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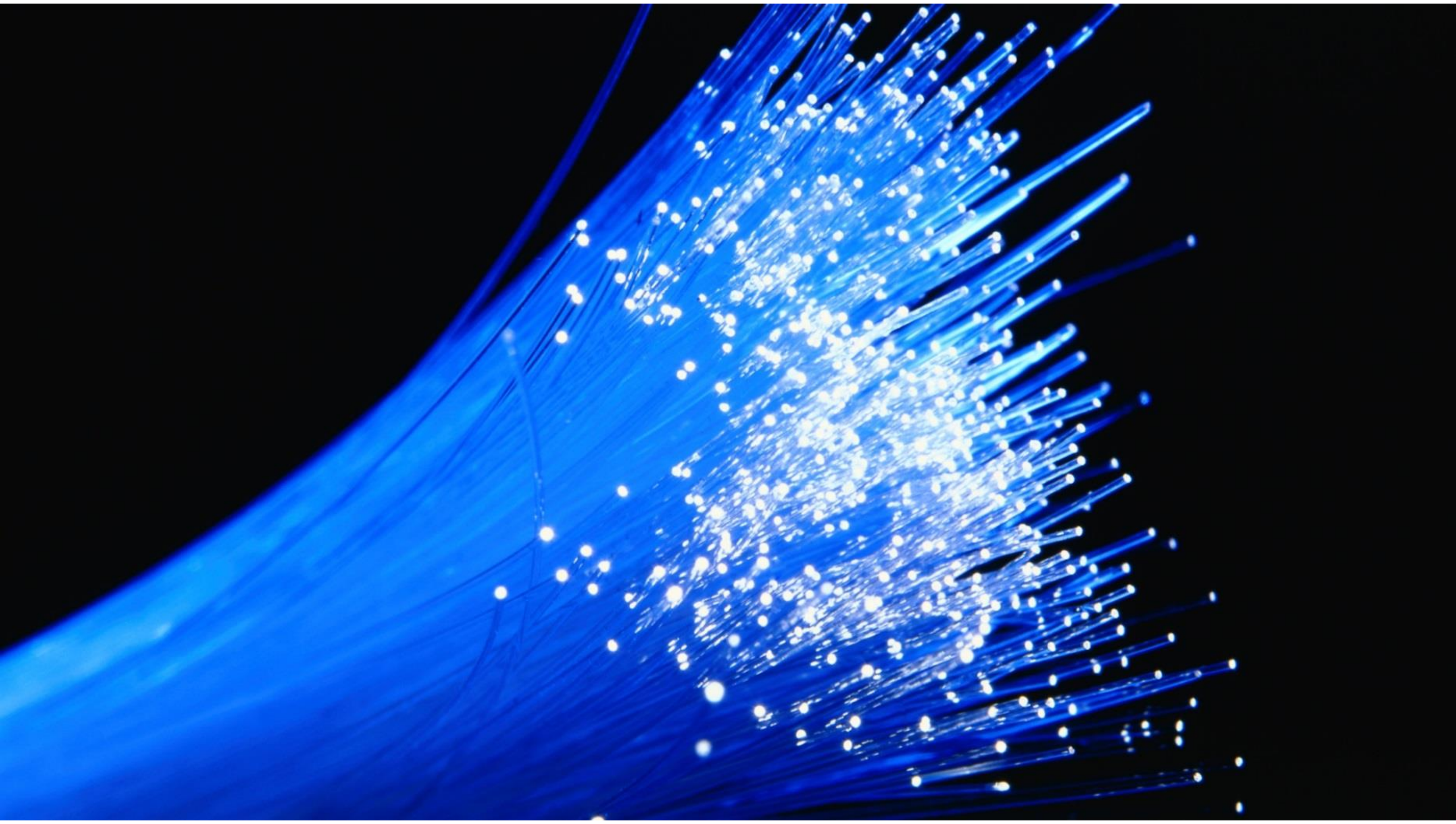

Guide to Fiber Planning for Communities and Utilities

Prepared for the Commonwealth of Kentucky

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Introduction: The Potential for Community and Utility Broadband Enterprises

This guide represents a collaboration between the Commonwealth of Kentucky and CTC Technology & Energy, the Commonwealth's broadband advisor. The guide was prepared because, in light of the planned KentuckyWired network, the Commonwealth's Finance Cabinet concluded that there is a need for high-quality, independent guidance to Kentucky's communities and utilities as they consider their local broadband options.

We believe that broadband access to the Internet is an important tool for economic, educational, and civic growth and discourse—and that it is as imperative in rural communities as it is in urban and suburban areas. To that end, we seek to build broadband capacity and enhance broadband adoption by providing the Commonwealth's local governments and utilities with tools that will help them plan for their broadband futures.

In straightforward language, this guidebook explores a range of technical, business, and partnership models. Importantly, the guidebook also frankly assesses the benefits and risks of broadband initiatives, so that readers can determine the best approach for their unique circumstances. While the guidebook often focuses on utilities as the entity considering broadband deployment, a local government or regional consortia may be the guiding force in the project, and the same guidance would apply. (A local government might also seek to partner with a utility on a broadband project.)

This guidebook is not meant to be a comprehensive guide—every community or utility that considers the feasibility of building broadband networks must customize analysis of its own needs, potential benefits, and risks. Instead, the guidebook focuses on providing independent guidance to enable readers to understand the type of questions they should ask. It also offers guidance on issues such as what kinds of costs a local broadband initiative is likely to incur, what type of financing and funding opportunities exist, and what the risks and rewards of broadband networking might be for the local government or utility.

Utilities, especially, are well positioned to play an essential role in building world-class broadband networks in rural areas. Some of the most successful examples of cutting-edge networks have been those of locally-owned electric utilities. The networks in Chattanooga, TN and Lafayette, LA,[1] are both examples of this situation. Bristol Virginia Utilities (BVU) was among the nation's first utilities to build a fiber-to-the-premises (FTTP) network to serve residents, local businesses and community institutions such as schools and libraries.[2] BVU, similar to many other networks

[1] 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
[2] Christopher Mitchell, *Broadband At the Speed of Light*.

built and operated by cooperative or 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 broadband success of electric utilities is that they already have experience in managing infrastructure. They own repair trucks and employ field engineers who can perform installations and conduct maintenance. Existing utilities also have experience with customer service, managing individual accounts, and staffing call centers to handle questions or complaints. A utility-owned broadband enterprise can frequently count on its electric operation to serve as an important anchor user of the network. The network can serve essential needs for internal utility operations and electric plant management. And utilities have established institutional structures to provide for community participation and local buy-in—either through a municipal or a cooperative governance mechanism.

We recommend a robust feasibility analysis to understand and address financial risk. 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 significant investment or new enterprise.

But financials should not be the exclusive metric for evaluating the benefits of broadband infrastructure. Local communities 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 and coop members. Broadband is an essential tool that can support public goals, including economic development, enhancing health care quality, and providing enhanced educational opportunities.

Accordingly, we begin with a broad overview of the benefits of broadband—to establish a framework for understanding why local leaders will want to become engaged on the issue of broadband in their communities.

1. Benefits of Broadband for Your Community

As with any significant investment, a broadband initiative requires detailed financial analysis and a calculation of the potential return on investment. Financial considerations are obviously critical for any significant infrastructure investment. However, cash flow may not be your only metric for evaluating the feasibility or the importance of a broadband infrastructure program. Many utilities define their success metrics more broadly and include the benefits "beyond the balance sheet"—the intangible societal reward that broadband offers the entire community and might deliver to your members.

This chapter provides a general discussion of a range of direct and indirect benefits that may arise from a utility broadband initiative. These benefits include economic development and improved educational and health care outcomes.

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. Now these same principles hold true for broadband.[3] 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."[4]

Today, most businesses consider broadband an important local resource.[5] 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.[6] 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 telecommunication needs. Though broadband is a central part of any package to attract or retain businesses, it does not in

[3] 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

[4] William Lehr, *Anchor Institutions Help Secure Broadband's Promise*, [Massachusetts Institute of Technology 2012]. 6. Available at: http://www.shlb.org/resources

[5] 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/

[6] 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; *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

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 utility-owned broadband network. The enhanced connectivity the network can offer has been a central component to several local economic development success stories. Large firms like Northrup 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.[7] Alpha Natural Resources, after a merger with another company, decided to retain their headquarters in Bristol because of the local broadband resources available, keeping hundreds of jobs in the region.[8] 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 utility-focused or institutional community broadband projects.

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 utility fiber project in Lafayette, LA, created a series of online videos with customer testimonials featuring local small businesses.[9] In one video a local web designer notes how he work more productively as a result of the network's fast speeds and symmetrical upload capacity. [10] In another, the general manager of a local hotel explains how the high-speed and reliable broadband access as an important marketing point for attracting guests on business travel and hosting conventions.[11] A local photographer explains how, thanks to symmetrical upload speeds, he can now share photos with clients more quickly; "what I used to do overnight, I do over lunch."[12] 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

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[7] Christopher Mitchell, *Broadband At the Speed of Light*, p. 14-15.
[8] Christopher Mitchell, *Broadband At the Speed of Light*, p. 14-15.
[9] "LUSFiberLafayette – Youtube," YouTube, LUS Fiber account page, https://www.youtube.com/user/LUSFiberLafayette/videos
[10] "LUS Fiber Business Testimonial – Daniel Kedinger," YouTube, LUS Fiber account, https://www.youtube.com/watch?v=KLDxd3HR7Rs
[11] "Joddy Cormier Testimonial," YouTube, LUS Fiber account, https://www.youtube.com/watch?v=Y3NuMUQ5EVY
[12] "Travis Gauthier Testimonial" YouTube, LUS Fiber account, https://www.youtube.com/watch?v=xr22eXUabGg

video conferencing. Access to broadband capable of supporting these uses allows rural communities to retain telecommuting residents who have to commute or are otherwise only in the region temporarily.[13] 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 utility's broadband network.[14] Powell, WY, although rural and isolated, has a fiber-to-the-premise network. This infrastructure has attracted employers such as Alpine Access, a virtual call center management firm, to hire Powell residents for their business.[15]

And a locally owned broadband utility keeps local resources in the community, brings money into a community, and enables money to stay there. The benefits of keeping broadband spending local has a multiplier effect; your utility gets the benefit of the dollar itself, and the local community gets the benefit of that dollar being spent over and over locally.

Indeed, Norwood Light Broadband, the municipal fiber network operator in Norwood, Massachusetts, makes that point directly to its potential customers. Visitors to the town's "Entering Norwood" website see the value proposition spelled out for them:

"Do you own a house or business in Norwood? Do you have children that go to school in Norwood? Your money will do a lot more good keeping it in town instead of lining the pockets of multi-billion dollar conglomerates like Verizon & Comcast. When you write out a check to the Town of Norwood, your money stays in town working for you."[16]

Educational Outcomes

Meeting the bandwidth demands of 21st century schools is usually one of the central goals of a utility fiber broadband project. School districts in communities with utility fiber networks often already meet, or even exceed, emerging recommendations for school bandwidth capacity.[17] 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

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[13] Masha Zager, "Electrical Co-ops Build FTTH Networks," *BroadbandCommunities*, March/April 2013, 19. http://www.bbpmag.com/2013mags/mar-apr/BBC_Mar13_ElectricCoOps.pdf

[14] Christopher Mitchell, *Broadband At the Speed of Light*, p. 15

[15] Steven Ross and Masha Zager, *What Fiber Broadband Can Do For Your Community*, *BroadbandCommunities*, Fall 2013, 21. http://bbcmag.com/Primers/BBC_Aug13_Primer.pdf

[16] "Norwood Light Broadband: 'For the People, by the People,'" Entering Norwood website. http://www.enteringnorwood.com

[17] The State Educational Technology Directors Association (SETDA), an organization which recommends future bandwidth targets for schools, released an influential 2012 report on ultra-high-speed broadband access to US K-12 schools. SEDTA recommends that, for every 1,000 combined students and staff, there should be 100 mbps of bandwidth available by the 2014/15 school year, a target which should rise to 1,000 mbps (1 Gigabit per second) by 2017/18. 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

schools and libraries. E-rate support provides a revenue stream to the Commonwealth, which has taken a consolidated approach to applying for E-rate subsidies..

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.[18] 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.[19]

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. In addition, a growing number of states are administering student academic achievement testing online.

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' 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."[20]

Indeed, the FCC has noted that telemedicine may be the "greatest driver" for higher bandwidth in the United States.[21]

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[18] "2010 E-Rate Program and Broadband Usage Survey: Report," Federal Communications Commission, January 6, 2011. http://transition.fcc.gov/010511_Eratereport.pdf

[19] "2010 E-Rate Program and Broadband Usage Survey: Report," Federal Communications Commission.

[20] United Health: Center for Health Reform & Modernization, *Modernizing Rural Health Care: Coverage, quality and innovation* [UnitedHealth: Working Paper 6, July 2011] 42. http://www.unitedhealthgroup.com/~/media/UHG/PDF/2011/UNH-Working-Paper-6.ashx; *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

[21] *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

Telemedicine's benefits will only be realized with adequate bandwidth to support the applications and services both for institutions such as hospitals as well as 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.[22] The FCC reports that health care facilities' broadband needs regularly exceed 100 Mbps. As Table 1, from the FCC's National Broadband Plan, demonstrates, medical applications such as image transfer require 100 Mbps, a number which will multiply by the number of simultaneous users of that application.

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[23]

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 providers. 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.[24]

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

[23] 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

[24] *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Federal Communications Commission, FCC 12-150, December 21, 2012, Appendix B, paras. 7, 11. http://www.fcc.gov/document/fcc-releases-healthcare-connect-order

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.[25] 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.[26] 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.[27]

Table 2: Estimated Bandwidth Needs for Telehealth Services[28]

Health Care Use or Service	Minimum Bandwidth (Mbps)			Typical Bandwidth (Mbps)			Optimal Bandwidth (Mbps)		
	Low	Avg	High	Low	Avg	High	Low	Avg	High
Video Conferencing (non-HD)	0.4	1.0	1.5	0.4	3.5	10	0.8	14	50
Video Conferencing (HD)	1.0	1.5	2.0	1.0	8.1	23	1.5	22	50
Administrative Use	0.4	1.1	1.5	0.4	3.5	10	0.8	13	50
Cardiovascular/Echo cardiology	1.0	3.4	9.5	1.0	6.4	10	1.5	18	50
Dentistry	0.4	1.0	1.5	1.0	3.2	10	1.0	14	50
Dermatology	0.4	1.3	2.0	1.0	3.4	10	1.5	12	50
Dialysis/ESRD	1.0	1.4	1.5	1.0	5.3	10	1.5	21	50
Electronic Medical Records	1.0	1.4	1.5	1.0	7.6	14	1.5	22	50
Emergency Rm/Trauma Care	0.4	6.9	27.0	1.0	9.0	27	1.5	32	100
Gastroenterology	1.0	1.4	1.5	1.0	5.3	10	1.5	21	50

[25] *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Appendix B, para 12, notes 42, 43.

[26] 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

[27] *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Appendix B, para. 14, note 49.

[28] Universal Service Administrative Company, "Health Care Provider Broadband Needs Assessment Summary," Letter to Wireline Competition Bureau, Federal Communications Commission. Docket WC 02-60, Appendix A, April 12, 2012. Available at http://apps.fcc.gov/ecfs/comment/view?id=6017029788

Health Care Use or Service	Minimum Bandwidth (Mbps)			Typical Bandwidth (Mbps)			Optimal Bandwidth (Mbps)		
	Low	Avg	High	Low	Avg	High	Low	Avg	High
Obstetrics/Gynecology	1.0	1.4	1.5	1.0	4.5	10	1.5	18	50
Orthopedics	0.4	1.1	1.5	1.0	4.2	10	1.5	16	50
Pathology	1.0	1.4	1.5	1.0	4.4	10	1.5	16	50
Physical Therapy	0.4	1.1	1.5	1.0	4.2	10	1.5	16	50
Primary Care	0.4	1.1	1.5	1.0	4.2	10	1.5	16	50
Psychiatry & Counseling	0.4	1.2	1.5	0.8	3.4	10	1.0	14	50
Radiology - MRI/CAT	1.0	4.6	10.0	1.0	9.0	20	1.5	34	100
Radiology - X-ray	1.0	3.1	10.0	1.0	7.5	20	1.5	33	100
Rehabilitation	1.0	1.4	1.5	1.0	5.3	10	1.5	21	50
Remote Monitoring	1.0	3.5	10.0	1.0	6.5	10	1.5	40	100
Specialist Care	0.4	5.5	23.0	1.0	8.0	23	1.5	17	50
Speech Therapy	0.4	1.2	1.5	1.0	3.8	10	1.5	15	50
Training/Education	0.4	1.2	1.5	0.6	3.2	10	0.8	12	50
Ultrasound	1.0	1.4	1.5	1.0	5.3	10	1.5	21	50
Average	0.7	2.1	4.9	0.9	5.4	13	1.4	20	58

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.[29] Moreover, "telemedicine is dynamically changing with new technologies and expanding applications."[30] Consequently, "the growth curve for broadband needs associated with telemedicine is difficult to overstate."[31]

[29] *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Appendix B, para. 20.
[30] *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Appendix B, para. 10, note 31.
[31] *Rural Health Care Support Mechanism*, WC Docket No. 02-60, Report and Order, Appendix B, para. 10, note 33.

2. Understanding Broadband Supply and Demand

A first step for any utility considering building a broadband network is to quantify and understand the potential market and the threat, if any, of competition (even from lower level products that do not meet reasonable standards for broadband[32] but that may serve to limit revenue opportunities). In this chapter, we will offer an overview and guidance on how to assess community demand for specific broadband services and applications, and the actual availability of broadband services to meet that demand.

Assessing Broadband Demand

Collecting detailed and accurate information about the potential demand for broadband in your service territory, particularly in the areas you plan to serve first with broadband, is one of the most important steps in planning a broadband project. Expectations for what applications, services and performance capabilities the network must provide is important to know early on, as this information can guide decisions around network design and engineering.

Most importantly, a viable project requires sufficient market to succeed, particularly given that selling broadband services is different from your experience with electric service in that many consumers still choose not to purchase broadband services. A clear understanding of institutional broadband demand is also fundamental to building a sustainable business plan. For example, securing buy-in and support from anchor institutions upfront can ensure secure contracts for providing broadband service later and, further, ensure that the new network has a stable revenue stream.

For these reasons, demand assessment should be viewed as the first component of a vital engagement strategy to gain the support and participation of stakeholders in the project.

In our experience, there exists a gap between the availability or supply of broadband and the demand of local residents, businesses, and institutions for faster and more robust, ubiquitous, and affordable service in almost every community across the United States. The reasons for this are many, but the critical question utilities need to answer before developing any broadband plan is: *How great is the gap in your community and will the market respond to your utility filling that gap?*

Sources of Broadband Demand

Quantifying broadband demand to a degree sufficient for planning an infrastructure project will require a substantial amount of time, effort, and direct engagement with a range of local

[32] As of this writing in the spring of 2015, the Federal Communications Commission's definition of broadband is 25 megabits per second (Mbps) downstream and 3 Mbps upstream.

institutions and the public. To begin the assessment process, you should identify different types of broadband users. These include:

- Government
    - Local government office operations
    - Public works departments, including water or sewer
    - Public safety, including police, fire and other first responders

- Education
    - K-12 schools, including private, public, and charter schools
    - Libraries
    - Local universities, community colleges, and technical schools

- Health care providers
    - Hospitals
    - Community clinics
    - Physician offices and other facilities
    - Skilled care facilities

- Commercial and industrial
    - Area utilities (including your utility and your own needs)
    - Major area employers
    - Business and industrial parks

- Small business
    - Local chambers of commerce
    - Business improvement districts

- Residents

For purposes of broadband planning, governmental and institutional facilities are sometimes collectively referred to as "community anchor institutions" (CAI). Because these entities are often among the largest purchasers of broadband services in a community, the process of determining CAI needs for broadband can offer a very good barometer of the demand in your community—not just now, but how it is likely to grow over time. These organizations typically have a firm grasp of their current broadband use (i.e., capacity, service levels, cost), and routinely project how much capacity they will need to meet future growth plans. CAIs are also often likely to be the driving force behind an infrastructure investment in your community because the potential revenue relative to the cost of construction is far better for connecting a single CAI than for a residential neighborhood. Thus, it will likely be more efficient and productive for you to focus, at least initially, on governmental and institutional stakeholders.

Assessment Activities

The process of assessing broadband demand in a community is typically nuanced and will require different methods of engagement for different stakeholders. In our experience, online surveys tend to be more reliable and useful for business surveys than for residential surveys. Other stakeholder engagement may require in-person meetings such as for large institutions or government agencies that are likely to have more complex and specific needs.

Activities to assess demand may include:

- Informal conversations
- In-person interviews
- Stakeholder meetings
- Open meetings with public input
- Surveys, both by mail and online

The assessment process will vary and utility leaders should tailor it to build upon existing resources and institutions as much as possible. For example, assessing business and residential demand is challenging and will frequently require extensive mail or telephone surveys. These can be costly and time-consuming, particularly if they are to result in statistically significant data.

One shortcut to getting a sense of residential and small business demand is to talk to staff within the relevant local government offices who field calls from potential consumers who are unable to locate the broadband services they seek. This might be the cable franchising authority, an economic development authority, or an IT department. In almost any community there is a relatively steady stream of calls, complaints, and requests for help from small business and residential consumers who hope that their government will be able to help them identify (or incent the availability of) a type of service that they cannot currently obtain. Indeed, many of these calls may be coming to your utility as members seek to encourage the utility to add broadband service to existing services.

Similarly, if you have access to a comprehensive list of local businesses' e-mail addresses from the local chamber of commerce or economic development agency, an online tool can offer a cost-effective alternative to mailing surveys. Your local or regional chamber of commerce is an important stakeholder, and a good resource for getting a sense of small business needs; broadband is frequently a high priority area for local chambers of commerce nationwide.

Ultimately, a utility's demand assessment program will be tailored to its members. In the case of Co-Mo Electric Cooperative, which serves 25,000 members in central Missouri, assessing demand for fiber deployment in its service area meant going back to its roots. Before the coop energized its first electric line in 1939, its founders went door-to-door to sign up members for electric service. Nearly 75 years later, when the coop's leaders sensed a growing interest in high-speed broadband service, the coop launched an outreach effort to its 25,000 members and initially secured a commitment from 25 percent of them to purchase a new service. That was enough confirmed demand to support a business case for fiber-to-the-home infrastructure, and in 2010 Co-Mo launched a subsidiary, Co-Mo Comm, to build and deliver "Co-Mo Connect" fiber to its members.[33]

As the coop describes its fiber project, "Co-Mo's leaders never actively sought out the opportunity to get into a completely new line of work. Rather, the people asked for the service. For-profit companies that provided these communication services to cities around Co-Mo Country had no intention of extending them here. There simply were too few potential customers per square mile. Sound familiar? So Co-Mo and its members stepped up to make the project a reality."[34]

Co-Mo is building its fiber in stages, including to areas where a minimum number of members have committed to purchasing services and paid a $100 deposit (only slightly more, in inflation-adjusted terms, than the $5 the first members paid to commit to electric service).[35] Ultimately, the coop hopes to build the fiber network throughout its electric service area. Currently Co-Mo Comm has about 1,500 miles of fiber through its 4,000 mile electric plant, and take rates have ranged from 15 percent to 40 percent immediately after announcing opening an area to more than 50 percent within 12 months after construction.

Assessing Broadband Supply: How to Understand Actual Availability in Your Community

An assessment of supply is all about understanding what kind of competition you may face if you enter the broadband market. It's important to know what Internet connectivity services are available in your community – and their actual capabilities – because even products that do not meet the federal standard for "broadband" may create competition for your products, particularly among members who are very price-sensitive.

Similarly, it's crucial that you understand the competitive dynamic with regard to video services, as that is a product that you are likely to include in your offerings and for which you may face competition from a cable provider (in the more densely populated parts of your service territory) and from satellite.

Developing this picture requires a couple different approaches to survey the marketplace. We recommend taking the following initial steps:

- Review of the National Broadband Map
- Review of broadband and cable providers' websites

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[33] "Co-Mo History," Co-Mo Electric Cooperative. http://co-mo.coop/history.aspx. *See also:* "Co-Mo Connect." http://www.co-mo.net/Co-Mo_Connect/About.html

[34] Ibid.

[35] "Co-Mo Connect Expanding into Tipton, Versailles; Signups Open Now," *News*, Co-Mo Electric, Aug. 15, 2014. http://www.co-mo.coop/news/newsdetail.aspx?itemID=276. *See also*: "Co-Mo History," Co-Mo Electric Cooperative. http://co-mo.coop/history.aspx.

- Mapping based on technical data collection
- Mapping based on stakeholder interviews

National Broadband Map

The National Broadband Map (NBM) was created in 2011 with the goal of providing a database to track broadband availability down to the neighborhood level. The National Telecommunications and Information Administration, in collaboration with the Federal Communications Commission, administers the map. The NBM contains the aggregated information of various state-level broadband mapping initiatives. It represents the first time that the United States government has attempted to collect this data in one central location, to ideally provide a picture of true broadband availability in local communities.

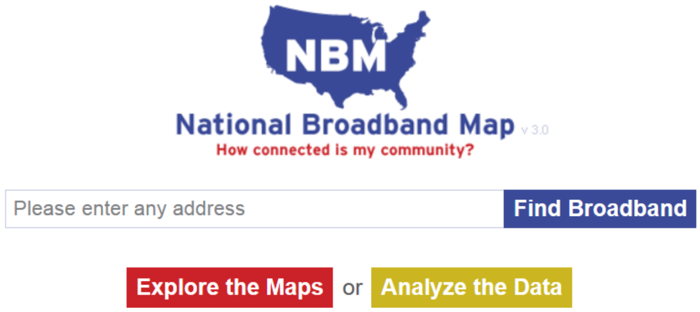
However, it is important to note that the NBM data have several limitations that impact their overall accuracy and usefulness. The map relies heavily on self-reporting by commercial internet service providers—all of whom use different methodologies to quantify their service levels. Thus, there are reports of service providers overstating their service areas and connection speeds.[36] The NBM also tracks availability only down to the Census block level (which, in rural America, can represent large areas). If any location in that block is reported as being served by a broadband provider, the entire block will be shown as served—even through most of the residents may not actually have access. NBM search results could therefore paint an overly optimistic picture of broadband availability relative to the reality on the ground.

The map also fails to distinguish between residential broadband and business class services: enterprise-level connectivity sold only to institutions, government, and businesses. NBM search results could indicate high-speed broadband services are available in an area, but then these could be business-class only providers who do not offer their services to residents. Finally, the NBM collects no information on the cost of broadband services listed as available. Therefore broadband services could be available in a certain area, but at prices that make them unaffordable to most area residents or businesses.

Keeping these limitations in mind, the NBM is a good first step in identifying your community's broadband supply. The map's user-friendly website (see Figure 1) allows you to search by state, county, city, or a single address.

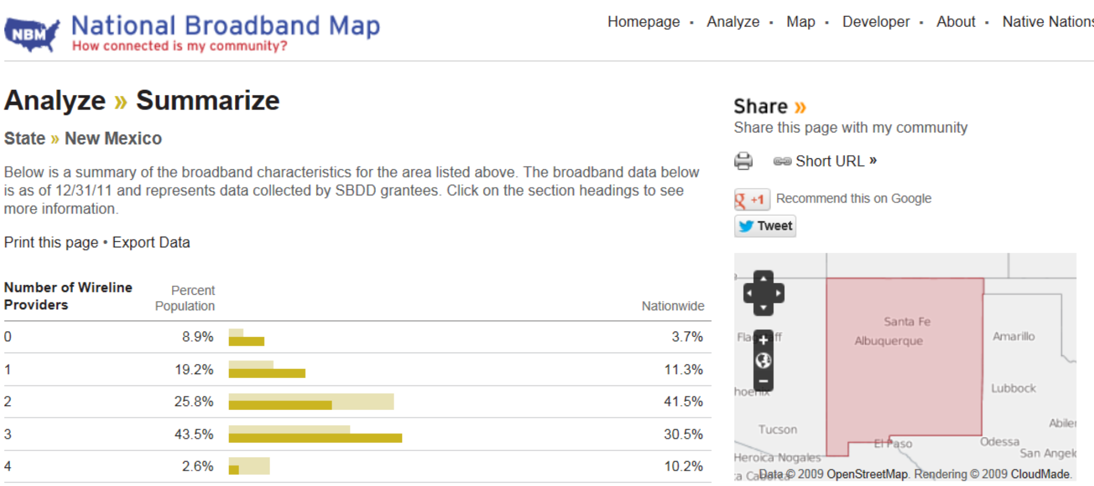
[36] In 2010, state and local officials in Mississippi petitioned the FCC to fix the inaccurate information the NBM reports for their state. See: Robert Lee Long, "Broadband maps wrong," *Desoto Times Tribune*, Jan. 15, 2013. http://www.desototimes.com/articles/2013/01/15/news/doc50f4ab3304cc9169653588.txt

Figure 1: National Broadband Map website



The NBM website also allows you to access summary data for the state as a whole (see Figure 2), or for other geographies (e.g., congressional district, native lands, city, county). And you can export data in a number of file formats for further analysis or mapping.

Figure 2: Example of NBM Search Results

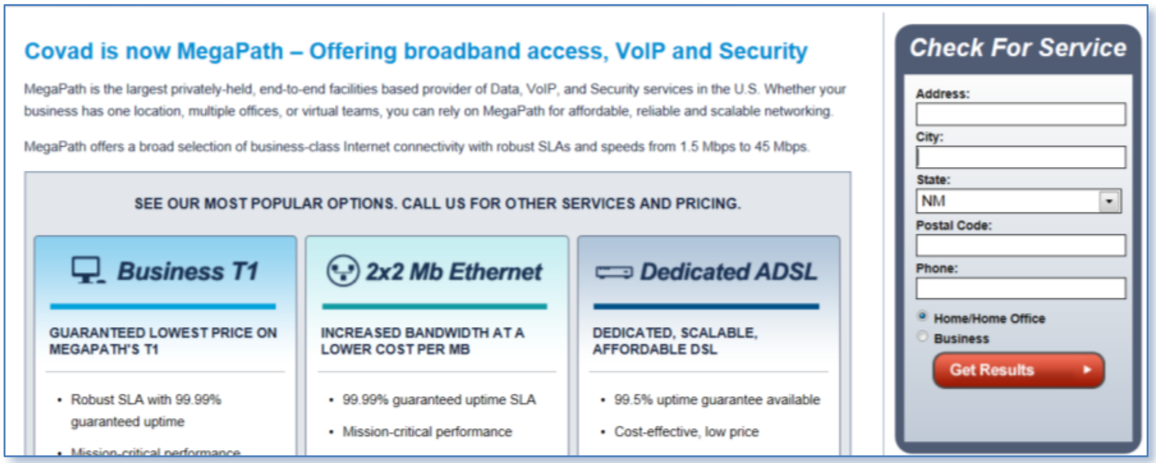


The NBM data include a list of all reported service providers in a given geography that can assist you with the next level of research into your local broadband supply: Determining what service providers are active in your community.

Broadband Providers' Websites

Commercial broadband providers frequently offer detailed information about their services on their websites. Often, you can use an individual address in your community to pinpoint the availability of broadband from a given company (see Figure 3). Indeed, this strategy is likely to give you more granular data than the National Broadband Map, whose database is less granular than the broadband providers' own internal databases.

Figure 3: Service Provider Website with Search Function



When we discuss service providers, we are often referring to "last-mile" providers, or the companies that will connect an individual home or business to the Internet. At a high level, these last-mile services providers can be categorized as follows:

- *Incumbent wireline providers*. These include the large incumbents, such as the phone and cable companies. Local incumbents may also include small local phone companies or local co-ops, which are smaller and more locally and regionally focused than the large national carriers. Getting information about incumbent services can be difficult because the big providers, in particular, consider their coverage data to be proprietary.

- *Business-focused wireline providers*. At the higher end of the market are companies that focus largely or completely on high-capacity connections for small and large businesses.

- *Competitive wireline providers*. These are companies on the smaller side who are attempting to compete with the incumbents. Even in rural areas, there usually exist one or two local wireline competitors, most of them reselling DSL provided by the phone company, but some of them operating over their own limited fiber footprints combined with phone company capacity.

Similar in nature to the wireline last-mile providers are various wireless providers:

- *Satellite providers*. Popular in rural areas where wireline infrastructure is particularly limited, these providers can sell service to virtually any resident or business. However, their products usually have slower speeds and other technical challenges, are more expensive, and include highly restrictive data caps compared to DSL, cable, or fiber-based broadband services.

- *Mobile (cellular) providers*. The NBM provides basic data, and on the providers' sites you can often plug in an address to determine whether service is available. Mobile service areas are often challenging to define in less densely populated areas, however. The same holds true where there is challenging terrain (e.g., canyons, mountains) because it is hard to reliably propagate wireless signals there.

- *Fixed wireless providers*. Fixed wireless service relies on a set of point-to-point wireless links to provide wireless broadband to residents and business. The providers are usually small companies, or sole proprietorships, that offer service over a certain area of a city or in rural areas that are unserved by wireline incumbents. As a result the providers may not be listed on the NBM and thus you may need to utilize alternative resources such as the Wireless Internet Service Providers Association (WISPA) site that offers a tool to search for fixed wireless providers in a community.[37]

Middle mile networks and backhaul providers: In contrast to last-mile providers are "middle-mile" networks, which, as their name implies, operate the infrastructure necessary to connect the last-mile providers to the Internet backbone. The large phone and cable companies are all middle-mile providers in the sense that they bring their long-haul capacity through most communities. There are also small middle-mile networks in states and regions. Examples of this type of providers include Level3, AboveNet, Zayo, Allied, Cogent, and Tata. Smaller middle-mile networks typically do not sell services directly to residents or business customers, and they often have limited "footprints" or service areas. Here again the NBM does not identify these providers, so you will need to.

Knowing the middle mile providers in and near your service territory is important not only so that you understand the competition you will face, but also because you will need a middle mile network to connect your local network to the Internet backbone.

If long-haul or backbone fiber optics pass near or through your service territory, they likely attach to your poles, so your internal records are the first crucial resource for understanding what providers are present. Utility poles that carry fiber optic cables often have banjo-shaped storage loops in the cables (Figure 4). They may also have tags identifying their owners. Underground fiber may have manholes and markers identifying their owner and providing contact information (primarily as a warning to others who may dig near the fiber.)

[37] See http://www.wispa.org/find-a-wisp

Figure 4: Aerial Fiber Optic Cable with Storage Loop

Mapping Based on Technical Data Collection

There is a considerable amount of work you can do in the field to try to determine the location of infrastructure and the quality of services throughout your electric service territory. For aerial plant, you can rely on your internal records to determine who is attached to your poles and what the type, and quality, of their attachment. In many communities, outside plant may be buried, in which case your local permitting office may be able to advise you regarding who is in the rights of way. Where plant is buried on private land, there may not be adequate public record of the infrastructure.

Before you attempt to gather any hard data, there are several assumptions you can safely make about broadband technology locations. In the case of cable modem broadband service, you should expect to find service mostly in and near population centers, and mostly in residential areas. For DSL, the availability of service depends on proximity to a provider’s central office. Finally, mobile broadband access depends on both proximity to cellular antennas and terrain (because topography can have a big impact on the uniformity of coverage from a given antenna).

Cable TV Broadband

Cable broadband service is typically only available in cities and towns with sufficient population density to support the operator’s business model. If you are a jurisdiction of some population density, you likely have cable infrastructure. In sparsely populated rural areas, you likely do not.

Cable providers operate under an agreement with a local franchising authority designated by the local government. Their service footprint is delineated by the agreement. If a municipality is the franchising authority, you can expect to find service throughout much of that municipality. However, while franchising agreements require a certain standard of service, they often require the provider to build only to areas surpassing a certain population density. In many parts of the country, cable companies have negotiated franchise agreements that have not obligated them to build out to communities with fewer than 20 homes per square mile, or to areas that are not contiguous with the rest of the cable system. This is a very important point to take into account as you study supply. Initial impressions may indicate that an entire jurisdiction has cable broadband service, when in fact portions of the community are not served due to low population density in those areas. In virtually all communities throughout the country, cable service is, to some extent, marked by a patchwork of gaps of this kind.

In many smaller, rural towns, there may be a cable system offering video services, but that system has not been upgraded to offer broadband Internet. In this case, you face a video competitor but not one who can compete for Internet data services.

Digital Subscriber Line (DSL)

In sparsely populated areas, DSL is often the only wireline broadband service available. DSL infrastructure does not require a new build-out to the premises, because it runs over the copper telephone lines that exist nationwide. In the case of DSL supply, then, the main issue is not population density, but proximity to provider infrastructure.

DSL signals are routed through phone lines via a provider’s central office; your state government will know the locations of these central offices. DSL providers may also have installed DSL cabinets, which extend the distance of service by another 15,000 to 18,000 feet, so it is important to determine if and where these cabinets exist. The farther the user is from the central office or cabinet, the weaker and less reliable the DSL signal will be. The signal ceases to be viable outside of a distance of 15,000 to 18,000 feet.

Even within this range, signal strength varies greatly, and service is not guaranteed; a DSL provider will have a finite number of circuits at a given central office, and potential new subscribers may find that the provider has no capacity available.

Fiber Optics

Fiber optic technology is used for 1) fiber-to-the-premises (FTTP) broadband service, 2) the backbone portions of DSL and cable TV networks, 3) long-distance intercity or interstate links, and 4) high-volume connections for commercial and institutional customers.

Some communities are served by small local FTTP providers, who provide high-speed data, video, and voice services. If your community receives these services, you are probably aware of them.

FTTP is usually concentrated in more built-up areas and new housing or business developments, or where a rural telephone company has built FTTP with federal funding.

Mobile (3G and 4G)

Mobile broadband service is available across greater areas than wireline service, but coverage varies a great deal. Important factors include the locations of wireless towers, the physical topography of the area, and what generation of service the incumbent providers offer.

Competition from mobile broadband is important to assess because these services are so important to consumers, and becoming more popular all the time. Even though mobile services are very different in capability to the services you are likely to offer over a fiber network, some consumers are satisfied with mobile, while others will not purchase both mobile and land-line broadband for cost purposes. In addition, the large incumbent phone companies are concentrating their broadband investments in the mobile space (as opposed to FTTP), and they serve both their traditional phone markets and those where they do not have a wireline footprint; as a result, you should assume that mobile services will grow in capacity and popularity with time and will provide significant competition to your broadband services.

3. Understanding Broadband Technologies

Not all broadband technologies are created equal. As telecommunications providers plan for the future, understanding the advantages and disadvantages of different broadband technologies and their capabilities to deliver certain services and application is critically important. Broadband is a loose term that can be applied to a range of different technologies—each of which offers different capabilities and limitations. Within the context of broadband, there is a wide range of speeds and reliability.

One of the main factors creating this range is the different types of infrastructure used to deliver 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.

Wired/Wireline Technology

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

One of the predominant physical media supporting communications within the U.S. and the rest of the world continues to be twisted-pair copper wiring. These are the legacy copper lines originally built 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 provide download speeds of up to 25 Mbps. Some providers offer DSL speeds of 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.

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.

Locations outside of that range will not be able to get broadband-speed DSL service. Residents within this radius can subscribe to DSL, but the download and upload speeds they receive will depend 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 technology can deliver.

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. Equipment designers assume that typical broadband customers will consume much more data than they share. Therefore, network capacity for most DSL equipment is divided 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.

Hybrid Fiber-Coaxial (Cable Television)

After twisted-pair copper lines, the next most recognizable telecommunications infrastructure is coaxial cable used in cable television technology. Cable television systems originated in the late 1940s and rose to popularity in the 1980s and1990s. 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, and thereafter are coaxial cable.

Cable operators have extended fiber optics progressively closer to their subscribers' premises but have generally stopped at nodes about one mile from the premises, using coaxial cable for the last mile. Thus, their networks are a hybrid of fiber and coaxial infrastructure. Comcast, for example, typically only constructs fiber optics to the premises of businesses that subscribe to Metro Ethernet and other advanced services (i.e., generally for symmetrical services faster than 50 Mbps).

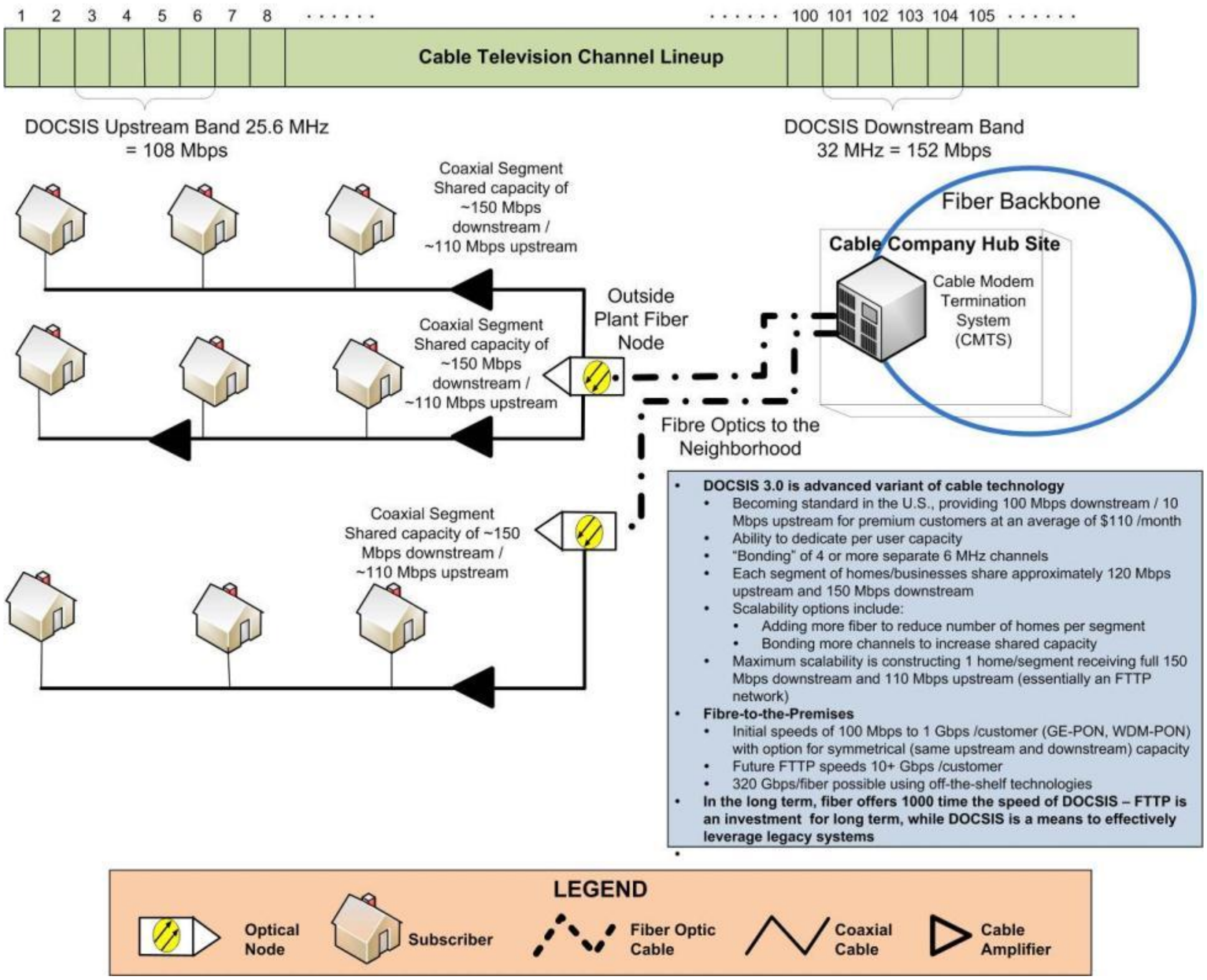
Cable operators have discussed constructing fiber optics to the premises, starting with new greenfield developments, but so far have generally not done so. They have typically opted instead to install new coaxial cables to new users, even though the construction cost to new premises is approximately the same.

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

Theoretically, there is significant room for upgrading the speeds in a cable system, especially if there is access to high-speed fiber optic backbone. For example, Virgin Mobile is offering 1.5 Gbps service in Britain over a cable network, presumably by bonding more than 30 channels. It is critical to note that these are peak speeds, and that the capacity is shared by all customers on a particular segment of coaxial cable; this is typically hundreds of homes or businesses. Speeds decrease during bandwidth "rush hours" when more users simultaneously use greater amounts of data. For example, residential bandwidth use typically goes up a great deal during evening hours when more people use streaming video services and other large data applications.

Figure 5 illustrates sample DOCSIS 3.0 network architecture.

Figure 5: Sample DOCSIS 3.0 Network



Ultimately, the maximum speed over an HFC network is limited by the physics of the cable plant; although an HFC network has fiber within certain portions of the network, the coaxial connection to the customer is generally limited to less than 1 GHz of usable spectrum in total. By comparison, the capacity of fiber optic cable is orders of magnitude greater and is limited, for all intents and purposes, only by the electronic equipment connected to it—allowing for virtually limitless scalability into the future by simply upgrading the network electronics.

Thus, while DOCSIS 3.0 is more than adequate for the high-speed demands of most residential customers in the current market, it will not have the same longevity as fiber-to-the-premises, which is basically immune from obsolescence.

Another drawback to cable broadband service 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 for upstream transmission—

generally for 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 and combine other frequencies for uploading data, but these technologies are still in development, and almost all cable systems still have only 5 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 to 100 Mbps, but upload speeds of up to 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.

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 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 itself is declining, but costs associated with construction to existing premises remain high. (In a greenfield setting, the cost of fiber optic network construction is the same on a per-unit basis as coaxial or DSL.) 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. 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.

Figure 6 illustrates a sample FTTP network, demonstrating how high levels of capacity and reliability are brought directly to the premises. Figure 7 illustrates at a higher level of detail how an FTTP network provides connectivity without a technical bottleneck to the Internet or other service providers, and can also provide a flexible, high-speed backbone for wireless services.

Figure 6: Sample FTTP Network

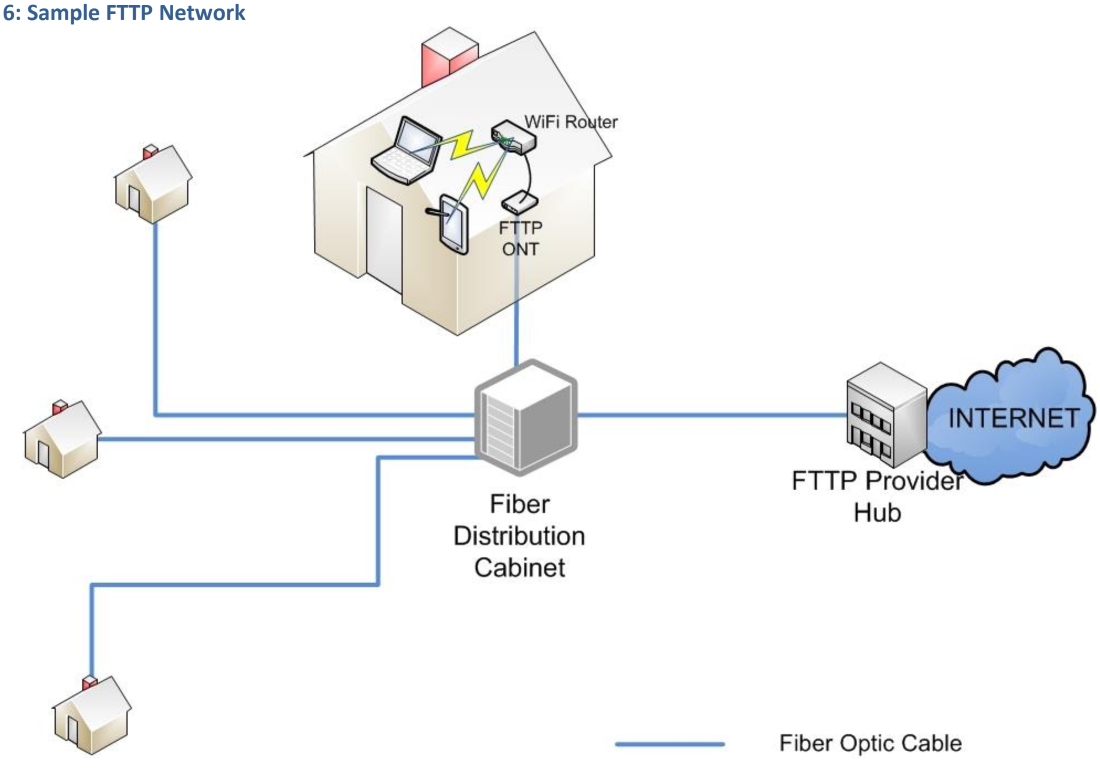
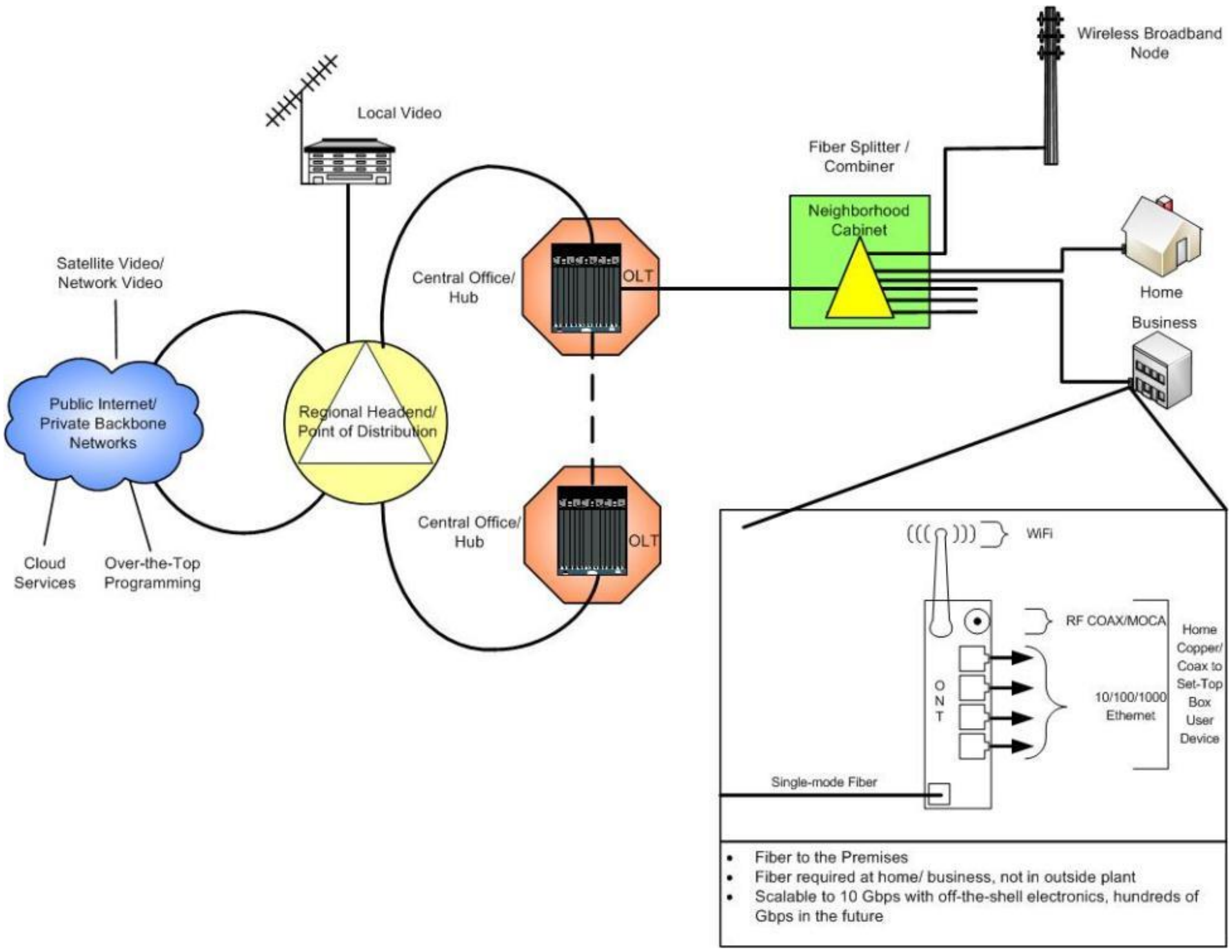


Figure 7: Sample FTTP Network (Detailed)



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 iPhones, Android devices, and tablets starting 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. Similarly, in a residence or in a local Wi-Fi deployment by a cable or wireless provider, 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 is constantly improving, under most scenarios these technologies are not capable of supporting applications for 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 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.

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 and receives signals from 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. Furthermore, even where wireless capacity exists for video and other bandwidth-demanding services, wireless service providers typically charge for usage, limiting how much capacity and what applications can be affordably used.

Applications	**Technology (Download/Upload Service Speeds)[38]**		
	2G/2.5G–EDGE/GPRS, 1xRTT (128 Kbps–300 Kbps/ 70 Kbps–100 Kbps)	3G–EVDO Rev A, HSPA+ (600 Kbps–1.5 Mbps/500 Kbps–1.2 Mbps)	4G – WiMAX/LTE (1.5 Mbps–6 Mbps/500 Kbps–1.2 Mbps)
Simple text e-mails without attachments (50 KB)	Good (2 seconds)	Good (1 second)	Good (1 second)
Web browsing	Good	Good	Good
E-mail with large attachments (500 KB)	OK (14 seconds)	Good (3 seconds)	Good (1 second)
Play MP3 music files (5 MB)	Bad (134 seconds)	OK (27 seconds)	Good (7 seconds)
Play video files (100 MB for a typical 10-min. YouTube video)	Bad (45 minutes)	OK (9 minutes)	Good (3 minutes)
Maps and GPS for smartphones	Bad	OK	Good
Internet for home	Bad	OK	Good

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 through an auction carried out by the FCC.

[38] These data assume a single user. For downloading small files up to 50 KB, it assumes that less than 5 seconds is good, 5-10 seconds is OK, and more than 10 seconds is bad. For downloading large files up to 500 KB, it assumes that less than 5 seconds is good, 5-15 seconds is OK, and more than 25 seconds is bad. For playing music, it assumes that less than 30 seconds is good, 30-60 seconds is OK, and more than 100 seconds is bad. For playing videos, it assumes that less than 5 minutes is good, 5-15 minutes is OK, and more than 15 minutes is bad.

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.

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. 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, and accessing a virtual private network (VPN). Even satellite Internet providers themselves caution against using these applications in conjunction with their services. 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.

TV White Space Technology

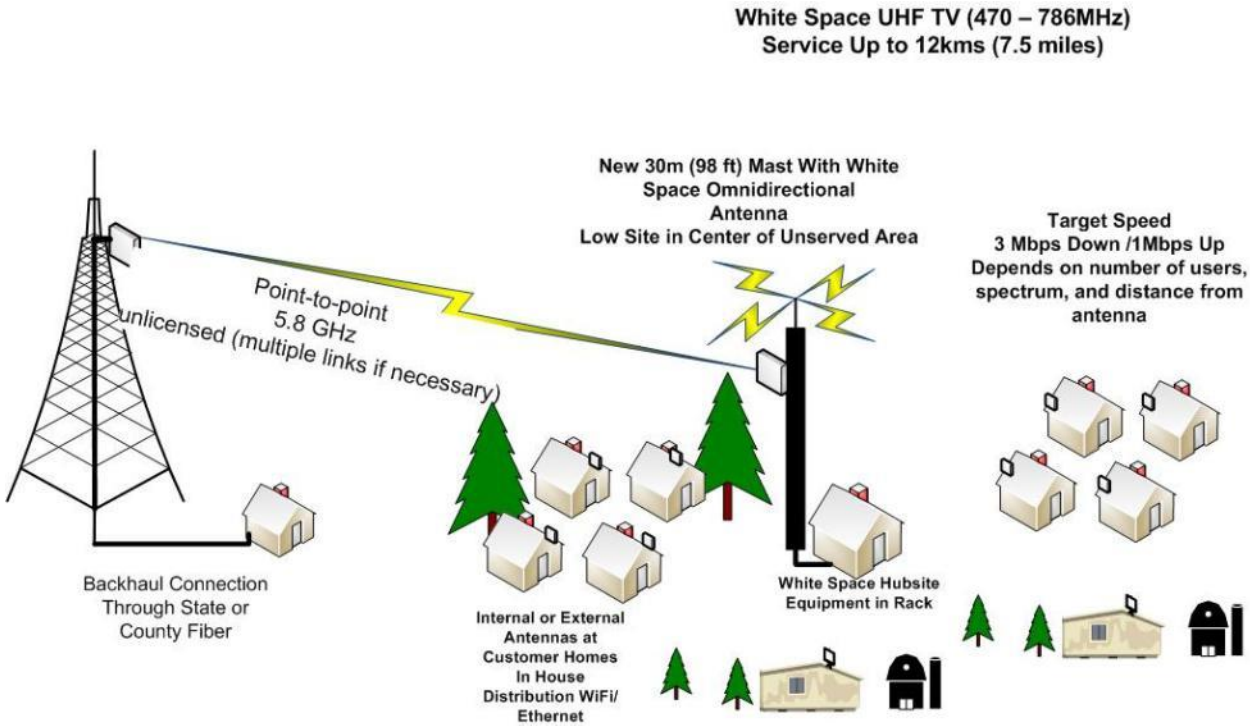
In 2009, the FCC approved the use of unused portions of the broadcast television spectrum for wireless broadband, sometimes referred to as "super Wi-Fi." The authorization allows new wireless hardware to use vacant television frequencies called TV white space (or simply white spaces). Devices must check 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 heavily utilized, there are often unused channels available.

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.

Because TV white space technology is in an early phase of development, equipment is not yet mass-produced or standardized. Therefore user devices are still expensive—typically $500 or more apiece. The transmission speeds and other capabilities of the technology are likely to improve in the coming years, relative to current early-adopter equipment. White space equipment supporting broadband is expected to be able to support point-to-point connections up to 7.5 miles and point-to-multipoint service radii of a few miles. Equipment supports 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 provide greater speeds. The available speeds will depend upon the number of open channels in a given area, as well as the number of users.

Initial deployment of TV white space devices will likely focus on fixed wireless networks. A base station connects to multiple homes, institutions, or businesses. The connection to the individual users is typically over Wi-Fi, since smartphones, tablets, and laptops do not yet have the chips and antennas to directly use white spaces technology. Pilot TV white space networks have focused on connecting remote schools and libraries to base stations located at larger institutions that have Internet access. Other white spaces networks are used for machine-to-machine communications across oil fields and mining operations.

It is also uncertain how much channel capacity will be available to TV white space devices. The FCC is currently developing plans to auction some TV spectrum to mobile operators, which means that spectrum will no longer be available for white spaces use. 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.



Limitations

In addition to the limited range of Wi-Fi and TVWS networks, mobile wireless broadband has technological limitations relative to wireline. These include:

1) *Lower speeds.* At their peaks, today's newest wireless technologies, WiMAX and LTE, provide only about one-tenth the speed available from FTTP and cable modems. In coming years LTE Advanced may be capable of offering Gbps speeds with optimum spectrum and a dense build-out of antennas—but even this will be shared with the users in a particular geographic area and can be surpassed by more advanced versions of wireline technologies (with Gbps speeds already provided by some FTTP providers today).

2) *More asymmetrical capacity, with uploads limited in speed.* As a result it is more difficult to share large files (e.g., video, data backup) over a wireless service, because these will take too long to transfer; it is also less feasible to use video conferencing or any other two-way real-time application that requires high bandwidth. (See below for more details.)

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

hour movie. That has left consumers with a dilemma: Pay up for more data or hold back on using the device's best features."[39]

4) *Limitations on applications.* For example, users of smartphones and some tablet computers are limited to approved applications by service providers or device manufacturers. Apple limits the applications that can operate on its iPhone and iPad devices. Although Android is an open platform, Verizon Wireless blocks uploads of video from Android wireless devices on its networks by disabling the feature unless the user is on a private Wi-Fi network. The FCC has reiterated that wireless providers have almost unlimited latitude to manage usage on their networks, in effect applying network neutrality rules only to wired networks; service providers can therefore expand their "management" of applications beyond the devices they provide to blocking or slowing applications from users with aircard-equipped PCs or home networks. The 3GPP protocols underlying LTE and subsequent technologies are designed to enable service providers to manage capacity based on application type (i.e., to prioritize particular types of traffic and make others lower priority).

Broadband Applications and Bandwidth Demands

Broadband is not an end in itself. The value of broadband is in its ability to reliably and consistently deliver applications—from Internet content, e-mail, and distance learning to telehealth and e-commerce. Broadband applications also include telecommuting, videoconferencing, data backup, Voice over Internet Protocol (VoIP), distance learning, security cameras, and remote access.

Broadband must provide the needed applications to and from users, whether they are individual citizens, public school buildings, businesses, or some other organization. Higher-quality broadband means more flexibility in using and adding applications, and applications running better and more reliably. Therefore, a suitable broadband connection requires taking into account all of the presently used applications, all of the users using them, and all of the applications that users might need in the future. The service should also be scalable, in the event that a user group outgrows the connection.

Broadband is important to residential users, but an occasional outage, while frustrating, is acceptable. Some organizations, on the other hand, could not operate if they could not connect, or if customers or suppliers could not reach them. While websites and e-commerce are typically "hosted" away from the business at a data center, many other applications must connect to the business. For those businesses, having both primary and backup connections is an option, as is a

[39] Cecilia Kang, "New iPad users slowed by expensive 4G network rates," *Washington Post*, March 22, 2012. http://www.washingtonpost.com/business/economy/new-ipad-users-slowed-by-expensive-4g-network-rates/2012/03/22/gIQARLXYUS_story.html?hpid=z2

service-level agreement (SLA) with a provider, guaranteeing a particular level of performance, with penalties for nonperformance.

For both businesses and citizens, applications can run radically differently if high-capacity, high-quality broadband is available for a reasonable cost. Given suitable assumptions, entire classes of applications—server access, videoconferencing, video upload, server backup, telecommuting, and distance learning, for example—require more than 5 Mbps downstream. These applications are not currently supported by satellite, and hence will require other broadband services. The applications can be supported by higher-speed DSL services and higher-end cable services if those services are available.

This is more of an issue for businesses; 5 Mbps DSL services require the appropriate proximity to a phone central office, and therefore might not be available at a business location, even if the phone company has lines to the business. Cable may adequately support the applications, but again, cable might not be present at the business location. And these speed requirements assume a single user; as more users are added, the suitability of DSL and cable modem services quickly declines. Cable services from the smaller providers in smaller markets also become significantly more expensive above 5 Mbps—typically more than $100 per month. In other words, even businesses with some broadband availability will face availability and cost barriers that may slow or stop their use of broadband applications.

Table 3 below describes the performance of common broadband applications, given a particular broadband service speed.[40] This table defines performance needs from today's perspective. The demand for higher-capacity connections will continue to rise—as, for example, more users (citizens and small businesses alike) explore public or private "cloud computing" services, which support and deliver hosted applications and storage over the Internet. Unlike traditional hosting services, cloud computing requires no special equipment beyond Internet access and a personal computer, and many companies are aggressively marketing cloud-based services for personal and business use.

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[40] The table assumes a single user. For downloading small files up to 1 MB, download time less than 10 seconds is good, 10 to 15 seconds is fair, and more than 15 seconds is not acceptable. For uploading videos of 1 GB, upload time less than 30 minutes is good, 30 to 90 minutes is fair, and more than 90 minutes is not acceptable. For downloading high-definition videos (2 GB), download time less than 10 minutes is good, 10 to 15 minutes is fair, and more than 15 minutes is not acceptable. For applications such as videoconferencing and remote server access, the table assumes no concurrent usage of the same application by the same user. Server back-up will normally occur during off-peak times (10 p.m. to 6 a.m.). For telemedicine files up to 160 MB, download time of less than 30 seconds is good, 30 to 60 seconds is fair, and more than 60 seconds is unacceptable.

Table 3: Performance of Applications over Various Broadband Speeds

Applications	**56 Kbps/ 56 Kbps** *(Dial-up, maximum speed)*	**256 Kbps/ 256 Kbps** *(DSL)*	**768 Kbps/ 384 Kbps** *(DSL; Satellite; 3G Wireless)*	**1 Mbps/ 384 Kbps** *(DSL; Satellite 3G/4G Wireless)*	**3 Mbps/ 768 Kbps** *(DSL; Satellite; 4G Wireless)*	**7 Mbps/ 768 Kbps** *(DSL; Cable; 4G Wireless)*	**10 Mbps/ 1 Mbps** *(DSL; Cable; Fiber; 4G Wireless)*	**15 Mbps/ 2 Mbps** *(DSL; Cable; Fiber)*	**20 Mbps/ 2 Mbps** *(Cable; Fiber)*	**50 Mbps/ 10 Mbps** *(Cable; Fiber)*	**100 Mbps/ 10 Mbps** *(Fiber)*	**1 Gbps/ 100 Mbps** *(Fiber)*
Simple text e-mail without attachments (50 KB)	OK (8 sec.)	Good (2 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)
Receive e-mail with medium attachments or graphics (500 KB)	Bad (72 sec.)	OK (16 sec.)	Good (6 sec.)	Good (4 sec.)	Good (2 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)
Download small files (e.g., a fifty-page text document with limited graphics) (1 MB)	Bad (3 min.)	OK (32 sec.)	OK (11 sec.)	Good (8 sec.)	Good (3 sec.)	Good (2 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)	Good (1 sec.)
Download large files (e.g., new software or a large program update) (500 MB)	Bad (20 hr.)	Bad (5 hr.)	Bad (87 min.)	Bad (67 min.)	OK (23 min.)	OK (10 min.)	Good (7 min.)	Good (5 min.)	Good (4 min.)	Good (80 sec.)	Good (40 sec.)	Good (1 sec.)
Download high-definition (HD) video (5 GB)	Bad (9 days)	Bad (44 hr.)	Bad (15 hr.)	Bad (12 hr.)	Bad (4 hr.)	Bad (96 min.)	Bad (67 min.)	Bad (45 min.)	OK (34 min.)	Good (14 min.)	Good (7 min.)	Good (40 sec.)
Upload videos, presentations (1 GB)	Bad (40 hr.)	Bad (9 hr.)	Bad (6 hr.)	Bad (6 hr.)	Bad (3 hr.)	Bad (3 hr.)	Bad (134 min.)	OK (67 min.)	OK (67 min.)	Good (14 min.)	Good (14 min.)	Good (80 sec.)
Daily incremental backup, up to 20 GB	Bad (> 1 day)	Bad (> 1 day)	Bad (> 1 day)	Bad (> 1 day)	Bad (> 1 day)	Bad (> 1 day)	Bad (> 1 day)	Bad (23 hr.)	Bad (23 hr.)	OK (5 hr.)	OK (5 hr.)	Good (27 min.)
Telemedicine (e.g., radiological images such as mammograms) (160 MB download)	Bad (7 hr.)	Bad (84 min.)	Bad (28 min.)	Bad (22 min.)	Bad (8 min.)	Bad (4 min.)	Bad (3 min.)	Bad (86 sec.)	Bad (64 sec.)	Good (26 sec.)	Good (13 sec.)	Good (2 sec.)

Applications	**56 Kbps/ 56 Kbps** *(Dial-up, maximum speed)*	**256 Kbps/ 256 Kbps** *(DSL)*	**768 Kbps/ 384 Kbps** *(DSL; Satellite; 3G Wireless)*	**1 Mbps/ 384 Kbps** *(DSL; Satellite 3G/4G Wireless)*	**3 Mbps/ 768 Kbps** *(DSL; Satellite; 4G Wireless)*	**7 Mbps/ 768 Kbps** *(DSL; Cable; 4G Wireless)*	**10 Mbps/ 1 Mbps** *(DSL; Cable; Fiber; 4G Wireless)*	**15 Mbps/ 2 Mbps** *(DSL; Cable; Fiber)*	**20 Mbps/ 2 Mbps** *(Cable; Fiber)*	**50 Mbps/ 10 Mbps** *(Cable; Fiber)*	**100 Mbps/ 10 Mbps** *(Fiber)*	**1 Gbps/ 100 Mbps** *(Fiber)*
Web browsing	Bad	Bad	OK	OK	Good	Good	Good	Good	Good	Good	Good	Good
Interactive online applications (online meeting presentation, document sharing, gaming)	Bad	Bad	Bad	OK	OK	Good	Good	Good	Good	Good	Good	Good
Videoconferencing streaming at 384 Kbps (desktop/single user)	Bad	Bad	Bad	Bad	OK	OK	OK	Good	Good	Good	Good	Good
Telecommuting/remote server access/VPN client	Bad	Bad	Bad	Bad	Bad	Bad	OK	OK	OK	Good	Good	Good
Multi-point videoconferencing streaming at 768 Kbps for a group of five to six	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Good	Good	Good
Stream HD video (3 – 5 Mbps)	Bad	Bad	Bad	Bad	Bad	OK	OK	Good	Good	Good	Good	Good
Distance learning	Bad	Bad	Bad	Bad	Bad	Bad	Bad	OK	OK	Good	Good	Good

4. Survey of Business Models

This chapter is intended to provide communities and utilities with an overview of several different business models for a local broadband network. Public entities should balance control, risk, and reward when evaluating which model will most likely meet their goals. Utilities and local governments also should perform a robust feasibility analysis. 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.

Retail Services

In the most common utility broadband model, the coop or municipal builds a fiber-to-the-premises infrastructure and offers retail Internet services to businesses and residences. In some cases, the coop will also offer phone service (a "double play" bundle) or phone and video (a "triple play").

Douglas Electric Cooperative, which serves members over a 2,200 square mile area in southern Oregon, offers a double-play bundle through Douglas Fast Net (DFN).[41] The coop founded DFN more than a decade ago with a straightforward goal: "to deliver high-speed broadband to everyone in Douglas County—even those in outlying areas that might not have gotten service before."[42] In addition to its retail residential and business services, DFN has "brought unparalleled service to the medical and education community."

In terms of direct financial factors, such a retail FTTP network entails significant risk because of the size of the upfront capital commitment necessary and the ongoing operating costs to run the network.

In this business model, the utility may also be an *over-builder*, providing services in competition with the existing phone and/or cable incumbents. Though the incumbents' products may not meet the federal definition for broadband, they can still provide stiff competition for a utility's superior services. While the potential exists for the community to obtain sufficient market penetration necessary to support enough cash flow, sustaining enough customers can be a significant challenge, particularly when well-resourced incumbent providers can aggressively market or discount services in response to the entry of a competitive provider.

Financing in this network is usually through bonding secured through identified utility funds or other revenue source.

[41] "Bundles," Douglas Fast Net. http://www.douglasfast.net/bundles/
[42] "About DFN," Douglas Fast Net. http://www.douglasfast.net/about/

Open Access

In this model, the utility 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 utility 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 utility theoretically 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 utility, including the interest of retail providers to offer services over the network[43] and the retail providers’ marketing success, have the potential to reduce revenues below break-even cash flow needs.

Financing in this network is usually through bonding secured through identified utility funds or other revenue source.

Alternative Model: Institutional/Middle Mile

In this model, the utility seeks to offer dark fiber[44] connections, through a lease, to institutions and businesses. The utility can lease the excess fiber to recover incremental costs, so long as the leased fiber contract is structured so it does not violate internal, state, and federal safety requirements. Under the lease, the utility would receive a revenue stream with very little risk associated. This model requires less involvement in operations than does a retail model because it does not require the utility to go into the business of providing communications services itself. At the same time, the model leverages such assets as the utility’s considerable right-of-way knowledge and maintenance capabilities.

Experience suggests that this is the business and technical model with the highest possibility of financial success and with the lowest risk for the utility. This model can facilitate a modest portion of the potential enabled by broadband while still minimizing risk. This model requires a smaller capital investment than does more extensive fiber deployment and experience suggests that the

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[43] The well-known UTOPIA (Utah Telecommunications Open Infrastructure Agency, a joint project of 14 communities in suburban and rural Utah) network encountered exactly these problems—difficulty finding providers to offer services over the network, and uneven marketing efforts by those providers that did offer services.

[44] Dark fiber refers to the lease of point-to-point fiber strands. The lessee of dark fiber is responsible for adding electronics to “light” the fiber.

utility could realize a modest revenue stream from this model—at the same time as meeting its own communications needs and reducing the cost of leasing circuits.

This model for fiber construction and leasing has been successfully implemented by a number of utilities for nearly a decade.

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

5. Understanding Capital and Operating Costs

This chapter is intended to provide communities and utilities with an idea of the range of different costs for a local fiber network. Because actual costs depend so greatly on the network being constructed, we have included ranges of costs for illustration.

This chapter focuses on a retail service model offered over fiber-to-the-premises (FTTP), which has been the most common among coop and municipal utilities. Under the retail model, the local government or utility becomes a competitive provider of voice, video, and data services. The model assumes the utility will define and update services on an ongoing basis, establish consumer level sales and marketing efforts, and establish consumer support services. The retail model requires a broad range of staff additions, training, marketing, and other activities to run and maintain.

Capital Costs

Capital costs include fiber construction, installation to premises, electronics, and preparation of central office/hub facilities. At a general level, an FTTP build in an area of moderate density (i.e., 50 to 200 homes per mile), including electronics, might cost anywhere from $800 to $1,500 to pass each home or business, and an additional $400 to $750 per location connected. As with any infrastructure construction, costs may vary widely depending on the specific area being built—and some costs will rise as the distance between premises increases.

The cost range depends on many factors, but primarily on the 1) breakdown between overhead and underground plant, 2) density of premises per mile of plant, 3) size of the project/available economies of scale, 4) length of the deployment, 5) prevailing labor costs, and 6) amount of pole make ready required.

We note that in areas of very low density (i.e., less than 10 passings per mile), the cost can exceed $10,000 per home/business passed.

We have developed cost estimates for the various outside plant components based on available industry pricing for fiber and facility construction. A good practice is to perform detailed designs of representative areas of the system and generate estimates for each one, since there are numerous factors that can impact costs in a particular service area, including:

- Home density
- Average home setbacks
- Percentage of overhead (aerial) versus underground construction
- Utility pole conditions and loading
- Congestion of underground right-of-way
- Soil conditions

- Restoration requirements for right-of-way disturbances, sometimes driven by permitting authorities, historical preservation organizations, and even homeowners' associations

Overhead (Aerial) Construction

Where space on utility poles exists, overhead construction is the preferred method for most fiber optic construction because it is typically far less expensive and time consuming than underground construction. In an aerial electric utility area the cooperative can install all-dielectric self-supporting (ADSS) fiber cable in the utility space, thus avoiding pole replacement if the pole does not have sufficient clearance in the communications space.

Estimated unit costs for the various outside plant construction materials and labor needed in developing the sample design are itemized in Table 4 and Table 5.

While materials costs are fairly consistent (depending upon volume), labor rates can vary greatly depending on the geographic region and the demand for personnel to perform outside plant construction. Labor costs will vary substantially according to demand for service. It is difficult to calculate labor charges without receiving firm bids from fiber optic construction companies. Furthermore, a utility can potentially reduce costs by using in-house labor. Thus it is necessary to examine labor costs within a likely range. Table 5 provides the most likely and worst-case labor estimates used in calculating our cost estimates.

Table 4: Aerial Construction Material Cost Assumptions

Item	Unit	Cost
60 count fiber	Foot	$0.65
48 count fiber	Foot	$0.52
24 count fiber	Foot	$0.44
60 fiber splice case	Each	$338.75
48 fiber splice case	Each	$271.00
4 way tap 300 ft.	Each	$188.00
6 way tap 325 ft.	Each	$231.50
8 way tap 225 ft.	Each	$275.00
12 way tap 200 ft.	Each	$365.00
Fiber distribution cabinet (FDC)	Each	$13,000
Hardware	Foot	$0.50
Strand	Foot	$0.27
288 count ADSS fiber	Foot	$3.75
48 count ADSS fiber	Foot	$1.45

Table 5: Aerial Construction Labor Cost Assumptions

Item	Unit	Low case	High case
Place strand	Foot	$1.25	$2.00
Place ADSS fiber	Foot	$3.25	$4.50
Lash cable	Foot	$1.80	$2.50
Splicing	Each	$10.00	$45.00
Place FDC	Each	$2,000	$5,000
Place taps	Each	$15.00	$40.00

Selecting a range of assumptions based on the discussion above, we find that aerial FTTP construction cost can range from $25,000 to $75,000 per route mile. These estimates do not include costs for make ready—the process by which utility poles are prepared for new cable attachments.

Make ready is necessary to ensure that structural and safety requirements are met, often dictated by individual cooperative electric standards, local and national codes. Prior to construction, the entire construction route, including all utility poles, must be surveyed to determine make ready requirements, generate permit applications, and develop pole attachment agreements with the utility pole owners (if not owned by your cooperative).

If you have to locate on another entity's poles, attachment fees and make ready costs, in particular the make ready costs, represent the greatest degree of uncertainty and cost variance for overhead construction.

We note that an electric cooperative has the option of putting its fiber in the power space on its own utility poles. This eliminates make ready costs and ensures that there will be space for the fiber. The disadvantages of this type of placement are that only personnel trained in the power space can work on the fiber or, if taps are located in the power space, install it to homes. Also, only all-dielectric self-supporting (ADSS) fiber can be used. Additional cables, including those for service drops to homes and businesses, cannot be overlashed to ADSS fiber—limiting the scalability of the installed fiber.

Utility company requirements, condition of existing plant, local permitting requirements and local code are all unique to an individual service area. In addition, some utility pole owners allow the new provider to survey and perform any necessary changes on their own, while others require that their own crews complete the make ready work.

During the make ready survey, each pole is visited and attachments on the pole are identified and recorded. The height of the pole, down guy size, anchor status, and location of pole attachments are captured in a "stick drawing." In addition, the proposed new cable attachment type and location is determined following utility pole owner, Rural Utility Services (RUS), and

National Electrical Safety Code (NESC) requirements. Required changes in existing utility attachments are documented. Each utility examines the requested changes and submits an estimate for clerical, engineering, and inspection costs to the new operator. Typical make ready work on the aerial plant includes raising or lowering lines, adding ground bonds, changing down guys, adding anchors, adding guards and adding new attachment clamps. In some cases the entire utility pole must be replaced for the new operator to attach to the pole.

Once the make ready estimate is paid by the new operator, the utility or its contractor is permitted to complete the make ready. When construction is completed, the utility companies make a final inspection to ensure the plant was built according to plans. The utility companies then compare actual costs to estimated costs and reconcile the account. CTC estimates the average cost to complete make ready to range from $2,500 per mile, in an area where poles are not crowded, to over $50,000 per mile, where poles are crowded and many poles need to be replaced.

Underground Construction

Underground fiber optic construction can vary greatly in cost depending on the type of construction, availability of space in the right-of-way, permitting requirements, and local ordinances in the areas of construction. In particular, traffic monitoring, lane closures, street and sidewalk repair (if any exist), and existing underground utility locations can affect the overall cost of construction. Many of the unknowns of underground construction cannot be determined until the final detailed design and walk-out are performed. Table 6 and Table 7 provide the material and labor costs used in our preliminary budgetary estimates. Due to the range of labor rates associated with construction, we include both low and high case labor rates.

Table 6: Underground Construction Material and Labor Rates

Material	Unit	Cost
60 count fiber	Foot	$0.65
48 count fiber	Foot	$0.52
24 count fiber	Foot	$0.44
60 fiber splice case	Each	$338.75
48 fiber splice case	Each	$271.00
4 way tap 300 ft.	Each	$188.00
6 way tap 325 ft.	Each	$231.50
8 way tap 225 ft.	Each	$275.00
12 way tap 200 ft.	Each	$365.00
Conduit	Foot	$2.00
Splice vaults	Each	$550.00
Tap vaults	Each	$200.00
Fiber distribution cabinet	Each	$13,000
Hardware	Foot	$0.50

Table 7: Underground Construction Labor Rates

Labor Item	Count	Low Case	High Case
Place conduit	Foot	$1.80	$3.00
Trench	Foot	$8.00	$20.00
Bore	Foot	$10.00	$30.00
Pull fiber	Foot	$1.00	$2.50
Splicing	Each	$10.00	$45.00
Place FDC	Each	$3,000	$5,000
Place tap vaults	Each	$150.00	$500.00
Place splice vaults	Each	$650.00	$1,500

Selecting a range of assumptions based on the discussion above, we find that underground FTTP construction cost ranges from $60,000 to $250,000 per route mile, with the worst-case in a dense environment with extensive, costly restoration and hand digging required to locate existing utilities.

Compared to many fiber construction projects targeting particular buildings or types of customers, complete FTTP construction is more costly on a per route mile basis. An FTTP network must be designed to serve all potential customers and service taps are needed to serve every premises. Unlike middle-mile or backbone fiber, FTTP, by definition, needs to pass each location.

User Installation

Each customer needs to be physically connected to the system, and most operators install service only to premises that subscribe to the service. Some operators have focused on sales to limited portions of their service areas as the infrastructure is installed, to achieve an economy of scale in the installation.

Cost depends on a range of factors including the distance of the premises from the right-of-way, whether the drop is aerial or underground. Installation cost typically ranges from $300 to $600, but can reach thousands of dollars if the house or business is extremely far from the road or requires construction under roads or driveways.

Electronics Costs

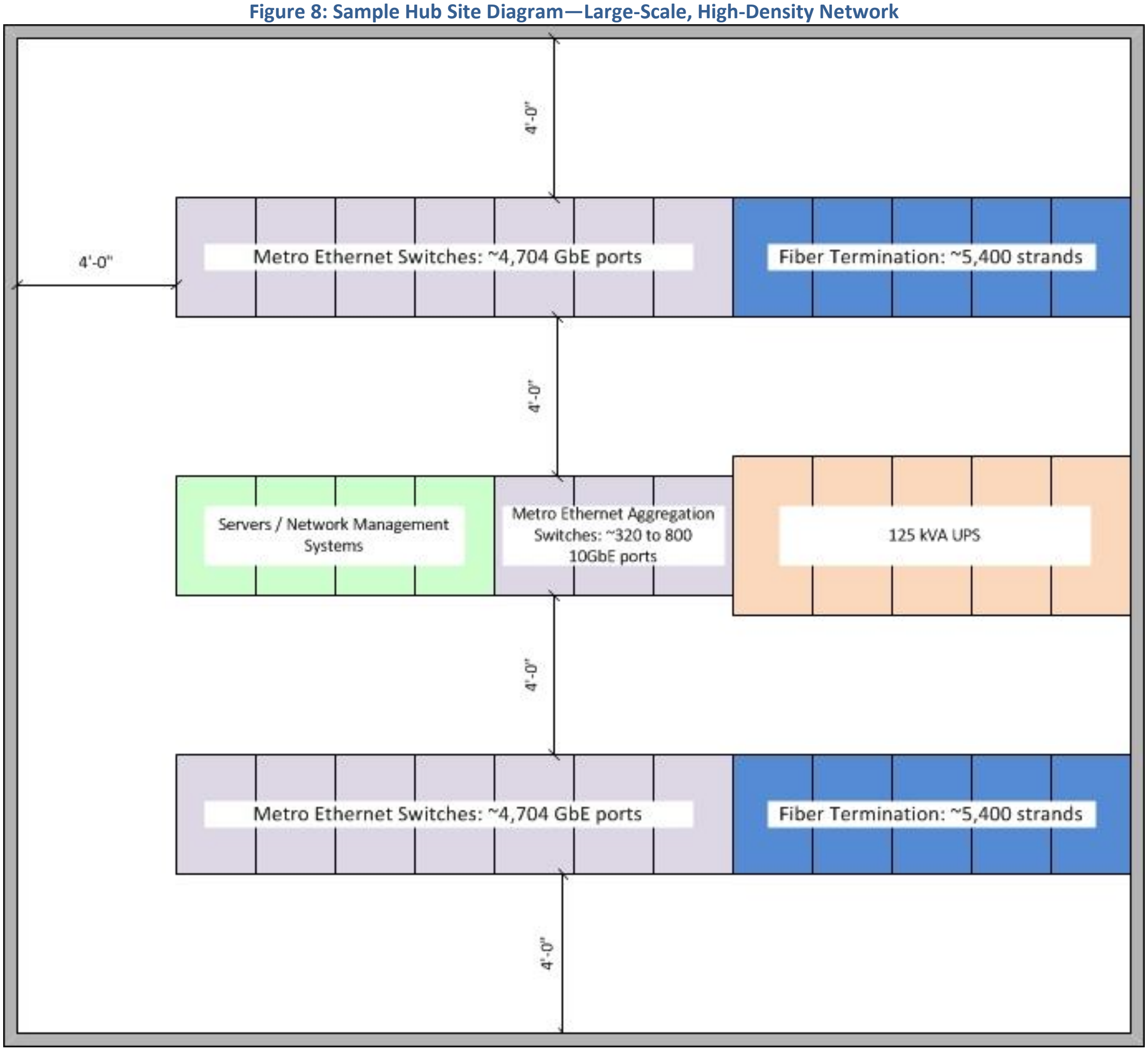
FTTP electronics include core electronics (routers, aggregation switches, optical line terminals) and user premises electronics (ONT/Ethernet switch/router). Additionally, if the provider is offering video services, the user will require set-top converters and potentially a video headend.

The type and scale of the core electronics depend on the size of the network. A typical range, per activated customer, is $100 to $600. The premises electronics range from $200 to $600 per activated customer.

Facility Construction and Fixed Network Equipment Costs

The network headend or central office requires space for network electronics, servers to support a range of network management and service provisioning functions, and collocation space for potential third-party providers. The estimated space requirement for the headend—as well as the cost of the equipment—is largely dependent on the size of the network. Figure 8 illustrates a hub site for a large-scale network.

Figure 8: Sample Hub Site Diagram—Large-Scale, High-Density Network



Hub sites are necessary to aggregate fiber connections and to house FTTP transport electronics. The number of size hub facilities depends on the size and physical distribution of the system and the electronics selected (e.g., active Ethernet, PON). Hub facilities can be co-located in substation premises (Figure 9) and can also be located in outdoor cabinets or small prefabricated buildings (Figure 10). The size can range from two standard racks for fiber termination and distribution equipment, to a 2,000 square foot space. The cost of each hub building and the associated power backup ranges from $10,000 to $500,000.

Figure 9: Hub Facility Colocation in Power Utility Substation

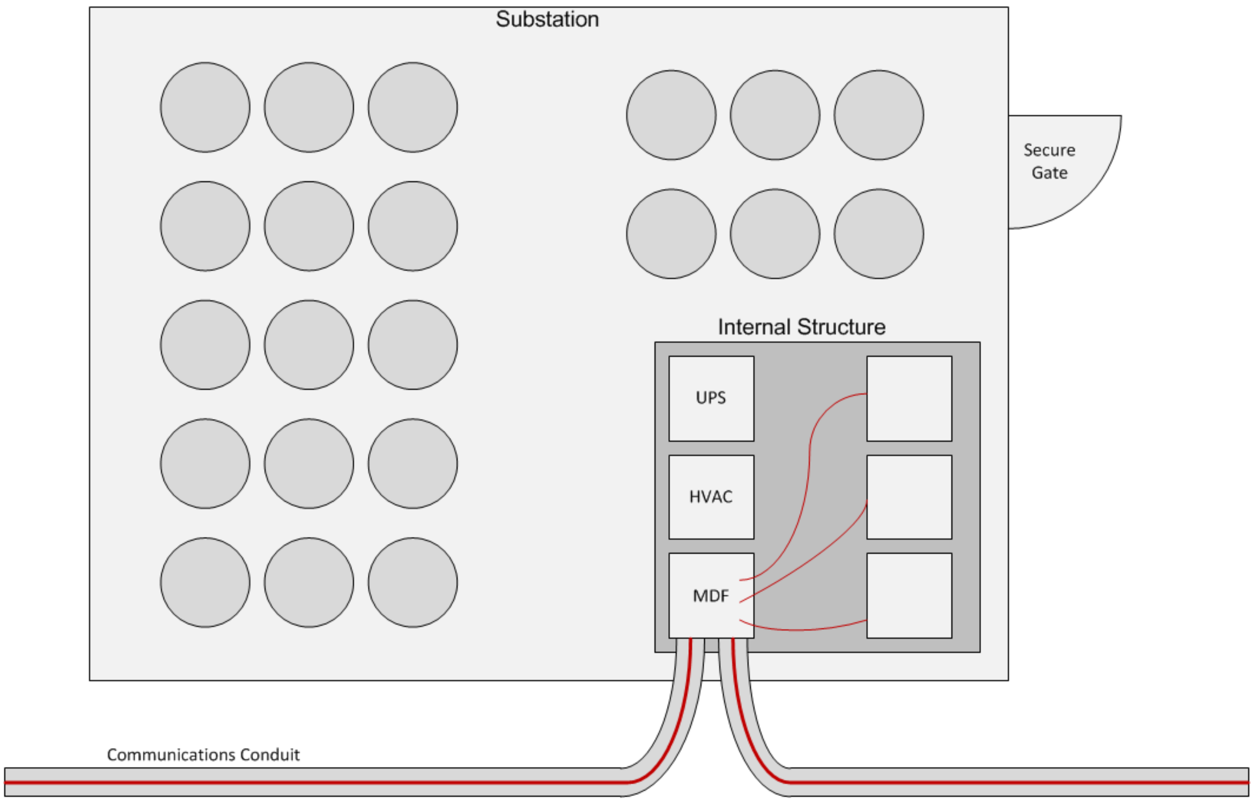


Figure 10: Hub Facility in Cabinet

The headend and hubs house central networking and application hardware necessary for the central operator to maintain and operate an FTTP system. The equipment includes core networking equipment, servers, and network operations and management equipment, incorporating all fixed costs for provisioning advanced VoIP telephony, Internet, and video distribution services comparable to competing services available today. The headend and hubs will also include space for other service providers to collocate their equipment.

Operating Costs

Operating costs for an 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.

Financing

Generally, a utility should assume two kinds of bonds: First, a 20-year bond to cover the cost of new fiber. Given current interest rates, we assume such bonds would be issued at an interest rate based on current market conditions and would be paid off in equal principal and interest payments over the 20-year depreciable life of the fiber.

Second, we assume an additional bond to cover the remaining implementation costs, including headend equipment, operating equipment, customer premises equipment and other miscellaneous costs. Most of this equipment investment depreciates over seven to 10 years and the financial projections should include reinvestment and upgrade costs to keep the equipment useful over 20 years. This second bond is paid off over 10 years (reflecting the shorter life of the assets than that of fiber) at an interest rate based on current market conditions.

You will need to include bond issuance costs, a debt service reserve, and an interest reserve based on current market conditions. Any federal or other grant funds received for construction of the FTTP network would reduce the size of the bonds and the associated debt service.

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 new or innovative services, which require more consumer education to build demand. The ability to leverage other local resources will also impact the required sales and marketing staffing. 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 cooperative 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.

Considering all aspects of the operation, the cooperative will likely require skills in the following disciplines:

Sales/promotion	Finance
Internet and related technologies	Vendor negotiations
Staff management	Networking (addressing, segmentation)
Strategic planning	Marketing

Marketing and Sales

It is important to be proactive in setting customer expectations, addressing security concerns, and educating customers on how to initiate services.

Internet Bandwidth

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. Oversubscription is defined as the ratio of the backbone transit Internet connection to the sum of the Internet connections provided to the utility members. 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, or even $100 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 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 (if any) represent an ongoing operational cost. Ongoing maintenance and software licensing fees for hub and network electronics can exceed 15 percent of the accrued investment in the equipment. Ongoing maintenance on outside plant, exclusive of pole rental and locates, is approximately 2 percent of the initial capital cost per year, although this will vary depending on the amount of construction in and around the rights-of-way; a utility will be able to better estimate the number after a few years of operations.

Telephone Service

Most utility networks 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 (often exceeding 10 percent per year). 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 service areas, 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 3 percent of revenues or more.

Churn

Residential customers tend to switch services 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 1 percent per month. Churn costs include the cost of acquiring and hooking up a new customer. 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 Replacement

Any equipment under the utility’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.

Facilities

The addition of new staff and inventory requires allocation of office and warehousing space. Like any commercial provider, the utility will need to invest in office space, warehousing space, network equipment space, and a retail storefront to help market the new services.

Training

Training of existing utility staff is important to fully realize the economies of adding a business unit. An acceptable benchmark is 4 percent of payroll per year.

6. Understanding the Breadth of Revenue Sources

This chapter summarizes briefly a range of revenue sources on which your broadband utility is likely to depend. The three key markets for broadband service are residential, business, and institutional. In addition to high quality data (Internet) services, you are likely to offer video (cable) to the residential market. These revenue opportunities are summarized at a high level below and neither this list nor this discussion is exhaustive. As with any significant new investment or service offering, a utility should conduct market research to gather data regarding how willing potential customer/member groups would be to switch to your services at various price levels. This chapter also discusses the significant customer service and localism advantages that a utility can use to benefit members and customers and to secure revenues.

Revenues from Residential Consumers

The primary form of revenues your broadband enterprise will require is revenues from your residential members or customers. The residential market is at the core of a fiber-to-the-premises network and also represents a very important target market for your project because building to the home is so capital intensive.

The success of the retail services model generally depends on the utility's ability to compete in a consumer market with established and experienced providers. Many municipal FTTP networks that have been successful are located in rural or small town communities where competition is limited or nonexistent and the utility possesses a strong branding or trust image with its citizens. And of course, these utilities have strengths with respect to existing facilities, operations, construction, brand-name, image, and marketing.

In larger cities, the likelihood of facing difficulty obtaining such retail market penetration increases. Denser areas generally have a greater presence of incumbent Internet providers, and the local phone company is more likely to offer wireline broadband service. The addition of competitive mobile wireless services can make it very challenging for the utility to achieve sufficient market share to realize sufficient revenues.

Getting pricing right is a critical part building sufficient revenues, because of its impact on the adoption of service.[45] It is important to keep in mind that maximizing market share is not necessarily the same as maximizing revenue – a very inexpensive product can drive market share, but if the revenue generated cannot maintain operations and financing payments, then the model is not sustainable. As a result, we recommend generating a model with pricing that maximizes revenue generation rather than market share. Internet packages should ideally be priced to be competitive with existing area Internet service providers while offering higher capacity connections.

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[45] We recommend that market research be conducted by the utility to provide data on how willing residents and businesses would be to switch to a new service provider at various price levels.

As you contemplate your revenue sources, avoid the temptation to replicate industry products, services, and prices. Competing against the incumbents through imitation is a difficult, if not impossible, proposition. Offering a non-differentiated triple play against the cable or telephone company is a common mistake that has been made by small competing providers, both public and private. The large incumbents are adept at playing the game of bundling and promotions, and driving up net revenue per user. Their marketing follows a similar script: We have the fastest Internet, the best cable lineup, and the best quality telephone.

If new entrants, such as a utility broadband provider, focus only on the services offered by incumbents, they stand at a significant disadvantage—because incumbents' costs are much lower for direct Internet access, cable programming, telephone system access, technical support, and customer support. Examples of the programming cost advantage are shown in the figures below, but these are understated—Comcast's cost advantage has continued to increase since these charts were created.

Figure 11: Programming Expense as a Percentage of Cable Revenue—Comcast vs. Utility Competitor

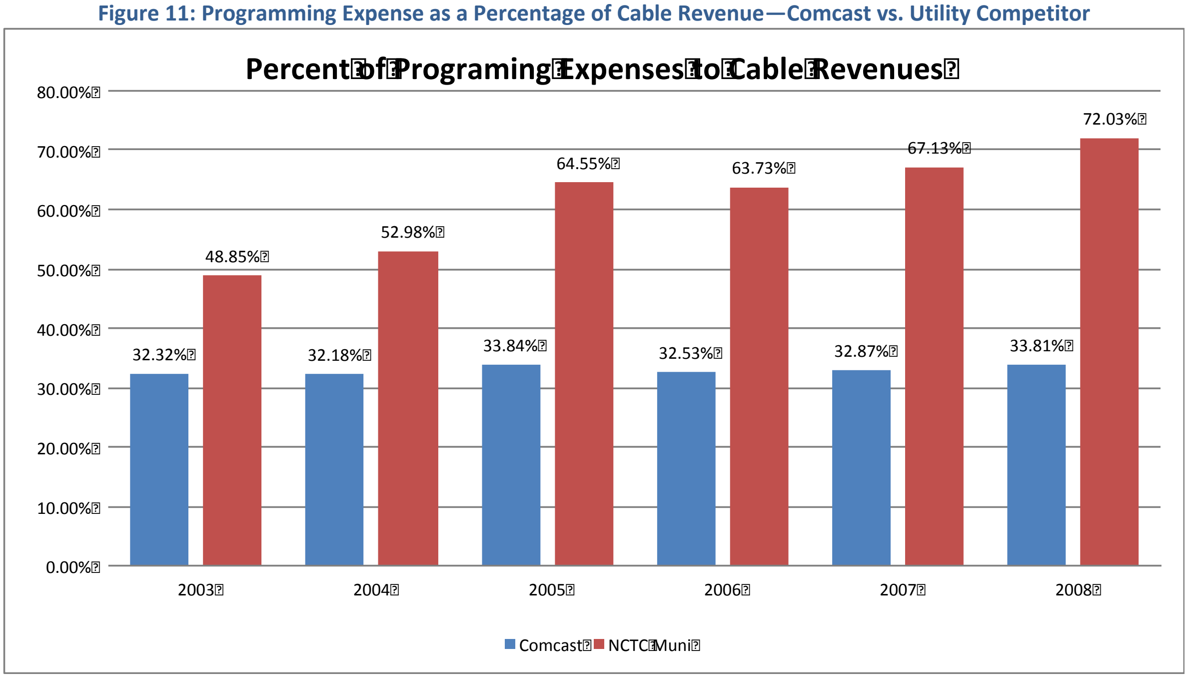
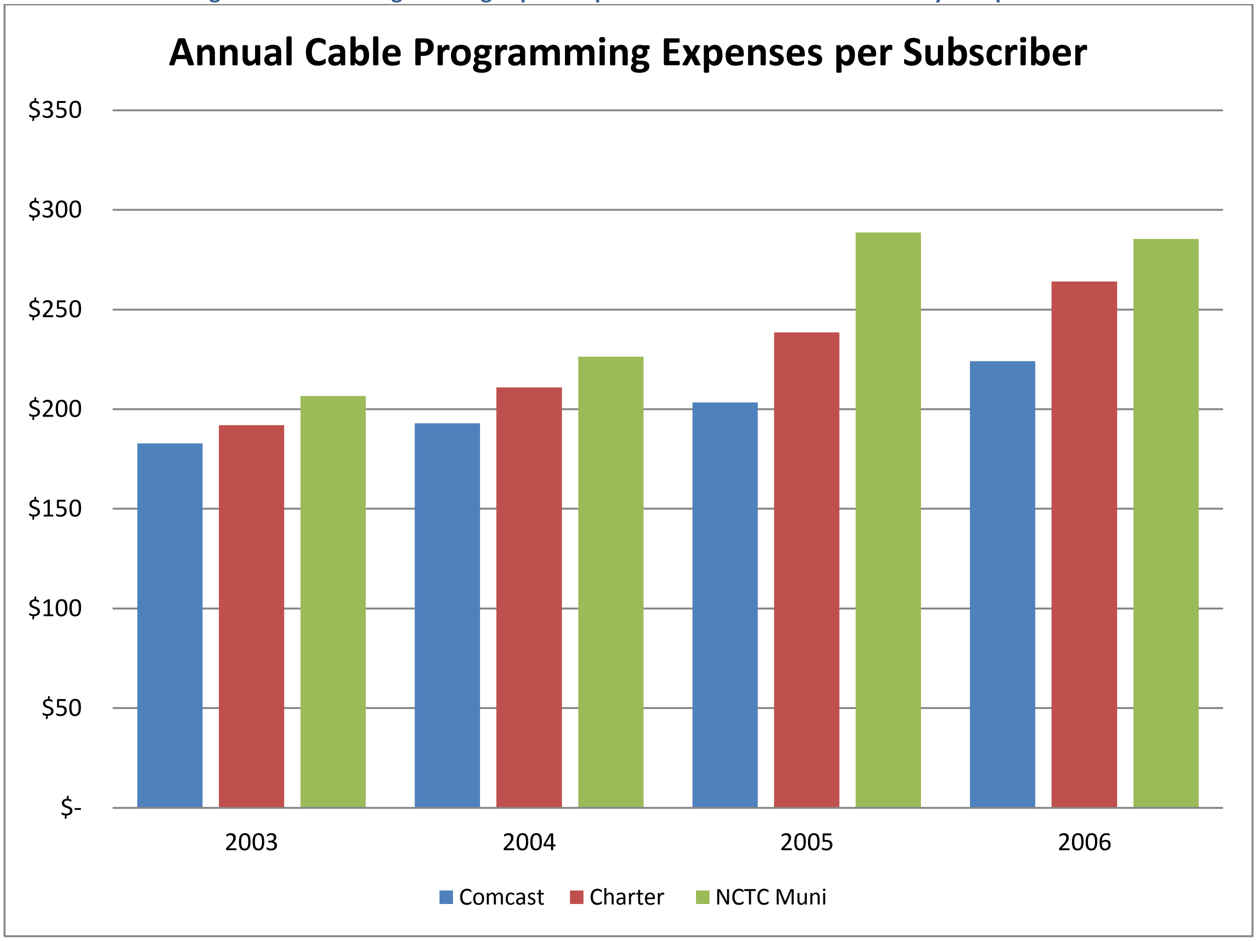


Figure 12: Cable Programming Expenses per Subscriber—Comcast vs. Utility Competitor



Indeed, while you may wish to offer cable video services as a way to gain market share, it's important to note, in light of the massive cost advantages held by the incumbents, that it will be challenging to make much margin on this product.

New broadband entrants need to embrace differentiated services and a new playbook if they hope to achieve success in the market. Incumbents have established business models built around bundled triple-play services and many tiers of broadband access. If utilities simply market a me-too offering that emulates incumbents, they will suffer from the competitive forces arrayed against them. Rather, utilities can offer the premium products enabled by fiber optics (such as 1 Gbps service) and differentiate and brand themselves as singular and incomparable locally.

Instead of chasing carrier pricing and marketing, we recommend that utilities that build fiber-to-the-premises networks play to their great strength—the fiber infrastructure—by offering a symmetrical Gigabit data connection and other very high bandwidth options as their primary upsell options.

Utilities should consider offering this gold-standard service because incumbents cannot match it for residents and small businesses in your service territory.

Focusing on an unparalleled data connection and enabling alternative video programming and other applications would also aggressively move your utility ahead of the "unbundling" curve[46] and would eliminate a major source of pricing pressure on the business. This is not to say however that a more traditional video package is not required—at least in the short-term.

Finally, focusing on a Gigabit service would position your utility to benefit from the substantial buzz created by Google Fiber's current expansion in multiple cities around the United States. Unlike a me-too offering that matches carrier standard services, a utility Gigabit service would align the utility with what is perceived as the state-of-the-art offerings that are available in only limited communities nationwide.

Revenues from Business Consumers

The potential market for businesses is an attractive one, in that business customers focus on data services, in which utility fiber-to-the-premises networks specialize. In addition, the fee structure for services such as Metro Ethernet to larger enterprise customers can be considerably higher. However, while enterprise opportunities are important and will be a critical opportunity, there are substantially lower numbers of customers in this market, depending on the makeup of your service territory. The majority of the small business market is retail, and many of these will likely settle for a low-end data connection. For medium to large businesses, there is frequently more competition to serve that market segment than small business and residential segments, and much of the market tends to be locked into three- to five-year contract obligations with existing carriers.

Revenues from Anchor Institutions, Including Government and Utility Services

Governments buy a lot of connectivity services—to support internal operations, public safety functions, and a range of other applications. Typically, localities lease circuits from a telecommunications company at rates that sometimes represent extraordinary profit for the provider. Worse, the circuits are usually relatively low-bandwidth connections, because the retail costs of very high bandwidth services make those connections simply unaffordable.

[46] According to recent Pew Research data, about half of Americans say they would have a hard time giving up their Internet connections (53 percent) or cell phones (49 percent)—but only about one-third would have difficulty giving up television (35 percent) or landline telephones (28 percent). Andrea Caumont, "Americans increasingly view the internet, cellphones as essential," Pew Research Center, Feb. 17, 2014. http://www.pewresearch.org/fact-tank/2014/02/27/americans-increasingly-view-the-internet-cellphones-as-essential/

A utility fiber optic network can deliver substantially better services to government buyers at comparable or modestly-increased costs. In this way, your local public institutions could become one of your most important customers

Capacity requirements for government operations have grown exponentially over the past 15 years, and there is nothing to suggest that the pace of growth will abate over the next 15 years. In addition, most government operations and community anchors are already overtaxed in terms of their broadband capacity—meaning that they already require much more bandwidth today, let alone tomorrow. In practical terms, that means that your utility has a business opportunity—to deliver a cost-effective alternative—and to enable governments to deliver the capacity they need to adequately support their internal operations and those of community anchors.

Indeed, the full range of community anchor institutions are big buyers of connectivity among and between each other, and to the Internet. And like government operations, community anchor institutions have seen—and are likely to continue to see—their bandwidth needs grow exponentially.

Revenues from Schools and Libraries, Supported by E-Rate

A very significant potential revenue stream for state and community-owned fiber networks is one that hinges on a September 2010 Federal Communications Commission (FCC) order. In that decision, the FCC for the first time made non-regulated non-profit and public networks eligible for the E-rate subsidy under the Universal Service Fund.

The Commonwealth has capitalized on E-rate subsidies for many years through its consolidated network, so local operators in Kentucky would likely not be able to capture E-rate funding for local networks. We have included the program description here and elsewhere in the guide to provide a more complete picture of the funding environment for local schools and libraries.

E-rate is by no means a free lunch for network operators; the requirements for becoming an E-rate provider, including participation in a competitive procurement process and extensive paperwork, are necessarily strict. But there are simply enormous positive financial implications for governments (such as the Commonwealth) that choose to become E-rate providers. Serving schools and libraries means realizing the benefits of E-rate subsidies that can range as high as 90 percent depending on the level of poverty in your community.

The Multiplier Effect

Both in terms of avoiding costs and increasing revenues, public and coop-owned networks deliver one additional benefit: They keep money in your community. Whereas circuits leased from a large national provider require the delivery of a big monthly check to a potentially far-away corporate entity, monthly fees paid to a government-owned network stay in the community—to be spent on other government services, and to be multiplied when locally employed network employees go out to eat or spend money at other local businesses.

This is true of federal and regional grants and subsidies, too. When a grant or subsidy becomes a revenue source for a locally owned and operated network, that money creates benefits for the network's bottom line, and has an extended impact in the local area based on a multiplier effect.

The Importance of Customer Service in Driving Revenue Goals

Because it will be almost impossible for a utility to match the incumbents' likely aggressive pricing response to competition, we believe that broadband utilities' take rates will be driven by differentiation, particularly that of advanced, singular higher end and Gigabit services that the market seems increasingly interested in, that Google Fiber is driving demand for, and—crucially—that the traditional cable and phone incumbents are unable to provide over their existing infrastructure.

Beyond that distinction, however, utility networks also have another potentially powerful form of differentiation. In our experience, community-based networks are able to increase take rates through differentiation based on localism—appealing to consumers to invest in their own communities by buying services from a local, publicly owned network, even if those services may be more costly than the incumbent's offerings.

The success of the publicly owned Greenlight FTTP network in the City of Wilson, North Carolina illustrates this point. Launched with a target take rate of 30 percent, Greenlight has reached 35 percent penetration over six years by offering a high-quality product and delivering a consistent marketing message about investing in the community. For example, the network's website features a prominent headline—"Support Your Community, Switch to Greenlight"—and lists, among its reasons to switch, "[k]eep your money in the local economy, instead of sending it away to national providers."[47]

If your utility's marketing efforts can differentiate your network in a similar manner and capture some percentage of consumers based on the appeal of localism, this approach offers an advantage the incumbents cannot replicate.

[47] "Greenlight community broadband," http://www.greenlightnc.com/

In perhaps the most important form of differentiation, you may be able to increase take rates and thus revenues (even in the face of aggressive competitive pricing by incumbents) through a very robust customer service presence.

The power of high-quality customer service is due in part to the national incumbents' incredibly *poor* reputations in that regard. Incumbents routinely score abysmally in surveys of customer satisfaction.[48] As a practice, they reduce or eliminate their local presence whenever possible, have limited local offices, and are widely known for long wait times on their telephone help lines.

In our experience, responsiveness in customer service has served as the single most powerful factor in enabling smaller, competing networks to gain market share against the incumbents. We know of a small regional FTTP provider in the Midwest whose customers have been targeted by Comcast with introductory pricing that it simply cannot match. That service provider has successfully dealt with that competition through top-shelf customer service—building customer loyalty that is unprecedented and that we do not believe could be achieved by Comcast.

From the minute this provider entered the local market, it has protected its brand, its customer relationships, and its reputation. During its construction phases, for example, it has ensured that its crews minimize traffic disruptions. It has focused on projecting an image of a local company that cares about the local community. It not only has a local call center for trouble reports, but it offers the kind of customer service that will escalate a dissatisfied customer's call directly to the company's vice president, whose desk sits in a local office.

This small provider approaches its market with an acute awareness that customer service is one of the only areas in which it can differentiate itself from the incumbents—and it has withstood significant competitive challenges by operating with that in mind every day.

Based on our knowledge of the utility environment, customer service is frequently of prime importance to utilities and we thus assume that outstanding service—from the time of construction through service delivery and billing—will serve to enable revenues.

[48] See, for example, data compiled by the American Customer Satisfaction Index. Comcast and its competitors have consistently ranked near the bottom of American companies: http://goo.gl/l2xbwU; Comcast ranked lowest among competing companies in 2013: http://goo.gl/mRdtBL

7. Risks of Broadband Initiatives

There is risk involved in pursuing a broadband initiative, just as there is with any major capital project or expansion of utility operations. Many of these risks impact municipal utilities more than other entities such as coops, in part because of industry-driven challenges to public projects.

This chapter briefly introduces a range of potential risk factors and challenges that utility leaders 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 and should not automatically dissuade utilities from pursuing broadband projects. Rather, by understanding what risks and challenges your network may face, you can factor them into evaluating what type of network, ownership, or business model will be most appropriate for your utility.

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.

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 national communications industry and related industries. That is because the competition enabled by a high-capacity FTTP infrastructure would be perceived as a direct challenge to the interests of incumbent players in the current market structure.

Legislative risk refers to potential changes in law that can cripple a public broadband project. In our experience, it is not uncommon for self-interested incumbents to lobby for legislative change that would prohibit or hamper competitive broadband efforts, sometimes including those already underway. In some states, existing laws 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.

In some states, there also exist limitations on the right of electric coops to enter the broadband business.[49]

The majority of these state laws are not flat-out bans on public or coop 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.

We strongly recommend you seek legal counsel that can evaluate the relevant laws in your state.[50] 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 that impacts municipal utilities or coops may relate only to public-facing retail networks, meaning that there is still the option to build and run an institutional or anchor-focused network. The law in a state may prohibit only telecommunications services (phone), meaning one would still have the flexibility to provide data (Internet) service. Conduct a thorough analysis with qualified legal advice to understand the relevant laws and then proceed accordingly.

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

[49] See, for example, the restrictions on Tennessee coops: State of Tennessee, Office of the Attorney General, Opinion No. 14-33, "Authority of Electric Cooperative to Provide Broadband Internet Service." http://www.tn.gov/attorneygeneral/op/2014/op14-33.pdf

[50] 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

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 utility 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 utility 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 a vendor.

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 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 or inefficient operations.

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 utility may be able to obtain contracts prior to making a major investment to connect, whereas with a fiber-to-the-premises initiative, a substantial investment is required before signing up a single customer.

8. Benefits of Broadband for Utility Operations and AMI

The availability of robust fiber in the core of the network and deep into the distribution system can greatly benefit an electric utility and support the overall business case for fiber-to-the-premises and other fiber strategies. Though utility applications are not sufficient on a stand-alone basis to support a business case for fiber-to-the-premises, a fiber project has significant benefits for utility operations. In addition, by allowing two-way communication and the transmission of real-time information between members/consumers and utilities, fiber-based Smart Grid technologies enable utilities to better manage the power grid as an integrated system and adjust supply to changing demand. At the same time, the technologies allow end-users to make more informed decisions about energy consumption. This is particularly effective where prices vary depending upon demand.

Generally, electric utilities have an increasing need for robust communications capabilities at distribution and transmission assets including substations, field devices, and customer premises. Utilities are thus well served by deployment of fiber to substations, motor-operated switches, distributed generation sites, data collection points, and other locations.

Among utilities' fiber-enabled applications are SCADA, Smart Grid, other automation applications, and security.

SCADA

To address supervisory control and data acquisition (SCADA) and distribution automation (DA) needs, many utilities have implemented fiber connections to distribution and transmission substations. Fiber offers higher reliability, lower latency, and more robust connections than radio-based or leased-line options. It also offers the ability to support high-capacity needs such as high-definition photos, imagining, and video monitoring.

Smart Grid and Other Automation Applications

Electric utilities have explored and implemented power line carrier (PLC), point-to-point radio, meshed radio, and other technologies to address initial needs for Smart Grid applications and other distribution and customer automation applications such as:

- Advanced metering infrastructure (AMI)
- Automatic meter reading (AMR)
- Load management (LM)
- Outage management (OM)
- Demand-side management (DSM)

Power line carrier and radio alternatives have served many of these applications. For many Smart Grid and customer applications, an advanced broadband connection such as fiber-to-the-premises is not required. In addition, for customer applications such as AMI, effectiveness (performance and cost) requires connection of all customer meters in a given geographical area. Even the inability to connect to 10 percent of meters in a geographical area reduces automated metering infrastructure benefits. However, leveraging fiber connectivity can greatly enhance the performance of the application.

Every AMI system requires a data concentration point. With PLC systems this occurs at the distribution substation. With mesh radio this is at a collector that supports a cluster of 100 to 300 meters. Fiber backhaul provides a utility-controlled circuit with higher reliability, lower latency, and higher capacity than leased alternatives. This will allow for improved performance of outage events, voltage alarms, and other events. Fiber connections also offer superior performance for:

- *Remote switching.* Fiber provides a high deterministic, low latency, highly secure, and responsive connection.

- *Recloser monitoring and reconfiguration.* An AMI system can offering monitoring of a recloser but does not have the capacity support download of settings or reconfiguration files. Fiber also provider a low-latency connection allowing a utility to use reclosers as monitoring point for a conservation voltage reduction (CVR) strategy

- *Distributed generation.* Fiber provides a real-time low latency connection that allows proactive monitoring of distributed generation connected to the grid. The connection is not only important for monitoring delivery of energy, but for disconnecting the distributed generator during distribution system outages to prevent backfeed—critical for crew safety.

- *Consumer automation:* Some consumers; residential, farms, and small business have become more proactive in smart grid applications and may benefit from a fiber connection at their premises. These applications include:
    - Consumer-added green power sources (solar, wind)
    - Customer interaction with utility
    - Smart thermostats, appliances, and in-home control devices
    - Real-time and green pricing signals
    - Plug-in hybrid electric cars (charging and grid energy storage)

Security

Industry security requirements, including those set by the National Energy Regulatory Commission (NERC), are expanding in terms of increased and more stringent requirements—as well as in terms of which utilities are required to adhere to them. When compared to leasing options, the use of utility-owned and maintained fiber increases the security and control the utility has over sensitive consumer and system data.