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LARIMER COUNTY

COMMITTED TO EXCELLENCE

Broadband Feasibility Study

Prepared for Larimer County, Colorado
December, 2018

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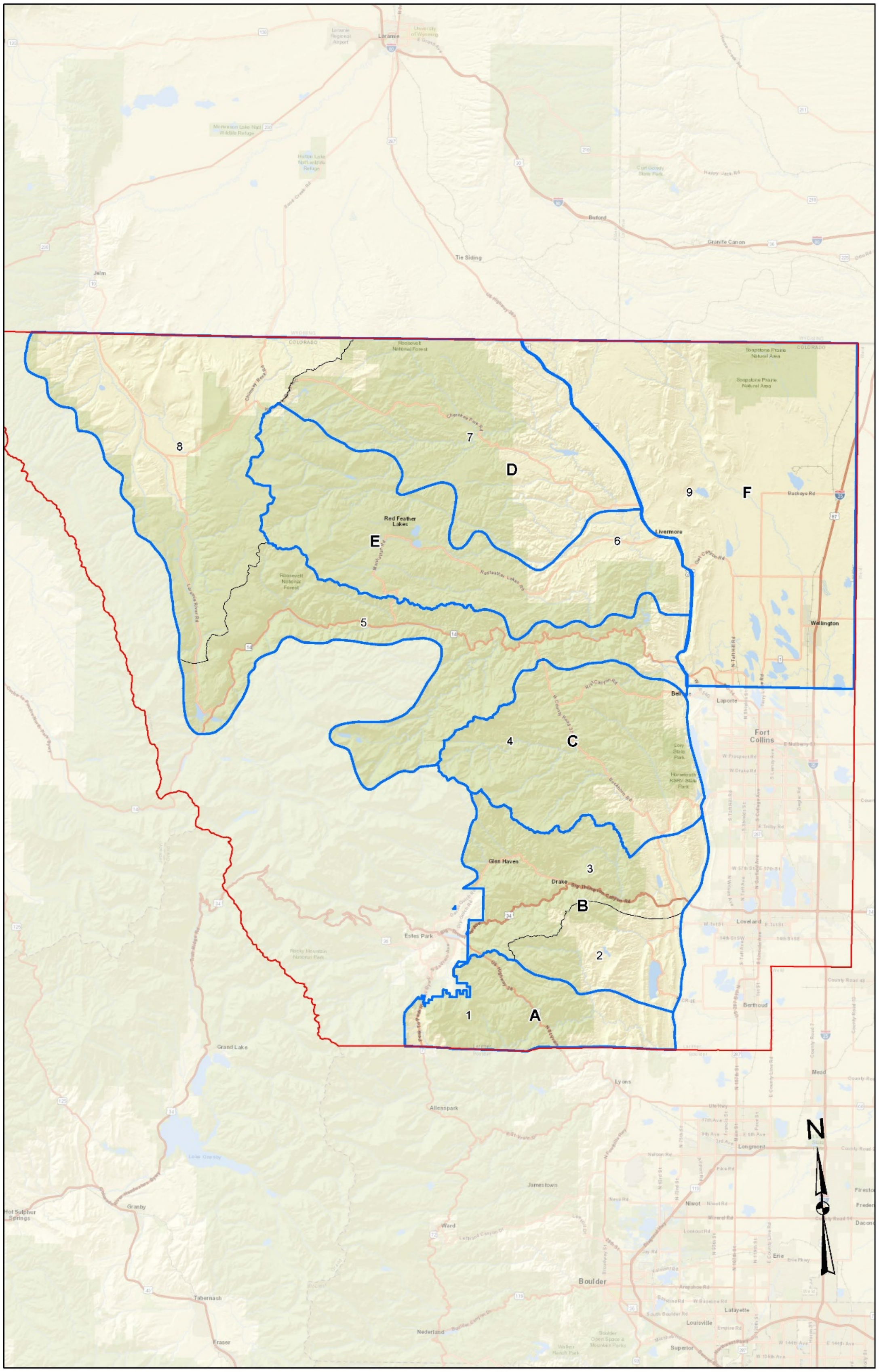

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1 Executive Summary

In March 2017, Larimer County, Colorado (the County), engaged with CTC Technology & Energy (CTC) to conduct a phased feasibility study (the Project) of options to make broadband available to every resident and business within the unincorporated areas of the County. This report summarizes our findings.

1.1 Key Findings

This report establishes a baseline for the County as it continues to consider viable options to address broadband availability in the unincorporated areas of the County.

- Discussions with private sector providers in the County raised a number of issues:
    - **Some target areas are within the existing or planned footprint of private providers and power authorities**
    - **Permitting processes are a key focus for providers**
    - **The County may need to work with multiple providers to achieve its goals**
- Key findings from the residential survey include the following:
    - **Nine in 10 survey respondents have some form of internet connection (home connection or smartphone)**
        - Fixed wireless and satellite providers each hold 20 percent of the market
        - DSL is the primary connection for 19 percent of responding households
        - 18 percent of responding households have cable modem access
        - 15 percent use another technology (mobile, fiber, dial-up, or other)
        - 8 percent of households responded that they do not have internet
    - **About one-half of respondents indicated that the County should install a state-of-the-art communications network; 33 percent of respondents indicated that the County should offer services directly**
- We caution the County not to infer that low adoption rates automatically mean low availability or affordability. No doubt there are households that wish to remain "off the grid" or do not wish to pay for internet access. That said, **one-fourth of respondents who**

do not have internet indicated that internet access is not available at their homes, and another fourth indicated it was too expensive for them.

- Most of the survey responses align across all areas, indicating that the conclusions drawn in this analysis likely apply to the entirety of the surveyed areas. However, in the area that includes the Highway 14 corridor, Laramie River Road, and Cherokee Park Road **(survey Area D), the least populated of the six survey areas, 18 percent of respondents indicated they do not have internet access.** This area also includes the highest concentration of satellite access and second-lowest concentration of fixed wireless access.

- Although a "Dig-Once" policy is good practice in more densely developed areas than the County, **we do not suggest the County enact a policy that would deploy disparate segments of fiber in concert with other construction projects.** Rather, the County would be better served to pursue its idea of a "road development fee" that could be aggregated in an escrow account and used to fund a future targeted broadband infrastructure project.

- In contrast to the suggestions offered by local internet service providers (ISP), our analysis suggests that **the existing regulatory environment is not prohibitive to deployment, and that adjusting existing policies would make little to no difference in the economics of deployment for wireless ISPs (WISP) and other ISPs.**

- **Areas with a density of less than 10 households per square mile (survey areas C, D, and F) are unlikely to see investment from the private sector.** A middle-mile network that could provide dependable backhaul to wireless deployments in these areas may improve the probability of investment, but the low density presents an extremely challenging business case for either the public or private sector. Conversely, **areas with a density greater than 10 households per square mile (survey areas A, B, and E) are more likely to see private investment in the future.** Unsurprisingly, these areas are seeing deployment and service provision by ISPs (e.g., CenturyLink, FRII, Rise Broadband, etc.).

- The outside plant (OSP) for a middle-mile fiber network that would reach within 5 miles of 99.66 percent of households in the unincorporated areas of the County might cost **$31 million**; the OSP for a network that would reach within 3 miles of 98.58 percent of households would cost an estimated **$38.79 million.**[1]

[1] This is a high-level cost estimate based on approximate mileage and estimated average cost to build. The cost estimate did not look at specific routes or conditions. The estimated cost could be significantly higher or lower.

- The OSP to support a nearly ubiquitous fiber-to-the-premises (FTTP) network would cost between $5,800 and $11,900 per passing, **totaling between $72.96 million and $148.81 million.** The core network electronics would total an additional $1.5 million to $2 million, and per-subscriber costs would total an estimated $1,870 to $5,370, depending in part on the size of the subscriber's property.[2]

- Due to the extremely low density of passings across the survey areas, **we were unable to generate a business case in which the County could recover the initial capital investment and earn a level of revenue necessary to cover debt service payments, operating costs, and maintenance costs for an FTTP or middle-mile deployment.**

- Given this, **we recommend the County not build costly infrastructure on speculation**. Rather, we suggest the County continue to consider the feasibility of a future deployment and continue to pursue alternative options that would "move the needle" in specific, targeted areas where the economics make sense.

Ultimately, one of the most important steps the County must take is to determine what it is able and willing to do in terms of supporting the deployment of broadband infrastructure; clarifying its capabilities in this regard will help illuminate for the private sector the degree to which the County is truly able to "partner" to address connectivity in the unincorporated areas.

1.2 Project Background

The County is well aware that there is a lack of availability of broadband in its unincorporated areas. Indeed, the County reports that 48 percent of private land does not have access to broadband, and anecdotal evidence suggests that it is a significant challenge for businesses and residents outside of the major population centers in the County to access affordable, dependable, high-speed internet service.

County stakeholders assert that "broadband is a critical part of every community's infrastructure that impacts the economy, safety, well-being, education and overall connectedness of [Larimer County] residents, businesses and institutions."[3] With that in mind, the County's vision is to enable the availability of high-speed, reliable, and affordable internet to all homes and businesses in the County.

In the first phase of the Project, CTC engaged with the County's Broadband Steering Committee, managers, and officials to better understand the County's goals and the local broadband

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[2] This is a high-level cost estimate based on approximate mileage and estimated average cost to build. The cost estimate did not look at specific routes or conditions. The estimated cost could be significantly higher or lower.

[3] "Larimer Broadband Project," Larimer County, CO. Available: https://www.larimer.org/broadband (accessed April 2018).

landscape. CTC team members also met with representatives of private sector providers to understand the challenges they encounter in deploying broadband infrastructure in the County, and steps the providers thought the County could take to help facilitate deployment.

Additionally, CTC developed and administered a residential survey to six "survey areas"—unincorporated areas of the County identified using the County Mountain Resilience Plan[4]— to obtain statistically valid information on the broadband landscape in unincorporated areas of the County.

Phase II of this project focused on developing a comprehensive Mapping Tool (Appendix C) that documents the communications infrastructure in the County; a gap analysis and future needs analysis to understand the results of the survey in the context of the broadband marketplace nationwide; a review of the regulatory environment within the County; and a "Dig Once" policy, specific to the County (Appendix D).

Phase III entailed developing a cost estimate and business case for the County network.

1.3 Discussions with the County Suggest that The County Is Open to Many Options, While the Private Sector Reported That the County Should Clearly Articulate its Plans

CTC held a series of on-site meetings with County representatives to understand the County's goals and objectives, and to discuss the particular challenges of deploying broadband services to unincorporated areas of the County. Our findings include the following:

- The County's goal is to find a solution that will enable 100 Mbps (download) residential and 200 Mbps commercial services to every home and business in the County, reaffirming its assertion that "Everywhere is Somewhere";
- The County wants to focus efforts on its unincorporated areas;
- The County aims to facilitate rather than fund the solution; and
- The County does not have a preconceived idea of the best course of action; rather, it aims to develop a "toolkit" that will enable it to take a multi-tiered approach.

For more discussion of these topics, please see Section 2.1.

[4] "Mountain Resilience Plan," Larimer County, CO. Available: https://larimercompplan.com/document/mountain-resilience-plan (accessed April 2018).

Our discussions with providers in the area illuminated, from the private sector's viewpoint, specific deployment challenges and steps the County might take to help facilitate future deployments. Our findings include the following:

- Deploying broadband infrastructure is expensive in many parts of the County's target areas;
- Some target areas are within the existing or planned footprint of private providers and power authorities;
- Permitting processes are a key focus for providers;
- The County may need to work with multiple providers to achieve its goals;
- It will be important for the County to determine and articulate its own plans; and
- Consumer demand will drive the County's efforts.

For more discussion of these topics, please see Section 2.2.

1.4 The Residential Survey Indicated that Nine in 10 Residents Have Some Form of Internet Connection, and Reliability Ranks as the Most Important Aspect of Their Connection, Followed by Speed

As part of its efforts to evaluate and improve the area's internet access and quality, Larimer County conducted a survey of residents in selected unincorporated areas of the County in early 2018. Key findings include:

- Larimer County residents are highly connected, with nine in 10 respondents having some form of internet connection (home connection or smartphone). Residents in the area directly west of Ft. Collins appear to be well-connected, with 95 percent having some internet service. In comparison, nearly one-fifth of households in the northwest part of the County do not purchase internet services.
- Fixed wireless, satellite, DSL, and cable modem have almost equal shares of the market at approximately one-fifth each. Use of a fixed wireless connection is higher in the southern and northeastern parts of the County compared with other areas, while use of a cable modem connection is highest in the area directly west of Ft. Collins, and use of a satellite connection is highest in the northwest area of the County.
- Reliability of the internet connection ranks as the most important aspect of internet service, followed by connection speed. Residents are generally satisfied with the speed

and reliability of their internet service, but the high importance placed on these factors may signal some willingness to switch providers if needs are not being met.

- Respondents indicated a willingness to switch to a very high-speed internet connection, especially at monthly prices at or lower than $70 per month or for upfront installation fees at or below $100. Willingness to switch drops sharply at higher price points.

- One-half of respondents' employers allow telework, and 31 percent of responding households have a member who already teleworks. Three-fourths of household members who can telework and with fast home internet connections do telework from home.

- One-half of respondents purchase satellite television service, while 21 percent receive television service through the internet, 15 percent have antenna (over-the-air) television service, and 12 percent have cable television. The most important television programming features are local programming and news programming.

- About one-half of respondents indicated that the County should install a state-of-the-art communications network, including 33 percent who indicated that the County should offer services directly.

Section 4 of this report documents the survey process, discusses methodologies, presents results, and provides key findings that will help Larimer County assess the current state and ongoing needs of its residents regarding high-speed communications services. A copy of the survey is included in Appendix A. Maps of selected question responses are included in Appendix B.

1.5 The County's Regulatory Environment Is Not Prohibitive to Private Deployment

In an effort to identify and address suggestions from the private sector, we reviewed regulatory materials identified by the County. Our technical review found that County regulations are neither onerous nor expensive, and that they are unlikely to be a significant barrier to private broadband deployment. While it makes sense to continually evaluate and adjust permitting and other ordinances as technology and the industry evolves, the existing County regulations are not unfavorable to private providers. For more on this topic, please see Section 5.

1.6 Deploying Middle-Mile Fiber or Fiber-to-the-Premises Would Be Extremely Expensive

The cost for the County to deploy fiber infrastructure to a significant portion of the unincorporated areas would be prohibitively expensive.

1.6.1 Deploying OSP for a Middle-Mile Network Would Cost $31 Million to $38 Million

We developed routes for a potential middle-mile fiber network that would bring fiber infrastructure close to the majority of the households within the unincorporated portions of the County. These routes followed major roadways to locate infrastructure within both 3 and 5 miles of households. The 5-mile scenario would entail 266.6 road miles of fiber, reaching within 5 miles of 99.66 percent of households in the County. Table 1 provides a summary of this scenario.

Table 1: Summary of Routes and Households in 5-Mile Scenario

Survey Area	Resiliency Area(s)[5]	Area (Sq. Miles)	Road Miles	Percent of Households Within 5 Miles of Fiber
A	1	89	17.9	100.00%
B	2,3	182	45.7	100.00%
C	4	179	30.8	99.71%
D	5,7,8	710	90.8	99.11%
E	6	233	28.3	99.97%
F	9	398	53.2	99.16%
	Total	1,791	266.6	99.66%

In the 3-mile scenario, the County would deploy 333.7 road miles of fiber, reaching within 3 miles of 98.58 percent of households in the County. Table 2 provides a summary of this scenario.

Table 2: Summary of Routes and Households in 3-Mile Scenario

Survey Area	Resiliency Area(s)	Area (Sq. Miles)	Road Miles	Percent of Households Within 3 Miles of Fiber
A	1	89	29.8	99.68%
B	2,3	182	48.6	99.61%
C	4	179	47.5	99.35%
D	5,7,8	710	100.9	94.34%
E	6	233	31.7	99.72%
F	9	398	75.2	98.76%
	Total	1,791	333.7	98.58%

We then developed a high-level estimate of costs for both aerial and underground fiber construction, ranging from $40,000 to $80,000 per mile for aerial deployment, and $95,000 to $250,000 per mile for underground deployment. These ranges account for variations in ground condition, fiber routing, necessary splices, special crossings, and other variables. Assuming a 50/50 mix of aerial and underground fiber deployment, we estimate that the 5-mile scenario

[5] Resiliency area refers to the County's "Mountain Resilience Plan" (https://larimercompplan.com/document/mountain-resilience-plan).

would cost just under $31 million, and the 3-mile scenario would cost $38.79 million. For further discussion of these estimates, please see Section 6.

1.6.2 Deploying OSP for a Nearly Ubiquitous FTTP Network Would Cost $73 Million to $149 Million

Expanding on the middle-mile network discussed above, we estimated the cost of a nearly ubiquitous (i.e., reaching all households included in the middle-mile design) FTTP network. We estimated the cost per passing based on the size and density of each survey area, and projected a low- and high-end estimate for each. These estimates are shown in Table 3.

Table 3: Estimated FTTP OSP Cost Per Mile by Survey Area

Survey Area	Resiliency Area(s)	Low-Cost	Mid-Cost	High-Cost
A	1	$5,000	$7,000	$10,000
B	2,3	$5,000	$7,000	$10,000
C	4	$6,000	$9,000	$13,000
D	5,7,8	$8,000	$12,000	$17,000
E	6	$5,000	$7,000	$10,000
F	9	$7,000	$10,000	$14,000
	Average:	**$5,810**	**$8,340**	**$11,860**

We then used the mileage of each area to calculate the total cost and the average cost per household, shown in Table 4.

Table 4: Estimated FTTP OSP Cost by Survey Area

Survey Area	Resiliency Area(s)	Low-Cost	Mid-Cost	High-Cost
A	1	$6,110,000	$8,554,000	$12,220,000
B	2,3	12,575,000	17,605,000	25,150,000
C	4	10,038,000	15,057,000	21,749,000
D	5,7,8	9,720,000	14,580,000	20,655,000
E	6	17,395,000	24,353,000	34,790,000
F	9	17,122,000	24,460,000	34,244,000
	Total:	**$72,960,000**	**$104,609,000**	**$148,808,000**
Average cost per household:		**$5,800**	**$8,300**	**$11,900**

We note that the low-cost estimates reflect the costs to deploy in ideal conditions; we do not anticipate that costs would be this low in a County deployment, given the County's topographical characteristics. Given this, we estimate that the fiber to support a nearly ubiquitous FTTP deployment will total between $104.61 million and $148.81 million.

These estimates only entail the deployment of OSP for the network. To "light" the network, connect subscribers, and provide service, the County would need to deploy $1.5 to $2 million worth of core network electronics. The County would also incur an additional cost of $1,870 to

$5,370 per subscriber, depending on the length of the fiber drop necessary to connect the subscriber's house to the network and the electronics deployed to support that subscriber. For further discussion, please see Section 6.5. These costs are very high compared to other networks nationwide. To understand these costs in context of other deployments, please see Section 6.6.

1.6.3 We Were Unable to Create a Business Case for Deploying FTTP

Given the high cost of deployment and extremely low density in the unincorporated areas of the County, we were unable to develop a business case that would recover the County's investment, pay any necessary financing debt service payments, and fund the operations and maintenance of the FTTP network.

1.7 Recommendations

The following outlines our recommendations, based on the comprehensive analysis completed during this project.

1.7.1 Do Not Deploy Fiber on Speculation

Although the residential survey shows some demonstrated need and desire for greater connectivity, we do not recommend that the County pursue the costly middle-mile and FTTP options proposed in this report. Rather, we encourage the County to continue to consider steps it can take, such as the creation of an account for a future targeted infrastructure deployment and the alternative technologies discussed in this report, to address issues on an area-by-area, neighborhood-by-neighborhood basis. Rural broadband is a complex problem being discussed nationwide, and there is no "silver bullet" solution to the economics of deploying infrastructure to every home in rural America.

1.7.2 Consider Alternative Solutions for Areas with a Housing Density of Less Than 10 Households per Square Mile

The County's higher-density areas (survey areas A, B, and E) are more likely to see further investment as demand increases and the private sector continues to deploy to regions with a higher return on investment. Areas with lower density (survey areas C, D, and F) are unlikely to see significant private investment in the near term but may be good candidates for three innovative strategies that the County might employ to facilitate broadband deployment. We note that these solutions need dependable backhaul, which a County middle-mile network may provide. These strategies, including a case study of their potential efficacy, are discussed further in Section 7.

1.7.2.1 "Internet in a Box"

Common barriers to fixed wireless deployment in rural areas include accessing dependable and robust backhaul, aggregating sufficient demand, and obtaining mounting assets and power for antennas. It is unlikely that larger regional based providers will make an investment in low density rural areas. Even for an innovative provider, the costs make it difficult to achieve even a break-even cash flow, much less to obtain a return on investment (ROI). Recently, smaller communities have addressed these issues by leveraging their specific circumstances and collective strength to deploy smaller neighborhood networks. That is, provided the community can surmount the traditional obstacles, it can deploy the "internet in a box."

In an "internet in a box" deployment, a group of potential customers (e.g., a homeowner or neighborhood association, community group, etc.) would form a broadband entity that can coordinate with a backhaul provider, the owner(s) of potential mounting assets, and an energy provider to obtain affordable connectivity, attachments, and power. From there, using wireless assets purchased from a specialized equipment vendor, such as California-based Mimosa Networks, the community can develop and deploy a network to support its users' needs. We note that Mimosa is not just an equipment vendor—it also provides user-friendly interfaces and front-end management tools to administer and manage the network.

The County, in conjunction with the REA, might be able to assist communities looking to employ this type of solution. Indeed, **as a potential backhaul source, with the REA as pole owner and power provider in one, the partnership could use its specific strengths to enable focused and engaged groups (e.g., neighborhoods, homeowners' associations, etc.) in unincorporated areas to facilitate an "internet in a box" deployment.**

If the County can effectively package this concept, it can offer "internet in a box" to grassroot associations or cooperatives throughout unincorporated areas of the County.

1.7.2.2 Newly Available 3.5 GHz Spectrum

The Citizens Broadband Radio Service (CBRS) is a new band of spectrum being made available by the FCC in the 3.5 GHz range.[6] From a technical perspective, this spectrum will be suitable for a variety of indoor and outdoor uses, from Wi-Fi to long-distance wireless links to Long-Term Evolution (LTE) service. The 3.5 GHz band (3550–3700 MHz) presents an opportunity for non-traditional wireless providers—such as local governments, WISPs, and community organizations—to deliver wireless broadband service.

1.7.2.3 WIDOX 3.1

An additional emerging technology is Advintive's WIDOX 3.1, a wireless alternative that is built on a cable DOCSIS platform and can provide "cable-like" service to extremely remote areas. WIDOX may be especially useful in rural areas that are traditionally difficult to serve, and that will

[6] CBRS is a "semi-licensed" band, meaning that a portion of the spectrum will be reserved for unlicensed, general access use. Note that the FCC has yet to completely authorize the use of CBRS and has not yet auctioned off licenses—so rule changes may affect how CBRS is practically implemented. The timing is discussed further in Section **Error! Reference source not found.**.

be extremely expensive on a per-passing basis to serve with FTTP (i.e. Survey areas C, D, and F). The technology can offer

Advintive also claims that WIDOX 3.1 hardware offers low-latency service[7] at speeds of up to 27 Mbps download and 10 Mbps upload speeds per channel. The County is uniquely poised to enhance such a deployment because it has ample available spectrum. Given this, multiple channels could be bonded to enable higher speeds in areas where the spectrum is available. One unique factor that sets WIDOX 3.1 apart is that it can offer these speeds all the way to the edge of the service area without the significant signal loss that characterizes some wireless solutions.

1.7.3 Implement a Focused Mechanism to Fund Future Development Rather Than a Dig-Once Policy

Over the course of this project, CTC met with key stakeholders from County departments who helped identify "priority corridors" for a Dig-Once policy that would encourage and incentivize coordination between the County and the private sector when excavating the public right-of-way (PROW), as well as making optimal use of County road and utility projects. This type of approach can help a local government protect the PROW, minimize disruptions associated with construction projects, and in many cases significantly reduce the costs typically associated with the installation of utilities and conduit. In addition, once the PROW becomes crowded, the options for future construction are reduced, leaving only less-desirable methods and more costly locations for construction of additional infrastructure; Dig Once may alleviate that concern.

Our discussions illuminated that, save for a few priority corridors identified by the County, the effort to implement and regulate such a policy would not merit the potential savings in infrastructure deployment costs in the majority of the County, especially because the County would be beholden to constructors' plans and routes. Further, fiber and conduit assets may be deployed well before their potential use for a larger solution, which could degrade the quality and dependability of the infrastructure.

Given this, the County suggested—and we support—a "road development fee" that could be aggregated in an escrow account and saved for a targeted future communications infrastructure project. The development of this mechanism would need to be considered by a qualified communications attorney.

We have included a detailed discussion of a potential Dig-Once policy, including drawings, in Appendix D.

[7] WIDOX 3.1 latency is 10 to 15 milliseconds, see: http://www.advintive.com/technology/widox-3-1/widox-3-1-faqs/ (Accessed November, 2018).

2 Stakeholder Meetings

Over the course of Phase I of the project, CTC engaged in on-site meetings with stakeholders and providers in the County to get a clear idea of the project, the broadband landscape, and any potential partnerships with the private sector that may be able to help the County achieve its goals.

2.1 Discussions with County Stakeholders Helped Frame the Problem and a Blueprint for a Solution

In early October 2017, CTC met with County representatives to better understand the County's goals, as well as the unique challenges associated with addressing broadband availability. These discussions helped to frame this report and will inform the structure of subsequent phases of the Project.

These on-site meetings sought to engage County employees, including representatives from the public affairs, economic development, resiliency, and County Manager's offices, to develop a sense of broadband needs in the County. While CTC asked some specific questions, stakeholders were also encouraged to have a free-flowing discussion about their broadband needs and the role they believe the County should take in addressing any gaps they felt existed in the market.

The goals of these discussions included:

- Understanding the background on the County's initiative
- Defining the areas of the County where the Project will focus its efforts
- Identifying key Project goals and objectives
- Outlining the County's "best case" outcome of this phase of the Project
- Gauging the level of involvement—from "hands off" to full retail service provider—the County hopes to take in the process
- Illuminating the County's competitive landscape for broadband services (see Section 3)

2.1.1 "Everywhere is Somewhere"

As a core guiding tenet of this initiative, County stakeholders assert that "broadband is a critical part of every community's infrastructure that impacts the economy, safety, well-being, education and overall connectedness of [Larimer County] residents, businesses and institutions."[8] With that

[8] "Larimer Broadband Project," Larimer County, CO. Available: https://www.larimer.org/broadband, (accessed April 2018).

in mind, the County's vision is to enable inclusive, high-speed, reliable, and affordable internet to all homes and businesses in the County.

Our initial discussions revealed that 48 percent of private land in the County is not served by broadband. This problem initially proved so overwhelming to the County that its initial desire to address the situation never gained traction. Further, stakeholders reported that emergency management issues from two previous disasters showed how isolated, and in turn vulnerable, some areas of the County are. County representatives detailed complete connectivity outages lasting for days at a time, with little to no response from incumbent providers to help avoid repeating the issue in the future.

As the problem became more obvious, and an increasing number of residents in unincorporated areas voiced frustration with the scant availability and/or high price of broadband service, the County began to look in earnest at its potential role in addressing the problem.

Reflecting a pragmatic approach to the problem, the County's goal is to help "move the needle" on countywide broadband availability. Although 1 Gigabit per second (Gbps, or "gig") speeds have received increased attention nationwide, the County recognizes that such speeds are well beyond the needs of residents and businesses in its underserved and unserved areas. Indeed, many residents and businesses only have access to services well below the Federal Communications Commission's definition of broadband—25 Megabits per second (Mbps) download/3 Mbps upload. Given this, the County's goal is to find a solution that will enable 100 Mbps residential and 200 Mbps commercial services to every home and business in the County, reaffirming its assertion that "Everywhere is Somewhere."

2.1.2 The County Wants to Focus Its Efforts on Unincorporated Areas

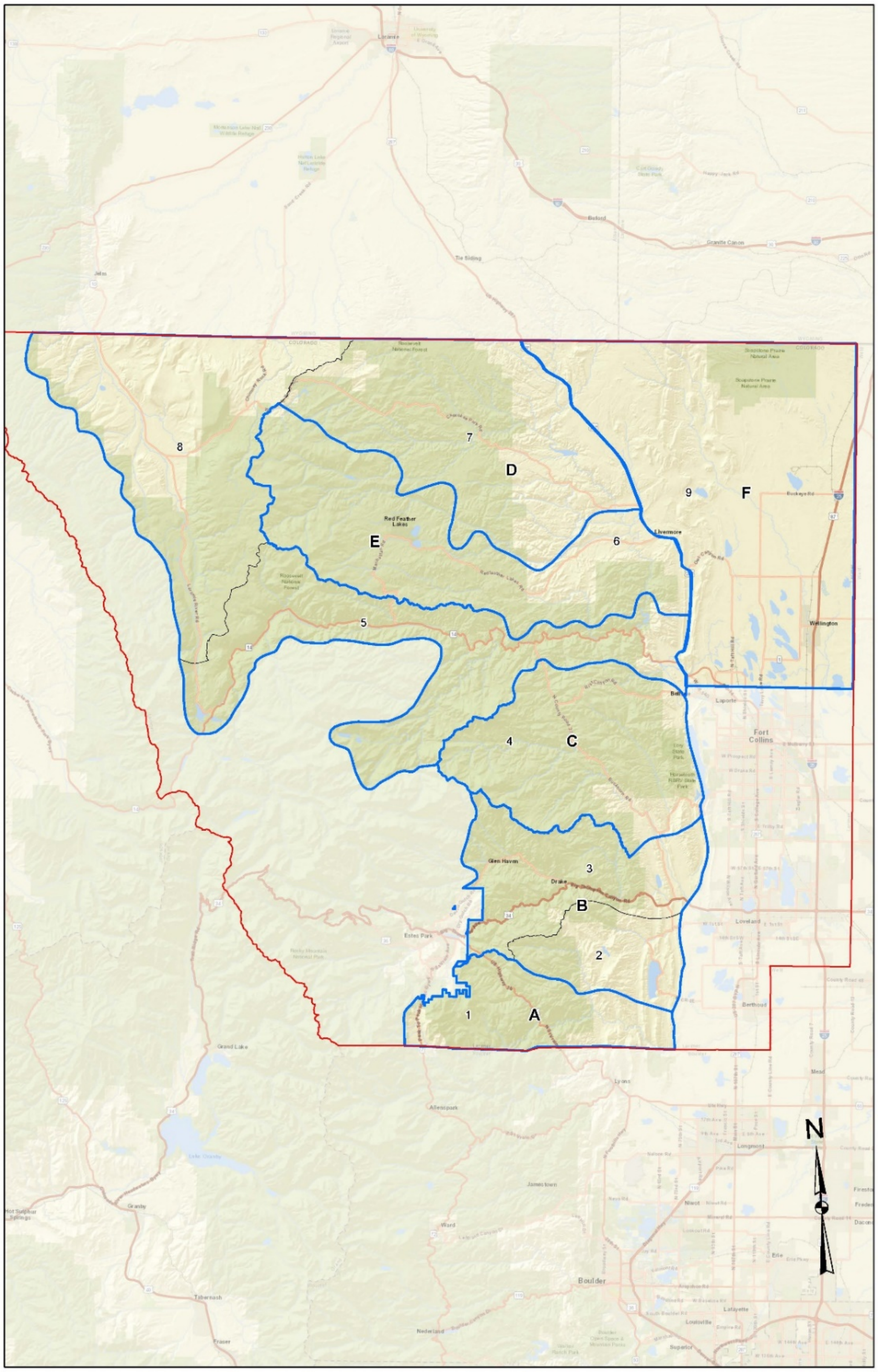
Stakeholders noted an understanding of the challenges of ubiquitous broadband availability in the County, including the distance between population centers outside of the southeastern portion of the County, the population density in these areas, and the overall size of the County itself. Recognizing that these challenges were less of a problem in the larger cities, and that the cities themselves were already making steps to address the issue, the County shifted its perspective—looking to address the broadband problem in the unincorporated areas of the County.

The County developed a map of the areas in which it wishes to focus its efforts, using the Mountain Resilience Plan as a starting point.[9] From the eight areas identified in the plan, the

[9] "Mountain Planning Areas," Larimer County, CO. Available: https://www.larimercompplan.com/mountain-planning-areas (accessed April 2018).

County selected a ninth area to include in the Project's efforts. Figure 1 is a map of these areas. Alphabetical characters on this map indicate Survey Areas, discussed further in Section 4.

Figure 1: Unincorporated Areas of Larimer County for Inclusion in Broadband Project



2.1.3 The County Aims to Facilitate Rather Than Fund the Solution

Discussions with stakeholders revealed that unlike the cities of Estes Park, Fort Collins, Greeley, and Loveland, the County has little interest in becoming a retail service provider—that is, deploying infrastructure, providing internet service, and handling customer relationships. Rather, the County is looking for actionable steps it can take to coordinate with the private sector to facilitate the deployment of internet service to every home and business in the unincorporated areas of the County. This insight spurred our discussions with local providers, discussed in Section 2.2, below.

2.1.4 The County Does Not Have a Preconceived Idea of the Best Course of Action

The County is approaching this Project with commendable openness. Stakeholders expressed an earnest desire to understand the current broadband environment based on the results of the statistically valid survey (see Section 4), rather than anecdotal information. Further, County stakeholders expressed their understanding that the solution may be more of a "toolkit," representing a multi-faceted strategy to address the unincorporated areas of the County on a case-by-case basis.

County representatives encouraged thoughtful reflection on the results of all phases of the Project before determining a strategy to move forward. We believe this patience and diligence may help the County garner actionable solutions to address broadband issues for the greatest number of County residents and businesses.

2.2 Partner Discussions Led to Important Insights

Engaging local and regional providers was an essential component of CTC's community outreach on behalf of the County. We facilitated in-depth discussions about two complementary issues: 1) the County's plans to serve target areas, and 2) the providers' current footprints, infrastructure, and service offerings in these areas.

These discussions sought to achieve the following objectives regarding the County's target areas:

- Include providers in the County's planning and strategic process
- Determine what services, if any, are currently offered by local and regional providers
- Identify existing infrastructure that may be available for County use
- Gather providers' perspectives regarding steps the County may take to support and spur private-sector investment and deployment
- Foster collaboration between the public and private sectors to encourage the greatest potential for broadband deployment and expansion

The County scheduled the series of on-site and teleconference meetings in December 2017 and January 2018. In an effort to stimulate frank discussions with providers, County representatives did not attend these discussions. CTC met with nearly a dozen local providers, ranging from very small wireless internet service providers (WISPs) to large incumbents with a national footprint.

In the sections below, we describe our findings.

2.2.1 Deploying Broadband Infrastructure Is Expensive in Many Parts of the County's Target Areas

Throughout CTC's discussions with providers, the high cost to deploy broadband infrastructure in the County's desired target areas was often central to the conversation. Most providers we spoke with noted that the County's target areas are likely not well-served today because it will be expensive and challenging to deploy infrastructure there.

Particularly for the private sector, the necessary return on investment (ROI) simply does not exist in these areas to justify infrastructure deployment and expansion. Even for providers that may have infrastructure nearby, the sparse density and complex terrain—especially in the western and northwestern portions of the County—make expanding to these areas difficult and unlikely.

2.2.2 Some Target Areas Are Within the Existing or Planned Footprint of Private Providers and Power Authorities

Certain portions of the County's target areas—specifically the southern portions of the County—are being served today, particularly by smaller regional WISPs. In some of these locations, providers may not currently be active, but have plans to offer service to these areas in the near future.

Areas where service providers are expanding or plan to expand service are typically more densely populated than other portions of the County's target locations. While these areas are hardly urban, they contain a reasonable potential customer base and often lack access to a variety of provider choices. This makes these areas desirable to potential providers that seek a reasonable ROI to justify the cost of extending service there.

Providers that have begun extending service to these areas already have an existing footprint nearby. Thus, the incremental cost to bring service to these locations is significantly less than if the providers sought to serve areas much farther away from their existing infrastructure.

Additionally, discussions with representatives from local power authorities (Poudre Valley Rural Electric Association (PVREA) and Platte River Power Authority (PRPA)) illuminated two potential strategies. In the first, PVREA's future construction efforts in unincorporated areas of the County may enable the County to co-build or lease dark fiber from PVREA, which may enable the County to connect some anchor institutions to bring fiber into communities. Second, Platte River Power Authority may be open to a lit service arrangement, wherein the County could use PRPA fiber as one piece of its overall strategy. Both authorities are open to further discussion with the County in the future.

2.2.3 Permitting Processes Are a Key Focus for Providers

Complex, confusing, time-consuming, and expensive permitting processes were raised in every provider discussion CTC held. That is, every private-sector provider with which CTC engaged had input and experiences regarding difficult permitting processes in Larimer County, the state of Colorado, and even throughout the United States.

While frustration with expensive and convoluted public permitting processes is not unique to Colorado or Larimer County, there are distinct local characteristics and complicating factors, especially in the County's target areas. Specifically, some of the County's identified target areas contain significant acreage of public land over which the County has no jurisdiction and for which gaining access to public rights-of-way (PROW) can be extremely cost- or time-prohibitive. Providers indicated that in some locations, the process is not at all straightforward, and it may be nearly impossible to even *begin* the permitting process to gain access.

Several providers indicated that access to federally owned land is especially onerous and can take nearly two years to even receive an answer, let alone permission. In some cases, even after waiting for long periods after seeking access to federal land, providers' applications are rejected. Long waiting periods can significantly affect a provider's ability to develop infrastructure, hinder speed to market, and substantially alter construction and deployment plans.

All the providers indicated that any steps the County can take to streamline its own permitting processes could be a major incentive to infrastructure deployment. Some providers claimed that simply having transparent policies and procedures combined with simplified costs and a guaranteed timeline would be sufficient. Others asked that the County consider waiving permitting fees entirely for private-sector infrastructure deployment, particularly in target areas.

2.2.4 The County May Need to Work with Multiple Providers to Achieve Its Goals

Given the vast range of potential customers and terrain that spans the County's target areas, it may be appropriate for the County to consider developing a combination of solutions that focuses on how best to serve certain areas. A global approach to deploying infrastructure and expanding service offerings in the County's target areas may not be feasible. Instead, working with multiple providers to develop necessary infrastructure to incent private investment and service expansion may be in the County's best interest.

2.2.5 It Will Be Important for the County to Determine and Articulate Its Own Definitive Plans

Every group of representatives with which we spoke indicated that they would be amenable to working with the County to achieve public-sector goals, especially given that the County does not seek to directly compete in the retail space with private industry.[10] However, these were preliminary discussions, and an ongoing dialogue will be necessary to flesh out what is truly possible between the County and the local providers.

Ultimately, one of the most important steps the County must take is to determine what it is able and willing to do, which will help illuminate for the private sector the degree to which the County is truly able to "partner." For example, if the County were willing to deploy fiber infrastructure in key locations to support WISP expansion of last-mile service, it would be important to articulate that willingness in concrete terms throughout ongoing discussions with private providers.

2.2.6 Consumer Demand Will Drive the County's Efforts

CTC released a survey in January 2018 to identify the broadband services used by residents in the County's target areas. This market research is a critical complement to the provider discussions we held because it will help further refine the County's target areas (i.e., by focusing on areas where broadband services are most limited, or where residents perceive the greatest need). Aggregating the responses to these surveys will aid the County in understanding where the greatest need exists, which will be a vital part of the planning process going forward. Detailed analysis of the survey responses is available in Section 4.

[10] We note that the County has not entirely ruled out the possibility of acting as the retail service provider in certain situations where no alternative exists, but that entering the market as a for-choice provider is not one of the County's chief objectives. Rather, it would be a last-resort approach that the County may consider if private providers are unwilling or unable to serve certain areas.

3 Competitive Assessment

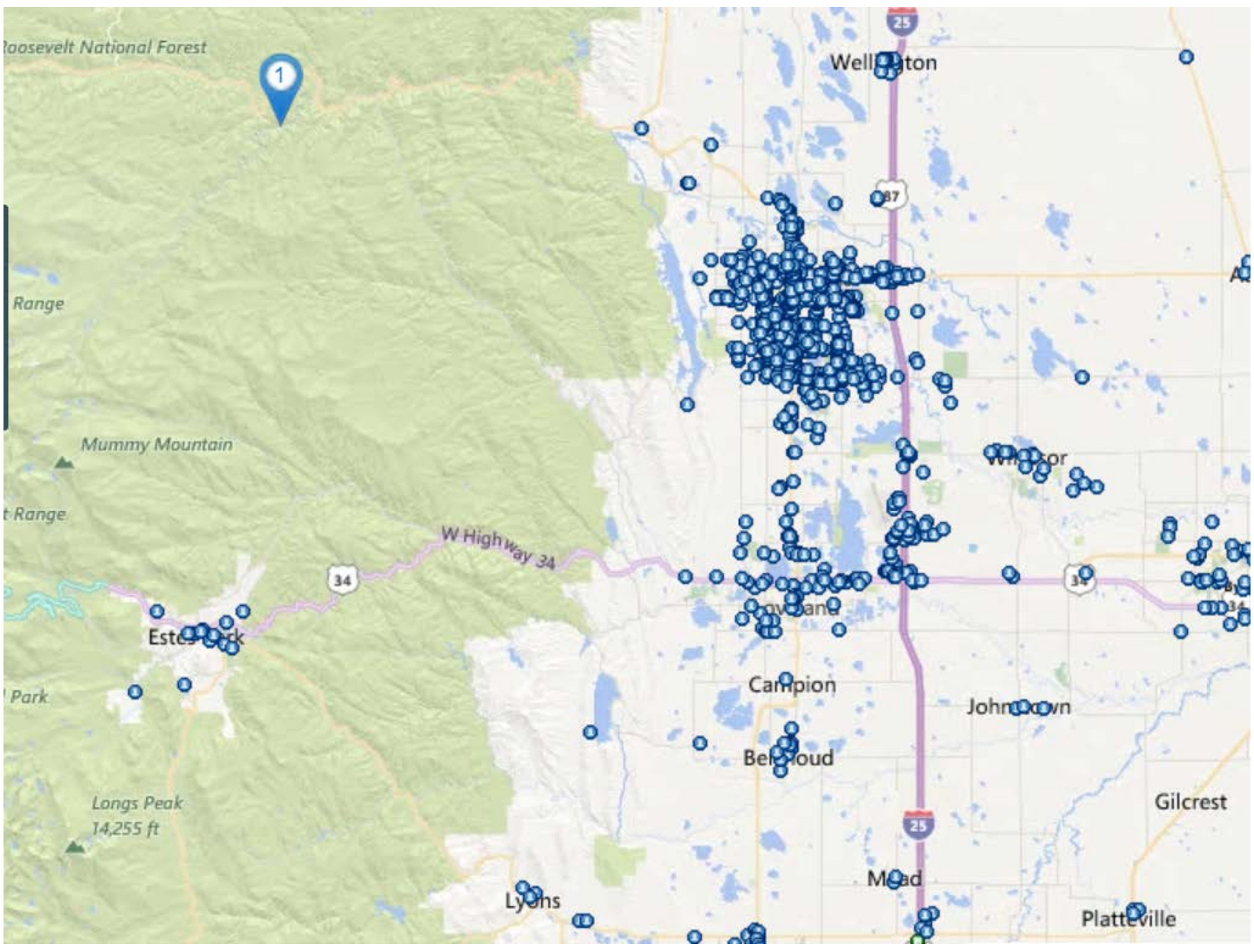
3.1 Enterprise Service Providers in Larimer County

This section provides an overview of broadband services available to medium and large business customers in Larimer County. We identified 10 enterprise service providers in the region that offer data transport services with speeds that range from 1 megabit per second (Mbps) to 10 gigabits per second (Gbps).

3.1.1 Overview of Service Availability and Pricing

Figure 2 shows the locations of lit buildings in the County, as serviced by some of the providers described below.

Figure 2: Lit Buildings in the County[11]



[11] Obtained from FiberLocator, March 2018. Infrastructure data available on FiberLocator is gathered from information provided by network carriers, which may not be complete. This is not intended to be a comprehensive representation of all fiber in the area.

Service providers that do not own infrastructure in the County offer lit services[12] through agreements with other local providers—tailoring these services to customers' requirements (e.g., speed, class of service). Service to locations close to the provider's network infrastructure is generally priced lower than service to more distance locations.

Comprehensive pricing comparisons are difficult, if not impossible, to compile for two reasons. First, service providers rarely make pricing publicly available, and will typically provide quotes only for a bona fide potential customer. Second, enterprise service providers do not have standard rates. Unlike the residential services that CenturyLink and Comcast deliver for a set monthly fee, enterprise services such as these are customized to individual customers' specific needs—and priced accordingly.

Enterprise service providers in the County offer Ethernet and Dedicated Internet Access (DIA) services. Ethernet service can be classified into three types: Ethernet Private Line (EPL or E-Line), Ethernet Virtual Private Line (EVPL), and ELAN. These services may be known by different names among providers.

EPL is a dedicated, point-to-point, high-bandwidth Layer 2 private line between two customer locations. EVPL service is like EPL but is not dedicated between two locations. Instead, it provides the ability to multiplex multiple services from different customer locations (i.e., multiple virtual connections) to another point on the network. ELAN is a multipoint-to-multipoint connectivity service that enables customers to connect physically distributed locations across a Metropolitan Area Network (MAN), as if they are on the same Local Area Network (LAN).

Internet services over Ethernet are typically classified under two categories: Dedicated Internet Access (DIA) and Multiprotocol Label Switching (MPLS) based IP Virtual Private Networks (IP-VPN). Providers prefer to offer DIA services between locations on their networks (on-net) and provision MPLS-based services for connecting locations that are off-net (using last-mile connectivity from CenturyLink or Comcast) to avoid construction and installation costs.

MPLS-based networks provide high performance for real-time applications—such as voice and video—and are typically priced higher.

Customers can choose a type of Ethernet service based on their bandwidth demands and the number of locations they need to connect. Typically, Ethernet services are used by large business that have IT staff to manage their network.

[12] A "lit service" is one where the service provider owns and operates the network electronics which connect to, and "light," a fiber optic network.

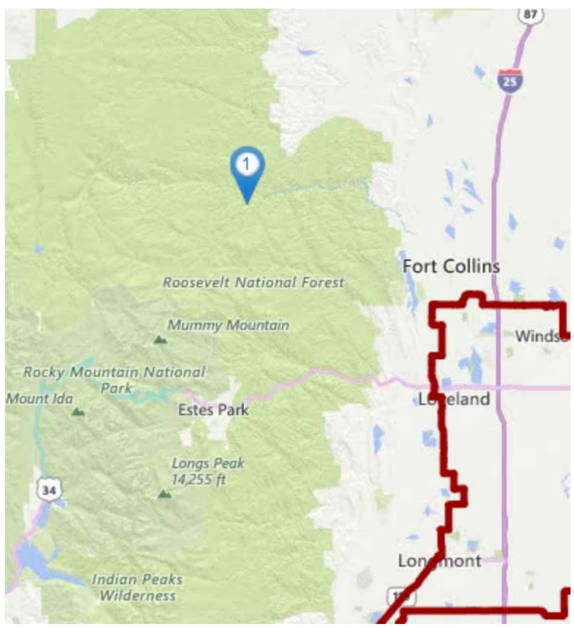
3.1.2 Enterprise Services

The carriers that provide these services in the County include Birch, CenturyLink, Comcast, FRII, Level (3), MegaPath, MHO, TDS, Windstream, XO, and Zayo. Prices depend on the bandwidth, location, proximity to the existing network, and network configuration; whether the service is protected or unprotected; and whether the service has a switched or mesh structure. Additional non-recurring charges may be assessed for installation, equipment, or other services.

Birch offers Ethernet and DIA services in the region. It can offer up to 1 Gbps symmetric service.[13]

CenturyLink provides point-to-point inter-city and intra-city configurations for full-duplex data transmission. The company offers Ethernet speeds of 2 Mbps to 100 Gbps.[14] Figure 3 shows part of the CenturyLink metro fiber network in the region.

Figure 3: CenturyLink Metro Fiber Network[15]

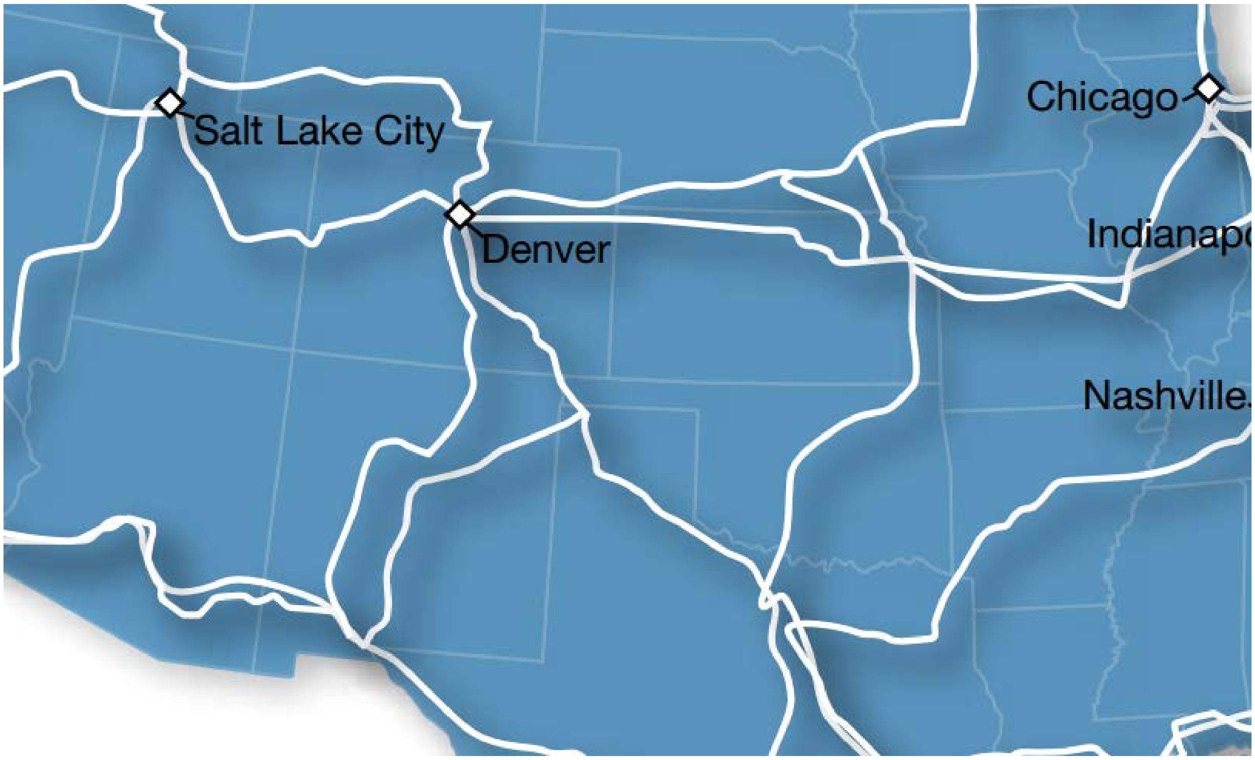


Comcast provides DIA and Ethernet services. Its EPL service enables customers to connect their customer premises equipment (CPE), such as a modem, using an Ethernet interface, as well as using any Virtual Local Area Networks (VLAN) or Ethernet control protocol across the service without coordination with Comcast. EPL service is offered with 10 Mbps, 100 Mbps, 1 Gbps, or

[13] http://www.birch.com/solution/size/enterprise, accessed March 2018.
[14] http://www.centurylink.com/business/networking/ethernet.html, accessed March 2018.
[15] Obtained from FiberLocator, March 2018. See footnote 11.

10 Gbps Ethernet User-to-Network Interfaces (UNI) and is available in speed increments from 1 Mbps to 10 Gbps.[16] Comcast's fiber optic backbone network is depicted in Figure 4.[17]

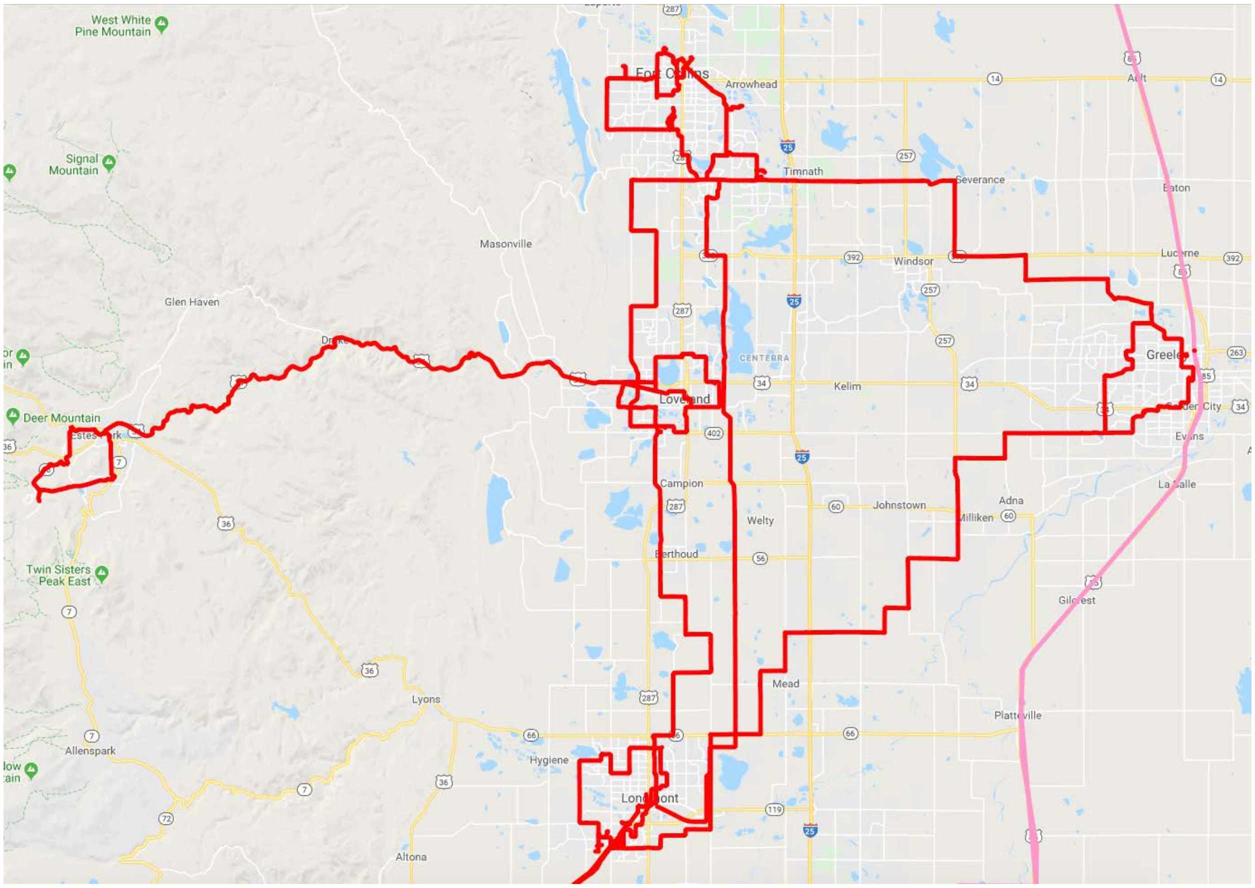
Figure 4: Comcast Fiber Routes



Level (3)'s Metro Ethernet dedicated service is available in 3 Mbps to 1 Gbps and its Ethernet Virtual Private Line (VPL) offers speeds ranging from 3 Mbps to 10 Gbps.[18] It is an end-to-end, Layer 2, switched Ethernet service delivered via an MPLS backbone. Internet services are available in a range of speeds up to 10 Gbps with 100 Gbps service additionally offered in some areas.[19] Level (3)'s network in the region is depicted in Figure 5, below.

[16] Increments lower than 10 Mbps are not available for "off-net" services. http://business.comcast.com/ethernet/products/ethernet-private-line-technical-specifications, accessed March 2018.
[17] http://business.comcast.com/about-us/our-network, accessed March 2018.
[18] http://www.level3.com/en/products/private-line-services/, accessed March 2018.
[19] http://www.level3.com/en/products/secure-internet-services/, accessed March 2018.

Figure 5: Level(3) Metro Network[20]



Based out of Fort Collins, Front Range Internet (FRII) offers carrier Ethernet and DIA services in the region by leveraging other Tier 1 carrier networks. FRII's standard metro Ethernet solution offers speeds ranging from 3 Mbps to 1 Gbps.[21] They also offer service over a fiber ring capable of speeds from 10 Mbps to 10 Gbps.[22]

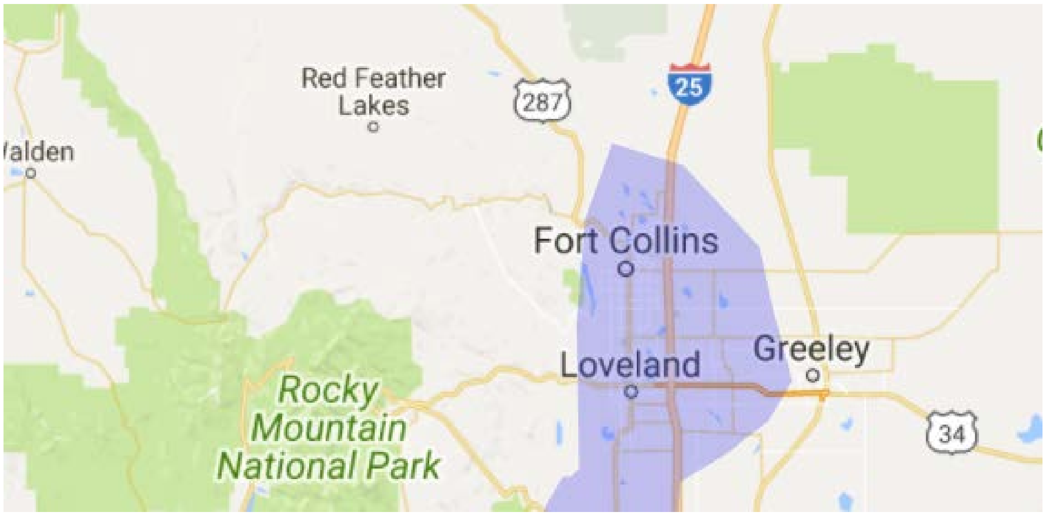
MegaPath offers Ethernet, DSL, T1, and cable services with speeds of up to 1 Gbps symmetric for business customers in certain parts of the County.[23] The lowest plan offered is for 1.5 Mbps download speeds at $45 per month. Higher speeds are available on a case-by-case basis.[24]

MHO Networks provides DIA and Ethernet services in the County, as shown in the figure below. It primarily serves small to medium-size businesses but also offer services to carriers and

[20] Obtained from FiberLocator, March 2018. See footnote 11.
[21] https://frii.com/commercial/ethernet, accessed March 2018 .
[22] https://frii.com/10-gb-fiber/, accessed March 2018.
[23] http://www.megapath.com/services/, accessed March 2018.
[24] http://www.megapath.com/data/ethernet/, accessed March 2018.

enterprises. DIA speeds from 10 Mbps up to 4 Gbps are available. Their Metro Ethernet service provides connectivity within the area with speeds from 10 Mbps to 1 Gbps.[25]

Figure 6: MHO Business Services Coverage Map[26]

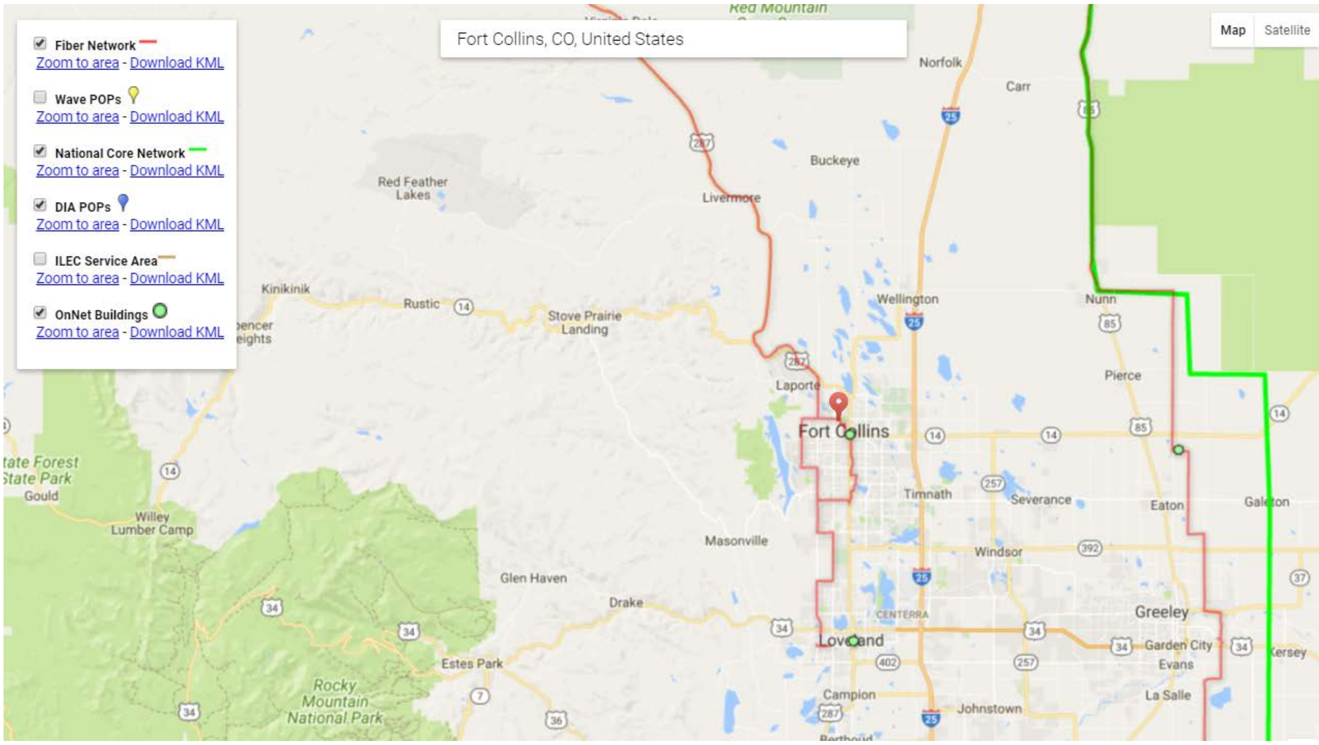


TDS Telecom offers Metro Ethernet services in speeds scalable from 2 Mbps to 10 Gbps in the region.[27]

Windstream Communications has a nationwide presence serving major metropolitan areas. In the County, it offers speeds up to 1 Gbps.[28] A 1 Gbps DIA service in the County would cost around $3,000, based on the location. Figure 7, below, shows the Windstream network in the region.[29]

[25] http://www.mho.com/services, accessed March 2018.
[26] https://www.mho.com/coverage-co/, accessed March 2018.
[27] https://tdsbusiness.com/carrier-wholesale.html, March 2018.
[28] https://www.windstreambusiness.com/shop/products/co/fort-collins, accessed March 2018.
[29] Obtained from FiberLocator and http://carrier.windstreambusiness.com/interactive-map/, accessed March 2018. See footnote 11.

Figure 7: Windstream Network Map (with Points-of-Presence)[30]

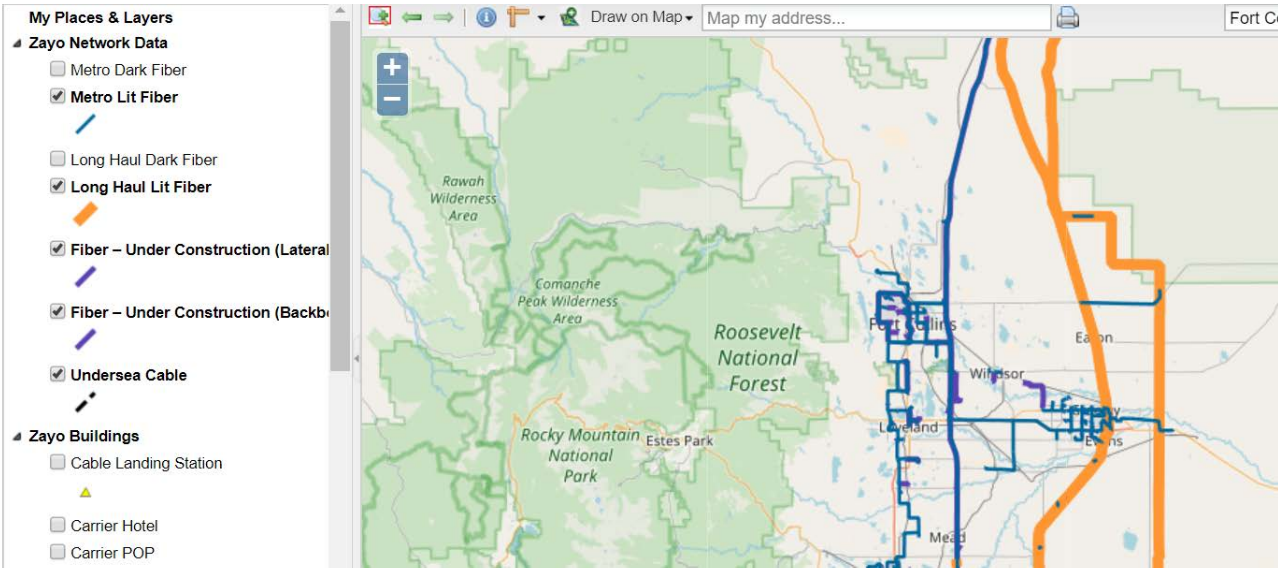


XO Communications offers carrier Ethernet and DIA services at multiple bandwidth options, from 3 Mbps to 100 Gbps, over its Tier 1 IP network.[31,32]

Zayo delivers Ethernet in three service types, with bandwidths ranging from 100 Mbps to 10 Gbps and optional quality of service (QoS) guarantees and route protection, based on customer needs. Service options include Ethernet-Line, which provides point-to-point and point-to-multipoint configurations with reserved bandwidth availability; Ethernet-LAN, with multipoint configurations having a guaranteed service level; and Ethernet Private Dedicated Network (E-PDN)—a completely private, managed network operated by Zayo, with dedicated fiber and equipment.[33] The Zayo network map illustrating its long-haul and metro fiber in the region is provided in the figure below.[34]

[30] Obtained from FiberLocator, March 2018. See footnote 11.
[31] http://www.xo.com/carrier/transport/ethernet/, accessed March 2018
[32] http://www.xo.com/network-services/internet-access/ip-transit/100G/, accessed March 2018.
[33] http://www.zayo.com/ethernet, accessed March 2018.
[34] http://www.zayo.com/solutions/global-network/, accessed March 2018.

Figure 8: Zayo Network Map[35]



Zayo's pricing for 1 Gbps and 10 Gbps point-to-point Ethernet circuits between two on-net locations in Denver is provided in the table below.

Table 5: Zayo 1 and 10 Gbps Ethernet Transport On-Net Pricing in Denver

Speed	60-Month Contract	12-Month Contract
1 Gbps	$1,165	$1,596
10 Gbps	$2,745	$3,760

Pricing for a 1 Gbps and 10 Gbps DIA service for an on-net location in Denver is provided in the table below.

Table 6: Zayo 1 and 10 Gbps DIA pricing in Denver

Speed	60-Month Contract	12-Month Contract
1 Gbps	$3,083	$5,138
10 Gbps	$14,666	$24,444

[35] Obtained from FiberLocator, March 2018. See footnote 11.

3.2 Residential and Small Business Services in the County

Residential and small business customers in Larimer County have access to a range of services, though individual service options are largely dependent on location. Table 7 lists the service providers and minimum price for each type of service that is available in at least some part of the County. These prices were reported by the carriers and were accurate at the time of this report. We note these prices may have changed.

Table 7: Overview of Residential and Small Business Data Services in Larimer County

Service Type	Provider	Minimum Price (per month)
Cable	Comcast	$29.99
	TDS	Case-by-case
DSL	Birch	$39.95
	CenturyLink	$45
Satellite	HughesNet	$49.99
	Viasat[36]	$59.99
Mobile/Wireless Internet Service Provider	AT&T	$14.99
	Sprint	$15
	T-Mobile	$20
	Verizon	$20
	Airbits	$29
	Cricket	$30
	Estes Valley Networks	$35
	Rise Broadband	$42.95
	Colorado Wireless Exchange	$45
	FRII	$64.95

3.2.1 Cable

Comcast offers download speeds from 15 Mbps up to 1 Gbps starting at $29.99 per month, as shown in Table 8. Discounted prices are available if bundled with another service like voice or TV, or with a one-year agreement.[37] Comcast recently launched gigabit-speed service in the County. With a two-year agreement, gigabit service is available for $89.99 per month; 2 Gbps service is $299.99 per month.

[36] Formerly Exede Internet.
[37] http://www.comcast.com/internet-service.html, accessed March 2018.

Table 8: Comcast Residential Internet – Internet Only

Package	Internet Speed	Monthly Price
Performance Starter	Up to 15 Mbps download	$29.99
Performance Plus	Up to 60 Mbps download	$29.99
Performance Pro	Up to 150 Mbps download	$39.99
Blast! Pro	Up to 250 Mbps download	$49.99
Gigabit Internet	Up to 1 Gbps download	$89.99
Gigabit Internet Pro	Up to 2 Gbps download	$299.95

For small business customers, multiple options are available with 150 Mbps download speed service at $249.50 per month with a two-year agreement.[38] A 1 Gbps service may also be available in some locations.[39]

Table 9: Comcast Small Business Internet – Internet Only

Package	Internet Speed	Monthly Price
Starter Internet	Up to 25 Mbps download	$69.95
Deluxe 50 Internet	Up to 50 Mbps download	$109.95
Deluxe 75 Internet	Up to 75 Mbps download	$149.95
Deluxe 100 Internet	Up to 100 Mbps download	$199.95
Deluxe 150 Internet	Up to 150 Mbps download	$249.95
Gig Internet	Up to 1 Gbps download	Site-specific

TDS offers business internet speeds of up to 100 Mbps in the area.[40]

3.2.2 DSL

Birch provides DSL-based business services in the region starting at $39.95 per month for 3 Mbps download speeds and 512 Kbps upload speeds. For an increased price, speeds up to 24 Mbps are available.[41]

CenturyLink offers DSL service for residential customers starting at $45 per month for unbundled, or "standalone" internet service with download speeds between 1.5 Mbps and 25 Mbps. Speeds from 40 Mbps start at $55 per month and range up to 200 Mbps at $85 per month.

[38] https://business.comcast.com/internet/business-internet, accessed March 2018.
[39] https://business.comcast.com/gig, accessed March 2018.
[40] http://hellotds.com/business/internet, accessed March 2018.
[41] http://www.birch.com/products/birchnetwork/birchnet-broadband, accessed March 2018.

3.2.3 Satellite

Satellite internet access is available in the area as well. HughesNet has four residential packages available and four geared toward businesses. With uniform download and upload speeds, plans are differentiated by their monthly data allowances. Residential offerings include an "anytime" allowance, plus a larger 50 GB "bonus bytes" allowance, which can be used from 2 a.m. to 8 a.m. Business offerings include a "business period" allowance to be used between 8 a.m. and 6 p.m., plus a smaller 25 GB "anytime" allowance. All packages require a two-year agreement. Details and pricing are listed in the tables below.

Table 10: HughesNet Satellite Residential Plans[42]

Package	Internet Speed	Monthly Data Allowance (Anytime + Bonus Bytes)	Monthly Price
Gen5 10 GB	25 Mbps down/3 Mbps up	10 GB + 50 GB	$49.99
Gen5 20 GB	25 Mbps down/3 Mbps up	20 GB + 50 GB	$59.99
Gen5 30 GB	25 Mbps down/3 Mbps up	30 GB + 50 GB	$79.99
Gen5 50 GB	25 Mbps down/3 Mbps up	50 GB + 50 GB	$129.99

Table 11: HughesNet Satellite Business Plans[43]

Business Package	Internet Speed	Monthly Data Allowance (Business Period + Anytime)	Monthly Price
Business 25	25 Mbps down/3 Mbps up	25 GB + 25 GB	$69.99
Business 50	25 Mbps down/3 Mbps up	25 GB + 25 GB	$89.99
Business 75	25 Mbps down/3 Mbps up	50 GB + 25 GB	$129.99
Business 150	25 Mbps down/3 Mbps up	100 GB + 50 GB	$239.99

Viasat (formerly Exede Internet) also offers residential and business satellite services in the County. Residential plans provide between 12 Mbps and 30 Mbps download and 3 Mbps upload for all plans. A 12 Mbps down/3 Mbps up plan starts at $30 per month for 10 GB of data. Data used between 3 a.m. and 8 a.m. are not counted toward the monthly total. The other plans provide unlimited data starting at 12 Mbps down and 3 Mbps up for $50 per month and go up to 30 Mbps down and 3 Mbps up for $100. After reaching 150 GB in a month, a customer's traffic

[42] https://www.hughesnet.com/get-started accessed March 2018.
[43] https://business.hughesnet.com/get-started accessed March 2018.

may be de-prioritized behind other customers for the remainder of the month. Viasat's business-class product provides 15 Mbps download speeds and 4 Mbps upload.[44]

Table 12: Viasat Satellite Residential Plans[45]

Download Speed	Upload Speed	Monthly Data Allowance (Anytime + Bonus Bytes)	Monthly Price for 3 Months	Standard Monthly Price
12 Mbps	3 Mbps	10 GB	$30.00	$50.00
12 Mbps	3 Mbps	Unlimited	$50.00	$70.00
25 Mbps	3 Mbps	Unlimited	$70.00	$100.00
30 Mbps	3 Mbps	Unlimited	$100.00	$150.00

3.2.4 Wireless

Verizon offers two 4G LTE data packages with multiple choices for data allowances and pricing, depending on the desired mobility and equipment chosen. The data-only mobile plan offers monthly prices that range from $20 for a 2 GB data allowance to $710 for a 100 GB data cap. A connected device can be added for $5 per month.[46]

Verizon's LTE Internet (Installed)[47] plan is a data-only 4G LTE service used on a fixed home device with Wi-Fi connectivity and wired Ethernet for up to four devices. Available download speeds are 5 Mbps to 12 Mbps and upload speeds are 2 Mbps to 5 Mbps. Monthly prices range from $60 for a 10 GB data allowance to $150 for a 40 GB data cap. Overages are charged at $10 per additional GB. A two-year contract is required, with a $350 early termination fee. Verizon offers a $10 monthly deduction for every month completed in the contract.

AT&T offers three tiers of 4G Long-Term Evolution (LTE) wireless data service in the area:

- 250 MB per month download allowance for $14.99 per month
- 3 GB per month download allowance for $30 per month
- 5 GB per month download allowance for $50 per month

[44] https://www.exede.com/business-order-availability, accessed March 2018.
[45] https://www.exede.com/plan-results/unlimited-basic, accessed March 2018.
[46] https://www.verizonwireless.com/plans/data-only-plan/, accessed March 2018.
[47] https://www.verizonwireless.com/home-services/lte-internet-installed/, accessed March 2018.

Each of these plans has an overage fee: $14.99 per 250 MB on the 250 MB plan and $10 per 1 GB on the 1 GB, 3 GB, and 5 GB plans. There are also equipment charges, with or without a contract, and an activation fee up to $45.[48]

Sprint offers 4G LTE wireless data in the County. The three data packages offered are $15 per month for a 100 MB data allowance, $50 per month for a 6 GB data allowance, and $110 per month for a 30 GB data allowance. Sprint charges $.05 for each MB over the limit. A two-year contract is required, as well as an activation fee of $36 and equipment charges. There is an early termination fee of $200.

T-Mobile offers month-to-month wireless data options for mobile hot spots or tablet devices. Pricing is based on the total amount of data needed per month; plans with 6 GB of data or more allow the customer to carry over unused data into subsequent months (up to 22 GB). The 2 GB plan costs $20 per month; increased data limits are available at incremental costs in a total of six packages, up to $85 per month for up to 22 GB of data. Depending on current promotions, the $35 activation fee is sometimes waived.[49]

Cricket Wireless offers 4G LTE wireless service with a download speed of up to 8 Mbps with five options for data allowance packages. Starting at $30 per month for 2 GB of allowed data, options increase to an unlimited data allowance for $60 per month. There is a $15 activation fee, but no contract or early termination fees.[50]

Airbits offers wireless internet service in the County with three speed options. Service starts at 1 Mbps for $29 per month up to 12 Mbps for $79 per month.[51]

Colorado Wireless Exchange offers wireless internet service with speeds from 5 Mbps at $45 per month to 10 Mbps at $65 per month. There is also a membership fee of $100 or $150 that includes the installation fees.[52]

Estes Valley Networks offers wireless broadband service in the County with three residential speed options. Plans are available at $29 per month at 1 Mbps speeds, $49 per months at 6 Mbps

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[48] https://www.att.com/shop/wireless/plans/planconfigurator.html, accessed March 2018.
[49] http://www.t-mobile.com/cell-phone-plans/mobile-internet.html, accessed March 2018.
[50] https://www.cricketwireless.com/support/plans-and-features/cricket-plans-and-features/customer/plans.html accessed March 2018.
[51] https://www.airbits.com/airbits-high-speed-internet/,accessed March 2018.
[52] http://www.cwx.net/, accessed March 2018.

speeds, and $79 per months for 12 Mbps.[53] Business-class services are also available. A 6 Mbps download speed service is available at $49 and a 12 Mbps service is priced at $79 per month.[54]

Rise Broadband is a wireless internet service provider (WISP) that provides services in some parts of the County with speeds up to 25 Mbps for residential customers at $29.95 per month (12-month promotional price). Speeds up to 5 Mbps are available for $19.95 per month. After the first 12 months, prices increase by $10 per month. Business-class 35 Mbps service is $79.95 per month, while 50 Mbps service is $99.95 per month with a one-year agreement. Business customers can reduce their monthly cost by $5 by signing a two-year agreement and by $10 by signing a three-year agreement.[55]

Front Range Internet (FRII) offers its WiFRII wireless service to both residential and business customers. Residential customers can receive speeds between 20 Mbps and 60 Mbps starting at $64.95 per month while business customers can receive speeds between 25 Mbps and 60 Mbps with plans starting at $149.95 per month.[56] Table 13 details residential service plans and Table 14 details business plans. All plans require a one-time setup fee of $99 and include a static IP address and the required wireless equipment.

Table 13: FRII Wireless Residential Plans

Download Speed	Upload Speed	Monthly Price
20 Mbps	10 Mbps	$64.95
40 Mbps	15 Mbps	$79.95
60 Mbps	20 Mbps	$99.95

Table 14: FRII Wireless Business Plans

Download Speed	Upload Speed	Monthly Price
25 Mbps	5 Mbps	$149.95
50 Mbps	10 Mbps	$199.95
60 Mbps	15 Mbps	$249.95

[53] http://www.estesvalley.net/residential.html, accessed March 2018.
[54] http://www.estesvalley.net/business.html, accessed March 2018.
[55] https://www.risebroadband.com/small-business/packages/, accessed March 2018.
[56] https://frii.com/wifrii/, accessed March 2018.

FRII also offers custom commercial wireless solutions including point-to-point, point-to-multipoint, and mesh configurations.[57] Pricing for these custom solutions varies.

[57] https://frii.com/commercial/custom-wireless/, accessed March 2018.

4 Residential Survey

As part of an effort to evaluate and improve high-speed communications services across the region, especially in more sparsely-populated areas, the County conducted a mail survey of randomly selected residences within specific areas of the County in January 2018. The survey captured information about residents' current communications services, satisfaction with those services, desire for improved services, willingness to pay for faster internet speeds, and opinions regarding the role of the County regarding internet access and service. A copy of the survey instrument is included in Appendix A. Maps of selected survey responses are included in Appendix B.

Although the conclusions contained in this report are statistically valid, we note that the information gathered by the survey is the opinions of those who responded to the survey at the time of their response. It should not be assumed that the opinions discussed below represent the entirety of residents in the unincorporated areas of the County.

4.1 Survey Process Overview

Larimer County acquired the services of Columbia Telecommunications Corporation (CTC) to help assess internet access in the region and evaluate options to improve service in select areas of the County. CTC and its partner market research firm, Clearspring Research (together, the "Consultant"), coordinated and managed the survey project, including development of the draft questionnaire, sample selection, mailing and data entry coordination, survey data analysis, and reporting of results. CTC and Clearspring have substantial experience conducting similar surveys for municipalities and utilities nationwide.

4.1.1 Coordination and Responsibilities

A project of this magnitude requires close coordination between the County and the Consultant managing the project. This section briefly describes the project coordination and responsibilities.

In the project planning phase, County management and the Consultant discussed the primary survey objectives, the timing of the survey and data needs, and options for the survey process. The project scope, timeline, and responsibilities were developed based on those discussions.

The Consultant developed the draft survey instrument (questionnaire) based on the project objectives and provided it to County staff for review and comment. County staff provided revisions and approved the final questionnaire, selected specific geographies for survey sampling and analysis, and provided the names and addresses of residents within those geographies from which the list of recipients was selected. The Consultant randomly selected 8,375 households across six separate geographic regions to receive the survey packet, coordinated all printing, mailing, and data entry efforts, and provided regular updates regarding survey responses. The

Consultant performed all data coding and cleaning, statistical analyses, response summaries, and reporting of results.

The primary responsible party at Larimer County was the Broadband Program Manager, guided by the Broadband Steering Committee. The primary responsible parties at Consultant were the Principal Engineer, the Principal Research Consultant, and the Research Director.

4.1.2 Survey Mailing and Response

A total of 8,375 survey packets were mailed first-class in January 2018. The survey sample was designed to provide statistically valid results using minimum criteria within each of six specific regions in the unincorporated areas of the County. The sample was obtained by identifying residential locations in each survey area, identifying the appropriate mailing address for the parcel owner of each location (to ensure the survey reached the owner of any seasonal homes), and removing duplicates from the list. Then, a random sampling of each area was selected.

The goal of the survey was to receive at least 200 valid responses within each of the six separate geographical areas. Reaching this level would provide statistically valid responses with a confidence interval of approximately ± 7.0 percent at the 95 percent probability level for each individual area. That is, responses would provide a valid representation of the total households within that region within a 7.0 percent margin 19 times in 20. At the aggregate level across all six regions, the designed confidence interval was within ± 3.0 percent.

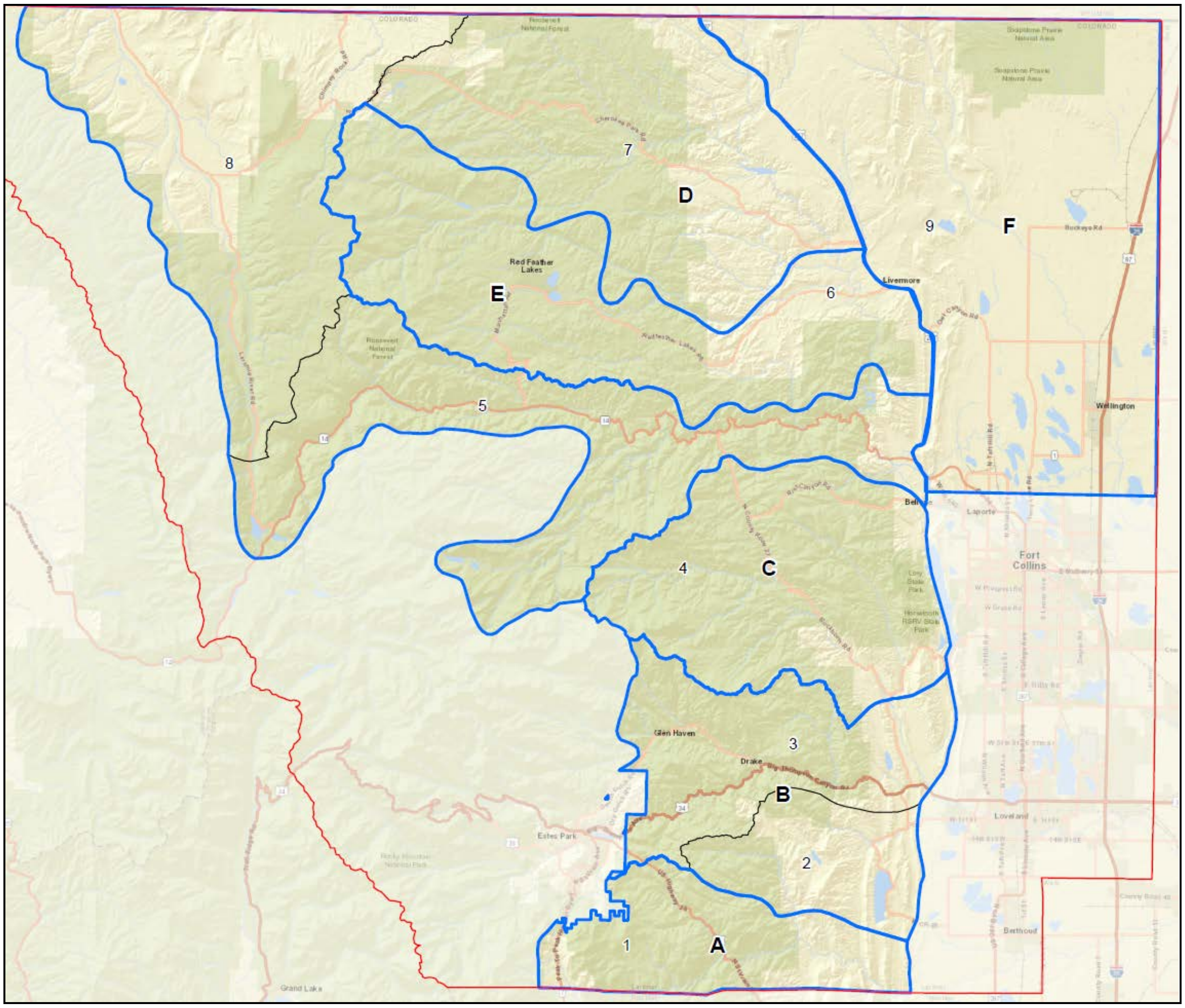
The number of households, the number of survey packets mailed, and responses in each geographic area is summarized in Table 15. The areas with lower estimated response rates have higher concentrations of non-permanent residences (seasonal dwellings, etc.) and it was therefore assumed that fewer would respond to the survey. As is evident in Table 15, the actual response rate was much higher than estimated.

Table 15: Survey Areas and Response

Area	Households	Survey Packets Mailed	Estimated Response %	Actual Responses	Actual Response %
A	1,222	1,178	15%	393	33.4%
B	2,515	1,340	15%	473	35.3%
C	1,673	1,340	15%	392	29.3%
D	1,215	1,177	10%	375	31.9%
E	3,479	2,000	10%	555	27.8%
F	2,446	1,340	15%	470	35.1%
Missing				12	
Total	12,550	8,375		2,670	31.9%

Areas A, B, and C are generally in southern portions of the County while areas D, E, and F are in northern portions of the County. The geographic areas are illustrated in Figure 9.

Figure 9: Survey Areas



Recipients were provided with a postage-paid business reply mail envelope in which to return the completed questionnaire. A total of 2,670 useable questionnaires were received by the date of analysis,[58] providing a gross response rate of 31.9 percent. The margin of error for aggregate results at the 95 percent confidence level for 2,670 responses is ±1.7 percent across the entire region in aggregate. That is, for questions with valid responses from all survey respondents, one would be 95 percent confident (19 times in 20) that the survey responses lie within ±1.7 percent of the population as a whole (all households within each region). The confidence intervals for each region vary between ±3.8 percent and ±4.3 percent based on the number of households

[58] At least 53 responses were received after analysis had begun, and are not included in these results.

and responses, as show in Table 16. These are well within the initial sample design, since response rates were much higher than anticipated.

Table 16: Confidence Intervals by Area

Area	Households	Responses	Confidence Interval ±
A	1,222	393	4.1%
B	2,515	473	4.1%
C	1,673	392	4.3%
D	1,215	375	4.2%
E	3,479	555	3.8%
F	2,446	470	4.1%
Missing ID		12	
Total	12,550	2,670	1.7%

4.1.3 Data Analysis

The survey responses were entered into SPSS[59] software and the entries were coded and labeled. SPSS databases were formatted and cleaned, and a comprehensive verification process for a sample of responses was completed prior to the data analysis. Address information was merged with the survey results using the unique survey identifiers printed on each questionnaire such that results could be mapped, if desired. The survey data was evaluated using techniques in SPSS including frequency tables, cross-tabulations, and means functions. Statistically significant differences between subgroups of response categories are highlighted and discussed where relevant.

The survey data were weighted to compensate for disproportionate sampling stratification and response among some area and age groups. The data were weighted to match the area distribution and the age distribution in the population according to the database and 2010 US Census[60] counts.

Since older persons are more likely to respond to surveys than younger persons, the age-weighting corrects for the potential response bias based on the age of the respondent. In this manner, the results more closely reflect the opinions of the Larimer County adult population within the survey region. The age distribution for the adult population and for survey respondents is summarized in Table 17. Note that the Census age population represents the non-City (i.e. excluding Ft. Collins and Loveland) portion of Larimer County as a proxy for the survey region.

[59] Statistical Package for the Social Sciences (http://www-01.ibm.com/software/analytics/spss/)
[60] https://www.census.gov/data/datasets/2010/dec/demographic-profile-with-geos.html

Table 17: Age Distribution

Age Cohort	Census Pop. (Adult, 2010)	% Adult Population	**Survey Responses	% Responses
18-44	25,017	36.2%	276	10.6%
45-64	31,113	45.0%	1,229	47.1%
65+	13,023	18.8%	1,104	42.3%
Total	69,153	100.0%	2,609	100.0%
**Not all respondents provided their age.				

In addition to the age weighting used to mitigate age bias in the responses, all results for the aggregate area are weighted to reflect the different sizes and number of responses within each of the six geographic areas. Table 18 summarizes the number and distribution of households in the database for each area, as well as the sample response distribution by area.

Table 18: Area Distribution

Area	Households	% Households	Responses	% Responses
A	1,222	9.7%	393	14.8%
B	2,515	20.0%	473	17.8%
C	1,673	13.3%	392	14.7%
D	1,215	9.7%	375	14.1%
E	3,479	27.7%	555	20.9%
F	2,446	19.5%	470	17.7%
Missing ID			12	
Total	12,550		2,670	

The survey weights were created by taking the ratio of the distribution of each area-age combination in the population to the distribution in the survey sample. Table 19 shows the percentage of the total population that falls within each area-age combination; Table 20 shows the same distribution for the survey sample.

Table 19: Area by Age Distribution for Adult Population

	Age 18-44	Age 45-64	Age 65+	TOTAL
Area A	3.5%	4.4%	1.8%	**9.7%**
Area B	7.2%	9.0%	3.8%	**20.0%**
Area C	4.8%	6.0%	2.5%	**13.3%**
Area D	3.5%	4.4%	1.8%	**9.7%**
Area E	10.0%	12.5%	5.2%	**27.7%**
Area F	7.1%	8.8%	3.7%	**19.5%**
TOTAL	**36.2%**	**45.0%**	**18.8%**	**100%**

Table 20: Area by Age Distribution for Survey Sample

	Age 18-44	Age 45-64	Age 65+	TOTAL
Area A	1.6%	7.3%	6.0%	**14.9%**
Area B	1.8%	8.9%	7.2%	**17.9%**
Area C	2.0%	7.2%	5.4%	**14.7%**
Area D	.8%	5.5%	7.8%	**14.0%**
Area E	1.9%	9.6%	9.3%	**20.8%**
Area F	2.5%	8.5%	6.6%	**17.6%**
TOTAL	**10.6%**	**47.1%**	**42.4%**	**100%**

The survey weight for each cell equals the population percentage divided by the sample percentage. Through the weighting process, any reporting of aggregate results is reflective of the population across the entire survey area based on the age of the respondents and the area from which the response was received.

The following sections summarize the survey findings.

4.2 Survey Results

The results presented in this report are based on analysis of information provided by 2,670 respondents from an estimated 12,550 households in the portion of the County being surveyed. Results are representative of the set of households within this entire region with a confidence interval of ±1.7 percent at the aggregate level. Breakouts within the six different survey regions are provided for key questions, and results for each individual region are generally available with confidence intervals between ±3.8 and ±4.3 percent, as discussed previously.

Unless otherwise indicated, the percentages reported are based on the "valid" responses from those who provided a definite answer and do not reflect individuals who said "don't know" or otherwise did not supply an answer because the question did not apply to them. Key statistically-significant results ($p \leq 0.05$) are noted where appropriate.

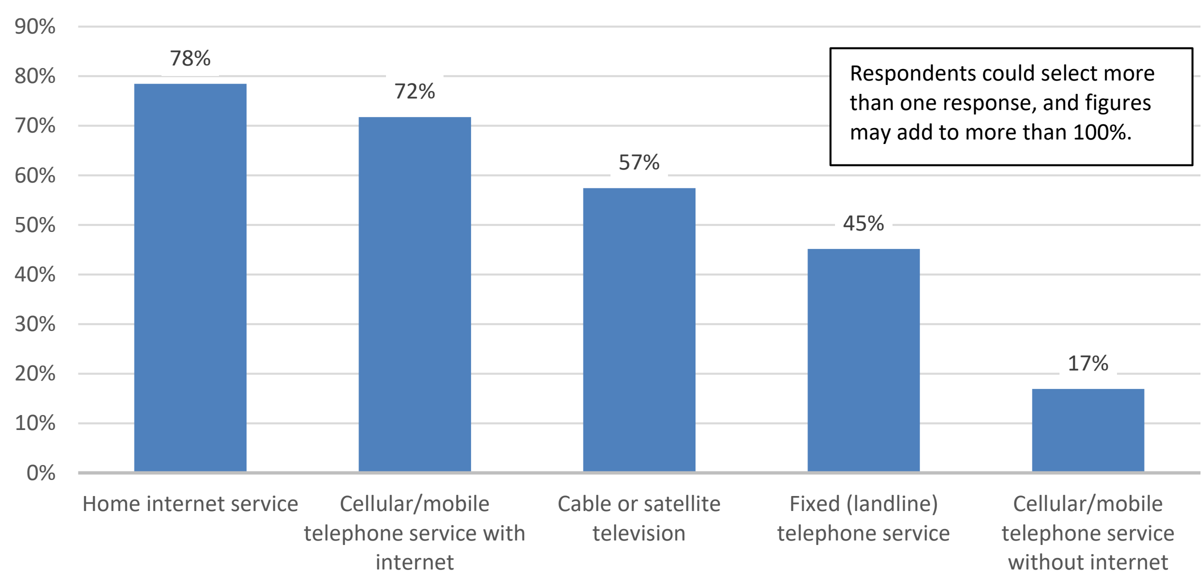
4.2.1 Home Internet Connection and Use

Respondents were asked about their home internet connection types and providers, use of the internet for various activities, and satisfaction and importance of features related to internet service. This information provides valuable insight into residents' need for various internet and related communications services.

4.2.1.1 Communications Services

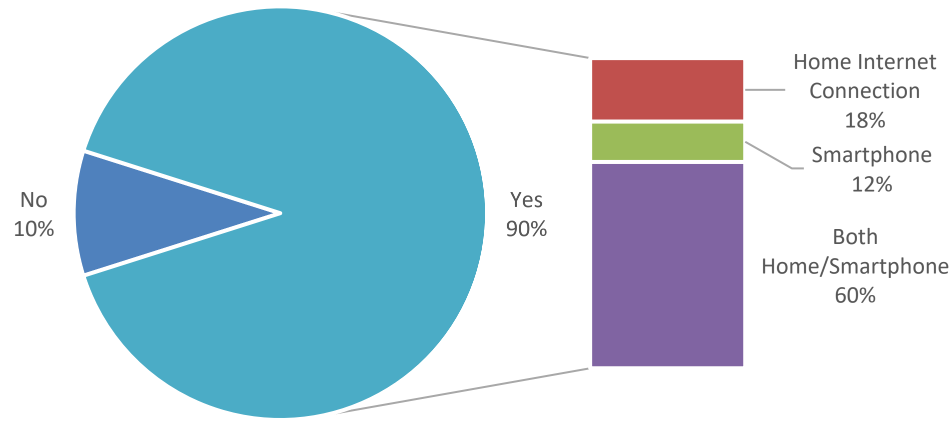
Respondents provided information about the communication services currently purchased for their household. As illustrated in Figure 10, 78 percent of respondents purchase home internet service, and 72 percent purchase cellular/mobile telephone service with internet.

Figure 10: Communications Services Purchased



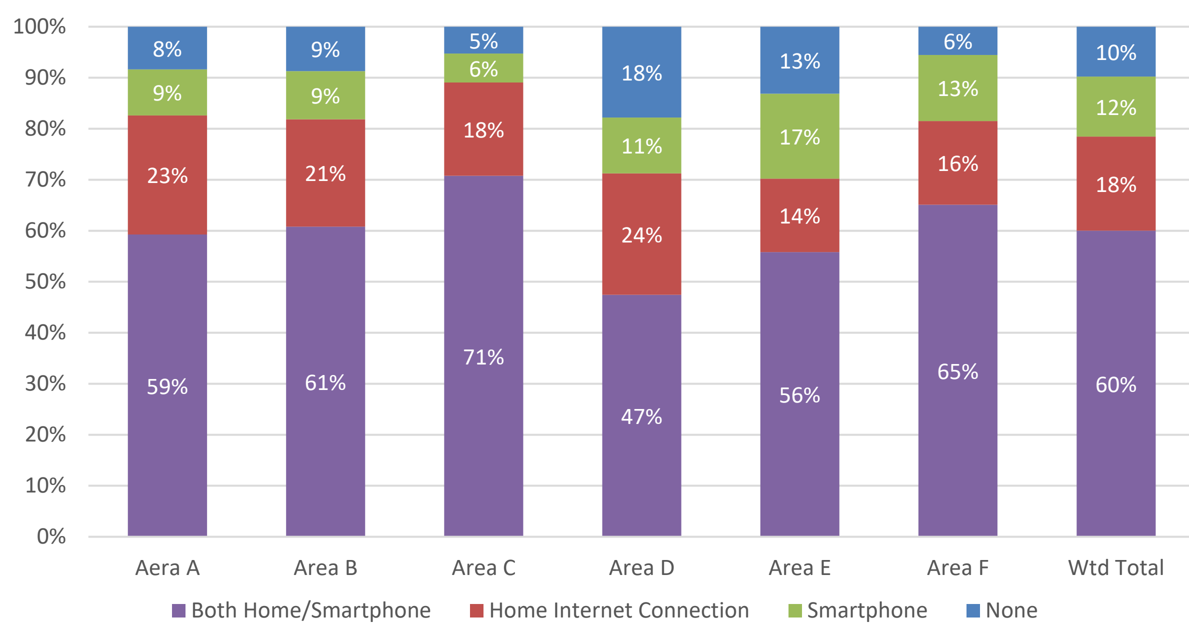
Nine in 10 respondents have some internet access, including 60 percent who have both home internet service and a cellular/mobile telephone service with internet (smartphone), as illustrated in Figure 11. Another 18 percent of respondents have a home connection only (no smartphone), and 12 percent have a smartphone only (no home internet).

Figure 11: Purchase Internet Services



As shown in Figure 12, residents of Area C appear to be well-connected, with seven in 10 having both a home internet connection and a smartphone. Just five percent do not have internet access. In comparison, nearly one-fifth of Area D residents do not purchase internet services for the household.

Figure 12: Internet Services Purchased by Area of Residence



Total internet access by demographics is illustrated in Table 21. Older respondents, those with a lower household income, and those with a lower level of education are among those who are somewhat less likely to have internet, although saturation is high among all demographic groups.

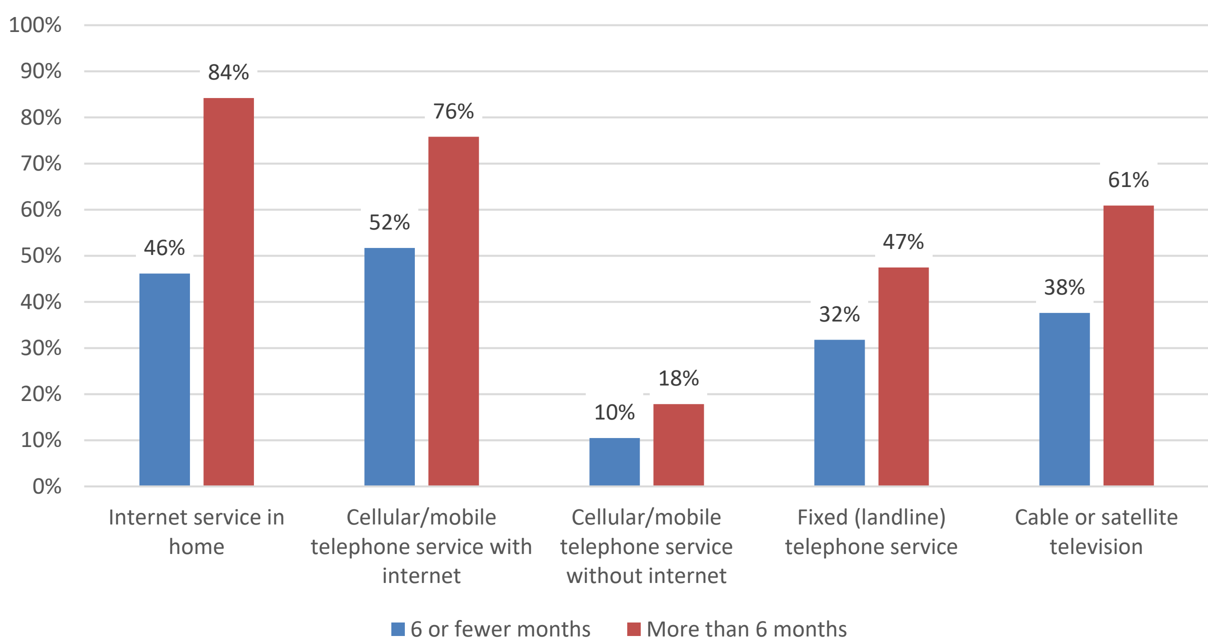
Table 21: Internet Access by Key Demographics

		Home Internet Connection	Smartphone	Both Home/ Smartphone	Total Internet Access	No Internet Access	Weighted Count
Area	A	23%	9%	59%	**92%**	8%	258
	B	21%	9%	61%	**91%**	9%	528
	C	18%	6%	71%	**95%**	5%	356
	D	24%	11%	47%	**82%**	18%	262
	E	14%	17%	56%	**87%**	13%	734
	F	16%	13%	65%	**94%**	6%	519
Gender	Female	17%	13%	60%	**91%**	9%	1279
	Male	20%	10%	61%	**91%**	9%	1326
Age group	18 to 34 years	21%	14%	63%	**97%**	3%	203
	35 to 44 years	8%	12%	76%	**96%**	4%	738
	45 to 54 years	20%	9%	65%	**93%**	7%	338
	55 to 64 years	21%	12%	55%	**88%**	12%	837
	65 years and older	28%	12%	43%	**83%**	17%	493
Race/Ethnicity	Other race/ethnicity	16%	10%	61%	**87%**	13%	210
	White/Caucasian only	19%	12%	61%	**91%**	9%	2325
Race/Ethnicity	No response	20%	12%	50%	**82%**	18%	135
Education	HS education or less	19%	15%	51%	**84%**	16%	342
	Two-year college or technical degree	18%	11%	60%	**90%**	10%	463
	Four-year college degree	19%	10%	63%	**92%**	8%	961
	Graduate degree	17%	14%	62%	**93%**	7%	834
Income	Less than $50,000	28%	16%	40%	**84%**	16%	351
	$50,000 to $74,999	23%	14%	50%	**88%**	12%	391
	$75,000 to $99,999	16%	14%	63%	**92%**	8%	432
	$100,000 to $149,999	14%	10%	70%	**94%**	6%	596
	$150,000 to $199,999	13%	10%	69%	**92%**	8%	345
	$200,000 or more	15%	7%	71%	**94%**	6%	319
Children in HH	No Children in HH	21%	13%	55%	**89%**	11%	1837
	Children in HH	13%	9%	74%	**96%**	4%	762
Total Household Size (Adults + Children)	1	22%	13%	44%	**79%**	21%	257
	2	21%	13%	55%	**90%**	10%	1348
	3	18%	11%	67%	**95%**	5%	360
	4 or more	11%	9%	76%	**95%**	5%	632
Own/rent residence	Own	18%	12%	61%	**90%**	10%	2540
	Rent	20%	19%	59%	**98%**	2%	61
	6 or fewer months	16%	22%	30%	**68%**	32%	360

		Home Internet Connection	Smartphone	Both Home/ Smartphone	Total Internet Access	No Internet Access	Weighted Count
Time at Residence in past year	More than 6 months	19%	10%	66%	**95%**	5%	2243
Number of years lived at current address	Less than 1 year	11%	21%	61%	**93%**	7%	199
	1 to 2 years	9%	16%	66%	**92%**	8%	256
	3 to 4 years	19%	9%	69%	**97%**	3%	412
	Five or more years	20%	11%	58%	**89%**	11%	1739

About one-third of those who lived in the home for fewer than six months out of the past year have no internet, and another 22 percent have a smartphone only. Just under one-half of this subsegment has a home internet connection other than a smartphone. This group of residents is also less likely to purchase other communication services, as shown in Figure 13.

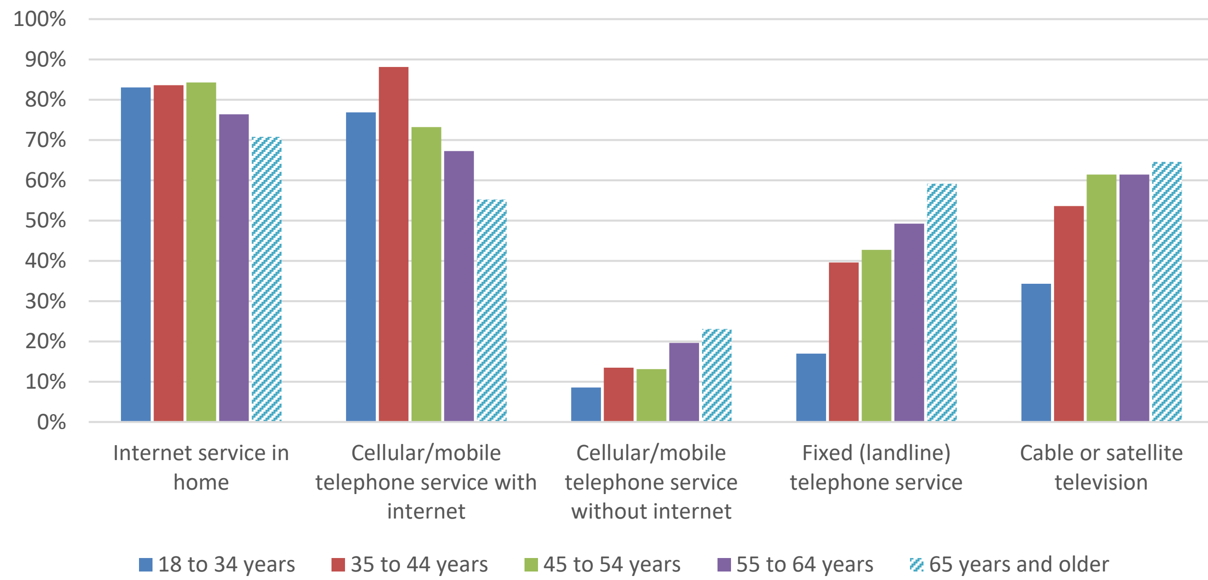
Figure 13: Services Purchased by Length of Time at Residence in Past Year



Other communication services are used less widely in households, compared with purchase of internet services. More than one-half of respondents purchase cable or satellite television service, 45 percent have fixed (landline) telephone service, and 17 percent have cellular/mobile service without internet.

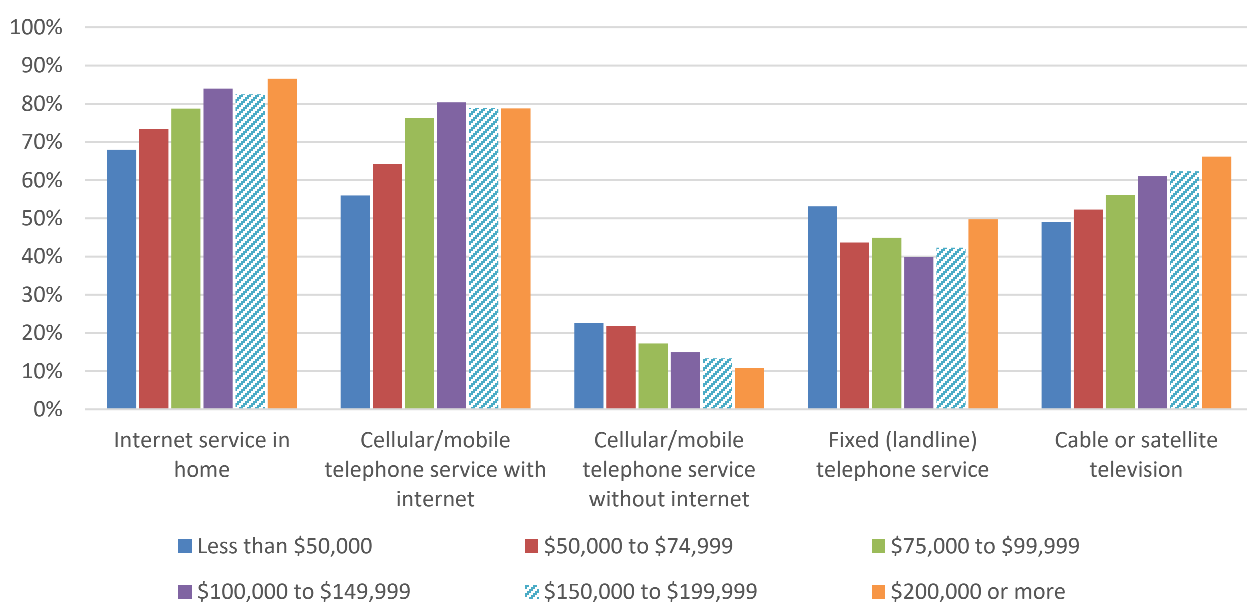
Purchase of these other communication services is correlated with age of the respondent, as illustrated in Figure 14, and is particularly low for those ages 18 to 34. Just one-third of respondents in the 18 to 34 age cohort purchase cable or satellite television service, and just 17 percent have fixed (landline) telephone service.

Figure 14: Services Purchased by Age of Respondent



The use of communication services is also associated with household income. In particular, respondents who earn under $50,000 per year are less likely to purchase internet services, and they are somewhat more likely to purchase landline telephone service (see Figure 15).

Figure 15: Services Purchased by Household Income



4.2.1.2 Importance of Communication Services

Respondents were asked to indicate the importance of various communications services to their household, using a scale where 1 is "Not at All Important" and 5 is "Very Important." The mean importance of various service aspects is illustrated in Figure 16, while detailed responses are illustrated in Figure 17. Cellular/mobile telephone service, high-speed internet connection, and internet connection of any speed are the most important communications service aspects, while fixed (land-line) telephone service, basic cable telephone service, and premium cable television service are significantly less important.

Figure 16: Importance of Communications Service Aspects (Mean Ratings)

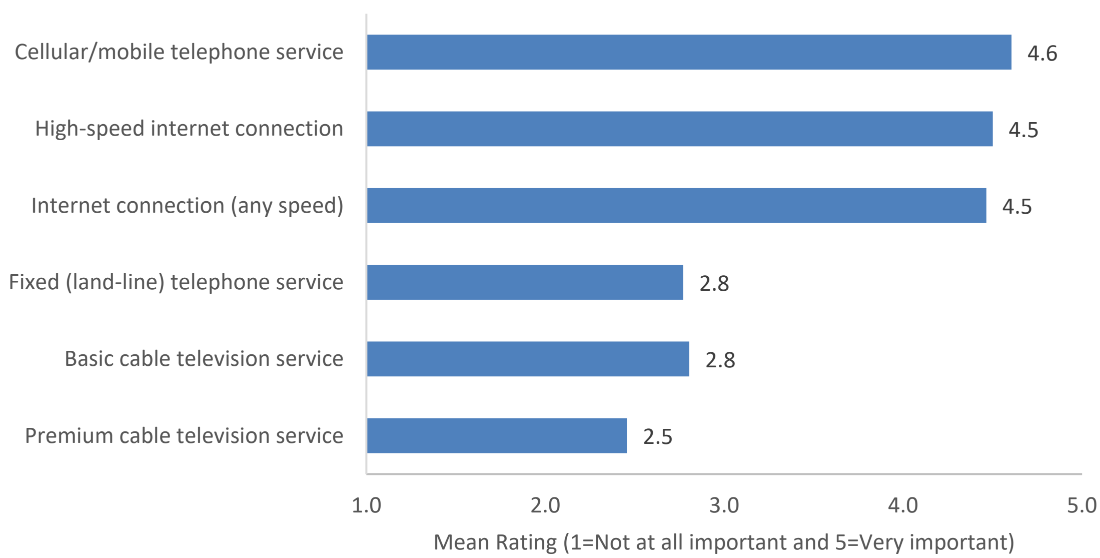
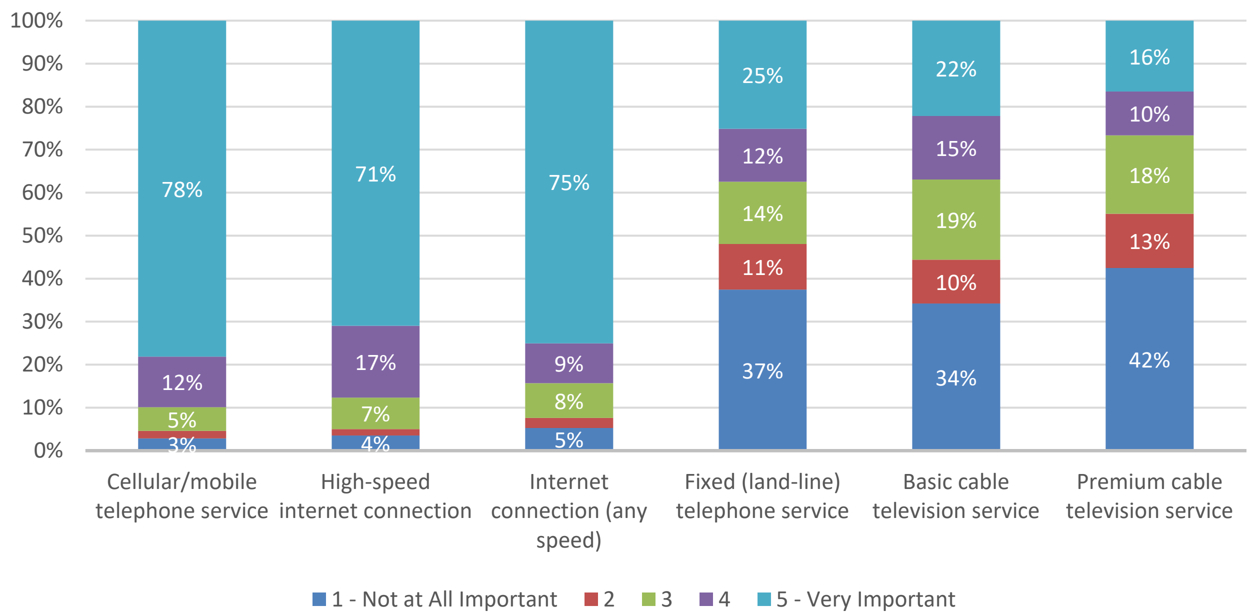


Figure 17: Importance of Communications Service Aspects



As would be expected, those who purchase internet services (either home internet connection or cellular/mobile internet) place more importance on having internet services compared with non-users. However, it is notable that almost four in 10 non-users say that internet service (either high-speed or any speed) is very important (see Figure 18). One-half of these individuals lived in the home for fewer than six months out of the past year. They cited lack of availability and high costs as barriers to having internet.

Figure 18: Importance of Internet Service Aspects by Purchase of Internet Services

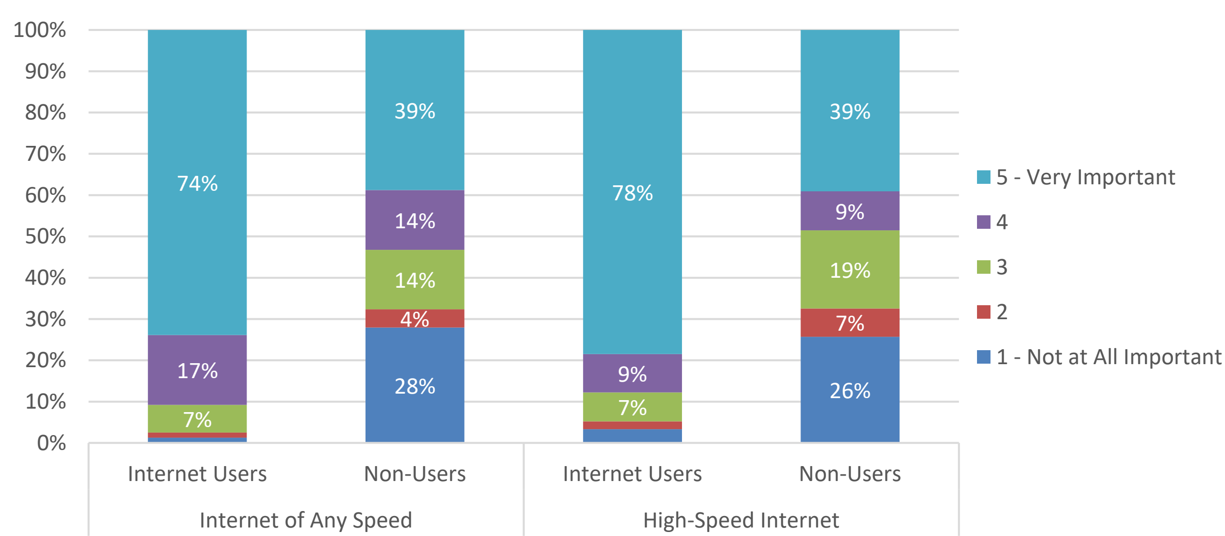
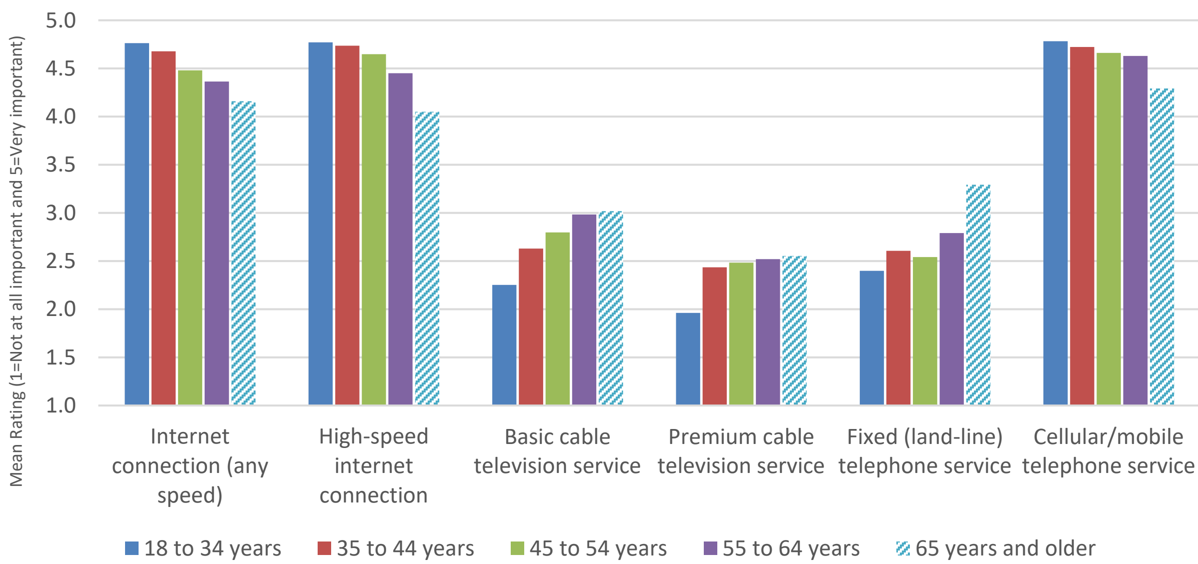


Figure 19 illustrates the mean ratings given to importance of communications services by the age of the respondent. The importance of internet connection (high speed or any speed) and cellular/mobile telephone service is lower for those ages 65 and older.

Figure 19: Importance of Communication Services by Age of Respondent



4.2.1.3 Personal Computing Devices

Respondents were asked to indicate the number of personal computing devices they have in the home. As might be expected, almost all (100 percent) respondents with internet access (either home connection or smartphone) have at least one personal computing device. Additionally, 69 percent of respondents without internet access have a personal computing device.

About six in 10 respondents have five or more personal computing devices. Another 24 percent have three or four devices, and 12 percent have one or two devices (see Figure 20).

As illustrated in Figure 21, residents of Area D are somewhat less likely to have internet connection and to have computing devices in the home.

Figure 20: Number of Personal Computing Devices

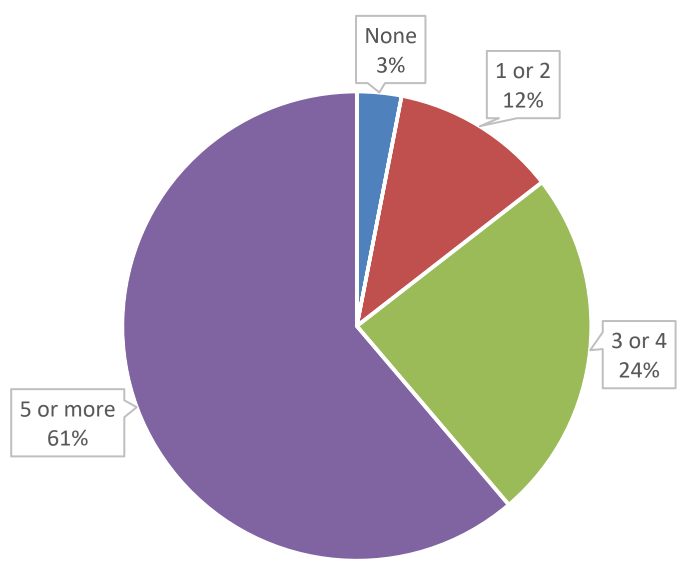
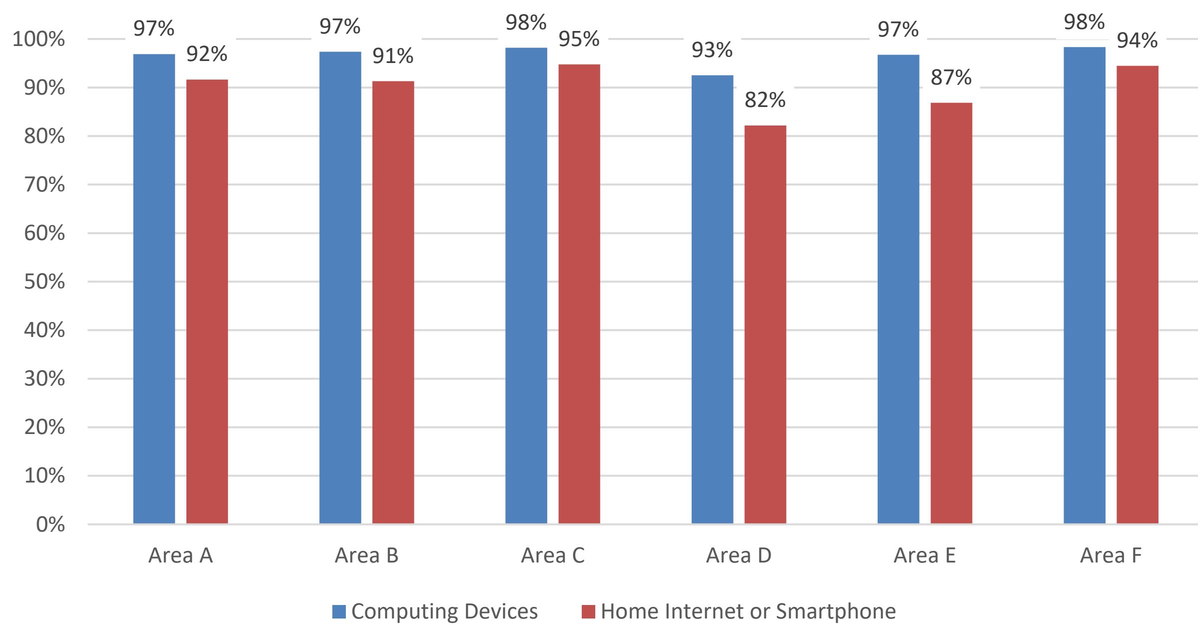
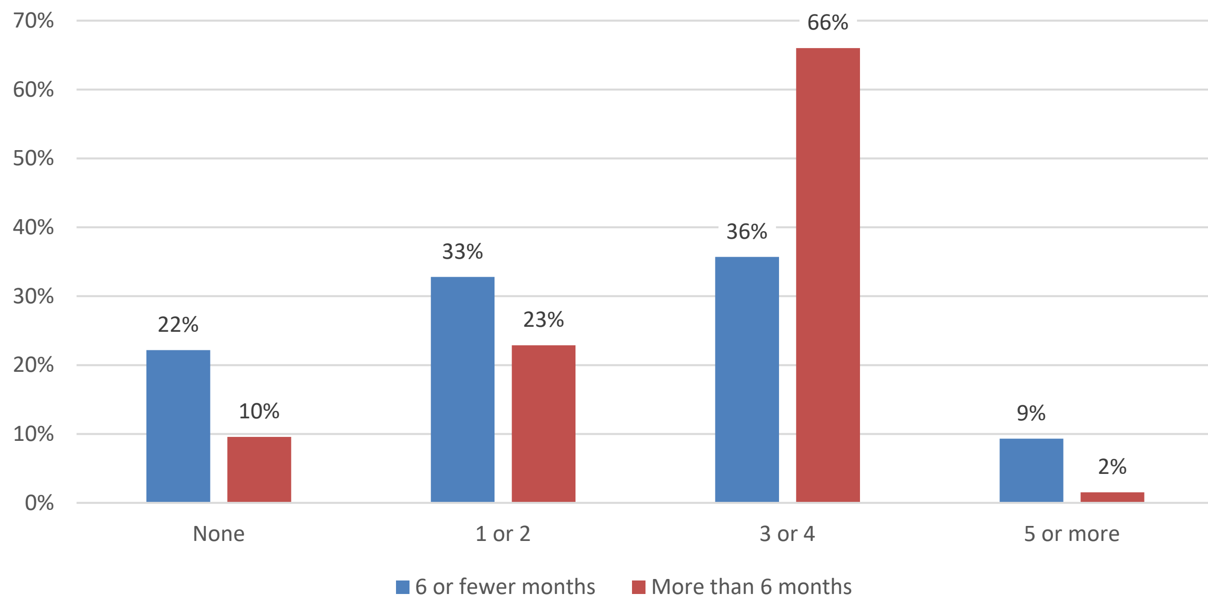


Figure 21: Internet Connection and Computing Devices in Home by Area of Residence



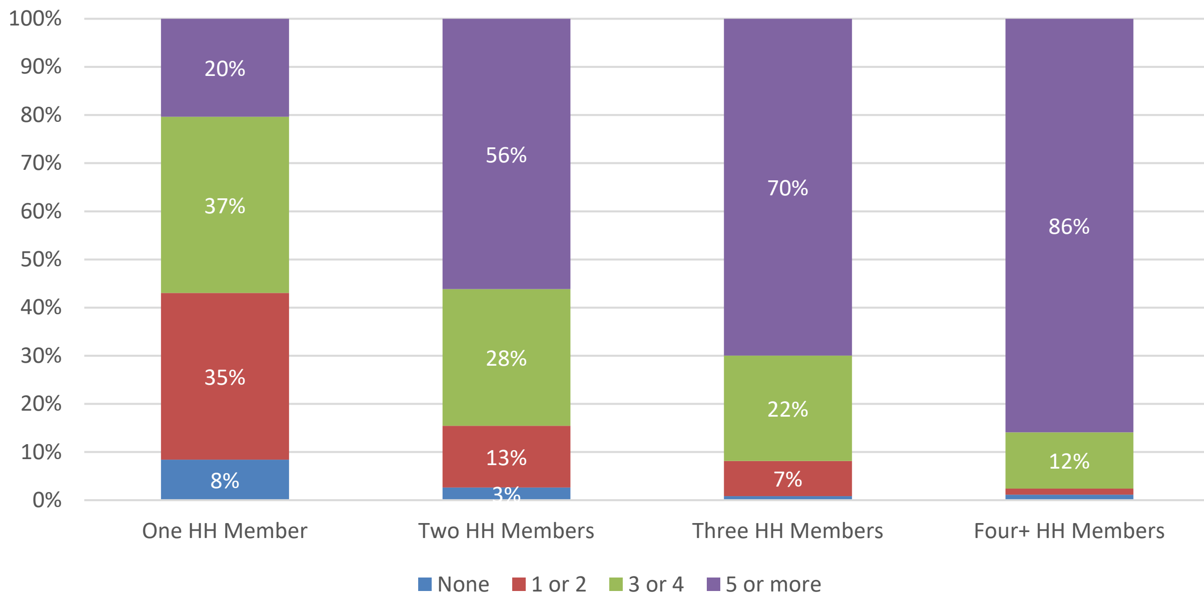
Additionally, those who have lived in their residence for more than six months in the past year are also more likely to have computing devices in the home (see Figure 22).

Figure 22: Number of Personal Computing Devices in Home by Length of Time at Residence



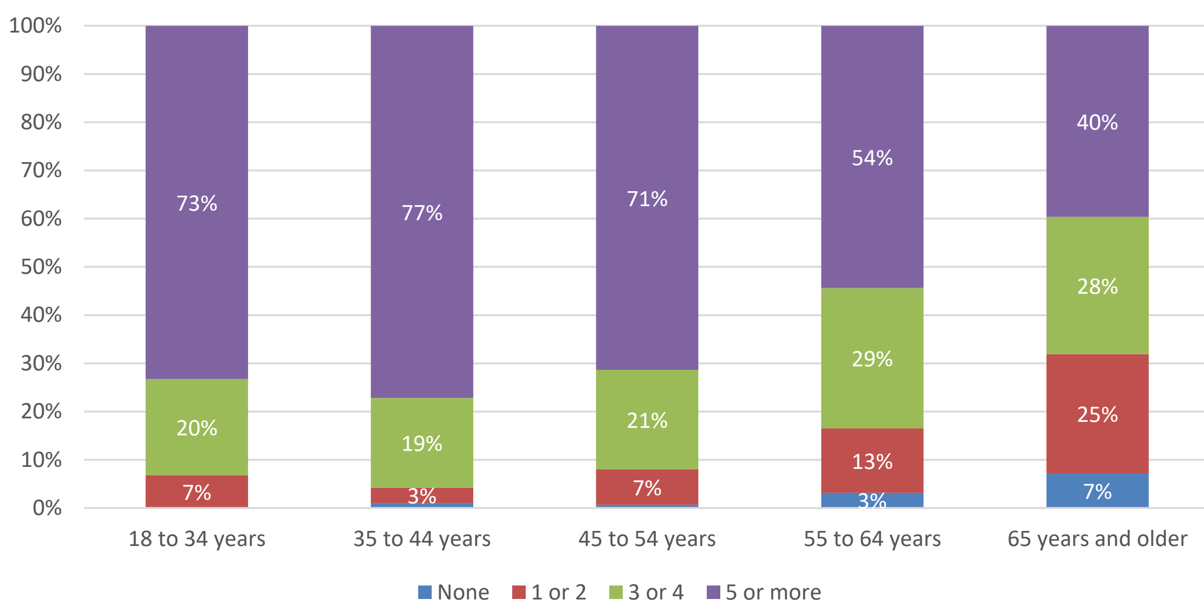
The number of personal computing devices in the home correlates with the number of people residing in the home. 86 percent of households with four or more residents have at least five personal computing devices (see Figure 23).

Figure 23: Number of Personal Computing Devices in Home by Household Size



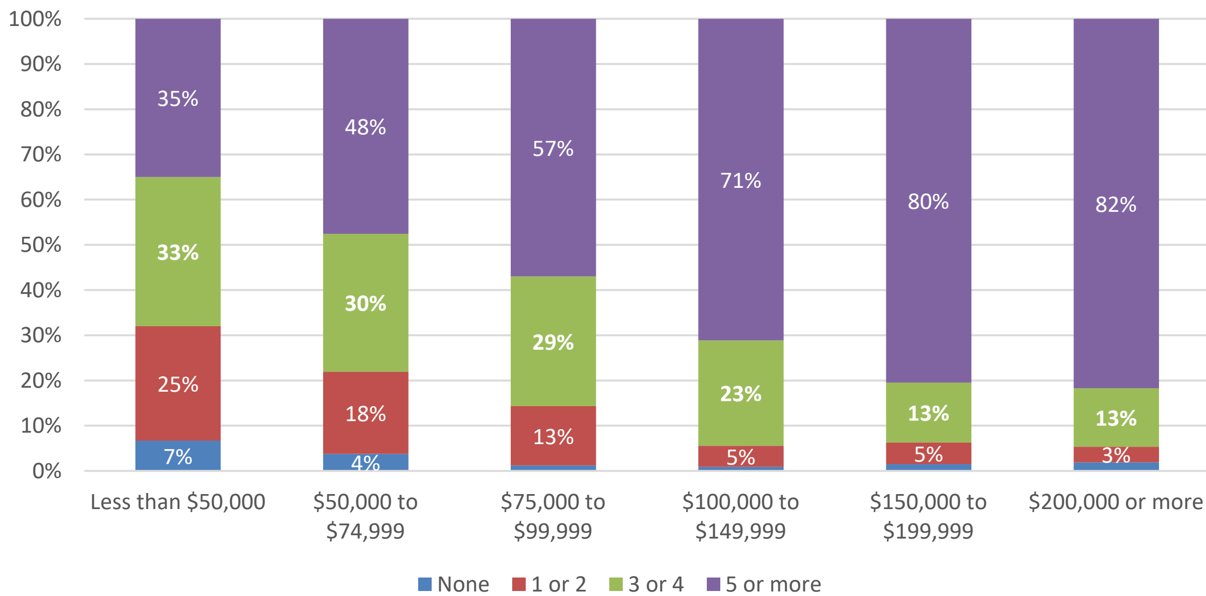
Respondents ages 55+ have fewer personal computing devices in the home compared with younger respondents, as illustrated in Figure 24.

Figure 24: Have Computing Device(s) and Internet in Home by Age of Respondent



The number of computing devices in the home is also correlated with household income. Eight in 10 of those earning $150,000 or more per year have at least five computing devices (see Figure 25).

Figure 25: Have Computing Device(s) and Internet in Home by Household Income



4.2.1.4 Internet Services Purchased

Respondents were asked about their purchase of internet services for their home, as well as the cost and speed of services purchased.

As shown in Figure 26, a majority of homes (92 percent) reported having home internet service. Fixed wireless, satellite, DSL, and cable modem have almost equal shares of the market at approximately one-fifth each. Cellular/mobile (six percent), and fiber (three percent) represent smaller shares of the study area.

Figure 26: Primary Home Internet Service

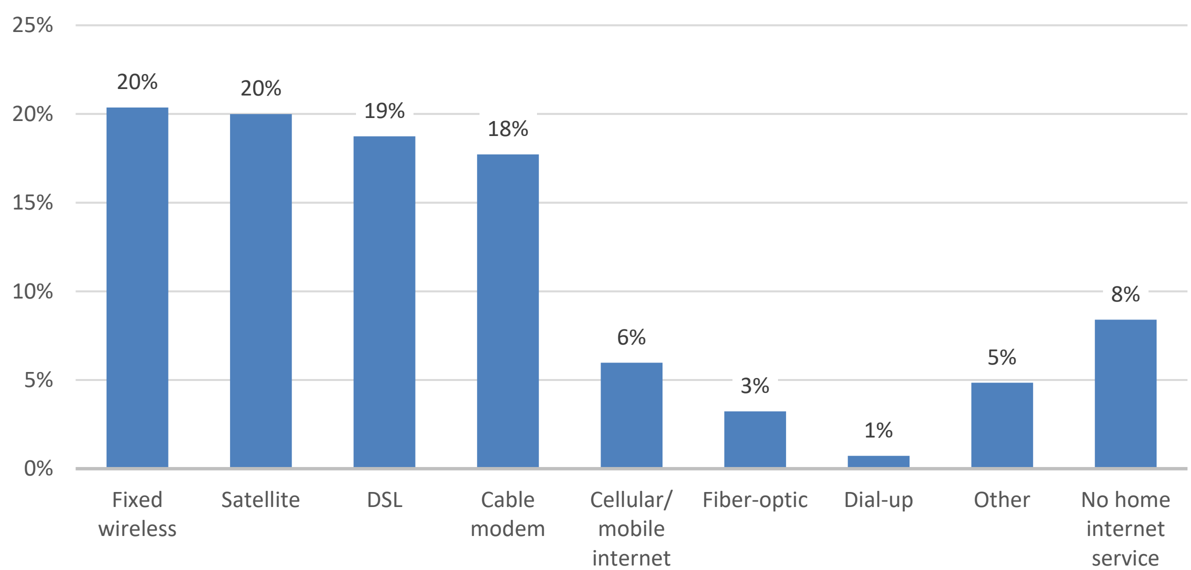
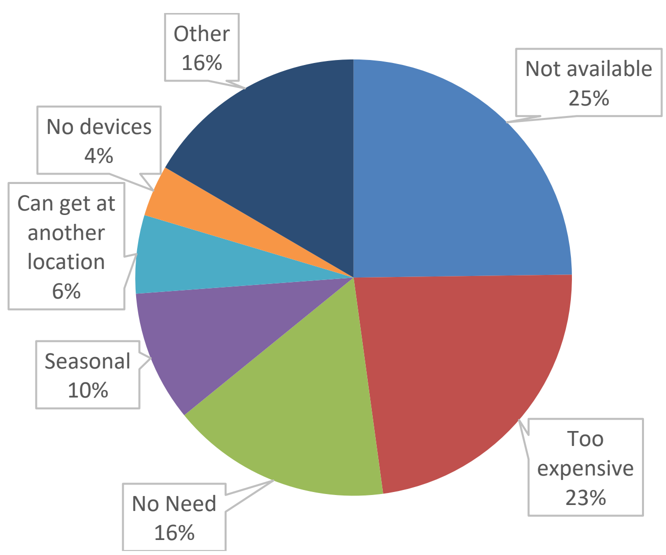


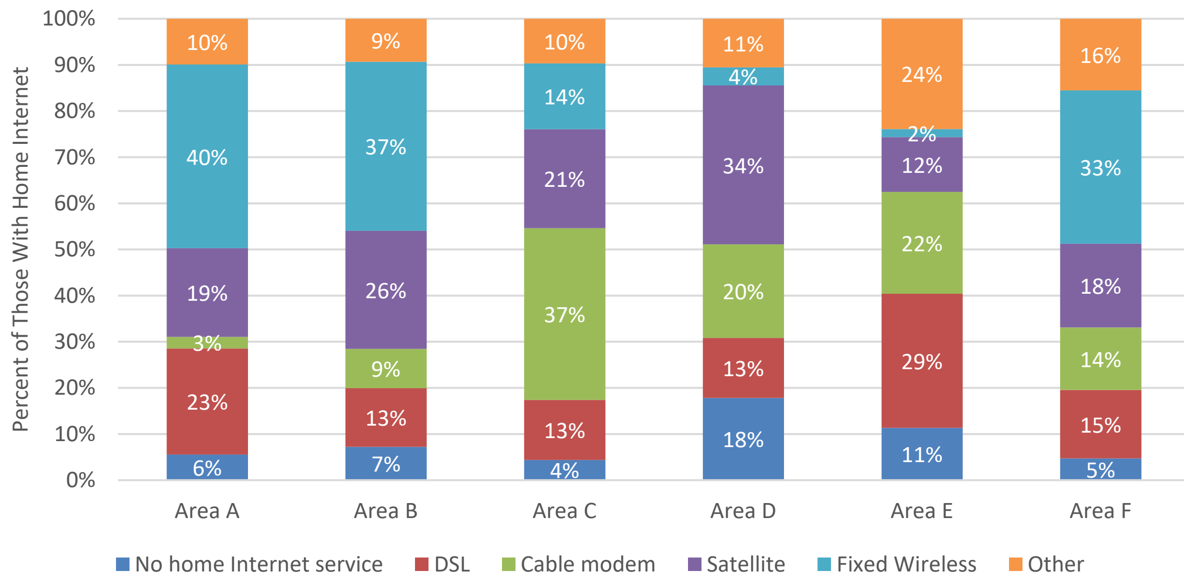
Figure 27: Primary Reason to Not Have Internet



One-fourth of responding households without internet access (and who provided a response) said that lack of availability at the location is the main reason for not purchasing home internet service, and another 23 percent cited expensive costs as the primary barrier to home internet usage.

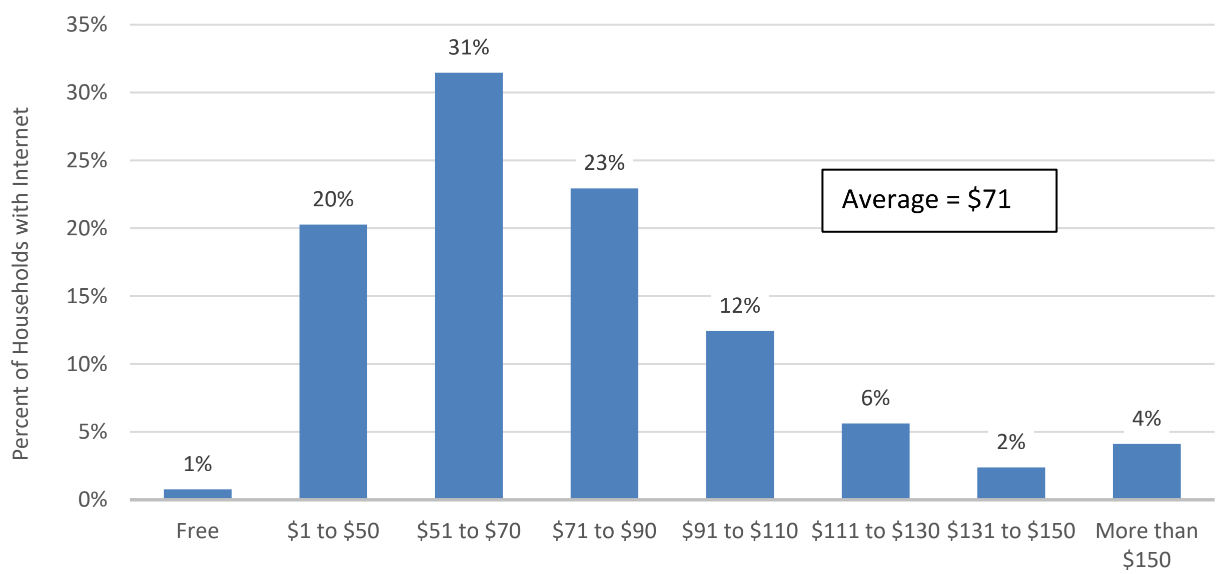
As indicated earlier, residents of Area D are less likely to have a home internet connection. Use of a fixed wireless connection is higher in Areas A, B, and F compared with other areas, while use of a cable modem connection is highest in Area C and use of a satellite connection is highest in Area D (see Figure 28).

Figure 28: Primary Home Internet Service by Area of Residence



Respondent households pay approximately $71 per month for internet service, on average. Approximately one-fourth of respondents with home internet pay over $90 per month (see Figure 29).

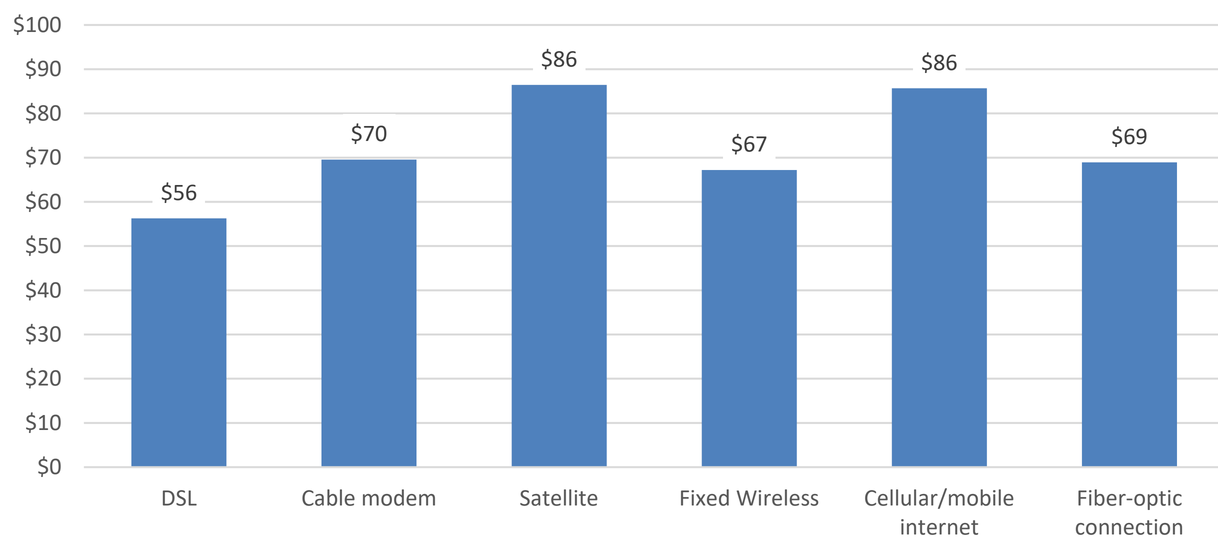
Figure 29: Monthly Price for Internet Service



The estimated average monthly price for internet service is highest for satellite and cellular/mobile internet, at $86. Average costs for cable modem, fixed wireless, and fiber-optic internet service are very similar at around $70, while the estimated average monthly price for

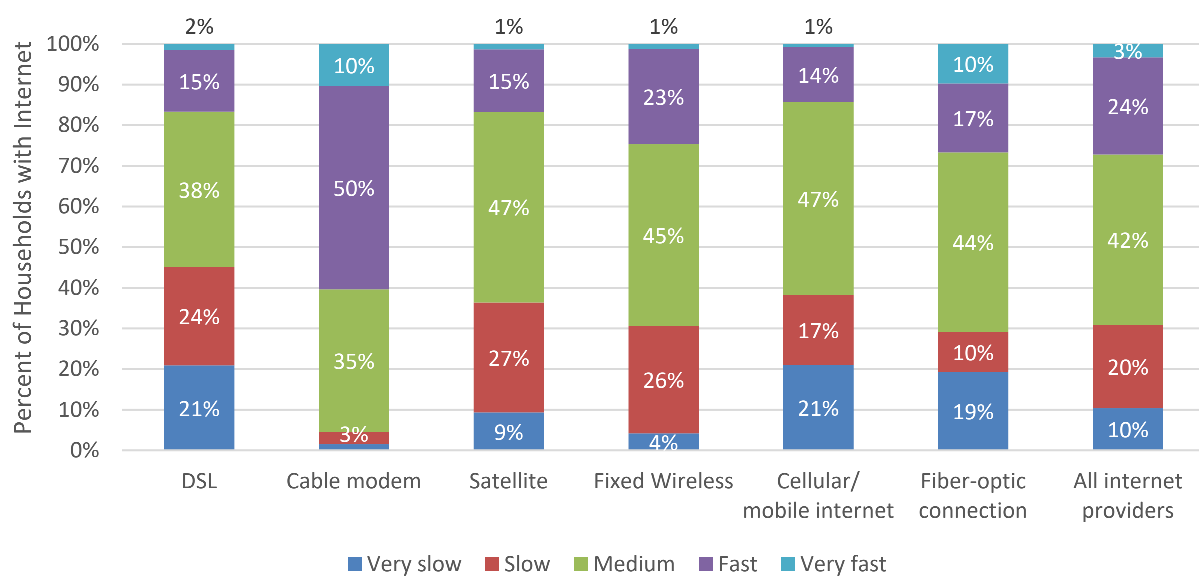
DSL service is slightly lower (see Figure 30).

Figure 30: Estimated Average Monthly Price for Internet Service



Most internet subscribers described their internet speed as "medium" (42 percent) or "fast" (24 percent), while only three percent said it was "very fast." Three in 10 respondents described their connection as "slow" (20 percent) or "very slow" (10 percent), as illustrated in Figure 31. Cable modem subscribers rated their connection faster than did those with other types of internet connections.

Figure 31: Internet Speed (Respondent Opinion) by Connection Type



4.2.1.5 Internet Service Aspects

Respondents were also asked about the importance of, and satisfaction with, a number of internet service aspects. The importance and satisfaction levels are compared in the following tables and graphs.

4.2.1.5.1 Importance

Respondents were asked to rate their levels of importance and satisfaction with various internet service aspects. Respondents rated connection reliability as the most important aspect, followed by connection speed, as shown in Table 22. The ability to bundle with television service is relatively unimportant compared with other service aspects.

Table 22: Importance of Internet Service Aspects

Service Aspect	Mean	Percentages
Speed of Connection	4.6	7% 24% 68%
Reliability of Connection	4.9	9% 90%
Price of Services	4.4	14% 26% 58%
Overall Customer Service	4.3	16% 30% 51%
Ability to Bundle with TV service	2.6	32% 18% 24% 13% 13%
		1 - Not at All Important; 2; 3; 4; 5 - Very Important

4.2.1.5.2 Satisfaction

Overall, respondents were moderately satisfied with aspects of their internet service, as shown in Table 23. Respondents rated the reliability and speed of their connection as the aspects with which they are most satisfied. The lowest satisfaction aspect was for the price of service, which is typical in satisfaction surveys.

Specifically, 35 percent are somewhat or very satisfied with the speed of their internet connection, while 35 percent expressed some dissatisfaction. Approximately 43 percent are satisfied with reliability of their internet connection, and 28 percent are dissatisfied. Only a small segment of subscribers is very satisfied with these services.

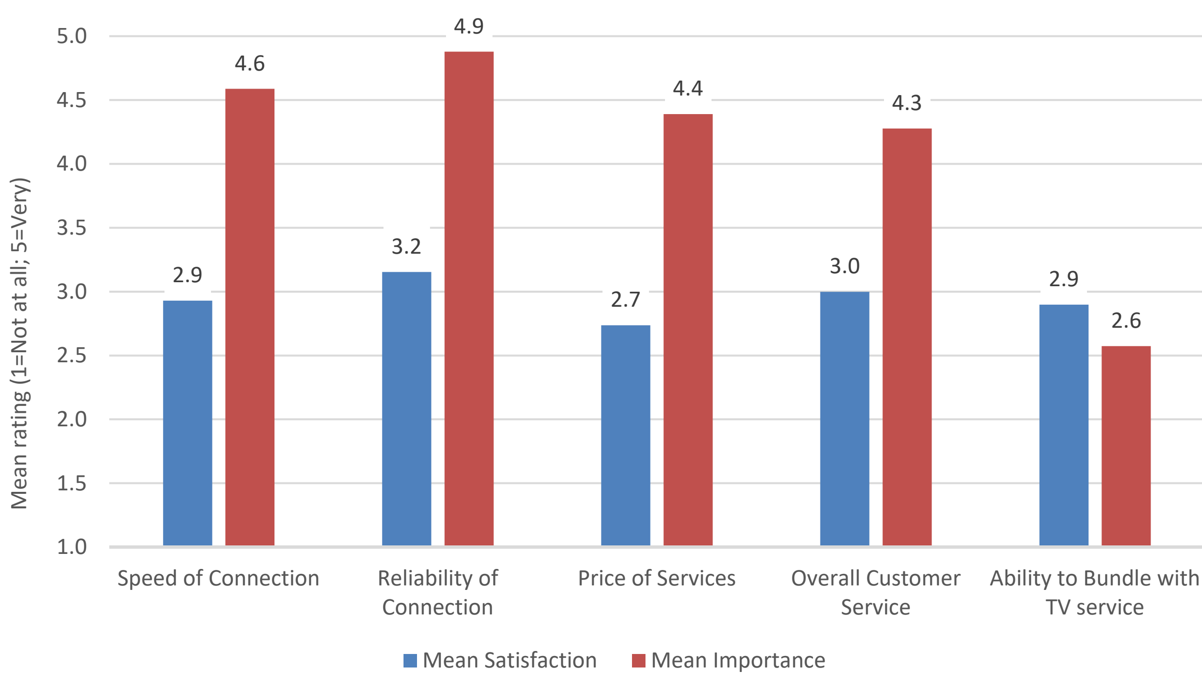
Table 23: Satisfaction with Internet Service Aspects

Service Aspect	Mean	Percentages: 1 - Very Dissatisfied	2	3	4	5 - Very Satisfied
Speed of Connection	3.2	17%	18%	30%	25%	10%
Reliability of Connection	3.2	13%	15%	30%	30%	13%
Price of Services	2.4	16%	23%	38%	16%	7%
Overall Customer Service	2.7	14%	17%	35%	23%	11%
Ability to Bundle with TV service	2.8	16%	11%	48%	18%	8%

4.2.1.5.3 Performance

Comparing respondents' stated importance and satisfaction with service aspects allows an evaluation of how well internet service providers are meeting the needs of customers (see Figure 32). Aspects that have higher stated importance than satisfaction can be considered areas in need of improvement. Aspects that have higher satisfaction than importance are areas where the market is meeting or exceeding customers' needs. However, it should be cautioned that the extremely high level of importance placed on some aspects (such as reliability) may make it nearly impossible to attain satisfaction levels equal to importance levels.

Figure 32: Importance of and Satisfaction with Internet Service Aspects



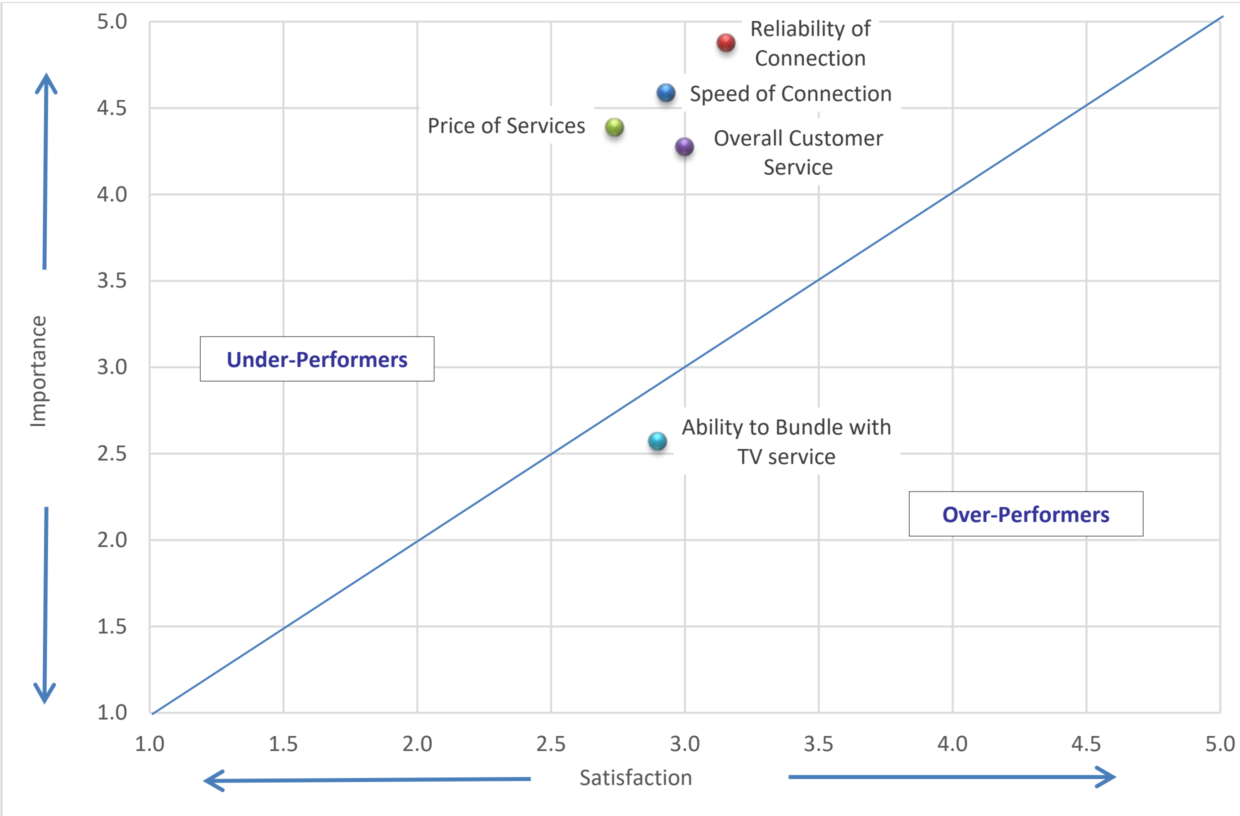
The difference between importance and satisfaction of home internet aspects is also presented in the "gap" analysis table (see Table 24). This analysis demonstrates the "gap" between respondent's satisfaction with a service attribute, and the importance of the attribute. As shown, the average respondent reported that the price of service, overall customer service, reliability of connection, and speed of connection were either "important" or "very important". However, the average respondent was either neutral or reported "not satisfied" with these service attributes. The "gap" between importance and satisfaction demonstrates that respondents are not satisfied with the service attributes they find important. The largest gap between importance and performance is for price, overall customer service, and reliability of connection.

Table 24: Internet Service Aspect "Gap" Analysis

	Mean Satisfaction	Mean Importance	GAP < = >	Customer Expectations
Price of Services	2.9	4.6	-1.7	Not Met
Overall Customer Service	3.2	4.9	-1.7	Not Met
Reliability of Connection	2.7	4.4	-1.7	Not Met
Speed of Connection	3.0	4.3	-1.3	Not Met
Ability to Bundle with TV service	2.9	2.6	0.3	Exceeded

The importance scores and performance scores were plotted to help visually determine areas in which internet service providers are doing well and areas that might need improvement. Figure 33 compares the importance and satisfaction in a "quadrant" analysis. Those aspects for which importance is higher than satisfaction are above the equilibrium line and are defined as "underperformers." As is typical, the cost of internet service is well off the line, as satisfaction with costs is typically low. Reliability, connection speed, and overall customer service are other under-performing service areas. The mediocre satisfaction levels could indicate a willingness to switch internet service providers if these needs are not being met.

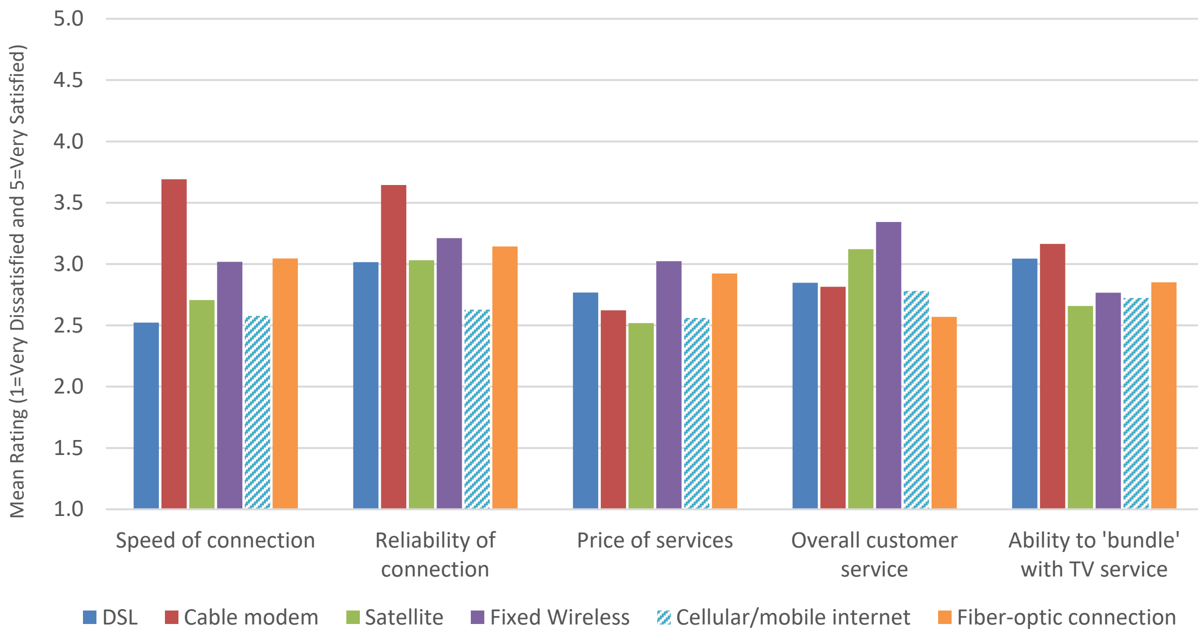
Figure 33: Internet Service Aspect "Quadrant" Analysis



4.2.1.5.4 Connection Type

Only slight differences in importance of internet service aspects by connection type were found (most notably that ability to bundle is somewhat less important for those with fixed wireless). However, there are significant differences in satisfaction by connection type for some key aspects of service, as illustrated in Figure 34. Cable modem users have a higher level of satisfaction with speed and reliability of service, compared with those who have other types of internet connections. Fixed wireless users are more satisfied with price of service and overall customer service compared with others.

Figure 34: Satisfaction with Internet Service Aspects by Connection Type



The gap between importance and satisfaction for the leading connection types was converted to an index score for each service aspect. This illustrates "the percentage of expectations fulfilled." Gap index scores are shown in Table 25. Cable modem internet providers are better meeting expectations (high ratio of satisfaction to importance) for connection speed and connection reliability compared with other provider types, as discussed previously. Fixed wireless providers are better meeting expectations for price of service and customer service compared with others. DSL, cable modem, and fixed wireless providers are over-performing for ability to bundle services (high satisfaction compared with relatively low importance).

Table 25: Gap Index Score by Internet Service Provider

	Satisfaction / Importance Gap Index*				
	Speed of connection	Reliability of connection	Price of service	Customer service	Ability to bundle
DSL	56%	62%	64%	67%	118%
Cable modem	80%	75%	59%	67%	123%
Satellite	59%	62%	57%	73%	96%
Fixed Wireless	65%	65%	71%	78%	126%
Cellular/mobile internet	57%	54%	56%	66%	97%
Fiber-optic connection	66%	64%	63%	59%	102%
ISP Average	64%	65%	62%	70%	113%
***Percent of expectations met = Satisfaction / Importance**					

4.2.1.6 Willingness to Pay for Faster Internet

Respondents were asked if they would be willing to switch to high-speed internet service (10+ times faster than DSL) for various price levels. The mean willingness to switch across this array of questions is illustrated in Figure 35, while detailed responses are illustrated in Figure 36.

Figure 35: Willingness to Switch to High-Speed Internet at Price Levels (Mean Ratings)

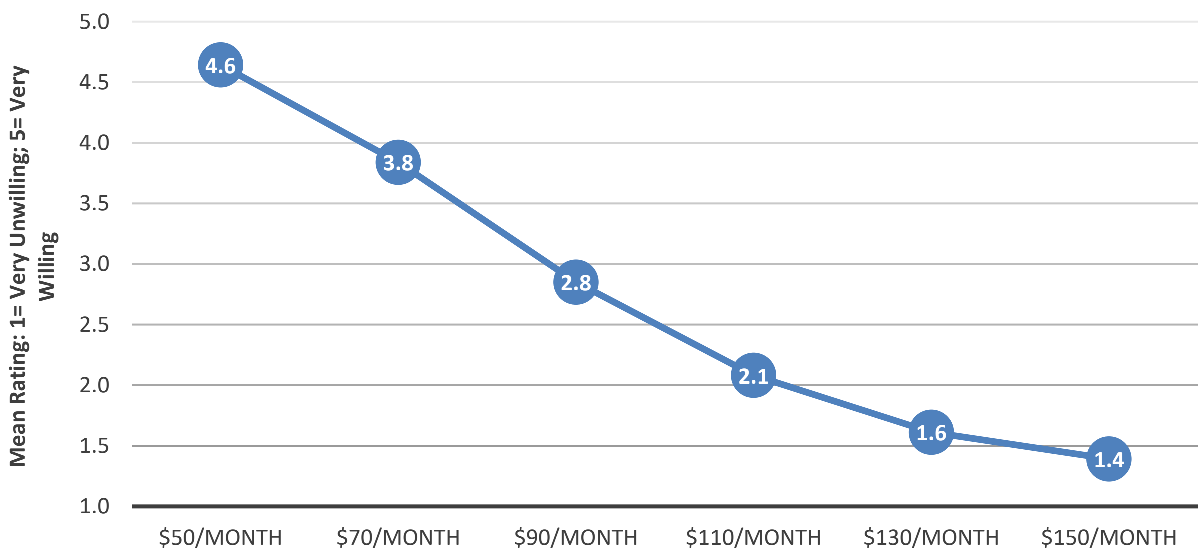
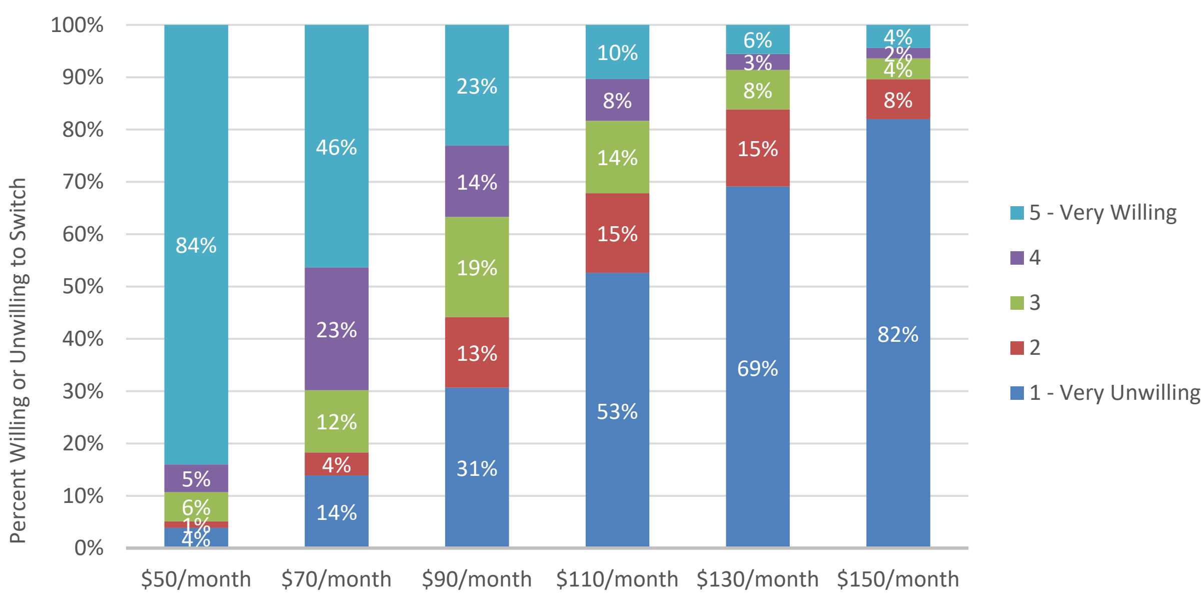


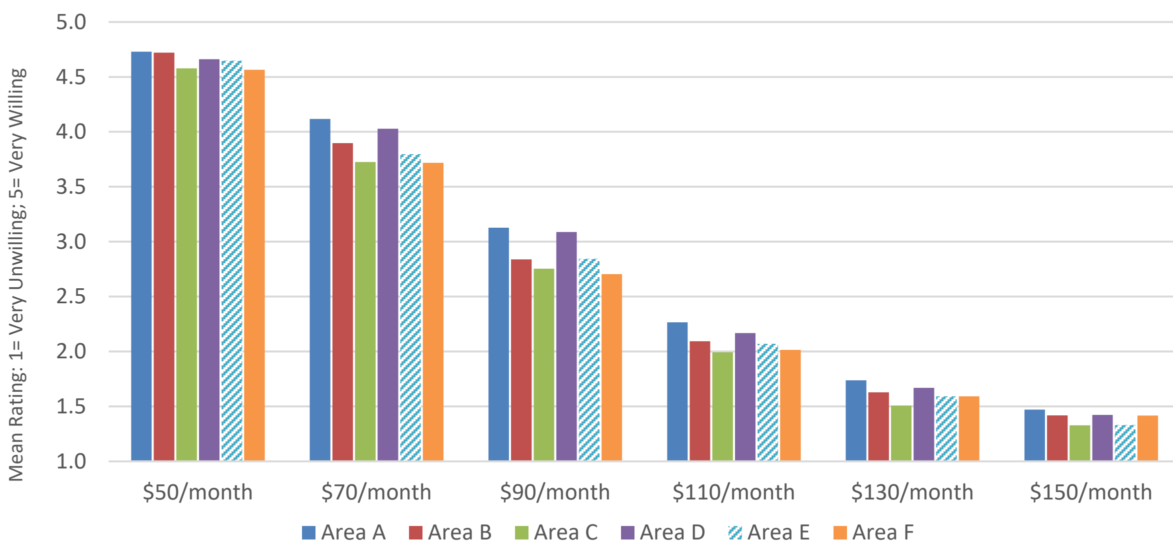
Figure 36: Willingness to Switch to High-Speed Internet at Various Price Levels



As depicted in Figure 35 and in Figure 36, respondents' willingness to switch to high-speed internet service (defined at 10+ times faster than DSL in the survey) is very high at $50 per month, but drops considerably as the price increases. At a price of approximately $90 per month, the mean rating falls below 3.0 (neither willing nor unwilling). From another perspective, 89 percent are somewhat or very willing to switch to high-speed internet for $50 per month, dropping to six percent at $150 per month.

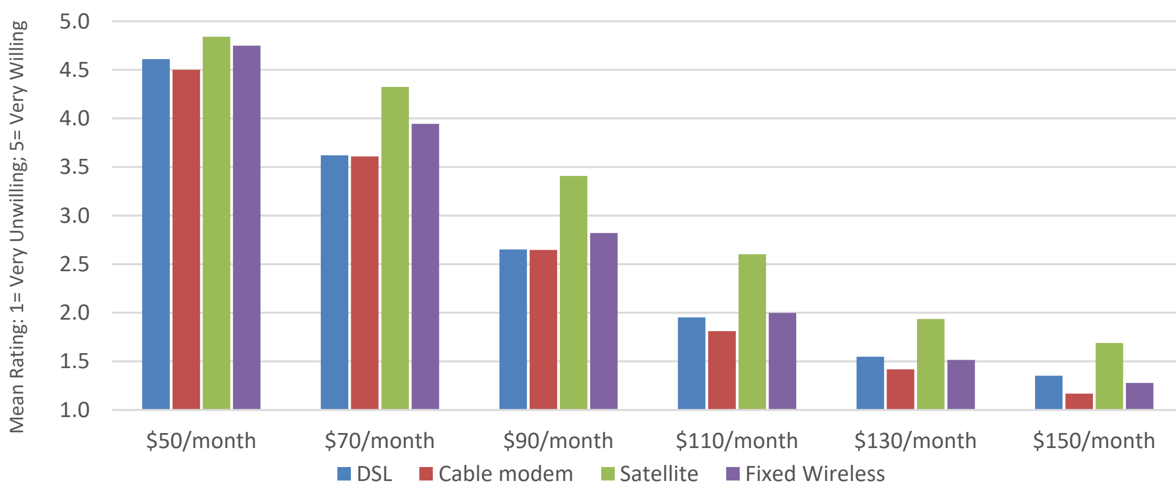
The willingness to switch to high-speed internet does not vary strongly by area of residence (see Figure 37). Those in Areas A and D would be somewhat more likely than residents of other areas to switch at the $70 and $90 per month price points.

Figure 37: Willingness to Switch to High-Speed Internet by Price and Area of Residence



The willingness to switch to very fast internet service is correlated with connection type. Specifically, those who subscribe to satellite internet service would be more likely to switch to a high-speed connection at various price points (see Figure 38).

Figure 38: Willingness to Switch to High-Speed Internet by Price and Connection Type



Internet users ages 65+ would be less likely than younger subscribers to switch to high-speed internet at various price points. Additionally, high income households, particularly those earning $150,000 or more per year, would be more willing than lower income households to switch to high-speed internet (see Figure 39 and Figure 40).

Figure 39: Willingness to Switch to High-Speed Internet by Price and Age of Respondent

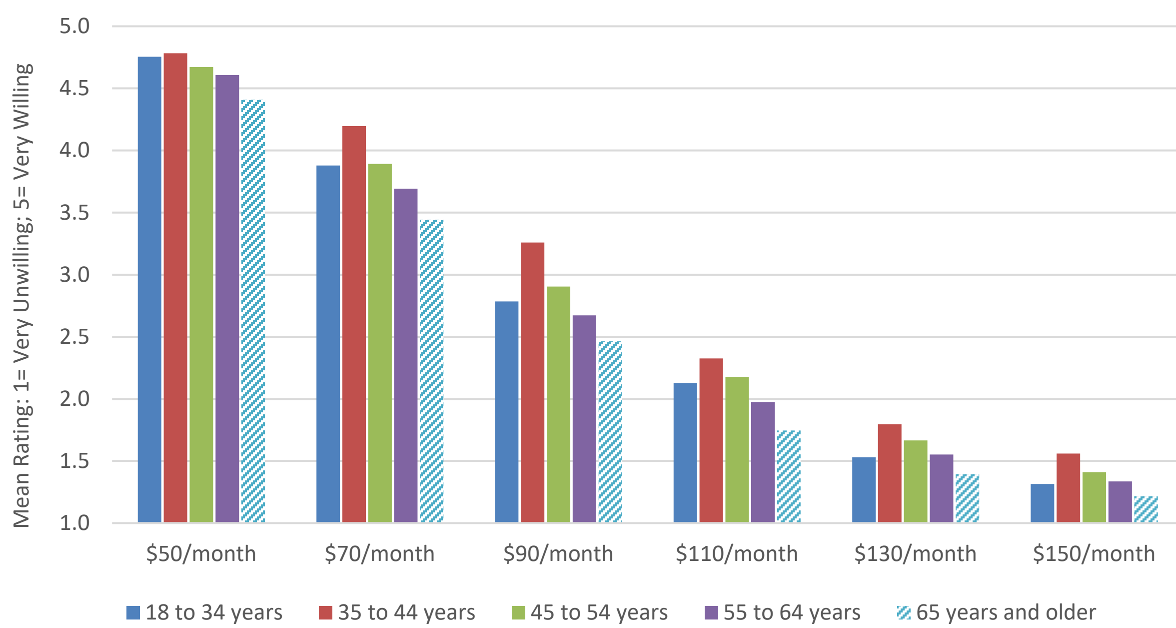
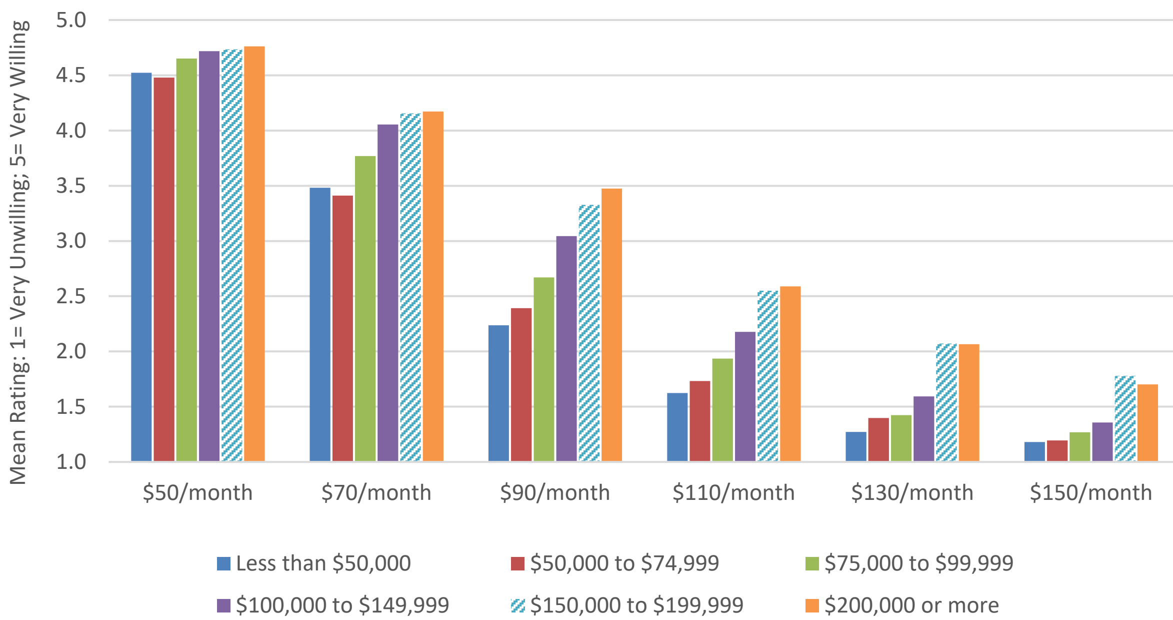


Figure 40: Willingness to Switch to High-Speed Internet by Price and Household Income

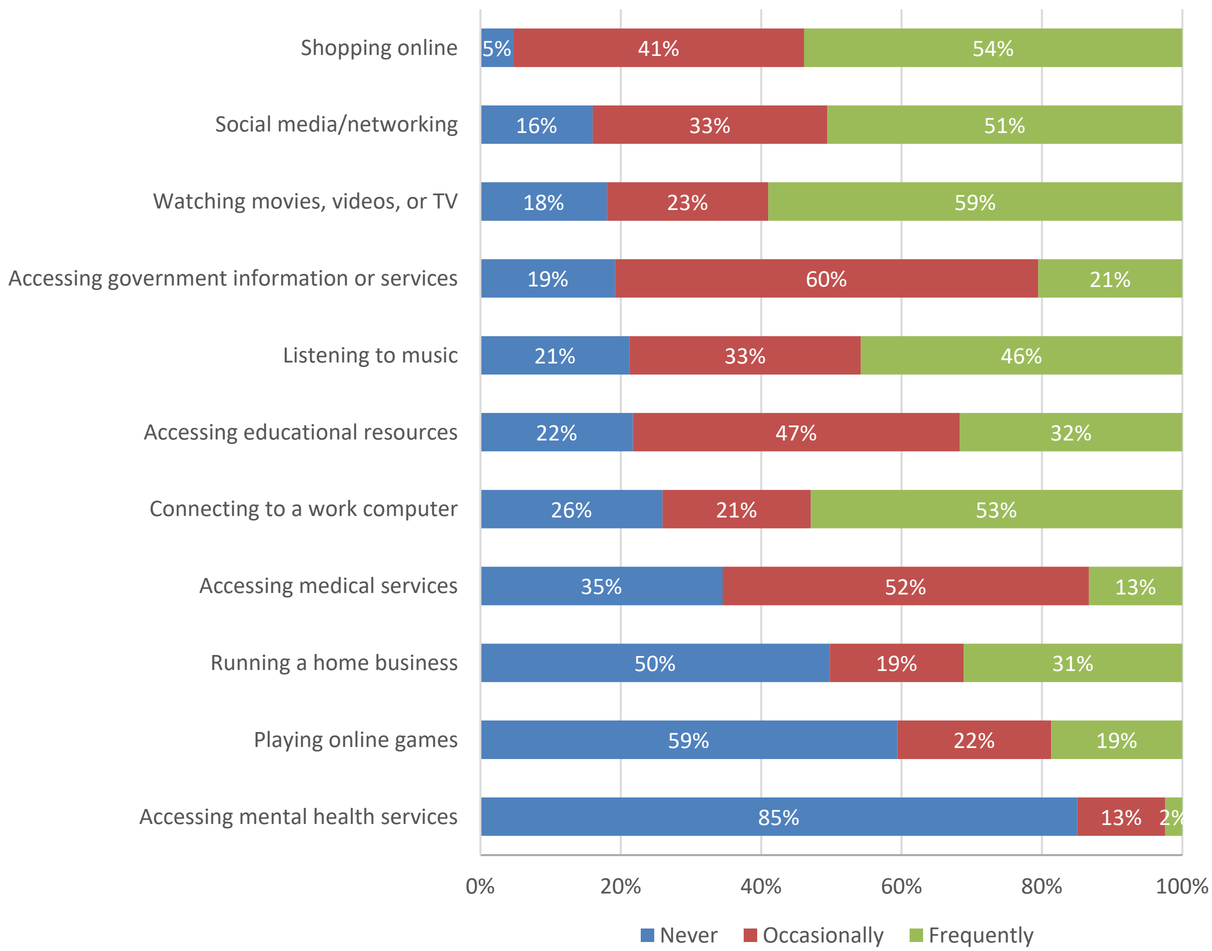


4.2.1.7 Internet Uses and Importance

Respondents were asked about their use of the internet for various activities, as illustrated in Figure 41. Among those items listed, the internet is most frequently used for shopping online, social media/networking, and watching movies, videos, or TV.

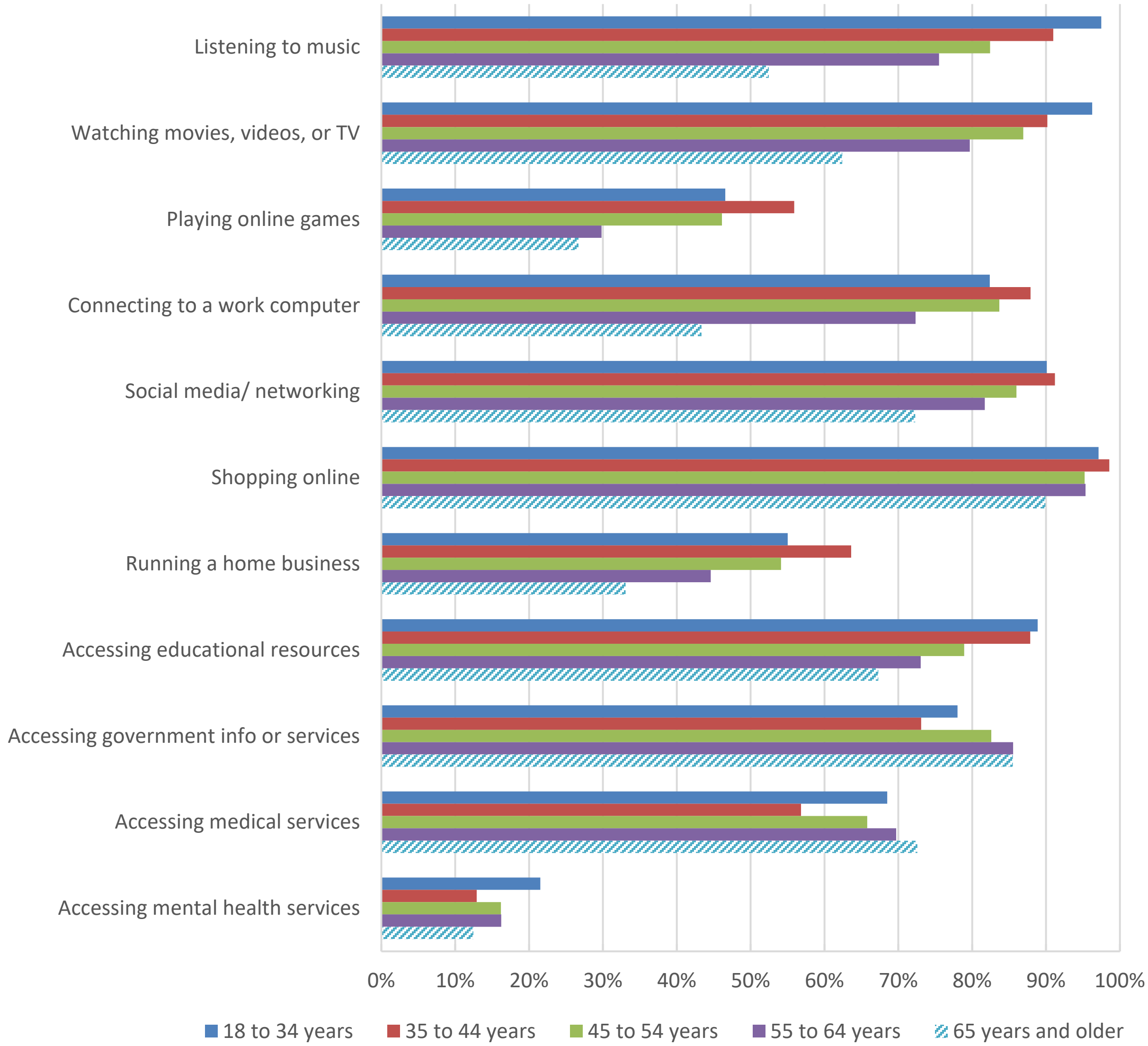
Eight in 10 respondents use the internet to access government information/services or to access educational resources at least occasionally. Use of the internet for running a home business, playing online games, or accessing mental health services is less frequent than the other activities included in this question.

Figure 41: Frequency of Home Internet Activities



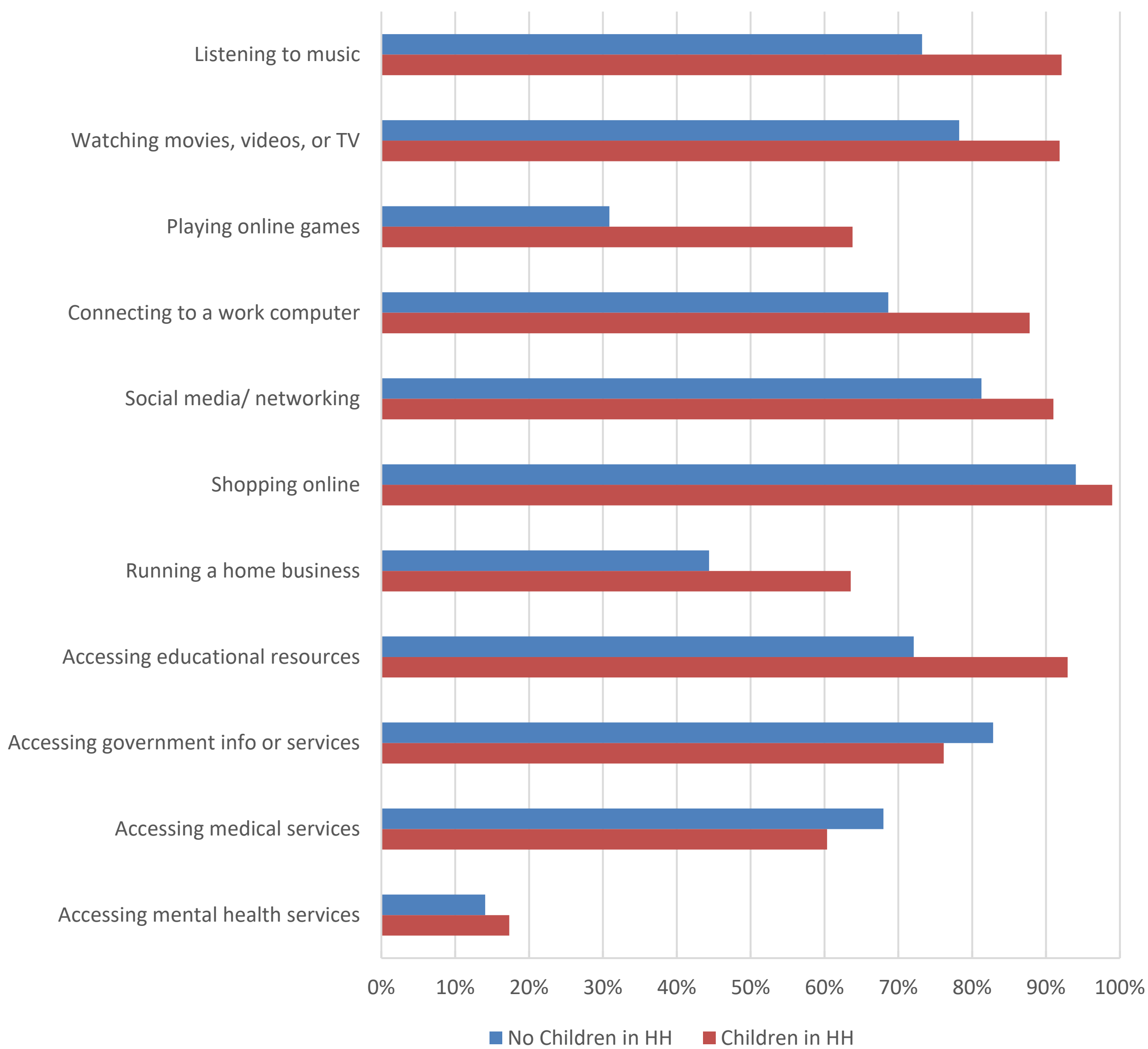
The use of the internet for some activities varies by age, as illustrated in Figure 42. Younger respondents are much more likely to use the internet for many applications, especially listening to music and watching videos or movies. Internet subscribers ages 65+ are less likely to ever use the internet for many of the various activities evaluated, with the exception of accessing government information/services and accessing medical services.

Figure 42: Home Internet Activity by Age of Respondent (Percent Ever Using)



Similarly, respondents with children age 18 and under in the household are more likely to use the internet for various activities, with the exception of accessing government information/ services and accessing medical services (see Figure 43).

Figure 43: Home Internet Activity by Children in Household (Percent Ever Using)



Respondents were asked to rate the importance of aspects when selecting a home internet provider. The mean importance of various service aspects is illustrated in Figure 44, while detailed responses are illustrated in Figure 45.

Figure 44: Importance of Aspects in Selecting Home Internet Service (Mean Ratings)

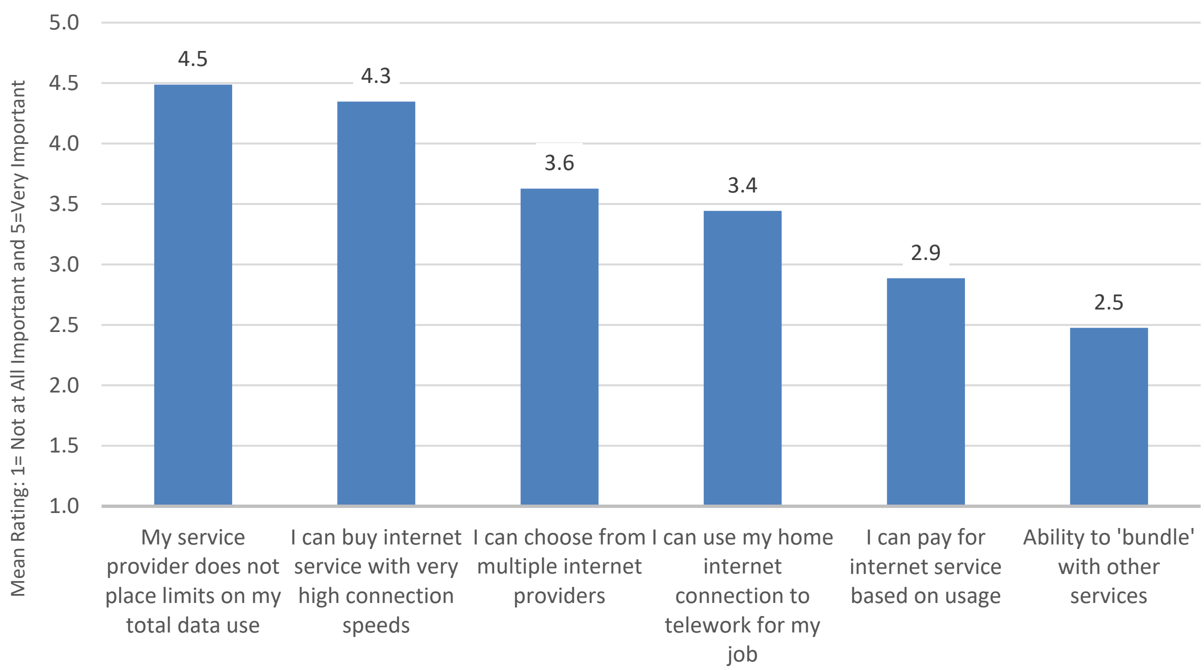
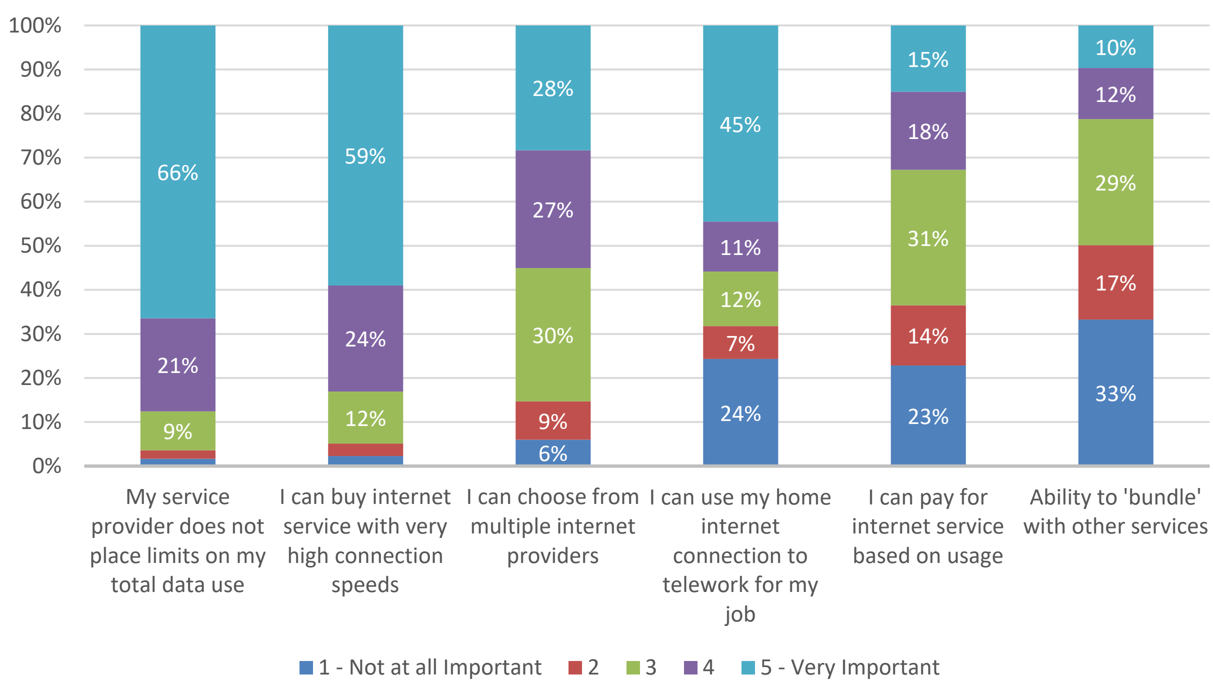


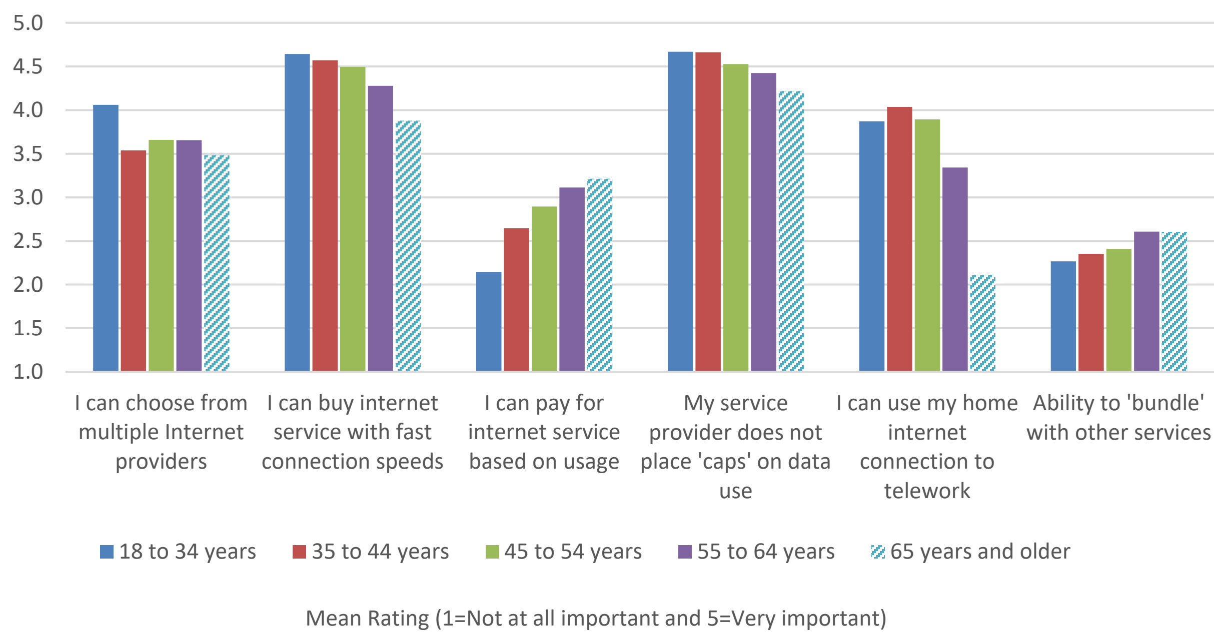
Figure 45: Importance of Aspects in Selecting Home Internet Service



The most important aspects are the service provider not placing "caps" on data use and having the ability to buy internet service with very high connection speeds, with at least six in 10 saying these aspects are "very important." The ability to choose from multiple internet providers is somewhat important to respondents. The least important aspect of home internet service is having the ability to bundle with other services.

In general, the importance placed on buying internet service with fast connection speeds, not having "caps" on data use, and using a home internet connection to telework is less important to respondents ages 65 and older, while being able to pay for service based on usage is somewhat more important to this group. Additionally, respondents ages 18 to 34 placed more importance on the ability to choose from multiple internet providers, compared with older respondents (see Figure 46).

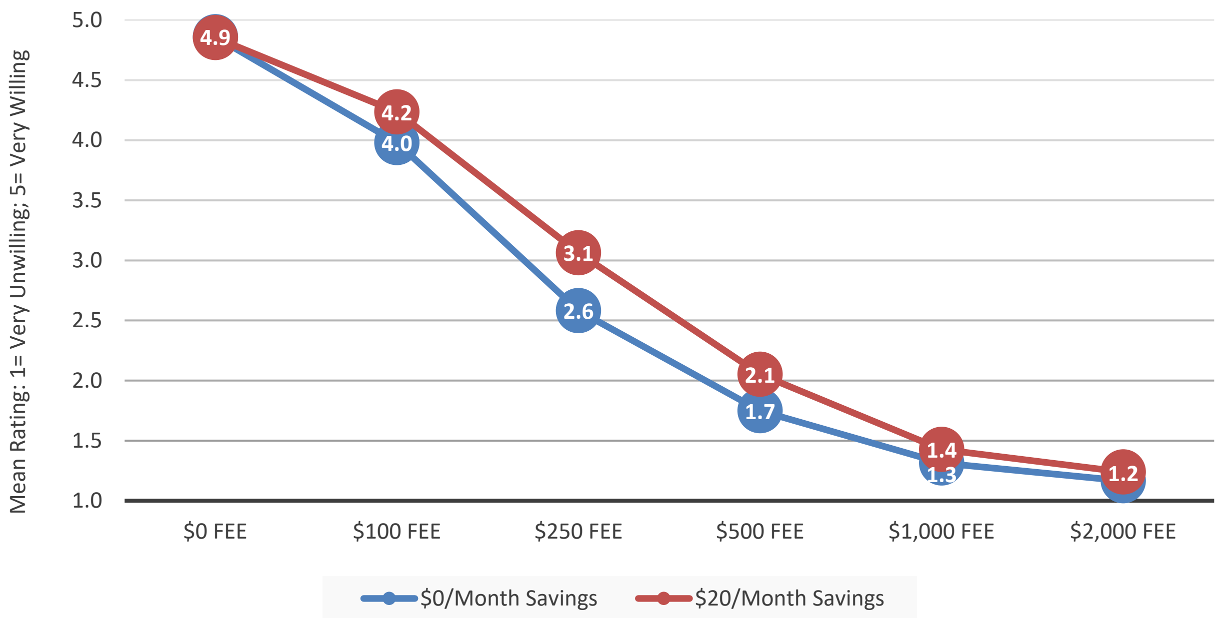
Figure 46: Importance of Aspects in Selecting Home Internet Service by Age of Respondent



4.2.1.8 Willingness to Pay Installation Fee for High-Speed Internet Service

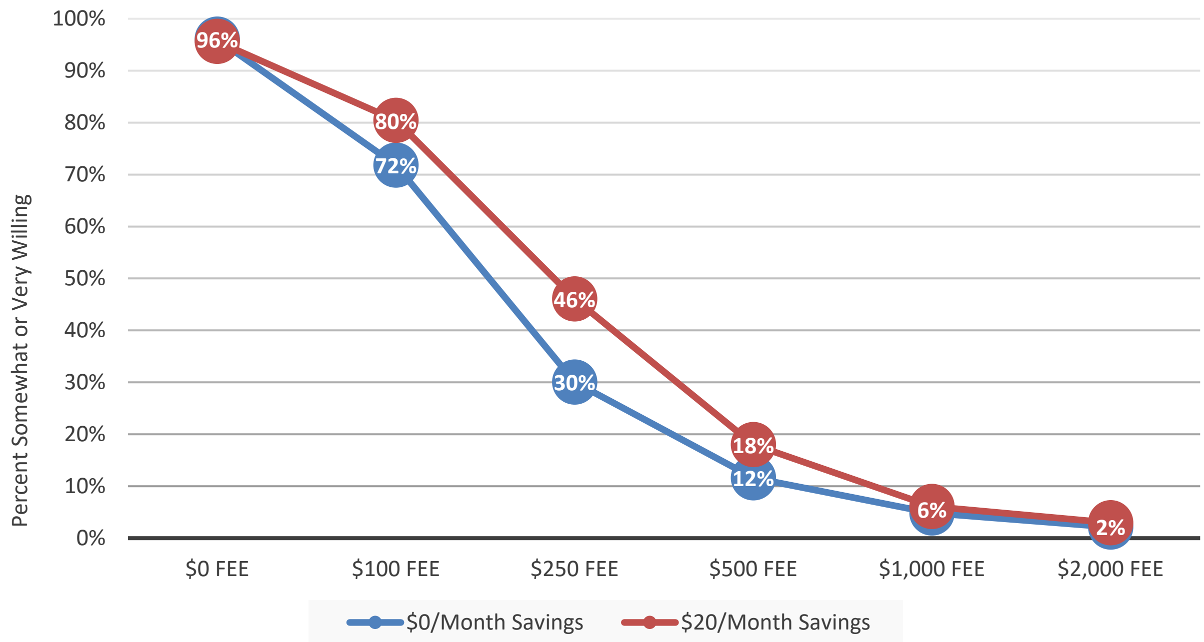
Respondents were asked if they would be willing to pay a one-time installation fee in exchange to having access to a high-speed internet connection, for either no savings per month or for $20 savings per month. Almost all respondents would be very willing to switch to the network for no installation fee (for $0 savings and for $20 savings), as would be expected. Additionally, they would be more willing to pay the fee for some savings on their monthly communications bill. Respondents are somewhat willing to pay a $100 installation fee, particularly for $20 per month savings, but willingness to pay an installation fee falls sharply at higher price points, as shown in Figure 47.

Figure 47: Willingness to Pay Installation Fee for High-Speed Internet Service (Mean Ratings)



Almost all respondents are somewhat or very willing to pay no fee to connect to the network. The majority would pay a $100 installation fee for no savings (72 percent) or a $20 savings per month (80 percent). Approximately 46 percent would be at least somewhat willing to pay a $250 installation fee for a $20 per month savings, but this falls to 30 percent if there were no monthly savings on their bill, as illustrated in Figure 48.

Figure 48: Willingness to Pay Installation Fee for High-Speed Internet Service



Only slight differences in the willingness to pay an installation fee by area of residence were found, as illustrated in Figure 49 and Figure 50. Residents of Area D are somewhat more likely to pay an installation fee at higher price points, compared with residents of other areas, particularly for $20 per month savings.

Figure 49: Willingness to Pay Installation Fee by Area of Residence

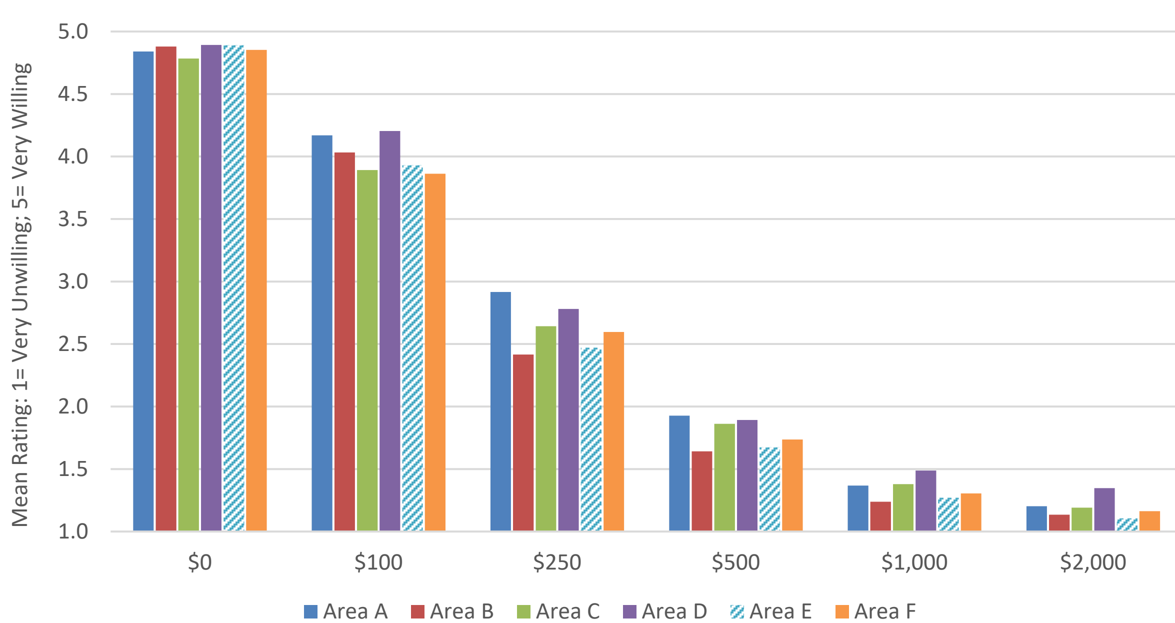
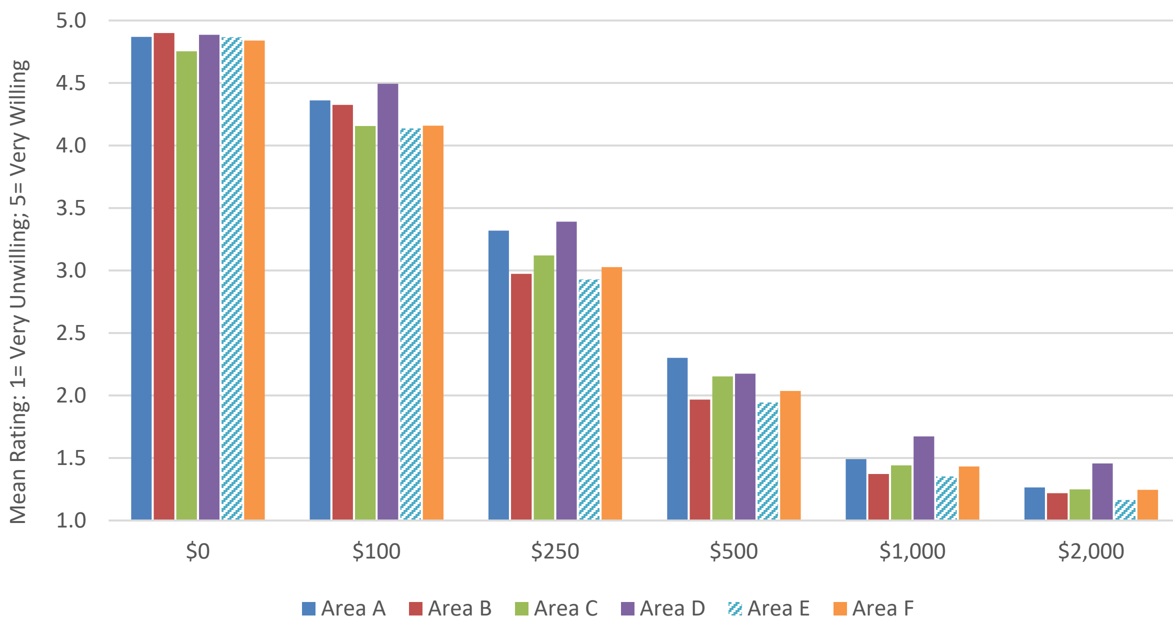


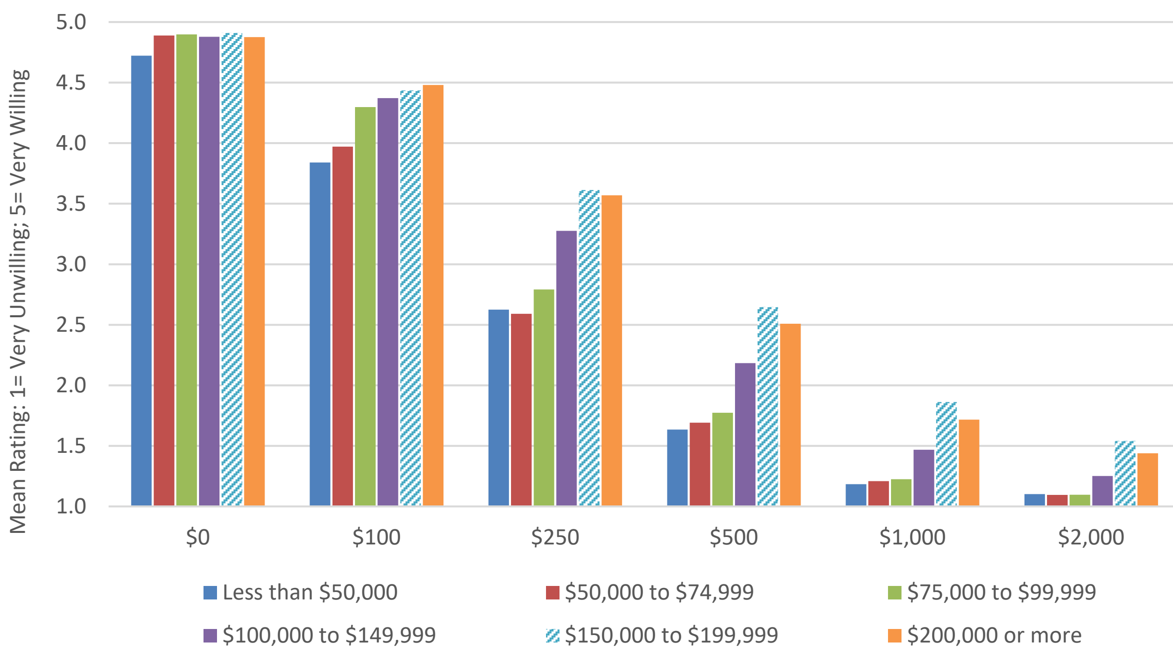
Figure 50: Willingness to Pay Installation Fee for $20/Month Savings by Area of Residence



For most price points, the willingness to pay an installation fee (for either no monthly savings or for a $20 per month savings) is correlated with household income (see Figure 51 and Figure 52). In particular, those earning $150,000 or more per year would be more likely than lower income households to pay an installation fee in exchange for high-speed internet.

Figure 51: Willingness to Pay Installation Fee by Household Income

Figure 52: Willingness to Pay Installation Fee for $20/Month Savings by Income



4.2.2 Television and Telephone Service

Respondents were asked to evaluate the importance of television programming features. The most important television programming aspects are local programming and news programming, while the least important is children's programming, as illustrated in Figure 53 and Figure 54.

Figure 53: Importance of Television Programming Features

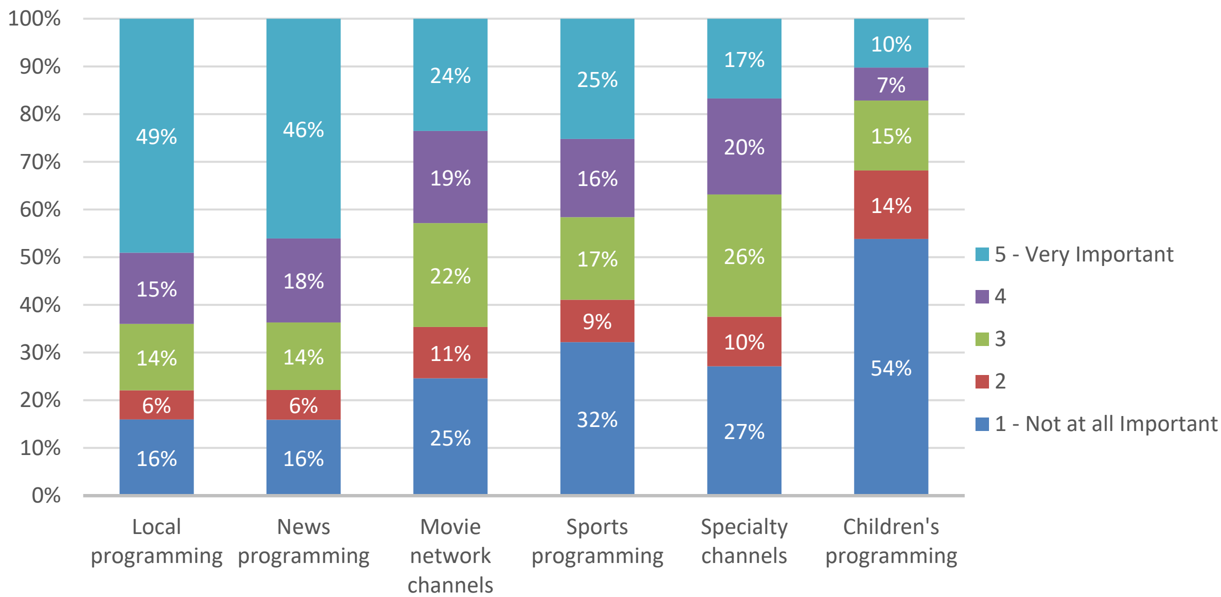
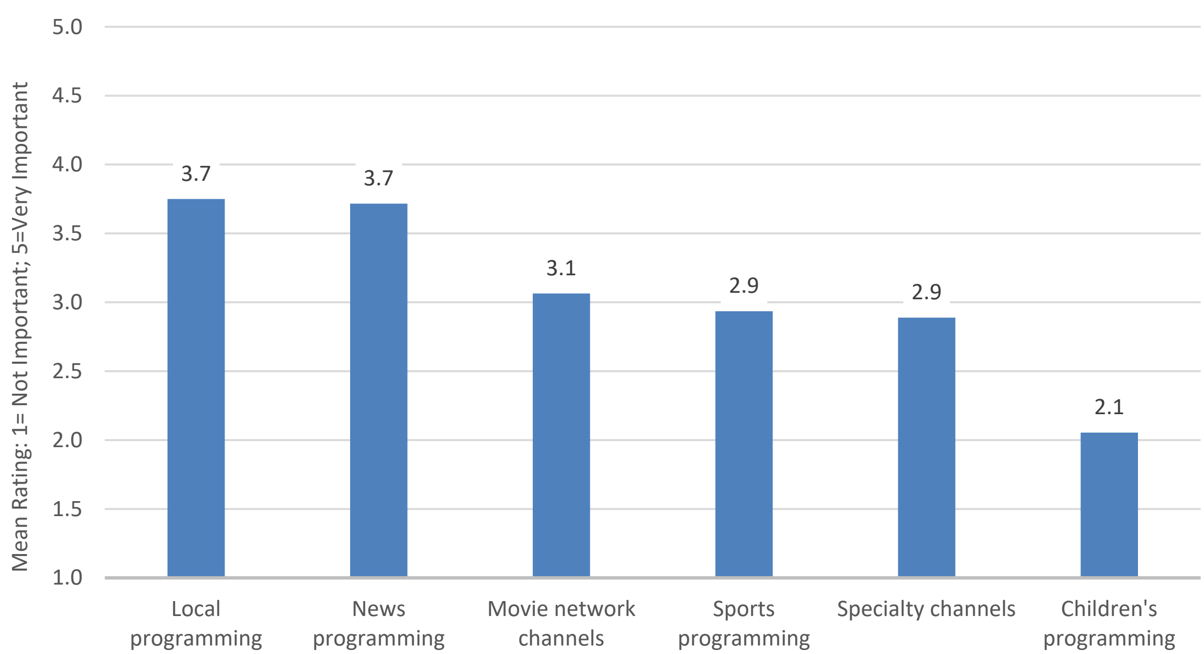
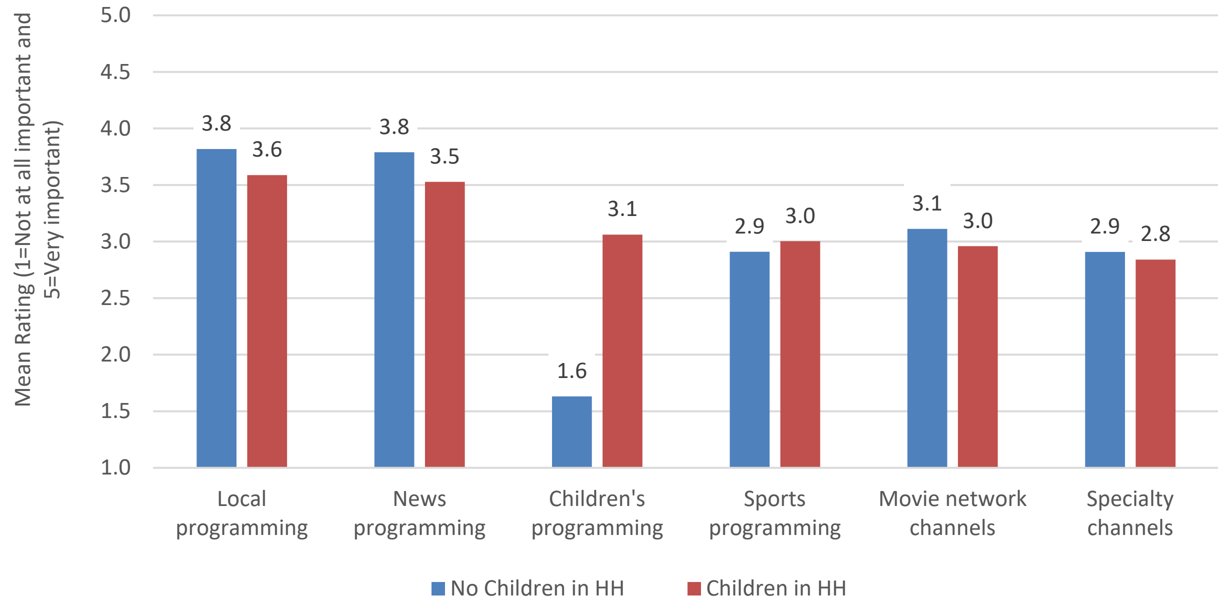


Figure 54: Importance of Television Programming Features (Mean Ratings)



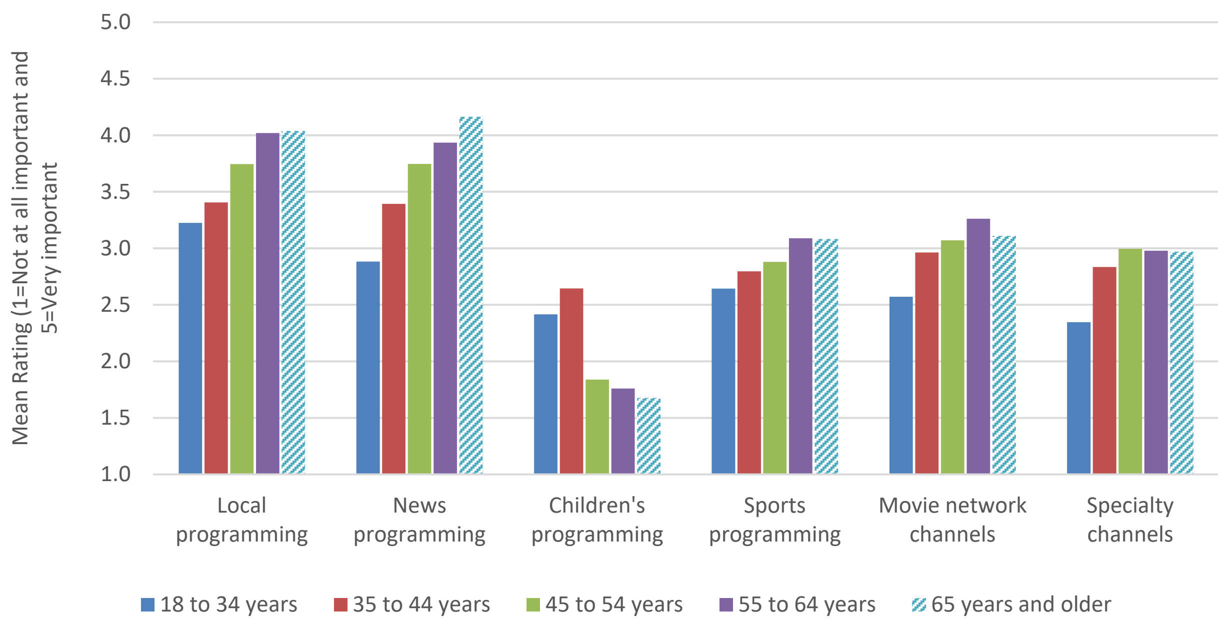
However, those with children in the household placed significantly more importance on children's programming, as shown in Figure 55.

Figure 55: Importance of Television Programming Aspects by Children in Household



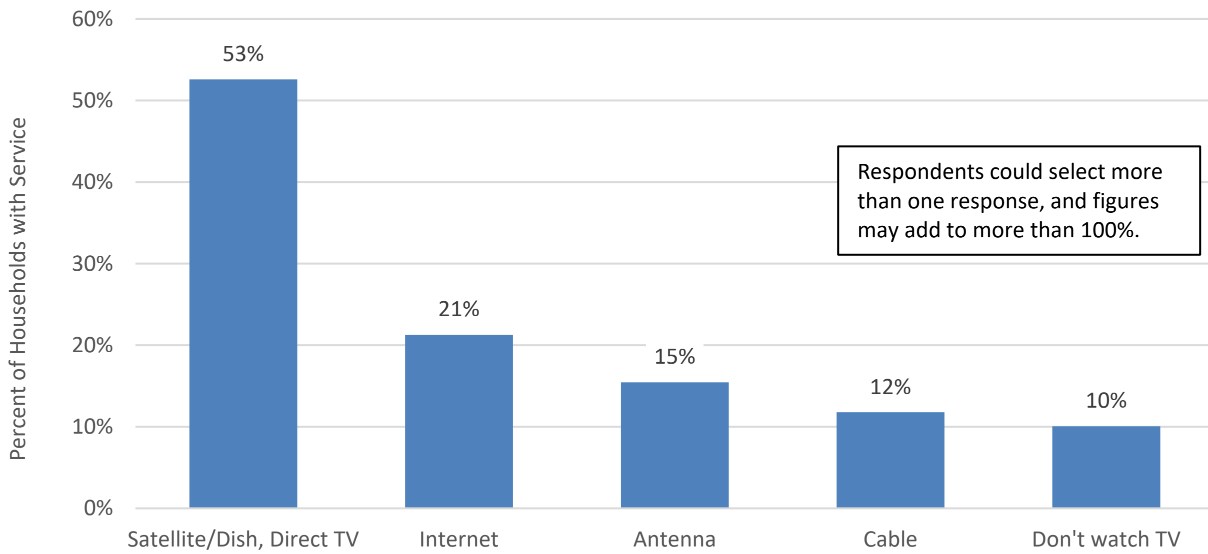
Additionally, the importance placed on most types of programming is lower for those ages 18 to 34, compared with older respondents, with the exception of children's programming (please see Figure 56).

Figure 56: Importance of Television Programming Aspects by Age of Respondent



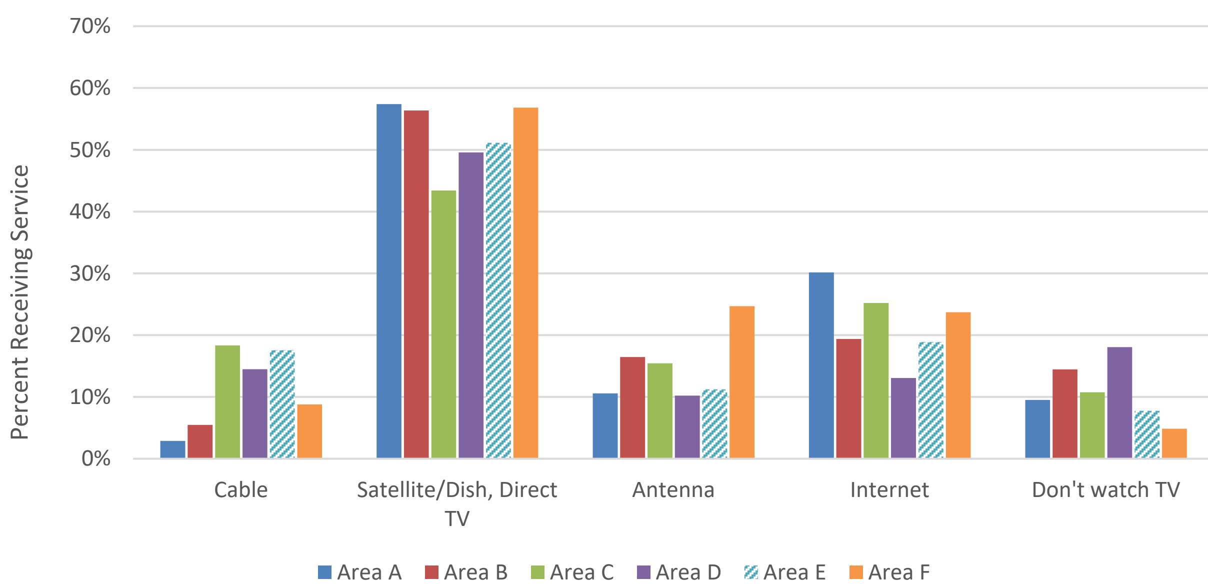
More than one-half of respondents purchase satellite television service. Market share is much lower for internet-based, antenna (over-the-air), or cable television. One in 10 respondents do not watch television (see Figure 57).

Figure 57: Types of Television Service in Home



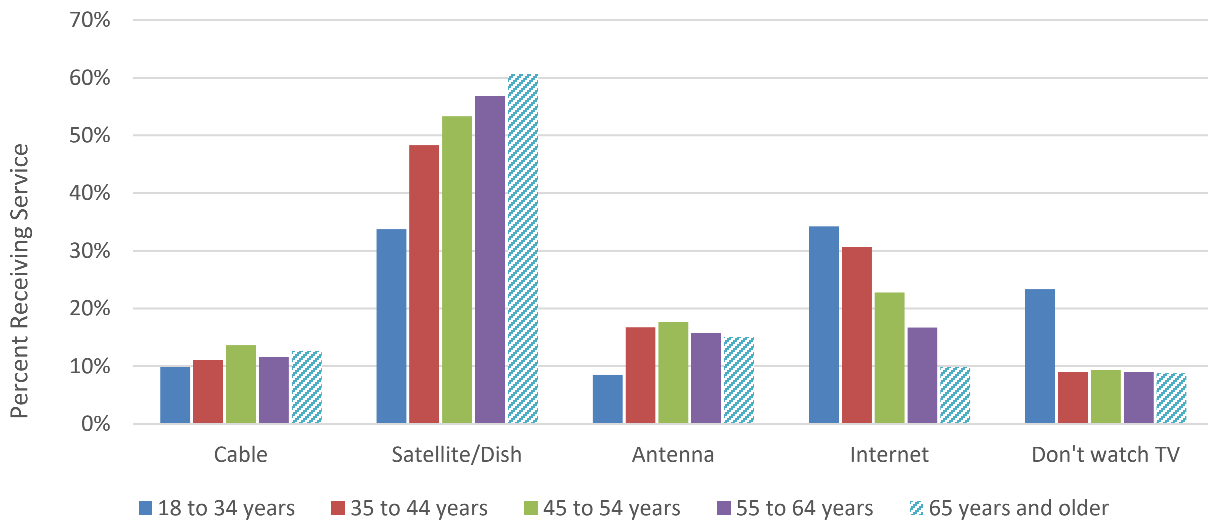
Satellite is the leading television service across all areas but has a somewhat higher market share in Areas A, B, and F. Area F residents are more likely to have over-the-air service compared with residents of other areas. Internet-based television is highest in Area A, with three in 10 households subscribing. Nearly one-fifth of residents of Area D do not watch television (see Figure 58).

Figure 58: Types of Television Service in Home by Area of Residence



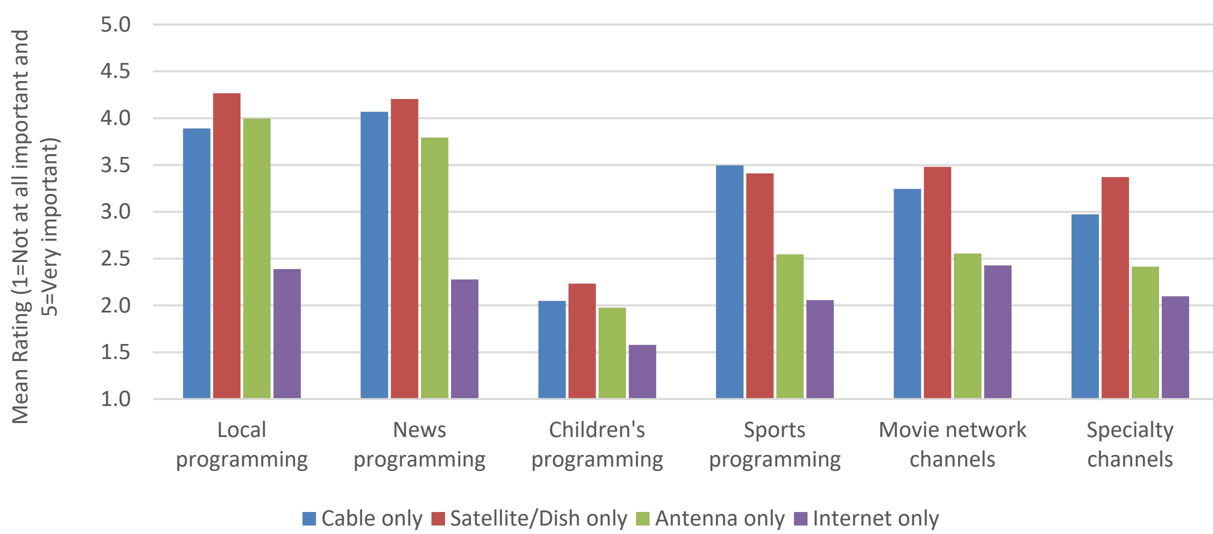
Subscription to television services varies significantly by age of respondent. Specifically, the use of internet television decreases as age of respondent increases, while the use of satellite increases with age. Nearly one-fourth of respondents age 18 to 34 do not watch television (see Figure 59).

Figure 59: Types of Television Service in Home by Age of Respondent



Additionally, one in 10 respondents (and 26 percent of those under age 35) exclusively use internet-based television service. Two-thirds of internet-only users are under age 45. In comparison, roughly three in 10 cable and satellite TV subscribers are under age 45. Internet-only users place less value on various types of programming content, as might be expected (see Figure 60).

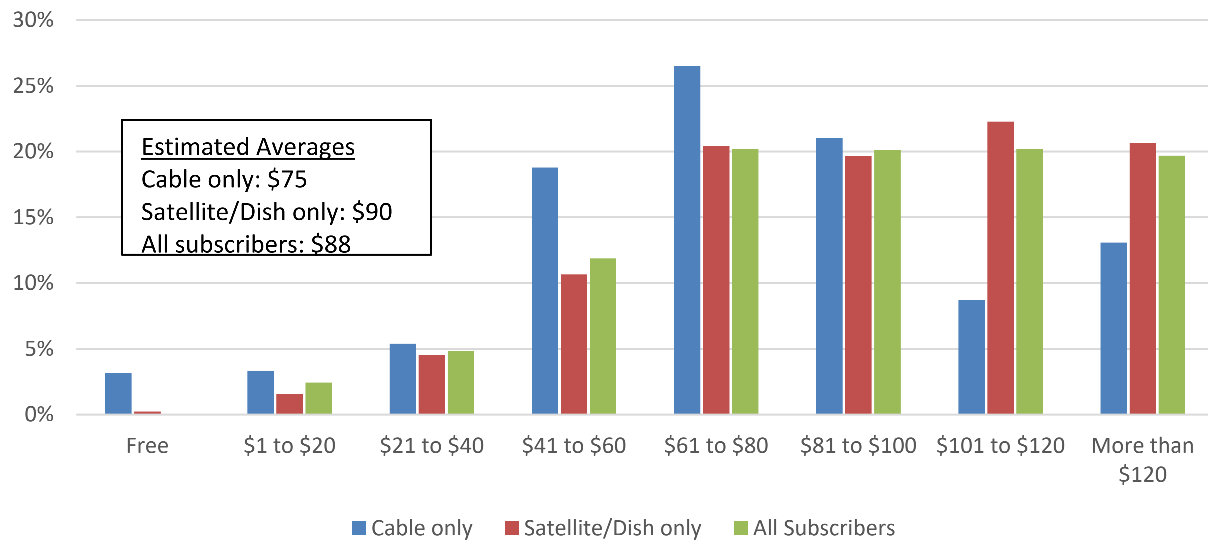
Figure 60: Importance of Television Programming Aspects by Television Service



The estimated average monthly price for cable or satellite television service is $88, with four in

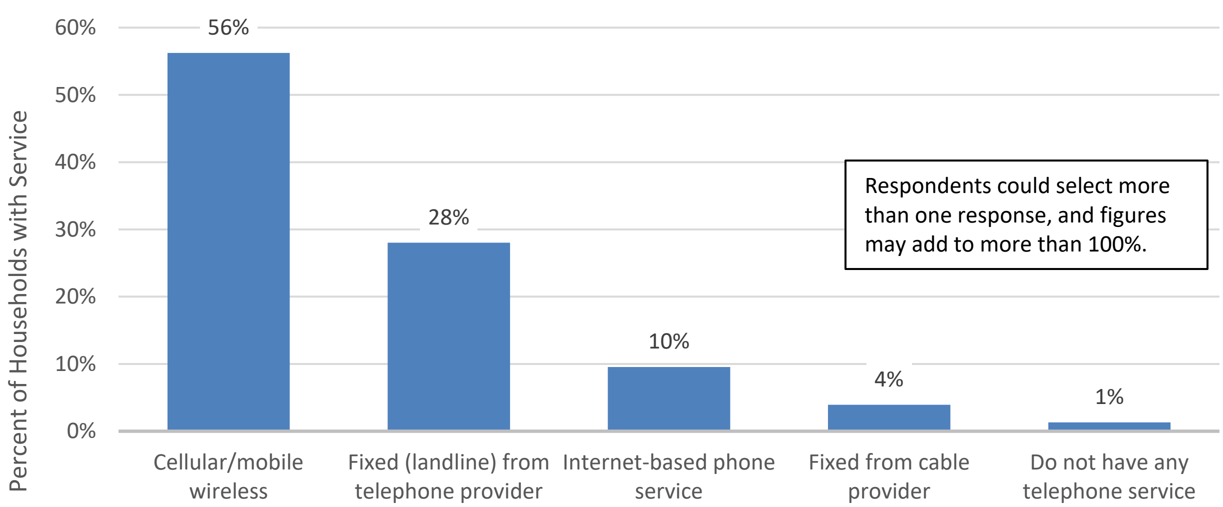
10 respondents paying over $100 per month, as illustrated in Figure 61. The estimated cost per month is higher for satellite television compared with cable television.

Figure 61: Monthly Price of Cable or Satellite TV Service



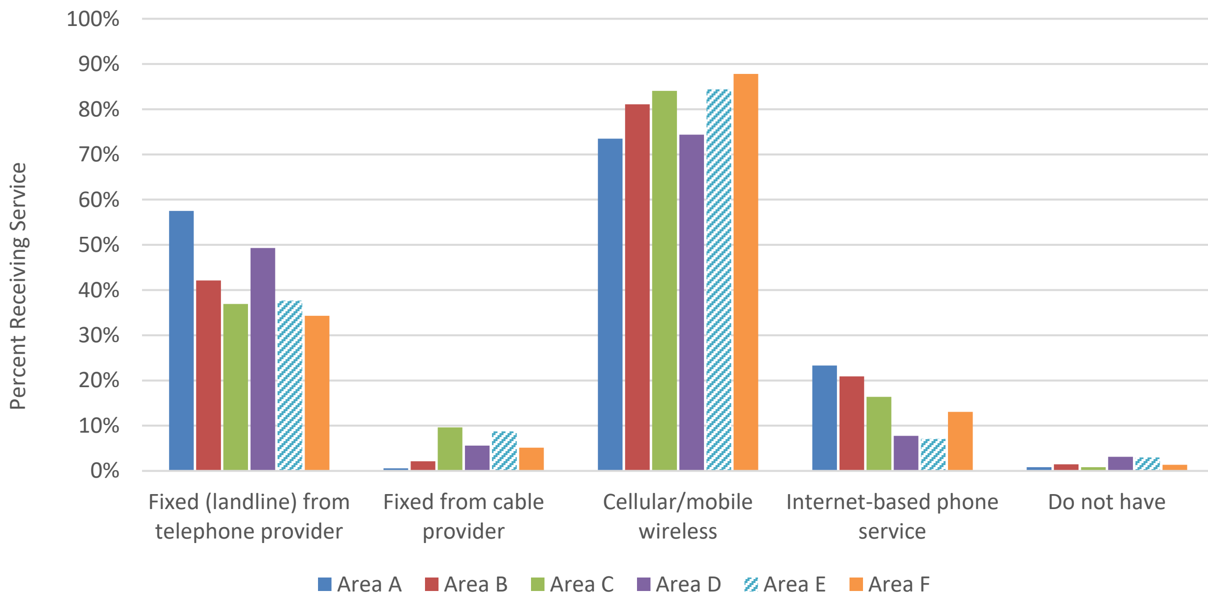
Respondents were asked about their home and mobile telephone services. As illustrated in Figure 62, 56 percent of respondents have a cellular/mobile telephone. About one-third of respondents have a landline, including 28 percent from a traditional telephone provider and four percent from a cable provider. One in 10 have internet-based telephone service.

Figure 62: Home Telephone Service(s)



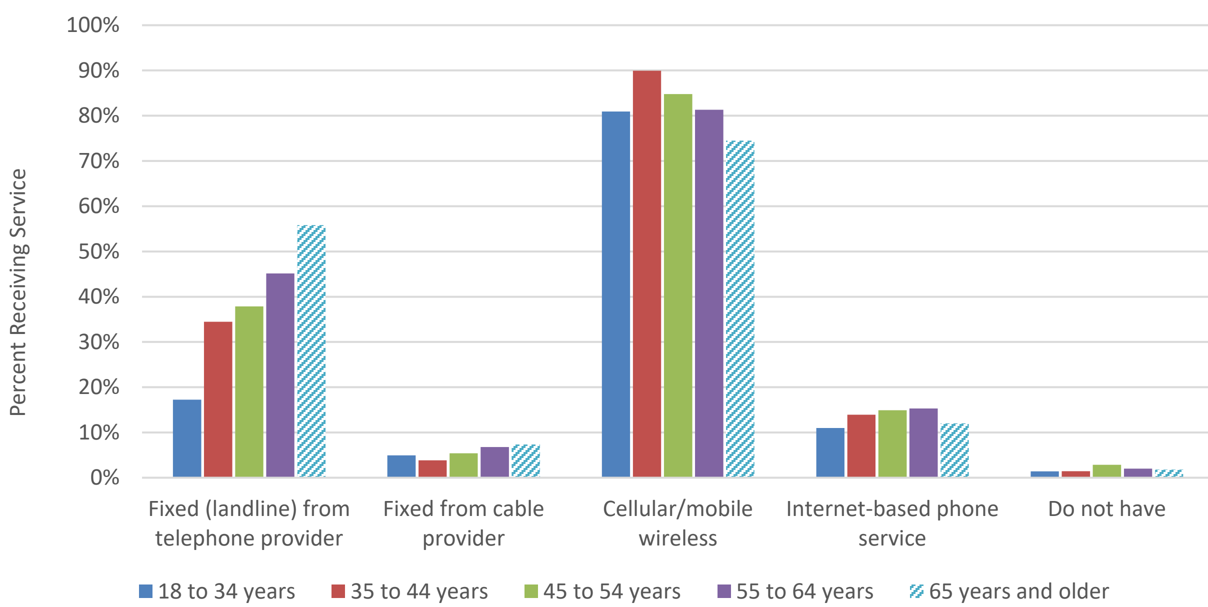
The use of cellular/mobile wireless service is somewhat lower in Areas A and D, while the use of landline service from a telephone provider is somewhat higher in these areas (see Figure 63).

Figure 63: Home Telephone Service(s) by Area of Residence



As illustrated in Figure 64, use of landline telephone service tends to increase as the age of the respondent increases, while use of cellular/mobile wireless telephone tends to decrease with age.

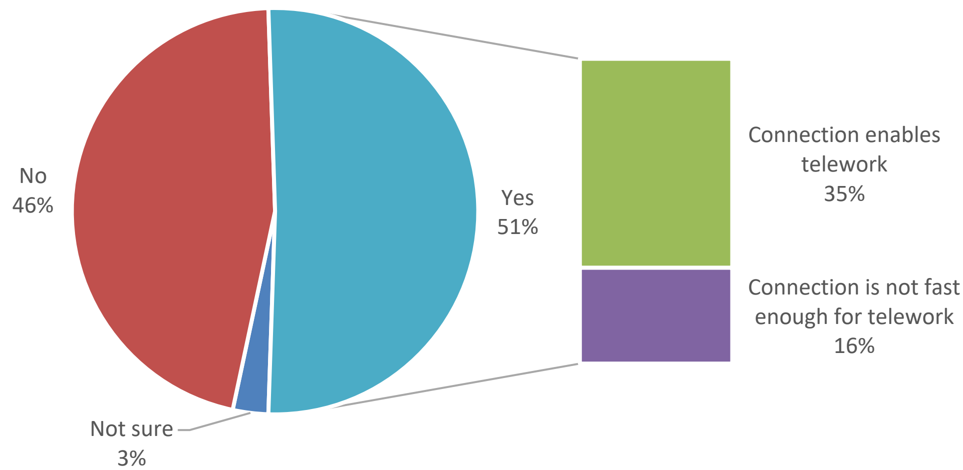
Figure 64: Home Telephone Service(s) by Age of Respondent



4.2.3 Internet Use for Jobs/Careers/Education

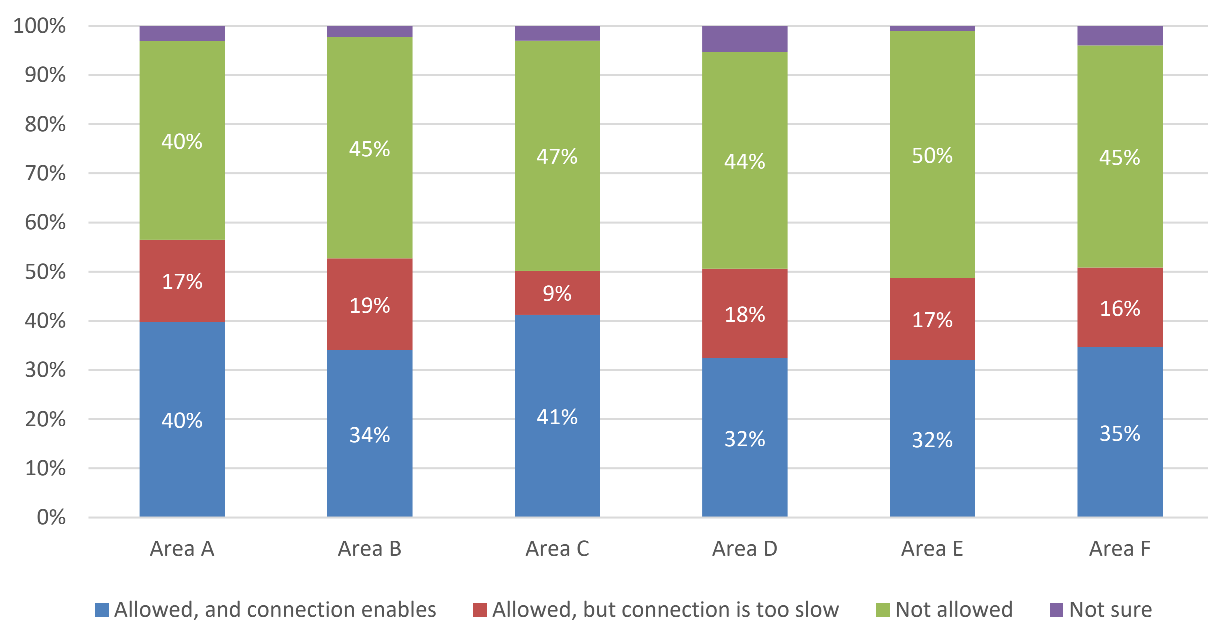
One-half of respondents indicated that a member of their family is allowed by their employer to telework, including 35 percent who said their internet connection enables telework. Another 16 percent said their internet connection was not fast enough to allow telework (see Figure 65).

Figure 65: Employer Allows Teleworking



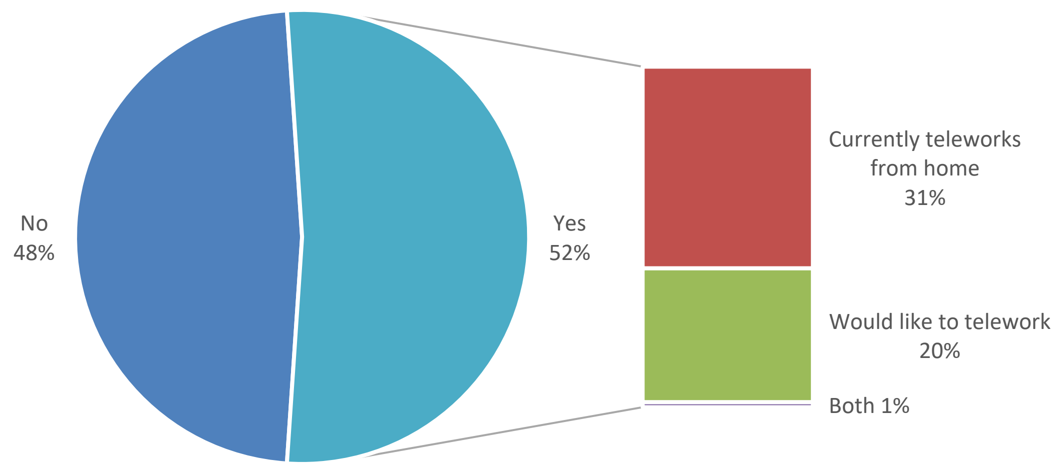
The proportion of respondents who are allowed to telework and who have a fast-enough internet connection is slightly higher in Areas A and C, as shown in Figure 66.

Figure 66: Employer Allows Teleworking by Area of Residence



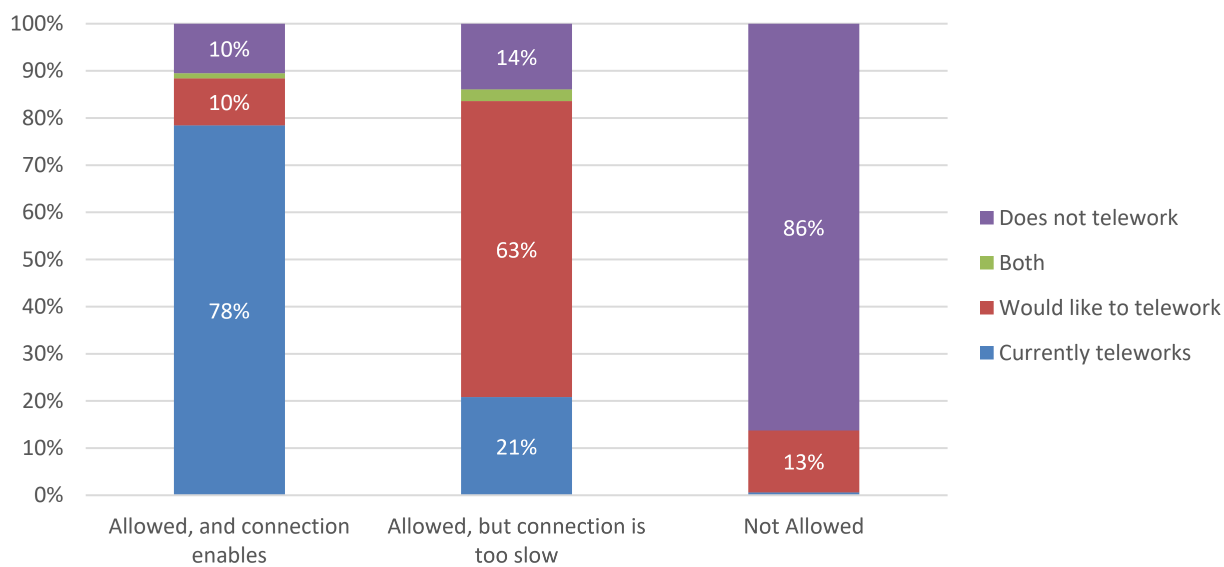
As shown in Figure 67, approximately 31 percent of respondents indicated that someone in their family already teleworks from home and another 20 percent would like to telework.

Figure 67: Household Member Teleworking Status



Three-fourths (78 percent) of household members who are allowed to telework and who have a fast-enough home internet connection do indeed telework from home. Additionally, 63 percent of those who are allowed to telework but have a slow connection indicated that someone in their household would like to telework (see Figure 68). This indicates that a substantial additional share may telework if feasible, allowed by their employer, and if their connection were fast enough to enable telework.

Figure 68: Teleworking Status by Ability to Telework



Those under age 55 and those with a higher estimated household income are more likely to have a household member who teleworks or would like to telework, as shown in Figure 69 and Figure 70.

Figure 69: Teleworking Status by Age of Respondent

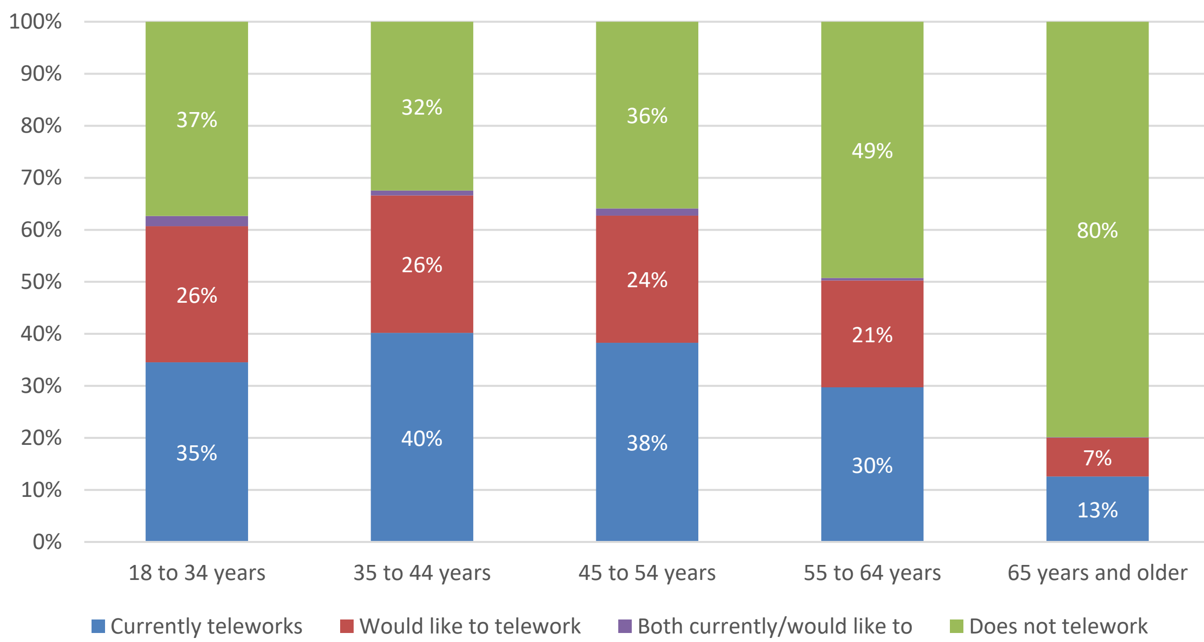
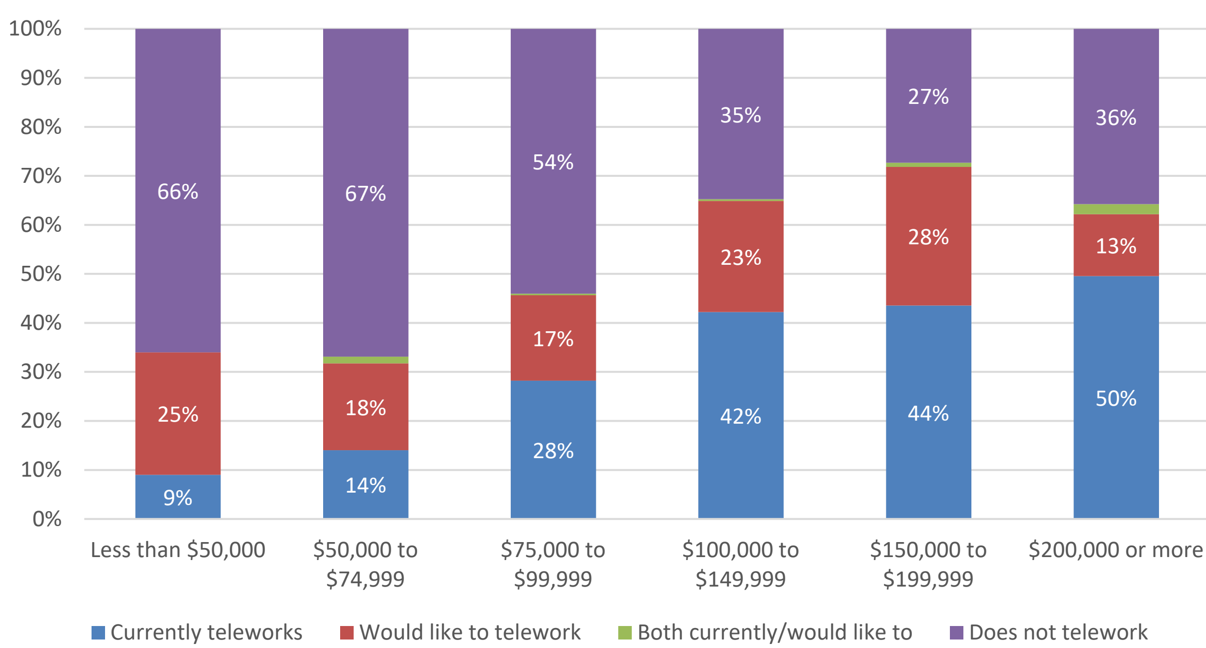


Figure 70: Teleworking Status by Household Income



One-third of respondents have a home-based business, and another 11 percent are planning to start one within the next three years, as illustrated in Figure 71. Of those who operate or are planning to start a home-based business, 75 percent indicated that a high-speed internet connection is (or would be) very important to this business, and 18 percent said it would be somewhat important (see Figure 72).

Figure 71: Own or Plan to Start a Home-Based Business

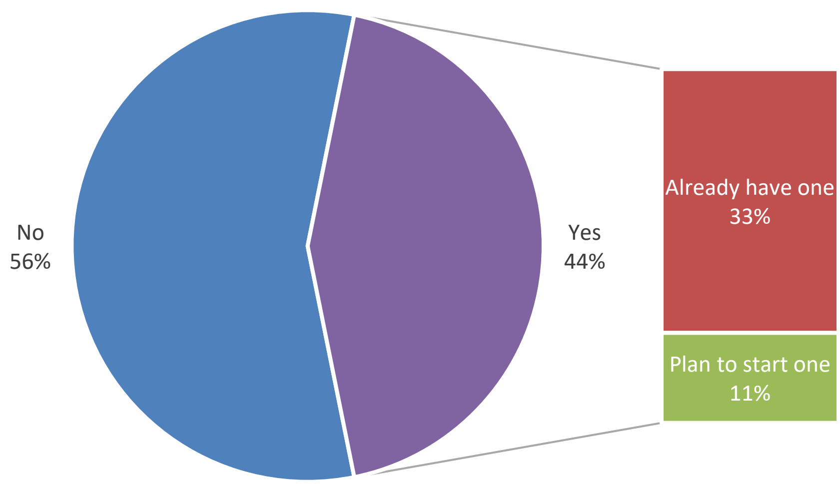
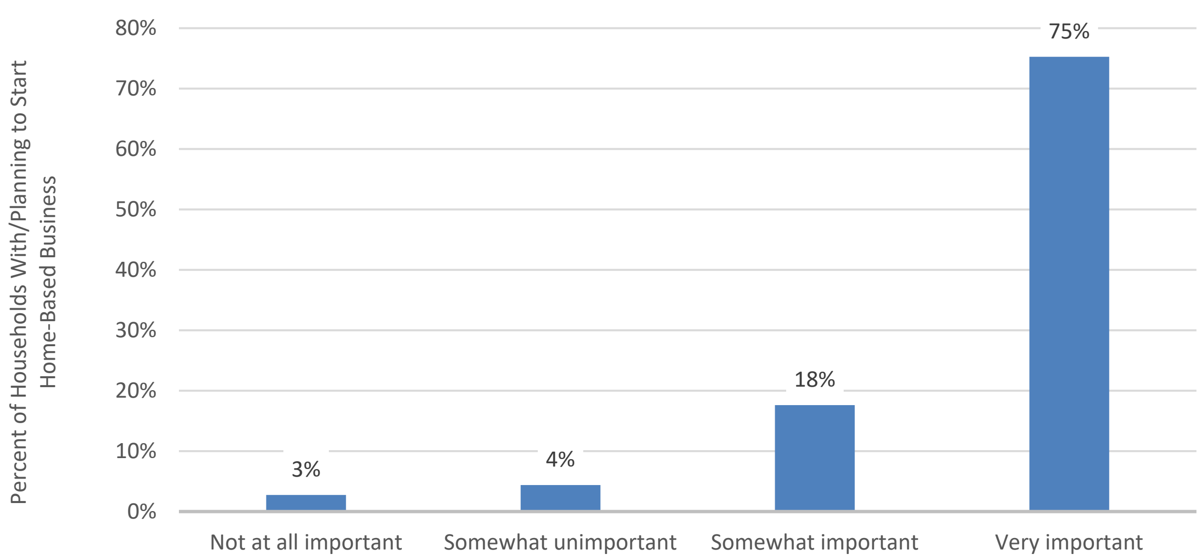
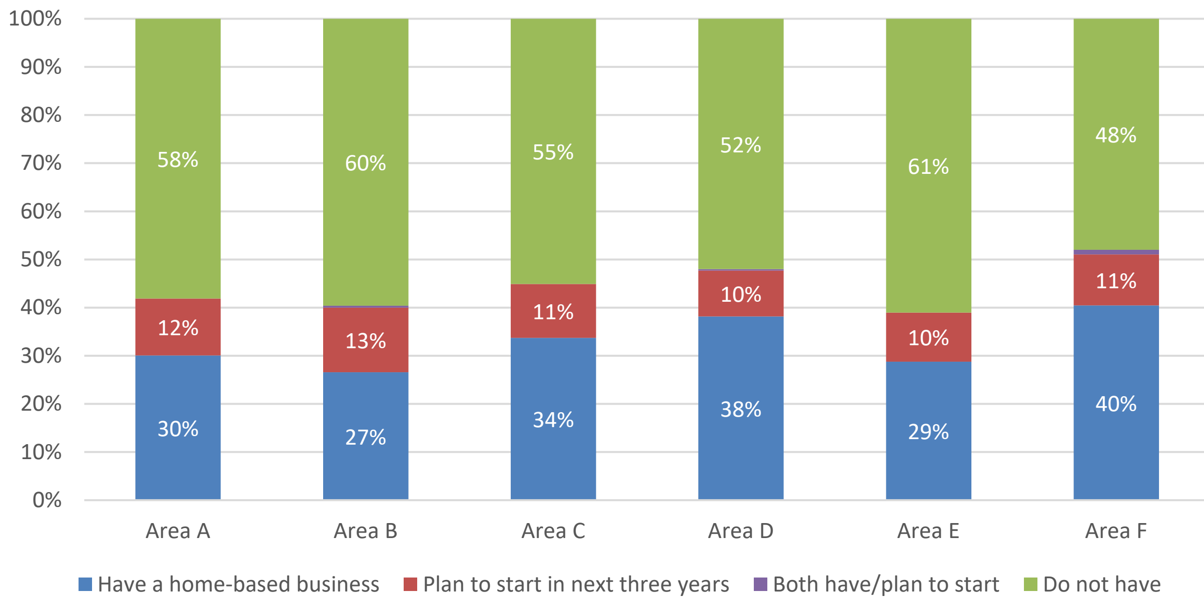


Figure 72: Importance of High-Speed Internet to Existing or Potential Home-Based Business



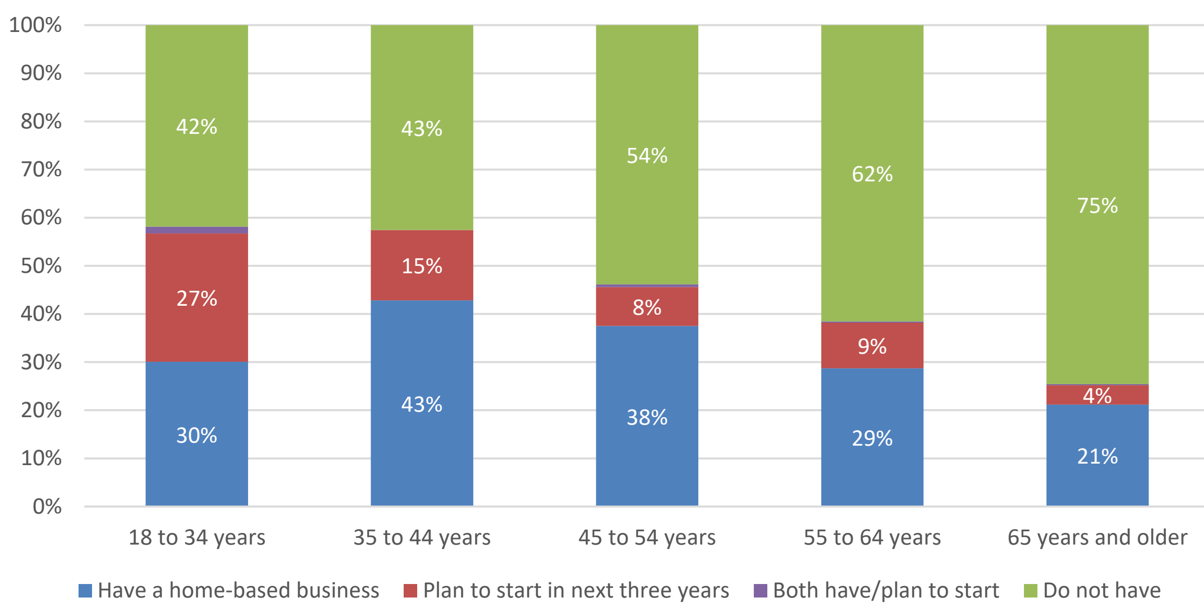
Slight differences in saturation of home-based business by area of residence were found. As shown in Figure 73, Area D and Area F residents are among the most likely to either have or plan to start a home-based business in the next three years.

Figure 73: Own or Plan to Start a Home-Based Business by Area of Residence



As might be expected, the likelihood of having or planning to start a home-based business tends to decline as age increases (see Figure 74). Those ages 35 to 44 are more likely than others to already have a home-based business, while those ages 18 to 34 are more likely to plan to start a home-based business in the next three years.

Figure 74: Own or Plan to Start a Home-Based Business by Age of Respondent



In addition, respondents were asked if they or a household member use an internet connection for educational purposes, such as completing assignments, research, or study related to coursework or formal education. Overall, 58 percent reported using the internet for educational reasons (compared with approximately eight in 10 who earlier reported using the internet at least occasionally to access education resources). Residents of Area A and Area D are somewhat less likely to use the internet for educational purposes (see Figure 75).

Figure 75: Use of Internet for Educational Purposes by Area of Residence

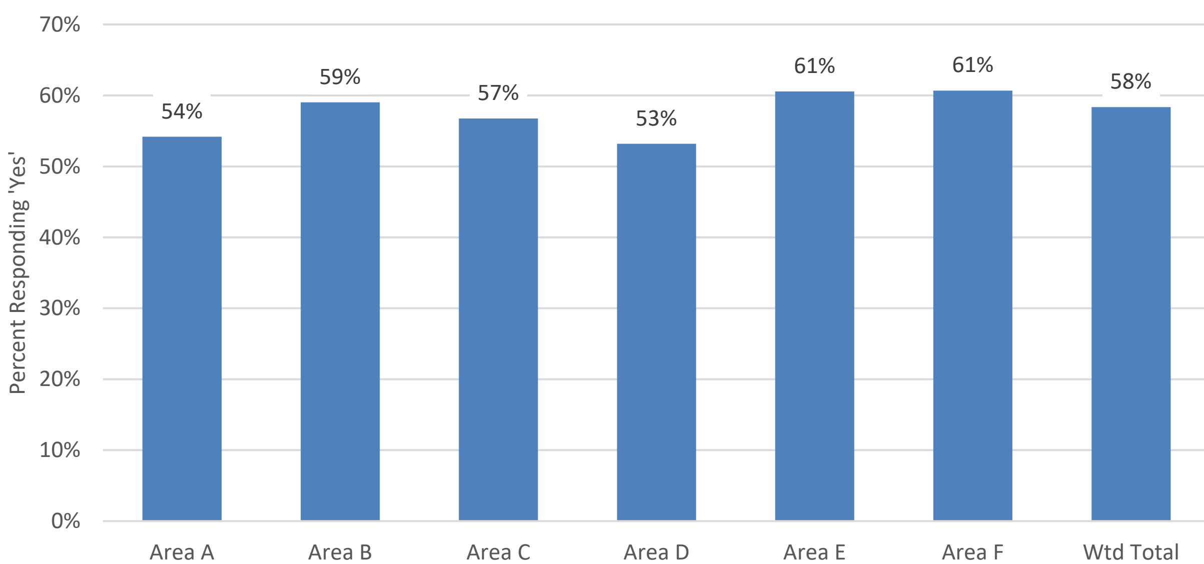
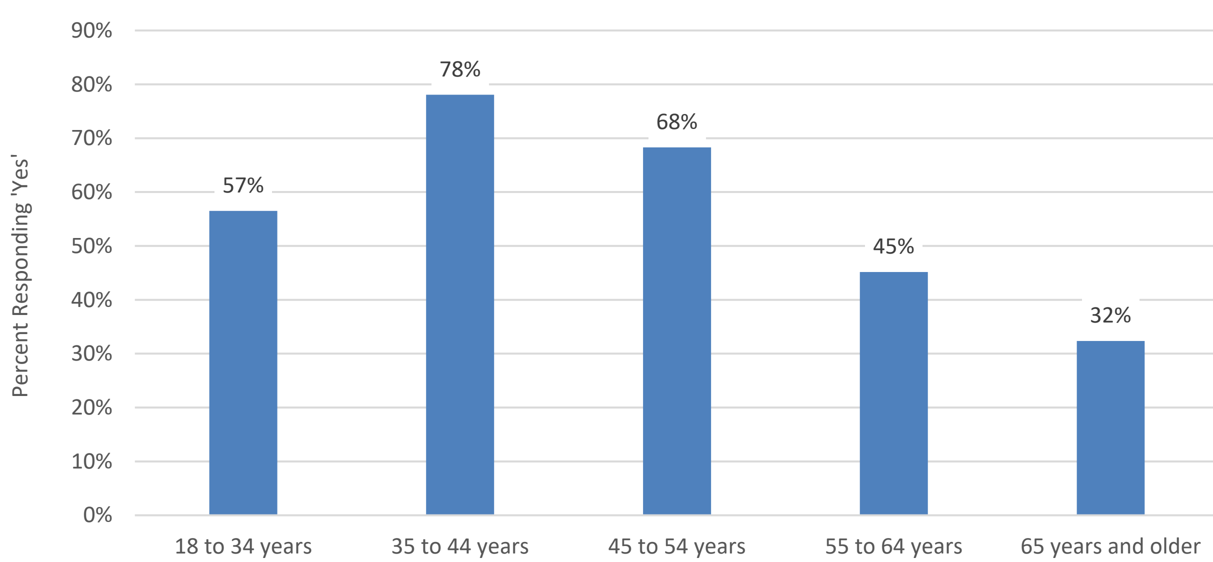


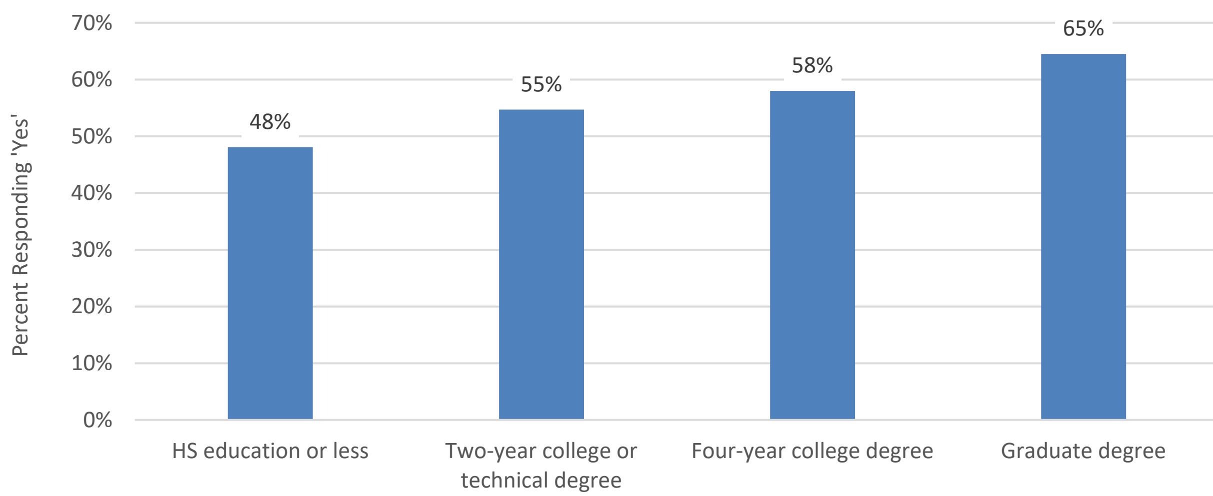
Figure 76: Use of Internet for Educational Purposes by Age of Respondent



Respondents ages 35 to 44 are more likely than older and young respondents to have a household member who uses the internet for educational purposes (see Figure 76); they are also more likely to have children age 18 and under in the household. (Two-thirds of respondents ages 35 to 44 have children in the household.) Approximately 84 percent of those with children in the household use the internet for educational purposes, compared with 45 percent of those without children in the home.

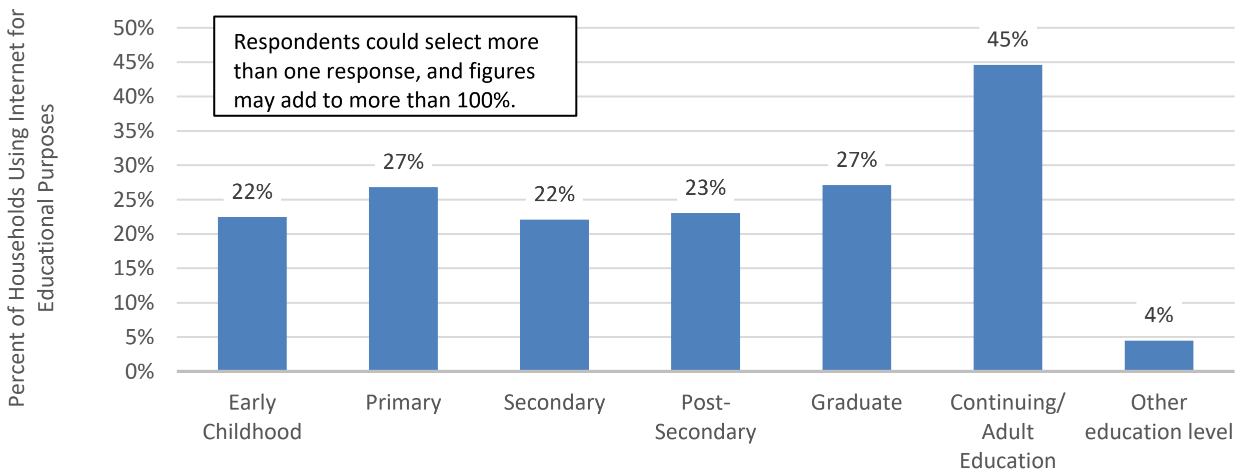
Additionally, use of the internet for educational purposes is also correlated with level of education completed. About one-half of those with a high school education or less use the internet for educational purposes, compared with roughly two-thirds of those with a graduate degree (see Figure 77).

Figure 77: Use of Internet for Educational Purposes by Education Completed



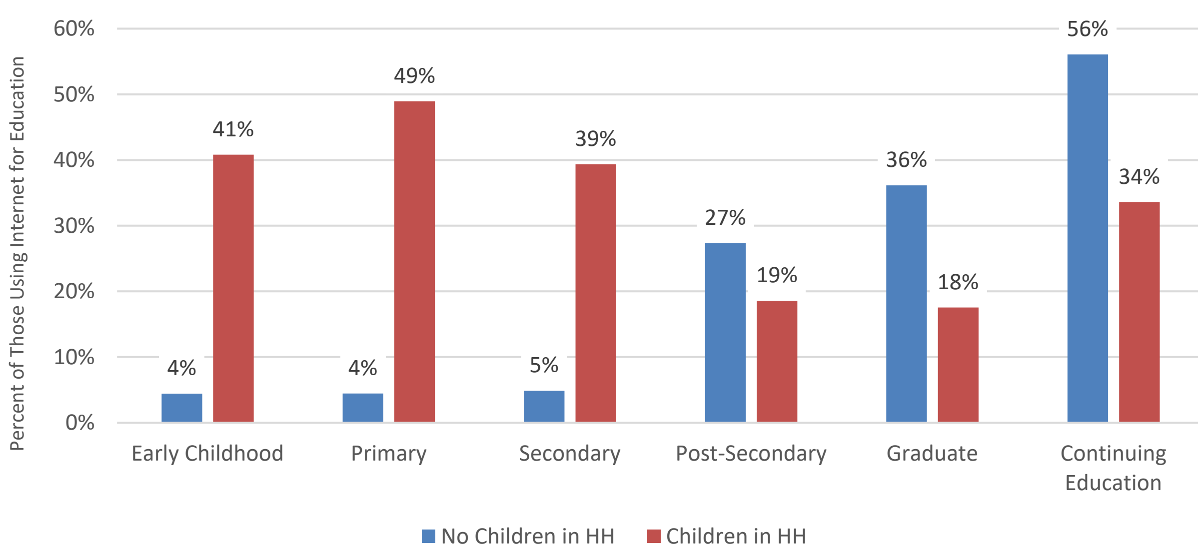
Among those who use the internet for educational purposes, 45 percent indicated it is used for continuing and adult education, while fewer use it for other education levels (see Figure 78).

Figure 78: Education Level for Which Internet Connection Is Used



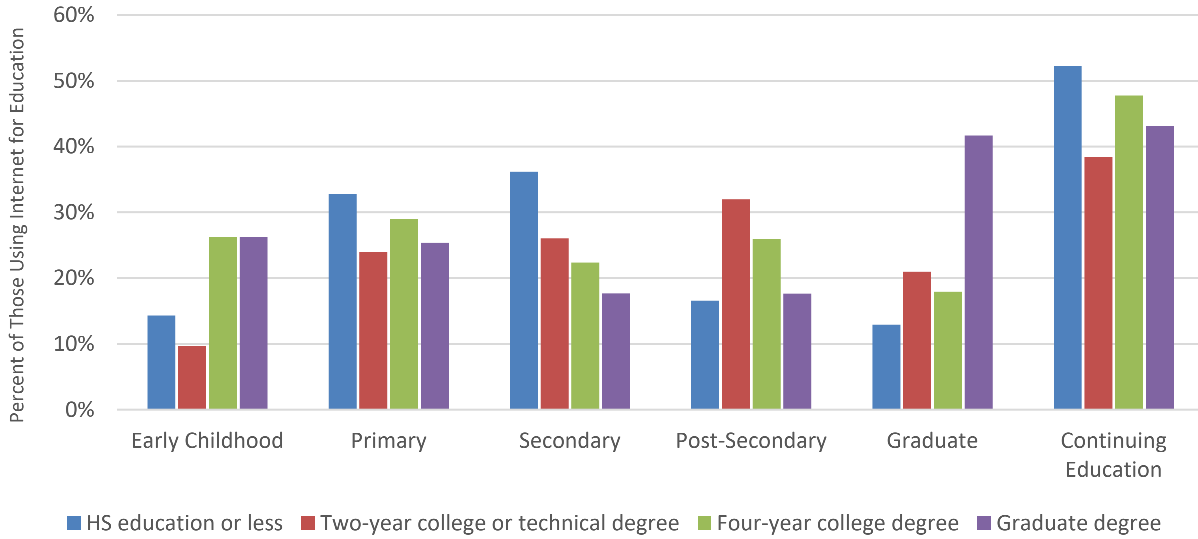
Use of the internet for educational purposes is related to presence of children in the household, as might be expected, particularly for early childhood, primary, and secondary education needs. Those without children in the household are more likely to use the internet for post-graduate, graduate, or continuing education (see Figure 79).

Figure 79: Education Level for Which Internet Connection Is Used by Children in Household



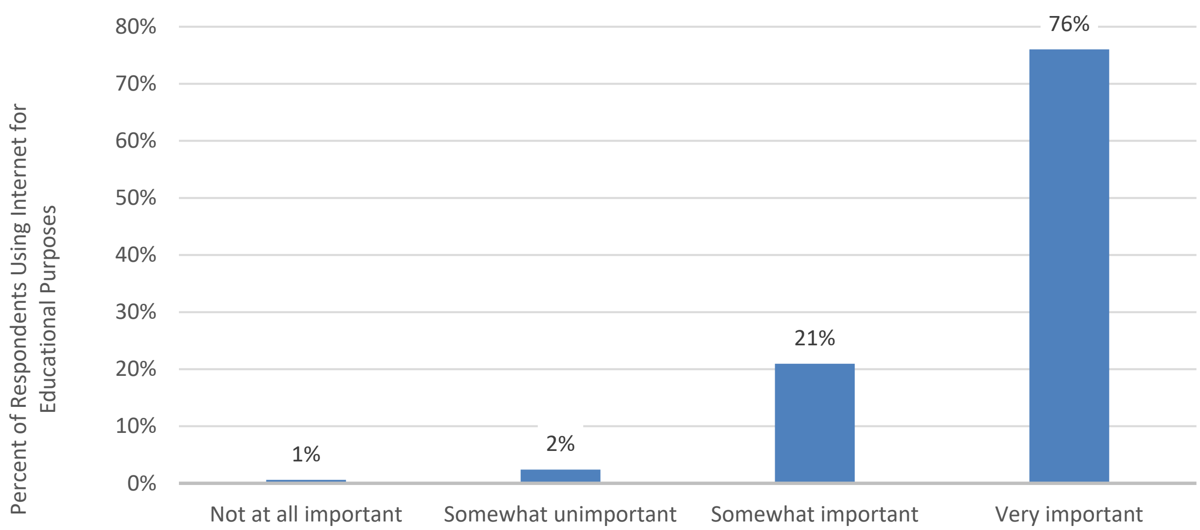
The education level for which an internet connection is used is also correlated with the education level completed by respondents, which is intuitive. For example, those with a graduate degree are more likely than others to use the internet for graduate level educational purposes (see Figure 80).

Figure 80: Education Level for Which Internet Connection Is Used by Education Completed



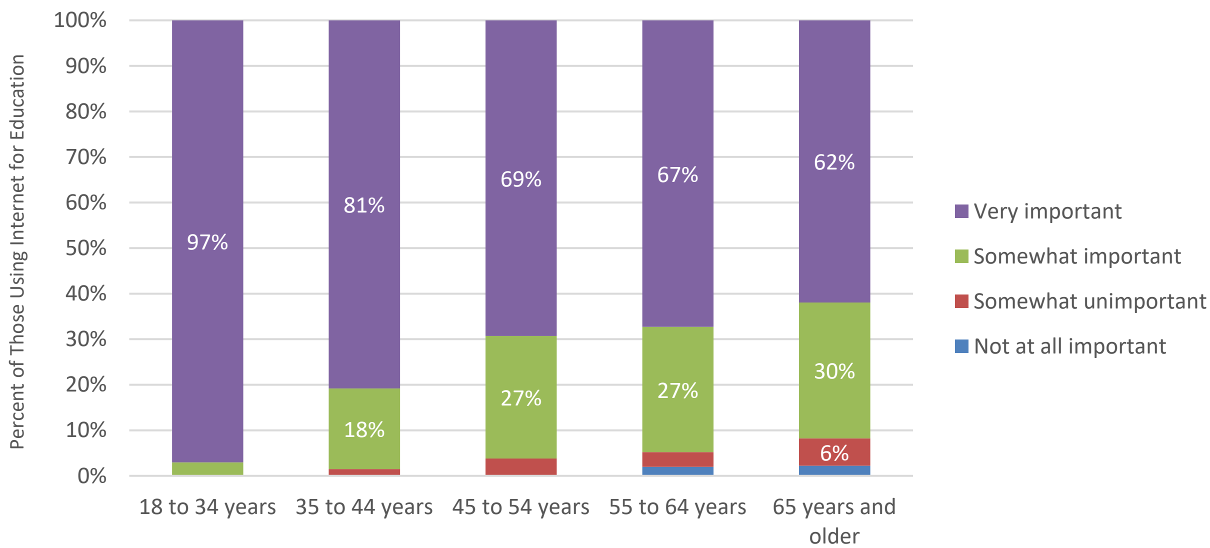
Among those who use the internet for educational purposes, three-fourths said that a high-speed internet connection is very important. Another one-fifth said it is somewhat important for their education needs (see Figure 81).

Figure 81: Importance of High-Speed Internet for Education Needs



The importance placed on high-speed internet for educational needs tends to decline as age increases, as indicated in Figure 82. Nearly all (97 percent) of those ages 18 to 34 who use the internet for educational purposes said a high-speed connection is very important, compared with 62 percent of those 65 years and older.

Figure 82: Importance of High-Speed Internet for Education Needs by Age of Respondent



4.2.4 Respondents' Perception of Larimer County's Role

Respondents were asked their opinions about Larimer County's role in providing or promoting broadband communications services within the area. The most favorable opinions were for the County to help ensure that all residents, students, and teachers have access to competitively-priced broadband services, with over one-half strongly agreeing. There is less agreement that the County should build a publicly-financed network (to either offer services to the public OR for private sector companies to offer network services); more than one-third of respondents strongly agreed with these statements. Figure 83 illustrates the mean ratings, while Figure 84 provides detailed responses to each portion of the question.

Figure 83: Opinions About the Role(s) for Larimer County (Mean Ratings)

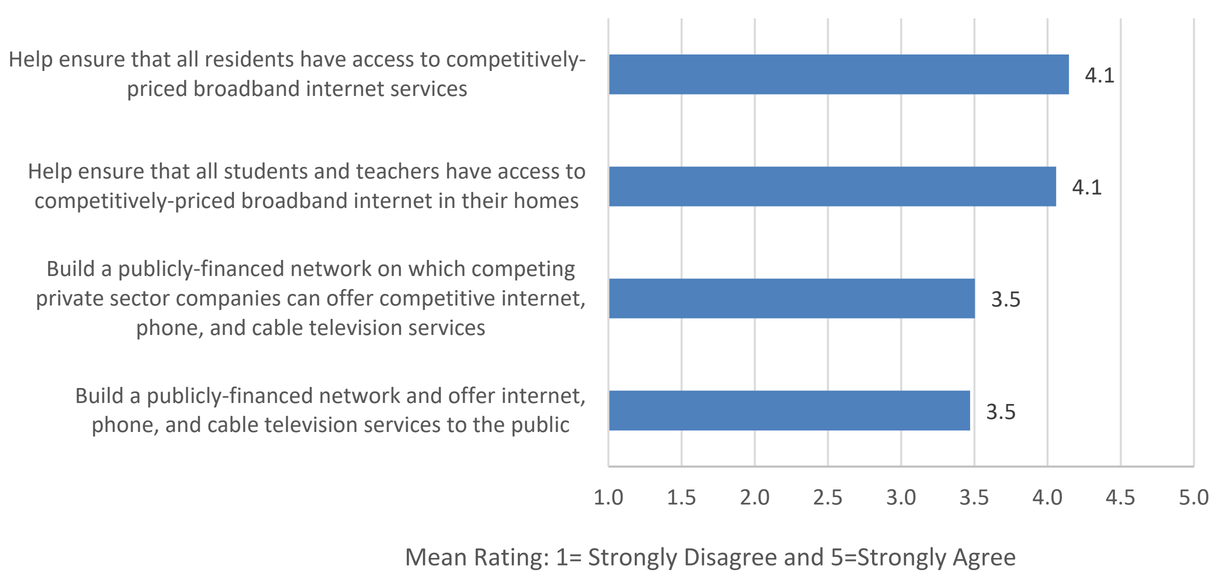
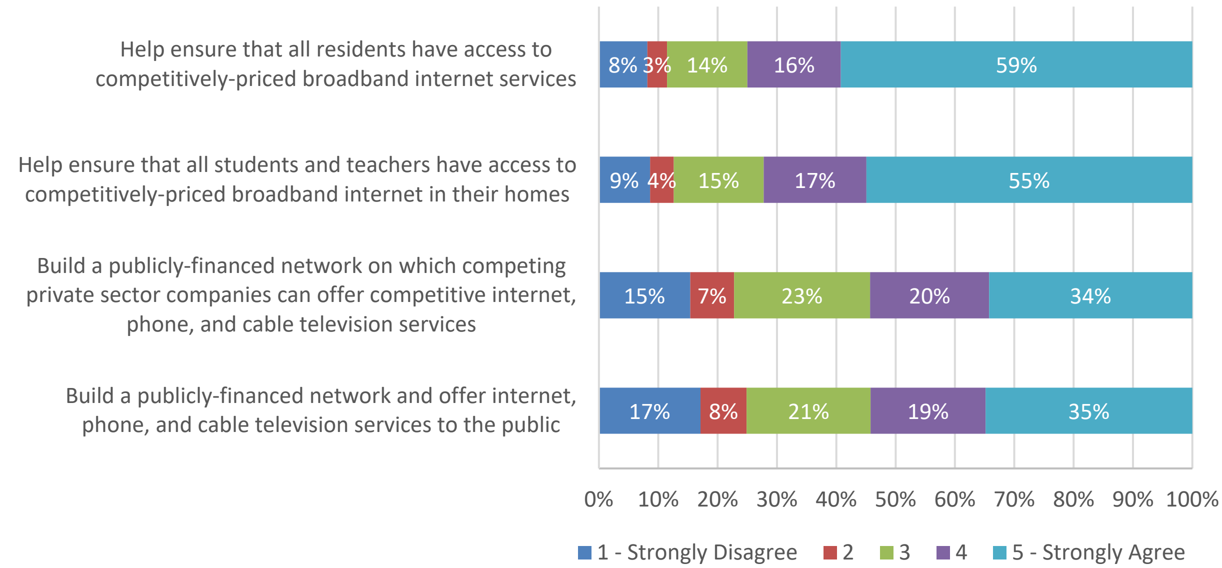


Figure 84: Opinions About the Role(s) for Larimer County



Younger respondents and newer residents showed greater support for the County's role in providing or promoting broadband internet service, as illustrated in Figure 85 and Figure 86.

Figure 85: Opinions About the Role(s) for Larimer County by Age of Respondent

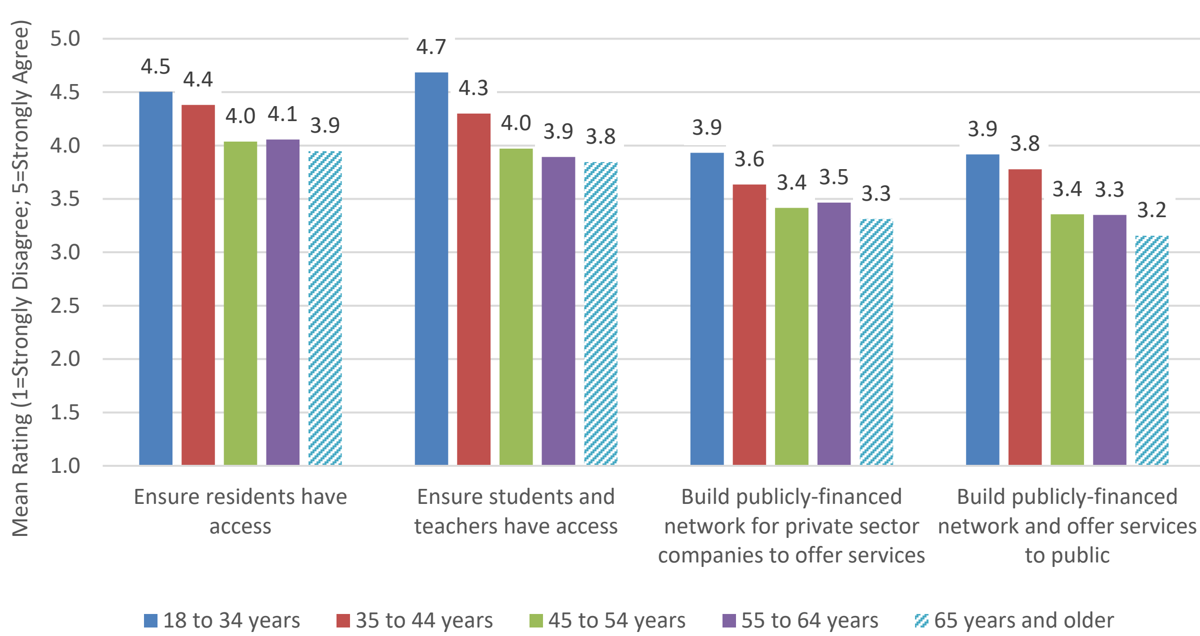
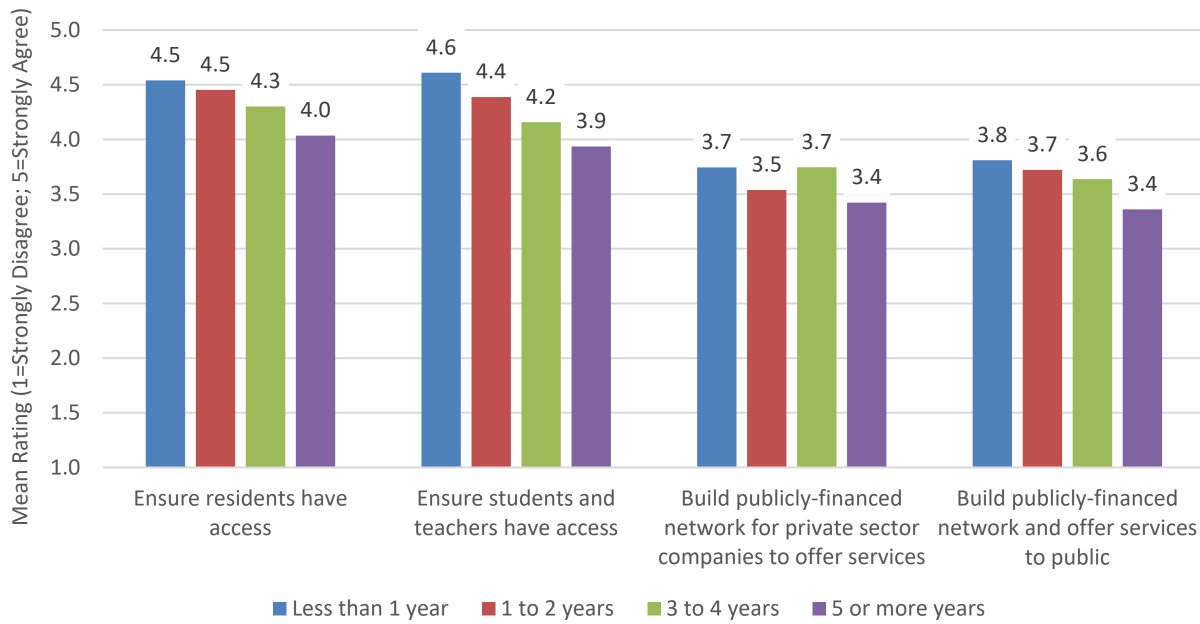


Figure 86: Opinions About the Role(s) for Larimer County by Length of Residence



Respondents were also asked their opinion of the current broadband market. More than one-half somewhat or strongly agreed that high-speed internet is an essential service, and four in ten agreed that availability is a factor in deciding where to live. Three in 10 somewhat or strongly agreed that the market currently provides high-speed internet at prices they can afford (see Figure 87). Overall agreement about the broadband internet market is moderate, as shown in Figure 88.

Figure 87: Opinions About the Broadband Internet Market

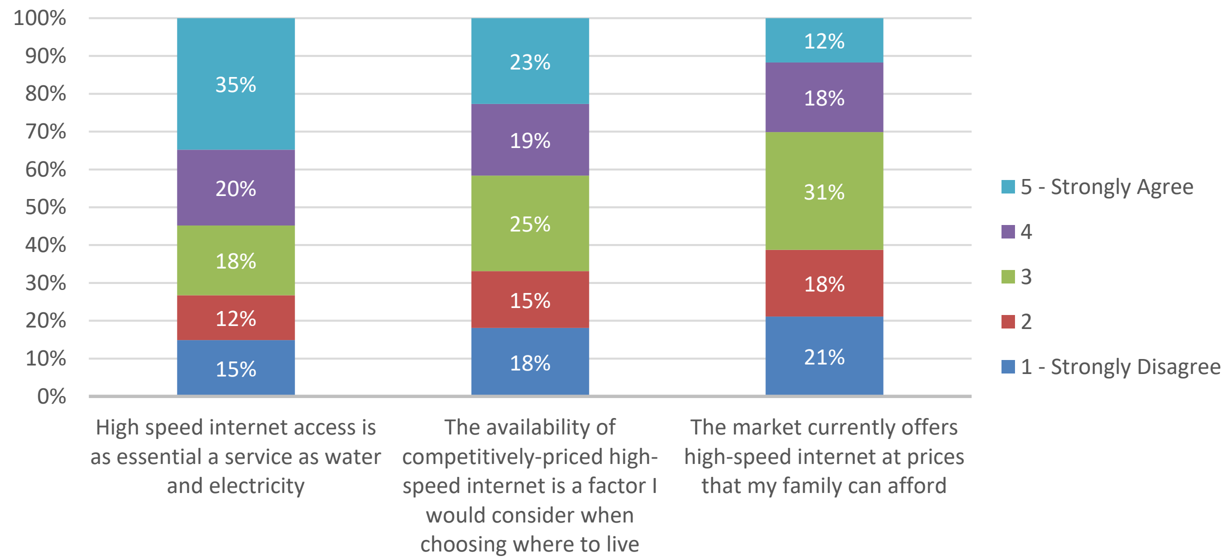
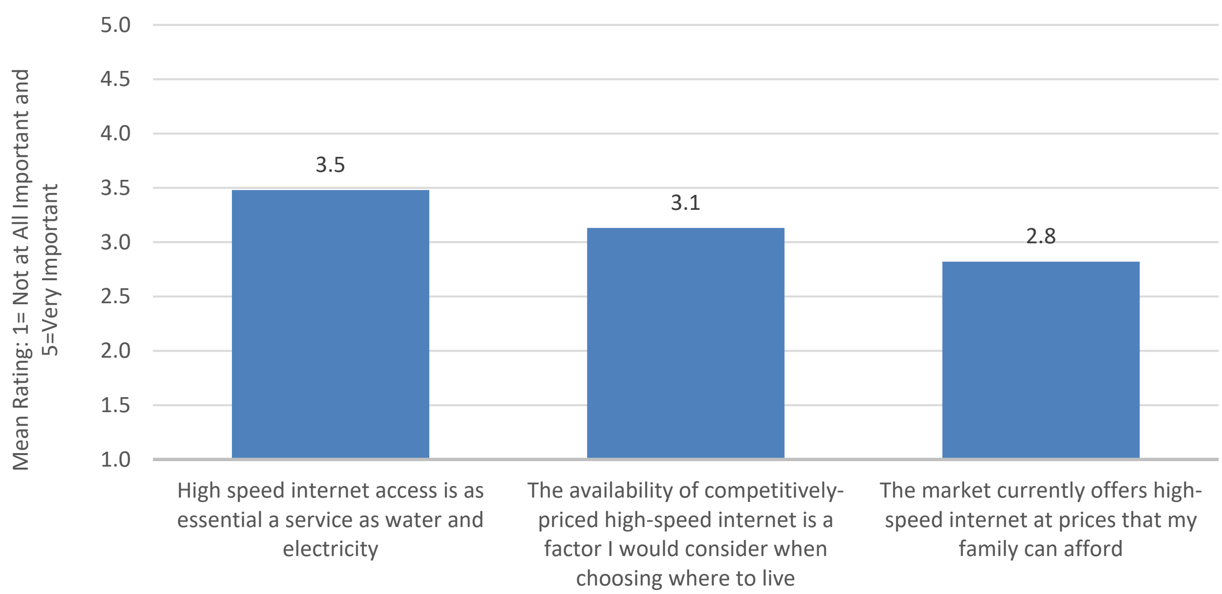


Figure 88: Opinions About the Broadband Internet Market (Mean Ratings)



Respondents ages 65 years and older are less likely than younger respondents to perceive high speed internet access as an essential service or to agree that availability of high-speed internet is a factor when deciding where to live (see Figure 89). Similarly, agreement with these statements declines somewhat as length of residence increases, as shown in Figure 90.

Figure 89: Opinions About the Broadband Internet Market by Age of Respondent

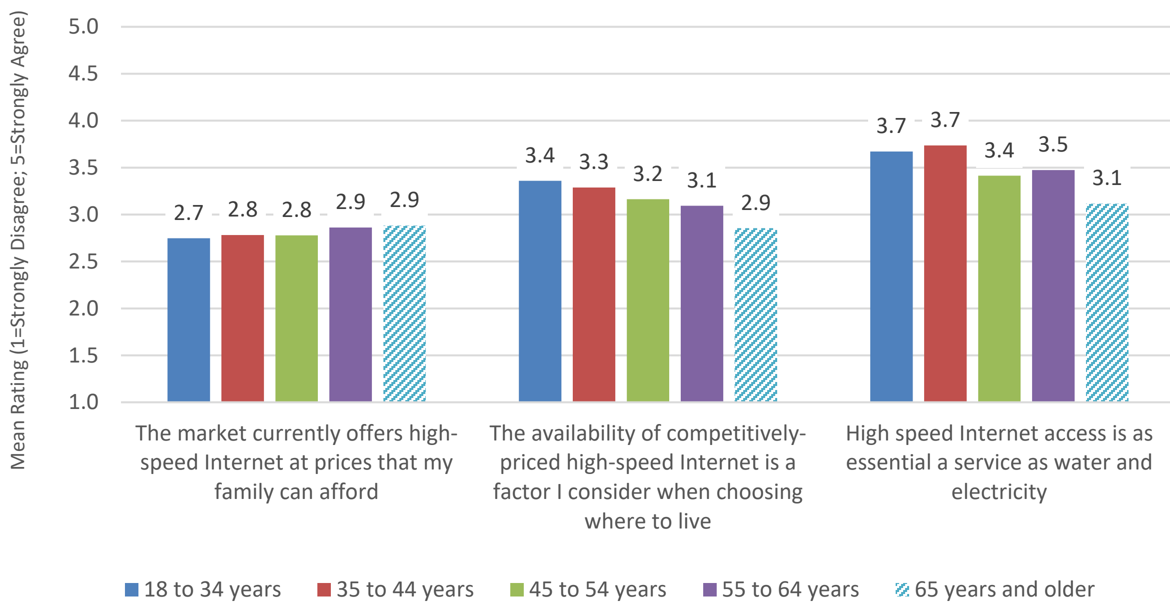
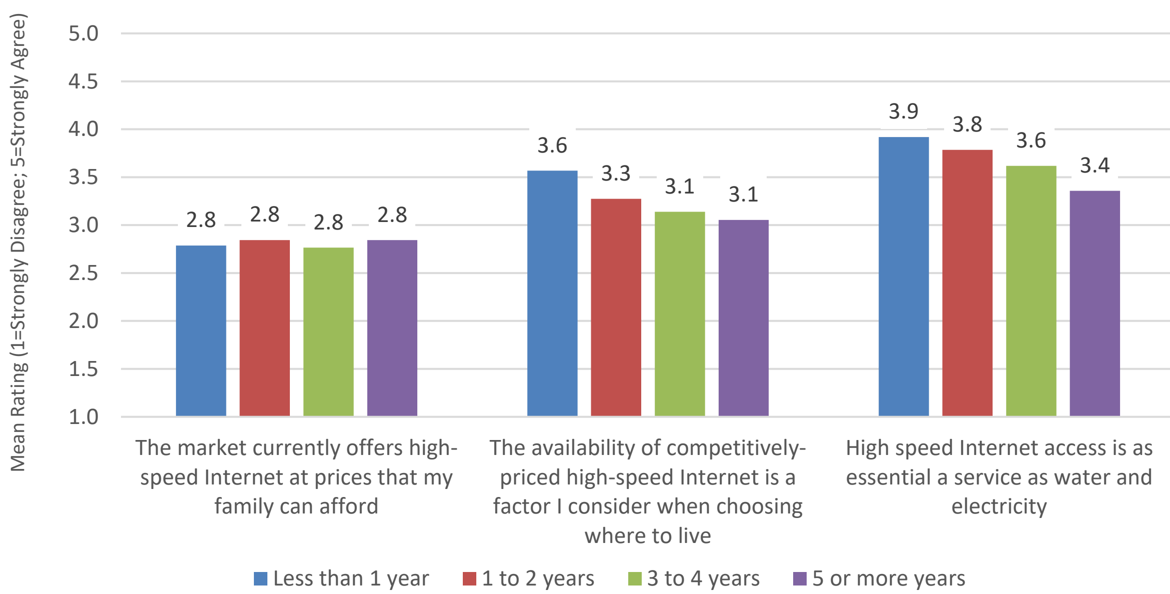
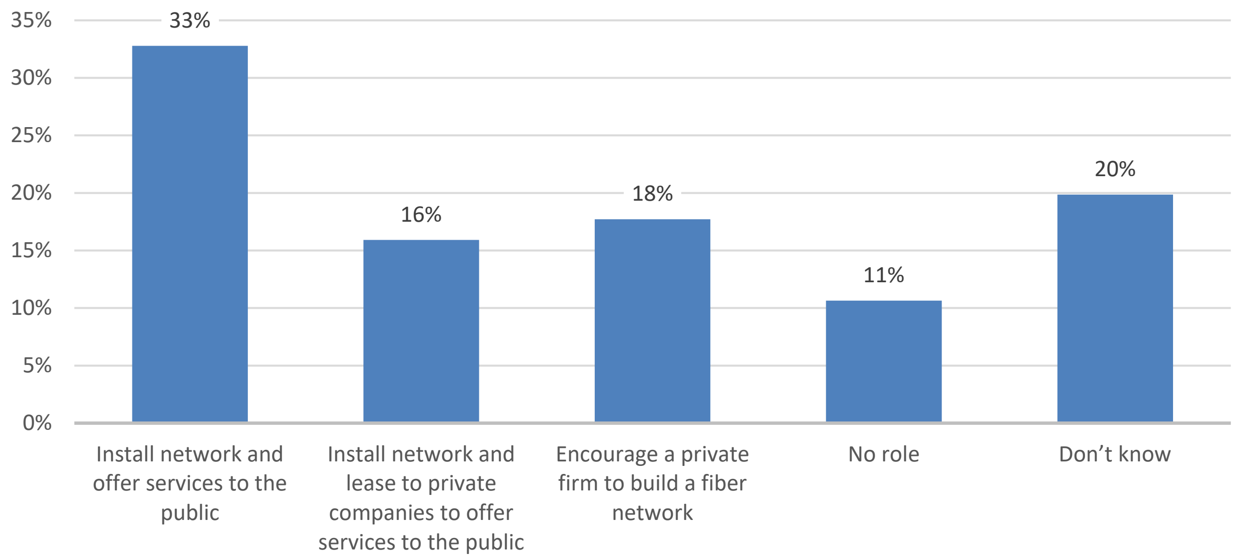


Figure 90: Opinions About the Broadband Internet Market by Length of Residence



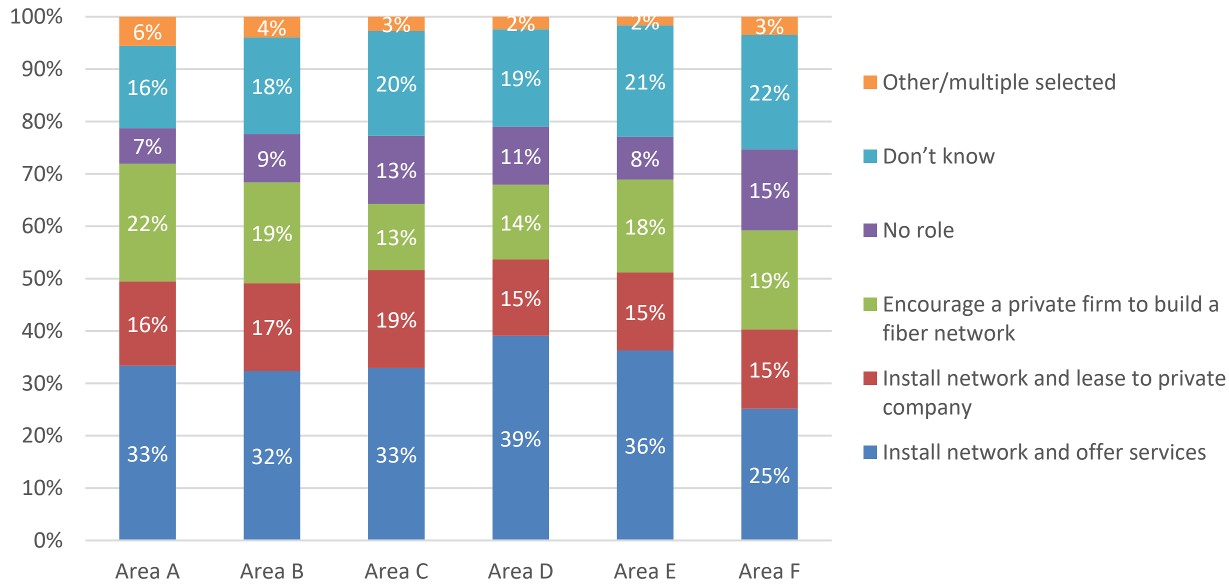
Respondents were asked what should be the ***main*** role of the County with regards to internet infrastructure and services. About one-half of respondents indicated that the County should install a state-of-the-art network, including 33 percent who indicated that the County should offer services directly. Only 11 percent said the County should play no role, and 20 percent of respondents were unsure, as illustrated in Figure 91.

Figure 91: MAIN Role of Larimer County in Broadband Access



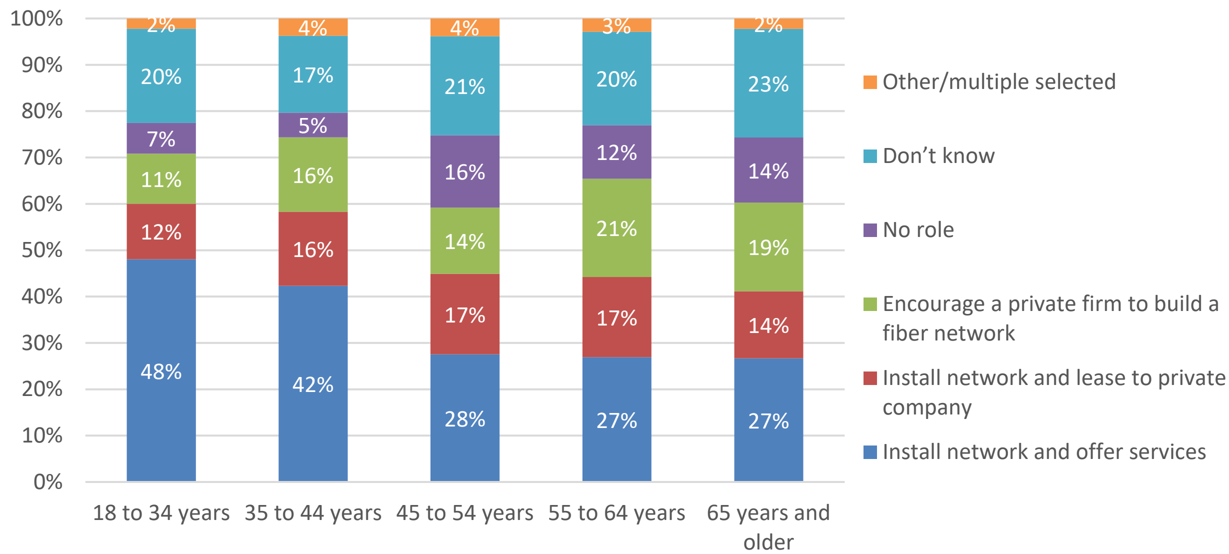
Residents of Area F were somewhat less likely to indicate that the County should install a broadband network and offer services to the public, as shown in Figure 92.

Figure 92: MAIN Role of Larimer County in Broadband Access by Area of Residence



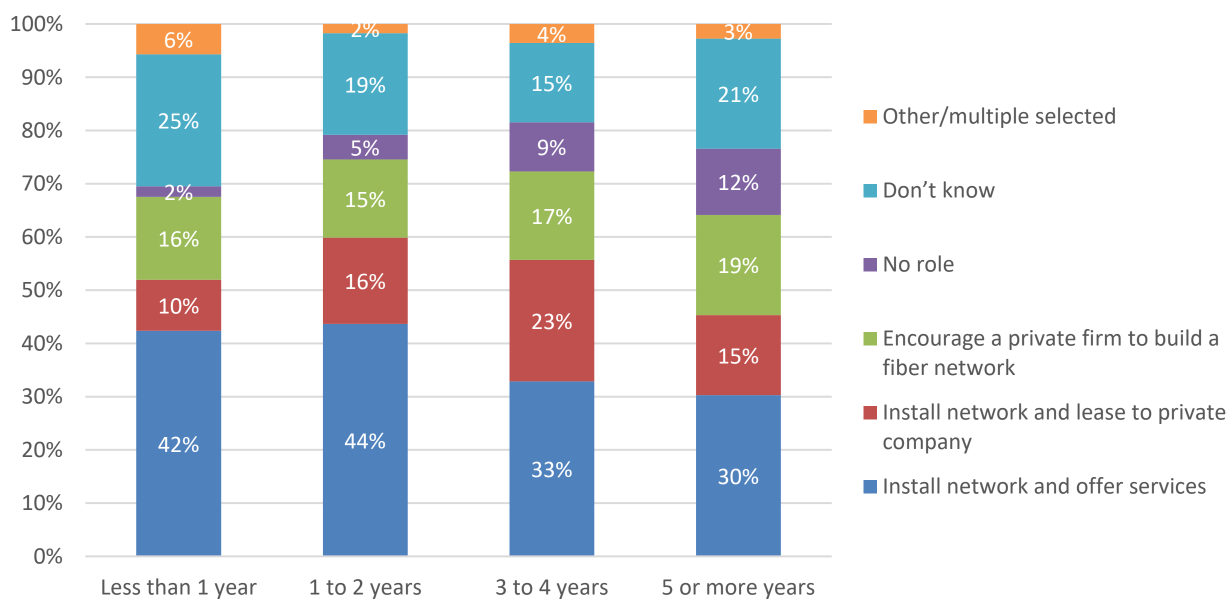
Support for installation of a state-of-the-art network tends to be higher among those ages 18-44, compared with older respondents. Approximately six in 10 said the County should install the network, including 48 percent of 18- to 34-year-olds and 42 percent of 35- to 44-year-olds who said the County should offer services directly (see Figure 93).

Figure 93: MAIN Role of Larimer County in Broadband Access by Age of Respondent



Similarly, support for installation is higher for newer residents (who tend to be younger), compared with those who have been residing in the area for five or more years (see Figure 94).

Figure 94: MAIN Role of Larimer County in Broadband Access by Years Lived at Residence



These responses indicate some desire to have a state-of-the-art communications network and for the County to play some role in its installation. It should be noted that this question did not specifically ask about how that network should be financed or funded. Questions regarding consumers' willingness to pay monthly fees or installation costs for access to that network were presented previously.

4.2.5 Respondent Information

Respondents were asked their opinions about Larimer County's role in providing or promoting broadband communications services within the area. The most favorable opinions were for the County to help ensure that all residents, students, and teachers have access to competitively-priced broadband services, with over one-half strongly agreeing. There is less agreement that the County should build a publicly-financed network (to either offer services to the public OR for private sector companies to offer network services); more than one-third of respondents strongly agreed with these statements. Figure 95 illustrates the mean ratings, while Figure 96 provides detailed responses to each portion of the question.

Figure 95: Opinions About the Role(s) for Larimer County (Mean Ratings)

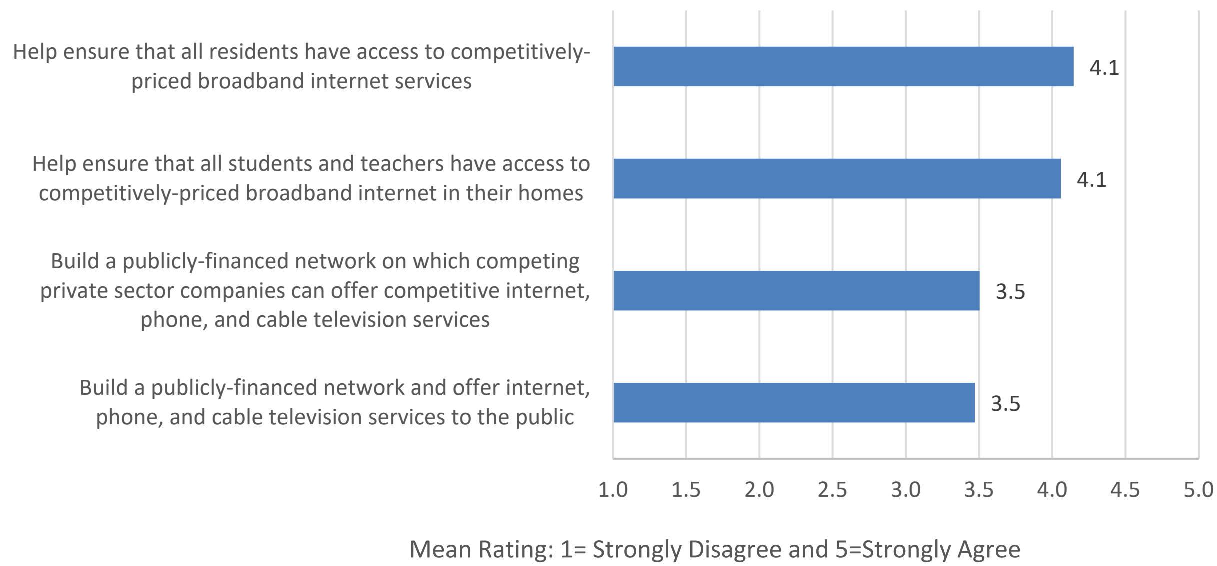
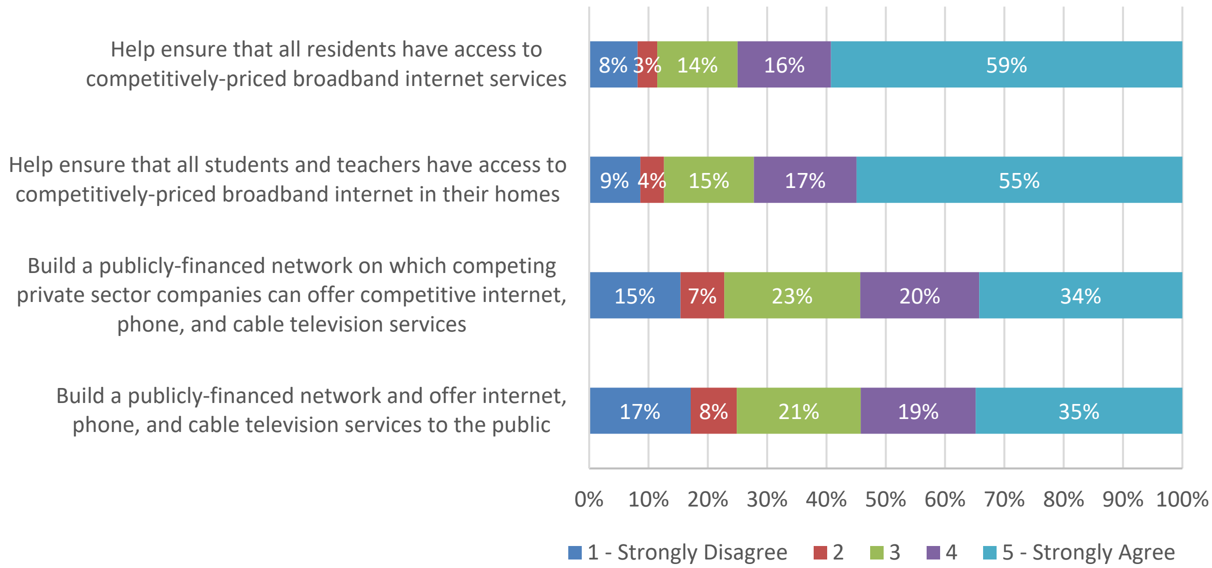


Figure 96: Opinions About the Role(s) for Larimer County



Younger respondents and newer residents showed greater support for the County's role in providing or promoting broadband internet service, as illustrated in Figure 97 and Figure 98.

Figure 97: Opinions About the Role(s) for Larimer County by Age of Respondent

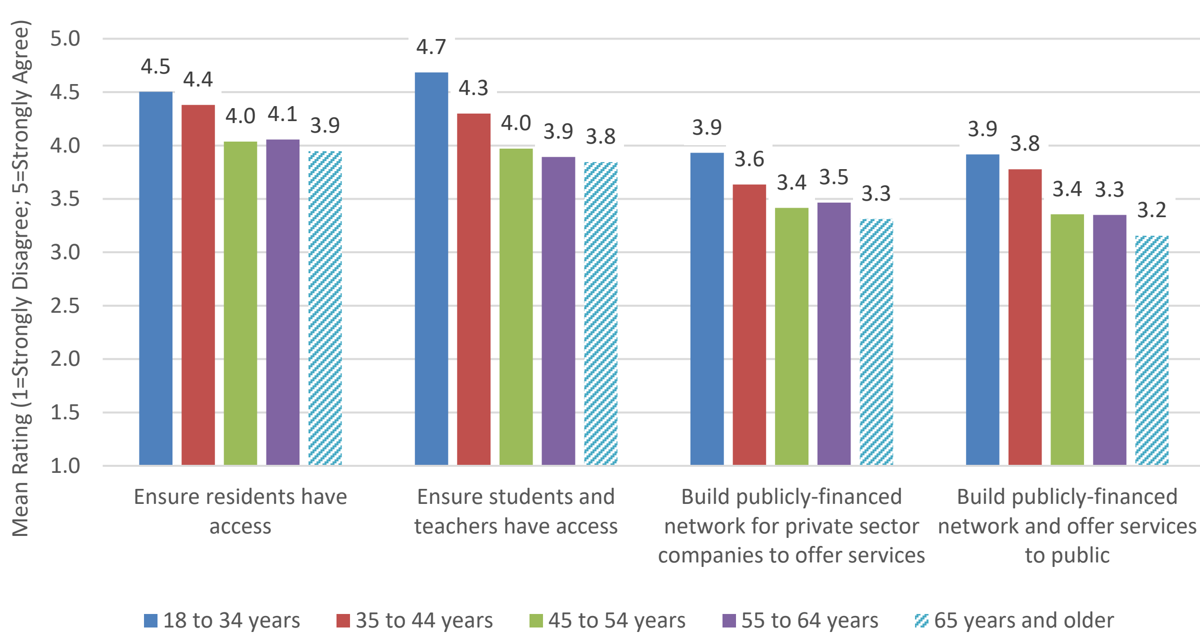
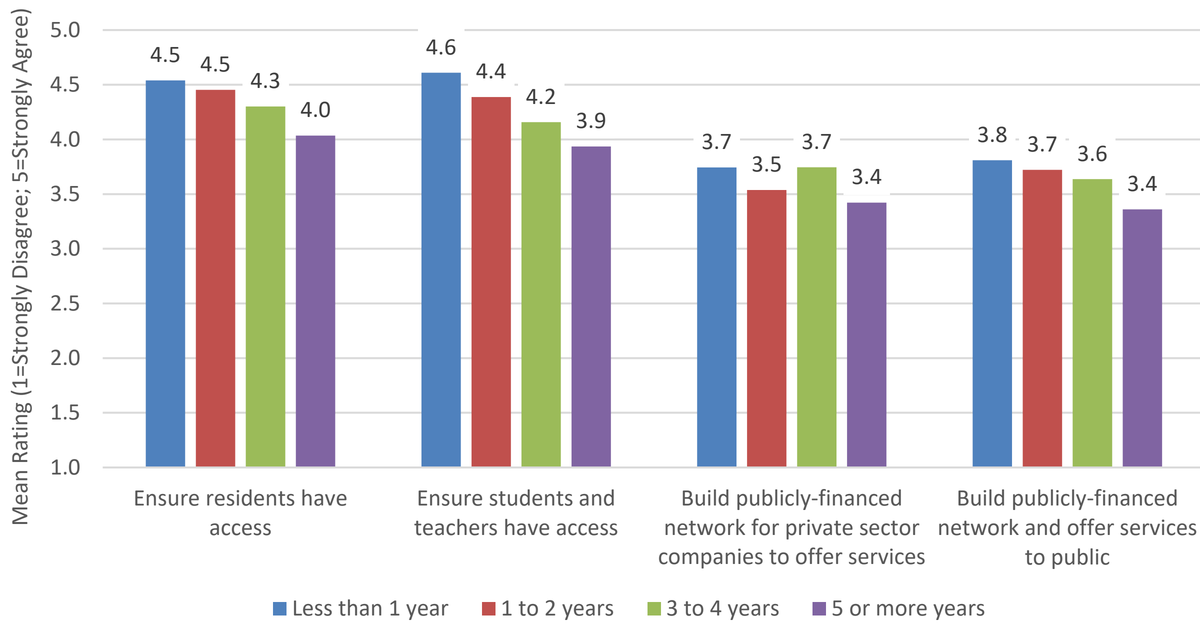


Figure 98: Opinions About the Role(s) for Larimer County by Length of Residence



Respondents were also asked their opinion of the current broadband market. More than one-half somewhat or strongly agreed that high-speed internet is an essential service, and four in ten agreed that availability is a factor in deciding where to live. Three in 10 somewhat or strongly agreed that the market currently provides high-speed internet at prices they can afford (see Figure 99). Overall agreement about the broadband internet market is moderate, as shown in Figure 100.

Figure 99: Opinions About the Broadband Internet Market

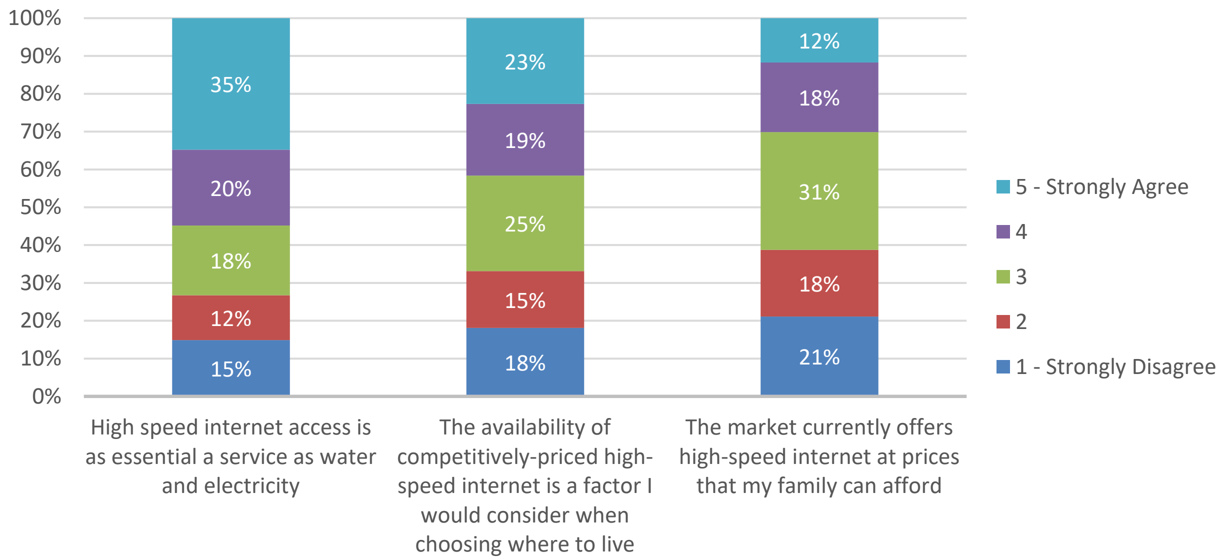
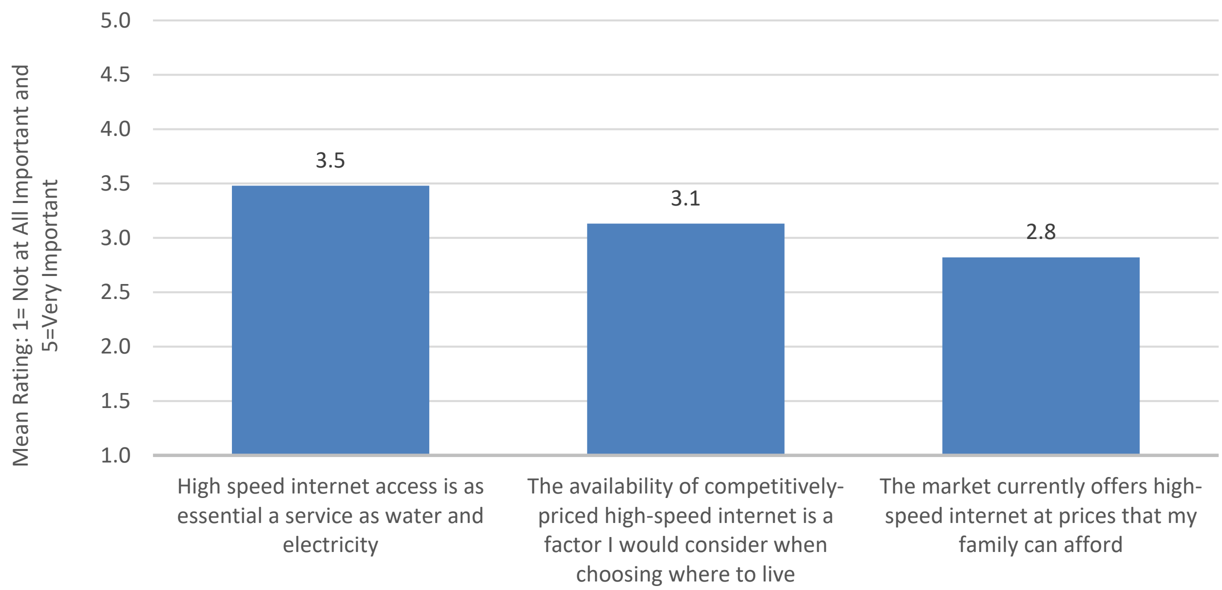


Figure 100: Opinions About the Broadband Internet Market (Mean Ratings)



Respondents ages 65 years and older are less likely than younger respondents to perceive high speed internet access as an essential service or to agree that availability of high-speed internet is a factor when deciding where to live (see Figure 101). Similarly, agreement with these statements declines somewhat as length of residence increases, as shown in Figure 102.

Figure 101: Opinions About the Broadband Internet Market by Age of Respondent

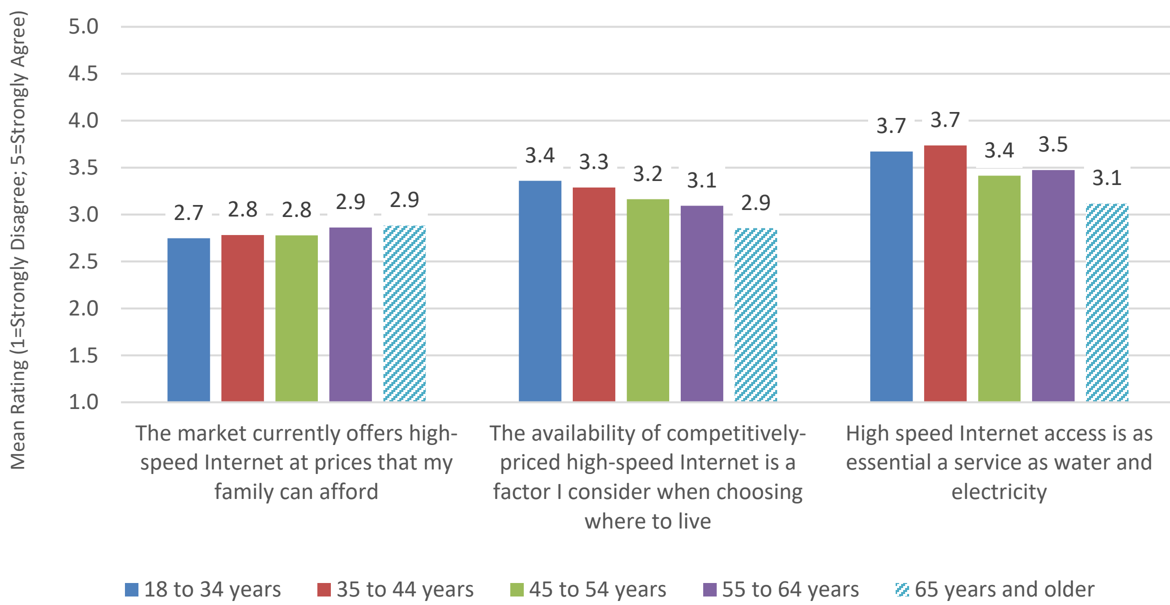
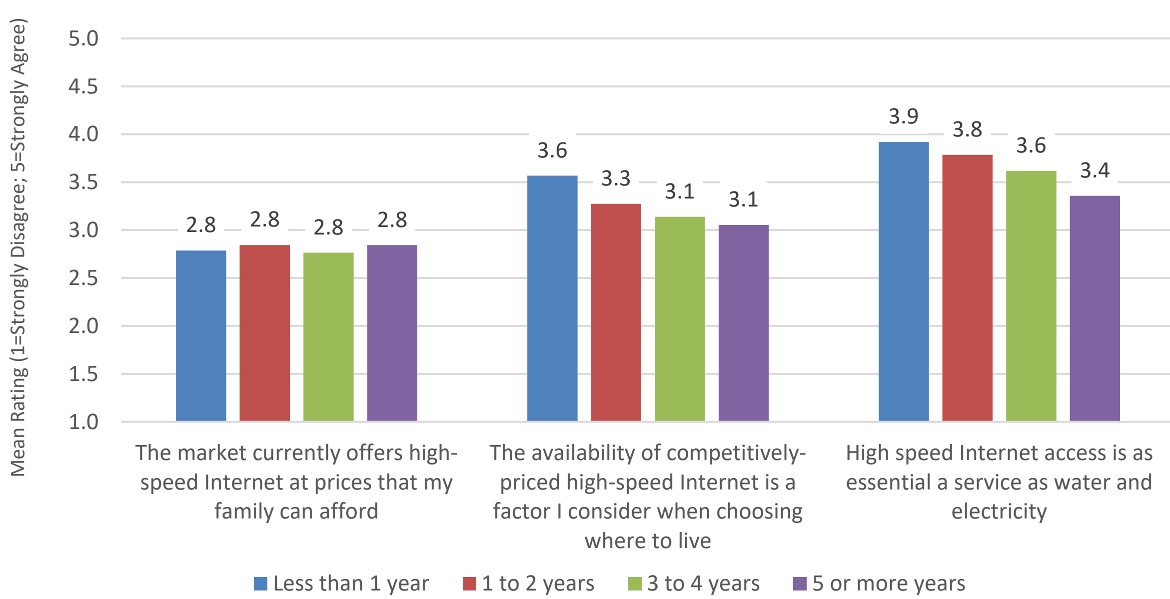
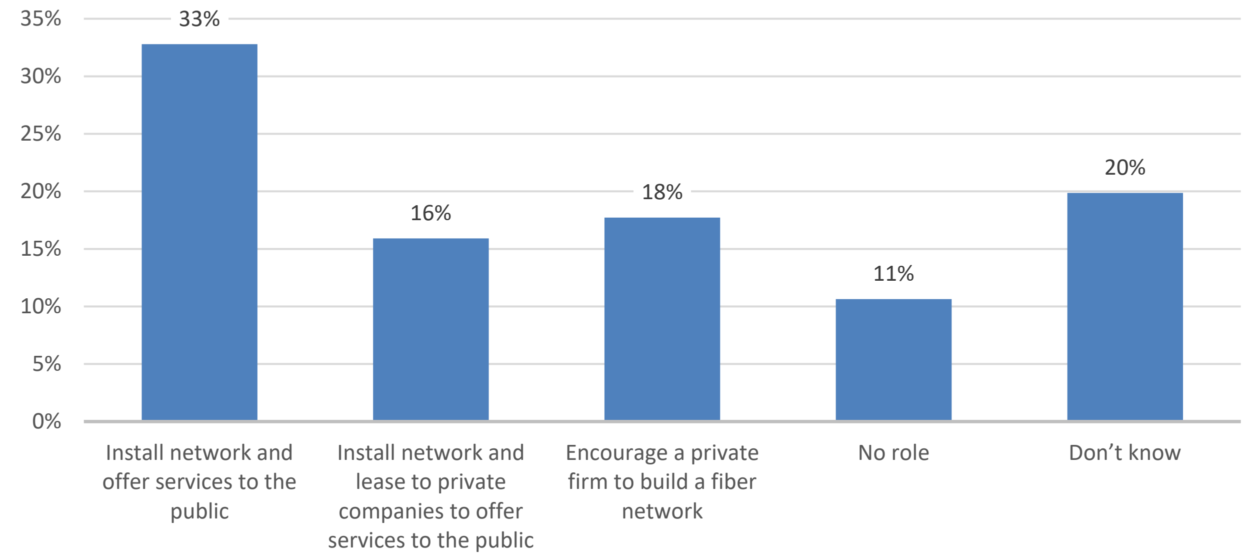


Figure 102: Opinions About the Broadband Internet Market by Length of Residence



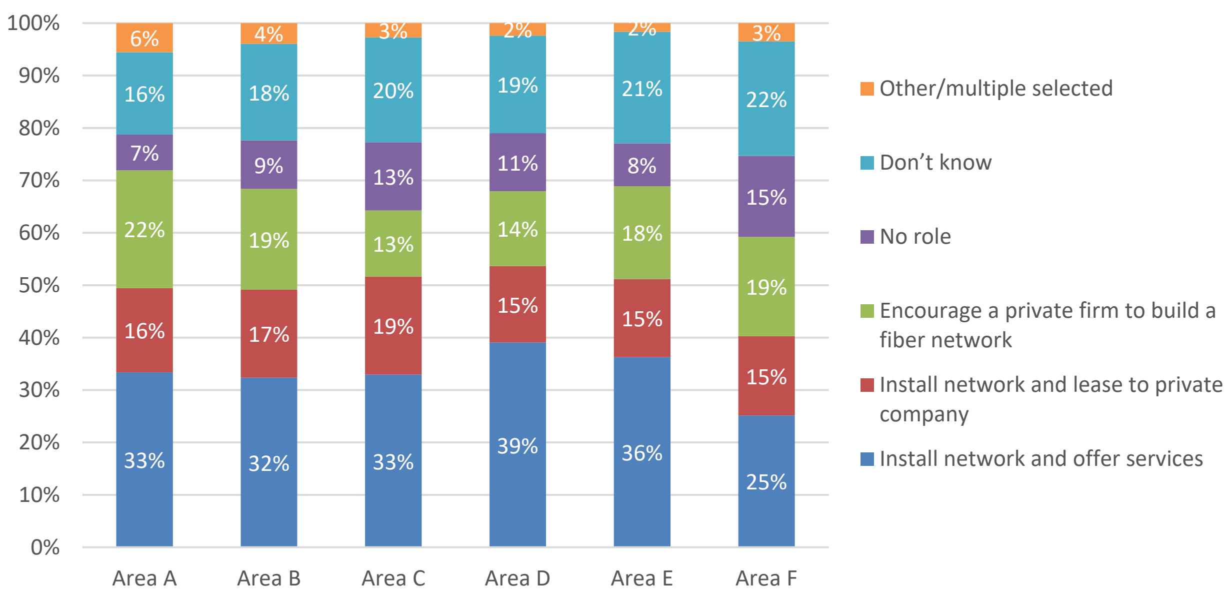
Respondents were asked what should be the ***main*** role of the County with regards to internet infrastructure and services. About one-half of respondents indicated that the County should install a state-of-the-art network, including 33 percent who indicated that the County should offer services directly. Only 11 percent said the County should play no role, and 20 percent of respondents were unsure, as illustrated in Figure 103.

Figure 103: MAIN Role of Larimer County in Broadband Access



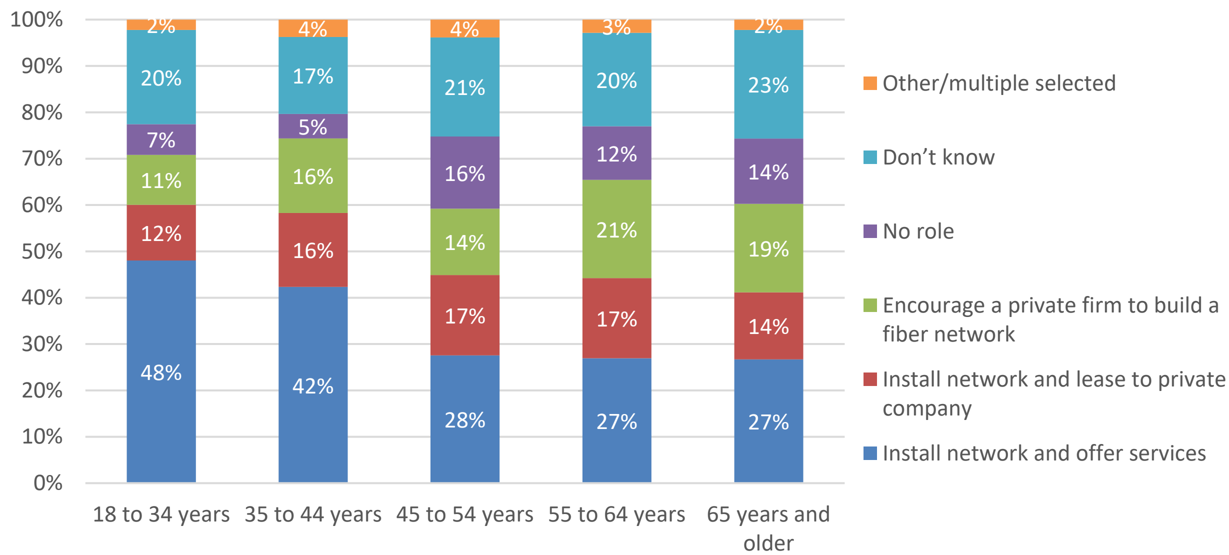
Residents of Area F were somewhat less likely to indicate that the County should install a broadband network and offer services to the public, as shown in Figure 104.

Figure 104: MAIN Role of Larimer County in Broadband Access by Area of Residence



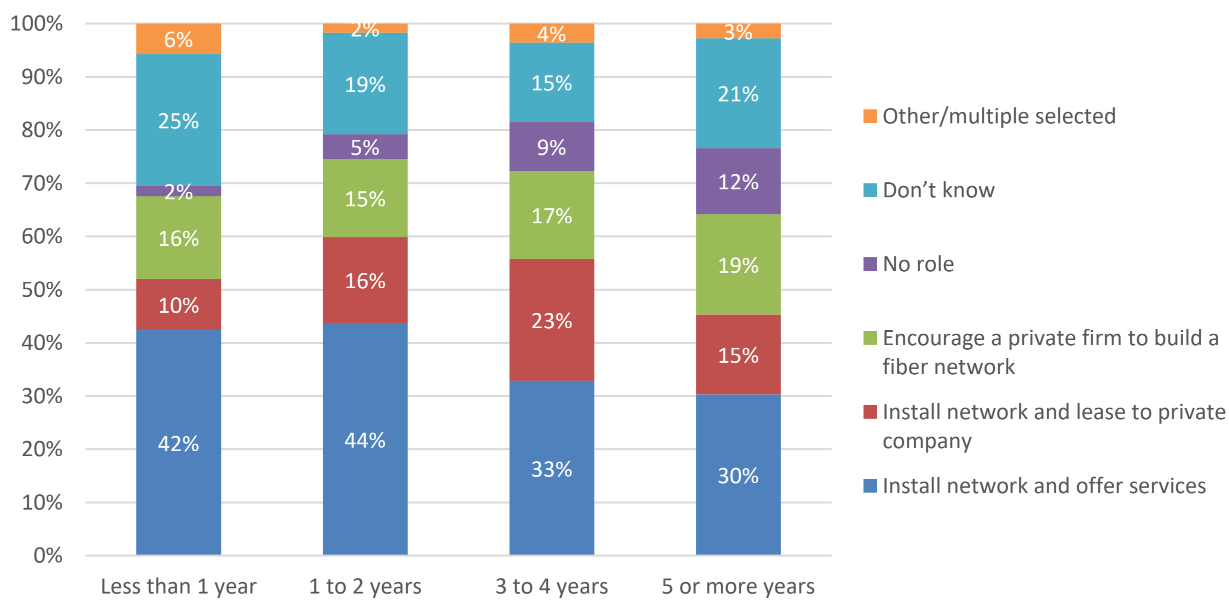
Support for installation of a state-of-the-art network tends to be higher among those ages 18-44, compared with older respondents. Approximately six in 10 said the County should install the network, including 48 percent of 18- to 34-year-olds and 42 percent of 35- to 44-year-olds who said the County should offer services directly (see Figure 105).

Figure 105: MAIN Role of Larimer County in Broadband Access by Age of Respondent



Similarly, support for installation is higher for newer residents (who tend to be younger), compared with those who have been residing in the area for five or more years (see Figure 106).

Figure 106: MAIN Role of Larimer County in Broadband Access by Years Lived at Residence



These responses indicate some desire to have a state-of-the-art communications network and for the County to play some role in its installation. It should be noted that this question did not specifically ask about how that network should be financed or funded. Questions regarding consumers' willingness to pay monthly fees or installation costs for access to that network were presented previously.

5 Regulatory Environment Review

Providers across the United States have cited local regulatory concerns as a key reason for not deploying to a given area, and some providers in the County made this claim, as we discussed in Section 2.2. In many cases, this is not an unfounded claim. Expensive and onerous permitting processes may be prohibitive for private providers, especially smaller companies that may lack the resources to meet the logistical and financial requirements of permitting and building in a given jurisdiction.

One of CTC's key tasks in this engagement was to evaluate the County's regulatory environment to determine the degree to which legislation and local ordinances may hinder the private sector's ability to successfully deploy broadband infrastructure and extend service to the County's target areas. In this task, we reviewed:

- County Land Use Code,
- County Land Information Locator materials,
- County Road Information Locator materials,
- County Access Permitting,
- County Building Permits,
- County Commercial Radio Service Regulations,
- County Contractor Licensing materials,
- Colorado Rules of Civil Procedure 106(a)(4), and
- Colorado Small Cell Bill HB17-1193.

While there are complexities in the state of Colorado around public broadband deployment, these regulations do not apply to private industry. Further, the steps to overcome these are relatively straightforward—and the County and the jurisdictions within it have already taken the steps necessary to be able to deploy broadband infrastructure where it makes sense.

Our review of local regulations in the County evaluated these policies from a technical and business standpoint, and it indicates that the County's policies are unlikely to be a significant barrier to private broadband deployment. Based on our experience in other jurisdictions where the private sector has successfully deployed infrastructure, the County's policies are not significantly onerous, cumbersome, or expensive.

While it makes sense to continually evaluate and adjust permitting and other ordinances as technology and the industry evolves, the existing County regulations are not unfavorable to private providers. Although some providers have claimed anecdotally that local regulations and processes are a primary reason for not having deployed infrastructure in certain areas, it is more likely that those providers simply cannot achieve the return on investment (ROI) necessary to make such a deployment worthwhile.

Simply put, building infrastructure in the County is expensive, as we note in Section 6. Even if the County fully streamlined all its processes and reduced or removed all permitting fees, the private sector would still be unlikely to invest in a significant buildout.

6 Potential Fiber Deployment Costs

Construction of a fiber network designed specifically to connect County residences in unincorporated areas would be a costly effort. In this section, we provide an overview of the technical approach and cost estimate we developed to examine the feasibility of constructing a middle-mile and an FTTP network that could reach the most possible residences in the County.

We note that the cost of these deployments is very high relative to other deployments nationwide. We do not see a viable business model that could recover the County's investment in such a network, given the potential customer base in the unincorporated areas of the County. The cost estimate presented in this section is for illustrative purposes only.

6.1 Fiber Route Estimation Methodology

We developed potential routes along major roadways that would reach the most residences possible in the unincorporated areas of the County. We projected two potential scenarios:

- Routes along major roadways that would pass within 3 miles of the most possible parcel center points in the unincorporated areas, and
- Routes along major roadways that would pass within 5 miles of the most possible parcel center points in the unincorporated areas.

6.1.1 3-Mile Scenario

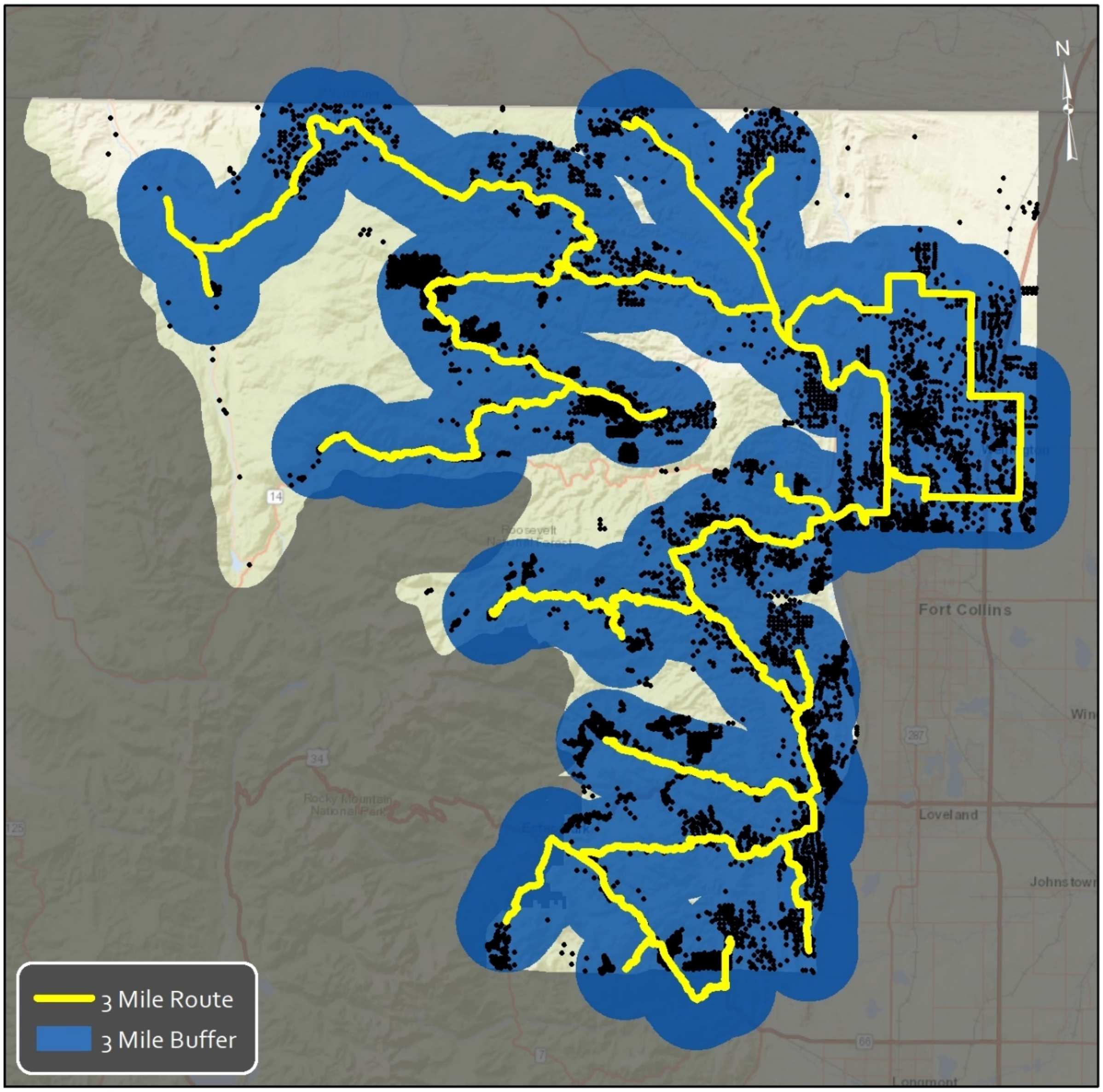
The 3-mile scenario would entail deploying 333.7 road miles of fiber, reaching within 3 miles of 98.58 percent of houses in the unincorporated areas of the County.

Table 26: Summary of Routes and Households in 3-Mile Scenario

Survey Area	Resiliency Area(s)	Area (Sq. Miles)	Road Miles	Percent of Households Within 3 Miles of Fiber
A	1	89	29.8	99.68%
B	2,3	182	48.6	99.61%
C	4	179	47.5	99.35%
D	5,7,8	710	100.9	94.34%
E	6	233	31.7	99.72%
F	9	398	75.2	98.76%
	Total	1,791	333.7	98.58%

Figure 107 provides an illustration of these routes.

Figure 107: Fiber Routes That Pass Within 3 Miles of the Majority of Residences in the Unincorporated Portions of the County



6.1.2 5-Mile Scenario

The 5-mile scenario would entail deploying 266.6 road miles of fiber, reaching within 5 miles of 99.66 percent of houses in the unincorporated areas of the County.

Table 27: Summary of Routes and Households in 5-Mile Scenario

Survey Area	Resiliency Area(s)	Area (Sq. Miles)	Road Miles	Percent of Households Within 5 Miles of Fiber
A	1	89	17.9	100.00%
B	2,3	182	45.7	100.00%
C	4	179	30.8	99.71%
D	5,7,8	710	90.8	99.11%
E	6	233	28.3	99.97%
F	9	398	53.2	99.16%
	Total	1,791	266.6	99.66%

Figure 108 provides an illustration of these routes.

Figure 108: Fiber Routes That Pass Within 5 Miles of the Majority of Residences in the Unincorporated Portions of the County

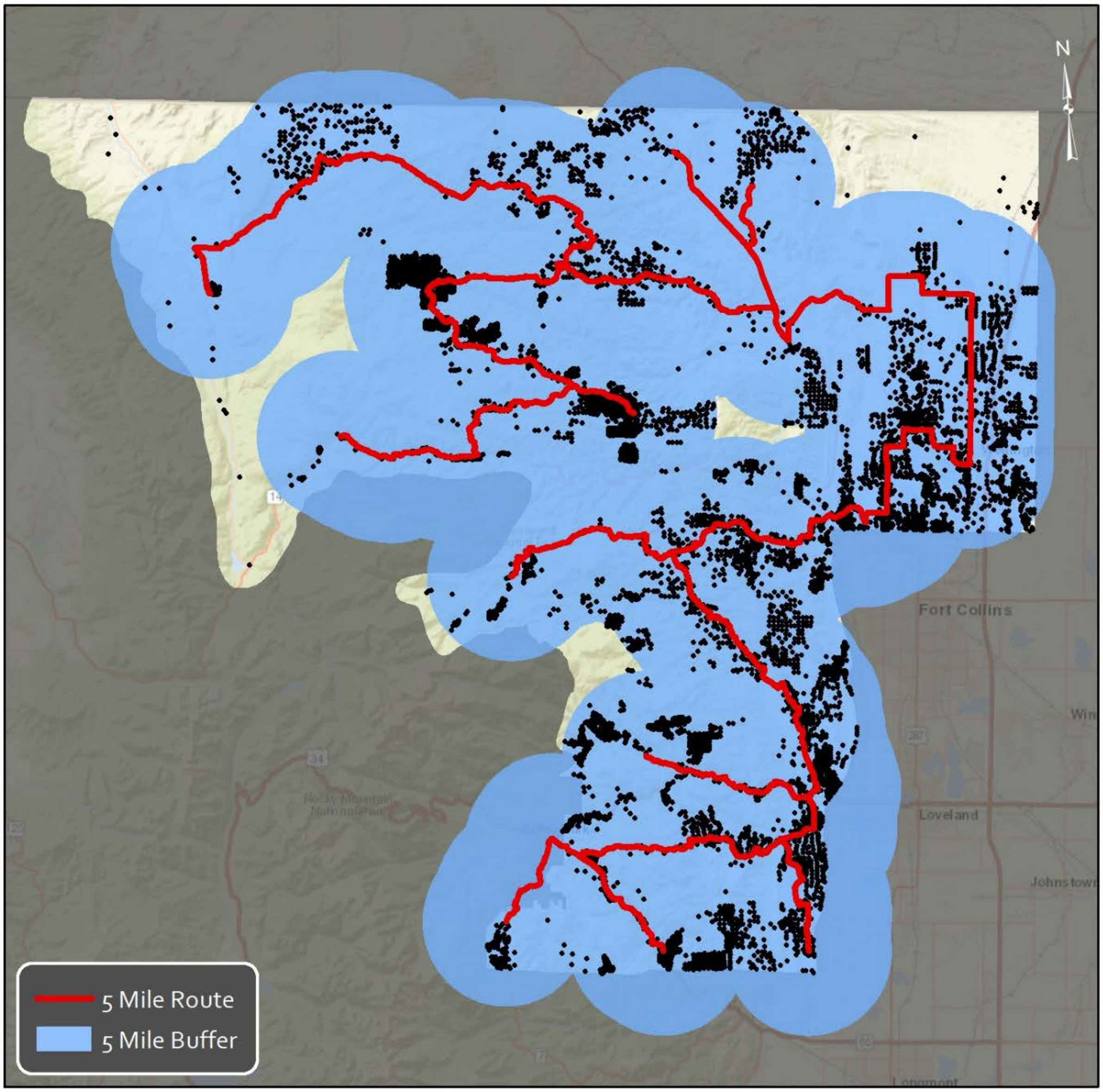
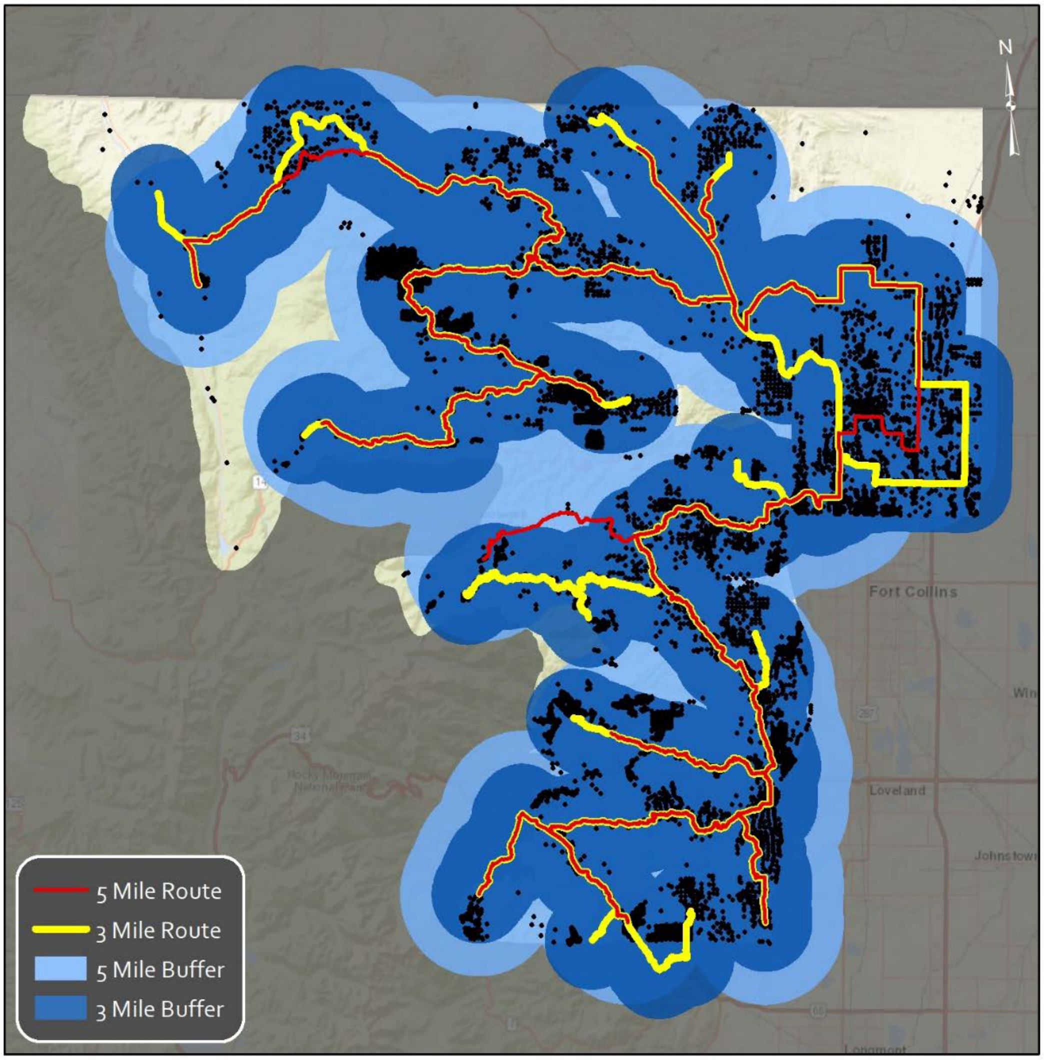


Figure 109 provides an illustrative comparison of these scenarios

Figure 109: Comparison of 3-Mile and 5-Mile Scenarios



6.2 OSP Technical Assumptions

Beyond the physical fiber optic cable routing, several technical design and construction attributes have an impact on costs, including the following:

- **Fiber strand count:** The number of individual fiber strands provided in a single cable correlates to the capacity of the cable. Due to the vast effective bandwidth of fiber, it is feasible to scale the rate of data transmission carried by even a single fiber strand to meet all of the County's needs indefinitely; however, the cost of network electronics increases exponentially with this capacity.

  On the other hand, the material cost of fiber strands represents a very minor component of the overall cost of fiber construction (about $0.01 per strand per foot, compared to

$15 to $25 per foot for the total cost of typical construction). It is thus prudent to install a cable of sufficient size to meet any conceivable requirements to ensure these needs can be met with a configuration of electronics that are as low-cost as possible. In fact, with sufficient fiber strands, the County can increase network capacity many orders of magnitude above current levels with little or no change to its network electronics.

While we anticipate no portion of the network will require more than a few dozen strands, cost estimates are based on the installation of a 288-count cable along most segments of the network. This will ensure sufficient capacity for nearly any conceivable expansion of internal needs, fiber leasing, or even future support of business or residential services.

- **Underground versus aerial construction:** The cost estimates anticipate a 50/50 split of aerial and underground fiber, with fiber cables placed in a 2-inch conduit where the utility pole make-ready cost is too high (see below) or where existing utilities are underground. Because the County does not own its own utility poles, aerial construction will require negotiating pole attachment agreements. These agreements generally require recurring fees per pole, and generally require the attacher to pay the cost of any upgrades or modifications to the utility poles necessary to support the new attachment.
- **Make-ready:** Make-ready is the preparation of a utility pole to accommodate a new cable. This can be accomplished through moving the existing cables or, if there is not enough space, replacing the pole with a larger pole. Make-ready is one of the largest variables that affect the cost of fiber construction. The amount of aerial construction, the size and quality of poles, the number of poles per mile, and the number of existing attachments all play into the make-ready costs. If access to the utility poles is not granted or make-ready and pole replacement costs are too high, the network would have to be constructed underground—which could significantly increase the cost of construction.
- **Conduit size and quantity:** Using industry best practices, cost estimates are based on the installation of fiber in a flexible plastic conduit that provides a path into which fiber cable can be installed. Conduit also allows cable slack to be pulled to accommodate repairs, and enables the installation of new cable to expand capacity.

  We assume underground construction will consist primarily of horizontal, directional drilling to minimize PROW impact and to provide greater flexibility to navigate around other utilities. While cost estimates are based on the placement of a single 2-inch High-Density Polyethylene (HDPE) flexible conduit, it should be noted that placing additional conduits simultaneously results in relatively minor increases in cost, within limits.

Depending on material prices, 2-inch conduit is preferable along backbone routes, as it can accommodate one or more additional large-strand-count fiber cables in each, with sufficient space for additional smaller cables for purposes of placing "lateral" connections to future locations.

- **Handhole placement and size:** Handholes are enclosures installed underground in which conduit terminates for the purpose of providing access to conduit for installing cable, as well as to house cable splice enclosures and cable slack loops required for future repairs. Handholes generally must be placed at intersections of multiple conduit paths, or where the conduit path makes a sharp change in direction. Handholes provide important access points to underground conduit, enabling expansion of the conduit infrastructure (i.e., installation of a lateral connection to a new network location) without disrupting conduit or installed cables.

  While cable can be pulled upwards of several thousand feet at a time, cost estimates for the County network assume installation of handholes every 500 feet on average, ensuring that the infrastructure supports cost-effective expansion to new sites, including access to businesses that might be targets of commercial network operators seeking to lease County fiber (or conduit space).

- **PROW restoration and fees**: The network cost estimates assume that the County may have to pay encroachment fees for construction along or under State roads—as well as railroad crossing application and licensing fees, which can total upwards of $15,000 per crossing.[61] The cost estimates assume that the County will incur typical costs for permanent asphalt and concrete restoration required for utility "test pitting" necessary to verify the location of other utilities in the path of the fiber to prevent damage; generally, this consists of excavation within small areas of less than 2 feet in diameter.

6.3 OSP Cost Assumptions

Our engineers determined a low- and high-range estimate for both aerial and underground deployments. This section discusses the specifics of these estimates.

6.3.1 Aerial Construction

We estimate that aerial construction will cost $40,000 to $80,000 per mile, depending on the specific conditions of the respective area. Our assumptions are outlined below:

[61] Additional costs for steel encasement of conduit may also apply.

- Low: $40,000 per mile. No make-ready or tree trimming required to install fiber and strand in the communications space. This estimate assumes long stretches of aerial construction without any splicing or route changes.

- High: $80,000 per mile. High make-ready costs, tree trimming, and traffic mitigation required. Splicing required along the route, or aerial plant is deployed in shorter sections relative to the low-cost estimate.

6.3.2 Underground Construction

We estimate underground construction to cost $95,000 to $250,000 per mile, similarly depending on the specific conditions of the area. Our assumptions are outlined below:

- Low: $95,000 per mile. Conduit installed using a plow along long stretches of roadway without splicing or route changes. Plowing would only be feasible in areas with sandy or silty soil, little to no rock, and no required surface restoration.

- High: $250,000 per mile. Conduit installed via directional boring or trenching, with traffic mitigation required. This estimate is for areas with high levels of rock or expensive surface restoration.

6.4 Middle-Mile OSP Cost Estimate

Using the routes presented in Section 6.1 and the technical and cost estimates presented in Section 6.3, we estimated the cost to deploy a fiber "backbone" that could potentially be used as a middle-mile network throughout the unincorporated areas of the County. This network would not provide internet services to residences, but rather would be used as a platform upon which the County could deploy additional fiber infrastructure to connect key County facilities, schools, and communities. Additionally, this middle-mile network may help lower barriers to deployment for the local WISPs, encouraging increased service offerings for households in unincorporated areas.

We estimate that it would cost the County roughly $116,300 per mile, or $38.79 million to deploy the 3-mile model, and $31 million to deploy the 5-mile model. We note that these costs are only for middle-mile fiber OSP, and do not include core or network electronics, fiber laterals, or drops into individual premises.

OSP (layer 1, also referred to as the physical layer) is both the most expensive part of the network and the longest lasting. These cost estimates are inclusive of all engineering, project management, quality assurance, and construction labor anticipated to be necessary to implement the network on a turnkey basis, and are based on relatively conservative pricing assumptions. The following summarizes the scope anticipated by each of the cost estimates:

- **Engineering:** Includes system level architecture planning, preliminary designs and engineering field walk-outs to determine candidate fiber routing; development of detailed engineering prints and preparation of permit applications; and post-construction "as-built" revisions to engineering design materials
- **Project Management / Quality Assurance**: Includes expert quality assurance field review of final construction for acceptance, review of invoices, tracking progress, and coordination of field changes
- **OSP Construction**: Consists of all labor and materials related to "typical" underground OSP construction, including conduit placement, utility pole make-ready construction, fiber installation, and surface restoration; includes all work area protection and traffic control measures inherent to all roadway construction activities
- **Railroad, Bridge, and Interstate Crossings**: Consists of specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate/controlled access highways
- **OSP Fiber Splicing**: Includes all labor related to fiber splicing of outdoor fiber optic cables
- **Fiber Termination/Building Entrance**: Consists of all costs related to fiber lateral installation into network sites, including OSP construction on private property, building penetration, inside plant construction to a typical backbone network service "demarcation" point, fiber termination, and fiber testing

Actual costs may vary due to unknown factors, including: 1) costs of private easements, 2) congestion in the PROW, 3) variations in labor and material costs, and 4) subsurface hard rock.

Costs for underground placement were estimated using available unit cost data for materials and estimates on the labor costs for placing, pulling, and boring fiber based on construction in comparable markets. The material costs were generally known apart from unknown economies of scale and inflation rates, and barring any sort of phenomenon restricting material availability and costs.

6.5 Fiber-to-the-Premises Cost Estimate

We extended our middle-mile estimate to determine a high-level estimate of the cost of a nearly ubiquitous (i.e., reaching all households included in the middle-mile design) FTTP deployment to the unincorporated areas of the County. This network would use the middle-mile network described above as a backbone, add increased distribution fiber, and deploy drop cables from the distribution fiber in the ROW to individual premises.

6.5.1 FTTP OSP Cost Estimate

Our engineers estimated the average cost per passing (e.g., a home, business, or facility) for each of the survey areas, and further calculated a low- and high-cost metric for each area, based on the size, density, and topographical conditions of each. These estimates are shown in Table 28.

Table 28: Estimated FTTP OSP Cost Per Passing by Survey Area

Survey Area	Resiliency Area(s)	Low-Cost	Mid-Cost	High-Cost
A	1	$5,000	$7,000	$10,000
B	2,3	$5,000	$7,000	$10,000
C	4	$6,000	$9,000	$13,000
D	5,7,8	$8,000	$12,000	$17,000
E	6	$5,000	$7,000	$10,000
F	9	$7,000	$10,000	$14,000
	Average:	**$5,810**	**$8,340**	**$11,860**

We then extrapolated the mileage of each survey area to understand the low-, mid-, and high-range costs for each survey area, and calculated the average cost per household, shown in Table 29.

Table 29: Estimated FTTP OSP Cost by Survey Area

Survey Area	Resiliency Area(s)	Low-Cost	Mid-Cost	High-Cost
A	1	$6,110,000	$8,554,000	$12,220,000
B	2,3	12,575,000	17,605,000	25,150,000
C	4	10,038,000	15,057,000	21,749,000
D	5,7,8	9,720,000	14,580,000	20,655,000
E	6	17,395,000	24,353,000	34,790,000
F	9	17,122,000	24,460,000	34,244,000
	Total:	**$72,960,000**	**$104,609,000**	**$148,808,000**
Average cost per household:		**$5,800**	**$8,300**	**$11,900**

We note that the low-cost estimates reflect the costs to deploy in ideal conditions; we do not anticipate that costs would be this low in a County deployment, given the County's topographical characteristics. Given this, we estimate that the fiber to support a nearly ubiquitous FTTP deployment will total between $104.61 million and $148.81 million.

6.5.2 Central Network Electronics Costs

We estimate that central network electronics will cost an estimated $1.5 to $2 million. These costs may increase or decrease depending on take rate and the costs may be phased in as subscribers are added to the network. The central network electronics consists of the electronics to connect subscribers to the FTTP network at the core, hubs, and cabinets.

6.5.2.1 Core Electronics

The core electronics connect the hub sites and connect the network to the internet. The core electronics consist of high-performance routers, which handle all of the routing on both the FTTP network and to the internet. The core routers should have modular chassis to provide high availability in terms of redundant components and the ability to "hot swap"[62] line cards and modular in the event of an outage. Modular routers also provide the ability to expand the routers as demand for additional bandwidth increases.

These costs do not include the service provider's Operational Support Systems (OSS) such as provisioning platforms, fault and performance management systems, remote access, and other operational support systems for FTTP operations.

6.5.2.2 Distribution and Access Electronics

The distribution network electronics aggregate the traffic from the FDCs and send it to the core sites to access the internet. The core sites consist of high-performance aggregation switches, which consolidate the traffic from the many access electronics and send it to the core for route processing. The distribution switches typically are large modular switch chassis that can accommodate many line cards for aggregation. The switches should also be modular to provide redundancy in the same manner as the core switches.

The access network electronics at the FDCs connect the subscribers' customer premises equipment (CPE) to the FTTP network. We recommend deploying access network electronics that can support both GPON and Active Ethernet subscribers to provide flexibility within the FDC service area. We also recommend deploying modular access network electronics for reliability and the ability to add line cards as more subscribers join in the service area. Modularity also helps reduce initial capital costs while the network is under construction or during the roll out of the network.

We anticipate that distribution and access electronics will cost $220 per subscriber.

6.5.3 Customer Premises Equipment and Service Drop Installation (Per Subscriber Costs)

Additional per-subscriber expenses include the cost of the optical network terminal (ONT) at the premises, a portion of the optical line termination (OLT) costs at the hub, the labor to install and configure the electronics, and the incidental materials needed to perform the installation.

[62] A "hot swappable" line card can be removed and reinserted without the entire device being powered down or rebooted. The control cards in the router should maintain all configurations and push them to a replaced line card without the need for reconfirmation.

CPEs are the subscriber's interface to the FTTP network. We estimate that the CPE, including activation and installation, will cost $650 per subscriber.

Each activated subscriber would also require a fiber drop cable installation, which would cost $1,000 to $4,500 per subscriber, depending on the distance of the subscriber's building from the ROW, and the condition of the land.

In total, we estimate an additional cost of $1,870 to $5,370 per subscriber, depending on the length of the fiber drop necessary, and the electronics deployed to support that subscriber.

6.6 Comparison to Other Network Deployment Estimates

The costs to deploy nearly ubiquitous fiber within the County are prohibitive. We cannot project a viable scenario in which the County could recover its investment in the fiber infrastructure and operate the new enterprise with a positive cash flow. The County is not alone in this regard. Indeed, many rural jurisdictions that have pursued ubiquitous or nearly ubiquitous deployments have faced prohibitive costs.

As shown in Table 30, the County averages 9.93 households per square mile, and our FTTP estimates range between $8,300 per passing and $11,900 per passing.

Table 30: Households per Square Mile and Cost per Passing by Survey Area

Survey Area	Resiliency Area(s)	Households per Sq. Mile	Mid-Range Cost per Passing	High-Range Cost per Passing
A	1	13.66	$7,000	$10,000
B	2,3	13.79	$7,000	$10,000
C	4	9.33	$9,000	$13,000
D	5,7,8	1.71	$12,000	$17,000
E	6	14.95	$7,000	$10,000
F	9	6.15	$10,000	$14,000
	Average:	**9.93**	**$8,300**	**$11,900**

We compared these metrics to three other similar deployments, and the County's costs fall on the high- to outlier-side of other similar localities, as shown in Table 31.

Table 31: Passing Density and Estimated Costs Nationwide

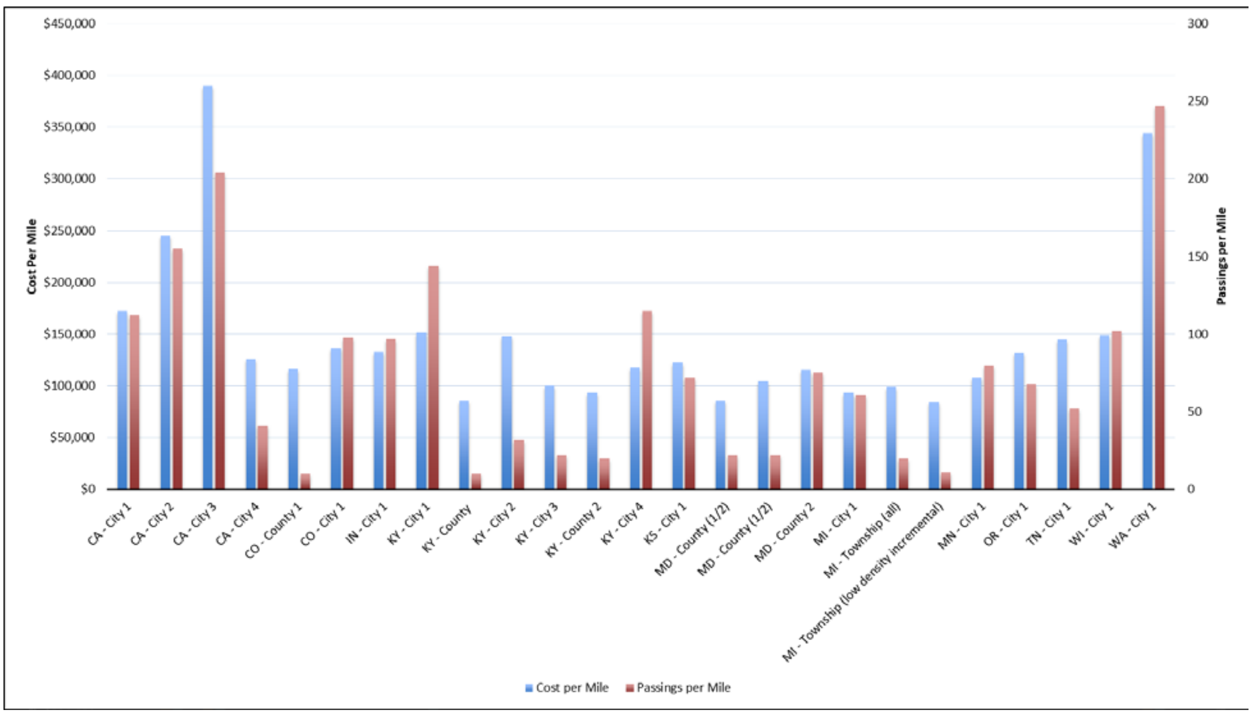
Locality	Total Sq. Mileage	Passings per Sq. Mile	Cost per Passing
Larimer County	1,791	13.66	$8,300 – $11,900
Southern U.S. County	250	18	$9,010
Southern U.S. County	518	47	$4,600
Northern Midwest Township	17	92	$4,900

Although the County is much larger than any of the above deployments, the comparison on a per-passing basis illustrates that the cost of nearly ubiquitous FTTP infrastructure in the County could be well beyond other estimates we have seen.

Further, a compounding concern of deployment is not only the cost to deploy, but also the potential passings a deployment could reach. These passings would generate revenue to operate and maintain the network, as well as recover any initial capital investment in the asset. A low per-mile passing density decreases the chances of the deployer recovering its investment or generating enough revenue to operate the network.

As shown in Figure 110, although the County's cost per mile is on par with many other deployments, its passings per mile is the lowest in our experience. Given this, the County would have an exceptionally hard time generating enough revenue from subscribers to operate the network.

Figure 110: Cost per Mile and Passings per Mile Nationwide



7 Exploring Alternative Technological Solutions

As the County considers potential alternatives to a full-scale FTTP buildout, nontraditional technologies and approaches are likely to be of particular interest. We cannot overstate that the cost to build FTTP, and even backbone and middle-mile fiber, in the County's target areas will be incredibly high. Given this, a prudent next step may be to explore alternative technologies with a lower price tag that might enable improved services for specific areas of the County.

The solutions discussed in this section would require an entity—potentially the County—to deploy a fiber backbone to reach near the unincorporated areas, and then to lease backhaul services to traditional service providers (e.g., WISPs) and other competent organizations that are willing and able to offer service.

Leasing backhaul services to nontraditional groups like homeowner or neighborhood associations and other similar collections of citizens would allow those groups to be active participants in solving their connectivity challenges. While this is a new concept, the technology and business models to support it are being explored and executed worldwide. As the case study below illustrates, this approach has been successfully carried out by a small group of citizens in Washington state.

7.1 Cooperating to Overcome Traditional Barriers, or "Internet in a Box"

The high cost to enter the broadband market for small providers can be extremely challenging, especially for those that aim to serve areas that may not have a quick or complete ROI. In areas where population density is very low, and a substantial investment in expensive network infrastructure and equipment would be necessary to support only a handful of customers, it is often simply not feasible for a traditional provider to increase speeds or upgrade their network.

Enabling and supporting fixed wireless connectivity is an important way that the County might help expand service availability throughout the unincorporated areas. Beyond that, there are emerging new technologies and practices that may bridge gaps in areas where even traditional fixed wireless service is not financially feasible. There may be demand in these areas, but some may be so remote that there simply is not a significant enough ROI to deploy substantial infrastructure and equipment. Moreover, fixed wireless service may rely on only one access point to serve many customers and customers over a long range, which results in diminished service quality, widening the availability gap even further for rural users.

As demand for greater connectivity increases and more private and public entities seek to do more with less, creative solutions to solve connectivity issues are beginning to emerge. Rural WISPs may be limited in their ability to place wireless access points due to limited physical locations that are high enough and rated for wireless connectivity. Even in areas where towers exist, there may be limited backhaul, or the available circuits may be cost prohibitive, as evidenced in our discussions with WISPs in the County.

Common barriers to fixed wireless deployment in rural areas include accessing dependable and robust backhaul, aggregating sufficient demand, and obtaining mounting assets and power for antennas. It is unlikely that larger regional based providers will make an investment in low density rural areas. Even for an innovative provider, the costs make it difficult to even a break-even cash flow, much less obtaining a ROI. Recently, smaller communities have addressed these issues by leveraging their specific circumstances and collective strength to deploy smaller neighborhood networks. That is, provided the community can surmount the traditional obstacles, with the support of a provider such as the County or the local REA, it can deploy the "internet in a box."

In an "internet in a box" deployment, a group of potential customers (e.g., a homeowner or neighborhood association, community group, etc.) would form a broadband entity that can coordinate with a backhaul provider, the owner(s) of potential mounting assets, and an energy provider to obtain affordable connectivity, attachments, and power. From there, using wireless assets purchased from a specialized equipment vendor, such as California-based Mimosa Networks, the community can develop and deploy a network to support its users' needs. We note that Mimosa is not just an equipment vendor—it also provides user-friendly interfaces and front-end management tools to administer and manage the network.

The County, in conjunction with the REA, might be able to assist communities looking to employ this type of solution. Indeed, **as a potential backhaul source, with the REA as pole owner and power provider in one, the partnership could use its specific strengths to enable focused and engaged groups (e.g., neighborhoods, homeowners' associations, etc.) in unincorporated areas to facilitate an "internet in a box" deployment.**

If the County can effectively package this concept, it can offer "internet in a box" to grassroot associations or cooperatives throughout unincorporated areas of the County.

7.2 Newly Available 3.5 GHz Spectrum Means New Wireless Service Opportunities

The Citizens Broadband Radio Service (CBRS) is a new band of spectrum being made available by the FCC in the 3.5 GHz range. From a technical perspective, this spectrum will be suitable for a variety of indoor and outdoor uses, from Wi-Fi to long-distance wireless links to LTE service. CBRS is a "semi-licensed" band, meaning that a portion of the spectrum will be reserved for unlicensed, general access use. Note that the FCC has yet to completely authorize the use of CBRS and has not yet auctioned off licenses—so rule changes may affect how CBRS is practically implemented.

7.2.1 Three User Tiers

The 3.5 GHz band (3550–3700 MHz) presents an opportunity for non-traditional wireless providers, such as local governments and small ISPs, to provide wireless broadband service. The proposed FCC rules emphasize flexibility in hopes of encouraging innovative use of the spectrum. They specify two categories of radio devices—one envisioned for indoor use and one envisioned for outdoor use. The available spectrum will be divided among three user tiers: Incumbent users, Priority Access License (PAL) holders, and General Authorized Access (GAA) users.

The incumbent tier will be used to protect existing operators, such as radar systems and fixed satellite systems, from interference. The FCC will define areas around these incumbent users where new users of the 3.5 GHz spectrum may not operate.

Up to seven channels between 3550 and 3650 MHz may be licensed within a single census tract (an area that generally contains 1,200 to 8,000 people, with an optimal size of 4,000); a single PAL entity may acquire up to four. The licenses will last three years and are not renewable.[63] PALs are not restricted to existing wireless providers and may be acquired by any type of entity such as a small business or local government.

The third tier, GAA users, will be able to operate in any channel not reserved for incumbent users or PAL holders. They may also operate opportunistically in unused PAL channels.

Use of the 3.5 GHz band will be governed by a Spectrum Access System (SAS). Devices operating in the 3.5 GHz spectrum must register with the centralized SAS, which will ensure that wireless devices are not operating outside of their licensed channels. Each wireless device must be registered with the SAS. If there is a channel conflict detected within a license area, the SAS will automatically instruct devices operating with a lower-tier license to stop using the channel to avoid interference.

This three-tiered license approach, the limits on the area and duration of each license, and the limit on the number of licenses held by a single entity in each area may open the door for small WISPs and non-traditional wireless operators such as local governments, school and library systems, and other community organizations to provide their own wireless services to the community.

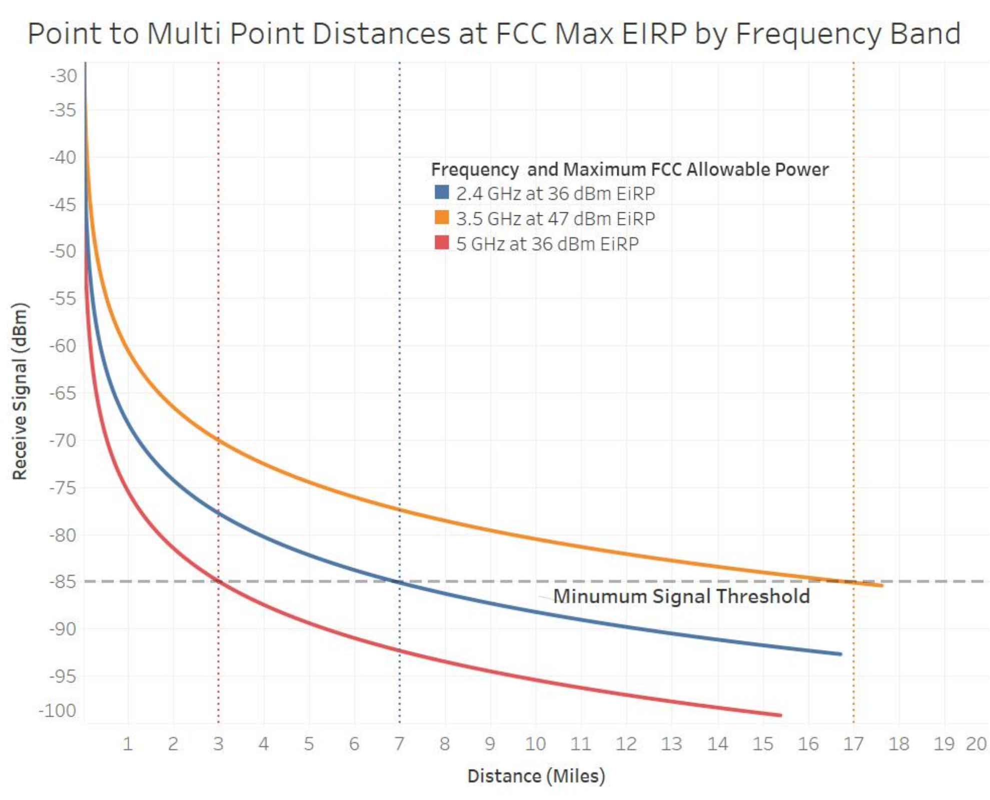
[63] As of January 2018, the FCC is considering requests to expand the size of the license area as well as the duration of the license. *See:* "Google, Starry, NYC face off against big carriers over proposed 3.5 GHz CBRS rule changes." FierceWireless*.* https://www.fiercewireless.com/wireless/google-starry-nyc-face-off-against-big-carriers-over-proposed-3-5-ghz-cbrs-rule-changes (accessed January 2018).

7.2.2 Signal Strength and Propagation

The properties of the 3.5 GHz band make it suited for both outdoor and indoor use. Because wireless signals are significantly impacted by environmental factors such as geography, obstacles, and interference from other radio frequency (RF) sources, wireless coverage must be engineered for a specific service area. However, given certain assumptions about the environment and assuming a minimum signal threshold at which a device will be able to maintain a reasonable connection, we can compare how various wireless bands will perform in a given area.

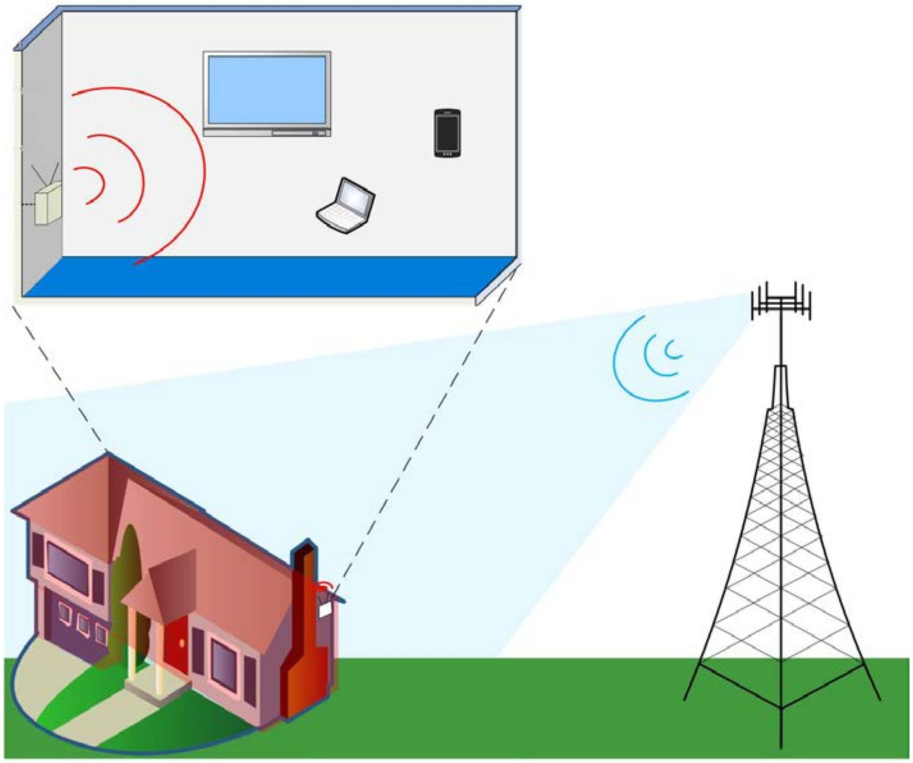
Given high-enough transmit power and a lack of obstacles, an omnidirectional antenna (such as a Wi-Fi hotspot) could provide reasonable service up to one-quarter mile from the transmitter. At the transmit power level currently allowed by the FCC for outdoor use (47 dBm EIRP), a point-to-multipoint antenna, such as those used by WISPs, may be able to reach customers over 17 miles away.

Figure 111: Distances the 3.5 GHz Band May Reach



At these power levels, 3.5 GHz transmitters may be able to provide service at a significantly greater distance than either the 2.4 GHz or 5 GHz bands. As higher-frequency signals are more sensitive to physical obstacles, this wavelength may not be able to penetrate buildings or trees except at close range without a significant reduction in quality of the service. That said, 3.5 GHz may be useful for connecting to outdoor devices, such as traffic controls, externally mounted antennas, or devices such as smartphones and tablets that are being used outdoors where Wi-Fi service may not be available. If manufacturers adopt 3.5 GHz equipment in consumer devices, a WISP may be able to provide wireless internet access in a portion of the County with only a few access points and without the need to install equipment to receive and re-transmit the signal.

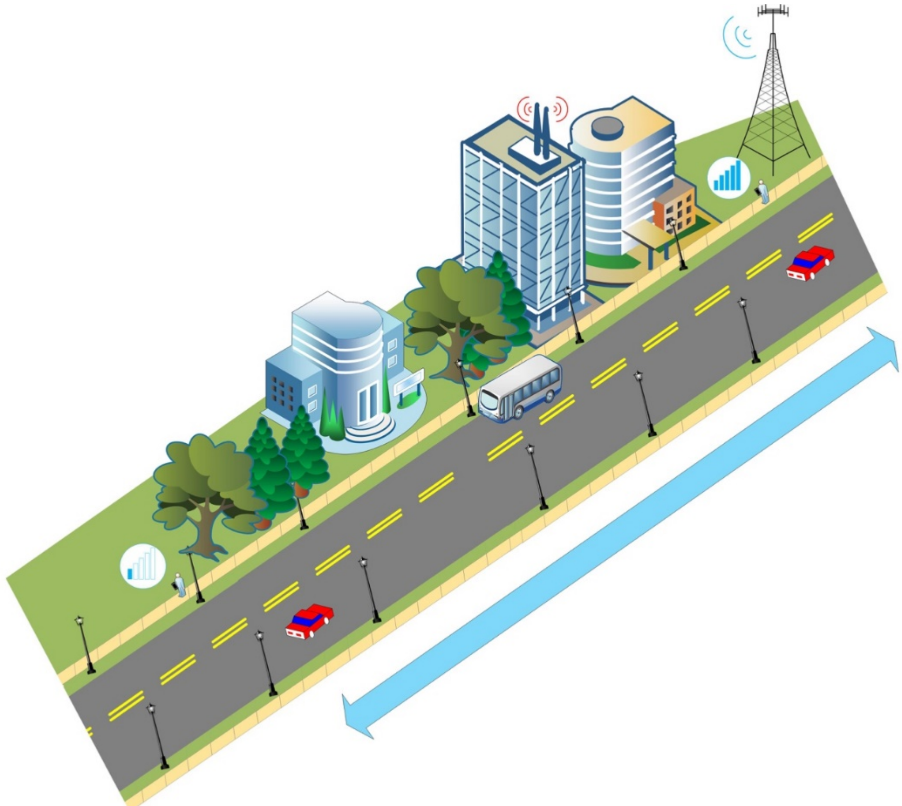
Figure 112: Outdoor Wireless Antenna Can Connect to an Indoor Wi-Fi or DAS Network



The bandwidth provided by the 3.5 GHz band will depend heavily on the equipment deployed, the wireless standard used, the distance of the user from the transmitter, and the RF operating environment. In general, the maximum theoretical speed of a wireless connection increases with the frequency, so a 3.5 GHz service should provide slightly faster speeds than a 2.4 GHz connection, and slightly slower speeds than a 5 GHz connection in a similar environment. That is, speeds in the hundreds of Mbps will be possible.

3.5 GHz services should also experience less interference from other wireless operators in the same area. Unlicensed bands like 2.4 GHz and 5 GHz are more likely to have several transmitters operating in the same area (such as other service providers, home networks, and even cordless phones and other consumer appliances), which can cause interference and reduce the quality of the network service. The amount of interference in a given area may change frequently as devices are turned on and off. Because operation in the 3.5 GHz spectrum is governed by the tiered licensing system and a centralized SAS, interference can be minimized.

Figure 113: Distance and Obstacles Will Impact Wireless Signal Strength



In areas not reserved for incumbent use, the spectrum will be allocated to PAL holders and GAA users. PALs will be distributed by auction as 10 MHz channels within a census tract.

7.3 WIDOX 3.1

An additional emerging technology is Advintive's WIDOX 3.1, a wireless alternative that is built on a cable DOCSIS platform and can provide "cable-like" service to extremely remote areas. WIDOX may be especially useful in rural areas that are traditionally difficult to serve, and that will be extremely expensive on a per-passing basis to serve with FTTP (e.g., survey areas C, D, and F). Like traditional wireless service, WIDOX 3.1 can offer an alternative solution in areas where wireline infrastructure may be complicated or expensive to build. But unlike traditional wireless service, Advintive claims that its WIDOX 3.1 solution "provides five times greater wireless coverage than MiLTE."[64]

[64] For more information on MiLTE, please see: http://www.advintive.com:80/technology/widox-3-1/overview, (Accessed November, 2018).

While WIDOX 3.1 is an emerging technology and significant data to support Advintive's claims do not yet exist, it appears that the WIDOX 3.1 hardware may support data, voice, and video services in rural areas. Using a combination of DOCSIS technology—it will work with both 3.0 and 3.1 protocols—and full spectrum UHF wireless technology, WIDOX 3.1 can serve about a 20-mile radius, and even further in certain cases, depending on the terrain and other issues like tree cover. WIDOX 3.1 can function in near line-of-sight. Unlike technologies that require clear line-of-sight, near line-of-sight means that small buildings and foliage will not impede the signal. This could make WIDOX 3.1 a very promising solution for areas like survey areas C, D, and F where the target service areas are large and sparsely populated.

Advintive also claims that WIDOX 3.1 hardware offers low-latency service[65] at speeds of up to 27 Mbps download and 10 Mbps upload speeds per channel. Given the County's available spectrum, multiple channels could be bonded to enable higher speeds in areas where the spectrum is available. One unique factor that sets WIDOX 3.1 apart is that it can offer these speeds all the way to the edge of the service area without the significant signal loss that characterizes some wireless solutions. According to Advintive, "All subscribers receive the same high data rate regardless of distance from the base station within the service area."[66]

As with all wireless service, WIDOX 3.1 requires wireline backhaul to the tower, as well as a power source at the tower. Advintive recommends that, at a minimum, the height of the top of the tower infrastructure be at least 100 feet above the service area for that tower. The County may be able to encourage the private sector to explore WIDOX 3.1 technology to support service to its target areas, especially those in the hardest-to-reach areas. If the County can provide tower infrastructure (or access to land where towers can be constructed), backhaul connectivity, and access to power, the private sector could potentially license the necessary UHF frequency to deploy a WIDOX 3.1 solution in targeted portions of the County.

7.4 Case Study: Doe Bay Internet Users Association

Living on the eastern edge of an island in the middle of Puget Sound, residents of Doe Bay, WA, were limited to DSL as their only wireline internet option—and all the DSL providers depended on CenturyLink's copper wires, which offered speeds well below the FCC's definition of

[65] WIDOX 3.1 latency is 10 to 15 milliseconds, see: http://www.advintive.com/technology/widox-3-1/widox-3-1-faqs/ (Accessed November, 2018).

[66] "WIDOX 3.1 FAQs", *Advintive*, available: http://www.advintive.com/technology/widox-3-1/widox-3-1-faqs/ (Accessed November, 2018).

broadband and were prone to extended outages. In late 2013, all services that depended on CenturyLink went out for ten days due to a severed underwater cable.[67]

Around this time, the community began looking for ways to improve its broadband options. When it became clear that no ISPs were willing to make the investment necessary to enable better service, they decided they could solve the problem themselves. They formed a nonprofit—the Doe Bay Internet Users Association (DBIUA)—and took it upon themselves to design, build, operate, and maintain a wireless network that would meet the broadband needs of their community. The network began providing wireless service to members in June 2014; by December of that year, members were reporting some of the fastest download speeds on the island.[68]

Today, DBIUA has grown to more than 60 members. They paid back their initial start-up loan a year early, purchased back-up equipment for when their radios fail, and still have been able to lower the rates members pay for service.[69] A core group of members volunteer most of the labor necessary to deploy, maintain and upgrade the network. The network provides download and upload speeds ranging from 5 Mbps to 50 Mbps, depending on where a user is on the network and the overall number of users. Unlike all other providers available at the time it launched, DBIUA offered users symmetrical throughput[70] with no data caps or throttling.[71] Though maintaining a wireless network requires a fair amount of ongoing monitoring and maintenance, DBIUA has proven that a dedicated group of neighbors can steward its own last-mile wireless network as well as any private ISP.

7.4.1 Spreading a Wholesale Connection Across a Community

No one in the group is a professional network engineer, but Chris Sutton, one of the founding members, is a software developer with experience in server and network management.[72] His experience has been instrumental in getting the network set up and troubleshooting problems

[67] Brodkin, Jon. "How a Group of Neighbors Created Their Own Internet Service." ArsTechnica. http://www.arstechnica.com/information-technology/2015/11/how-a-group-of-neighbors-created-their-own-internet-service/ (accessed July 23, 2018).

[68] Doe Bay Internet Users Association. "Fastest Internet Speeds on Orcas." http://dbiua.org/2014/12/21/fastest-internet-speeds-on-orcas/ (accessed July 23, 2018).

[69] Doe Bay Internet Users Association. "Growing and Costs Going Down!" DBIUA. http://dbiua.org/2016/02/04/growing-and-costs-going-down/ (accessed July 23, 2018).

[70] Doe Bay Internet Users Association. "Symmetrical Throughput." DBIUA. http://dbiua.org/symmetrical-throughput/ (accessed July 23, 2018).

[71] Doe Bay Internet Users Association. "An Un Throttled Experiment." DBIUA. http://dbiua.org/2016/02/10/an-un-throttled-experiment/ (accessed July 23, 2018).

[72] Brodkin, Jon. "How a Group of Neighbors Created Their Own Internet Service." ArsTechnica. http://arstechnica.com/information-technology/2015/11/how-a-group-of-neighbors-created-their-own-internet-service/ (accessed July 23, 2018).

that arise. He documents DBIUA's success and failures and provides a detailed technical description of the network on DBIUA's website.[73]

DBIUA purchases wholesale internet connections from two providers and distributes the connection to members' households using a variety of wireless radios. Initially, no wired providers were willing to offer an affordable wholesale rate for backhaul to the internet, but wireless towers on the mainland are just 10 miles from Doe Bay. DBIUA was able to purchase a licensed microwave connection from Bellingham-based StarTouch for $11,000. The microwave connection comes in to a 50-foot water tower, the only structure tall enough to serve as a point-to-point link to a tower on the mainland.[74] In 2016, they negotiated an additional wired connection for $900 a month from Rock Island Communications, an ISP owned by the local electric cooperative.[75] Their network gateway now divides traffic across these two connections.[76]

At the base of the water tower is a Cisco switch that connects back to three radios on top of the tower; those radios distribute the connection to more than 200 additional radios located in trees, on poles, and on members' rooftops. They use a combination of point-to-point and point-to-multipoint Ubiquiti rocket radios (though some have now been upgraded to Ubiquiti Iso and Prism Stations).

Almost all of the radios operate in the unlicensed 5.8 GHz and 900 MHz bands, with the exception of one radio that uses the 3.65 GHz band.[77] The mountainous terrain and towering trees pose a serious challenge to signal propagation, and the group lacked the funds to build wireless towers, so they used a drone to determine which trees had the clearest line of sight to the previous network node. They then hired tree climbers to install radios in trees with the best views.

Ubiquiti NanoStations receive the signal close to members' homes[78] and Ubiquiti airRouters bring the signal into the home and create a Wi-Fi network for end users.[79] Sutton explains that at the outset, the group decided on one equipment vendor, and he does not regret his decision

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[73] Doe Bay Internet Users Association. "Technical Details." DBIUA. https://dbiua.org/technical-details/ (accessed August 20, 2018).
[74] Brodkin, Jon. "How a Group of Neighbors Created Their Own Internet Service." ArsTechnica. http://arstechnica.com/information-technology/2015/11/how-a-group-of-neighbors-created-their-own-internet-service/ (accessed July 23, 2018).
[75] Initially, Rock Island refused to provide them with a wholesale rate because it did not believe they were an ISP.
[76] Doe Bay Internet Users Association. "Net Neutrality." DBIUA. http://dbiua.org/2017/12/15/net-neutrality/ (accessed July 23, 2018).
[77] Doe Bay Internet Users Association. "Radios We Use." DBIUA. http://dbiua.org/2016/02/29/radios-we-use/ (accessed July 23, 2018).
[78] Doe Bay Internet Users Association. "Radios We Use." DBIUA. http://dbiua.org/2016/02/29/radios-we-use/ (accessed July 23, 2018).
[79] Doe Bay Internet Users Association. "My Favorite Ubiquity Wifi Router." DBIUA. http://dbiua.org/2016/02/18/my-favorite-ubiquity-wifi-router/ (accessed July 23, 2018).

to use Ubiquiti equipment. However, now that they are more financially stable, he has switched to more reliable (but more difficult to configure) Cisco edge routers.[80]

7.4.2 Network Expands and Rates Fall

The idea for the network came from a small group of neighbors who realized a microwave connection was their only option for better broadband but could not afford the connection on their own. They brought the idea to a local potluck and found plenty of neighbors desperate for an alternative to DSL. They put together a budget and estimated they would need roughly $25,000 to cover the capital cost of equipment and the installation of the microwave receiver. To pay back a $25,000 loan in three years and cover the ongoing bandwidth costs, they needed to find 23 households willing to pay $75 per month, plus $125 in equipment fees.

They were the only ISP in the area offering broadband without data caps, so demand for their service was intense. As more neighbors signed up, they were able to use new members' properties to place more relay points and extend the signal to additional areas. Members were happy to let DBIUA install radios in well-positioned trees, open fields and rooftops to help them connect additional neighbors.

By early 2016, DBIUA had grown to more than 60 members. This left DBIUA flush with enough cash to pay back its loan a year early, add an additional backhaul connection from a local wired provider, buy back-up equipment, and create a healthy reserve fund.[81]

When they still had excess cash, they decided to lower their rates. Instead of dropping their rate outright, they took a phased approach where the price members pay decreases the longer they are members. For the first 18 months, new members pay $75 a month. Then the price drops to $65 for six months, and then $55 for six months, bottoming out at $45 a month for members who have been with DBIUA for three years or more.[82]

Even with this new pricing structure, DBIUA continues to build up its reserve funds, so in June 2017, it had its first "No Fee" month, during which members were not charged for service.[83]

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[80] Doe Bay Internet Users Association. "Ubiquity vs Cisco." DBIUA. http://dbiua.org/2016/01/28/ubiquity-vs-cisco/ (accessed July 23, 2018).
[81] Doe Bay Internet Users Association. "Orcas Internet Options." DBIUA. http://dbiua.org/2016/01/30/orcas-internet-options/ (accessed July 23, 2018).
[82] Doe Bay Internet Users Association. "Orcas Internet Options." DBIUA. http://dbiua.org/2016/01/30/orcas-internet-options/ (accessed July 23, 2018).
[83] Doe Bay Internet Users Association. "No Fee Month." DBIUA. http://dbiua.org/2017/05/09/no-fee-month/ (accessed July 23, 2018).

7.4.3 The Challenges of Having No One to Call When Something Goes Wrong

DBIUA consistently provides a faster and more reliable connection than CenturyLink but keeping a wireless network humming along through rough Pacific Northwest winters is not without its challenges. Atmospheric conditions can reduce signal strength and slow the bitrate, and sometimes users experience outages.

Sutton generally leads the task of troubleshooting and shares his finding on the group's website. He uses Nagios, an open source network watchdog program, to monitor the network and Cacti, an open source data logging program, to record uptime, ping time, signal strength, noise, bitrate, and bandwidth every five minutes. These programs provide valuable information when a member reports a problem.[84] DBIUA has also begun experimenting with adding Raspberry Pi computers to access point equipment boxes to monitor battery voltage and run speed tests to help predict outages before they occur.

Many of the problems stems from a radio losing power. Sometimes they just need to ask another member to flip the breaker in their breaker box. Other times someone needs to adjust or re-crimp a power cable. Early on, they learned the limits of how many radios can be daisy chained together off a single Power over Ethernet (POE) cable.[85] They also learned how to factor in line loss when carrying power over longer distances.[86]

The most dramatic form of network failure is radios becoming dislodged from the tree, which happened for the first time this past winter.[87] They diagnosed the problem themselves with a drone, but fixing it required professional tree climbers and good weather for tree climbing, which is in short supply on Orcas Island in the winter. When an important relay point failed high up in a tree in the midst of bad weather, they added an additional radio to another site and modified the network to make sure everyone had some coverage while they waited for a clear day for a tree climber to reinstall the radio. Without access to towers, bucket trucks and line crews, DBIUA members are somewhat at the mercy of the weather.

7.4.4 Limits of a Volunteer-Run Organization

A large part of DBIUA's success stems from the dedicated volunteer labor of a core group of members. Chris Sutton has been instrumental as a technical advisor, and many members lend a

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[84] Doe Bay Internet Users Association. "Troubleshooting." DBIUA. http://dbiua.org/2016/03/30/troubleshooting/ (accessed July 12, 2018).
[85] Doe Bay Internet Users Association. "Troubleshooting." DBIUA. http://dbiua.org/2016/03/30/troubleshooting/ (accessed July 12, 2018).
[86] Doe Bay Internet Users Association. "Line Loss." DBIUA. http://dbiua.org/2016/03/30/line-loss/ (accessed July 12, 2018).
[87] Doe Bay Internet Users Association. "Rough Winter." DBIUA. http://dbiua.org/2018/02/28/rough-winter/ (accessed July 12, 2018).

hand to install and maintain the radios. Administrative burdens are minimal thanks to software Sutton adapted that keeps track of the radios and automatically bills members' credit cards each month.[88]

Still, relying on volunteer labor has its limits. The members with the technical knowledge to install and maintain radios have a limited amount of spare time they can dedicate to this project, and the network has reached a point of complexity where simply maintaining it could be a part-time job. The group decided to stop taking new members in October 2016, partially because another ISP began offering fixed LTE service in the neighborhood. However, Sutton also cited not having enough time to complete additional installations.[89]

Instead of expanding, DBIUA is refining its existing network. It continues to deliver symmetrical broadband service to its members on a remote island at a price even many large urban ISPs cannot beat. They have backup equipment and a growing reserve fund. Rock Island and T-Mobile are entering the market but can hardly compete with unlimited service and no data caps for $45 per month. DBIUA has found a sustainable business model, as long as the volunteer labor does not dry up. The group is proof that a dedicated group of neighbors with some technical knowledge can solve the challenge of providing last-mile connectivity with their own ingenuity and hard work.

[88] Doe Bay Internet Users Association. "Billing System." DBIUA. http://dbiua.org/2016/04/28/billing-system/ (accessed July 12, 2018).
[89] Doe Bay Internet Users Association. "No New Members." DBIUA. http://dbiua.org/2016/10/06/no-new-members/ (accessed July 12, 2018).

Appendix A – Residential Survey

This Appendix is included as a separate PDF attachment.

Appendix B – Maps of Selected Survey Responses

The maps included in this Appendix illustrate the location of various responses. For clarity, responses have been shifted so that each response data point is visible. As such, the locations of each response are not accurate to scale, rather, they illustrate the general area of each response.

Figure 114: Internet Adoption in Larimer County

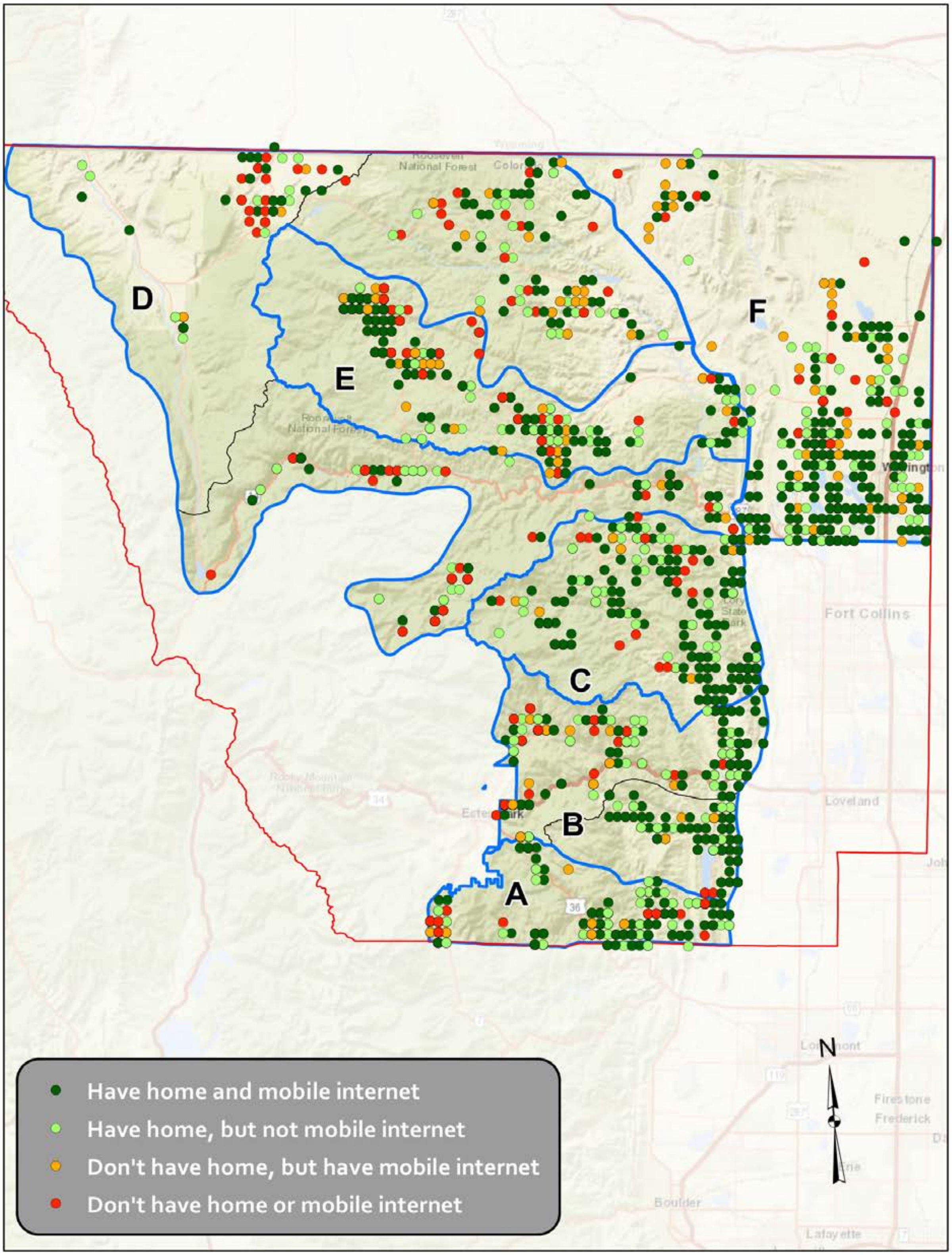


Figure 115: Primary Internet Technology in Larimer County

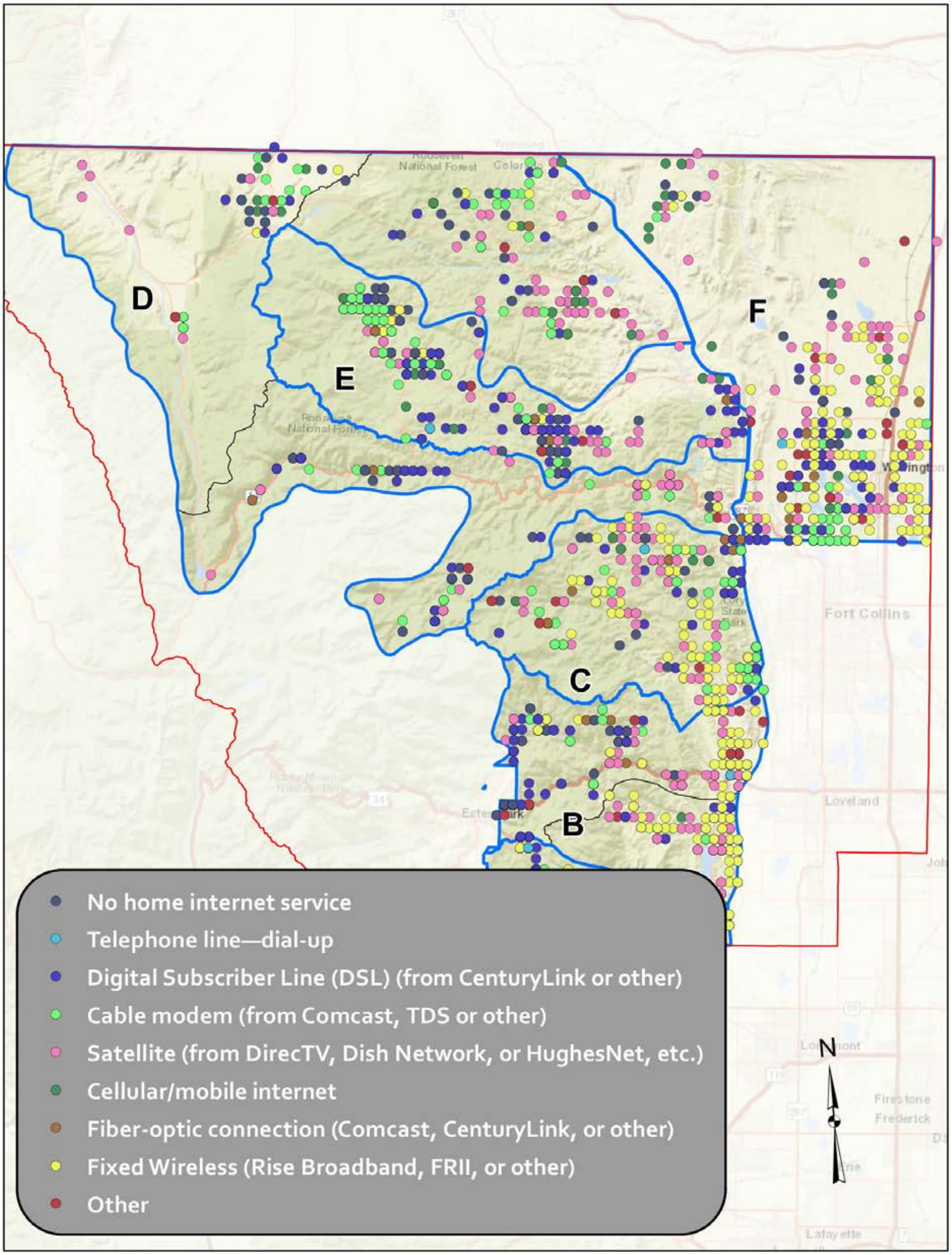


Figure 116: Reason for Not Subscribing to Internet in Larimer County

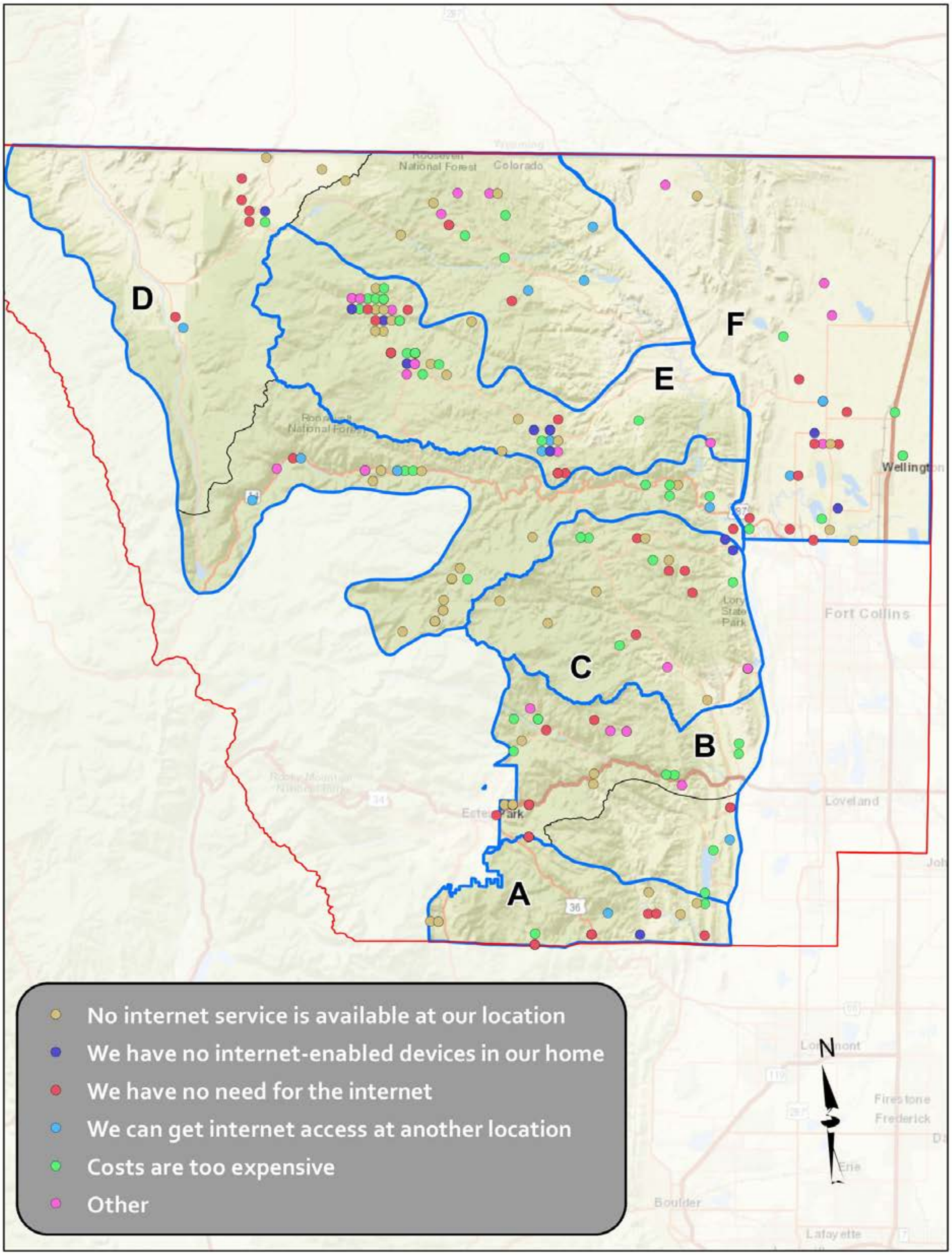


Figure 117: Agreement that Larimer County Should Help Ensure that All Residents Have Access to Competitively Priced Broadband Internet Services

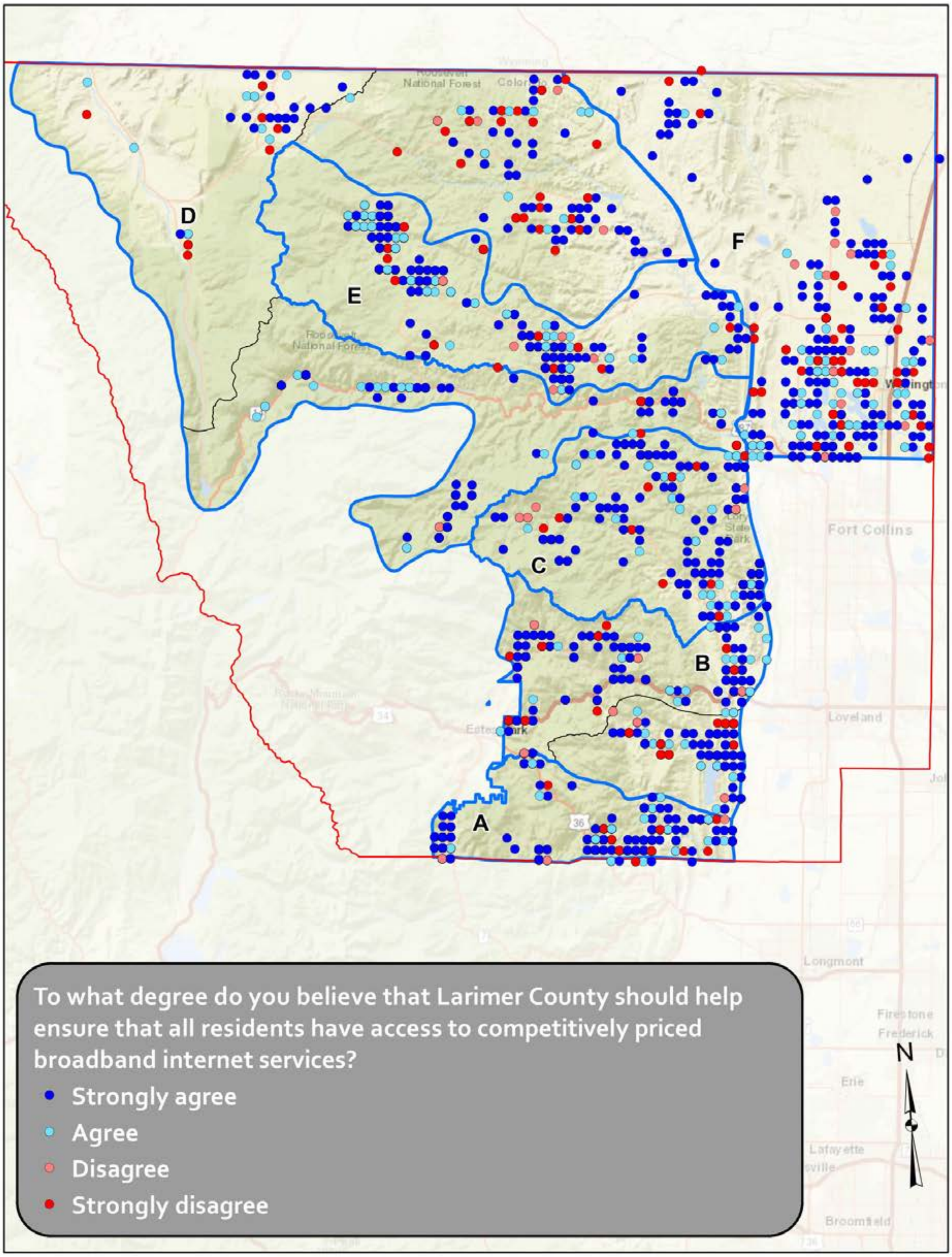


Figure 118: Agreement that Larimer County Should Help Ensure that All Students and Teachers Have Access to Competitively Priced Broadband Internet in Their Homes

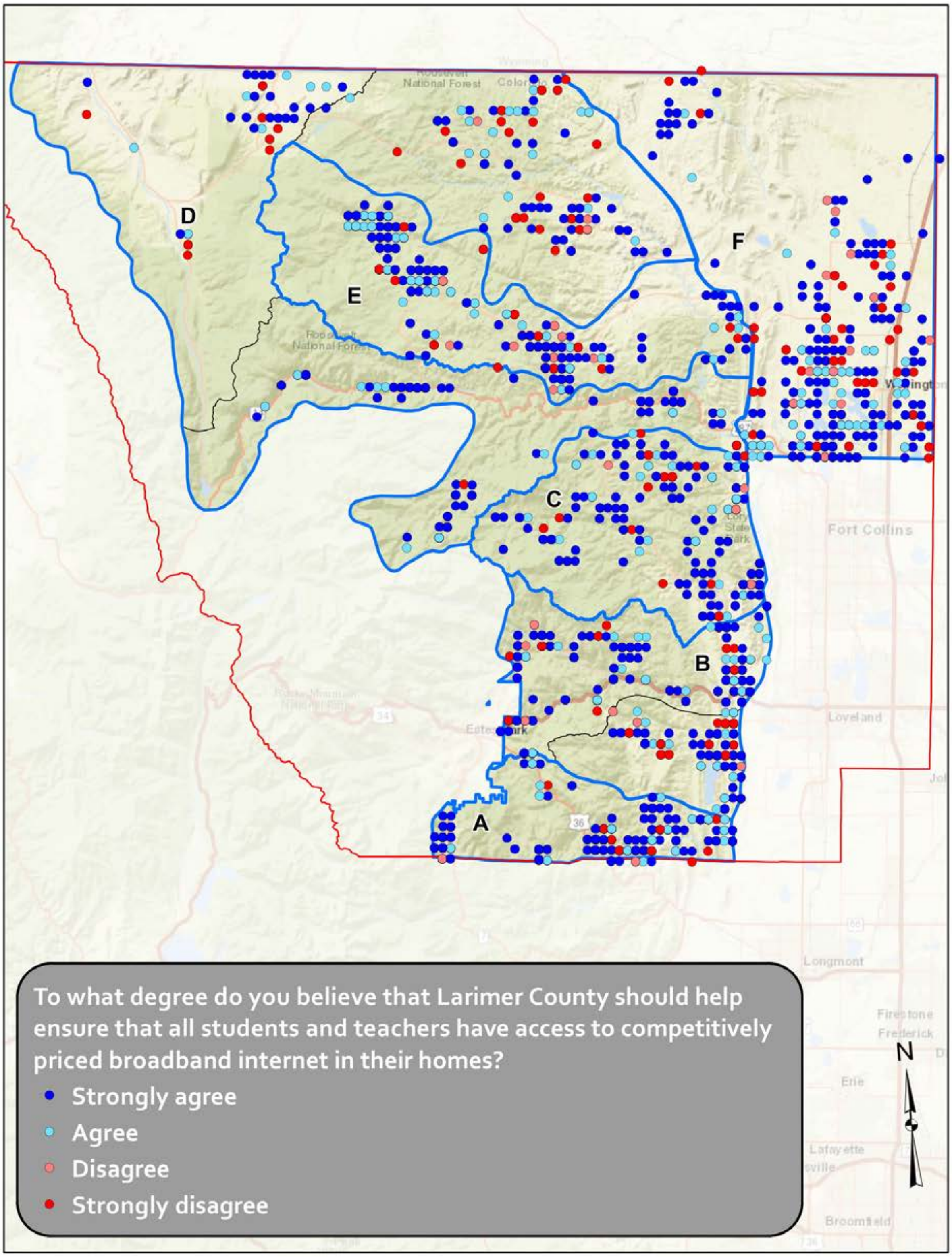


Figure 119: Agreement that Larimer County Should Build a Publicly Financed Network on which Competing Private Sector Companies Can Offer Competitive Internet, Phone, and Cable Television Services

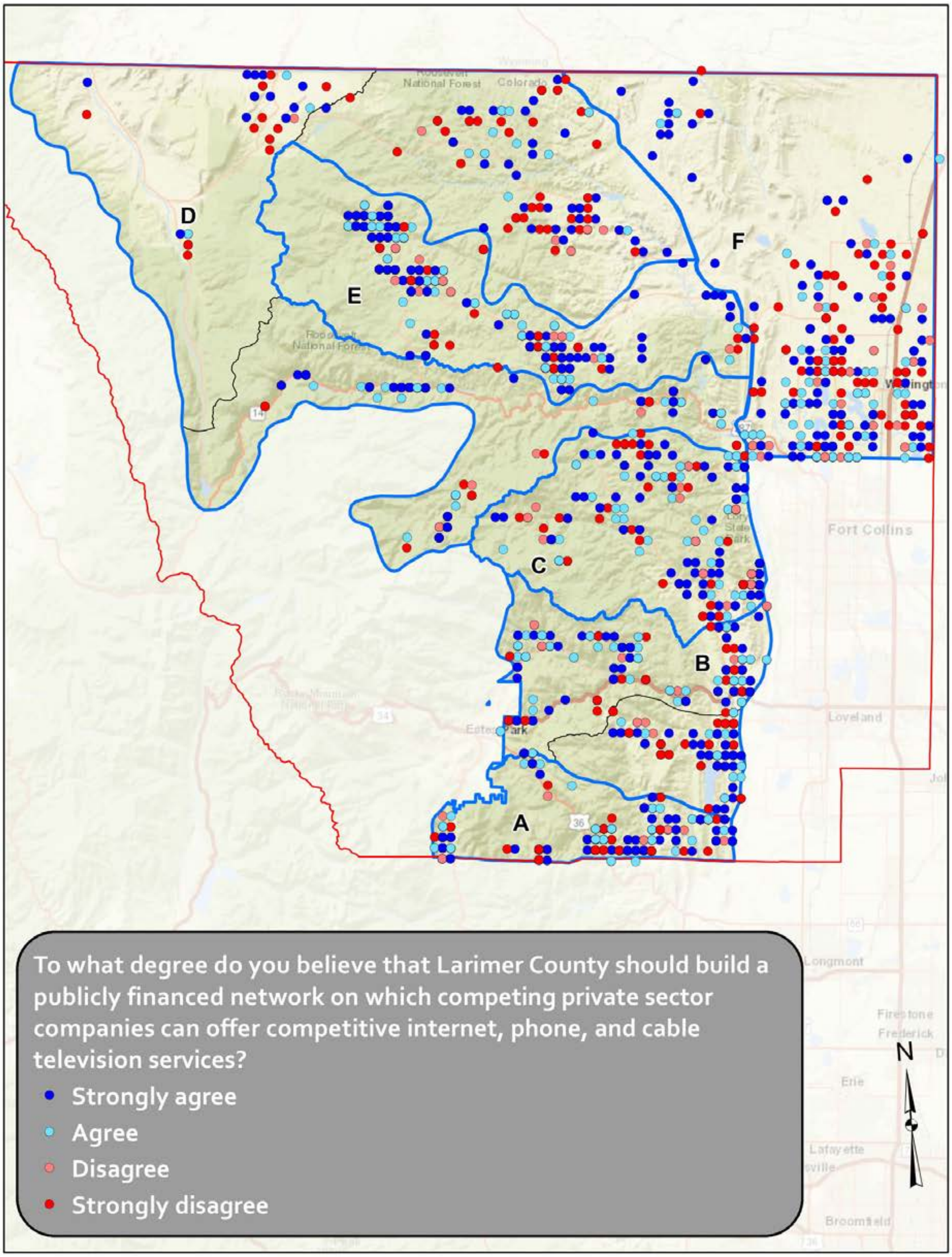


Figure 120: Agreement that Larimer County Should Build a Publicly Financed Network for the County to Offer Internet, Phone, and Cable Services to the Public

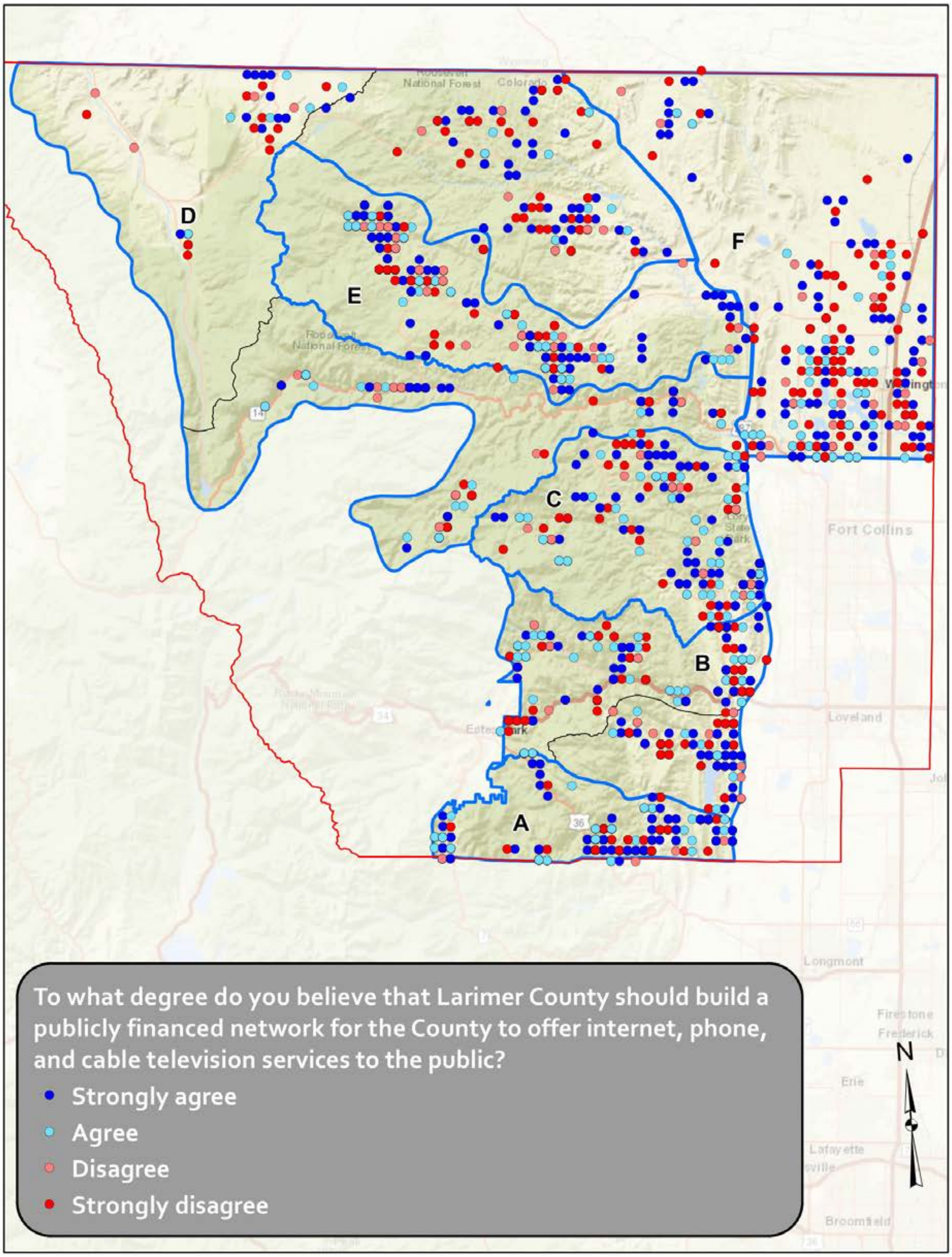


Figure 121: Belief that the Market Currently Offers High-Speed Internet at Affordable Prices

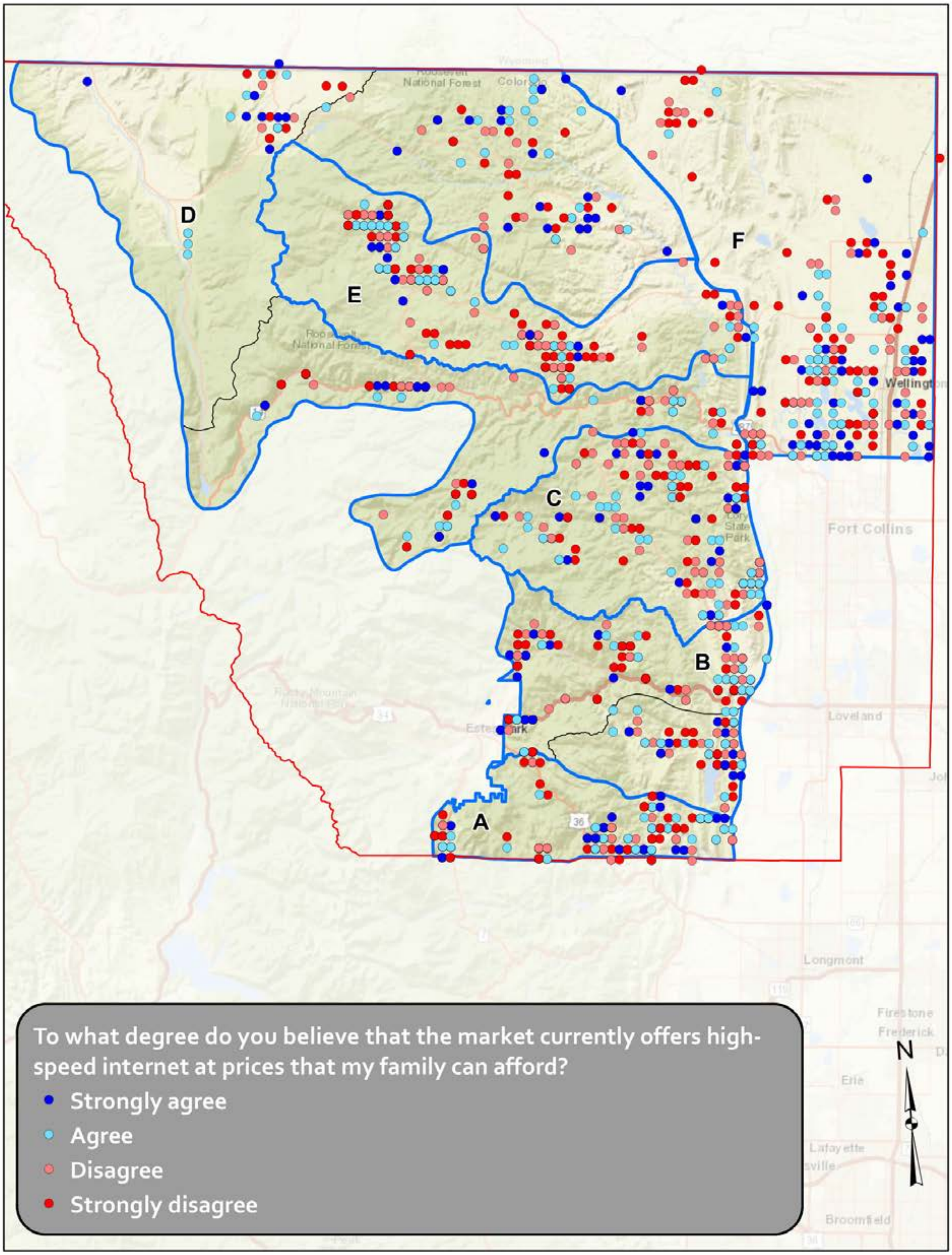


Figure 122: Belief that the Availability of Competitively Priced High-Speed Internet Is a Factor to Consider When Choosing Where to Live

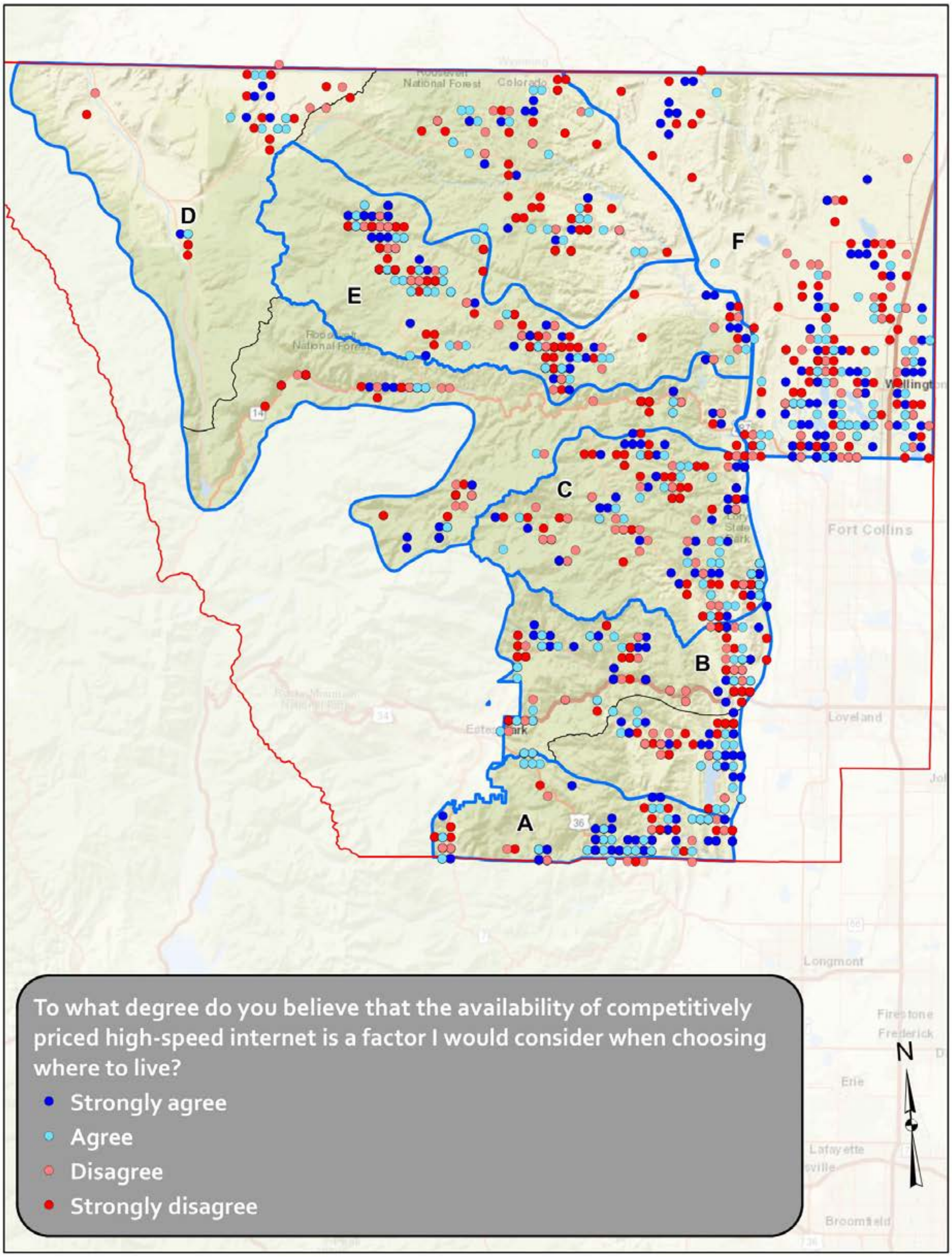
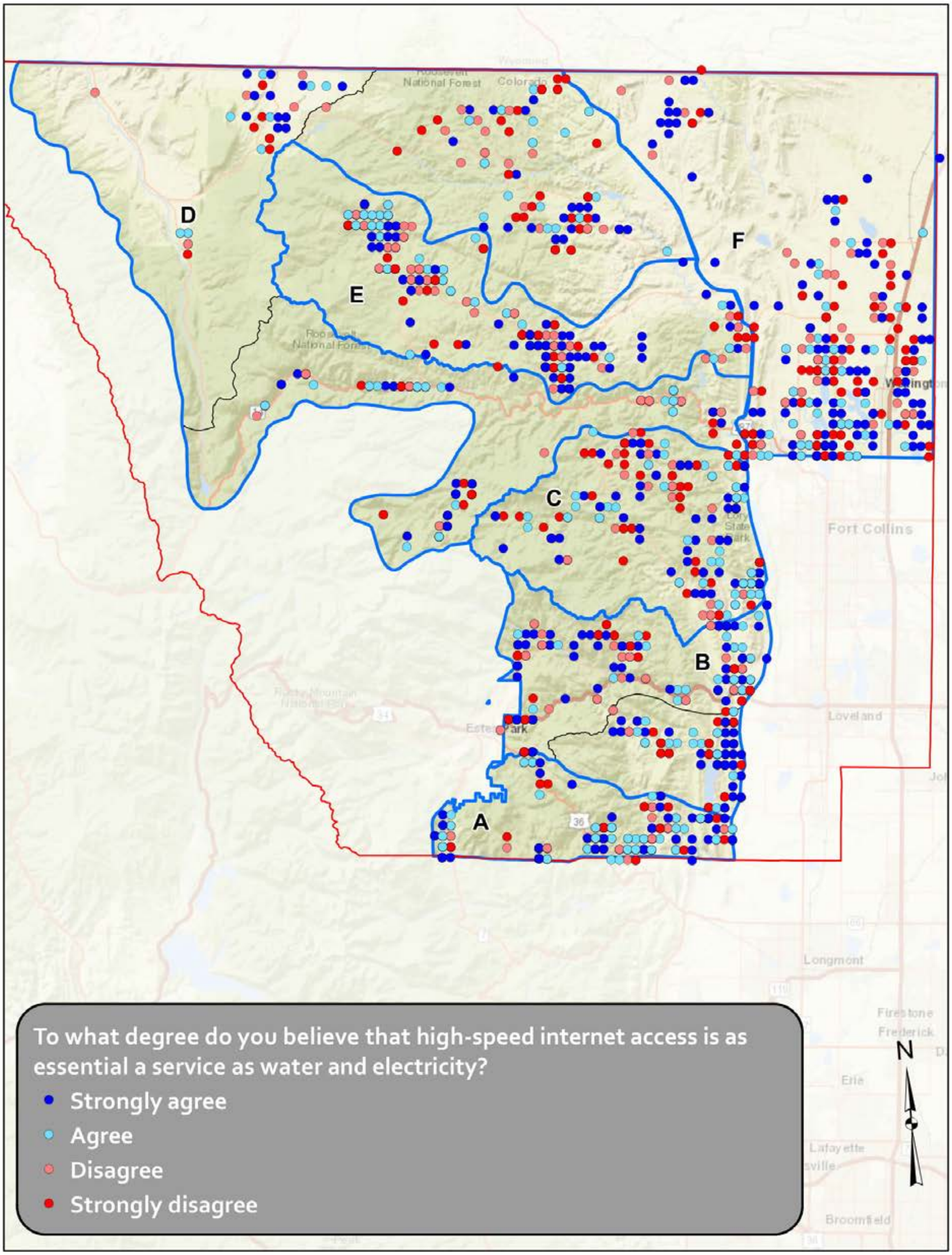


Figure 123: Belief that High-Speed Internet Access Is as Essential a Service as Water and Electricity



Appendix C – GIS Mapping Tool

This Appendix was delivered to the County as a .mpk file in September 2018.

Appendix D – Dig Once Policy

As the County considers options for improving access to broadband throughout the community, one of the primary challenges associated with any scenario it may pursue involves the high cost of installing underground conduit for running fiber.

By encouraging coordination and incentivizing efforts between the County and the private sector when excavating the PROW, as well as making optimal use of County road and utility projects—an approach referred to as "Dig Once"—the County can protect the PROW, minimize disruptions associated with construction projects, and in many cases significantly reduce the costs typically associated with the installation of utilities and conduit. In addition, once the PROW becomes crowded, the options for future construction are reduced, leaving only less-desirable methods and more costly locations for construction of additional infrastructure; Dig Once may alleviate that concern.

A Dig Once approach is also beneficial to the County in greenfield deployments to reduce construction costs associated with future communications facilities. This is a key consideration as the County continues to expand and new developments and roads are constructed.

Benefits of Dig Once

Dig Once policies reduce the long-term cost of building communications facilities by capitalizing on significant economies of scale through:

1. Coordination of fiber and conduit construction with utility construction and other scheduled disruptive activities in the PROW, such as road, sewer, or sidewalk construction
2. Construction of spare conduit capacity where multiple service providers or entities may require infrastructure

These economies of scale exist because fiber optic cables and conduit are relatively inexpensive, often contributing less than one-quarter of the total cost of new construction. While material costs typically fall well below $40,000 per mile (even for large cables containing hundreds of fiber strands), the costs of labor, permitting, and engineering commonly drive the total fiber construction price toward $200,000 per mile for standalone projects, especially in mountainous terrain and metropolitan areas.

Dig Once opportunities reduce the cost of a fiber optic build to support connectivity to government facilities and institutions, or last-mile construction to homes and businesses. And, if private sector providers lease space in County infrastructure to deliver high-speed wired or wireless broadband services, the leases can create a long-term revenue stream for the County.

Besides reducing overall costs of all underground work in the PROW, both utility- and telecommunications-related, Dig Once policies facilitate private communications network deployment into underserved or hard-to-reach areas. The incremental placement of conduit through a Dig Once policy will help to create additional options for providers. This can promote deployment of broadband service in areas that might not otherwise be justifiable for private sector providers from a cost-benefit perspective.

Dig Once Recommendations for the County

Dig Once efforts have taken many different forms around the country (see examples in Appendix A). Dig Once approaches range from implementing business processes to adopting legislative measures that enforce standards and specifications for additional conduits that can be used by the County or leased to other companies. The business processes might include offering favorable terms in master agreements, such as use of government buildings or properties for hub facilities, or reduced costs for placements on County infrastructure, such as buildings or light poles.

We recommend that the County take the following steps based on our experience developing related ordinances, specifications, and guidelines for other municipalities and in accordance with best practices related to Dig Once policies:

1) Develop a procedure to systematically track and manage construction projects in the PROW, and to create a repository of data on existing infrastructure
2) Prioritize future projects suitable for Dig Once conduit construction, based on a scoring mechanism
3) Develop a standard engineering specification for Dig Once conduit
4) Estimate incremental costs for Dig Once conduit construction during a project's design stage
5) Facilitate coordination with excavators
6) Evaluate Dig Once considerations during new project bids

Transportation and utility projects are immediate opportunities for Dig Once coordination. The County can potentially work in parallel to implement coordination with non-County utilities through filing requirements and timely outreach.

We note, too, that while Dig Once promises many benefits to the County and the public, Dig Once construction is still costly—so the County should strive to implement policies in a cost-effective and useful way. Communication between the County and the companies that would potentially use the conduit is critically important. The County's IT and GIS staff play a key role in tracking infrastructure and sharing information.

In short, a Dig Once approach would seek to create opportunities for collaboration among the County, utility operators, and commercial broadband providers with the goals of:

- Maximizing the usable space with the PROW;
- Reducing cost in areas where there is no PROW and construction must be under the road;
- Reducing disruption to the public associated with new construction;
- Reducing the cost of deploying new broadband infrastructure; and
- Extending the lifespan of roadway and sidewalk surfaces.

Implementing New Policies to Support Infrastructure Development in County Rights-of-Way

The County would benefit from developing a process to track planned, ongoing, and completed excavation in a timely way and for identifying and prioritizing potential projects for County participation through this comprehensive Dig Once policy approach. We also recommend the County develop a way to quickly notify interested parties and to coordinate participation with excavators. The impact on the excavator can be minimized by using a well-defined process that minimizes delays.

Develop a Procedure to Track and Manage Infrastructure

We recommend, at a high level, the following type of procedure. First, the County needs to be aware of its needs for fiber optics and the needs of other potential users. These can be mapped as potential sites, neighborhoods, or corridors of interest based on reporting from County departments and discussions with service providers.

These areas of interest should feed into a prioritization plan. This will enable the County to quickly identify whether a proposed excavation should be part of Dig Once.

The County should take efforts to be aware of excavation as soon as possible. For excavation initiated by the County, opportunities should be reviewed as soon as a department begins planning one. The County could require that any suitably sized or located County projects involving excavation (such as road restoration or sewer installation) that are paid for or overseen by the County should include a default installation of conduit, unless the project lead overseeing the project can demonstrate why such a requirement cannot be met.

For those projects initiated by utilities or communications excavators, there should be regular consultations with those entities to discuss and identify projects long before they are designed and permitted.

To evaluate the best-fit option available for coordinated construction and installation of Dig Once conduit, it will be important for the County to have a mechanism to identify which projects are planned, which have entered construction, what the target dates are, and which projects are completed.

If the County identifies an area as a likely Dig Once opportunity, it should require that the excavator submit plans and incremental cost estimates to the County prior to permitting; the plans would need to include conduit per the Dig Once specifications. The County should review the plans and cost estimates for consistency with Dig Once requirements. If the plans are compliant and the cost estimates reasonable per local costs and industry standards, the project would proceed as proposed; otherwise, the applicant would need to resubmit compliant plans.[90]

After the excavator installs the conduit, the County should inspect the conduit for quality and compliance with the Dig Once requirements. If the conduit is compliant, the excavator would submit as-built information. If the conduit is not compliant, the excavator and the County would negotiate a remedy, and the excavator would perform the negotiated remedy. The County would then re-inspect the conduit; if the conduit is compliant, the excavator would submit the as-built information and request reimbursement.

The excavator's as-built information should include scale plans of the completed project, including:

1. Vertical and horizontal position of conduit and vaults
2. Geographic coordinates for manholes
3. Edge-of-curb (outside edge of ROW) and depth offset measurement every 50 feet
4. Colors, diameters, and materials of conduit

In addition, the excavators responsible for any permitted infrastructure, even if not Dig Once, should be required to submit final design drawings so that the County can maintain an inventory of broadband infrastructure, whether for use by the County or other public entities.

[90] Based on our experience, a typical benchmark range for incremental labor and materials for adding two additional conduit to a four-conduit trench or bore, in the same bank, is approximately 25 percent to 33 percent of the cost of the original four-conduit project. The percentage is likely to be lower if the original project is a larger-scale project, such as a water or sewer project.

This information can be made accessible through a GIS platform along with details on capital improvement projects. The County would need to address potential concerns of sharing proprietary information with competitors, potentially by requiring non-disclosure agreements (NDA) and by controlling access (via credentials) to information shared with the County that other registered parties would not be able to see.

Criteria to Prioritize Projects for Building

Because of the costs associated with conduit engineering and installation, even as part of a Dig Once framework, it is necessary to prioritize construction to ensure that 1) priorities are identified when Dig Once opportunities emerge, and 2) resources are not wasted in designing and building conduit that is unlikely to be used.

For example, some highly rural areas are likely to not need conduit; if conduit is installed there, it may go unused for extended periods of time—and could be damaged or crushed—so any initial cost savings would be lost. Even in mountainous regions without PROW where conduit construction must take place under the roadway—seemingly ideal conditions for Dig Once—construction of conduit may not be worthwhile if the conduit will sit unused.

We observe that the following factors typically result in less useful conduit, based on our experience in a range of Dig Once settings:

- Ability to use utility poles along the same path with a reasonable cost of attachment
- Excavation projects that extend only a short distance, such as for a few blocks
- Excavation projects isolated from other projects and existing fiber and conduit infrastructure
- Excavation projects in parts of low-density rural areas, not in proximity to County facilities, community institutions, or large developments
- Excavation projects that only affect the top layer of the street
- Rural areas where conduit may be forgotten or unused for a long period of time—thus requiring rodding and roping at an additional cost to prepare the conduit for use
- Rural areas where joint use is not feasible and private internet service providers would not have an interest in serving the local community

We also note that the cost of conduit construction is approximately 50 percent higher in Dig Once opportunities where the excavator is not digging a trench, or where the trench cannot be shared or needs to be widened for placement of the Dig Once conduit; these areas have less of a cost benefit than other Dig Once opportunities.

To ensure that Dig Once projects are both financially feasible and consistent with the County's long-term goals, we recommend prioritization based on the following factors:

1. Lack of cost-effective alternatives due to physical constraints in the vicinity—specifically, locations where the build must occur under the road due to limited greenspace primarily in mountainous areas
2. Potential interest in conduit from partners or customers (e.g., government departments, service providers, or developers)
3. Lack of existing locality communications infrastructure in the vicinity
4. Ability to place conduit over long, continuous corridors
5. Proximity of the project to government and community anchor facilities requiring service
6. Lack of capacity on utility poles along the route
7. Low risk to Dig Once communications infrastructure (e.g., electrical and communications conduit in Dig Once construction is in closer proximity to the Dig Once conduit than other types of utilities, making the Dig Once conduit more visible to the excavator and therefore easier to avoid in the event the excavator's conduit needs to be repaired)
8. Limited delays to the installation of critical government communications infrastructure (i.e., the incremental days for Dig Once coordination must not create a public safety risk)
9. Beneficial project cost (i.e., prioritizing projects with lower-than-average costs)
10. Synergies with opportunistic major projects, such as highway, mass transit, or bridge replacement
11. Plans for major PROW crossings, such as railroad, water, highway, or interstate, which often are difficult for private carriers to facilitate or justify
12. Conduit placement for building fiber into key sites, data centers, or facilities deemed potential targets for redevelopment

As opportunities emerge, or as existing opportunities are reviewed, we recommend they be evaluated, scored using the criteria above, and ranked.

Estimation of Incremental Costs

The County needs to understand the incremental costs associated with design and construction of the additional infrastructure to determine whether the project is a good opportunity for Dig Once. We recommend providing exceptions or foregoing the excess conduit construction if the cost-benefit analysis does not show a reasonable outcome.

To assess the costs and benefits, we recommend the County examine both the likely public and institutional need for the conduit, and separately reach out to private sector service providers to determine their interest. If the incremental construction and maintenance cost is less than the estimated benefit over a period of 20 years, the conduit, as a long-term asset, is a good value. It is also important to consider the benefit of reducing damage and disruption to roads and the PROW, and of placing conduit in a compact, efficient place in busy PROW that otherwise would become crowded with each uncoordinated conduit placed in the future.

For cost estimation purposes, the incremental cost is the cost of additional materials (e.g., conduit, vaults, location tape, building materials) and labor (e.g., incremental engineering, incremental design, placement and assembly of incremental conduit, placement of incremental vaults, interconnection, testing, and documentation). The cost does not have to include roadway or sidewalk restoration or paving (which we assume to be part of the original project) beyond that which is required for placing vaults for the County's conduit within paved or concrete surfaces outside of the original project boundaries.

In a trenching project, where trenches are joint, the cost would not include trenching or backfilling. Where the Dig Once trench is separate from the original trench, the incremental cost would include trenching and backfill, but would not include repaving or restoring the road surface (again, assumed to be part of the original project). Average costs may be derived based on multiple contractor pricing schedules. As the County gains experience by participating in projects, it will develop a more accurate sense of cost.

Coordination with Excavators

Coordinating with excavators—potentially through quarterly outreach or filing requirements—is an important best practice, even if only County excavators are engaged. The earlier opportunities are known, the earlier they can be considered for Dig Once. That enables (but does not guarantee) more coordination among excavators, as well as earlier engineering and lower costs.

We recommend the County consider notifying excavators as soon as possible of excavation projects where they may be able to take advantage of joint trenching. A formal timeline, such as a 60-day window for excavators to decide whether and how to participate, will allow a reasonable amount of time for decision-making.

Greenfield Deployments

During the construction of new neighborhoods, particularly in rural areas (or rural areas that are becoming suburban), conduit may be installed as part of backbone routes as well as connections to each individual building on new or expanded roads. The main roads could have a bank of three or more 4-inch conduit, and two 4-inch conduit may be placed along secondary routes. This plan will provide maximum flexibility for future needs.

The construction costs will be substantially lower than a build in which construction will disrupt traffic and commerce and damage streets and sidewalks. In addition, construction in a planned bank will reduce the amount of space used by the conduit, relative to separate builds. The County may wish to have more detailed discussions with potential users of the conduit to optimize the capacity decisions along the various routes.

In greenfield construction, where open ground is available, trenching is probably the most cost-effective choice. We recommend placement under grass parkway (if it exists) between the sidewalk and the road, or under the sidewalk. This will provide greater accessibility in the event of repairs, relative to installation under the road.

Updating the County's Engineering Standards and Specifications to Support Dig Once

If the County seeks to implement a Dig Once policy that requires construction of additional conduit for fiber optic capacity, we recommend it develop standards and specifications to expedite planning and decision-making, which collectively will enable the County to take advantage of opportunities as they emerge. We have provided a sample approach below.

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

1. Capacity—sufficient conduit needs to be installed, and that conduit needs to have sufficient internal diameter, to accommodate future users' cables and to be segmented to enable conduit to be shared or cables added at a future date

2. Segmentation—users need to have the appropriate level of separation from each other for commercial, security, or operational reasons

3. Access—vaults and handholes need to be placed to provide access to conduit and the ability to pull fiber; vaults need to be spaced to minimize the cost of extending conduit to buildings and other facilities that may be served by fiber

4. Costs—materials beyond those that are likely to be needed will add cost, as will the incremental labor to construct them; beyond a certain point, trenches need to be widened or deepened to accommodate conduit
5. Robustness—the materials, construction standards, and placement need to reasonably protect the users' fiber, and not unduly complicate maintenance and repairs
6. Architecture—sweeps, bend radius, and vault sizes need to be appropriate for all potential sizes of fiber

We recommend further discussions with private carriers to better develop a specification. It may also be appropriate to have a different specification for different projects. Based on our knowledge of a range of Dig Once efforts, we believe the following sample approach is suitable for major corridors and can be modified as discussions proceed with excavators in the PROW:

- Two 4-inch spare conduit, minimum SDR 11 HDPE, each of a separate color or unique striping to simplify identification of conduits within vaults and between vaults (in the event conduit must be accessed or repaired at intermediate points); of the two 4-inch conduit, one conduit may be reserved for use by a specific County department and the other for the general use of the County
- Composite vaults sized for the likely number of cables, placed in the sidewalk or available green space within the PROW, as close to the curb, gutter, or outside edge of ROW as possible
- Vaults spaced at intervals of 600 feet or less, typically at intersections (in urban and suburban areas)
- Sweeping conduit bends with a minimum radius of 36 inches to allow cable to be pulled without exceeding pull-tension thresholds when placing high-count fiber cables (e.g., 864-count)
- Conduit placed in the same trench directly above the excavator's infrastructure or, where this is not possible, placed with minimal horizontal offset to minimize cost

Typical drawings contain the recommended standards for depth, bend, location, location tape, and vaults/handholes.

Figure 124 (below) is a typical diagram showing Dig Once coordination with a communications excavator. **Error! Reference source not found.**Figure 125 is a typical diagram showing Dig Once coordination with a water, power or gas excavator, and provides two options—one with Dig Once conduit directly above the utility, and one with Dig Once conduit offset laterally.

Ideally, the Dig Once conduit is placed over the excavator utilities. This reduces or eliminates the need for additional trenching and would incur the lowest incremental cost. With the permission of the utility owner, it may be possible to place the Dig Once conduit directly over the utility conduit (see "Model A" in **Error! Reference source not found.**Figure 125 below). Reducing the clearance between the utility and the Dig Once conduit will reduce or eliminate any incremental excavation to accommodate the Dig Once conduit.

In some scenarios, the conduit may need to be offset horizontally from the utility Infrastructure. This may be the case where the infrastructure is a water pipe that should be offset for ease of maintenance. Offsetting the Dig Once conduit may also reduce the risk of the conduit being damaged by a broken water pipe or by repair to that pipe. "Model B" in **Error! Reference source not found.**Figure 125 depicts a Dig Once scenario in an offset trench.

These scenarios assume that the County has identified a given corridor as suitable for conduit installation, and that it has justified the incremental cost and effort for installation, potentially based on a standard set of criteria.

It is important to note that the above approach is designed to create consistency and predictability in costs and deployment and, of necessity, is a compromise among the potential users. Some users might prefer larger conduit for consistency with earlier builds. Others might seek a larger count of smaller conduit, to provide more flexibility. If an excavation project has a longer time horizon and sufficient budget, it may be possible to customize the Dig Once build, potentially adding conduit or adding vaults at certain locations.

The County can express a willingness to work with the excavator on an approach suited to its project. We also recommend the County be open to a wide range of specifications, such as having additional microduct installed at the time of microtrenching by telecommunications providers.[91] In this case, the County can require the provider to install a County microduct and terminate the County microduct in designated handholes.

We suggest that the County require that all handholes have custom covers for easy identification. Labeling the covers with the owner's name will help reduce problems with locates, repair, and abandonment.

[91] Microtrenching is an increasingly common construction approach in urban and congested areas, especially for installation from the road to premises, or for connection to wireless infrastructure.

Figure 124: Typical Diagram – Dig Once Coordination with a Communications Excavator

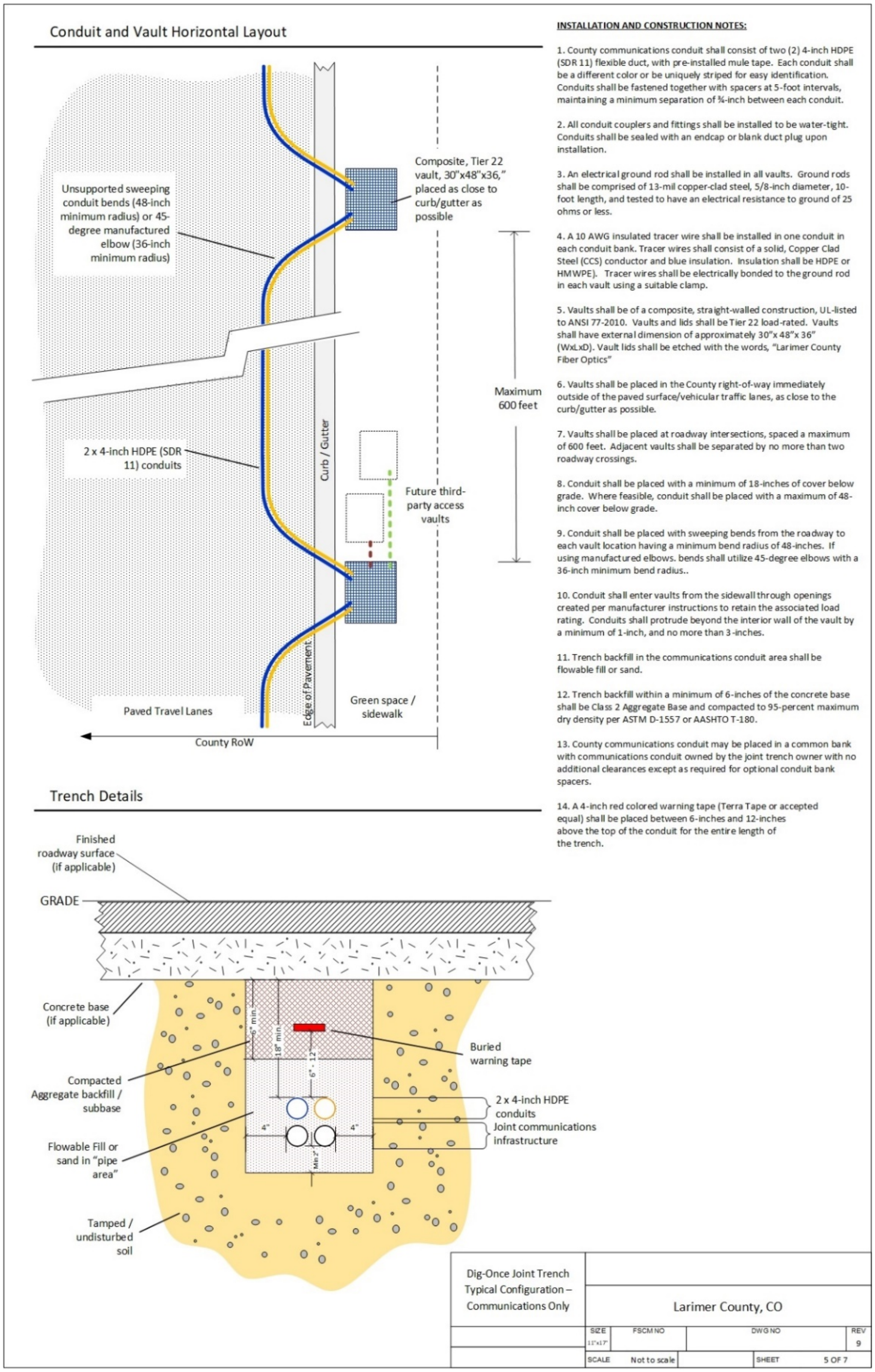


Figure 125: Typical Diagram – Dig Once Coordination with a Water, Power, or Gas, Excavator