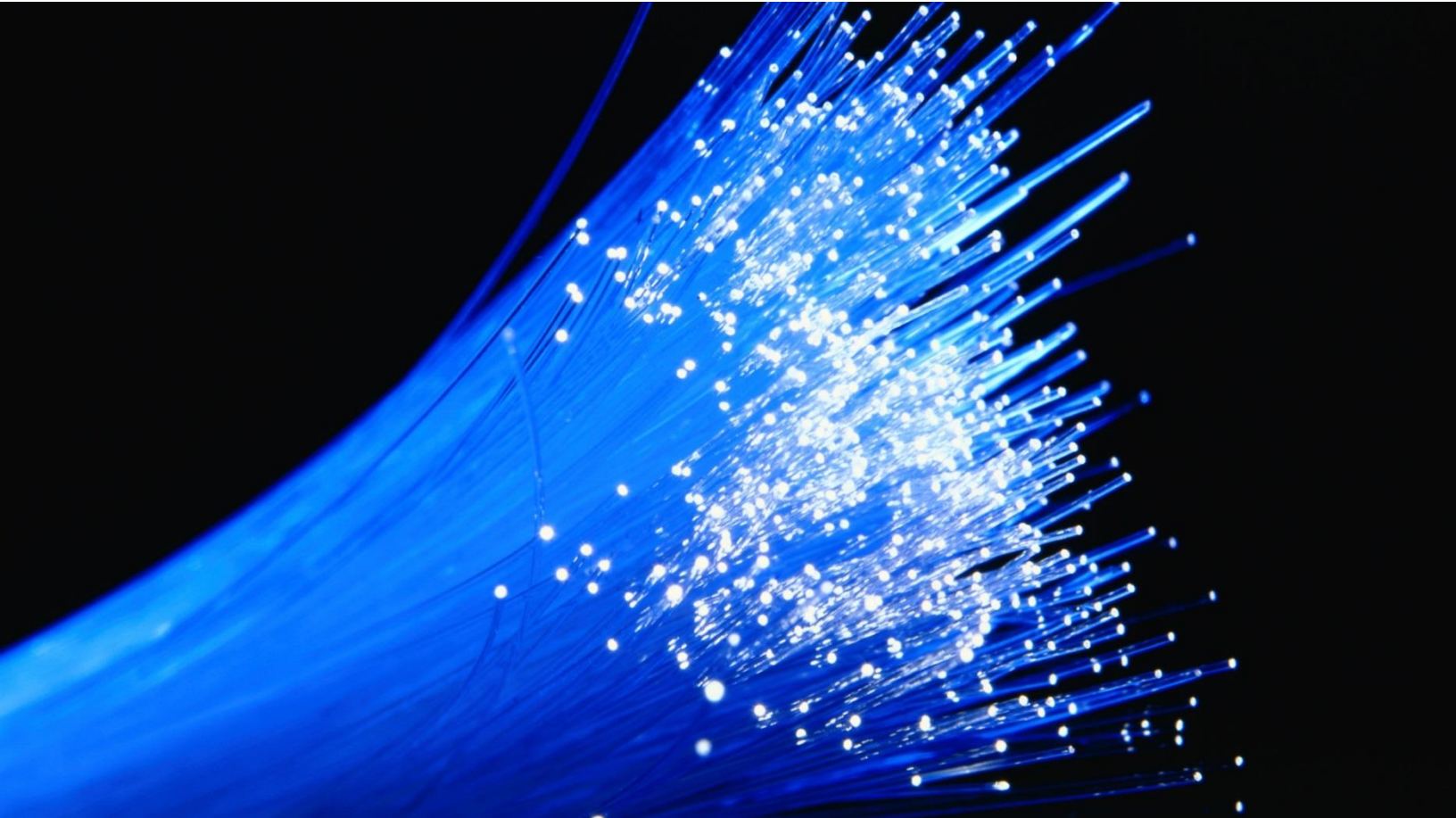


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Broadband in Connecticut: Opportunities for the State and Localities to Enable World-Class Broadband

**Prepared for the Connecticut Office of Consumer Counsel
March 2016**

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1 Executive Summary

Advanced communications networks rank among the most important infrastructure assets of our time—for purposes of economic development and competitiveness, innovation, workforce preparedness, healthcare, education, and environmental sustainability. In the brief two decades since the advent of the commercial Internet, broadband access has become a necessity in the daily lives of Americans and fundamental to the American economy.

The Connecticut State Broadband Office (SBO, part of the Connecticut Office of Consumer Counsel) and other stakeholders are considering how to facilitate development of the advanced networks that will enable the next generation of broadband services in the state. The SBO was created by statute in response to unprecedented demand by 46 Connecticut communities calling for more robust broadband connections around the state through the CT Gig project.¹ Since its formation, the SBO has worked alongside these communities and other key stakeholders to better understand the broadband challenges that communities face and to identify opportunities to ameliorate those challenges.

On average, Connecticut is relatively well-served in terms of broadband, certainly as well as, or better than, many other states with similar demographics. Nonetheless, there are gaps in service—as there are in other areas throughout the country. In that light, this report discusses opportunities for Connecticut to gain a competitive edge by simulating and facilitating next-generation broadband investment, including tools and recommendations for both state and local government policymakers regarding how to expand and enable networks capable of gigabit (1 Gbps, or “Gig”) speeds and beyond.

Specifically, the report recommends levers for enabling and incenting investment—including low- and modest-cost strategies that are focused on creating an environment in which private capital is attracted to broadband deployment opportunities in the state.

Our focus is on increasing deployment of optical fiber to increase the availability of ultra-high-speed, gigabit or higher broadband services. Fiber all the way to the home and business is not yet available anywhere on a comprehensive, statewide basis, but is rapidly emerging in major metropolitan areas where Google Fiber, AT&T, or CenturyLink are active—just as it did in many major Verizon markets (including the New York City metropolitan area) a decade ago. Fiber is increasingly recognized as the ultimate platform for communications networks because it is a

¹ Gregory Hladky, “46 Connecticut Cities and Towns Join Ultra-High-Speed Internet Project” *Hartford Courant*, December 19, 2014, <http://www.courant.com/politics/capitol-watch/hc-46-connecticut-cities-and-towns-join-ultrahighspeed-internet-project-20141219-story.html> (accessed March 2016).

highly scalable (in theory, infinitely scalable) and adaptable medium that enables development and use of the communications applications of today and the future.

Connecticut is poised to become a leader in the United States—and certainly in New England—in fiber deployment because of its unique regulatory environment and the wide-spread interest and engagement at the municipal level in advancing fiber availability. Indeed, the CT Gig effort, based on a grassroots, from-the-bottom-up model, is unmatched anywhere else in the country.

Fiber networks advance access to the digital economy in three important ways. First, fiber enables Gig services, including multi-Gig and 100 Gig+ services that currently are in demand by technology sectors such as the biotech, health care, high-tech manufacturing, and insurance industries in Connecticut. This demand is only growing.

Second, fiber deployment allows communities to reach unserved and underserved areas where residents or businesses may not currently be able to obtain broadband services above dial-up speeds without having to pay thousands of dollars for network installation, as some deployment models enable the public sector to work with private providers to direct infrastructure to needed areas.

Third, if a municipality, as part of a partnership agreement, facilitates a build into limited-income areas, the municipality has the opportunity to support provision of at least a minimum level of broadband service to any connected resident: a level of service adequate to complete homework assignments or online job applications.

This report was prepared by CTC Technology & Energy in late 2015 and early 2016 in its capacity as the SBO's independent broadband consultant. Over the course of our engagement, we performed the following tasks:

1. Analyzed the competitive environment within Connecticut and compared Connecticut with competing states to determine how Connecticut and its municipalities should address the issue of promoting state-of-the-art broadband deployment.
2. Developed a cost estimate for a statewide gigabit fiber-to-the-premises (FTTP) network (and guidance for localities regarding how to estimate the cost of such infrastructure within their borders) as well as the estimated cost of a statewide middle mile network to support government users of high-capacity broadband.²

² As we discuss in Section 5, fiber optics are increasingly recognized as the ultimate platform for communications networks—a theoretically-infininitely scalable and adaptable medium that enables development and use of the communications applications of today and the future. Appendix A contains a glossary of technical terms used in this document.

3. Developed a range of strategic options to enable new private and public sector broadband deployment within the state.
4. Discussed and evaluated a range of business models appropriate for the state's localities as they seek ways to stimulate and enable new broadband construction in their communities, together with private partners.

1.1 Summary of Recommendations for Connecticut Policymakers

The broadband infrastructure and services available in Connecticut are meeting most of the needs of citizens today, but they do not confer a competitive advantage as technology continues to evolve. The incremental FTTP deployments thus far by Connecticut's incumbents, Comcast and Frontier, are welcome—and their ongoing investment in the state is to be commended. But as AT&T, CenturyLink, and Google Fiber deploy FTTP technology all the way to the home and business on a far greater scale in some metropolitan markets nationwide, those cities are gaining a competitive advantage.

Fortunately, due to the level of municipal engagement in Connecticut, the state is in an enviable position to become New England's leader in digital infrastructure. We recommend immediate action, however, because Connecticut's competitor states, including Massachusetts and New York, are making massive public investments in next-generation broadband infrastructure.

As a result, we recommend policy strategies that would seek to enhance the opportunities for construction of advanced infrastructure in Connecticut. In addition, state leaders could consider funding programs, tax incentives, or other legislative proposals to support innovative last-mile projects to provide Connecticut communities with access to advanced broadband and help make rural counties more competitive.

For example, the prospects for public-private partnerships in the broadband market have never been greater; as of this writing, there is private capital looking for opportunities to invest in new models for broadband deployment.

A significant reason for the interest in Connecticut comes from the CT Gig project, which the SBO developed in close partnership with most of the localities in the state. The CT Gig project is an innovative strategy to incent private and public investment in Connecticut. Through a multi-year engagement process with both the private and public sectors, the SBO and the localities have created momentum in Connecticut for more broadband investment. A number of localities have begun discussions with potential private partners.

Because of the engagement of the municipalities and so many other stakeholders through the CT Gig project, we expect that the state could be a very attractive place for such investments.

Legislative action and regulatory moves can also help attract capital by facilitating coordination and collaboration among localities to develop innovative partnerships. This approach would improve the state’s potential to capture private investment—and even more so if the state were to provide matching grants and financial support for projects seeking to enhance high-speed broadband services (as Massachusetts and New York are doing).

The efforts of Connecticut’s municipalities and the SBO have created a new dynamic and momentum for the issue of fiber expansion in the state—which is leading to new attention and action by the incumbents. Many of the recommendations in this report are designed to keep that momentum going, and to ensure that Connecticut is on a path toward developing over time the broadband infrastructure that will confer a competitive advantage.

CTC’s recommendations for state policymakers are focused on three areas:

- Funding and financing programs
- Planning and coordination
- Positioning the state to attract private investment

Recommendations related to each of these areas are discussed in Section 3, below, and are summarized briefly here:

1. Enable new investment by providing competitively awarded funding

A state program to support innovative last-mile projects would complement the planning and coordination activities the CT Gig project has already enabled. There are several examples nationwide of state governments funding last-mile projects to develop fiber infrastructure in underserved areas.³

A grant program would be a means of maintaining the considerable momentum that has been created by the CT Gig project over the past two years. It could catalyze new efforts at the local level, in both urban and rural communities. A grant program would also enable Connecticut to compete for private broadband investment that would otherwise flow to neighboring states.

2. “Dig once” and place conduit and fiber optics during construction projects

³ More information on this recommendation can be found in our March 2016 report, “Recommendation: The Potential for Pilot Funding for Gigabit Networking in Connecticut” (http://www.ct.gov/occ/lib/occ/2016-0309_ctc_report_pilot_funding_program.pdf). That report includes a detailed discussion of the need for such a grant program; recommendations for developing a program based on best practices; and a discussion of programs created in other states and lessons learned from those experiences.

Another means for the state to improve broadband deployment and access is to facilitate the expansion of public and private sector broadband infrastructure by reducing the cost of network construction. To accomplish this, the state could develop a robust “dig once” policy that prioritizes coordination among broadband providers and the deployment of conduit and fiber during all capital improvement projects.⁴ Dig once policies are considered an international best practice not only for reducing disruptions in the public right-of-way such as roads and highways, but also for facilitating competition in the broadband marketplace.

3. Maximize the benefits of the E-rate subsidy program

Based on the interviews we conducted in the state, Connecticut schools and libraries have not yet maximized their opportunities to utilize the federal funding programs.

We therefore recommend that state leaders and legislators consider modest funding to support schools and libraries with their communications technology planning and E-rate applications.⁵ Modest support could dramatically improve the opportunity of those schools and libraries to receive better services at lower per-unit prices and with the full, currently-unrealized benefits of the federal E-rate subsidy program. Modest state support with the planning process could also greatly help the less-resourced schools and libraries that have little or no information technology staff and little familiarity with advanced communications technologies.

4. Facilitate greater efficiency in the “make-ready” portion of fiber deployment

One of the most critical, unpredictable, and high-cost elements of fiber outside plant construction is the “make-ready” process. At times, that process requires three or more companies to dispatch crews with specialized equipment and bucket trucks to move their physical attachments on the communications portion of utility poles, causing slowdowns and duplicate expense for deployments. This recommendation suggests that there is a way for the state to enable and encourage all of this work to be done by one company rather than by many, thus realizing the efficiencies of “one truck roll” or “one touch,” rather than three, four, five, or more truck rolls.

5. Create an infrastructure bank modeled on Connecticut’s acclaimed Green Bank

The Connecticut Green Bank has successfully leveraged limited public funds to spur a significant amount of private investment in clean energy infrastructure. Using similar financing tools,

⁴ See “Brief Engineering Assessment: Efficiencies available through simultaneous construction and co-location of communications conduit and fiber,” White Paper, CTC, 2009, <http://www.ctcnet.us/CoordinatedConduitConstruction.pdf> (accessed March 2016).

⁵ The federal government, through the FCC’s Universal Service Fund program for schools and libraries (informally known as E-rate), provides funding support to schools and libraries. While the E-rate funding level will vary by school district (it ranges from 20 to 90 percent, based on a combination of the rural nature and level of poverty in the local community), the average funding level in Connecticut is between 40 and 50 percent.

Connecticut could enable a new wave of investment in the critically important, next-generation broadband infrastructure the state needs to compete in the 21st century.

The success of the Green Bank demonstrates the state's ability to work in partnership with private financial markets to jump-start investment. Making lower-cost financing available for investment in telecommunications infrastructure would allow both private and public entities to increase their investments in broadband networks. Low-cost financing options may also allow private companies to invest in infrastructure in regions where the potential return on investment is relatively low, such as rural and low-income areas.

6. Create a certification program to identify office buildings with robust broadband

In our observation, even in the most sophisticated markets across the country, it can be difficult for businesses to determine what broadband services are available in a given area. This challenge applies both to businesses already located in a given market and those that are considering relocating to that market.

A potential enhancement in Connecticut would be a program to identify and certify buildings connected with the fastest, most reliable broadband connections. It could mirror the WiredScore initiative in New York City—a program launched in 2013 under Mayor Bloomberg in partnership with the New York City Economic Development Corp.⁶

A similar tool in Connecticut could help prospective tenants identify buildings with sufficient broadband access and could encourage owners to take greater steps to enhance broadband in commercial buildings. These steps could include paying the upfront costs to wire buildings to enable more than one provider to serve a tenant,⁷ or allowing competitive providers to install infrastructure in buildings. (In some cases, building owners only allow a few providers to install the necessary equipment and serve tenants.) In addition, building owners may have a greater incentive to pay for the construction costs to connect their buildings to additional network providers.

1.2 Summary of Opportunities for Localities in Connecticut

A handful of models for localities to enable new broadband networks have emerged over the past few years and are evolving at a rapid rate. Indeed, new case studies appear to be emerging on a monthly basis. As of this writing, we have divided the range of existing and emerging models

⁶ "WiredScore, First Ever Connectivity Certification Service, Expands Nationally," PR Newswire, <http://www.prnewswire.com/news-releases/wiredscore-first-ever-connectivity-certification-service-expands-nationally-300072080.html> (accessed March 2016).

⁷ This could potentially include conduit, as well as in-building or campus fiber or cable pathways, which would be available to a provider that passes the building—enabling the provider to connect without constructing from the curb.

into the following categories, each of which is described and evaluated in more detail in Section 4, below. In addition, Appendix B contains a “Checklist for Localities for Building a Partnership,” which summarizes the models and identifies some of the priorities that will drive many public sector decision-makers.

1. Municipal Broadband: Local public investment and risk

In this model, localities build, own, and operate FTTP networks themselves. This is a very high-risk and high-reward proposition, with a respectable track record in communities across the country. In our observation, however, this is a difficult model to replicate, particularly for communities that do not own their own municipal electric utilities. The risk and challenge involved in this model suggests that it will be adopted infrequently. Aggressive anti-municipal efforts by incumbent phone and cable companies make this model even more challenging.

2. Middle Mile Broadband: Local construction of fiber to serve internal government needs

In this model, localities build less extensive networks to address “middle mile” needs, thus ensuring the availability of fiber optics or conduit to government users and key community anchor institutions, but not reaching all the way to the home or business. This is a proven best practice with two decades of empirical data that demonstrates its viability, albeit with a limited goal and purpose. This is a relatively low-risk strategy with narrow (but important) rewards.

3. Middle Mile Plus: Local construction of fiber to enable service to key commercial and economic development areas

In this model, localities route their middle mile networks to reach key economic or community development targets, such as business parks, historic downtowns, or revitalization areas. Local governments are increasingly considering this low-risk, modest-impact opportunity to attract new businesses and retain existing employers.

In one variation of this model, a town or city can partner with a private company to share the cost of deploying fiber that will provide connectivity to public institutions while at the same time enabling the private entity to use fiber in a parallel conduit or sheath to market to private sector competitors.

4. Public Facilitation of Private Investment: The locality seeks to attract private investment

In this model, localities encourage new private investment through economic development incentives and other measures to reduce costs for private sector infrastructure deployment. While this strategy will not guarantee private investment, it does mean that a community could attract attention as a potential investment opportunity. This model relies on private companies to make the investment, while partner communities take steps to enable them to build in an expeditious, efficient, low-cost manner. Though Google Fiber is the most prominent example,

there is also significant interest among smaller companies that have fewer resources than Google but can deliver next-generation broadband to businesses and institutions on a targeted basis.

5. Public Funding with Private Execution: The traditional “P3” model

In this model, localities negotiate formal public–private partnerships that resemble transit and toll-road construction projects, with public funding and private execution. The rewards of such an effort can be very high, and it outsources many of the headaches to a private partner, but this model entails significant public cost and risk.

6. Shared Risk: Both public and private sectors invest

In this model, localities create hybrid models in which a locality and private partner find a creative way to share some mix of the capital, operating, and maintenance costs of a broadband network. This approach holds particular promise for communities that are willing to take some risk in order to attract private investment. The most prominent variation on this approach has been one in which the locality builds ubiquitous fiber throughout a community and then leases it to a private partner that will pay for use of the fiber and bear all operating risk (and potentially share some capital risk). The City of Westminster, Maryland, partnered with Ting Internet in the first example of this approach and the City of Santa Cruz, California, is in the final stages of development of the same model. Huntsville, Alabama announced that it has an agreement with Google Fiber for lease of substantial city-owned fiber to serve the residential and small business markets.

7. Targeted Rural Strategies: Modest public investment in wireless for unserved areas

While rural communities have fewer options and less market power than do their metro-area counterparts, modest strategies are emerging for rural broadband projects in which the community shares some risk with a private partner. Most shared-risk projects to date have been in metro areas, but those projects may be more challenging to replicate in rural communities, where the cost of fiber deployment, even in a shared-investment scenario, may still be prohibitive due to a variety of factors, including the distance between homes and businesses. The shared-investment and shared-risk strategy, however, is still applicable to rural communities—perhaps using other technologies that secure the benefits of broadband even if they do not result in the kinds of speeds that fiber enables.

2 Why Connecticut and Its Localities Should Address Broadband Needs

2.1 Next-Generation Broadband Represents a Critical, Necessary Element of Competitiveness for Which Business Demand Is Present and Increasing

Advanced broadband capabilities are at the core of many technological advances. As a result, the common perception of robust broadband capabilities has shifted from a luxury to an essential service. Today, the average single-family home no longer has one or two connected devices but six or seven;⁸ companies are increasingly relying on bandwidth-rich applications to conduct business; and most industries have already been disrupted by technological innovations—and those that have not are ripe for disruption. This does not even account for the trillions of dollars that high-technology industries are predicted to add to the global economy in the next 10 years.⁹ As a result, economic competitiveness, both now and especially in the future, will increasingly be dependent on access to robust, affordable, high-speed Internet connections.

High-speed communications are not only an engine for commerce, but also for integration of the many, diverse areas of the U.S. into an increasingly global economy. High-bandwidth broadband is widely recognized as a key driver of a state's future economic competitiveness because it:

- Enables small business creation and growth.
- Enables job creation and the enhanced, multiplied economic activity that accompanies it.
- Supports businesses with very high bandwidth needs, such as digital media and software.
- Attracts and helps retains businesses of all sizes.
- Enables workforce education.
- Enables telework and distributed work.
- Promotes major development initiatives such as revitalization zones or event bids.

There is a sound economic basis for states and regions to continue to upgrade their broadband capabilities. For example, small and medium businesses are dependent on affordable, high-speed

⁸ See “2015 Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment” GN Docket No. 14-126, FCC, ¶ 29, February 4, 2015, https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-10A1_Rcd.pdf (accessed March 2016); Verizon, “Sharing Speed with Multiple Connected Devices” at 1 <http://www.verizon.com/cs/groups/public/documents/adacct/bandwith-and-multiple-device.pdf> (accessed March 2016).

⁹ James Manyika, et al., “Disruptive Technologies: Advances That Will Transform Life, Business, and the Global Economy” McKinsey and Company, May 2013, <http://www.mckinsey.com/business-functions/business-technology/our-insights/disruptive-technologies> (accessed March 2016).

access to compete—and large businesses increasingly look to locate in areas with very high-speed access. Home-based businesses may emerge or fail based on the Internet speeds available to them. Affordable access to very high-speed broadband also incents development of the collaborative, distributed work that is a hallmark of the emerging global economy.

High-bandwidth broadband is also regarded as a facilitator of political discourse and activity—the most important medium for communication and expression of political ideas since the advent of television.

2.2 Fiber Optics to the Home, Business, and Institution Represent the Best, Most Future-Proof Communications Infrastructure

Fiber optics all the way to the home and business offer current and future speeds that are several orders of magnitude higher than the other technologies that are considered to compete with it today. As a technical matter and as a matter of physics, those other technologies cannot deliver the same capacity and scalability as fiber-to-the-premises (FTTP). For example:

- Copper networks, operated by the phone companies, including Frontier, have fiber in the backbone of the network, but much of the “last mile” copper dates back many decades and, in some cases, a century. Copper networks cannot keep up with today’s requirements and are in many cases already at or near obsolescence.
- Coaxial networks, operated by the cable companies, including Comcast, also have fiber in the core of the network, but with coaxial cable in the last mile that was deployed in the 1970s and 1980s. These networks can be engineered to offer higher speeds that will be quite competitive in the short term, particularly for residential applications, but cannot keep pace in the long-run with fiber’s ability to scale to dramatically higher speeds that are needed to attract and retain data-driven businesses.
- Wireless networks, which offer tremendous benefits with respect to mobility and convenience, are limited in speeds and therefore serve as complements—not alternatives—to high-bandwidth wired connections like fiber.

A service or product that meets even the FCC’s minimum broadband definition (25 megabits per second downstream) will deliver a fraction of the speed that fiber can deliver using existing, affordable, off-the-shelf technologies (i.e., Gigabit Ethernet, 1,000 times one megabit). These speeds will grow dramatically as new equipment become available. The speeds possible over copper, coaxial cable, and wireless networks will also grow, but as a matter of physics, cannot keep up with fiber’s ability to scale.

As a result, fiber all the way to the home or business represents the Holy Grail of communications infrastructure—a future-proof investment that can be easily, inexpensively upgraded to new speeds as more advanced electronics are developed.

That is not to say that the substantial investment in Connecticut by current providers such as Frontier and Comcast is not valuable. The fact that Connecticut has substantial penetration of broadband compared to many other states is a testament to the value of that investment. Nonetheless, in planning for the future, it is clear that FTTP will be the standard, and if the state or its municipalities is going to invest time or resources into advancing digital infrastructure deployment, we recommend that it be future-proof fiber technology.

Fiber also represents the new standard for world-class markets. This is the infrastructure that already exists in New York City and its suburbs, and that is emerging in Silicon Valley; Salt Lake City; Charlotte; Raleigh/Durham; Atlanta; Chicago; Louisville; Los Angeles; San Diego; Austin; and nearly 100 other cities selected either by Google Fiber, AT&T, or CenturyLink.

The following graphics illustrate the capacity of different communications technologies. (Detailed discussion of the different capabilities of these technologies is included in Section 5 below.)

Figure 1 illustrates the comparative upload (sending data up to the Internet) and download (pulling data down from the Internet) speeds of various technologies. Note that the faster speeds all require fiber optics all the way to the home or business, as are under construction by Google Fiber, AT&T, CenturyLink, and (in select areas) Frontier.

Figure 1: Comparative Speeds of Various Technologies

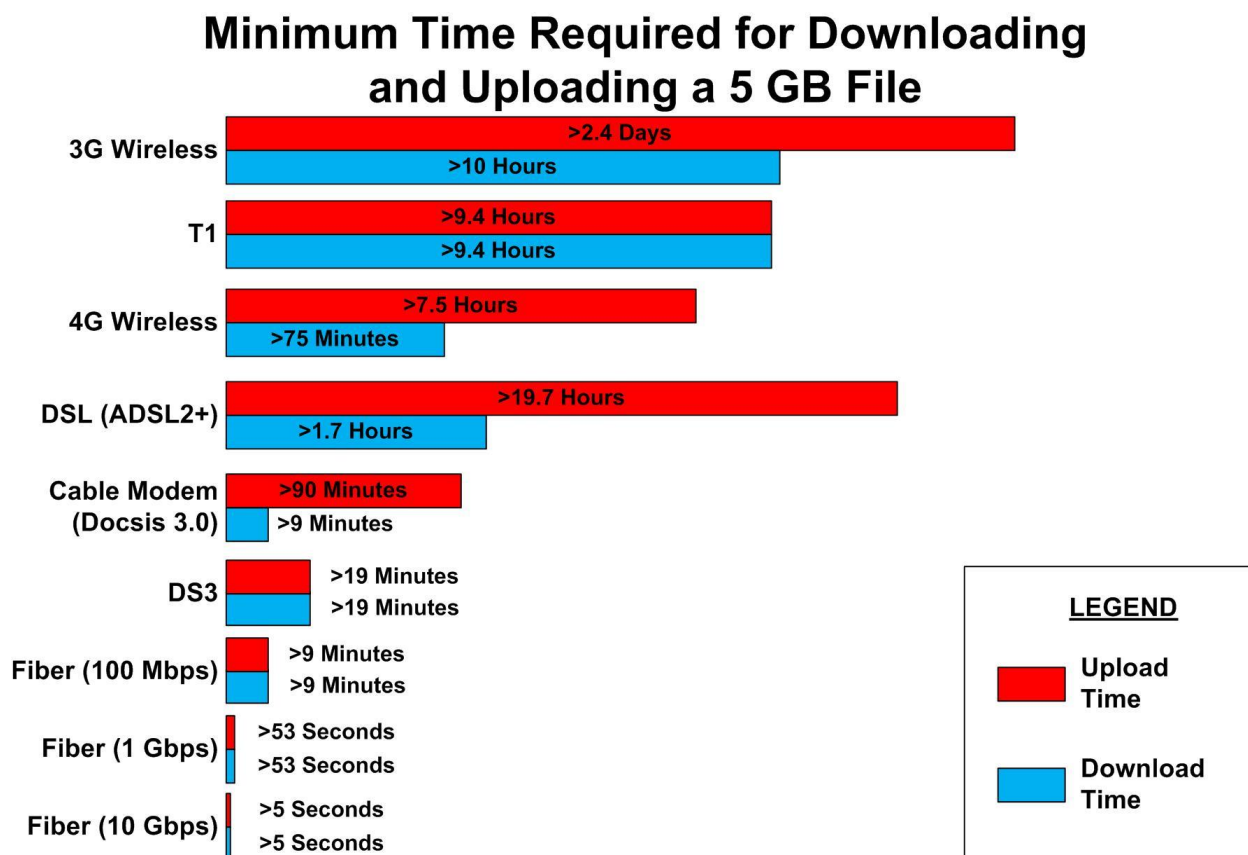
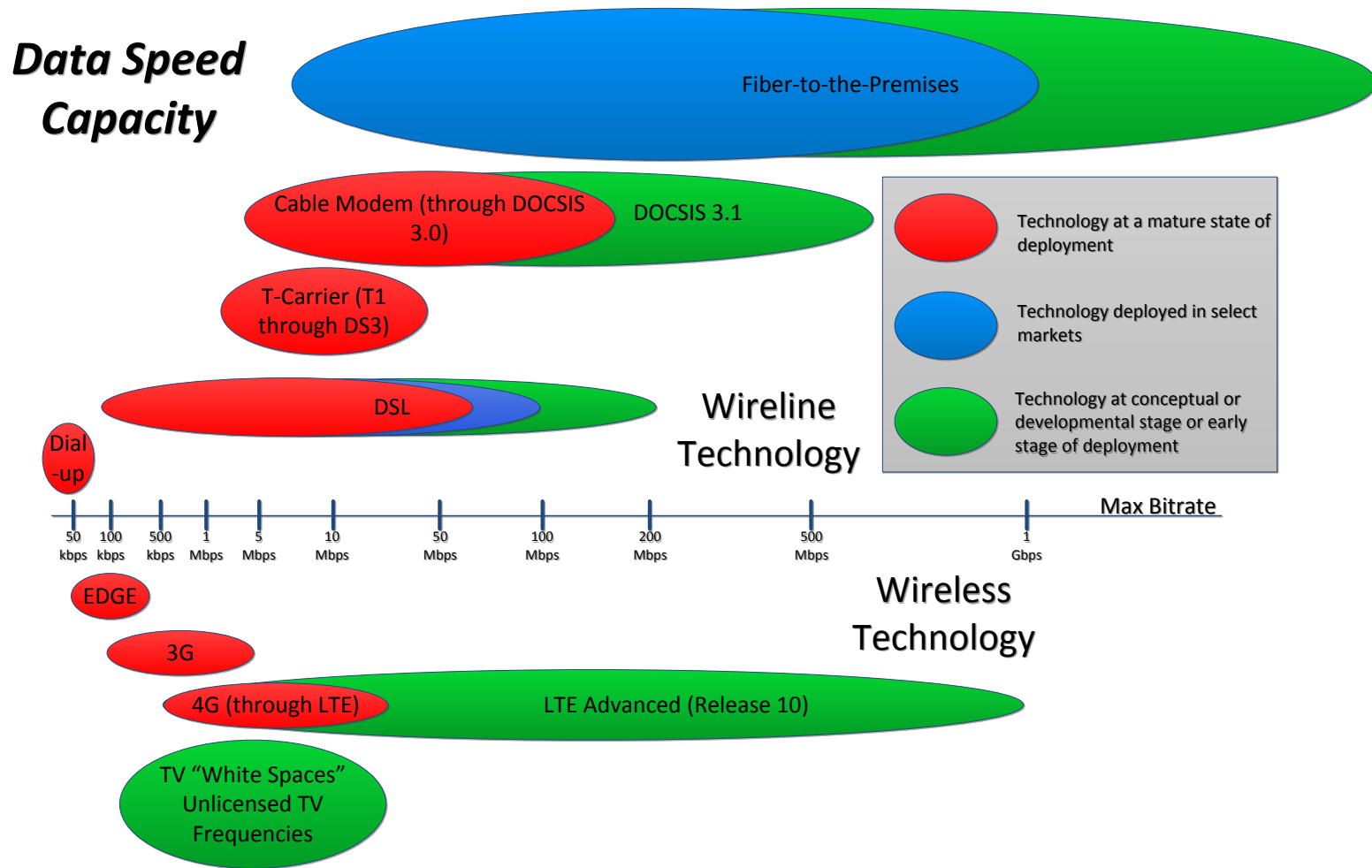


Figure 2, below, illustrates the current and likely future capacity of various technologies, including the new DOCSIS 3.1 technology that Comcast plans to implement at some point in the coming years. Note that the wireless technologies depicted below the line in the graphic generally cannot match in speed the wireline technologies (above the line) and thus serve as a mobile complement to wireline rather than as an alternative.

In the figure, LTE Advanced specifies the capability of 1 Gbps download speeds for users. We note that this relies on a development path of LTE that provides premium quality of service to high-bandwidth users, as well as the deployment of smart antenna technology and sufficient fiber and base station deployment to make all of this available. (As described in Section 5 below, advanced wireless technologies require fiber optics very close to the wireless radios to offer the capacity illustrated here.) We also note that in the same period that this type of speed becomes available for LTE, typical fiber speeds to the premises will be in the 10 to 100 Gbps range.

Figure 2: Wireline and Wireless Capacity



2.3 Though Many Connecticut Consumers Currently Are Well-Served by Existing Networks, State and Local Leaders Should Further Enable the Deployment of Next-Generation Broadband

Like most of New England, Connecticut and its cities have not yet experienced extensive private sector investment in the most robust, most future-proof communications infrastructure.

The very high speeds that are enabled over fiber optics are increasingly viewed as the emerging international standard. Google Fiber's announced FTTP deployments in a dozen or so cities (and counting), for example, will deliver gigabit (1,000 megabits) speeds at a price of \$70 per month. That is an order-of-magnitude higher speed than is affordably available to most consumers in the United States, including in Connecticut.

While there are many parts of Connecticut that are reasonably well-served today by current providers, some parts of the state are unable to access high-speed Internet at affordable prices. In our site visits to the state, we documented cases where businesses only have access to lower-speed DSL; we understand that this situation persists in some commercial areas and in certain rural towns, particularly those that were never served by cable television.¹⁰

Our interviews with officials from Connecticut localities further suggest some frustrations with gaps in broadband availability and challenges with affordability for some members of the community. According to officials of the City of Hartford, for example, the city receives frequent complaints, particularly from businesses, about challenges with accessing affordable broadband services. On parts of Main Street close to downtown Hartford, only inadequate DSL service is available on one side of the street. Businesses in several areas can access only unreliable DSL services that are insufficient to meet their business needs.¹¹ According to New Haven officials, there are also unserved pockets in downtown New Haven where service is both expensive and unreliable, such that applications like Skype and Voice-Over-IP (VoIP) and basic Web searches and file downloads cannot be used consistently or effectively.¹² Local officials in some rural areas report similar complaints, and that some businesses and institutions struggle to get adequate service to meet their needs.¹³

¹⁰ "A Brief Overview of Broadband Deficiencies in Connecticut," CTC Technology & Energy, January 2016, http://www.ct.gov/occ/lib/occ/2016-0124_ctc_report_on_connecticut_broadband_deficiencies.pdf (accessed March 2016).

¹¹ Interview with Mr. Darrell Hill, Chief Operating Officer, and Ms. Sabina Sitaru, Chief Innovation Officer, City of Hartford, October 27, 2015.

¹² Interview with Mr. Doug Hausladen, Director of Transportation, Traffic, & Parking, and Mr. Daryl Jones, Controller, City of New Haven, October 28, 2015.

¹³ Interview with Ms. Lisa Pellegrini, First Selectwoman, Town of Summers, October 27 2015.

Many Connecticut residents and businesses have a relatively broad range of services available, as compared to many other states, as has been noted in reports by the FCC.¹⁴ However, as compared to FTTP areas (such as Verizon FiOS build areas and the many emerging Google Fiber and AT&T markets), Connecticut, and New England in general, have not seen the same levels of investment in next-generation fiber networks.

Neither of Connecticut's primary incumbent wired providers (Frontier and Comcast) has indicated plans to widely deploy FTTP facilities throughout its service territory in the state. Rather, the incumbents are planning incremental upgrades of their networks that, while a very encouraging and positive development, do not ensure world-class communications networks on a ubiquitous basis in the state. While these improvements will significantly increase capacity over current levels where the upgrades are made, they will eventually be unable to keep up with skyrocketing demand for network capacity as increasingly bandwidth-rich applications emerge.

Verizon offers its FiOS FTTP service in part of Greenwich but has not indicated any plans of extending the service more broadly.

2.3.1 Comcast

Comcast operates a high-quality, reliable hybrid fiber-coaxial system that can compete against other offerings in today's Connecticut marketplace. Comcast has also indicated that it will upgrade its networks in Connecticut to the next generation of cable modem technology, known as DOCSIS 3.1, at some point in the coming years. That upgrade, if it is also supported by additional fiber construction, will enable Comcast to offer gigabit speeds to many Connecticut consumers.

Comcast's network, however, is limited by its lack of fiber—even with advanced electronics and software, its system cannot keep pace with the potential speeds of fully-fiber networks such as those under construction by Google Fiber and, to some degree, AT&T and CenturyLink. Cable systems are bound by the inherent limitations of the coaxial cable that runs from their nodes into the home. An additional limitation arises from the shared nature of cable modem service—bandwidth within a neighborhood is shared rather than dedicated. As a result, speeds may be significantly decreased by one's neighbors' simultaneous use of their cable modems.

In addition, the DOCSIS 3.1 technology will not be available for those in rural areas not served by cable television or in business areas that are outside Comcast's existing footprint. (Because the traditional footprint of cable companies was residential only, for purposes of selling one-way cable video products, cable networks frequently do not reach into business areas where there is

¹⁴ "2015 Measuring Broadband America Fixed Broadband Report," FCC, December 30, 2015, <https://www.fcc.gov/reports-research/reports/measuring-broadband-america/measuring-broadband-america-2015> (accessed March 2016).

no return sufficient for new infrastructure investment. As a result, some business areas do not have the benefit of Comcast's networks and extension of the infrastructure to those businesses can be prohibitively expensive.)

Comcast has also announced that it will offer "Gigabit Pro, its new symmetrical 2 Gbps residential broadband service delivered via fiber-to-the-premises technology,"¹⁵ in certain markets nationwide, including Hartford and New Haven in Connecticut.¹⁶ According to industry reports, Gigabit Pro will only be available to customers "within one-third of a mile of Comcast's fiber network"¹⁷—and the service will also require construction of fiber to customers' premises. Initial reports indicated that Comcast was charging up to \$500 for installation and \$500 for service activation, and that the process for a single subscriber to be connected could take eight weeks or longer.¹⁸

(Further, detailed discussion of the technical capabilities of cable company infrastructure can be found in Section 5.2.)

2.3.2 Frontier Communications

Frontier is the primary incumbent local exchange carrier in much of Connecticut, where it offers DSL and other copper-line services to most of the state and provides fiber services such as Metro Ethernet to businesses. Because the cost of the fiber services is substantially higher than the DSL services, small and medium-sized businesses may have difficulty affording these enhanced services.

DSL represents a relatively low-bandwidth form of broadband—a network of roads, not superhighways. DSL runs on telephone network copper wires, which simply cannot handle the same capacity as fiber or even as Comcast's hybrid fiber-coaxial (HFC) networks. As capacity requirements increase, DSL is likely to fall further behind cable.¹⁹

¹⁵ Jeff Baumgartner, "Comcast Promos 'Gigabit Pro' for \$159/Month," *Multichannel News*, July 13, 2015, <http://www.multichannel.com/news/technology/comcast-promos-gigabit-pro-159month/392124> (accessed March 2016).

¹⁶ "Experience fast like never before: Xfinity Gigabit Internet Pricing and Plans," Comcast, <http://www.xfinity.com/multi-gig-offers.html> (accessed March 2016).

¹⁷ Baumgartner, "Comcast Promos 'Gigabit Pro' for \$159/Month."

¹⁸ Jon Brodtkin, "Comcast's 2Gbps Internet costs \$300 a month with \$1,000 startup fees," *Ars Technica*, July 13, 2015, <http://arstechnica.com/business/2015/07/comcasts-2gbps-internet-costs-300-a-month-with-1000-startup-fees/> (accessed March 2016).

¹⁹ The limitations of DSL are illustrated Verizon's investment, over the past decade, to supplement its old copper phone networks with new FTTP networks in limited metropolitan areas within its existing footprint. New York City and some of its suburban areas have seen this new FTTP investment from Verizon.

Even with newer DSL versions, such as the VDSL fiber-to-the-cabinet service providing download speeds of approximately 50 Mbps,²⁰ its speed is significantly lower than what is available over cable or fiber. From a technical standpoint, DSL is a short-term solution in a market where bandwidth needs are growing exponentially and high, symmetrical capacity is increasingly needed for small businesses and for popular applications like video-downloads, video-gaming, and video-conferencing. Aging copper plant is not capable of meeting these growing needs in the long-run.

In a very positive development, Frontier has recently started upgrading some limited facilities in Connecticut to fiber-to-the-home. The company is launching its FiberHouse product in limited portions of West Hartford, specifically proposing to focus on three different locations of varying income levels in West Hartford. Frontier is also experimenting with fiber to a multi-dwelling unit in Stamford, and is building fiber in a green-fields project in the housing development of West Haven.

(Further, detailed discussion of the technical capabilities of DSL can be found in Section 5.3.)

2.3.3 Mobile Broadband

Wireless technology is the current focus of investment by the two largest phone companies, AT&T and Verizon, and its use is growing exponentially. It is critical to understand, however, that wireless does not supplant or compete with wireline broadband; rather, these technologies inherently serve to enhance and complement each other. Fiber offers over a hundred times the speed.²¹ Though impressive for a mobile service, mobile broadband technologies such as LTE cannot support some of the ultra-high-speed applications made possible by fiber. This is why mobile broadband base stations are themselves connected by fiber, the optimal technology to transport hundreds of individual mobile broadband connections over the network.

At the same time, however, the key advantage of wireless cannot be mirrored by fiber; wireless offers mobility and connectivity during movement.

While wireless offers these dramatic benefits, it cannot offer the very high bandwidth applications for business, health care, education, and the environment that fiber enables. A further significant challenge with respect to wireless is that some mobile broadband companies place restrictive bandwidth caps on the products they sell consumers. For consumers who purchase such a product, their monthly allotment of bandwidth could be reached in just a few hours of streaming video or backing up files to the cloud. Along with speed and reliability, these bandwidth caps are a significant reason why mobile products cannot offer the same functionality

²⁰ Exact speeds depend on condition and length of copper wires. The download speed of DSL services we observed in Hartford, on Main Street, ranged from 1.2 Mbps to 2.7 Mbps.

²¹ Comparing a 15 Mbps LTE connection to a 10 Gbps business-grade fiber Ethernet service, or faster fiber service.

as a wired product. (Further discussion of the technical capabilities of wireless can be found in Section 5.5.)

2.3.4 Verizon FiOS

Verizon's FiOS investment began in the early 2000s, and the company negotiated cable franchises and then built FTTP quite aggressively in select suburban and urban areas within its existing footprint, primarily on the east coast, but with some investment in the Pacific northwest and other regions. In Connecticut, Verizon built FTTP only in parts of Greenwich.

2.4 Affordability of Service Is as Important as Availability

Affordability is obviously a crucial aspect of enabling Connecticut citizens and businesses to enjoy broadband speeds enabled by fiber networks. The competing claims regarding "gig speeds" in Connecticut often focus on availability but without a clear discussion of affordability. In some pockets where FTTP is technically available, the installation costs can be prohibitively expensive. For example, Scotts' Jamaican Bakery in Hartford received a written quote from Comcast that a fiber installation to the premises would cost over \$600,000. That quote was later reduced to around \$250,000, a price still completely out of reach for a small business. Monthly recurring charges were not insignificant either. Several other Hartford businesses reported, and our tests confirmed, that they were purchasing low-speed Internet connections with high latency and jitter—services not even capable of voice-over-IP or video applications—but were still paying hundreds of dollars a month for service. Our interactions with municipal officials from other cities and towns indicates that these types of challenges persist in certain pockets of the state, notwithstanding the largely favorable average download speeds in Connecticut.

2.5 Connecticut Is Part of a Very Competitive Broadband Region

At the national level, eight out of the 10 states with the highest average connection and peak connection speeds are located in the Northeastern and Mid-Atlantic states.²² Those states include Delaware, Washington, D.C., Maryland, Massachusetts, New Jersey, New York, Rhode Island, and Virginia. In the fourth quarter of 2015, Connecticut was in twelfth place for its peak connection speeds (68.6 Mbps), and was in 13th place for its average connection speeds (15.9 Mbps).²³ Its growth rates in these categories from 4th quarter 2014 were 18 percent and 27 percent, respectively, which is roughly in the middle of the growth rate of U.S. states.²⁴

²² As reported by Akamai in the industry-standard "State of the Internet, Q3 2015" report, <https://www.akamai.com/us/en/multimedia/documents/report/q3-2015-soti-connectivity-final.pdf> (accessed March 2016).

²³ Discussion with David Belson, Akamai Senior Director, Industry & Data Intelligence, March 1, 2016.

²⁴ *Id.*

As a point of comparison to Akamai’s data, the FCC’s recent “Measuring Broadband Report” indicated that Connecticut ranks second among all states in terms of average download speed when “aggregated across ISPs and technologies.”²⁵ The Connecticut sample in that report primarily comprised cable modem subscribers (63 out of 65 subscribers), so this ranking is an indication that residents in Connecticut who have access to cable service are generally well-served. The sample did not include any DSL subscribers, which likely is the point of differentiation between the FCC report and the Akamai findings (the latter being representative of Internet usage as a whole, not just an evaluation of cable download speeds).

2.6 Neighboring States Are Providing Extensive Public Funding for Next-Generation Broadband

In the past year, two of Connecticut’s neighboring states—Massachusetts and New York—announced initiatives to expand access to robust connections. In Massachusetts, Governor Charlie Baker endorsed a \$50 million initiative started by his predecessor, Governor Deval Patrick, to expand broadband in Western Massachusetts, the most underserved area in the state.²⁶ Massachusetts ranks fourth in average connections speeds and third in peak connection speeds, but according to the Governor’s office, 45 towns in Western Massachusetts must rely on DSL or dial up. As a result, the funds will be directed toward those towns, in an effort to encourage municipal and private sector broadband investment in the region.

In New York, Governor Andrew Cuomo launched a \$500 million broadband initiative. The Governor’s “Broadband for All” campaign established a “goal to ensure that every New Yorker has access to high-speed Internet service by the end of 2018.”²⁷ The program is making funding contingent on matching funding from the broadband providers, which will have the effect of leveraging the state’s funds to increase broadband investment in New York by a total of \$1 billion. The providers must commit to make Internet speeds of at least 100 Mbps available, except in limited cases in regions that are particularly remote, where providers will be permitted to offer 25 Mbps speeds.²⁸

²⁵ Section D. Methodology and Sampling Plan for Statewide Statistics, “2015 Measuring Broadband America Fixed Broadband Report,” FCC, December 30, 2015, <https://www.fcc.gov/reports-research/reports/measuring-broadband-america/measuring-broadband-america-2015> (accessed March 2016).

²⁶ Jim Levulis, “Baker Administration Commits Money To Western Mass. Broadband,” *WAMC*, February 18, 2015, <http://goo.gl/5RhGJ3> (accessed March 2016).

²⁷ “Governor Cuomo Launches #Broadband4All Campaign Rallying Support for New NY Broadband Program,” <https://goo.gl/CJ3BoI> (accessed March 2016).

²⁸ The state established key qualifications for providers and communities interested in utilizing the funding: First, matching private-sector investments. Broadband providers will contribute, on average, at least 50 percent of the capital needed, which will push the size of the program above \$1 billion. The state’s investment will serve to stimulate competition in the broadband market where none or little exists—improving affordability and quality

2.7 The CT Gig Program Has Engaged Communities and Catalyzed New Broadband Opportunities, Including Some Incumbent Upgrades

Connecticut has benefited from its CT Gig effort, which built organizational and governance structures to support local communities in planning and implementing broadband networks. Taking a statewide approach to supporting last-mile broadband deployment in local communities represents a best practice nationwide and was a particular achievement by the state.²⁹

CT Gig's organizational support has catalyzed dynamic processes at local and regional levels. The CT Gig program has demonstrated that a well-designed and well-organized statewide effort creates a valuable framework and encourages collaborative effort toward a shared goal. The effort has promoted learning among different local and regional entities, as well as sharing of assets and insight, and capitalizing on economies of scale (e.g., in big-picture terms of buying services, and in detail-oriented areas such as buying data sets to support the planning efforts). And all of these collaborative efforts prepare communities to act quickly when opportunities—for federal funding, regional funding, private sector partnership, and so on—present themselves.

In addition, and perhaps most significantly, the incumbents have demonstrated awareness of the CT Gig effort, including through new upgrades and investments. Frontier, for example, has started upgrading some facilities in Connecticut to FTTP, a remarkable and positive development. And Comcast has stated that it will upgrade its existing systems in Connecticut to faster speeds as part of that company's nationwide deployment of DOCSIS 3.1 technologies, though there is no timeline yet for upgrades in Connecticut.

of service. Second, unprecedented broadband speed. Broadband providers must deliver Internet access rates of at least 100 Mbps, with funding priority given to those delivering the highest speeds at the lowest cost. In certain limited cases, providers may offer 25 Mbps rates to the exceptionally remote unserved and underserved areas of the State (meeting the FCC's minimum definition for broadband) scalable to 100 Mbps or more—if this provides the best means of achieving universal broadband access to the region.

²⁹ CT Gig is a collaboration of municipalities in Connecticut that seek to develop partnerships with Internet service providers to create gigabit-speed fiber networks. (*CT Gig Project*. <http://www.osc.ct.gov/gig/>). It emerged out of a series of focus groups organized by the Connecticut Office of the Consumer Counsel and Connecticut Technology Council with business leaders around the State. (Bill Vallée, "Gigabits Across Connecticut," *Broadband Communities Magazine*, Jan./Feb. 2015, p. 48, <http://goo.gl/oPqRFJ>.) Business leaders in the state expressed their desire for options for gigabit broadband services and for more competition among providers of higher speed broadband service. (Id.) In addition, they wanted to upgrade broadband in communities across the State to enable employees to work remotely from home. (Id.) The project was launched in September 2014 and included the cities of New Haven, West Hartford, and Stamford. (Id.) The three cities issued a joint request for qualifications (RFQ) to solicit ideas and proposals from companies that would be interested in partnering with the communities to build competitive fiber networks. (Id.) The cities later invited other municipalities in the State to join the RFQ. By December 2014, 46 municipalities, representing 50 percent of the State's population, joined the RFQ. State officials continue to encourage additional municipalities to join the collaboration (Kent Pierce, "CT towns to upgrade to Gigabit to increase Internet speed," *News8*, Jan. 14, 2015, <http://goo.gl/CZdl19>) and the number of participating members grew to more than 100 towns and cities. (All links accessed March 2016.)

3 Recommendations for Advancing Connecticut's Broadband Environment

3.1 Create a Grant Program to Stimulate Projects at the Local Level

CTC recommends that state leaders consider creating a broadband grant program to catalyze and incent local government and private investment in the infrastructure that enables gigabit and beyond services—FTTP.

The neighboring states of New York and Massachusetts have created two of the three most significant state funding mechanisms for next-generation broadband (the other state is California).

A grant program would be a means of maintaining the considerable momentum that has been created by the CT Gig program over the past two years. It could catalyze new efforts at the local level, in both urban and rural communities. And a grant program would enable Connecticut to compete for private broadband investment that would otherwise flow to neighboring states.

Connecticut may not desire to match New York's large-scale state funding initiative, but significant opportunities for progress exist at modest levels of funding. For example, in 2015, the Minnesota state legislature included \$10,588,000 in funds for the Border-to-Border Broadband Infrastructure grant program.³⁰ The funds were targeted at expanding broadband service in unserved and underserved regions throughout Minnesota with grants up to \$5 million that could provide up to 50 percent of project development costs.

Construction of a new fiber optic network is underway in rural, south-central Minnesota thanks to a public-private partnership, called the RS Fiber Cooperative, and the state's grant program. The network will eventually pass more than 6,200 potential customers across 10 cities and 17 townships. The network will be built in phases, with the first phase expected to cost \$15 million. The state contributed \$1 million to the effort through the rural broadband grant program, and the participating municipalities have financed the rest with \$8.7 million in general obligation bonds, as well as additional bank loans. Once completed, the first phase of the network will allow the cooperative to offer better broadband than is currently available in the area using wireless

³⁰ "Broadband Grant Program," Minnesota Department of Employment and Economic Development, <http://mn.gov/deed/programs-services/broadband/grant-program/> (accessed March 2016).

transmitters. The cooperative will use the revenue it begins to generate to service the bonds and finance the construction of the last-mile portion of the fiber network.³¹

Similarly, under Governor Pat Quinn, Illinois launched the “Illinois Gigabit Communities Challenge.” The program awarded up to \$4 million in seed funding to “the most promising ultra high-speed broadband deployment projects in Illinois.”³² The challenge was open to any private or public organization and required projects to connect at least 1,000 end users to an ultra-high-speed broadband network capable of delivering speeds of 1 Gbps.

In another useful example, the California Advanced Services Fund (CASF) offers both grants and loans to assist in construction or upgrade of broadband infrastructure in areas that are not served or are underserved by existing broadband providers.³³ The CASF program also has a Consortia Grant program that funds regional consortia to promote ubiquitous broadband deployment and to advance broadband adoption in unserved and underserved areas.³⁴

More information on this recommendation can be found in our March 2016 report, “Recommendation: The Potential for Pilot Funding for Gigabit Networking in Connecticut.”³⁵ That report includes extensive, detailed discussion of the need for such a grant program; recommendations for developing a program based on best practices; and discussion of programs created in other states and lessons learned from those experiences.

3.2 Create a “One Truck Roll” Pole Access Environment

We recommend that the parties in Connecticut consider developing a mechanism for more efficient “make-ready” in the communications space on utility poles. This recommendation is based on our experience in other parts of the country, our brief high-level surveys in Connecticut, and our discussions with broadband stakeholders and pole owners. Reducing the number of entities needed to perform simple, previously approved moves of existing attachments in the

³¹ Nancy Madsen, “Minnesota Rural Broadband Development a Game Changer,” *Government Technology*, July 20, 2015, <http://www.govtech.com/dc/articles/Minnesotas-Rural-Broadband-Development-a-Game-Changer.html> (accessed March 2016).

³² “Illinois Gigabit Communities Challenge,” Broadband Illinois, <http://www.broadbandillinois.org/Use-it/Illinois-Gigabit-Challenge.html> (accessed March 2016).

³³ An “unserved” area is an area that is not served by any form of wireline or wireless facilities-based broadband, such that Internet connectivity is available only through dial up service. An “underserved” area is an area where broadband is available, but no wireline or wireless facilities-based provider offers service at advertised speeds of at least 6 Mbps download and 1.5 Mbps upload. *California Advanced Services Fund (CASF) Infrastructure Grant and Revolving Loan Account*. <http://www.cpuc.ca.gov/General.aspx?id=8246> (accessed March 2016).

³⁴ In 2011, the program approved Year 1 budgets and three-year budget allowances for seven regional consortia totaling \$1.7 million. An additional seven grants were approved for \$1.05 million in 2012 and two additional grants totaling \$550,000 in 2014. *California Advanced Services Fund –Rural and Urban Regional Broadband Consortia Account*. <http://www.cpuc.ca.gov/General.aspx?id=870> (accessed March 2016).

³⁵ Available at: http://www.ct.gov/occ/lib/occ/2016-0309_ctc_report_pilot_funding_program.pdf (accessed March 2016).

communications space on poles may significantly improve the speed and cost of building new communications infrastructure in the state.

This type of policy, referred to as “one-touch” or “one-truck-roll” make-ready (OTMR) can reduce the time to construct or improve infrastructure, reduce overall cost, reduce complexity, and reduce the negative impact on the public as the various parties work to prepare the communications space on the poles for new or enhanced attachments.

In the absence of OTMR, the standard practice for an attacher is to go through several steps to attach to poles. These can be costly and time-consuming and still leave the attacher with substantial potential delay and cost—because it must rely on the good will and timeliness of the existing attachers to take steps to provide space on the poles. In many cases, existing attachers are competitors that do not have an interest in a swift process.

With OTMR, many steps in the process of building or upgrading infrastructure can be skipped, saving time and money, and reducing the burden on existing and new broadband providers, while still retaining the parts of the process that ensure safety.

3.2.1 The Traditional Make-Ready Process

In a traditional process, the attacher obtains a pole attachment agreement from the pole owner (or in joint-ownership areas, the multiple pole owners) that certifies the attacher as an entity entitled to be on the pole and establishes the rules for being on the poles. The attacher then applies for permits for each pole. In Connecticut, where most poles are jointly owned by the electric utility and the phone company, a prospective attacher must obtain a separate attachment agreement with each owner.

The new attacher conducts its own engineering analysis of the current situation at the pole and then proposes to the pole owner(s) where and how it will attach. The pole owner then conducts its own analysis. Depending on local rules and practices, the attacher, pole owner, and existing attachers may conduct a multi-party survey that includes all the parties with attachments, which could be three, four, five, or more entities. Alternatively (or in addition), the pole owner(s) may determine which utilities need to move and how, and whether a pole must be replaced.

In Connecticut, a substantial portion of this process in the communications portion of the poles is managed by incumbent telephone company Frontier Communications. The Electric Distribution Companies (Eversource and United Illumination) serve as the “Single Pole

Administrator” for their service areas, but Frontier is responsible for pole attachment work in the communications space under a 2014 Public Utilities Regulatory Authority (PURA) decision.³⁶

In the traditional process, existing attachers are then required to move their infrastructure within a set period of time; in the case of Connecticut, PURA has determined the required time period.³⁷ In 2008, PURA adopted a make-ready Order that includes a 45-day deadline for the pole owners³⁸ to perform engineering and provide estimates and a 45-day deadline for all the attached entities to complete make-ready after the applicant agrees to proceed. If a pole must be replaced, an additional 35 days is added to the second 45-day period.

If these deadlines are respected by the pole owners and attachers, they have the potential to greatly speed deployment and provide predictability for the new attacher and its investors.

In our experience across the country, the make-ready process that follows permitting can in practice prove slow. In most cases, each existing attacher separately sends a crew to make the move. These moves are not generally coordinated and may require lane and sidewalk closures each time. The total cost is higher than necessary, because each move is planned and executed separately. The existing attachers then invoice the new attacher separately. The new attacher must wait until all existing attachers are done before it can get started in placing its own attachment.

As a practical matter, then, the new attacher can face delays as a result of this multi-party, multi-step process. Delays on a short stretch of poles, or even a single pole, can slow down deployment of large-scale projects.

Where poles need to be replaced, the pole owner will place a second pole. If the existing attachers are slow to move their attachments to the new pole, the old pole is left in place for an extended period. A large number of “double poles” offers visual evidence that make-ready is frequently a slower process than intended.

³⁶ Docket No. 11-03-07, DPUC Investigation into the Appointment of a Third Party Statewide Utility Pole Administrator for the State of Connecticut, October 8, 2014.

³⁷ Docket No. 07-02-13, DPUC Review of the State’s Public Service Company Utility Pole Make-Ready Procedures – Phase 1, April 30 2008.

³⁸ In Connecticut, on all poles where both the power company and the telephone company are attached, both the power company and the telephone company need to perform engineering and respond. This is the overwhelming majority of cases. On poles where the power company is attached and the telephone company is not attached, only the power company performs the engineering and the estimate. On poles where power is not attached and the telephone company is attached, only the telephone company performs the engineering and the estimate.

The traditional approach is not designed for a world with multiple providers on a pole—it scales poorly and becomes complex and expensive with multiple cable and wireless providers and highly burdensome on the pole owners and attachers.

Subsequent filings in Connecticut PURA docket 11-03-07 provide 2015 statistics on pole attachment and make-ready in the Eversource service area. The docket indicates that out of 728 applications for pole attachment, 475 did not meet the timeframes required by regulation. Of these, 424 were for the initial 45-day engineering and estimate process by the pole owners, 34 were for make-ready not requiring pole replacement, and 17 were for make-ready requiring pole replacement.^{39,40}

3.2.2 The One-Touch Make-Ready Process

Eversource engineers, in multiple discussions with the SBO and CTC, suggested that the state would be well-served by a one-touch approach for the communications space on poles. They further suggested, based on these statistics and further knowledge about the applications, that the approach would significantly improve the timeliness of engineering, cost estimates, and make-ready.

In an environment where the parties adopt OTMR for the communications space on the poles, there will be small but important changes. The first is that a qualified contractor that meets applicable industry standards can be hired by the new attacher or the pole owner (depending on the details of the agreement). The existing attachers are notified, and the work is done and documented.

The public and the parties all benefit from the work being done at once in a number of ways:

- There is only one set of lane closures, which accommodates the make-ready and the placement of the new attachment.
- The time and place of make-ready becomes predictable, both on a week-by-week basis and on an aggregate project-level basis.
- The total cost (both to attachers and electric rate payers) is reduced.
- Existing attachers do not need to invoice or be reimbursed.

³⁹ [http://www.dpuc.state.ct.us/dockcurr.nsf/\(Web+Main+View/All+Dockets\)?OpenView&StartKey=11-03-07](http://www.dpuc.state.ct.us/dockcurr.nsf/(Web+Main+View/All+Dockets)?OpenView&StartKey=11-03-07) (accessed March 2016).

⁴⁰ Note that the delayed make-ready application numbers have already been decremented by the number of applications that were not pursued by the applicants after the engineering and cost estimate, and also by the number of applications delayed in the engineering and estimate process in the first. As a result, the percentage of make-ready moves behind schedule may be significantly higher than these statistics make it appear.

- Work is done safely by a professional, qualified contractor who is a central point of contact for information on work status, work supervision, and documentation.
- There is no need for a long period of double poles in the event poles need to be replaced, which reduces both the public safety concerns associated with double poles and the aesthetic concerns.

The incentives in the one-touch approach for the communications space vastly improve on the traditional approach—existing attachers are not required to expend time and attention on make-ready for new attacher, and there is no temptation created for an existing attacher to delay or effectively block a new entrant or upgrade.

The one-touch process enables efficiency and other benefits not only for incremental construction, but also for high-volume construction as in where a new competitor enters the market.

A one-touch environment for the communications space will benefit not only new attachers but also existing incumbent attachers by making it easier for incumbents to upgrade. For example, as Frontier upgrades its infrastructure and adds new fiber optics to support new services, it will need to modify attachments. Similarly, as Comcast upgrades to DOCSIS 3.1 technology, it will need to modify attachments to build fiber deeper into its network. In a one-touch environment, its upgrades will likely be more efficient.

At the same time, one-touch maintains important safety precautions. Attachers still need to get a pole attachment agreement, they still need to do pole engineering according to the rules of pole owner, and work needs to be performed by a contractor certified by the pole owner. OTMR is not typically done for make-ready in the electrical space, which requires a contractor certified by the electric utility for that work and must be overseen by that utility.

Generally, one-touch policies do not apply to make-ready that might interrupt service (as opposed to routine movements of attachments in which there is no risk of service interruption). In the OTMR policy recently adopted by the City of Louisville, for example, make-ready that may interrupt service can only be conducted after 30 days if the attacher does not perform the make-ready itself.⁴¹

⁴¹ Though it has drawn praise for its innovative approach to speeding deployment times, the Louisville OTMR policy has also resulted in a lawsuit by AT&T, which claims that the state and federal governments—not the city—have authority over such matters. See <https://goo.gl/5BCQvN> (accessed March 2016).

In Connecticut, the vast majority of communications infrastructure in state is on aerial poles, and underground construction is extremely costly in rocky areas. If OTMR can speed make-ready, it can drastically reduce cost and risk to new deployers and increase speed to build.

OTMR policies are widely regarded as efficient ways to speed broadband deployment, including by some phone and cable companies. CTIA-The Wireless Association, for example, recommended in 2010 that the FCC consider rules enabling attachers to “use pre-approved and pre-certified contractors to complete make-ready work.”⁴² Comcast Corporation also spoke approvingly of proposals to expedite infrastructure access, such as timeframes for stages of make-ready attachment and use of third party contractors....⁴³

The policies have received significant support from the competitive side of the industry,⁴⁴ as well as from public sector groups focused on enabling new broadband opportunities.⁴⁵

3.3 Create an Infrastructure Bank Modeled on the State’s Green Bank

The first-in-the-nation Connecticut Green Bank has successfully leveraged limited public funds to spur a significant amount of private investment in clean energy infrastructure. Using similar financing tools in a Broadband Bank, Connecticut could enable a new wave of investment in the critically important, next-generation broadband infrastructure the state needs to compete in the 21st century.

The Connecticut Green Bank has offered a variety of low-cost financing options, enabling municipalities, companies and consumers to cover the initial cost of investing in renewable energy generation and improving energy efficiency. This allows borrowers to spread the payback period across the full useful life of their investment. Though only in its fourth year of operation, the Connecticut Green Bank has already become a much heralded model that many have encouraged other states to emulate in order to curb greenhouse emissions.⁴⁶ The Green Bank’s successful track record has led private financial institutions to step in and offer their own clean

⁴² Filing with Federal Communications Commission by CTIA – The Wireless Association, 2010, <https://prodnet.www.neca.org/publicationsdocs/wwpdf/81710ctia2.pdf> (accessed March 2016).

⁴³ Filing with Federal Communications Commission by Comcast Corporation, August 2010, <http://apps.fcc.gov/ecfs/document/view?id=7020708182> (accessed March 2016).

⁴⁴ For example, the Fiber to the Home Council has strongly endorsed this approach. <http://www.ftthcouncil.org/d/do/1959> (accessed March 2016).

⁴⁵ The Next Century Cities organization of broadband-focused local governments has also endorsed one-touch strategies. <http://nextcenturycities.org/2016/01/06/one-touch-make-ready-policies-the-dig-once-of-pole-attachments/> (accessed March 2016).

⁴⁶ Ellen Kan, “Connecticut Leads in Energy Efficiency,” Yale Daily News, October 29, 2015, <http://yaledailynews.com/blog/2015/10/29/connecticut-leads-in-energy-efficiency/> (accessed March 2016); Andrew Belden, et al. “Financing Clean Energy,” Union of Concerned Scientists, July 2015, <http://www.ucsusa.org/sites/default/files/attach/2015/07/financing-clean-energy.pdf> (accessed March 2016).

energy financing products,⁴⁷ and has attracted substantial private investment in the Bank, allowing it to scale and expand its offerings.⁴⁸

The success of the Green Bank demonstrates the state's ability to work in partnership with private financial markets to jump-start investment in a sector of the economy that offers numerous benefits beyond the balance sheet. In order to incent the markets to increase delivery of affordable, high-speed broadband to unserved or underserved areas,⁴⁹ Connecticut could create a similar Broadband Bank, using the Connecticut Green Bank as a model.

A robust, reliable broadband network is a public good that benefits businesses, schools, hospitals, local governments and private residents in a variety of ways. However, these benefits do not always factor in to private companies' decision whether or not to take on capital-intensive network build-outs and upgrades. Private companies reasonably invest only when they can cover their costs and earn a profit. They are not incentivized to make their investment decisions solely on economic development goals or educational opportunities in the region.

Modeling a Broadband Bank on the Green Bank to create a 21st century infrastructure bank that provides low-cost financing options for next-generation telecommunication networks would help increase levels of investment to reflect the way communication infrastructure serves the public good. Similar to clean energy infrastructure, fiber networks have a high upfront cost, and deliver their return over a long period of time. Private capital markets are unlikely to be attracted to investments that are likely to take decades to offer robust returns. By taking actions to jump-start investment in fiber optic networks, Connecticut can ensure that its citizens are at the leading edge of digital technology and are positioned to best reap the benefits from the many applications that are currently being developed to make use of high-capacity data networks, such as high-fidelity meeting tools, telemedicine, and augmented reality.⁵⁰

Making lower-cost financing available for investment in telecommunications infrastructure would allow both private and public entities to increase their investments in broadband networks. Municipalities that determine that they need additional investment to keep their

⁴⁷ "Greenworks Lending Announces Closing C-PACE Transactions Totaling \$1 Million," Connecticut Green Bank, August 26, 2015, <http://www.ctgreenbank.com/1172-2/> (accessed March 2016).

⁴⁸ "Green Bank and Hannon Armstrong Partner for Commercial Clean Energy Financing," PR Newswire, December 17, 2015, <http://www.prnewswire.com/news-releases/green-bank-and-hannon-armstrong-partner-for-commercial-clean-energy-financing-300194976.html> (accessed March 2016).

⁴⁹ "A Brief Overview of Broadband Deficiencies in Connecticut," CTC Technology & Energy, January 2016, http://www.ct.gov/occ/lib/occ/2016-0124_ctc_report_on_connecticut_broadband_deficiencies.pdf (accessed March 2016).

⁵⁰ "Killer Apps in the Gigabit Age," Pew Research Center, October 9, 2014, http://www.pewinternet.org/files/2014/10/PIP_KillerAppsInGigabitAge_100914.pdf (accessed March 2016).

region economically competitive would find it easier to achieve positive cash flow in their own investments in broadband infrastructure. They could service the debt in a variety of ways, ranging from leasing network capacity to private carriers, offsetting internal communication costs, offering retail data transport services, raising property taxes in the area, using incremental tax revenues from the increased property values that have historically followed new fiber networks,⁵¹ or a blend of many of these. As the market matures and successful business models begin to prove out, private financial institutions will become more willing to finance municipal network build outs themselves.

In addition to lowering the cost of the financing, an infrastructure bank can play a valuable role in bringing both expertise and creativity to next-generation infrastructure. At this time, it is not certain how business models will develop. Traditional financing entities have been hesitant to enter these new markets with long pay-out periods. Just as in the energy realm, it might be that the borrowers could be local governments, non-profits, neighborhood cooperatives, or even individuals, paying for last-mile connections themselves to lower the cost of monthly services. A bank with expertise in the economics and a public mandate to encourage new solutions can be a critical catalyst in accelerating adoption.

The low-cost financing options may also allow private companies to invest in infrastructure in regions where the potential return on investment is relatively low, such as rural and low-income areas. Lowering the cost of capital helps encourage investment in these areas, where the time needed to achieve positive cash flow can be significantly longer than in wealthy, urban areas. If the incumbent carriers choose not to make such investment themselves, the bank's financing options would make it easier for a start-up or business from another sector to enter the broadband market.

In Europe, the European Infrastructure Bank has already made capital available at a low cost for both public⁵² and private sector⁵³ actors that wish to expand telecommunication infrastructure in underserved regions. While support for infrastructure banks has swelled in the US in recent years, thanks in part to Connecticut's Green Bank's success in spurring investment in clean energy

⁵¹ Ryan Knutson, "How Fast Internet Affects Home Prices," *Wall Street Journal*, June 30, 2015, <http://www.wsj.com/articles/SB11064341213388534269604581077972897822358> (accessed March 2016).

⁵² "Germany: EIB and NBank promote broadband rollout in Lower Saxony," European Infrastructure Bank, November 12, 2015, <http://www.eib.org/infocentre/press/releases/all/2015/2015-260-eib-und-nbank-fordern-breitbandausbau-in-niedersachsen.htm> (accessed March 2016).

⁵³ "Gigaclear Rural Broadband Plan Gets €25M EIB Support," January 20, 2016, <http://www.fibre-systems.com/news/story/gigaclear-rural-broadband-plan-gets-%E2%82%AC25m-eib-support> (accessed March 2016).

infrastructure,⁵⁴ there are few working examples of infrastructure banks in the United States at this time. Connecticut Congresswoman Rosa DeLauro has introduced legislation to authorize a National Infrastructure Bank multiple times,⁵⁵ and although her proposal has gained support amongst environmental and union groups,⁵⁶ the legislation has not made it through the political gridlock in Congress. Former Secretary of State Hillary Clinton has made establishing and funding a National Infrastructure Bank a prominent part of her campaign's infrastructure plan.⁵⁷

By creating a Broadband Bank to support investment in the digital infrastructure critical for the state's success and leadership in the coming decades, Connecticut would once again prove itself a pioneer in effectively leveraging limited public funds in support of the public good.

3.4 Adopt a "Dig Once" Policy

We recommend that the municipalities and state leaders consider a "Dig Once" policy to require any excavation plans fitting specified criteria to include municipal use conduit or fiber, unless the state or municipality opts out of the excavation project. This would require the installation of state or municipal communications infrastructure in excavation projects where the municipality determines that it is both financially feasible and consistent with the municipality's long-term goals to develop the municipality's communication infrastructure.

3.4.1 The Case for Dig Once Policies

The construction of fiber optic communications cables is a costly, complex, and time-consuming process. The high cost of construction is a barrier to entry for potential broadband communications providers. In addition, available space is diminishing in the public rights-of-way (ROW). Moreover, cutting roads and sidewalks substantially reduces the lifetime and performance of those surfaces.

⁵⁴ "Connecticut Homeowners Investing Heavily in Solar, Reducing Energy Costs with Connecticut Green Bank Financing," Connecticut Green Bank, <http://www.ctgreenbank.com/connecticut-homeowners-investing-heavily-solar-reducing-energy-costs-connecticut-green-bank-financing/> (accessed March 2016).

⁵⁵ "DeLauro Introduces National Infrastructure Development Bank Act," Congresswoman Rosa DeLauro, January 23, 2015, https://delauro.house.gov/index.php?option=com_content&view=article&id=1799:delauro-introduces-national-infrastructure-development-bank-act&catid=41&Itemid=177 (accessed March 2016).

⁵⁶ Erin Bzymek, "Infrastructure Bank Will Jumpstart National Investment in Transportation, Water, Communication Systems and Electric Grid," Blue Green Alliance, June 27, 2013, <http://www.bluegreenalliance.org/news/latest/infrastructure-bank-will-jumpstart-national-investments-in-transportation-water-communication-systems-and-electric-grid> (accessed March 2016).

⁵⁷ "Hillary Clinton's Infrastructure Plan: Building Tomorrow's Economy Today," Hillary Clinton; The Briefing, November 30, 2015, <https://www.hillaryclinton.com/briefing/factsheets/2015/11/30/clinton-infrastructure-plan-builds-tomorrows-economy-today/> (accessed March 2016).

Accordingly, encouraging or requiring simultaneous construction and co-location of facilities in the public ROW will reduce the long-term cost of building communications facilities. This is because there are significant economies of scale through:

1. Coordination of construction with road construction and other disruptive activities in the public ROW.
2. Construction of spare conduit capacity where multiple service providers or entities may require infrastructure.

The reason that these economies are available is primarily because fiber optic cables and installation materials alone are relatively inexpensive, often contributing to less than one-quarter of the total cost of new construction. While material costs typically fall well below \$40,000 per mile (even for large cables containing hundreds of fiber strands), labor, permitting, and engineering costs commonly drive the total price toward \$200,000 per mile if conducted as a stand-alone project.

Moreover, as the ROW becomes more crowded with communications infrastructure and other utilities, the cost of new construction can grow rapidly. In general, however, it is in the best interests of both public and private entities for the public sector to identify construction collaboration opportunities that share the burden of expensive and duplicative labor-related costs and efficiently utilize physical space in the ROW.

If fiber construction is coordinated with a major road or utility project that is already disrupting the ROW in a rural area, the cost of constructing the fiber, communications conduit, and other materials can range from \$10,000 per mile up. However, if fiber construction is completed as part of a separate stand-alone project, the cost of constructing fiber and communications conduit can range from \$95,000 to \$200,000 per mile and even higher in complex urban environments.

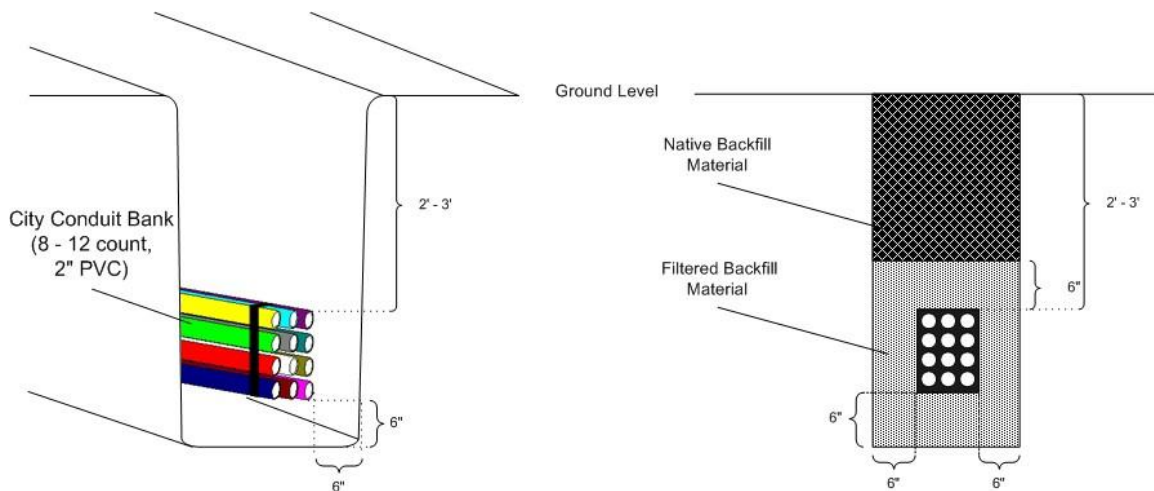
There are numerous methods for constructing fiber optic infrastructure. In particular, underground construction using protective conduits generally provides the most scalable, flexible, and durable method for developing long-term communications infrastructure, but is also typically more expensive than aerial construction methods requiring attachments to utility poles. Underground construction can be preferable despite the cost because of the limit in the quantity of cables and attachments that can be placed on existing utility poles in more crowded areas, and because aerial construction is more exposed and vulnerable to outside conditions.

Banks of conduits constructed simultaneously (Figure 3), or large conduits segmented with inner duct, provide multiple pathways for the installation of multiple fiber optic cables located

in close proximity, with the ability to remove, add, or replace fiber optic cables without disturbing neighboring cables.

Conversely, multiple conduits installed at different times must be physically spaced, often by several feet, to prevent damage to one while installing the next. Once the ROW becomes crowded, often the choices of construction methods are reduced, leaving only less desirable methods and more costly locations for construction of additional infrastructure.

Figure 3: Underground Conduit Bank for Multiple Users



Some of the key savings achieved through coordinated construction efforts include:

- Incremental labor and material costs, through reduced crew mobilization expenses and larger bulk material purchases
- Trenching or boring costs, particularly when coordination enables lower-cost methods (e.g., trenching as opposed to boring) or allows multiple entities to share a common trench or bore for their independent purposes
- Traffic control and safety personnel costs, particularly when constructing along roadways requiring lane closures
- Engineering and survey costs associated with locating existing utilities and specifying the placement of new facilities
- Engineering and survey costs associated with environmental impact studies and approvals
- Lease fees for access to private easements, such as those owned by electric utilities

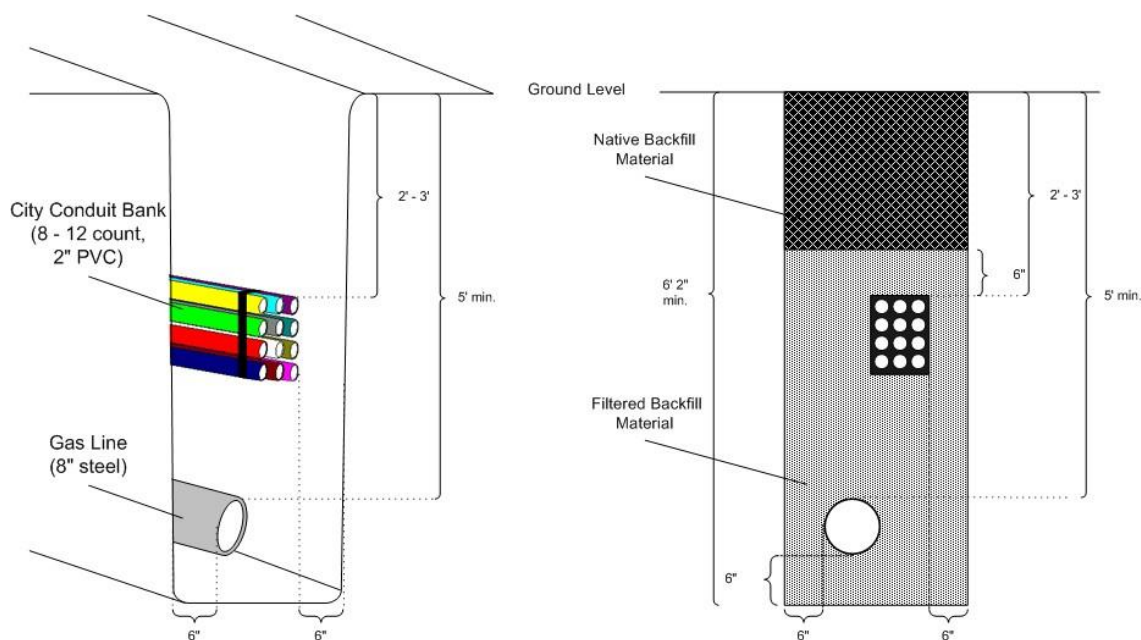
- Railroad crossing permit fees and engineering
- Restoration to the ROW or roadway, particularly in conjunction with roadway improvements
- Bridge crossing permit fees and engineering

3.4.2 Coordinating Digital State Highway Construction with Other Utility Projects Reduces Costs

Where other types of construction are occurring within or along the ROW, such as highway construction or resurfacing, roadway widening, sidewalk repairs, bridge construction, and water or gas main installation, there is an opportunity to place telecommunications infrastructure at an overall reduced cost and with reduced disruption to public ROW.

Figure 4 illustrates how a multi-user conduit bank might be installed with a gas main, water main, power line, or other large utility installation requiring trenching. We note that in a case like this, it is important to ensure proper backfill of trench material and facilitate future access to both the conduit and the other utility for repair by offsetting the two utilities horizontally and requiring a somewhat wider trench. This offsets somewhat the potential cost savings by requiring a larger trench and multistep backfill process. Nonetheless, cost savings are still substantial.

Figure 4: Example Coordinated Conduit Bank and Gas Main Installation



3.4.3 Criteria for Prioritization

The cost of installing conduit is drastically reduced when a trench is already dug. However, the cost is still significant, and the state or municipality will need to prioritize projects that achieve

the most value for the money spent and maximize the likelihood of the conduit being used. To ensure that Dig Once projects are both financially feasible and consistent with the state or municipality's long-term goals, we propose prioritization based on the following range of factors:

- Ability to place conduit over long, continuous corridors across the state or municipality
- Proximity of the project to state or municipal facilities requiring service
- Lack of existing state or municipal communications infrastructure in the vicinity
- Potential interest in conduit from partners or customers (e.g., Municipality departments, service providers, or developers)
- Lack of cost-effective alternatives due to physical constraints in the vicinity (e.g., targets of opportunity such as bridges or freeway underpasses)
- Lack of capacity on utility poles along the route
- Risk to Dig Once communications infrastructure (e.g., water, gas, and sewer need to be placed deep underground and Dig Once infrastructure placed far above that infrastructure to reduce likelihood of damage to the Dig Once conduit during an emergency utility repair; this is less true of electrical and communications excavation that is in closer proximity to the Dig Once conduit, making the Dig Once conduit easier to avoid)
- Delays to critical infrastructure (i.e., the incremental days for Dig Once coordination must not create a public safety risk)
- Project cost (i.e., prioritizing projects with lower-than-average costs)
- Synergies with opportunistic major projects, such as highway mass transit, or bridge replacement
- Major right-of-way crossings, such as railroad, water, highway, interstate etc. Often times these are difficult for private carriers to facilitate or justify
- Conduit placement for building laterals into key sites, data centers, or facilities deemed potential targets for redevelopment
- In addition to Dig Once, we recommend that where pedestrian sky bridges or tunnels are being installed as part of the downtown redevelopment efforts, conduit be placed along these access corridors where appropriate.

As opportunities emerge, or as existing opportunities are reviewed, we recommend they be evaluated based on the above prioritization. We recommend scoring and ranking each potential project on the above criteria.

3.4.4 Standard Specification

The challenge in developing a standard specification for a Dig Once project is to incorporate the requirements of known and unknown users, and to provide sufficient capacity and capability without excessive costs.

We considered the following factors in developing a conduit specification:

1. Capacity—sufficient conduit needs to be installed, and that conduit needs to have sufficient internal diameter, to accommodate future users' cables and to be segmented to enable conduit to be shared or cables added at a future date
2. Segmentation—users need to have the appropriate level of separation from each other for commercial, security, or operational reasons
3. Access—vaults and handholes need to be placed to provide access to conduit and the ability to pull fiber. Vaults need to be spaced to minimize the cost of extending conduit to buildings and other facilities that may be served by fiber
4. Costs—materials beyond those that are likely to be needed will add cost, as will the incremental labor to construct them. Beyond a certain point, trenches need to be widened or deepened to accommodate conduit
5. Robustness—the materials, construction standards, and placement need to reasonably protect the users' fiber, and not unduly complicate maintenance and repairs
6. Architecture—sweeps, bend radius, and vault sizes need to be appropriate for all potential sizes of fiber

We recommend further discussions with private carriers to better develop a specification. It may be appropriate to have a different specification for different projects. Based on our knowledge of similar efforts in other cities, and our analysis, we believe the following standardized approach is suitable for major corridors and can be modified as discussion continues with excavators in the rights-of-way:

- Four two-inch conduit, minimum SDR 11 HDPE, each of a separate color or unique striping to simplify identification of conduits within vaults and between vaults, in the event conduit must be accessed or repaired at intermediate points. Conduit count can be reduced if the corridor is assessed not to justify the capacity.

- Composite vaults having dimensions of 30" x 48" x 36" (W x L x D), placed in the sidewalk or available green space within the city or municipality right-of-way, as close to the curb or gutter as possible
- Vaults spaced at intervals of 600 feet or less, typically at the intersection of a city or municipality block
- Sweeping conduit bends with a minimum radius of 36 inches to allow cable to be pulled without exceeding pull-tension thresholds when placing high-count fiber cables (e.g., 864-count)
- Conduit placed in the same trench directly above the excavator's infrastructure or, where this is not possible, placed with minimum horizontal offset, to minimize cost

It is important to note that the proposed approach is designed to create consistency and predictability in costs and deployment and, of necessity, is a compromise among the potential users. If an excavation project has a long time horizon and sufficient budget, it is possible to customize the Dig Once build, potentially adding conduit or adding vaults at particular locations. This plan provides a baseline approach.

The approach is a compromise among different types of users of conduit constructed under dig once. Some users might prefer larger conduit for consistency with earlier builds. Others sought a larger count of smaller conduit, to provide more flexibility and the capability for more providers to participate with smaller cable counts.

Two-inch conduit has become a standard size for a wide range of construction projects, and can support the widest range of use cases. A single two-inch conduit can accommodate a range of multi-cable configurations, while retaining recommended fill ratios, allowing a single user to serve its backbone and "lateral"/access cable requirements with a single, dedicated conduit. A few example cable configurations supported by a single two-inch conduit, which are not supported by smaller conduit, include:

- Two medium backbone cables (e.g., 144-strand to 288-strand cables) and one smaller "feeder" cable (e.g., 24-strand cable);
- Large backbone cable (e.g., 864-strand) and two or more smaller feeder cables; or
- Three medium backbone cables.

Compared to placing fewer, larger conduits segmented with innerduct, this approach provides greater opportunity for individual conduit to be intercepted and routed for future vault installation by a particular user. Additionally, two-inch conduit is substantially cheaper to install

and physically more flexible than larger varieties, offering more options to route around existing utilities and other obstructions. Placing four conduit will provide a standard allotment of one or two conduit for State or municipality use and provide capacity for other use and for spares.

We recommend SDR 11 HDPE in all cases except where conduit is exposed in to the elements (for example, as a riser to building entry), or under extreme levels of pressure (such as under a train or trolley track). SDR 11 HDPE designs will generally support standard highway and railway loads with less than 1 percent deflection when buried with two feet of cover.

3.5 Maximize the Benefit of the E-Rate Program

We recommend that state leaders consider modest funding for one or two positions to support schools and libraries with their communication planning and E-rate applications.⁵⁸ Modest support could dramatically improve the opportunity of those schools and libraries to receive better services at lower per-unit prices and with the full, currently-unrealized benefits of the federal E-rate subsidy program. Modest state support with the planning process could also greatly help the less-resourced schools and libraries that have fewer local resources, little or no information technology staff, and little or no sophistication about communications technologies.

In the past three funding years, Connecticut schools and libraries in the aggregate have received less than 1 percent of the total E-rate funding awarded across the country.⁵⁹ We believe this amount could be increased with more coordination, planning, and centralized support from the state—as well as through targeted support to pay some portion of the costs not subsidized by the federal E-rate program.

3.5.1 Consider Provision of Resources for Central Administration and Coordination

There is significant opportunity for the state to support broadband procurement by schools, libraries, and hospitals through aggregated bidding and purchasing, centralized planning and procurement, and consolidation of needs.

According to state officials, many Connecticut schools are not receiving the full E-rate subsidy for which they qualify, largely because they are not knowledgeable about the program and cannot

⁵⁸ The federal government, through the FCC's Universal Service Fund program for schools and libraries, which is informally known as E-rate, provides funding support to schools and libraries. Similarly, the federal government provides funding support to rural hospitals through the Healthcare Connect Fund. Other programs fund equipment and services, both through the FCC and the Department of Agriculture's Rural Utilities Service.

The Healthcare Connect program requires a 35 percent local match from the healthcare facility applying for the funding. While the E-rate funding level will vary by school district (it ranges from 20 to 90 percent, based on a combination of the rural nature and level of poverty in the local community), the average funding level in Connecticut is between 40 and 50 percent.

⁵⁹ <http://e-ratecentral.com/us/stateInformation.asp?state=CT> (accessed March 2016).

fully exploit it.⁶⁰ The better resourced schools are able to hire specialized consultants to assist with their E-rate strategies and applications at the district level, but for those schools that are unable to pay for such specialized support, there does not exist at the state level a support and planning mechanism that would provide them the same benefits as their more resourced counterparts.

According to officials of the State Library, that agency does not have staff dedicated solely to the E-rate process and providing support to libraries across the state.⁶¹ And libraries are at a great disadvantage if they do not receive support at the state level. The technology budget for some public libraries in Connecticut is less than \$1,000 per year.⁶² Given such constrained resources, many libraries contract for low level, inexpensive services rather than exploring ways to procure higher level, more costly services that would be substantially subsidized by the E-rate program.⁶³

We therefore believe that there is opportunity for the state to help schools and libraries to make better use of federal funding programs. We also believe that in doing so, the state can, in the aggregate, increase the number of dollars flowing into the state from sector-specific federal broadband funding programs.

One model we suggest for consideration is the one implemented in North Carolina. When the State of North Carolina decided to fund K–12 broadband services through the state’s non-profit higher education network, the North Carolina Research and Education Network (the North Carolina counterpart to Connecticut’s CEN), NCREN undertook to centralize all E-rate applications so that schools were entirely relieved of this burden. Since then, the net amount of E-rate funds flowing in to the state has increased dramatically—while the schools have increased their Internet utilization more than ten-fold.

3.5.2 Provide Targeted Support to Schools and Libraries to Offset Their Costs Not Covered by E-Rate

State leaders should also consider providing targeted subsidies directly to school districts and libraries to defray their broadband costs. On average, Connecticut schools and libraries are eligible for approximately 40 to 50 percent federal funding—which leaves a 50 to 60 percent funding amount that is required locally. Many of these schools and libraries, particularly those where the local community has less resources available for broadband, would benefit from financial support from the state to cover the costs of the local match and enable them to

⁶⁰ Interviews with Mr. Doug Casey, Executive Director, Connecticut Commission for Educational Technology, January 4 and February 2, 2016.

⁶¹ Interviews with Mr. Kendall Wiggin, Connecticut State Librarian, January 4 and February 2, 2016.

⁶² *Id.*

⁶³ *Id.*

purchase better, higher-bandwidth services. (As a point of reference, the State of Nebraska covers 85 percent of the difference between its educational entities' local broadband costs and their E-rate reimbursement.⁶⁴)

In addition, the state funding, if combined with federal program planning and consulting support, could enable Connecticut to increase the amount of federal funds flowing into the state. The percentages of the subsidies will not vary, but if the institutions are able to buy costlier, higher-bandwidth services, the absolute dollar figure flowing into the state will increase—at the same time as the schools and libraries will benefit from significantly enhanced communications services.

3.6 Create a Certification Program to Identify Office Buildings with Robust Broadband

In our observation nationally, even in the most sophisticated markets it can be difficult for businesses to determine what communication services are available in a given area. This challenge applies both to businesses already located in a given market and those that are considering relocating to that market. Even though, in a recent survey, office location decision-makers ranked connectivity as their top priority when selecting an office location, the same survey revealed that less than half receive detailed information on connectivity services prior to signing their lease.⁶⁵

A voluntary program that certifies the quality of connectivity services available in Connecticut office buildings could provide critical information for office location decision-makers, and incentivize building owners to take steps to improve available services and relevant internal building infrastructure.

Such a program could be modeled on the WiredScore initiative in New York City—a program launched in 2013 under Mayor Bloomberg in partnership with the New York City Economic Development Corp. WiredScore is now a standalone company that “evaluates a building's connectivity by examining the number and quality of Internet service providers (ISP) as well as the bandwidth capabilities and reliability of connections that are based on the building's

⁶⁴ Neb.Rev.Stat. 79-1003(13).

⁶⁵ “Office Workers Rank Reliable Internet Connectivity #1 Priority in New Survey,” PR Newswire, June 29, 2015, <http://www.prnewswire.com/news-releases/office-workers-rank-reliable-internet-connectivity-1-priority-in-new-survey-300105711.html> (accessed March 2016).

infrastructure.”⁶⁶ The company also provides technical assistance to business owners that wish to improve their ranking.⁶⁷

WiredScore is expanding to additional cities including Chicago, Boston, Washington, D.C., Seattle, San Francisco,⁶⁸ and London.⁶⁹ To date, WiredScore has certified more than 400 properties in 30 cities.⁷⁰ In the case of London, the mayor partnered with WiredScore, contributing £50,000 to cover the initial consultation and certification costs for a handful of London office buildings.⁷¹ Presumably, once a critical mass of buildings receive a connectivity score, other building owners in the area feel pressure to certify their property in order to remain competitive.

If state leaders do not wish to create a Connecticut-specific certification tool, the state could enter into a similar partnership with WiredScore, promoting its services across the state and providing an initial subsidy to help some building owners to cover the initial cost of certification.

WiredScore, or a similar tool built specifically for Connecticut, could help prospective tenants identify buildings with sufficient broadband access and encourage building owners to take greater steps to enhance available broadband services in commercial buildings. These steps could include paying the upfront costs to wire buildings in a way that enables more than one provider to serve tenants, or allowing competitive providers to install infrastructure within the building. In addition, building owners may have a greater incentive to pay the necessary construction costs to connect their buildings to additional providers’ core fiber network.

As the availability of communication services becomes more transparent, building owners and developers will feel an increasing amount of pressure to secure high-quality broadband services for their tenants. While building owners alone may be unable to overcome a local lack of fiber infrastructure, incentivizing them to improve services may encourage them to partner with grassroots and municipal efforts to improve communication infrastructure in the area.

⁶⁶ PR Newswire, “WiredScore, First Ever Connectivity Certification Service, Expands Nationally,” <http://www.prnewswire.com/news-releases/wiredscore-first-ever-connectivity-certification-service-expands-nationally-300072080.html> (accessed March 2016).

⁶⁷ “Frequently Asked Questions, WiredScore, <http://wiredscore.com/public/faq> (accessed March 2016).

⁶⁸ PR Newswire, “WiredScore, First Ever Connectivity Certification Service, Expands Nationally,” <http://www.prnewswire.com/news-releases/wiredscore-first-ever-connectivity-certification-service-expands-nationally-300072080.html> (accessed March 2016).

⁶⁹ “Wired Certification Awarded to Ten London Buildings, Kicking off Partnership with Mayor of London,” Market Wired, October 22, 2015, <http://www.marketwired.com/press-release/wired-certification-awarded-ten-london-buildings-kicking-off-partnership-with-mayor-2066048.htm> (accessed March 2016).

⁷⁰ “Exclusive Q&A: What you need to know about Wired Certification,” *Bisnow*, December 2, 2015, <https://www.bisnow.com/san-francisco/news/office/wiredscores-david-weinstein-on-wired-certification-53069> (accessed March 2016).

⁷¹ “Mayor of London launches major drive to boost connectivity in capital,” Mayor of London, June 15, 2015, <https://www.london.gov.uk/press-releases/london-technology-week> (accessed March 2016).

4 Potential Broadband Business Models for Local Governments

Local governments have before them a range of potential broadband investment models. A handful of models for localities to enable new broadband networks have emerged over the past few years and are evolving at a rapid rate. Indeed, new models appear to be emerging on a monthly basis. As of this writing, however, we have divided the range of existing and emerging models into the following categories:

1. **Municipal Broadband:** Localities build, own, and operate FTTP networks themselves in the “municipal broadband” model. This is a very high-risk and high-reward proposition, with a respectable track record in communities across the country.
2. **Middle Mile Broadband:** Localities build less extensive networks to address “middle mile” needs, thus ensuring the availability of fiber optics to government users and key community anchor institutions, but not reaching all the way to the home or business.
3. **Middle Mile Plus:** Localities route their middle mile networks to reach key economic or community development targets, such as business parks, historic downtowns, or revitalization areas.
4. **Public Facilitation of Private Investment:** Localities encourage new private investment through economic development incentives and other measures to reduce costs for private sector infrastructure deployment.
5. **Public Funding, with Private Execution:** Localities negotiate formal public–private partnerships that resemble transit and toll-road construction projects, with public funding and private execution.
6. **Shared Public and Private Risk and Cost:** Localities create hybrid models where a locality and private partner find a creative way to share the capital, operating, and maintenance costs of a broadband network.
7. **Targeted Rural Strategies:** While rural communities have fewer options and less market power than do their metro-area counterparts, modest strategies are emerging for rural broadband projects in which the community shares some risk with a private partner.

Each of these models is described and evaluated, at a high level, below.

4.1 Municipal Broadband: Local Public Investment and Risk

In this model, localities build, own, and operate FTTP networks themselves in the “municipal broadband” model. This is a very high-risk and high-reward proposition, with a respectable track

record in communities across the country. In our observation, however, this is a difficult model to replicate, particularly for communities that do not own their own municipal electric utilities. The risk and challenge involved in this model suggests that it will be adopted infrequently. Aggressive anti-municipal efforts by incumbent phone and cable companies make this model even more risky.

Despite the risks, about 100 local communities have built hybrid fiber-coaxial (HFC) networks (the architecture used by the cable companies) or FTTP networks to comprehensively serve the residential and business markets.

Some of these networks date back almost two decades; the great majority were deployed in the first decade of the 21st century. In almost every case, these networks have been deployed in towns and largely rural areas. Some, but not all, of these towns already had cable modem service, but many of them were unserved or close to unserved by broadband service at all. The majority of these municipal public-facing networks were deployed by municipal electric utilities.

This correlation is not surprising for a number of reasons. First, it is in communities where the private sector did not have a business case for electrification, where local governments chose to build public power. Not surprisingly, those same communities did not see significant private sector investment in broadband, much as a century earlier they did not see private investment in power—and thus chose, in both cases, to make that investment themselves for the benefit of the broader community.

Second, the challenge of undertaking a public-facing communications project is reduced for a municipal electric utility relative to a local government that is not already a power provider. A range of elements of a communications network overlap those of a power network, including the poles on which the infrastructure is built, the facilities in which hubs are located, the skills and equipment of field staff, and even in some cases the billing, operating, and customer service systems that support the service offerings.

A minority of the municipal public-facing networks were built by localities that were not power utilities. It is important to note, however, that the economics of FTTP are extremely challenging given the very high capital costs and the modest revenues possible, particularly in light of competition from lesser broadband technologies.

Unlike with other public utilities such as water and sewer, city communications networks do not operate in a monopoly environment, and a number of competitors, however inferior, do exist. These include far lower bandwidth options such as DSL, cable modem service, and mobile wireless service. (In contrast, some of the municipal FTTP networks were built a decade or more ago at a time when there may not have been much or any competition in those rural towns).

Tremendous successes have been achieved by such public FTTP networks as those in Lafayette, Louisiana; Chattanooga, Tennessee; and Wilson, North Carolina—all of which are municipal electric utilities that achieved substantial efficiencies. (In 2012, the Benton Foundation and the Institute for Local Self-Reliance published a study about the utilities' FTTP networks in these cities.⁷²)

The most dramatic successes of these networks are in the benefits that do not necessarily show up on the financial statements—the enhanced productivity, innovation, education, health care, company recruitment, and related benefits that are the reason for the communications investment in the first place. Thus, even those public entities that have found it challenging to make FTTP networks self-sustaining on a balanced sheet basis can still claim significant success based on these other benefits—which some call positive externalities or ancillary benefits, but that are more central to the purpose of the network than any other factor.

4.2 Middle Mile Broadband

In this model, localities build less extensive networks to address “middle mile” needs, thus ensuring the availability of fiber optics to government users and key community anchor institutions, but not reaching all the way to the home or business. This is a proven best practice with two decades of solid empirical data that demonstrates its viability.

Many Connecticut towns are among the hundreds of communities that have used this strategy, with a range of variations. Among these communities around the country are Austin, Albuquerque, Boston, Chicago, Los Angeles, New York City, San Antonio, San Francisco, Seattle, Washington, D.C., and hundreds of suburban and rural towns and counties.

Two decades of public sector experience demonstrate that city or town ownership of a fiber network enables localities to better meet growing demands for communications capacity and functionality, while reducing risk by hedging against private sector price increases for managed communications services. By owning its infrastructure, a locality can determine how much it will pay for the initial infrastructure and also manage ongoing operating expenses, keeping them relatively constant—even as the network's capabilities increase over time.

Without control over its own network, a locality's costs for carrier-provided communications services may increase significantly with time—both because of carriers increasing their pricing and because the community's communications needs will grow enormously in the decade ahead.

⁷² Kendrick, Julie, “The Broadband Challenge,” *The Line*, July 18, 2012. <http://www.thelinemedia.com/features/broadband071812.aspx> (accessed March 2016). See also: Mitchell, Christopher, “Broadband At the Speed of Light: How Three Communities Built Next-Generation Networks,” Institute for Local Self-Reliance, April 2012. <http://www.ilsr.org/wp-content/uploads/2012/04/muni-bb-speed-light.pdf> (accessed March 2016).

Additionally, the locality may find itself limited in bandwidth at its sites and in its Smart City deployment; the community may be limited to the services that service providers have available in that particular neighborhood or limited to the services that can be purchased under a given year's appropriation.

The whole range of emerging applications localities currently wish to enable, including remote traffic signalization, will be joined in short order by high-bandwidth, high-cost applications such as traffic camera and surveillance camera backhaul, remote sensors, and other devices, as well as a full range of Smart City and Internet of Things deployments. A robust publicly owned fiber network would make far more cost-effective not only the applications that require backhaul of wireline connectivity, but also those such as traffic signalization and remote sensors that could require wireless.

4.3 Middle Mile Plus: Incremental and Targeted Fiber Construction

In this model, a community would offer dark fiber⁷³ connections, through a lease, to institutions and businesses.

CTC's experience suggests that this is the business and technical model with the highest possibility of financial success and with the lowest risk for Connecticut localities. This model can facilitate a modest portion of the public goals related to new broadband deployment while still minimizing risk. This model requires a smaller capital investment than does more extensive fiber deployment and could allow the community to realize a modest revenue stream from this model—at the same time as meeting its own communications needs and reducing the cost of leasing circuits.

This model for fiber construction and leasing has been successfully implemented by a range of localities across the United States for nearly two decades.

Significantly, though this model will fill a market vacuum for selected business customers, it will not necessarily address the needs of residents and small businesses. The model does offer some incentives for a private provider to construct FTTP infrastructure, but is unlikely to be enough to attract all necessary private sector investment in FTTP because it does not significantly lower the costs of market entry.

4.4 Public Facilitation of Private Investment

The model focuses not on a public sector investment, but on modest measures the public sector can take to enable or encourage greater private sector investment. The most prominent example

⁷³ Dark fiber refers to the lease of point-to-point fiber strands. The lessee of dark fiber is responsible for adding electronics to "light" the fiber.

of this model is Google Fiber's deployments, including its networks in Austin, Kansas City, Nashville, and elsewhere. Ting Internet⁷⁴ is taking a similar approach in smaller markets, including Holly Springs, North Carolina and Sandpoint, Idaho.

This model is seen as the ideal for many communities that wish to minimize public cost. At least in Google Fiber's deployments, the private sector partner's requirements have largely focused on making local government processes more efficient. In return for these relatively low-cost public sector commitments, the communities that are partnering with Google Fiber or Ting Internet benefit from the company's deployment of FTTP infrastructure (and, in many cases, competitive responses in the form of upgrades by the incumbent cable and telephone companies).

While this model reduces the public sector's cost and risk compared to other models, there is a potential public relations risk. Public expectations can get very high with the announcement of new fiber deployment. If a local government is strongly identified as a partner, it may be held accountable by the community if something goes wrong with the private sector partner's business plan or deployment.

A further challenge of this model is that private investors will deploy capital only in areas where they see a return on investment. The partnership model here does not confer upon the municipality much leverage to expand deployment patterns to neighborhoods that are of less interest to the private investor.

4.4.1 Sample Strategies for Encouraging Private Investment

There are a number of strategies that localities can take to encourage new private investment and reduce some of the costs and time for private sector entities to deploy advanced broadband services. These can, for example, take the form of specific economic development incentives such as tax benefits to encourage providers to build new infrastructure. Metronet, a small Midwest ISP, developed a partnership with the City of Crawfordsville, Indiana, to purchase the municipal utility's fiber network.⁷⁵ The city is assisting Metronet with financing the purchase and expanding the footprint of the fiber network.

Communities typically offer this type of benefit to new entrants in a market that are willing to invest in next-generation infrastructure, but they can offer those benefits to incumbents if the incumbents will also invest in the same kind of infrastructure.

⁷⁴ Ting, <https://ting.com/> (accessed March 2016).

⁷⁵ "MetroNet plans to expand current fiber optic system," *The Paper of Montgomery County Online*, Mar. 18, 2014, <http://goo.gl/5eHuJt> (accessed March 2016).

Another key strategy is for the community to develop and strengthen the local infrastructure assets that enable the deployment of broadband.⁷⁶ These include public assets such as fiber, conduit, and real estate. For example, new network deployments can benefit enormously from access to existing government fiber strands, underground communications conduit in which fiber is placed, or real estate where equipment or exterior huts can be located.

Communities can further facilitate the underground construction of conduit and fiber by implementing a “dig-once” policy for all road and related transportation projects, as discussed above, and facilitating in-building access through construction specifications for new buildings.⁷⁷

Building and expanding community infrastructure over time is a low-cost, low-risk strategy that will have real impact and expand options down the road. For example, the City of Mesa, Arizona, began a dig-once initiative in the early 2000s; the city intended to install its own rings of conduit during private sector construction projects, then sell access back to the private sector. Any time the city opened up a street, such as to install water or sewer utilities, it put in conduit.⁷⁸ In some instances, the city also added fiber to empty conduit for city purposes or to potentially lease to private providers. In total, the city installed as much as 200 miles of conduit.⁷⁹ Mesa targeted four economic development areas in particular, with redundant conduit, fiber, and electric infrastructure.⁸⁰ Among those areas was the land around the Phoenix-Mesa Gateway Airport, where Apple announced in early 2015 that it would build a \$2 billion data center.⁸¹

A third important strategy is to improve access to information—an asset that communities might not have considered.⁸² Sharing information demonstrates a willingness to engage with the private sector to spur investment. Communities should seek to make data available wherever possible both for public and private uses.

Geographic information systems (GIS) or similar databases that hold information such as street centerlines, home and business locations, demographics, and details on existing utilities, public infrastructure, rights-of-way, and available easements can be extremely helpful for a locality’s

⁷⁶ “Gigabit Communities: Technical Strategies for Facilitating Public or Private Broadband Construction in Your Community,” CTC Technology & Energy, Jan. 2014, p. 6–12, <http://www.ctcnet.us/gigabit/> (accessed March 2016).

⁷⁷ For more discussion of “dig once” policies and related collaborative strategies, see “Gigabit Communities.”

⁷⁸ “Transcript: Community Broadband Bits Episode 139,” Institute for Local Self-Reliance, Feb. 26. 2015, <http://goo.gl/pFzN6k> (accessed March 2016).

⁷⁹ *Id.*

⁸⁰ *Id.*

⁸¹ “Governor Doug Ducey Announces Major Apple Expansion in Arizona,” News Release, Office of the Arizona Governor, Feb. 2, 2015, <http://goo.gl/gxtgoC> (accessed March 2016).

⁸² “Gigabit Communities,” p. 13–16.

own broadband planning, potential public–private partnerships, or a network service provider that is evaluating the deployment of new infrastructure in a community.

Access to this information may attract and speed new construction by private partners, while enabling the community to meet its goals for new, better broadband networks—and potentially to realize revenues for use of the assets.

Finally, localities can take steps to enable broadband construction by making government processes around permitting, rights-of-way access, and inspections more efficient and smooth.⁸³ In some communities, for example, permitting processes have been moved online, alleviating the need for wasteful and time-consuming paper-based processes. These actions can signal to private partners that there is an investment opportunity in the jurisdiction and that the locality will not be a bottleneck or create additional costs.

These steps should take into consideration the needs of the community, balance public interest and public safety, and account for local resources and capacity. For example, localities can choose to be fully transparent about their permitting and rights-of-way processes—including timelines—to enable the communications industry to expeditiously plan and deploy networks.

4.4.2 Potential Benefits and Pitfalls

The above strategies can make a difference in the economics of buildout for a private partner. However, they will not dramatically change the underlying economics of broadband network construction and operation. In a best-case scenario, the public sector can reduce the cost of outside plant construction for a broadband network by up to an estimated 8 percent.⁸⁴

Thus these measures can be substantial, but not transformative. Indeed, many incumbents overstate the extent to which local government and regulation are hurdles for developing next-generation broadband infrastructure. Communities should be wary, then, of private sector entities seeking benefits without offering concrete investment proposals.

4.4.3 Case Study: Holly Springs, NC

Over the course of many years, the Town of Holly Springs designed, engineered, and constructed a backbone fiber network to connect municipal buildings. To their great credit, Holly Springs' visionary elected officials chose to build a fiber network with dramatically higher capabilities than the need apparent at the time—knowing that a robust fiber backbone might attract interest from private ISPs that recognize the potential to leverage that backbone to more efficiently build their own FTTP infrastructure.

⁸³ *Id.*, p. 14.

⁸⁴ “Gigabit Communities.”

But a robust backbone network was not enough. The town’s government also developed policies and strategies to attract private broadband investment. As a result, Ting Internet announced in mid-2015 that it will bring “crazy fast fiber internet” to the homes and businesses of Holly Springs. Ting plans to expand on Holly Spring’s existing fiber pathways and offer symmetrical gigabit Internet access to homes and businesses.

A key factor in Ting’s decision to invest in Holly Springs was the fact that the town not only was willing to lease excess fiber in its backbone, but that it also brought best practices to bear in its willingness to work with Ting and facilitate Ting’s efforts. Among other things, the town offered efficient government processes, access to information and facilities, and facilitation and support—all of which boosted Ting’s confidence about this community as an investment opportunity.

4.5 Public-Private Partnerships: Public Funding and Private Execution

In this model, localities negotiate formal public-private partnerships that resemble transit and toll-road construction projects, with public funding and private execution.

This model, which involves a substantial amount of public investment, is a variation on the traditional municipal ownership model for broadband infrastructure—but with private rather than public sector execution. In this model, a selected private partner takes responsibility for some combination of design, construction, financing, operations, and maintenance,⁸⁵ funded by the public partner over some period of time.

While the field is very fast developing and constantly changing, two companies responded to the Connecticut RFQ with fully articulated business models and business propositions for localities: Macquarie Capital and SiFi Networks. In a very interesting and promising development in Connecticut, Frontier also has subsequently made some proposals for partnerships that are loosely based on this model but that likely entail lower cost and risk.

All three companies are proposing relatively new approaches—each with the same core concept (though with considerably different detail): The public sector’s willingness to contract in the long term is what will enable and secure construction of the network.

The model offers considerable benefits to the public sector by removing significant logistical barriers from large-scale public broadband projects and offering a comprehensive solution (including extensive turnkey private execution and private capital) for the entire community.

⁸⁵ “Financial Structuring of Public-Private Partnerships (P3s),” U.S. Department of Transportation, 2013, <http://goo.gl/gCJZK> (accessed March 2016).

These variations on the private execution, public funding model are as of yet untested; we urge caution for that reason. But we note that this model is a promising means by which to develop a network that can—if funded by the public sector—serve the entirety of the community, not just the parts selected by a private investor.

4.5.1 Macquarie and SiFi Proposals

These two companies submitted different proposals, but with some commonalities. We describe each one briefly below, and then suggest some areas for further evaluation that apply to both.

4.5.1.1 Macquarie Capital

Macquarie Capital and its partner companies have pioneered a model in the broadband market in the U.S.⁸⁶ They propose to provide financing, construction, operations, and service delivery over the network. To fund all this activity and investment, the locality will pay Macquarie on an ongoing basis by placing a monthly fee on all local property owners' utility bills. Macquarie intends that multiple ISPs will compete over the network, giving consumers a choice of providers and the benefits of price competition (and creating a revenue stream for ISPs, which will pay Macquarie).

Macquarie intends that the ISPs will commit to installing and offering a free, basic level of service to all in the community (thus presumably justifying the utility fee). The ISPs will then have the opportunity to sell enhanced services, for a fee, to generate revenues.

Macquarie projects that network revenues will grow substantially over time; as service revenues generated by the ISPs increase, Macquarie commits to sharing some of its revenues with the locality, thus offsetting the locality's obligations to Macquarie (remittance of the monthly utility fee charged to property owners).

The Macquarie model is attractive to communities given the turnkey private financing, deployment, operations, and revenue-sharing solution that Macquarie promises to deliver. However, the requirement of guaranteed public funding in the form of a utility fee paid by all residents is not politically acceptable in many communities.

Macquarie is an experienced and sophisticated entity, and offers an attractively comprehensive solution. We note, however, that its open access business model is not tested and that the utility fee is likely to prove a heavy lift politically in most American communities.

4.5.1.2 SiFi Networks

In the SiFi Networks approach to this model, the fiber-to-the-home network is built and operated by SiFi and its partners at public sector expense. SiFi will provide financing and, with its partners,

⁸⁶ "Macquarie Capital," Macquarie Group, <http://goo.gl/uvUEjv> (accessed March 2016).

turnkey construction and operations—all of which will be compensated by lease payments from the public sector partner. SiFi will then bring to the community one or more ISP partners, with which the locality will contract to provide open access services over the network.

In SiFi's vision, the ISPs will make minimum payment guarantees to the locality in return for the opportunity to provide services over the network; those amounts will be negotiated and based on the public sector partner's actual costs. If multiple competing ISPs or even a single ISP is willing to make such commitments on a long-term basis, and if those ISPs are viable entities—with commitments backed by real resources—then the model will reduce the public sector partner's risk in terms of the ongoing payments to SiFi and its partners.

The viability of the model thus hinges on the willingness of ISPs to make such commitments, and the ISPs' confidence that they can realize sufficient revenues and margins to justify the commitments.

SiFi has suggested in recent communications that it will enter in partnerships of this sort with localities that are designed to be risk-free for the locality (i.e., that the locality can cancel the partnership and depart its financial obligations at any time). However, we note that, without the city's long-term guarantee of the debt, the project may not be financeable. Potential investors would presumably require robust assurances that SiFi would and could stand behind the city's obligations in the event that the city chose to exit the agreement. We are therefore frankly concerned about the viability of such an arrangement, particularly with respect to the likelihood of financing under this "easy exit" plan, but we do consider it worthy of consideration.

4.5.1.3 Common Benefits and Areas for Further Evaluation

Both the Macquarie and SiFi proposals are, from a policy perspective, compelling to many communities, particularly in two respects:

- First, the proposed models could ensure that FTTP is built throughout the community rather than (as in some private sector business models) to select or "desirable" areas only.
- Second, the "open access" element of the model has the theoretical potential to enable competition over the network, though that competition may not materialize immediately.

At the same time, there are concerns with both proposals that require further evaluation by communities that are interested in the models.

First, there exists both political and financial risk for the public sector because public funding is used to fund an infrastructure that some residents may not want or choose to use. Indeed, if the broadband network is unsuccessful at generating revenue to cover all public sector costs, the public sector often remains on the hook for those payments. At its core, this model thus involves the public sector essentially becoming the guarantor in the event that the partnership does not

secure sufficient revenue to cover all costs, including the profit margins required by the private partners.

Second, while the model does not require the public sector partner to bond for financing, the partnership financing will most likely be considered by auditors, state authorities, and the bond markets as counting against the public sector entity's borrowing capacity.

Third, we have concerns that, as compelling as the open access model is, it is essentially untested in the U.S., and the novelty of the model presents risk for the community. Our concerns about the novelty of the open access model would be alleviated if Macquarie or SiFi had deployed this model in other markets and if resulting data were available. However, to our knowledge, neither Macquarie nor SiFi has executed this model in any other city.

Fourth, the models are very dependent on the success of the ISPs, in an open access environment, at generating revenues. We strongly recommend that localities do rigorous, independent analysis of financial models offered by potential partners and that they pay particular attention to projections of future revenues that appear to reduce the public's long-term costs and risks. These revenue projects are not guaranteed by the companies and if they prove to be too optimistic, the locality's long-term costs may be greater than they appear. For example, we are concerned about financial models that project unrealistic increases in service revenue based on an annual consumer price index (CPI) escalation factor. Industry experience suggests that consumer data service fees have declined rather than grown over time (unlike cable television fees).

Fifth, we recommend that the company should be required to demonstrate conclusively that creditworthy and technically qualified ISPs will commit to provide services under the framework established by the company. Given the newness of the open access model and the dependence of the model on the ISPs successfully selling services and supporting their customers, the commitment of such ISPs is critical to the viability of the model. Furthermore, the company should demonstrate that the ISPs are willing to meet the financial obligations imposed on them by the business model. In the case of Macquarie, the ISPs would have to commit to providing a minimum level of service at no cost to all customers (and then have the opportunity to provide higher level service at a fee); we believe that ISP willingness to take this risk is a critical factor in the viability of the model. In the case of SiFi, the ISPs would have to commit to minimum payments to the community in an amount equal to the community's obligations to SiFi; again, we believe that this willingness should be demonstrated before the community assume that the model will work.

In summary, we believe the Macquarie and SiFi proposals are promising, but untested, and therefore require extensive additional evaluation and assurances.

4.5.2 Frontier Communications Proposal

An additional promising development in Connecticut recently is that the telephone incumbent has suggested that it may be interested in public-private partnerships.⁸⁷ In materials presented to several Connecticut municipalities, Frontier Communications suggests a model for public funding to support its construction of a fiber-to-the-home network capable of symmetrical speeds of up to a gigabit.⁸⁸

Under Frontier's proposal, the construction would be dependent on municipal commitments to pay a fixed monthly amount based on the total number of homes, which would be paid to Frontier monthly for 15 years, with a decline in payment amounts after the first five years. The monthly base payment would cover all the homes in the agreed area. In return for this funding, Frontier will build fiber to pass all the homes in the agreed area.

Frontier offers that, in addition to constructing, operating, and maintaining the network, and offering speeds up to a gigabit, Frontier will provide a basic level of Internet access for all residences in the municipality as part of the base service payment from the municipality. In other words, each residence could receive some minimum level of broadband at no additional cost above that of the monthly fee paid on its behalf by the locality.

For residents who want higher speed broadband services, they will be able to purchase services of up to a gigabit, and Frontier will credit them the amount of the payment paid by the municipality to cover the base service.

To ensure competitive choice, Frontier also promises to allow other ISPs, for a fee, to access its last-mile fiber facilities.

We consider these initial Frontier proposals to be interesting and worthy of further consideration by localities that are interested in the public cost/private execution model. For rural communities, in particular, this approach, if structured well, offers a lower cost and lower risk means of ensuring buildout of FTTP than the option of funding the entire project or making a 30-year commitment.

We do note that the overall merits of Frontier's proposal cannot be determined without examining the terms in significantly greater detail than that provided in introductory materials—

⁸⁷ We give credit to Frontier for this creative new proposal and, at the same time, credit the localities and CT Gig programs with creating the environment in which this proposal arose.

⁸⁸ It appears that most, if not all, of Frontier's existing Gigabit deployments do not offer symmetrical speeds. Frontier FiberHouse promotional materials for Connecticut describe a Simply GigaHouse speed tier of 1 Gigabit download/100 Mbps upload.

and that much will depend on the specifics of what Frontier commits to build and whether it undertakes enforceable commitments.

That said, the approach offers several noteworthy benefits for Connecticut municipalities. The company's existing infrastructure throughout the state may allow Frontier to complete a network build-out faster and for less money than a new entrant or a competitor with a smaller footprint. Frontier's suggestion to offer a "free" basic level of Internet access in return for the monthly base payment will also help many communities achieve the policy goal of universal service.

In addition, unlike the SiFi and Macquarie models, the viability of Frontier's model does not hinge on the ISP's ability to generate sufficient revenues to cover the municipality's obligations. Put otherwise, this model does not require the public entity to assume any operating risk; rather, it is a straight subsidy model. In the SiFi and Macquarie models, in contrast, the public sector entity bears the risk in the event that network revenues fall short of the obligated levels. (On the flip side, the Frontier model also does not give the public partner any form of ownership interest in the network or share in potential financial upside, as do the SiFi and Macquarie models).

The following are some of the issues that interested localities should explore with Frontier to ensure that this partnership offer delivers its promised benefits:

Buildout Obligations. It is essential to understand what will be built, where, and when. In return for the monthly payment from the locality, Frontier should make enforceable commitments regarding what it will build, on what timeline, and how its buildout can be verified by the locality.

Related to this issue, it's critical that the public funds be used to build new infrastructure and that Frontier not attempt to use its existing infrastructure while receiving public subsidy. In the materials provided, Frontier notes that its existing Fiber-to-the-Curb infrastructure is already sufficient to provide many locations with the basic level of Internet access that it will offer as part of the base payment from the municipality. We recommend that an interested locality ensure that the contracts with Frontier will indeed require sufficient new construction.

Service Levels and Pricing. It is essential to understand whether Frontier's proposed service offerings satisfy local market demands and community policy objectives. We recommend that interested localities use the negotiation and contracting process to ensure that Frontier's pricing reflects the benefits of the funding paid by the locality. Based on the materials we saw, Frontier's initial proposal does not specify the speed of the basic tier of service that will be available to all community members and how that relates to current offers.

The materials also do not include pricing information for the proposed gigabit service or any other service tiers. Municipalities hoping that the availability of affordable gigabit service will help them compete against other communities and attract residents may want to consider how

pricing could influence their ability to achieve their goals. This consideration will be particularly important in rural areas where no competition with cable services exists to constrain pricing. Frontier’s existing residential gigabit offerings appear to be substantially higher-priced than competitive offerings available from established incumbents like AT&T and CenturyLink as well as new entrants like Google Fiber. According to February 2016 marketing materials, Frontier’s Simply GigaHouse 1 Gig/100 Mbps service cost \$249.99 when bundled with FrontierTV Select package. In contrast, CenturyLink’s 1 Gig service in Platteville, WI is \$79.95/month when bundled with PrismTV service.⁸⁹

Infrastructure Access and Competition. Frontier’s preliminary proposal suggests that the company will commit to allowing competitors to provide service over its network, for a fee. While this suggestion is intriguing and will appeal to many communities that are hoping that their investment will enable new competition over the infrastructure built with their funds, we note that the fees competitors must pay (unless limited by the contract with the municipality) may be prohibitive and that other providers may face significant difficulties competing on price against a company with a long-term agreement for a public subsidy. If this potential for competition is an important goal for a locality, the details of how the competition mechanism will work—and at what price—should be part of the negotiation with Frontier.

4.6 Public-Private Partnerships: Shared Risk and Execution

In this model, localities create hybrid models where a locality and private partner find a creative way to share the capital, operating, and maintenance costs of a broadband network.

Shared risk models are in their early days. We have only a few emerging projects and it’s hard to conclude anything on that basis. But the shared risk models are more likely to emerge in more metro areas where private capital is going to find greater return. The public risk, private execution model can obviously benefit more rural communities because the public is providing a revenue stream to the private partner and is essentially guaranteeing the debt in order to make the financing viable and low interest. These private execution public risk models have potential import and applicability for rural areas and less dense areas, but they come at a real cost, which is inevitable because rural broadband is simply a very costly proposition.

A public-private partnership model based on shared investment and risk plays to the strengths of both the public and private sector partners. Most localities consider FTTP deployment not as a moneymaker, but as a powerful tool for education and economic development. Thus in a shared investment model, the risk is shared but the community still receives 100 percent of the benefits it seeks—recognizing that the benefits do not all appear on the project’s financial

⁸⁹ “Platteville has speeds up to 1 Gig,” CenturyLink, <https://www.centurylink.com/fiber/plans-and-pricing/platteville-wisconsin/> (accessed March 2016).

statements. For the private partner, a shared investment means less upfront capital (risk), with an opportunity for future revenues.

Among other enormous benefits to this model, cities can not only provide fiber to the private sector—for compensation and to get gigabit and beyond service to the public—but can also secure extensive fiber throughout their communities for internal uses, including municipal and municipal utility operations, public safety, and emerging Smart City and Internet of Things (IoT) applications.

This model will provide an institutional or public sector network of the future—more extensive than any network that served city or county needs in the past, because the fiber will go everywhere in the community. It will have the potential to serve every conceivable application, from traffic signal control to air quality monitoring, from robust and secure public safety communications to high-end videoconferencing between universities and schools.

Public sector use is ancillary to the core benefit of enabling a competitive gigabit (and beyond) product over fiber to every home and business in the community—but, in the long run, it has the potential to enable transformative public sector use and services. And indeed, local governments' track record of securing considerable savings and enormous operational capabilities over fiber is already demonstrated.⁹⁰

We note, however, that while this model offers an extraordinary opportunity for innovation, it is in no way a sure thing for communities. We do not have the data points to develop the best practices necessary for success. At the moment, early actors are developing new and exciting partnerships to bring next-generation broadband to their communities. We describe some of those projects in the brief case studies below.

4.6.1 Case Study: Westminster, MD

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 12 years ago to bring better fiber connectivity to community anchor institutions through a middle mile fiber network. In 2010, the State of Maryland received a large

⁹⁰ See, for example: "Community Broadband Creates Public Savings," Fact Sheet, Institute for Local Self-Reliance, <https://goo.gl/kCEZcC> (accessed March 2016).

award from the federal government to deploy a regional fiber network called the Inter-County Broadband Network (ICBN) that included infrastructure in Westminster.⁹¹

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 quickly realized that they were going to have to do something unique. Unlike FTTP success stories such as Chattanooga, Tennessee, they did not have a municipal electric utility to tackle the challenge. They also did not have the resources, expertise, or political will to develop from scratch a municipal fiber service provider to compete with the incumbents. As a result, they needed to find a hybrid model.

As the community evaluated its options, it became clear that the fiber infrastructure itself was the city's most 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, then an upstart ISP with a strong track record of customer service as a mobile operator. Ting shared Westminster's vision of a true public-private partnership and of maintaining an open access network. 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.

⁹¹ "The Project," Inter-County Broadband Network, <http://goo.gl/GjBC26> (accessed March 2016).

Based on 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 between the city and Ting ensures 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 city 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.

4.6.2 Case Study: Santa Cruz, CA

In what we believe is the first of many similar projects to come nationwide, the City of Santa Cruz has adopted a variation on the Westminster model. In December 2015, the City Council in Santa Cruz signed an agreement that potentially delivers tremendous value to local residents while sharing risk between the public and private sector.

The Santa Cruz City Council approved an agreement between the city and a local ISP, Cruzio. The city will build, own, and maintain a fiber network; Cruzio, which is a DSL reseller, will migrate many of its DSL customers over to the city's fiber network—and will actively pursue additional new customers to buy broadband services over the fiber. As in the Westminster agreement, Cruzio will pay the city both a per-passing and a per-subscriber fee for its use of the city's fiber.

Cruzio is a small company, which creates a certain amount of partnership risk for the city. But from the city's standpoint, it is a very attractive partner—a locally based, locally owned company

that employs Santa Cruz residents. In fact, the name of the company incorporates the city's name.

For Santa Cruz, identifying a local partner was a key factor in its negotiations. Cruzio's localism was so important to the city that in early 2015, the Council directed city staff to negotiate exclusively with Cruzio.

Cruzio has operated in the city since the early days of the Internet when it was a dialup ISP. In the broadband era, it migrated to some wireless service and to reselling phone company DSL. The logical next step is for Cruzio to migrate to fiber—which is what the relationship with the city will enable it to do.

The benefits of the partnership to the city include not only owning a next-generation network—and all the positive externalities that come with such a network—but also supporting and enabling an important local employer and longtime partner in the community.

4.6.3 Case Study: Urbana/Champaign, IL

The University of Illinois and the cities of Urbana and Champaign, Illinois have worked together over many years to expand their broadband infrastructure and connectivity. Those efforts included the development of the Urbana-Champaign Big Broadband (UC2B) network, which is now owned and operated by a not-for-profit corporation.⁹² Through a range of different strategies and using local private capital, state funds, and federal funds, UC2B built fiber rings specifically engineered to enable FTTP deployment in the most cost-effective manner. It also built FTTP in neighborhoods with the lowest broadband adoption rates, on the theory that those would be the last places that the private sector would deploy.

UC2B's existing investment and willingness to share future risk attracted a private partner, iTV-3, an Illinois company with FTTP experience. The two partners entered into an agreement that gives iTV-3 access to UC2B fiber on a lease basis at no cost in return for meeting the community's goals of deploying additional FTTP with the following requirements:⁹³

1. Gigabit service speeds
2. Wholesale access on the network to competing companies
3. No cherry picking—all neighborhoods have equal opportunity to get services if presales reach 50 percent of residents

⁹² "About," Urbana-Champaign Big Broadband Not-for-Profit, <http://uc2b.net/about/> (accessed March 2016).

⁹³ "Urbana-Champaign Big Broadband Not-for-Profit (UC2B NFP) to Hold Expansion News Conferences," News Release, UC2B NFP, May 29, 2014, <http://goo.gl/twLRPO> (accessed March 2016).

Under this model, Champaign/Urbana receives 100 percent of the economic development, competition, and digital inclusion benefits it seeks in return for taking on approximately 30 percent of the partnership's financial risk. The model also means the community can focus on driving demand and adoption, while relying on an experienced private partner to handle customer service, marketing, and operations.

As of the date of this writing, UC2B's private partner has announced that it is selling its broadband operations. Under the terms of the partnership, all obligations will transfer to the new owner.

4.6.4 Case Study: Google Fiber/Huntsville

In February 2016, the city of Huntsville, Alabama, a technology hub for the area, announced that its municipal electric utility will build fiber optics throughout its community (presumably, to pass all or most businesses and homes), and that Google Fiber will lease much of that fiber in order to provide gigabit services to residences and small businesses

The announcement between Huntsville and Google Fiber is a variation on the model pioneered in Westminster, though the payment terms are different and provide a key contrast. Google Fiber will lease fiber from Huntsville based on a rate sheet that provides for various levels of pricing based on amounts and volume. In contrast, Ting's obligations to Westminster are based in part on how much fiber it uses and in part on how many customers it secures and revenues it generates. As a result, Westminster will have less predictability and certainty about its revenues from Ting, but has the potential to share in upside in the event that Ting is very successful in that market.

As in Westminster and Santa Cruz, the Huntsville model puts the locality in the business of building infrastructure, a business it knows well after a century of building roads, bridges, and utilities. The model leaves to the private sector (in this case, Google Fiber and any other provider that chooses to lease Huntsville fiber) all aspects of network operations, equipment provisioning, and service delivery.

Interestingly, the Huntsville model holds the potential for competition among providers, as Google Fiber will not be the exclusive user of the fiber and other entities can also choose to lease fiber based on Huntsville Utilities' established rates. We anticipate that there will be other ISP users of the city's fiber, particularly to serve larger businesses and institutions, though we question whether the economics exist for another provider to compete against Google Fiber in the residential market, at least in the short-term. Over the long term, however, market demand and structures may change and new opportunities for competition may arise. By building and owning its own fiber assets, the city of Huntsville has ensured it will be able to react to those changes and maximize its benefits.

4.7 Targeted Rural Wireless Strategies

In rural areas throughout the United States, where the cable and phone industries have not built robust communications infrastructure, there exists a significant deployment challenge: The extremely high capital costs for deploying communications infrastructure and services, and the relatively modest potential revenues. Both the high costs and the low likely revenues are driven by the fact that rural areas have low population density.

The State of New York is addressing this challenge through a massive rural broadband funding program of \$500 million that is intended to be matched by an equivalent amount of private capital. The Commonwealth of Massachusetts is addressing its rural challenge with an infusion of \$50 million for the rural unserved towns in the west of that state.

Frankly, absent proportional amounts of public funding, whether state, local, or federal, we see no clear path to deployment of next-generation FTTP infrastructure in the rural parts of Connecticut (or any other rural area of the United States not eligible for substantial FCC subsidy), though we note that the state is fortunate that its rural footprint is smaller than many other states, including New York and Massachusetts.

Rather than the kind of comprehensive rural solution for FTTP and next-generation gigabit services that are inconceivable absent massive public funding, we note that there are some targeted and lower bandwidth strategies emerging that require less public funding but could potentially enable development of new competitive broadband services with the capability to address the needs of rural Connecticut, but that frankly will be at lower bandwidth than the optimal gigabit networks that are more viable for the densely populated parts of the state.

Among the potential solutions are creative public-private partnerships that can be seeded with modest public funding and developed at a local level to address unserved and underserved areas and gaps in coverage. For example, rural Garrett County, in far western Maryland, is a relatively remote Appalachian community bordered by West Virginia and Pennsylvania. The county has struggled to get broadband in a number of its remote, mountainous areas. Where broadband is available, it is inadequate DSL service that does not meet the Federal Communications Commission's new speed benchmark for broadband service, let alone the requirements for home-based businesses or home schooling. The incumbent provider has not made any plans to expand or upgrade service offerings.

Though mobile broadband is available in some parts of the county, data caps mean that it is not viable for economic or educational activities. (Parents who homeschool 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 that fiber and additional public funding to support the deployment of 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 businesses in the newly served areas.

The county's outlay of funds will be \$750,000, which will be matched by a grant from the Appalachian Regional Commission (ARC)—and which will be more than matched by DNG's commitment of both capital and operating funds. That relatively modest county contribution (which was then leveraged for the ARC economic development funding) made the economics of this opportunity very attractive to DNG, and secured a broadband buildout for an area that would otherwise not be attractive for private sector broadband investment.

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 the 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 county that do not have access to some kind of broadband communications options. These options may be modest—not the robust speeds available in metro markets—but they are significantly better than nothing, and a huge economic development achievement from the county's standpoint.

5 Fiber Is Superior to Alternatives for Capacity, Security, and Long-Term Cost

The quality and speed of a connection will vary based on the capacity and limitations of the last-mile technology used. This report presents an overview of the four most common technologies used to deliver last-mile broadband data services to homes and businesses: fiber-to-the-premises (FTTP), digital subscriber line (DSL), hybrid fiber-coaxial (HFC), and wireless. Figure 2, above, shows the current and predicted capacity of broadband technologies.

5.1 Fiber-to-the-Premises (FTTP)

Fiber optic cables are the medium of choice for data transfer. They have enormous bandwidth capacity, which enables operators to offer symmetrical download and upload speeds. Fiber is also not subject to interference, and does not require amplifiers to carry a signal long distances.⁹⁴ This is why the vast majority of the Internet backbone comprises bundles of fiber cable strands.

Once a premises is connected to fiber, there is no need for significant outside plant infrastructure investment for decades. If more bandwidth is needed, the operator need only upgrade the network electronics, rather than having to replace the cables.

The electronics needed to provide 1 Gbps speed over a fiber-to-the-premises (FTTP) network are already widely available at an affordable price, and the price of the electronics needed to support 10 Gbps connections are declining rapidly.

5.1.1 Technical Capacity and Limitations

Fiber is one of the few technologies that can legitimately be referred to as “future-proof,” meaning that it will be able to provide customers with better and faster service offerings to accommodate growing demand.

The biggest advantage that fiber offers is bandwidth. A strand of standard single-mode fiber optic cable has a theoretical physical capacity in excess of 10,000 GHz,⁹⁵ far in excess of the entire wireless spectrum combined, and thousands of times the capacity of any other type of wired medium, which can be symmetrically allocated between upstream and downstream data flows using off-the-shelf technology.

Further, modern fiber can provide extremely low losses within a wide range of frequencies, or wavelengths, of transmitted optical signals, enabling long-range transmissions. Compared to a signal loss on the order of tens of decibels (dB) over hundreds of feet of coaxial cable, a fiber

⁹⁴ Maximum distances depend on specific electronics—six to 25 miles is typical for fiber optic access networks.

⁹⁵ Conservative estimate derived from the channel widths of the 1285 to 1330 nm and 1525 to 1575 nm bands in G.652 industry-standard single-mode fiber optics.

optic cable can carry a signal of equivalent capacity over several miles, without amplification, with minimal signal loss.

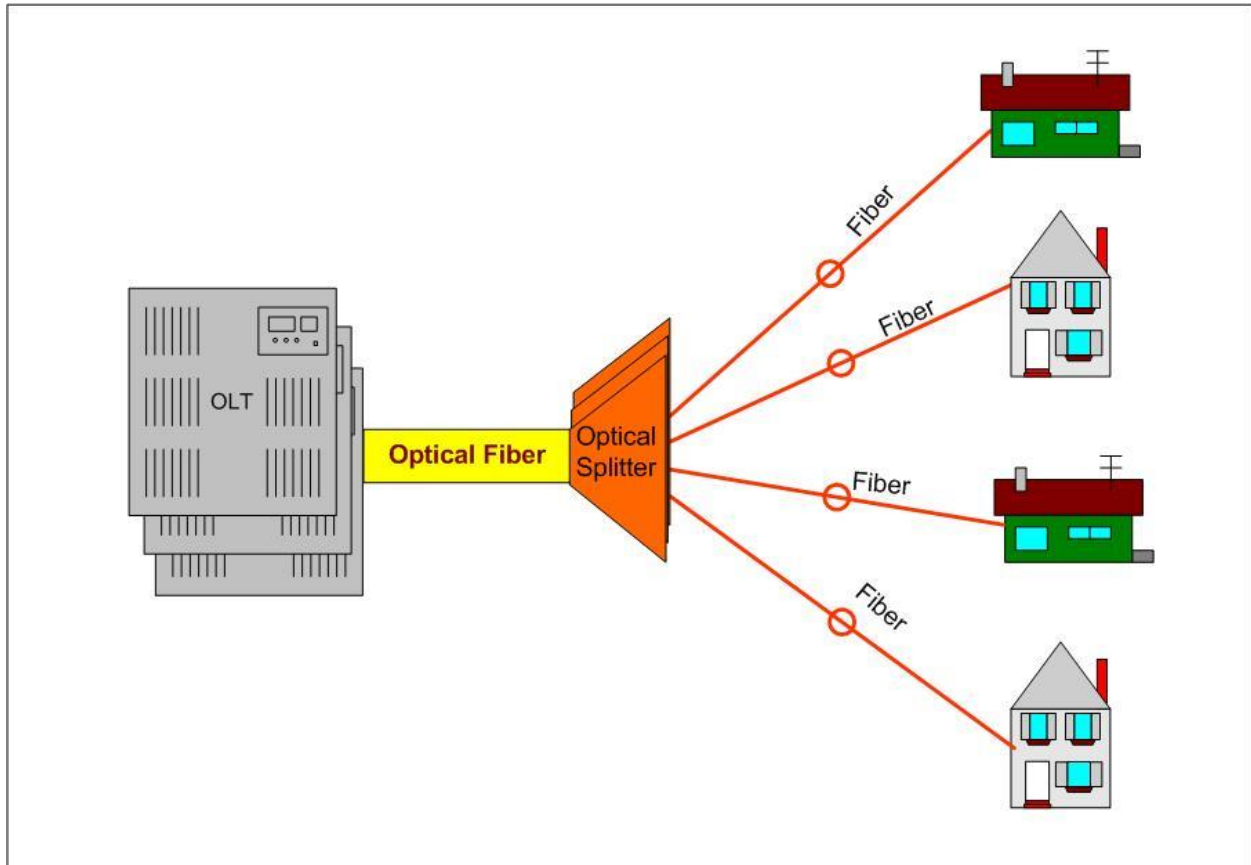
Moreover, weather and environmental conditions do not cause fiber cables to corrode over time in the way that metallic components can, which means that fiber has lower maintenance costs.

5.1.2 Factors Impacting Quality and Speed of Service

The following factors will determine an FTTP customer's service speed and quality:

- **Network electronics:** Core equipment in an FTTP network is housed at a central office (CO) or video headend office (VHO). As network electronics continue to improve, FTTP providers will be able to add higher tiers of service.
- **Network architecture:** Some FTTP operators use passive optical network (PON) technology, splitting the fiber capacity in a neighborhood cabinet to connect up to 64 users (Figure 5). This architecture provides less capacity per user than a direct fiber network (also known as active Ethernet or point-to-point) but is still able to sustain 100 Mbps to users. Currently deployed PON networks have capacity of 2.5 Gbps/622 Mbps (GPON) or 10 Gbps/2.5 Gbps (10GPON) for a single shared PON.

Figure 5: FTTP-PON Network Architecture



5.1.3 Future Capacity and Lifespan of Investment

Using off-the-shelf electronics, an FTTP network can deliver speeds well in excess of what most customers need today, and service providers can continue to upgrade network electronics to offer improved tiers of service. The outside plant can last for decades with minimal maintenance.

5.2 Hybrid Fiber-Coaxial

Cable broadband technology is currently the primary means of providing broadband services to homes and businesses in most of the United States. Because of its relative ubiquity in the majority of urban, suburban, and small-town areas and its inherently greater capacity than commercial wireless solutions and copper telephone lines (the medium underlying digital subscriber line, or DSL, service), HFC cable networks will be the main pathway for broadband communications for most homes and businesses for the foreseeable future.

Coaxial cables were originally designed to provide video services, and were sufficient in the early years of data communications, when usage was low compared to our current expectations. However, as demand for data capacity increased, coaxial networks became insufficient to support high-speed services. On an increasingly large scale, cable operators are now deploying

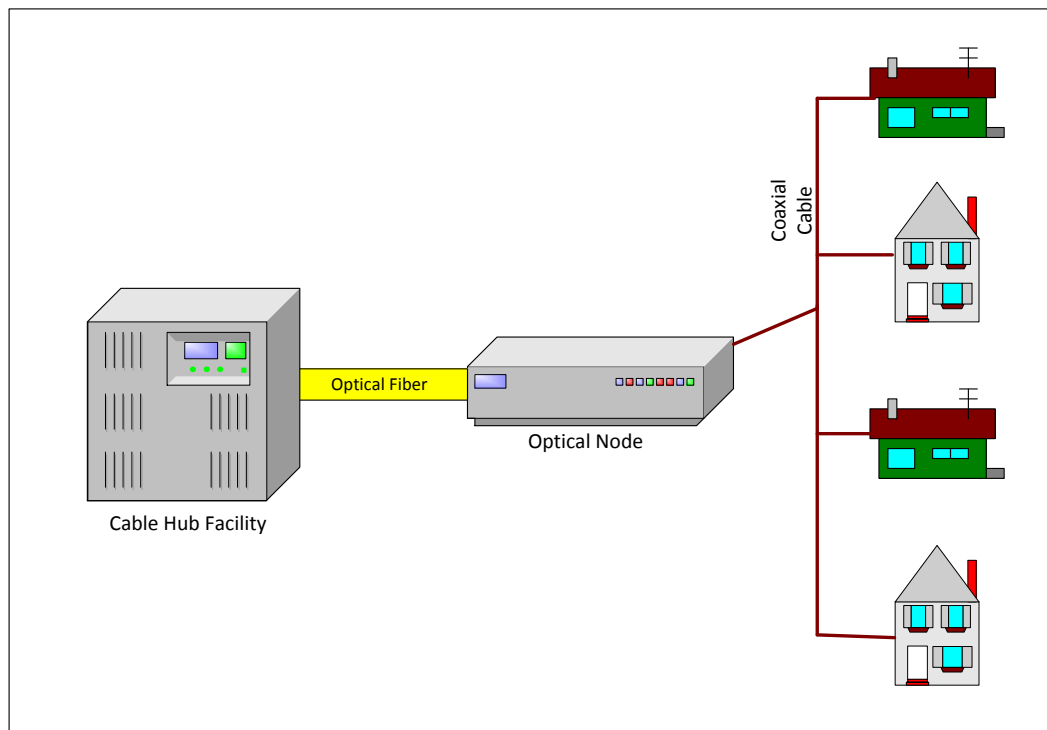
fiber to replace large portions of their networks because, for a given expenditure in communications hardware, fiber can reliably carry many times more capacity over many times greater distances than coaxial cable or any other communications medium. Thus, coaxial cable networks have transformed into hybrid fiber-coaxial (HFC) networks.

5.2.1 Technical Capacity and Limitations

Although there are a number of limitations inherent in cable systems relative to fully fiber optic networks, cable system capabilities will increase over the next few years with the deployment of new technologies and the extension of fiber closer to customers.⁹⁶

In an HFC network, headend or hub locations house the core transmission equipment. Fiber connections extend from these hubs to multiple nodes, each of which serves a given geographical area (e.g., a neighborhood). These optical nodes are electronic devices located outdoors, attached to aerial utility lines or placed in pedestals. The equipment in the node converts the optical signals carried on fiber into electronic signals carried over coaxial cables. Coaxial cable then carries the video, data, and telephony services to individual customer locations (Figure 6).

Figure 6: HFC Network Architecture



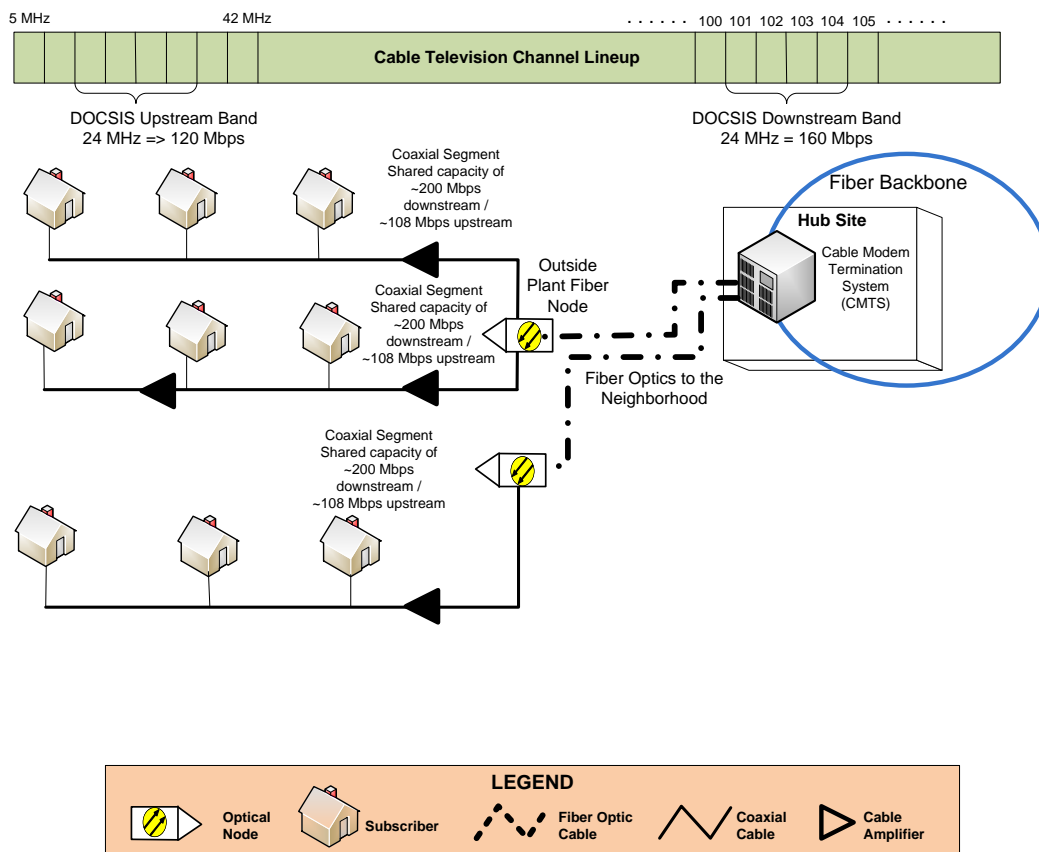
⁹⁶ Cable is not as scalable “out of the box” as communications systems that were designed from the outset to provide Internet-type broadband data services. Issues include coaxial cable’s limitations in terms of physical capacity, a physical architecture optimized for broadcast communications, and a significant remaining migration path to full end-to-end Internet Protocol (IP) operations.

Cable operators have extended fiber optics progressively closer to their subscribers, but for cost reasons have generally stopped at nodes about one mile from the premises. Comcast, for example, typically only constructs fiber to the premises of customers that subscribe to Metro Ethernet and other advanced services.

The current leading cable technology for broadband data, known as data over cable service interface specifications version 3.0 (DOCSIS 3.0), makes it possible for cable operators to increase capacity relative to earlier cable technologies by bonding multiple channels together (Figure 7). The DOCSIS 3.0 standard requires that cable modems bond at least four channels, for connection speeds of up to 200 Mbps downstream and 108 Mbps upstream (assuming use of four channels in each direction). A cable operator can carry more capacity by bonding more channels.

It is critical to note that these are peak speeds, and that the capacity is shared by all customers—typically hundreds of homes or businesses—on a particular segment of coaxial cable. Speeds may decrease during bandwidth “rush hours,” when more users simultaneously use greater amounts of bandwidth. For example, residential bandwidth use typically goes up considerably during evening hours, when more people use streaming video services and other large data applications.

Figure 7: DOCSIS 3.0 Network Architecture



Although the standard is still in the test phase, both Comcast and Time Warner have announced plans to begin upgrading their systems to DOCSIS 3.1 in 2016. The cable industry states that DOCSIS 3.1 will provide 10 Gbps downstream capacity and 1 Gbps upstream. This will not be possible for most actual cable systems—a typical system with 860 MHz capacity might have the first 192 MHz assigned to upstream, leaving approximately 660 MHz for downstream.⁹⁷ Even with 10 bps/Hz efficiency, the actual downstream capacity for a shared node area would be closer to 6 Gbps than 10 Gbps, and that capacity will be aggregated among a few hundred users.

Expansion of downstream spectrum to 1.2 GHz (and potentially to 1.7 GHz) is also being considered.⁹⁸

5.2.2 Factors Impacting Quality and Speed of Service

The following factors will determine a cable broadband customer's service speed and quality:

1. **Bandwidth capacity of cable plant:** Most coaxial portions of a cable network have capacity of 750 or 860 MHz, but they can be upgraded to 1 GHz and beyond. If the cable corrodes, the available bandwidth shrinks, limiting possible connection speed.
2. **Number of customers sharing a node:** Cable capacity is shared among all the users connected to a given node, so connection speeds will decrease significantly during peak usage hours. Cable companies can reduce the number of customers sharing a node by putting fiber deeper into their systems and moving the node closer to the customers.
3. **Proximity of customer to node/fiber:** Another advantage of moving the node closer to the customer is that signals travel less distance on coaxial cable. With progressively shorter stretches of coaxial cable, the inherent problems with reliability and interference decrease.
4. **Standards and protocols:** Cable operators can make faster connection speeds available by dedicating more channels to data services and upgrading their networks to later versions of industry standards. DOCSIS 3.1 makes more efficient use of available spectrum, freeing up more bandwidth for data download and upload. However, customers would need to purchase new, DOCSIS 3.1-enabled cable modems.

Cable operators often offer services with “blast” or “burst” speeds of “up to” more than 100 Mbps. Although a customer may be able to access these speeds on occasion, the actual speeds available will probably be significantly lower during peak usage hours.

⁹⁷ Almost all cable systems in the U.S. currently have less than 50 MHz of bandwidth in the upstream direction.

⁹⁸ “An evolutionary approach to Gigabit-class DOCSIS,” *CED Magazine*, July 5, 2012, <http://www.cedmagazine.com/articles/2012/07/an-evolutionary-approach-to-gigabit-class-docsis> (accessed March 2016).

5.3 Digital Subscriber Line (DSL)

During the last century, phone companies connected virtually every home and business in the U.S. to a strand of copper wire. Copper has a fraction of the bandwidth capacity of coaxial cable, and suffers from greater signal loss and interference—but because of its ubiquity, digital subscriber line (DSL) technology over copper has been an important way for people to connect to the Internet.

In some scenarios, DSL operators can offer speeds that fit the FCC's definition of broadband. However, while DSL has been an impressive retrofit of existing infrastructure, copper cable is reaching its physical limitations as a broadband medium, and will not be able to meet future bandwidth needs.

5.3.1 Technical Capacity and Limitations

Bandwidth limits on copper cables are directly related to the underlying physical properties of the medium. Higher data rates require a broader frequency range of operation. Twisted-pair copper wire is limited to a few tens of megahertz in usable bandwidth, at most, with dramatic signal loss increasing with distance at higher frequencies.

The main determinant of DSL speed is the length of the copper line from the telephone company central office. In systems operated by large telecommunications companies, the average length is 10,000 feet, corresponding to available DSL speeds between 1.5 Mbps and 6 Mbps. In systems operated by small companies in rural areas, the average length is 20,000 feet, corresponding to maximum speeds below 1.5 Mbps.

The fastest copper telephone line technologies widely deployed in outside cable plant in the United States are VDSL and VDSL-2, the technologies underlying AT&T's U-verse and other services. Because these technologies use high frequencies, they are limited to 3,000 feet over typical copper lines and require fiber to the node (FTTN)—much closer than in most HFC systems. Therefore, in order to operate VDSL and VDSL-2, telecommunications companies must invest in large-scale fiber optic construction and install remote cabinets in each neighborhood.

In practice, telephone companies using VDSL-2 over highly upgraded copper lines have been able to provide 25 Mbps over a single copper pair and 45 Mbps over two pairs to the home or business—but it took a significant investment to make it possible for a small percentage of the copper phone lines to temporarily keep pace with cable. Providing even greater speeds will require some combination of even deeper fiber construction, a breakthrough in transmission technology over copper lines, and conditioning and upgrading of the existing copper lines.

New “G.Fast” technology standards enable speeds up to 1 Gbps over a single twisted-pair copper cable (and declining to about 150 Mbps as distances increase).⁹⁹ In early 2015 Sckipio demonstrated G.Fast speeds greater than 100 Mbps over nearly 500 meters, and in October 2015 Calix demonstrated speeds over 1 Gbps up to approximately 250 meters (820 feet).¹⁰⁰ Alcatel-Lucent has conducted a trial of the technology with more than 30 operators worldwide, but commercial deployments are just beginning.¹⁰¹ Because the G.Fast standard is designed to work over short lengths of copper loop, deployments will still require significant investments to deploy fiber close to end-user premises. As a result, G.Fast has so far mostly been focused on deployments using telephone wires inside buildings.

5.3.2 Factors Impacting Quality and Speed of Service

The following factors will determine a DSL customer’s service speed and quality:

- **Length of copper line/proximity to fiber:** The longer a signal has to travel over copper cable, the slower the possible connection speed.
- **Condition of copper cable:** Copper cable corrodes over time. As it deteriorates, interference increases and the available bandwidth shrinks, limiting the possible connection speed.
- **Number of copper pairs available:** To overcome the inherent limits of copper cable, some operators bundle multiple copper pairs.

5.3.3 Future Capacity and Lifespan of Investment

It is only a matter of time before the growing demand for bandwidth comes up against the physical limitations of copper as a medium for transporting data. Even if an operator can satisfy present demand using existing copper assets, it is a significant challenge to upgrade a DSL network in a way that the majority of a large scale network can continue to serve future demand. Many telecommunications companies are minimizing their investment in copper lines, and some are abandoning copper lines for wireless services or migrating to FTTP. New investment in DSL will likely become obsolete within a decade.

⁹⁹ Mikael Ricknas, “Gigabit speeds over telephone wires get closer thanks to new G.fast standard,” *PCWorld*, <http://www.pcworld.com/article/2856532/gigabit-speeds-over-telephone-wires-get-closer-thanks-to-new-gfast-standard.html> (accessed March 2016)

¹⁰⁰ “Calix Announces Innovations in G.fast and Vectoring at Broadband World Forum,” Calix, October 20, 2015, <https://www.calix.com/press-release/2015/10/calix-announces-innovations-in-g-fast-and-vectoring-at-broadband.html> (accessed March 2016).

¹⁰¹ Sean Kinney, “G.fast deployments need to pick up,” *RCR Wireless News*, January 6, 2016, <http://www.rcrwireless.com/20160106/network-infrastructure/g-fast-deployments-need-to-pick-up> (accessed March 2016).

5.4 Fixed Wireless

The high cost of building wired networks in low-density rural areas often leaves rural residents without a wired broadband option. Wireless Internet Service Providers (WISPs) are potentially able to fill these coverage gaps, sending signals from base stations to antennas on or near customer premises. But WISPs are not able to offer connection speeds on a market-wide basis comparable to cable or FTTP built to each premises, and often need to impose data caps on customers to manage limitations on capacity. Accordingly, although fixed wireless service is an important tool to connect the unconnected, it will not offer the quality of service that the most advanced wireline providers can provide. Even as wireless technologies continue to advance, they will still lag the performance available from fiber optics, simply because of the relative challenge in providing high-capacity connections wirelessly over long distances.

5.4.1 Technical Capacity and Limitations

Smaller WISPs like the New York capital region's Hudson Valley Wireless use the same unlicensed spectrum bands as Wi-Fi, which does not have strong long-distance transmission qualities. (This is in contrast to the large mobile carriers like AT&T, Sprint, T-Mobile, and Verizon Wireless, which offer 3G/4G service using licensed spectrum.) WISPs may also use other unlicensed or semi-licensed bands like 3.5 GHz or 900 MHz, but these also have low data speed capabilities.

Most wireless networking solutions require the antenna at the customer premises to be in the line of sight of the base station antenna. This can be especially challenging in mountainous regions. It is also a problem in areas with dense vegetation or multiple tall buildings. WISPs often need to lease space at or near the tops of radio towers; even then, some customers may be unreachable without the use of additional repeaters. And because the signal is being sent through the air, climate conditions like rain and fog can impact the quality of service.

Some wireless providers in rural areas have begun to use vacant television frequencies called TV white space (or simply white space) to provide service. These TV bands have much better non-line-of-sight transmission qualities than the unlicensed bands; however, because white space technology is still in an early phase of development, compatible equipment is far more expensive than other off-the-shelf wireless equipment.

Wireless equipment vendors offer a variety of point-to-multipoint and point-to-point solutions. Point-to-multipoint solutions are more affordable to implement and are typically used in a WISP environment. However, they limit the capacity of the network, particularly in the upstream, making the service inadequate for applications that require high-bandwidth connections.

Fixed wireless systems built with off-the-shelf equipment today tend to have an aggregate capacity between 100 and 250 Mbps. With innovations like higher-order multiple input, multiple output (MIMO) antennas, and the use of spatial multiplexing, these capacities will likely increase

across vendors to as fast as 750 Mbps. It is important to note, however, that this is the aggregate capacity; bandwidth will be shared among up to 200 users connected to a single base station.

5.4.2 Factors Impacting Quality and Speed of Service

The following factors will determine a fixed wireless customer's service speed and quality:

- **Wireless equipment used:** Different wireless equipment has different aggregate bandwidth capacity and uses a range of different spectrum bands, each with its own unique transmission capabilities.
- **Backhaul connection:** Although the bottleneck tends to be in the last-mile connection, if a WISP cannot get an adequate connection back to the Internet from the tower, equipment upgrades will not be able to increase available speeds beyond a certain point.
- **Unobstructed line of sight:** Most wireless networking equipment require a clear, or nearly clear, line of sight between antennas for optimum performance. WISPs often lease space near the tops of radio towers in order to cover the maximum number of premises with each base station. In mountainous regions, many premises may not have a clear line of sight to a radio tower.
- **Weather conditions and foliage:** Depending on the spectrum used, weather conditions like rain or fog may cause interference. Also, line-of-sight paths that are clear during the winter may be obstructed by foliage during the warmer months.

5.4.3 Future Capacity and Lifespan of Investment

Wireless equipment generally requires replacement every five to 10 years, both because exposure to the elements causes deterioration, and because the technology continues to advance at a rapid pace, making equipment from a decade ago mostly obsolete. The cost of deploying a wireless network is generally much lower than deploying a wireline network, but the wireless network will require more regular investment.

5.5 Mobile Wireless

Cellular wireless carriers have been consistently increasing their data speeds with the rollout of faster and higher capacity technologies, such as Long-Term Evolution (LTE)¹⁰². Over the past few years, they have provided data plans with speeds comparable and in many cases greater than a typical residential customer's Internet service.

5.5.1 Technical Capacity

Wireless providers operate a mixture of third-generation (3G) and fourth-generation (4G) technologies. The service providers typically provide devices (telephones, smartphones, air cards,

¹⁰² LTE is a 4G cellular wireless technology offering data speeds of typically around 30 Mbps.

tablet computers) bundled with 3G or 4G services. Devices may not be easily portable from carrier to carrier, because differences in the technologies used by the carriers limit compatibility of the devices (discussed below). Therefore, the purchase of a device may restrict a user's choice of service providers.

The strict definition of 4G from the International Telecommunications Union (ITU) was originally limited to networks capable of peak speeds of 100 Mbps to 1+ Gbps depending on the user environment.¹⁰³ According to that definition, 4G technologies¹⁰⁴ are not yet deployed.

In practice, a number of existing technologies (e.g., LTE, WiMAX) are called 4G and represent a speed increase over 3G technologies as well as a difference of architecture—more like a data cloud than a cellular telephone network overlaid with data services. The ITU and other expert groups have more or less accepted this.¹⁰⁵

¹⁰³ "Development of IMT-Advanced: The SMaRT approach," Stephen M. Blust, International Telecommunication Union, <http://www.itu.int/itu-news/manager/display.asp?lang=en&year=2008&issue=10&ipage=39&ext=html> (accessed March 2016).

¹⁰⁴ Such as LTE Advanced under development.

¹⁰⁵ "ITU softens on the definition of 4G mobile," *NetworkWorld*, December 17, 2010, <http://www.networkworld.com/news/2010/121710-itu-softens-on-the-definition.html> (accessed March 2016).

Table 1: Typical Performance for Advertised 2G/3G/4G Services

| Applications | Technology (Download/Upload Service Speeds) ¹⁰⁶ | | |
|---|--|--|--|
| | 2G/2.5G—EDGE/GPRS, 1xRTT (128 Kbps–300 Kbps/ 70 Kbps–100 Kbps) | 3G—EVDO Rev A, HSPA+ (600 Kbps–1.5 Mbps/500 Kbps–1.2 Mbps) | 4G – WiMAX/ LTE (1.5 Mbps–30 Mbps/500 Kbps–5 Mbps) |
| Simple text e-mail without attachments (50 KB) | Faster (2 seconds) | Faster (1 second) | Faster (1 second) |
| Web browsing | Faster | Faster | Faster |
| E-mail with large attachments or graphics (500 KB) | Average (14 seconds) | Faster (3 seconds) | Faster (1 second) |
| Play MP3 music files (5 MB) | Slower (134 seconds) | Average (27 seconds) | Faster (7 seconds) |
| Play video files (100 MB for a typical 10-min. YouTube video) | Slower (45 minutes) | Average (9 minutes) | Faster (3 minutes) |
| Maps and GPS for smartphones | Slower | Average | Faster |
| Internet for home | Slower | Average | Faster |

5.5.2 Limitations

Most businesses and residents will find that wireless broadband has technological limitations relative to wireline. These include:

- 1) *Lower speeds.* At their peaks, today’s newest wireless technologies, WiMAX and LTE, provide only about one-tenth the speed available from FTTP and cable modems. In coming years, LTE Advanced may be capable of offering Gbps speeds with optimum spectrum and a dense build-out of antennas—but even this will be shared with the users in a particular geographic area and can be surpassed by more advanced versions of wireline technologies (with Gbps speeds already provided by some FTTP providers today).
- 2) *More asymmetrical capacity, with uploads limited in speed.* As a result, it is more difficult to share large files (e.g., video, data backup) over a wireless service, because these will take too

¹⁰⁶ This table assumes a single user. For downloading small files up to 50 KB, it assumes that less than 5 seconds is faster, 5–10 seconds is average, and more than 10 seconds is slower. For downloading large files up to 500 KB, it assumes that less than 5 seconds is faster, 5–15 seconds is average, and more than 25 seconds is slower. For playing music, it assumes that less than 30 seconds is faster, 30–60 seconds is average, and more than 100 seconds is slower. For playing videos, it assumes that less than 5 minutes is faster, 5–15 minutes is average, and more than 15 minutes is slower.

long to transfer; it is also less feasible to use video conferencing or any other two-way real-time application that requires high bandwidth.

- 3) *Stricter bandwidth caps.* Most service providers limit usage more strictly than wireline services. Though wireless service providers may be able to increase these caps as their technologies improve, it is not clear whether the providers will keep ahead of demand. A *Washington Post* article about Apple's iPad with 4G connectivity highlights the issue: "Users quickly are discovering the new iPad gobbles data from cellular networks at a monstrous rate. Some find their monthly allotment can be eaten up after watching a two-hour movie. That has left consumers with a dilemma: Pay up for more data or hold back on using the device's best features."¹⁰⁷

From a residential customer's perspective, a mobile wireless data cap may still be sufficient for a light user of the Internet. And, for certain users, higher connection speed may be considered a more desirable feature than unlimited, unfettered data.

Mobile broadband is only available where cell service exists. Furthermore, there are some areas, particularly in rural areas, where the cell service is relatively weak, or where upgrades have not taken place, and the broadband service is limited to slower service with speeds comparable to telephone dial-up. In contrast, "4G" LTE mobile data service is available with download speeds up to 30 Mbps and upload speeds up to 5 Mbps.

For most residential users, video streaming is the largest use of data. Use of streaming online video on smartphones, TVs and tablets through applications like YouTube, Netflix, Hulu, HBO Go, and other over-the-top (OTT)¹⁰⁸ services continues to increase. If a mobile broadband carrier offers 20 Mbps speed at the 8 GB data limit, one could only stream YouTube videos for six hours or watch two movies on Netflix with the 8 GB data cap. This is a major limitation for the average customer.

¹⁰⁷ Cecilia Kang, "New iPad users slowed by expensive 4G network rates," *Washington Post*, March 22, 2012, http://www.washingtonpost.com/business/economy/new-ipad-users-slowed-by-expensive-4g-network-rates/2012/03/22/gIQRXLXYUS_story.html?hpid=z2 (accessed March 2016).

¹⁰⁸ "Over-the-top" (OTT) content is delivered over the Internet by a third-party application or service. The ISP does not provide the content (typically video and voice) but provides the Internet connection over which the content is delivered.

6 Cost Estimate for Construction of Fiber-to-the-Premises Throughout Connecticut

The following is a high-level estimate of the cost to deploy the outside plant (OSP) infrastructure for an FTTP network across Connecticut. We note that the SBO is not advocating wholesale deployment of fiber across the state. These numbers are being offered in response to questions from various stakeholders about a “total build cost,” and to help municipal officials develop a rough estimate of the cost of a fiber build in their communities.

6.1 Potential Range of Construction and Electronics Costs

A statewide FTTP network deployment would cost an estimated \$3.2 billion, inclusive of anticipated OSP construction (labor, materials, engineering, permitting, equipment shelters) and core network electronics. That estimated range of statewide costs reflects a per-passing cost of \$1,060 to \$3,760.¹⁰⁹

Table 2 summarizes the total estimated OSP and core electronics costs, broken down for the three types of population densities we used in our model—high, medium, and low.

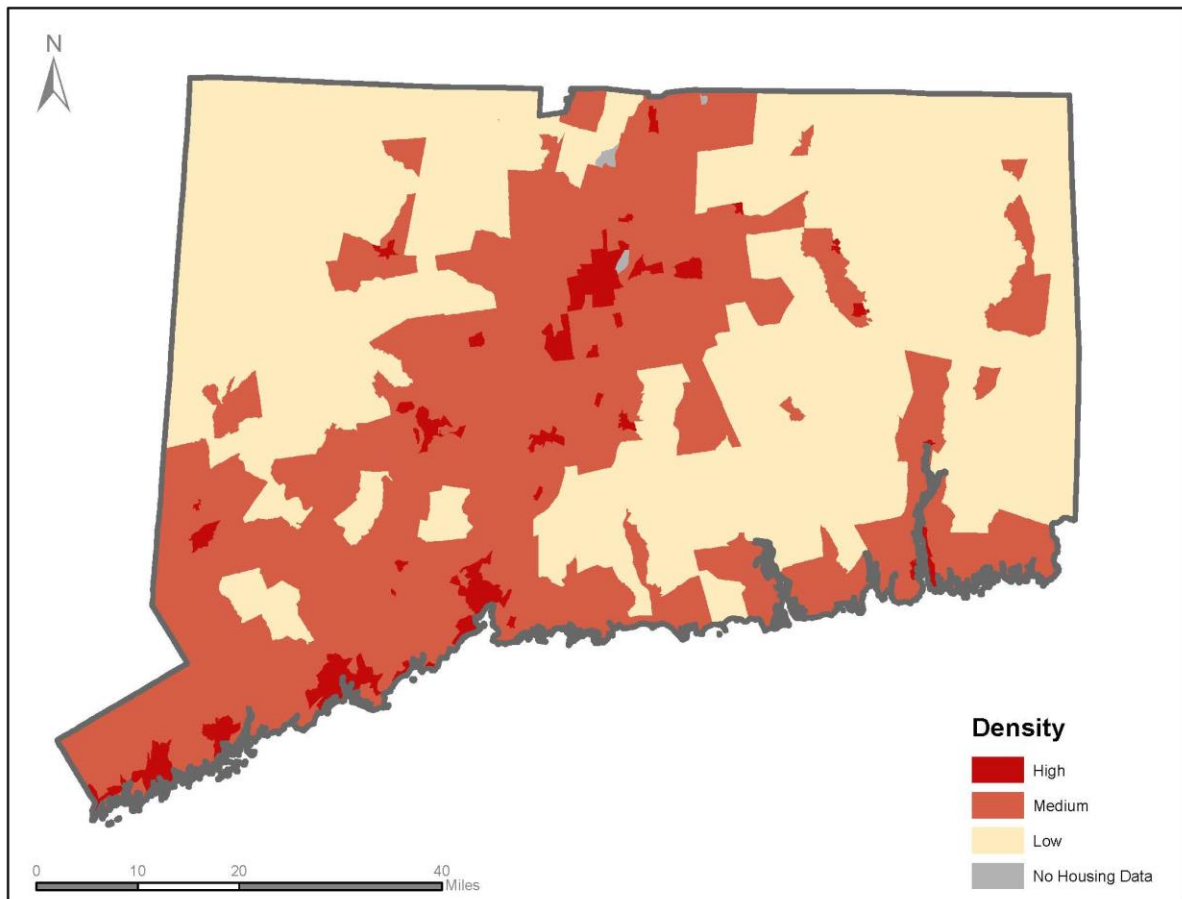
Table 2: Estimated FTTP OSP and Core Electronics Costs

| Area Description | Passings | FTTP OSP Cost per Passing | Core Electronics Cost per Passing | Totals |
|------------------|----------|---------------------------|-----------------------------------|------------------------|
| High Density | 425,000 | \$1,060 | \$215 | \$541,875,000 |
| Medium Density | 875,000 | \$1,960 | \$215 | \$1,903,125,000 |
| Low Density | 200,000 | \$3,760 | \$215 | \$777,000,000 |
| <i>Total</i> | | | | \$3,222,000,000 |

Figure 8 is a map illustrating the distribution of the three types of population densities across the state, based on Census tracts.

¹⁰⁹ The passing count includes individual single-unit buildings and units in small multi-dwelling and multi-business buildings as single passings. It treats larger buildings as single passings.

Figure 8: Population Density Map of the State of Connecticut



For each type of population density, we applied different assumptions to generate the cost per passing. Our model assumes a mix of aerial and underground fiber construction, based on the prevailing mix of utilities in the state. Material costs were estimated using available pricing for a sample bill of materials; the material costs were generally known, with the exception of unknown economies of scale and inflation rates, and barring any sort of phenomenon restricting material availability. Labor costs for placing, pulling, and boring fiber were estimated based on the cost of similar construction in comparable markets.

Electronics costs were estimated based on the manufacturers' pricing for the components, and on costs per passing we have derived in our work on similar projects. These costs include the cost of the core electronics equipment, as well as the cost of network configuration and integration.

6.2 Potential Range of Subscriber Costs

Each activated subscriber would require a fiber drop installation and electronics, which would add roughly \$950 to \$2,700 per subscriber. The biggest variable in the cost of adding a subscriber is the drop installation. A short aerial drop can cost as little as \$250 to install, whereas a long

underground drop installation can cost upwards of \$2,000. The other per subscriber expenses include the cost of the optical network terminal (ONT) at the premises, a portion of the optical line termination (OLT) costs at the hub, the labor to install and configure the electronics, and the incidental materials needed to perform the installation. The numbers provided in the table below are averages and will vary depending on the type of premises and the internal wiring available at each premises.

Table 3: Per Subscriber Cost Estimates

| | Low Estimate | High Estimate |
|---|--------------|---------------|
| Drop Installation and Materials | \$250 | \$2,000 |
| Subscriber Electronics (ONT and OLT) | \$400 | |
| Electronics Installation | \$200 | |
| Installation Materials | \$100 | |
| Total | \$950 | \$2,700 |

6.3 Assumptions and Caveats Underlying These Cost Estimates

Actual costs may vary due to unknown factors, including the costs of private easements, utility pole replacement, and make-ready; variations in labor and material costs; and the state's operational and business model. We have incorporated suitable assumptions to address these factors based on our experiences in other FTTP projects.

As with any utility, the design and associated costs for construction will vary with the unique physical layout of the service area; no two streets are likely to have the same configuration of fiber optic cables, communications conduit, underground vaults, and utility pole attachments.

Costs will further vary due to soil conditions, such as the prevalence of subsurface hard rock; the condition of utility poles and the feasibility of aerial construction involving the attachment of fiber infrastructure to utility poles; and crossings of bridges, railways, and highways.

6.4 Description of Cost-Estimation Methodology

To estimate costs for a statewide network, we extrapolated the costs for strategically selected sample designs on the basis of street mileage and passings. Specifically, we developed sample FTTP designs to generate costs per passing for each density area (high, medium, and low).

Our observations determined that for the low-density areas, utilities are primarily aerial, but the low density requires more construction of fiber to reach a smaller number of homes in an area. The high cost of constructing to low-density areas is often the reason for a lack of existing telecommunications services in these areas.

High- and medium-density urban areas tend to have more underground utilities; utilities are predominantly aerial in residential areas.

Medium-density areas tend to have the greatest variation in the percentages of aerial versus underground construction. Generally, the newest subdivisions and developments tend to be entirely underground, whereas older neighborhoods have aerial construction. Suburban areas also tend to have more rear easements for utilities, which can increase the cost of construction.

The assumptions, sample designs, and cost estimates were used to extrapolate a cost per passing for the OSP. This number was then multiplied by the number of households in each area based on U.S. Census data.¹¹⁰

The following table outlines some of the key assumptions for each area.

Table 4: Assumptions for Each Population Density Category

| | High Density | Medium Density | Low Density |
|------------------------------------|---------------------|-----------------------|--------------------|
| Aerial Construction | 83% | 87% | 93% |
| Poles per Mile | 46.50 | 31.51 | 34.40 |
| Moves per Pole | 3 | 2 | 1 |
| Poles Requiring Make-Ready | 25% | 20% | 30% |
| Poles Requiring Replacement | 4% | 3% | 5% |
| Intermediate Rock | 20% | 20% | 20% |
| Hard Rock | 10% | 10% | 10% |

The actual cost to construct FTTP to every premises in the state could differ greatly from the estimate due to changes in the assumptions underlying the model. For example, if access to the utility poles is not granted or make-ready and pole replacement costs are too high, the network would have to be constructed underground—which could significantly increase the cost of construction. Alternatively, if the state were able to partner with a local telecommunications provider and overlash to existing pole attachments, the cost of the build could be significantly lower. Further and more extensive analysis would be required to develop a more accurate cost estimate across the entire state.

¹¹⁰ The low-density sample design was 96 miles of construction, extrapolated over 8,700 miles. Variations in home densities and assumptions could significantly change the cost to construct FTTP across the State.

6.5 Applying Methodology to Local Communities

The methodology outlined above could be applied by an individual town to develop a high-level estimate of the cost of building FTTP within its boundaries. Assuming the build area is large enough to support the calculation, a local community that seeks to better understand its potential costs could use its Census-derived population density, its actual level of aerial and underground utilities, and the per-passing costs estimated here to perform a similar high-level calculation. We note, however, that there are substantial economies of scale in engineering and construction, so a small project would need to take into account planning, engineering, and mobilization costs.

6.6 Network Architecture

OSP (layer 1, also referred to as the physical layer) is both the most expensive part of the network and the longest lasting. The architecture of the physical plant determines the network's scalability for future uses and how the plant will need to be operated and maintained; the architecture is also the main determinant of the total cost of the deployment.

Figure 9 (below) shows a logical representation of the high-level FTTP network architecture we recommend. This design is open to a variety of architecture options. The drawing illustrates the primary functional components in the FTTP network, their relative position to one another, and the flexibility of the architecture to support multiple subscriber models and classes of service.

The recommended architecture is a hierarchical data network that provides critical scalability and flexibility, both in terms of initial network deployment and its ability to accommodate the increased demands of future applications and technologies. The characteristics of this hierarchical FTTP data network are:

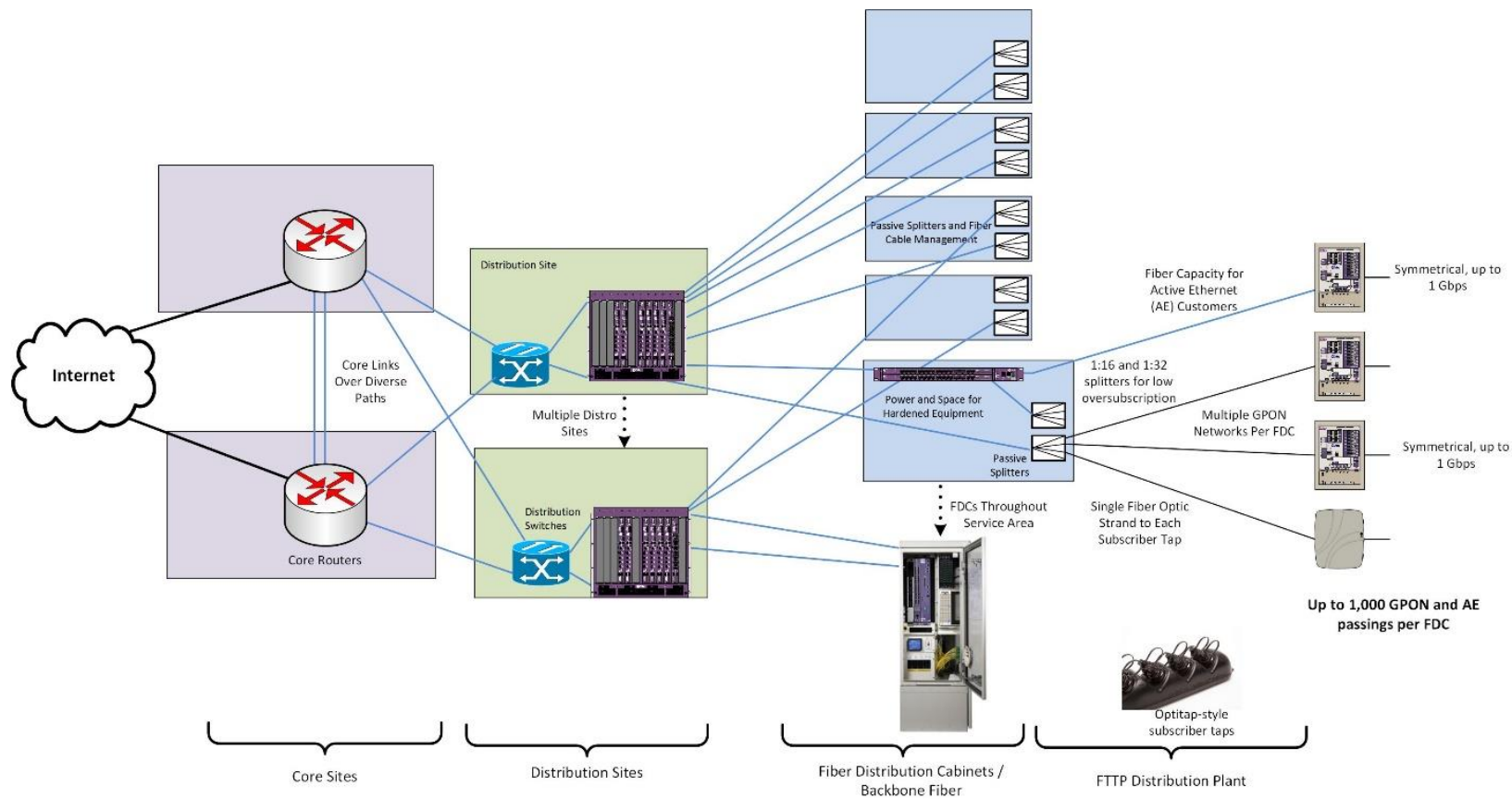
- Capacity – ability to provide efficient transport for subscriber data, even at peak levels
- Availability – high levels of redundancy, reliability, and resiliency; ability to quickly detect faults and re-route traffic
- Diversity – physical path diversity to minimize operational impact resulting from fiber or equipment failure
- Efficiency – no traffic bottlenecks; efficient use of resources
- Scalability – ability to grow in terms of physical service area and increased data capacity, and to integrate newer technologies
- Manageability – simplified provisioning and management of subscribers and services

- Flexibility – ability to provide different levels and classes of service to different customer environments; can support an open access network or a single-provider network; can provide separation between service providers on the physical layer (separate fibers) or logical layer (separate VLAN or VPN)
- Security – controlled physical access to all equipment and facilities, plus network access control to devices

This architecture offers scalability to meet long-term needs. It is consistent with best practices for an open access network model that might potentially be required to support multiple network operators, or at least multiple retail service providers requiring dedicated connections to certain customers. This design would support a combination of Gigabit Passive Optical Network (GPON) and direct Active Ethernet services (with the addition of electronics at the fiber distribution cabinets), which would enable the network to scale by migrating to direct connections to each customer, or reducing splitter ratios, on an as-needed basis.

The design assumes placement of manufacturer-terminated fiber tap enclosures within the right-of-way or easements, providing water-tight fiber connectors for customer service drop cables and eliminating the need for service installers to perform splices in the field. This is an industry-standard approach to reducing both customer activation times and the potential for damage to distribution cables and splices. The model also assumes the termination of standard lateral fiber connections within larger multi-tenant business locations and multi-dwelling units.

Figure 9: High-Level FTTP Architecture



7 Federal Funding Opportunities for Local Governments

Federal funding is an important element of most large-scale public sector broadband deployments. Federal funding opportunities vary dramatically in size and target a wide variety of deployment scenarios and end users. This section provides information on a few of the significant federal funding opportunities available to communities in Connecticut in 2016. Additional smaller opportunities may emerge in any given year—examples of the always-changing landscape of broadband funding.

7.1 Economic Development Administration Grants for Distressed Areas

The U.S. Department of Commerce’s Economic Development Administration oversees programs that have provided economic assistance to distressed communities for many years. Public broadband projects in distressed communities are eligible for funding under both the Public Works and Economic Adjustment Assistance programs.

Broadband funding has not been a significant part of the EDA funding portfolio to date; the program’s online annual reports (2007-2014) include only five references to relevant projects.¹¹¹ One of those grants was given in 2013 to the Vermont Digital Economy Project, a partnership between EDA and the Council on Rural Development, to “improve online access within twenty-five core communities and other targeted locations, strengthen online communications within the state, and enhance community and non-profit economic development functions.” The size of that award is unclear, although Vermont received a total of six grants together worth \$6.5 million in 2013.¹¹²

That said, both construction and technical assistance are eligible for EDA funding. Moreover, it appears that applicants can apply existing federal funds toward the cost-share, which allows them to leverage available resources. A brief overview of the program follows (based on the Federal Funding Opportunity announcement, or FFO).

For FY2016, the EDA requested \$85 million for Public Works and \$53 million for Economic Adjustment Assistance (EAA).¹¹³ The average Public Works award is \$1.4 million, with investments ranging from \$200,000 to \$3 million. EDA has historically awarded 80 to 150 Public Works projects annually. The average EAA award is \$820,000, with investments ranging from

¹¹¹ EDA annual reports are available online at <https://www.eda.gov/annual-reports/> (accessed March 2016).

¹¹² “Annual Report: Vermont,” EDA, <https://www.eda.gov/annual-reports/fy2013/states/vt.htm> (accessed March 2016).

¹¹³ “EDA Fiscal Year 2016 Budget Request At-A-Glance,” EDA: Newsroom, March 2, 2015, <http://www.eda.gov/news/press-releases/2015/02/03/fy16-budget.htm> (accessed March 2016).

\$100,000 to \$1.25 million. EDA has historically awarded funds for 70 to 140 EAA projects annually.

Applicants must typically make a matching contribution of at least 50 percent of the total award. In cases of extreme economic distress (i.e., substantially lower per capita income or higher unemployment than the qualifying levels), this requirement may be reduced to only 20 percent. The cost-share can be provided through “in kind” contributions.

In recent years, EDA has shifted to rolling deadlines for applications.¹¹⁴ The application period is considered open until the EDA makes the next FFO announcement. The FY2016 FFO was issued on December 10, 2015.

The funding announcement repeatedly emphasizes the importance of consulting with the appropriate regional EDA contacts. Regional staff is available to review project proposals, assess proposed cost shares, and preview all application materials. Though optional, we believe that such consultation will be very advantageous.¹¹⁵

7.2 E-Rate Program for Services to Schools and Libraries

The Schools and Libraries Universal Service Fund program, known as E-rate, provides financial assistance to help schools and libraries obtain affordable broadband. The program is administered through the Universal Service Administrative Company (USAC) under the authority of the Federal Communications Commission (FCC).

Under the program, eligible schools and libraries may receive discounts ranging from 20 percent to 90 percent of the pre-discount price of eligible services. The discount rate given to schools and libraries is based on the percentage of students eligible for free or reduced price lunch or an alternative mechanism to determine need. (Libraries receive funding at the discount level of the school district in which they are located.)

For example, a school with 75 percent to 100 percent of students eligible for free or reduced price lunch would receive a 90 percent E-rate discount on eligible broadband services, and thus pay only 10 percent of the cost of those services. In addition, schools and libraries located in rural areas may also receive an additional 5 percent to 10 percent discount compared to urban areas.

Eligible schools, libraries, and consortia of schools and libraries apply for E-rate support every funding year (July 1 through June 30). E-rate applicants are generally required to seek competitive bids for the services they seek to purchase using E-rate funds; the price of eligible products and

¹¹⁴ This is a change from previous grant cycles, which included separate funding cycles with establishes deadlines. See, e.g., EDA, FY2015 FFO Fact Sheet (noting FY2015 phased application period), <https://www.eda.gov/funding-opportunities/files/2015-EDAP-FFO-Fact-Sheet.pdf> (accessed March 2016).

¹¹⁵ EDA regional contacts are available online at: <https://www.eda.gov/contact/> (accessed March 2016).

services must be the primary factor in selecting the winning bid. Requests for telecommunications services and Internet connections (commonly referred to as Category 1 services) receive first priority for funding. The remaining funds are allocated to requests for support for internal connections and basic maintenance of internal connections (referred to as Category 2 services), beginning with the most economically disadvantaged schools and libraries.

The FCC recently announced improvements to the program designed to achieve new efficiencies with the available funds and maximize its benefits for the nation's schools and libraries. The FCC established three new goals for the program:

1. Ensuring affordable access to high-speed broadband.
2. Maximizing the cost-effectiveness of spending for E-rate supported purchases.
3. Making the E-rate application process and other E-rate processes fast, simple, and efficient.

Generally, the E-rate process begins in the fall and closes in the spring. The USAC website provides a detailed overview,¹¹⁶ including video guides documenting each step of the application process.¹¹⁷ The window during which schools and libraries can apply to USAC for funding is open from winter to spring preceding the start of the funding year.

USAC opens the application window in mid-winter and closes the window the following March or April. The exact dates differ each year and are announced on the USAC website.

7.3 Healthcare Connect Program for Services to Rural Hospitals

The Healthcare Connect Fund (HCF) provides a 65 percent subsidy to eligible health care providers and facilities for broadband service from providers including municipal or state organizations. While the focus is on serving rural facilities, teaching hospitals and urban/suburban facilities will be eligible if they are part of an in-state consortium that includes rural facilities. The program is administered through USAC under the authority of the FCC.

The HCF is intended to provide Health Care Providers (HCP) access to broadband services, particularly in rural areas, and to encourage the formation of state and regional broadband networks linking HCPs. Significantly, while the program is intended to benefit rural providers,

¹¹⁶ See, USAC, Schools and Libraries (E-rate), "Applicant Process" (with separate links describing each of the requisite forms), <http://www.usac.org/sl/applicants/default.aspx> (accessed March 2016).

¹¹⁷ See USAC, Schools and Libraries (E-rate), "Online Learning Library" (providing dozens of short videos for each step of the application process), <http://www.usac.org/sl/about/outreach/online-learning.aspx> (accessed March 2016).

consortia of urban and rural providers may also participate, so long as the majority of the members of the consortia (at least 51 percent) are rural.¹¹⁸ HCPs may include public or nonprofit entities including post-secondary schools offering health care instruction (e.g., teaching hospitals or medical schools); community health centers or health centers providing health care to migrant; a local health department or agency; a community mental health center; a not-for-profit hospital; a rural health clinic, or a dedicated emergency room of a rural for-profit hospital.

In particular, the HCF is intended to achieve three goals:

1. Increase broadband access to primarily rural HCPs.
2. Encourage the development of interconnected broadband health care networks.
3. Maximize the cost-effectiveness of the federal Universal Service dollars spent on services for health care.¹¹⁹

The HCF is intended to help expand health care providers' access to the high-bandwidth connections they need for modern telemedicine by:

- Addressing the artificial limitations on broadband connection types that have been a part of Universal Service support;
- Fostering the creation of consortia among rural and urban HCPs to share resources;
- Increasing the participants' portion of financial responsibility, but reducing their overall costs by improving buying power through the creation of a more competitive marketplace;
- Supporting a broad range of broadband services from a diverse set of providers and encouraging HCPs to build their own broadband networks where cost-effective; and
- Including service upgrades that are required to support new health care applications.¹²⁰

¹¹⁸ Applicants can determine if an HCP is located in a rural area by using the Rural Health Care (RHC) Program's Eligible Rural Areas Search Tool.

¹¹⁹ Oliver, L., Jan. 10, 2013, "The FCC's Healthcare Connect Fund," <http://www.usac.org/res/documents/rhc/training/2013/healthcare-connect-fund-webcast.pdf> (accessed March 2016).

¹²⁰ See FCC, USAC, Dec. 12, 2013, Press Release: "FCC Creates Healthcare Connect Fund to Expand Access to Robust Broadband Healthcare Networks, Improve Care and Lower Costs for Patients Nationwide," <http://www.fcc.gov/document/new-healthcare-connect-fund-expands-access-broadband-healthcare> (accessed March 2016).

Significantly, the FCC order creating the HCF states that the fund will, in addition to expanding broadband access for rural HCPs, “encourage the creation of state and regional broadband health care networks.”¹²¹

States and municipalities can benefit from the Healthcare Connect Fund by being selected as service providers to build broadband networks using federal funding. Unlike grants, which offer one-time money, the HCF offers a sustainable source of financial subsidy for rural HCPs, just as E-rate does for schools and libraries. Moreover, because funding is provided through the Universal Service Fund, it is not subject to annual appropriations. This means that HCF provides an ongoing funding stream for rural broadband projects. The FCC has capped funding for all Rural Health Care (RHC) programs, including HCF, at \$400 million per year on a first-come, first-served basis. This cap is seldom reached, however; in FY 2015, for instance, funding requests for HCF totaled roughly \$61 million.¹²²

¹²¹ In the Matter of Rural Healthcare Support Mechanism, Dec. 12, 2012, Report and Order, WC Docket No. 02-60, at 3, https://apps.fcc.gov/edocs_public/attachmatch/FCC-12-150A1.pdf (accessed March 2016).

¹²² USAC, Rural Healthcare, “Funding Information”, <http://www.usac.org/rhc/healthcare-connect/funding-information/default.aspx> (accessed March 2016).

Appendix A: Glossary of Technical Terms

- Asymmetric** Data service with more capacity in the downstream (network to user) direction than the upstream (user to network) direction. Asymmetric services are often less costly to deploy and, because many uses of the Internet are heavier in the downstream direction, asymmetric services can suit the needs of many types of users. Asymmetric services are less well-suited to users who host data, who use many interactive multimedia applications, or who frequently upload large files.
- Bandwidth** Available range of frequencies (or number of channels) over a cable or over the air. Bandwidth is typically measured in the frequency range available (kHz or MHz).
- Backhaul** The transport of telecommunications network traffic from the outer edge of the network back to the central core. A common example is wireless backhaul, which is the connection from a wireless base station or tower to the wireless network core.
- CableCard** A device that is provided by the cable service provider or embedded in a retail device (e.g., television monitor) that allows access to digital cable services and maintains signal security without having to use a cable provider's set-top box.
- CCAP** Converged Cable Access Platform—Integration of the data and video portion of the cable architecture into one platform.
- CODEC** EnCOder-DECoder—converts between different types of video streams. A CODEC provides video in a known format, such as MPEG-2 or H.264.
- Compression** Reduction in the size of a video stream by computer processing, which takes advantage of symmetry and repetition in images and the stillness of a video picture over time. Widely available compression algorithms reduce the size of video by factors of tens or hundreds.
- DOCSIS 3.X** The latest version of a Data Over Cable Service Interface Specification telecommunication standard that enables the transmission of high-speed IP-based data and voice over the cable network and provides interoperability between devices of different manufacturers. Like Wi-Fi and Ethernet, DOCSIS made it possible to build less expensive, mass-produced devices.
- Ethernet** The name of the technology invented by the Xerox Corporation for a 10 Mbps shared resources LAN, subsequently incorporated into Institute of Electrical and Electronics Engineers standard IEEE 802.3. Ethernet, like Wi-Fi, is a widely adopted

standard that creates interoperability between different vendor devices and a widely adopted technical approach to networking. Almost all wired computer network interfaces are Ethernet, and Ethernet is now a typical interface on a digital television.

| | |
|----------------|--|
| FTTP | Fiber-to-the-premises |
| Headend | A cable system operator's central cable TV facility, which receives satellite and off-air video feeds and inserts signals into the cable system. The headend also includes data and voice switching and administrative services. |
| HFC | Hybrid Fiber Coax—A standard cable TV architecture in which the backbone network is fiber optic cable and the last-mile access network is coaxial cable. HFC is a scalable architecture, in which capacity can be increased by building fiber closer to users. |
| HDTV | High-Definition Television—Video/images of higher resolution than standard definition (SD), resulting in enhanced picture quality. Common HDTV signal resolutions are 1920 x 1080 and 1280 x 720. |
| Hub | Key facilities on a network that are served by the network backbone. Typically, hubs are connected to each other and the headend over redundant fiber paths. |
| IP | Internet Protocol—A set of networking standards and an addressing scheme which emerged with the Internet and is also frequently used in private networks. |
| MHz | Megahertz—Unit of measurement for frequency and bandwidth. One MHz is one million cycles per second. AM radio is between 0.54 and 1.6 MHz; FM radio is between 88 and 108 MHz; and over-the-air television frequencies range between 54 and 700 MHz. |
| Modem | MOdulator-DEModulator, typically providing an interface between a cable (telephone, cable TV, or fiber optic) and data terminal equipment. |
| MPEG | Motion Picture Experts Group—A video standard for full-motion, entertainment-quality television. Most cable television uses the MPEG-2 standard. |
| Node | A component in a Hybrid Fiber Coaxial network that converts between optical and electrical signals and resides at the boundary between the fiber optic cable and coaxial cable. Since the capacity of fiber optics is much greater than coaxial cable, a cable system with optical service nodes serving fewer subscribers provides greater capacity for interactive services. |

PEG Public, Educational, and Governmental programming. PEG channels, studios, and equipment are provided in cable franchise agreements. Public access is typically operated by a nonprofit entity or by the cable operator, and is intended to provide members of the public with the ability to produce and broadcast television programs. Educational channels are operated by schools or higher education institutions. Government channels are operated by local governments and typically air public meetings and government information.

QAM Quadrature Amplitude Modulation—The presentation of data on a carrier signal in a cable or over the air by using different combinations of its phase and amplitude. QAM is the technique used on cable systems for digital video and cable modem services. It makes it possible for a cable system to carry six (64-QAM), eight (256-QAM), or 10 (1024-QAM) Mbps of data for each MHz of frequency used.

Spectral Efficiency A measure of the efficiency of data transmission over bandwidth (or spectrum), which determines the amount of useful information per unit of spectrum (devoid of error correction and other parameters aiding smooth transmission). It is usually measured in bps/Hz.

Appendix B: Checklist for Localities for Building a Partnership

1. Determine your priorities
 - a. Competition?
 - b. Enhanced service?
 - c. Equity and service to all?
 - d. Public control over infrastructure?
 - e. Risk avoidance?
2. Consider private investment and public facilitation
 - a. Make available public assets like fiber and conduit
 - b. Share GIS data
 - c. Streamline permitting and inspection processes
 - d. Offer economic development incentives to attract private broadband investment
3. Consider private execution with public funding
 - a. Identify revenue streams that can be directed to a private partner
 - b. Issue RFP for private turnkey execution
4. Consider shared investment and risk
 - a. Evaluate using assets to attract private investment
 - b. Evaluate funding new assets to attract private investment
 - c. Evaluate building new fiber assets to businesses and/or homes for leasing to private ISPs