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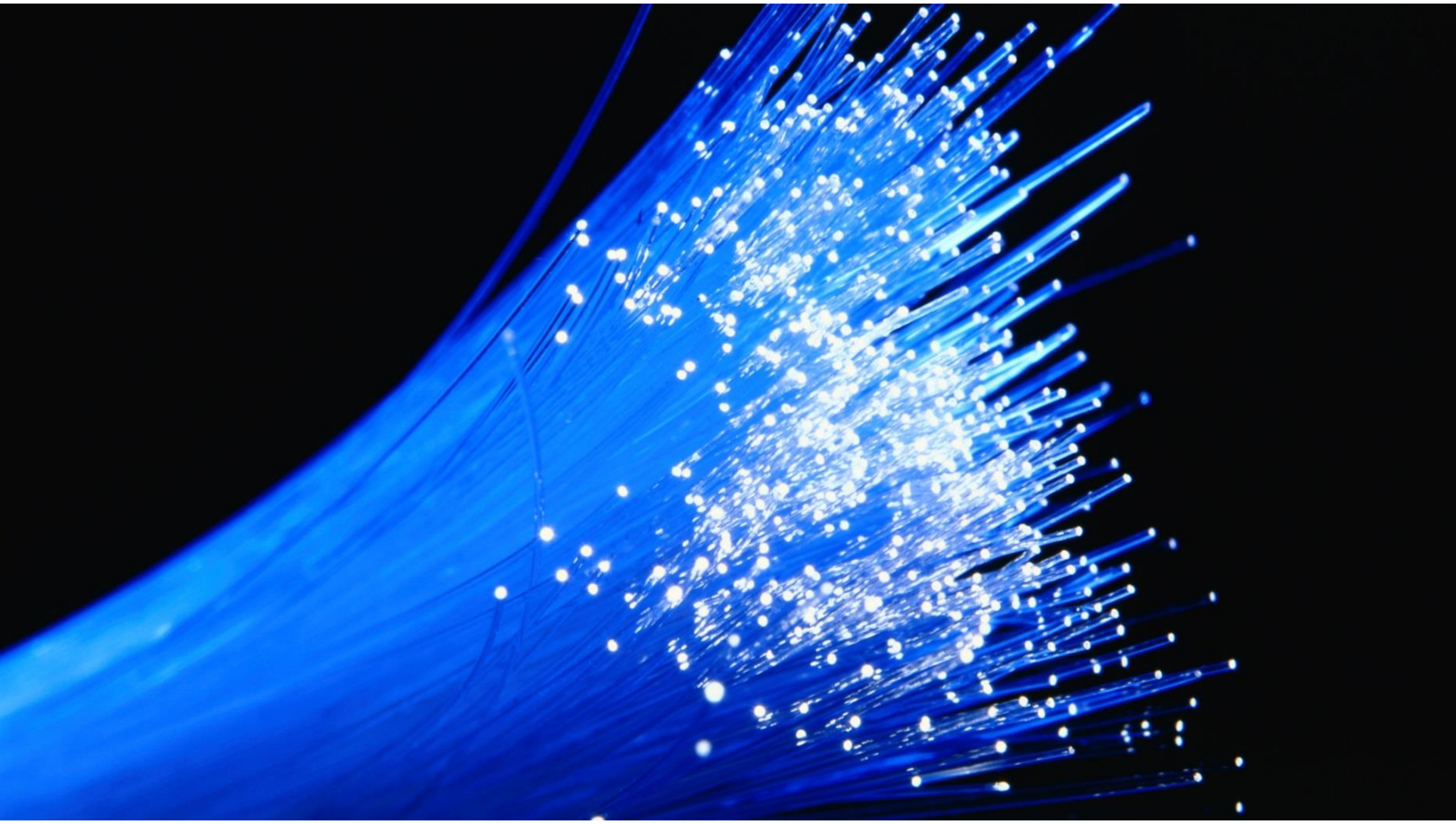

Public-Private Partner Feasibility Study for Broadband in the North End

Prepared for Harford County, MD
January 2017

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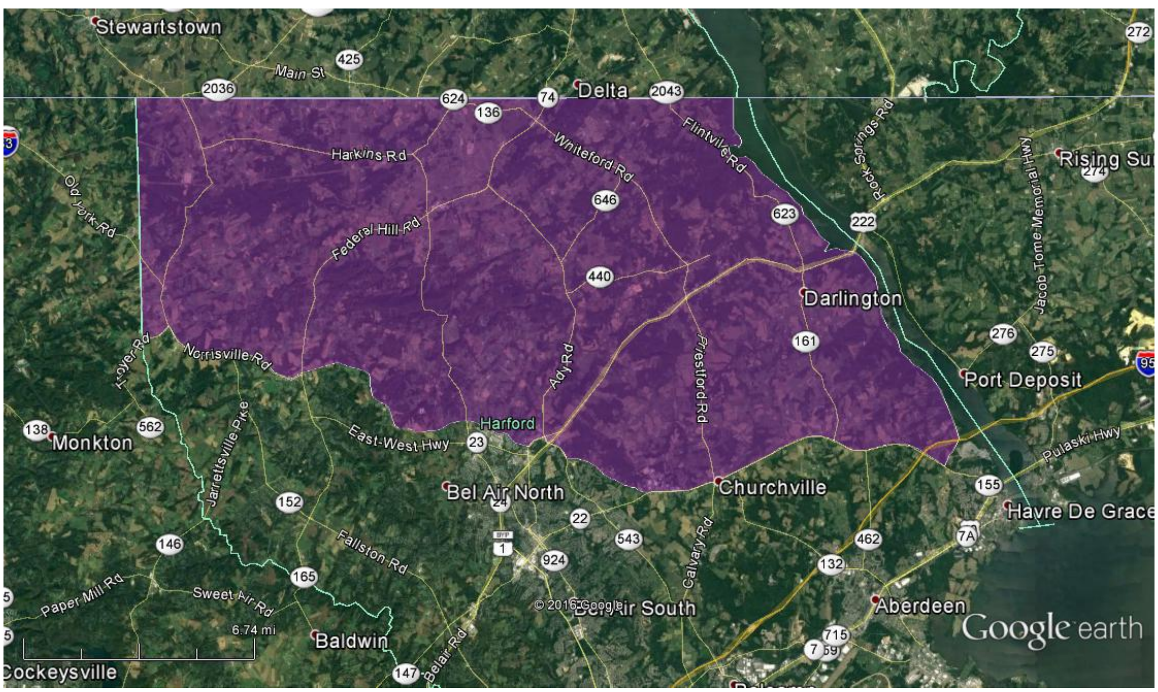
1 Executive Summary

1.1 Project Background

Located in Northwest Maryland at the headwaters of the Chesapeake Bay, Harford County has an estimated population of 250,290 and an estimated 91,037 households.[1] The County encompasses a range of population densities and geographies. Southern Harford County stretches nearly to the suburbs of Baltimore and is somewhat densely populated, while the County becomes increasingly rural and sparsely populated as it extends north toward the Maryland-Pennsylvania border.

The County's "North End" is defined as the area north of the east-west boundary created by several roadways—Highway 155, Highway 22, Highway 543, Highway 23, and Highway 138 (see the map in Figure 1). The County's North End consists mainly of farmland and widely-distributed households, and has limited internet access options for residents and businesses in the region.

Figure 1: Harford County North End Boundary



This lack of affordable and reliable broadband internet service hinders the County's economic and educational development. Not only are the County's North End residents unable to capitalize on the

[1] https://www.census.gov/quickfacts/table/PST045215/24025,00 Accessed November, 2016

wide array of educational resources available on the internet, but local businesses are also becoming less able to remain competitive in today's increasingly internet-dependent marketplace.

The County's North End presents a unique challenge to deployment of robust and reliable network infrastructure. While the local topography makes constructing an all-fiber network extremely expensive, the sparsely populated North End has made incumbent and new internet service providers (ISPs) reluctant to invest in infrastructure expansion for the relatively low number of new customers they are likely to gain.

The County faces complexity as it evaluates how to serve its entire diverse geographic area. The needs of the southern portion of the county differ greatly from those in the North End, and the County must determine what steps it can take to effectively bridge availability gaps for the entire vast region.

1.2 Methodology

The County seeks to evaluate the feasibility of developing infrastructure or taking other steps to facilitate the availability of broadband internet to Harford County's North End—specifically covering approximately 12,900 households and businesses (passings) in this region. The County engaged CTC Technology & Energy (CTC) to evaluate gaps in current service; assess current partnership models in the broadband industry; identify potential partners that may work with the County; and outline some of the financial and practical implications of developing infrastructure to address some of the County's connectivity gaps.

This report was prepared in late 2016 and early 2017, and aims to identify actions that Harford County government can take to encourage and enable infrastructure development. It also outlines a pragmatic and conservative projection of the potential financial implications of these actions.

One of the primary objectives of this study is to present and evaluate potential models for partnership between the County and one or more private partners to facilitate the expansion of broadband internet services. This study analyzes partnerships in similar localities; identifies risks and opportunities in each partnership model; suggests strategies to attract, encourage, and facilitate partnership; and presents demonstrated potential partner interest.

Further, our analysis evaluated three possible deployment options:

- A tower lease option, with County fiber enabling private partner fixed wireless expansion by offering tower attachments and transport over existing fiber;
- A hybrid fiber-wireless option, in which a private partner would lease County fiber-to-the-neighborhood and County installed poles to expand services;

- A fully fiber-to-the-premises (FTTP) option, in which the County would construct fiber to each premises in the North End, and potentially lease that fiber to a private partner.

We evaluated these deployment options through analysis of high-level conceptual design summaries, including technical specifications.

Finally, this report presents and discusses capital and operational cost estimates for each deployment option, as well as the level of revenue necessary to sustain the operation.

1.3 Goals and Objectives

The County's overarching goal is to partner with the private sector to develop a feasible solution to enable reliable broadband internet service for the residents and businesses in the North End of Harford County.

1.3.1 Only Dial-Up and Satellite Service is Currently Available in Portions of the County's North End

Internet service options for the sparsely populated North End are often currently limited to dial-up or satellite—both inadequate options for provision of services sufficient to meet the needs of current County households. Dial-up speeds reach a maximum of 56 kilobits per second (Kbps) under optimal conditions, and satellite connections—though much faster than dial-up—come with low data caps that limit the amount of data customers can download or upload in a monthly billing cycle. Further, satellite connectivity comes with a high equipment, installation and monthly price, and is limited by local topography, and adversely affected by latency issues. As data needs continue to increase, the available service options in Harford County will become increasingly less adequate.

A robust fiber or hybrid fiber-wireless network would address these issues and provide a reliable infrastructure that is both scalable and adaptable to the inevitable rise in data demand. Such a fixed network would require significant construction and maintenance, as well as a large County investment.

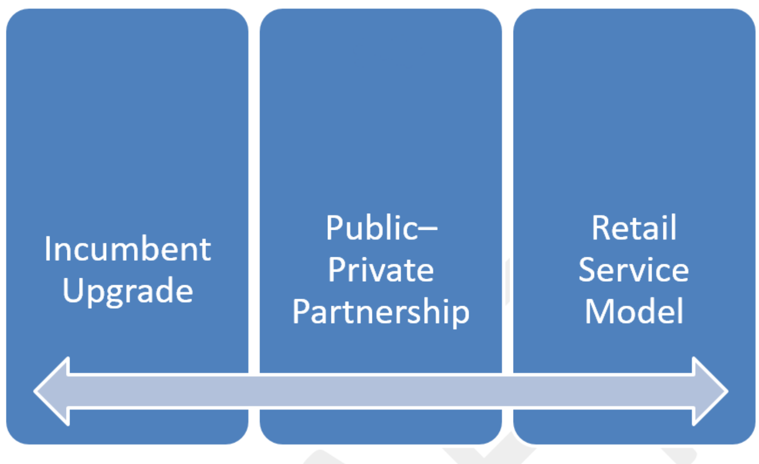
The County looks to solve this problem by partnering with a member of the private sector to "share the load" of network expansion. Encouraged by the many recent public–private partnerships throughout the U.S., the County seeks to understand and use available options, and to identify steps it can take to encourage infrastructure development to the area.

1.4 Service Models Range from Incumbent Upgrades to Public Ownership

There are several potential service models a public entity can consider as it evaluates how best to address its broadband availability gaps. The options range from simply relying on local incumbent service providers to upgrade their infrastructure,[2] to a full public FTTP deployment, in which the locality provisions service over a network that it constructs and owns.

Somewhere between a fully private and an entirely public approach is the possibility of a public–private partnership, which plays to the strengths of each entity, and helps manage risk. There is also significant variation within the framework of public–private partnerships, and the public and private entities can tailor their unique goals and needs to develop a mutually beneficial arrangement.

Figure 2: Service Models Continuum



On one end of the spectrum lies a full public retail service model in which the locality deploys and maintains network infrastructure, and then provides service to end users over the public network. This approach involves tremendous financial and operational risk for the public entity because the locality must secure financing to build the network, as well as establish a significant enough revenue stream to maintain the network infrastructure and cover all costs associated with network and retail service operations. If incoming revenue does not cover these costs, the locality must find alternatives—such as using funds from the public entity's general operating budget—to cover any shortfall.

[2] Note that there is a distinction between incumbent providers and competitive providers; competitive providers can install new infrastructure to offer service to an expanded area, but we focus on incumbent providers because of their existing large footprint in most communities. The incumbent provider's costs to upgrade infrastructure within an existing network footprint is likely to be lower than a competitive provider's cost to deploy an entirely new, or "greenfield," network.

In a retail service model, the public entity is responsible for all network infrastructure, including the electronics required to "light" the fiber and, in the case of a wireless deployment, all the equipment necessary to establish a robust wireless network. Retail operations costs encompass everything from customer outreach and marketing, to call center staff, to customer premises equipment (CPE), to retail store space where customers can go to establish service, pay their bill, or receive technical and other support. The cost to the public entity for operating a for-choice retail ISP is significant, varied, and unpredictable.

On the other end of the spectrum, localities can take small steps in the course of normal business—such enacting a dig-once policy to encourage incumbent providers to upgrade their existing infrastructure to keep pace with the growing demand for access to greater connectivity. In this approach, the locality does not take significant steps or risk toward enabling or providing service, but instead relies on the private sector. However, even if the locality takes certain steps, it still has little to no control over whether any of the modest measures it takes will incite local incumbent providers to action. That is, even if the locality takes steps to encourage private investment, there is no guarantee that its efforts will pay off in the form of incumbent providers investing in upgrades to their legacy infrastructure to keep pace with the growing demand for access to greater connectivity. While this approach entails only nominal risk to the public entity, there is also minimal control, and the locality is relying entirely on the private sector to address concerns with the local broadband market.

In recent years, a mutually beneficial middle ground has emerged in the form of public–private partnerships that have enabled meaningful competition in some cities, counties, and states throughout the U.S. For many localities, the prospect of a retail service model is daunting and unappealing, but waiting for incumbent providers to upgrade their networks and provide higher speeds and greater access is not sufficient. Often, a public–private partnership that balances the needs, risks, and rewards of the public and private sectors is a viable approach that helps achieve the locality's goals, while not putting undue burden on the private sector or positioning the locality to directly compete with local providers.

1.4.1 Public–Private Partnership Models

There is little political will among the County's leadership to pursue a full public retail deployment where the County acts as an ISP, and incumbent investment in infrastructure to date has not successfully addressed availability gaps in the North End. Public–private partnerships balance risk, benefit, and control between two partners that aim to accomplish a common goal. Each party capitalizes on their inherent strengths while leveraging the partner's strengths to mitigate risk, creating shared benefits for each, and a level of control appropriate to the terms of the partnership.

1.4.2 Public–Private Partnership Framework

Three distinct partnership models have emerged in recent years that can help localities achieve their goals by engaging the private sector:

1. Private investment, public facilitation;
2. Private execution, public funding; and
3. Shared investment and risk.

The first model presents the lowest risk to the County, but also provides the County with the least amount of control over network assets. The second presents significantly elevated risk to the County, but also increases potential benefits. The third is an opportunity for both parties to creatively share the risk and benefit of network expansion. These models are discussed in greater depth with case studies in section 2.

1.4.2.1 Risks of a Public Retail Service Model

A public entity that enters the broadband market as a retail service provider is likely to face a breadth of financial, operational, and practical challenges. Starting any business from scratch is time-consuming and expensive and comes with a steep learning curve, and most startup businesses do not succeed.[3] This is not to say that any public entity that enters the market as an ISP will fail; on the contrary, there are examples throughout the U.S. of successful localities deploying networks and acting as broadband service providers. But it is important to understand the range of potential risks a locality may face, especially in the initial years when the public entity must balance network construction and implementation, and the startup of operations.

Perhaps the greatest benefit of a public retail model is that the network infrastructure is a valuable tangible asset that the public entity owns and controls. The public entity can choose when and where to deploy network infrastructure, and once the infrastructure is in place, it becomes a resource that that locality can potentially leverage in multiple ways. For example, if a locality places excess fiber while deploying a public FTTP network, the locality can use the fiber to directly serve its own customers and can lease excess strands to other entities for use. In this way, the fiber serves not only as the infrastructure over which the locality provides service directly to end users, but it also provides additional modest revenue to help support ongoing network operations. While this is an important benefit, deploying a fiber network is complex and expensive, and even wireless solutions rely on a robust backbone.

[3] Neil Patel, "90% Of Startups Fail: Here's What You Need To Know About The 10%," *Forbes*, last modified January 16, 2015, accessed December 14, 2016, http://www.forbes.com/sites/neilpatel/2015/01/16/90-of-startups-will-fail-heres-what-you-need-to-know-about-the-10/#92b813d55e19.

Additionally, network and business operations tend to be unpredictable and costly, and often represent a great risk for public networks. The locality must launch a successful marketing and advertising effort that convinces a sizeable portion of potential customers to switch from their current service providers. It is crucial for the public entity to have a focused product that can successfully compete with the level of service that customers are currently receiving from their existing service providers—at a compelling price point.

A challenge new market entrants face is customer inertia, or the tendency of people to retain the service they have because it is "good enough," and the prospect of making a change is more daunting than simply sticking with what they know. This is complicated further by the fact that the locality is an unknown quantity with no track record to prove that it can uphold its marketing promises, and potential subscribers may be skeptical of the locality's ability to competently provide service.

In addition to successfully acquiring new customers, the locality must take steps to ensure that it retains existing customers once they have purchased service. This requires skilled staff to support technical, billing, and other inquiries, and carefully navigating the locality's responsibilities as a retail service provider. While certain customer issues are not the locality's fault, this may not prevent the public entity from shouldering the blame for problems like websites not loading, tablets that fail to connect to in-home wireless, or malware being installed on a customer's personal computer. It takes qualified and well-trained staff to gracefully navigate the range of customer issues that may come through the ISP's support line. And because community members often hold public entities to a higher standard than other for-choice businesses, the locality can expect that it may be the target of undue criticism—especially if it does not provide sufficient customer support.

Further, localities that enter the retail market directly may be targeted by incumbent providers that make it challenging for the public entity to compete. Incumbent providers may use a variety of tactics, including lowering prices to a point with which the public entity cannot compete because it lacks the economies of scale that the private competitor has. One advantage of a public–private partnership is that the public entity is not competing in the marketplace. And private entities are likely to be equipped to understand the retail business and can help the locality mitigate its risk in this area.

At a minimum, a locality that enters the market as a retail service provider can expect to hire and train a range of new personnel, or engage contractors to fulfill these roles—from staff that can perform fiber splicing, to customer service representatives, to network engineers. The locality must also secure space for its network central office (CO), warehouse space to store network equipment like the fiber itself and CPEs, and space to house retail operations and call center staff. Certain elements of owning and operating a network, and running a for-choice ISP require responsiveness 24 hours per day, 7 days per week, 365 days per year. In certain cases, such as when the locality is beholden to a service level agreement (SLA), there may be steep penalties for failing to respond to issues within a specified timeframe.

Finally, network and retail service operations require an ongoing influx of funds to be sustainable, and many of these endeavors do not reach a “break even” point for many years. That is, the business may operate at a loss for several years after the network has been deployed and the locality is serving customers. The business may require the locality to allocate general funds or levy a special tax to support it, especially in the early years. There is also no guarantee that the incoming revenues will ever be sufficient to cover all the costs associated with maintaining the network and the retail service business. In other words, the retail business may not ever become self-sustaining.

It is important to reiterate that many public entities operate successful for-choice ISP businesses, and have for many years. Whether it makes sense to pursue a retail service model depends on a variety of factors that are specific to each locality; a successful retail service model that one public entity launched is unlikely to be truly replicable by a different public entity. For example, even two cities (or counties) that are nearly geographically and demographically identical may have very different existing market conditions, and the favorability of the existing competitive environment plays an important role. Or, perhaps one locality can deploy a network much more quickly than another—speed to market is also a determining factor in the success of any business. The bottom line is that deploying a network and starting up an ISP as a public entity is risky and there are many details to consider to determine whether it makes sense for a public entity to pursue this approach.

In part, due to the array of risks associated with starting an ISP as a public entity, and because of the emergence of private providers willing to work collaboratively with localities toward a mutual goal, public–private partnerships have gained momentum in recent years. Although the business models may evolve and change, it is likely that broadband public–private partnerships will continue to grow in popularity as private providers seek to expand and localities seek to address their connectivity needs.

1.4.3 Examples of Hybrid Fiber-Wireless Partnership Models

One potential model that the County can consider, which we discuss in Section 1.5.3, is partnering with the private sector to support deployment of wireless service to address availability gaps in the North End. In this model, the County would develop infrastructure to support the private sector offering wireless-based retail service. Two Maryland counties—Garrett and Howard—have used a similar approach with seemingly positive results, though it is still early in their processes to gather significant data points to make a determination about their success.

1.4.3.1 Garrett County, Maryland

Garrett County, in far western Maryland, is a relatively remote community in Appalachia bordered by Pennsylvania and West Virginia. The County has struggled to get broadband in many of its remote, mountainous areas. Where broadband is available, it is inadequate digital subscriber line (DSL) service that does not meet the Federal Communications Commission's (FCC) minimum definition for broadband service, let alone the requirements for home-based businesses. The incumbent provider there has not indicated that it plans to expand or upgrade service offerings.

Though mobile broadband is available in some parts of Garrett County, 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 monthly bandwidth allotment in one day of downloading educational videos. Beyond these challenges for residents, the County has struggled to attract and retain businesses and teleworkers.

In response, the County has gradually and incrementally built out fiber in some areas, with a focus on connecting specific institutions. And in September 2015, the County Council approved a contract with a private partner to leverage some of the County's fiber and additional public financing to support the deployment a fixed wireless broadband network that will serve up to 3,000 currently unserved homes in the most remote parts of the county. The private partner, Declaration Networks Group (DNG), will also put its own capital toward the construction of the network, and will apply its technical and operational capabilities to managing the network. The partnership involves cost to the County, but also massive benefit for residents and business in the newly served areas.

From an economic development perspective, the County's investment represents enormous value for the dollar. This investment will enable residents in 3,000 homes to buy cost-effective broadband service that they cannot access now, and that will make possible telework, home-based businesses, and home schooling. This investment will also enable the county to close the Homework Gap for many students in County schools who do not currently have broadband in their homes—an increasingly critical lack of service.

As the network is deployed over the next few years, the County will reduce to nearly zero the number of homes in the Garrett County that do not have access to some kind of broadband communications options. These options may be modest—not the robust speeds available in metropolitan markets—but they are significantly better than nothing, and a huge economic development achievement from the County's standpoint.

1.4.3.2 Howard County, Maryland

Located in central Maryland between Baltimore and Washington, D.C., Howard County, Maryland has the second-highest median income in the U.S.[4] Despite its proximity to two of the nation's largest metropolitan population centers, one being the nation's capital, portions of Howard County lacked reliable, non-mobile broadband options until very recently. As in Garrett County, many residents could purchase only mobile broadband service, which comes with caps that severely limit users' ability to connect.

Although mobile broadband may be better than no connectivity at all, it does not allow for a variety of internet-based activities—namely, any activity that requires significant bandwidth use. Residents who rely on mobile broadband alone and who are subject to data caps must be hypervigilant about their use, which often means that simple online activities that many Americans take for granted are inaccessible.

Following a grassroots effort by residents in western Howard County, the County's leadership rolled out a plan in 2016 to partner with Freedom Broadband, an ISP based in neighboring Carroll County. The partnership aims to bring high-speed broadband to underserved areas of the County, particularly the western portion.

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). Howard County's public–private partnership makes use of the ICBN and the County's existing dark fiber network to support wireless network equipment owned by Freedom Broadband. The equipment is situated atop a water tower in Mount Airy, Maryland, just northwest of the Howard County line. The private partner can then serve customers in western Howard County, where some 15,000 households are currently underserved or unable to purchase high-speed broadband.

The plan is intended to serve approximately 80 percent of the currently-underserved western portion of Howard County. While it is not an immediate fix to the County's broadband availability gaps, it is one step toward County leadership partnering with the private sector to meet residents' needs. The arrangement allows the County to address areas in its western region that currently do not have access to reliable high-speed broadband, and enables Freedom Broadband to expand its service area beyond Carroll County.

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[4] Amanda Yeager, "Howard ranks 2nd in nation in median income at $108,844," *Baltimore Sun*, last modified September 30, 2013, accessed December 14, 2016, http://www.baltimoresun.com/news/maryland/howard/ellicott-city/ph-ho-cf-howard-income-1003-20130930-story.html.

1.4.4 Examples of FTTP Partnership Models

Public–private partnerships are overall a relatively new development in the broadband industry, and they are continually evolving as new companies emerge and localities seek creative ways to bridge connectivity gaps. One potential option that the County may decide to consider is an FTTP partnership, in which the County deploys an FTTP network to the North End and then leases dark fiber infrastructure to a private provider (see Section 1.5.2) to provision service. Because this model is likely to be very expensive (see Section 4), it may not be desirable to the County, but it is still important to note that it has had preliminary success with the right balance of risk and control and a clear set of mutual goals—including Westminster, Maryland, in nearby Carroll County.

1.4.4.1 Westminster, Maryland

The City of Westminster, Maryland, is a bedroom community of both Baltimore and Washington, D.C. where 60 percent of the working population leaves in the morning to work elsewhere. The area has no major highways and thus, from an economic development perspective, has limited options for creating new jobs. Incumbents have also traditionally underserved the area with broadband.

The City began an initiative more than a decade ago to bring better fiber connectivity to community anchor institutions (CAIs) through a middle mile fiber network. The ICBN network for which the state received a grant in 2010 included infrastructure in Westminster.

Westminster saw an opportunity to expand the last mile of the network to serve residents. At the time, though, it did not have any clear paths to accomplish this goal. City leaders looked around at other communities and realized they would have to do something unique. Unlike FTTP success stories like Chattanooga, Tennessee, the Town 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 incumbent providers. As a result, they needed to find a hybrid model.

As the community evaluated its options, it became clear that the fiber infrastructure itself was the City's most significant asset. All local governments spend money on durable assets with long lifespans, such as roads, water and sewer lines, and other infrastructure that is used for the public good. The leaders asked, "Why not think of fiber in the same way?" The challenge then was to determine what part of the network implementation and operations the private sector partner would handle and what part could be the City's responsibility.

The hybrid model that made the most sense required the City to build, own, and maintain dark fiber, and to look to partners that would light the fiber, deliver service, and handle the customer relationships with residents and businesses. The model would keep the City out of network operations, where a considerable amount of the risk lies in terms of managing technological and customer service aspects of the network.

The City solicited responses from potential private partners through a request for proposals (RFP). Its goal was to determine which potential partners were both interested in the project and shared the City's vision.

The City eventually selected Ting Internet, an upstart ISP with a strong track record of customer service as a mobile virtual network operator (MVNO). Ting shared Westminster's vision of a true public–private partnership and of maintaining an open access network. Ting has committed that within two years it will open its operations up to competitors and make available wholesale services that other ISPs can then resell to consumers.

Under the terms of the partnership, the City is building and financing all of the fiber (including drops to customers' premises) through a bond offering. Ting is leasing fiber with a two-tiered lease payment. One monthly fee is based on the number of premises the fiber passes; the second fee is based on the number of subscribers Ting enrolls.

Based on very preliminary information, given that this is a market in development as we write, we believe this is a highly replicable model.

What is so innovative about the Westminster model is how the risk profile is shared between the City and Ting. The City will bond and take on the risk around the outside plant infrastructure, but the payment mechanism negotiated is such that Ting is truly invested in the network's success.

Because Ting will pay Westminster a small monthly fee for every home and business passed, Ting is financially obligated to the City from day one, even if it has no customers. This structure gives the City confidence that Ting will not be a passive partner, because Ting is highly incented to sell services to cover its costs.

Ting will also pay the City based on how many customers it serves. Initially, this payment will be a flat fee—but in later years, when Ting's revenue hits certain thresholds, Ting will pay the City a small fraction of its revenue per user. That mechanism is designed to allow the City to share in some of the upside of the network's success. In other words, the City will receive a bit of entrepreneurial reward based on the entrepreneurial risk the City is taking.

Perhaps most significantly, there is also a mechanism built into the contract that ensures that the two parties are truly sharing risk around the financing of the outside plant infrastructure. In any quarter in which Ting's financial obligations to the City are insufficient to meet the City's debt service, Ting will pay the City 50 percent of the shortfall. In subsequent quarters, if Ting's fees to the Town exceed the debt service requirements, Ting will be reimbursed an equivalent amount. This element of the financial relationship made the deal much more attractive to the City because it is a clear demonstration of the fact that its private partner is invested with it.

1.5 Three Potential Partnership Models Appear to Fit the County's Objectives – Two are Risky

As the case studies of different partnership models show, there is no one-size-fits-all approach for any community, and the partnership that best meets a locality's needs, will likely need to be tailored to be mutually beneficial to the public and private entities. Based on the County's goals, we determined that there are three potential partnership alternatives that the County may want to consider as it evaluates how best to meet its connectivity needs.

The partnership alternatives we believe are most likely to fit with Harford County's objectives are:

- A tower lease option, with County fiber enabling private partner fixed wireless expansion by offering tower attachments and transport over existing fiber;
- A hybrid fiber-wireless option, in which a private partner would lease County fiber-to-the-neighborhood and County installed poles to expand services;
- A fully fiber-to-the-premises (FTTP) option, in which the County would construct fiber to each premises in the North End, and potentially lease that fiber to a private partner.

We anticipate the capital cost associated with each of these models will vary widely, as shown in Table 1.

Table 1: Projected Capital Costs for Potential Partnership Models

	Tower Lease		Hybrid Fiber-Wireless	FTTP – Dark Fiber Lease
Total Cost (OSP Only – No Electronics)	$0	**65% Aerial**	$43,481,000	$49,702,000
		All Underground	$52,375,000	$60,719,000

Please note that the above cost do not include the required electronics or wireless equipment. These costs in the proposed partnership model are the responsibility of the ISP. For reference we have provided an estimate of the electronic costs, including customer activation costs, in Section 3 and Section 4.

We do not recommend that the County pursue an FTTP or hybrid fiber-wireless option at this point. Based on our analysis, neither of these models makes financial sense for the County, and both are expensive and have a high risk. Further, because the County can reach approximately half of its target area by taking very modest measures using its existing assets, it is not advisable to pursue a high-cost, high-risk model that entails the County installing significant fiber.

The per-passing costs are high in the County's North End, and it will be expensive and challenging to build fiber throughout this area. The "per passing cost" is the approximate cost to pass a premises with fiber optics. This cost does not include the cost of the drop cable or the CPEs; it is simply the cost to run fiber in front of a location.

The County would need to recover costs at a much higher rate than is likely with an FTTP deployment, even with a public–private partnership. As we note in Section 6.2.1, the County would need a partner to pay a $27.00 per-passing fee plus an additional $76.50 per subscriber per month. This is more than 4 times higher than the agreement Westminster developed with Ting Internet.

Similarly, we project that in a fiber-wireless hybrid model, the County will need to recover approximately $19.98 per passing and an additional $56.61 per subscriber fee per month. Although not quite as high as the fees necessary in a full FTTP model, these are still extremely high—approximately 3.33 times the fees that Ting pays in Westminster. It is also important to note that the arrangement with Ting in Westminster was especially favorable to public entity and is unlikely to be replicated in other locations.

The only scenario in which it would make sense for the County to invest in an FTTP network, or even a hybrid-wireless network, is if it had no intentions of recovering its capital expenditures and if it planned to subsidize ongoing operations costs. Even the most favorable partnership we have seen to date does not realize fees anywhere close to those necessary for the County to recover its investment in an FTTP or a fiber-wireless hybrid model.

The County's least-risk option is to make use of its existing assets, including any of its existing fiber and its 5 towers, to support and enable private provision of fixed wireless service. This option enables the County and its partner(s) to reach more than 50 percent of the targeted 12,900 potential customers in the North End. Each of the other models will also reach this 50 percent, but even with those more expensive models, reaching the last 50 percent of the currently underserved area is very high risk and will cost the County a significant amount of money with minimal return on its investment. Moreover, with customers or a private partner willing to pay increased costs for elevated antenna masts at the customer premises, it may be possible to close much of the coverage gap for the remaining North End.

1.5.1 Middle-Mile Fiber to Incent Wireless Investment

This approach is the most straightforward and least risky for the County to consider because it does not entail significant public investment. In this approach, the County simply makes use of assets that it already has--existing fiber and communications towers. One or more private providers would use the County's existing assets to support deployment of fixed wireless network equipment, and would then offer retail service to end users.

Although this type of service cannot support ultra-high speeds associated with an FTTP deployment, fixed wireless can offer speeds that exceed digital subscriber line (DSL) service. More importantly, the speeds a fixed wireless service can offer are significantly higher than what is available via dial-up or satellite, which is the only type of service currently available to some North End residents.

We estimate that the County can reach approximately half of the currently underserved population in the North End by simply making use of its existing assets and partnering with the private sector. Again, the County's cost and risk is nominal in this approach and, based on our conversations with providers, we believe there is a private sector appetite for this. The cost to the County with this model.

1.5.2 Fiber-to-the-Premises (FTTP) – Dark Fiber Lease

In this approach, the County would develop and deploy a dark fiber network that it would own, and then lease to one or more private providers for use. This is the most expensive option, and is thus the most financially risky. We project that it will cost approximately $49.7 million to deploy an FTTP network, assuming a 65 percent aerial network deployment. If the County were to construct the FTTP network all underground, that number increases to $60.7 million.

1.5.3 Hybrid Fiber-Wireless Option with County-Funded Wireless Equipment

The County may determine that an FTTP investment is too risky because of the large upfront capital costs it entails, and that a middle-mile fiber to incent private investment approach does not appropriately address its connectivity needs. As we noted, a middle ground between these two approaches is a hybrid fiber-wireless option. This approach still requires a significant investment from the County, but is less expensive than an FTTP model and allows the County to develop infrastructure further into the target service area. If the County were to take this approach, the total projected cost would be approximately $43.5 million for a 65 percent aerial deployment, and approximately $52.4 million for an all underground deployment.

1.5.4 SWOT Comparison of Alternatives

It is important to consider the interplay of risk and reward in any approach the County takes, and to balance what is most meaningful for the County with what is feasible. A strengths, weaknesses, opportunities, and threats (SWOT) analysis can reveal important information to help determine the best way to proceed with a given project.

Table 2: SWOT Analysis of Potential Partnership Models

	Middle-Mile Fiber to Incent Wireless Investment	Hybrid Fiber-Wireless Option	Fiber-to-the-Premises – Dark Fiber Lease
Strengths	Enables greater connectivity with little County investment or risk.	Middle-of-the-road solution between full fiber and wireless-only deployments—could enable broader deployment than wireless alone, without the risks of an FTTP build.	Most scalable and future-proof infrastructure investment. Does not have same limitations as wireless deployment; fiber is not restricted to line-of-sight.
Weaknesses	Can only reach approximately half the North End without additional County investment; no future plan for reaching remainder of target area.	Relies on private partner(s) to market and sell services to recoup any of County's investment.	FTTP is a Premier product that may be too expensive/unnecessary for many users.
Opportunities	Enables the County to foster positive relationships with the local provider community.	Enables deeper penetration into target area with less investment than full FTTP deployment, and supports future private investment.	Once fiber is in the ground, it is a "future proof" technology that can support a range of deployments and other needs for many years to come.
Threats	The County is relying entirely on the private sector and has minimal control.	County must incur significant cost, and has no guarantee that it will recoup any of its expenses.	Very expensive to deploy FTTP, particularly in areas where it may be difficult to build.

1.5.5 Potential Partners

CTC held preliminary discussions with wireless internet service providers (WISPs) in the area to gauge interest in partnership with the County to provide affordable, reliable internet service. In these discussions, we explained the County's goals, offered potential business models, and allowed the provider to make any suggestions as to what would inhibit or incent partnership.

While only one company was marginally interested in a fully FTTP model, we identified five companies who expressed potential interest in serving the North End via a hybrid fiber-wireless model.

Each provider-expressed concerns toward the models proposed, and wanted further figures for determining feasibility. Providers are acutely aware of the low population density of the area, and wanted to ensure the project would make financial sense to help both the company and the County to recover the initial investment of network deployment. In addition, providers were quick to emphasize that standard pole and tower lease fees would be excessive, due to the low number of potential customers in the County's North End.

Providers also suggested solutions to accomplish the County's goals, including using existing structures rather than building new poles, and expediting County processes to allow for provider construction. We discuss these potential partners, solutions, and summaries of our conversations further in section 2.4.

1.6 The County Can Easily Reach Approximately Half of the Currently Underserved Population

As the case study in Howard County illustrates, it is not always possible to address the entirety of a locality's concerns right away. We anticipate that Harford County can reach about half of the underserved population in the North End through modest, inexpensive measures—such as leveraging its existing assets to support one or more private providers deploying wireless equipment on existing towers within Harford County. However, the remaining 50 percent of the population that the County aims to serve will be more difficult and expensive to reach, regardless of the County's approach.

Put simply, if the County is willing and able to make a sizeable investment, it can deploy an FTTP network deep into the North End to serve the target customer base. The estimated cost to construct the proposed FTTP OSP throughout the County's North End target service footprint ranges from approximately $49.7 to $60.7 million, depending on the amount of aerial construction performed.

Alternatively, the cost to take an incremental approach in which the County offers use of its existing fiber and tower assets to a private provider that will install fixed wireless equipment to serve end users is effectively zero. This approach does not require a capital investment by the County, just administrative and support costs to allow ISP access to towers and to provide backhaul over existing fiber.

Between these two approaches is the possibility that the County can adopt a hybrid fiber-wireless network concept, in which the County deploys fiber infrastructure deeper into the target service area. Doing this will increase the network's aggregate capacity and reduce challenges with achieving the desired wireless cover area. However, it also increases capital costs because of the expense associated with deploying fiber and setting poles.

In a hybrid approach, the County will deploy backbone and distribution fiber but will not deploy fiber to the "last mile." Instead, the fiber will support various alternatives to serve the last mile, and the fiber that the County deploys will support a range of technologies. For example, a robust backbone and distribution fiber deep into the North End can support fixed wireless solutions and cellular networks including 5G. In one version of this approach, where the County deploys a dense backbone and distribution fiber deep into North End, we anticipate its costs to be approximately $43.5 million to $52.4 million.

This approach represents a likely upper-bound to the range of potential hybrid fiber-wireless solutions. Other conceivable configurations falling between the use of only existing towers and this far more robust model that provides ubiquitous, high-speed coverage, may be feasible with tradeoffs in cost versus capacity and ubiquitous coverage as the slide bar moves along the scale towards wireless and away from fiber. We offer the particular scenarios presented in this analysis as key data points that bound the potential range of costs and benefit, and recommend that the County further consider these hybrid approaches in more detail, potentially working with candidate private partners to more precisely understand their business requirements.

2 Public–Private Partnership Models

2.1 Model 1 – Private Investment, Public Facilitation

The first partnership model represents the lowest level of risk to the County. While not a fully mutually-beneficial partnership, it focuses on modest steps the County can take to facilitate implementation and delivery of broadband services.

In this model, the County partners with a member of the private sector who is willing to invest capital, and design and deploy infrastructure. In addition, the private partner would assume responsibility for asset management, network services, and customer relations. In turn, the County facilitates construction through economic and procedural incentives, including tax benefits, streamlined permitting, public rights-of-way access, and allowing contracted inspectors to accelerate construction project timelines. In a best-case scenario, these processes can reduce the cost of outside plant construction by up to an estimated 8 percent.

Examples of this model are most visible in the efforts of Google Fiber in cities such as Austin, Kansas City, and Nashville. Though Google primarily works with larger municipalities, there is significant demonstrated evidence of smaller companies' interest in entering a partnership like this model. These companies look to maximize their potential by offering local businesses and institutions targeted services.

This partnership model is ideal for communities wishing to keep public cost as low as possible, and frequently results in increased broadband marketplace competition and incumbent equipment upgrades. However, in an un- or underserved locality such as the North End, these benefits most likely would not be immediately realized. Further, this model prevents the County from obtaining any control over the installed network assets or construction timeline, and can prove to be a public relations risk if something goes wrong on the partner's end.

2.1.1 Case Study: Holly Springs, NC

The town of Holly Springs, North Carolina is a fantastic example of this partnership model in practice. Based on Town-made design and engineering plans, the Town built a robust fiber backbone capable of a dramatically higher capacity than broadband need deemed necessary at the time of construction. By creating a future-proof, widely distributed infrastructure, the Town possessed a powerful tool to attract potential private partners. Leveraging this fiber asset, the Town sought partners capable of bringing last-mile fiber to each household and business in the area.

In addition to the infrastructure itself, the Town created policies and procedures, which clearly demonstrated its interest in facilitating partnership. By streamlining government processes, allowing access to information and facilities, and providing project facilitation and support, the Town demonstrated its desire to be an active partner with the private sector.

In mid-2015, Ting Internet announced it would partner with Holly Springs to expand network connections throughout the area. Not only did the Town attract Ting with the ability to lease middle-mile fiber, but it also secured its confidence by enacting advantageous policy. Ting's investment in the town is well underway with construction to the first few large residential subdivisions complete, and the official activation of its first FTTP customer announced in January 2017.

2.2 Model 2 – Private Execution, Public Funding

The second model is a higher public risk, higher public benefit variation on the traditional municipal ownership model for broadband infrastructure. Similar to current models used in the U.S. for highways, toll roads, and bridges, this model is frequently used in Europe.

In this model, the public entity makes a significant investment, while the private partner assumes a combination of engineering, construction, financing, operations, and/or maintenance responsibilities. Depending on the partnership, sources of public capital may come from the local government, or in some models, a fee assessed on local property owners.

This model benefits the public partner as it capitalizes on the private partner's strengths to provide turnkey network services over an extended period (20-40 years). By removing the logistical barriers to a locality accomplishing such a large project, the partnership provides an effective solution for both parties by enabling private execution and capital.

The solution comes with the highest public risk of our three proposed models. If the private partner is unable to generate enough revenue to recover cost, or even sustainable profit margins, the public partner is still responsible, assuming the role of guarantor for the project. Further, the competitive nature of the broadband marketplace introduces inherent political problems. Were the County unable to garner enough support for the project, or a significant number of residents choose not to use the infrastructure, progress may be stalled or thwarted entirely.

2.2.1 Case Study: Macquarie Capital

Macquarie Capital pioneered this model in broadband infrastructure, proposing a scenario for network expansion. By using public funding, it looks to execute a complete FTTP network with potential long-term revenue benefits for the public.

In its proposed model, Macquarie offers to provide network financing, construction, operations, and service delivery. In return, the locality pays Macquarie on an ongoing basis using funds collected from placing a monthly fee on property owners' utility bills. The model suggests that as time passes, multiple ISPs will be able to compete to use the network to provide services to local homes and businesses, effectively lowering prices for customers.

Macquarie theorizes that after the construction period, service revenue will grow over time. As this occurs, a portion of the profits will be shared with the locality.

This model has been implemented to construct UTOPIA, a broadband network infrastructure of 15 communities in Utah. The partnership secured Macquarie to finish construction and provide network service for 30 years, using capital generated from the monthly property owner utility fee. Deterred by the fee, several communities have opted out of the UTOPIA project, revealing a large risk in the Macquarie model: the suggested utility fee may prove too heavy a political lift in some communities.

2.2.2 Case Study: SiFi Networks

SiFi Networks proposes another yet-untested model to use public funds and private partner contracts to build an FTTP infrastructure. In this option, the ISP providing service offsets the public partner's costs with monthly payments to the partner to use the city's infrastructure.

Compensated by lease payments from the public sector, SiFi Networks provides financing and turnkey network construction and operations. After the initial build-out, SiFi Networks brings the public partner one or more ISPs to provide services. The ISP(s) then contract(s) with the locality to pay for the opportunity to use the network at a negotiated rate based on the locality's actual cost.

The main benefit of this model lies with actual cost-negotiated payments from the ISP(s) to offset lease payments to SiFi Networks. The inherent risk hinges on SiFi Networks' chosen ISP(s)' ability to realize significant revenue and profit margins. If the service provider were unwilling or unable to continue under the model, the local government is left to bear the burden of payments to SiFi Networks.

2.2.3 Case Study: Symmetrical Networks

Symmetrical Networks suggests a partnership similar to the above models, but with a few important changes, namely giving the public partner choice in the ISP to use, and the potential to negate the public partner's monthly payments.

In Symmetrical Networks' plan, the company and its partners build, finance, and provide turnkey construction of a network operated by a public partner-chosen ISP. The public partner pays Symmetrical Networks a lease payment, which will cover the company's debt service, operating costs, and margins. In turn, the ISP pays the public partner an amount equal to the public partner's payment to Symmetrical Networks.

It is important to note that this model is estimated to be viable with a community take rate of 35 percent. Like SiFi Network's model, the viability of the partnership hinges on the ISP's ability to generate sufficient revenue to cover its payment to the locality, its costs, and an acceptable operating margin. Thus, there is significant inherent risk to the public partner. If revenue falls beneath obligatory levels, the locality is still responsible for payments to Symmetrical Networks.

2.3 Model 3 – Shared Investment and Risk (Public – Private Partnership)

The third model represents a partnership in the truest sense of the word. In this model, the unique strengths of both partners are capitalized, and the primary benefit arises from each partner sharing the heavy lifting of the project.

In this model, both partners develop a strategy to work together to realize their common goal in a framework unique to the project and locality itself. The public and private partners both leverage assets as appropriate, and negotiate logistics such as service provision, customer service operations, and maintenance to effectively realize their common goal. For greatest success, both must demonstrate willingness and an ability to compromise for the greater success of the project.

This concept manifests in a variety of ways. Frequently, the public partner provides fiber already in use for civil services, and the private partner invests to expand said fiber to develop a robust FTTP infrastructure. The public partner receives multiple "off the balance sheet" benefits, including substantial educational, health, and environmental benefits. Additionally, the private partner secures considerable upfront and long-term savings and enormous operational capabilities.

2.3.1 Case Study: Westminster, MD

The city of Westminster, MD demonstrates one of the most successful instances of this type of partnership. Greatly underserved by incumbent providers, and located in an area with no major highways, the City found itself with little potential for economic development. In 2010, Maryland won a federal award to bring fiber infrastructure to the state, and fiber was constructed within the City.

The City wanted to expand the fiber within City limits, but did not have a municipal utility to help encounter the problem. Further, the City had neither the resources, expertise, nor the political will to build a competitive ISP. The City made a visionary shift in perspective: viewing the fiber assets brought by the state as an asset like water and sewage lines, noting the possibility of using the infrastructure for public good.

The City decided to build, own, and maintain dark fiber. They then sought a partner to light the fiber, provide service, and handle customer relations. This allowed the City to remain independent of network and customer operations, mitigating management risks.

After releasing a request for proposals, the City partnered with Ting Internet, who shared the City's vision of an open-access network facilitated by a strong partnership. While there are elements of risk to both partners, the partnership ensures both sides will be active partners in the deal. The City assumes the risk of funding the dark fiber, while Ting will pay the City a two-tiered lease payment, one portion based on the number of passings in the network, and the second portion based on the number of subscribers on the network. This structure incents Ting to both accrue customers, and continue to provide quality service to those already subscribed.

Further, the partnership secures mutual financial benefit for both partners after the network is deployed and functioning. Any quarter where Ting's lease obligations are less than what the City needs to cover debt service, the provider will pay the City half of the deficit. In any quarter where Ting's obligations are greater, the provider will be reimbursed the equivalent amount. Lastly, once Ting hits certain revenue thresholds, it will share the revenue, awarding the City's risk.

This partnership is a solid example of ideal mutuality in a partnership: capitalizing on strengths, mitigating risk, and reaping shared rewards.

2.3.2 Case Study: Garrett County, MD

Garrett County demonstrates a successful partnership, which closely resembles Harford County's own broadband landscape at present.

The area is a relatively remote community, which struggled to obtain dependable internet service due to its mountainous terrain and remote households. Before construction, the only service available was either the inadequate speed of DSL or mobile wireless broadband, hindered greatly by data caps. For this reason, the county struggled to attract and retain businesses and teleworkers, and enable home-based businesses and schooling.

The County decided to gradually build fiber out to certain institutions, hoping they could eventually leverage the asset to attract a partner to help to expand the network to households in the area. In September 2015, Declarations Networks Group (DNG) partnered with the County to deploy a fixed-wireless network to the underserved areas in the County. After an initial County investment of $750,000, matched by the Appalachian Regional Commission (ARC), DNG committed to more than match the County to provide both capital and operational expertise to the project, enabling the County to reduce the number of homes without broadband access options to nearly zero percent.

While this partnership does entail a sizeable County investment, the money comes with enormous economic value for the dollar, enabling home schooling, teleworking, and bringing Internet service to roughly 3,000 under- or unserved homes. The County's ability to provide dark fiber, coupled with its willingness to take on some of the risk attracted DNG, enabled the partnership to bring broadband to nearly every home in the County.

2.4 Potential Partners

One of the County's goals in this feasibility analysis was to understand the private sector's willingness to partner with the County to address connectivity gaps.

2.4.1 Overview of Discussions with Potential Partners

CTC conducted high-level discussions with WISPs in the Harford County area to gauge the amount of interest in the County's goals, identify concerns, and assess the feasibility of partnership with the County. In identifying these potential partners, we surveyed 18 ISPs and WISPs, five of which expressed potential interest in providing services to the North End.

In these discussions, we explained the County's goals, identified potential challenges of the project, and requested the provider share any concerns or strategies for bringing services to the area. We also gauged the provider's presence in Harford County, as well as inquired about their experience with operating fixed-wireless equipment and networks.

Of those providers not interested, the primary determiner was the low population density of the area, deeming large investment in new infrastructure for a small customer base unfeasible. Multiple potential providers expressed that they would not be able to justify standard pole leasing fees due to the low number of customers served. Companies also were quick to suggest that partnerships frequently involve assuming non-traditional roles, processes, and services for which they felt unfit or simply did not want to navigate cumbersome responsibilities with little payoff.

The providers who expressed interest were clear that expansion needed to make sense financially. Further, that the County would need to understand the unique pricing schemes necessary for both user and provider to make service provision feasible. Each provider had unique models it suggested for the North End, each with unique concerns. Most providers expressed a need for high speed internet from the county, and expressed that County willingness to build middle mile fiber enhances the attractiveness of the project greatly.

Freedom Broadband – Interested in provision over a fixed-wireless network, using existing structures (buildings, silos, water towers etc.) as poles or towers. In this business model, Freedom provides service fee incentives to new customers to allow Freedom to place electronics on customer's premises, enabling the provider's footprint to expand at a lower cost. The company's main concern is obtaining wholesale-lit fiber within the County to broadcast internet to residences and businesses. Freedom is not interested in using County-provided electronic equipment for the last mile of the network, unless it is the same hardware it is already using in other networks. Freedom is interested in a partnership model like the one it is currently involved in in Howard County. In this partnership, Freedom and the County have an amicable "loose" agreement where the partners share information, and the County suggests where Freedom's expansion would be most beneficial for both parties.

Port Networks – Interested in further discussion to identify a solution, but expressed if a viable plan is created, it would be very interested in partnership. Port Networks' main concern is the feasibility of the project, suggesting if the County could "identify and cultivate demand" in such a way that network expansion seems viable, it would be very interested. In Port's suggestions, County-built middle mile fiber is necessary, and Port Networks would own and operate the wireless electronics to deliver last-mile services.

Quantum Internet Services – Interested in both fixed-wireless and greenfield FTTP models. Quantum would like to develop a strategy to serve both the North End and the more densely-populated southern parts of the County. In its estimation, the biggest concern in the North End is the price of construction, coupled with the headache of bureaucratic process. Were Quantum to pursue expansion, the project would need to be: "very attractive financially." Quantum expressed it would be especially interested in a model where the County builds and lights poles, and provides space on the poles for a feasible lease fee. Further, the provider would need to figure out how to get connectivity into the County, but Quantum's representatives do not believe that will be a difficult task.

Sugarloaf Network Systems – Interested in a fixed-wireless model where the County provides high-speed internet, and Sugarloaf constructs 96-foot poles (enough to reach 10 to 20 feet above tree tops) to broadcast signals between towers throughout the North End. In this model, Sugarloaf expects the County to facilitate zoning and permitting to expedite pole construction. Sugarloaf's primary concern is being able to own their own poles so that they do not have to deal with the logistics of electronics maintenance on privately owned poles. In turn, it is also concerned about providing power to these poles, especially in remote areas. For this model, the network infrastructure is mostly wireless, providing backhaul connections across terrain where OSP fiber may not be feasible.

Telegia – Interested in a true partnership, with solid measurable benefits for both parties. The company is open to the models proposed in this report, but with a clear emphasis that the County would need to facilitate processes on its end and allow the partner to operate a successful ISP. Telegia stressed that pole lease rates would need to reflect the low number of customers being served, and County network assets would need to be managed in a way that outages and other issues are quickly and efficiently solved. In our discussions, pricing for Telegia plans for similar network infrastructure models were quite high compared to more densely-populated areas, but the company points out that at times, customers need to share some of the cost of building in excessively difficult surrounding terrain.

2.4.2 The County Can Partner Imminently with One or More Wireless Providers for Minimal Investment

The County is in a position to take small steps and incur minimal cost to work with one or more private partners to encourage deployment a fixed wireless solution in the North End, and there appears to be significant interest from the private sector in partnering with the County.

The existing towers could serve nearly 50 percent of potential customers in the effective coverage area. That is, the County can encourage deployment with low-cost tower attachments and backhaul from the towers. With this approach private WISPs could potentially reach approximately half of its target 12,900 passings in the North End. As we noted, this does not address the remaining 50 percent of passings, which will be more difficult to reach.

However, if the County lowers barriers for WISP's, this may enable the private sector to take its own steps toward penetrating the North End beyond the initial, easily-served 50 percent. The County may work with its partner(s) to develop contractual obligations that ensure the partner(s) continue to obtain additional customers,[5] which may help toward the County's goal of serving approximately 12,900 passings in the North End—particularly if the County decides to offer tower access at no cost to one or more private providers.

Of course, the County cannot force a partner to build or deploy in areas where the private provider cannot obtain a favorable return on investment (ROI), which is why the incumbent upgrade model we discussed in Section 1.4 is often not sufficient to address many communities' needs. But if the County can find ways to incent investment by offsetting costs for one or more private partners, this may be a reasonable approach to driving infrastructure deployment deeper into the target service area. If a private provider does not have to pay for access to a tower or backhaul, it may be more willing or able to deploy.

[5] While CTC cannot provide legal guidance, we encourage the County to work with its legal counsel to ensure that any partnership contract it enters is carefully negotiated to ensure the most mutually favorable partnership arrangement.

3 Middle Mile Fiber and Tower Access to Incent Investment

Developing a solution to address the need for improved broadband services in the more rural areas of the County presents unique challenges, particularly if the strategy must provide a return on investment and ongoing revenues that cover operating costs. Without consideration of secondary economic development benefits in the long-term, the market potential in the County's North End is not likely to support an FTTP deployment, given the low density of potential business and residential customers. We thus begin our examination of technical strategies to deliver broadband connectivity to the North End with a relatively low-risk approach that could potentially attract a private partner with little or no new investment by the County.

Specifically, the proposed technical solution consists of a WISP-installed fixed, unlicensed broadband wireless network leveraging only existing County fiber and communications towers. This approach would enable a commercial provider to deliver fixed wireless broadband services to a large percentage of the underserved and unserved residents and businesses at speeds comparable to, or greater than that of DSL and similar fixed wireless services available in neighboring Counties (generally 10 Mbps, or less). For a limited number of customers, speeds upwards of 50 Mbps would be a reasonable target, particularly for businesses.

The County might be able to reduce cost barriers sufficiently to attract a commercial provider simply by offering access to existing communications towers, as well as HMAN fiber for backhaul. Alternatively, the County could conceivably build and operate the network itself with contractor support. In either case, this strategy represents a conservative approach to facilitating a much-needed service to existing residents and businesses, while promoting economic growth that might lead to more robust services in the future.

The following sections describe the technical approach and associated deployment costs of this candidate approach. Please note that the costs presented in this section would be the responsibility of the WISP.

3.1 Technical Approach

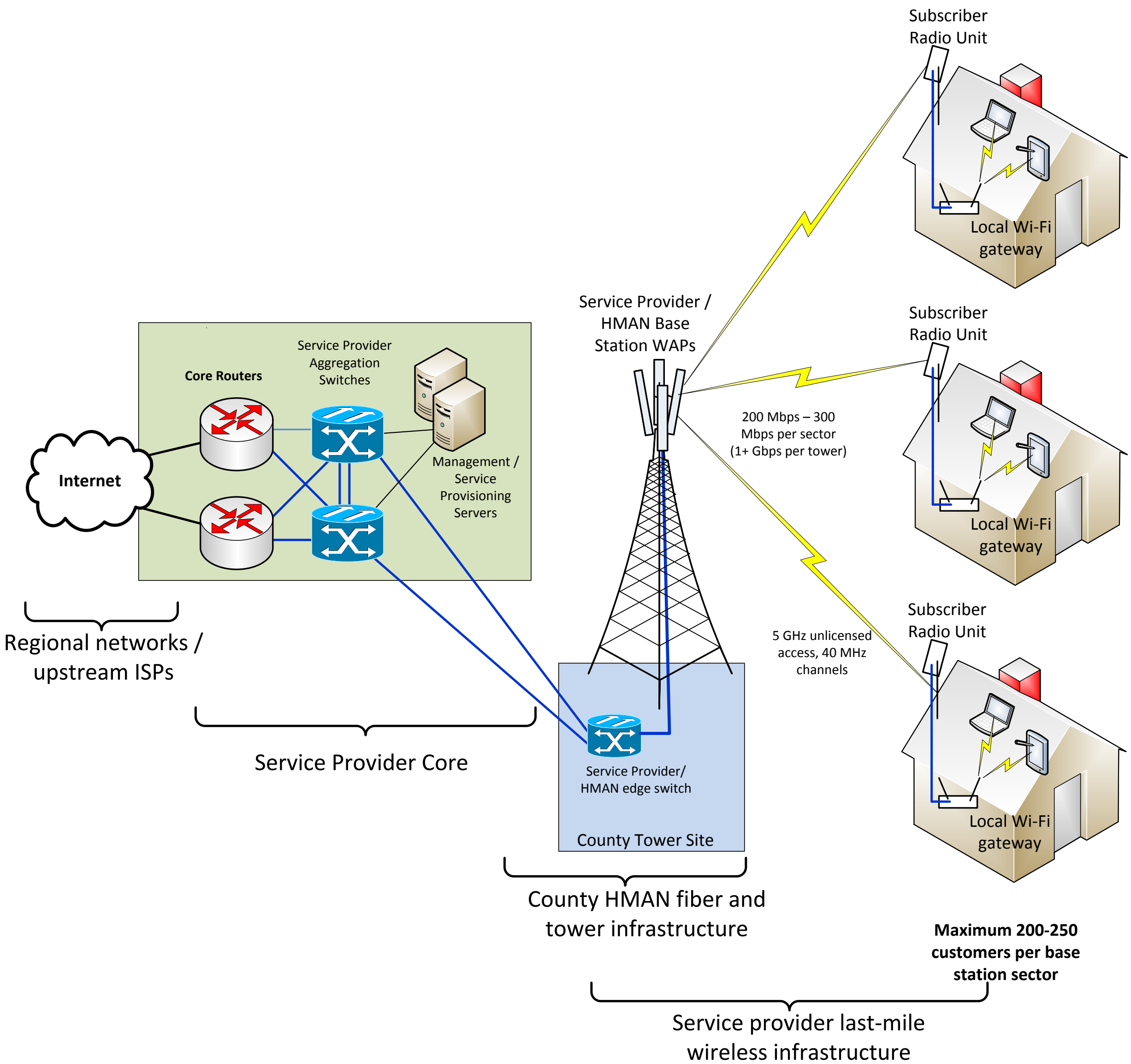
The proposed plan consists of creating broadband wireless access points from towers currently supporting County radio communications, and leveraging HMAN fiber optics for backhaul connectivity. At each tower location, base station wireless equipment would be installed to communicate directly with CPEs located within an estimated range of up to five miles. The base station radios would operate in the unlicensed 5 GHz band, which provides substantially more spectrum than the 2.4 GHz band, allowing the use of multiple, non-overlapping 40 MHz channels at each location to increase capacity and coverage. We anticipate each tower would be equipped with up to four dedicated base station radios and directional antennas, each providing coverage over a 90-degree sector.

Communications in the 5 GHz band, as with 2.4 GHz unlicensed spectrum, are prone to degradation due to physical obstructions, and unlicensed bands have the inherent challenge of interference from other widespread, competing uses. However, the use of multiple input, multiple output (MIMO) technology, similar to that which is used in the most recent versions of Wi-Fi (802.11n and 802.11ac), coupled with high-gain directional antennas provides substantial tolerance for obstructions and interference, as well as much greater range compared to typical mobile applications of this spectrum (e.g. Wi-Fi and cordless phones, for example).

Each antenna should be installed on the towers as high as possible to maximize the potential for line-of-sight (LOS) to the CPE. At the customer location, the CPE will likely be mounted to the side or roof of the building facing the closest tower. The CPE can also be mounted to a pole on the roof of a building, and will connect directly to an indoor customer interface device providing both Wi-Fi and hardwired Ethernet connections.

A high-level schematic illustrating this candidate solution is shown in Figure 3.

Figure 3: Wireless Broadband Concept



This solution would not support mobile access, but rather would be limited to connections between the base station radios and CPE radios installed in fixed locations. In other words, each connection will be part of an engineered solution, with installation effort comparable to that of direct broadcast satellite television service.

3.1.1 Tower Sites

There are five candidate towers currently used for County radio communications, each connected to HMAN fiber (Figure 4). Each of these towers are relatively large structures capable of supporting long-range microwave communications equipment, and likely could support the comparatively minimal structural and electrical requirements of the candidate broadband solution with little or no modification. Each would be used to support up to four base station radios mounted at a height near the top of the structure, as listed:

- Conowingo Tower (FCC registration 1234643), 340 feet
- Hickory Tower (FCC registration 035848), 322 feet
- Lapidium Tower (FCC registration 1062377), 170 feet
- Madonna Tower (FCC registration 1062375), 170 feet
- Whiteford Tower (FCC registration 1062373), 200 feet

We note that all but the Conowingo tower are County-owned, which is owned by the State of Maryland. A candidate commercial provider would likely incur lease fees for access to this tower, unless the County could negotiate access on its behalf.

Figure 4: Candidate Wireless Broadband Towers

Conowingo Tower

Hickory Tower

Lapidium Tower

Madonna Tower

Whiteford Tower

3.1.2 Technical Specifications

The following summarize the key technical specifications for the radio hardware used as the basis for our conceptual design and cost estimates.

- Four base station radios per tower, each providing the following:
    - Outdoor base station radio unit supporting 5 GHz transmission, 40 MHz channel widths, and 300 Mbps MIMO transmission (2x2 spatial stream configuration, or greater)
    - Gigabit Ethernet interface to HMAN or commercial provider handoff supporting "QinQ" double frame tagging
    - Directional sector antennas providing a minimum gain of at least 16 dBi
    - RF output power of at least 22 dBm

- CPE configuration providing:
    - Outdoor customer radio module supporting 5 GHz transmission, 40 MHz channel widths, and 300 Mbps MIMO transmission (2x2 spatial stream configuration, or greater)
    - Integrated directional antenna providing a minimum gain of at least 23 dBi
    - RF output power of at least 22 dBm
    - Separate indoor customer gateway router providing 802.11ac / 802.11n Wi-Fi access, Gigabit Ethernet customer interface, and PoE support for outdoor radio module

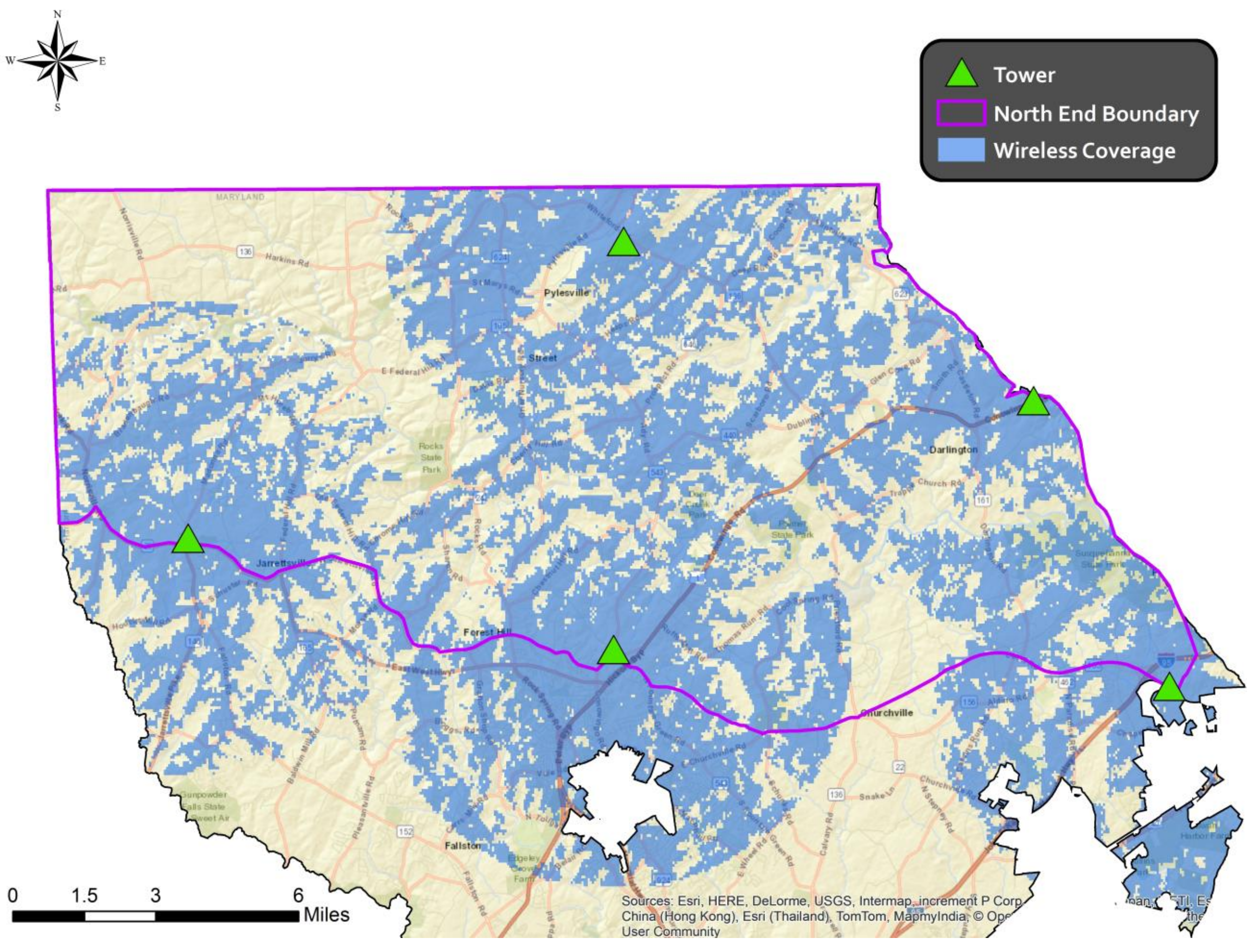
Candidate hardware includes the Cambium PMP 450i, Proxim Tsunami, and Ubiquiti airMAX product lines.

3.1.3 Capacity and Coverage Estimates

The total coverage area of this solution within the North End target area will be impacted by the ability to mount CPE antennas in an elevated location with line-of-sight (LOS), or near LOS, to a base station antenna. Radio Frequency (RF) interference is a potential source of degradation when using unlicensed frequencies, though in practice, the high directionality of the antennas and the rural nature of the target coverage area will provide significant protection from this type of interference.

Figure 5 provides a relatively conservative modeling of predicted coverage based on the hardware technical specifications described above, as well as: 1) placement of base station antennas at the highest point on the candidate towers; and 2) placement of CPE antennas at 15 feet or more above ground level. We used the "Longley-Rice" Irregular Terrain Model to provide a relatively conservative coverage analysis, incorporating an average ground clutter height of 45 feet to account for foliage, manmade structures, and anything else that might impact radio wave propagation. While the focus of our analysis and cost estimates are the North End boundary depicted in the figure, these coverage models demonstrate that significant coverage could be achieved towards the south in more populated, central areas of the County.

Figure 5: Overview of Predicted Wireless Coverage



In total, we estimate the candidate solution will provide coverage over 149 square miles within the County, of which 102 square miles fall within the target North End boundary. This equates to approximately 8,100 potential North End customers (“passings”), or 62 percent of the total 12,900.

The coverage depicted above is neither guaranteed, nor necessarily the upper limit. Coverage beyond the five-mile target radius per tower is feasible on a case-by-case basis, but for capacity purposes, the conceptual design seeks to limit this range. Furthermore, our design model and cost estimates assume CPE antennas are mounted at a modest average height of only 15 feet above ground level. Indeed, we can expect nearly any resident or business with a taller mounting structure, or who is willing to install a taller antenna mast, would be able to achieve connectivity to one of the five identified base station sites. Effective range of the technology with no obstructions in the transmission path approaches 30 miles. One approach to expanding this particular approach would be to construct of a limited number of additional tower structures to fill coverage gaps and/or subsidize customer activation costs for installations requiring “enhanced” mounting structures to improve wireless coverage from existing tower structures.

Currently, available hardware designed to support fixed, point-to-multipoint networks can achieve line rates of 200 Mbps to 300 Mbps per radio. Consequently, it might be possible to deliver more than 1 Gbps of aggregate capacity from each tower equipped with up to four radios. Actual speeds delivered will depend on wireless coverage and the number of customers connected.

Maximum possible connection speeds per customer can vary substantially with radio signal levels, interference, and related factors. As an example, Figure 6 illustrates in greater detail the anticipated primary coverage from the Madonna Tower. Even within just two to three miles of the tower, coverage can vary substantially due to terrain, but overall this model suggests the configuration is capable of delivering reliable connectivity to the vast majority of this area. In this figure, signal levels of -70 dBm and higher (denoted by green, yellow, orange, and red) suggest the ability to achieve the highest data rates supported by the hardware (>200 Mbps). Lower signal levels of less than -90 dBm may still offer reliable connectivity at lower speeds, or in some cases may require higher elevation mounting of customer radio units.

Figure 6: Example Primary Coverage Area – Madonna Tower

With each base station radio (i.e. sector) of this type typically capable of supporting connections to approximately 200 to 250 customers in a point-to-multipoint configuration, applying a reasonable oversubscription ratio of approximately 10:1 suggests the wireless access network could be expected to reliably deliver 10 Mbps connections to most residential and small business users. Providers generally rate-limit individual customer connections for "best-effort" service tiers to help ensure equitable access to available capacity by all customers. It would be possible to offer higher speed connections in the range of 50 Mbps, or more, as part of a premium subscription level with guaranteed quality levels to a very limited number of customers, keeping in mind that the total capacity ultimately is shared by all customer connections.

Furthermore, as capacity demand scales, it would be possible to further increase network capacity by adding additional base station radios and sector antennas to each tower, physically staggering the antenna mounting so that the total channel capacity in the 5 GHz band could be reused without conflict between overlapping and adjacent sectors.

3.2 Cost Estimates

This section presents cost estimates for the implementation and operations of the wireless solution described in previous sections. Cost breakdowns are provided for all anticipated direct costs, irrespective of the potential ownership and operating models.

Our cost models assume that the network would be operated by an established commercial service provider or the County, both of which would have pre-existing backbone network infrastructure, as well as basic network operations support and administrative infrastructure and staffing that could be scaled to support the network. These costs do not include the increased marketing, sales, and other required commercial operating expenses. Prior to pursuit of a wireless offering provided directly by the Count, additional technical, financial, and marketing analysis is likely required.

3.2.1 Capital and Operating Cost Estimates

The upfront costs for the implementation of the fixed wireless solution, estimated at approximately $206,000 (Table 3), comprise the installation of base station radio hardware, as well as backhaul network fiber and electronics. The configuration and cost of network electronics would likely vary only marginally depending on whether a commercial service provider or the County owns and operates the network electronics. These costs are essentially fixed to a take-rate of nearly 50 percent of potential customers in the effective coverage area.

Table 3: Fixed Wireless Base Station Implementation Cost Estimate

Description	Qty.	Estimated Unit Cost	Extended Cost
Base station radio, antenna, and installation hardware (per sector) • 5 GHz, 2x2 MIMO radios • 90-degree directional sector antenna (up to four radios per tower)	16	$5,000	$80,000
Base station radio and antenna installation and engineering (per tower)	5	$10,000	$50,000
Annual base station maintenance • Hardware maintenance contract • Assumes one radio failure/tower climb per year	1	$20,000	$20,000
Tower structural analysis	5	$2,000	$10,000
Backhaul network switch (e.g. Cisco ME 3400-12CS, including required SFP GBIC's and installation costs)	5	$6,000	$30,000
Annual switch maintenance	5	$1,200	$6,000
Network management server and licensing	1	$10,000	$10,000
		Total:	**$206,000**

The cost associated with the activation of customers, including the CPE electronics and installation labor, are variable with respect to take-rate. At nearly any reasonable take-rate, these represent a majority of the total capital costs, but are incurred only as the corresponding subscribers begin to generate revenue for the network. Table 4 presents estimated costs per subscriber, as well as total capital outlay for varying take rates.

Table 4: Variable Subscriber Activation Cost Estimates

Description	Unit Price	Qty.	Extended Price
CPE radio and antenna	$700	1	$700
Wi-Fi customer gateway	$100	1	$100
CPE installation and provisioning	$500	1	$500
Cabling and mounting hardware	$150	1	$150
Total Per Subscriber Cost:			**$1,450**
Total cost at 5-percent take-rate:			**$585,800**
Total cost at 20-percent take-rate:			**$2,343,200**
Total cost at 35-percent take-rate:			**$4,099,150**

Maintenance costs associated with manufacturer hardware maintenance contracts and repairs of backbone infrastructure are estimated at approximately $26,000.

The following table summarizes anticipated capital costs and annual incremental backbone maintenance expenses for a 35 percent take-rate scenario.

Table 5: Total Estimated Capital and Incremental Backbone Maintenance Costs – 35 Percent Take Rate Scenario

Item	Estimated Cost
Base Station Equipment • GHz sector radio hardware • HMAN or Commercial Provider fiber access equipment for backhaul	$136,000
Base Station Engineering and Installation • System design • Tower structural analysis • Radio and network equipment installation	$60,000
Network management server and software licensing	$10,000
Fixed Infrastructure Cost Subtotal:	**$206,000**
Subscriber Activation Costs (at 35 percent take-rate) • GHz outdoor access network radio • Indoor Wi-Fi gateway • Onsite radio mounting and installation	$4,099,150
Subscriber Activation Cost Subtotal: ***(dependent upon take-rate)***	**$4,511,200**
Total Capital Cost:	**$4,717,200**
Total Annual Maintenance Costs: ***(Base Station Infrastructure only)***	**$26,000**

4 Ubiquitous FTTP Network Concept

Compared to the conservative last-mile wireless broadband solution presented in Section 3, a Fiber-to-the-Premises (FTTP) solution deployed ubiquitously throughout the County's North End represents the opposite end of the spectrum in terms of cost and risk. Naturally, an FTTP network would provide the greatest degree of capacity and scalability – the highest cost, but the longest lasting and most future-proof approach.

Specifically, we now explore a candidate FTTP approach that 1) provides a scalable FTTP deployment to reach all candidate 12,900 passings; 2) can equally support any standards-based and emerging FTTP technology; and 3) provides expansive scalability to meet any reasonable future requirement—a solution that most certainly does not support a short-term or medium-term financial business case, but that could conceivably contribute positively to an aggressive, long-term (20+ year) strategy for economic growth.

The following sections describe the technical approach and associated deployment costs of this candidate approach.

4.1 FTTP Network Design

The physical outside plant (OSP) 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. Within this category of expenses, we include supporting infrastructure, including physical shelters for electronics, electrical power systems, and environmental control components.

Higher layer components include the OLT hardware (access layer); distribution network switches; and core network routers and switches; and network management systems—and depending on the business model and role of a given network operator, this might also include the application-layer systems required for the delivery of video content, voice and video communications, home automation services, and so on. In this case, we include only those systems pertinent to the delivery of high-speed internet services, but which can also support any range of voice, video, and other interactive services that one or more service providers might want to deliver as an over-the-top (OTT) internet-based service or out-of-band using dedicated fiber and/or lit capacity within the active FTTP network.

The particular technical approach and network electronics architecture drive certain baseline requirements for the underlying fiber optic infrastructure, such as fiber strand capacity requirements in certain segments of the network, type and quantity of outdoor equipment and fiber distribution cabinets, and requirements for physical path diversity of backbone connections. In consideration of the relatively long lifespan of the fiber infrastructure compared to particular network electronics options, service offerings, or even business models, the system-level design developed for purposes of our cost estimates assumes a best-in-class approach that is flexible enough to accommodate a wide range of short-term and long-term technical approaches.

The recommended design is a hierarchical data network with different attributes at each layer, targeting a balance of critical scalability and flexibility, both in terms of the initial network deployment and the capability to accommodate the increased demands of future applications and technologies.

The functional objectives driving this hierarchical FTTP data network are:

- ***Capacity –*** ability to provide efficient transport for subscriber data, even at peak levels, supporting any passive splitting ratio and/or dedicated fiber connections to each customer, with little or no oversubscription except at the core layer where peering occurs with upstream ISPs so that capacity can be increased readily as demands dictate;

- ***Availability and physical path diversity –*** provide high levels of redundancy, reliability, and resiliency to quickly detect faults and re-route traffic around diverse fiber paths in the event of a fiber break or equipment failure, with the option to place active backbone nodes located within close proximity to every potential customer and interconnected over diversely routed backbone rings;

- ***Scalability –*** ability to grow in terms of physical service area and increased data capacity, and to integrate newer technologies, with sufficient fiber capacity to support ongoing reduction of PON split ratios and/or increase in dedicated Active Ethernet connections.

- ***Flexibility –*** ability to provide different levels and classes of service into different customer environments, as well as the ability to support an open access network or a single-provider network. Separation between service providers can be provided on the physical (separate fibers) or logical (separate VLAN or VPN) layers.

- ***Security –*** controlled physical access to all equipment and facilities, plus network access control to devices.

4.1.1 Design Overview and Key Metrics

The network design model includes a backbone network layer providing connectivity between a single primary hub facility and fiber distribution cabinets (FDC) located throughout the North End target area, leveraging existing HMAN infrastructure to the extent possible. We include in this a dedicated, hardened shelter to serve as a central hub and to accommodate core network electronics. Even if an existing site or shelter could be utilized, maintaining physical separation from County facilities supports a broader range of operating models by avoiding issues related to physical site access by contractors and/or the staff of a candidate private partner functioning as the network operator.

Furthermore, our design model assumes service areas for each FDC encompassing roughly the same number of serviceable passings. Specifically, the backbone design targets a density of approximately 500 passings per hub / FDC, creating service areas for each that can be accommodated through a consistent configuration of network electronics and physical cabinet layout—an important consideration for maintenance and support efficiencies.

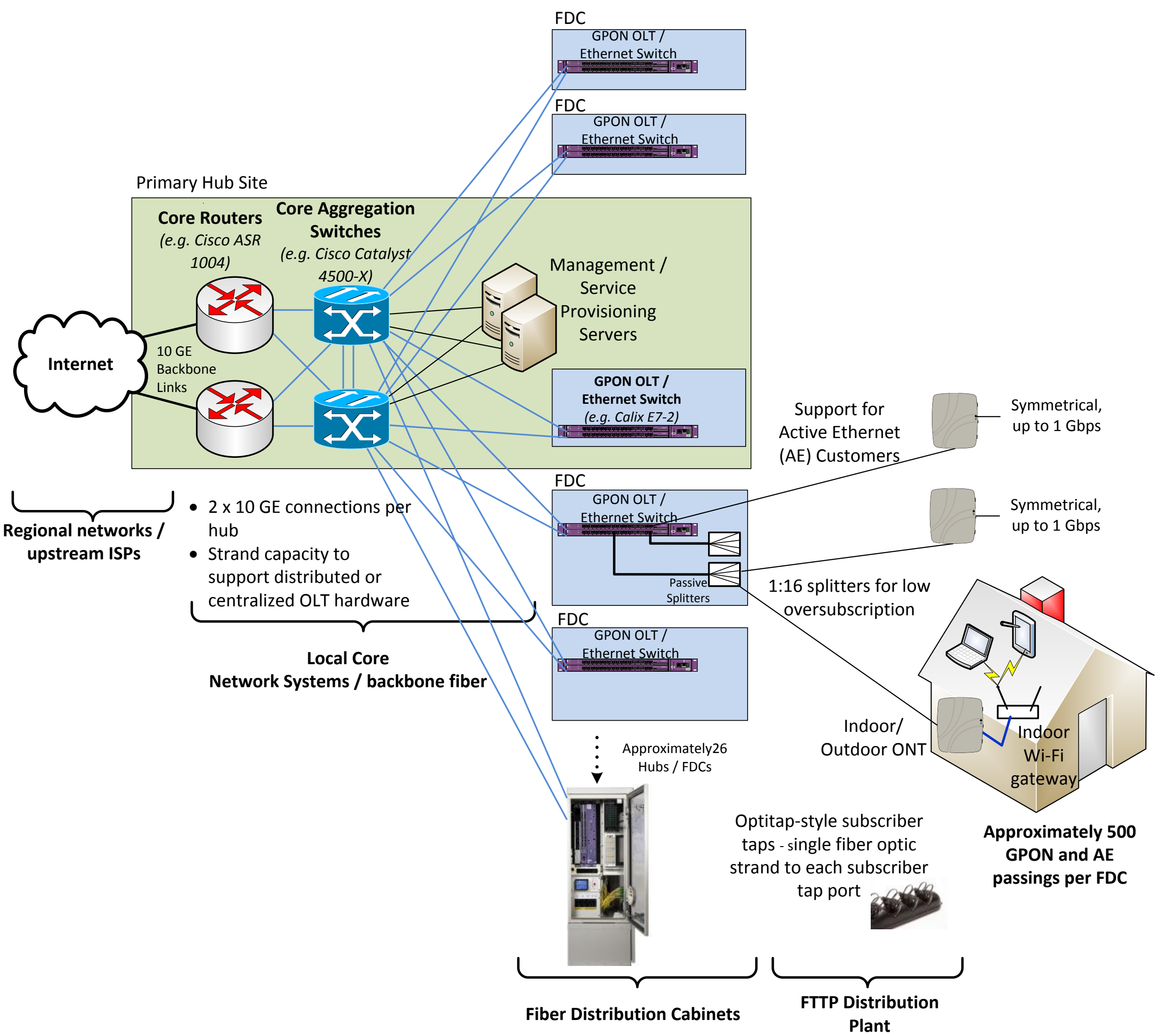
The backbone network, consisting of approximately 81 miles of fiber routes, almost all of which overlap with required FTTP distribution plant routes, would provide fully diverse connectivity between four primary hub locations and 26 FDCs. Coupled with an appropriate network electronics configuration, this design serves to greatly increase the reliability of fiber services provided to the customers compared to that of more traditional cable and telephone networks. The backbone design minimizes the average length of non-diverse distribution plant between the provider's electronics and each customer (less than a couple of miles in most cases, even in this rural environment), thereby reducing the probability of service outages caused by a fiber break.

For the sake of cost estimation, we assume the backbone network will include:

- A single equipment shelter functioning as a core and distribution-layer hub to support redundant core network electronics. The hub structure will likely consist of a pre-fabricated concrete shelter (approximately 10-foot by 12-foot), equipped with redundant air conditioners, backup generator and uninterruptible power supplies, and an inert gas fire suppression system;
- FDCs placed at approximately 26 additional locations along the backbone fiber routes, functioning as active distribution hubs suitable to support hardened network electronics with backup power and an active heat exchanger; and
- A dedicated fiber cable of at least 288-strand count.

Figure 7 illustrates the recommended reference design model for the FTTP network. The drawing 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 7: High-Level FTTP Architecture



The distribution fiber plant, encompassing the physical fiber cable from the hubs to the customers, is based on a "home-run" fiber architecture—meaning a dedicated fiber strand is available from a given hub to each passing. Compared to more traditional FTTP designs that generally employ optical splitters in the field (between the hubs and the premises in the figure above), thereby reducing the size of "feeder" cables, this design requires larger strand-counts and hub facilities capable of terminating a greater quantity of fiber strands.

This home-run architecture offers greater scalability to meet long-term needs, and is consistent with best practices for an open access network model that might potentially be required to support multiple network operators, or at least multiple retail service providers requiring dedicated physical connections to some or all customers. Whether centralizing network electronics in the primary hub locations and including only passive splitters in each FDC, deploying a combination of active and passive components, or implementing a fully active Ethernet network with dedicated connections to each customer, this design model fully supports any of these technical approaches.

The design model assumes placement of manufacturer-terminated fiber "taps" within the right-of-way or County easements, providing environmentally hardened fiber connectors for customer service drop cables. This is an industry-standard approach to minimize customer activation times and reduces the potential for damage to distribution cables and splices by eliminating the need for service installers to perform splices in the field. The design model and assumptions employed for cost estimation yield the following totals:

Table 6: Summary of Physical Plant Design Model Metrics

Total passings	12,943
Average Passing density	26.2 passings per street mile
Total hubs	1
Total FDCs	26
Total backbone routes (new and existing)	80.9 miles
Total standalone backbone routes	4.1
Total distribution plant path	499 miles

4.1.2 Backbone and Primary Hub Site

The primary hub site(s) in an FTTP network generally contain core network electronics that aggregate physical connectivity from the access and distribution layers of the networks, and may also contain servers and other systems related to the provision of particular services and applications. The proposed network design includes a single primary hub site comprised of an equipment shelter providing secure datacenter-like environments for sensitive network electronics, as well as hosting Operational Support Systems (OSS) for one or more providers, such as provisioning servers, fault and performance management systems, and remote access systems.

The hub would provide a point-of-presence for any business partner, content provider, or service provider for collocation purposes, and to gain access to the subscriber network to deliver services via the FTTP network. Furthermore, providers and businesses can gain access to these core resources at any location along the diversely routed backbone ring in the event space requirements or physical access needs demand separate facilities for a given provider or customer.

For cost estimation purposes, we assume that primary hub will involve the placement of a precast concrete shelter providing an operating environment similar to that of a data center. This includes clean power sources, UPS batteries, and diesel power generation for survival through sustained commercial outages. The facility must provide strong physical security, limited/controlled access, environmental controls for humidity and temperature, and an inert gas fire suppression system.

Although we expect the hub would be located at an existing County facility, such as the Emergency Operations Center (EOC), constructing these as dedicated shelters allows access to be controlled for outside contractors and staff responsible for FTTP operations—and conversely, to limit the need to provide access for these individuals to County infrastructure outside of their purview.

Figure 8: Sample Hub Facility

In the proposed design, the hub will house core, distribution, and access-layer network components. The distribution network is the layer between the network core and the access electronics that facilitates the aggregation of connections to the Optical Line Termination (OLT) access hardware, and can comprise multiple physical and electronic aggregation points that vary in function and scale depending on the specific design. In this model, the primary hub functions as the only distribution node, and contains OLT access network electronics and passive splitter components for customer access in the immediate vicinity.

The backbone fiber will support diversely-routed 10 GE uplinks from OLT hardware in each FDC to form high-availability distribution layers, including aggregation of redundant and diversely routed uplinks from access OLT hardware.

The primary hubs will serve as peering points for outside connections; house core systems for third-party service providers leveraging the County network as a last mile open access provider; and facilitate dedicated connections to high-end business customers requiring connections at speeds of 10 Gbps, or greater.

We note that our cost estimates are based on Cisco hardware at anticipated discount levels in the core and distribution layers of the network to offer a conservative estimate for a scalable architecture, though a wide range of manufacturers, including Juniper, Ciena, Alcatel-Lucent, Avaya, Brocade, and others have competitive offerings in some or all the required categories.

4.1.3 Access Network Hubs and Electronics

Access network electronics will be housed primarily in Fiber Distribution Cabinets (FDCs) located throughout the service footprint. FDCs can be placed in the right-of-way, either on a concrete pad or mounted on a pole, or can reside in a building. Our model recommends installing sufficient FDCs to support higher-than-anticipated levels of subscriber penetration and future growth potential. 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.

Specifically, the proposed design model includes 26 secondary hubs consisting of environmentally-hardened equipment cabinets to house access-layer electronics, optical splitters, and related passive fiber optic termination materials. The proposed fiber backbone will provide diverse physical paths between all hub locations so that the only single points of failure in the network exist in the “last mile” physical plant between the subscribers and the nearest hub enclosure or shelter.

The distribution fiber cable plant downstream from each hub/FDC consists of feeder and access fiber. The feeder fiber generally provides connectivity between each FDC and multiple network access points (NAPs) located throughout the distribution plant, consisting of fiber splice enclosures and/or optical splitters. The access fiber generally consists of cable plant connecting individual customer fiber connections to these aggregation NAPs, and may include outdoor taps providing environmentally hardened connectors for customer drop cables.

The distribution and access network design proposed in this report is flexible and scalable enough to support two different electronics architectures:

1. Housing the core, distribution, and access network electronics centrally within the primary hubs, using only passive devices (optical splitters and patches) within each of the FDCs; or
2. Pushing the distribution and access network electronics further into the network by housing them at the FDCs.

By housing all access network electronics only in primary hubs, the network would not require power at the individual FDCs. Choosing a network design that only supports this architecture may reduce certain implementation costs by allowing for smaller, passive FDCs in the field. However, this architecture will limit the redundancy capability from the FDCs to the hubs. By pushing the network electronics further into the field, the network gains added resiliency by allowing the access electronics to be fed from the redundant backbone network with automatic path protection switching to protect in the event of a fiber break. If backbone fiber is cut, the subscribers connected to a given FDC would still have network access.

Selecting a design that supports both models, as proposed, would allow the County to accommodate many years of shifting technology trends. In this case, the FDCs would be slightly larger, require electrical power connections, and contain active heat exchangers and backup battery systems (Figure 9), but would mitigate physical limitations to technology choices.

Figure 9: Active FDC Example (Calix OD-2000)

This design also increases the attractiveness of the FTTP infrastructure as a utility to facilitate access for competitive providers seeking to target specific market niches and requiring a limited initial investment in hardware of their own. The fiber-rich design allows these providers to enter the market with a small deployment of network electronics (i.e., placing electronics only at the primary hub sites for a small number of customers), while allowing them to grow their network in response to demand by pushing electronics closer to their subscribers as capacity or particular service level requirements dictate.

In this model, we assume the use of Gigabit Passive Optical Network (GPON) electronics for the vast majority of subscribers, and Active Ethernet for a small percentage of subscribers (typically business customers) that request a premium service or require greater bandwidth. GPON is the most commonly provisioned FTTP service—used, for example, by Verizon (in its FiOS systems), Google Fiber, and Chattanooga EPB. Furthermore, we believe that this hybrid GPON-Active Ethernet architecture, particularly when coupled with the recommended physical architecture, will fully meet demand for the entire lifecycle of the initial hardware platform deployment of at least five to seven years.

Providers of gigabit services today typically provide these services on GPON platforms. Even though the GPON platform is limited to 1.24 Gbps upstream and 2.49 Gbps downstream for the subscribers connected to a single PON splitter, operators have found that the statistical variations in actual subscriber usage generally means that all subscribers can obtain 1 Gbps on a peak basis (without provisioned rate-limiting), even if the capacity is shared by multiple users in a PON.

GPON supports high-speed broadband data, and is easily leveraged by triple-play carriers for voice, video, and data services. The GPON OLT uses single-fiber (bi-directional) SFP modules to support multiple (most commonly 32) subscribers per PON. GPON uses passive optical splitting, which is performed inside fiber distribution cabinets (FDCs), within the access network, or both, connecting fiber interfaces on the OLTs to the customer premises. In the proposed "home-run" access network architecture, all splitters are housed in the FDCs, each of which is equipped to support roughly 500 customers.

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-generation voice-over-IP (SIP and MGCP) services. For subscribers receiving Active Ethernet service, a single dedicated fiber connects between the subscriber premises and an access network Ethernet switch with no optical splitting. Because AE requires dedicated fiber (home-run) from the OLT to the CPE, and because each subscriber uses a dedicated SFP on the OLT, there is a significant equipment cost differential at the access layer to provision an AE subscriber versus a GPON subscriber. The recommended fiber plant design will provide Active Ethernet service or GPON service to all passings, enabling a range of electronics configurations based on the mix of services being offered. Furthermore, the recommended design entails the placement of equipment capable of providing a mix of both GPON and AE connections—managed and provisioned on a common platform, either from the same OLT line cards or by mixing different line cards in the same hardware chassis.

Although likely cost-prohibitive for several years, particularly in rural deployments, the emerging NG-PON2 and more recently announced XGS-PON standards promising to deliver 10 Gbps services over PON networks demonstrate that the physical fiber infrastructure built now will support future generations of electronics providing capacity increases of many orders of magnitude.

4.1.4 Customer Premises Equipment (CPE) and Service Drops

In the final segment of the recommended FTTP distribution plant, fiber runs from the FDC to subscriber taps located in the right-of-way near the customers' homes and office buildings. The taps consist of factory assembled connector housings in which the fiber strands terminate. The service installer uses a pre-connectorized drop cable to connect the tap to the subscriber premises without the need for fiber optic splicing. The drop cable extends from the subscriber tap (either on the pole or underground) to the building, enters the building, and connects to customer premises equipment (CPE).

We have specified two CPE kits (residential and business) to offer various features and capabilities and to meet subscriber requirements, either of which can be provided in an indoor or outdoor configuration. Both consist primarily of an Optical Network Terminal (ONT) capable of either GPON or Ethernet media conversion (or both), providing copper-based (RJ-45) Gigabit Ethernet interfaces at the customer demarcation. The recommended design includes installation of an uninterruptible power supply (UPS) for each, and installation of at least one network cable drop within the home or business to connect to customer equipment.

Either CPE configuration can support symmetrical gigabit per second service rates, and include an integrated VoIP gateway to provide telephone services. The residential CPE configuration includes an internet gateway with WiFi capabilities. The business CPE assumes the customer provides their own firewall or router at the service demarcation, but includes additional costs for more extensive indoor cabling and service provisioning support.

4.2 FTTP Network Cost Estimates

FTTP deployment will entail costs in three basic categories:

1. OSP labor and materials
2. Network electronics
3. Subscriber activation costs (service drop cables and CPE)

We examine costs for our design model in terms of a range varying with respect to the percentage of viable aerial construction (i.e. fiber attached to existing utility poles). On the lower-end, our model assumes a mix of aerial (65 percent) and underground fiber construction (35 percent), based on our field review of utility pole conditions in the target North End service area. [6]

The estimated cost to construct the proposed FTTP OSP throughout the existing County's North End target service footprint ranges from approximately $49.7 to $60.7 million, depending on the amount of aerial construction performed—which corresponds to a cost of approximately $3,840 to $4,690 per passing,[7] not including drop cable installation, CPE, or network electronics. With estimated core network electronics costs of $368,000 (not including OLT hardware that is somewhat take-rate dependent), the average per-passing cost jumps to a range of approximately $3,940 to $4,790.

With average per-customer activation costs ranging from approximately $1,690 to $3,540, including CPE and drop cable installation, the total network implementation cost, including OLT electronics, is estimated to range from $58.7 million to $78.1 million at a take rate of 35 percent. Please note this take rate is only used as a placeholder for discussion in this section; as seen in the financial analysis in Section 6.1, take rate has a significant impact on construction cost, cash flow, and net income. Table 7 summarizes the cost estimates.

[6] 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.

[7] 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.

Table 7: Estimated FTTP Deployment Costs (Assuming a 35 Percent Take Rate)

Cost Component	Total Estimated Cost	
	Lower End (65% Aerial)	**Upper-End** (All underground)
Backbone OSP Construction Costs		
OSP Engineering	$8,867,000	$8,867,000
Quality Control/Quality Assurance	$3,273,000	$3,273,000
General OSP Construction Cost	$35,370,000	$46,387,000
Special Crossings	$0	$0
Backbone and Distribution Plant Splicing	$860,000	$860,000
Backbone Hub, Termination, and Testing	$1,332,000	$1,332,000
Subtotal	**$49,702,000**	**$60,719,000**
Backbone Network Electronics Costs		
Core and Distribution Network Equipment	$368,000	$368,000
Access Equipment (GPON and Active Ethernet OLT)	$948,000	$948,000
Subtotal:	**$1,316,000**	**$1,316,000**
Subscriber Activation Costs		
FTTP Service Drop and Lateral Installations	$4,792,000	$13,193,000
Customer Premises Equipment and Installation	$2,861,000	$2,861,000
Subtotal:	**$7,653,000**	**$16,054,000**
Total Estimated Cost:	**$58,671,000**	**$78,089,000**

In the sections following, we describe our cost estimation methodology, and provide more detail on the estimated costs. We also discuss assumptions related to operating costs, and discuss implementation-phasing considerations.

Please note that in the financial section we present a partnership model based on the contract between Westminster MD and Ting. In this model Westminster MD is responsible for the OSP costs and the FTTP service drops and laterals. Ting is responsible for the core and distribution network equipment, access equipment, and customer premises equipment.

4.2.1 OSP Cost Estimation Methodology and Assumptions

Reaching every residence and business within the County's North End target footprint will require building FTTP infrastructure along the vast majority of the nearly 493 miles of applicable roadways. As with any utility, the design and associated costs for construction vary with the unique physical layout of the service area—no two streets are likely to have the exact same configuration of fiber optic cables, communications conduit, underground vaults, and utility pole attachments.

We surveyed a broad sampling of the target service area to estimate averages for key metrics impacting construction methodology and cost, such as requirements for special crossings (bridges, railways, etc.), the number of utility poles per mile, and the estimated level of utility pole make-ready construction required to facilitate aerial construction of fiber.

The survey of candidate routes revealed certain key metrics related to aerial infrastructure that informed the cost estimate. In general, we believe aerial construction is viable as a cost savings alternative to underground construction along as much as 65 percent of the total network routes. While Verizon utility poles are generally crowded and less viable, the BGE pole infrastructure is generally in good condition and has substantial available space for new attachments in the communications space. There are many 45 to 55 foot poles, mitigating attachment clearance issues more common with shorter poles. To establish the lower-end range of cost, we estimate only about five percent of the poles along aerial routes will require significant make-ready work, and less than two percent of the poles would require replacement.

Recognizing that pole attachments are an uncertainty and dependent upon utility pole owner cooperation regardless of pole condition, we establish an upper-end range of costs based on estimates for a completely underground build.

We subdivided the target service area based on passing density, and generated sample designs within strategically defined areas intended to be representative of the entire service area for purposes of extrapolation. Specifically, we created separate sample designs for "high" density areas averaging 39.3 passings per street mile, and "low" density areas averaging 25.3 passings per street mile. We note that although both of these areas reflect relatively low-density environments in comparison to typical FTTP deployments, the resulting topology between each is sufficiently varied so as to require different sample designs for extrapolation purposes. These sample designs, coupled with key metrics derived through GIS analysis and field surveys, were used to estimate quantities for corresponding labor and material units.

4.2.2 Fiber Construction Cost Estimates

The fiber construction cost estimates detailed below entail a turnkey implementation executed using contractor resources from design to acceptance testing. Backbone and distribution fiber plant implementation costs are estimated to range from $49.7 to $60.7 million, depending on the amount of aerial construction performed. At a take rate of 35 percent, we estimate fiber service drop connections costing an additional $4.8 to $13.2 million (from about $1,060 to just over $2,900 per drop on average), yielding a total OSP cost range of approximately $54.5 million to $73.9 million.

Cost estimates assume the installation of 2-inch flexible HDPE conduit using horizontal directional drilling along all underground routes (two 2-inch conduits along underground backbone routes). Cost estimates are inclusive of all project management, quality assurance, engineering, permitting, materials, and labor anticipated, including permanent hard surface restoration, traffic control, and work area protection. Table 8 and Table 9 provide OSP construction costs broken down by key line items and passing density for the lower-end and upper-end scenarios, respectively.

Table 8: FTTP OSP Construction Cost Estimates – Lower-End (65 Percent Aerial)

Cost Component	Phase 1	Phase 2	Phase 3	Total Estimated Cost
	Backbone	High Density (Avg. 39.3 passings/mi)	Low Density (Avg. 25.3 passings/mi)	
Backbone OSP Construction Costs				
OSP Engineering	$1,236,000	$574,000	$7,057,000	$8,867,000
Quality Control/Quality Assurance	$456,000	$212,000	$2,605,000	$3,273,000
General OSP Construction Cost	$1,890,000	$2,534,000	$30,946,000	$35,370,000
Special Crossings	$0	$0	$0	$0
Backbone and Distribution Plant Splicing	$4,000	$59,000	$797,000	$860,000
Backbone Hub, Termination, and Testing	$106,000	$153,000	$1,073,000	$1,332,000
			Subtotal:	**$49,702,000**
Subscriber Activation Costs				
FTTP Service Drop and Lateral Installations	$0	$792,000	$4,000,000	$4,792,000
			Subtotal:	**$4,792,000**
			Total Estimated Cost:	**$54,494,000**
Total Estimated Passings:	N/A	1,401	11,542	12,943

Table 9: FTTP OSP Construction Cost Estimates – Upper-End (All Underground)

Cost Component	Phase 1 Backbone	Phase 2 High Density (Avg. 39.3 passings/mi)	Phase 3 Low Density (Avg. 25.3 passings/mi)	Total Estimated Cost
Backbone OSP Construction Costs				
OSP Engineering	$1,236,000	$574,000	$7,057,000	$8,867,000
Quality Control/Quality Assurance	$456,000	$212,000	$2,605,000	$3,273,000
General OSP Construction Cost	$2,615,000	$3,307,000	$40,465,000	$46,387,000
Special Crossings	$0	$0	$0	$0
Backbone and Distribution Plant Splicing	$4,000	$59,000	$797,000	$860,000
Backbone Hub, Termination, and Testing	$106,000	$153,000	$1,073,000	$1,332,000
			Subtotal:	**$60,719,000**
Subscriber Activation Costs				
FTTP Service Drop and Lateral Installations	$0	$1,763,000	$11,430,000	$13,193,000
			Subtotal:	**$13,193,000**
			Total Estimated Cost:	**$73,912,000**
Total Estimated Passings:	N/A	1,401	11,542	12,943

The cost components itemized in the tables above include the following scope of tasks:

- ***Engineering*** – includes system level architecture planning, preliminary designs and field walk-outs to determine candidate fiber routing; development of detailed engineering prints and preparation of permit applications; and post-construction "as-built" revisions to engineering design materials.

- ***Quality Control / Quality Assurance*** – includes expert quality assurance field review of final construction for acceptance.

- ***General OSP Construction*** – consists of all labor and materials related to "typical" underground or aerial OSP construction, including conduit placement, utility pole make-ready construction, aerial strand installation, fiber installation, and surface restoration; includes all work area protection and traffic control measures inherent to all roadway construction activities.

- ***Special Crossings*** – consists of specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate / controlled access highways.
- ***Backbone and Distribution Plant Splicing*** – includes all labor related to fiber splicing of outdoor fiber optic cables.
- ***Backbone Hub, Termination, and Testing*** – consists of the material and labor costs of placing hub shelters and enclosures, terminating backbone fiber cables within the hubs, and testing backbone cables.
- ***FTTP Service Drop and Lateral Installations*** – consists of all costs related to fiber service drop installation, including OSP construction on private property, building penetration, and inside plant construction to a typical backbone network service "demarcation" point; also includes all materials and labor related to the termination of fiber cables at the demarcation point. A take rate of 35 percent was assumed for standard fiber service drops.

Where applicable, cost estimates are based on contract labor and material rates we have seen in other competitively bid fiber projects, including FTTP projects in the local vicinity.

4.2.3 Network Electronics Cost Estimates

Core, distribution, and access layer network electronics are estimated at a total cost of approximately $1.3 million, not including CPE. An additional cost for CPE of $2.9 million at a take rate of 35 percent yields a total network electronics cost of $4.2 million. All cost estimates include estimated installation and integration costs. Table 10 provides estimated network electronics costs, broken down by project "phases" corresponding to areas of defined passing density.

Table 10: FTTP Network Electronics Cost Estimate

Cost Component	Phase 1	Phase 2	Phase 3	Total Estimated Cost
	Backbone	High Density (Avg 39.3 passings/mi)	Low Density (Avg. 25.3 passings/mi)	
Backbone Network Electronics Costs				
Core and Distribution Network Equipment	$368,000	$0	$0	$368,000
Access Equipment (GPON and Active Ethernet OLT)	$0	$105,000	$843,000	$948,000
			Subtotal:	**$1,316,000**
Subscriber Activation Costs				
Customer Premises Equipment and Installation	$0	$310,000	$2,551,000	$2,861,000
			***Subtotal*:**	**$2,861,000**
			Total Estimated Cost:	**$4,177,000**

CPE equipment and installation costs are estimated at approximately $630 for a standard residential subscriber and $700 for a business subscriber, both inclusive of onsite configuration of the CPE, installation of an uninterruptible power supply (UPS), and installation of at least one network cable drop within the home or business to connect to customer equipment.

4.2.4 Network Maintenance Costs

Fiber optic cable is resilient compared to copper telephone lines and cable TV coaxial cable. The fiber itself does not corrode, and fiber cable installed over 30 years ago is likely still in use and in good condition. However, fiber can be vulnerable to accidental cuts by unrelated construction, traffic accidents, and severe weather. One of the larger costs associated with OSP maintenance are associated with performing locates for underground plant in response to locate requests initiated through the state-mandated one-call “811” damage prevention system (i.e. the Miss Utility System).

Costs associated with maintenance and repair can be highly variable on a year-to-year basis, particularly for required undergrounding, relocations due to new construction conflicts, and fiber breaks - but over time, these costs trend towards averages we have seen in networks of varying size. In particular, for budgetary purposes, we recommend planning for expenses associated with OSP maintenance of approximately 2 percent of the total construction cost, or approximately $1.09 million to $1.48 million at a take-rate of 35 percent. Included within this figure is an estimated fiber break per year for every 10 miles of plant, with repair costs ranging from $5,000 to $10,000 per incident.

An estimated $170,000 annually is required for network electronics maintenance. This covers a range of strategies entailing a mix of manufacturer maintenance contracts and warehousing spare components. In general, the level of equipment redundancy provided by the recommended architecture eliminates the need for maintenance contracts that provide rapid, advanced replacement of failed hardware. Instead, our estimates include costs for maintenance contracts providing next-business-day replacement of failed components for the core and distribution layers of the network, as well as an annual budgetary estimate equivalent to 15 percent of the total cost of access layer equipment to cover spares, replacements, and/or equivalent maintenance contracts.

The estimated operating costs including staffing will vary from business model to business model. Please refer to Section 6 for an overview of our specific estimates for the business model analyzed for Harford County.

5 Hybrid Fiber-Wireless Network Concept

A hybrid fiber-wireless approach to broadband in the County's North End represents a middle ground between a last-mile wireless network limited to County towers (Section 3) and a ubiquitous FTTP network deployment (Section 4). It may be unclear as to where to draw the line between fiber and wireless for Harford County, outside the context of negotiations with a particular commercial provider or private partner, but as can be seen by current industry trends, there is a complementary relationship between fiber optic infrastructure and wireless last-mile access networks that warrants examination.

Pushing fiber optics deeper into the target service area increases the aggregate capacity of the network and reduces the challenges associated with achieving the desired wireless coverage, but naturally drives capital construction costs upwards towards that of FTTP. On the other hand, less fiber tends to reduce capital construction costs, but also decreases network capacity. Also, as the balance shifts from investments in fiber towards wireless infrastructure, a larger proportion of the costs take on the form of construction or leases for towers, utility poles, and other elevated mounting structures that may not have the same long-term benefits as fiber.

Regardless of where we adjust the slider bar on the scale from wireless to fiber, any reasonable scenario within this general approach could encourage private investment in wireless infrastructure, while representing a springboard for even more fiber-rich options in the future. The potential alignment of a hybrid fiber-wireless approach with current industry trends towards small cell deployments makes this approach particularly interesting as a longer-term infrastructure investment to facilitate these commercial deployments as the demand grows.

This section describes the current state of the wireless broadband industry in the context of the requirements and costs driving current trends towards small cell deployments, and provides a technical solution that the County could employ to meet current needs, encourage private investment, and generate revenue through infrastructure leases to commercial carriers in the future.

5.1 Current State of the Wireless Market

The way we access the internet has changed dramatically over the past decade. The rapid proliferation of smartphones and tablet computers has fueled an explosive growth in demand for mobile bandwidth. Increasingly, people access bandwidth-intensive applications, like media streaming and video calling, from their mobile devices. Globally, mobile traffic is expected to increase 12- to 15-fold from 2012 to 2018.[8]

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

In many areas of the country, wireless carriers are making major investments in their mobile networks to try to keep up with customer needs.[9] In the sections that follow, we identify some of the key technical and economic issues facing the wireless market nationwide.

5.1.1 The Densification of Cellular Networks

While the transition to LTE technologies allows wireless carriers to expand the capacity of their existing macro-cell towers, tower upgrades alone will not keep pace with growing demand. In high-density urban areas, investment in new towers has begun to level off. Instead, major carriers are investing heavily in small cell sites and distributed antenna systems (DAS).[10] Small cell deployments increased 140 percent in 2015, with the growth rate expected to continue to swell.[11] Although 5G standards will not be set until 2020, many experts expect small cells to be the basis of 5G deployments in urban areas.[12]

While there have been some misleading claims about 5G making fiber obsolete, the reality is that fiber will serve as the backbone of 5G deployments, with wireless backhaul in some cases augmenting, not replacing fiber.[13] Companies like Zayo and Crown Castle have invested heavily in fiber networks to serve as backhaul connections for cellular sites.[14] Instead of relying on a handful of fiber connections to towers and base stations, carriers now want fiber (or at least gigabit-capable) backhaul connections to as many small cell and DAS sites as possible. While some carriers are expanding their own fiber holdings, network densification efforts will inevitably force carriers to rely heavily on other dark fiber providers for backhaul connectivity.[15]

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

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

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

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

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

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

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

5.1.2 Economic Challenges for Small Cell Deployment

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

The high cost of constructing fiber remains a major hurdle for the small cell business model. Dark fiber providers are working closely with carriers to build metro fiber rings that pass through targeted areas, but the buildouts often take 18 to 24 months to complete, and a single contract with an anchor tenant is often not enough to justify the investment. In order to make the investment pay off, fiber-backhaul providers often try to sign up multiple tenants along their fiber routes.[16] Some also offer lit and dark fiber services to owners of buildings that their extended networks pass, further helping to improve the business case for the investment in fiber.[17]

The high cost of getting fiber to small cell nodes has led Sprint to embrace a wireless backhaul strategy for its densification efforts. While this will allow the company to cut deployment costs in the short term, analysts predict that if network traffic continues to increase, the company will eventually need fiber backhaul to its cell sites.[18]

Some municipalities are beginning to replace aging infrastructure with new infrastructure that is specially designed to make small cell deployments quicker, more affordable, and less aesthetically intrusive. Streetlights can be an ideal spot for a small cell site, but most current small cell designs can only support a single service provider, and constructing fiber and power to the site can be expensive. New York is in the process of replacing 250,000 streetlight poles with multi-tenant poles, capable of serving all four major carriers. The streetlights will contain a single antenna, managed by a neutral host. New York City's wireless strategist expects tenancy on the City's priciest poles to cost around

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

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

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

$650 per month.[19] Los Angeles and San Jose have also begun deploying fiber-connected, small-cell-ready streetlights, known as SmartPoles, through a Smart City partnership with Phillips and Ericsson.[20]

Local government assets that are in close proximity to available dark fiber or conduit will be particularly valuable to carriers as they search for economical ways of deploying small cells. Jurisdictions with extensive fiber assets will be able to capitalize on the growing demand for fiber backhaul by leasing fiber or conduit to carriers. Availability of fiber optics and mounting structures for wireless infrastructure could strengthen the business case for private carriers to deploy in more rural, underserved areas that might otherwise be too expensive to serve. If jurisdictions can offer affordable dark fiber services in these areas, it may help ensure small cells are deployed equitably.

5.1.3 The Impact of Millimeter Wave Technology on Fixed Deployments

In most markets, the cable and telecom companies generally enjoy a duopoly, which can reduce competitive pressure to invest in network improvements or expand service to unserved areas. Google Fiber provided a welcomed new entrant in a select group of markets. When Google announced it would start offering service in a city, the local cable and telecom incumbents often responded with a flurry of new investment and price cuts.[21]

Recently, Google announced it would pause its fiber-to-the-premises (FTTP) expansion plans. While some initial reports interpreted the announcement as Google giving up on tackling access, the company has emphasized that it is looking into more cost-effective ways to deliver gigabit internet service to end users.

Although no one can be sure what Google Fiber will look like in the future, its recent acquisition of the fixed wireless ISP Webpass likely offers a hint. Webpass uses wireless backhaul technologies to offer broadband speeds up to 1 Gbps to customers in multi-dwelling units (MDUs). The service, which currently is priced at $60 a month, relies on fixed millimeter wave (mmWave) antennas to send massive amounts of data over short distances, along direct lines of sight.[22]

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

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

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

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

Exactly how Google will integrate mmWave radios into its access strategy remains to be seen, but it is clear that wireless backhaul will play an important role going forward. Google Fiber President Dennis Kish has publicly stated that the company will take a hybrid approach in the future, relying on both wired and wireless technologies to deliver gigabit speeds to end users.[23]

The shift in Google Fiber's strategy is just one example of how recent advances in mmWave technologies are changing the economics of broadband deployment. Facebook is working with mmWave radios as part of its attempts to connect the unconnected and underserved across the globe.[24] AT&T recently announced that it plans to use mmWave radios along powerlines to provide backhaul connections to small cell and DAS sites, as well as to offer multi-gig residential services.[25] In Santa Cruz, California, local ISP Cruzio used $50,000 worth of mmWave radio transmitters to deliver gigabit speeds to 15 commercial and MDU residential locations, primarily in the downtown area. The project allowed the company to avoid the high cost of wired construction in urban areas and deliver upgraded service just three months after the project was announced.[26]

The high cost of building to the end customers' premises has made it hard for new entrants to compete with incumbent providers. While mmWave radios may not always be able to match the speeds of an FTTP or DOCSIS 3.1 HFC system, they can potentially deliver gigabit speeds at a much lower deployment cost because the very last segment of the fiber or coaxial cable connection is replaced by a wireless link. This creates an opportunity for new entrants to enter the fixed internet market. The startup Starry has plans to use mmWave radios to build a nationwide fixed wireless ISP, capable of delivering gigabit speeds at a fraction of the price consumers currently pay.[27] Starry CEO Chet Kanojia predicts that the lower cost of Starry's network buildout will allow it to turn a profit with just five to 10 percent of the market share, rather than the near 50 percent that most wired buildouts require.

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

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

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

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

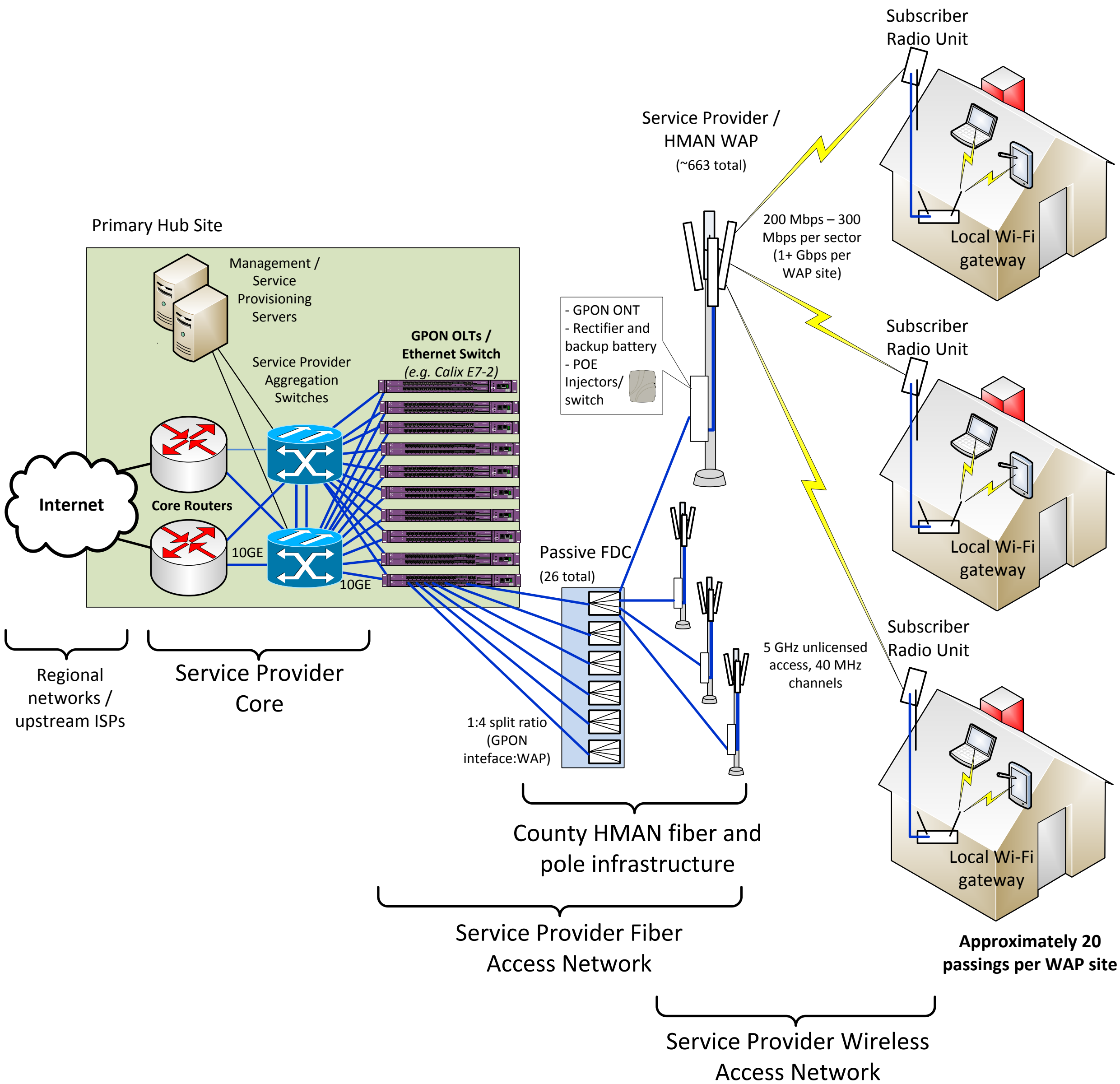
[27] Kevin Eck, "Where is He Now? Aereo Founder Chet Kanojia Looking to Disrupt Another Industry," *Ad Week*, October 24, 2016, http://www.adweek.com/tvspy/where-is-he-now-aereo-founder-chet-kanojia-looking-to-disrupt-another-industry/180606

5.2 Technical Approach

We now examine a potential technical strategy to address the County's North End broadband needs that strikes a balance between deploying new fiber and leveraging less costly wireless technologies for the customer connectivity in the last mile. In this case, the "last mile" consists of a hybrid GPON-wireless access network leveraging unlicensed frequencies, with wireless connectivity comprising only the last 1,500 feet or less. This approach seeks to reduce the capital costs relative to an FTTP deployment, while establishing a fiber footprint and wireless infrastructure capable of meeting the vast majority of potential requirements for future small cell deployments, and even provide an upgrade path to gigabit connectivity using emerging millimeter wave technologies.

Figure 10 provides a high-level overview of the architecture developed for this scenario.

Figure 10: Hybrid Fiber-Wireless Design Overview



The technical approach seeks to offer nearly ubiquitous coverage throughout the County North End, but in a targeted manner that uses wireless connectivity essentially to replace the service drop and a portion of the distribution plant compared to the FTTP design presented in Section 4. As with the FTTP design, this hybrid network would include a hardened shelter to serve as the central hub for the network. Unlike the FTTP design model, we propose centralization of the fiber optic access network equipment within the hub, requiring only passive components at intermediate locations within the fiber plant. In this scenario, we propose the use of GPON hardware as a resilient and relatively low cost fiber optic access network technology.

The physical fiber plant would consist of an estimated 356 route miles, including a backbone interconnecting the hub to a total of 26 fiber distribution cabinets (FDCs) located throughout the service area. The FDCs would house only passive optical components, including splitters. Fiber extending from the FDCs would connect to Wireless Access Points (WAPs) spaced approximately 2,500 to 3,000 feet apart along the right-of-way, each targeting a coverage radius of approximately 1,500 feet. In total, the design encompasses 663 WAP locations. The fiber network would contain sufficient strand capacity to facilitate an eventual migration to FTTP for some or all of the coverage area. In the meantime, each WAP and FDC would serve as access points to provide direct fiber connectivity for a limited number of customers with high bandwidth requirements.

Our design model and cost estimates are based on the use of unlicensed 5 GHz point-to-multipoint technology, leveraging a similar, but lower-cost version of the hardware proposed for the last-mile wireless solution in Section 3. Each WAP would consist of up to four base station radios and sector antennas providing coverage within a 90- or 120-degree arc to increase capacity and enhance coverage reliability, each serving approximately 20 potential customers, on average. The network would employ 4-way splitters in the GPON portion of the network so that each GPON interface on the OLT hardware would serve a total of four WAPs (a total of up to 16 WAP radio sectors).

Although substantially more tolerant of physical obstructions and interference at these relatively short distances, unlicensed 5 GHz frequencies would still necessitate line-of-sight (LOS), or near LOS, between the WAP antennas and each candidate customer to ensure high-speed, reliable connectivity. Furthermore, by anticipating this requirement in the initial design, the physical infrastructure is more likely to support a direct upgrade path to gigabit and higher speed connections using millimeter wave and future technologies. As such, our design model and cost estimates assume the installation of steel poles to facilitate WAP antenna mounting at heights of 50 to 60 feet, similar to what is used for traffic surveillance cameras and wireless communications equipment along highways. This would place antennas above the tree line and other nearby obstructions and foliage in most cases. Each WAP pole would be equipped with a weather-proof (eg. NEMA 4X) enclosure to securely house the GPON ONT (or other fiber optic access equipment) and backup power supply.

At the customer location, the CPE would likely be mounted to the side or roof of the building facing the closest tower. The CPE can also be mounted to a pole on the roof of a building, and will connect directly to an indoor customer interface device providing both Wi-Fi and hardwired Ethernet connections.

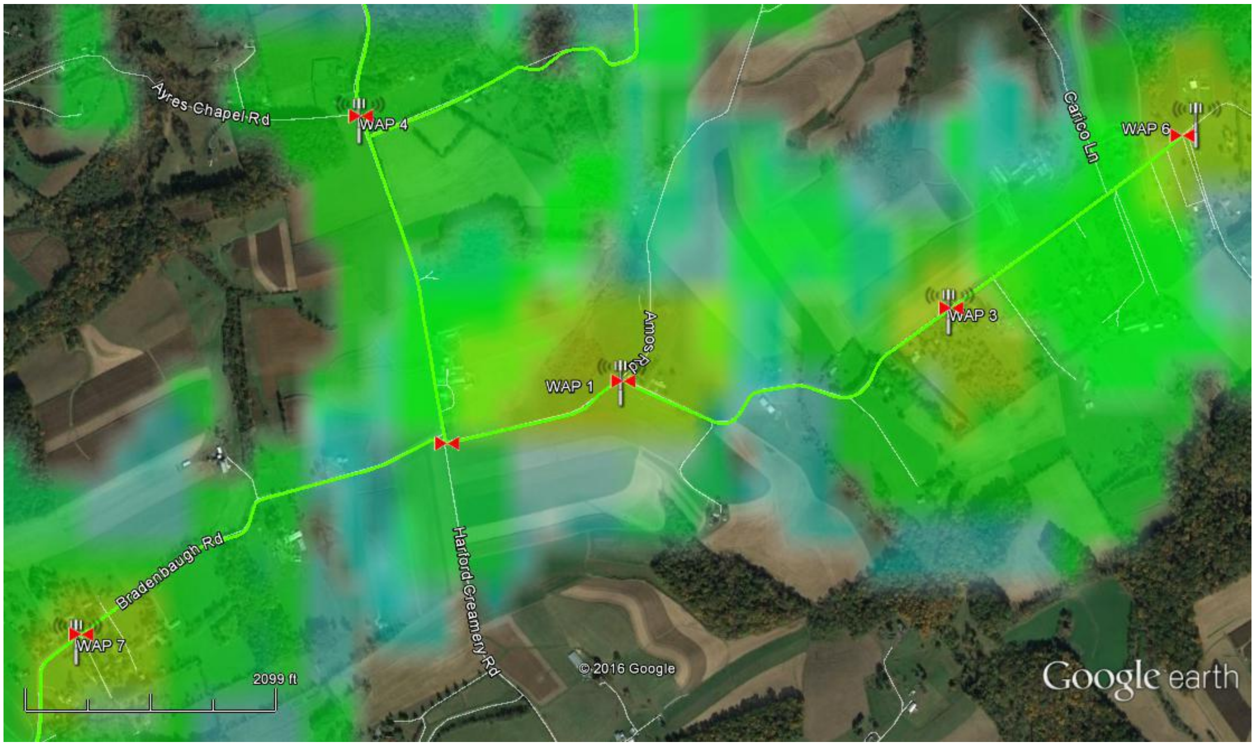
The WAP poles could be used simultaneously to support the proposed fixed wireless broadband solution, as well as multiple commercial small cell deployments, with both electrical power and fiber optics for backhaul offering a ready-made solution to support expansion of mobile broadband services.

5.2.1 Coverage and Capacity

On the scale of fiber versus wireless, the particular scenario presented leans towards a more fiber-rich design. As noted, the objective of the presented design would be ubiquitous coverage, but targeting fixed connectivity to residents and businesses rather than mobile access in unpopulated or undeveloped areas. Of the approximately 195 square miles in the County's North End target area, this design would provide primary coverage over at least 170 square miles. WAP pole locations and sector antenna alignment could be optimized for each localized coverage area to minimize the impact of obstructions.

Figure 11 illustrates the fiber path and anticipated coverage provided by the hybrid fiber-wireless network within a low-sample sample portion of the North End service area. This provides a relatively conservative modeling of predicted coverage based on the hardware technical specifications similar to those provided in Section 4.1.3, above, as well as: 1) placement of WAP antennas on poles at approximately 50 feet in height; and 2) placement of CPE antennas at 15 feet or more above ground level. Again, we used the "Longley-Rice" Irregular Terrain Model to provide a relatively conservative coverage analysis, incorporating an average ground clutter height of 45 feet to account for foliage, manmade structures, and anything else that might impact radio wave propagation.

Figure 11: Sample Hybrid Fiber-Wireless Coverage



With an average of only five customers per WAP sector, the network would support individual customer connection speeds up to the full data rates supported by the radio hardware, in the range of approximately 200 to 300 Mbps. Service levels of 50 Mbps to 100 Mbps could be reliably delivered to all subscribers. The combined GPON and wireless network would effectively deliver FTTP-like capacity in aggregate, with the scalability to increase capacity by reducing the split ratio in the GPON portions of the network, adding WAP radios and overlapping sector antennas to WAPs using additional radio channels, or both.

5.3 Cost Estimates

The hybrid fiber-wireless solution will entail costs in following basic categories:

1. OSP labor and materials, including WAP utility pole installations
2. Network electronics (fiber and wireless)
3. Subscriber activation costs (CPE and installation)

As with the FTTP model, we examine costs for our design model in terms of a range varying with respect to the percentage of viable aerial construction for the fiber optic portions of the network (i.e. fiber attached to existing utility poles). On the lower-end, our model assumes a mix of aerial (65 percent) and underground fiber construction (35 percent), based on our field review of utility pole conditions in the target North End service area.

The estimated cost to construct the proposed OSP throughout the existing County's North End target service footprint ranges from approximately $43.5 million to $52.4 million, depending on the amount of aerial construction performed—which corresponds to a cost of approximately $3,360 to $4,050 per passing (a savings of at least $500 per passing compared to FTTP),[28] not including CPE or network electronics. With estimated backbone and distribution network electronics costs (including both GPON and WAP radio equipment) of $3.1 million, the average per-passing cost jumps to a range of approximately $3,820 to $4,500. Unlike the FTTP model, the distribution network electronics are not variable with take-rate, as we assume the network is provisioned for full coverage. Strictly speaking, the installation of WAP electronics and GPON OLT hardware could be deployed in stages corresponding to initial subscription requests within the particular coverage area of a WAP, or even individual WAP sectors, though likely with reduced cost-efficiencies.

With average per-customer activation costs of approximately $485, including CPE, the total network implementation cost is estimated to range from $48.8 million to $57.7 million at a take rate of 35 percent (a savings of between $10 million and $20 million compared to FTTP).[29] Please note this take rate is only used as a placeholder for discussion in this section; as seen in the financial analysis in Section 6.2, which shows the impact of take rate on construction cost, cash flow, and net income. Table 7 summarizes the cost estimates.

[28] 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.

[29] 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.

Table 11: Estimated Hybrid Fiber-Wireless Deployment Costs (Assuming a 35 Percent Take Rate)

Cost Component	Total Estimated Cost	
	Lower End (65 Percent Aerial)	**Upper-End** (All Underground)
Backbone OSP Construction Costs		
OSP Engineering	$6,621,000	$6,621,000
Quality Control/Quality Assurance	$2,444,000	$2,444,000
General OSP Construction Cost	$22,464,000	$31,358,000
Special Crossings	$0	$0
Backbone and Distribution Plant Splicing	$685,000	$685,000
Utility poles for WAP mounting	$10,940,000	$10,940,000
Backbone Hub, Termination, and Testing	$327,000	$327,000
Subtotal	**$43,481,000**	**$52,375,000**
Backbone Network Electronics Costs		
Core and Distribution Network Equipment	$352,000	$352,000
Access Equipment (GPON and Active Ethernet OLT)	$2,781,000	$2,779,000
Subtotal:	**$3,133,000**	**$3,131,000**
Subscriber Activation Costs		
Customer Premises Equipment and Installation	$2,197,000	$2,197,000
Subtotal:	**$2,197,000**	**$2,197,000**
Total Estimated Cost:	**$48,811,000**	**$57,703,000**

In the sections following, we describe our cost estimation methodology, and provide more detail on the estimated costs. We also discuss assumptions related to operating costs, and discuss implementation phasing considerations.

5.3.1 OSP Cost Estimation Methodology and Assumptions

Reaching every residence and business within the County's North End target footprint with the proposed hybrid fiber-wireless design requires an estimated 356 miles of fiber - about 140 miles less than FTTP. To generate the OSP fiber estimates for this solution, we adapted the FTTP sample designs (described in Section 4.1) and resulting cost estimates primarily by: 1) eliminating the distribution plant associated with fiber taps beyond the feeder cables and splice enclosures; 2) reducing fiber strand counts, where appropriate; 3) reduced unit pricing for FDCs to accommodate a shift to passive-only distribution equipment; and 4) adjusted handhole quantities to reflect fiber access only at WAP locations, or as required for fiber pulling purposes (i.e. direction changes at roadway intersections).

Field survey analysis and related assumptions and estimations for fiber construction presented in Section 4.2 remain the same whether for the hybrid fiber-wireless solution or an FTTP network.

The primary addition to the OSP capital cost estimates includes the WAP poles, which include a 60-foot steel pole, equipment enclosure, and backup power system at an estimated cost of $16,500 each.

5.3.2 Fiber Construction Cost Estimates

The fiber construction cost estimates detailed below entail a turnkey implementation executed using contractor resources from design to acceptance testing. Backbone and distribution fiber plant implementation costs are estimated to range from $43.5 million to $52.4 million, depending on the amount of aerial construction performed.

Cost estimates assume the installation of 2-inch flexible HDPE conduit using horizontal directional drilling along all underground routes (two 2-inch conduits along underground backbone routes). Cost estimates are inclusive of all project management, quality assurance, engineering, permitting, materials, and labor anticipated, including permanent hard surface restoration, traffic control, and work area protection. Table 12 and Table 13 provide OSP construction costs broken down by key line items and passing density for the lower-end and upper-end scenarios, respectively.

Table 12: Hybrid Fiber-Wireless OSP Construction Cost Estimates – Lower-End (65 Percent Aerial)

Cost Component	Phase 1	Phase 2	Phase 3	Total Estimated Cost
	Backbone	High Density (Avg 39.3 passings/mi)	Low Density (Avg. 25.3 passings/mi)	
Backbone OSP Construction Costs				
OSP Engineering	$1,236,000	$344,000	$5,041,000	$6,621,000
Quality Control/Quality Assurance	$456,000	$127,000	$1,861,000	$2,444,000
General OSP Construction Cost	$1,890,000	$1,289,000	$19,285,000	$22,464,000
Special Crossings	$0	$0	$0	$0
Backbone and Distribution Plant Splicing	$4,000	$39,000	$642,000	$685,000
Utility Poles for WAP Mounting	$0	$627,000	$10,313,000	$10,940,000
Backbone Hub, Termination, and Testing	$106,000	$30,000	$191,000	$327,000
			Total Estimated Cost:	**$43,481,000**
Total Estimated Passings:	N/A	1,401	11,542	12,943

Table 13: Hybrid Fiber-Wireless OSP Construction Cost Estimates – Upper-End (All Underground)

Cost Component	Phase 1	Phase 2	Phase 3	Total Estimated Cost
	Backbone	High Density (Avg 39.3 passings/mi)	Low Density (Avg. 25.3 passings/mi)	
Backbone OSP Construction Costs				
OSP Engineering	$1,236,000	$344,000	$5,041,000	$6,621,000
Quality Control/Quality Assurance	$456,000	$127,000	$1,861,000	$2,444,000
General OSP Construction Cost	$2,615,000	$1,806,000	$26,937,000	$31,358,000
Special Crossings	$0	$0	$0	$0
Backbone and Distribution Plant Splicing	$4,000	$39,000	$642,000	$685,000
Utility Poles for WAP Mounting	$0	$627,000	$10,313,000	$10,940,000
Backbone Hub, Termination, and Testing	$106,000	$30,000	$191,000	$327,000
			Total Estimated Cost:	**$52,375,000**
Total Estimated Passings:	N/A	1,401	11,542	12,943

The cost components itemized in the tables above include the following scope of tasks:

- ***Engineering*** – includes system level architecture planning, preliminary designs and field walk-outs to determine candidate fiber routing; development of detailed engineering prints and preparation of permit applications; and post-construction "as-built" revisions to engineering design materials.

- ***Quality Control / Quality Assurance*** – includes expert quality assurance field review of final construction for acceptance.

- ***General OSP Construction*** – consists of all labor and materials related to "typical" underground or aerial OSP construction, including conduit placement, utility pole make-ready construction, aerial strand installation, fiber installation, and surface restoration; includes all work area protection and traffic control measures inherent to all roadway construction activities.

- ***Special Crossings*** – consists of specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate / controlled access highways.
- ***Backbone and Distribution Plant Splicing*** – includes all labor related to fiber splicing of outdoor fiber optic cables.
- ***Backbone Hub, Termination, and Testing*** – consists of the material and labor costs of placing hub shelters and enclosures, terminating backbone fiber cables within the hubs, and testing backbone cables.

Where applicable, cost estimates are based on contract labor and material rates we have seen in other competitively bid fiber projects, including FTTP projects in the local vicinity.

5.3.3 Network Electronics Cost Estimates

Core, distribution, and access layer network electronics are estimated at a total cost of approximately $3.1 million, not including CPE. An additional cost for CPE of $2.2 million at a take rate of 35 percent yields a total network electronics cost of $5.3 million. All cost estimates include estimated installation and integration costs. Table 14 provides estimated network electronics costs, broken down by project "phases" corresponding to areas of defined passing density.

Table 14: FTTP Network Electronics Cost Estimate

Cost Component	Phase 1	Phase 2	Phase 3	Total Estimated Cost
	Backbone	High Density (Avg 39.3 passings/mi)	Low Density (Avg. 25.3 passings/mi)	
Backbone Network Electronics Costs				
Core Network Equipment	$352,000	$0	$0	$352,000
Distribution and Access Equipment (GPON OLT and WAP equipment)	$0	$166,000	$2,613,000	$2,779,000
			Subtotal:	**$3,131,000**
Subscriber Activation Costs				
Customer Premises Equipment and Installation	$0	$238,000	$1,959,000	$2,197,000
			***Subtotal*:**	**$2,197,000**
			Total Estimated Cost:	**$5,328,000**

CPE equipment and installation costs are estimated at approximately $485 for a standard residential or business subscriber, both inclusive of onsite installation and configuration of the outdoor wireless access and indoor customer gateway.

5.3.4 Network Maintenance Costs

As with the FTTP approach, one of the larger costs associated with OSP maintenance are associated with performing locates for underground plant in response to locate requests initiated through the state-mandated one-call "811" damage prevention system (i.e. the Miss Utility System).

Costs associated with maintenance and repair can be highly variable on a year-to-year basis, particularly for required undergrounding, relocations due to new construction conflicts, and fiber breaks - but over time these costs trend towards averages we have seen in networks of varying size. In particular, we recommend planning for expenses associated with OSP maintenance of approximately 2 percent of the total construction cost, or approximately $870,000 to $1.04 million, which is not variable with respect to take-rate. Included within this figure is an estimated fiber break per year for every 10 miles of plant, with repair costs ranging from $5,000 to $10,000 per incident, as well as basic maintenance of utility poles and associated enclosures.

An estimated $447,000 annually is required for network electronics maintenance. This covers a range of strategies entailing a mix of manufacturer maintenance contracts and warehousing spare components. In general, the level of equipment redundancy provided by the recommended architecture eliminates the need for maintenance contracts that provide rapid, advanced replacement of failed hardware. Instead, our estimates include costs for maintenance contracts providing next business day replacement of failed components for the core and distribution layers of the network, as well as an annual budgetary estimate equivalent to 15 percent of the total cost of access layer equipment to cover spares, replacements, and/or equivalent maintenance contracts.

6 Partnership Models and Financial Analysis

In this section we present the financial analysis for the County leasing assets to encourage ISP's to offer services in the North End. The models reviewed include:

- A fully fiber-to-the-premises (FTTP) option (Dark FTTP Lease), in which the County would construct fiber to each premises in the North End, and lease that fiber to a private partner.
- A hybrid fiber-wireless option (Hybrid Fiber-Wireless Network Lease), in which a private partner would lease County fiber-to-the-neighborhood and County installed poles to expand services;

For each model we compare the required fees to maintain positive cash flow to the fees paid by Ting to the City of Westminster.

As seen in the analysis, the required fees are substantially higher than what Ting has agreed to pay the City of Westminster. This is since the housing density in the North End is low, which increasing the FTTP per-passing cost. The County is likely to see per-passing costs range from $3,820 to $4,500 in a hybrid fiber-wireless model, while they range from $3,840 to $4,690 in a ubiquitous FTTP approach.

We conducted a high-level analysis of the cost per passing in various states in the U.S., including California, Colorado, Indiana, Kentucky, Michigan, Washington, and Wisconsin. Our analysis showed an average per-passing cost of just under $1,400, based on the per-passing costs in the several communities we evaluated.

It is important to note the per-passing costs ranged from $1,100 to over $1,600; as such, we encourage localities to use caution when examining costs estimates from other communities. Actual costs will depend on housing densities, construction types, traffic control requirements, make-ready, and other factors.

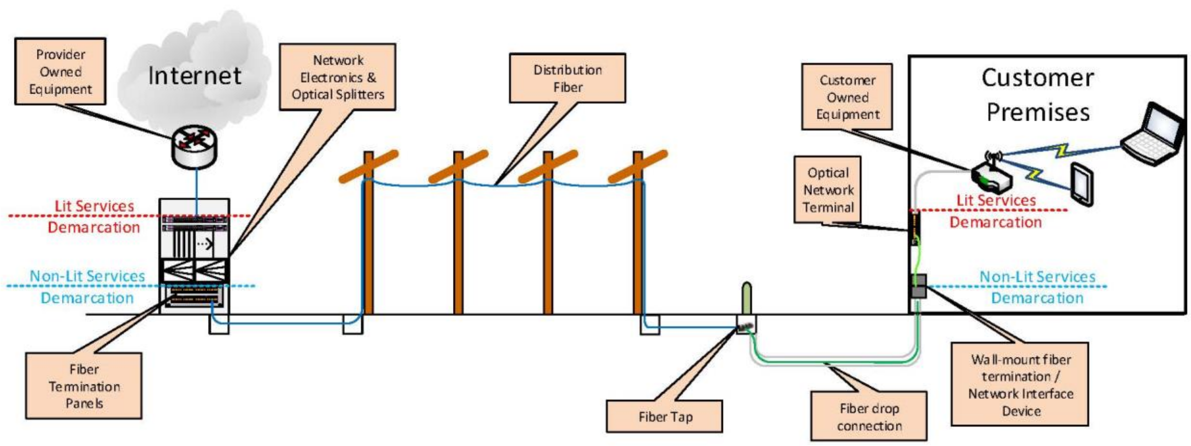
These costs do not consider the cost of network electronics necessary to "light" the network. Additionally, these do not include the cost for installing the customer drop cable, which is the fiber extension that connects a customer's premises to the fiber network.

6.1 Dark FTTP Lease

In our FTTP – Dark Fiber Lease model, presented in Section 4, we looked at two potential deployment options. The first proposes an entirely underground deployment, while the second looks at constructing both overhead and underground fiber, with 65 percent aerial and 35 percent underground fiber. The financial analysis in this section assumes that the County constructs and owns the fiber-to-the-premises (FTTP) infrastructure up to a demarcation point at the customer's home or business, and leases the dark fiber backbone, distribution fiber, and fiber drop cables to a private partner. The private partner would be responsible for all network electronics and customer premises equipment (CPE)—as well as network sales, marketing, and operations.

Figure 12 illustrates the demarcation points between County-owned and partner-owned infrastructure.

Figure 12: Demarcation between County and Partner Network Elements



The financial analysis presented here represents a minimum requirement for the County to obtain a break-even cash flow each year, excluding any potential revenue from other dark fiber lease opportunities that may be available to the County. We have provided a complete financial model in Excel format that can be leveraged to show the impact of changing assumptions. The spreadsheet can be an important tool for the county to use if it negotiates with a private partner.

In our modeling, we compared a similar dark FTTP deployment in the city of Westminster, MD. In their contract with Ting Internet, the city negotiated a per-passing fee ($6) plus per-subscriber fee ($17) per month for dark fiber usage. That is, Ting pays the city for every premises the network passes, plus an additional fee for every subscriber receiving service over the network, totaling $6 per non-subscribed passing and $23 per subscribed passing. As such, the take rate is vitally important to the feasibility of the project.

We include this reference to demonstrate what pricing is attractive enough to incent partnership, the financial implications of that pricing, as well as what Westminster pricing would look like in relation to network deployment costs for the North End. In all models, the required per-passing and per-subscriber fees are extremely high in relation to Westminster's partnership, while charging similar lease fees paid by Ting in Westminster MD will result in cumulative cash deficits over twenty years of greater than $80 million.

We have included a presentation of four scenarios for both build-out types (all underground and overhead/underground). These include a base case which projects what fees are necessary to maintain a positive cash flow each year, followed by three scenarios which demonstrate the implications of changing said fees and other variables.

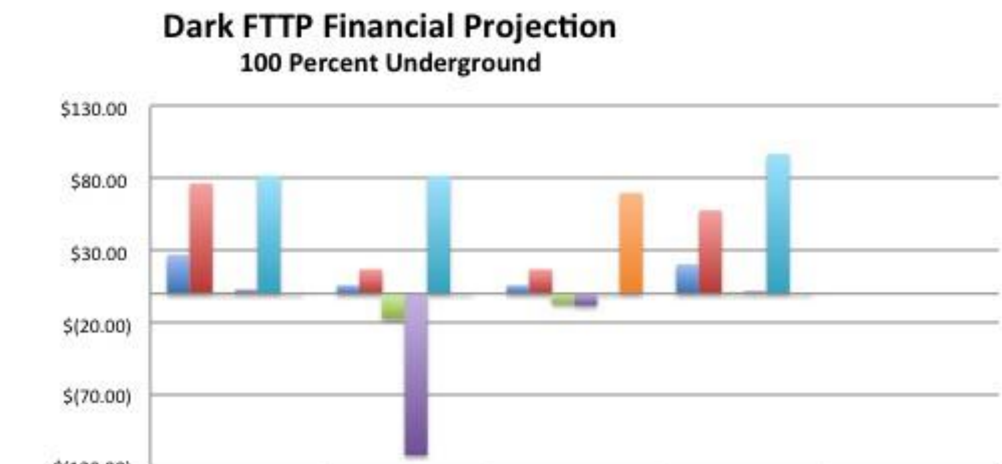
6.1.1 Dark FTTP Lease – Underground – Summary and Comparison

Our first infrastructure model proposes a completely underground FTTP build-out, including fiber drops to the customer premises. In this model, a private partner leases the fiber, provides network electronics to "light" the network, and manages all customer relations. To maintain a positive cash flow, and provided the private partner could obtain a 35 percent take rate, the County would need to charge $27.00 per passing per month, plus an additional $76.50 per subscriber per month (4 ½ times higher than the fees paid by Ting in Westminster). It should be noted that both fees are extremely high, and it is very unlikely that a private partner would agree to pay such high fees.

From there, we applied the same pricing that Ting is paying the city of Westminster to illustrate the impact of the high build cost in the northern part of Harford County. We then suggest what would be necessary in terms of grant funding (or other funding sources which would not need to be paid back) to operate with a positive cash flow while charging the same prices as in Westminster. Finally, we propose a highly unlikely scenario of a 70 percent take rate to illustrate how expensive lease fees would be, even at an extremely aggressive take rate.

We have included a graphic comparison of the four scenarios in Figure 13.

Figure 13: Dark FTTP Lease Scenario Comparison – Underground



	Take Rate 35 Percent - Maintain Cash Flow	Take Rate 35 Percent - Westminster Passing & Subscriber Fees	Take Rate 35 Percent - Westminster Passing & Subscriber Fees, Grant Funding	Take Rate 70 Percent - Maintain Cash Flow	
Passing Fee (per month)	$27.00	$6.00	$6.00	$20.40	
Subscriber Fee (per month)	$76.50	$17.00	$17.00	$57.80	
Cummulative Cash - Year 5 ($000,000)	$0.656	$(17.147)	$(6.736)	$0.119	
Cummulative Cash - Year 20 ($000,000)	$3.193	$(112.062)	$(8.000)	$2.035	
Bond ($000,000)	$82.000	$82.000	$-	$97.000	
Grant ($000,000)	$-	$-	$70.000	$-	

Each scenario is discussed in greater detail below.

6.1.1.1 Dark FTTP Lease Underground Base Case Scenario

In our base case scenario, we present what would be necessary to maintain positive cash flow given the estimated construction and operating costs. In this model, we assume a private partner can obtain and maintain a 35 percent take rate.[30] For reference, Table 15 summarizes our FTTP cost estimates from Table 9 in Section 4.2.

[30] Most overbuilders typically obtain at least a 35 percent take rate when entering a new market.

Table 15: Dark FTTP Underground OSP Cost Estimate Summary

Item	Cost
OSP Engineering	$8,867,000
Quality Control/Quality Assurance	3,273,000
General OSP Construction Cost	46,387,000
Special Crossings	-
Backbone and Distribution Plant Splicing	860,000
Backbone Hub, Termination, and Testing	1,332,000
Total Estimated OSP Cost	$60,719,000

The above estimate does not include fiber drop costs. In our modeling, we assume the County will be responsible for all fiber drops into customers' premises. For an entirely underground model, we estimate the drop costs at $2,912 each. For 12,943 total premises, at a take rate of 35 percent, drop costs would total just under $13.2 million.

We have provided a condensed income and cash flow statement for this scenario in Table 16.

Table 16: Dark FTTP Underground Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$33,810	$8,352,990	$8,352,990	$8,352,990	$8,352,990
Total Cash Expenses	(807,680)	(1,868,350)	(1,868,350)	(1,868,350)	(1,868,350)
Depreciation	(956,950)	(5,734,610)	(3,095,750)	(3,095,750)	(3,133,750)
Interest Expense	(820,000)	(3,044,600)	(2,351,580)	(1,508,710)	(483,660)
Taxes	-	-	-	-	-
Net Income	$ (2,550,820)	$ (2,294,570)	$1,037,310	$1,880,180	$2,867,230

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$254,630	$405,720	$1,264,680	$2,225,610	$3,182,200
Depreciation Reserve	-	251,130	302,190	250,840	11,580
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$254,630	$656,850	$1,566,870	$2,476,450	$3,193,780

Please note that we used a "flat model" in the analysis, which means that inflation and operating cost increases (including salaries) are not used because it is assumed that operating cost increases will be offset by increases in operator lease payments over time (and likely passed on to subscribers in the form of increased prices). We anticipate that the County will apply an inflation factor, typically based on a Consumer Price Index (CPI), to the portion of the per-subscriber fee that covers projected operating expenses during negotiations with a private partner.

6.1.1.2 Dark FTTP Lease Underground Financing

This financial analysis assumes that the County will cover all its capital requirements with general obligation (GO) bonds. We assumed that the County's bond rate would be four percent.

We expect that the County will take three 20-year bonds—one each in years one, two, and three—for a total of $82 million in financing. (The difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment.) The resulting principal and interest (P&I) payments will be the major factor in determining the County's long-term financial requirements; P&I accounts for about 77 percent of the County's annual costs in our base case model after the construction period.

We project that the bond issuance costs will be equal to 1.0 percent of the principal borrowed. For the bond, we assumed that neither a debt service reserve or interest reserve account is required. Principal repayment on the bonds will start in year two.

Table 17 shows the income statement for this base case scenario.

Table 17: Dark FTTP Lease Underground Income Statement

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
a. Revenues					
Per Passing	$20,960	$4,193,530	$4,193,530	$4,193,530	$4,193,530
Fiber leases (net)	-	-	-	-	-
Total	$33,810	$8,352,990	$8,352,990	$8,352,990	$8,352,990
c. Operating Costs					
Operation Costs	$490,430	$990,850	$990,850	$990,850	$990,850
Labor Costs	317,250	877,500	877,500	877,500	877,500
Total	$807,680	$1,868,350	$1,868,350	$1,868,350	$1,868,350
d. EBITDA	$(773,870)	$6,484,640	$6,484,640	$6,484,640	$6,484,640
e. Depreciation	956,950	5,734,610	3,095,750	3,095,750	3,133,750
f. Operating Income (EBITDA less Depreciation)	$ (1,730,820)	$750,030	$3,388,890	$3,388,890	$3,350,890
g. Non-Operating Income					
Interest Income	$ -	$630	$760	$630	$30
Interest Expense (20 Year Bond)	(820,000)	(3,045,230)	(2,352,340)	(1,509,340)	(483,690)
Total	$(820,000)	$ (2,351,580)	$ (2,351,580)	$ (1,508,710)	$ (483,660)
h. Net Income (before taxes)	$ (2,550,820)	$ (2,294,570)	$1,037,310	$1,880,180	$2,867,230
i. Facility Taxes	$ -	$ -	$ -	$ -	$ -
j. Net Income	$ (2,550,820)	$ (2,294,570)	$1,037,310	$1,880,180	$2,867,230

In this scenario, the County would operate with a net income deficit of over $2 million until year 9, at which point net income becomes positive and is just under $1 million, and greater than $2.8 million by year 20.

Table 18 shows the cash flow statement for this base case scenario.

Table 18: Dark FTTP Lease Underground Cash Flow Statement

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
a. Net Income	$ (2,550,820)	$ (2,294,570)	$ 1,037,310	$ 1,880,180	$ 2,867,230
b. Cash Outflows					
Debt Service Reserve	$ -	$ -	$ -	$ -	$ -
Interest Reserve	-	-	-	-	-
Depreciation Reserve	-	(91,750)	(49,530)	(49,530)	(50,140)
Financing	(205,000)	-	-	-	-
Capital Expenditures	(18,446,500)	-	-	-	-
Total	$ (18,651,500)	$ (91,750)	$ (49,530)	$ (49,530)	$ (50,140)
c. Cash Inflows					
Interest Reserve	$ -	$ -	$ -	$ -	$ -
Depreciation Reserve	-	-	-	-	-
Investment Capital	-	-	-	-	-
20-Year Bond Proceeds	20,500,000	-	-	-	-
Total	$20,500,000	$ -	$ -	$ -	$ -
d. Total Cash Outflows and Inflows	$1,848,500	$ (91,750)	$ (49,530)	$ (49,530)	$ (50,140)
e. Non-Cash Expenses - Depreciation	$956,950	$5,734,610	$3,095,750	$3,095,750	$3,133,750
f. Adjustments					
Proceeds from Additional Cash Flows (20 Year Bond)	$ (20,500,000)	$ -	$ -	$ -	$ -
g. Adjusted Available Net Revenue	$ (20,245,370)	$3,348,290	$4,083,530	$4,926,400	$5,950,840
h. Principal Payments on Debt					
20 Year Bond Principal	$ -	$3,198,130	$3,891,020	$4,734,020	$5,759,670
Total	$ -	$3,198,130	$3,891,020	$4,734,020	$5,759,670
i. Net Cash	$254,630	$150,160	$192,510	$192,380	$191,170
j. Cash Balance					
Unrestricted Cash Balance	$254,630	$405,720	$1,264,680	$2,225,610	$3,182,200
Depreciation Reserve	-	251,130	302,190	250,840	11,580
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$254,630	$656,850	$1,566,870	$2,476,450	$3,193,780

This scenario keeps the County operating with a positive cash flow, with a cumulative unrestricted cash balance of $1.2 million by year 10, and almost $3.2 million by year 20.

6.1.1.3 Dark FTTP Lease Underground Capital Additions

Significant network expenses—known as "capital additions"—are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building a fiber network. (Again, because the County's responsibility will be limited to OSP and drops, we have not included any costs for core network equipment, or CPE.) This analysis projects that the capital additions (including vehicles and test equipment) in year one will total approximately $18.4 million. These costs will total approximately $32.3 million in year two, $15.9 million in year three, and roughly $8 million in year four. This totals over $74.2 million in capital additions for years one through four.

These additions are shown in greater detail in Table 19.

Table 19: Dark FTTP Lease Underground Capital Additions

Capital Additions	Year 1	Year 2	Year 3	Year 4
Outside Plant and Facilities				
Total Backbone and FTTP	$18,215,700	$30,359,500	$12,143,800	$ -
Additional Annual Capital	-	-	-	-
Total	$18,215,700	$30,359,500	$12,143,800	$ -
Last Mile and Customer Premises Equipment				
Average Drop Cost	$40,800	1,846,200	3,768,100	7,539,200
Additional Annual Replacement Capital	-	-	-	-
Total	$40,800	$1,846,200	$3,768,100	$7,539,200
Miscellaneous Implementation Costs				
Vehicles	$50,000	$50,000	$ -	$ -
Emergency Restoration Kit	50,000	50,000	-	-
Work Station, Computers, and Software	5,000	3,000	6,000	-
Fiber OTDR and Other Tools	85,000	-	-	-
Additional Annual Capital	-	-	-	-
Total	$190,000	$103,000	$6,000	$ -
Replacement Costs for Depreciation				
Network Equipment	$ -	$ -	$ -	$ -
Last Mile and Customer Premises Equipment	-	-	-	-
Miscellaneous Implementation Costs	-	-	-	-
Total	$ -	$ -	$ -	$ -
Total Capital Additions	$18,446,500	$32,308,700 $74,212,300	$15,917,900	$7,539,200

6.1.1.4 Dark FTTP Lease Underground Operating and Maintenance Expenses

The cost to deploy a dark FTTP network goes far beyond fiber implementation. Network deployment requires maintenance and technical operations, support personnel, and other functions. In this model, we assume that the County's partner will be responsible for lighting the fiber and selling service. As such, the County's financial requirements are limited to expenses related to OSP infrastructure and network administration.

The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span while network test equipment will need to be replaced after five years.

These expanded responsibilities will require the addition of new staff. We assume the County will add a total of seven full-time-equivalent (FTE) positions within the first three years, and will then maintain that level of staffing. Our assumptions include one FTE for OSP management, one FTE for GIS and record keeping, one FTE for HR and administrative support, and four FTEs for fiber plant maintenance and operations. Salaries and benefits are based on estimated market wages, and benefits are estimated at 35 percent of base salary (added to the labor cost listed in Table 20). Table 20 summarizes these assumptions.

Table 20: Dark FTTP Lease Underground Labor Expenses

New Employees	Year 1	Year 2	Year 3	Base Salary
OSP Manager (GIS & Other)	0.50	1.00	1.00	$130,000
GIS	0.50	1.00	1.00	$80,000
HR, Admin & Support Allocations	0.50	1.00	1.00	$80,000
Fiber Plant O&M Technicians	1.00	1.00	4.00	$90,000
Total New Staff	2.5	4	7	

Locates and ticket processing will be significant ongoing operational expenses for the County. Based on our experience in other jurisdictions, we estimate that a contract for locates will cost $130,600[31] in year one, and increase to $522,300 from year two on. If the County decides to perform this work in house, the contract expense would be eliminated—but staffing expenses would increase.

Additional key operating and maintenance assumptions include the following:

- Insurance is estimated to be $50,000 in year one and $75,000 from year two on.
- Office expenses are estimated to be $2,400 annually.
- Contingency expenses are estimated at $10,000 in year one and $25,000 in subsequent years.

[31] Based on $3,750 per month per 50 miles of underground fiber plant.

- Legal fees are estimated to be $100,000 in year one, $50,000 in year two, and $25,000 from year three on.
- Consulting fees are estimated at $100,000 in year one and $20,000 from year two on.

Fiber network maintenance costs are calculated at 0.5 percent of the total construction cost, per year. This is in addition to staffing costs to maintain the fiber.

These expenses, as well as principal and interest payments, are shown in Table 21.

Table 21: Dark FTTP Lease Underground Operating Expenses and Debt Service Costs

Operating Expenses & P&I	Year 1	Year 5	Year 10	Year 15	Year 20
Insurance	$50,000	$75,000	$75,000	$75,000	$75,000
Office Expenses	2,400	2,400	2,400	2,400	2,400
Locates & Ticket Processing	130,600	522,300	522,300	522,300	522,300
Contingency	10,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance	91,080	303,600	303,600	303,600	303,600
Legal	100,000	25,000	25,000	25,000	25,000
Consulting	100,000	20,000	20,000	20,000	20,000
Education and Training	6,350	17,550	17,550	17,550	17,550
Sub-Total	$490,430	$990,850	$990,850	$990,850	$990,850
Labor Expenses	$317,250	$877,500	$877,500	$877,500	$877,500
Sub-Total	$317,250	$877,500	$877,500	$877,500	$877,500
Total Expenses	$807,680	$1,868,350	$1,868,350	$1,868,350	$1,868,350
Principal and Interest	$820,000	$5,549,710	$6,242,600	$6,242,730	$6,243,330
Facility Taxes	-	-	-	-	-
Sub-Total	$820,000	$5,549,710	$6,242,600	$6,242,730	$6,243,330
Total Expenses, P&I, and Taxes	$1,627,680	$7,418,060	$8,110,950	$8,111,080	$8,111,680

The County's expenses will total more than $1.6 million in year one, and rise to roughly $8.1 million by year ten and beyond.

6.1.1.5 Dark FTTP Lease Underground Scenario 2 – City of Westminster Pricing

Our second scenario demonstrates the implications of using the city of Westminster's pricing. In this scenario, we have projected the results of using a $7 per passing fee, with an additional $16 per subscriber fee. We have assumed a take rate of 35 percent.

As shown in Table 22, significant cash flow shortages are seen with the city of Westminster pricing. The cumulative cash flow shortage exceeds $112 million by the end of year 20.

Table 22: Dark FTTP Lease Underground Scenario 2 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$7,520	$1,856,220	$1,856,220	$1,856,220	$1,856,220
Total Cash Expenses	(807,680)	(1,868,350)	(1,868,350)	(1,868,350)	(1,868,350)
Depreciation	(956,950)	(5,734,610)	(3,095,750)	(3,095,750)	(3,133,750)
Interest Expense	(820,000)	(3,044,600)	(2,351,580)	(1,508,710)	(483,660)
Taxes	-	-	-	-	-
Net Income	$ (2,577,110)	$ (8,791,340)	$ (5,459,460)	$ (4,616,590)	$ (3,629,540)

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$228,340	$ (17,398,880)	$ (49,023,770)	$ (80,546,690)	$ (112,073,950)
Depreciation Reserve	-	251,130	302,190	250,840	11,580
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$228,340	$ (17,147,750)	$ (48,721,580)	$(80,295,850)	$ (112,062,370)

Using this pricing scheme results in a net income of negative $3.6 million by year 20, a difference from our base case of over $5.5 million. Further, this model creates a cumulative unrestricted cash balance deficit greater than $112 million by year 20.

6.1.1.6 Dark FTTP Lease Underground Scenario 3 – Westminster Pricing with Additional Grant Funding

To offset the enormous deficit generated by using the city of Westminster pricing, we looked at the impact of including $70 million in startup funds. These funds would be from grants or other sources, which would not need to be repaid. All other assumptions (pricing and take rate) remained the same as Scenario 2.

The resulting income and cash flow statements are shown in Table 23.

Table 23: Dark FTTP Lease Underground Scenario 3 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$7,520	$1,856,220	$1,856,220	$1,856,220	$1,856,220
Total Cash Expenses	(807,680)	(1,868,350)	(1,868,350)	(1,868,350)	(1,868,350)
Depreciation	(956,950)	(5,734,610)	(3,095,750)	(3,095,750)	(3,133,750)
Interest Expense	-	630	760	630	30
Taxes	-	-	-	-	-
Net Income	$ (1,757,110)	$ (5,746,110)	$ (3,107,120)	$ (3,107,250)	$ (3,145,850)

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$753,340	$ (6,987,560)	$ (7,395,650)	$ (7,701,770)	$ (8,012,230)
Depreciation Reserve	-	251,130	302,190	250,840	11,580
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$753,340	$ (6,736,430)	$ (7,093,460)	$ (7,450,930)	$ (8,000,650)

While the increase in initial startup funding does lessen the County's overall deficit, this scenario is still unable to generate positive cash flow, and results in a cumulative unrestricted cash balance deficit just over $8 million at the end of year 20.

6.1.1.7 Dark FTTP Lease Underground Scenario 4 – 70 Percent Take Rate

For our final scenario, we proposed an extremely high take rate of 70 percent to suggest what pricing would be necessary to obtain a positive cash flow. It should be understood that this take rate is highly improbable, and is being discussed for purposes of demonstration only.

In order to generate and maintain positive cash flow, a per-passing fee of $20.40 and per subscriber fee of $57.80 would be necessary from the private partner. These prices are nearly three times those received by the city of Westminster.

An income and cash flow statement for this scenario is shown in Table 24.

Table 24: Dark FTTP Lease Underground Scenario 4 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$25,550	$9,453,160	$9,453,160	$9,453,160	$9,453,160
Total Cash Expenses	(807,680)	(1,868,350)	(1,868,350)	(1,868,350)	(1,868,350)
Depreciation	(956,950)	(8,372,870)	(3,095,750)	(3,095,750)	(3,133,750)
Interest Expense	(820,000)	(3,622,700)	(2,807,230)	(1,815,760)	(609,910)
Taxes	-	-	-	-	-
Net Income	$ (2,559,080)	$ (4,410,760)	$1,681,830	$2,673,300	$3,841,150

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$246,370	$ (215,590)	$309,500	$1,063,520	$1,813,190
Depreciation Reserve	-	335,570	513,270	461,920	222,660
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$246,370	$119,980	$822,770	$1,525,440	$2,035,850

If the partner able to obtain a take rate of 70 percent, and the partner agreed to the fees proposed above, cash flow would become positive by year 10, resulting in a net income of nearly $1.7 million and a cumulative unrestricted cash balance of roughly $300,000. By year 20, these values would increase to roughly $3.8 million and $2 million respectively. Again – both the required fees and take-rates in this scenario are unlikely.

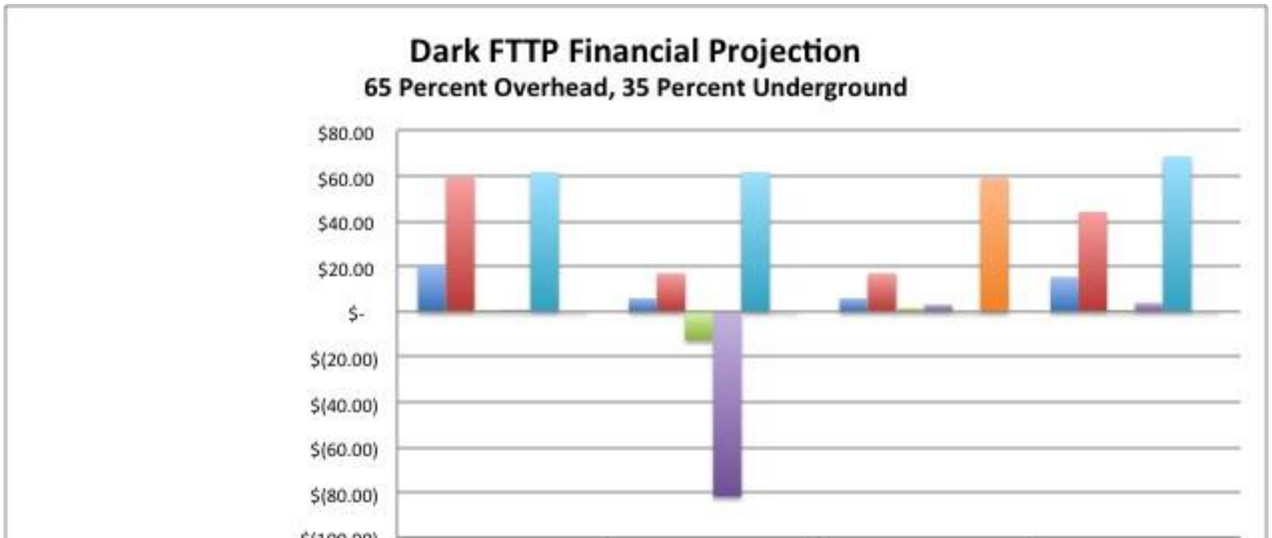
6.1.2 Dark FTTP Lease – Overhead/Underground – Summary and Comparison

Our second infrastructure model proposes a combination of overhead and underground fiber buildout. In this model, we estimate a total of 65 percent overhead and 35 percent underground fiber. The combination aerial and underground fiber lowers total construction costs by roughly $11 million, though lease pricing for this model remains quite high to attract partnership (3 1/3 times higher than what Ting pays the city of Westminster).

We investigated similar scenarios to Section 6.1.1.1 to assess feasibility and make a realistic comparison to the city of Westminster.

A comparison of all four scenarios is provided in Figure 14 for reference.

Figure 14: Dark FTTP Scenario Comparison – Overhead/Underground



	Take Rate 35 Percent - Maintain Cash Flow	Take Rate 35 Percent - Westminster Passing & Subscriber Fees	Take Rate 35 Percent - Westminster Passing & Subscriber Fees, Grant Funding	Take Rate 70 Percent - Maintain Cash Flow
Passing Fee (per month)	$21.00	$6.00	$6.00	$15.40
Subscriber Fee (per month)	$59.50	$17.00	$17.00	$44.20
Cummulative Cash - Year 5 ($000,000)	$0.168	$(12.549)	$1.911	$0.695
Cummulative Cash - Year 20 ($000,000)	$0.505	$(81.821)	$3.163	$4.022
Bond ($000,000)	$61.750	$61.750	$-	$68.750
Grant ($000,000)	$-	$-	$59.000	$-

6.1.2.1 Dark FTTP Lease Overhead/Underground Base Case Scenario

In our base case scenario, we present what would be necessary to maintain positive cash flow given the estimated construction and operating costs. Like the entirely underground model, necessary per-passing and subscriber fees are extremely high, at $21 and $59.50, respectively. This also assumes the private partner can obtain and maintain a take rate of 35 percent. However, with some underground construction costs mitigated by aerial construction, the fees necessary from the private partner are slightly lower than the entirely underground model.

For reference, Table 25 summarizes our overhead/underground FTTP cost estimates from Table 8 in Section 4.2.2.

Table 25: Dark FTTP Overhead/Underground OSP Cost Estimate Summary

Item	Cost
OSP Engineering	$8,867,000
Quality Control/Quality Assurance	3,273,000
General OSP Construction Cost	35,370,000
Special Crossings	-
Backbone and Distribution Plant Splicing	860,000
Backbone Hub, Termination, and Testing	1,332,000
Total Estimated OSP Cost	$49,702,000

The above estimate does not include fiber drop costs. In our modeling, we assume the County will be responsible for all fiber drops into customers' premises. For a combination overhead/underground model, we estimate to the drop costs at $1,158 each. For 12,943 total premises, at a take rate of 35 percent, drop costs would total just over $5.2 million.

We have provided an income and cash flow statement for this scenario in Table 26.

Table 26: Dark FTTP Lease Overhead/Underground Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$26,300	$6,496,770	$6,496,770	$6,496,770	$6,496,770
Total Cash Expenses	(740,200)	(1,700,080)	(1,700,080)	(1,700,080)	(1,700,080)
Depreciation	(786,770)	(3,594,300)	(2,544,900)	(2,544,900)	(2,582,900)
Interest Expense	(670,000)	(2,286,120)	(1,763,030)	(1,126,690)	(352,890)
Taxes	-	-	-	-	-
Net Income	$ (2,170,670)	$ (1,083,730)	$488,760	$1,125,100	$1,860,900

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$81,800	$5,100	$236,980	$508,460	$775,040
Depreciation Reserve	-	162,930	108,250	12,850	(270,460)
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$81,800	$168,030	$345,230	$521,310	$504,580

Please note that we used a "flat model" in the analysis, which means that inflation and operating cost increases (including salaries) are not used because it is assumed that operating cost increases will be offset by increases in operator lease payments over time (and likely passed on to subscribers in the form of increased prices). We anticipate that the County will apply an inflation factor, typically based on a Consumer Price Index (CPI), to the portion of the per-subscriber fee that covers projected operating expenses during negotiations with a private partner.

6.1.2.2 Dark FTTP Lease Overhead/Underground Financing

This financial analysis assumes that the County will cover all its capital requirements with general obligation (GO) bonds. We assumed that the County's bond rate would be four percent.

We expect that the County will take three 20-year bonds—one each in years one, two, and three—for a total of $61.75 million in financing. (The difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment.) The resulting principal and interest (P&I) payments will be the major factor in determining the County's long-term financial requirements; P&I accounts for about 73 percent of the County's annual costs in our base case model after the construction period.

We project that the bond issuance costs will be equal to 1.0 percent of the principal borrowed. For the bond, we assumed that neither a debt service reserve nor interest reserve account is required. Principal repayment on the bonds will start in year two.

Table 27 shows the income statement for this scenario.

Table 27: Dark FTTP Lease Overhead/Underground Income Statement

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
a. Revenues					
Per Passing	$16,300	$3,261,640	$3,261,640	$3,261,640	$3,261,640
Fiber leases (net)	-	-	-	-	-
Total	$26,300	$6,496,770	$6,496,770	$6,496,770	$6,496,770
c. Operating Costs					
Operation Costs	$422,948	$822,580	$822,580	$822,580	$822,580
Labor Costs	317,250	877,500	877,500	877,500	877,500
Total	$740,198	$1,700,080	$1,700,080	$1,700,080	$1,700,080
d. EBITDA	$ (713,898)	$4,796,690	$4,796,690	$4,796,690	$4,796,690
e. Depreciation	786,770	3,594,300	2,544,900	2,544,900	2,582,900
f. Operating Income (EBITDA less Depreciation)	$ (1,500,668)	$1,202,390	$2,251,790	$2,251,790	$2,213,790
g. Non-Operating Income					
Interest Income	$ -	$410	$270	$30	$ (680)
Interest Expense (20 Year Bond)	(670,000)	(2,286,530)	(1,763,300)	(1,126,720)	(352,210)
Total	$ (670,000)	$ (1,763,030)	$(1,763,030)	$(1,126,690)	$ (352,890)
h. Net Income (before taxes)	$ (2,170,670)	$ (1,083,730)	$488,760	$1,125,100	$1,860,900
i. Facility Taxes	$ -	$ -	$ -	$ -	$ -
j. Net Income	$ (2,170,670)	$ (1,083,730)	$488,760	$1,125,100	$1,860,900

This scenario would generate a net income of almost $490,000 by year 10, increasing to over $1.8 million by year 20.

Table 28 shows the cash flow statement for this scenario.

Table 28: Dark FTTP Lease Overhead/Underground Cash Flow Statement

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
a. Net Income	$ (2,170,670)	$ (1,083,730)	$488,760	$1,125,100	$1,860,900
b. Cash Outflows					
Debt Service Reserve	$ -	$ -	$ -	$ -	$ -
Interest Reserve	-	-	-	-	-
Depreciation Reserve	-	(57,510)	(40,720)	(40,720)	(41,330)
Financing	(167,500)	-	-	-	-
Capital Expenditures	(15,116,800)	-	-	-	-
Total	$ (15,284,300)	$ (57,510)	$ (40,720)	$ (40,720)	$ (41,330)
c. Cash Inflows					
Interest Reserve	$ -	$ -	$ -	$ -	$ -
Depreciation Reserve	-	-	-	-	-
Investment Capital	-	-	-	-	-
Start Up Funds	-	-	-	-	-
Grants (infrastructure)	-	-	-	-	-
Grants (customer premises)	-	-	-	-	-
20-Year Bond Proceeds	16,750,000	-	-	-	-
Total	$16,750,000	$ -	$ -	$ -	$ -
d. Total Cash Outflows and Inflows	$1,465,700	$ (57,510)	$ (40,720)	$ (40,720)	$ (41,330)
e. Non-Cash Expenses - Depreciation	$786,770	$3,594,300	$2,544,900	$2,544,900	$2,582,900
f. Adjustments					
Proceeds from Additional Cash Flows (20 Year Bond)	$ (16,750,000)	$ -	$ -	$ -	$ -
g. Adjusted Available Net Revenue	$ (16,668,200)	$2,453,060	$2,992,940	$3,629,280	$4,402,470
h. Principal Payments on Debt					
20 Year Bond Principal	$ -	$2,415,030	$2,938,260	$3,574,840	$4,349,350
Loan Principal	-	-	-	-	-
Total	$ -	$2,415,030	$2,938,260	$3,574,840	$4,349,350
i. Net Cash	$81,800	$38,030	$54,680	$54,440	$53,120
j. Cash Balance					
Unrestricted Cash Balance	$81,800	$5,100	$236,980	$508,460	$775,040
Depreciation Reserve	-	162,930	108,250	12,850	(270,460)
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$81,800	$168,030	$345,230	$521,310	$504,580

This scenario maintains a positive cash flow, resulting in a cummulative unrestricted cash balance of just over $775,000 by year 20.

6.1.2.3 Dark FTTP Lease Overhead/Underground Capital Additions

Significant network expenses—known as "capital additions"—are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building a fiber network. (Again, because the County's responsibility will be limited to OSP and drops, we have not included any costs for core network equipment, or CPE.) This analysis projects that the capital additions (including vehicles and test equipment) in year one will total approximately $15.1 million. These costs will total approximately $25.7 million in year two, $11.4 million in year three, and roughly $3 million in year four. This totals over $55.2 million in capital additions for years one through four.

Table 29 shows these additions in greater detail.

Table 29: Dark FTTP Lease Overhead/Underground Capital Additions

Capital Additions		Year 1	Year 2	Year 3	Year 4
Outside Plant and Facilities					
Total Backbone and FTTP		$14,910,600	$24,851,000	$9,940,400	$ -
Additional Annual Capital		-	-	-	-
	Total	$14,910,600	$24,851,000	$9,940,400	$ -
Last Mile and Customer Premises Equipment					
CPE (residential and small commercial)		$ -	$ -	$ -	$ -
CPE (medium commercial)		-	-	-	-
CPE (enterprise)		-	-	-	-
Average Drop Cost		16,200	734,200	1,498,500	2,998,100
Additional Annual Replacement Capital		-	-	-	-
	Total	$16,200	$734,200	$1,498,500	$2,998,100
Miscellaneous Implementation Costs					
Vehicles		$50,000	$50,000	$ -	$ -
Emergency Restoration Kit		50,000	50,000	-	-
Work Station, Computers, and Software		5,000	3,000	6,000	-
Fiber OTDR and Other Tools		85,000	-	-	-
Additional Annual Capital		-	-	-	-
	Total	$190,000	$103,000	$6,000	$ -
	Total Capital Additions	$15,116,800	$25,688,200	$11,444,900	$2,998,100

6.1.2.4 Dark FTTP Lease Overhead/Underground Operating and Maintenance Expenses

The cost to deploy a dark FTTP network goes far beyond fiber implementation. Network deployment requires sales and marketing, network maintenance and technical operations, and other functions. In this model, we assume that the County's partner will be responsible for lighting the fiber and selling service. As such, the County's financial requirements are limited to expenses related to OSP infrastructure and network administration.

The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span while network test equipment will need to be replaced after five years.

These expanded responsibilities will require the addition of new staff. We assume the County will add a total of seven full-time-equivalent (FTE) positions within the first three years, and will then maintain that level of staffing. Our assumptions include one FTE for OSP management, one FTE for GIS and record keeping, one FTE for HR and administrative support, and four FTEs for fiber plant maintenance and operations. Salaries and benefits are based on estimated market wages, and benefits are estimated at 35 percent of base salary (added to the labor cost listed in Table 30). Table 30 summarizes these assumptions.

Table 30: Dark FTTP Lease Overhead/Underground Labor Expenses

New Employees	Year 1	Year 2	Year 3	Base Salary
OSP Manager (GIS & Other)	0.50	1.00	1.00	130,000
GIS	0.50	1.00	1.00	80,000
HR, Admin & Support Allocations	0.50	1.00	4.00	80,000
Fiber Plant O&M Technicians	1.00	1.00	1.00	90,000
Total New Staff	2.5	4	7	

Locates and ticket processing will be significant ongoing operational expenses for the County. Based on our experience in other jurisdictions, we estimate that a contract for locates will cost $10,700 in year one, increase to $21,400 in year two, and increase to $42,700 from year three on. If the County decides to perform this work in house, the contract expense would be eliminated—but staffing expenses would increase.

Additional key operating and maintenance assumptions include the following:

- Pole attachment fees are $20 per year per pole (with a total of 11,316 poles).
- Insurance is estimated to be $50,000 in year one and $75,000 from year two on.
- Office expenses are estimated to be $2,400 annually.
- Contingency expenses are estimated at $10,000 in year one and $25,000 in subsequent years.
- Legal fees are estimated to be $100,000 in year one, and $25,000 from year two on.
- Consulting fees are estimated at $100,000 in year one and $20,000 from year two on.

Fiber network maintenance costs are calculated at 0.5 percent of the total construction cost, per year. This is in addition to staffing costs to maintain the fiber.

Table 31 summarizes these expenses, as well as principal and interest payments.

Table 31: Dark FTTP Lease Overhead/Underground Operating Expenses and Debt Service Costs

Operating Expenses & P&I	Year 1	Year 5	Year 10	Year 15	Year 20
Insurance	$50,000	$75,000	$75,000	$75,000	$75,000
Office Expenses	2,400	2,400	2,400	2,400	2,400
Locates & Ticket Processing	45,700	182,800	182,800	182,800	182,800
Contingency	10,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance	74,550	248,510	248,510	248,510	248,510
Legal	100,000	25,000	25,000	25,000	25,000
Consulting	100,000	20,000	20,000	20,000	20,000
Education and Training	6,350	17,550	17,550	17,550	17,550
Pole Attachment Expense	33,948	226,320	226,320	226,320	226,320
Sub-Total	$422,948	$822,580	$822,580	$822,580	$822,580
Labor Expenses	$317,250	$877,500	$877,500	$877,500	$877,500
Sub-Total	$317,250	$877,500	$877,500	$877,500	$877,500
Total Expenses	$740,198	$1,700,080	$1,700,080	$1,700,080	$1,700,080
Principal and Interest	$670,000	$4,178,060	$4,701,290	$4,701,530	$4,702,240
Facility Taxes	-	-	-	-	-
Sub-Total	$670,000	$4,178,060	$4,701,290	$4,701,530	$4,702,240
Total Expenses, P&I, and Taxes	$1,410,198	$5,878,140	$6,401,370	$6,401,610	$6,402,320

The County's expenses total over $1.4 million in year one, and rise to just above $6.4 million in year 10 and beyond.

6.1.2.5 Dark FTTP Lease Overhead/Underground Scenario 2 – Westminster Pricing

Our second scenario demonstrates the implications of using the city of Westminster's pricing. In this scenario, we have projected the results of using a $7 per passing fee, with an additional $16 per subscriber fee. We have assumed a take rate of 35 percent.

As shown in Table 32, with the city of Westminster pricing, significant cash flow shortages are seen. The cumulative cash flow shortage exceeds $81 million by the end of year 20.

Table 32: Dark FTTP Lease Overhead/Underground Scenario 2 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$7,520	$1,856,220	$1,856,220	$1,856,220	$1,856,220
Total Cash Expenses	(740,200)	(1,700,080)	(1,700,080)	(1,700,080)	(1,700,080)
Depreciation	(786,770)	(3,594,300)	(2,544,900)	(2,544,900)	(2,582,900)
Interest Expense	(670,000)	(2,286,120)	(1,763,030)	(1,126,690)	(352,890)
Taxes	-	-	-	-	-
Net Income	$ (2,189,450)	$ (5,724,280)	$ (4,151,790)	$ (3,515,450)	$ (2,779,650)

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$63,020	$ (12,712,470)	$ (35,683,340)	$ (58,614,610)	$ (81,550,780)
Depreciation Reserve	-	162,930	108,250	12,850	(270,460)
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$63,020	$ (12,549,540)	$ (35,575,090)	$ (58,601,760)	$ (81,821,240)

By charging this pricing scheme, the County would be operating with a net income deficit of greater than $2.7 million and an unrestricted cash balance deficit of over $81.5 million by year 20.

6.1.2.6 Dark FTTP Lease Overhead/Underground Scenario 3 – Westminster Pricing with Grant Funding

To offset the enormous deficit generated by using the city of Westminster pricing, we looked at the impact of including $59 million in startup funds. These funds would be from grants or other sources, which would not need to be repaid. All other assumptions (pricing and take rate) remained the same as Scenario 2.

The resulting income and cash flow statements are shown in Table 33.

Table 33: Dark FTTP Lease Overhead/Underground Scenario 3 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$7,520	$1,856,220	$1,856,220	$1,856,220	$1,856,220
Total Cash Expenses	(740,200)	(1,700,080)	(1,700,080)	(1,700,080)	(1,700,080)
Depreciation	(786,770)	(3,594,300)	(2,544,900)	(2,544,900)	(2,582,900)
Interest Expense	-	410	270	30	(680)
Taxes	-	-	-	-	-
Net Income	$ (1,519,450)	$ (3,437,750)	$ (2,388,490)	$ (2,388,730)	$ (2,427,440)

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$150,520	$1,748,740	$2,285,670	$2,862,200	$3,433,830
Depreciation Reserve	-	162,930	108,250	12,850	(270,460)
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$150,520	$1,911,670	$2,393,920	$2,875,050	$3,163,370

Were the County able to acquire the proposed startup funding, this model would operate with a net income of $3.4 million by year five, and $2.4 million by year 20. The cumulative unrestricted cash balance would start at $150,000 by the end of year one, and grow to around $3.4 million by year 20.

6.1.2.7 Dark FTTP Lease Overhead/Underground Scenario 4 – 70 Percent Take Rate

For our final scenario, we proposed an extremely high take rate of 70 percent to suggest what pricing would be necessary to obtain a positive cash flow. It should be understood that this take rate is highly improbable, and is being discussed for purposes of demonstration only.

In order to generate and maintain positive cash flow, a per-passing fee of $15.60 and per subscriber fee of $44.20 would be necessary from the private partner. These prices are roughly 2.5 times those received by the city of Westminster.

An income and cash flow statement for this scenario is shown in Table 34.

Table 34: Dark FTTP Lease Overhead/Underground Scenario 4 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$19,540	$7,228,880	$7,228,880	$7,228,880	$7,228,880
Total Cash Expenses	(740,200)	(1,700,080)	(1,700,080)	(1,700,080)	(1,700,080)
Depreciation	(786,770)	(4,643,440)	(2,544,900)	(2,544,900)	(2,582,900)
Interest Expense	(670,000)	(2,555,160)	(1,974,790)	(1,268,900)	(410,490)
Taxes	-	-	-	-	-
Net Income	$ (2,177,430)	$ (1,669,800)	$1,009,110	$1,715,000	$2,535,410

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$75,040	$499,040	$1,677,180	$2,945,410	$4,208,740
Depreciation Reserve	-	196,510	192,180	96,780	(186,530)
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$75,040	$695,550	$1,869,360	$3,042,190	$4,022,210

If the partner could obtain such a high take rate, and agreed to the fees proposed above, the County would be operating with a net income just over $1 million by year 10, and an unrestricted cash balance of $1.6 million by year 10, increasing to $4.2 million by year 20. Again, both the required fees and take-rates in this scenario are unlikely.

6.2 Hybrid Fiber-Wireless Network Lease

In our Hybrid Fiber-Wireless Network Lease model, presented in Section 5, we suggest the possibility of a fiber distribution network connected to fixed wireless antennas, which broadcast internet service to homes and businesses in the County.

The financial analysis presented here represents a minimum requirement for the County to obtain a break-even cash flow each year, excluding any potential revenue from other dark fiber lease opportunities that may be available to the County. We have provided a complete financial model in Excel format that can be leveraged to show the impact of changing assumptions. The spreadsheet can be an important tool for the county to use if it negotiates with a private partner.

This analysis assumes that the County constructs fiber to County-owned poles, and is responsible for maintaining both the fiber and the poles. The partner adds core electronics to “light” the fiber, installs and maintains wireless access points on the poles, as well as customer-premises equipment (CPEs) and internal wiring. The partner is also responsible for all network sales, maintenance, and operations.

To mitigate fiber construction costs, we have investigated two potential fiber deployment options. The first proposes an entirely underground fiber deployment, while the second looks at constructing both overhead and underground fiber, with 65 percent aerial and 35 percent underground fiber.

For comparison between all models presented in this report, we propose the partner pays the County on a per-passing[32] and per-subscriber basis to use the County fiber and poles. We have compared the per-passing and per-subscriber fees to those obtained by the city of Westminster, MD in its partnership with Ting Internet.

We include this reference to demonstrate what pricing is attractive enough to incent partnership, the financial implications of that pricing, as well as what Westminster pricing would look like in relation to network deployment costs for the North End. In all models, the required per-passing and per-subscriber fees are extremely high in relation to Westminster's partnership, while charging similar lease fees will result in cash deficits greater than $76 million.

We have included a presentation of four scenarios for both build-out types (all underground and overhead/underground). These include a base case which projects what fees are necessary to maintain a positive cash flow each year, followed by three scenarios which demonstrate the implications of changing said fees, funding, and take rates.

6.2.1 Hybrid Fiber-Wireless Network Lease – Underground – Summary and Comparison

Our first infrastructure model proposes a completely underground fiber buildout to County-owned poles, upon which a private partner installs wireless access points to broadcast internet signals to homes and businesses. In this model, the County owns and maintains the fiber and poles, while the partner leases the fiber, provides network electronics to "light" the fiber, owns and maintains the wireless electronics, and manages all customer relations.

To maintain a positive cash flow, and provided the private partner could obtain a 35 percent take rate, the County would need to charge $19.98 per passing per month, plus an additional $56.61 per subscriber per month. It should be noted that both fees are high—in this case 3.33 times the fees Ting pays the city of Westminster—and it is very unlikely that a private partner would agree to pay such high fees.

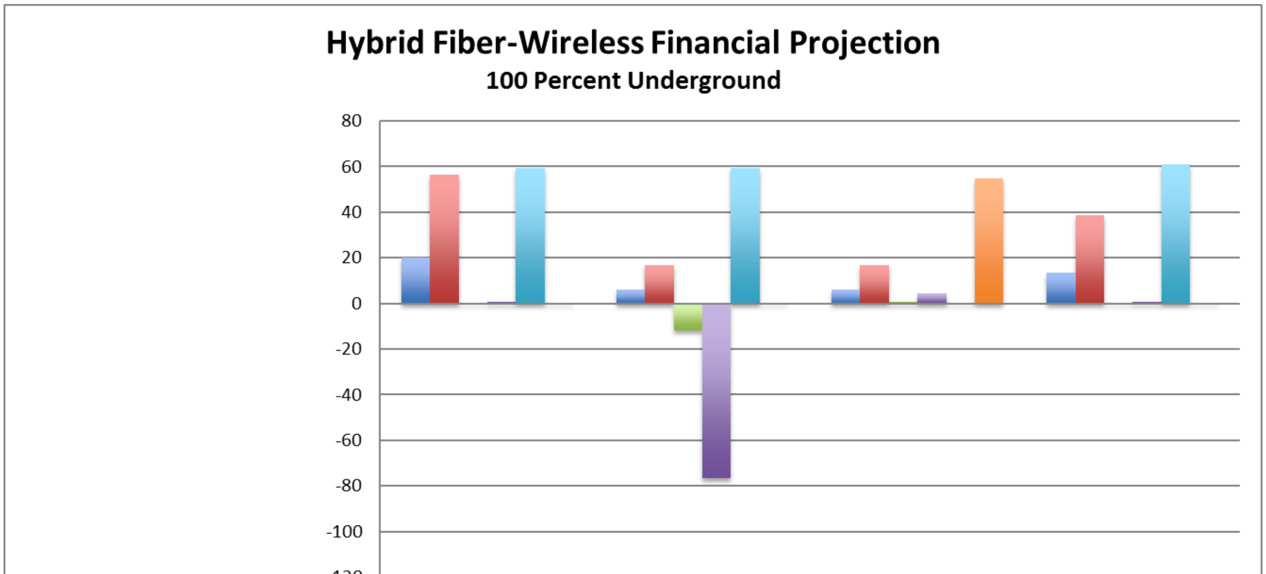
From this base case, we applied the same pricing that Ting is paying the city of Westminster to illustrate the impact of the high build cost in the northern part of Harford County. We then suggest

[32] Hybrid fiber-wireless models do not have "passings" in the same sense that a fully fiber-to-the-premises (FTTP) network would. For this metric, we approximated the number of premises reached by the wireless signal. For example, in a network scenario where a wireless signal reaches 1,000 homes, there would be 1,000 passings. We have used the term "per-passing" to enable comparison to the fully-fiber models presented in this report.

what would be necessary in terms of grant funding (or other funding sources which would not need to be paid back) to operate with a positive cash flow while charging the same prices as in Westminster. Finally, we propose a highly unlikely scenario of a 70 percent take rate to illustrate how expensive lease fees would be, even at an extremely aggressive take rate.

Figure 15 provides a graphic comparison of these four scenarios.

Figure 15: Hybrid Fiber-Wireless Network Lease Scenario Comparison - Underground



	Take Rate 35 Percent - Maintain Cash Flow	Take Rate 35 Percent - Westminster Passing & Subscriber Fees	Take Rate 35 Percent - Westminster Passing & Subscriber Fees, Grant Funding	Take Rate 70 Percent - Maintain Cash Flow
Passing Fee (per month)	19.98	6	6	13.62
Subscriber Fee (per month)	56.61	17	17	38.59
Cummulative Cash - Year 5 ($000,000)	0.249	-11.604	0.842	0.233
Cummulative Cash - Year 20 ($000,000)	0.571	-76.469	4.244	0.795
Bond ($000,000)	59.5	59.5	0	61
Grant ($000,000)	0	0	55	0

6.2.1.1 Hybrid Fiber-Wireless Network Lease Underground Base Case Scenario

In our base case scenario, we present what would be necessary to maintain positive cash flow given the estimated construction and operating costs. In this model, we assume a private partner can obtain and maintain a 35 percent take rate.[33] For reference, Table 35 summarizes our fiber cost estimates from Table 12 in Section 5.3

[33] Most overbuilders typically obtain at least a 35 percent take rate when entering a new market.

Table 35: Hybrid Fiber-Wireless Underground OSP Cost Estimate Summary

Item	Cost
OSP Engineering	$6,621,000
Quality Control/Quality Assurance	2,444,000
General OSP Construction Cost	31,358,000
Special Crossings	-
Backbone and Distribution Plant Splicing	685,000
Utility Poles for WAP Mounting	10,940,000
Backbone Hub, Termination, and Testing	327,000
Total Estimated OSP Cost	$52,375,000

We have provided a summarized income and cash flow statement for this scenario in Table 36.

Table 36: Hybrid Fiber-Wireless Underground Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$25,020	$6,181,210	$6,181,210	$6,181,210	$6,181,210
Total Cash Expenses	(762,060)	(1,570,500)	(1,570,500)	(1,570,500)	(1,570,500)
Depreciation	(823,630)	(2,678,150)	(2,678,150)	(2,678,150)	(2,678,150)
Interest Expense	(704,000)	(2,195,470)	(1,689,640)	(1,074,250)	(325,550)
Taxes	-	-	-	-	-
Net Income	$ (2,264,670)	$ (262,910)	$242,920	$858,310	$1,607,010

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$80,460	$47,800	$116,930	$186,540	$258,830
Depreciation Reserve	-	200,850	238,600	276,350	312,620
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$80,460	$248,650	$355,530	$462,890	$571,450

Please note that we used a “flat model” in the analysis, which means that inflation and operating cost increases (including salaries) are not used because it is assumed that operating cost increases will be offset by increases in operator lease payments over time (and likely passed on to subscribers in the form of increased prices). We anticipate that the County will apply an inflation factor, typically based on a Consumer Price Index (CPI), to the portion of the per-subscriber fee that covers projected operating expenses during negotiations with a private partner.

6.2.1.2 Hybrid Fiber-Wireless Network Lease Underground Financing

This financial analysis assumes that the County will cover all its capital requirements with general obligation (GO) bonds. We assumed that the County’s bond rate would be four percent.

We expect that the County will take three 20-year bonds—one each in years one, two, and three—for a total of $59.5 million in financing. (The difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment.) The resulting principal and interest (P&I) payments will be the major factor in determining the County's long-term financial requirements; P&I accounts for about 74 percent of the County's annual costs in our base case model after the construction period.

We project that the bond issuance costs will be equal to 1.0 percent of the principal borrowed. For the bond, we assumed that neither a debt service reserve or interest reserve account is required. Principal repayment on the bonds will start in year two.

Table 37 shows the income statement for this scenario.

Table 37: Hybrid Fiber-Wireless Underground Income Statement

Income Statement		Year 1	Year 5	Year 10	Year 15	Year 20
a. Revenues						
Per Passing		$15,510	$3,103,210	$3,103,210	$3,103,210	$3,103,210
Fiber leases (net)		-	-	-	-	-
	Total	$25,020	$6,181,210	$6,181,210	$6,181,210	$6,181,210
c. Operating Costs						
Operation Costs		$444,810	$814,500	$814,500	$814,500	$814,500
Labor Costs		317,250	756,000	756,000	756,000	756,000
	Total	$762,060	$1,570,500	$1,570,500	$1,570,500	$1,570,500
d. EBITDA		$ (737,040)	$4,610,710	$4,610,710	$4,610,710	$4,610,710
e. Depreciation		823,630	2,678,150	2,678,150	2,678,150	2,678,150
f. Operating Income (EBITDA less Depreciation)		$ (1,560,670)	$1,932,560	$1,932,560	$1,932,560	$1,932,560
g. Non-Operating Income						
Interest Income		$ -	$500	$600	$690	$780
Interest Expense (20 Year Bond)		(704,000)	(2,195,970)	(1,690,240)	(1,074,940)	(326,330)
	Total	$ (704,000)	$ (1,689,640)	$ (1,689,640)	$ (1,074,250)	$ (325,550)
h. Net Income (before taxes)		$ (2,264,670)	$ (262,910)	$242,920	$858,310	$1,607,010
i. Facility Taxes		$ -	$ -	$ -	$ -	$ -
j. Net Income		$ (2,264,670)	$ (262,910)	$242,920	$858,310	$1,607,010

In this scenario, the County would operate with a negative net income until year nine. By year 10, net income would become positive to almost $243,000, growing to just over $1.6 million in year 20.

We have provided a cash flow statement in Table 38.

Table 38: Hybrid Fiber-Wireless Underground Cash Flow Statement

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
a. Net Income	$ (2,264,670)	$ (262,910)	$242,920	$858,310	$1,607,010
b. Cash Outflows					
Debt Service Reserve	$ -	$ -	$ -	$ -	$ -
Interest Reserve	-	-	-	-	-
Depreciation Reserve	-	(66,950)	(66,950)	(66,950)	(66,950)
Financing	(176,000)	-	-	-	-
Capital Expenditures	(15,902,500)	-	-	-	-
Total	$ (16,078,500)	$ (66,950)	$ (66,950)	$ (66,950)	$ (66,950)
c. Cash Inflows					
Interest Reserve	$ -	$ -	$ -	$ -	$ -
Depreciation Reserve	-	-	-	-	-
Investment Capital	-	-	-	-	-
20-Year Bond Proceeds	17,600,000	-	-	-	-
Total	$17,600,000	$ -	$ -	$ -	$ -
d. Total Cash Outflows and Inflows	$1,521,500	$ (66,950)	$ (66,950)	$ (66,950)	$ (66,950)
e. Non-Cash Expenses - Depreciation	$823,630	$2,678,150	$2,678,150	$2,678,150	$2,678,150
f. Adjustments					
Proceeds from Additional Cash Flows (20 Year Bond)	$ (17,600,000)	$ -	$ -	$ -	$ -
g. Adjusted Available Net Revenue	$ (17,519,540)	$2,348,290	$2,854,120	$3,469,510	$4,218,210
h. Principal Payments on Debt					
20 Year Bond Principal	-	2,334,280	2,840,010	3,455,310	4,203,920
Loan Principal	-	-	-	-	-
Total	$ -	$2,334,280	$2,840,010	$3,455,310	$4,203,920
i. Net Cash	$80,460	$14,010	$14,110	$14,200	$14,290
j. Cash Balance					
Unrestricted Cash Balance	$80,460	$47,800	$116,930	$186,540	$258,830
Depreciation Reserve	-	200,850	238,600	276,350	312,620
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$80,460	$248,650	$355,530	$462,890	$571,450

This model will end year one with an unrestricted cash balance of about $80,400. By the end of year 20, the County will have a cumulative unrestricted cash balance of almost $259,000.

6.2.1.3 Hybrid Fiber-Wireless Network Lease Underground Capital Additions

Significant network expenses—known as “capital additions”—are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building a fiber network. (Again, because the County’s responsibility will be limited to OSP, we have not included any costs for core network equipment, or CPE.)

This analysis projects that the capital additions (including vehicles and test equipment) in year one will total approximately $15.9 million. These costs will total almost $26.3 million in year two, and about $10.4 million in year three. This totals over $52.6 million in capital additions for years one through four.

Table 39 summarizes these capital additions.

Table 39: Hybrid Fiber-Wireless Underground Capital Additions

Capital Additions		Year 1	Year 2	Year 3
Outside Plant and Facilities				
Total Backbone and FTTP		$15,712,500	$26,187,500	$10,475,000
Additional Annual Capital		-	-	-
	Total	$ 15,712,500	$ 26,187,500	$ 10,475,000
Miscellaneous Implementation Costs				
Splicing		$ -	$ -	$ -
Vehicles		50,000	50,000	-
Emergency Restoration Kit		50,000	50,000	-
Work Station, Computers, and Software		5,000	3,000	4,000
Fiber OTDR and Other Tools		85,000	-	-
Additional Annual Capital		-	-	-
	Total	$ 190,000	$ 103,000	$ 4,000
Replacement Costs for Depreciation				
Network Equipment		$ -	$ -	$ -
Last Mile and Customer Premises Equipment		-	-	-
Miscellaneous Implementation Costs		-	-	-
	Total	$ -	$ -	$ -
	Total Capital Additions	$15,902,500	$26,290,500	$10,479,000

6.2.1.4 Hybrid Fiber-Wireless Network Lease Underground Operating and Maintenance Expenses

The cost to deploy a fiber network goes far beyond implementation of the fiber. Network deployment requires maintenance and technical operations, support personnel, and other functions. In this model, we assume that the County's partner will be responsible for lighting the fiber and selling service. As such, the County's financial requirements are limited to expenses related to OSP infrastructure and network administration.

The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span while network test equipment will need to be replaced after five years.

These expanded responsibilities will require the addition of new staff. We assume the County will add a total of six full-time-equivalent (FTE) positions within the first three years, and will then maintain that level of staffing. Our assumptions include one FTE for OSP management, one FTE for GIS and record keeping, one FTE for HR and administrative support, and three FTEs for fiber plant maintenance and operations by year three. Salaries and benefits are based on estimated market wages, and benefits are estimated at 35 percent of base salary (added to the labor cost listed in Table 40). Table 40 summarizes these assumptions.

Table 40: Hybrid Fiber-Wireless Underground Labor Expenses

New Employees	Year 1	Year 2	Year 3	Base Salary
OSP Manager (GIS & Other)	0.50	1.00	1.00	130,000
GIS	0.50	1.00	1.00	80,000
HR, Admin & Support Allocations	0.50	1.00	1.00	80,000
Fiber Plant O&M Technicians	1.00	1.00	3.00	90,000
Total New Staff	2.5	4	6	

Locates and ticket processing will be significant ongoing operational expenses for the County. Based on our experience in other jurisdictions, we estimate that a contract for locates will cost $97,500[34] in year one, and increase to $195,000 in year two, and $390,100 from year three on. If the County decides to perform this work in house, the contract expense would be eliminated—but staffing expenses would increase.

Additional key operating and maintenance assumptions include the following:

- Insurance is estimated to be $50,000 in year one and $75,000 from year two on.
- Office expenses are estimated to be $2,400 annually.

[34] Based on $3,750 per month per 50 miles of underground fiber plant.

- Contingency expenses are estimated at $10,000 in year one and $25,000 in subsequent years.
- Legal fees are estimated to be $100,000 in year one, $50,000 in year two, and $25,000 from year three on.
- Consulting fees are estimated at $100,000 in year one and $20,000 from year two on.

Fiber network maintenance costs are calculated at 0.5 percent of the total construction cost, per year. This is in addition to staffing costs to maintain the fiber.

Table 41 shows a summary of operating and maintenance expenses, as well as principal and interest payments for years one through 20.

Table 41: Hybrid Fiber-Wireless Underground Operating Expenses and Debt Service Costs

Operating Expenses & P&I	Year 1	Year 5	Year 10	Year 15	Year 20
Insurance	$50,000	$75,000	$75,000	$75,000	$75,000
Office Expenses	2,400	2,400	2,400	2,400	2,400
Locates & Ticket Processing	97,500	390,100	390,100	390,100	390,100
Contingency	10,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance	78,560	261,880	261,880	261,880	261,880
Legal	100,000	25,000	25,000	25,000	25,000
Consulting	100,000	20,000	20,000	20,000	20,000
Education and Training	6,350	15,120	15,120	15,120	15,120
Pole Attachment Expense	-	-	-	-	-
Sub-Total	$444,810	$814,500	$814,500	$814,500	$814,500
Labor Expenses	$317,250	$756,000	$756,000	$756,000	$756,000
Sub-Total	$317,250	$756,000	$756,000	$756,000	$756,000
Total Expenses	$762,060	$1,570,500	$1,570,500	$1,570,500	$1,570,500
Principal and Interest	$704,000	$4,023,920	$4,529,650	$4,529,560	$4,529,470
Facility Taxes	-	-	-	-	-
Sub-Total	$704,000	$4,023,920	$4,529,650	$4,529,560	$4,529,470
Total Expenses, P&I, and Taxes	$1,466,060	$5,594,420	$6,100,150	$6,100,060	$6,099,970

6.2.1.5 Hybrid Fiber-Wireless Network Lease Underground Scenario 2 – City of Westminster Pricing

In our second scenario, we examined the feasibility of using the pricing agreed upon by Westminster, MD and Ting Internet. In their agreement, Ting pays the city $6 per passing, plus $17 per subscriber. We have assumed a 35 percent take rate for this model.

A financial summary of this model is included in Table 42.

Table 42: Hybrid Fiber-Wireless Underground Scenario 2 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$7,520	$1,856,220	$1,856,220	$1,856,220	$1,856,220
Total Cash Expenses	(762,060)	(1,570,500)	(1,570,500)	(1,570,500)	(1,570,500)
Depreciation	(823,630)	(2,678,150)	(2,678,150)	(2,678,150)	(2,678,150)
Interest Expense	(704,000)	(2,195,470)	(1,689,640)	(1,074,250)	(325,550)
Taxes	-	-	-	-	-
Net Income	$ (2,282,170)	$ (4,587,900)	$ (4,082,070)	$ (3,466,680)	$ (2,717,980)

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$62,960	$ (11,804,970)	$ (33,360,790)	$ (54,916,130)	$ (76,468,790)
Depreciation Reserve	-	200,850	238,600	276,350	312,620
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$62,960	$ (11,604,120)	$ (33,122,190)	$ (54,639,780)	$ (76,156,170)

With this pricing, the County would be operating with a net income of negative $2.7 million by year 20, and a cumulative unrestricted cash shortage of $76.47 million by year 20.

6.2.1.6 Hybrid Fiber-Wireless Network Lease Underground Scenario 3 – Westminster Pricing with Additional Grant Funding

To offset the enormous deficit generated by using the city of Westminster pricing, we looked at the impact of including $55 million in startup funds. These funds would be from grants or other sources, which would not need to be repaid. All other assumptions (including pricing and take rate) remained the same as scenario 2.

A financial summary of this model is included in Table 43.

Table 43: Hybrid Fiber-Wireless Underground Scenario 3 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$7,520	$1,856,220	$1,856,220	$1,856,220	$1,856,220
Total Cash Expenses	(762,060)	(1,570,500)	(1,570,500)	(1,570,500)	(1,570,500)
Depreciation	(823,630)	(2,678,150)	(2,678,150)	(2,678,150)	(2,678,150)
Interest Expense	-	500	600	690	780
Taxes	-	-	-	-	-
Net Income	$ (1,578,170)	$ (2,391,930)	$ (2,391,830)	$ (2,391,740)	$ (2,391,650)

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$342,960	$641,470	$1,736,900	$2,832,810	$3,931,400
Depreciation Reserve	-	200,850	238,600	276,350	312,620
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$342,960	$842,320	$1,975,500	$3,109,160	$4,244,020

Though this model would operate with a net income of negative $2.4 million from year five on, by year 20, the cumulative total cash balance would be $4.24 million. Essentially, the fees paid by the partner are slightly higher than the expenses.

6.2.1.7 Hybrid Fiber-Wireless Network Lease Underground Scenario 4 – 70 Percent Take Rate

Our final scenario looks at a highly improbable take rate of 70 percent. In this model, the County would still need to charge the partner $13.62 per passing and $38.59 per subscriber, or roughly 2.27 times the price Ting pays Westminster.

A financial summary of this model has been included in Table 44.

Table 44: Hybrid Fiber-Wireless Underground Scenario 4 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$17,050	$6,311,370	$6,311,370	$6,311,370	$6,311,370
Total Cash Expenses	(762,060)	(1,570,500)	(1,570,500)	(1,570,500)	(1,570,500)
Depreciation	(823,630)	(2,678,150)	(2,678,150)	(2,678,150)	(2,678,150)
Interest Expense	(704,000)	(2,253,000)	(1,734,890)	(1,104,570)	(337,690)
Taxes	-	-	-	-	-
Net Income	$ (2,272,640)	$ (190,280)	$327,830	$958,150	$1,725,030

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$72,490	$32,400	$181,280	$330,640	$482,680
Depreciation Reserve	-	200,850	238,600	276,350	312,620
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$72,490	$233,250	$419,880	$606,990	$795,300

Though this extremely high take rate generates a positive net income of almost $328,000 and a cumulative total cash balance of $7950,000 by year 20, it is highly improbable that the County will be able to obtain such a take rate.

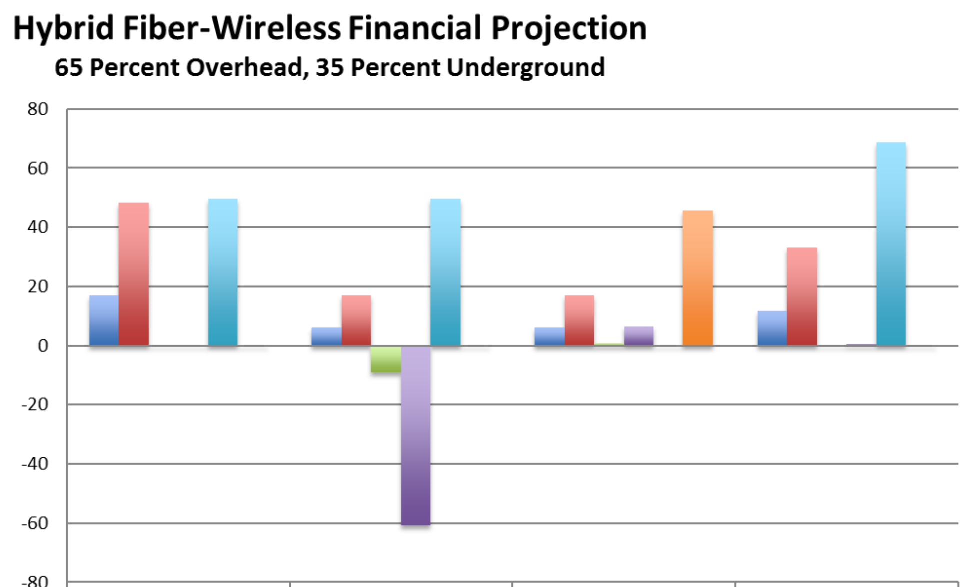
6.2.2 Hybrid Fiber-Wireless Network Lease – Overhead/Underground – Summary and Comparison

Our second infrastructure model proposes a combination of overhead and underground fiber buildout. In this model, we estimate a total of 65 percent overhead and 35 percent underground fiber. The combination aerial and underground fiber lowers total construction costs by roughly $8.9 million, though lease pricing for this model remains quite high to attract partnership.

We investigated similar scenarios as those presented in Section 6.2.1 to assess feasibility and make a realistic comparison to the city of Westminster.

A comparison of all four scenarios is provided in Figure 16 for reference.

Figure 16: Hybrid Fiber-Wireless Network Lease Comparison - Overhead/Underground



	Take Rate 35 Percent - Maintain Cash Flow	Take Rate 35 Percent - Westminster Passing & Subscriber Fees	Take Rate 35 Percent - Westminster Passing & Subscriber Fees, Grant Funding	Take Rate 70 Percent - Maintain Cash Flow
Passing Fee (per month)	17.1	6	6	11.67
Subscriber Fee (per month)	48.45	17	17	33.07
Cummulative Cash - Year 5 ($000,000)	0.222	-9.189	0.961	0.228
Cummulative Cash - Year 20 ($000,000)	0.304	-60.617	6.294	0.588
Bond ($000,000)	49.7	49.7	0	68.75
Grant ($000,000)	0	0	45.7	0

6.2.2.1 Hybrid Fiber-Wireless Network Lease Overhead/Underground Base Case Scenario

In our base case scenario, we present what would be necessary to maintain positive cash flow given the estimated construction and operating costs. Like the entirely underground model, necessary monthly per-passing and subscriber fees are extremely high, at $17.10 and an additional $48.45, respectively—nearly 2.85 times those agreed upon by Ting and the city of Westminster. This also assumes the private partner can obtain and maintain a take rate of 35 percent. However, with some underground construction costs mitigated by aerial construction, the fees necessary from the private partner are slightly lower than the entirely underground model.

For reference, Table 46 summarizes the cost estimates presented in Table 12 in Section 5.3.

Table 45: Hybrid Fiber-Wireless Overhead/Underground OSP Cost Estimate Summary

Item	Cost
OSP Engineering	$ 6,621,000
Quality Control/Quality Assurance	2,444,000
General OSP Construction Cost	22,464,000
Special Crossings	-
Backbone and Distribution Plant Splicing	685,000
Utility Poles for WAP Mounting	10,940,000
Backbone Hub, Termination, and Testing	327,000
Total Estimated OSP Cost	$ 43,481,000

We have also included a financial summary of this base case in Table 46.

Table 46: Hybrid Fiber-Wireless Overhead/Underground Base Case Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$21,420	$5,290,220	$5,290,220	$5,290,220	$5,290,220
Total Cash Expenses	(710,670)	(1,441,450)	(1,441,450)	(1,441,450)	(1,441,450)
Depreciation	(690,220)	(2,233,450)	(2,233,450)	(2,233,450)	(2,233,450)
Interest Expense	(588,000)	(1,833,980)	(1,411,610)	(897,730)	(272,520)
Taxes	-	-	-	-	-
Net Income	$ (1,967,470)	$ (218,660)	$203,710	$717,590	$1,342,800

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$41,450	$54,960	$99,910	$144,640	$191,360
Depreciation Reserve	-	167,520	149,720	131,920	112,630
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$41,450	$222,480	$249,630	$276,560	$303,990

This base case would maintain a positive cash flow, generating a net income of almost $204,000 by year 10, which would grow to roughly $1.34 million by year 20. The County's unrestricted cash balance remains positive throughout the projection, growing to approximately $191,000 by year 20.

6.2.2.2 Hybrid Fiber-Wireless Network Lease Overhead/Underground Financing

This financial analysis assumes that the County will cover all its capital requirements with general obligation (GO) bonds. We assumed that the County's bond rate would be four percent.

We expect that the County will take three 20-year bonds—one each in years one, two, and three—for a total of $49.7 million in financing. (The difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment.) The resulting principal and interest (P&I) payments will be the major factor in determining the County's long-term financial requirements; P&I accounts for about 71 percent of the County's annual costs in our base case model after the construction period.

We project that the bond issuance costs will be equal to 1.0 percent of the principal borrowed. For the bond, we assumed that neither a debt service reserve nor interest reserve account is required. Principal repayment on the bonds will start in year two.

An income statement for this base case is included in Table 47.

Table 47: Hybrid Fiber-Wireless Overhead/Underground Income Statement

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
a. Revenues					
Per Passing	$13,280	$2,655,900	$2,655,900	$2,655,900	$2,655,900
Fiber leases (net)	-	-	-	-	-
Total	$21,420	$5,290,220	$5,290,220	$5,290,220	$5,290,220
c. Operating Costs					
Operation Costs	$393,423	$685,450	$685,450	$685,450	$685,450
Labor Costs	317,250	756,000	756,000	756,000	756,000
Total	$710,673	$1,441,450	$1,441,450	$1,441,450	$1,441,450
d. EBITDA	$ (689,253)	$3,848,770	$3,848,770	$3,848,770	$3,848,770
e. Depreciation	690,220	2,233,450	2,233,450	2,233,450	2,233,450
f. Operating Income (EBITDA less Depreciation)	$ (1,379,473)	$1,615,320	$1,615,320	$1,615,320	$1,615,320
g. Non-Operating Income					
Interest Income	$ -	$420	$370	$330	$280
Interest Expense (20 Year Bond)	(588,000)	(1,834,400)	(1,411,980)	(898,060)	(272,800)
Total	$ (588,000)	$ (1,411,610)	$ (1,411,610)	$ (897,730)	$ (272,520)
h. Net Income (before taxes)	$ (1,967,470)	$ (218,660)	$203,710	$717,590	$1,342,800
i. Facility Taxes	$ -	$ -	$ -	$ -	$ -
j. Net Income	$ (1,967,470)	$ (218,660)	$203,710	$717,590	$1,342,800

This model would generate a negative net income until year eight, at which point net income becomes positive, growing to $1.3 million by the end of year 20.

Table 48 shows the cash flow statement for this scenario.

Table 48: Hybrid Fiber-Wireless Overhead/Underground Cash Flow Statement

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
a. Net Income	$ (1,967,470)	$ (218,660)	$203,710	$717,590	$1,342,800
b. Cash Outflows					
Depreciation Reserve	-	(55,840)	(55,840)	(55,840)	(55,840)
Financing	(147,000)	-	-	-	-
Capital Expenditures	(13,234,300)	-	-	-	-
Total	$ (13,381,300)	$ (55,840)	$ (55,840)	$ (55,840)	$ (55,840)
c. Cash Inflows					
Interest Reserve	$ -	$ -	$ -	$ -	$ -
Depreciation Reserve	-	-	-	-	-
Investment Capital	-	-	-	-	-
20-Year Bond Proceeds	14,700,000	-	-	-	-
Total	$14,700,000	$ -	$ -	$ -	$ -
d. Total Cash Outflows and Inflows	$1,318,700	$ (55,840)	$ (55,840)	$ (55,840)	$ (55,840)
e. Non-Cash Expenses - Depreciation	$690,220	$2,233,450	$2,233,450	$2,233,450	$2,233,450
f. Adjustments					
Proceeds from Additional Cash Flows (20 Year Bond)	$ (14,700,000)	$ -	$ -	$ -	$ -
g. Adjusted Available Net Revenue	$ (14,658,550)	$1,958,950	$2,381,320	$2,895,200	$3,520,410
h. Principal Payments on Debt					
20 Year Bond Principal	-	1,949,690	2,372,110	2,886,030	3,511,290
Total	$ -	$1,949,690	$2,372,110	$2,886,030	$3,511,290
i. Net Cash	$41,450	$9,260	$9,210	$9,170	$9,120
j. Cash Balance					
Unrestricted Cash Balance	$41,450	$54,960	$99,910	$144,640	$191,360
Depreciation Reserve	-	167,520	149,720	131,920	112,630
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$41,450	$222,480	$249,630	$276,560	$303,990

This scenario maintains a positive cash flow throughout the first 20 years, with an unrestricted cash balance of $41,450 at the end of year one, growing to just over $190,000 by year 20.

6.2.2.3 Hybrid Fiber-Wireless Network Lease Overhead/Underground Capital Additions

Significant network expenses—known as "capital additions"—are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building a fiber network. (Again, because the County's responsibility will be limited to OSP, we have not included any costs for core network equipment, or CPE.)

This analysis projects that the capital additions (including vehicles, computers, and test equipment) in year one will total approximately $13.2 million. These costs will total almost $21.8 million in year two, and about $8.7 million in year three. This totals over $43.7 million in capital additions for years one through four.

Table 49: Hybrid Fiber-Wireless Overhead/Underground Capital Additions

Capital Additions		Year 1	Year 2	Year 3
Outside Plant and Facilities				
Total Backbone and FTTP		$13,044,300	$21,740,500	$8,696,200
Additional Annual Capital		-	-	-
	Total	$13,044,300	$21,740,500	$8,696,200
Miscellaneous Implementation Costs				
Splicing		$ -	$ -	$ -
Vehicles		50,000	50,000	-
Emergency Restoration Kit		50,000	50,000	-
Work Station, Computers, and Software		5,000	3,000	4,000
Fiber OTDR and Other Tools		85,000	-	-
Additional Annual Capital		-	-	-
	Total	$190,000	$103,000	$4,000
Replacement Costs for Depreciation				
Network Equipment		$ -	$ -	$ -
Last Mile and Customer Premises Equipment		-	-	-
Miscellaneous Implementation Costs		-	-	-
	Total	$ -	$ -	$ -
	Total Capital Additions	$13,234,300	$21,843,500	$8,700,200
			$43,778,000	

6.2.2.4 Hybrid Fiber-Wireless Network Lease Overhead/Underground Operating and Maintenance Expenses

The cost to deploy a fiber network goes far beyond fiber implementation. Network deployment requires maintenance and technical operations, support personnel, and other functions. In this model, we assume that the County's partner will be responsible for lighting the fiber and selling service. As such, the County's financial requirements are limited to expenses related to OSP infrastructure and network administration.

The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span while network test equipment will need to be replaced after five years.

These expanded responsibilities will require the addition of new staff. We assume the County will add a total of six full-time-equivalent (FTE) positions within the first three years, and will then maintain that level of staffing. Our assumptions include one FTE for OSP management, one FTE for GIS and record keeping, one FTE for HR and administrative support, and three FTEs for fiber plant maintenance and operations by year three. Salaries and benefits are based on estimated market wages, and benefits are estimated at 35 percent of base salary (added to the labor cost listed in Table 50). Table 50 summarizes these assumptions.

Table 50: Hybrid Fiber-Wireless Overhead/Underground Labor Expenses

New Employees	Year 1	Year 2	Year 3	Base Salary
OSP Manager (GIS & Other)	0.50	1.00	1.00	130,000
GIS	0.50	1.00	1.00	80,000
HR, Admin & Support Allocations	0.50	1.00	1.00	80,000
Fiber Plant O&M Technicians	1.00	1.00	3.00	90,000
Total New Staff	2.5	4	6	

In addition to staff, locates and ticket processing will be significant ongoing operational expenses for the County. Based on our experience in other jurisdictions, we estimate that a contract for locates will cost $34,100[35] in year one, and increase to $68,300 in year two, and $136,500 from year three on. If the County decides to perform this work in house, the contract expense would be eliminated—but staffing expenses would increase.

Additional key operating and maintenance assumptions include the following:

- Insurance is estimated to be $50,000 in year one and $75,000 from year two on.
- Office expenses are estimated to be $2,400 annually.
- Contingency expenses are estimated at $10,000 in year one and $25,000 in subsequent years.
- Legal fees are estimated to be $100,000 in year one, $50,000 in year two, and $25,000 from year three on.
- Consulting fees are estimated at $100,000 in year one and $20,000 from year two on.

[35] Based on $3,750 per month per 50 miles of underground fiber plant.

Fiber network maintenance costs are calculated at 0.5 percent of the total construction cost, per year. This is in addition to staffing costs to maintain the fiber.

These operating expenses and principle and interest payments are summarized in Table 51.

Table 51: Hybrid Fiber-Wireless Overhead/Underground Operating Expenses and Debt Service Costs

Operating Expenses & P&I	Year 1	Year 5	Year 10	Year 15	Year 20
Insurance	$50,000	$75,000	$75,000	$75,000	$75,000
Office Expenses	2,400	2,400	2,400	2,400	2,400
Locates & Ticket Processing	34,100	136,500	136,500	136,500	136,500
Contingency	10,000	25,000	25,000	25,000	25,000
Fiber & Network Maintenance	65,220	217,410	217,410	217,410	217,410
Legal	100,000	25,000	25,000	25,000	25,000
Consulting	100,000	20,000	20,000	20,000	20,000
Education and Training	6,350	15,120	15,120	15,120	15,120
Pole Attachment Expense	25,353	169,020	169,020	169,020	169,020
Sub-Total	$393,423	$685,450	$685,450	$685,450	$685,450
Labor Expenses	$317,250	$756,000	$756,000	$756,000	$756,000
Sub-Total	$317,250	$756,000	$756,000	$756,000	$756,000
Total Expenses	$710,673	$1,441,450	$1,441,450	$1,441,450	$1,441,450
Principal and Interest	$588,000	$3,361,300	$3,783,720	$3,783,760	$3,783,810
Facility Taxes	-	-	-	-	-
Sub-Total	$588,000	$3,361,300	$3,783,720	$3,783,760	$3,783,810
Total Expenses, P&I, and Taxes	$1,298,673	$4,802,750	$5,225,170	$5,225,210	$5,225,260

In this model, the County's expenses in year one would be almost $1.3 million, growing to $5.2 million in year 10 and beyond.

6.2.2.5 Hybrid Fiber-Wireless Network Lease Overhead/Underground Scenario 2 – City of Westminster Pricing

Our second scenario demonstrates the implications of using the pricing agreed upon by the city of Westminster and Ting Internet. In this scenario, the partner would pay the County $7 per passing and an additional $16 per subscriber to lease the fiber and pole space from the County. This model assumes the partner can obtain and maintain a 35% take rate.

Table 52 demonstrates a financial summary of this scenario.

Table 52: Hybrid Fiber-Wireless Overhead/Underground Scenario 2 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$7,520	$1,856,220	$1,856,220	$1,856,220	$1,856,220
Total Cash Expenses	(710,670)	(1,441,450)	(1,441,450)	(1,441,450)	(1,441,450)
Depreciation	(690,220)	(2,233,450)	(2,233,450)	(2,233,450)	(2,233,450)
Interest Expense	(588,000)	(1,833,980)	(1,411,610)	(897,730)	(272,520)
Taxes	-	-	-	-	-
Net Income	$ (1,981,370)	$ (3,652,660)	$ (3,230,290)	$ (2,716,410)	$ (2,091,200)

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$27,550	$(9,356,040)	$ (26,481,090)	$ (43,606,360)	$ (60,729,640)
Depreciation Reserve	-	167,520	149,720	131,920	112,630
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$27,550	$ (9,188,520)	$ (26,331,370)	$ (43,474,440)	$ (60,617,010)

With this pricing scenario, we project a negative net income greater than $2 million through year 20, and a cumulative cash flow shortage of $60.62 million by year 20.

6.2.2.6 Hybrid Fiber-Wireless Network Lease Overhead/Underground Scenario 3 – Westminster Pricing with Additional Grant Funding

Our third scenario suggests a possible solution to offset the cash flow shortage generated by Westminster/Ting pricing by proposing startup funds of $45.7 million. These funds would need to be grant money, or come from other sources which would not need to be repaid. Like scenario 2, we assume the partner will be able to obtain and maintain a 35 percent take rate.

We have included a financial summary of this scenario in Table 53.

Table 53: Hybrid Fiber-Wireless Overhead/Underground Scenario 3 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$7,520	$1,856,220	$1,856,220	$1,856,220	$1,856,220
Total Cash Expenses	(710,670)	(1,441,450)	(1,441,450)	(1,441,450)	(1,441,450)
Depreciation	(690,220)	(2,233,450)	(2,233,450)	(2,233,450)	(2,233,450)
Interest Expense	-	420	370	330	280
Taxes	-	-	-	-	-
Net Income	$ (1,393,370)	$ (1,818,260)	$ (1,818,310)	$ (1,818,350)	$ (1,818,400)

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$62,550	$793,400	$2,588,800	$4,383,980	$6,181,150
Depreciation Reserve	-	167,520	149,720	131,920	112,630
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$62,550	$960,920	$2,738,520	$4,515,900	$6,293,780

While additional grant funds will offset the shortage created by low lease fees, this model would operate with a net income of negative $1.3 million in year one growing to roughly negative $1.8 million in years five and on, and a cumulative cash balance of $6.29 million by year 20.

6.2.2.7 Hybrid Fiber-Wireless Network Lease Overhead/Underground Scenario 4 – 70 Percent Take Rate

For our final scenario, we proposed an extremely high take rate of 70 percent to suggest what pricing would be necessary to obtain a positive cash flow. This take rate is highly improbable, and is being discussed for purposes of demonstration only.

To generate and maintain positive cash flow, a per-passing fee of $11.67 and per subscriber fee of $33.07 would be necessary from the private partner. These prices are roughly 1.95 times those received by the city of Westminster.

An income and cash flow statement for this scenario is shown in Table 54.

Table 54: Hybrid Fiber-Wireless Overhead/Underground Scenario 4 Financial Summary

Income Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Total Revenues	$14,610	$5,407,760	$5,407,760	$5,407,760	$5,407,760
Total Cash Expenses	(710,670)	(1,441,450)	(1,441,450)	(1,441,450)	(1,441,450)
Depreciation	(690,220)	(2,233,450)	(2,233,450)	(2,233,450)	(2,233,450)
Interest Expense	(588,000)	(1,883,640)	(1,450,600)	(923,720)	(282,690)
Taxes	-	-	-	-	-
Net Income	$ (1,974,280)	$ (150,780)	$282,260	$809,140	$1,450,170

Cash Flow Statement	Year 1	Year 5	Year 10	Year 15	Year 20
Unrestricted Cash Balance	$34,640	$60,210	$197,960	$335,490	$475,010
Depreciation Reserve	-	167,520	149,720	131,920	112,630
Interest Reserve	-	-	-	-	-
Debt Service Reserve	-	-	-	-	-
Total Cash Balance	$34,640	$227,730	$347,680	$467,410	$587,640

This extremely high take rate would result in a positive net income by year 10, totaling $1.45 million in year 20. Cash flow remains positive throughout the scenario, resulting in a cumulative cash balance of just over $587,600 by year 20.

Appendix A – Glossary of Terms

Access Fiber – The fiber in an FTTP network that goes from the FDCs to the optical taps that are located outside of homes and businesses in the ROW.

AE – Active Ethernet; a technology that provides a symmetrical (upload/download) Ethernet service and does not share optical wavelengths with other users. For subscribers that receive AE service—typically business customers that request a premium service or require greater bandwidth—a single dedicated fiber goes directly to the subscriber premises with no optical splitting.

CPE – Customer premises equipment; the electronic equipment installed at a subscriber's home or business.

Distribution Fiber – The fiber in an FTTP network that connects the hub sites to the fiber distribution cabinets.

Drop – The fiber connection from an optical tap in the ROW to the customer premises.

FDC – Fiber distribution cabinet; houses the fiber connections between the distribution fiber and the access fiber. FDCs, which can also house network electronics and optical splitters, can sit on a curb, be mounted on a pole, or reside in a building.

FTTP – Fiber-to-the-premises; a network architecture in which fiber optics are used to provide broadband services all the way to each subscriber's premises.

GPON – Gigabit passive optical network; the most commonly provisioned FTTP service—used, for example, by Verizon (in its FiOS systems), Google Fiber, and Chattanooga Electric Power Board (EPB). GPON uses passive optical splitting, which is performed inside FDCs, to connect fiber from the Optical Line Terminals (OLTs) to multiple customer premises over a single GPON port.

IP – Internet Protocol; the method by which computers share data on the Internet.

LEC – Local Exchange Carrier; a public telephone company that provides service to a local or regional area.

MDU – Multi-dwelling unit; a large building with multiple units, such as an apartment or office building.

OLT – Optical line terminal; the upstream connection point (to the provider core network) for subscribers. The choice of an optical interface installed in the OLT determines whether the network provisions shared access (one fiber split among multiple subscribers in a GPON architecture) or dedicated AE access (one port for one subscriber).

OSP – Outside plant; the physical portion of a network (also called "layer 1") that is constructed on utility poles (aerial) or in conduit (underground).

OSS – Operational Support Systems (OSS); includes a provider's provisioning platforms, fault and performance management systems, remote access, and other OSS for FTTP operations. The network's core locations house the OSS.

OTT – Over-the-top; content, such as voice or video service, that is delivered over a data connection.

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

POTS – "Plain old telephone service;" delivered over the PSTN.

PSTN – Public switched telephone network; the copper-wire telephone networks that connect landline phones.

QoS – Quality of service; a network's performance as measured on a number of attributes.

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

VoIP – Voice over Internet Protocol; telephone service that is delivered over a data connection.