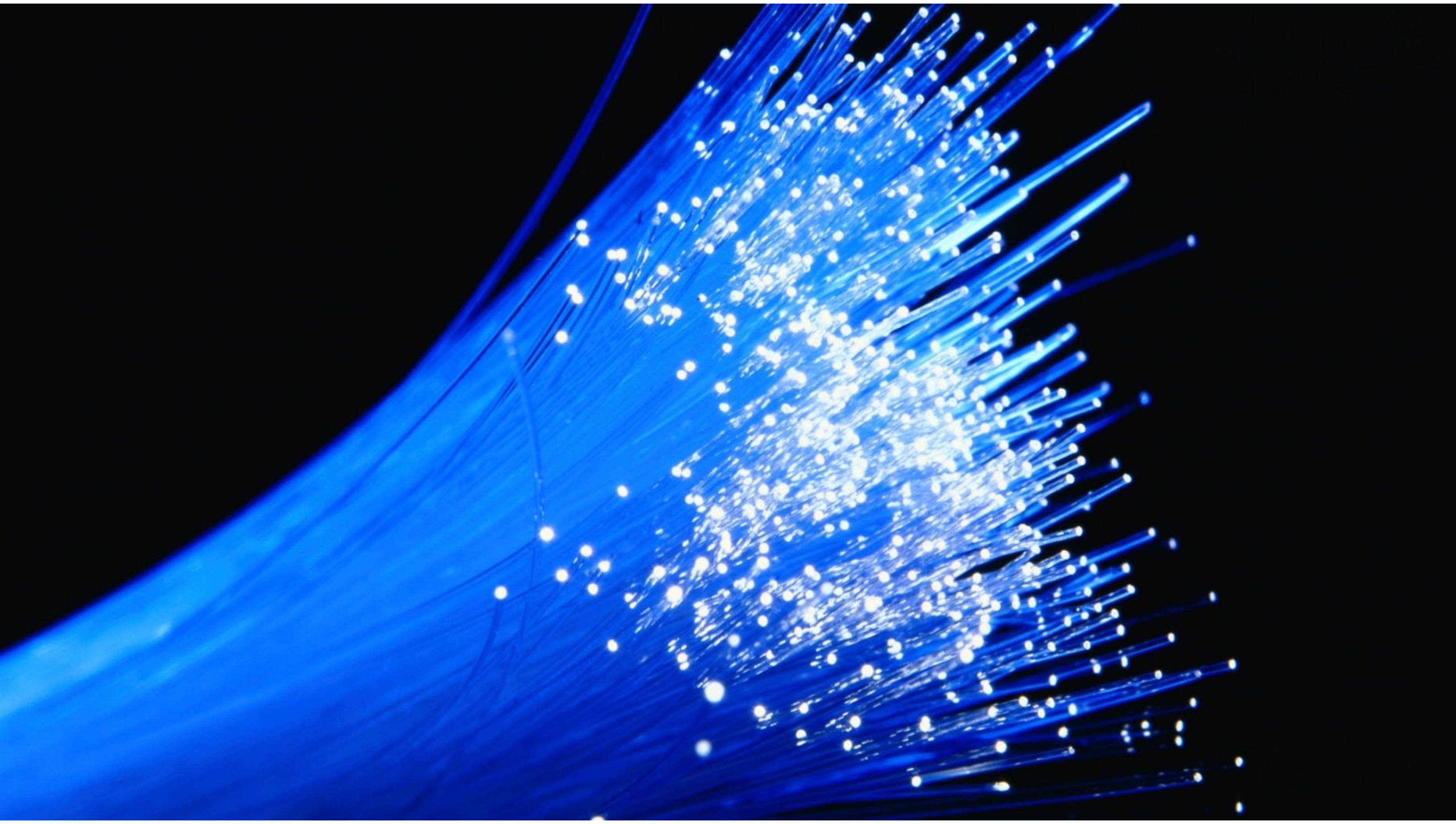
ctc technology & energy

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

Figures

Tables

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 overbuild[7]
- 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, AT&T

[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.

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 City, Kansas and Austin,

---

[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.

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

---

[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.

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

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 2014[19] 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 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.

---

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

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

[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.

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 cables[28] 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 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

[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 ot found.**.

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.

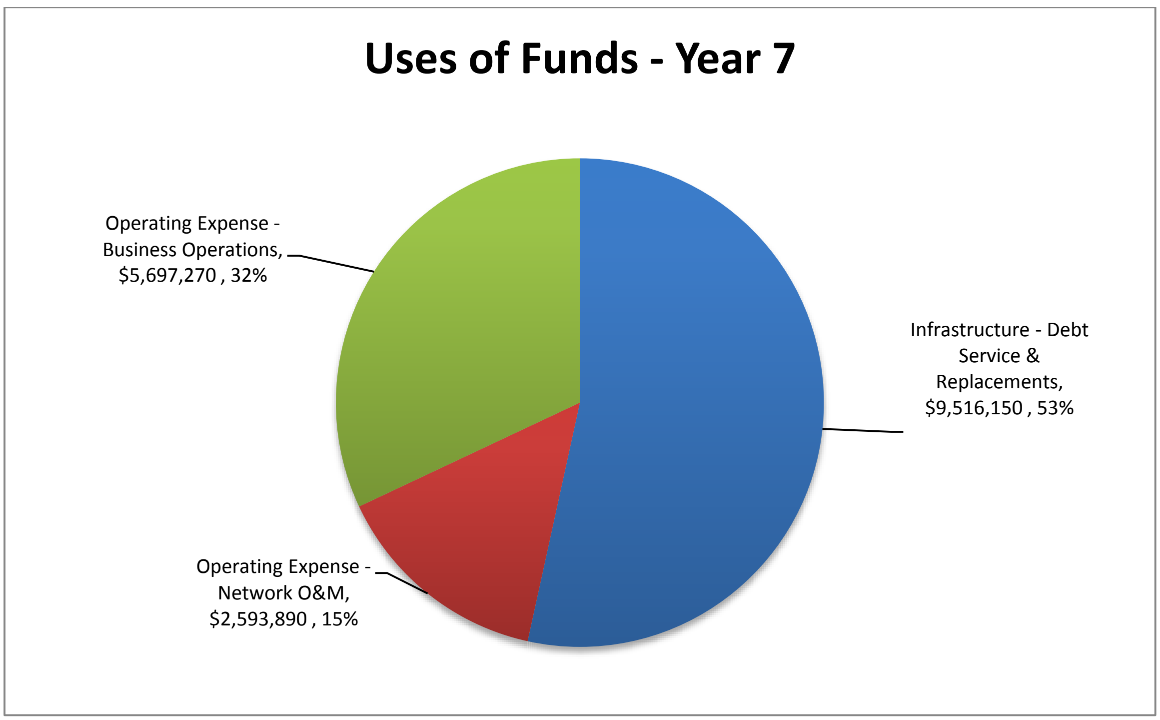
Absent a private entity building and operating an FTTP network with unfettered data access, we recommend that the City consider pursuing a public–private partnership that leverages each party's strengths, shares financial risks, and provides unfettered data access to the community. These recommendations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

1.5 Breakdown of How Capital and Operations Funds Are Allocated

To further illustrate potential City FTTP 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 FTTP 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



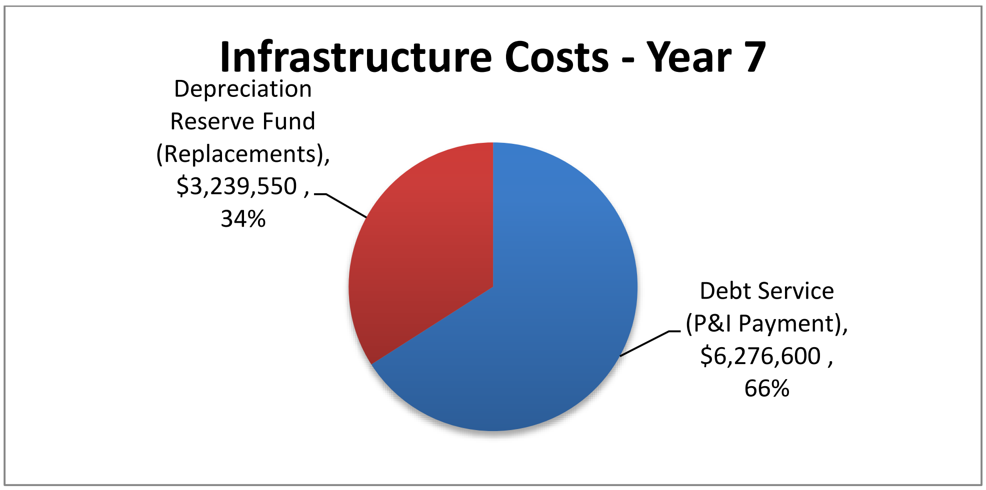
Of the remaining uses of funds, 32 percent is estimated for operating the business and 15 percent is estimated for network maintenance (fiber and electronics).

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

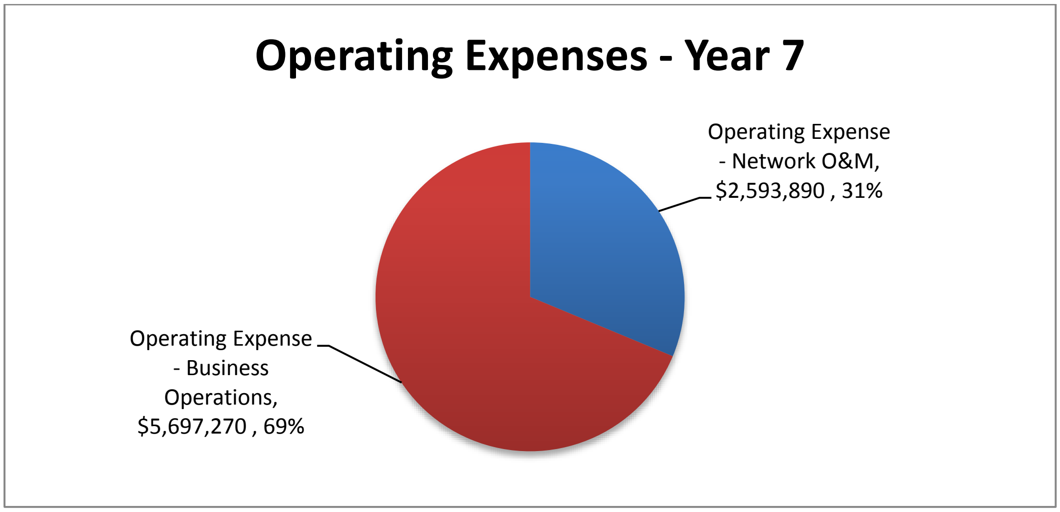
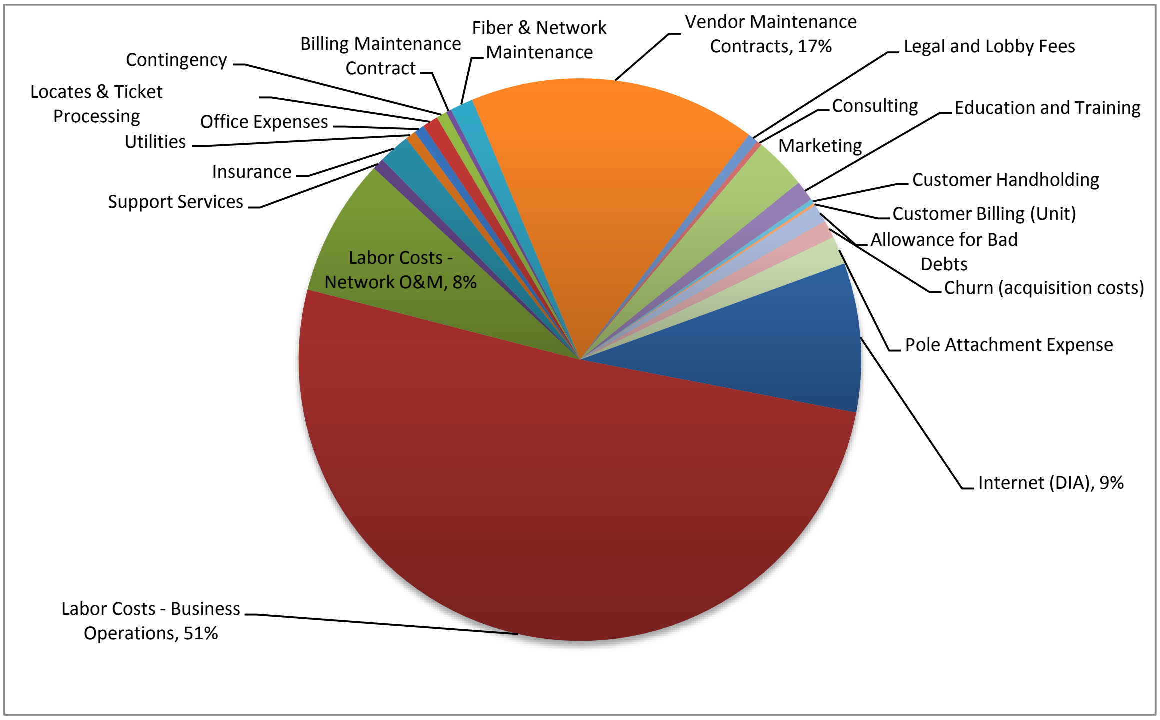


Figure 4 further breaks down the estimated operating expenses. Labor costs for business operations expenses account for 51 percent of all operating expenses, which reflects the high cost of labor in the City. As we noted, private providers are at an advantage because they can generally leverage existing 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 partners

[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.

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 Gbps[33] 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 elicit a partner, or if for some reason negotiations with a potential partner do not pan out, the City will

[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).

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

[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

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.

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.

[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.

These are all examples of OTT[42] 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 FTTP 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 FTTP 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 have access to important information to keep operations running smoothly, even when they are away from the office.

---

[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.

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

[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.

a range of services through the same physical medium, requiring only an 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

---

[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.

electronics and backup power that may be necessary to provide the level of secure service 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 access[54] 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 network in terms of performance, reliability, and consumer perceptions based on providers' marketing.

[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.

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 ration's 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

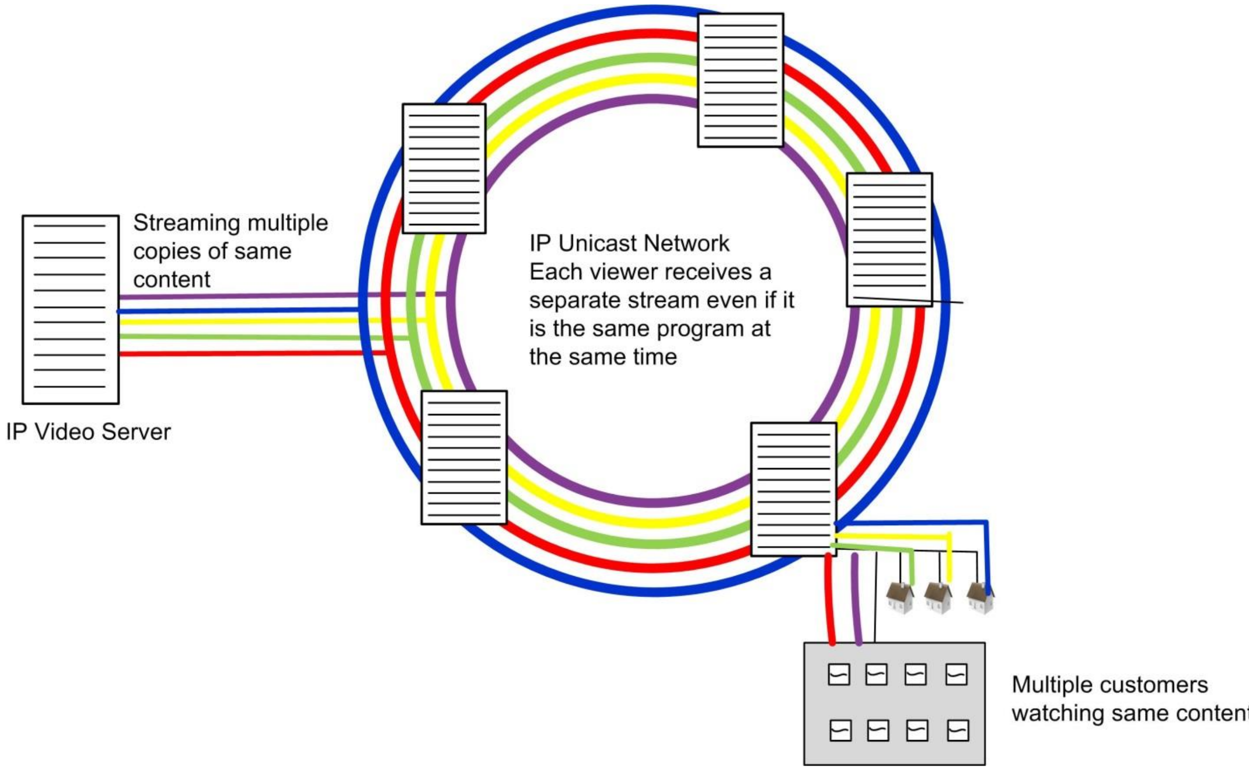
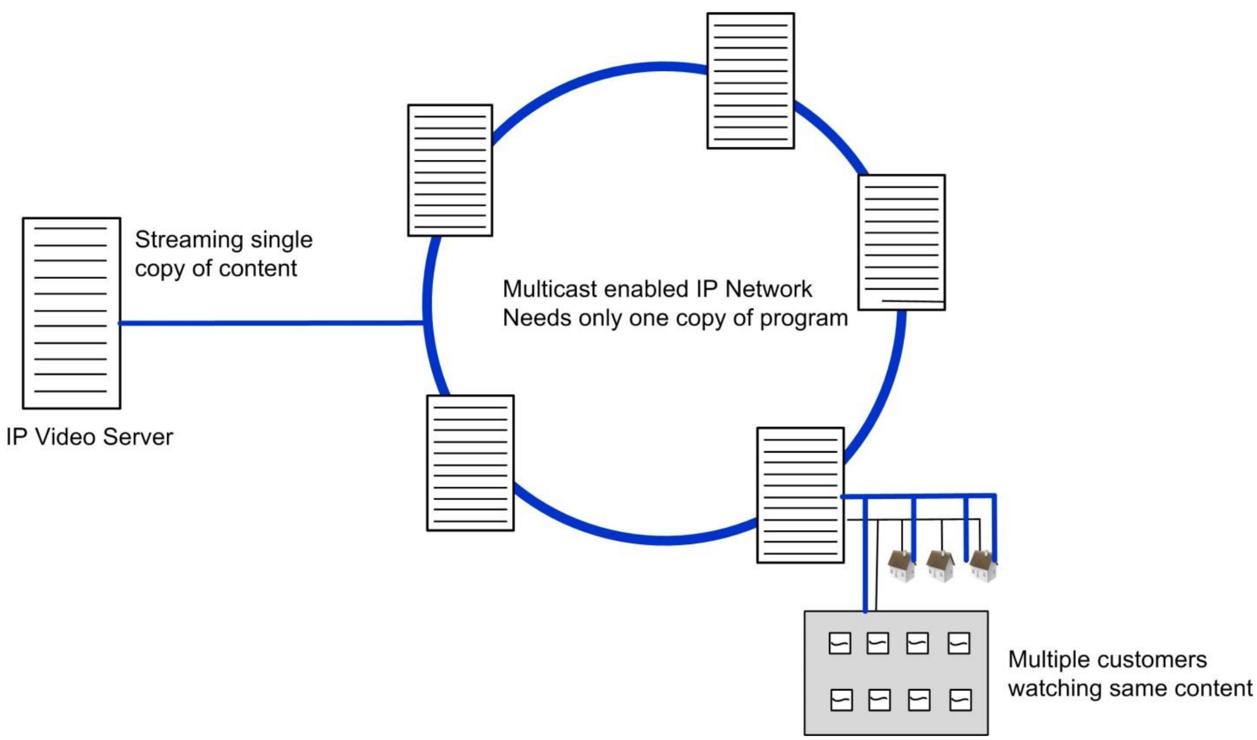


Figure 6: Multicast IP Network Carries Single Copy of Single Video Channel



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.

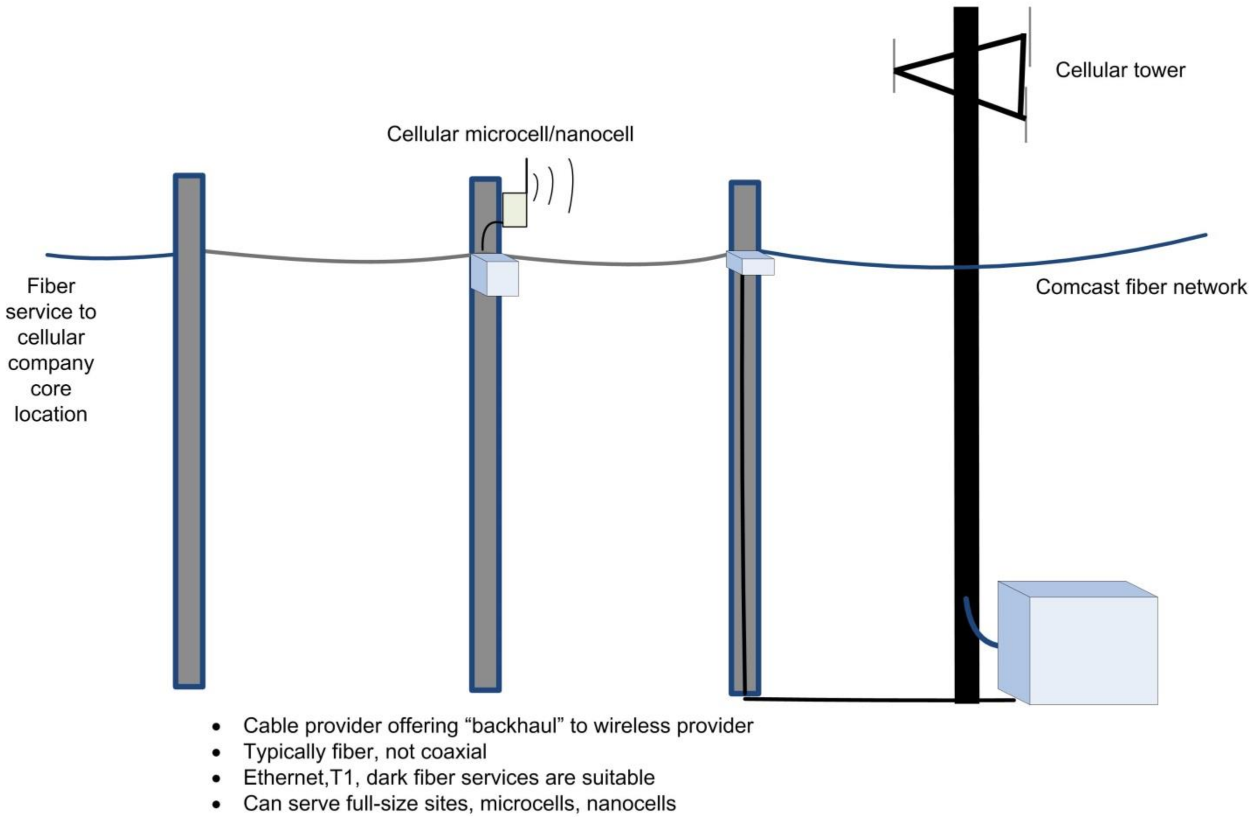
---

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.

[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.

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.

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 Gbps[78]—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

[78] "802.11ac:The fifth Generation of Wi-Fi Technical White Paper," Technical White Paper, Cisco Systems, August 2012

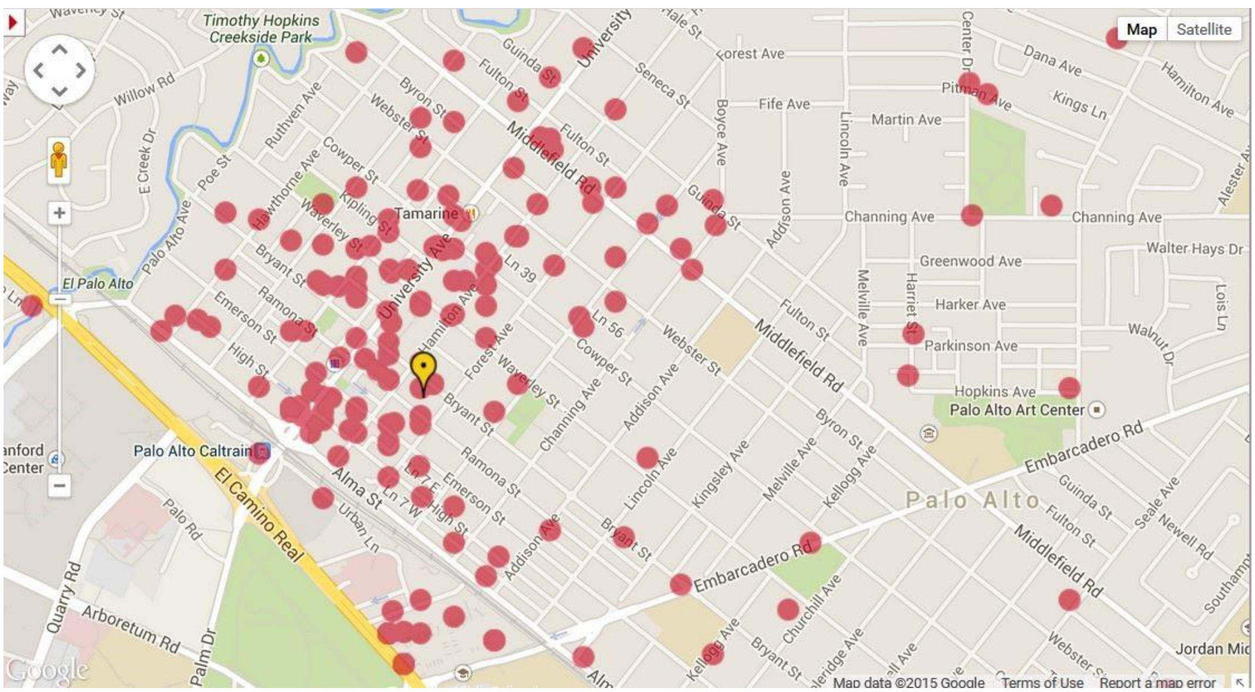
[79] "Amendments in IEEE 802.11ad enable Multi-gigabit throughput and groundbreaking capacity," IEEE Standards Association, January 8, 2013, http://standards.ieee.org/news/2013/802.11ad.html, and "Samsung Develops 802.11 AD Wi-Fi, But Will it be Sunk by Poor Penetration?" *DailyTech*, October 14, 2014,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

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.

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]

In June 2013, Comcast launched a "homespot" network[81] 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.

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

[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 percent[83] 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.

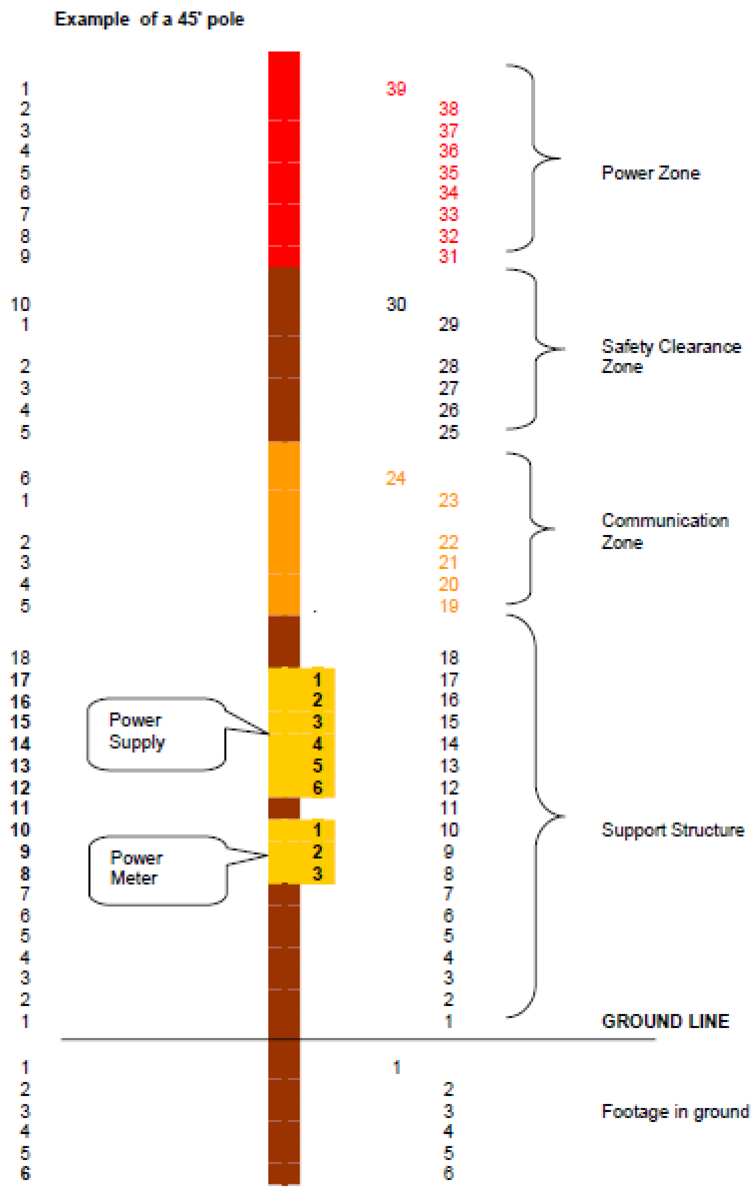
It is important to note that in addition to the backbone there is a considerable presence of fiber optic lateral connections, or "drop cables." Drop cables connect the backbone to the customer premises. Often the drop cables provide additional access to customers as they may provide at least supplemental 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 FTTP 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 some[86] 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 limited ability

[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.

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	10
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 FTTP. Further, permits are likely to be mostly unnecessary for the FTTP enterprise. Only powered devices in the right-of-way (ROW) require permitting and our expectation is that most of the FTTP 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 FTTP 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 FTTP 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.

[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.

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 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

Factor	Technology			
	Active Ethernet (AE)	Passive Optical Networking (PON)		
		GPON	10G-PON	WDM-PON
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
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

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

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 electronics[100] 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] 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

[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, 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.

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 fiber[104] 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 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

[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.

[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.

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.

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]

[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).

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 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.

---

[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/

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

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 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).

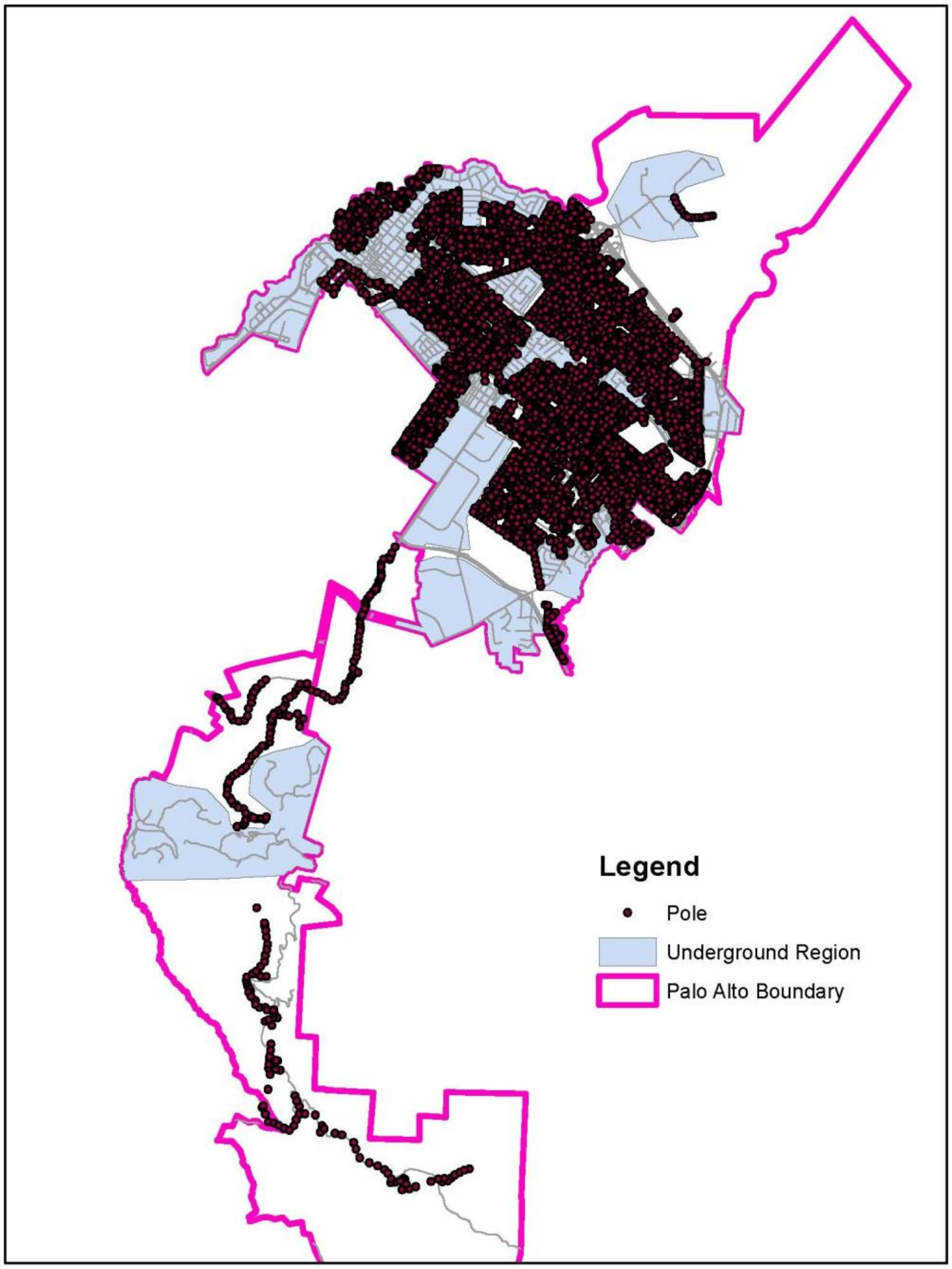
The majority of the City has aerial utilities and therefore aerial plant is a key part a citywide fiber network. Aerial plant is typically less expensive to build than underground plant, and in Palo Alto this is especially the case.[117] The City has the exclusive right to place fiber in a designated 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 CPAU staff.) Having

---

[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 restricted space, but reserved for use by the power utility. In the Palo Alto power space, construction and

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



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.

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

[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.

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

[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.

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 passing[123] 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.

[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 buildings[126] 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.

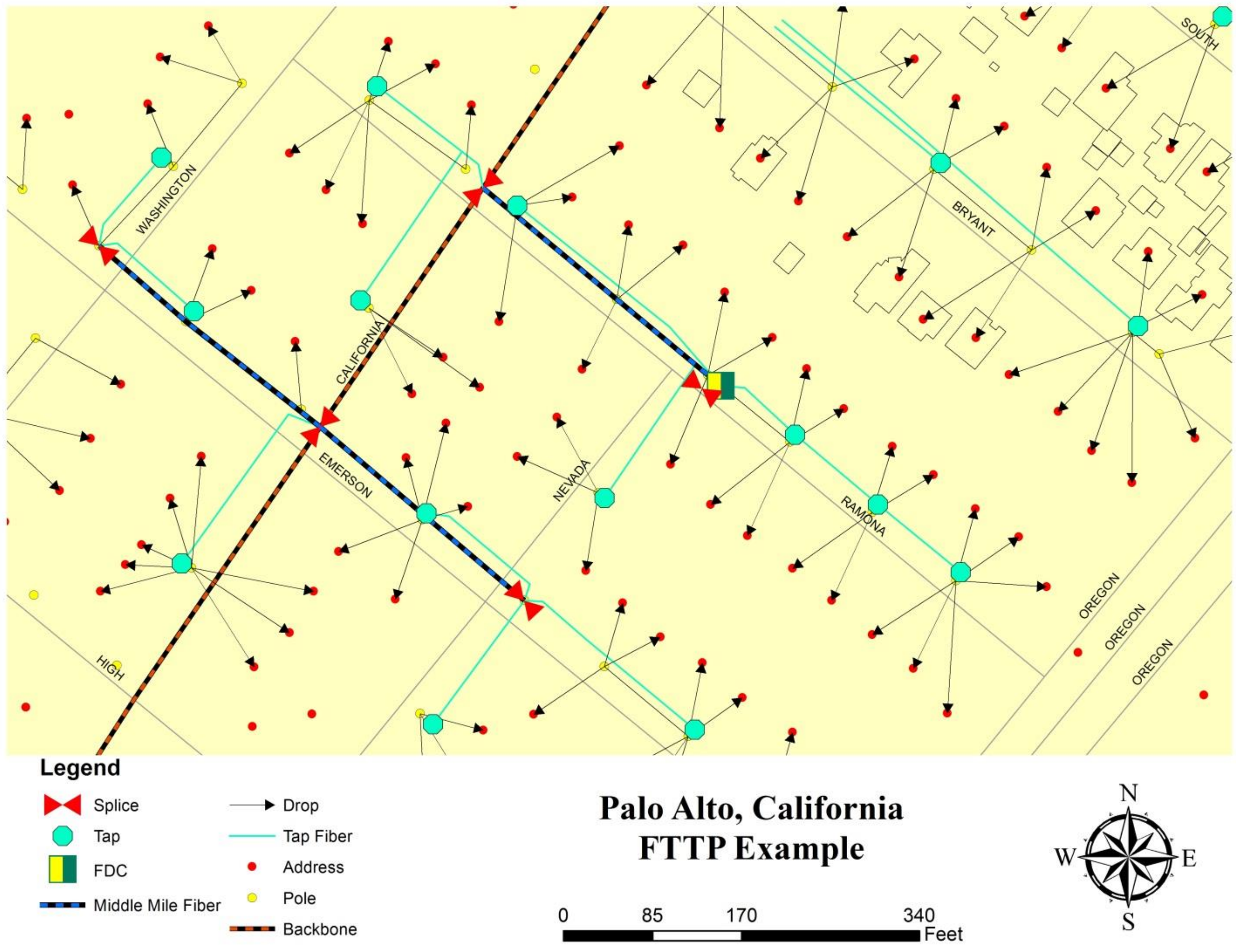
[126] The Census data indicate the number of households in structures with a range of units. For calculating the number of households, we assumed that a structure with 5 to 9 units has an average of 8 units, a structure with 10 to 19 units has an average of 16 units, and a structure with 20 or more units 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 ArcGIS[129] 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

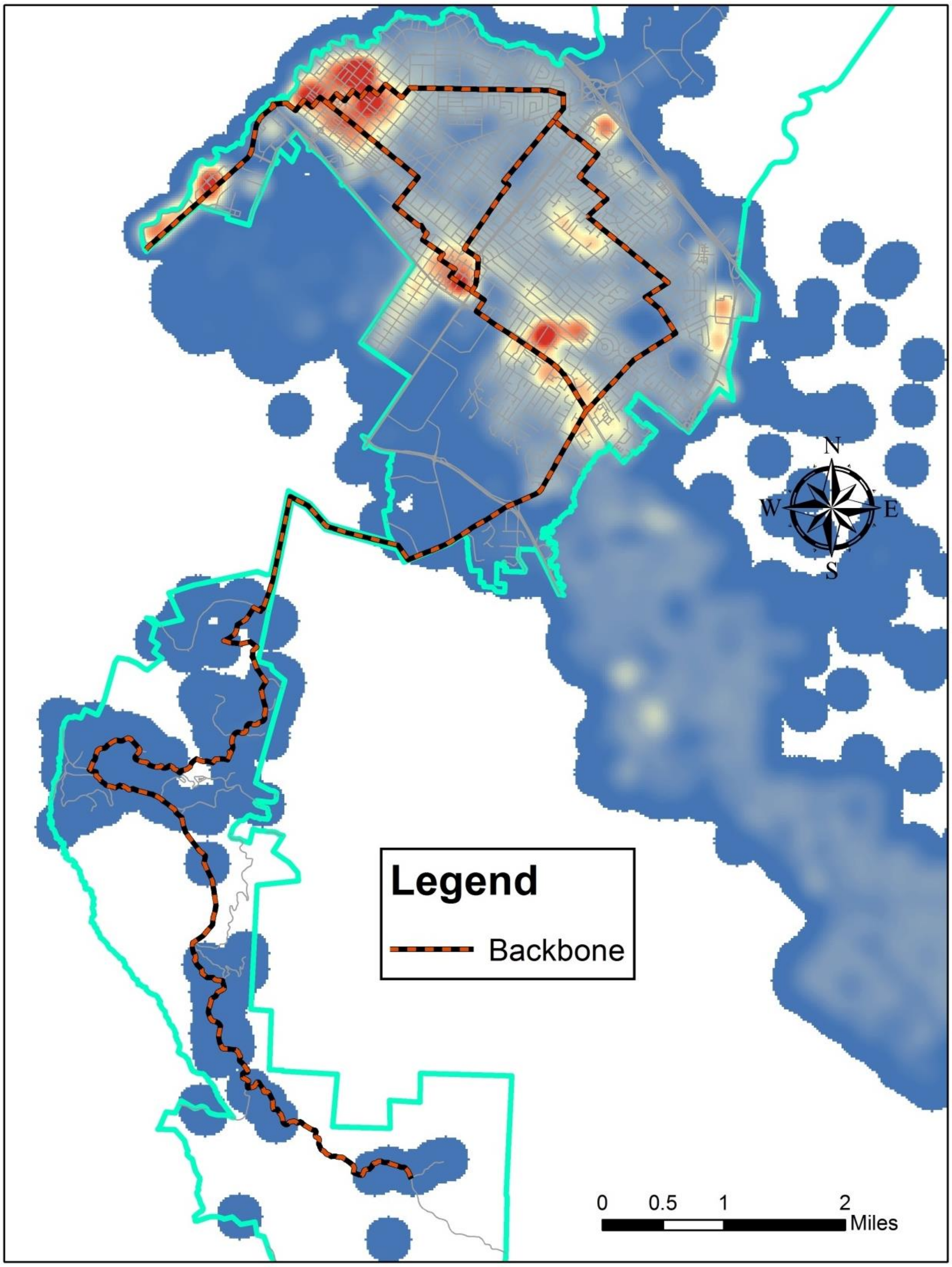
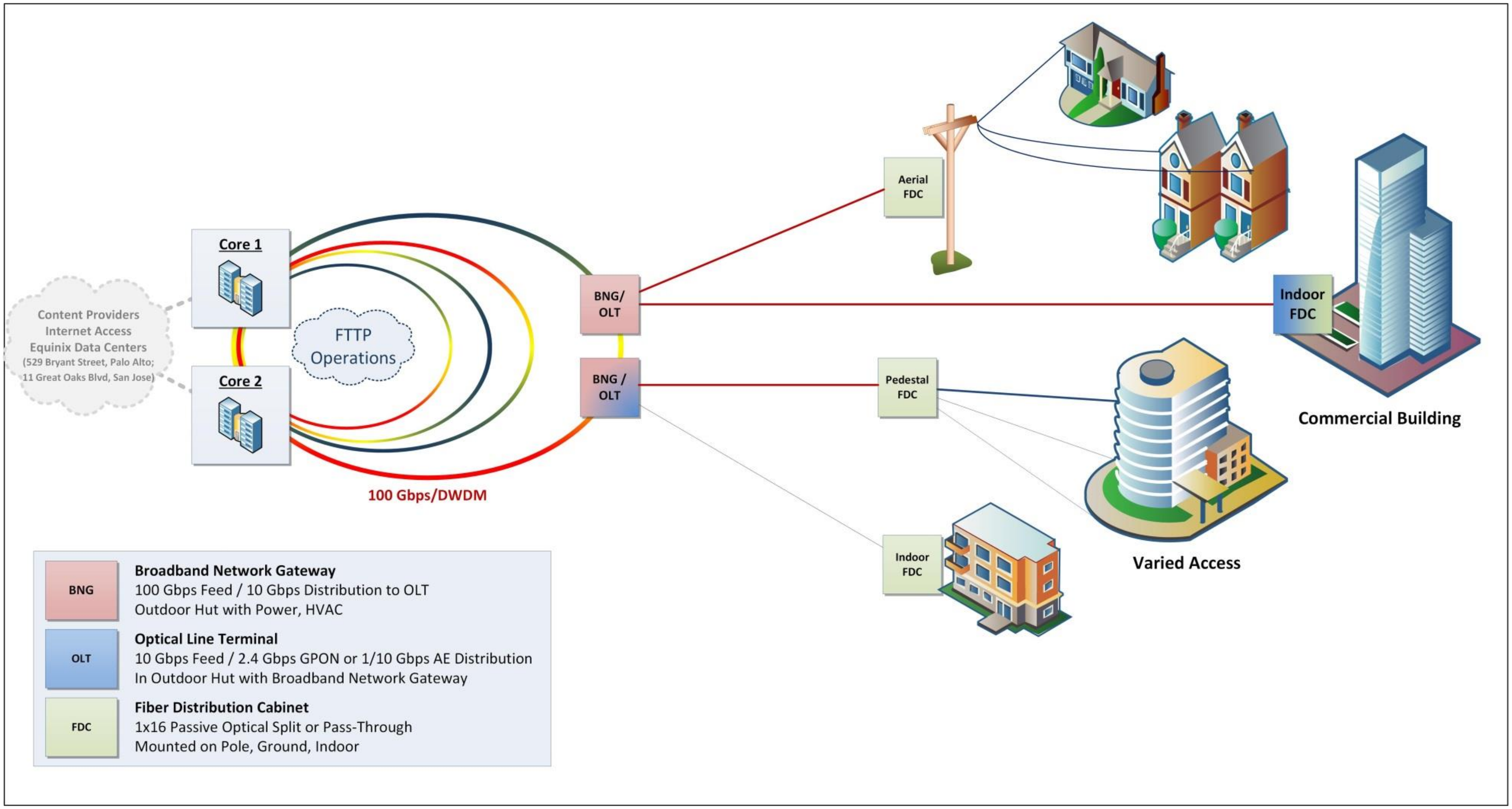


Figure 15: High-Level FTTP Architecture



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

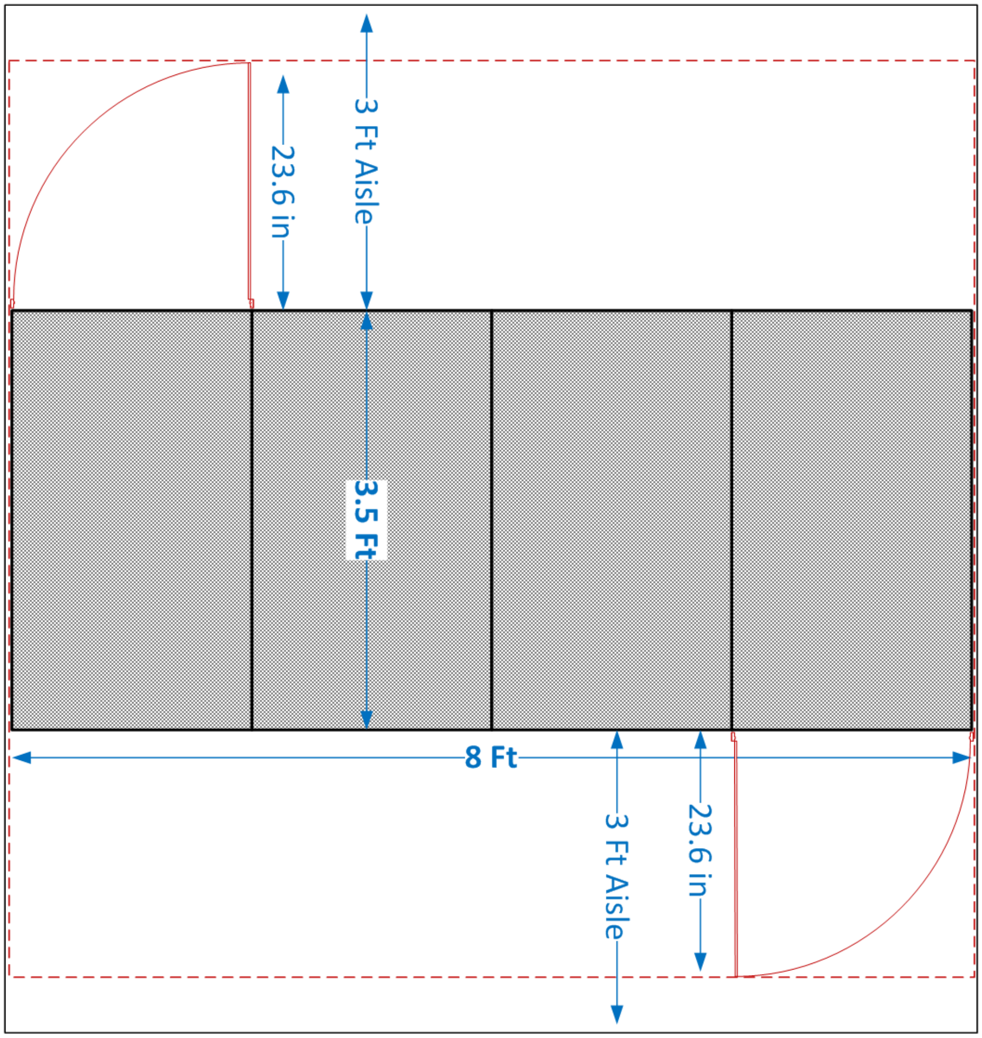


Figure 17: Sample List of Materials for Core Location

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 OLT[133]

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 Slitter 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 fiber[134] 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
ONT Kit – Residential SFU – Basic	ONT, Enclosure, NID, 8hr UPS, Ethernet	$ 395
ONT Kit – Residential SFU – Premium	ONT, Enclosure, NID, 8hr UPS, Ethernet, Advanced Wi-Fi	$ 455
ONT Kit – Residential SFU – AE Access	ONT, Enclosure, NID, 8hr UPS, Ethernet, Advanced Wi-Fi, AE Access	$ 555
ONT Kit – Residential MDU – Basic	ONT, Enclosure, NID, Indoor Cabling, 8hr UPS, Ethernet	$ 766
ONT Kit – Residential MDU – Premium	ONT, Enclosure, NID, Indoor Cabling, 8hr UPS, Ethernet, Advanced Wi-Fi	$ 826
ONT Kit – Residential MDU – AE Access	ONT, Enclosure, NID, Indoor Cabling, 8hr UPS, Ethernet, Advanced Wi-Fi, AE Access	$ 926
ONT Kit – Business (SFU) – Basic	ONT, Enclosure, NID, 8hr UPS, Ethernet	$ 366
ONT Kit – Business (SFU) – Premium	ONT, Enclosure, NID, 8hr UPS, Ethernet, Advanced Wi-Fi	$ 426
ONT Kit – Business (SFU) – AE Access	ONT, Enclosure, NID, 8hr UPS, Ethernet, Advanced Wi-Fi, AE Access	$ 526
ONT Kit – Business (MDU) – Basic	ONT, Enclosure, NID, Indoor Cabling, 8hr UPS, Ethernet	$ 766
ONT Kit – Business (MDU) – Premium	ONT, Enclosure, NID, Indoor Cabling, 8hr UPS, Ethernet, Advanced Wi-Fi	$ 826
ONT Kit – Business (MDU) – AE Access	ONT, Enclosure, NID, Indoor Cabling, 8hr UPS, Ethernet, Advanced Wi-Fi, AE Access	$ 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 roads offer an apt comparison to the broadband environment, as this analogy helps illustrate what the competitive environment looks like.

---

[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.

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

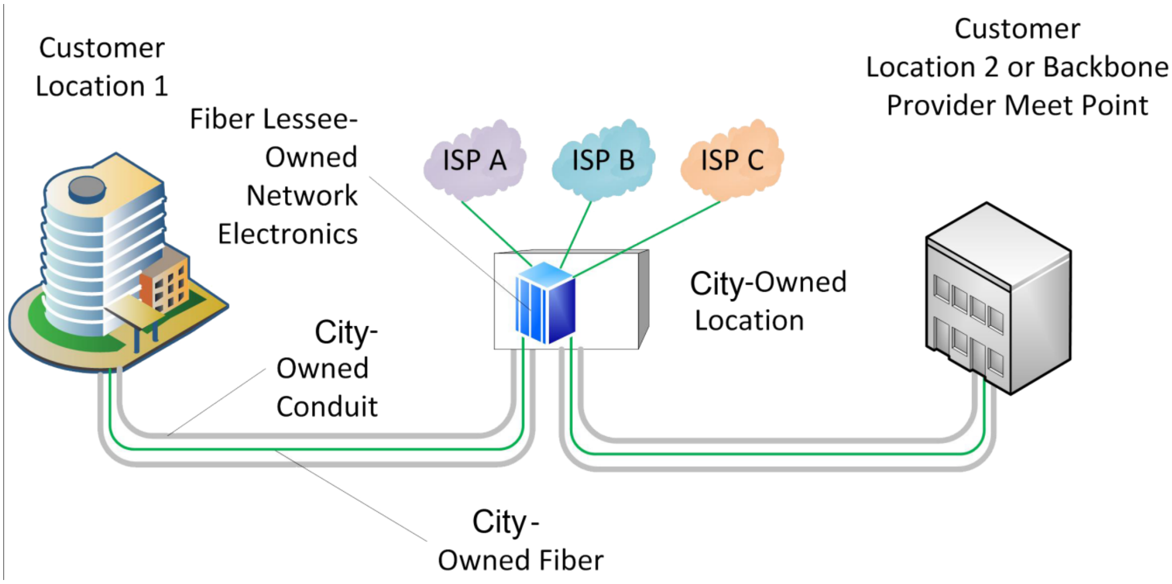
A wholesale or open access model separates the "infrastructure" from the "retail" services. In a perfect market, consumers would have access to any service provider they desire. Separating the infrastructure from the service is a step in that direction. In the City's case, licensing fiber to wholesale 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.

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

[141] Lambdas can also fit into this model.

services can be priced in various ways—and the provider, not the City, will determine actual pricing.

Figure 25: Wholesale Lit Services

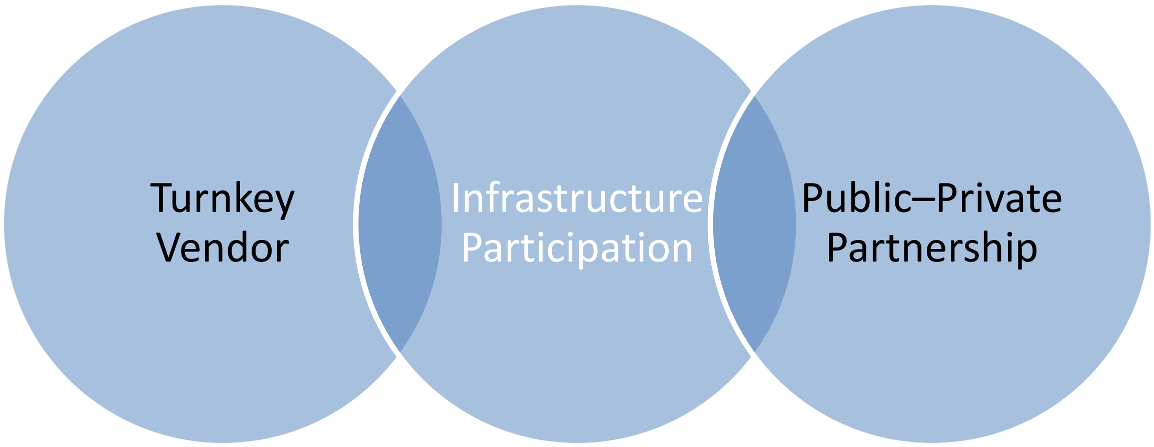


As we noted, an in-depth evaluation of the City's fiber is necessary to determine to what degree (if any) existing assets are valuable and able to be used for the FTTP endeavor.

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 natives[149]—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

---

[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.

do not take the leap because they want specific programming that is only available 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

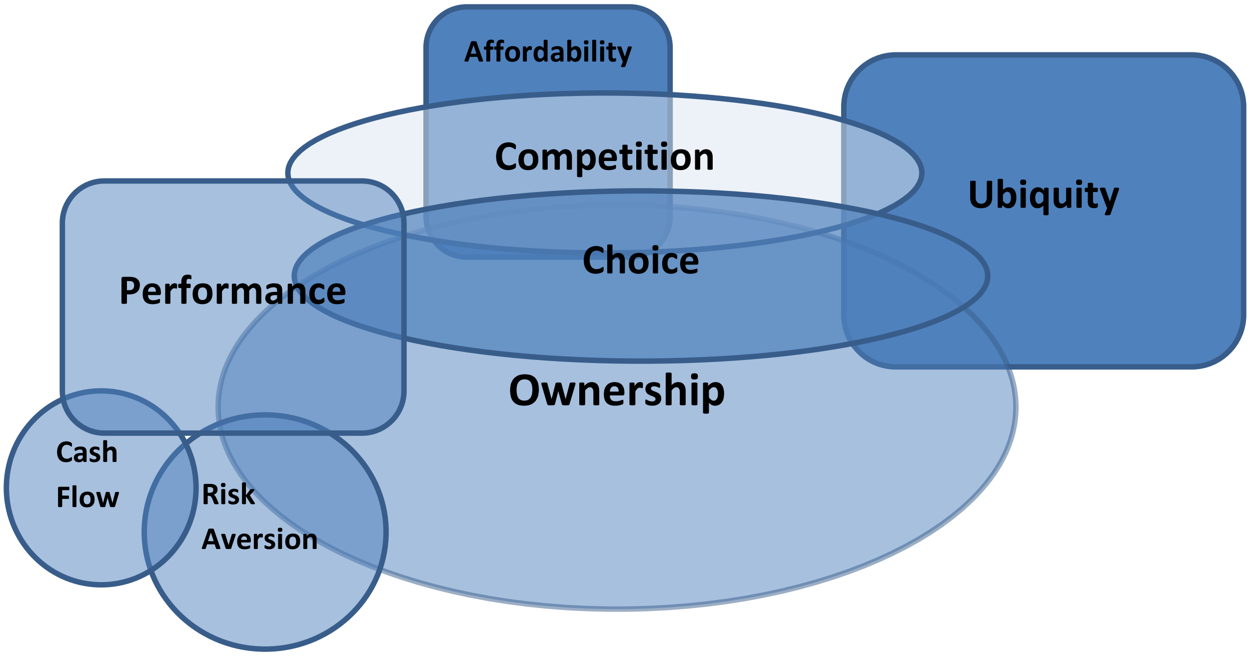
A: Align **C:** Conflict **NI:** No Impact **NA:** Not Applicable

	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 FTTP network's viability by setting it apart from incumbent providers. Thus, there are no real disadvantages to making performance a top priority for the FTTP 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 City will likely have to seek outside funding to support construction and the FTTP network's startup costs. It is

[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.

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.

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

[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.

"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]

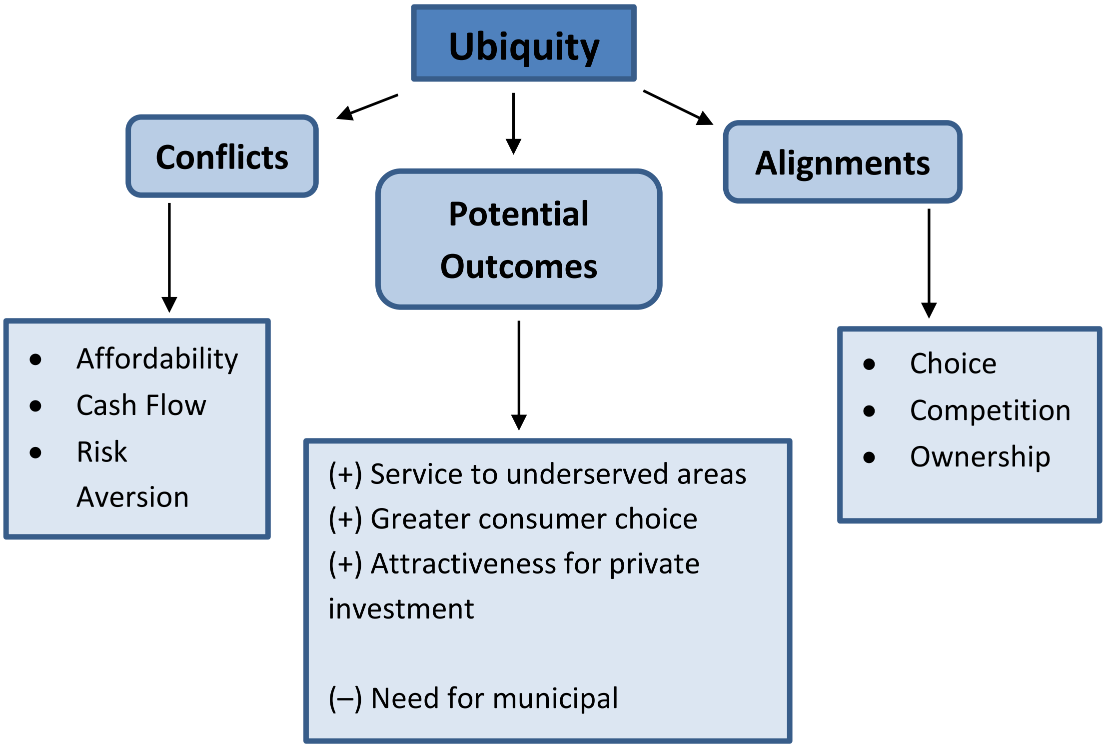
Figure 28 shows conflicts, alignments, and potential outcomes associated with prioritizing ubiquity.

---

[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 provider(s), if any, can offer services over the network. It can regulate which service providers

[169] http://lusfiber.com/index.php/about-lus-fiber/historical-timeline, accessed June 2015.
[170] http://www.chattanoogan.com/2007/9/21/113785/Cable-Group-Files-Suit-To-Try-To-Block.aspx, accessed June 2015.

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. While the City

---

[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.

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

Reward	Risk: High	Risk: Low
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,

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

and can potentially help convince consumers to sign up for service, thereby achieving ubiquity in a lower risk fashion.

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, EBIDTA 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 area[176] 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 stories[178] 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.

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

[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.

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 incumbent providers that make it challenging for the municipality to compete.[182] This can include

[181] This potential is highest in the concessionaire model.
[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.

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 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 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

---

[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).

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 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

[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).

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]

[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).

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 particular targeted four economic development areas, including developing redundant conduit, fiber, and electric infrastructure. Among those areas was land around the Phoenix-Mesa Gateway

---

[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).

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 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.

[194] http://azgovernor.gov/governor/news/governor-doug-ducey-announces-major-apple-expansion-arizona (Accessed April, 2015).

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.

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

[195] http://uc2b.net/about/ (Accessed April, 2015).

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.

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

[196] http://uc2b.net/wordpress/wp-content/uploads/2014/05/UC2B-iTV3-Press-Packet.pdf (Accessed April, 2015).

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 fiber[197], 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.

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.

---

[197] Fiber configured to support a GPON architecture.

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 FTTP 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 FTTP 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 FTTP 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 FTTP network. Because the City has experience maintaining and overseeing a dark fiber network, costs to continue this and add responsibilities for the new FTTP 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 FTTP network is separate from the existing dark fiber network (e.g., the existing network does not contain enough spare capacity to support an FTTP 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 FTTP 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. 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.

[198] Jon Brodkin, "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).

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 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.

---

[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.

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.

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

[201] http://www.reuters.com/article/2015/06/15/idUSnGNX1v7Cv8+1c4+GNW20150615, accessed June 2015.

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 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	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

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	$89,230	$711,430	$711,430	$711,430	$711,430
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	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
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)	(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)
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	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

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		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 (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 FTTP 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 FTTP 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	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%				

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	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%				

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	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%

Reducing labor costs (salaries and overhead) by 40 percent would enable the FTTP 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	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%				

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	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%				

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	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%

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	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%

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

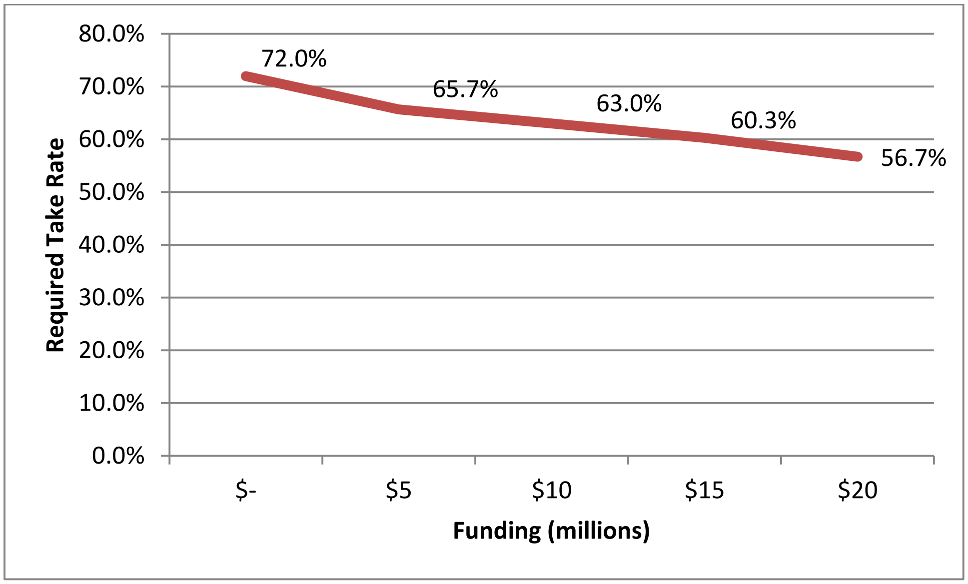
Cash Flow Statement	1	5	10	15	20
Unrestricted Cash Balance	$3,277,645	$10,107,325	$6,753,840	$4,948,700	$3,202,930
Depreciation Reserve	-	4,608,650	8,693,850	2,980,380	5,455,570
Interest Reserve	2,000,000	-	-	-	-
Debt Service Reserve	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Total Cash Balance	$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%

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%				

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	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%

Appendix A – Existing Palo Alto Market Assessment

[This page intentionally left blank.]

Appendix B – Financial and Cost Analysis

[This page intentionally left blank.]