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On a Mission

Falmouth, Massachusetts Fiber Optic Network High-Level Design

Prepared for FalmouthNet

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Contents

Executive Summary

FalmouthNet, Inc., a 501(c)(3) non-profit organization, engaged Tilson to create a high-level design, bill of materials, and construction cost estimate for FalmouthNet, a community-based fiber optic network to serve the homes and businesses of Falmouth, Massachusetts. Tilson is a Portland, Maine-based telecommunications firm with more than 15 years of experience designing, building, and maintaining fiber optic networks.

A high-level design in the telecommunications industry is a computer-generated design that utilizes available street routing, address and utility pole locations, and geographic feature data to create a first draft design of a network. It includes a graphic representation of the network path and a bill of materials and labor that can be used to estimate costs, determine work-flows, and advise the final design process. FalmouthNet requested high-level designs for three network types: GPON, XGSPON, and XGSPON with an Active Ethernet (AE) overlay. The main differences among the three network types are capacity, protocol, and fiber utilization. A more detailed discussion of the different network types is described below in the Fiber Optic Network Technologies section. Table 1 below shows the estimated costs per passing, per subscriber, and the total project cost for the three different network types.

Network Type	Cost per Passing	Cost per Subscriber	Total Project Cost
GPON	$1,750	$887	$56,571,129
XGSPON	$1,783	$887	$57,440,411
XGSPON + AE	$1,862	$891	$59,530,898

Table 1: Construction Cost Estimates by Network Type

There is a fourth option which Tilson recommends FalmouthNet consider. GPON and XGSPON networks are typically deployed with a 1 to 32 fiber split ratio. This means that the capacity of a single GPON or XGSPON transmission is shared among 32 subscribers. Because XGSPON has significantly more capacity than GPON, the split ratio can be doubled to 1:64 while still providing twice the downstream and four times the upstream capacity over GPON. Despite the additional capacity, XGSPON in a 1:64 split configuration has approximately the same cost as 1:32 GPON. Moreover, deploying XGSPON initially means no hardware costs will be sunk and when demand is nearing capacity, increasing it is as simple as adding a card to the OLT and reconfiguring the split ratio. Tilson estimates that an XGSPON network with a 1:64 split ratio would cost $1,747 per passing, $887 per subscriber, and the total project cost would be $56,502,331.

The comprehensive details of Tilson's high-level design, bill of materials, and cost estimates have been provided to FalmouthNet, Inc. The details of the aforementioned items are summarized in the following report.

Approach

Tilson's design, cost projections, and report endeavors to address the objectives outlined in the Request for Proposals (RFP) from FalmouthNet. Upon review of the RFP, we flagged certain objectives as being key to our approach. They include:

- The network must have the ability to provide access to all premises in the Town of Falmouth.
- The network should be expandable in a manner as efficient and effective as possible to increase capacity and to accommodate advances in technology.
- The network design throughout should allow for the potential of multiple ISPs simultaneously offering service and allow for the use of protocols other than IP.
- The network must be capable of providing at least symmetrical 1 Gigabit/second data connections to the internet to all customers with the additional capability of offering lower speed services.
- The network must be capable of supporting Voice over IP telephony, Internet Protocol Television (IPTV), and other internet-based video services, including interactive video services.
- The network and its construction must adhere to all current and generally accepted technical standards and codes.
- The design report should provide a comparison of PON versus Active Ethernet, including considerations of capital costs, operational differences, and power consumption.
- The report should provide an evaluation of the use of micro-trenching as opposed to mixed aerial/buried construction.

To meet these criteria and ascertain the most accurate high-level cost projection, Tilson's design architecture and topology leverage industry standard passive optical network (PON) attributes and elements that result high capacity and bandwidth, reliability, and scalability. Tilson's PON design incorporates ring topology in network access transport, star topology with centralized neighborhood passive distribution, industry standard 1:32 optical split ratios,[1] and 1:1 fiber strand to service address allocation from the distribution cabinet.

For sufficient current and future bandwidth delivery, Tilson recommends the utilization of XGSPON[2] optical technology over GPON technology. Tilson has included cost projections for both in the Cost Estimate section of this report.

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[1] Tilson also provides an alternative 1:64 split configuration for early deployment, which can be easily upgraded to 1:32 split configuration as bandwidth demands dictate. This helps to reduce initial deployment cost without compromise to system performance.

[2] XGS-PON is an updated standard for Passive Optical Networks (PON) that can support higher speed 10 Gbps symmetrical data transfer and is part of the family of standards known as Gigabit-capable PON, or GPON. GPON stands for Gigabit PON or 1 Gigabit PON. The "X" in XGS represents the number 10, and the letter "S" stands for symmetrical, XGSPON = 10 Gigabit Symmetrical PON.

Tilson's design yielded total projected outside plant construction of 378 miles, of which 97 miles (26%) is underground and 280 miles (74%) aerial. These statistics are significant as underground construction is considerably more costly than aerial construction.

The condition of the existing utility poles is another critical consideration. Attachment to these poles must meet both the pole owner's requirements and the National Electric Safety Code (NESC) standards. Many of Falmouth's existing utility poles either do not meet current NESC standards or there is insufficient space to accommodate an additional attachment without breaching the NESC rules. In these instances, the owner and/or current lessees must perform work, generally known as makeready, to correct deficiencies and make room for another lessee. The cost of this work is generally borne by the newly attaching entity; in this case FalmouthNet.

Tilson performed a site survey to obtain insight into the extent of the makeready necessary for FalmouthNet to receive attachment licenses from Eversource, the current pole lessor or lessor agent. The network, as currently designed, would necessitate attachment to 11,887 poles, of which approximately 1,043 would require makeready work. Based on a sampling of the 1,043 makeready poles, Tilson estimates the cost for makeready could range between $15,000 per mile and $20,000 per mile of aerial plant.[3] The cost projections in this report use the $20,000 per mile estimate but note that it may be possible to obtain cost concessions from Eversource given the significant number of NESC noncompliant pole structures that exist today.

Tilson's cost analysis includes projected average cost per mile for both aerial and underground plant, projected cost per passing unit, and projected cost per subscriber. For accuracy, the average cost per aerial and underground mile were derived separately from the bill of materials and labor. The cost per passings unit is derived by dividing the aggregate outside plant and network hardware cost by the total number of passings. Similarly, the projected cost per subscriber is derived by dividing the aggregate outside plant and network cost by the total number of subscribers and adding that quotient to the average cost per installation.[4]

Tilson noted that the passing count in the 2020 Falmouth Broadband Feasibility Study performed by CCG Consulting included 14,232 year-round residential homes, 7,800 seasonal homes, and 2,000 business establishments for a total passing count of 24,032 units. To determine service locations for the high-level design, Tilson utilized the Massachusetts state address dataset which includes 25,795 addresses. To reconcile the 1,763 unit difference, Tilson reviewed the 2014 Town of Falmouth Housing Demand Study & Needs Analysis by RKG Associates. In that report, RKG places the 2014 total housing units at 22,200, with 7,800 of them seasonal. RKG cites a 10% growth in both residential home categories between the years 2010 and 2014. If a similar growth trend continued through 2021, the projected total residential units would be in the range of 26,000. The Falmouth EDIC reports 4,293 business

[3] The actual makeready cost will be determined by Eversource and, although utility companies utilize some structure and standards in their cost estimation process, each pole has unique challenges, and each company has their method of pricing and cost estimation. The final cost will not be known until Eversource leads a field survey and provides their cost estimates.
[4] The installation costs are referred to as success based capital as it is applicable only to actual paying subscribers.

establishments in 2014. The U.S. average percentage of businesses that are home based is 50%. So even if the total business establishments remained flat through 2021, the estimated number of business and commercial units is likely more than the 2,000 cited in the CCG Feasibility Study, suggesting the total passings could be as high as 28,000. For projecting cost per passing and cost per subscriber, Tilson used the Massachusetts state address dataset count of 25,795.

The materials and labor pricing in the cost estimate represent current market pricing. The industry has experienced significant price volatility over the last 12 months as well as extended lead times. Tilson recommends that FalmouthNet include a contingency of at least ten percent of total project cost in their financial planning.

Site Survey

When designing a fiber optic network, network engineers must decide whether to place the fiber aerially attached to utility poles, along with the power and phone lines, or to place them underground in buried conduit. Both aerial and underground fiber can function equally well. The primary consideration in determining aerial or underground construction is cost. Installing aerial fiber is generally much less expensive than underground fiber. However, the age and state of the utility poles can be a major factor in determining the cost of aerial fiber. Older or broken poles may need to be repaired or replaced before aerial fiber can be attached. Poles crowded with pre-existing power and telecommunications lines must be reorganized to make space for new fiber attachments. The costs associated with repairing, replacing, and reorganizing utility poles to prepare them for aerial fiber attachment are collectively known as makeready costs. If the makeready costs are high enough, such as when multiple poles need to be replaced because they are too short and there is not enough room for fiber attachments, then underground fiber can be the more affordable option.

To design the most cost-effective network and to determine where to utilize aerial or underground fiber, Tilson conducted a site survey of every utility pole in Falmouth. Using utility pole location data obtained from the Town of Falmouth, Tilson created a smartphone/tablet application that its engineers used to map the utility poles and upload photos and observations for each individual pole. Over the course of 46 days, four Tilson engineers spent over 300 hours driving a combined total of 1,245 miles to observe and characterize over 11,000 utility poles in Falmouth. Their findings strongly influenced the usage of aerial and underground fiber in Tilson's high-level network design and the resulting bills of materials and cost estimates.

The following pages summarize the findings of the site survey with maps depicting the locations of utility poles with potential or critical issues. The complete dataset from the site survey has also been made available to FalmouthNet.

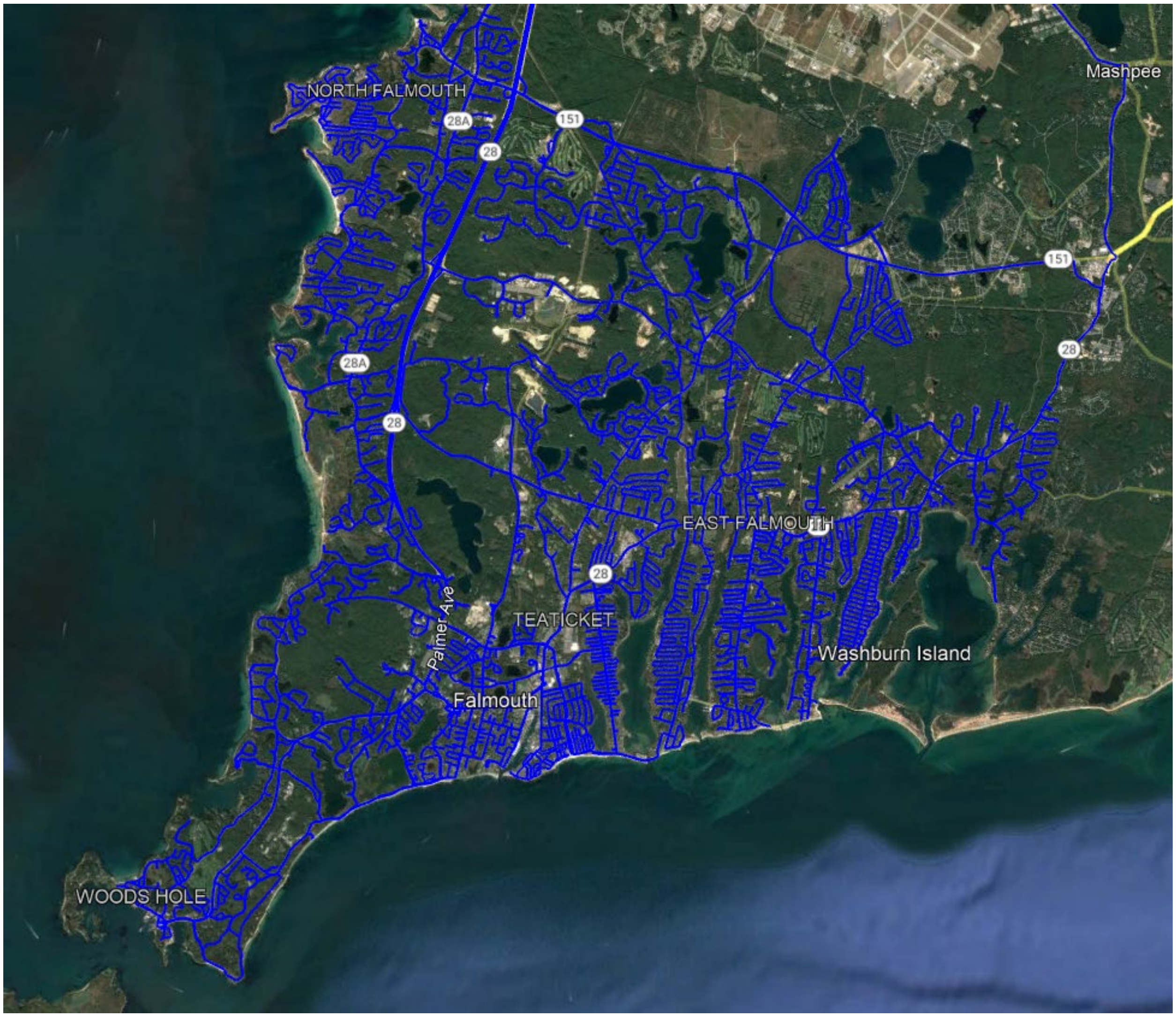

Figure 1: Site Survey Route

The blue lines in Figure 1 show the 1,245-mile route, recorded in real-time, driven by Tilson engineers to assess the state of the utility poles in Falmouth.

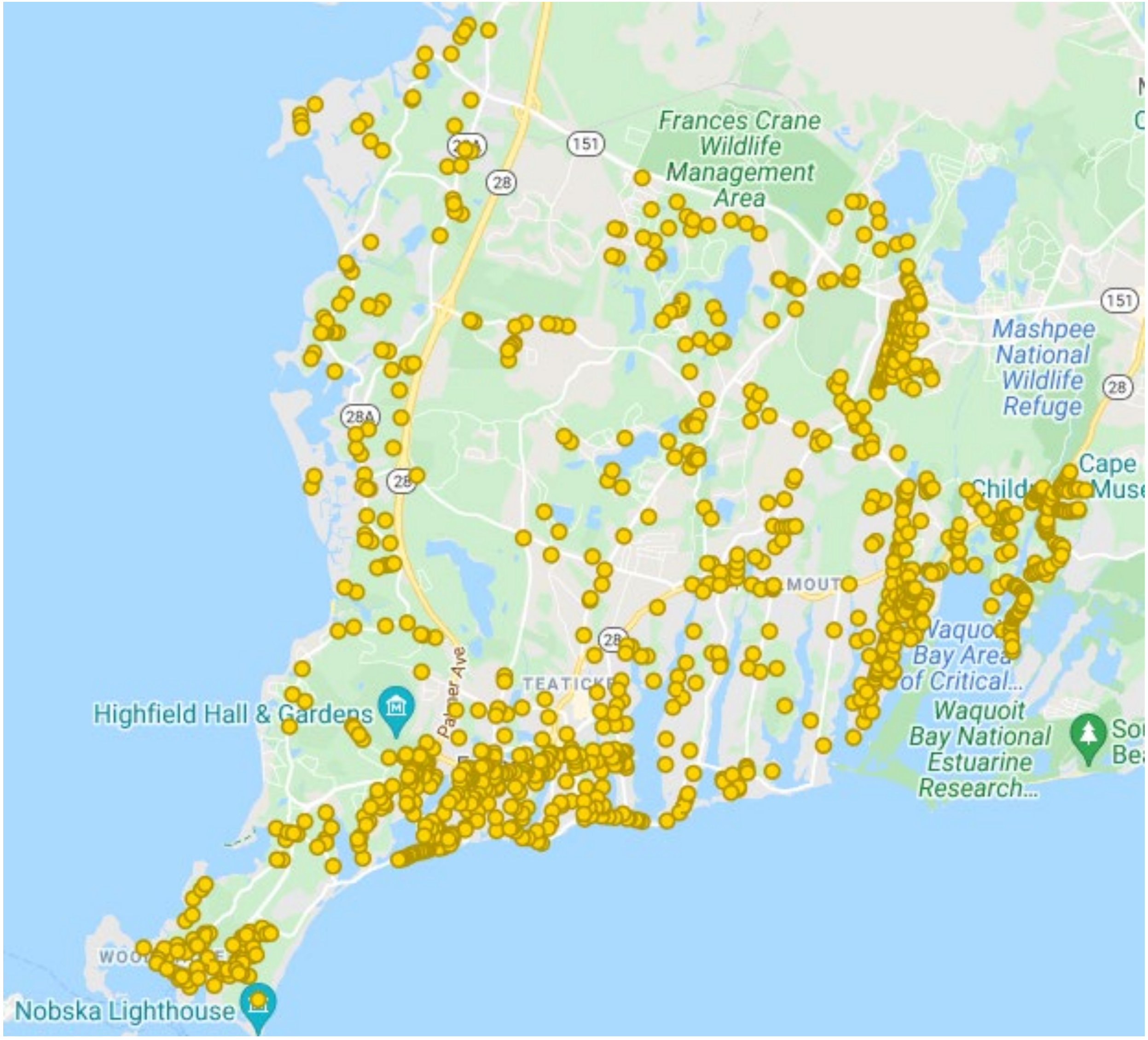

Figure 2: Potential make-ready issues

The yellow dots in Figure 2 indicate the locations of utility poles which would require makeready work to prepare them for aerial fiber attachments. Makeready work is a common requirement anytime new lines are attached to utility poles, especially older poles. Makeready work typically includes reorganizing the lines on the pole to ensure that there is adequate space between them, adjusting the span of cables that cross over roadways so that there is adequate clearance for taller cars and trucks to safely pass underneath, and adding or adjusting guy lines to keep the pole upright. Tilson engineers flagged 1,021 utility poles as having potential makeready issues, many of which were clustered around the more densely-populated southern side of Falmouth.

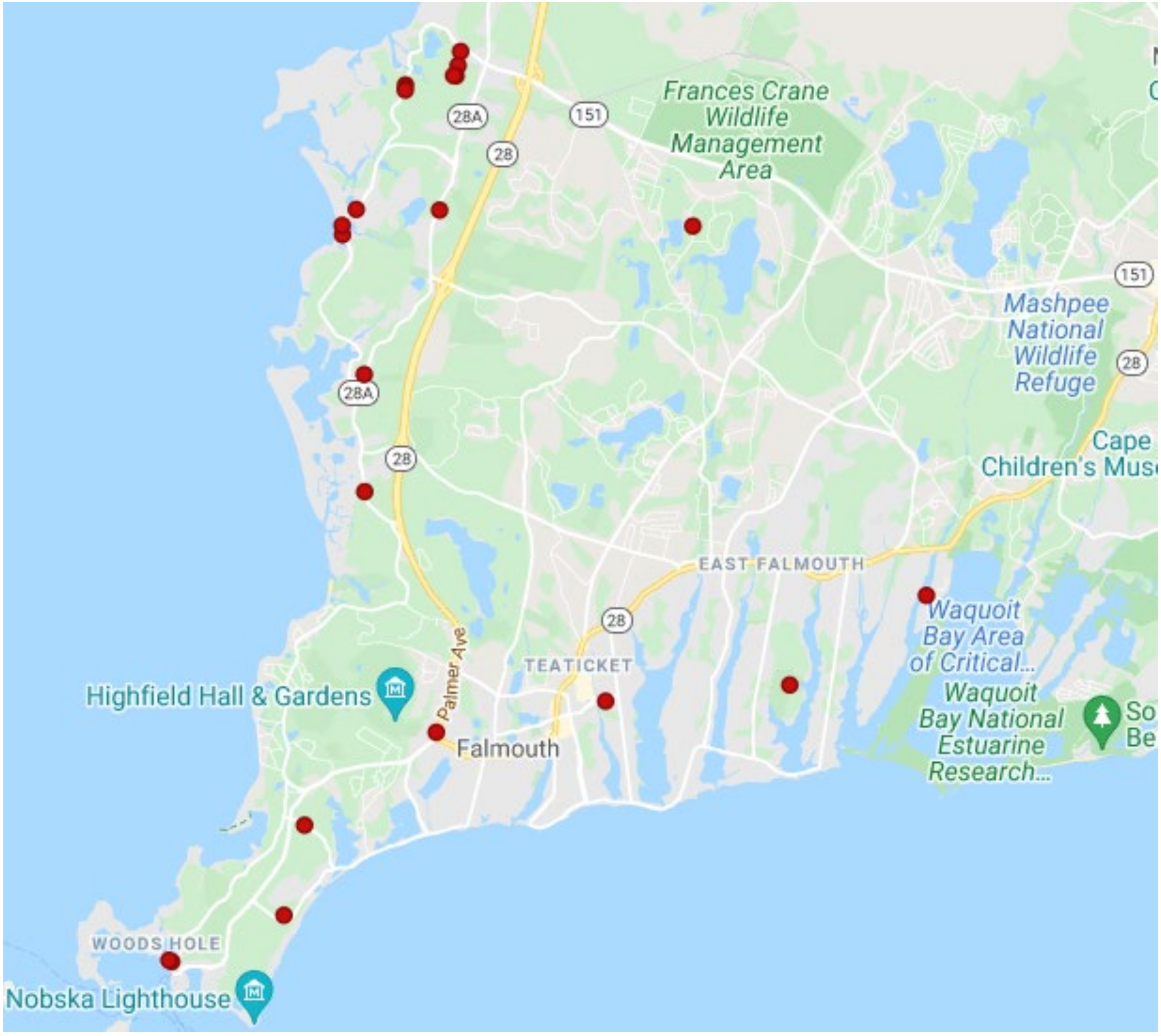

Figure 3: Critical Issues

The red dots in Figure 3 indicate utility poles that Tilson engineers flagged as having critical issues. Critical issues typically include leaning poles that must be reset in the ground, broken poles that must be replaced, partially repaired/replaced poles that must have lines transferred to the new pole, and poles that do not have adequate space for additional lines. Tilson engineers identified 22 poles, most of which are located in the southern and western regions of Falmouth, as having critical issues that must be addressed before aerial fiber can be attached.

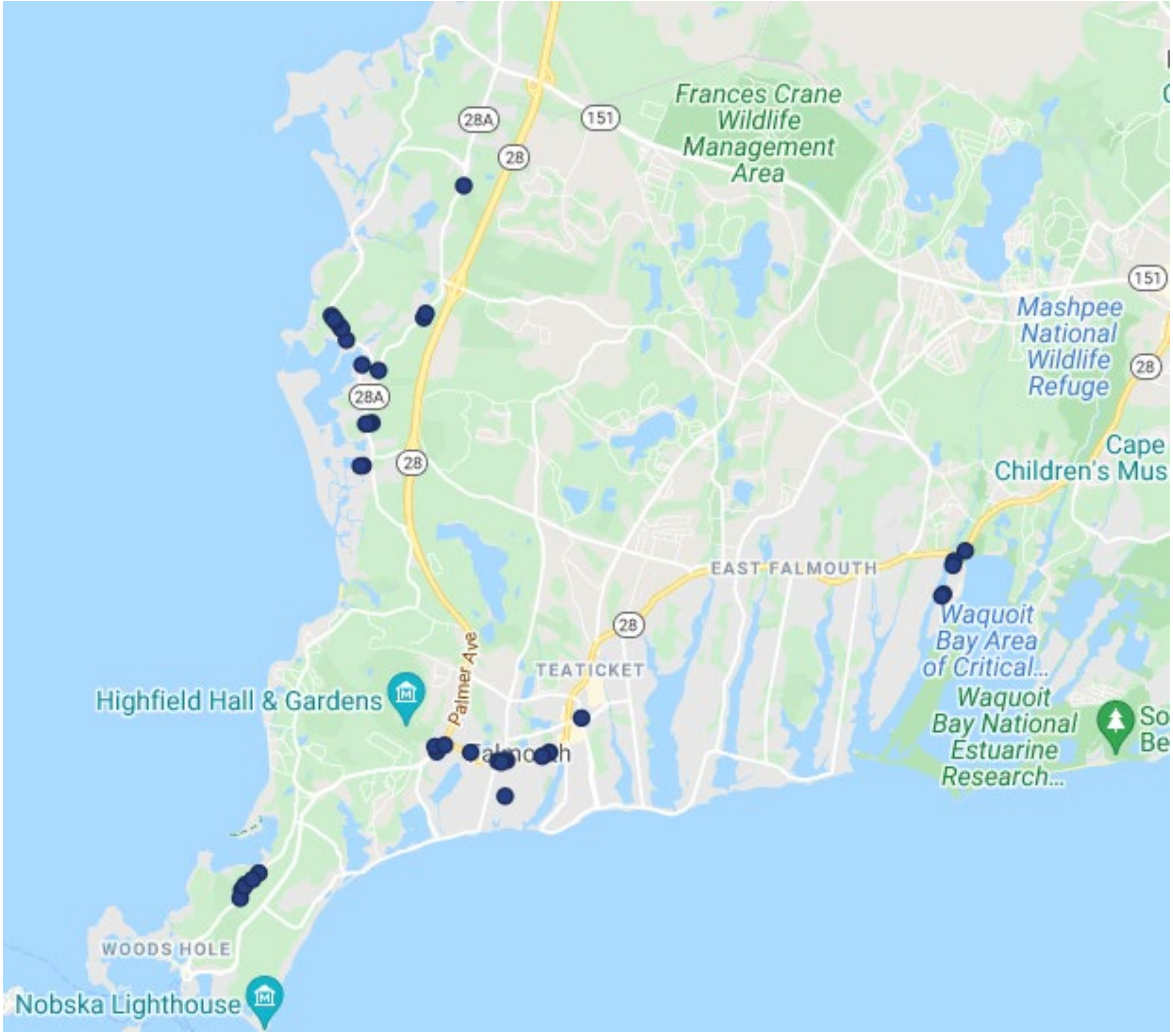

Figure 4: Consider Underground Fiber

The blue dots in Figure 4 indicate utility poles (or groups of utility poles) where critical issues, such as necessary pole replacements, or enough makeready issues, such as multiple pole height or span adjustments, warrant consideration of underground fiber as a more cost-effective alternative to aerial fiber. Tilson engineers identified 46 utility poles (or groups of utility poles), primarily around the same southern and western regions where critical issues were identified, where underground fiber should be considered.

High-Level Design

Utilizing GIS-based map data, the Massachusetts state address dataset, information gathered during the site survey, and and Tilson's high-level network design software, Tilson generated a high-level design that depicts cable routing, aerial and underground construction methods, and bills of material and labor for cost estimation.

Tilson used the pole location data provided by the Town of Falmouth, as well as aerial photography references to determine where aerial cable can be built and where underground cable will be necessary. Locations were selected for both active cabinets[5] and passive splitter cabinets and the address geocoding was utilized to establish residential and business connections.

[5] The active cabinets house the optical electronics for network transport and distribution while the passive cabinets contain only passive optical splitters utilized in PON architecture.

Figure 5: High-Level Design

The light green lines in Figure 5 represent aerial fiber attached to utility poles along roadways. The orange lines represent underground fiber in buried conduit. In this high-level design, 74% of the fiber is aerial and 26% is underground.

Figure 6: Feeder, Distribution, and Drop Fiber and Hubs

In Figure 6, the blue dots and lines represent active cabinets and feeder fiber, while the green dots and lines represent passive splitter cabinets and distribution fiber. Feeder fiber is the fiber optic cable utilized to connect from the active cabinets to the passive splitter cabinets, while the distribution fiber feeds individual subscriber connections from the passive splitter cabinets to devices placed on utility poles or in underground vaults located near the home or business. The red lines and dots represent subscriber connection terminals and the fiber cable placed between the terminal and the home. This cable is commonly referred to as the drop.

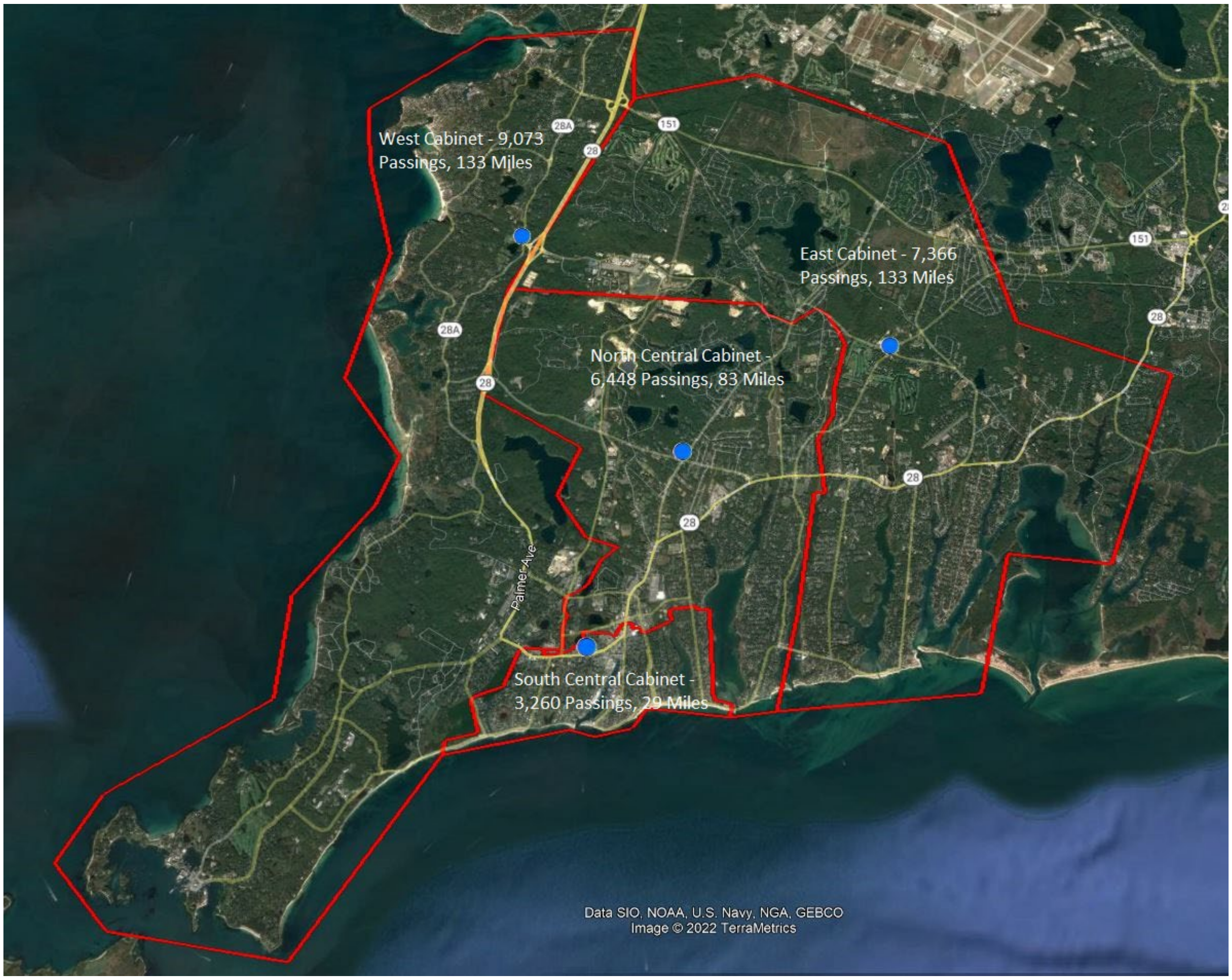

Figure 7: Cabinet Locations

The blue circles Figure 7 depict the locations of the active cabinets that house the OLTs. The red boundaries depict the areas they serve. The captions list the number of premises passed and the number of miles of fiber optic cable in those areas.

Permitting

Tilson researched third-party permit requirements for placement of the aerial and underground fiber. The design's cable routing generally follows public rights-of-way, so most will require approval only from the Town of Falmouth. Private easement identification is generally undertaken in the final design and pre-construction stage, so no private easement locations have been identified. If private easement encroachment is chosen to facilitate the construction process, or if routing necessitates underground construction through a designated wetland, that cost will need to be added to the project budget. Similarly, if new utility poles need to be installed in a designated historic site, National Environmental Protection Act (NEPA) processes will need to be adhered to which may result in additional expenses.

Tilson did identify approximately 60,000 feet of state road encroachment along Routes 28 and 151 that will require permits with MassDOT, as well as pole attachment license application fees with Eversource. Both fees have been included in the project cost estimate.

Fiber Optic Network Technologies

FalmouthNet requested that Tilson analyze the cost and benefits of three different fiber optic broadband network technologies: Gigabit Passive Optical Network (GPON), 10 Gigabit Passive Optical Network (XGSPON), and Active Ethernet (AE).

Passive optical networks are based on managed point to multi-point technologies. In the case of GPON and XGSPON, a single distribution fiber originating at the active cabinet routes to a passive cabinet where it is split into multiple individual feeder fibers, each then routing to a customer's premises. The ratio of the single distribution fiber to multiple feeder fibers typically ranges between 1:16 to 1:128. A 1:16 radio means one distribution fiber is split to feed 16 feeder fibers serving 16 individual customers. Higher ratios result in more users sharing a finite amount of bandwidth. GPON provides 2.5 Gigabits per second (Gbps) of data throughput in the downstream direction, from the internet toward the home, and 1 Gbps of upstream data throughput, from the home to the internet. XGSPON has significantly more throughput capacity, providing 10 Gbps in the downstream and another 10Gbps in the upstream. This enables delivery of Gigabit service to multiple homes without fear of network contention.[6]

The standard split ratio in PON networks is 1:32, although both lesser and greater splits are possible. If GPON is employed, the 2.5 Gbps downstream and 1 Gbps upstream capacity will be shared by up to 32 users. XGSPON, with its symmetrical 10 Gbps capacity, offers ten times the downstream and twenty times the upstream capacity over GPON. When statistical demand is factored in, 10 Gbps will provide substantial throughput capacity across 32 Gigabit users for the foreseeable future.

GPON and XGSPON technologies are scalable, in that the size of the split ratio can be adjusted to accommodate changes in throughput demand. Regardless of the split configuration, however, GPON inherently has insufficient bandwidth to provide full Gigabit service to multiple users in today's usage environments without significant risk of network contention. XGSPON can be initially deployed in a 1:64 split configuration, reducing the cost per passing to only a modest increase over GPON, and can be easily reconfigured to lower split rations when and if demand increases dictate additional bandwidth. The reconfiguration to a lower split ratio can be done selectively, on a neighborhood by neighborhood basis, as bandwidth demands warrant. In each neighborhood, the ratio reduction can be deferred until bandwidth usage reaches capacity threshold, helping to defer capital until demand warrants. In a 1:64 split XGSPON, the aggregate capacity will still be twice that of GPON in the downstream and four times the capacity in the upstream. Additionally, unlike the upgrade from GPON to XGSPON, virtually none of the initial cost in a 1:64 split XGSPON deployment is sunk. Conversion to 1:32 split configurations can be done when demands dictate, deferring some capital cost.

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[6] Because users infrequently demand data at exactly the same instant, multiple users can satisfactorily share the GPON bandwidth. But as bandwidth demands increase, the likelihood of network contention becomes greater.

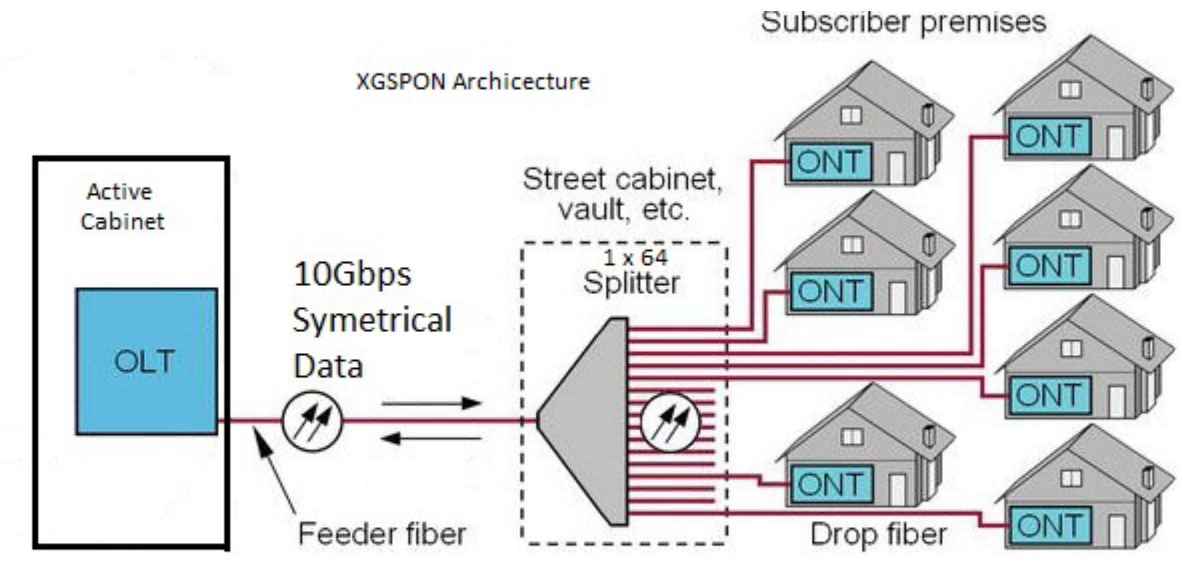

Figure 8: XGSPON Architecture

In contrast, Active Ethernet is a point-to-point technology that connects each end user to the central office via a dedicated fiber. The increased fiber strand counts needed to support AE dramatically increases construction and maintenance costs and offers little, if any, benefits to the residential and small-to-midsize business user. AE currently supports symmetrical throughputs up to 10 Gbps and is generally requested by a 10% to 20% subset of commercial and business customers.

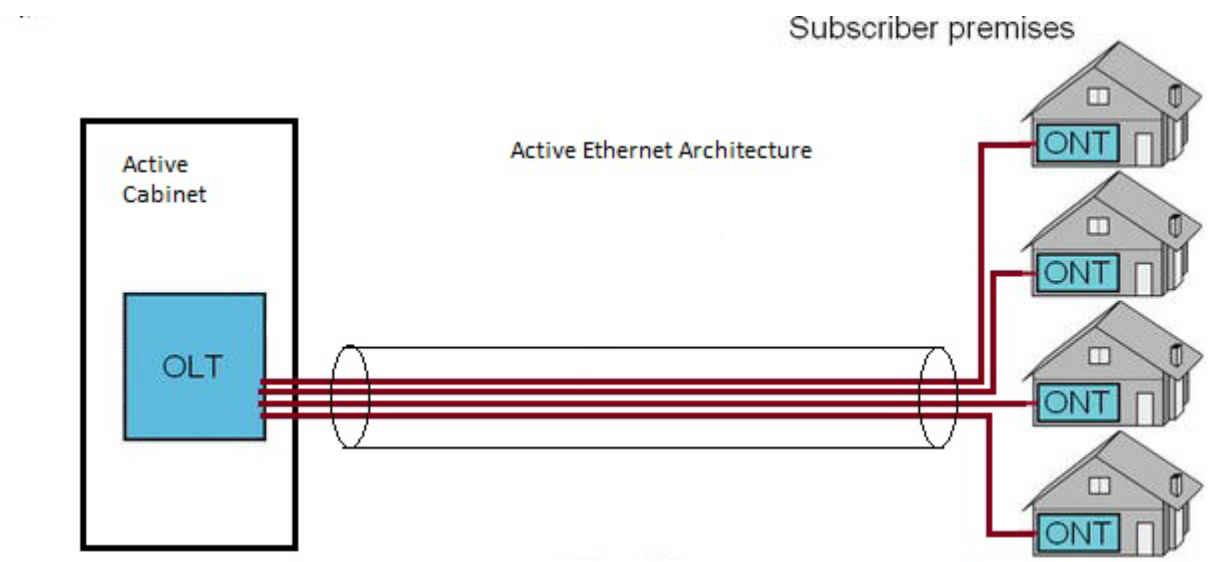

Figure 9: Active Ethernet Architecture

Network Reliability

Tilson recognizes that network reliability is an important aspect of any network design and we have strived to strike a balance between reliability and economy. Redundant connections to every house may be possible but they are not economically feasible in a residential or hybrid residential, commercial fiber to the premises network. However, redundant connections to each active cabinet and hot standby redundant interface and supervisor modules incorporated into key network components can dramatically improve reliability by providing automatic alternate connectivity routes and critical network management functionality during failure events. To that end, Tilson has designed the network's active cabinet connectivity using an active ring architecture, and, where feasible, specified critical network elements with hot stand-by redundant modules.

Figure 7 identifies the proposed routing for the middle mile backhaul fibers that provide interconnection from the headend to the active cabinets. The red line depicts the fiber route that utilizes fibers already included in the feeder and distribution design. The seven light blue segments identify where fiber will need to be placed to close gaps in the ring. These gaps exist because distribution and feeder fiber in these locations was not needed for last mile connectivity. The light blue areas represent approximately 5,000 feet of additional construction with an estimated cost of $42,500, which has been included in the project budgets. The ring configuration provides two independent, diverse route connections between the central office cabinet[7] and each active cabinet. If the ring gets severed, or one link fails, the alternate connection maintains uninterrupted connectivity to the central office. This feature substantively improves network reliability. Tilson highly recommends incorporating the bidirectional, redundancy ring in the design but, if FalmouthNet decides to forego it, the cost can be omitted from the project cost estimate.

[7] A central office, sometimes referred to as a headend, is the location that houses the key IP network hardware such as routers, switches, and management servers and is where interconnection to the system's Internet connection is made.

Figure 10: Active Ring Architecture

Cost Estimate

Tilson utilized the high-level design's bill of materials and project statistics to derive a comprehensive breakdown of materials, labor components, and appurtenances needed to construct the network. The comprehensive breakdown includes the network core, peering, and management hardware items that Tilson believes will be necessary to provide interconnection to a direct internet access source and provide end user service across the network. The scope and delivery of Tilson's engagement excludes planning and deployment of operational support systems such as billing, subscriber management, workforce management and other back of office functions. These choices and selections should be planned and executed prior to the network going live.

Each of Tilson's cost projections included in this report summarize the construction costs on a macro category level and provides cost per mile, cost per passing, and cost per subscriber, with the latter based on the 50% projected take rate identified in the 2020 Falmouth Broadband Feasibility Study. Additionally, copies of Tilson's cost model for each of the technology scenarios, which contain comprehensive breakdowns of materials, labor, and anticipated third party costs for permitting and licensing, have been provided to FalmouthNet. Unit pricing for each material and labor component in the models represent market pricing as of February 2022. As previously noted in this report, the broadband and telecom industry have experienced significant demand and pricing volatility over the last twelve months. Tilson recommends that a contingency reserve of at least 10% of the total project cost be factored into FalmouthNet's final financial plan.

Three scenarios are represented in the Cost Estimate section below. The scenarios include a ubiquitous coverage fiber to the premise network utilizing lower bandwidth GPON technology, a ubiquitous coverage fiber to the premise network utilizing higher bandwidth XGSPON technology, and a ubiquitous coverage network utilizing XGSPON technology with an accompanying Active Ethernet overlay that could serve up to 20% of the estimated 2,000 business and commercial establishments.

The incremental cost of the 20% Active Ethernet overlay is $3,028,567, regardless of whether it is a applied to a GPON or XGSPON system. The cost increase accounts for the following:

- Added fiber count
- Upsizing the fiber distribution hubs to accommodate more fibers
- Added fusion splicing
- Added OLT chassis and AE modules
- Added incremental ONT costs (for the 20%)
- Increased cost for 20% of the MSTs
- Added fiber management due to significant increase in fibers egressing the active cabinets
- Upsizing the cabinets to buildings to house the AE chassis and fiber management

In addition to these costs, construction of the Active Ethernet overlay would also require real estate on which to place four 8' by 12' hub buildings. The site preparation and electrical service installation costs are included in the building costs portion of the cost estimate.

FalmouthNet requested construction cost estimates for discreet regions of Falmouth. Table 2 below breaks down the construction cost per mile for four regions defined by the cabinets that serve them. A cabinet houses network equipment called an Optical Line Terminal (OLT) which provides internet connectivity to premises in the area that are connected to the network.

Cabinet	Route Miles	GPON	XGSPON	XGSPON + AE
North	83	$9,923,000	$10,114,000	$10,562,000
South	29	$3,467,000	$3,534,000	$3,691,000
East	133	$15,900,000	$16,206,000	$16,924,000
West	133	$15,900,000	$16,206,000	$16,924,000

Table 2: Network Construction Cost Estimates per Mile Estimates by Cabinet

Each scenario's budget was derived from the high-level design which, by nature, is not 100% accurate. However, Tilson believes that, excluding any significant changes undertaken in the final network design and planning process, these projections represent pro-forma accuracy that can reasonably be used to determine overall investment, payback, and rate of return for the project.

GPON 1:32 Split Ratio

Infrastructure Capital	Total Aerial Cost ($)	Aerial Cost/Mile	Aerial Cost/Passing	Total Underground Cost ($)	Underground Cost/Mile	Underground Cost/Passing	Total Cost ($)	Blended Cost/Mile	Blended Cost/Passing
Outside Plant	$23,070,287	$82,273	$1,209	$14,161,407	$145,829	$2,111	$40,880,953	$108,288	$1,585
Hub, Transport and Access							$4,249,377	$11,256	$165
Vehicles, Tools, Real Estate & Other							$0	$0	$0
Infrastructure Total	**$23,070,287**	**$82,273**	**$1,209**	**$14,161,407**	**$145,829**	**$2,111**	**$45,130,330**	**$119,544**	**$1,750**

Subscriber Installation			Total Cost ($)		Blended Cost/Sub
Installation (Labor and Materials)			$9,883,230		$766
Customer Premise Electronics			$1,557,570		$121
Total Subscriber Installation Capital			**$11,440,800**		**$887**

Total Project Cost			Total Project Cost ($)		Total Cost/Sub ($)
Total Cost Per Subscriber			**$56,571,130**		**$4,386**

	Total Aerial Cost ($)	Aerial Cost/Mile	Aerial Cost/Passing	Total Underground Cost ($)	Underground Cost/Mile	Underground Cost/Passing	Total Cost ($)	Blended Cost/Mile	Blended Cost/Passing
Engineering	$2,523,043	$8,998	$132	$672,998	$6,930	$100	$3,196,041	$8,466	$124
Makeready	$5,608,200	$20,000	$294	$0	$0	$0	$5,608,200	$14,855	$217
Strand & Hardware	$0	$0	$0	$0	$0	$0	$1,327,063	$3,515	$51
Pedestals, Vaults & Conduit	$0	$0	$0	$0	$0	$0	$2,322,196	$6,151	$90
Fiber Optic Cable	$1,834,783	$6,543	$96	$642,566	$6,617	$96	$2,477,349	$6,562	$96
Service Taps	$729,143	$2,600	$38	$256,313	$2,639	$38	$985,456	$2,610	$38
Fiber Management	$1,697,945	$6,055	$89	$585,477	$6,029	$87	$2,283,422	$6,048	$89
Video Processing	$0	$0	$0	$0	$0	$0	$0	$0	$0
Network & Transport	$0	$0	$0	$0	$0	$0	$2,063,220	$5,465	$80
OLT & Distribution	$0	$0	$0	$0	$0	$0	$2,186,158	$5,791	$85
Buildings and Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0
Vehicles, Tools and Machinery	$0	$0	$0	$0	$0	$0	$0	$0	$0
Construction Labor	$10,677,173	$38,077	$559	$12,004,053	$123,613	$1,790	$22,681,226	$60,080	$879
Installation	$0	$0	$0	$0	$0	$0	$9,883,230	$26,179	$383
CPE	$0	$0	$0	$0	$0	$0	$1,557,570	$4,126	$60
Other Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Project Cost	**$23,070,287**	**$82,273**	**$1,209**	**$14,161,407**	**$145,829**	**$2,111**	**$56,571,130**	**$149,849**	**$2,193**

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XGSPON 1:32 Split Ratio

Infrastructure Capital	Total Aerial Cost ($)	Aerial Cost/Mile	Aerial Cost/Passing	Total Underground Cost ($)	Underground Cost/Mile	Underground Cost/Passing	Total Cost ($)	Blended Cost/Mile	Blended Cost/Passing
Outside Plant	$23,070,287	$82,273	$1,209	$14,161,407	$145,829	$2,111	$40,880,953	$108,288	$1,585
Hub, Transport and Access							$5,118,659	$13,559	$198
Vehicles, Tools, Real Estate & Other							$0	$0	$0
Infrastructure Total	**$23,070,287**	**$82,273**	**$1,209**	**$14,161,407**	**$145,829**	**$2,111**	**$45,999,611**	**$121,847**	**$1,783**

Subscriber Installation			Total Cost ($)		Blended Cost/Sub
Installation			$9,883,230		$766
CPE			$1,557,570		$121
Total Subscriber Installation Capital			**$11,440,800**		**$887**

Total Project Cost			Total Project Cost ($)		Total Cost/Sub ($)
Total Cost Per Subscriber			**$57,440,411**		**$4,454**

	Total Aerial Cost ($)	Aerial Cost/Mile	Aerial Cost/Passing	Total Underground Cost ($)	Underground Cost/Mile	Underground Cost/Passing	Total Cost ($)	Blended Cost/Mile	Blended Cost/Passing
Engineering	$2,523,043	$8,998	$132	$672,998	$6,930	$100	$3,196,041	$8,466	$124
Makeready	$5,608,200	$20,000	$294	$0	$0	$0	$5,608,200	$14,855	$217
Strand & Hardware	$0	$0	$0	$0	$0	$0	$1,327,063	$3,515	$51
Pedestals, Vaults & Conduit	$0	$0	$0	$0	$0	$0	$2,322,196	$6,151	$90
Fiber Optic Cable	$1,834,783	$6,543	$96	$642,566	$6,617	$96	$2,477,349	$6,562	$96
Service Taps	$729,143	$2,600	$38	$256,313	$2,639	$38	$985,456	$2,610	$38
Fiber Management	$1,697,945	$6,055	$89	$585,477	$6,029	$87	$2,283,422	$6,048	$89
Video Processing	$0	$0	$0	$0	$0	$0	$0	$0	$0
Network & Transport	$0	$0	$0	$0	$0	$0	$2,063,220	$5,465	$80
OLT & Distribution	$0	$0	$0	$0	$0	$0	$3,055,439	$8,093	$118
Buildings and Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0
Vehicles, Tools and Machinery	$0	$0	$0	$0	$0	$0	$0	$0	$0
Construction Labor	$10,677,173	$38,077	$559	$12,004,053	$123,613	$1,790	$22,681,226	$60,080	$879
Installation	$0	$0	$0	$0	$0	$0	$9,883,230	$26,179	$383
CPE	$0	$0	$0	$0	$0	$0	$1,557,570	$4,126	$60
Other Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Project Cost	**$23,070,287**	**$82,273**	**$1,209**	**$14,161,407**	**$145,829**	**$2,111**	**$57,440,411**	**$152,152**	**$2,227**

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XGSPON 1:64 Split Ratio

Infrastructure Capital	Total Aerial Cost ($)	Aerial Cost/Mile	Aerial Cost/Passing	Total Underground Cost ($)	Underground Cost/Mile	Underground Cost/Passing	Total Cost ($)	Blended Cost/Mile	Blended Cost/Passing
Outside Plant	$23,070,287	$82,273	$1,209	$14,161,407	$145,829	$2,111	$40,880,953	$108,288	$1,585
Hub, Transport and Access							$4,180,579	$11,074	$162
Vehicles, Tools, Real Estate & Other							$0	$0	$0
Infrastructure Total	**$23,070,287**	**$82,273**	**$1,209**	**$14,161,407**	**$145,829**	**$2,111**	**$45,061,532**	**$119,362**	**$1,747**

Subscriber Installation			Total Cost ($)		Blended Cost/Sub
Installation			$9,883,230		$766
CPE			$1,557,570		$121
Total Subscriber Installation Capital			**$11,440,800**		**$887**

Total Project Cost			Total Project Cost ($)		Total Cost/Sub ($)
Total Cost Per Subscriber			**$56,502,331**		**$4,381**

	Total Aerial Cost ($)	Aerial Cost/Mile	Aerial Cost/Passing	Total Underground Cost ($)	Underground Cost/Mile	Underground Cost/Passing	Total Cost ($)	Blended Cost/Mile	Blended Cost/Passing
Engineering	$2,523,043	$8,998	$132	$672,998	$6,930	$100	$3,196,041	$8,466	$124
Makeready	$5,608,200	$20,000	$294	$0	$0	$0	$5,608,200	$14,855	$217
Strand & Hardware	$0	$0	$0	$0	$0	$0	$1,327,063	$3,515	$51
Pedestals, Vaults & Conduit	$0	$0	$0	$0	$0	$0	$2,322,196	$6,151	$90
Fiber Optic Cable	$1,834,783	$6,543	$96	$642,566	$6,617	$96	$2,477,349	$6,562	$96
Service Taps	$729,143	$2,600	$38	$256,313	$2,639	$38	$985,456	$2,610	$38
Fiber Management	$1,697,945	$6,055	$89	$585,477	$6,029	$87	$2,283,422	$6,048	$89
Video Processing	$0	$0	$0	$0	$0	$0	$0	$0	$0
Network & Transport	$0	$0	$0	$0	$0	$0	$2,063,220	$5,465	$80
OLT & Distribution	$0	$0	$0	$0	$0	$0	$2,117,359	$5,609	$82
Buildings and Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0
Vehicles, Tools and Machinery	$0	$0	$0	$0	$0	$0	$0	$0	$0
Construction Labor	$10,677,173	$38,077	$559	$12,004,053	$123,613	$1,790	$22,681,226	$60,080	$879
Installation	$0	$0	$0	$0	$0	$0	$9,883,230	$26,179	$383
CPE	$0	$0	$0	$0	$0	$0	$1,557,570	$4,126	$60
Other Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Project Cost	**$23,070,287**	**$82,273**	**$1,209**	**$14,161,407**	**$145,829**	**$2,111**	**$56,502,331**	**$149,667**	**$2,190**

XGSPON 1:64 Split Ratio with 20% Active Ethernet Overlay

Infrastructure Capital	Total Aerial Cost ($)	Aerial Cost/Mile	Aerial Cost/Passing	Total Underground Cost ($)	Underground Cost/Mile	Underground Cost/Passing	Total Cost ($)	Blended Cost/Mile	Blended Cost/Passing
Outside Plant	$24,313,004	$86,705	$1,274	$14,696,555	$151,339	$2,191	$42,662,346	$113,007	$1,654
Hub, Transport and Access							$5,374,308	$14,236	$208
Vehicles, Tools, Real Estate & Other							$0	$0	$0
Infrastructure Total	**$24,313,004**	**$86,705**	**$1,274**	**$14,696,555**	**$151,339**	**$2,191**	**$48,036,654**	**$127,243**	**$1,862**

Subscriber Installation			Total Cost ($)		Blended Cost/Sub
Installation			$9,883,230		$766
CPE			$1,611,014		$125
Total Subscriber Installation Capital			**$11,494,244**		**$891**

Total Project Cost			Total Project Cost ($)		Total Cost/Sub ($)
Total Cost Per Subscriber			**$59,530,898**		**$4,616**

	Total Aerial Cost ($)	Aerial Cost/Mile	Aerial Cost/Passing	Total Underground Cost ($)	Underground Cost/Mile	Underground Cost/Passing	Total Cost ($)	Blended Cost/Mile	Blended Cost/Passing
Engineering	$2,993,133	$10,674	$157	$963,989	$9,927	$144	$3,957,122	$10,482	$153
Makeready	$5,608,200	$20,000	$294	$0	$0	$0	$5,608,200	$14,855	$217
Strand & Hardware	$0	$0	$0	$0	$0	$0	$1,327,063	$3,515	$51
Pedestals, Vaults & Conduit	$0	$0	$0	$0	$0	$0	$2,325,724	$6,161	$90
Fiber Optic Cable	$2,201,285	$7,850	$115	$771,395	$7,944	$115	$2,972,681	$7,874	$115
Service Taps	$795,134	$2,836	$42	$279,536	$2,879	$42	$1,074,669	$2,847	$42
Fiber Management	$1,781,105	$6,352	$93	$585,477	$6,029	$87	$2,366,582	$6,269	$92
Video Processing	$0	$0	$0	$0	$0	$0	$0	$0	$0
Network & Transport	$0	$0	$0	$0	$0	$0	$2,063,220	$5,465	$80
OLT & Distribution	$0	$0	$0	$0	$0	$0	$3,311,089	$8,771	$128
Buildings and Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0
Vehicles, Tools and Machinery	$0	$0	$0	$0	$0	$0	$0	$0	$0
Construction Labor	$10,934,147	$38,993	$573	$12,096,158	$124,561	$1,804	$23,030,305	$61,004	$893
Installation	$0	$0	$0	$0	$0	$0	$9,883,230	$26,179	$383
CPE	$0	$0	$0	$0	$0	$0	$1,611,014	$4,267	$62
Other Capital	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Project Cost	**$24,313,004**	**$86,705**	**$1,274**	**$14,696,555**	**$151,339**	**$2,191**	**$59,530,898**	**$157,689**	**$2,308**