New America Foundation

The Art of the Possible

An Overview of Public Broadband Options

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About the Authors

New America's Open Technology Institute

The Open Technology Institute formulates policy and regulatory reforms to support open architectures and open source innovations and facilitates the development and implementation of open technologies and communications networks. OTI promotes affordable, universal, and ubiquitous communications networks through partnerships with communities, researchers, industry, and public interest groups and is committed to maximizing the potentials of innovative open technologies by studying their social and economic impacts – particularly for poor, rural, and other underserved constituencies. OTI provides in-depth, objective research, analysis, and findings for policy decision-makers and the general public.

CTC Technology & Energy

CTC Technology & Energy is an independent communications and IT engineering consulting firm with more than 25 years of experience. We work at the highest levels on cutting-edge communications networking projects for public sector and non-profit clients throughout the U.S. Current projects include long-term fiber optic and wireless regional communications interoperability initiatives in the Washington, D.C. area funded by the U.S. Department of Homeland Security; design and implementation of wireless networks; and engineering design and business modeling and project oversight for broadband networks.

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Introduction

Broadband has become a critical infrastructure for communities in the 21st century. From a variety of sectors, including commerce, education, healthcare and government services, the demands for more advanced, reliable, and affordable broadband is challenging local governments to develop effective strategies for connecting their citizens, businesses, and institutions. Communities lacking access altogether or still relying on first generation networks will find themselves on the wrong side of the digital divide and will find it challenging to attract and retain businesses, provide quality education, and deliver modern healthcare. Local government and community investment can serve as a path for bringing next generation broadband, while also developing network infrastructure and models to meet specific community needs and aspirations.

In the U.S., local governments and communities have taken the lead in building next generation broadband infrastructure. In more than 100 cities and towns across America, a public entity provides services to homes and businesses throughout the community.[1] In many hundreds more, the locality provides cutting-edge communications services to such key community facilities as schools, libraries, hospitals, and senior centers. Indeed, public broadband networks in cities and rural towns are providing some of the fastest broadband connections to residents, businesses, and community anchor institutions.

This public effort has been made necessary by the failure of incumbent industries to build next generation infrastructure. As Blair Levin, architect of the Federal Communications Commission's National Broadband Plan, noted in a speech in June 2012:

> For the first time since the beginning of the commercial internet, the United States does not have a national wire line provider with plans to build a better network than the currently best available network.[2]

Cable and telephone incumbents that often serve as the only broadband providers in most communities have not committed to making significant upgrades or investment in new infrastructure to ensure that each and every community has access to next generation broadband. And despite the attention surrounding Google Fiber announcements, the project remains limited in scope and will impact only a small fraction of the American public. Most communities will not have the benefit of an additional private competitor to spur higher speeds and more affordable access.

1 *See* "Community Network Map," Institute for Local Self-Reliance, http://www.muninetworks.org/communitymap (accessed May 5, 2014).
2 Blair Levin, "Upgrading America: Achieving a Strategic Bandwidth Advantage And a Psychology of Bandwidth Abundance To Drive High-Performance Knowledge Exchange," (remarks given at Fujitsu Conference on Paving the Road to Unlimited Bandwidth: Technologies and Applications for a Connected Age, San Jose, California, June 13, 2012) remarks available at http://www.gig-u.org/blog/upgrading-america-blair-levin-addresses-fujitsu-conference (accessed May 5, 2014).

The challenge, however, for other localities seeking to build new broadband capabilities is to develop a plan for a sustainable and scalable project that meets the unique needs and aspiration of the community while accounting for the financial realities and other risks unique to each broadband project. That means there is no one-size-fits-all approach to developing a successful public broadband network. In some cases, a public network may not make sense at all. In others, the best strategy may be to start with a small network that connects only government and community anchor institutions. For others, an extensive, multi-service fiber network connecting residences and businesses may be the only means to ensure the community is not left behind in the digital economy.

The one thing communities cannot do is sit on the sidelines. Even the process of evaluating whether a public network is appropriate can be beneficial to community leaders as a means to better understand the communications needs of their residents, businesses, and institutions and whether existing services and networks are keeping pace.

The purpose of this report is to enable communities to begin the evaluation of their broadband options. The report begins with an overview of different network ownership and governance models, followed by an overview of broadband technologies to help potential stakeholders understand the advantages and disadvantages of each technology. It then provides a brief summary of several different business models for publicly owned networks. The final two chapters focus on the potential larger local benefits and the risks of a publicly funded broadband project.

Chapter 1: Ownership & Governance Models

This chapter summarizes a range of structures for organizing public broadband projects. The model selected should be based on the needs, resources, and goals of the local community. Ideally, it should be based on existing organizational and governance structures that enable the local community to build on strong existing relationships. This chapter addresses models that range from a centrally coordinated government initiative to a shared partnership between a private entity and local government. Related to the organizational structure is the ownership model, which can include public ownership, public-private partnerships, or cooperative ownership. This chapter will provide an overview of these organizational, governance, and ownership models in order to enable communities to think about how to structure broadband projects while also satisfying the policy goals of the community—goals that relate to control, risk, and reward. The models are not meant to be definitive but to provide communities with a number of examples and to highlight the benefits and challenges of several ownership and governance models.[3]

Balancing Control, Risk and Reward

Communities should consider three primary issues when first considering a public broadband project:

1. **Control—**who owns the network and decides how it operates
2. **Risk—**the costs associated with developing and running the network balanced against the revenue it generates
3. **Reward—**the benefits achieved through successful implementation of the project

3 For an additional overview of organizational models for municipal broadband networks, *see* Craig Settles, *Building the Gigabit City: A Planning Guide*, (eBook: Smashwords 2013), Kindle and PDF. Available at: https://www.smashwords.com/books/view/313806 (accessed May 5, 2014).

Not surprisingly, these three metrics come with their own trade-offs. Achieving all three—the desired level of control, minimum risk, and maximum reward—is difficult. Officials should consider carefully which components of these three items are important, and be prepared to make sacrifices where appropriate. A community can maintain substantial control and earn high rewards relatively easily if it is willing to take on all of a project's risk. Giving up some of the risk will likely also result in giving up some control. The degree to which a community chooses to balance these issues relates directly to the goals of the project, which should be decided at the outset.

Control is an issue that requires trade-offs. A community may or may not wish to control an entire network or even parts of a network. In some instances it is beneficial for a municipality, county, or tribal government to become a service provider itself and to sell services over the infrastructure it has built. In other cases, the community has no interest in this level of control, as long as it can guarantee that a private partner is meeting certain goals for the project such as affordability, level of service, or serving a specific constituency.

Achieving these goals does not necessarily require the local government to control or provide the service. However, ensuring sufficient accountability for the private partner will require developing a strong governance model. A locality seeking partners should therefore: figure out the specific goals of the project, determine what kind of control or accountability measures these goals require, and evaluate its risk tolerance. This analysis will help decide what kind of ownership and governance models are most suited for a project.

Every community will define **risk** differently, but most often, the term "risk" refers to financial commitments. Some communities have no tolerance for financial risk at all, while others can afford to spend significant resources for a potential long-term payoff. If a community has a significant financial stake in the network being built, it will likely need to have strong assurances that it will be able to break even on the investment, or that the network will pay for itself over time, or at minimum will service debt from bonds or other financial instruments.

Non-financial risks also exist, including the risk of falling short of stated goals. Local governments can reduce financial risk with a good private partner, but without the right arrangement, there can be a high risk of failing to achieve a number of goals that led the community to pursue a broadband project in the first place. Community-driven goals such as open access, increased competition, affordable pricing, universal service, economic development, and service to public institutions are potential aspirations that may not be realistic without taking a greater financial risk. Communities should seriously consider that it is also a risk to do nothing. Entering into a costly infrastructure project with or without private partners is certainly a risk, but so is the prospect of citizens and businesses lacking sufficient access to high-speed Internet and the associated benefits it provides.

With respect to **reward**, as is true with risk, the most common measurement of success is financial. However, with due consideration to financial goals and constraints, communities can also measure success based on other benefits such as spurring economic development or improving educational and healthcare outcomes. After all, building a network that prioritizes these aspirations is often among the reasons for public sector involvement in broadband planning and provisioning. Yet these types of rewards for a community are not specifically reflected in the financial statements of the community broadband enterprise. It would be unusual for a municipality, county, or tribe to enter the broadband market simply to generate income like a private company. Such community benefits can be more difficult to evaluate than revenues and profits, but they should not be ignored.

Public Ownership

In a public ownership model, a local government takes the lead in building and operating the broadband network. Generally speaking, publicly led projects use bond financing to pay for capital construction costs and revenue from subscribers or from leasing capacity to private providers to pay for operational costs. As a result of taking on much of the financial risk, these communities enjoy high levels of control over the project. The local governments design the network, determine service offerings and prices, operate the network, and control future decisions including when to expand the network or upgrade services. Even when a local government decides to organize a broadband project itself, the project structure can vary depending on the resources and local organizations available. In addition, there are a number of models where the locality builds and operates the network, but opens the network to private providers to offer retail Internet access or related services to the public.

Municipal Electric Utility

Some of the most successful examples of community broadband networks have been those where a locally owned municipal electric utility plays a central role in the project. The networks in Chattanooga, TN and Lafayette, LA[4] are both examples of this situation. Bristol Virginia Utilities (BVU) was among the nation's first municipal utilities to build a fiber-to-

4 Christopher Mitchell, *Broadband At the Speed of Light: How Three Communities Built Next-Generation Networks*, [Institute for Local Self-Reliance, April 2012]. Available at http://www.ilsr.org/wp-content/uploads/2012/04/muni-bb-speed-light.pdf. (accessed May 5, 2014).

the-premises (FTTP) network to serve residents, local businesses, and community institutions such as schools and libraries.[5] BVU, similar to many other networks built and operated by municipal electric utilities, offers a full suite of retail services—including broadband, cable television, and telephone —directly to the public.

Part of the reason for the success of municipal electric utilities in deploying broadband services is that they already have experience in managing infrastructure. They own repair trucks and employ field engineers who can perform installations and conduct maintenance. Utilities also have experience with customer service, managing individual accounts, and staffing call centers to handle questions or complaints. With a local electric utility as a partner, the network automatically has an important anchor tenant to financially support the network. Finally, they also have established institutional structures to provide for local oversight. Public utilities have boards of directors to guide their activities as well as mechanisms for oversight by a city council or other governing body. Since local supervision is a natural component of public utilities, community control and input are likely to be built into the network.

City Department

Not every community has a locally owned electric utility to serve as the lead for their project. However, it is still possible for localities to operate their own broadband networks. Instead of a branch of a power utility, the networks can be operated as a division of local government, perhaps within an information technology (IT) department. Since local utilities provide significant resources and experience that help lessen some of the financial and operational risks associated with broadband projects, communities that wish to proceed without the possibility of a utility as a partner will have to address these risks in a different way. The choice is usually to use a more cautious approach. For example, communities may choose to build out the network slowly over time, or choose not to issue large and project-specific bonds. In these instances, there is more of a focus on serving the connectivity needs of local government and community anchor institutions before considering a full FTTP network to serve residents.

Santa Monica, CA is an example of a successful community network operated by the municipality through an IT department.[6] Santa Monica chose to implement a community network in a cautious manner. Build-out of the network occurred gradually, focusing first on serving communications needs of the local government and community anchor institutions such as libraries and a local university. The network expanded over time by following a local 'dig once' strategy, a process that took advantage of already planned construction to install fiber when road maintenance occurred. The city further leveraged its fiber network to support local businesses by working with commercial building owners and property managers to cover the up-front costs of build-out to those locations. The Santa Monica City Net now offers up to 10 Gbps broadband service to at least 19 commercial buildings. Businesses in these buildings can choose from over 160 Internet Service Providers (ISPs), providing a range of services including IP transit, virtual private networks, and cloud services, all of which are interconnected to the Santa Monica network Internet exchange point in Los Angeles.[7]

Another example is Farmington, a city in northwest New Mexico. The city already has about 80 miles of fiber in its possession. Currently, the municipality's electric utility, the Farmington Electric Utility System, is the only user of this fiber, but the city is exploring expanding the use of the fiber to provide

5 Christopher Mitchell, *Broadband At the Speed of Light.*

6 For a case study of Santa Monica's network, *see* Eric Lampland and Christopher Mitchell, *Santa Monica City Net: An Incremental Approach to Building a Fiber Optic Network* [Institute for Local Self-Reliance, March 2014] Available at: http://www.ilsr.org/santa-monica-city-net/ (accessed May 5, 2014).

7 "Santa Monica Information Systems," City of Santa Monica, Santa Monica City Net, http://www.smgov.net/departments/isd/smcitynet.aspx (accessed May 5, 2014).

service to residents and businesses. After studying possible business models, the city determined that leasing the municipally owned fiber to existing ISPs is the best option. The resulting partnership model therefore is public ownership and private operation, allowing the city to offer use of the fiber at a low cost while guaranteeing an open access network to private providers. The city stands to benefit financially, both from leasing the fiber and from the economic development benefits of better broadband service in the community.

Leverett, a small town in rural western Massachusetts, is in the process of building its own FTTP network. Leverett received a support grant from the Massachusetts Broadband Institute to do initial feasibility planning for a local broadband network. When asked whether to move forward with the proposal, Leverett voters overwhelmingly supported a referendum to request bond funding financed by an increase in property taxes to pay for the network.[8] Leverett then issued a Request for Proposals for network design and construction and selected a vendor. The network is currently under construction with the goal to have the network complete and providing service by the end of 2014.[9]

Public-Private Partnership

Santa Monica, CA, Farmington, NM, and Leverett, MA all illustrate how many local broadband projects can be considered both municipal networks and public-private partnerships. In some sense, every infrastructure project involves both public and private participation. In traditional business models used by incumbent providers, infrastructure still must be built in public rights-of-way and often on publicly owned or regulated utility poles. In public ownership models, private entities are hired to build, operate, or maintain the network (or some combination of the three). Therefore, even in models where infrastructure is owned, operated, and maintained by a municipality, county, tribal government, or another local public entity, the private sector will play some role and will benefit from the public investment.

However, not every community has to finance or operate a local broadband network on its own. In some cases, it makes sense to share the risks, rewards, and control of the project across several parties. Partners can include private for-profit companies, local non-profits, and even local residents. The variety of public-private partnership models reflects the diversity of interests, goals, and resources among communities. In some cases the locality plays only a limited role in a partnership and may only provide access to rights-of-way or other city infrastructure such as light poles or local government buildings. In other cases a local government may agree to become an anchor tenant and pay for service on the network for an extended period, providing business case stability for the network project partner. In more extensive partnerships, the locality can play a larger role, such as paying for part or all of the network construction and leaving the operation of the network to the project partner.

When capital or operational costs of the local network are shared between the public and private partners, the public entity is in a better position to drive its policy goals (and the private partner is able to address its business goals). Sharing the risks and benefits of a project allows communities to pursue projects that may otherwise be unattainable. It can be a formidable challenge for a local jurisdiction to conduct a costly build-out to unserved areas and the same can be true for private providers; a public-private partnership can help control costs for all parties. Yet, public-private partnership models are relatively new for broadband and are in a constant state of change largely driven by the business needs and interests of companies

8 Lisa Gonzalez, "Network Moves Forward in Leverett, Western Massachusetts," *Community Broadband Networks*, December 20, 2012. http://www.muninetworks.org/content/network-moves-forward-leverett-western-massachusetts (accessed May 5, 2014).

9 Susan Crawford and Robyn Mohr, *Bringing Municipal High-Speed Internet Access to Leverett, Massachusetts*, [Harvard University - Berkman Center for Internet & Society, December 2013]. Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2366044 (accessed May 5, 2014).

that are willing to partner with local communities. For that reason, communities should approach them with a certain amount of caution and apply a critical lens to partnership models as well as to claims that any financial or other risks to the community can be removed entirely.

The most talked about example of a public-private partnership is the Google Fiber project in the Kansas City area. After a public search and application process, Google chose Kansas City, KS and Kansas City, MO as partners for a public-private broadband project because of their commitment to facilitate access to local infrastructure and rights-of-way.[10] Kansas City, MO also committed to waive local permitting fees and even provided Google with dedicated city staff to support the project. Some commenters point out that these terms amount to public subsidies for Google Fiber.[11]

In return, Google has agreed to build and operate the network and provide Internet access service with 1 Gbps speeds. Google Fiber will not serve all households in the Kansas City metropolitan area; rather, Google will build the fiber only in neighborhoods (called 'fiberhoods') where enough residents (between five and 25 percent of households, depending on the estimated cost of construction in the fiberhood) pre-register for service. At the end of the registration period in the Kansas City area, 90 percent of neighborhoods qualified.[12] Google has indicated a willingness to offer fiberhoods another opportunity to qualify for service, but only recently provided details for such a process.[13]

An emerging, smaller-scale example of a public-private partnership for a local broadband network is Westminster, MD. In 2013, the Westminster City Council voted to fund two FTTP pilot projects, one in a business area and another in a large residential senior community. The city is building fiber optics to all premises in the pilot areas and is in the process of seeking private providers who are interested in selling competing services to residents and businesses over that fiber. The council left open the possibility of expanding the network to other areas of the city at a later point.

Westminster and Kansas City are both examples of a municipal partner facilitating access to local infrastructure in return for varying levels of commitment from private partners to build a fiber network and/or offer next-generation broadband service. This approach reflects the reality that municipalities and other local governments control local rights-of-way and conduit while private firms have more experience providing telecommunications services to customers. In the Kansas City model, the local governments do not commit funds to build the network and, as a result, face limited financial risks associated primarily with transaction costs and forgone revenues. However, it is important to note the relative uniqueness of Google Fiber's projects in Kansas City and other locations. In many examples, despite favorable rights-of-way policies, most incumbent broadband providers have not been willing to provide a level of service on par with Google's commitments. In contrast, by owning the fiber itself, Westminster is able to ensure that fiber-based services are extended to all areas it selects.

There is also another trade-off: in the Kansas City-area arrangement, the communities have ceded control over the projects to their partners. Google leads the projects and makes all current and future operational decisions. Local leaders cannot determine

10 Testimony of Milo Medin, Google Inc., Field Hearing before the Committee on Oversight and Government Reform, 112 Cong., 1st sess., April 18, 2011. Available at: http://oversight.house.gov/wp-content/uploads/2012/01/TestimonyofMiloMedin_1.pdf (accessed May 5, 2014).

11 Timothy B. Lee, "How Kansas City taxpayers support Google Fiber," *Ars Technica*, September 7, 2012, http://arstechnica.com/tech-policy/2012/09/how-kansas-city-taxpayers-support-google-fiber/ (accessed May 5, 2014).

12 Kevin Lo, "Congratulations, Kansas City!" *Google Fiber Blog*, September 9, 2012, http://googlefiberblog.blogspot.com/2012/09/congratulations-kansas-city.html. (accessed May 5, 2014); *also see* Stacey Higginbotham, "Google Fiber is coming to 90% of eligible Kansas City neighborhoods," GigaOm, September 10, 2012, http://gigaom.com/2012/09/10/google-fiber-is-coming-to-90-of-eligible-kansas-city-neighborhoods/ (accessed May 5, 2014).

13 Carlos Casas, "More KC-area residents can sign up for Fiber this afternoon," *Google Fiber Blog*, March 11, 2014, http://googlefiberblog.blogspot.co.uk/2014/03/more-kc-area-residents-can-sign-up-for.html (accessed May 5, 2014).

how the network is designed, the services offered, or the prices charged to customers. Nor do they control whether the network will be built out to all residents, upgraded in the future, or even if it will operate at all over the long-term. Those decisions ultimately will rest with the private partner.

In contrast, Westminster has taken more financial risk but has secured more control over the network. The community determined that it can better ensure meeting its goals by funding part of the infrastructure. In a related model, the community can provide an alternative form of funding by agreeing to provide the private operator with a steady revenue stream through a long-term agreement to use the network. A local government could agree to share some portion of capital or operating costs with the private partner to incent the private partner to offer next-generation service. It is up to the community to negotiate any service level requirement or other conditions on the local investment. This type of partnership makes sense in communities where the subsidy for a private provider is relatively modest compared with the economic benefits for small businesses, institutions, or residents.

Cooperative Model

In many rural parts of the country, electricity is provided by electric cooperatives. Several of these member-owned organizations can trace their history back to the push for rural electrification in the 1930s. At that time, the newly formed cooperatives received targeted loans and technical support from the federal government to build out electric transmission lines to unserved areas. Some communities also formed cooperatives to operate local telephone networks. Today, some cooperative electric utilities and cooperative phone companies are constructing broadband networks within their existing service areas. Similar to municipally owned electric utilities, cooperative utilities are in many way natural partners for public broadband projects. Working with a co-op enables benefits such as access to utility poles, existing maintenance crews, and experience with customer support. Many of the cooperatives building these broadband networks have received, or are eligible for, federal loan and grant support from programs targeted to broadband deployment and other rural development initiatives.

Kit Carson is a cooperative electric utility in New Mexico serving nearly 30,000 members. Kit Carson applied for and received $63.7 million in combined grant and loan funding from the USDA's Broadband Initiative Program to build a 2,400-mile FTTP network.[14] Prior to receiving the funding, Kit Carson offered dial-up and limited DSL service to its members. The fiber project will connect thousands of households, businesses, and nearly 200 community anchor institutions that are located in the cooperative's service area.

Co-Mo Electric Cooperative is a 25,000-member cooperative utility located in central Missouri. Co-Mo attempted to secure federal funding for a FTTP network but was denied on several occasions. However, through door-to-door outreach and member-to-member conversations, Co-Mo received 25 percent pre-sale commitments from existing electrical customers to also purchase broadband services, enough to justify building an FTTP network with its own funds.[15] Co-Mo is constructing the network in a phased deployment over the next few years. The end goal is to expand the network through Co-Mo's entire electricity service area. In December 2013 the cooperative announced a series of speed

14 "New Mexico Broadband Program – BTOP Grantees in New Mexico," New Mexico Department of Information Technology, http://www.doit.state.nm.us/broadband/btopsnm.shtml (accessed May 5, 2014).

15 Masha Zager, "Electric Co-ops Build FTTH Networks," *Broadband Communities Magazine*, March/April 2013, 18-20. http://bbcmag.epubxp.com/i/118605/8 (accessed May 5, 2014).; also see Lisa Gonzalez, "Electric Cooperatives Expand Broadband In Missouri," Community Broadband Networks, May 23, 2012, http://www.muninetworks.org/content/electric-cooperatives-expand-broadband-missouri (accessed May 5, 2014).

increases on its broadband service tiers, including upgrading its top speed offering to 1 gigabit per second.[16]

There are currently only a few viable examples of cooperatives formed specifically for broadband service (rather than phone or electric service) and most depend upon local governments for support rather than individual subscribers. East Central Vermont Community Fiber Network (ECFiber) is a cooperative project between 24 towns in rural Vermont to build an FTTP network in their communities.[17] ECFiber is organized with an inter-local contract according to Vermont law, where municipalities contract with each other to provide services and the cooperative has a governing board consisting of delegates appointed by the select board or city council in each of the member towns. ECFiber contracts with ValleyNet, a local non-profit with extensive experience bringing Internet connectivity to residents and businesses in the region, to operate the network.

Another example is WiredWest, a project among towns in western Massachusetts to build and operate a regional FTTP broadband network. WiredWest is an inter-municipal cooperative according to state law, which will allow it to issue municipal bonds.[18] Founded in 2011 by 22 member communities, the project now boasts 42 municipalities. Each municipality that joins WiredWest is given a representative on the cooperative's board of directors and the project is led by an executive committee that is elected from existing board members. WiredWest is planning to build a last-mile fiber network by capitalizing on improved access to middle-mile fiber thanks to the MassBroadband 123 project, a middle-mile network in western Massachusetts with state funding and federal support from the Broadband Technology Opportunities Program. The cooperative has received support from a network planning grant from the Massachusetts Broadband Institute as well as membership dues, donations, and in-kind staffing support contributions from volunteers. Like other cooperative broadband projects, WiredWest has also been collecting pre-subscription pledges for service from area residents and businesses in order to prove market demand and bolster the project's business planning.

16 "Co-Mo Connect Announces Gigabit Pricing, Free Speed Upgrades," Co-Mo Electric Cooperative, http://www.co-mo.coop/news/newsdetail.aspx?itemID=256 (accessed May 5, 2014).

17 Christopher Mitchell, "Community Broadband Bits 9," Community Broadband Bits Podcast, Institute for Local Self-Reliance, http://www.muninetworks.org/content/community-broadband-bits-9-leslie-nulty-ecfiber-vermont (accessed May 5, 2014).

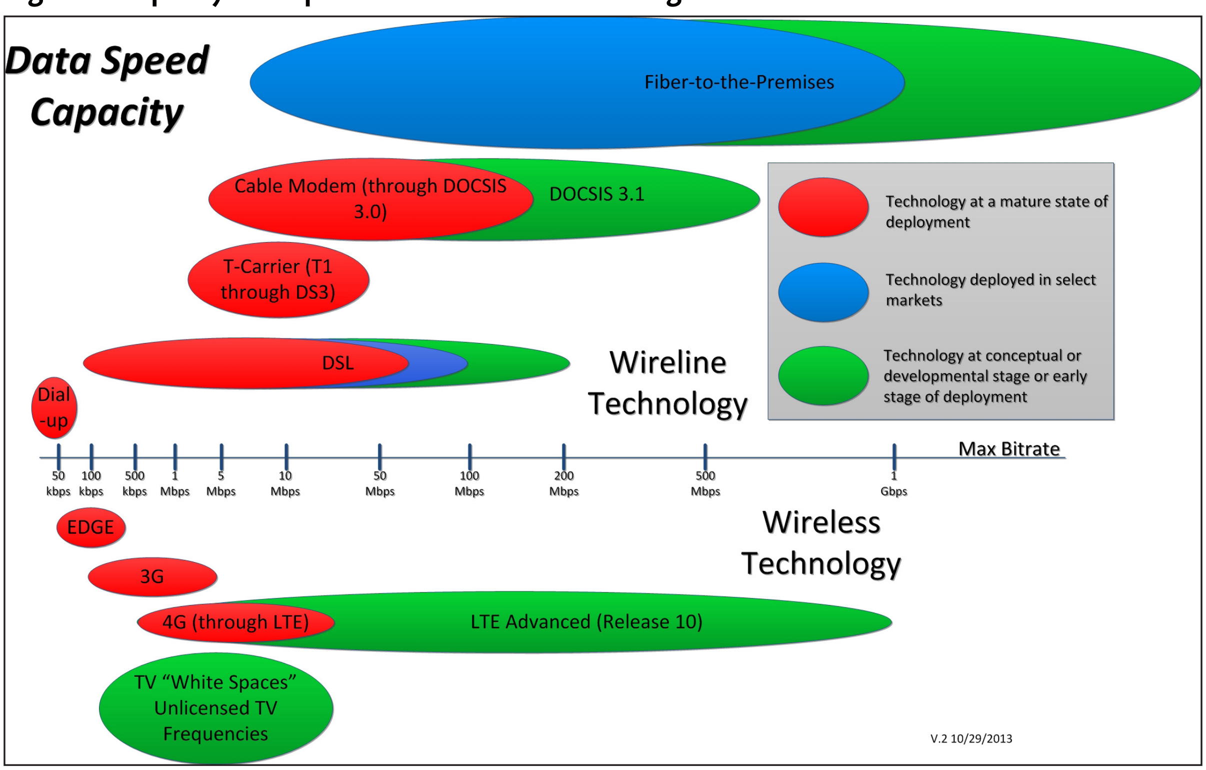
18 Lisa Gonzalez, "WiredWest Makes Significant Progress in 2012," *Community Broadband Networks*, February 3, 2013, http://www.muninetworks.org/content/wiredwest-makes-significant-progress-2012 (accessed May 5, 2014).

Chapter 2: Understanding Broadband Technologies

Not all broadband technologies are created equal. As city leaders and stakeholders think about their communications needs for the present and in the future, understanding the advantages and disadvantages of different broadband technologies and their capabilities to deliver certain services and application is critically important. Broadband does not have a specific standard. Rather, it is a loose term that can be applied to a range of different technologies that each offer different capabilities and limitations. For example, two households can both subscribe to Internet service deemed 'broadband' but have very different experiences when it comes to speeds or reliability.

The underlying reason for this difference often can be traced to the type of infrastructure used to offer the service. DSL, cable, fiber optics, Wi-Fi, wireless 4G, and other technologies all provide a form of broadband service. However, the inherently different physical properties of these technologies as well as their network architectures impact the type and quality of online activities available to users. As the capacity and technical requirements of Internet applications and services continue to evolve, it is important to understand how different broadband technologies can support different uses and applications. This chapter will provide short discussions of the main types of broadband technologies used to provide Internet service and IP (Internet protocol) communications. Each section will examine the properties of the technology in question, its advantages and disadvantages, and its scalability to meet future demands.

Figure 1. Capacity and Speed of Broadband Technologies



Wired/Wireline Technologies

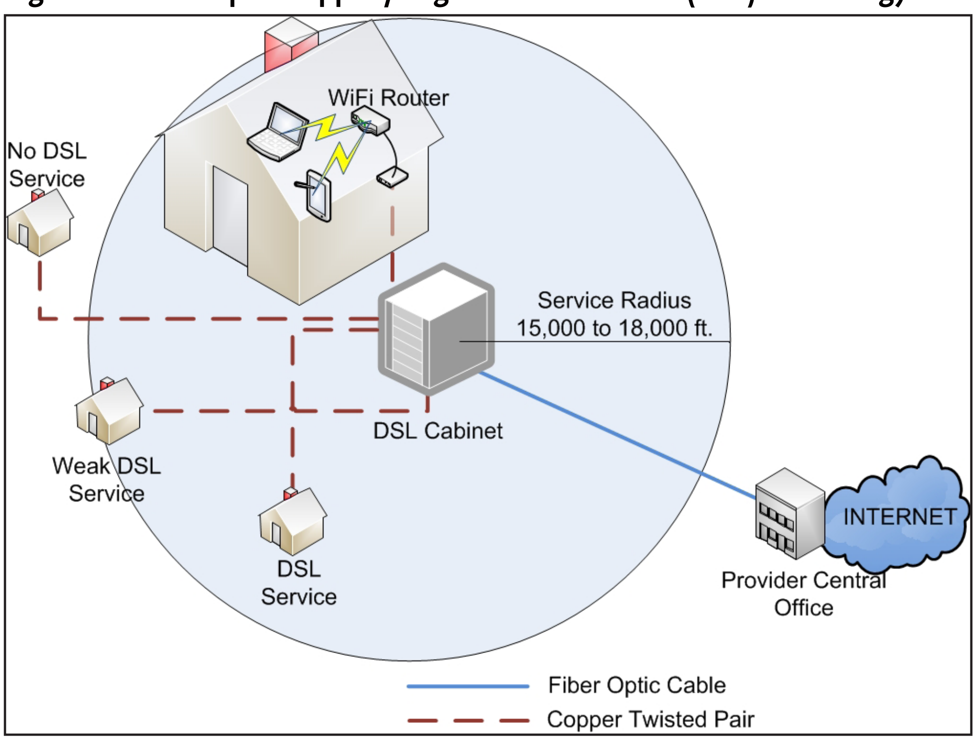
Twisted-pair Copper / Digital Subscriber Line (DSL) Technology

One of the predominant physical media supporting communications within the U.S. continues to be twisted-pair copper wiring. These are the legacy copper lines used for traditional telephone service. Copper wiring conducts data as electrical signals at various frequencies. Dial-up Internet service via the telephone network is provided on the same frequencies used to transmit basic voice service. The relatively narrow spectrum is the reason for the slow speeds of dial-up connections. Because dial-up modems use the full voice circuit, they cannot be used simultaneously with traditional telephone calls on the same line.

Digital Subscriber Line (DSL) service utilizes the same legacy copper telephone lines as dial-up, but the technology transmits data at higher and wider frequencies separate from those used for voice calls. This enables DSL technology to provide speeds faster than dial-up and allows for simultaneous use with traditional telephone voice service. The main advantage of copper-based DSL technology is the already wide availability of copper telephone lines. Traditional copper wire networks have proven to be highly adaptable, and various updates to DSL technology have allowed speeds to increase modestly over the past two decades. Regardless of these incremental advancements, however, broadband over copper wiring will always be limited by the physical properties of copper lines.

Typical DSL lines can provide download speeds of up to 25 Mbps. Some providers offer DSL speeds of up to 40 Mbps or more in areas where additional network upgrades have been installed. Research continues on ways to improve DSL performance further. Yet future developments will continue to be subject to the physical limits of a network that relies on copper wiring for all or part of the broadband service.

Figure 2. Twisted-pair Copper / Digital Subsciber Line (DSL) Technology



DSL technology relies on electrical signals to transmit data. These signals degrade substantially over distances of a few miles, and higher frequency signals degrade more quickly. Thus, the *length* of a copper line is a key determinant of the speeds of a connection. This characteristic is especially relevant for DSL since it utilizes the higher frequencies that degrade over distance. The physical limit of electrical signals is why DSL service is only available to residents who live less than two or three miles away from certain network operator equipment.[19] Locations outside of that range will not be able to get DSL service. Residents within this radius can subscribe to DSL, but download and upload speeds will vary based on their relative proximity to the network equipment. Only those who live in very close proximity will be able to enjoy the highest speeds the network can deliver because actual speeds begin to decline after a few thousand feet.

In addition, DSL services typically offer far slower upload speeds than download speeds. The ratio of broadband download speeds to upload speeds varies but is typically 10:1. The choice to provide asymmetrical speeds is an engineering decision; copper-based networks are capable of offering symmetrical service. The assumption is that typical residential broadband customers will consume much more data than they share. Therefore network capacity is divided in order to prioritize downloading data over uploading it.

Slower upload speeds were less of a concern when broadband users were primarily consumers of data (i.e., browsing websites and downloading content) but Internet use is increasingly shifting to applications that require faster upload speeds. Connections must have reliable upstream capacity to facilitate activities like sharing media (e.g., pictures and videos) and video conferencing. Businesses value higher upload speeds as well because they enable the quick transfer of large files for easy collaboration and review, use of cloud computing services, and high-quality video conferencing applications.

19 Here the main piece of networking equipment is the central office terminal or a remote digital subscriber line access multiplexer (DSLAM).

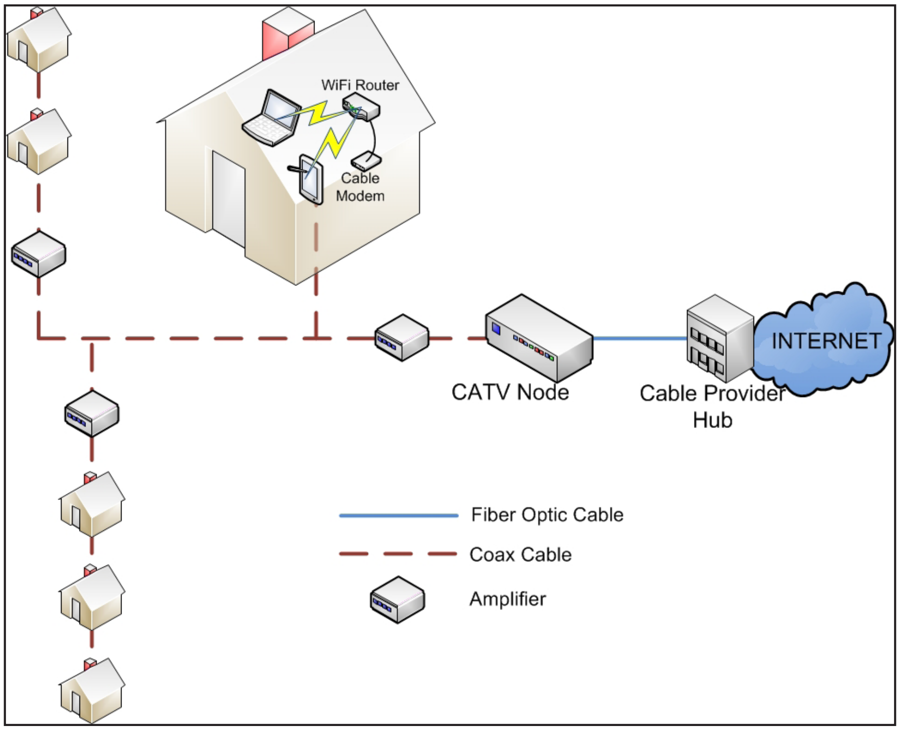
Coaxial Cable / Cable Modem Technology

After twisted-pair copper lines, the next most recognizable telecommunications infrastructure is cable. Cable television systems originated in the late 1940s and rose to popularity in the 1980s and 1990s. Cable television programming is carried into the user's home via coaxial cable. Like telephone networks, these systems have been updated to provide Internet service. Cable technology is commonly called "hybrid fiber-coaxial" or HFC. This is because most cable systems consist of fiber connections from the headend or hub facility (the cable counterpart of the telephone central office) to a "node" within a mile or less of the customer premises.

The underlying conductive material for coaxial cable is aluminum, which transmits data as electrical signals. Coaxial cable is able to conduct higher electrical frequencies, resulting in higher network capacity and faster Internet speeds than DSL. Electronic hardware upgrades can also improve the speeds the network can deliver. Yet because the base material of cable networks is the metallic cable, it is subject to a similar set of limitations as telephone lines. Cable networks are susceptible to having their electrical signals degrade sharply over distance and thus require amplifiers to regenerate the electrical signal. Transmissions over coaxial cable lines are also subject to electromagnetic interference, and signal leakage can occur if cables are damaged or connectors are loose.

Another drawback to cable broadband serivce is asymmetric speeds. When cable networks were first designed, signals only had to travel in one direction: downstream. The network's purpose was to re-broadcast television channels through the coaxial cable from a central location to individual subscribers. A small set of frequencies was allocated

Figure 3. Coaxial Cable / Cable Modem Technology



for upstream transmission, generally limited to communication with cable set-top boxes. Even after the integration of broadband, the frequencies often utilized for uploading data by subscribers remain limited. Advances in cable broadband technology such as DOCSIS 3.1 allow cable providers to repurpose other frequencies for uploading data, but these technologies are still in development, and almost all cable systems have only five percent of the total capacity in the upstream direction.

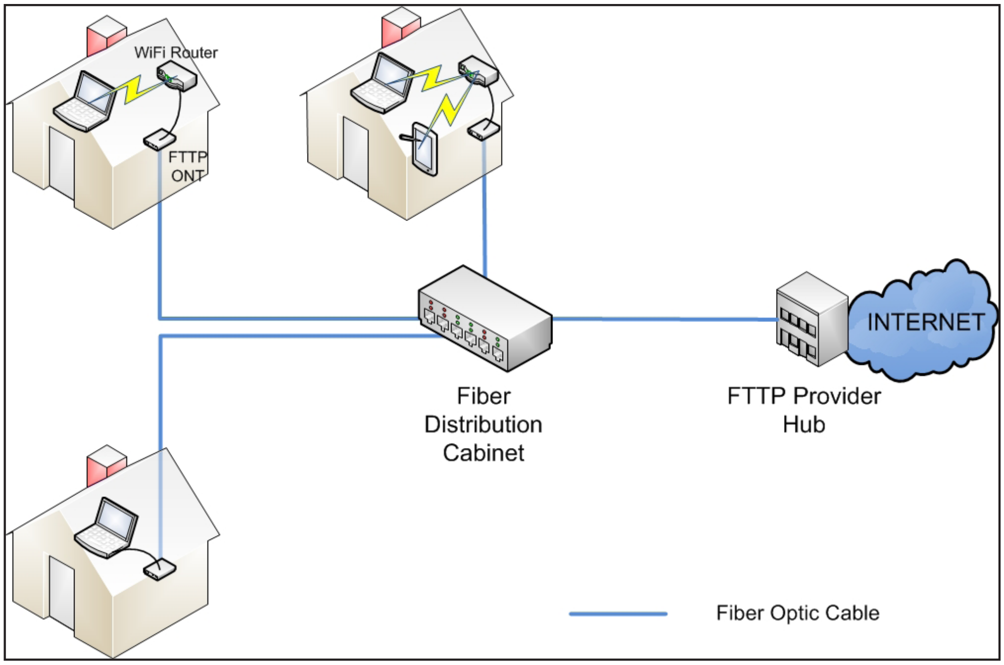
As a result, cable networks are designed to offer much faster download than upload speeds. Typical cable broadband subscription plans offer download speeds of up to 20 or 50 Mbps, but upload speeds of only 2, 4, or 10 Mbps. As is the case with DSL networks, this is an architectural design choice and the underlying infrastructure is capable of offering symmetrical service. Cable-based Internet providers are in the process of upgrading speeds, and introducing speeds of 100 Mbps or more. Future upgrades may allow cable networks to deliver theoretical download speeds of 500 Mbps or even 1 Gbps, but doing so would require cable companies to divert some capacity in the network away from television services.[20]

Fiber Optic Technology

Fiber is the newest and most advanced form of wireline communications infrastructure. Fiber cables contain thin strands of glass (or in some cases plastic). Most commercial broadband providers already use fiber in portions of their network architecture, but then connect the user over wireless, coaxial, or copper lines. Since the 1980s, fiber has been incorporated into middle-mile and backhaul connections, the lines that are used to aggregate data traffic and provide high-capacity transport between cities and across continents. Fiber optic cables have a range of fiber strands depending on the specific application—a

20 Some claim 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 200 MHz to 250 MHz assigned to upstream, leaving 600 MHz to 650 MHz for downstream. Even with 10 bps/Hz efficiency, the actual capacity for a shared node area would be closer to 6 Gbps than 10 Gbps, and the capacity will be shared among a few hundred users. *See The State of the Art and Evolution of Cable Television and Broadband Technology* [CTC Technology & Energy, October 2013]. Available at http://www.ctcnet.us/publications/the-state-of-the-art-and-evolution-of-cable-television-and-broadband-technology/ (accessed May 5, 2014).

Figure 4. Fiber Optic Technology



backbone fiber cable could have hundreds of strands. A fiber cable serving a neighborhood or a few buildings would have a few dozen strands and a cable to an individual apartment or house might have one or two strands of fiber.

Fiber carries data as a series of pulses of light, traveling from one end of the fiber to the other. This is a major change from the electrical signals of metal conductor-based networks of telephones and cable television. Fiber cables and their optical light signals do not experience most of the physical limitations of metal-based networks. Optical light signals can travel great distances with minimal signal deterioration. Typical fiber networks can carry broadband data signals up to 50 miles between electronics. The superior range eliminates the need for electrical power and equipment in the middle of most networks. Fiber networks also have lower operating costs relative to cable and DSL networks because they require less staffing and maintenance.

Fiber networks also have better reliability. With less equipment needed to operate the network, there are fewer points of failure that could disrupt communications. Optical fibers do not conduct electricity and are immune to electromagnetic interference. These properties allow optical fibers to be deployed where conductive materials would be dangerous or ineffective, such as near power lines or within electric substations. Lastly, fiber optics do not corrode due to weather and environmental conditions in the same way that metallic components can deteriorate over time.

Once installed, fiber optics have few technical limitations. The main drawback for fiber optic networks is the upfront cost and process of building out to connect institutions, homes, apartments, and businesses. The price for fiber optic cable is declining, but costs associated with labor and construction remain high. As a result, the build-out of fiber optics, especially to individual residences, is relatively limited as compared to the deployment of DSL or cable technology—because DSL and cable can leverage existing infrastructure and minimize new construction. The largest national FTTP network is Verizon's FiOS. Verizon has built the network in several major U.S. markets but has stated it has no plans to expand its service area.[21] Other FTTP networks include municipal fiber networks such as those in Chattanooga, TN; Bristol, VA; and Lafayette, LA; as well as the Google Fiber projects.

Despite the potentially high upfront construction costs, fiber networks can be continually upgraded to faster and faster speeds. Fiber provides a broad communications spectrum and has a capacity of thousands of Gbps *per individual fiber* with off-the-shelf networking hardware. Even lower-priced equipment easily provides 1 Gbps service. The main limitation on the speeds fiber networks can achieve are not based on the properties of the fiber optic cables themselves but instead on the processing power of the networking equipment connected to the network. Fiber's ability to scale has led some to describe it as "future-proof."

Fiber networks using "Active Ethernet" or comparable technologies provide symmetrical download and upload speeds, in contrast to DSL or cable broadband services. Such upload speeds are particularly useful for institutions and businesses and can readily facilitate the sharing of extremely large data files. For example, one hospital sending a patient's medical images to another hospital makes it possible to perform remote treatment and surgery and support next generation high-definition video conferencing known as "virtual presence." Fiber networks can scale to meet the demands of the next generation of Internet services and applications without a need for construction in the future to upgrade.

Wireless Technologies

Use of mobile and wireless broadband has skyrocketed since the introduction of the first iPhone in 2007. As a result, there is a growing expectation for robust and ubiquitous wireless connectivity. But just like wireline infrastructure, wireless broadband services are supported by a range of different technologies, each with their own advantages and disadvantages. This section will examine the most common technologies, including 3G/4G, Wi-Fi, and satellite.

No matter the type of wireless technology, the quality of wireless connections is affected by several factors, such as:

- the over-the-air radio frequencies or spectrum utilized
- the user's proximity to a transmission tower or antenna
- physical barriers such as buildings, trees or terrain
- weather
- the type of wireline connection at the tower or router (i.e., whether or not it is connected to a DSL, point-to-point wireless, or fiber-optic service and the speed of that connection)

The variable nature of all of these factors means that wireless performance can be unpredictable. High speeds are possible, but only if environmental and other conditions allow. It is also important to note that wireless networks are largely composed of wireline technology. For example, when a user accesses the Internet on a smartphone, the initial connection is from the device wirelessly to the provider's nearest tower. But all subsequent data transmission from the antenna onward through the network likely occurs via wireline copper or fiber networks.[22] Similarly, in a residence, a Wi-Fi router provides wireless flexibility and allows multiple users to connect to the underlying DSL, cable, or fiber broadband connection. Wireless technologies provide flexible, convenient, and mobile communication, but have tradeoffs with respect to data capacity and reliability. While the speed of mobile and wireless technologies are constantly improving, under most scenarios they are not capable of supporting applications for

21 Sean Buckley, "Verizon's McAdam: New FiOS markets are not in the cards," FierceTelecom, December 9, 2013 http://www.fiercetelecom.com/story/verizons-mcadam-new-fios-markets-are-not-cards/2013-12-09 (accessed May 5, 2014).

22 In some cases, mostly in rural areas, the backhaul connection to the tower can be a point-to-point wireless link.

telehealth, interactive distance learning, or high-definition "virtual presence" video conferencing, all of which require very large amounts of bandwidth and reliable connections.

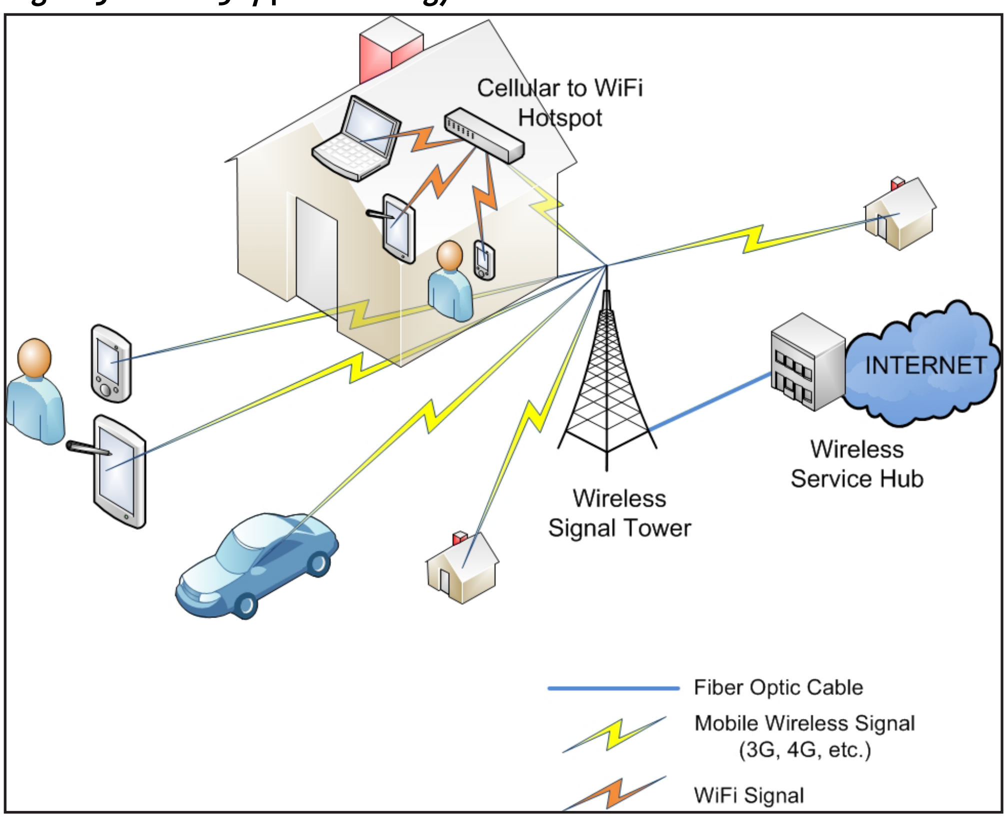
Mobile 3G/4G Technology

3G and 4G are terms used to describe a cellular provider's different mobile broadband offerings. However, 3G and 4G stand for "third-" or "fourth-generation" of mobile broadband and do not refer to specific mobile technologies. Different wireless providers employ different wireless technologies. The term 4G was originally intended to designate wireless services with 1 Gbps capability, but is now mostly a marketing term that can encompass a number of different mobile technologies. In practice, 4G refers to mobile technologies such as Evolved High Speed Packet Access (HSPA+), WiMAX, and Long-Term Evolution Release 8 (LTE) employed by wireless carriers.

The greatest advantage of 3G/4G services is mobility. With basic feature phones, smartphones, and other mobile devices the user connects to a series of antennas and base stations that are attached to cell phone towers or, in more urban settings, located on tall buildings. If placed on a mountain top or high tower with minimal line of sight restrictions, wireless services have a transmission distance of over 40 miles. However, more typically networks are designed with coverage and data capacity as the main goal, not point-to-point distance. Therefore, the transmission radius for most 3G/4G towers is about one mile. The smaller radius is intended to ensure adequate bandwidth for all customers accessing that tower, avoid scenarios in which too many individuals are competing for limited capacity, and provide the capability for users to simultaneously connect to more than one antenna.

As is the case with all wireless technologies, the main limitation on 3G/4G networks is the variability of connection quality and speeds. Typical 3G

Figure 5. Mobile 3G/4G Technology



technologies have maximum download speeds of 1 to 2 Mbps and upload speeds of less than 1 Mbps. Typical 4G technologies have theoretical maximum download speeds from 42 Mbps to 100 Mbps and upload speeds from 11.5 Mbps to 50 Mbps. The speed users actually experience in everyday use may be significantly lower due to environmental factors or how many users are sharing access at a tower. Even when a 3G/4G network is designed in small-cell radius to decrease the number of subscribers falling within coverage of the cell, the number of other user devices simultaneously trying to communicate with the antenna can cause congestion. Likewise, the technology used to connect the wireless antenna to the rest of the network, whether copper or fiber optic cable, can influence the actual data speeds available to users. Recent testing has shown that typical 4G speeds are usually between 4 to 13 Mbps download and 2 to 6 Mbps upload.[23]

3G/4G networks are most limited with regard to upload speeds. This limitation is a byproduct of the technology itself. Upload speeds will always be slower than download speeds given that 3G/4G wireless antennas are point-to-multipoint, meaning that a single antenna broadcasts a signal to many devices. This approach makes it simpler for transmission to go downstream to cellular users, from the single point out to the many devices. It is more difficult to manage incoming traffic from multiple devices to the single antenna, as is the case when users send data. In addition, power and battery limitations mean that the signal strength of transmissions from smartphones or other end-user devices is significantly weaker than signals from the tower, further limiting upload speeds unless a user is very close to a tower. Thus, 3G/4G networks will be optimized to deliver significantly faster download speeds than upload speeds. The asymmetrical service of 3G/4G networks limits the types of applications they can sustain, such as high-definition video conferencing applications or large-scale online file backup services that require access to higher upload speeds.

Wi-Fi Technology

Wi-Fi routers have become commonplace in households, offices, coffee shops, airports, public spaces. Wi-Fi is a wireless networking standard known as 802.11 developed by the Institute of Electrical and Electronics Engineers (IEEE). Wi-Fi currently operates in the United States within the 2.4 GHz and 5 GHz frequency bands allocated by the FCC for unlicensed use. This designation means that individual users do not require a license from the FCC and allows the public to purchase Wi-Fi equipment approved by the FCC and operate it freely. This is different than 3G/4G networks that have equipment designed to only operate on the frequencies where a mobile operator has a license, typically purchased at an auction carried out by the FCC.

There are advantages and disadvantages to operating on unlicensed spectrum. With worldwide access to those frequencies, manufacturers of Wi-Fi equipment can take advantage of significant economies of scale, as equipment does not need to be designed for a single operator or licensee. As a result, Wi-Fi equipment is substantially less expensive than 3G/4G technology. In addition, Wi-Fi has access to larger and more contiguous frequencies compared to most licensed frequencies, which are broken into smaller and more discrete sections in order to allow multiple operators to obtain exclusive licenses. The shared common pool of frequencies in the 2.4 GHz and 5 GHz bands allows Wi-Fi devices to operate on wider channels to increase capacity and speeds. Most Wi-Fi equipment offers maximum download and upload speeds between 50 and 100 Mbps and updates to the 802.11ac standard could allow for maximum speeds up to 500 Mbps.

23 Mark Sullivan, "TechHive's Wireless Week: Testing America's Networks," *TechHive*, May 20, 2013, http://www.techhive.com/article/2039053/techhives-wireless-week-testing-americas-networks.html (accessed May 5, 2014).

The drawback of operating on unlicensed spectrum is that Wi-Fi devices must co-exist with other Wi-Fi devices in the band as well as other unrelated consumer devices. For example, in the 2.4 GHz band, Wi-Fi devices share spectrum with garage door openers, TV remote controls and microwave ovens. These devices create interference in the band that can inhibit the performance of Wi-Fi connections. The density of other Wi-Fi devices in the area can also have an impact. The Wi-Fi standard has a built-in contention protocol to manage this issue. Wi-Fi devices are designed to detect other Wi-Fi devices and not broadcast at the same time. However, too many Wi-Fi radios operating in a small area and all on the same frequencies can cause significant performance degradation.

The FCC also has regulations on operation within the unlicensed bands used by Wi-Fi that include limitations on transmit power in order to accommodate more devices and users in the band. Thus, Wi-Fi networks have limited range compared to 3G/4G networks. High-end Wi-Fi routers have a range of around 800 feet, or approximately one to two city blocks. These devices are called "omnidirectional" in that they broadcast their signal equally in all directions. Directional Wi-Fi antennas that broadcast their signal focused in a single path can have a range of 2 to 4 miles, depending on environmental conditions. Further limiting the range is the fact that Wi-Fi utilizes higher frequency spectrum, where signals cannot penetrate walls and foliage or travel as far as signals operating at lower frequencies.

Wi-Fi was designed as a wireless local area networking solution, and is therefore ideal for supporting and sharing connectivity over a small area such as a home, office, campus, or public park. It is largely a complementary technology to a wireline connection; thus, the speeds a Wi-Fi connection provides are usually a reflection of the speeds of the underlying DSL, cable, or fiber optic connection that connects to a router that then provides connectivity to end-user devices. Over small areas and with a small number of users, Wi-Fi networks can support most widely available Internet applications including higher bandwidth streaming video or video conferencing depending upon the speed of the wired connection at the router. However, as one expands the coverage area and adds more users, a Wi-Fi network's ability to support higher-bandwidth uses diminishes and it offers connectivity and speeds similar to 3G/4G service.

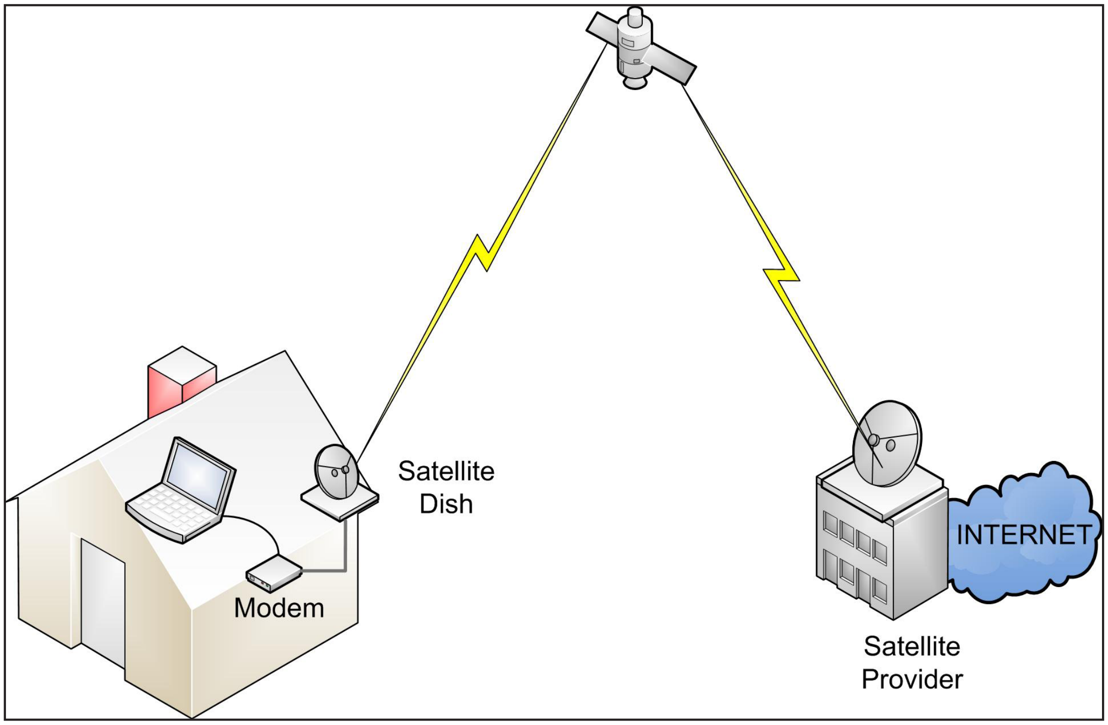
Satellite Broadband Technology

Internet satellite service is available to any potential customer who can install a satellite dish and has an unobstructed view facing the part of the sky where the satellite orbits. As a result, satellite service is typically cited as an option for rural residents who do not have access to wireline services such as fiber, cable, or DSL. The greatest benefit of satellite service is its ability to provide connectivity to the most remote areas, since it can serve areas that have no wireline infrastructure. The capacity and speeds of satellite service have increased with improvements in the technology. However, compared with wireline technologies, satellite service is fundamentally constrained by unavoidable physical properties and the number of users it must accommodate.

Traditional satellite Internet service is limited by the technology. The distances involved in sending signals to and from satellites create delays in the transmission. This delay is known as latency in networking terminology. Latency can make certain online activities difficult or impossible for satellite users.[24] Trying to conduct an online video conference over a connection with high latency will result in the video appearing choppy, broken, and otherwise unusable. Satellite communications also create challenges for VoIP, multiplayer online gaming,

24 The company O3b is deploying a low-orbit satellite Internet service that will have much lower latency than traditional geosynchronous orbit satellite Internet service. O3b's service is deployed in orbit above the equator and intended for use in the developing world. It will not be available at higher latitudes on Earth. See http://www.o3bnetworks.com/

Figure 6. Satellite Broadband Technology



and accessing a virtual private network (VPN). Even satellite Internet providers themselves caution against using these applications in conjunction with their services.[25] Satellite signals are also affected by environmental conditions. For example, heavy cloud cover can block transmission.

Satellite networks are susceptible to congestion as well. In the same way that 3G/4G service is affected by too many customers using the same towers simultaneously, satellite service is affected by the numbers of users who simultaneously access the same satellite. Standard satellite Internet service offers download speeds of up 15 Mbps with much slower upload speeds of 2 to 3 Mbps. However, given the high number of users a single satellite must accommodate, the service usually has significant caps or limits on how much data a single subscriber can consume. The highest-priced plans provide only 25 GB of data a month for residential subscribers, or a maximum of 45 GB for business plans. By comparison, wireline home broadband services have monthly limits of 150 to 300 GB of data, if they have any data limits at all. Monthly subscription fees for satellite connections are also nearly three times as expensive as comparable plans from cable providers.[26]

TV White Space Technology

In 2009, the FCC approved the use of unused portions of the broadcast television spectrum for wireless broadband, referred to as "super Wi-Fi" by the past Chairman. The authorization allows new wireless hardware to use vacant television frequencies called TV white space (or simply white spaces). Devices must check an approved database to determine what frequencies are open in a local area. Rural areas, with few television broadcasters, have large amounts of TV white space, making them particularly attractive areas for deployment using this technology. Even in urban areas where the broadcast spectrum is more

25 See 'Are there activities that are not recommended for use with a satellite connection?' "High-Speed Broadband Satellite Internet FAQs" HughesNet. http://www.hughesnet.com/index.cfm?page=FAQ (accessed May 5, 2014).

26 For example, ViaSat Exede's Internet service includes 12 Mbps download, 3 Mbps upload speeds and 25 GB cap for $130/ month. HughesNet's Internet service includes 15 Mbps download, 2 Mbps upload speeds and 40 GB cap for $130/ month Time Warner Cable charges $34,99/month (for the first 12 months) for a 15 Mbps download, 1 Mbps upload service. Comcast charges $39,99/month (for the first 12 months) for a 25 Mbps download, 5 Mbps upload service.

heavily utilized, there are often unused channels available.

The goal of allocating the TV white spaces band for unlicensed use is to create a market, similar to Wi-Fi, for approved equipment that the public can purchase to utilize these frequencies. The main advantage over current Wi-Fi access is that signals operating on frequencies in the TV band have much better transmission qualities than the frequencies used by current Wi-Fi devices. The signals can penetrate physical obstructions, like exterior building walls and foliage, that block Wi-Fi and satellite signals. Signals can also travel greater distances at lower power, so larger areas can be covered by a network.

Since TV white space technology is in an early phase of development, the capabilities of the technology are somewhat uncertain. White space equipment supporting broadband is expected to be able to support point-to-point connections up to 7.5 miles between antennas and broadband service speeds of up to 12 Mbps over a standard TV channel of 6 MHz. Access to additional channels can increase the overall capacity of a network and accommodate more users at the 12 Mbps rate. As a result, the capacity of the network will depend upon the number of open channels in a given area.

Initial deployment of TV white space devices will likely focus on fixed wireless networks, including point-to-point connections to individual homes, institutions, or communities, with service to the user over Wi-Fi, since smartphones, tablets, and laptops do not yet have the chips and antennas to receive white space signals. For example, pilot TV white space networks have focused on connecting remote schools and libraries to institutions with Internet access. The greatest limitation around white space technology is that it is still largely under development. It is also uncertain how much channel capacity will be available to TV white space devices. The FCC is currently developing plans to free up more of the TV spectrum to auction to mobile operators. There are also discussions underway to potentially add more frequencies outside of the TV band to the FCC approved databases, meaning TV white space devices could be designed to operate in those additional frequencies as well as those within the existing TV band.

Figure 7. Bandwidth Needs of Individual Broadband Applications

	56 Kbps	768 Kbps	1 Mbps	10 Mbps	20 Mbps	50 Mbps	100 Mbps	1 Gbps
Download MP3 music file (4 MB)	Poor (10 min.)	OK (42 sec.)	Good (32 sec.)	Good (3 sec.)	Best (1 sec.)			
Online software purchase (500 MB)	Poor (20 hr.)	Poor (87 min.)	Poor (67 min.)	OK (7 min.)	Good (4 min.)	Good (80 sec.)	Good (40 sec.)	Best (1 sec.)
HD movie download (5 GB)	Poor (9 days)	Poor (15 hr.)	Poor (12 hr.)	Poor (67 min.)	OK (34 min.)	Good (14 min.)	Good (7 min.)	Best (40 sec.)
Skype video call	Poor	OK	Good	Best				
Stream HD video	Poor		OK	Good	Best			

Figure 8. Bandwidth Needs of Institutional Broadband Applications

	56 Kbps	768 Kbps	1 Mbps	10 Mbps	20 Mbps	50 Mbps	100 Mbps	1 Gbps
Video-conference between two users	Poor	OK		Good	Best			
Online higher education courses	Poor			OK	Good	Best		
Video-conferencing with several users	Poor			OK	Good	Best		
Telehealth (Remote X-rays, HD video consultations)	Poor					Good		Best

Chapter 3: Public Network Business Models

This chapter is intended to provide local governments with an overview of several different business models for a public broadband network. As was discussed above in regard to ownership models, communities need to balance control, risk, and reward when evaluating which model will most likely meet their goals. Communities also should perform a robust feasibility analysis to demonstrate that a business case exists and that social and economic goals will be realized through a particular business model. It is important to note, however, that all such projects and business models entail financial and other risks for the community—at the same time as enabling enormous direct and indirect benefits.

We begin with a brief overview of different business models for a public fiber network. We then provide a more detailed list of the potential operational costs for two network business models: 1) an "institutional/middle-mile" model where the network provides services to government and community anchor institutions, with the ability to lease excess capacity to private providers, and 2) a "retail" model, in which a local government becomes a competitive provider of broadband services, potentially including voice, video and data.

Retail Service

In this model, a local government builds a fiber-to-the-premises (FTTP) infrastructure and offers retail phone, video, and Internet services to businesses and residences. In terms of direct financial factors, a "pure" retail FTTP network operated by the community entails more significant risks than other business models because of the size of the upfront capital commitment necessary and the ongoing operating costs to run the network. In this business model, the locality may also be an "over-builder," providing services in competition with the existing phone and/or cable incumbents. Although the potential exists for the community to obtain sufficient market penetration and cash flow to sustain the network, this can be a significant challenge, particularly when well-resourced incumbent providers can aggressively market or discount services in response to the entry of a public provider.

Open Access

In this model, the local government builds, owns, and maintains fiber optics all the way to homes and businesses. Rather than becoming a provider serving the public, however, it leases access to private providers who then offer services directly to the public. Under the open access model, the community can operate and maintain the fiber and the transport electronics, or it can contract these tasks out to a private sector partner. Private providers then lease access to the infrastructure which they use to deliver phone, video, and Internet services.

Thus a "wholesale" or "open access" model separates the infrastructure from the retail service. In this way, the community addresses the high cost of market entry for providers and facilitates the ability of multiple providers to serve residents and businesses over the same infrastructure. The result is the potential for new competition.

The business model involves significant risk with respect to recovery of project costs through network revenues. A number of factors outside the control of the local government, including the interest of retail providers in offering services over the network and the retail providers' marketing success, have the potential to reduce revenues below break-even cash flow needs.

Institutional/Middle-Mile Model

In this model, a local government builds a network focused on connecting government and community anchor institutions, including government agencies, schools, libraries, and hospitals. It can also lease out excess capacity to private providers offering services to the public.

This model requires a smaller capital investment than does more extensive FTTP deployment. Experience also suggests that the community can realize a modest revenue stream by leasing parts of the network while at the same time reducing its own cost of purchasing communications services from private providers. This model requires less involvement in operations than does a retail model because it does not require a local government to go into the business of providing communications services itself. Though this model has the potential to benefit some business customers, it is unlikely to address the needs of most residents and small businesses. The model offers some incentives for a private provider to construct its own infrastructure, but may not be enough to attract private sector investment in a community-wide FTTP network because it lowers the cost of outside plant construction by only a few percent.

Examples of Cost Savings from Local Institutional/Middle-Mile Networks

The following local governments, school districts, or other anchor institutions were able to realize substantial cost savings by shifting their broadband services from private providers to local options.

- Santa Monica, CA operates its own institutional network in conjunction with the school district and a local college. By self-provisioning their bandwidth needs instead of purchasing commercial services, within a few years of operation the three local partners were saving a combined $500,000 *annually* on their telecommunication service budgets.[i]
- Martin County, FL operates an institutional network among several local partners. The school district in Martin County saves over $82,000 annually purchasing services from this local network rather than from commercial entities. Once the school district's share of capital investment payments for the local fiber network is completed in 2017, the annual IT budget savings are expected to grow to $340,000 annually. In addition to substantial savings, the local network also provides the school system with superior networking speeds of 1 Gbps.[ii]
- Martinsville, VA saves approximately $140,000 on telephone services alone by self-provisioning services over the local fiber network rather than leasing from a private provider.[iii]
- The City of Greenacres, FL saves over $24,000 a year, while increasing bandwidth capacity sixfold by switching their service from a commercial provider to a locally owned county fiber network.[iv]
- Highland Public School system, located in Medina County, OH, saves $82,000 a year after switching broadband service to a local municipal network.[v]
- In Royal Oak, MI, a suburb of Detroit, the municipal government and school district are partnering on constructing a local fiber network to serve their sites. The school district estimates that self-provisioning their broadband will save them over $114,000 annually.[vi]

i – Masha Zager, "Santa Monica City Net: How to Grow a Network," *Broadband Communities Magazine*, May/June 2011, p. 44 – 47.
ii – Lisa Gonzalez and Christopher Mitchell, *Florida Fiber: Martin County Saves Big with Gigabit Network*, [Institute for Local Self-Reliance, June 2012].
iii – Lisa Gonzalez, "Broadband Boosts Economy in Southern Virginia," *Community Broadband Networks*, June 14, 2012, available at: http://www.muninetworks.org/content/broadband-boosts-economy-southern-virginia
iv – Lisa Gonzalez, "Greenacres Florida Connects to Palm Beach County Network," *Community Broadband Networks*, July 5, 2012, available at: http://www.muninetworks.org/content/greenacres-florida-connects-palm-beach-county-network
v – Lisa Gonzalez, "Highland Schools in Ohio First to Connect to Medina County Fiber Network," *Community Broadband Networks*, July 19, 2012, available at: http://www.muninetworks.org/content/highland-schools-ohio-first-connect-medina-county-fiber-network also see; Lisa Gonzalez, "Medina County, Ohio Celebrates Fiber Network Completion," *Community Broadband Networks*, May 1, 2013, available at: http://www.muninetworks.org/content/medina-county-ohio-celebrates-fiber-network-completion
vi – Lisa Gonzalez, "City and School District Team Up for Fiber in Royal Oak," *Community Broadband Networks*, April 18, 2013, available at: http://www.muninetworks.org/content/city-and-school-district-team-fiber-royal-oak-michigan

Infrastructure Participation

Most local governments own assets in key locations that could reduce FTTP deployment costs for private providers. Construction costs could be reduced through use of such assets as fiber optics, communications conduit, and facilities. In this model, the public sector makes available to a private sector entity, for lease, selected assets that will enable the private entity to more efficiently and expeditiously build and operate a network. Extending fiber into business parks and selected neighborhoods could provide some attraction to a private sector investor or operator. The model seeks to encourage private investment. However to attract an investment, public financing guarantees may be required—entailing public risk, with limited control.[27]

A Comparison of Operational Costs for Institutional and Retail Public Fiber Networks

The following section presents a high-level overview of the types of operational costs involved in the two types of public fiber network business models described above: 1) institutional or middle-mile networks serving government facilities and community anchor institutions, and 2) fiber-to-the-premises networks serving residents and business customers. Costs will vary from community to community and network to network and cannot be precisely measured without custom analysis. Rather than offering precise numbers, this section is meant to provide a general overview of the range of operational costs of different public network models.

Institutional/Middle-Mile Networks

Operating costs will vary dramatically based on the business model selected, services offered, performance of services offered (best-effort data rates vs. committed interface rates), customer support levels (8am-5pm weekdays vs. 24/7), market size (number of subscribers and geographic footprint of service area), and other factors. Some of the key cost areas are summarized below. Legal fees are not included in this list, but will likely be an essential budget item to consider.

Community outreach and marketing: If a network plans to serve only community anchor institutions this cost should be relatively low. A need exists to work with the anchors to understand changes in their needs or expectations, as well as any changes in their locations or other plans. A broader network offering that includes providing last-mile transport services will require greater outreach and an ongoing marketing effort.

Staffing: Networks need technicians to manage and maintain the physical infrastructure. The phrase 'outside plant' refers to the physical cable and lines of the network. Outside fiber plant typically requires one technician per 80 to 100 route miles of plant. This function can also be contracted out. Network management staff depends upon the size of the network (miles) and number of locations served. Network management staffing requirements range from an internal allocation of existing staff from a local government information technology department, to the addition of one to three new staff members.

Network operations center (NOC): Network operations centers include staff who monitor network conditions and ensure levels of service quality and reliability. Contracting NOC services can range from $2,000 per month to well over $20,000 per month. Factors that will impact the cost include route miles, number of access points, number of connected users, type and expectations of users, hours of support, and level of troubleshooting conducted.

Maintenance: If fiber maintenance is done internally the majority of this cost becomes a staffing expense. Locates for underground plant (the requirement to identify and mark existing plant when construction is underway nearby so as to avoid construction-related damage to existing infrastructure) will be an ongoing expense. For aerial plant, pole attachment fees represent a

27 Detailed discussion of this model and related strategies can be found in the following report: Joanne Hovis and Andrew Afflerbach, *Gigabit Communities: Technical Strategies for Facilitating Public or Private Broadband Construction in Your Community*, [CTC Technology & Energy, January 2014]. Available at http://www.ctcnet.us/wp-content/uploads/2014/01/GigabitCommunities.pdf (accessed May 5, 2014).

continuing operational cost. Maintenance fees for hub and network electronics can exceed 15 percent of the accrued electronic investment.

Internet: The size of a data pipe to the Internet will vary according to the levels of oversubscription rates and bandwidth sharing on a network. For example, a city warehouse may be served adequately by a connection with an oversubscription ratio of 50 to 1 (meaning the bandwidth is shared among a large number of other sites), while more data-intensive anchor institutions may require a one-to-one ratio (meaning a set level for each site). The cost of commodity bandwidth varies greatly across the country. In locations that have competitive backhaul markets, access can be less than $1 per month per Mbps—while less competitive market can see prices of more than $40 to $80 per month per Mbps.

Fiber-to-the-Premises (FTTP)

As with an institutional network, operating costs for a FTTP network will vary dramatically based on the business model selected (retail, open access), services offered (broadband only, triple play), performance of services offered (best-effort data rates vs. committed interface rates), customer support levels (8am-5pm weekdays vs. 24/7), size of market (number of subscribers and geographic footprint of service area), and other factors. Some of the key cost areas are summarized below. Legal fees are not included in this list, but will likely be an essential budget item.

Staffing: Sales and marketing staff are critical to the success of the business. Staffing requirements are highly dependent upon the local market; the more competitive the market, the greater role sales and marketing will play. The same rule applies for more innovative services, which require more consumer education to build demand. The ability to leverage other community resources will also impact the required sales and marketing staffing and effort. A contract administrator might be required if the operation provides high-end data services, dark fiber, and other specialized services.

Technical staff requirements will vary based on the services offered, which services are hosted, number of shifts, and other factors. For example, if the locality maintains its own cable television headend, the network will need at least one technician for its maintenance. The same is true for the broadband offering. Are the servers located on-site or are they part of a wholesale service provided by another vendor? Requirements for field and support technicians can vary from one per 2,000 customers to one per 3,500 customers per shift. In addition, the operation may need a systems administrator and supporting staff. Customer service representatives and help desk support often range from one per 2,000 customers to one per 3,500 customers per shift. Outside fiber plant typically requires one technician per 80 to 100 miles of route miles of plant. This function can also be contracted out. Staffing costs also need to include ongoing training and other overhead costs.

Internet: The size of the data pipe to the Internet and ultimate bandwidth cost per subscriber will vary according to the level of oversubscription and bandwidth sharing on the network. For example, a residential-class broadband service may have an oversubscription ratio of 50 to 1, while some data-intensive businesses require a one-to-one ratio. Further, the cost of commodity bandwidth varies greatly across the country. In locations that have competitive backhaul markets, access can be less than $1 per month per Mbps, while less competitive markets can see prices of more than $40 per month per Mbps.

Billing: The cost of billing will vary based on the services and options offered. Billing for a data-only service can be relatively easy and cost less than $1 per month per subscriber. Billing for cable television and telephone services is more complex and require additional capital and operating costs.

Maintenance: If fiber maintenance is done internally the majority of this cost becomes a staffing expense. For underground plant, an additional expense will arise from "locates." For aerial plant, pole attachment fees represent an ongoing operational cost. Ongoing maintenance fees for hub and network electronics can exceed 15 percent of the accrued investment in the equipment.

Telephone service: Most public systems offering telephone services today will find a partner to provide the interconnection to the public telephone network. This is typically negotiated on a case-by-case basis in the local market. The fees can often exceed 50 percent of the retail service price.

Video content: Fees for video content depend upon two factors: number of subscribers and the channels offered. Each cable operator must negotiate the right to place a given channel in its lineup. Operators pay the content owners a monthly fee per subscriber rather than a flat fee. Content fees continue to rise at a faster rate than other expenses. Small cable operators have limited buying power and typically do not have a content ownership stake (like some large cable operators), so they are often forced to sell cable services at a breakeven point or, worse, as a loss leader.

Bad debt and collections: In the retail market, some residential customers will move without paying their final bills and some businesses will go bankrupt or otherwise close their doors. In some communities, the bad debt percentage can remain relatively low (under 0.5 percent of revenues); in more challenging circumstance, losses can rise to as much as three percent of revenues or more.

Churn: Residential customers tend to respond to promotional offers. Some communities also have a high resident turnover. Customer churn rates can range from a few percent per year to more than one percent per month. Churn costs include the cost of acquiring and hooking up a new customer, less any connection fees charged. In a competitive market, most customer connection charges are waived, so churn can cost an operator more than $400 for each new customer acquired.

Equipment replacements: Any equipment under the locality's control is relatively secure, so replacements are scheduled at predictable intervals and funded through depreciation accounts. If the service has customer premises equipment, that equipment is subject to theft and damage.

Chapter 4: Economic, Educational, and Healthcare Benefits "Beyond the Balance Sheet"

Any significant public infrastructure project requires detailed financial analysis to calculate a return on investment. Public broadband projects are no exception to this business practice. However, project-specific cash flow estimates should not be the exclusive metric for evaluating the benefits of public broadband infrastructure. Local governments should consider defining their success more broadly to include the "benefits beyond the balance sheet"—the intangible societal rewards that broadband offers the community as a whole and delivers to individual citizens. While economists like to call these benefits "positive externalities," it is our view that these are foundational to public broadband projects, rather than "external," and should be named accordingly.

This chapter provides a general discussion of a range of those intangible benefits that may inform an evaluation of a public broadband project. The benefits will vary depending upon the design of the network, who it serves, and what applications it supports. Local governments are in the business of administering services to meet the needs of their residents: providing education, building and maintaining roads, overseeing public safety, and maintaining parks and recreation. Broadband is the latest essential tool that can support public goals. Improved local access to broadband can have positive impacts for communities that are not captured on a network's revenue and expense calculations. Broadly, these indirect benefits can include encouraging economic development, increasing property values, enhancing health care quality, narrowing the digital divide, providing enhanced educational opportunities, and enabling job search and training opportunities. Some of these benefits are explored in greater detail below.

Economic Development

Local infrastructure has long played a central role in business development. In previous eras, whether a town was included on a railroad network impacted which businesses would choose to locate there and how the local economy would develop. Today access to major roads or highways still plays a central role to commercial development—and these same principles hold true for broadband.[28] As William Lehr of MIT summarized in a 2012 paper on broadband infrastructure, "a growing body of empirical evidence attests to the significant contribution of broadband to economic growth, productivity improvements, and job creation."[29]

Today, most businesses consider broadband an important local resource.[30] Growing evidence shows that broadband availability and affordability is now a significant factor for businesses, putting it on par with transportation infrastructure and a skilled local workforce.[31] Major local businesses are an important constituency to engage when first assessing the feasibility of a public broadband project. Companies that are the largest area employers, particularly if they are the branch of a larger national or international firm, typically have very advanced broadband and

28 Sharon E. Gillet, et al., *Measuring the Economic Impact of Broadband Deployment*, [MIT's Communications Futures Program, February 2006]. http://cfp.mit.edu/publications/CFP_Papers/Measuring_bb_econ_impact-final.pdf (accessed May 5, 2014).

29 William Lehr, *Anchor Institutions Help Secure Broadband's Promise*, [Massachusetts Institute of Technology 2012]. 6. Available at: http://www.shlb.org/resources (accessed May 5, 2014).

30 Joan Engebretson, "Comcast study: Broadband boosts real estate metrics," *Connected Planet*, September 26, 2011. http://blog.connectedplanetonline.com/unfiltered/2011/09/26/comcast-study-broadband-boosts-real-estate-metrics/ (accessed May 5, 2014).

31 Ken Demlow, "Proving a Link Between Broadband and Economic Development," *Broadband Communities Magazine*, March/April 2012, 68-70. http://bbpmag.com/2012mags/march-april/BBC_Mar12_ProvingLink.pdf (accessed May 5, 2014); *also see*, Ken Demlow, "Broadband and Economic Development in Appalachia," *Broadband Communities Magazine*, August/September 2012, 40-42. http://www.bbpmag.com/2012mags/aug_sept/BBC_Aug12_Appalachia.pdf (accessed May 5, 2014).

telecommunication needs. Though broadband is a central part of any package to attract or retain businesses, it does not in and of itself guarantee success in economic development—nor did rail or highway access in previous centuries. Rather, communities where there is an absence of sufficient broadband service will be at a significant disadvantage for attracting and retaining businesses and will likely have difficulty encouraging the development of new local businesses.

Bristol, VA was one of the first communities to launch a municipal broadband network. The enhanced connectivity the network can offer has been a central component to several local economic development success stories. Large firms like Northrop Grumman and CGI (an international IT and business process service firm) located facilities in the Bristol area, creating a total of 700 jobs, 30 percent of which went to local residents.[32] Alpha Natural Resources, after a merger with another company, decided to retain its headquarters in Bristol because of the local broadband resources available, keeping hundreds of jobs in the region.[33] While Bristol's OptiNet service uses a full retail model serving residences and businesses, targeted connectivity to support individual large-scale businesses and commercial industrial park sites can also be part of the mission of more city-focused or institutional community broadband projects.

Santa Monica, CA has a municipal institutional/middle-mile network that offers dark fiber lease agreements to individual local businesses and ISPs. The fiber network traces its history back to the late 1990s. Based on the initial success of the network, Santa Monica leaders decided to expand. They surveyed local businesses to see if their broadband needs were being met and found that businesses did not have access to, or could not afford, the higher bandwidth connections they required.[34] In the past few years, Santa Monica's network and the ultra-high-speed and affordable access it provides have been recognized as a critical asset for local businesses.[35] The network is particularly valuable for companies that work in digital content, such as video production or online game developers. As Brad Cox, chair of a local business development group, notes in an article about the top employers in Santa Monica "[Businesses with digital content] have huge files they move back and forth amongst production units. Dark fiber is a competitive advantage for them."[36]

Larger businesses and firms specializing in digital media are the most obvious beneficiaries of high bandwidth, but improved broadband access can also be a boon to small and home-based businesses. These are the businesses whose bandwidth demands may resemble those of residential households more so than large industrial businesses and who currently subscribe to traditional business-class services. LUS Fiber, the local utility operating the municipal fiber network in Lafayette, LA, created a series of online videos with customer testimonials featuring local small businesses.[37] In one video, a local Web designer notes how he can work more productively as a result of the network's high speeds and symmetrical upload capacity.[38] In another, the general manager of a local hotel explains how the fast and reliable broadband access is an important marketing point for attracting guests on business travel and hosting conventions.[39] A local photographer explains how, thanks to symmetrical upload speeds, he can now share photos with clients more quickly: "what I used

32 Christopher Mitchell, *Broadband At the Speed of Light*, p. 14-15.
33 Christopher Mitchell, *Broadband At the Speed of Light*, p. 14-15.
34 Masha Zager, "Santa Monica City Net: How to Grow a Network," *Broadband Communities Magazine*, May/June 2011, 44-47. http://www.bbpmag.com/2011mags/mayjune11/BBC_MayJun11_SantaMonica.pdf (accessed May 5, 2014).
35 "Top 25 Innovations in Government – Ash Center," Harvard University, Ash Center for Democratic Governance and Innovation. Updated May 2, 2011 http://www.ash.harvard.edu/Home/News-Events/Press-Releases/Innovations/Top-25-Innovations-in-Government-Announced/Top-25-Innovations-in-Government (accessed May 5, 2014).
36 Ashley Archibald, "Top 10 Employers Show Stability, Growth," *Santa Monica Daily Press*, April 22, 2013, http://smdp.com/top-10-employers-show-stability-growth/121371 (accessed May 5, 2014).
37 "LUSFiberLafayette – Youtube," YouTube, LUS Fiber account page, https://www.youtube.com/user/LUSFiberLafayette/videos (accessed May 5, 2014).
38 "LUS Fiber Business Testimonial - Daniel Kedinger," YouTube, LUS Fiber account, https://www.youtube.com/watch?v=KLDxd3HR7Rs (accessed May 5, 2014).
39 "Joddy Cormier Testimonial," YouTube, LUS Fiber account, https://www.youtube.com/watch?v=Y3NuMUQ5EVY (accessed May 5, 2014).

to do overnight, I do over lunch."[40] It can be difficult to quantify benefits such as these, but enabling small businesses to expand and operate more efficiently represents a considerable "off the balance sheet" benefit for the local economy.

Additional economic development benefits can accrue when the network is built out to the entire community. For example, residents with fast and reliable access can telecommute, the feasibility of which is contingent on a home broadband connection that can support work-related online applications like accessing a VPN, transferring large data files, and participating in high-quality video conferencing. Access to broadband capable of supporting these uses allows rural communities to retain telecommuting residents.[41] Similarly, robust home connectivity also empowers companies that utilize virtual workplaces such as virtual calling centers. For example, DirecTV chose Bristol, VA as the location for a virtual call center because of the city's municipal broadband network.[42] Powell, WY, although rural and isolated, has attracted employers such as Alpine Access, a virtual call center management firm, to hire residents because of Powell's FTTP network.[43]

Educational Outcomes

A significant number of the nation's schools suffer from inadequate Internet access and insufficient bandwidth, which precludes creative and expansive online learning or collaborative work. A 2010 FCC survey of schools receiving support from the Universal Service Fund's E-rate program found that nearly 80 percent of respondents reported that their broadband connections do not fully meet their needs.[44] Outdated local telecommunications infrastructure is one reason why schools are struggling to meet their broadband needs. Many schools still rely on limited copper wire-based connections that, while considered advanced in the 1990s, are now inadequate. Cost is another factor: the same 2010 FCC survey of schools indicated that even if better bandwidth options were available, high costs could serve as a barrier to adoption.[45]

More teachers and students are browsing and using the Internet simultaneously, leading to a growing demand for bandwidth. As online content becomes standard in all classrooms, school administrators must ensure their networking facilities can accommodate such concurrent usage demands. In May 2012, the State Educational Technology Directors Association (SETDA), an organization which recommends future bandwidth targets for schools, released a compelling report on ultra-high-speed broadband access to U.S. K-12 schools. For every 1,000 combined students and staff SETDA recommend that there should be 100 Mbps of bandwidth available by the 2014/15 school year, a target which should rise to 1 Gbps by 2017/18.[46] As Christine Fox, one of the authors of the SETDA report, states:

> Students shouldn't go to school and wonder, if they turn on the light, is it going to dim the light in another room? They also shouldn't wonder, if they go to download a video, is it going to slow the access to the classroom across the hall?[47]

The main driver of bandwidth demand is not a specific application or new product. Rather, it is the fact that more classrooms are online and those classrooms each have more and more connected devices.

40 "Travis Gauthier Testimonial" YouTube, LUS Fiber account, https://www.youtube.com/watch?v=xr22eXUabGg (accessed May 5, 2014).
41 Martha Zager, "Electrical Co-ops Build FTTH Networks," 19.
42 Christopher Mitchell, *Broadband At the Speed of Light*, p. 15.
43 Steven Ross and Masha Zager, *What Fiber Broadband Can Do For Your Community*, BroadbandCommunities, Fall 2013, 21. Available at: http://bbcmag.com/Primers/BBC_Aug13_Primer.pdf (accessed May 5, 2014).
44 "FCC Releases Data from E-rate program and Broadband usage survey," Federal Communications Commission, January 6, 2011. http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-303959A1.pdf (accessed May 5, 2014).
45 "FCC Releases Data from E-rate program and Broadband usage survey," Federal Communications Commission, January 6, 2011. http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-303959A1.pdf (accessed May 5, 2014).
46 Christine Fox, et al., *The Broadband Imperative: Recommendations to Address K–12 Education Infrastructure Needs*, [Washington D.C.: State Educational Technology Directors Association, May 2012], http://www.setda.org/web/guest/broadbandimperative (accessed May 5, 2014).
47 Grant Gross, "Education group: Schools need 100Mbps per 1,000 broadband users," *ComputerWorld*, May 21, 2012, https://www.computerworld.com/s/article/9227379/Education_group_Schools_need_100Mbps_per_1_000_broadband_users (accessed May 5, 2014).

Some schools and colleges have experimented with giving students laptops or tablets and others are experimenting with "bring your own device" (BYOD) initiatives, where students use their existing laptops, tablets, or smartphones for classroom learning. A mobile learning report found that about half of high school students and 40 percent of middle school students have a smartphone or tablet—a 400 percent increase from 2007.[48] Assuming continued growth over the next five years, student use of mobile devices will significantly increase bandwidth demands on K–12 networks.

A growing number of states are also beginning to administer student academic achievement testing online. SETDA reports that at least 33 states are already delivering at least one test via technology. Moreover, the Department of Education is advocating for a greater use of online testing through the Common Core State Standards initiative, which requires schools in 46 states and the District of Columbia to "administer 'next generation' assessments almost exclusively online."[49] The new assessments for the "Smarter Balanced" and "Partnership for the Assessment of College and Career Readiness" (PARCC) consortia will be conducted electronically in 2014.

National guidelines require that once such online assessments are implemented, all students in a grade must take the tests (which may include high-definition videos and sound files) simultaneously,[50] leading to greater network traffic during testing. In fact, as the Center for Digital Education explains, "adherence to Common Core guidelines will force school districts across the nation to rethink the way they handle networking and computing in a number of mission-critical areas."[51] At the FCC's March 2013 Gigabit Challenge public workshop, Dr. Kecia Ray, a representative of the Nashville, TN public school system, noted that when students were engaged in online testing, the school district would issue an order to all other school staff to cease their online activity in order to preserve bandwidth.[52]

Distance learning, or remote education, requires high bandwidth in order for teachers and students in different locations to participate in the same class through online video conferencing. Students can take language classes offered at neighboring schools without having to physically commute during the day, or sign up for advance placement classes even if such courses are not offered at their own schools. At the FCC's March 2013 workshop, William Wallace, executive director of the U.S. Ignite initiative, discussed the possibility of an elementary school science class partnering with staff from a research university to offer more personalized learning experiences. The university staff would share video feeds from microscopes and other active research experiments and then work collaboratively to guide the students through what they are viewing.[53] Such courses are not taught over Skype or traditional individual videoconferencing programs but over more advanced programs that offer higher-quality resolution and a more immersive, interactive experience.

Meeting the bandwidth demands of 21st century schools is usually one of the central goals of a public fiber broadband project. School districts in areas with public fiber networks often already meet, or

48 Tanya Roscorla, "5 Ways to Prepare Schools for Bring Your Own Device," *Center for Digital Education*, December 10, 2012. http://www.centerdigitaled.com/news/5-Ways-to-Prepare-Schools-for-Bring-Your-Own-Device.html (accessed May 5, 2014).

49 Ian Quillen, "Bandwidth Demands Rise as Schools Move to Common Core," *Education Week: Digital Directions*, October 17, 2012, Vol. 6. 19-20. http://www.edweek.org/dd/articles/2012/10/17/01bandwidth.h06.html (accessed May 5, 2014).

50 Center for Digital Education, *Preparing for the Common Core State Standards: School districts face an opportunity to reinvest in network infrastructure*, [Center for Digital Education, 2012], 2, 3, http://images.erepublic.com/documents/CDE12+STRATEGY+Comcast_V.pdf (accessed May 5, 2014).

51 Center for Digital Education, *Preparing for the Common Core State Standards: School districts face an opportunity to reinvest in network infrastructure*, 2.

52 Dr. Kecia Ray, panel remarks given at FCC Workshop on Gigabit Community Broadband Networks, Federal Communications Commission, Washington, DC, March 27, 2013. Video available at: https://www.fcc.gov/events/gigabit-workshop-1 (accessed May 5, 2014).

53 William Wallace, panel remarks given at FCC Workshop on Gigabit Community Broadband Networks, Federal Communications Commission, Washington, DC, March 27, 2013.

even exceed, SETDA's recommendations for school bandwidth capacity.[54] Connecting schools to a public network also offers the benefit of potentially tapping into funding from the federal E-rate program that subsidizes the cost of telecommunications services for schools and libraries. E-rate support could provide a helpful revenue stream to support the operation of a public network.

Healthcare Outcomes: The Benefits of Telemedicine

High-speed broadband can also improve healthcare outcomes and reduce a range of healthcare costs. Nationally, the need for bandwidth by clinics and hospitals is growing dramatically and is fundamental to state and local interests. Telemedicine and telehealth do not refer to a single technology or medical application. Instead, they capture a wide array of broadband-enabled healthcare services, including electronic sharing of medical records, remote monitoring of patients with chronic diseases, and communicating via videoconference with medical personnel in distant locations. Combined, these innovations are "transforming medical care by changing the way care is delivered and how people access medical services."[55]

The FCC has noted that telemedicine may be the "greatest driver" for higher bandwidth in our country.[56] Dr. Jonathan Linkous, CEO of the American Telemedicine Association, estimates that 10 million Americans were served by telehealth in 2012.[57] There are already 200 telemedicine networks in the United States, with over 2,000 participating medical institutions.[58] These numbers are expected to rise. A 2011 study of 1,006 physicians found that more than half report that they do not use telemedicine at all.[59] This suggests a huge opportunity for continued expansion which may be enabled by new laws providing reimbursement to providers for telehealth services. Nineteen states and the District of Columbia currently have "telemedicine parity laws" requiring private insurers to cover telemedicine, and a larger number of states provide some Medicaid reimbursement for telemedicine services.[60]

The role of broadband in patient health care is even greater if the definition is broadened to include patients' informal access to medical information online. The Pew Internet and American Life Project found that 72 percent of Internet users (and 59 percent of American adults) looked online for health information in the year previous to the study.[61] The discussion below examines the potential benefits of the many applications that health care facilities use (and will use in the future), most of which require advanced and reliable broadband access.

Ameliorating staffing shortages: Telemedicine can compensate for a lack of staff in a particular healthcare specialty. For instance, according to an American Telemedicine Association case study, there

54 Christopher Mitchell, *Florida Fiber: How Martin County Saves Big with a Gigabit Network*, [Institute for Local Self-Reliance, June 2012]. Available at http://www.ilsr.org/florida-fiber-gigabit/ (accessed May 5, 2014); *also see* Christopher Mitchell, *Broadband At the Speed of Light: How Three Communities Built Next-Generation Networks*.

55 United Health: Center for Health Reform & Modernization, *Modernizing Rural Health Care: Coverage Quality and Innovation* [UnitedHealth: Working Paper 6, July 2011] 42. Available at http://www.unitedhealthgroup.com/Health%20Reform/PerspectiveOnReform.aspx (accessed May 5, 2014); *see also* Statement of Chairman Julius Genachowski, *Rural Health Care Support Mechanism*, Federal Communications Commission, Dec. 12, 2012, http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-12-150A2.pdf accessed May 5, 2014).

56 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, Dec. 12, 2012, Appendix B, para. 13 https://www.fcc.gov/document/fcc-releases-healthcare-connect-order (accessed May 5, 2014).

57 Erin McCann, "Telehealth takes off in rural areas," *HealthcareIT News*, February 4, 2014. http://www.healthcareitnews.com/news/telehealth-takes-nationwide (accessed May 5, 2014).

58 United Health: Center for Health Reform & Modernization, *Modernizing Rural Health Care: Coverage Quality and Innovation*, 44. also see "What is Telemedicine," American Telemedicine Association, http://www.americantelemed.org/about-telemedicine/what-is-telemedicine#.U2fw8j_ihl0 (accessed May 5, 2014).

59 United Health: Center for Health Reform & Modernization, *Modernizing Rural Health Care: Coverage Quality and Innovation*, 46.

60 "State Telemedicine Policy Matrix," American Telemedicine Association, http://www.americantelemed.org/policy/state-telemedicine-policy (accessed May 5, 2014); *see also* "Arizona and Montana Governors Sign Telemedicine Bills into Law," American Telemedicine Association, http://www.americantelemed.org/news-landing/2013/04/10/arizona-and-montana-governors-sign-telemedicine-bills-into-law; also see Beth Hertz, "Telemedicine: Patient demand, cost containment drive growth," *Medical Economics*, February 10, 2013, http://medicaleconomics.modernmedicine.com/medical-economics/news/modernmedicine/modern-medicine-feature-articles/telemedicine-patient-demand-c (accessed May 5, 2014).

61 Susannah Fox and Maeve Duggan, *Health Online 2013*, [Pew Internet & American Life Project, January 2013]. Available at http://www.pewinternet.org/Reports/2013/Health-online/Summary-of-Findings.aspx (accessed May 5, 2014).

are only two board-certified pediatric dermatologists practicing within a 125-mile radius of Pittsburgh. Absent telemedicine, this shortage would lead to excessive travel and wait times for children in the region. To address that concern, the Children's Hospital of Pittsburgh established a telemedicine program in pediatric dermatology in January 2011. From its launch until November 2012, the hospital provided nearly 500 consultations through tele-dermatology. The response time for participants was less than one hour in the emergency room, and less than 12 hours for inpatient and ICU consults. These initial time-sensitive consultations were typically followed by an in-person visit. The consultations allowed for "more time-efficient, precise care, decreasing patient travel and expense, and even in many cases decreasing prolonged hospital stays."[62]

These benefits are amplified in rural areas, where staff shortages are not strictly limited to particular medical specialties. While there are, on average, 105 primary care physicians to every 100,000 people in urban areas, that number plummets to only 65 physicians per 100,000 residents in rural areas.[63] Lacking access to telemedicine, rural residents must often travel long distances to receive medical care. In fact, rural primary care physicians report that more than half of their patients who require specialty care must travel more than 20 miles to get it. In contrast, only 6 percent of urban patients are required to do so.[64]

Reducing costs and other economic benefits: By reducing or eliminating travel time, telemedicine also offers significant economic benefits. Indeed, telemedicine "bends the cost curve."[65] For example, the Missouri Telehealth Network reports that it has saved Missourians nearly 1,700 round-trip visits to specialists' clinics in neighboring cities, resulting in saved fuel costs of more than $293,000.[66] These economic benefits are particularly significant at nursing facilities, where an effective telehealth program can prevent hospital transfers. In a recent assessment of telehealth technologies, NEHI (formerly the New England Health Institute) reported that "extended care eVisits" can dramatically reduce the need for hospitalization. Such eVisits provide voice and/or videoconference functionality, connecting a physician hub to nursing home residents at their bedsides. In one case study, such technology led to a 57 percent reduction in transfers. A study in New York concluded that 40 percent of nursing home hospitalizations were avoidable. With hospitalizations costing an estimated $12,000 per incident, eVisits, which cost as little as $40, could generate millions of dollars in annual savings.[67]

The economic benefits of telemedicine can also be observed on Nantucket, an island 30 miles from the mainland in Massachusetts. The Nantucket Cottage Hospital has historically had to pay for specialists' travel and lodging expenses to serve its patients. It has now begun to offer telemedicine, performed by doctors at Massachusetts General Hospital, which reduces those costs. Dr. Margot Hartmann, chief executive officer of Nantucket Cottage Hospital, explains that the hospital's telemedicine program has saved nearly $29,000 annually because "two dermatologists now visit only four times a year, but appear on screen six times a month and see 1,100 patients a year."[68] These benefits are not unique to

62 "Telemedicine Case Studies: Pediatric Teledermatology: Improving Access in an Academic Children's Hospital," American Telemedicine Association, http://www.americantelemed.org/learn/telemedicine-case-studies/case-study-full-page/pediatric-teledermatology-improving-access-in-an-academic-children-s-hospital (accessed May 5, 2014).

63 United Health: Center for Health Reform & Modernization, *Modernizing Rural Health Care: Coverage Quality and Innovation*, 14.

64 United Health: Center for Health Reform & Modernization, *Modernizing Rural Health Care: Coverage Quality and Innovation*, 18.

65 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, Dec. 12, 2012, para. 26.

66 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, Dec. 12, 2012, para. 26, note 63.

67 Erin Bartolini and Nicholas McNeill, *Getting to Value: Eleven Chronic Disease Technologies to Watch*, [New England Health Institute, June 2012], 8. Available at: http://www.nehi.net/publications/30-getting-to-value-eleven-chronic-disease-technologies-to-watch/view (accessed May 5, 2014).

68 Pam Belluck, "With Telemedicine as Bridge, No Hospital Is an Island," *New York Times*, October 8, 2012, http://www.nytimes.

Nantucket. Absent telemedicine, about one-third of hospitalizations for rural patients have occurred at urban hospitals.[69] Telemedicine allows rural patients to remain close to home, avoiding costly transfers and adding to the local economy.[70]

Monitoring chronic conditions: Regardless of urban or rural distinction, telemedicine holds particular promise for remote monitoring of patients with chronic conditions at their homes. Nearly half of Americans (45 percent or 130 million people) suffer from at least one chronic condition such as arthritis, asthma, cancer, depression, diabetes, heart disease, or obesity.[71] That number is expected to increase to 157 million by 2020.[72] Treatment of these conditions already accounts for 75 percent of health care spending—$1.5 trillion annually.[73] Despite this enormous expense, most Americans with chronic conditions suffer from inadequate treatment. According to the National Center for Policy Analysis, less than one-fourth of patients with high blood pressure control it adequately. Twenty percent of patients with Type 1 diabetes fail to see a doctor annually and 40 percent of diabetics fail to regularly monitor their blood sugar level or receive recommended annual retinal exams.[74]

Telemedicine provides an effective option for monitoring chronic conditions. Through remote monitoring, these connected Americans can manage and address their chronic illnesses at dramatically lower costs by reducing hospital visits. Some studies have shown that remote monitoring programs can lead to a reduction in office visits by 10 percent, home visits by 65 percent, emergency room visits by 40 percent, and hospital admissions by 63 percent.[75]

Examples of successful telemedicine programs for chronic diseases abound. In a one-month test of a telemedicine-based care model for treatment of Parkinson's disease, 78 patients sent frequent video recordings (on average, 3.2 per day) from their homes to a treatment team via the Internet. The videos were used to inform therapeutic decisions, including drug adjustments. At the conclusion of the month, the participants demonstrated significantly less impairment on a standard rating scale.[76] Another study of patients discharged with congestive heart failure and chronic obstructive pulmonary disease found that remote monitoring substantially reduced hospital readmission rates.[77] Remote monitoring is especially helpful for the elderly, since approximately 84 percent of adults aged 65 or older suffer from at least one chronic condition.[78]

Enabling Electronic Medical Records: The continued adoption of Electronic Medical Records (EMR), which will require increasingly robust broadband connectivity, will help avoid inefficiencies and create projected savings of up to $81 billion annually—or $670 per household.[79] The use of EMR systems is expected to expand dramatically. While such systems have existed in some form for more than 30 years, the Centers for Disease Control and Prevention

com/2012/10/09/health/nantucket-hospital-uses-telemedicine-as-bridge-to-mainland.html?pagewanted=all&_r=1&&pagewanted=print (accessed May 5, 2014) *see also Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, Dec. 12, 2012, para. 26, note 63.

69 United Health: Center for Health Reform & Modernization, *Modernizing Rural Health Care: Coverage Quality and Innovation*.

70 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, Dec. 12, 2012, para. 1, note 3.

71 Erin Bartolini and Nicholas McNeill, *Getting to Value: Eleven Chronic Disease Technologies to Watch*, 2. *also see* "Health Fact Sheet," Pew Research Internet Project, updated December 16, 2013.

72 Amanda Hall, Michael Stellefson, and Jay Bernhardt, "Healthy Aging 2.0: The Potential of New Media and Technology," *Preventing Chronic Disease*, Center for Disease Control, Vol. 9, March 2012, http://www.cdc.gov/pcd/issues/2012/11_0241.htm (accessed May 5, 2014).

73 Edward Sondik, et al., "Progress Toward The Healthy People 2010 Goals And Objectives," *Annual Review of Public Health*, Vol 31:271-281, April 2010.

74 Devon Herrick, *Convenient Care and Telemedicine*, [National Center for Policy Analysis, NCPA Policy Report No. 305, November 2007], 8. Available at: http://www.ncpa.org/pdfs/st305.pdf (accessed May 5, 2014).

75 Jonathan Rintels, *An Action Plan for America: Using Technology and Innovation to Address Our Nation's Critical Challenges*, [Benton Foundation, November 2008], 15-16. http://www.benton.org/initiatives/broadband_benefits/action_plan (accessed May 5, 2014).

76 Frank Marzinzik et al, "Evaluation of a telemedical care programme for patients with Parkinson's disease," *Journal of Telemedice and Telecare*, Vol. 18: 322-327, September 2012, http://www.ncbi.nlm.nih.gov/pubmed/22912491 (accessed May 5, 2014).

77 Greg Slabodkin, "Remote Care Management Program to Be Rolled Out Nationwide," *Fierce Mobile Healthcare*, April 15, 2013, http://www.fiercemobilehealthcare.com/story/remote-care-management-program-be-rolled-out-nationwide/2013-04-15#ixzz2RNgTWgYx (accessed May 5, 2014).

78 Amanda Hall, Michael Stellefson, and Jay Bernhardt, "Healthy Aging 2.0: The Potential of New Media and Technology."

79 Jonathan Rintels, *An Action Plan for America: Using Technology and Innovation to Address Our Nation's Critical Challenges*, 18.

Table 1: Bandwidth Required to Achieve Full Functionality of Health IT Applications

Text-Only HER	Remote Monitoring	Basic E-mail + Web Browsing	SD Video Conferencing	HD Video Conferencing	Image Transfer (PACS)
0.025 Mbps	0.5 Mbps	1.0 Mbps	2.0 Mbps	>10 Mbps	100 Mbps

Source: Federal Communications Commission, *Health Care Broadband in America: Early Analysis and a Path Forward*, [FCC, OBI Technical Paper No. 5, August 2010], 5. Available at http://download.broadband.gov/plan/fcc-omnibus-broadband-initiative-%28obi%29-working-reports-series-technical-paper-health-care-broadband-in-america.pdf (accessed February 20, 2014).

reported in 2007 that only 34.8 percent of office-based physicians reported some EMR use. By 2012, EMR adoption had increased to 72 percent of office-based practices.[80] Significantly, in the 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act, Congress adopted an incentive payment system under Medicare and Medicaid to encourage health care providers to convert to electronic records. Providers currently receive these payments by demonstrating that they have achieved "meaningful use" of electronic records; by 2015, providers must adopt and exchange electronic records to receive full Medicare reimbursement.[81]

Bandwidth requirements of telemedicine: Telemedicine offers significant economic and health benefits, but these benefits will only be realized with adequate bandwidth to support the applications and services both for institutions such as hospitals and for patient households. Broadband capabilities in the United States are not yet sufficient to support the full range of telemedicine applications. In fact, of the 1,006 physicians responding to a 2011 survey by the UnitedHealth Group, 21 percent reported that broadband capability was a barrier in their use of telemedicine.[82] The FCC reports that health care facilities' broadband needs regularly exceed 100 Mbps.[83] As Table 1 (from the FCC's National Broadband Plan) demonstrates, medical applications such as image transfer require 100 Mbps, a number which is multiplied by the number of simultaneous users of that application.

Bandwidth requirements vary by application. Some telehealth activities are "asynchronous" and can be realized without real-time services. These include a variety of "store-and-forward" activities—including medical monitoring, e-mailing between patients and providers, and sharing medical images. Other activities require real-time or "synchronous" communications which include physician office visits conducted via videoconference, specialist visits that require high-definition video (e.g., dermatology), and real-time medical imaging in time-sensitive cases. This latter category is significantly more bandwidth-intensive.

Even store-and-forward telehealth applications can impose significant bandwidth demands—particularly when multiplied across a network with hundreds or thousands of users. Medical images such as X-rays are often digitally stored in large files; an MRI scan may consume many gigabytes of data, and files up to a terabyte have been seen with some medical studies. While store-and-forward applications require lower bandwidth than videoconferencing, for many fields—like tele-radiology and tele-dermatology—bandwidth needs are still high in order to ensure that high-quality images are transmitted properly. Moreover, a more robust network dramatically reduces the time needed to share such files. For instance, it would take six minutes to transmit a 45 MB MRI file over a 1 Mbps connection (assuming no competing traffic), whereas it would take only five seconds to transmit the same file over a 72 Mbps connection.[84]

80 Chun-Ju Hsiao and Esther Hing, *Use and Characteristics of Electronic Health Record Systems Among Office-based Physician Practices: United States, 2001-2012*, [Centers for Disease Control and Prevention December 2012], 1, http://www.cdc.gov/nchs/data/databriefs/db111.pdf (accessed May 5, 2014).

81 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, para. 23.

82 United Health: Center for Health Reform & Modernization, *Modernizing Rural Health Care: Coverage Quality and Innovation*, 46.

83 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, paras. 9-11.

84 *Rural Health Care Support Mechanism*, WC Docket No. 02-60,

Real-time telehealth applications such as video and audio conferencing require greater network capacity because they are particularly sensitive to latency (delay in delivery of data packets), jitter (variations in latency over time), and packet-loss.[85] For instance, a typical conversation cannot be transmitted with latencies greater than 300 milliseconds. Conferencing applications also require stable rates of latency. Data buffers cannot function with excessive jitter, which compromises the quality of a video or audio feed. High levels of packet loss or packets arriving out of order can also cause visible disruptions in an audio or video feed.

Bandwidth needs are especially high for emergency telehealth applications, such as remote video conferencing during crises. Emergency applications cannot be scheduled around network availability. Consequently, the network must be designed to accommodate the greatest level of potential use. Continuous telemetry of critically ill patients likewise demands a reliable network.[86] The same applies to tele-stroke applications, where treating physicians must be able to closely and accurately observe movements and facial expressions. Linda Oliver, Attorney Advisor to the FCC, explains that a rural hospital may be able to prevent premature stroke damage by transmitting a CT scan of a patient's head to a neurologist offsite—but only if the preventative medicine is administered "in a timely fashion." Transmitting such a scan could take 25 minutes via a copper based T-1 connection—with serious health consequences.[87]

Larger facilities will also have higher bandwidth requirements because they often must simultaneously support multiple patients. For instance, the Oregon Health Network reports that a 10 Mbps symmetrical connection is sufficient for most telehealth applications, but that larger facilities may require upwards of 100 Mbps.[88] Others likewise recommend that a rural clinic with five practitioners have 10 Mbps, but that hospitals require at least 100 Mbps.[89] The FCC reports that the largest clinics are already upgrading from 100 Mbps to gigabit connectivity.[90]

Broadband needs for telemedicine are projected to grow exponentially, in part because bandwidth needs are cumulative. As an initial matter, telemedicine needs must be layered on top of existing on-site bandwidth requirements, like e-mail, billing, and accessing patient records.[91] Moreover, "telemedicine is dynamically changing with new technologies and expanding applications."[92] Consequently, "the growth curve for broadband needs associated with telemedicine is difficult to overstate."[93]

There is risk involved in pursuing a broadband initiative, just as there is with any public project. It is

Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, paras. 7, 11.

85 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, para 12, notes 42, 43.

86 Sujansky & Associates LLC, *Applicability of the California Telehealth Network as the Network Infrastructure for Statewide Health Information Exchange*, [Sujansky & Associates LLC, October 2009], 10. Available at http://www.sujansky.com/docs/CTN_for_HIE_Assessment_SujanskyAndAssociates_2009-10-08_FINAL.pdf (accessed May 5, 2014).

87 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, para. 14, note 49.

88 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, para. 8, note 27.

89 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, para. 21, note 78.

90 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, para. 10, note 32.

91 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, para. 20.

92 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, para. 10, note 31.

93 *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 12, 2012, Appendix B, para. 10, note 33.

essential to thoroughly assess the risks. This chapter briefly introduces a range of potential risk factors and challenges that local leaders and stakeholders should consider as part of their planning process:

- Legislative and regulatory risks
- Political risks
- Legal risks
- Market and competitive risks
- Operational risks
- Financial risks

This is by no means a comprehensive list of risks—it is merely a starting point for understanding the key challenges of building and running a successful network. These risks should not automatically dissuade communities and local government from pursuing broadband projects. Rather, by understanding what risks and challenges public networks may face, leaders can factor them into evaluating what type of network, ownership, or business model will be most appropriate for the community.

Political, Legislative, and Legal Risks

The political, legislative and legal risks of attempting to deploy any communications infrastructure with a public component—regardless of the model—are significant. **Political risk** has been shown to be particularly large for very big investment projects like the construction of communications infrastructure across a town, county, or state. This is because such projects are especially visible and sometimes involve the use of public funds or public debt—which can make the project a lightning rod for opposition among competing elected officials or interest groups. Moreover, these projects are prone to controversy because of potential cost overruns, schedule delays, and benefit shortfalls.

Political challenges to local broadband projects often come from incumbent providers. The intensity of political opposition sometimes relates to the scope of the project proposed. A full fiber-to-the-premises network intended to provide residential voice, video, and data services to area citizens will often face more aggressive opposition than an institutional network designed to serve only community anchor intuitions like schools and libraries.

Legislative risk refers to potential changes in law that can cripple a public broadband project. It is not uncommon for self-interested incumbents to lobby for legislative change that would prohibit or hamper public broadband efforts, sometimes including those already underway. In some states, existing laws that create challenges for local public broadband initiatives by requiring localities to work under constraints do not apply to private companies. Such constraints can include pricing restrictions, service limitations, and process requirements. For example, in Colorado, state law prohibits local governments from directly or indirectly providing cable television service, telecommunications service, or advanced service unless local government receives specific voter approval.

The majority of these state laws are not flat-out bans on public projects. Rather, the laws create certain barriers and hurdles—and they come in different forms, so there are no hard-and-fast rules about how to approach them. Qualified legal counsel can evaluate the relevant laws in a state.[94] It is useful to pursue such guidance before ending any network planning attempts, as there may remain an opportunity to pursue local broadband goals. For example, the law may relate only to public-facing retail networks,

94 For detailed notes on the different state laws impacting local broadband networks, including references to the individual state codes, see "State Statutory Barriers to Public Broadband Initiatives," Baller Herbst Law Group. http://www.baller.com/comm_broadband.html#barriers (accessed May 5, 2014).

meaning that there is still the option to build and run an institutional or government network. The law in a state may prohibit only telecommunications services (phone), meaning one would still have the flexibility to provide data (Internet) service. A community should conduct a thorough analysis with qualified legal advice to understand the relevant laws and then proceed accordingly.

Legal risk is the risk from uncertainty due to legal actions or uncertainty in the applicability or interpretation of contracts, laws, or regulations. In other words, will an incumbent provider sue the partnership building a broadband project? Or will local or state laws or regulations be interpreted in such a way that the project may not proceed? For example, as indicated above, Colorado legislation prohibits local governments from directly or indirectly providing cable television service, telecommunications service, or advanced service unless the local government receives specific voter approval. Does this legislation restrict a Colorado locality from offering public Internet access in its council chambers? That would depend on interpretation—which is shaped through challenges in the court system.

Historically, efforts to deploy competing fiber-to-the-premises networks with some element of public ownership or financing have attracted significant local incumbent opposition. This opposition has manifested itself through efforts to sway local policymakers to vote against the venture, by forcing public referendums, and by leveraging the influence of incumbent trade associations to introduce new or amended legislation to block the effort. Interestingly, opposition to a local broadband effort may rise in proportion to the level of service a network proposes to offer. A middle-mile project, for example, might attract only local opposition and attention; a full fiber-to-the-premises model, on the other hand, might attract the attention of the entire national communications industry and related industries. That is because the competition enabled by a high-capacity fiber-to-the-premises infrastructure would be perceived as a direct challenge to the interests of incumbent players in the current market structure.

Marketplace, Operational, and Financial Risks

The key to ensuring a project's long-term sustainability is the ability to contain its marketplace, operational, and financial risks. **Market or competitive risk** is the risk of withstanding the likely responses of a competitor through a planned technology improvement, invention, acquisition, price reduction, or similar action. In simple terms, this is the risk that a new broadband project—like any new business venture—will not be able to attract enough customers or earn enough revenue to continue operating.

Operational risk is the risk of loss resulting from inadequate or failed internal processes, people and systems, or from external events. There are other risks that are potential consequences of operational risk events. For example, reputational risk (damage to an organization through loss of its reputation or standing) can arise as a consequence of operational failures—as well as from other events. Being aware of this risk may lead the planners of a community broadband project to favor an approach that brings all aspects of network operations in house—or the awareness of this risk may have exactly the opposite effect. A public entity with extensive network operations experience may want to handle network operations with internal staff and processes; one that does not have that type of institutional experience, or that does not have adequate staff resources to take on additional tasks, might decide that the better approach would be to contract for services with the private sector. A public–private partnership could lead to a similar splitting of responsibilities.

Tied in with these other risks are **financial risks**—the risk that a broadband enterprise will not have adequate cash flow to meet its financial obligations. This risk goes hand-in-hand with market and competitive risks. For example, if a public network fails to attract sufficient customers, the result will be insufficient cash to meet operational and debt service requirement. A broadband network that attracts plenty of customers might still run into financial trouble if, for example, it has cost overruns in its construction.

As is the case with the other risks described above, a project's marketplace, operational, and financial risks will vary with the scope of the project. A middle-mile project, for example, has a much lower market or competitive risk than a fiber-to-the-premises model. In the middle-mile fiber project a locality may be able to obtain contracts prior to making a major investment to connect facilities, whereas with a fiber-to-the-premises initiative, a substantial investment is required before even signing up a single customer.

This report provides communities with an overview of different types of public broadband projects, business models, potential community benefits, and common challenges or risks. Communities should consider three primary issues when first considering a public broadband project: 1) Control—who owns the network and decides how it operates, 2) Risk—the costs associated with developing and running the network balanced against the revenue it generates, and 3) Reward—the benefits achieved through successful implementation of the project. Achieving all three—the desired level of control, minimum risk, and maximum reward—is difficult.

Officials should consider carefully which components of these three items are the most important to them, and be prepared to make sacrifices where appropriate. A community can maintain substantial control and potentially earn higher rewards if it is willing to take on all of a project's risk. Giving up some of the risk will likely also result in giving up some control. The degree to which a community chooses to balance these issues relates directly to the goals of the project, which should be decided at the outset.

Deciding upon the most appropriate ownership and governance for a public broadband project is critically important for the success of the project. The model selected should be based on the individual needs, resources, and goals of the local community and should build upon existing organizational and governance structures that can help the project to succeed over the long term. There is no universal rule about which model is most appropriate. Communities should take into account political, legal, and legislative risks that may prohibit certain ownership models or require particular organizational structures to comply with legal restrictions. Similarly, communities should think about their communication needs for the present and in the future, and then evaluate the advantages and disadvantages of different broadband technologies and their capabilities to deliver certain services and applications. Building a network with the right technologies is important for ensuring that the network can accomplish the project's goals and be scalable for the future.

A robust feasibility analysis to demonstrate that a business case exists and that the social and economic goals will be realized through a particular business model is critical to mitigating financial risks and increasing the chances of success. However, it is important to note that no projects or business models are free of risk. There will always be some risks involved in pursuing a broadband initiative, just as there is with any public project. These should not automatically dissuade communities from pursuing broadband projects. Rather, by understanding what risks and challenges a network may face, one can factor them into evaluating what type of network, ownership, or business model will be most appropriate for the community.

Finally, any significant public infrastructure project requires detailed financial analysis to calculate a return on investment. Public broadband projects are no exception to this business practice. However, financial returns should not be the exclusive metric for evaluating the benefits of broadband infrastructure. Local governments should consider defining their success more broadly to include the "benefits beyond the balance sheet"—the intangible societal rewards that broadband offers the community as a whole and delivers to individual citizens. Broadband is the latest essential tool that can support public goals, including by supporting economic development, increasing property values, enhancing health care quality, and providing enhanced educational opportunities.

As government leaders evaluate their options it is important to focus on developing the most appropriate network model to meet the goals of the community, while accounting for fiscal realities and associated risks. There is no one-size-fits-all approach. There are any number of different permutations for a public project that a government can utilize, offering different benefits and tradeoffs. Local fiber networks are a significant investment but one that can provide enormous benefits over the long term. This report is a useful primer for local governments to begin evaluating broadband options, but it is not a substitute for a deliberate and comprehensive evaluation. Taking the time to perform the proper due diligence on any broadband project is critical to developing a successful, sustainable, and scalable project.

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