other purpose. There will be differences between the projected and actual results, because events and circumstances frequently do not occur as expected, and those differences may be material. CTC has no responsibility to update or certify this projection for events and circumstances occurring after the date of this projection.

Table of Contents
City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
June 7, 2015

Description	Page
Income Statement	3
Cash Flow Statement	4
Capital Additions	5
Depreciation	9
Expenses	10
Revenues - Site Based	11
Breakeven Analysis	12
Assumptions	13

City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
June 7, 2015

Income Statement

Year	1	2	3	4	5	6	7
a. Revenues							
Wireless Connection	\$ 444,000	\$ 444,000	\$ 444,000	\$ 444,000	\$ 444,000	\$ 444,000	\$ 444,000
Wireless Equipment and Connection Fees (non-recurring)	-	-	-	-	-	-	-
Total	\$ 444,000	\$ 444,000	\$ 444,000	\$ 444,000	\$ 444,000	\$ 444,000	\$ 444,000
b. Operating Expenses - Cash (not including taxes in line h)							
Operating Expenses	\$ 170,440	\$ 225,990	\$ 233,180	\$ 233,180	\$ 233,180	\$ 233,180	\$ 233,180
Operating Expenses - Misc.	242,700	150,200	150,200	150,200	150,200	150,200	150,200
Support Allocations	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Total	\$ 463,140	\$ 426,190	\$ 433,380	\$ 433,380	\$ 433,380	\$ 433,380	\$ 433,380
c. Revenues less Cash Operating Expenses (a-b)	\$ (19,140)	\$ 17,810	\$ 10,620	\$ 10,620	\$ 10,620	\$ 10,620	\$ 10,620
d. Operating Expenses - Non-Cash							
Depreciation	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400
e. Operating Income (d-c)	\$ (462,540)	\$ (425,590)	\$ (432,780)	\$ (432,780)	\$ (432,780)	\$ (432,780)	\$ (432,780)
f. Non-Operating Income							
Interest Income	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Investment Income	-	-	-	-	-	-	-
Interest Expense (Short-Term)	-	-	-	-	-	-	-
Interest Expense (Long-Term))	-	-	-	-	-	-	-
Interest Expense (Internal)	-	-	-	-	-	-	-
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
g. Net Income	\$ (462,540)	\$ (425,590)	\$ (432,780)	\$ (432,780)	\$ (432,780)	\$ (432,780)	\$ (432,780)
h. Taxes	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
i. Net Income After Fees & In Lieu Taxes	\$ (462,540)	\$ (425,590)	\$ (432,780)	\$ (432,780)	\$ (432,780)	\$ (432,780)	\$ (432,780)

City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
June 7, 2015

Cash Flow Statement

Year	1	2	3	4	5	6	7
a. Net Income (From Income Statement)	\$ (462,540)	\$ (425,590)	\$ (432,780)	\$ (432,780)	\$ (432,780)	\$ (432,780)	\$ (432,780)
b. Cash Outflows							
Debt Service Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Interest Reserve	-	-	-	-	-	-	-
Depreciation Operating Reserve	-	-	-	-	-	-	-
Financing	-	-	-	-	-	-	-
Capital Expenditures	\$ (3,324,160)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total	\$ (3,324,160)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
c. Cash Inflows							
Interest Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Depreciation Operating Reserve	-	-	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-	-	-
Short Term Financing	-	-	-	-	-	-	-
Long Term Financing (Bond)	-	-	-	-	-	-	-
Cash Start	-	-	-	-	-	-	-
Internal Loan	-	-	-	-	-	-	-
Internal Funding (non-loan)	3,324,160	-	-	-	-	-	-
Total	\$ 3,324,160	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
d. Total Cash Outflows and Inflows (b+c)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
e. Non-Cash Expenses - Depreciation	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400
f. Adjustments (Proceeds from)							
Short Term Financing	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Long Term Financing (Bond)	-	-	-	-	-	-	-
Internal Loan	-	-	-	-	-	-	-
Internal Funding (non-loan)	(3,324,160)	-	-	-	-	-	-
Total	\$ (3,324,160)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
g. Adjusted Available Net Revenue	\$ (3,343,300)	\$ 17,810	\$ 10,620	\$ 10,620	\$ 10,620	\$ 10,620	\$ 10,620
h. Principal Payments on Debt							
Short Term Bond/Loan Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Long Term Bond Principal	-	-	-	-	-	-	-
Internal Loan Principal	-	-	-	-	-	-	-
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
i. Net Cash	\$ (19,140)	\$ 17,810	\$ 10,620	\$ 10,620	\$ 10,620	\$ 10,620	\$ 10,620
Avoided Costs (see j and k below)	-	-	-	-	-	-	-
Adjusted Net Cash	\$ (19,140)	\$ 17,810	\$ 10,620	\$ 10,620	\$ 10,620	\$ 10,620	\$ 10,620
Cash Balance (Enterprise)							
Unrestricted Cash Balance	\$ (19,140)	\$ (1,330)	\$ 9,290	\$ 19,910	\$ 30,530	\$ 41,150	\$ 51,770
Depreciation Operating Reserve	-	-	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-	-	-
Total Cash Balance	\$ (19,140)	\$ (1,330)	\$ 9,290	\$ 19,910	\$ 30,530	\$ 41,150	\$ 51,770

City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
June 7, 2015

Capital Additions

Year	1	2	3	4	5	6	7
a. Fiber Implementation Costs							
Fiber (30 year depreciation)	\$ 287,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Expansion Fiber (30 year depreciation)	-	-	-	-	-	-	-
Headend and Hub Equipment (10 year depreciation)	-	-	-	-	-	-	-
Headend and Hub Equipment (7 year depreciation)	-	-	-	-	-	-	-
Network Equipment (6 year depreciation)	-	-	-	-	-	-	-
CAI Customer Equipment (6 year depreciation)	-	-	-	-	-	-	-
Total	\$ 287,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
e. Wireless Network Costs (7 year depreciation)							
Microwave (10 year)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Structures (20 year)	-	-	-	-	-	-	-
Access (10 year)	-	-	-	-	-	-	-
Network Equipment (7 year)	1,995,500	-	-	-	-	-	-
Spare Equipment (7 year)	25,000	-	-	-	-	-	-
Installation & Engineering (7 year)	1,016,160	-	-	-	-	-	-
Total	\$ 3,036,660	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
f. Wireless Customer Connection Cost (5 year depreciation)							
CPE	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total Capital	\$ 3,324,160	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
June 7, 2015

Principal and Interest Payments (Year 1 Financing)

	Payment Year	1	2	3	4	5	6	7	Total
Short Term Financing									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Payment	\$ -							
	Loan Amount/Balance (beginning of year)	\$ -	-	-	-	-	-	-	
	Loan Amount/Balance (end of year)	\$ -	-	-	-	-	-	-	
	Payment Start	2							
	Term (years)	7							
	Interest	4.00%							
Long Term Financing (Bond)									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Payment	\$ -							
	Loan Amount/Balance (beginning of year)	\$ -	-	-	-	-	-	-	
	Loan Amount/Balance (end of year)	\$ -	-	-	-	-	-	-	
	Payment Start	2							
	Term (years)	20							
	Interest	4.50%							
Internal Loan									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Payment	\$ -							
	Loan Amount/Balance (beginning of year)	\$ -	-	-	-	-	-	-	
	Loan Amount/Balance (end of year)	\$ -	-	-	-	-	-	-	
	Payment Start	2							
	Term (years)	3							
	Interest	2.00%							
Total									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total (all years)									
	Principal	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Interest	-	-	-	-	-	-	-	-
	Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
June 7, 2015

Depreciation

	Year	1	2	3	4	5	6	7
30 Year Capital Expenditures	\$	287,500	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
20 Year Capital Expenditures		-	-	-	-	-	-	-
10 Year Capital Expenditures		-	-	-	-	-	-	-
7 Year Capital Expenditures		3,036,660	-	-	-	-	-	-
6 Year Capital Expenditures		-	-	-	-	-	-	-
5 Year Capital Expenditures		-	-	-	-	-	-	-
Total	\$	3,324,160	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

	Year	1	2	3	4	5	6	7
Depreciation Total	\$	443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400	\$ 443,400

City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
June 7, 2015

Expenses

Year	1	2	3	4	5	6	7
Expenses							
<i>Operating Expenses</i>							
tbd	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
tbd	-	-	-	-	-	-	-
Marketing	10,000	7,500	7,500	7,500	7,500	7,500	7,500
Legal	10,000	2,500	2,500	2,500	2,500	2,500	2,500
Fiber Lease	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Site Lease	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Maintenance & Monitor	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Equipment Maintenance	-	59,800	59,800	59,800	59,800	59,800	59,800
Fiber Maintenance Fees	\$ 1,440	\$ 7,190	\$ 14,380	\$ 14,380	\$ 14,380	\$ 14,380	\$ 14,380
Contingency	-	-	-	-	-	-	-
Total	\$ 170,440	\$ 225,990	\$ 233,180	\$ 233,180	\$ 233,180	\$ 233,180	\$ 233,180
<i>Operating Expenses - Misc.</i>							
Attachment & Power Fees	\$ 124,200	\$ 124,200	\$ 124,200	\$ 124,200	\$ 124,200	\$ 124,200	\$ 124,200
Education and Training	-	-	-	-	-	-	-
Allowance for Bad Debts	13,000	13,000	13,000	13,000	13,000	13,000	13,000
Customer Acquisition Costs	92,500	-	-	-	-	-	-
Internet Connection Fee	13,000	13,000	13,000	13,000	13,000	13,000	13,000
Utilities	-	-	-	-	-	-	-
Total	\$ 242,700	\$ 150,200	\$ 150,200	\$ 150,200	\$ 150,200	\$ 150,200	\$ 150,200
<i>Taxes</i>							
Dark Fiber & IRU Taxes	-	-	-	-	-	-	-
City and State Taxes	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-
<i>Salary Allocations</i>							
Staff Allocations (Administration & Support)	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000
Total	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000
Grand Total	\$ 463,140	\$ 426,190	\$ 433,380	\$ 433,380	\$ 433,380	\$ 433,380	\$ 433,380

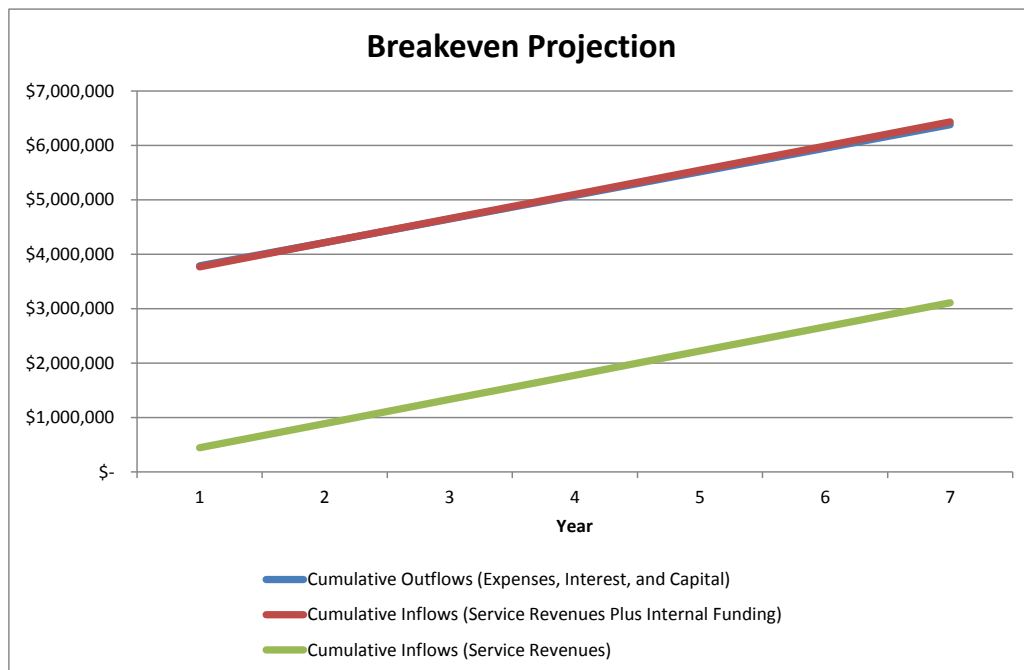
City of Palo Alto
Senerio II b - Blanket Wi-Fi 802.11 ac
Financial Projections Rev 1
June 7, 2015

Revenues - Site Based

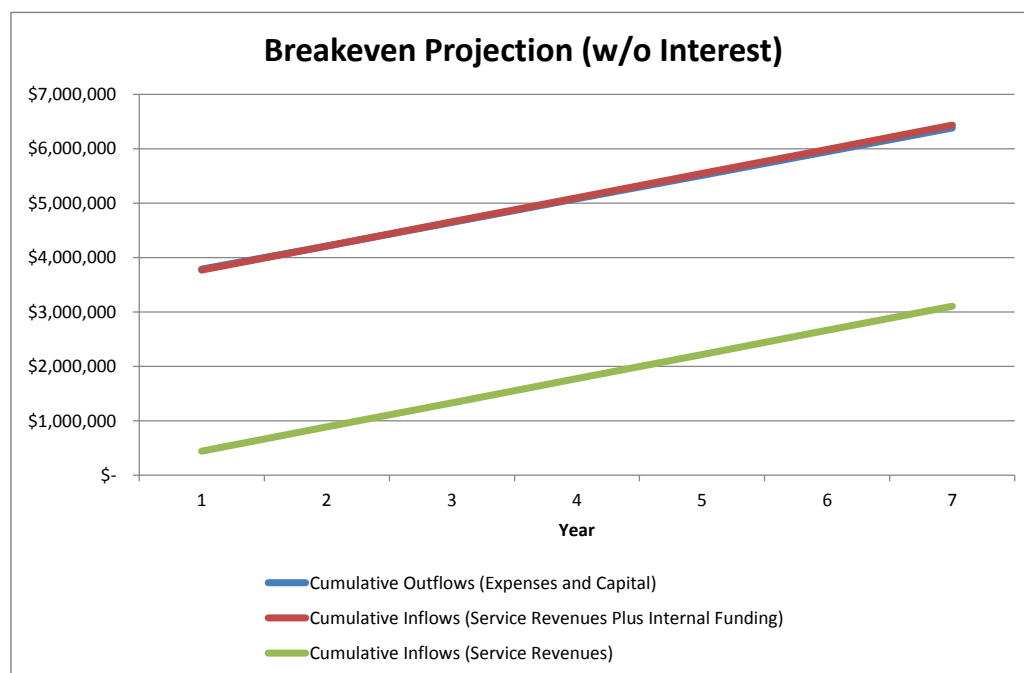
	Year	1	2	3	4	5	6	7
Wireless Connection								
Mobile	\$	444,000	\$	444,000	\$	444,000	\$	444,000
tbd		-		-		-		-
Total	\$	444,000	\$	444,000	\$	444,000	\$	444,000

Breakeven Analysis

Including interest, operating expenses, and capital in cash outflows



Including operating expenses, and capital in cash outflows (interest not included)



Assumptions

Page Title Information

Organization	City of Palo Alto
Plan Name	Senerio II b - Blanket Wi-Fi 802.11 ac
Location	Financial Projections Rev 1
Date	Palo Alto, CA
	June 7, 2015
	Wireless Financial Analysis - Scenario II b

Financial Assumptions

Finance Requirements

Beginning Cash	\$ -									
	Year									
	1	2	3	4	5					
Short Term Financing	\$ -	\$ -	\$ -	\$ -	\$ -					
Long Term Financing (Bond)	-	-	-	-	-					
Internal Loan	-	-	-	-	-					
Internal Funding (non-loan)	3,324,160	-	-	-	-	-	-	-	-	-
Total	\$ 3,324,160	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	Year									
	1	2	3	4	5	6	7	8	9	10
Depreciation Operating Reserve	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Year									
	1	2	3	4	5	6	7	8	9	10
Capital Expenditure Funded by Depreciation Reserve	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Unrestricted Cash Balance	\$ (19,140)	\$ (1,330)	\$ 9,290	\$ 19,910	\$ 30,530	\$ 41,150	\$ 51,770	\$ (368,610)	\$ (788,990)	\$ (1,209,370)
Depreciation Operating Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Debt Service Reserve	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Total Cash Balance	\$ (19,140)	\$ (1,330)	\$ 9,290	\$ 19,910	\$ 30,530	\$ 41,150	\$ 51,770	\$ (368,610)	\$ (788,990)	\$ (1,209,370)

Short Term Financing									
Bonding Finance Rate	4.00%	4.00%	4.00%	4.00%	4.00%				
Period (Years)	7	10	10	7	7				
Principal Repayment Period Start	2	2	2	1	1				
Bond/Loan Issuance Cost	1.00%	1.00%	1.00%	1.00%	1.00%				
Debt Service Reserve	0.00%	0.00%	0.00%	0.00%	0.00%				
Interest Reserve	no	no	no	no	no				
Interest Reserve Year 1 Financing	\$ -	\$ -							
Interest Reserve Year 2 Financing		\$ -	\$ -						
Interest Reserve Year 3 Financing			\$ -	\$ -					
Interest Reserve Year 4 Financing				\$ -	\$ -				
Interest Reserve Year 5 Financing					\$ -	\$ -			
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Long Term Financing (Bond)									
	4.50%	4.50%	4.50%	4.50%	4.50%				
Principal Repayment Period Start	20	20	20	20	20				
Bond Issuance Cost	1.00%	1.00%	1.00%	1.00%	1.00%				
Debt Service Reserve	5.00%	5.00%	5.00%	5.00%	5.00%				
Interest Reserve	yes	yes	yes	yes	yes				
Interest Reserve Year 1 Financing	\$ -	\$ -							
Interest Reserve Year 2 Financing		\$ -	\$ -						
Interest Reserve Year 3 Financing			\$ -	\$ -					
Interest Reserve Year 4 Financing				\$ -	\$ -				
Interest Reserve Year 5 Financing					\$ -	\$ -			
Total	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Internal Loan									
Finance Rate	2.00%	2.00%	2.00%	2.00%	2.00%				
Period (Years)	3	3	3	3	3				
Principal Repayment Period Start	2	2	2	1	1				
Other									
Investment Income	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Interest Earned on Available Cash	0.00%	0.00%	Linked to previous year cash balance		Use one or the other, but not both				
			Linked to depreciation and debt service reserve funds						

Wireless Customers											
		Year									
Wireless Connection		1	2	3	4	5	6	7			
Mobile		1,850	1,850	1,850	1,850	1,850	1,850	1,850			
tbd		-	-	-	-	-	-	-			
Total		1,850	1,850	1,850	1,850	1,850	1,850	1,850			
Incremental		1,850	-	-	-	-	-	-			
		Calculation of Average Speed per Customer									
Enter in speed (Mbps) of each service under year one		1	2	3	4	5	6	7	8	9	10
Wireless - Residential		10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Wireless - Business		10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Average Mbps		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Total Mbps		18,500	18,500	18,500	18,500	18,500	18,500.00	18,500.00	18,500.00	18,500.00	18,500.00
		(19,140)	(1,330)	9,290	19,910	30,530	41,150	51,770			

Wireless Customers												
		Year										
Wireless Connection		1	2	3	4	5	6	7				
Mobile		\$ 20.00	\$ 20.00	\$ 20.00	\$ 20.00	\$ 20.00	\$ 20.00	\$ 20.00				
tbd		\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -				

Operation & Maintenance Expense Assumptions

Taxes										
Dark Fiber & IRU Taxes	0.00%									
City and State Taxes	0.0000%		State	0.0000%		County	0.0000%		City	0.0000%
Sales tax is a pass through expense										
#DIV/0!										
Operating Expenses										
	1	2	3	4	5	6	7	8	9	10
tbd	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
tbd	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Marketing	\$ 10,000	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500	\$ 7,500
Legal	\$ 10,000	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500	\$ 2,500
Fiber Lease	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000
Site Lease	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000	\$ 24,000
Maintenance & Monitor	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000	\$ 75,000
Equipment Maintenance	\$ -	\$ 59,800	\$ 59,800	\$ 59,800	\$ 59,800	\$ 59,800	\$ 59,800	\$ 59,800	\$ 59,800	\$ 59,800
Fiber Maintenance Fees	\$ 1,440	\$ 7,190	\$ 14,380	\$ 14,380	\$ 14,380	\$ 14,380	\$ 14,380	\$ 14,380	\$ 14,380	\$ 14,380
Fiber Maintenance Fees (percentage of cumulative cost)	0.50%	2.50%	5.00%							
Contingency	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Operating Expenses - Misc.										
Allowance for Bad Debts	3.00%	of GPON, MetroE, and wireless services								
Customer Acquisition Costs	\$ 50.00	per Wireless Customer								
	1	2	3	4	5	6	7	8	9	10
DIA Sales (Mbps) (for MAN customers)	0	0	0	0	0	0	0	0	0	0
DIA Sell price	\$ 20.00	per Mbps per month								
	1	2	3	4	5	6	7	8	9	10
Internet Connection Fee	\$ 13,000	\$ 13,000	\$ 13,000	\$ 13,000	\$ 13,000	\$ 13,000	\$ 13,000	\$ 13,000	\$ 13,000	\$ 13,000
DIA for Services										
per Mbps per month	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50
oversubscription ratio	25	25	25	25	25	25	25	25	25	25
Internal Use										
Mbps Available for Internal (total)	-	-	-	-	-	-	-	-	-	-
per Mbps per month	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50	\$ 1.50
Total Cost Annual	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	1	2	3	4	5	6	7	8	9	10
Total BW used internally (Mbps)	-	-	-	-	-	-	-	-	-	-
Available BW to apply to other users	-	-	-	-	-	-	-	-	-	-
Needed for Wireless users	740	740	740	740	740	740	740	740	740	740
Net required for other users	740	740	740	740	740	740	740	740	740	740
Attachment & Power Fees										
	575	attachments at		\$ 216.00	per year		\$ 18.00	per month		
	1	2	3	4	5	6	7	8	9	10
Utilities	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

Salaries (Calculation Base 4)

Annual escalation 0.00% Above what rate increases are (applied to the FTE's only - first five rows of table below)

	1	2	3	4	5	6	7	8	9	10
Staff Allocations (Administration & Support)	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000
FTE (2)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
FTE (3)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
FTE (4)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
FTE (5)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
TBD	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
TBD	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
TBD	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000	\$ 50,000

Capital Requirement Assumptions**Miscellaneous Costs**

Misc. Equipment	\$ -	\$ -	\$ -		100%	year 6
tbd 1	\$ -	\$ -	\$ -		100%	year 6
tbd 2	\$ -	\$ -	\$ -		100%	year 6
tbd 3	\$ -	\$ -	\$ -		100%	year 6
tbd 4	\$ -	\$ -	\$ -		100%	year 6
tbd 5	\$ -	\$ -	\$ -		100%	year 6
tbd 6	\$ -	\$ -	\$ -		100%	year 8
Additional Annual Capital Costs	0.00%	Percent of Year 1 to Year 3 fiber implementation costs		Starts in year 4		

Implementation Costs

Base Network	1	2	3	4	5	Year 1 Build	Year 2 Build	Total
Fiber (30 year depreciation)	\$ 287,500	\$ -	\$ -			100%	0%	\$ 287,500
Headend and Hub Equipment (10 year depreciation)	\$ -	\$ -	\$ -			100%	0%	\$ -
Headend and Hub Equipment (7 year depreciation)	\$ -	\$ -	\$ -			100%	0%	\$ -
Network Equipment (6 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -			
CAI Customer Equipment (6 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -			
Customer pay?	Yes		For Years 1 to 5		Yes	For Replenishments		
Incremental A								
Fiber (30 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
Headend and Hub Equipment (10 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
Headend and Hub Equipment (7 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
Network Equipment (6 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
CAI Customer Equipment (6 year depreciation)	\$ -	\$ -	\$ -			40%	45%	\$ -
Incremental B								
Fiber (30 year depreciation)	\$ -	\$ -	\$ -		\$ -			\$ -
Headend and Hub Equipment (10 year depreciation)	\$ -	\$ -	\$ -		\$ -			\$ -
Headend and Hub Equipment (7 year depreciation)	\$ -	\$ -	\$ -		\$ -			\$ -
Network Equipment (6 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -			\$ -
CAI Customer Equipment (6 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -			\$ -
Total Network						Replacement		
Fiber (30 year depreciation)	\$ 287,500	\$ -	\$ -					
Headend and Hub Equipment (10 year depreciation)	-	-	-			100%	Year 11	
Headend and Hub Equipment (7 year depreciation)	-	-	-			100%	year 8	
Network Equipment (6 year depreciation)	-	-	-	-	-	100%	year 8	
CAI Customer Equipment (6 year depreciation)	-	-	-	-	-	100%	year 8	
Business Development & Support Engineering	\$ -	\$ -	\$ -					
	\$ 287,500	\$ -	\$ -	\$ -	\$ -			
Other Misc.								
Administration	\$ -	\$ -	\$ -	na	na	na	na	na
Operation and Network Equipment	\$ -	\$ -	\$ -	na	na	na	na	na
Expansion Fiber (30 year depreciation)	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Fiber (Accrued)	\$ 287,500	\$ 287,500	\$ 287,500					
Network Equipment (Accrued)	\$ -	\$ -	\$ -					
Business Development & Support (Accrued)	\$ -	\$ -	\$ -					
			\$ 287,500					

Wireless

Microwave (10 year)	\$ -	\$ -	\$ -	
Structures (20 year)	\$ -	\$ -	\$ -	
Access (10 year)	\$ -	\$ -	\$ -	

Network Equipment (7 year)	\$	1,995,500	\$	-	\$	-
Spare Equipment (7 year)	\$	25,000	\$	-	\$	-
Installation & Engineering (7 year)	\$	1,016,160	\$	-	\$	-
Total	\$	3,036,660	\$	-	\$	-
Accrued	\$	3,036,660	\$	3,036,660	\$	3,036,660

0%	year 8
0%	year 8
0%	year 8

#REF!

#REF!

Senerio II b - Blanket Wi-Fi 802.11 ac

18 month construction timeframe - Using FTTP backhaul (cost for FTTP distribution not included)

Parameters	802.11 g/n
Total Areas Sq. Mi.	11.5
Access Points/Sq. Mi	50
Outdoor Routers	575

Capital Costs

Fiber Access drops	\$	1,495,000	x
Backup power	\$	345,000	x
Fiber Core Electronics	\$	155,500	x
Fiber drops	\$	287,500	x
Installation	\$	743,750	x
Engineering & Oversight	\$	272,410	x
Capital Cost	\$	3,026,750	
	\$	3,299,160	

Capital Cost (Unit)

Wireless AP Hardware Cost	\$	2,100
Battery Backup Cost	\$	600
Fiber plant - service drop	\$	500
Fiber Core Electronics	\$	155,500
AC Power	\$	500

Installation Cost (Unit)

AP - Router & Power	1250
Fiber Hub Electronics	25000

Operating Expenses (yr)

Site Lease	24000	x
Equipment Maintenance	\$ 59,800	x
Fiber Lease	50000	x
Site Power \$18/mo./site	\$ 124,200	x
Maintenance & Monitor	\$ 75,000	x



EXCERPTED DRAFT MINUTES OF THE SEPTEMBER 2, 2015 UTILITIES ADVISORY COMMISSION MEETING

NEW BUSINESS

ITEM 1: ACTION: Staff Recommendation that the Utilities Advisory Commission Recommend that the City Council Defer Issuing a Request for Information on Partnership Opportunities for a Fiber-to-the-Premise Network; Issue a Request for Proposal(s) to Expand Wi-Fi Coverage to City Facilities and Public Areas, and Improve Wireless Communications for Public Safety and Utilities

Chief Information Officer Jonathan Reichental presented an update on the technological advancements in the telecommunication marketplace. There has been a lot of broadband and Internet activity since 1999 when the initial FTTP study was completed. There is an emergence of cellular technologies. Currently, 4G service allows download speed up to 12MB. There is a consortium developing 5G service, which will enable download speed of 1GB to 10GB, but 5G will probably not be available until 2020. *Smart cities* are paying attention to the emergence of the so-called “*Internet of Things*” (“IoT”), which connects people and various applications and devices (e.g. thermostats, traffic signals and multiple household appliances) to the Internet over ultra-high speed broadband connections. These innovations will change how people live and navigate within their everyday environment and will require the support of next-generation fiber networks, in addition to ubiquitous wireless connectivity in an increasingly mobile society.

Todd Henderson, Senior Technologist from the Information Technology Department and Jim Fleming, Senior Management Analyst from the Utilities Department made the staff presentation. Todd provided an update on Google Fiber. Palo Alto is one of 34 cities around the country being considered for Google Fiber. In May 2014, the City completed the Google fiber checklist. The City continues to have meetings with Google regarding a potential fiber deployment in Palo Alto. These meetings are currently focused on the California Environmental Quality Act (CEQA) and the City’s permitting processes for use of the public rights-of-way, utility pole attachments, conduit usage and dark fiber licensing. Staff anticipates Google will make a final decision on the San Jose metro area (Palo Alto, Mountain View, Santa Clara, Sunnyvale and San Jose) sometime this fall.

In May 2015, AT&T approached the City with intentions to bring GigaPower to Palo Alto. GigaPower will provide gigabit broadband and voice-over-IP services to residents, but will not include television programming, which will stay on their existing U-Verse system. The first phase of AT&T’s GigaPower deployment will install 27 new cabinets in Palo Alto that will be placed next to existing U-verse cabinets. AT&T has provided a sample permit application to the

Public Works Department for review. AT&T plans to begin construction in Q4 2015 and offer service sometime next year.

Fleming presented the scope of work, findings, and recommendations for the Fiber-to-the-Premises (FTTP) Master Plan study conducted by CTC Technology & Energy (CTC). Fleming highlighted some of the key findings from the report. The required customer take rate is between 57% - 72% depending on whether or not the City elects to use \$20 million from the Fiber Reserves to build and operate a city-owned FTTP network on a positive cash flow basis. The total capital investment to build the network is \$77.6 million over three years. Several factors make the required take rate and build costs higher in the Bay Area for an FTTP overbuilder (e.g. high cost of labor and materials, utility pole "make ready" requirements and replacement of utility poles). The report recommended the City not pursue a "for choice" retail broadband service. Traditional cable TV service should not be part of any offering due to the high cost of cable TV programming and consumer migration away from traditional pay-TV services offered by multi-channel video providers to "over-the-top" streaming video offerings such as Netflix. Incumbent telecommunications providers will use aggressive tactics to undermine a municipal network and customer acquisition initiatives. FTTP overbuilds by public or private entities generally do not offer an adequate return on investment, particularly in communities already well-served by the incumbent Internet service providers (ISPs). Using a public-private partnership model for FTTP deployment takes advantage of each entity's strengths and may reduce the risk of an overbuild in a competitive market. Through a RFI process, the City should explore three potential public-private partnership models.

Fleming presented the scope of work, findings, and recommendations for the wireless network plan conducted by CTC Technology & Energy. CTC made four recommendations:

1. Expand existing City Wi-Fi to other City facilities and adjoining public areas not currently served.
2. Install dedicated wireless facilities to address communication needs of Public Safety and Utilities.
3. Deploy a citywide mobile data network for public safety and other authorized users.
4. Consider citywide Wi-Fi for general public use, but deployment dependent on citywide fiber expansion. Wireless provides a mobility component to the fiber-optic

At the end of the presentations, staff made two recommendations. First, defer issuing an RFI to evaluate public-private partnership opportunities for FTTP until after December 31, 2015. Second, issue RFP(s) to expand Wi-Fi to improve wireless communications for Public Safety and Utilities and to expand coverage to City facilities and public areas not currently served by the City's existing Wi-Fi network.

Public Comment

Jeff Hoel sent comments on the first 111 pages of the FTTC report. One week is not enough time for the public to provide comment due to the length of the reports. Hoel does not agree with the estimated cost and some of the details in the report. The estimated cost is too high.

The estimated cost for premise connections is five times too high. The cost of living in the Bay Area does not support those estimates.

Herb Borock recognized the importance of data and is glad the City is addressing it. He does not agree with CTC's recommendation to provide Active Ethernet to small businesses, instead it should be targeting homes. This approach may cannibalize the existing "value added resellers" currently licensing dark fiber from the City. Google hired CTC to conduct a study on streamlining cities processes. Herb does not agree with a partnership model. The City should use the Fiber Fund to pay for drop cables and customers can pay for home connections. Active Ethernet is better than GPON for residents. A wireless survey was recently conducted and less than 10% of respondents thought it was important for the City to provide Wi-Fi service.

Bob Harrington presented a memorandum addressed to the UAC and the City of Palo Alto titled *"FTTP is critical to Palo Alto infrastructure."* This memorandum was written by Harrington, Andy Poggio and Christine Moe, members of the City's FTTP/Wireless Citizen Advisory Committee. In summary, FTTP is critical to Palo Alto because the City is situated in Silicon Valley with many startups; city-owned utilities is valuable and cost effective; emergency services and utilities can perform and respond better; universal access guaranteed by the City; and, City independence for fiber infrastructure will foster competition. Metcalfe's Law says that the number of Internet users is growing exponentially; redundancy will provide fail-safe protection. Harrington recommended that FTTP's goals are to provide universal access to all City residents and businesses. The memorandum recommended that the Council direct staff to immediately negotiate with potential private partners to build a city-owned FTTP network, and limit wireless investment to Public Safety and Utilities.

Commissioner Comments

Chair Foster asked Harrington, "Do you not fully agree with staff's recommendations?" Harrington replied that the City should start to negotiate immediately with the providers for a "co-build with a private network" approach.

Commissioner Schwartz asked Harrington about universal access and if he has any research regarding the percentage of homes in Palo Alto that do not have access to internet access. Harrington replied that he thought it was about 10 percent, but he does not really know for sure.

Commissioner Schwartz said the subcommittee meetings and reports provided a thoughtful review including what happened historically, what is different now, and emerging technologies. The fiber subcommittee supported staff's recommendation of waiting a few months because it will provide time for the major players to make their decision on whether or not they're really coming to Palo Alto. We also need to evaluate the cost of providing universal access. Would it be less expensive for the City to assist low income residences with broadband access rather than building its own network? Commissioner Schwartz stated that the idea to upgrade fiber for Utilities and Public Safety is good. There is a feeling that the City may not have a lot of leverage to negotiate with providers; we may not be able to get anything out of them.

Commissioner Schwartz asked a question about VTA rolling out fiber. Fleming replied that many transportation agencies are upgrading their systems with Wi-Fi capabilities for use by riders.

Commissioner Danaher agreed with Harrington that there is a need for high-speed Internet. The report was well done, but it was completed in June. The market has changed since then. Staff should get more information in the next 60 days. It makes sense to wait and collect more information. Commissioner Danaher also asked what the City can do to assure citywide coverage and affordable rates. Since connection fees may be expensive, can customers pay off the cost over time through their utility bills?

Commissioner Eglash stated that broadband is an important subject. He is impressed that we agree on the vision and goals of gigabit service, entrepreneurship and quality of life, but disagree on tactics. There is an open question about what the City does and what the private sector does. It's hard to know what the right line is between the public and private sectors. Utilities provides uniform service. Most of the City has access to broadband. Commissioner Eglash believes the recommendation to support Public Safety is terrific. Commissioner Eglash stated he has no concern about the extended delay for issuing the RFI to evaluate a public-private partnership. Everyone is committed and the delay could be valuable. There needs to be an assurance that gigabit broadband is available to the entire city. Staff should look at cities where Google has already deployed fiber in that regard. Commissioner Eglash asked how universal access works in these Google cities. Fleming replied that Google has done a good job with "digital inclusion" programs in all of the cities they've worked with to deploy fiber optics (e.g. slower speed, low cost broadband service tier for low-income residents). Google's goal is to serve all communities with their networks.

Vice Chair Cook stated that it's no longer 1999 or 2012 and we have to move forward. It is time for a consensus to take some action as Council Member Kniss has previously suggested. There is a risk of obsolescence with any technology. City may commit funds and then the network is obsolete. Don't want to create a stranded asset. Vice Chair Cook asked a question about what appears to be contradictory information about Wi-Fi versus 5G. Reichental answered that they are two separate technologies and that the projected target date for implementation of 5G is 2020. Vice Chair Cook asked about the concept of a fiber build-out being married to undergrounding of electric utilities. Vice Chair Cook asked whether we could ensure that when fiber is installed underground, the electric utility could also be undergrounded. Fong explained that generally the electric utility leads and the fiber utility follows so when electric facilities are undergrounded, fiber follows underground, and when electric facilities are constructed overhead on utility poles, fiber is also constructed overhead. This is because the construction of electric utilities tends to be far more involved than construction of fiber facilities. Vice Chair Cook is in favor of the public safety and emergency service Wi-Fi recommendations.

Vice Chair Cook agrees with Harrington's memo advocating utility independence and limiting wireless investment until the fiber issue is resolved. He prefers to see the fiber initiative move as quickly as possible.

Commissioner Hall asked if the FTTP model in the report is similar to the electric transmission open access network where the City or some entity would own the pathway and end-lighting but not be involved with the content. The content providers would be allowed to compete with one another. Commissioner Hall asked what the \$70 per month charge mentioned in the report is for fiber access only and not content. Fleming clarified that in a closed network, the customer would pay a flat fee for both access and content. Commissioner Hall asked how we would ensure universal access for everyone. Fleming replied that within the RFI, services will be costed out and may depend on which private partner the City negotiates with for FTTP. For example, Google provides a low end service for those who cannot afford the regular service. It's essentially free for seven years but the customer is required to pay a connection fee which can be spread out over time. Some models only build where there is a high rate of return on investment. Commissioner Hall said that it is his sense the UAC wants a pathway to universal access. Commissioner Hall asked if the City had to contribute a significant amount of money to ensure universal access which would eventually be recovered on utility bills, would it require a public poll or referendum or does City Council have the authority to mandate? City Attorney Molly Stump replied that more research needs to be done depending on the type of model and partnership.

Commissioner Ballantine stated that he was torn on several points. Universal access makes sense but how do we achieve it. In terms of point #8 on Harrington's memo ("*The right thing to do right now*"), is there an opportunity to capitalize on a public private partnership or would this be a missed opportunity. How does the City set up infrastructure like fiber and maintain it? Pipes and power lines do not change out very often. Internet infrastructure is typically replaced every 2 to 3 years. If residents are disappointed by wired connections they may go to wireless services. The better purchased wireless device offers better connectivity, so it's not universal access. There needs to be a fourth bullet on slide 9 of staff's presentation or CTC's recommendation to ensure universal access while exploring the partnership models.

Commissioner Danaher said that we're still gathering a lot of new information. By end of the year, we may decide a partnership model may not make sense. In the meantime, we should think of ways to incent providers who are currently interested in building out a network we want. We have an opportunity to think creatively over the next few months.

Chair Foster stated that in 2012, staff and the UAC concluded that FTTP build costs and required take rate were too high, and that financial risk worried people. What is different now is that Google, AT&T, etc. are changing the market. If AT&T and Google come to Palo Alto it may be the end of municipal FTTP in Palo Alto. The only way to proceed is if the Council does something bold such as approaching FTTP as a "public benefit" by issuing a referendum of a city funded FTTP and letting the voters decide. This approach would eliminate concerns about the take rate issue. How do we get to resolution? The staff report recommends delaying the

issuance of an RFI for a municipal FTTP and expanding Wi-Fi to emergency responders and City facilities including public areas. However, Harrington's memo is significantly different which states the goal of FTTP is to connect all households to a city-owned network, negotiate immediately with private partners to build a city network, and limit Wi-Fi to emergency responders only.

Commissioner Eglash stated that the RFP for Wi-Fi for Public Safety and Utilities should be separate from city facilities and parks.

ACTION:

Two motions were passed as follows:

On the matter of municipal Wi-Fi, Vice Chair Cook moved and Chair Foster seconded a motion to recommend that Council direct staff to:

Issue Request for Proposal(s) (RFP) to add dedicated wireless facilities to improve communications for Public Safety and Utilities departments; and optionally for expanding Wi-Fi coverage of City facilities and public areas.

The Commission's vote was 7-0 in favor of the motion with all Commissioners participating.

On the matter of municipal FTTP, Chair Foster moved and Vice Chair Cook seconded the recommendation that Council direct staff to recommend that the Council (1) adopt the goal of making FTTP connections to a fiber network available to all Palo Alto premises as soon as reasonably possible (potentially negotiate co-build with a private network); (2) defer issuing a Request for Information (RFI) until after December 31, 2015 to determine interest from the private sector in partnering with the City to build and operate a citywide fiber-to-the-premises (FTTP) network. The intervening time between now and the end of the year should enable emerging gigabit broadband services from the private sector to be settled; (3) during the time between now and end of year, direct staff to look at possibility of offering a city-owned FTTP as a public benefit; 4) direct staff to negotiate with private ISPs to obtain their assistance with a build out of a city-owned network while City assists them with their private network build out.

Commissioner Eglash moved and Commissioner Hall seconded a substitute motion to recommend Council direct staff to:

1) Defer issuing a Request for Information (RFI) until after December 31, 2015 to determine interest from the private sector in partnering with the City to build and operate a citywide fiber-to-the-premises (FTTP) network. The intervening time between now and the end of the year should enable emerging gigabit broadband services from the private sector to be settled 2) During the time between now and end of year, direct staff to evaluate the public benefit option of offering a city-owned FTTP.

The substitute motion passed on a 4-3 vote in favor with Commissioners Eglash, Hall, Danaher and Schwartz voting for the motion and Chair Foster, Vice Chair Cook and Commissioner Ballantine voting against the motion obviating the need for a vote on the original FTTP motion.

DRAFT