GEOGRAPHICAL INFORMATION CENTER
California State University, Chico

City of Redding
Master Broadband Plan

Telecommunications Infrastructure

Draft Version March 2019

City of Redding – Master Broadband Plan

Telecommunications Infrastructure

California State University, Chico

Geographical Information Center

Elaborated by

Jason Schwenkler, Geographical Information Center (GIC) Director

David Espinoza, GIC Broadband Specialist (lead author)

Courtney Farrell, GIC Project Manager

Susan Strachan, GIC Project Manager

Tyler Boyle, Senior GIS Analyst

Alice Patterson, Project Analyst

Cynthia Baricevic, GIS Assistant II

Dan Lucero, Assistant III

Luke Scholl, Technical Editor

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2. Executive Summary

The following Master Broadband Plan for the City of Redding aims to provide a comprehensive assessment of the current landscape of fixed broadband services for residential, business and industrial customers, recommendations for expanding and upgrading broadband infrastructure and services, and recommendations for developing and implementing local government policies which can support broadband infrastructure deployments, and improving broadband service adoption. The broadband assessment includes both fixed wireless and wireline services offered by Internet service providers (ISPs) and uses publicly available data from the California Public Utilities Commission (CPUC) and its Broadband Interactive Map. The recommendations for expanding broadband infrastructure and upgrading services focus on deploying a high-capacity and high-speed fiber-optic backbone to reach areas of interest (i.e., for economic development) in the city. The recommendations for developing and implementing local policies focus on reducing technical and economic barriers for new broadband infrastructure deployments and streamline permit and authorization process in public rights-of-way. The proposed policies also guide incorporating smart city capabilities in the City of Redding. The recommendations for improving broadband adoption include forming partnerships with existing organizations and programs to establish credibility and identifying best practices for outreach, implementation, follow-through and success.

3. Introduction

The City of Redding, founded in 1887, the county seat of Shasta County, is located along the Sacramento River, 162 miles north of Sacramento at the northern end of the Sacramento Valley. Figure 1 shows the location of Redding in California, "The Golden State". The city has a population of 91,236 (2017)[1] and 38,679 housing units (2017)[1] in over 33 square miles.

Relevant demographic statistics of Redding include the following:

- Average household size (2017): 2.43[1]
- Median age (2017): 38.2[1]
- Income per capita (2017): $26,996[1]
- Average household income (2015): $65,392[1]
- Median household income (2017): $46,389[1]

Figure 1. City of Redding location in California and Shasta County

The City of Redding is the center of trade and commerce for the upstate region of Northern California.[2] Redding has received a number of state grants over the last three years that are meant to assist in revitalizing downtown Redding. Among the numerous projects supported by these grants is a new Shasta County Courthouse currently under construction.

Redding has a wide variety of industries, including Sierra Pacific Industries, one of the largest lumber producers in the U.S. Other prominent business in Redding include Seco Manufacturing, and Knauf Fiberglass. Redding is home to Mercy Medical Center, one of the largest employers in all of Shasta County. Redding also has its own municipal electrical utility, the Redding Electric Utility (REU), which provides electric utility services for residential and commercial customers. Shasta County as a whole has a civilian labor force of 75,400 individuals as of 2015. Shasta County's three largest industries by number of employees were the service industry, government, and retail trade. Redding is also home to Mercy Medical Center, a 267-bed hospital that offers some of the most comprehensive health care in Northern

[1] U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates
[2] City of Redding. https://www.cityofredding.org

California. Shasta County is also home to 41 public elementary schools, 8 middle schools, and 15 high schools, as well as Shasta College and Simpson University. Lastly, Redding has a number of parks, an extensive system of trails through natural spaces, as well as the Redding Aquatic Center, which is the largest authorized provider of American Red Cross Learn-to-Swim Program in Shasta County.

Redding Electrical Utility (REU)

Redding is home to the Redding Electric Utility (REU), which provides electric utility services for residential and commercial customers. The REU was founded in 1921 after the utility was purchased from PG&E. In recent years, the REU has made great strides toward including various renewable sources of power including wind generation. The REU serves approximately 44,000 residential and commercial customers within the City of Redding. As of 2017, the REU's mix of power resources consisted of 47% large hydro, 25% natural gas, 23% wind, and 5% small hydro power. The REU also boasts an impressively low number and short duration of outages, less than half that of PG&E. The REU has 726 miles of 12,000 volt power lines, 11 substations, and 2 switchyards that provide power to a service territory of 61 square miles. The presence of the publicly owned REU and its extensive infrastructure, as shown in Figure 2, is a valuable asset that may potentially be leveraged in order to accelerate and reduce costs of future broadband deployments.

Figure 2. Redding Electric Utility infrastructure

The City of Redding is the largest city in the Shasta Cascade region and is the sixth-largest city in the Sacramento Valley and continues growing local businesses as well as attracting new ones. This report aims to provide recommendations for upgrading broadband infrastructure and services in an optimal and cost-efficient manner to continue fostering a modern competitive environment with access to fast and affordable internet services, needed for both residential and business customers.

3.1 Broadband Importance and Applications in Rural Northern California

Education

High-speed access is integral in connecting teachers to students, to parents and to educational resources. The rural digital divide diminishes access to educational opportunities, resources and sources of academic and professional support[3]. Without adequate high-speed connectivity, rural schools and students are challenged to obtain skills and information needed for success. Teachers and administrators also benefit from the capabilities associated with access to high-speed Internet service. Many rural school teachers and administrators cite connectivity limitations as the primary obstacle to effectively using technology in the classroom[4]. Additionally, students may lack broadband (or any) connectivity at home, putting them at a disadvantage when completing assignments that require online access and interaction. As more bandwidth intensive material moves online–such as educational videos, interactive learning tools, and video conferencing tools for teachers–connection speed is quickly becoming a major issue for rural educators[5]. By eliminating these barriers through expanded access, schools can provide curriculums that are currently unavailable due to limited resources or lack of subject-matter experts.

Health Care

The health care sector is emerging as a heavy user of telecommunications services. Improved imaging techniques produce large data files. Moving those files between providers requires substantial capacity. Telecommunications may be a limiting factor for the location of health care services. A location that does not have the telecommunications capacity for efficiently uploading and downloading large imaging files may find providers deciding either not to locate there or limit the services provided there[6]. Telehealth is a care delivery mode that can provide access to specialists for treatment of multiple conditions. It can provide more effective and efficient health care delivery by connecting physicians with physicians and patients with physicians[7]. The evidence for technologies that lower costs, connect remote populations, and expand the reach of urban-centered medical expertise is strong. Access to reliable, sufficient and affordable broadband is increasingly important to providing high-quality health care, and it has become an essential infrastructure need for all hospitals and health systems[8].

Agriculture

Rural broadband planning has historically excluded the importance of fast, reliable Internet access for agricultural areas. The rise of "precision agriculture" combined with increasing interest in the use of "telematics" and "big data" for agriculture, raises the question of how available broadband connectivity

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[3] Howley, C., Kim, K., & Kane, S. (2012, June). Broadband and Rural Education: An Examination of the Challenges, Opportunities, and Support Structures that Impact Broadband and Rural Education.

[4] Ibid.

[5] Ibid.

[6] Kuttner, H. (2012). Broadband for Rural America: Economic Impacts and Economic Opportunities. Broadband for Rural America: Economic Summit on the Future of Rural Telecommunications. Washington, DC.

[7] Kvedar, J. C. (2014, February). Connected Health: A Review of Technologies and Strategies to Improve Patient Care with Telemedicine and Telehealth. Health Affairs, 33(2), 194-199.

[8] Rural Health Information Hub. (2017). *Retrieved from https://www.ruralhealthinfo.org/topics/health-information-technology. Retrieved from https://www.ruralhealthinfo.org/.*

is for U.S. Farms[9]. Simply defined, precision agriculture is the application of information technology to farm-level production operations and management decision making. Precision agriculture also offers opportunities for improved farming efficiency, food safety and enhanced environmental sustainability[10]. Broadband is increasingly becoming the backbone for innovative technological tools farms and ranchers us to maintain greater control over plan and animal production, processing, distribution, and storage resulting in greater efficiencies and lower prices, safer growing conditions, safer foods and reduced environmental and ecological impact.

Manufacturing

According to the National Association of Manufacturers, manufacturers leverage the Internet to compete in global markets, deploy new technologies, connect their workforce and their customers, reduce costs, cut waste, enhance the environment and create safer, more reliable products[11]. Manufacturing establishments in rural areas are involved in a variety of sectors: value-added food production, natural resource processing, infrastructure management and clean-energy facilities. For these industries, adequate broadband service has been documented as necessary for food supply chain management, mining safety and transportation and logistics[12].

Economic Development

Broadband availability is positively related to employment growth. This relationship is stronger in areas with lower population density consistent with the theory that smaller or more isolated areas may benefit more from high-speed connections, giving businesses in these areas access to larger markets[13]. The overall relationship between broadband expansion and employment growth is positive. Moving from no broadband providers to 1-3 providers (the FCC groups 1-3 providers together in its reporting) is associated with employment growth that is higher by 6.4 percentage points over the seven-year period from 1999 to 2006[14]. Available broadband speed is also a factor in economic growth. Research shows that offering the minimum broadband service to all businesses and residents is not enough to close the rural digital divide. Poverty levels are about 2-6 percentage points lower in rural counties with high download speeds compared to otherwise similar counties[15]. There is a causal relationship between broadband adoption in rural areas (defined as county-level adoption rates >60%) and higher levels of median household income growth and reduced unemployment when compared with similar counties that did not meet the threshold)[16].

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[9] Whitacre, B., Gallardo, R., & Strover, S. (2014, June). Broadband's contribution to economic growth in rural areas - Moving towards a causal relationship.

[10] Aubert, B., Schroeder, A., & Grimaudo, J. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology.

[11] National Association of Manufacturers. (2017). Retrieved from www.man.org.

[12] Xu, L., Wu, H., & Shancang, L. (2014, November). Internet of Things in Industries: A Survey. IEEE Transactions on Industrial Informatics, 10(4).

[13] Kolko, J. (2010). *Does Broadband Boost Local Economic Development.* Public Policy Institute of California, San Francisco. Retrieved from http://www.ppic.org/content/pubs/report/r_110jkr.PDF

[14] Ibid.

[15] Whitacre, B., Mark, T., & Griffin, T. (2014). How COnnected are Our Farms. Choices: The Magazine of Food, Farm, and Resources Issues.

[16] Ibid.

Workforce Development

Broadband increases learning opportunities in rural communities through online education. Distance, online, and hybrid instruction provide access to learning for individuals who cannot always be physically present in a traditional classroom setting or who may not be available at the specific times classes are being offered. According to the Pew Research Center[17], 54% of Americans go online to look for job-related information and 45% have applied for a job online. Employers need broadband to access online training and classes to improve their employees' skills. Many businesses do not have the budgets to send employees to professional development or are too small to send an employee away from operations. Bringing professional development in-house eliminates those challenges.

Tribal Communities

American Community Survey data shows that residents of tribal lands often lack basic infrastructure and telecommunications services. Tribal lands are among the most underserved areas in terms of broadband service, often due to remote and challenging terrain, low incomes, lack of expertise with telecommunications and barriers associated with bureaucratic government programs (U.S. Government Accountability Office, 2016)[18] (Morran, 2016). As a result, the economic, educational and communication benefits associated with broadband are largely absent for most people living on tribal lands (Broadband for Tribal, n.d.).

Emergency Services

Scarcity of broadband capacity in rural areas limits emergency services' communication capacities and response capabilities. Cutting-edge technologies are critical for public safety communications allowing first responders to send and receive critical voice, video and data to save lives, reduce injuries, prevent crime and terror and notify community members about emergencies and disasters. Rural geographies are in need of integrated and interoperable systems to increase capacity, security and accessibility among emergency responders.

3.2 Broadband Definition (Federal and State) and California Coverage Goal

The term "broadband" commonly refers to high-speed Internet access that is always on and faster than traditional dial-up access (56kbps). This subsection presents federal and state definitions of broadband and statistics of served, underserved and unserved areas based on these definitions.

The Federal Communications Commission (FCC) defines advanced telecommunications capability (broadband) primarily in terms of downstream and upstream speeds, as this is a particularly useful metric for analyzing the deployment of these services. In the 2015 Broadband Progress Report[19], the FCC updated the definition of broadband to 25 Mbps downstream and 3 Mbps upstream (previously defined as 4 Mbps downstream and 1 Mbps upstream). In 2017, the California legislature changed the definition of unserved areas to areas where broadband is offered at slower speeds than 6 Mbps downstream and 1 Mbps

[17] Pew Research Center Internet & Technology. (2015). *Retrieved from www.pewinternet.org/2015/11/19/1-the-internet-and-job-seeking/*

[18] https://www.gao.gov/

[19] Federal Communications Commission (FCC). (2015, January). *2015 Broadband Progress Report.* Retrieved June 2017, from https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-10A1.pdf

upstream[20]. For more details on broadband service benchmarks see Appendix A - Broadband Service Benchmarks**.**

According to the FCC's 2016 Broadband Progress Report[21], nationwide there is a population of 33,981,660 (10% of the total population) without access to fixed broadband at current FCC broadband speed rates (25 Mbps downstream/3 Mbps upstream). Based on residence area, 10,551,623 residents without access are located in urban areas, and 23,430,037 are located in rural areas, accounting for 4% and 39% of the urban and rural population, respectively. At the state level, there is a population of around 2 million people (5% of the state population) without access to fixed broadband services at FCC speed rates. Breaking down this population by residence area, 920,182 of these residents are in urban areas (2% of urban population) and 1,096,984 are in rural areas (61% of rural population). Regarding tribal lands in California, 29,052 people (51% of the population) have no access to fixed broadband. This report also shows that only 37% of the United States', and 43% of California's populations have adopted broadband.

The California Public Utilities Commission's (CPUC) latest broadband service availability data[22], as of December 2017 and released on December 2018, provided statistics regarding recent availability for wireline (DSL, cable modem and fiber-to-the-home), and fixed wireless broadband services. Table 1 and Table 2 show the broadband availability by technology in California based on the CPUC's definitions of served (at least 6 Mbps downstream and 1 Mbps upstream), unserved (less than 6 Mbps downstream or 1 Mbps upstream), and no service (no availability or no available data) areas. The goal of the State of California is to provide access to 98% of California households[23].

Table 1. California households served by broadband by technology 2017 (CPUC 2018)

	Total Households	Served Households		Unserved Households with Slow Service		Unserved Households with No Service	
Wireline	13,113,840	12,505,598	95.4%	115,598	0.9%	492,645	3.8%
Fixed Wireless	13,113,840	450,718	3.4%	32,519	0.2%	12,630,604	96.3%
Combined	13,113,840	12,649,624	96.5%	92,128	0.7%	372,088	2.8%

Table 2. California rural and urban households served by technology 2017 (CPUC 2018)

	Statewide Households Served	Urban Households Served	Rural Households Served
Wireline	95.4 %	97.7%	53.6%
Fixed Wireless	3.4%	1.9%	30.8%
Combined	96.5 %	97.8%	72.5%

[20] California Legislative Information (CALEG). (2017, October). AB-1665 Telecommunications: California Advanced Services Fund. Retrieved Dec 2017, from https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB1665.
[21] Federal Communications Commission (FCC). (2016, January). *2016 Broadband Progress Report.* Retrieved June 2017, from https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-6A1.pdf
[22] California Public Utilities Commission (CPUC). *California Broadband Validation Methods: Round 2017.* Data as of Dec. 31st, 2016.
[23] Pub. Util. Code section 281(b)(1) states; "The goal of the program is, no later than December 31, 2015, to approve funding for infrastructure projects that will provide broadband access to no less than 98 percent of California households."

3.3 Broadband Demand Drivers

This subsection presents applications that, in recent years, have driven up broadband demand both in terms of customer and speed demands. There is an increasing reliance on broadband to perform multiple functions, and instances of consumers within a single household routinely using multiple applications simultaneously. According to the FFC's 2015 Broadband Progress Report[24], the following applications are the main drivers for broadband demand:

- **Video services:** Video services provide a wide range of options including video streaming, video on demand (VoD), IP TV, video games and video conferencing. According to the 2014 Sandvine Report, real-time entertainment such as video streaming is responsible for over 67% of downstream bytes during peak periods[25]. Table 3 shows downstream speeds for video services recommended by three technology companies. Based on 2014 consumer statistics, approximately 77% of households in the United States have at least one high-definition television (HDTV) set, and about 46% of all households have multiple HDTVs.[26] Video conferencing is also facing increasing levels of usage, such as for telemedicine and distance education.

Table 3. Recommended downstream speeds for video services

Service	Downstream	Recommendation
HD video	5 Mbps	Netflix
Ultra HD quality video	25 Mbps	Netflix
720p video	6 Mbps	Apple
1080p HD video	8 Mbps	Apple
HD video	5 Mbps	DISH

- **Data services:** According to the 2014 Sandvine report, web-browsing is responsible for approximately 10% of downstream data traffic during peak period Internet use. Data transfer is another application that is growing in demand and is commonly used in telecommuting. Downstream speeds impact the time websites take to fully load, and the time files take to transfer from servers to user's devices.
- **Voice services:** Voice services have been replacing traditional telephone service by allowing users to make phone calls using broadband connections; also called VoIP technology. According to the 2014 FCC Local Competition Report, residential VoIP subscribers increased from 19.7 million in

[24] Federal Communications Commission (FCC). (2015, February 4). *2015 Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment*. Federal Communications Commission Hearing, Washington, D.C., *FCC 15-10,* 21-25.

[25] Sandvine Intelligent Broadband Networks, Global Internet Phenomena Report, 2H 2014 at 5 (2014), https://www.sandvine.com/downloads/general/global-internet-phenomena/2014/2h-2014-global-internetphenomena-report.pdf (2014 Sandvine Report).

[26] See Press Release, Leichtman Research Group, The Majority of TV Sets Used in U.S. Households are Now HDTVs, 4K Ultra HDTV in Early Stages of Development (Mar. 7, 2014), http://www.leichtmanresearch.com/press/030714release.html.

December 2008 to 37.7 million in December 2013.[27] VoIP applications require a minimum of 100 kbps downstream and upstream speeds to enable real-time voice communications.

- **Social networking and cloud applications:** Social networking applications have increased in demand and, as of 2015, approximately 73% of adults online use a social networking site of some kind[28]. Cloud computing has also risen in demand due to its capability to allow users to store and access data and information (photos, music, emails, documents, etc.) over the Internet.
- **Machine-to-machine applications:** Machine-to-machine applications include smart meters, video surveillance, health care monitoring, transportation and package/asset tracking. In 2013, Cisco Systems reported that 33% of IP traffic originated with non-PC devices, but predicted that by 2018 the non-PC share of total IP traffic would grow to 57%.

This introduction section was intended to provide important broadband definitions and current context, both nation and statewide, to assist with understanding the importance of expanding broadband infrastructure deployments and adoption programs in the City of Redding. The following section presents the current broadband landscape in Redding based on CPUC's broadband service availability data.

[27] Industry Analysis and Technology Division, Wireline Competition Bureau, Local Telephone Competition: Status as of December 31, 2013 at 14 (Oct. 2014), http://transition.fcc.gov/Daily_Releases/Daily_Business/2014/db1016/DOC-329975A1.pdf.

[28] Maeve Duggan & Aaron Smith, Social Media Update 2013, Pew Res. Internet Project (Dec. 30, 2013), http://www.pewinternet.org/2013/12/30/social-media-update-2013/.

4. Current Broadband Landscape

4.1 Broadband Services Availability (Served, Unserved and No Service Areas)

This subsection presents the advertised broadband service availability in the City of Redding, based on the CPUC's broadband availability data as of December 2017 (released on December 2018). The advertised service availability data are collected by the CPUC from a majority of broadband service providers in the State. Most of the broadband availability is provided by last-mile broadband service providers[29]. Coverage data for wireline and fixed wireless providers are reported at the census block level. The data are mapped and validated for accuracy using CPUC's broadband validation methods[30]. For this report, broadband availability data plots are generated from the California Interactive Broadband Map[31].

Table 4 shows the major residential and business Internet service providers in Redding and the technology used to provide services, from DSL, cable and fiber optics, to terrestrial fixed wireless.

Table 4. Technology offerings by Internet service provider

Internet Service Provider	Service Type	Technologies Offered
AT&T California	Residential Only	• Asymmetric xDSL • ADSL2, ADSL2+
Allstream Business US, Inc.	Business Only	• Other Copper Wireline
Charter	Residential & Business	• Cable Modem DOCSIS 3.0 • Optical Carrier / Fiber to the end user
Com-Pair Services	Residential Only	• Terrestrial Fixed Wireless
Digital Path	Residential Only	• Terrestrial Fixed Wireless
EarthLink Business, LLC	Business Only	• Asymmetric xDSL • Other Copper Wireline • Cable Modem other than DOCSIS 1, 1.1, 2.0 or 3.0
Geolinks	Residential	• Fixed Wireless
Level 3 Communications	Business Only	• Other Copper Wireline
XO Communications	Business Only	• Other Copper Wireline
U.S. TelePacific	Business Only	• Optical Carrier / Fiber to the end user • Other Copper Wireline
PAETEC Communications	Business Only	• ADSL2, ADSL2+ • Optical Carrier / Fiber to the end user
NetFortris Acquisition	Business Only	• Other Copper Wireline
MCI	Business Only	• Optical Carrier / Fiber to the end user • Other Copper Wireline

[29] For a detailed description of last-mile broadband technologies see ***Appendix B: Middle-, Second- and Last-Mile Broadband Technologies***.

[30] California Public Utilities Commission (CPUC). *California Broadband Validation Methods: Round 2017.* Data as of Dec. 31st, 2016.

[31] CPUC's California Interactive Broadband Map available in http://www.broadbandmap.ca.gov/.

4.1.1 Wireline and Fixed Wireless Service Availability

Wireline Service Availability

Figure 3 shows the wireline served status and downstream speeds in Redding as of December 2016, and Figure 4 shows a closer look at the served status and downstream speeds available in downtown Redding. Most of Redding has wireline service with downstream speeds between 100Mbps and 500Mbps. Small pockets throughout the city are currently without wireline service. Downtown Redding is partially served with wireline downstream speeds between 100Mbps and 500 Mbps. Several blocks within downtown Redding are currently have no wireline service. It is important to note that for both cable- and DSL-based broadband service, coverage depends on the footprint of cable television and traditional telephone networks deployed in the city[32].

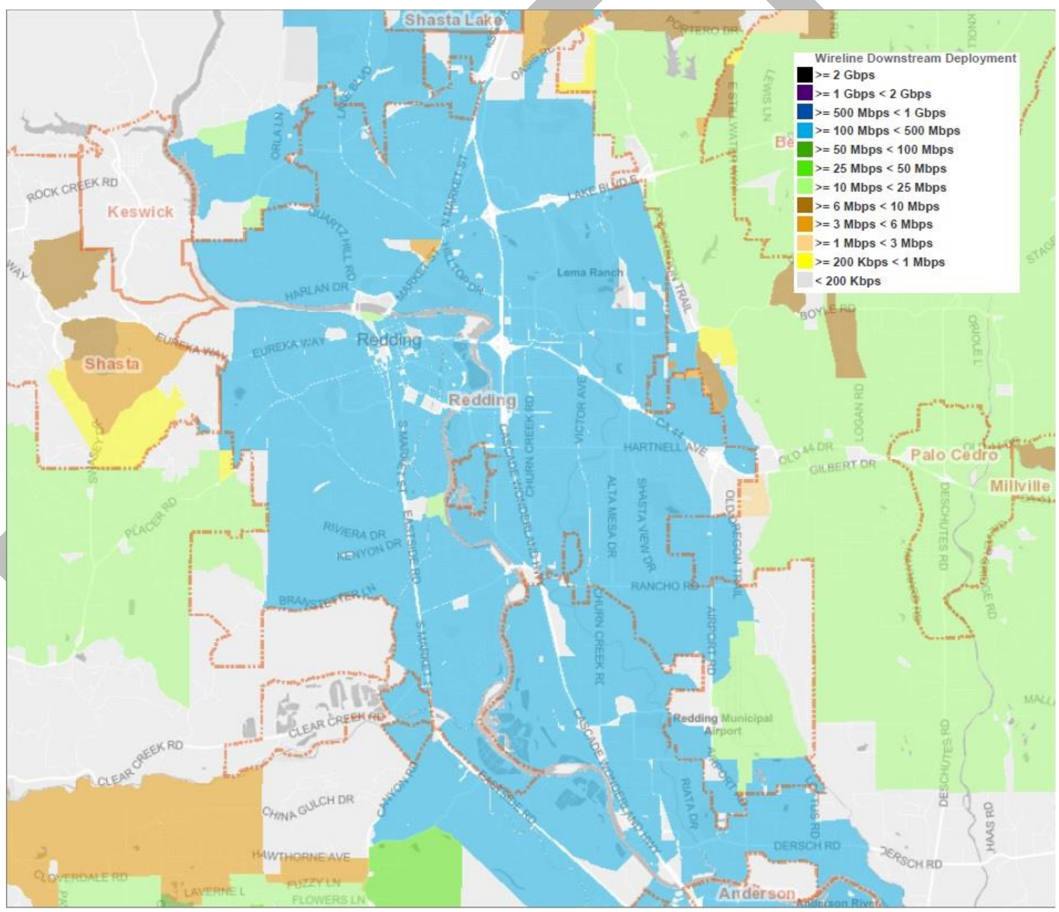

Figure 3. Wireline served status and downstream speeds (December 2017) in the City of Redding

[32] For more details on the technical capabilities and limitations of wired technologies, see ***Appendix B: Middle-, Second- and Last-Mile Broadband Technologies.***

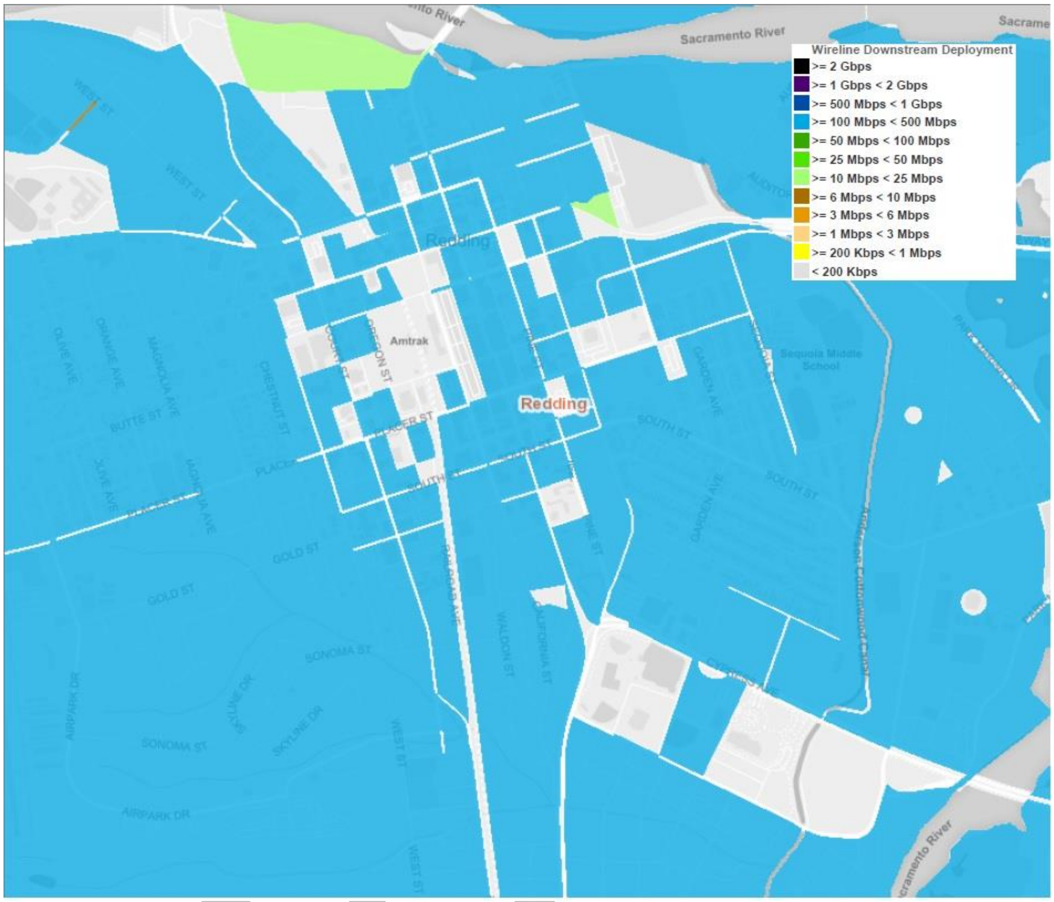

Figure 4. Wireline served status and downstream speeds (December 2017) in Redding's Downtown

Fixed Wireless Service Availability

Figure 5 and Figure 6 show the wireless served status and downstream speeds in Redding as of December 2017, as well as a closer look at the served status and downstream speeds available in downtown Redding. The majority of Redding is without wireless service; however, there are a number of isolated areas within the city with wireless service. Most of the scattered wireless service in Redding has downstream speeds between 10 and 25 Mbps; however, two small areas feature speeds between 1 and 2 Gbps. Downtown Redding is currently without any wireless service. Depending on the location of towers, access points or base stations, and line-of-sight (no visible obstructions) to customer premises, fixed wireless service can cover wide areas, however, environmental factors such as trees, buildings and topography can affect availability of the fixed wireless service[33].

[33] For more details on the technical capabilities and limitations of fixed wireless technologies, see ***Appendix B: Middle-, Second- and Last-Mile Broadband Technologies.***

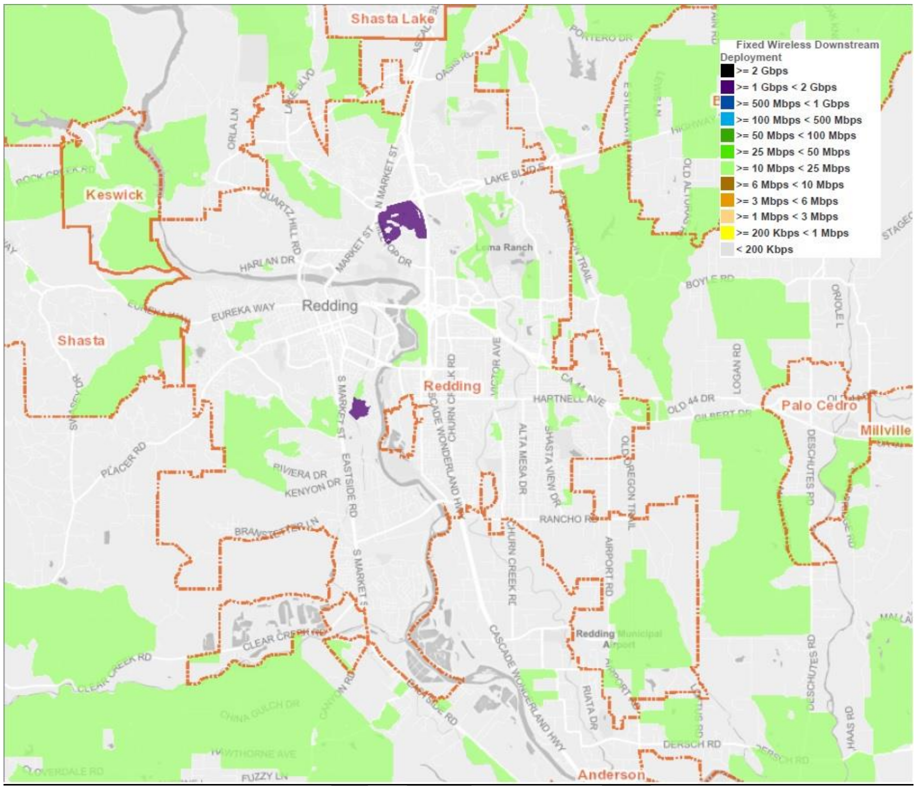

Figure 5. Fixed wireless served status and downstream speeds (December 2017) in the City of Redding.

Figure 6. Fixed wireless served status and downstream speeds (December 2017) in Redding's Downtown.

4.1.2 Advertised Download Speed Availability by ISP

AT&T California

AT&T offers a mix of Asymmetric xDSL, ADSL2 and ADLS2+ technologies within Redding for residential customers. Figure 7 shows broadband speeds offered by AT&T in Redding (December 2016). Asymmetric xDSL, speed offerings in the 768 Kbps-1 Mbps download range, are available on the outskirts of Redding (yellow areas). ADSL2 and ADSL2+ are offered in several scattered neighborhoods (brown and light-brown areas) with speeds 1 Mbps-10 Mbps, and more widespread (light-green areas) are speed offerings of 10-25 Mbps.

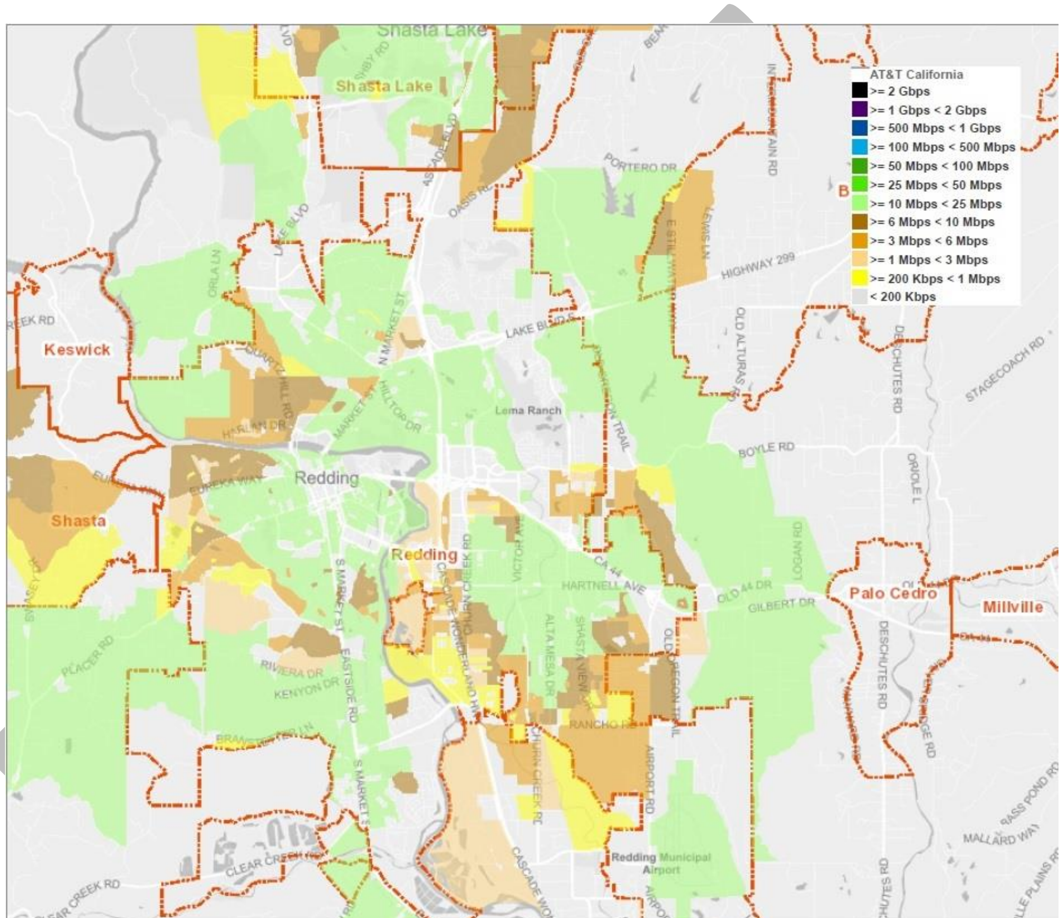

Figure 7. Broadband service speed offered by AT&T California in Redding (December 2017)

Allstream Business

Allstream Business is a business-class-only broadband service provider that offers broadband to Redding businesses using technology categorized as other copper wireline technology. Figure 8 shows broadband speeds offered by Allstream Business in Redding (December 2016). Allstream Business offers download speeds between 1 and 3 Mbps in a small area near Cypress Avenue in Central Redding.

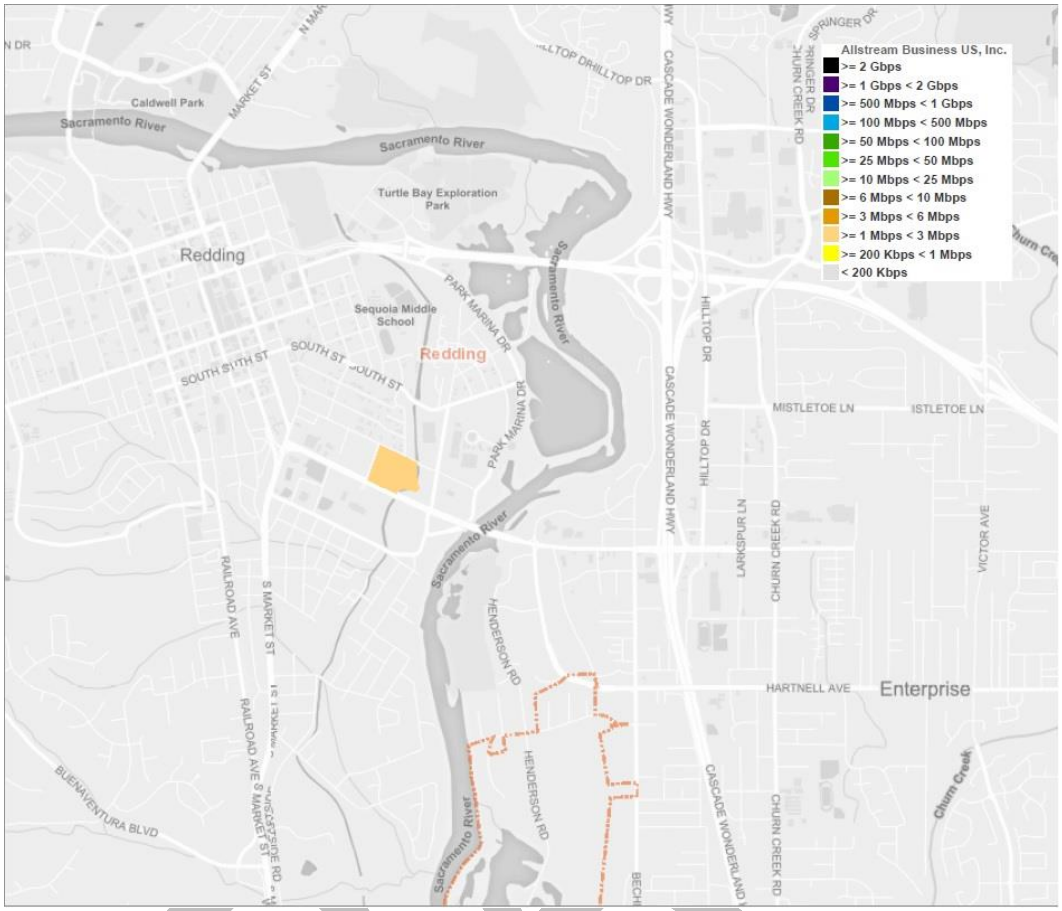

Figure 8. Broadband service speed offered by Allstream Business in Redding (December 2017)

Charter

Charter offers cable Internet service to residential customers using cable technology. Figure 9 shows speeds offered by Charter in Redding (December 2017). Charter advertised between 100 and 500 Mbps download speeds in most areas of the city (blue areas).

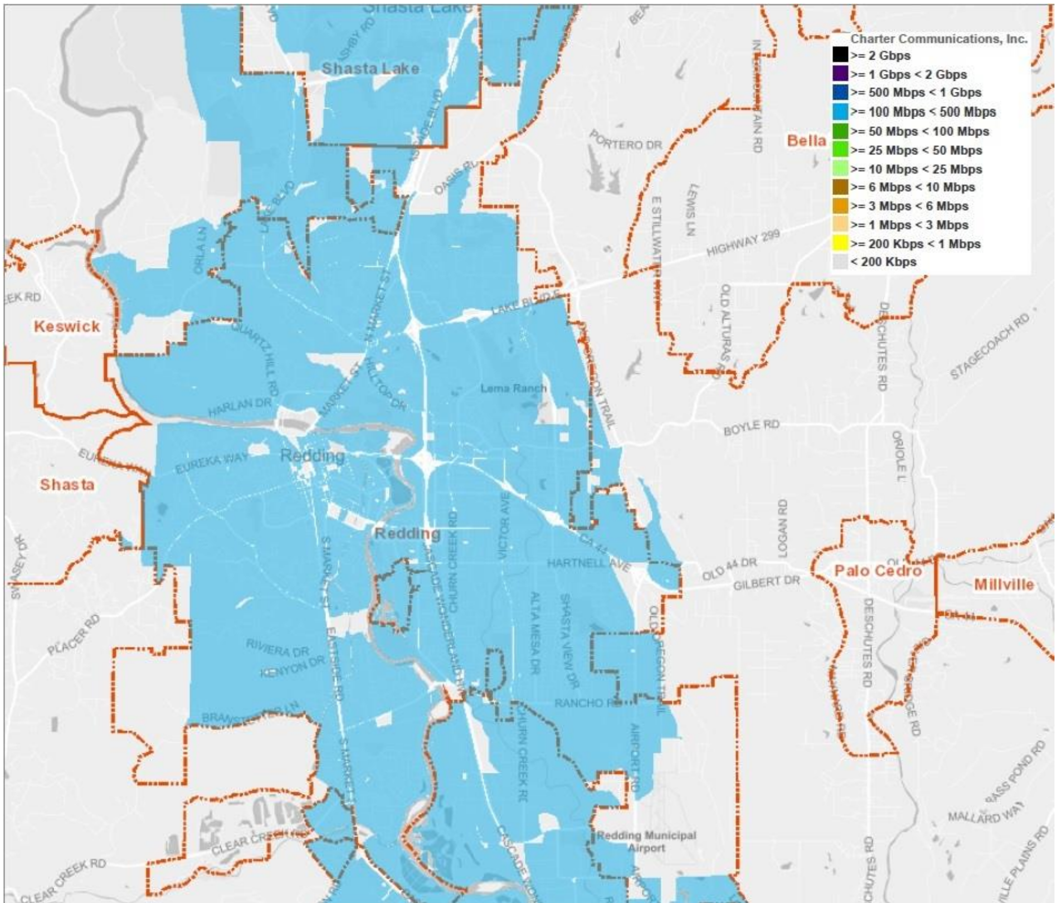

Figure 9. Broadband service speed offered by Charter in Redding (December 2017)

Charter also offers cable Internet service to business customers using fiber-to-the-end-user technology. Figure 10 shows speeds offered by Charter-Business in Redding (December 2017). Charter-Business offers service with speeds varying from 10-25 (light-green areas) Mbps to speeds of 2 Gbps (black areas) in many scattered locations throughout the city.

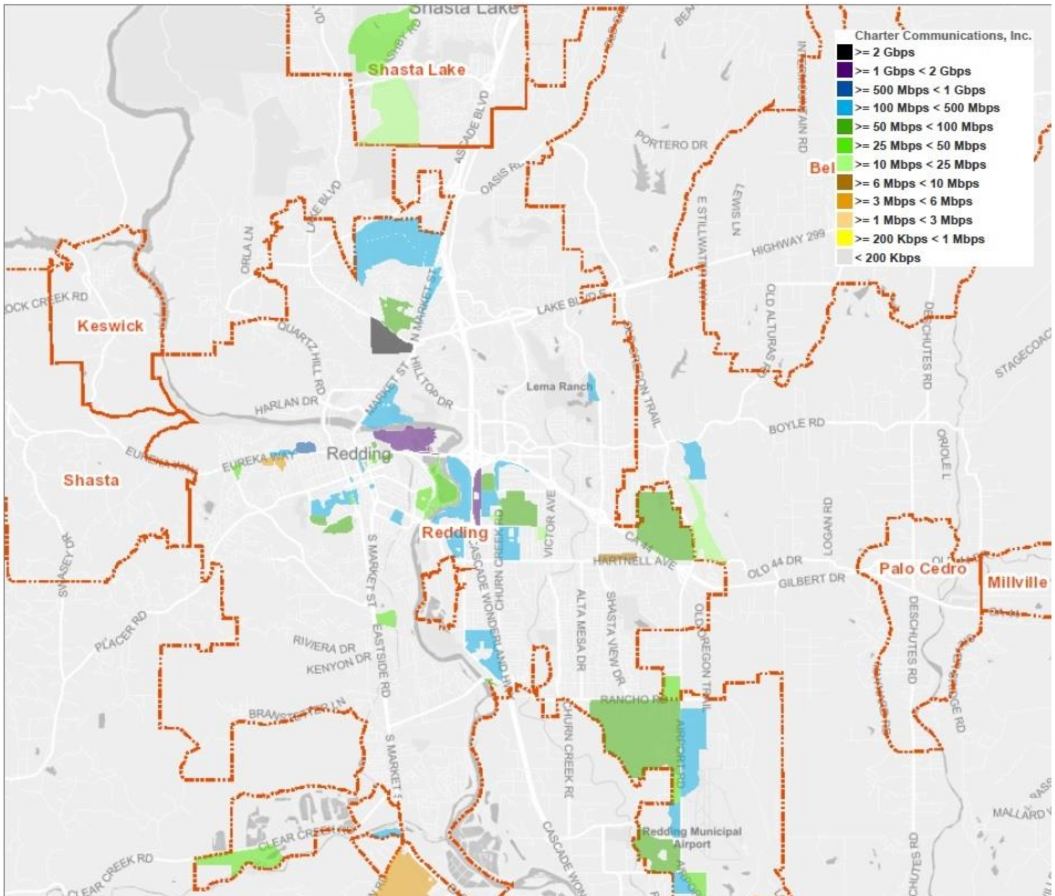

Figure 10. Charter's business class broadband service coverage in the City of Redding (December 2017)

Com-pair Services

Com-pair offers is a wireless service provider that concentrates on supplying rural parts of Northern California with broadband service. Com-pair serves only a small area in the northeast of Redding (Figure 11) with advertised speeds ranging from 10-25 Mbps (light-green areas).

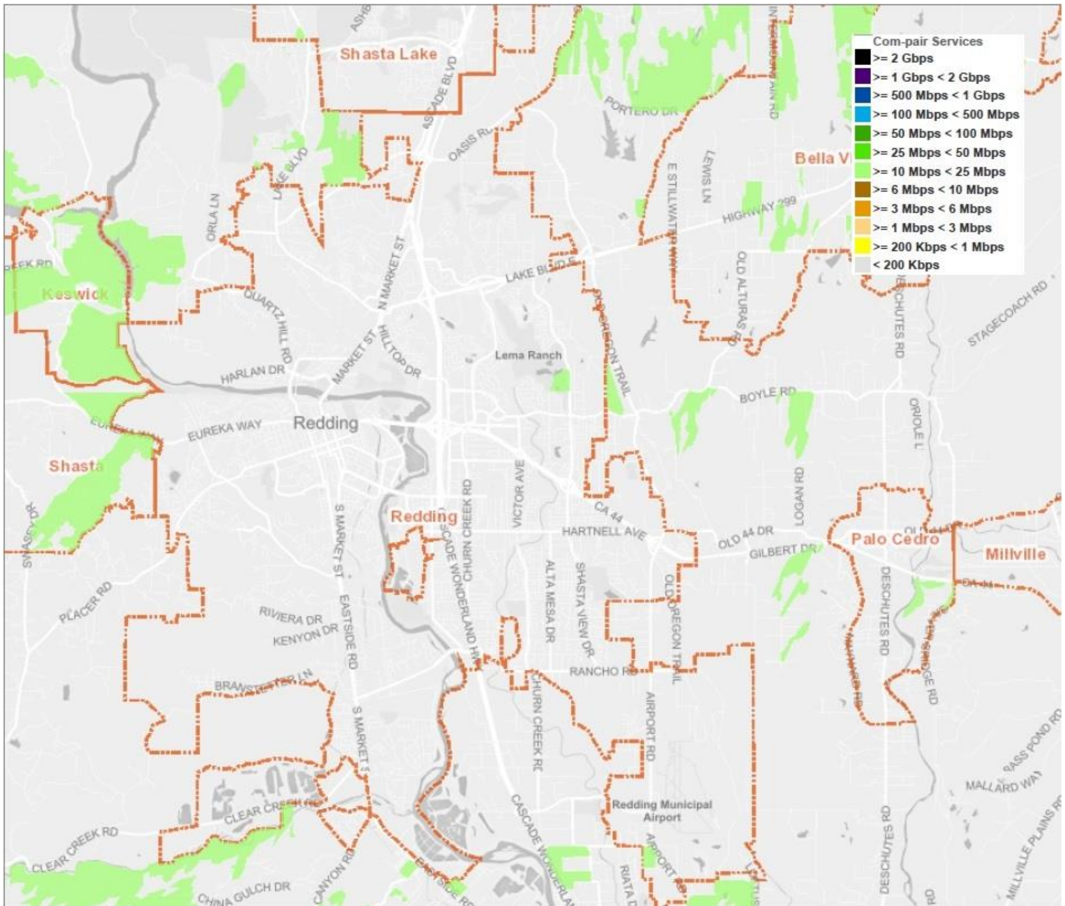

Figure 11. Broadband service speed offered by Com-pair in Redding (December 2017)

Digital Path

Digital Path is a wireless service provider that serves both business and residential customers in central and Northern California. Digital Path provides service to several scattered areas throughout Redding (Figure 12) with advertised speeds of 10-25 Mbps (light-green areas).

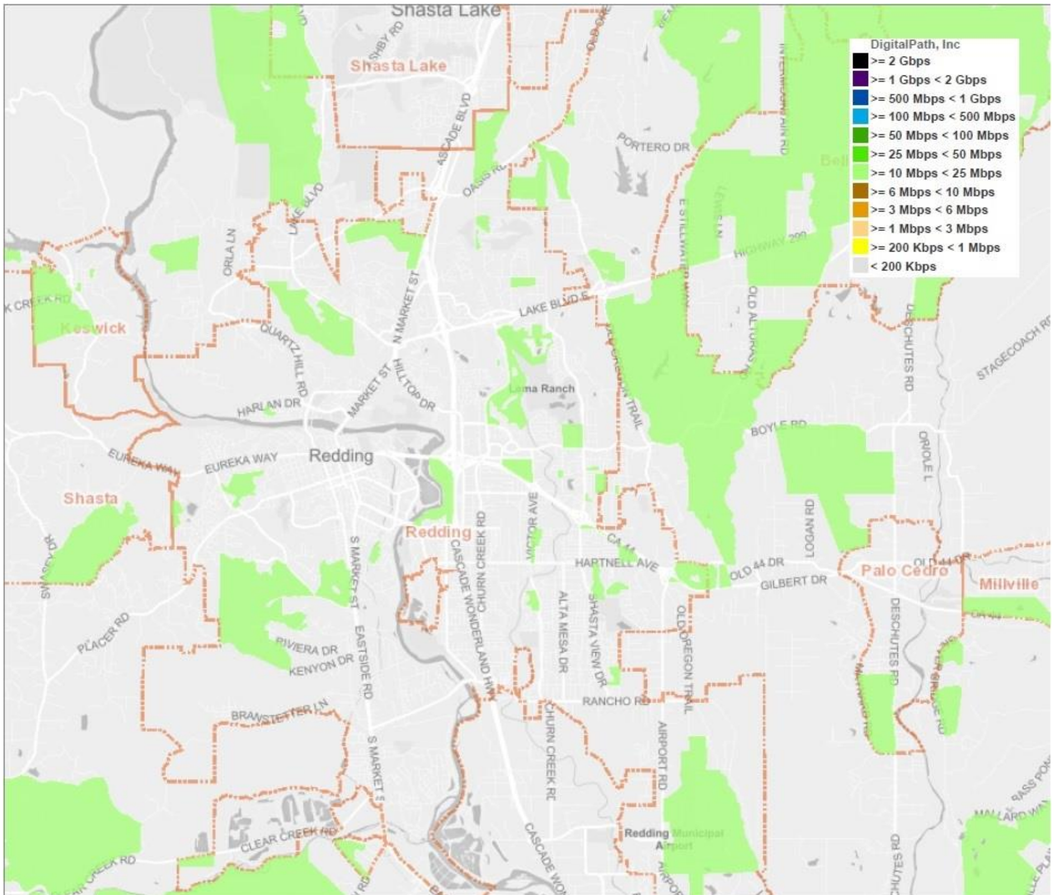

Figure 12. Broadband service speed offered by Digital Path in Redding (December 2017).

EarthLink Business

EarthLink Business is a business-class-only broadband service provider that uses a combination of asymmetric xDSL and other copper wireline. EarthLink serves only a small area in the southeast of Redding (Figure 13) with advertised speeds ranging from 1-3 Mbps (light-brown areas).

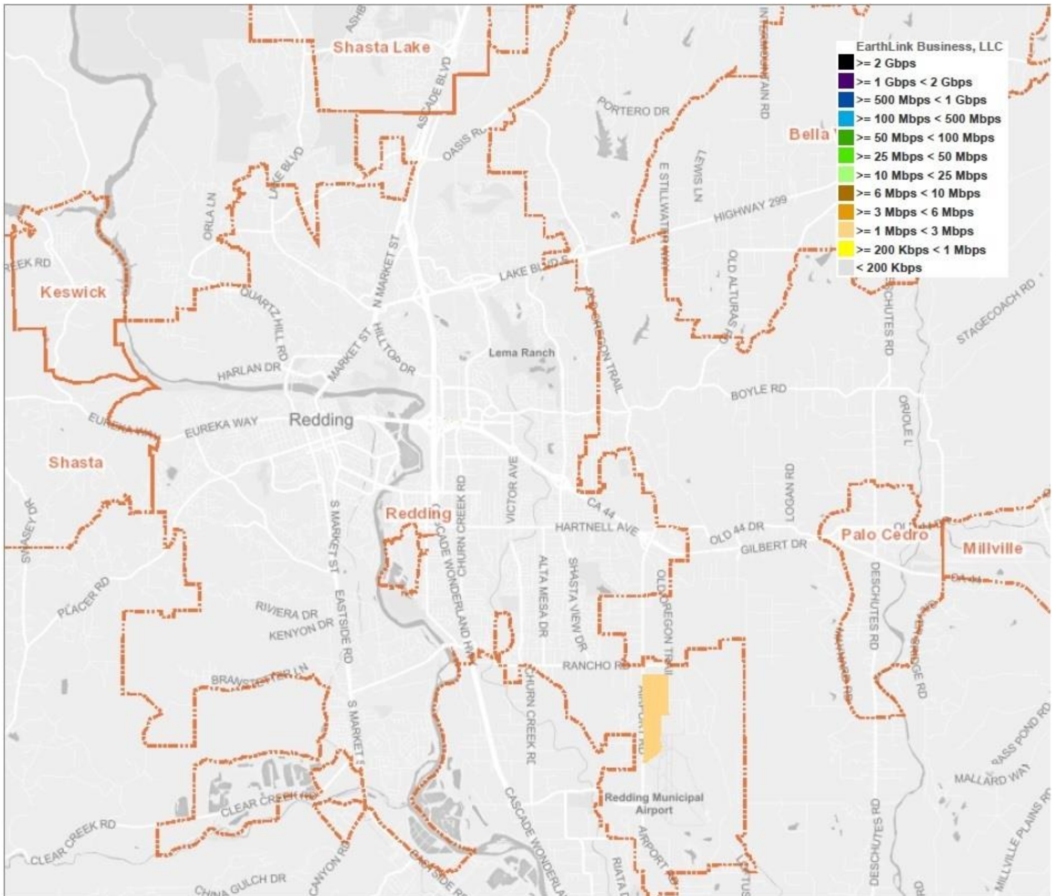

Figure 13. Broadband service speed offered by EarthLink Business in Redding (December 2017).

Geolinks

Geolinks is a broadband service provider that uses a terrestrial fixed wireless technology to provide broadband service to its customers. Geolinks serves only two small areas central Redding (Figure 14) with advertised speeds ranging from 1-2 Gbps (purple areas).

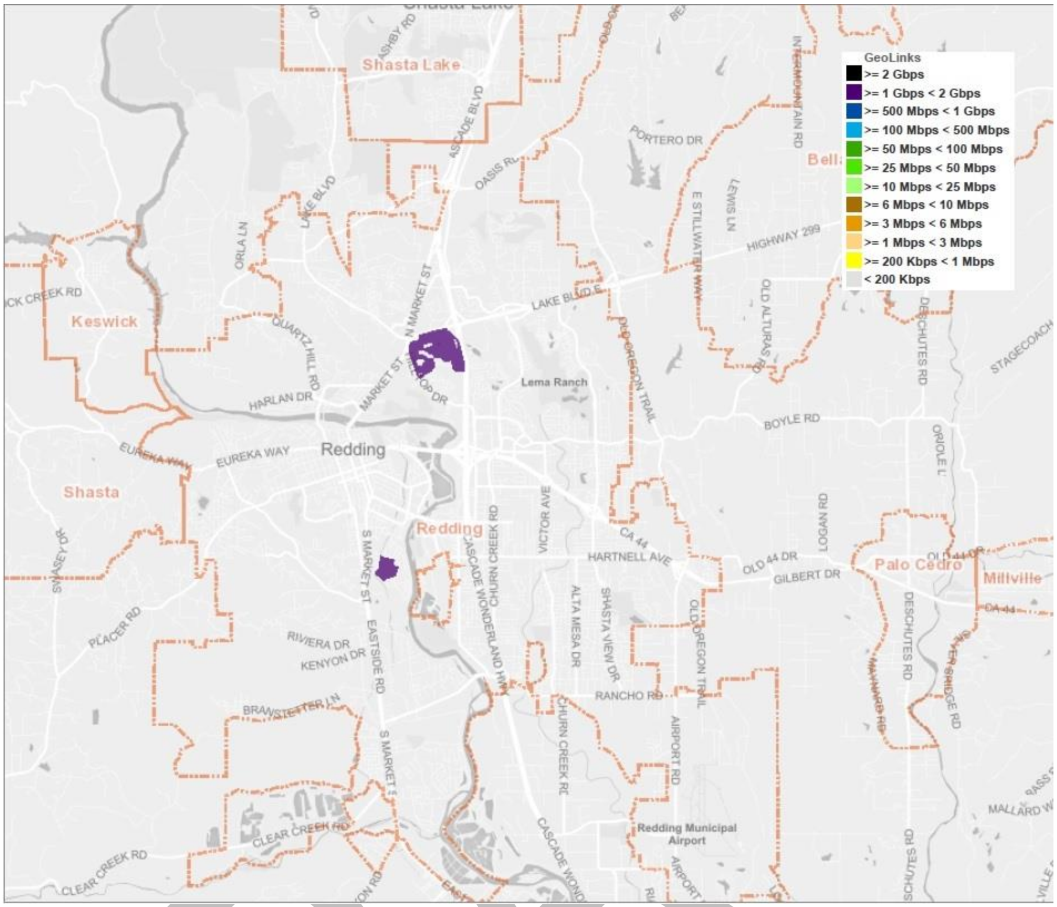

Figure 14. Broadband service speed offered by Geolinks in Redding (December 2017).

Level 3 Communications

Level 3 is a business-class-only broadband service provider that uses fiber-optic and other copper wireline technologies. Level 3 serves only a small area central Redding (Figure 15) with advertised speeds of 2 Gbps (black areas).

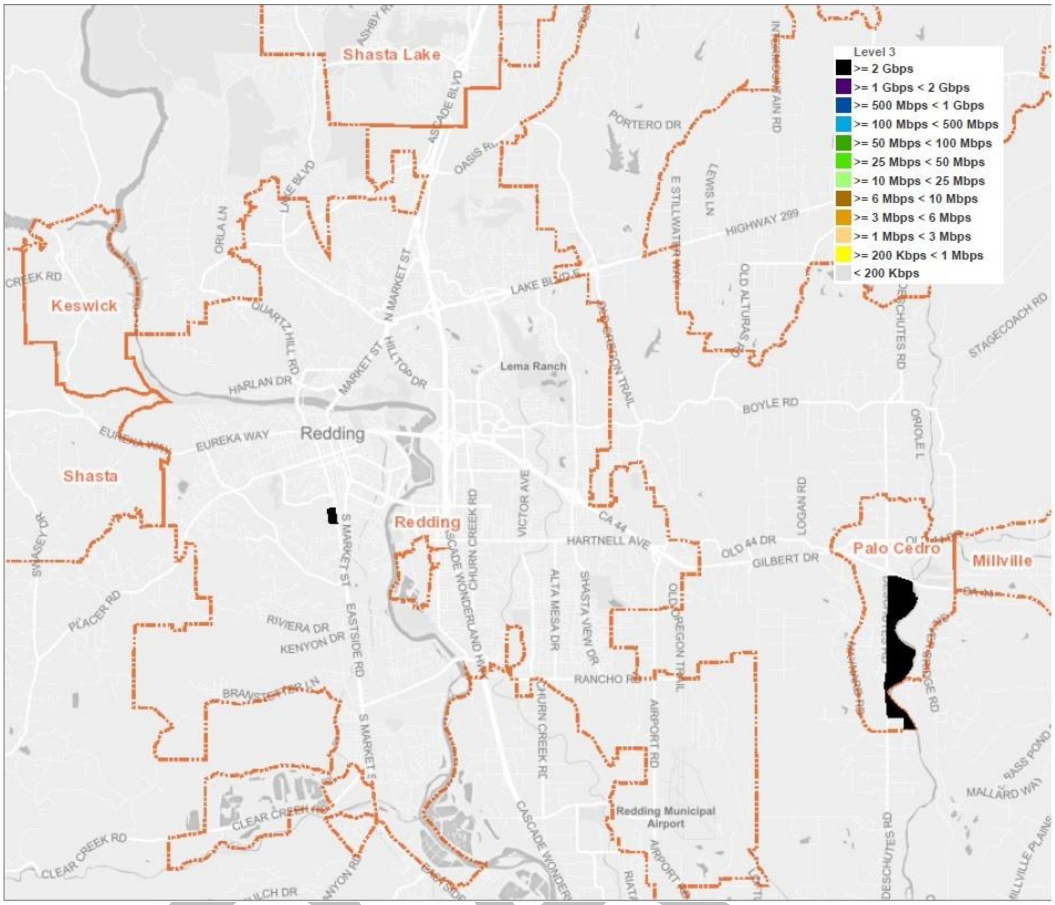

Figure 15. Broadband service speed offered by Level 3 in Redding (December 2017).

MCI

MCI is a business-class-only broadband service provider. MCI serves only a small area in central Redding and a larger area in southeast Redding (Figure 16) with advertised speeds ranging from 1-3 Mbps (light-brown areas) to 3-6 Mbps (brown area).

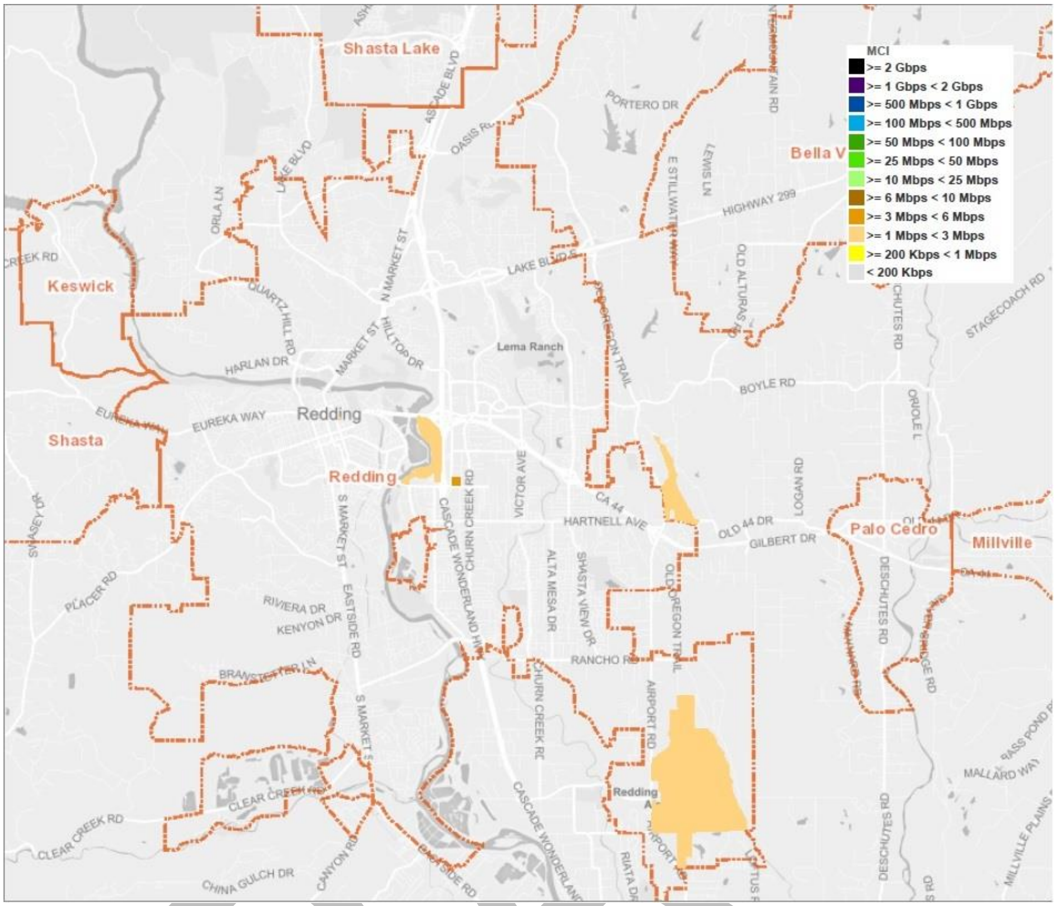

Figure 16. Broadband service speed offered by MCI in Redding (December 2017).

NetFortris

NetFortris is a business-class-only broadband service provider that uses toher coppwer wireline technology to provide broadband service in Redding. NetFortris serves only a small area in southeast Redding (Figure 17) with advertised speeds ranging from 1-3 Mbps (light-brown areas).

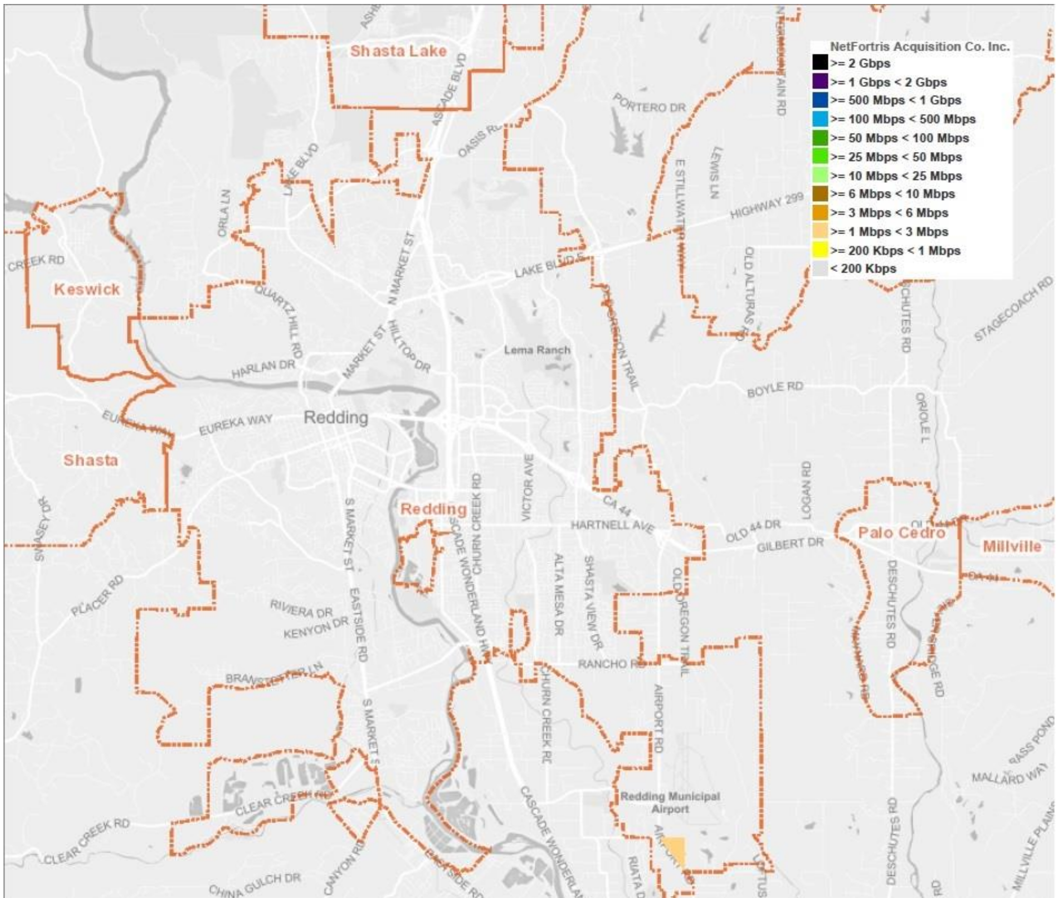

Figure 17. Broadband service speed offered by NetFortris in Redding (December 2017).

PAETEC Communications

PAETEC is a business-class-only broadband service provider. PAETEC serves only a small area in southeast (Figure 18) Redding with advertised speeds ranging from 50-100 Mbps (dark green areas).

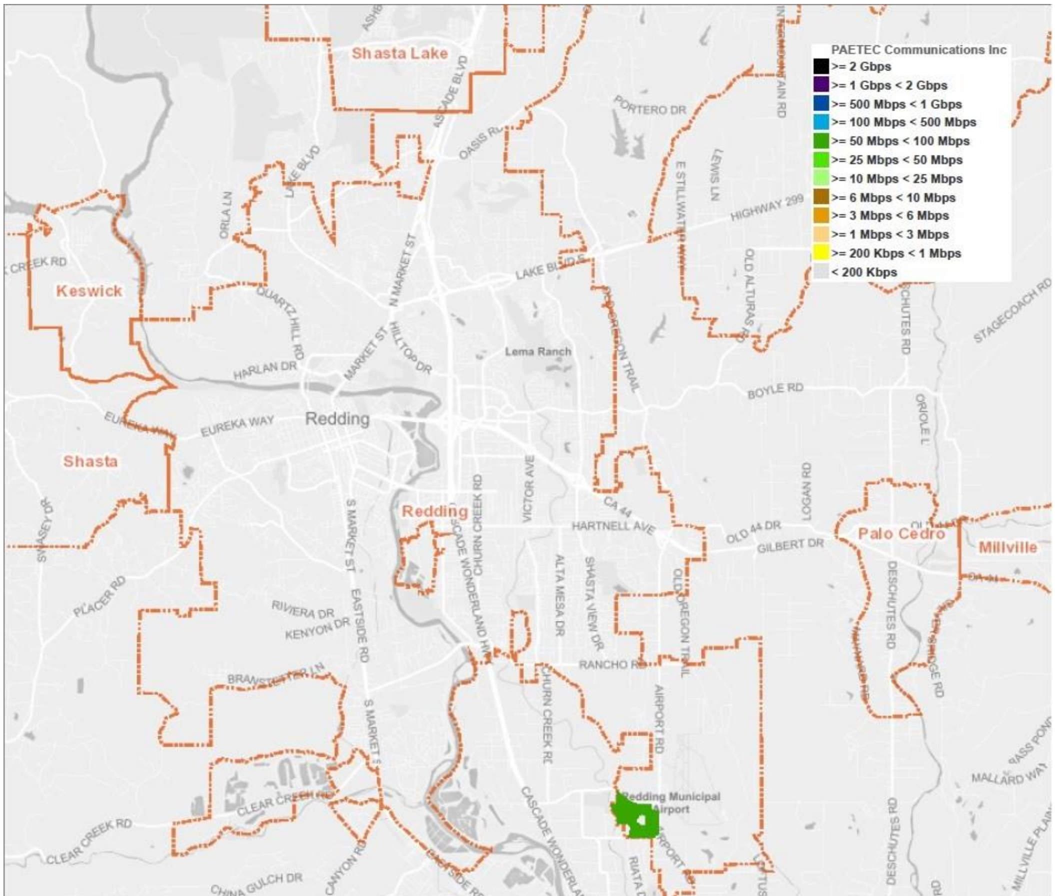

Figure 18. Broadband service speed offered by PAETEC in Redding (December 2017).

U.S. TelePacific

U.S. Telepacific is a business broadband service provider and optical carrier that offers fiber-to-the-end-user and copper wireline connectivity. U.S. Telepacific primarily serves businesses in the central Redding with a few other pockets in northern and eastern Redding. U.S. Telepacific’s advertised speeds include those ranging from 1.5 Mbps-10 Mbps (brown and light-brown areas) to 10 Mbps-100 Mbps (green to light-green areas. Figure 19 shows business-class broadband service provided by U.S. Telepacific.

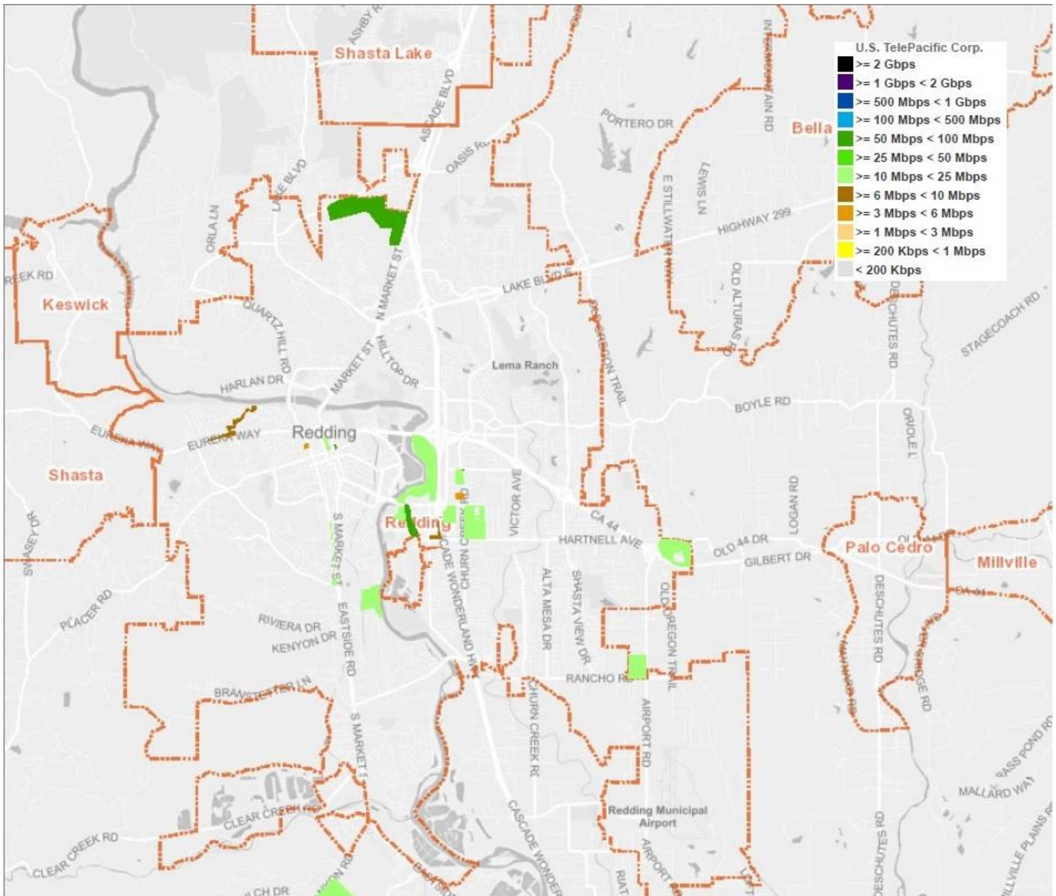

Figure 19. Broadband service speed offered by U.S. TelePacific in Redding (December 2017).

XO Communications

XO Communications is a business broadband service provider and optical carrier that offers fiber-to-the-end-user and copper wireline connectivity. XO Communications primarily serves businesses in central Redding with advertised speeds of 1.5 Mbps-3 Mbps (light brown areas) and 100 Mbps-500 Mbps (blue areas). Figure 20 shows business-class broadband service provided by XO Communications.

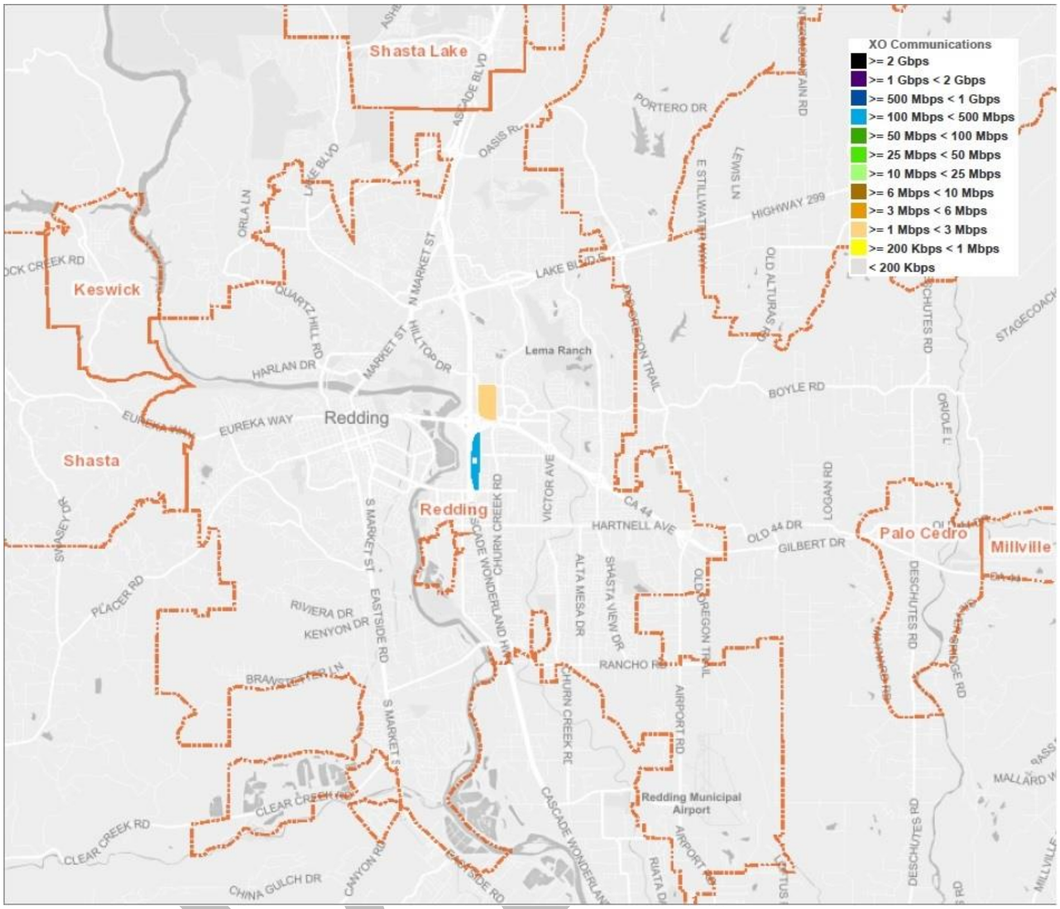

Figure 20. Broadband service speed offered by XO Communications in Redding (December 2017).

4.1.3 Measured Broadband Service and Download Speed Availability

The CalSPEED application is a professional-level broadband testing tool that allows conducting performance testing of both fixed and mobile broadband services. This application was developed at California State University, Monterey Bay and is used by the CPUC for measuring and validating broadband coverage from any broadband subscriber location. CalSPEED can be downloaded from www.calspeed.org. The broadband testing results are displayed in the user device and then sent to a CPUC server for displaying on the California Broadband Interactive Map[34]. CalSPEED measures broadband performance parameters, such as downstream and upstream speeds, latency, and jitter (see detailed definitions in ***Section 10: Glossary***). Results of CalSPEED can be used to validate broadband service availability in a specific geographic region and update the served or unserved (slow service or no service) status.

Figure 21 shows current CalSPEED results for fixed broadband services in the City of Redding. The current number of measurements (less than 20 points) does not allow to proper validation yet of broadband availability in the city. More measurement points would be required to assess levels of broadband availability for wireline and fixed wireless broadband providers.

[34] California Public Utility Commission (CPUC). Broadband Interactive Map. http://www.broadbandmap.ca.gov/.

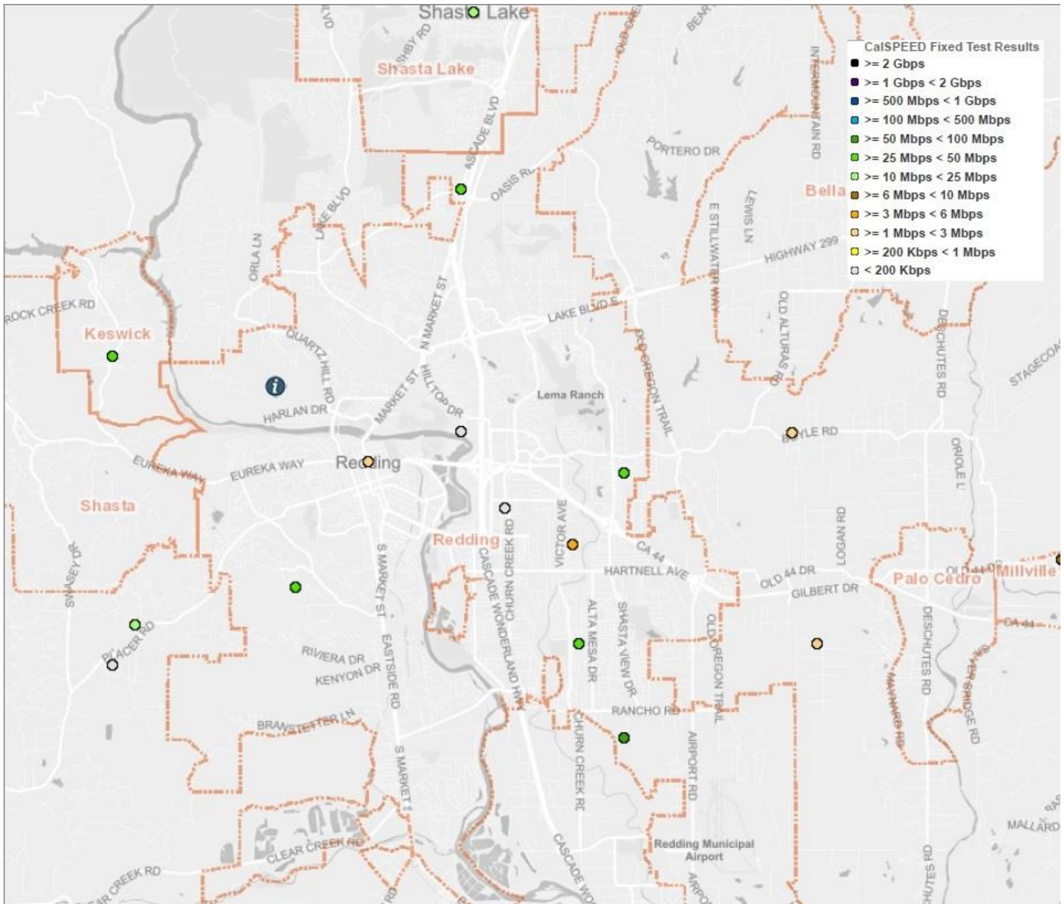

Figure 21. CalSPEED fixed test results for the City of Redding

4.2 Broadband Services Adoption

Residential broadband adoption is defined as the number of consumer broadband subscriptions divided by the total number of households within a defined geographic unit. Data about broadband subscriptions is confidential but the CPUC does publish a limited set of broadband adoption statistics by census tract. Figure 22 shows adoption rates in Redding.

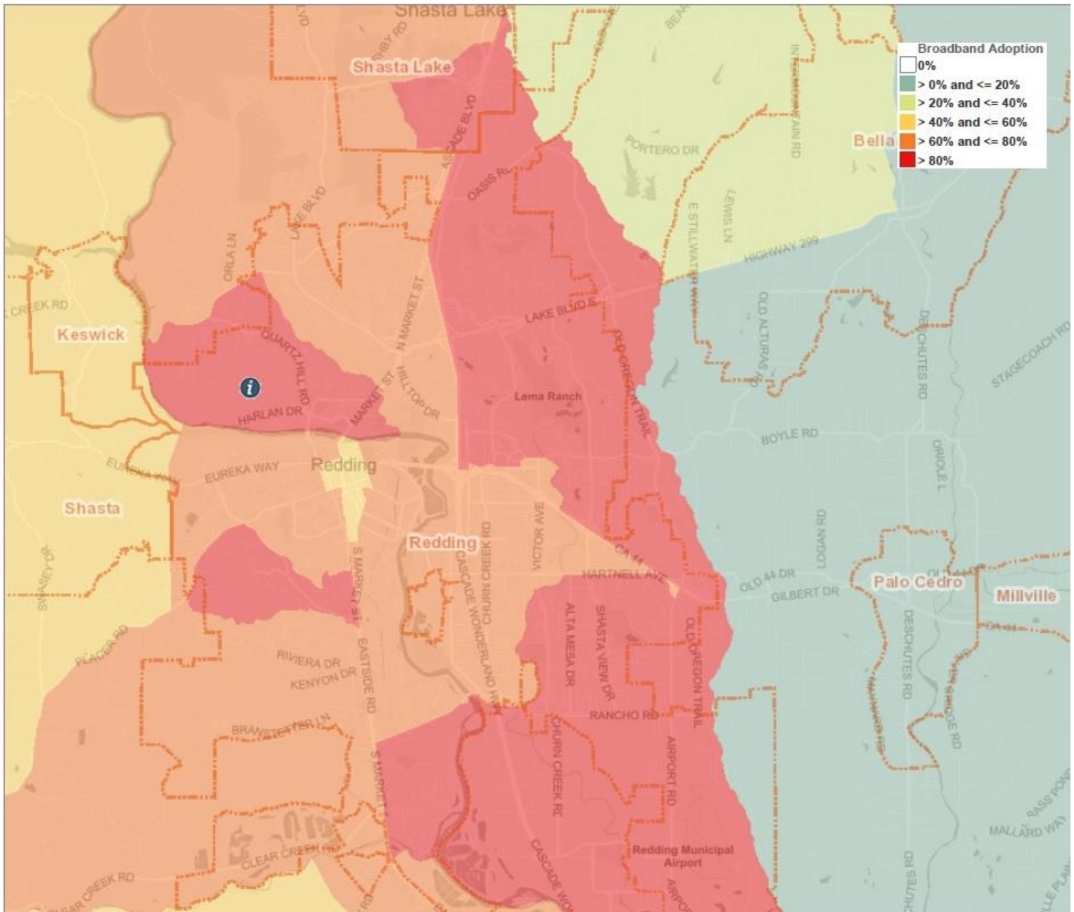

Figure 22. Broadband adoption rates in the City of Redding

Broadband adoption rates range from 60 to over 80 percent throughout most of Redding, with the highest adoption rates in the eastern edge of the city, as well as two areas in the west. Downtown Redding has the lowest broadband adoption rates in the city, with rates between 20 and 40 percent.

4.3 Middle-Mile Service Availability

This subsection presents middle-mile infrastructure available in the City of Redding area. The middle-mile segment provides high-speed and high-capacity transport and transmission of data communications from an aggregation point (i.e., central office, cable headend or wireless switching station) to an Internet point of presence (POP). For a detailed description on middle-mile broadband technologies see ***Appendix B: Middle-, Second- and Last-Mile Broadband Technologies***. Figure 23 shows the middle-mile infrastructure (fiber-optic-based backbones) in or near Redding offered by AT&T, Frontier, and Charter. AT&T, Charter, and Frontier also offer last-mile broadband services to residential subscribers in California; however, in the City of Redding, only AT&T and Charter are both a fiber-optic-backbone carriers and residential ISPs; Frontier does not have a residential service in the city.

It is important to note that fiber-optic carriers usually do not provide or report information of their fiber-optic routes. The route information presented in this subsection was collected over the past few years from unofficial discussions with ISP's personnel and local government staff with knowledge of fiber-optic deployments in the county. The Geographical Information Center (GIC) is currently working with ISPs and the CPUC to update and validate fiber-optic routes in rural Northern California.

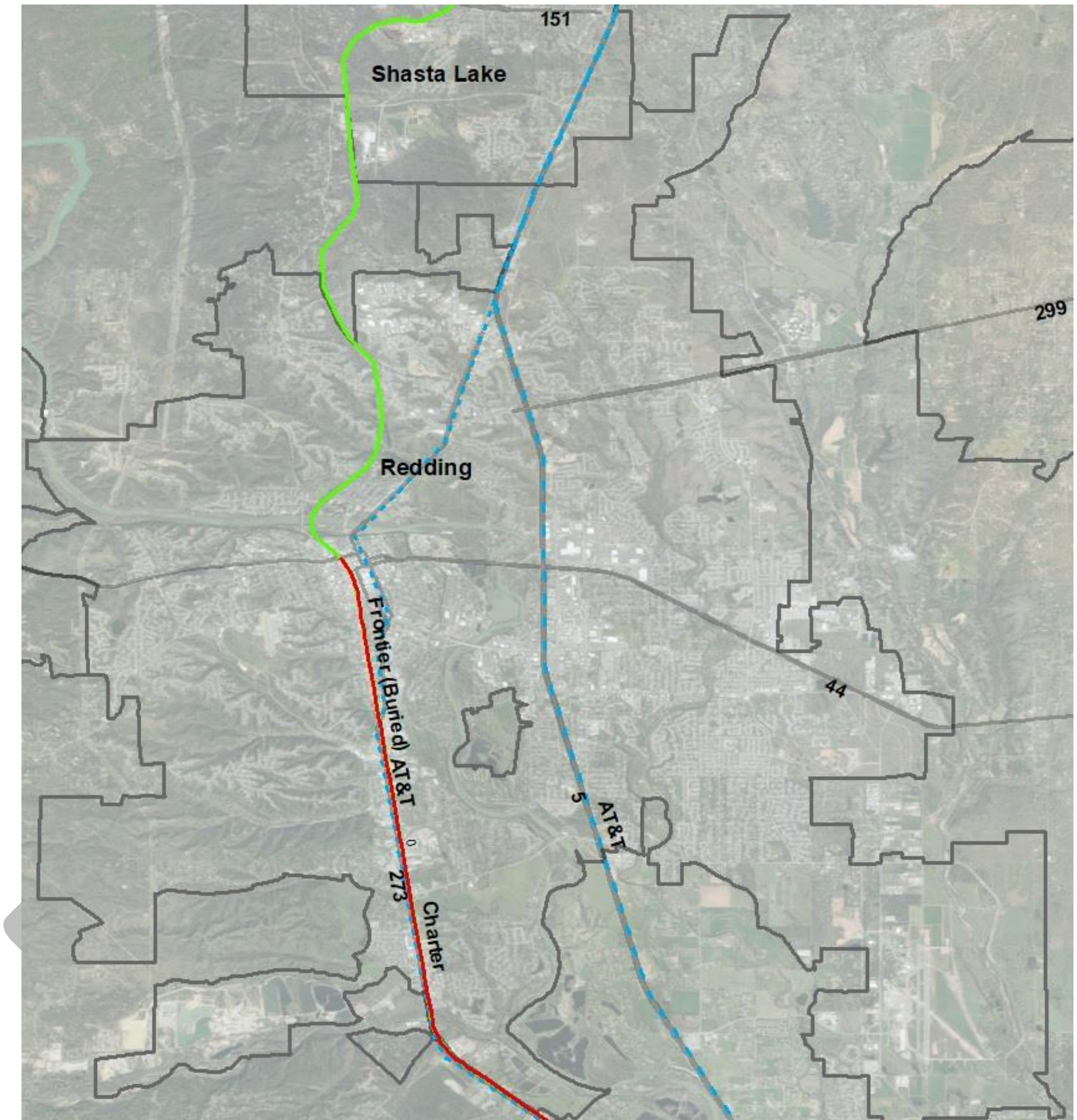

Figure 23. Middle-mile infrastructure in the City of Redding area

5. Broadband Infrastructure Upgrade Recommendations

5.1 Middle- and Last-Mile Network Upgrade Options

5.1.1 Fiber-to-the-Home (FTTH) Network Design

The Downtown Redding Internet Utility (Pilot) Whitepaper[35] states that the City of Redding is considering a proposal to research, develop, and potentially implement a new fiber Internet utility service. This initial service would be offered in the downtown area of Redding and serve as a pilot phase for both residential and commercial customers. The goal of the new utility is to spur economic development, help revitalize the downtown area, and make the city more competitive and marketable. This whitepaper highlights the uniquely advantage of Redding to provide this service by owning the existing infrastructure through the city-owned Redding Electric Utility (REU).

Based on the current broadband service coverage and maximum service speeds in the City of Redding, from 100 Mbps to less than 500 Mbps (Charter), this report supports that the next step for upgrading broadband service is deploying a fiber-optic network to provide gigabit services for residential, business, and industrial customers and community anchor institutions. This subsection presents a high-level technical design assessment for the proposed fiber service in the Downtown Redding pilot area.

For the design of the fiber-optic network presented in this subsection, the analysis uses technical guidelines and recommendations from industry and academic papers,[36,37,38] standard telecom industry infrastructure and deployment methods,[39,40] and manufacturer equipment descriptions and configurations,[41,42] among other sources. The main elements of the network are the following:

- **Access Node (core site or central exchange):** The access node houses all active fiber-optic transmission equipment, manages all fiber terminations, and facilitates the interconnection between the incoming optical fibers and active equipment. For equipment installation, it includes optical distribution frames, cable guiding system, uninterrupted power supply, climate control,

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[35] City of Redding Council (2017). Regular Meeting December 19, 2017, Agenda Packet (pp739-744). http://reddingcityca.iqm2.com/Citizens/FileOpen.aspx?Type=1&ID=2466&Inline=True.

[36] Federal Communications Commission (FCC). (2010, April). The Broadband Availability Gap - OBI Technical Paper NO.1. Retrieved from https://transition.fcc.gov/national-broadband-plan/broadband-availability-gap-paper.pdf

[37] Chatzi, S., Lazaro, J., Prat, J., & Tomkos, I. (2013). A Techno-Economic Study on the Outside Plant Cost of Current and Next-Generation Fiber-to-the-X Deployments. *Fiber and Integrated Optics, 32*(1), 12--27. doi:10.1080/01468030.2012.754070

[38] Rokkas, T. (2015). Techno-economic analysis of PON architectures for FTTH deployments: Comparison between GPON,XGPON and NG-PON2 for a Greenfield operator. *2015 Conference of Telecommunication, Media and Internet Techno-Economics (CTTE).* Munich: Germany.

[39] Fibre to the Home Council Europe - Network Infrastructure Committee. (2007). FTTH Infrastructure Components and Deployment Methods. FTTH Council Europe.

[40] Fibre to the Home Council Europe - D& O Committee. (2016). *FTTH Handbook - Edition 7.* Retrieved from Fibre to the Home Council Europe - Resources: http://www.ftthcouncil.eu/documents/Publications/FTTH_Handbook_V7.pdf

[41] Corning. *Communication Networks*. Retrieved from Corning : http://www.corning.com/worldwide/en/products/communication-networks/products.html

[42] Huber+Suhner. *Fiber To The Home*. Retrieved from Huber+Suhner Fiber To The Home: http://fibertothehome.hubersuhner.com/en/

and access node security. In the case of in passive optical networks (PON), each access node can serve up to a maximum of 100,000 users.

- **Primary Fiber Concentration Point (PFCP) (distribution site or local exchange):** PFCPs are located closer to the subscribers and aggregate traffic from SFCP. They can be located in underground or pole-mounted cable-joint closures or street cabinets. In the case of PON, handholes or manholes may house splitters (passive elements) and branching boxes, and in the case of Ethernet, cabinets may house switches and active electronics (active elements).
- **Secondary Fiber Concentration Point (SFCP) (fiber distribution cabinets or outdoor cabinets):** Each cabinet serves a single service area with 600 to 1,000 passings per service area. SFCPs are optimal or strategic points that enable drop cabling to be split out as close as possible to subscribers. They can be located in underground or pole mounted cable joint closures, or small street pedestal structures. SFCPs house splitters and Y-branches that help to disjoin drop cables (in the case of PONs) or active electronics (in the case of Ethernet).
- **Fiber Optic Feeder Cabling:** This cabling runs from access nodes to PFCPs and uses 10/40/100 Gbps core links (432 or 288 strands) over diverse paths (for PON or Ethernet) using underground or aerial deployment. For underground deployment, digging and laying conduit are required; for aerial deployment, pole make-ready is required.
- **Fiber Optic Distribution Cabling:** This cabling runs from PFCPs further into the network including redundant links, and consists of medium-sized fiber counts (48-192) using underground or aerial deployments. For underground deployment, digging and laying conduit are required; for aerial deployment, pole make-ready is required.
- **Subscriber Tap:** Fiber-optic housing located in the right-of-way near to the customer premises. The subscriber tap can be installed on a pole or underground.
- **Drop Cabling:** This cabling runs from taps to residences or buildings (maximum of 0.3 miles) and consist of 1 or 2 fiber cables using underground or aerial deployment. In the case of aerial deployment, drop cabling must withstand environmental conditions using armored cables.
- **Optical Network Unit (ONU):** Active equipment installed on the premises of subscribers.

Figure 24 shows a Fiber-to-the-Home (FTTH) configuration diagram and a subset of the main network elements described above.

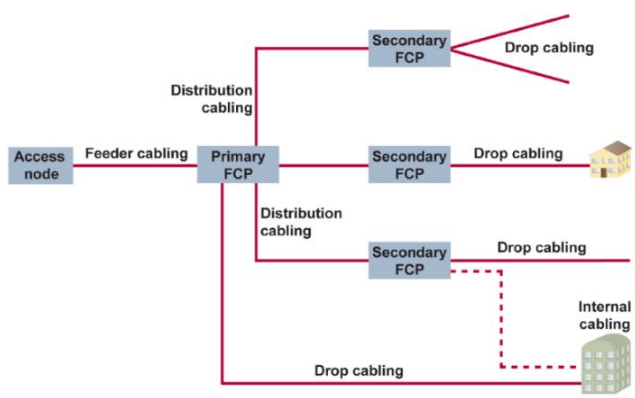

Figure 24. Main elements in a FTTH network infrastructure[43]

[43] Fibre to the Home Council Europe - D& O Committee. (2016). *FTTH Handbook - Edition 7.* Retrieved from Fibre to the Home Council Europe - Resources: http://www.ftthcouncil.eu/documents/Publications/FTTH_Handbook_V7.pdf

For carrying out the fiber network design assessment, the City of Redding Public Works Department provided geographic information systems (GIS) data of the downtown pilot project area such as land use by category (i.e., residential, office, retail, industrial, public, etc.), building footprint, census blocks, roads, poles, electric overhead, hydrants, pipes, manholes, among others. A subset of these GIS data is shown in Figure 23.

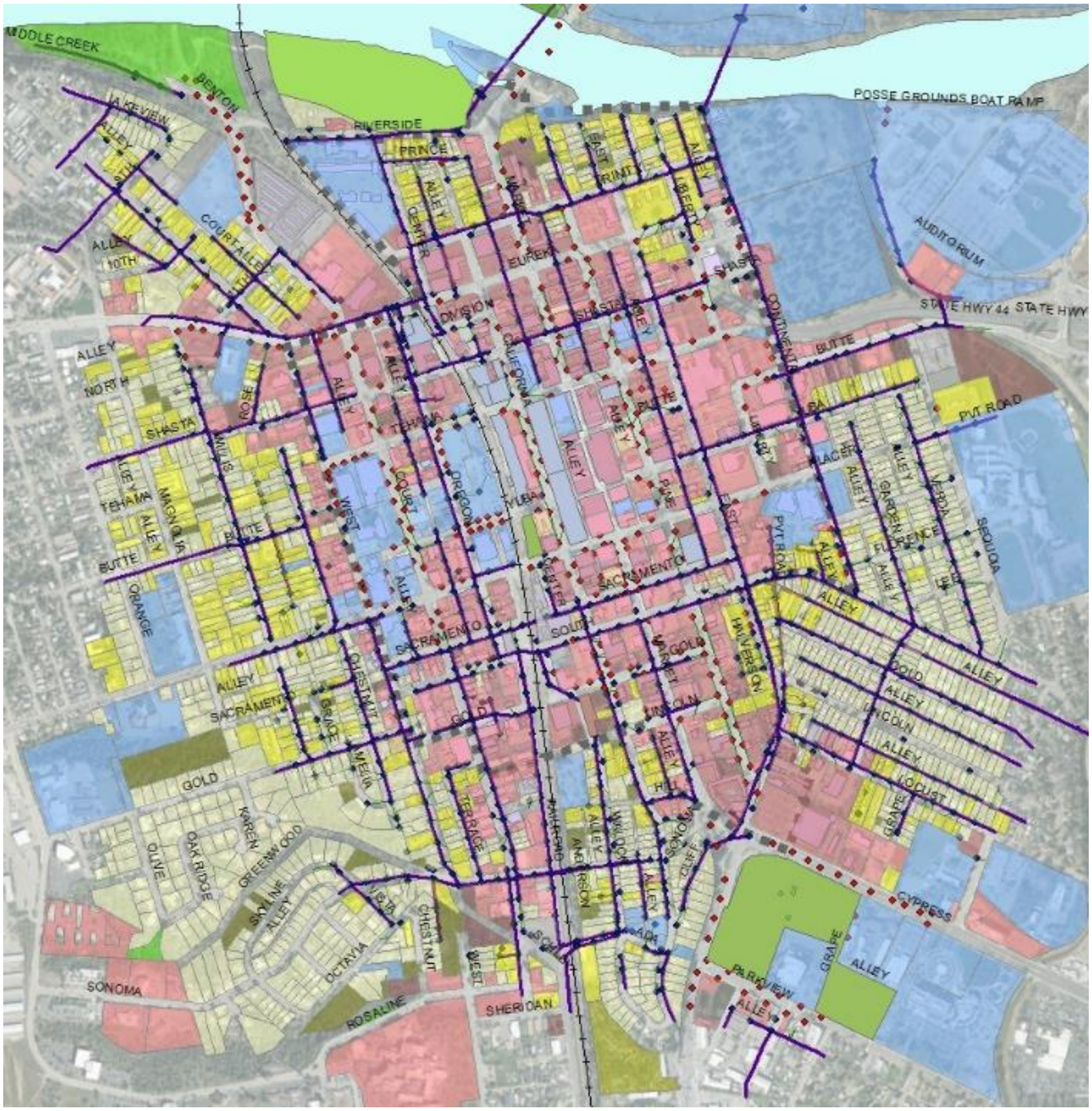

Figure 23. GIS data layers of Redding Downtown including land use, roads, poles, electric overhead, among others.

Other important GIS data used for the technical analysis was REU electrical usage of customers[44]. This approach was proposed by Steve Blum[45] based on the assumption that electrical usage patterns are good rough indicators of broadband service potential. The same approach was implemented in Blum's assessments for Healdsburg[46] and Palo Alto[47]. Table 5 shows electrical consumption ranges and customer classes used for this technical assessment and Figure 25 shows location of customer classes in the downtown pilot area.

Estimated Annual KWH	**Class**	**Color Code**
1,000,000+	A	Red
500,000 - 999,999	B	Orange
200,000 - 499,999	C	Yellow
50,000 - 199,999	D	Green
15,000 - 49,999	E	Blue
-2,000 - 14,999	F	Grey
Less than -2,000	G	Black

Table 5. Electric customers by consumption class

[44] These data did not include any information that identified customers or any other private customer information. The data only included electrical usage patterns of residential and business locations.
[45] Tellus Venture Associates – Management, planning and business development consulting for community broadband. https://www.tellusventure.com/
[46] Blum, S. (2015). Healdsburg Fiber Optic Network Assessment, 20 January 2015.
[47] Blum, S. (2011). Market Research Report - Citywide Ultra High-Speed Broadband System Project, City of Palo Alto, May 19, 2011. https://www.tellusventure.com/downloads/Palo-Alto-Fiber-Market-Research-Report-19May11.pdf

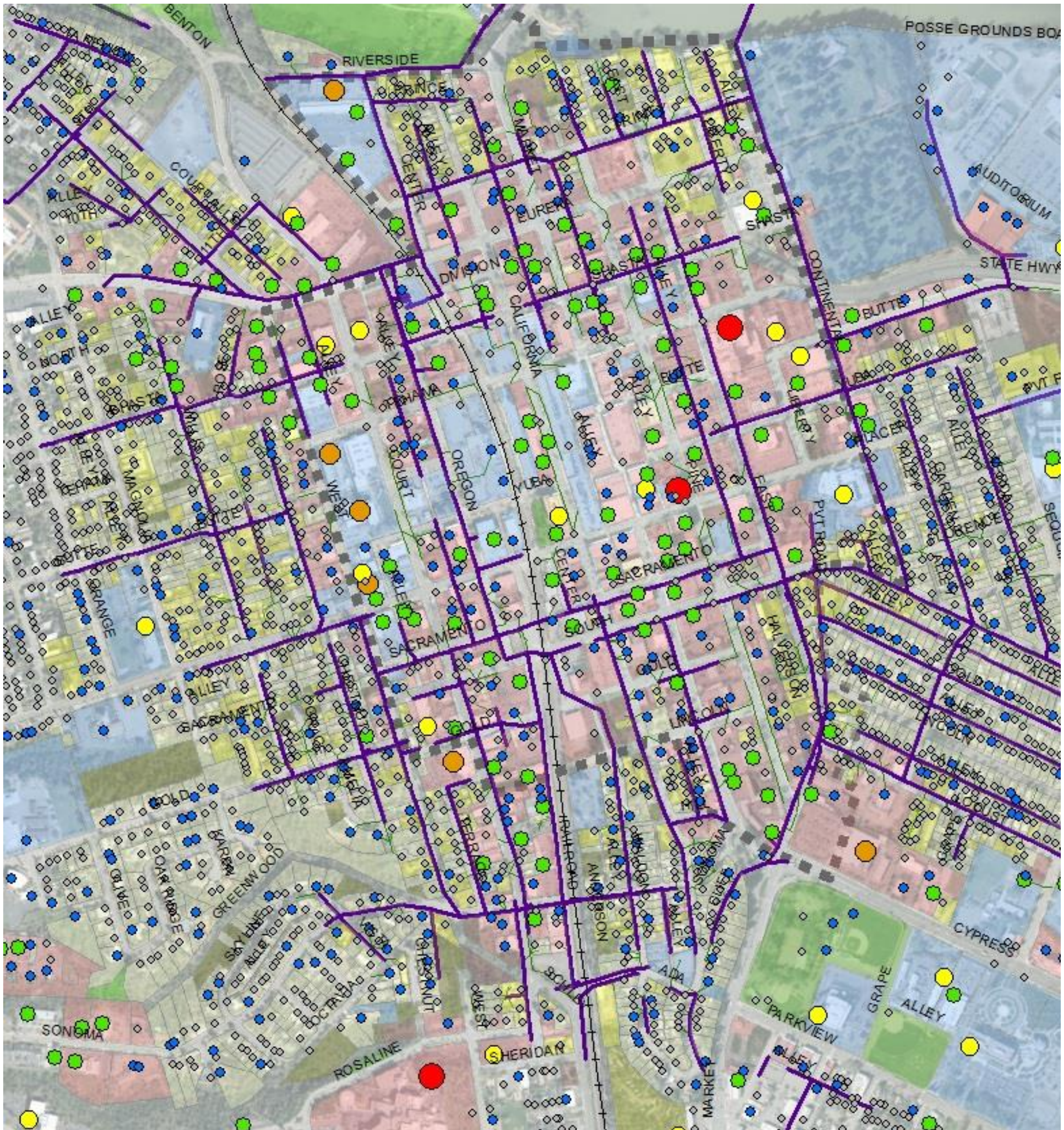

Figure 25. REU electrical usage patterns in Downtown Redding.

Figure 26 shows the design of a proposed fiber-optic network[48] for the Downtown Redding pilot project area. The design includes only the backbone or feeder fiber route that passes through the entire project area. The design does not include lateral fiber lines or customer drops, as these lines will be deployed later on based on specific customer locations. The network and feeder fiber route design criteria include:

- The interconnection point is located in a middle-mile aggregation facility to the south of Redding
- Optimized backbone or feeder fiber route to reach potential large business and industrial customers

[48] The network design underwent a few iterations in order to optimize the route and maximize customers reach. The design also incorporated a first round of feedback provided by the REU staff.

- Feeder fiber route uses wooden poles as recommended by REU staff
- Feeder fiber route follows electric primary overhead lines, and distribution fiber and drops (not included in the design and not shown in the diagram) will also follow secondary overhead lines
- PFCP (cabinets) are located in shared facilities with REU's substations
- SFCP (aerial cabinets) are located near to potential high demand areas
- Subscriber taps are located near to potential customers

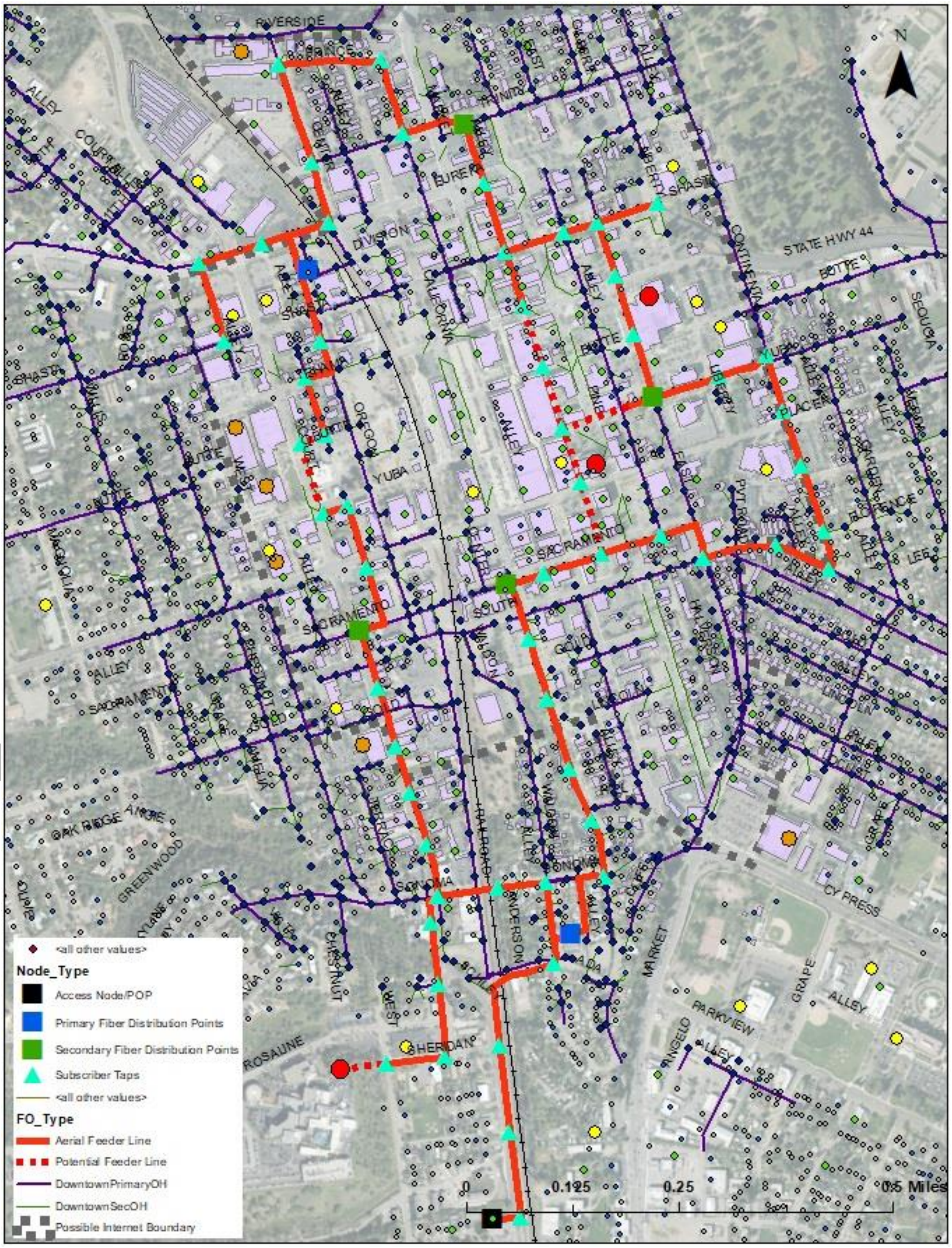

Figure 26. Fiber-optic network design for the City of Redding

It is important to highlight that this is a high-level fiber network design assessment and not a fully detailed technical fiber network design. Table 6 shows a summary of the main fiber-optic network elements for providing service to the Downtown Redding pilot area.

Table 6. Summary of main network elements for the FTTH network for the City of Redding

Item	Units	Total
Access Node	Units	1
Primary Fiber Concentration Point (PFCP)	Units	2
Secondary Fiber Concentration Point (SFCP)	Units	4
Subscriber Taps (Cable Splice Closure/Handholes)	Units	57
Fiber Aerial Deployment	Miles	4.41
Fiber Underground Deployment	Miles	0.55

The following subsection presents a high level cost assessment to estimate the cost of this FTTH/FTTB network.

5.1.2 High-Level Fiber-Optic Network Cost Assessment

The high-level cost assessment for the fiber-optic network in the Downtown Redding Pilot Project Area is based on a combination of cost data input from the National Telecommunications and Information Administration (NTIA)-Broadband USA, publicly available fiber network deployment reports, and communications with experts in the matter[49]. Table 7 shows the estimated and selected cost ranges and average costs of the main fiber network elements.

Table 7. Estimated unit costs (ranges and averages) for the main fiber-optic network elements for the Downtown Redding Pilot Project

Item Description	Estimated Low Cost (USD)	Estimated Average Cost (USD)	Estimated High Cost (USD)
Access Node (POP)	$958,775	$1,095,713	$1,232,650
Primary Fiber Concentration Point (PFCP)	$650,000	$675,000	$700,000
Secondary Fiber Concentration Point (SFCP)	$50,000	$75,000	$100,000
Subscriber Taps (Cable Splice Closure/Handholes)	$100	$250	$400
Aerial Fiber Deployment	$21,614	$44,037	$66,460
Underground Fiber Deployment	$98,760	$245,380	$392,000

[49] These costs are based on the following sources:

- CTC technology & energy (2015), Cost Estimates for FTTP Network Construction – Prepared for City of Santa Cruz, California, May 2015
- BroadbandUSA-NTIA (2017), Cost at-a-Glance: Fiber and Wireless Networks, May 2017
- National Telecommunications and Information Administration (NTIA) (2009-2015), Broadband Technology Opportunity Program (BTOP) – Projects Cost Summary, 2009-2015
- City of Chico Public Works Department, Underground Conduit Installation Cost Data
- Redding Electric Utility (REU), Cost Estimates to Install Fiber in Poles
- Steve Blum (2017), Recommendations for fiber cost estimation ranges for the CTC 2015 Report

Table 8 and Figure 27 show the estimated total deployment cost for the fiber-optic network in the Downtown Redding Pilot Project Area. The initial total cost estimate ranges from $2.6Million to $3.5M, and an average of $3Million.

Table 8. Estimated total deployment costs

Item Description – Initial Scenario	Quantity	Total Low Cost	Average Total Cost	Total High Cost
Access Node (POP)	1	$958,775	$1,095,713	$1,232,650
Primary Fiber Concentration Point (PFCP)	2	$1,300,000	$1,350,000	$1,400,000
Secondary Fiber Concentration Point (SFCP)	4	$200,000	$300,000	$400,000
Subscriber Taps	57	$5,700	$14,250	$22,800
Aerial Fiber Deployment	4.41	$95,317.74	$194,203.17	$293,088.60
Underground Fiber Deployment	0.55	$54,318	$134,959	$215,600
	Total Costs	**$2,614,111**	**$3,089,125**	**$3,564,139**

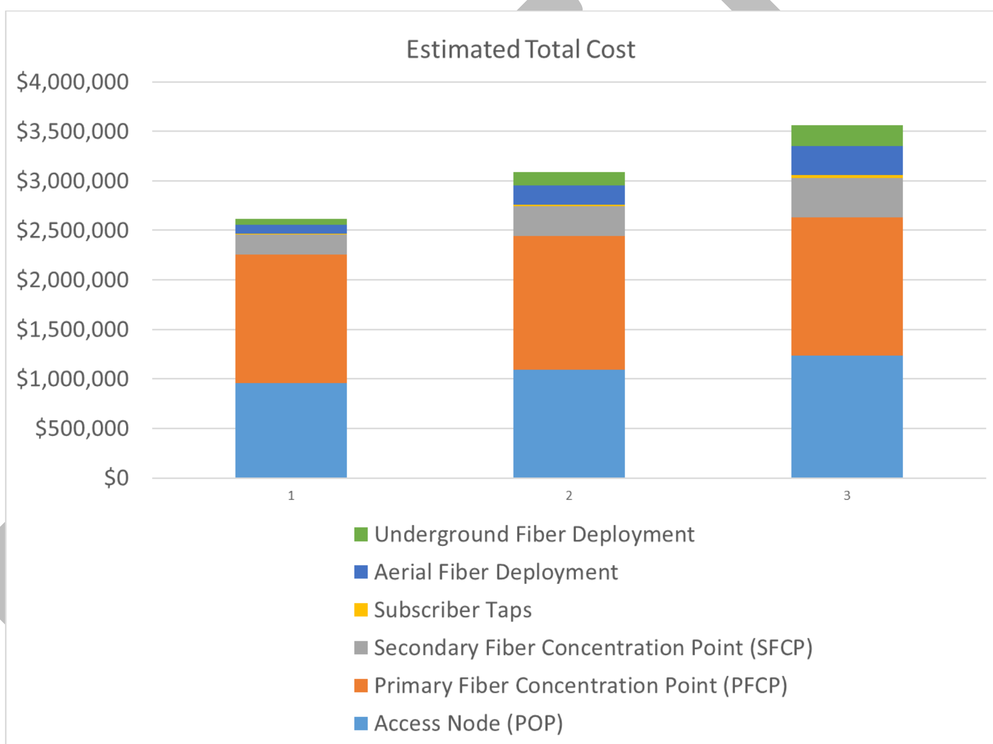

Figure 27. Estimated total fiber network cost for the Downtown Redding project area

Figure 28 shows network element cost percentages of the average total deployment costs which help to identify the main cost drivers. The main cost driver is the PFCP, 44%, followed by the access node, 36%. The least cost driver is the subscriber taps.

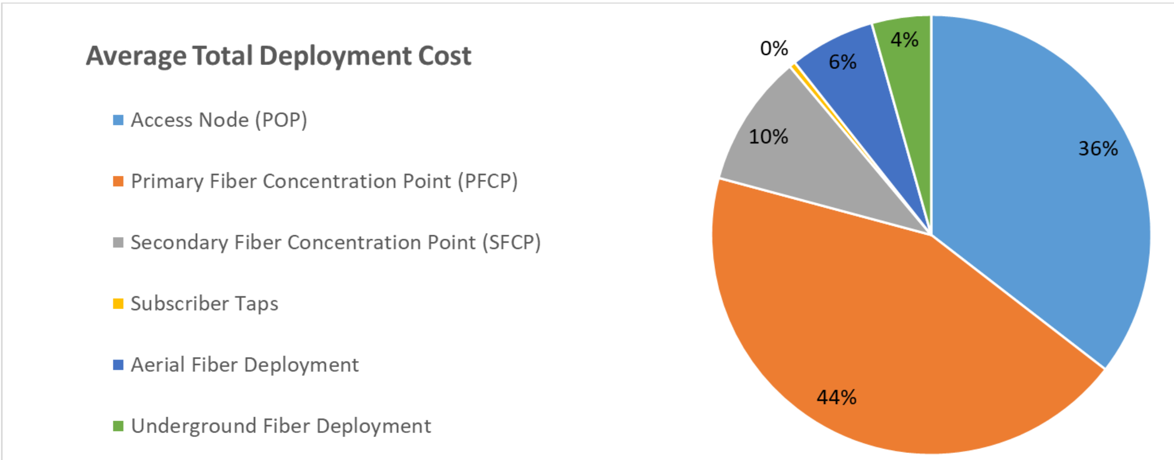

Figure 28. Main network element cost drivers for the fiber network in Downtown Redding

Network Design and Cost Optimization

After identifying the main cost drivers, the network design was optimized. The initial design included network elements (PFCP and SFCP) which could handle future growth of the network to a citywide scale. However, this potential network expansion may come after a few years, therefore, from a financial stand point, it would be better to optimize (reduce) the initial upfront cost to only necessary equipment to serve the pilot project areas. Furthermore, new generation of fiber network equipment and electronics comes after few years, then it makes sense to purchase latest equipment with enhanced capacity when the time for network expansion comes. The design of the network was optimized to network elements and total costs shown in Table 9 and Figure 29. The optimized network cost ranges from $1.9Million to $2.7Million, and an average of $2.3Million.

Table 9. Estimated optimized total deployment costs

Item Description – Optimized Scenario	Quantity	Total Low Cost	Average Total Cost	Total High Cost
Access Node (POP)	1	$958,775	$1,095,713	$1,232,650
Primary Fiber Concentration Point (PFCP)	1	$650,000	$675,000	$700,000
Secondary Fiber Concentration Point (SFCP)	3	$150,000	$225,000	$300,000
Subscriber Taps	57	$5,700	$14,250	$22,800
Aerial Fiber Deployment	4.41	$95,317.74	$194,203.17	$293,088.60
Underground Fiber Deployment	0.55	$54,318	$134,959	$215,600
	Total Costs	**$1,914,111**	**$2,339,125**	**$2,764,139**

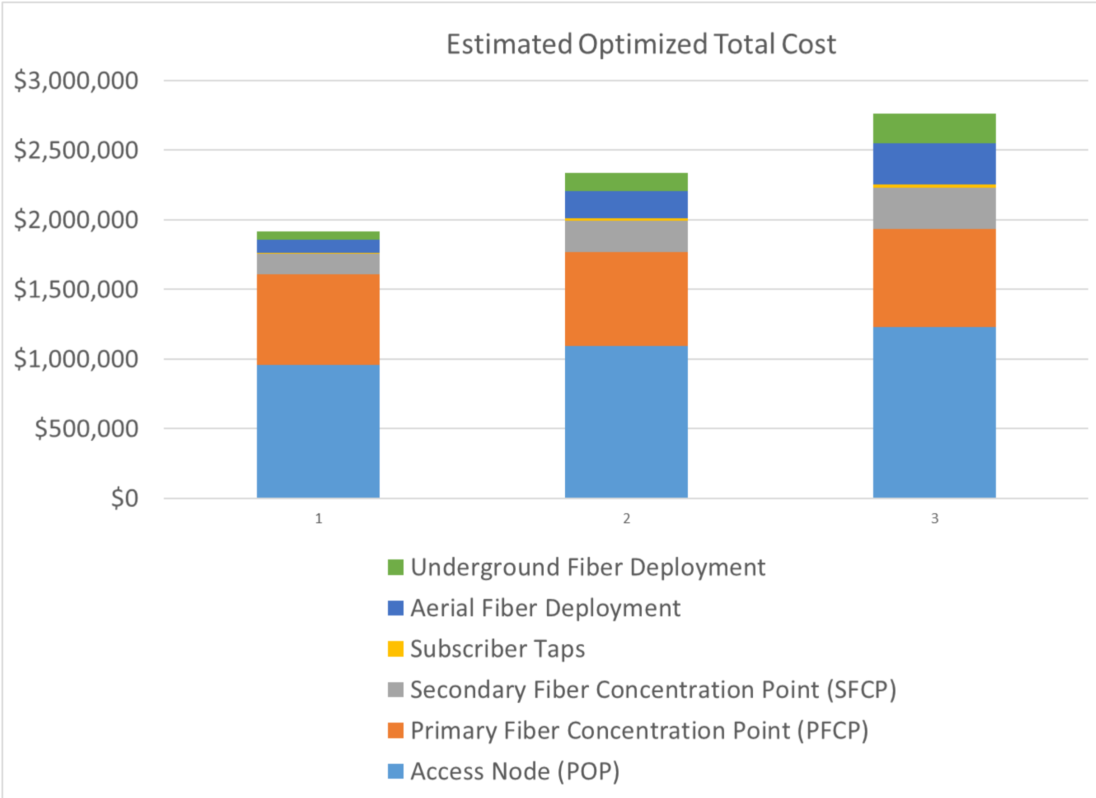

Figure 29. Estimated total fiber network cost for the Downtown Redding project area

Further Network Design and Cost Optimization

Further cost optimization can be achieved by identifying the main cost drivers and then optimizing the costs finding synergies with the city and REU infrastructure and operations. Figure 30 shows the main cost drivers of the optimized fiber network. The main cost driver is the access node, 47%, followed by the PFCP, 29%. Table 10 shows the estimated costs of the access node elements. If there is a REU or city-owned facility with appropriate infrastructure that can house the access node elements, then that would mean around $333,000 cost reduction in the access node cost. It is recommended further discussions among the potential project stakeholders in order to discuss synergies that could lead to more cost optimization. Cost optimization can come also from working together with the city public works department for underground fiber deployment in certain segments of the fiber network route.

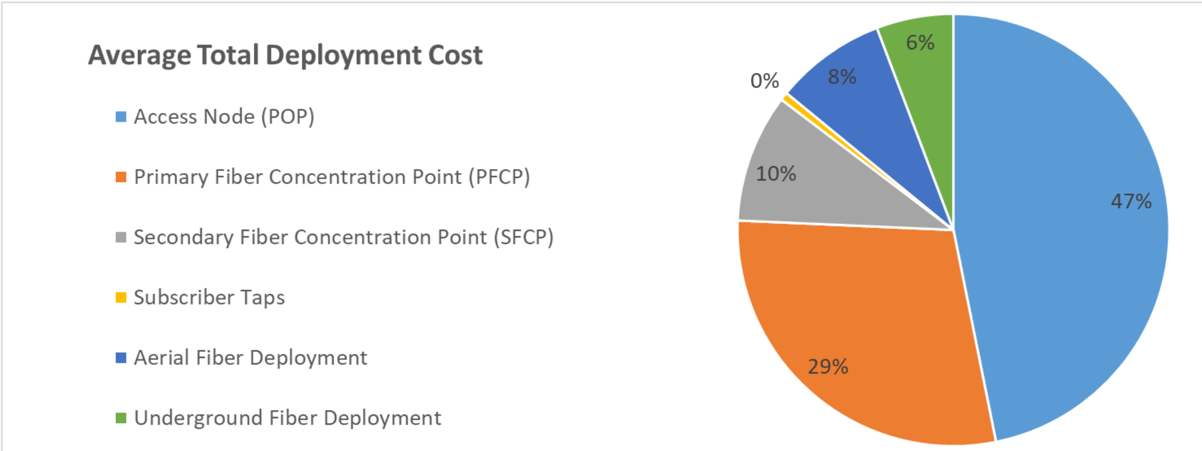

Figure 30. Main network element cost drivers for the optimized fiber network

Table 10. Estimated cost of access node elements

Access Node (POP)	Low Cost	Average Cost	High Cost
Communication Huts	$326,000	$334,000	$342,000
Generators	$70,000	$126,000	$182,000
Network Router	$15,000	$20,000	$25,000
Network Switch	$2,500	$5,000	$7,500
Patch Panel	$100	$300	$500
Transponder Card	$5,000	$7,500	$10,000
Network Transceiver	$100	$300	$500
Mounting Hardware, Cables, Battery & Cabinet	$300,000	$315,000	$330,000
Circuit Breaker Kit	$75	$113	$150
Battery and Rectifier System	$20,000	$27,500	$35,000
Network Node	$220,000	$260,000	$300,000
	$958,775	**$1,095,713**	**$1,232,650**

6. Policy Recommendations to Support Broadband Expansion

6.1 Policy Issues and Considerations

6.1.1 Assess and Implement Smart City Capabilities

Cities may increase operational efficiency by incrementally adopting cutting-edge broadband-based municipal services such as smart parking meters, smart traffic systems, digital information kiosks, smart energy-efficient lights, smart security and monitoring systems, among other services. Smart city services will allow Redding to provide services optimizing human resources and offering more detailed data on the provision and use of these automated services. The city may assess the feasibility (including both technical and financial aspects) of implementing and adopting smart city services and establishing partnerships with Internet service providers and technology companies to launch pilot projects in the city.

6.1.2 Ease for Broadband Infrastructure Deployments

Local governments should promote and support expansion of high-capacity middle-mile (fiber-optic backbone) and high-speed last-mile (wireline and wireless) networks to reach residential, business and industrial broadband customers in both urban and rural areas. The city can reach out to public utilities and/or ISPs to provide ubiquitous reliable and high-speed broadband Internet access. For that purpose, permit and authorization processes should provide detailed guidance and timely responses for requests of broadband infrastructure deployments and installation of telecommunications equipment. Additionally, the city can implement policies aimed to reduce barriers and streamline the permit process for broadband infrastructure deployments and facility upgrades. It is also important to find a balance between proper land use designations, based on the sustainable element of the general plan, and growing needs of broadband services in the city.

6.1.3 Priority Areas for Broadband Infrastructure Deployments

The city may identify priority areas for broadband deployments based on local needs (i.e., for residential, business and industrial services) and/or least attention from ISPs. The city can work together with public entities, non-government organizations, and business associations, among other interested parties, to identify priority areas and develop strategies for addressing broadband needs. In the case of residential broadband services, needs may include broadband services to enable work-related applications for telecommuting and telehealth applications, to high-quality entertainment applications and Internet-of-things applications. In the case of business and industrial broadband services, high-speed and high-quality services are paramount for local businesses to thrive in the growing digital economy; as they allow incorporating broadband Internet-based services and applications into daily processes. These may include services that provide access to a variety of competitive suppliers regardless of geographical location, automated logistics and coordination systems across companies' production and distribution processes, advertising to nationwide and global markets, and providing direct communication from company to customers, and vice versa, among other areas. The identified priority areas and needs should include future growth over the next decade.

6.1.4 Partnerships for Broadband Infrastructure Projects

The City of Redding should encourage the Redding Electric Utility to explore the option to provide fiber internet service and ISPs to expand broadband infrastructure and services to address the identified priority areas and needs. The city may develop a comprehensive data set of available broadband-related city-owned assets (called a broadband asset inventory), and make this information available to the public through an online map viewer. The city may lease some of these assets to support expansion of broadband services. The city may also evaluate options for establishing partnerships with the REU and ISPs for the deployment of municipal smart city services and, at the same time, support the deployment of infrastructure to provide cutting-edge residential, business and industrial broadband services. The city may also support deployment of the last-mile element (to reach final customers) using high-speed broadband technologies which may include but are not limited to fiber optics, cable, fixed wireless, 4G and 5G (small cells) mobile wireless, millimeter-wave and television white spaces (TVWS), among others, using terrestrial facilities or unmanned aerial system (UAS) platforms. New deployments should also accommodate future expansion of infrastructure based on growing broadband customer and speed demands, changes in technology and future utility providers. Partnerships may also be established with other public utilities and state organizations (i.e., Caltrans) to find efficiencies and synergies when deploying infrastructure in public rights-of-way (PROW).

6.1.5 Promote Broadband Services Adoption to Foster Economic Development

The City of Redding may promote and support partnerships between ISPs and public and private entities for broadband infrastructure deployments and broadband adoption programs in fields including, but not limited to, education, health care, agriculture, manufacturing, economic and workforce development, tribal communities, and emergency services. Adoption programs may include digital literacy training, broadband services implementation as a tool for strategic and everyday work processes, implementation of online service capabilities accessible to all residents, and training of a new digital workforce.

6.2 Policies for Promoting and Improving Telecommunications Infrastructure

This subsection presents a summary of recommended policies that may guide use of resources and promote expansion of modern broadband Internet services. The policies established herein may guide incorporating smart city capabilities in Redding and defining strategies for achieving modern policies and efficient permit processes for promoting expansion and upgrading of broadband infrastructure and services in accordance with the city's sustainability and land use policies and regulations, among others. These policies also promote cooperation between the city's public works, public utilities and ISP's broadband infrastructure projects to find synergies and achieve efficiencies. These policies are based on best practices from cities and counties in California (i.e., City of Morgan Hill[50] and County of Santa Cruz[51]).

[50] Tellus Venture Associates, Blum, S., *City of Morgan Hill 2035 General Plan – Telecommunications Infrastructure Final Report*. 12 September 2016. http://www.tellusventure.com/downloads/morgan_hill/morgan_hill_telecommunications_infrastructure_final_report_12sep2016.pdf

[51] California Broadband Council. (2014, January 15). *California Broadband Council-Overcome local barriers to deployment and adoption.* Retrieved from County of Santa Cruz-Recommended Actions to Expand Broadband: http://broadbandcouncil.ca.gov/uploadedFiles/Content/News/Santa%20Cruz%20County%20Broadband%20Update.1-28-2014.pdf

Additionally, some of these recommendations are based on policies and ordinances of other counties and cities such as the City of San Jose and County and City of San Francisco.

6.2.1 Dig-Once Policy

Depending on the approach taken regarding dig-once policies, they can help local governments and utility companies to work together to identify project synergies and to optimize resources for installation of conduit as part of county or city projects. A white paper by the Columbia Telecommunications Corporation (CTC) summarizes the following general approaches for dig-once policies[52]:

- Requiring an excavator who applies for a permit in the public right-of-way to notify utilities and other relevant entities (e.g., telecom companies and ISPs) about the excavation project and coordinate their participation.
- Requiring an excavator to install empty conduit for future use (also called "shadow conduit" installation policy). Depending on the policy, the excavator or the jurisdiction may then lease that excess conduit capacity.
- Undertaking a longer-term process, coordinating multi-year plans with excavators.

During meetings with local government officials in the northern California region, a common point of discussion was deciding when laying conduit was technically and financially feasible without interfering with timelines and operations on the main excavation project. Addressing this topic requires evaluating several factors and conducting a feasibility analysis covering the following points:

- Technical feasibility, maximizing available resources and reaching high-priority areas;
- Developing a technical specification for the dig-once conduit; and
- Developing an engineering cost model to estimate the incremental costs of the dig-once conduit.

6.2.2 Develop Conduit Specifications

Conduit specifications allow local governments, utility companies and ISPs to estimate costs of adding conduit in an excavation project in public rights-of-way, and carry out efficient planning and deployment of fiber optics on standard conduit deployments. These specifications can be developed and implemented in Redding and would achieve even higher efficiencies if adopted in a county or across an entire region. Conduit specifications include requirements and recommendations such as size, type and material of the conduit, conduit installation and placement in the trench parameters, depth and distance from utility infrastructure, vault installation parameters, and minimum distance between vaults or manholes, among other items. These specifications must be reviewed by public works departments to assess feasibility and practicality of such installations in a specific geographic area.

6.2.3 Master Lease Agreement

The purpose of this lease agreement is to reduce processing time and complexity for leasing a local government's broadband-related assets. A lease agreement allows for the installation, operation and maintenance of ISPs' telecommunications equipment on city-owned assets. To maximize effectiveness of

[52] Columbia Telecommunications Corporation. (2017, April). *ctc technology & energy.* Retrieved from Technical Guide to Dig Once Policies: http://www.ctcnet.us/wp-content/uploads/2017/04/CTC-White-Paper-Dig-Once-20170414.pdf

using a master lease agreement, the local government needs an up-to-date inventory of assets, which may include land, public rights-of-way, conduit, buildings, utility poles, light standards, towers, and any other property. This inventory must be publicly available for ISPs to review so they can assess the assets that they might want to lease, based on their broadband deployment planning. The agreement must include fee structures, agreement duration, renewal terms, access and responsibilities of the parties, and co-location rights, among other legal requirements.

6.2.4 Streamline Application Process and Permit Fees

Streamlining the processes involved in deploying broadband infrastructure allows for faster expansion of broadband infrastructure and services in the city. Additionally, charging at-cost permit fees might contribute to a competitive broadband service pricing in the region. In the context of rural northern California, with its lower population densities, geographically spread households and, in some cases, harsh geography, broadband deployment and operation are more expensive than in urban areas of California. This results in higher broadband prices and lower speed offers. Some ISPs in the Northern California region identified county or city asset leases and permit expenditures as significant operating expense drivers. Some options to address these issues include charging discretionary planning permits at cost, or removing requirements for broadband infrastructure within the public right-of-way to obtain a discretionary land use permit. Other identified issues to address include land use regulations and land use permits for certain broadband facilities (i.e. cabinets, racks, wireless facilities) within the public right-of-way.

6.3 Sample Telecommunications Element for the City of Redding General Plan

GOALS, POLICIES, AND ACTIONS

Goal T-1: **Promote implementation of municipal smart city capabilities and broadband-based services to increase operational efficiency**

Goal T-2: **Promote efficient expansion of broadband infrastructure to provide high-speed broadband Internet service**

- **Goal T-1: Promote Implementation of Municipal Smart City Capabilities and Broadband-Based Services to Increase Operational Efficiency**
    - **Policy T-1.1 (Promote Deployment of Municipal Smart City Services) –** Promote deployment of broadband infrastructure and services to provide broadband-based municipal smart city services.
        - **Action T-1.1.1 –** Assess potential priority areas for providing smart city services (i.e., parking meters, traffic systems, information digital kiosks, lights, security and monitoring systems).
        - **Action T-1.1.2 –** Promote including broadband facilities in all public buildings, major transportation and all public works projects.
    - **Policy T-1.2 (Develop Standards) –** Develop standards for preparing future construction and developments for broadband facilities and services.
        - **Action T-1.2.1 –** Develop broadband building and wiring standards to support broadband in new construction and buildings.
        - **Action T-1.2.2 –** Develop smart building requirements for new public, commercial, residential and industrial projects.

- **Policy T-1.3 (Assess Establishing Partnerships for Carrying Out Pilots) –** Assess potential partnerships with ISPs and technology companies for carrying out smart city pilots in municipal priority areas.
  - **Action T-1.3.1 –** Conduct a request for information (RFI) process on smart city projects addressed to ISPs and technology companies.
  - **Action T-1.3.2 –** Conduct a feasibility study to carry out smart city pilot projects including potential partners, project cost, business models, among others.
- **Policy T-1.4 (Online Municipal Services) –** Promote and make all municipal services available online.
  - **Action T-1.4.1 –** Enable all municipal services in the City of Redding portal.

- **Goal T-2: Promote Efficient Expansion of Broadband Infrastructure to Provide High-Speed Broadband Internet Service**
  - **Policy T-2.1 (Develop a Strategic Broadband Plan) –** Develop a strategic plan for supporting expansion of high-speed broadband infrastructure and services for residential, anchor institutions, business and industrial customers.
    - **Action T-2.1.1 –** Work with public entities, non-government organizations, and business associations, among other interested parties, to asses priority areas and needs of residential, business and industrial customers and community anchor institutions (education, public services, public safety, and health care).
    - **Action T-2.1.2 –** Based on the priority areas and needs assessment, develop a master plan to address them including objectives, strategies, partners, resources, and timelines, among other important planning elements.
  - **Policy T-2.2 (Dig-Once Policy) –** Promote collaboration among public works departments, utility companies and Internet service providers to find project planning synergies to optimize resources for installation of conduit and/or fiber optics as part of city projects.
    - **Action T-2.2.1 –** Develop and implement a local dig-once ordinance by assessing the potential role of the city and different dig-once policy approaches (i.e., open trench, shadow conduit, excess capacity utilization, etc.).
    - **Action T-2.2.2 –** Develop standards for deploying conduit and lateral connections. This will allow for cost estimations of the addition of conduit in an excavation project in public rights-of-way, and efficient planning and deployment of fiber on standard conduit deployments.
  - **Policy T-2.3 (Access to Public Assets and Develop a Master Lease) –** Assess feasibility of allowing ISPs to lease public assets (pubic rights-of-way, land, buildings, ducts, conduit, poles, towers, etc.) for deployment, upgrade or expansion of broadband networks.
    - **Action T-2.3.1 –** Develop an up-to-date inventory of broadband related city-owned assets and community anchor institutions which might include land, public rights-of-way, conduit, buildings, utility poles, light standards, towers, and any other property.
    - **Action T-2.3.2 –** Make the asset inventory available in geographic information system (GIS) format and make it publicly available through an online map viewer and data tables.
    - **Action T-2.3.3 –** Develop and implement a master lease aimed to reduce processing time and complexity for leasing the city's broadband-related assets. The agreement must include standard terms such as fee structures, agreement duration, renewal terms, access and responsibilities of the parties, and co-location rights, among other legal requirements.

- **Action T-2.3.4 –** Develop specific procedures for granting access and/or leasing assets in a fair and transparent manner to all interested ISPs.

- **Policy T-2.4 (Streamline Permit and Authorization Processes) –** Ensure transparent and fair permit and authorization processes for all ISPs. Streamline the process of deploying broadband infrastructure to allow faster and timely expansion of broadband infrastructure and services in the city.
  - **Action T-2.4.1 –** Review and assess current municipal permit and authorization application processes for deployment of broadband infrastructure, including requirements, steps, timelines, and costs associated with the applications.
  - **Action T-2.4.2 –** Update permit and authorization processes when, based on the assessment, efficiencies and faster processes can be achieved.
  - **Action T-2.4.3 –** Require digital plan files in GIS format for all upcoming works in PROWs and new developments (i.e., utilities, developers, contractors and others).
- **Policy T-2.5 (Assess Partnerships and Business Models for Infrastructure Deployments) –** Assess establishing active partnerships with ISPs and other technology companies for deploying and providing broadband services.
  - **Action T-2.5.1 –** Assess the potential role of the city as a partner to provide or expand broadband services.
  - **Action T-2.5.2 –** Assess potential business models for providing broadband services to priority areas under a public-private-partnership model.
  - **Action T-2.5.3 –** Assess potential private partners for carrying out broadband infrastructure deployments. Issue requests for proposals (RFPs) for private partners and explore negotiating, for example, the use of public assets or permit fees for shadow conduit deployments (outer or inner ducts).
  - **Action T-2.5.4 –** Explore partnerships with state agencies (i.e., Caltrans) to achieve interagency coordination.
- **Policy T-2.6 (Develop a Database of Upcoming Public Infrastructure Projects) –** Generate a database of upcoming public infrastructure projects (i.e., water, sewer, roads, paving, etc.) in public rights-of-way, including location, routes and estimated timelines.
  - **Action T-2.6.1 –** Identify and track upcoming public infrastructure projects and generate a database.
  - **Action T-2.5.2 –** Make the upcoming public infrastructure project database available in geographic information system (GIS) format and through an online map viewer.
- **Policy T-2.7 (Promote Validation of Broadband Service Availability and Speed) –** Promote crowd validation of broadband service availability and speed for residential, anchor institutions, business and industrial broadband services.
  - **Action T-1.3.1 –** Promote downloading and using the CalSpeed (or similar state-sponsored applications) for validating broadband service coverage and speed for broadband services in the city.

7. Recommendations to Improve Broadband Service Adoption

While broadband access is critical, adoption of broadband services is equally as important. Many community residents in the City of Redding need assistance finding low-cost Internet service, obtaining a computer and learning pertinent skills to navigate the online world successfully. Efforts to meet these needs will help the region to combat the inequitable distribution of broadband to rural areas, referred to as the “digital divide.” The digital divide is often more broadly defined as the discrepancy between the availability of technology among socioeconomic or racial/ethnic groups. The divide limits rural residents’ access to education, workforce training, healthcare and civic engagement.

Providing equipment and training opportunities will allow users to effectively understand and learn how broadband can improve their ability to conduct business, excel in school, manage their finances, participate in telehealth, apply for jobs, receive vocational training and function effectively in a digital world. These skills are critical to educational and career success and are accessible to more advantaged families but can be out of reach for disadvantaged communities due to socioeconomic challenges (e.g., educational background, time impacts of multiple jobs and long commutes).

Communities and organizations seeking to connect users with equipment and access to curriculums should establish partnerships with existing organizations and programs to establish credibility and identify best practices for outreach, implementation, follow-through and success. The following are suggested partners:

- Affordable housing communities
- Community action agencies
- Center for Healthy Communities at CSU, Chico
- Youth development agencies
- Workforce and one-stop job training agencies
- Multi-service agencies
- Rotary Club and other service organizations by community
- Senior citizen and veteran’s resource and service centers
- Butte-Tehama Community College
- Local libraries
- K-12 schools

Broadband also transforms the way small businesses operate, communicate with employees, and interact with customers. Broadband is an important tool for achieving strategic goals, improving competitiveness and efficiency, reaching customers, and interacting with vendors. Businesses use broadband connections to improve efficiency and productivity, both in their internal processes and their interactions with customers. The capability of and opportunities provide by broadband can translate into profits and producer surplus to businesses with a portion of the gains being passed to consumers.

Many businesses throughout the region do not have access to the speeds necessary to conduct day-to-day business. Because of this limited capacity, many smaller businesses are unaware of the growth potential that is attainable if they had better broadband. Economic development organizations, workforce agencies and chambers of commerce are examples of groups that can provide training and information to business owners to increase adoption and plan for growth and sustainability.

8. Conclusion

This Master Broadband Plan for the City of Redding aimed to provide the following:

- A comprehensive assessment of the current landscape of fixed broadband services for residential, business and industrial customers
- Recommendations for expanding and upgrading broadband infrastructure and services
- Recommendations for developing and implementing local government policies to support broadband infrastructure deployments
- Recommendations for improving broadband adoption through establishing partnerships with existing organizations and programs.

The recommendations for expanding broadband infrastructure and upgrading services focus on the Redding Electric Utility (REU) deploying a high-capacity and high-speed fiber optic network. This report presents a high level cost assessment of a fiber optic network in the Redding Downtown Pilot Project Area. The high level cost assessment for the downtown network design, after the design and cost optimization, provided a total cost range from $1.9M to $2.7M and an average of $2.3M. The cost assessment also describes further cost optimization (reduction) that can be achieved by assessing additional existing infrastructure that can be used in this fiber network deployment. It's recommended to have further discussions with the REU and Redding Public Works staff, among other potential project stakeholders.

The recommendations for developing and implementing local policies focus on reducing barriers for new broadband infrastructure deployments and streamlining permit and authorization process in public rights-of-way. The policies included a dig-once policy, the development of conduit specifications, a master lease agreement, and the streamlining of the application process and permit fees. Other recommended policies include incorporating smart city capabilities in the City of Redding. Finally, a sample of a General Plan-Telecommunications Element is also presented as a reference.

The recommendations for improving broadband adoption included establishing partnerships with existing organizations and programs to establish credibility and identify best practices for outreach, implementation, follow-through and success. Additionally, economic development organizations, workforce agencies and chambers of commerce were examples of groups that can provide training and information to business owners to increase adoption and to plan for growth and sustainability.

Finally, this study also recommended launching a CalSPEED campaign for residential and business customers to download and use this application to validate actual broadband service coverage and speeds provided by ISPs.

9. Appendices

9.1 Appendix A - Broadband Service Benchmarks

9.1.1 Downstream/Upstream Broadband Speeds (Mbps)

The FCC defines broadband (advanced telecommunications capability) primarily in terms of downstream and upstream speeds as 25 Mbps and 3 Mbps[53], respectively. The CPUC also uses speed as a metric to evaluate broadband service coverage, defining underserved areas to areas were broadband is offered at slower speeds than 6 Mbps downstream and 1 Mbps upstream[54].

9.1.1 Supplemental Benchmark Metrics

The FCC currently does not adopt non-speed performance metrics in their broadband progress reports (although it recognizes the importance of low latency and high consistency to provide advanced telecomm capability) due to currently lacking comprehensive data on factors other than speed. The following are supplemental broadband benchmarks, described in the FCC's 2016 Broadband Progress Report, which in the future will help evaluating quality-of-service in a more comprehensive manner.

Latency (ms)

Latency is defined as a measurement of the time it takes a data packet to travel through the network. It significantly impacts the performance of interactive, real-time applications, including VoIP, online gaming, videoconferencing, and VPN platforms.

Consistency

Consistency has the potential to significantly impact whether a service delivers broadband to provide consumers with meaningful access to interactive advanced services including VoIP, telemedicine, and online education applications using high-quality voice, data, graphics, and video telecommunications.

Packet Loss

The Measuring Broadband America program denotes a packet is lost if the latency exceeds 3 seconds or if the packet is never received. Packet losses might affect the perceived quality of phone calls or video conferencing.

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[53] Federal Communications Commission (FCC). (2016, January). *2016 Broadband Progress Report.* Retrieved June 2017, from https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-6A1.pdf

[54] California Public Utility Commission (CPUC). (2012, May). *Forth Annual DIVCA Report.* Retrieved June 2017, from http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Communications_-_Telecommunications_and_Broadband/Service_Provider_Information/Video_Franchising/4thDIVCAReportforYearEndingDec2010.pdf

9.2 Appendix B: Middle-, Second- and Last-Mile Broadband Technologies

This subsection describes current and new broadband technologies used by ISPs for middle-, second- and last-mile broadband networks. For this report, the definitions of middle-, second- and last-mile network segments follow the basic network structure from the FCC's Broadband Availability Gap Paper[55], shown in Figure 31. Based on an initial assessment of last-mile broadband networks and providers in the City of Redding and regional Internet fiber-optic backbones and providers, it is assumed that most broadband networks in the City of Redding consists only of middle- and last-mile network segments; therefore not including the second-mile network segment. The second-mile segment is mostly used in the case of fixed wireless broadband services, which aggregate traffic from several towers deployed in cascade configuration and sparsely located.

The middle-mile segment provides transport and transmission of data communications from an aggregation point (i.e., central office, cable headend or wireless switching station) to an Internet point of presence. Last-mile segment provides transport and transmission of data communications from a broadband modem provided by a local ISP to the first aggregation point in the network (i.e., remote terminal, wireless tower, or HFC node).

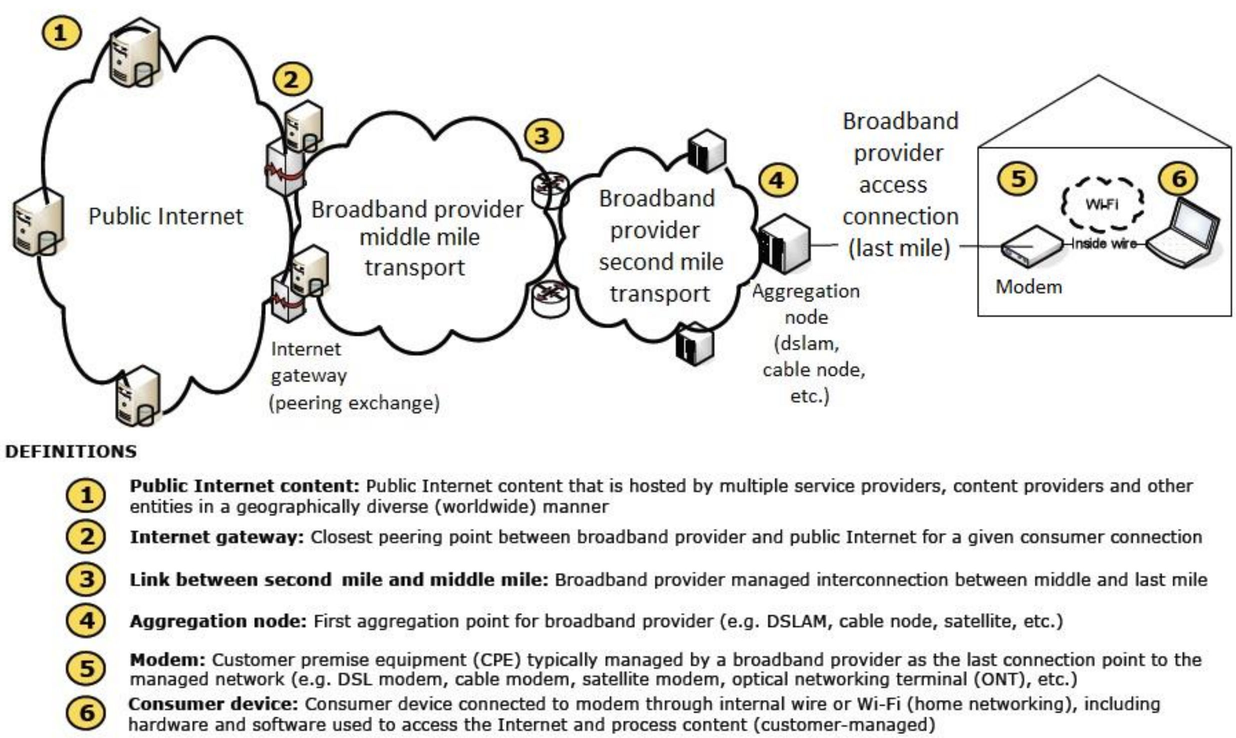

Figure 31. Basic network structure from FCC's The Broadband Availability Gap Paper

Commonly deployed middle-mile transport technologies include fiber optics, microwaves and satellite links. In 2010, the majority of central offices (approximately 95%) and nearly all cable nodes connected to the Internet through fiber-optic links. Once the transport requirement reaches 155 Mbps

[55] Federal Communications Commission (FCC). (2010, April). *The Broadband Availability Gap - OBI Technical Paper NO.1.* Retrieved from https://transition.fcc.gov/national-broadband-plan/broadband-availability-gap-paper.pdf

and above, the only effective transport mode is using a fiber-optic-based transmission backbone. Microwave and other terrestrial wireless technologies are well suited only when aggregated data is of a few hundred Mbps and relatively short middle-mile runs of 5 to 25 miles. However, microwave backhaul may be a critical transport component in the second-mile segment in the case of fixed wireless networks.

The following subsections describe most current technologies used for last-mile networks including wireline, wireless, and mobile technologies. It also describes new and innovative technologies, including some that are still in testing stage and are not commercially available yet.

9.2.1 Wireline Broadband

Wireline broadband includes digital subscriber line (DSL), cable modem and fiber-to-the-home. These technologies are primarily deployed in dense urban areas. Deployment and coverage limitations of these technologies include access to right-of-way and high costs of rolling underground lines.

Digital Subscriber Line (DSL)

DSL is defined as broadband service provided over traditional copper telephone lines (without disrupting regular telephone calls) already installed to homes and businesses. According to the FCC's 2016 Broadband Progress Report[56], this technology is the second most common service type with roughly 29% of the fixed broadband market. DSL offers the following speeds[57]:

a) **DSL over loops of 12,000 feet:** Uses ADSL2/ADSL2+ to provide rates of 6 Mbps downstream and 1 Mbps upstream. To provide faster speeds, DSL operators can bond loops (over 30 Mbps if sufficient number of copper loops are available) and continue to shorten loop lengths (see loops of 5,000 feet or 3,000 feet).
b) **DSL over loops of 5,000 or 3,000 feet:** Typically uses VDSL2 to provide 35 Mbps downstream and 6 Mbps upstream over 3,000 foot loops, and 20 Mbps downstream and 4 Mbps upstream over 5,000 foot loops.

Limitations of this technology include speed sensitivity to distance to central offices, not expanding of traditional telephone lines so the DSL footprint is not growing, and not providing higher date rates for growing speed demands of 50Mbps, 100Mbps and higher.

Cable Modem

Uses coaxial cables already installed by cable television operators to deliver video and sound. Cable modem can provide at least 1.5 Mbps and up to tens of Mbps and a few Gbps (cable networks upgraded to DOCSIS 3.1) downstream[58], and a few Mbps to 1 Gbps upstream. This technology provides the most common fixed broadband service in the United States accounting for around 59% of all fixed broadband customers. Benefits of this technology include large coverage areas for consistent fast speeds with low packet loss and latency. Limitations include low numbers of or single cable broadband providers in most areas.

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[56] Federal Communications Commission (FCC). (2016, January). *2016 Broadband Progress Report.* Retrieved June 2017, from https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-6A1.pdf
[57] Federal Communications Commission (FCC). (2010, April). *The Broadband Availability Gap - OBI Technical Paper NO.1.* Retrieved from https://transition.fcc.gov/national-broadband-plan/broadband-availability-gap-paper.pdf
[58] Federal Communications Commission (FCC). (2010). *National Broadband Plan*. Retrieved from FCC-National Broadband Plan: https://www.fcc.gov/general/national-broadband-plan

Fiber Optics

Fiber-optic technology converts electrical signals carrying data to light and sends the light through transparent glass fibers of a few microns. Fiber-based service can provide downstream speeds of around 20 Mbps to speeds around a few Gbps and upstream speed of around 5 Mbps to a few hundred Mbps. There are three basic types of FTTP deployments: point-to-point (P2P) networks, active Ethernet networks and passive optical networks (PON). PON makes up more than 94% of the residential FTTP (fiber-to-the-premises) deployments in the United States[59]. Benefits of fiber include proving consistently high speeds and transmitting at large distances without signal degradation. Limitations include requirement of new infrastructure, in comparison to DSL and cable modem using already deployed telephone and cable television infrastructure.

9.2.2 Fixed Wireless Broadband

Fixed wireless broadband includes Wi-Fi, WiMAX and LTE. These technologies are primarily deployed in areas were wireline technologies do not have complete coverage such as rural areas. Deployment and coverage limitations of these technologies come from obstructions (i.e. terrain and/or vegetation) between the antenna at the customer premises and the access point or base station located at a pole or tower. These obstructions can prevent or disrupt communications in fixed wireless radio links by causing attenuation, scattering, diffraction and absorption of electromagnetic waves.

Wi-Fi

Wi-Fi (IEEE 802.11 Standard) operates in unlicensed bands (2.4 GHz and 5.8 GHz) and was originally designed for wireless local area networks (WLANs) to enable communication among devices and stations in a range from tens to a few hundred feet, however, in the last few years, equipment manufactures developed Wi-Fi based long range solutions reaching several miles coverage. Wi-Fi can provide aggregated data rates of up to 600 Mbps[60] allowing it to provide downstream speeds of a few Mbps to tens of Mbps. Benefits of Wi-Fi include low cost of access points (APs) and customer premise equipment (CPEs) due to large economies of scale achieved by this technology. Limitations include potential interference leading to signal degradation due to operating in a widely used unlicensed spectrum.

WiMAX

WiMAX (IEEE 802.16 Standard) emerged as a high-capacity and long-range technology (up to 30 miles) for the provision of fixed and mobile broadband services for wireless metropolitan area networks (WMAN) and operates using licensed and the unlicensed bands. WiMAX was one of the technologies chosen by the ITU for providing IMT-Advanced services or 4G mobile services[61]. It achieves aggregated data rates up to 350 Mbps allowing it to provide speeds up to tens of Mbps downstream to customers. Limitations include low varieties of base stations (BSs) and CPEs due to most mobile operators and

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[59] Federal Communications Commission (FCC). (2010, April). *The Broadband Availability Gap - OBI Technical Paper NO.1.* Retrieved from https://transition.fcc.gov/national-broadband-plan/broadband-availability-gap-paper.pdf
[60] Institute of Electrical and Electronics Engineers (IEEE). (n.d.). IEEE Standards Association. (IEEE) Retrieved from http://standards.ieee.org/
[61] Institute of Electrical and Electronic Engineers (IEEE). (n.d.). *IEEE 802.16™: Broadband Wireless Metropolitan Area Networks (MANs)*. (IEEE Standards Association) Retrieved from http://standards.ieee.org/about/get/802/802.16.html

equipment manufactures shifting to LTE due to larger worldwide adoption of this technology for 4G mobile services.

LTE

Long-Term Evolution (LTE) was designed by the 3rd Generation Partnership Project (3GPP) group for mobile communications in densely populated areas (see mobile broadband). LTE has also been used to provide fixed broadband services in rural areas. LTE can achieve aggregated data rates up to 300 Mbps allowing it to provide speeds up to tens of Mbps downstream to customers. For benefits and limitations see LTE in the Mobile subsection.

9.2.3 Mobile Broadband

Mobile broadband includes packet-based data technologies such as 2G (GPRS, EDGE and CDMA2000), 3G (WCDMA, HSDPA, HSPA and CDMA2000 EV-DO), and 4G (LTE and WiMAX). Although evolution of these technologies has made mobile broadband services much more versatile and useful to consumers by providing mobility and portability, there are important differences between mobile and fixed broadband. Mobile transmissions, due to using wireless spectrum, operate under environmental factors that can impact the consistency of coverage and speeds. These technologies are primarily deployed in densely populated urban areas and in a smaller scale in rural areas. Coverage limitations of mobile broadband come from obstructions (i.e. terrain and/or vegetation) between base stations located at towers and mobile devices, and availability and access to licensed spectrum.

Legacy Technologies (2G and 3G)

These mobile technologies include packet-based data services that evolved from the GSM and CDMA mobile technologies. For GSM, these technologies include: GPRS and EDGE (100-130kbps data rates), UMTS or WDCMA (220-320kbps), HSPA (several Mbps). For CDMA these technologies include: CDMA2000 (307KBPS), CDMA2000 EV-DO (3.1 Mbps). Limitations of these legacy technologies include low speeds in comparison to new generation mobile broadband and wireline and fixed wireless broadband.

4G Long-Term Evolution (LTE)

Long-Term Evolution (LTE) was designed by the 3rd Generation Partnership Project (3GPP) group for mobile communications in densely populated areas and can achieve aggregated data rates up to 300 Mbps allowing to provide speeds up to tens of Mbps downstream and a few Mbps upstream to customers. The 3GPP group has released several versions of the LTE standard, from the first release (Rel-8 in 2008) to LTE-Advanced (Rel-11)[62]. LTE was one of the technologies chosen by the ITU for providing IMT-Advanced services or 4G mobile services, and operates in the same bands as its predecessor GSM, in addition to other bands. Most common LTE bands range from 700 MHz to 3.8 GHz. Benefits of this technology include data rates in some cases comparable to wireline and fixed wireless broadband services and providing flexible network design allowing combination of macro- and micro- cell sites to cover demand needs of specific geographical areas. Limitations include purchasing new devices that support LTE service and plans that might include data caps.

4G WiMAX

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[62] 3rd Generation Partnership Project (3GPP). *3GPP A Global Initiative*. (3rd Generation Partnership Project (3GPP)) Retrieved from http://www.3gpp.org/technologies/keywords-acronyms/98-lte

WiMAX was one of the technologies chosen by the ITU for providing IMT-Advanced services or 4G mobile services[63]. It achieves aggregated data rates up to 350 Mbps allowing to provide speeds up to tens of Mbps downstream to customers. Limitations include low varieties of base stations (BSs) and CPEs due to most mobile operators and equipment manufactures shifting to LTE due to larger worldwide adoption of this technology for 4G mobile services.

9.2.4 New Technologies for Middle- and Last-Mile

Millimeter-wave

Technology operating in millimeter waves is currently used for high-speed backhauling (point to point) to connect cell sites or access points to provide high-speed Internet[64]. There is assigned unlicensed and licensed spectrum for millimeter-wave technology. The unlicensed millimeter-wave spectrum operates in the 60 GHz band (57-66 GHz), offering 7 GHz of bandwidth, and the licensed millimeter-wave operates in the 71-76 GHz and 81-86 GHz, offering bandwidth from 10 to 80 MHz, although for shorter distances. Equipment working on these bands is affected by heavy atmospheric absorption, which limits range of operations but also unwanted interference. Millimeter-wave can achieve up to 2.5 Gbps for a mile point to point radio link.

Unmanned Aircrafts

The initiative of using solar-powered unmanned aerial vehicles (UAVs), also known as drones, flying at 12 miles above the ground to provide Internet service in unserved areas is currently led by Google and Facebook. In April 2014, Google acquired Titan Aerospace and started the Project SkyBender, which is currently testing drones using millimeter wave technology to transmit at data rates higher than 4G LTE[65]. In March 2014, Facebook acquired Ascenta, UK-based drone manufacturer, and is also currently testing solar-powered drones using free space optics (high-powered laser beams) to achieve high data rate transmissions[66]. It is likely that both Google and Facebook will use these narrow beam and high-frequency technologies (millimeter- wave and lasers) as high-capacity backhauls and other mobile and fixed wireless technologies (mentioned above) to connect final customers. The idea of using unmanned aerial vehicles (UAVs) or drones to deploy a backhaul network is innovative and promising, but it is still in a design and testing stage with no current commercial deployments.

Unmanned Super-Pressure Balloons

Delivering broadband services using super-pressure balloons travelling in the stratosphere is a Google X initiative known as the Project Loon. This project will allow customers in rural and remote

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[63] Institute of Electrical and Electronic Engineers (IEEE). *IEEE 802.16™: Broadband Wireless Metropolitan Area Networks (MANs)*. (IEEE Standards Association) Retrieved from http://standards.ieee.org/about/get/802/802.16.html

[64] Dehos, C., Gonzalez, J., De Domenico, A., Ktenas, D., & Dussopt, L. (2014). Millimeter-Wave Access and Backhauling: The Solution to the Exponential Data Traffic Increase in 5G Mobile Communications Systems? IEEE Communications Magazine, 88--95.

[65] Heilman, D. (2016, February 1). *Google's SkyBender Drones Could Deliver 5G Internet*. (Sci-Tech Today) Retrieved June 2017, from http://www.sci-tech-today.com/story.xhtml?story_id=13100C1INE20

[66] Miners, Z. (2015, July 30). Meet Aquila, Facebook's unmanned Internet drone. (PCWorld) Retrieved June 2017, from http://www.pcworld.com/article/2955212/software-social/facebook-aims-to-launch-unmanned-drone-by-yearend.html

areas to connect to the balloons network (in the stratosphere 12 miles above the ground) and then to the Internet[67]. In the stratosphere, twice as high as airplanes and the weather, there are many layers of steady winds which vary in direction and speed. The balloons will travel to the needed location or route by rising or descending into a layer of wind blowing in the desired direction. To provide the broadband service, the signal from customer's devices connect to a balloon network in the stratosphere, and then down to the global Internet on Earth, just as satellite service works at much higher latitudes, using free space optical (lasers) for the backhaul and radio frequency equipment for the access radio links. For the access radio links, the Loon project has conducted tests in rural areas in New Zealand, California and Brazil using both unlicensed ISM and licensed LTE bands. In 2014, the Loon project expressed their interest in using LTE bands and working in partnership with operators and telecommunications companies due to the potential to achieve universal access targets mandated by countries in a cost-effective manner in the short-term, while fiber-optic backbone and terrestrial networks are being deployed in the long-term.

Gigabit Satellite

This type of broadband technology is currently offered by the company O3b[68] which stands for "Other 3 Billion". This company provides satellite communication backhaul service offering low latency (less than 150ms) and data rates comparable to fiber-optic technology. O3B has a constellation of 12 satellites with a ground period of 360 minutes using the Ka-band providing a coverage of 45 degrees north/south latitudes. The satellites provide 10 beams per region (7 regions) totaling 70 remote beams for the entire constellation. Its latency is less than 150 milliseconds due to the use of Medium Earth Orbit (MEO) satellites. The maximum available aggregated throughput per beam (over a single transponder) is 1.6 Gbps (800 Mbps x 2) and each beam provides coverage of 400 miles.

Television White Spaces (TV White Spaces)

White spaces can be defined as part of the spectrum, available for a radio communication application at a given time in a given geographical area on a non-interfering/non-protected basis with regard to primary and other services. The TV White Spaces technology (IEEE 802.11af and IEEE 802.22 Standards) operates in white spaces of the broadcast television spectrum (from 54 MHz to 862 MHz)[69]. It was designed for wireless local area networks (WLANs) with a range up to a few miles and wireless regional area networks (WRANs) with a range up to several tens of miles. TVWS can achieve aggregated data rates of a few tens of Mbps allowing it to provide downstream speeds of a few Mbps. The TVWS technology has the advantage of enhanced propagation features due to the use of frequencies bellow 1 GHz allowing for the penetration of walls, vegetation, moderate hills and other obstacles.

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[67] X (Google X) - Project Loon. *Project Loon*. (X (Google X)) Retrieved from https://x.company/loon/

[68] O3b Networks. O3b Networks - Our Technology. Retrieved June 2017, from https://www.o3bnetworks.com/announcement.php

[69] Pietrosemoli, E., & Zennaro, M. (2013). TV White Spaces - A pragmatic Approach. ICTP-The Abdus Salam International Centre forTheoretical Physics.

10. Glossary

25/3 Mbps: An Internet connection with a download speed of 25 megabits per second and an upload speed of 3 megabit per second. Also, the speed at which the FCC considers an Internet connection to be broadband.

6/1 Mbps: An Internet connection with a download speed of 6 megabits per second and an upload speed of 1 megabit per second. Also, the speed at which the State of California considers an Internet connection to be broadband.

ADSL2+: The next step up from standard ADSL that generally provides a faster Internet speeds. Providers of ADSL2+ in Redding include AT&T and PAETEC Communications.

Asymmetric DSL: A DSL line where the upload speed is different from the download speed. Usually the download speed is much greater. Providers of asymmetric DSL include AT&T and Earthlink.

Backbone: A high-speed line or series of connections that forms a major pathway within a network.

Bandwidth: The capacity for data transfer of an electronic communications system.

bps: A measurement of how fast data is moved from one place to another via a network or Internet connection.

Broadband: High-speed Internet access that is always on and faster than the traditional dial-up access.

Broadband Assets: Government owned assets that may assist in the deployment of broadband infrastructure. Examples include towers or tall buildings that may be used to deploy wireless infrastructure and rights-of-way to run underground conduit and fiber-optic cables.

Cable Modem DOCSIS (Data Over Cable Service Interface Specification): An international telecommunications standard that permits the addition of high-bandwidth data transfer to an existing cable TV system.

Cloud computing: The use of a network of remote servers hosted on the Internet to store, manage, and process data. An alternative to the established practice of storing and processing data on a dedicated server or computing machine.

Coverage: The geographical areas in which an ISP provides Internet connections.

CPUC: The California Public Utilities Commission. The CPUC regulates services and utilities, protects consumers, safeguards the environment, and assures Californians' access to safe and reliable utility infrastructure and services. The essential services regulated include electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies.

Digital Divide: A measurement of technological equality in access to and adoption of broadband that provides metrics by census tract and county.

Download: An act or instance of transferring something (such as data or files) from a usually large computer to the memory of another device (such as a smaller computer) over a network or Internet connection.

Downstream: Data sent from a network service provider to a customer via the Internet.

DSL (Digital Subscriber Line): A category of technologies that transmit digital data over telephone lines. Providers of DSL include AT&T, PAETEC Communications, and Earthlink.

FCC: The Federal Communications Commission. The Federal Communications Commission regulates interstate and international communications by radio, television, wire, satellite, and cable in all 50 states, the District of Columbia and U.S. territories. An independent U.S. government agency overseen by Congress, the Commission is the federal agency responsible for implementing and enforcing America's communications law and regulations.

Fiber-optic cable: A type of cable used for very high speed data transmission.

Fiber-to-the-premises/fiber-to-the-home (FTTP/FTTH): The installation and use of optical fiber from a central point directly to individual buildings such as residences, apartment buildings and businesses to provide high-speed Internet access.

Fixed broadband: High-speed data transmission to homes and businesses using technologies such as T1, cable, DSL and FiOS. The term excludes the cellular data market.

Fixed wireless: The operation of wireless communication devices or systems used to connect two fixed locations with a radio or other wireless link.

Gbps (gigabits per second): A measurement, in terms of gigabits, of how fast data is moved from one place to another via a network or Internet connection. A gigabit equals 1,000 megabits.

ILEC (Incumbent local exchange carrier): A local telephone company which held the regional monopoly on landline service before the market was opened to competitive local exchange carriers, or the corporate successor of such a firm.

Internet-of-things: The interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data.

IPTV: The delivery of television content over Internet networks.

ISP (Internet Service Provider): An institution/business that provides access to the Internet. Examples of ISPs include AT&T, Comcast, Earthlink, etc.

Kbps (kilobits per second): A measurement, in terms of kilobits, of how fast data is moved from one place to another via a network or Internet connection.

Last-mile: The last segment of the connection between a communication provider (e.g., telephone company central office, ISP) and the customer (usually residential, but sometimes commercial).

Latency: A measurement of the time it takes a data packet to travel through the network. It significantly impacts the performance of interactive, real-time applications, including VoIP, online gaming, videoconferencing, and VPN platforms.

Long-Term Evolution (LTE): A fourth generation (4G) mobile communications standard for the high-speed wireless Internet connection of mobile devices (smartphones, tablets, etc.)

Machine to machine: Direct communication between devices through network or Internet connections.

Mbps (megabits per second): A measurement, in terms of megabits, of how fast data is moved from one place to another via a network or Internet connection. A megabit equals 1,000 kilobits.

Middle-mile: The network infrastructure that connects last mile networks to other network service providers, major telecommunications carriers, and the greater Internet.

No service: According to the CPUC standard, areas where broadband is offered at slower speeds than 6 Mbps downstream and 1 Mbps upstream.

OFDM (Orthogonal Frequency Division Multiplex): A form of transmission that uses a large number of close spaced carriers that are modulated with low rate data.

P2P: A network allowing two or more computers to communicate directly without having to use a router or other centralized server.

Packet Loss: The Measuring Broadband America program denotes a packet as lost if the latency exceeds 3 seconds or if the packet is never received. Packet losses might affect the perceived quality of phone calls or video conferencing.

Point of presence: An access point to the Internet and a physical location that houses servers, routers, etc. Also, an interconnection point within fiber-optic networks.

Public Right of Way (PROW): The right to cross property to go to and from another parcel. The right of way may be a specific grant of land or an "easement," which is a right to pass across another's land. The mere right to cross without a specific description is a "floating" easement. Some rights of way are for limited use such as repair of electric lines or for deliveries to the back door of a store.

Served: According to the CPUC standard, areas where broadband is offered at speeds of at least 6 Mbps downstream and 1 Mbps upstream. According to the FCC standard, areas where broadband is offered at speeds of at least 25 Mbps downstream and 3 Mbps upstream.

Telecommuting: Working from home through the use of the Internet, email, and by telephone.

Telemedicine: The use of telecommunication and information technology to provide clinical health care from a distance.

Throughput: How much stuff you can send through a connection. Throughput is what people usually mean when they use the term "bandwidth" and it is usually measured in bits-per-second (bps) A full page of English text is about 16,000 bits. A common configuration of DSL allows downloads at speeds of up to 1.544 megabits (not megabytes) per second, and uploads at speeds of 128 kilobits per second.

TVWS (TV White Space): A form of wireless technology that takes advantage of unused TV channels between the active ones in the VHF and UHF spectrum to transmit data.

Unserved: According to the FCC standard, areas where broadband is offered at slower speeds than 25 Mbps downstream and 3 Mbps upstream.

Upload: To transfer (something, such as data or files) from a computer or other digital device to the memory of another device (such as a larger or remote computer) over a network or Internet connection.

Upstream: Data transferred from a customer to a server via the Internet.

USDA: The United States Department of Agriculture.

VDSL (Very-high-bit-rate digital subscriber line): A digital subscriber line technology that provides faster data transmission than asymmetric digital subscriber line. AT&T is the only VDSL provider in Redding.

Video on demand (VoD): A system in which viewers choose their own filmed entertainment, by means of a PC or interactive TV system, from a wide selection.

VoIP technology: A technology that allows you to make voice calls using a broadband Internet connection instead of a regular (or analog) phone line.